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PRE-STANDARD

Industrial communication networks – Fieldbus specifications –
Part 4–22: Data-link layer protocol specification – Type SNpTYPE elements

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INDUSTRIAL COMMUNICATION NETWORKS – FIELDBUS SPECIFICATIONS –

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Following publication of this PAS, which is a pre-standard publication, the technical committee or subcommittee concerned may transform it into an International Standard.

This PAS shall remain valid for an initial maximum period of 3 years starting from the publication date. The validity may be extended for a single 3-year period, following which it shall be revised to become another type of normative document, or shall be withdrawn.

The list of all the parts of the IEC 61158 series, under the general title *Industrial communication networks – Fieldbus specifications*, can be found on the IEC web site.

INTRODUCTION

This PAS contains an additional profile – SNpTYPE – which may be integrated into a future new edition of the IEC 61158-4 series.

INDUSTRIAL COMMUNICATION NETWORKS – FIELDBUS SPECIFICATIONS –

Part 4–22: Data-link layer protocol specification – Type SNpTYPE elements

1 Scope

1.1 General

The data-link layer provides basic time-critical messaging communications between devices in an automation environment.

This protocol provides communication opportunities to all participating data-link entities

a) in a synchronously-starting cyclic manner, according to a pre-established schedule, and
b) in a cyclic or acyclic asynchronous manner, as requested each cycle by each of those data-link entities.

Thus this protocol can be characterized as one which provides cyclic and acyclic access asynchronously but with a synchronous restart of each cycle.

1.2 Specifications

This part of IEC 61158-4 specifies:

a) procedures for the timely transfer of data and control information from one data-link user entity to a peer user entity, and among the data-link entities forming the distributed data-link service provider;
b) the structure of the fieldbus DLPDUs used for the transfer of data and control information by the protocol of this part of IEC 61158-4, and their representation as physical interface data units.

1.3 Procedures

The procedures are defined in terms of:

a) the interactions between peer DL-entities (DLEs) through the exchange of fieldbus DLPDUs;
b) the interactions between a DL-service (DLS) provider and a DLS-user in the same system through the exchange of DLS primitives;
c) the interactions between a DLS-provider and a Ph-service provider in the same system through the exchange of Ph-service primitives.

1.4 Applicability

These procedures are applicable to instances of communication between systems which support time-critical communications services within the data-link layer of the OSI or fieldbus reference models, and which require the ability to interconnect in an open systems interconnection environment.

Profiles provide a simple multi-attribute means of summarizing an implementation's capabilities, and thus its applicability to various time-critical communications needs.

1.5 Conformance

This part of IEC 61158-4 also specifies conformance requirements for systems implementing these procedures.

This part of IEC 61158-4 does not contain tests to demonstrate compliance with such requirements.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 61588, *Precision clock synchronization protocol for networked measurement and control system*

ISO/IEC 7498-1, *Information technology – Open Systems Interconnection – Basic Reference Model: The Basic Model*

ISO/IEC 7498-3, *Information technology – Open Systems Interconnection – Basic Reference Model: Naming and addressing*

ISO/IEC 8802-3:2000, *Information technology – Telecommunications and information exchange between systems – Local and metropolitan area networks – Specific requirements – Part 3: Carrier sense multiple access with collision detection (CSMA/CD) access method and physical layer specifications*

ISO/IEC 10731, *Information technology – Open Systems Interconnection – Basic Reference Model – Conventions for the definition of OSI services*

IETF RFC 768, *User Datagram Protocol*

IETF RFC 791, *Internet Protocol*

IEEE 802.1Q, *IEEE Standard for Local and metropolitan area networks – Virtual Bridged Local Area Networks*

3 Terms, definitions, symbols, abbreviations and conventions

3.1 Reference model terms and definitions

This part of IEC 61158-4 is based in part on the concepts developed in ISO/IEC 7498-1 and ISO/IEC 7498-3, and makes use of the following terms defined therein.

3.1.1 acknowledgement [7498-1]

3.1.2 DL-address [7498-3]

3.1.3 DL-address-mapping [7498-1]

3.1.4 called-DL-address [7498-3]

3.1.5 calling-DL-address [7498-3]

3.1.6 DL-connection [7498-1]

3.1.7 DL-connection-end-point [7498-1]

3.1.8 DL-connection-end-point-identifier [7498-1]

3.1.9 DL-connection-mode transmission [7498-1]

3.1.10 DL-connectionless-mode transmission [7498-1]

3.1.11 decentralized multi-end-point-connection [7498-1]

3.1.12 DL-duplex-transmission [7498-1]

3.1.13 (N)-entity [7498-1]
DL-entity (N=2)
Ph-entity (N=1)

3.1.14 flow control [7498-1]

3.1.15 (N)-layer [7498-1]
DL-layer (N=2)
Ph-layer (N=1)

3.1.16 layer-management [7498-1]

3.1.17 DL-local-view [7498-3]

3.1.18 multi-endpoint-connection [7498-1]

3.1.19 DL-name [7498-3]

3.1.20 naming-(addressing)-domain [7498-3]

3.1.21 peer-entities [7498-1]

3.1.22 primitive name [7498-3]

3.1.23 DL-protocol [7498-1]

3.1.24 DL-protocol-connection-identifier [7498-1]

3.1.25 DL-protocol-control information [7498-1]

3.1.26 DL-protocol-data-unit [7498-1]

3.1.27 DL-protocol-version-identifier [7498-1]

3.1.28 DL-relay [7498-1]

3.1.29 reassembling [7498-1]

3.1.30 reset [7498-1]

3.1.31 responding-DL-address [7498-3]

3.1.32 routing [7498-1]

3.1.33 segmenting [7498-1]

3.1.34 sequencing [7498-1]

3.1.35 (N)-service [7498-1]
DL-service (N=2)
Ph-service (N=1)

3.1.36 (N)-service-access-point [7498-1]
DL-service-access-point (N=2)
Ph-service-access-point (N=1)

3.1.37 DL-service-access-point-address [7498-3]

3.1.38 DL-service-connection-identifier [7498-1]

3.1.39 DL-service-data-unit [7498-1]

3.1.40 DL-simplex-transmission [7498-1]

3.1.41 DL-subsystem [7498-1]

3.1.42 systems-management [7498-1]

3.1.43 DL-user-data [7498-1]

3.2 Service convention terms and definitions

This part of IEC 61158-4 also makes use of the following terms defined in ISO/IEC 10731 as they apply to the data-link layer:

3.2.1 acceptor

3.2.2 asymmetrical service

3.2.3 confirm (primitive);
requestor.deliver (primitive)

3.2.4 deliver (primitive)

3.2.5 DL-confirmed-facility

3.2.6 DL-facility

3.2.7 DL-local-view

3.2.8 DL-mandatory-facility

3.2.9 DL-non-confirmed-facility

3.2.10 DL-provider-initiated-facility

3.2.11 DL-provider-optional-facility

3.2.12 DL-service-primitive;
primitive

3.2.13 DL-service-provider

3.2.14 DL-service-user

3.2.15 DL-user-optional-facility

3.2.16 indication (primitive);
acceptor.deliver (primitive)

3.2.17 multi-peer

3.2.18 request (primitive);
requestor.submit (primitive)

3.2.19 requestor

3.2.20 response (primitive);
acceptor.submit (primitive)

3.2.21 submit (primitive)

3.2.22 symmetrical service

3.3 Common terms and definitions

NOTE Many definitions are common to more than one protocol Type; they are not necessarily used by all protocol Types.

3.3.1
DL-segment
single DL-subnetwork in which any of the connected DLEs may communicate directly, without any intervening DL-relaying, whenever all of those DLEs that are participating in an instance of communication are simultaneously attentive to the DL-subnetwork during the period(s) of attempted communication

3.3.2
extended link
DL-subnetwork, consisting of the maximal set of links interconnected by DL-relays, sharing a single DL-name (DL-address) space, in which any of the connected DL-entities may communicate, one with another, either directly or with the assistance of one or more of those intervening DL-relay entities

NOTE An extended link may be composed of just a single link.

3.3.3
frame
denigrated synonym for DLPDU

3.3.4
receiving DLS-user
DL-service user that acts as a recipient of DL-user-data

NOTE A DL-service user can be concurrently both a sending and receiving DLS-user.

3.3.5
sending DLS-user
DL-service user that acts as a source of DL-user-data

3.4 Additional Type SNpTYPE definitions

3.4.1
acyclic data
data which is transferred from time to time for dedicated purposes

3.4.2
bit
unit of information consisting of a 1 or a 0. This is the smallest data unit that can be transmitted

3.4.3
cell
synonym for a single DL-segment which uses RTFL communication model

3.4.4
communication cycle
fixed time period between which the root device issues empty frames for cyclic communication initiation in which data is transmitted utilizing CDC and MSC

3.4.5
cycle time
duration of a communication cycle

3.4.6
cyclic
events which repeat in a regular and repetitive manner

3.4.7
cyclic communication
periodic exchange of frames

3.4.8
cyclic data
data which is transferred in a regular and repetitive manner for dedicated purposes

3.4.9
cyclic data channel (CDC)
part of one or more frames, which is reserved for cyclic data

3.4.10
data
generic term used to refer to any information carried over a fieldbus

3.4.11
device
physical entity connected to the fieldbus

3.4.12
error
discrepancy between a computed, observed or measured value or condition and the specified or theoretically correct value or condition

3.4.13
gateway
device acting as a linking element between different protocols

3.4.14
inter-cell communication
communication between a RTFL device and a RTFN device or communication between a RTFL device and another RTFL device in different cells linked by RTFN

3.4.15
interface
shared boundary between two functional units, defined by functional characteristics, signal characteristic, or other characteristics as appropriate

3.4.16
intra-cell communication
communication between a RTFL device and another RTFL device in the same cell

3.4.17
link
synonym for DL-segment

3.4.18
master clock
global time base for the PCS mechanism

3.4.19
message
ordered sequence of octets intended to convey data

3.4.20
message channel (MSC)
part of one or more frames, which is reserved for acyclic data

3.4.21
network
set of devices connected by some type of communication medium, including any intervening repeaters, bridges, routers and lower-layer gateways

3.4.22
open network
any Ethernet-based network with no further restrictions

3.4.23
ordinary device (OD)
slave in the communication system, which utilizes RTFL for cyclic and acyclic data interchange with other ODs in the same logical double line

3.4.24
precise clock synchronization (PCS)
mechanism to synchronize clocks of RTFL devices and maintain a global time base

3.4.25
process data
data designated to be transferred cyclically or acyclically for the purpose of processing

3.4.26
process data object
dedicated data object(s) designated to be transferred cyclically or acyclically for the purpose of processing

3.4.27
protocol
convention about the data formats, time sequences, and error correction in the data exchange of communication systems

3.4.28
root device (RD)
master in the communication system, which organises, initiates and controls the RTFL cyclic and acyclic data interchange for one logical double line

3.4.29
real time frame line (RTFL)
communication model for communication with high real time requirements

3.4.30
real time frame network (RTFN)
communication model for communication with low real time requirements

3.4.31
switch
MAC bridge as defined in 802.1D

3.4.32
round trip time
transmission time needed by a DLPDU from the RD to the last OD in forward and backward direction

3.4.33
timing signal
time-based indication of the occurrence of an event, commonly as an interrupt signal, used for DL-user synchronization

3.4.34
topology
physical network architecture with respect to the connection between the stations of the communication system

3.5 Common symbols and abbreviations

NOTE Many symbols and abbreviations are common to more than one protocol Type; they are not necessarily used by all protocol Types.

3.5.1 CIDR Classless Inter-Domain Routing

3.5.2 DHCP Dynamic Host Configuration Protocol

3.5.3 DL- Data-link layer (as a prefix)

3.5.4 DLC DL-connection

3.5.5 DLCEP DL-connection-end-point

3.5.6 DLE	DL-entity
3.5.7 DLL	DL-layer
3.5.8 DLPCI	DL-protocol-control-information
3.5.9 DLPDU	DL-protocol-data-unit
3.5.10 DLM	DL-management
3.5.11 DLME	DL-management entity
3.5.12 DLMS	DL-management service
3.5.13 DLPDU	DL-protocol-data-unit
3.5.14 DLS	DL-service
3.5.15 DLSAP	DL-service-access-point
3.5.16 DLSDU	DL-service-data-unit
3.5.17 DNS	Domain name server
3.5.18 FCS	Frame check sequence
3.5.19 FIFO	First-in first-out
3.5.20 IANA	Internet Assigned Numbers Authority
3.5.21 IEEE	Institute of Electrical and Electronics Engineers
3.5.22 IETF	Internet Engineering Task Force
3.5.23 OSI	Open systems interconnection
3.5.24 Ph-	Physical layer (as a prefix)
3.5.25 PhE	Ph-entity
3.5.26 PhL	Ph-layer
3.5.27 QoS	Quality of service
3.5.28 RFC	Request for comments
3.5.29 UTF	Unicode transformation format

3.6 Additional Type SNpTYPE symbols and abbreviations

3.6.1 ACK	Acknowledgement
3.6.2 ADL	ACK data length

3.6.3 CDC Cyclic data channel

3.6.4 CDCL CDC line

3.6.5 CDCLPM CDCL protocol machine

3.6.6 CDCN CDC network

3.6.7 CDCNPM CDCN protocol machine

3.6.8 CDCS CDC send

3.6.9 CL Communication layer

3.6.10 CMD Command

3.6.11 DA Device address or destination address

3.6.12 DMR Delay measurement read

3.6.13 DMS Delay measurement send

3.6.14 FHPM Frame handling protocol machine

3.6.15 ID Identification

3.6.16 IP Internet protocol

3.6.17 IPv4 IP version 4

3.6.18 IPv6 IP version 6

3.6.19 IRQ Interrupt request

3.6.20 MAC Medium access control

3.6.21 MC Master clock

3.6.22 MSC-MTP Message channel message transfer protocol

3.6.23 MSC Message channel

3.6.24 MSCL MSC line

3.6.25 MSCLPM MSCL protocol machine

3.6.26 MSCN MSC network

3.6.27 MSCNPM MSCN protocol machine

3.6.28 MSCR MSC read

3.6.29 MSCS	MSC send
3.6.30 MSS	Maximum segment size
3.6.31 NMPM	Net management protocol machine
3.6.32 NV	Network verification
3.6.33 OD	Ordinary device
3.6.34 PD	Previous device
3.6.35 PID	Packet ID
3.6.36 PCS	Precise clock synchronization
3.6.37 PCSC	PCS configuration
3.6.38 PM	Protocol machine
3.6.39 RD	Root device
3.6.40 RTF	Real time frame
3.6.41 RTFL	Real time frame line
3.6.42 RTFLCFG	RTFL configuration
3.6.43 RTFLCTL	RTFL control
3.6.44 RTFN	Real time frame network
3.6.45 RTFNCS	RTFN connection setup
3.6.46 RTFNCR	RTFN connection release
3.6.47 RTFNSNR	RTFN Scan network read
3.6.48 RX	Receive direction
3.6.49 SA	Source address
3.6.50 SYNC	Synchronization
3.6.51 SYNC_START	SYNC start
3.6.52 SYNC_STOP	SYNC stop
3.6.53 TCP	Transmission control protocol
3.6.54 TSU	Time stamping unit

3.6.55 TX Transmit direction

3.6.56 UDP User datagram protocol

3.7 Conventions

3.7.1 Abstract syntax conventions

The data types BYTE and WORD used within this part of IEC 61158-4 are of the type Unsigned8 and Unsigned16 as specified in 5.2.

The DL syntax elements related to PDU structure are described as shown in Table 1.

- Frame part denotes the element that will be replaced by this reproduction.
- Data field is the name of the elements.
- Data Type denotes the type of the terminal symbol.
- Value/Description contains the constant value or the meaning of the parameter.

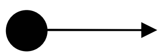
Table 1 – PDU element definition

Frame part	Data field	Data type	Value/description

3.7.2 Protocol machine description conventions

The protocol sequences are described by means of protocol machines. For the specification of protocol machines within this part of IEC 61158-4, the following graphical description language is used. Table 2 specifies the graphical elements of this description language and their meanings.

Table 2 – Conventions for protocol machine description

Graphical element	Description
	Each state of a protocol machine is uniquely identified using a descriptive name An action, if required, is performed by the protocol machine in this particular state
	A transition between different states of a protocol machine is caused by an event or a particular condition Conditions describing the state of a part of or of the whole system can be stated which have to be fulfilled to perform a certain transition Additionally actions which are performed when performing a certain transition can be stated
	The initial state of a protocol machine is labeled using this symbol

4 DL-protocol overview

4.1 Operating principle

Type SNpType of this series of international standards describes a real-time Ethernet technology which overcomes the requirements of modern automation technology. For the purpose of fast intra-machine communication Type SNpTYPE describes a communication model and protocol (RTFL) for fast real-time communication. Furthermore, networking of several parts of an automation system into an overall system is supported by the specification of a second communication model and protocol (RTFN). Type SNpTYPE is designed as a multi-master bus system. This makes networking of individual control systems to a distributed automated solution quite easy.

From an Ethernet point of view, a Type SNpTYPE network utilizes standard ISO/IEC 8802-3 Ethernet frames for both communication models.

4.2 Communication model

4.2.1 Overview

Type SNpTYPE technology essentially specifies two communication models with corresponding protocols. RTFL communication is intended for fast machine communication while RTFN provides for the networking of individual machines or cells. The corresponding protocols aim to offer an equal set of services for cyclic process data exchange as well as for acyclic message data communication.

For RTFL communication model, communication follows a line topology. RTFL communication is based on cyclic data transfer in an ISO/IEC 8802-3 Ethernet frame. This basic cyclic data transfer is provided by a special device, the root device (RD). Root devices act as communication master to cyclically initiate communication. The Ethernet frames originated by the root device are passed to the Type SNpTYPE ordinary devices (OD). Each ordinary device receives the frame, writes its data and passes the frame on. A RTFL network requires exactly one root device. The last ordinary device of a RTFL network sends the processed frame back. The frame is transferred back along exactly the same way to the root device so that it is returned by the first ordinary device to the root device as response frame. In backward direction, the ordinary devices read their relevant data from the frame.

For RTFN communication model, communication is based on point to point connections between participating devices.

Networking of different RTFL parts or cells of an automation system into an overall automation system is supported by the usage of RTFN communication and corresponding gateways.

4.2.2 RTFL device reference model

Type SNpTYPE services are described using the principles, methodology and model of ISO/IEC 7498-1 (OSI). The OSI model provides a layered approach to communications standards, whereby the layers can be developed and modified independently. The Type SNpTYPE specification defines functionality from top to bottom of a full OSI model. Functions of the intermediate OSI layers, layers 3 to 6, are consolidated into either the Type SNpTYPE data-link layer or the DL-user. The device reference model for a Type SNpType RTFL device is shown in Figure 1.

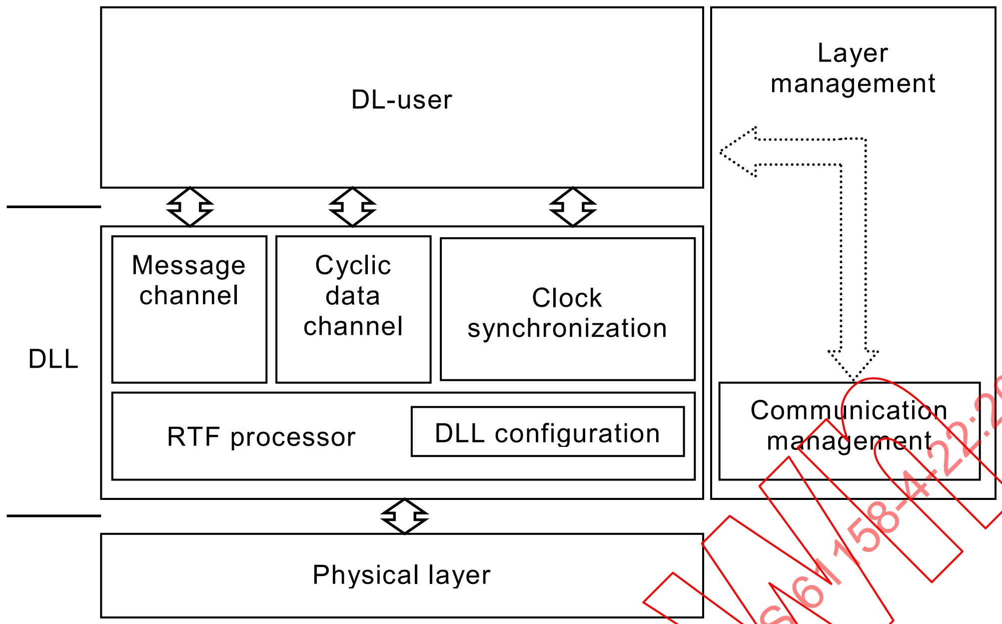


Figure 1 – RTFL device reference model

4.2.3 RTFN device reference model

Type SNpTYPE services are described using the principles, methodology and model of ISO/IEC 7498-1 (OSI). The OSI model provides a layered approach to communications standards, whereby the layers can be developed and modified independently. The Type SNpTYPE specification defines functionality from top to bottom of a full OSI model. Functions of the intermediate OSI layers, layers 3 to 6, are consolidated into either the Type SNpTYPE data-link layer or the DL-user. The device reference model for a Type SNpType RTFN device is shown in Figure 2.

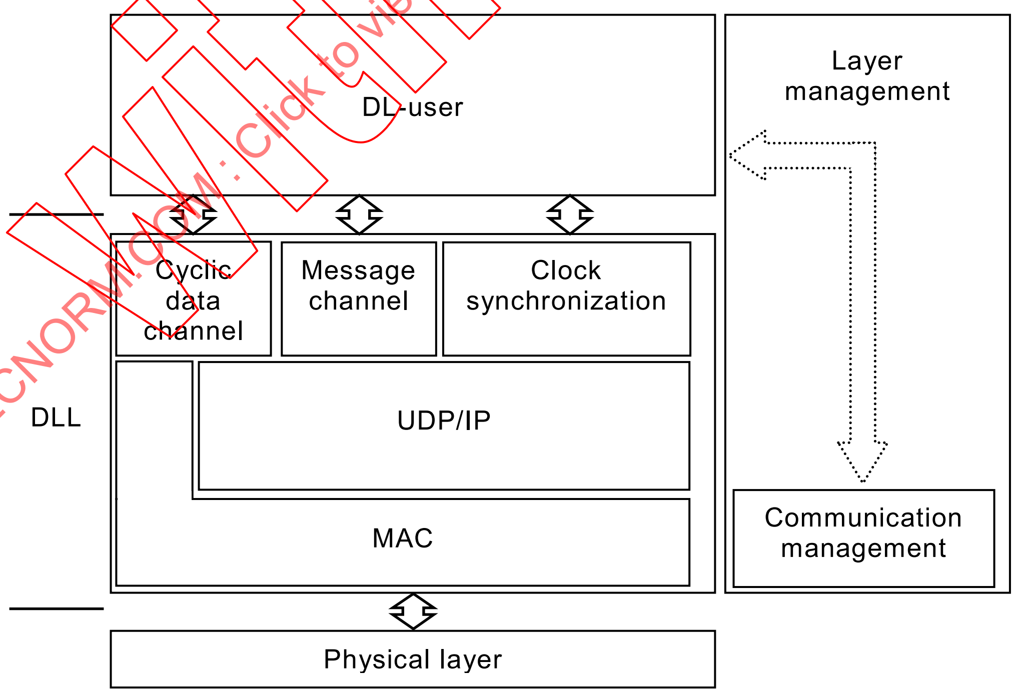


Figure 2 – RTFN device reference model

4.3 Topology

4.3.1 RTFL topology

A Type SNpTYPE network utilizing the RTFL communication model uses a line topology. Data transfer is handled by frame transfer from one device to the next device along a line. The last ordinary device returns the frame back to the root device along all participating ordinary devices. The line corresponds to the logical addressed device sequence. A logical double line is represented by the arrangement of all ordinary devices and the root device and the frame processing in forward and backward direction.

A logical double line is able to allow different network topologies. In a switch operated tree structure each ordinary device has a predecessor and a successor although they are not physically located immediately. The ordinary devices for the RTFL communication model should provide two Ethernet interfaces. This allows set-up of a physical line structure.

4.3.2 RTFN topology

A Type SNpTYPE network utilizing the RTFN communication model shall support all commonly used Ethernet topologies.

4.4 Frame processing

4.4.1 Communication model RTFL

4.4.1.1 Frame generation

For a Type SNpTYPE network utilizing the RTFL communication model the frame generation concept is specified. This concept shall be applied by the root device within a RTFL network to cyclically initiate communication. Frame generation depicts the generation of an RTF Ethernet frame into the RTFL network to be processed by all participating ordinary devices for communication purposes.

If the ordinary devices are arranged in a physical line frames should be directly forwarded from one interface to the next interface and processed on-the-fly (cut-through).

4.4.1.2 Error detection

For the purpose of error detection, each RTFL device shall verify the Ethernet frame checksum on receipt of the frame. On forwarding the frame to the next participant, the frame checksum is recalculated and re-written. In the case of a detected checksum failure, a device shall indicate this failure using a dedicated error bit within a Type SNpTYPE frame and writes the revised checksum. Other ODs can determine by this error bit the validity of the frame content.

A root device can detect the presence of errors within a communication cycle by the usage of the following three options.

- Verification of the frame checksum to detect failures between RD and the first OD.
- Verification of the error bit to detect the presence of a failure between two ODs.
- Verification of the round trip time for each frame to detect the loss of frames.

4.4.2 Communication model RTFN

This communication model does not apply any particular frame processing procedures. Frames are directly sent between communicating entities.

4.5 General communication mechanisms

4.5.1 Cyclic data channel (CDC)

The cyclic data channel (CDC) is intended for cyclic process data transfer.

For RTFL devices, the cyclic data channel (CDCL) is a frame section reserved within one or more frames for cyclic data. The devices write data in packets in the CDC and extract relevant data packets. Packets are identified by unique IDs (packet ID, PID). Each OD copies the packets in forward direction to the frame to make data available. All other ODs in the double line can read those packets on the return direction of the frame.

The uniqueness of a packet has to be assured by configuration for the whole communication environment of the packet. Packets used for inter-cell communication between different RTFL networks are labeled by a PID which is unique within all involved DL-segments, while packets within different communication environments (for example different DL-segments) can be labeled with the same PID unique only within their communication environment.

For RTFN devices, the cyclic data channel (CDCN) is based on cyclic point-to-point communication between two devices. Several unidirectional communication links are set up between devices. Each link may be configured with a different cycle time. This communication does not use acknowledgements. Large data volume is handled similar to the RTFL frame sequences. Communication can be based either at MAC or UDP level. A base RTFN cycle time has to be specified for RTFN devices. This time specifies a limit on how often CDCN messages are sent by the RTFN devices.

4.5.2 Message channel (MSC)

The message channel is intended for acyclic communication. Data is transferred in messages. The devices write data in addressed packets to the message channel, while the message channel can contain several messages. The individual message length is variable. A specific protocol, the message channel transfer protocol (MSC-MTP) is used to serve this channel.

For RTFL devices, the message channel consists of one frame (MSCL-frame) per communication cycle for acyclic data and inter-cell communication. There are three different priorities for messages which are used to reserve bandwidth according to the importance of the message. The priority is derived out of the service type of the message content. The size of MSCL-frames is configurable. If the MSC cannot hold all messages in a cycle, an OD can assign transfer space in one of the next cycles (assigning). Reservation includes prioritization depending on the service.

For RTFN devices, the message channel (MSCN) utilizes UDP/IP and the MSC message transfer protocol. There is no prioritization necessary.

4.6 Gateway

The gateway acts as linking element between RTFL and RTFN. In addition, it is a standard Ethernet gateway between Type SNpTYPE networks and the open network. A device incorporating gateway functionality can be an OD or a RD. The Gateway contains the following functionalities:

- MSC Gateway
- CDC Gateway

Gateway functionality is necessary to enable inter-cell communication. Inter-cell acyclic communication is communication between a RTFL device and a RTFN device or communication between a RTFL device and another RTFL device in a different logical double line (also called cell) interconnected via RTFN using a gateway. Messages must be transported over RTFL MSC (MSCL) as well as over RTFN MSC (MSCN) in order to reach their destination. The different addressing schemas in MSCL and MSCN require a translation as a gateway function. The MSC extended addressing mode facilitates inter-cell acyclic communication.

Inter-cell cyclic communication is the exchange of process data across the RTFN and RTFL network boundaries. The communication parameters for the process data packets contain packet identifiers. The packets are routed across the RTFN/RTFL boundary and the gateway takes care of the packet id resolution.

4.7 Interaction models

4.7.1 Overview

Depending on the specified communication models RTFL and RTFN Type SNpTYPE networks utilize different interaction models for cyclic data exchange.

4.7.2 Producer-consumer

Communication model RTFL uses the producer-consumer interaction model. It involves a single producer and a group of zero or more consumer(s). The model is characterized by an unconfirmed service requested by the producer to distribute its cyclic data and a correlated service indication in all available consumers.

4.7.3 Publisher-subscriber

Communication model RTFN utilizes the publisher-subscriber push interaction model for cyclic data exchange. Publisher-subscriber interactions involve a single publisher and a group of one or more subscribers. Two services are used, one confirmed and one unconfirmed. The confirmed service is used by the subscriber to request to join the publishing. The response to this request is returned to the subscriber. The unconfirmed service is used by the publisher to distribute its cyclic data to subscribers.

5 DLPDU structure

5.1 Overview

Networks of this protocol type use standard ISO/IEC 8802-3 Ethernet DLPDUs for transporting Type SNpTYPE DLPDUs.

5.2 Data types and encoding rules

5.2.1 Overview

To be able to exchange meaningful data across a Type SNpTYPE network, the format of this data and its meaning have to be known by communicating entities. This specification models this by the concept of data types.

The encoding rules define the representation of values of data types and the transfer syntax for the representation. Values are represented as bit sequences. Bit sequences are transferred in sequences of octets. For numerical data types the encoding is big endian style.

The data types and encoding rules shall be valid for the DLL services and protocols. The encoding rules for the Ethernet frame are specified in ISO/IEC 8802-3. The DLSDU of Ethernet is an octet string. The transmission order within octets depends upon MAC and PhL encoding rules.

5.2.2 Transfer syntax for bit sequences

For transmission across Type SNpTYPE DLL a bit sequence is reordered into a sequence of octets. Let $b = b_{n-1}$ to b_0 be a bit sequence. Denote k a non-negative integer such that 8(k - 1)

$< n < 8k$. Then b is transferred in k octets assembled as shown in Table 3. The bits b_i, $i > n$ of the lowest numbered octet are do not care bits.

Octet 1 is transmitted first and octet k is transmitted last. Hence the bit sequence is transferred as follows across the network:

..., b15, ..., b8, b7, b6, ..., b0

Table 3 – Transfer syntax for bit sequences

Octet number	1.	(k-1).	k.
—	$b_{8k-1} – b_{8k-8}$	$b_{15} – b_8$	$b_7 – b_0$

5.2.3 Unsigned Integer

Data of basic data type Unsignedn has values in the non-negative integers. The value range is 0 to 2^n-1. The data is represented as bit sequences of length n. The bit sequence

$$b = b_n\text{-}1 \ldots b_0$$

is assigned the value

$$\text{Unsignedn}(b) = b_{n-1}\times 2^{n-1} + \ldots + b_1\times 2^1 + b_0\times 2^0$$

EXAMPLE The value 276 = 0x0114 with data type Unsigned16 is transferred in two octets, first 0x01 and then 0x14.

The Unsignedn data types are transferred as specified in Table 4. Unsigned data types as Unsigned1 to Unsigned7 and Unsigned9 to Unsigned15 will be used too. In this case the next element will start at the first free bit position. The grouping of such data types shall end without resulting gaps.

Table 4 – Transfer syntax for data type Unsignedn

Octet number	1.	2.	3.	4.	5.	6.	7.	8.
Unsigned8	$b_7 – b_0$	—	—	—	—	—	—	—
Unsigned16	$b_{15} – b_8$	$b_7 – b_0$	—	—	—	—	—	—
Unsigned24	$b_{23} – b_{16}$	$b_{15} – b_8$	$b_7 – b_0$	—	—	—	—	—
Unsigned32	$b_{31} – b_{24}$	$b_{23} – b_{16}$	$b_{15} – b_8$	$b_7 – b_0$	—	—	—	—
Unsigned64	$b_{63} – b_{56}$	$b_{55} – b_{48}$	$b_{47} – b_{40}$	$b_{39} – b_{32}$	$b_{31} – b_{24}$	$b_{23} – b_{16}$	$b_{15} – b_8$	$b_7 – b_0$

5.2.4 Signed Integer

Data of basic data type Integern has values in the integers. The value range is from -2^{n-1} to 2^{n-1}-1. The data is represented as bit sequences of length n. The bit sequence

$$b = b_{n-1} \ldots b_0$$

is assigned the value

$$\text{Signedn}(b) = b_{n-2}\times 2^{n-2} + \ldots + b_1\times 2^1 + b_0\times 2^0 \text{ if } b_{n-1} = 0$$

and, performing two's complement arithmetic,

$$\text{Signedn(b)} = - \text{Integern}(\hat{}b) - 1 \text{ if } b_{n-1} = 1$$

EXAMPLE The value –276 = 0xFEEC with data type Signed16 is transferred in two octets, first 0xFE and then 0xEC.

The Signedn data types are transferred as specified in Table 5. Integer data types as Signed1 to Signed7 and Signed9 to Signed15 will be used too. In this case the next element will start at the first free bit position. The grouping of such data types shall end without resulting gaps.

Table 5 – Transfer syntax for data type Signedn

Octet number	1.	2.	3.	4.
Signed8	$b_7 - b_0$	—	—	—
Signed16	$b_{15} - b_8$	$b_7 - b_0$	—	—
Signed32	$b_{31} - b_{24}$	$B_{23} - b_{16}$	$b_{15} - b_8$	$b_7 - b_0$

5.2.5 Octet Array

The data type OctetArray[*length]* is defined below; *length* is the length of the octet array.

ARRAY [length] OF Unsigned8 OctetArray[*length*]

5.3 DLPDU identification

Type SNpTYPE DLPDUs inside an Ehternet frame shall be identified using the EtherType DLPDU field. The EtherType shall contain the value 0x9C40, which is the unique type field number that has been allocated by the IEEE EtherType Field Registration Authority for Type SNpTYPE telegrams.

NOTE This field number refers to Type SNpTYPE communication.

UDP packets are delivered depending on the destination port. For Type SNpTYPE frames inside an UDP datagram, the port shall be 0x9C40, which is the unique port number assigned by the Internet Assigned Numbers Authority (IANA) for Type SNpTYPE.

5.4 General DLPDU structure

5.4.1 Type SNpTYPE frame inside an Ethernet frame

The frame structure for a Type SNpTYPE frame inside an Ethernet frame consists of the data entries as specified in Table 6.

Table 6 – Type SNpTYPE frame inside an Ethernet frame

Frame part	Data field	Data type	Value/description
Ethernet	Dest MAC	BYTE[6]	Destination MAC address as specified in ISO/IEC 8802-3
	Src MAC	BYTE[6]	Source MAC address as specified in ISO/IEC 8802-3
	EtherType	BYTE[2]	0x9C40 (Type SNpTYPE)
	Type SNpTYPE frame	—	As specified in 5.4.4
	Padding	BYTE[n]	Shall be inserted if DLPDU is shorter than 64 octets as specified in ISO/IEC 8802-3
Ethernet FCS	FCS	Unsigned32	Standard Ethernet Checksum coding as specified in ISO/IEC 8802-3

5.4.2 Type SNpTYPE frame inside a VLAN tagged Ethernet frame

The frame structure for a Type SNpTYPE frame inside a VLAN tagged Ethernet frame consists of the data entries as specified in Table 7.

Table 7 – Type SNpTYPE frame inside a VLAN tagged Ethernet frame

Frame part	Data field	Data type	Value/description
Ethernet	Dest MAC	BYTE[6]	Destination MAC address as specified in ISO/IEC 8802-3
	Src MAC	BYTE[6]	Source MAC address as specified in ISO/IEC 8802-3
	VLAN Tag	BYTE[4]	0x8100 (tag protocol identifier) 0xC000 (two bytes tag control information as specified in IEEE 802.1Q)
	EtherType	BYTE[2]	0x9C40 (Type SNpTYPE)
	Type SNpTYPE frame	—	As specified in 5.4.4
	Padding	BYTE[n]	Shall be inserted if DLPDU is shorter than 64 octets as specified in ISO/IEC 8802-3
Ethernet FCS	FCS	Unsigned32	Standard Ethernet Checksum coding as specified in ISO/IEC 8802-3

5.4.3 Type SNpTYPE frame inside an UDP datagram

The frame structure for a Type SNpTYPE frame inside an Ethernet frame consists of the data entries as specified in Table 8.

Table 8 – Type SNpTYPE frame inside an UDP datagram

Frame part	Data field	Data type	Value/description
Ethernet	Dest MAC	BYTE[6]	Destination MAC address as specified in ISO/IEC 8802-3
	Src MAC	BYTE[6]	Source MAC address as specified in ISO/IEC 8802-3
	VLAN Tag (optional)	BYTE[4]	0x8100 (tag protocol identifier) 0xC000 (two bytes tag control information as specified in IEEE 802.1Q)
	EtherType	BYTE[2]	0x0800 (IP)
IP	Version header length	BYTE	0x45 (IP version(4) header length (5*4 octets))
	Service	BYTE	0x00 (IP type of service)
	Total length	Unsigned16	IP total length of service
	Identification	Unsigned16	IP identification packet for fragmented service
	Flags and fragments offset	Unsigned16	IP flags and IP fragment number
	Ttl	BYTE	Time to live
	Protocol	BYTE	0x11 (IP sub-protocol – this value is reserved for UDP)
	Header checksum	Unsigned16	IP header checksum
	Source IP address	BYTE[4]	IP source address of the originator
	Destination IP address	BYTE[4]	IP destination address of the recipient
UDP	Src port	WORD	UDP source port
	Dest port	WORD	0x9C40 (UDP destination port)
	Length	WORD	UDP length of frame
	Checksum	WORD	UDP checksum of frame
	Type SNpTYPE frame	—	As specified in 5.4.4
	Padding	BYTE[n]	Shall be inserted if DLPDU is shorter than 64 octets as specified in ISO/IEC 8802-3
Ethernet FCS	FCS	Unsigned32	Standard Ethernet Checksum coding as specified in ISO/IEC 8802-3
NOTE IP packet structure and coding requirements are as specified in IETF RFC 791.			

5.4.4 Type SNpTYPE frame structure

5.4.4.1 Introduction

The data structure of a Type SNpTYPE frame shall follow the general structure of a Type SNpTYPE frame as specified in Table 9.

Table 9 – General structure of a Type SNpTYPE frame

Frame part	Data field	Data type	Value/description
Type SNpTYPE frame	Header	OCTET[1]	Defines the DLPDU type
	Payload	OCTET[0-1499]	The content of this entry depends on the header information

5.4.4.2 Header

The DLPDU header shall distinguish the various Type SNpTYPE DLPDUs. The DLPDU header structure is shown in Table 10.

Table 10 – DLPDU header structure

Frame part	Data field	Data type	Value/description
Header	Frame type	Unsigned8	Identifies different DLPDU types

5.4.4.3 Payload

All transmitted data are permitted to have arbitrary bit sequences. The structure of data transmitted within payload field depends on the type of Type SNpTYPE DLPDUs.

5.5 Communication management DLPDUs

5.5.1 Network verification DLPDUs

The network verification (NV) DLPDUs are Type SNpTYPE frames and shall follow the structure specified in Table 11, Table 12, Table 13 and Table 14.

Table 11 – Network verification prepare DLPDU

Frame part	Data field	Data type	Value/description
Header	Frame type	Unsigned8	0x10: NV prepare message
NV header	Sequence number	Unsigned16	Continuous sequence number
NV data	MAC RD	BYTE[6]	MAC address of RD

Table 12 – Network verification environment DLPDU

Frame part	Data field	Data type	Value/description
Header	Frame type	Unsigned8	0x11: NV environment message
NV header	Sequence number	Unsigned16	Continuous sequence number
NV data	MAC RD	BYTE[6]	MAC address of the root device
	MAC PD	BYTE[6]	MAC address of the predecessor

Table 13 – Network verification information DLPDU

Frame part	Data field	Data type	Value/description
Header	Frame type	Unsigned8	0x12: NV information message
NV header	Sequence number	Unsigned16	Continuous sequence number
NV data	Identification data	—	Contains identification data of a device as specified in 5.5.3

Table 14 – Network verification acknowledgement DLPDU

Frame part	Data field	Data type	Value/description
Header	Frame type	Unsigned8	0x13: NV acknowledgement message
NV header	ACK sequence number	Unsigned16	Sequence number of acknowledged frame
NV data	ACK type	Unsigned8	Indicates the type of the acknowledged DLPDU

5.5.2 RTFN scan network read DLPDUs

The RTFN scan network read (RTFNSNR) DLPDUs are Type SNpTYPE frames and shall follow the structure specified in Table 15 and Table 16

Table 15 – RTFN scan network read request DLPDU

Frame part	Data field	Data type	Value/description
Header	Frame type	Unsigned8	0x80: RTFN scan network read request

Table 16 – RTFN scan network read response DLPDU

Frame part	Data field	Data type	Value/description
Header	Frame type	Unsigned8	0x81: RTFN scan network read response
RTFNSNR data	Identification data	—	Contains identification data of a device as specified in 5.5.3

5.5.3 Identification data

5.5.3.1 Identification data specification

The identification data field is part of NV DLPDUs as specified in 5.5.1 and RTFNSNR DLPUs as specified in 5.5.2. Identification data shall follow the structure specified in Table 17.

Table 17 – Identification data

Frame part	Data field	Data type	Value/description
Identification data	Version	Unsigned16	Version of the Type SNpTYPE protocol implementation
	SerialNumber	Unsigned32	Serial number of the device
	Vendor ID	Unsigned32	Identifies the vendor
	ProductNumber	Unsigned32	Product number of device
	RevisionNumber	Unsigned32	Revision number of device
	SymbolicDeviceNameSize	Unsigned16	Length of the symbolic device name string in octets
	SymbolicDeviceName	WORD[64]	Symbolic device name
	DeviceType	Unsigned32	0x00: unknown type
	PhyLinkPort1	Unsigned8	Link state of port 1
	PhyLinkPort2	Unsigned8	Link state of port 2
	RTF support	Unsigned8	0x00: no support 0x01: RTFL supported 0x10: RTFN supported 0x11: RTFL and RTFN supported
	IPv4 address	BYTE[4]	IPv4 address of the device
	IPv4 subnet mask	BYTE[4]	IPv4 subnet mask
	IPv4 gateway	BYTE[4]	IPv4 address of default gateway
	IPv4 1. DNS server	BYTE[4]	IPv4 address of 1. DNS server
	IPv4 2. DNS server	BYTE[4]	IPv4 address of 2. DNS server
	IPv6 address	BYTE[16]	IPv6 address of the device
	IPv6 CIDR	Unsigned8	IPv6 category address
	IPv6 1. DNS server	BYTE[16]	IPv6 address of 1. DNS server
	IPv6 2. DNS server	BYTE[16]	IPv6 address of 2. DNS server
	UseDHCP server	Unsigned8	Indicates the usage of a DHCP server
	MAC PD	BYTE[6]	MAC address of the predecessor
	Device MAC	BYTE[6]	MAC address of this device
	DeviceRole	Unsigned8	Indicates the role of this device within the network

5.5.3.2 PhyLinkPortX

The PhyLinkPortX field is part of the identification data and its coding is depicted in Table 18.

Table 18 – PhyLinkPortX

Bit	Value	Description
0 to 1	00	10 MBit/s data transfer rate
	01	100 MBit/s data transfer rate
	10	1 GBit/s data transfer rate
	11	10 GBit/s data transfer rate
2 to 3	00	Reserved
4	0	Half duplex
	1	Full duplex
5	0	Auto negotiation off
	1	Auto negotiation on
6	0	No link
	1	Link
7	0	Port not present
	1	Port present

5.5.3.3 RTF support

The RTF support field is part of the identification data and its coding is depicted in Table 19.

Table 19 – RTF support

Bit	Value	Description
0 to 3	0000	RTFL not supported
	0001	RTFL supported
4 to 7	0000	RTFN not supported
	0001	RTFN supported

5.5.3.4 UseDHCP

The UseDHCP field is part of the identification data and its coding is depicted in Table 20.

Table 20 – UseDHCP

Bit	Value	Description
0 to 3	0000	IPv4 static IP
	0001	IPv4 DHCP
	0010	IPv4 automatic IP
4 to 7	0000	IPv6 static IP
	0001	IPv6 DHCP
	0010	IPv6 automatic IP

5.5.3.5 DeviceRole

The DeviceRole field is part of the identification data and its coding is depicted in Table 21.

Table 21 – DeviceRole

Bit	Value	Description
0	0	RD not supported
	1	RD supported
1	0	Gateway not supported
	1	Gateway supported
2	0	OD not supported
	1	OD supported
3	0	Switch not supported
	1	Switch supported
4	0	PCS not supported
	1	PCS supported
5 to 7	000	Reserved

5.5.4 RTFN connection management DLPDU

The RTFN connection management (RTFNCM) DLPDU is a Type SNpTYPE frame and shall follow the structure specified in Table 22.

Table 22 – RTFN connection management DLPDU

Frame part	Data field	Data type	Value/description
Header	Frame type	Unsigned8	0x40: CDCN subscribe request 0x41: CDCN subscribe acknowledge 0x42: CDCN unsubscribe 0x44: CDCN unpublished
RTFNCM Header	Version	Unsigned8	CDCN protocol version
	ID data count	Unsigned16	Indicates the number of ID data packets listed within ID data data field
RTFNCM data	ID data 1	—	Indicates the 1st process data object of the connection which hast to be established as specified in 5.5.5
	...	—	—
	ID data N	—	Indicates the Nth process data object of the connection which hast to be established as specified in 5.5.5

The CDCN connection still alive DLPDU is a Type SNpTYPE frame and shall follow the structure specified in Table 23.

Table 23 – CDCN connection still alive DLPDU

Frame part	Data field	Data type	Value/description
Header	Frame type	Unsigned8	0x43: CDCN still alive

5.5.5 ID data

The ID data data field is part of the RTFN connection management DLPDU. Its structure is specified in Table 24.

Table 24 – ID data

Frame part	Data field	Data type	Value/description
ID data	Packet ID	Unsigned24	Unique identifier for a process data object
	UseUDP	Unsigned8	Indicates the usage of pure MAC frames or UDP protocol
	IP address	BYTE[4]	IP address of the subscriber

5.5.6 RTFL control DLPDU

The RTFL control (RTFLCTL) DLPDU is a Type SNpTYPE frame and shall follow the structure specified in Table 25.

Table 25 – RTFL control DLPDU

Frame part	Data field	Data type	Value/description
Header	Frame type	Unsigned8	0x30: RTFL control (CL reset)

5.5.7 RTFL configuration DLPDUs

The RTFL configuration (RTFLCFG) DLPDUs are Type SNpTYPE frames and shall follow the structure specified in Table 26 and Table 27.

Table 26 – RTFL configuration DLPDU

Frame part	Data field	Data type	Value/description
Header	Frame type	Unsigned8	0x20: RTFLCFG frame
RTFLCFG header	Sequence number	Unsigned16	Continuous sequence number
RTFLCFG data	Previous MAC address	BYTE[6]	MAC address of the predecessor device
	Next MAC address	BYTE[6]	MAC address of the successor device
	Next MAC alternative	BYTE[6]	MAC address of an alternative successor
	Device address	Unsigned16	Device address of the device
	MSCShortMsgSize	Unsigned16	Indicates maximal message size for un-segmented transfer
	Number of frames	Unsigned8	Indicates the number of frames for CDC and MSC communication channel
	Cycle time	Unsigned32	Indicate the cycle time of the communication cycle
	RTF timeout	Unsigned32	Timeout monitoring
	Master clock DA	Unsigned16	Indicates the device address of the device which integrates the master clock
	IPv4 address	BYTE[4]	IPv4 address of the device
	IPv4 subnet mask	BYTE[4]	IPv4 subnet mask
	IPv4 gateway	BYTE[4]	IPv4 address of default gateway
	IPv4 1. DNS server	BYTE[4]	IPv4 address of 1. DNS server
	IPv4 2. DNS server	BYTE[4]	IPv4 address of 2. DNS server
	IPv6 address	BYTE[16]	IPv6 address of the device
	IPv6 CIDR	Unsigned8	IPv6 category address
	IPv6 1. DNS server	BYTE[16]	IPv6 address of 1. DNS server
	IPv6 2. DNS server	BYTE[16]	IPv6 address of 2. DNS server
	UseDHCP server	Unsigned8	Indicates the usage of a DHCP server

Table 27 – RTFL configuration acknowledgement DLPDU

Frame part	Data field	Data type	Value/description
Header	Frame type	Unsigned8	0x21: RTFLCFG acknowledgement frame
RTFLCFG header	Sequence number	Unsigned16	Continuous sequence number

5.6 Cyclic data channel (CDC) DLPDUs

5.6.1 Cyclic data channel line (CDCL) DLPDU

The CDCL DLPDU is a Type SNpTYPE frame and shall follow the structure specified in Table 28.

Table 28 – CDCL DLPDU

Frame part	Data field	Data type	Value/description
Header	Frame type	Unsigned8	0x02: RTFL CDC write frame 0x03: RTFL CDC read frame
CDCL header	Cycle counter	Unsigned16	Indicates the number of the actual cycle
	Frame counter	Unsigned8	Indicates the number of a frame within a cycle
	Length	Unsigned16	Length in octets of CDC write pointer and cyclic data fields
	CDC write pointer	Unsigned16	Indicates the write section for cyclic communication
CDC payload	CDC data section	OctetArray[x]	Cyclic DLPDU data as specified in 5.7
CDCL status	Status	BYTE[1]	0x00: No failure 0x01: Check of FCS failed

5.6.2 Cyclic data channel network (CDCN) DLPDU

The CDCN DLPDU is a Type SNpTYPE frame and shall follow the structure specified in Table 29.

Table 29 – CDCN DLPDU

Frame part	Data field	Data type	Value/description
Header	Frame type	Unsigned8	0x60: RTFN CDC data frame
CDCN header	Version	Unsigned8	CDCN protocol version
	Size	Unsigned16	Indicates the size of cyclic data field
CDC payload	CDC data section	—	Cyclic DLPDU data as specified in 5.7

5.7 Cyclic data channel (CDC) DLPDU data

5.7.1 Cyclic data channel (CDC) DLPDU data arrangement

The arrangement of real-time data within the CDC data section shall follow the structure as specified in Table 30.

Table 30 – CDC DLPDU data arrangement

Frame part	Data field	Data type	Value/description
CDC data section	CDC packet 1	—	First configurable data object depicting in-/output data of participating devices
	…	—	—
	CDC packet N	—	Nth configurable data object depicting in-/output data of participating devices

5.7.2 Cyclic data channel (CDC) DLPDU data

The CDC DLPDU data is part of CDCL DLPDU as specified in 5.6.1 and CDCN DLPDU as specified in 5.6.2. The structure of CDCL DLPDU data shall be as specified in Table 31.

Table 31 – CDC DLPDU data

Frame part	Data field	Data type	Value/description
CDC packet	PID	Unsigned24	The packet ID uniquely identifies the process data object within a Type SNpTYPE network
	Len	Unsigned8	Length of the CDC DLPDU data packet including PID and Len field in octets
	Data	OctetArray [Len-4]	Process data

5.8 Message channel (MSC) DLPDUs

5.8.1 Message channel line (MSCL) DLPDU

5.8.1.1 Message channel line (MSCL) DLPDU specification

The MSCL DLPDU is a Type SNpTYPE frame and shall follow the structure specified in Table 32.

Table 32 – MSCL DLPDU

Frame part	Data field	Data type	Value/description
Header	Frame type	Unsigned8	0x00: MSC write frame 0x01: MSC read frame
MSCL Header	Cycle counter	Unsigned16	Indicates the number of the actual cycle
	MSCL control	Unsigned8	Contains control bits to set parameters for the communication
	System time	Unsigned64	Indicates the time at which the packet passed the master clock
	Reserved	Unsigned16	Reserved for further usage
	Length	Unsigned16	Length in octets of MSC write pointer and message data fields
	MSC write pointer	Unsigned16	Indicates the next write position in the message data section
	Assigned priority 1 count	Unsigned16	Indicates assigned priority 1 messages (highest priority)
	Assigned priority 2 count	Unsigned16	Indicates assigned priority 2 messages
	Assigned priority 3 count	Unsigned16	Indicates assigned priority 3 messages (lowest priority)
MSC data	MSC-MTP frame 1	—	Message data as specified in 5.9
	…	—	—
	MSC-MTP frame N	—	Message data as specified in 5.9
MSCL status	Status	Unsigned8	0x00: No failure 0x01: Check of FCS failed

5.8.1.2 MSCL control field

The MSCL control field is part of the MSCL DLPDU and its coding is depicted in Table 33.

Table 33 – MSCL control

Bit	Value	Description
0	1	Reset of assigned priority count fields, the previous applied priority reservations are invalid
1	1	Indicates that the line is running in diagnostic mode
2	1 0	Indicates that the PCS clocks are synchronized If a delay measurement is executed this bit is set to 0 until the delay measurement is finished
3	1	Timestamp is used for controlling local clock
4 to 7	0	Reserved for further usage

5.8.2 Message channel network (MSCN) DLPDU

The MSCN DLPDU is a Type SNpTYPE frame and shall follow the structure specified in Table 34.

Table 34 – MSCN DLPDU

Frame part	Data field	Data type	Value/description
Header	Frame type	Unsigned8	0x70: MSCN message
MSC data	MSC-MTP frame	—	Message data as specified in 5.9

5.9 Message channel DLPDU data - MSC message transfer protocol (MSC-MTP)

5.9.1 Overview

This sub-clause specifies the DLPDUs of the MSC message transfer protocol (MSC-MTP) which is used in MSC communication for both communication models RTFL and RTFN.

It provides a segmented and confirmed data transmission. If the data volume to be transferred is small enough, it is transferred using the MSC-MTP without segmentation. The maximum data volume which is transferred without segmentation is configuration dependent.

The MSC message transfer protocol shall be used for confirmed acyclic message exchange within MSCL DLPDUs as specified in 5.8.1 and MSCN DLPDUs as specified in 5.8.2.

5.9.2 MSC-MTP frame

5.9.2.1 MSC-MTP frame specification

The MSC-MTP frame is a Type SNpTYPE frame and shall follow the structure specified in Table 35.

Table 35 – MSC-MTP frame structure

Frame part	Data field	Data type	Value/description
MSC-MTP frame	Addr. type	Unsigned8	Indicates the addressing mode and the priority of the message
	Device DA	Unsigned16	Indicates the device address of the destination 0xFFFF: Broadcast address 0xFFFE: SEF multicast address
	Device SA	Unsigned16	Indicates the device address of the source
	Message length	Unsigned16	Indicates the total size of the MSC-MTP frame in octets
	IP address (optional)	BYTE[4] or BYTE[16]	Indicates the source or destination IP address in the case of extended addressing mode
	MSC-MTP frame data	—	As specified in 5.9.3

5.9.2.2 Address type

The MSC-MTP frame header shall distinguish between normal addressing mode and extended addressing mode. Extended addressing inserts an additional field (IP address) in the message header and facilitates inter-cell acyclic communication.

The address type field is part of the MSC-MTP frame and its coding is depicted in Table 36.

Table 36 – Address type

Bit	Value	Description
0 to 2	0000	Reserved
3 to 4	00	Priority 0 (not used)
	01	Priority 1
	10	Priority 2
	11	Priority 3
5	0	IP version 4
	1	IP version 6
6 to 7	00	Normal addressing mode
	01	Extended addressing mode, IP address is destination address
	10	Extended addressing mode, IP address is source address
	11	Reserved

5.9.3 MSC-MTP frame data

5.9.3.1 Init

The MSC-MTP Init is a Type SNpTYPE frame and shall follow the structure specified in Table 37.

Table 37 – MSC-MTP Init structure

Frame part	Data field	Data type	Value/description
MSC-MTP frame data	CMD	Unsigned3	0x1: Init frame
	Handle	Unsigned5	Identifies the session
	Version	Unsigned8	Indicates the version of the message transfer protocol
	Byte counter	Unsigned32	Indicates the message size

5.9.3.2 Init_Fast

The MSC-MTP Init_Fast is a Type SNpTYPE frame and shall follow the structure specified in Table 38.

Table 38 – MSC-MTP Init_Fast structure

Frame part	Data field	Data type	Value/description
MSC-MTP frame data	CMD	Unsigned3	0x2: Init_Fast frame
	Handle	Unsigned5	Identifies the session
	Version	Unsigned8	Indicates the version of the message transfer protocol
	Byte counter	Unsigned32	Indicates the number of transmitted data octets within this frame
	MSC-MTP message data		Data to be sent as specified in 5.9.4

5.9.3.3 Send

The MSC-MTP Send is a Type SNpTYPE frame and shall follow the structure specified in Table 39.

Table 39 – MSC-MTP Send structure

Frame part	Data field	Data type	Value/description
MSC-MTP frame data	CMD	Unsigned3	0x3: Send frame 0x4: Send_Last frame
	Handle	Unsigned5	Identifies the session
	Byte counter	Unsigned32	Indicates the number of transmitted data octets for this session including the content of this frame
	MSC-MTP message data	—	Segment of data to be sent as specified in 5.9.4

5.9.3.4 Acknowledgement

The MSC-MTP Acknowledgement is a Type SNpTYPE frame and shall follow the structure specified in Table 40.

Table 40 – MSC-MTP Acknowledgement structure

Frame part	Data field	Data type	Value/description
MSC-MTP frame data	CMD	Unsigned3	0x5: Acknowledgement frame
	Handle	Unsigned5	Identifies the session
	Version	Unsigned8	Indicates the version of the message transfer protocol
	Byte counter	Unsigned32	Confirmation of received octets
	MSS	Unsigned16	Maximum segment size

5.9.3.5 Abort

The MSC-MTP Abort is a Type SNpTYPE frame and shall follow the structure specified in Table 41.

Table 41 – MSC-MTP Abort structure

Frame part	Data field	Data type	Value/description
MSC-MTP frame data	CMD	Unsigned3	0x0: Abort frame
	Handle	Unsigned5	Identifies the session to be aborted

5.9.4 MSC-MTP message data encoding

5.9.4.1 Overview

The MSC-MTP message data depicts the payload of the MSC-MTP protocol. The MSC service used by a DLS-user and different DL-services available for the usage by DL-users are based on it.

5.9.4.2 MSC-MTP message data specification

The general structure of message data shall follow the structure specified in Table 42.

Table 42 – Data structure of a message

Frame part	Data field	Data type	Value/description
MSC-MTP message data	MSC service type	Unsigned8	Defines the type of service
	MSC service data	OctetArray[x]	Contains service data

5.10 Time synchronization

5.10.1 DelayMeasurement start

The DelayMeasurement start service shall be encoded as specified in Table 43.

Table 43 – DelayMeasurement start encoding

Frame part	Data field	Data type	Value/description
MSC-MTP message data	MSC service type	Unsigned8	0xF0: Indicates RTFL communication layer service
MSC service data	CL CMD	Unsigned8	0x01: DelayMeasurement start
	CMD handle	Unsigned8	Session identification number
	Repeat count	Unsigned8	Indicates the number of communication cycles used for propagation delay measurement

5.10.2 DelayMeasurement read

The DelayMeasurement read service shall be encoded as specified in Table 44.

Table 44 – DelayMeasurement read encoding

Frame part	Data field	Data type	Value/description
MSC-MTP message data	MSC service type	Unsigned8	0xF0: Indicates RTFL communication layer service
MSC service data	CL CMD	Unsigned8	0x02: DelayMeasurement read
	CMD handle	Unsigned8	Session identification number
	RTFL-delay	Unsigned32	Indicates the average delay between DLPDUs

5.10.3 PCS configuration

The PCS configuration service shall be encoded as specified in Table 45.

Table 45 – PCS configuration encoding

Frame part	Data field	Data type	Value/description
MSC-MTP message data	MSC service type	Unsigned8	0xF0: Indicates RTFL communication layer service
MSC service data	CL CMD	Unsigned8	0x03: PCS configuration
	CMD handle	Unsigned8	Session identification number
	Clock configuration	Unsigned32	Contains the configuration data for clock adjustment

5.10.4 Time synchronization service

The time synchronization service shall be encoded as specified in Table 46 and Table 47.

Table 46 – Time synchronization service request

Frame part	Data field	Data type	Value/description
MSC-MTP message data	MSC service type	Unsigned8	0xF4: Indicates common communication layer service
MSC service data	CL CMD	Unsigned8	0x12: Sync_Start request
	CMD handle	Unsigned8	Session identification number
	Sync ID	Unsigned16	Indicates the network wide unique ID for the requested sync interrupt

Table 47 – Time synchronization service response

Frame part	Data field	Data type	Value/description
MSC-MTP message data	MSC service type	Unsigned8	0xF4: Indicates common communication layer service
MSC service data	CL CMD	Unsigned8	0x13: Sync_Start response
	CMD handle	Unsigned8	Session identification number
	Sync ID	Unsigned16	Indicates the network wide unique ID for the requested sync interrupt
	Start time	Unsigned64	Indicates the start time of the sync interrupt

6 Telegram timing and DLPDU handling

6.1 Communication mechanism

6.1.1 Communication model RTFL

6.1.1.1 Overview

The Type SNpTYPE RTFL DLL transfers data in a cyclic manner. Data transfer is handled by telegram transfer from one device to the next along a logical double line. The line corresponds to the logical addressed device sequence and not necessarily to the physical topology. Therefore it is called a logical line.

Data transmission is initiated by the root device (RD) cyclically generating the RTF Ethernet frames and sending it to the first ordinary device (OD) in the logical line. Each OD in the line receives these Ethernet frames from its predecessor, writes its data into the frames and sends them on to the next OD in the logical line. Addressing and line setup is handled using MAC addresses. Each OD knows the MAC address of its logically next and previous device according to the configuration.

The last OD in the line writes its data to the frame but also reads required data and returns the frame to the logically previous OD. The RTFs are transferred along exactly the same way back to the RD and thus making a double line. In backward direction, the ODs read their relevant data from the RTF. This enables the exchange of data between ODs in one bus cycle.

6.1.1.2 Hardware property

The devices for the Type SNpTYPE RTFL DLL should provide two Ethernet ports. This allows easy set-up of a physical line structure. Figure 3 depicts the preferred hardware properties of a Type SNpTYPE RTFL device.

The frame processing units enable concurrent on-the-fly (cut-through) processing of Type SNpTYPE DLPDUs in forward and backward direction. Data to be sent is written in forward direction while receive data is extracted in backward direction. Time stamping unit (TSU) is required to determine the exact point in time of the receipt of DLPDUs. It is used for PCS to enable the adjustment of the real-time clock.

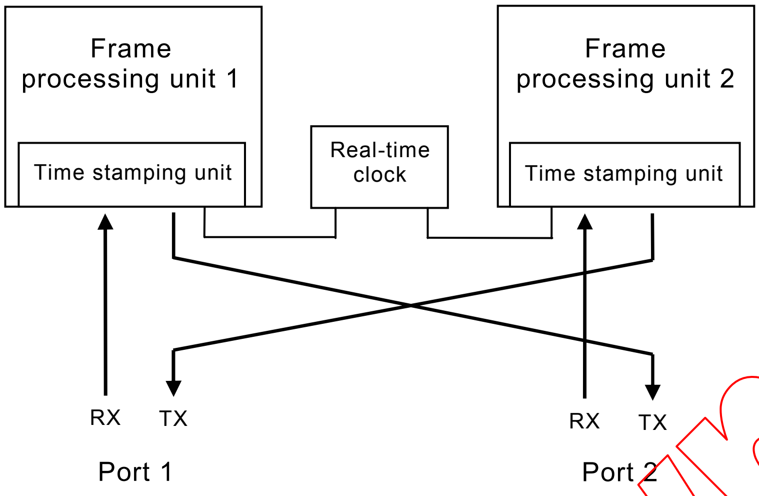


Figure 3 – Block diagram of hardware

6.1.1.3 Frame sequence

The sequence of transmitted Type SNpTYPE DLPDUs shall be repeated every communication cycle. The number and size of frames shall be dependent on the amount of process data and message data and is configuration dependent. Communication is always initiated by the root device.

The DLPDU length of the MSCL and CDCL DLPDUs shall remain constant and thus have the same length at each communication cycle. A communication cycle shall be characterized by the sequence of one MSCL DLPDU followed by at least one CDCL DLPDU. For the necessity of two or more CDCL DLPDUs, the frames shall be transmitted consecutive.

A communication cycle shall start with the MSCL DLPDU. A communication cycle shall be identified using the data field cycle counter as specified in 5.8.1 for MSCL and 5.6.1 for CDCL.

Figure 4 shows an arrangement of CDCL and MSCL DLPDUs. This figure shows an example of possible DLPDU arrangements and does not restrict other combinations which follow the specification stated above.

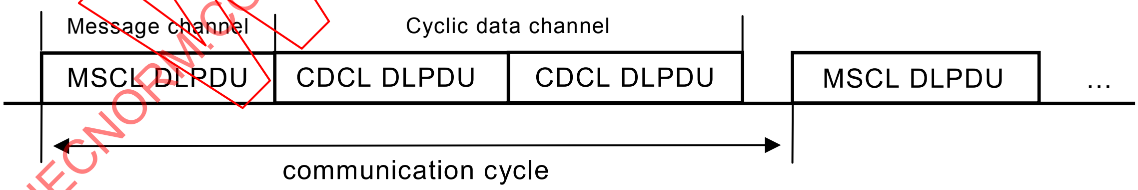


Figure 4 – Frame sequence

6.1.2 Communication model RTFN

The Type SNpTYPE RTFN DLL utilizes point-to-point connections. In order to set up a connection the communication participants use a protocol based on UDP as specified in IETF RFC 768. It is possible to set up several connections between communicating devices.

RTFN communication employs CDC and MSC mechanisms. Depending on the mechanism, communication utilizes either MAC frames or it is based on UDP. The direct MAC frame utilization reduces frame processing delays and is suitable for sending process data. Alternatively, UDP is used for cyclic data with the advantage of routability. For MSC based message exchange, UDP and the MSC-MTP are used. Cyclic and acyclic communication is not based on a common communication cycle.

CDCN is based on cyclic sending of an individual or a sequence of Type SNpTYPE CDCN DLPDUs, depending on the process data volume. The destination device does not acknowledge the receipt of data; error handling in case of packet failure must be provided by the DL-user. A base RTFN cycle time shall be specified for RTFN devices during configuration. This time specifies a lower limit on how often CDCN messages are sent by the RTFN devices.

MSCN is based on acyclic sending of Type SNpTYPE MSCL DLPDUs. Utilizing the MSC-MTP the destination device acknowledges the receipt of data.

Figure 5 illustrates a possible communication relationship between two devices (Device 1 and Device 2). There is exactly one acyclic connection (MSCN) in each direction (connections B and C). Device 1 sends cyclic data using one connection to device 2 (connection A). Device 2 uses two connections to send cyclic data to Device 1. This is useful in the case of the necessity for different cycle times for connection D and E. This figure shows an example of possible communication relationships and does not restrict other combinations.

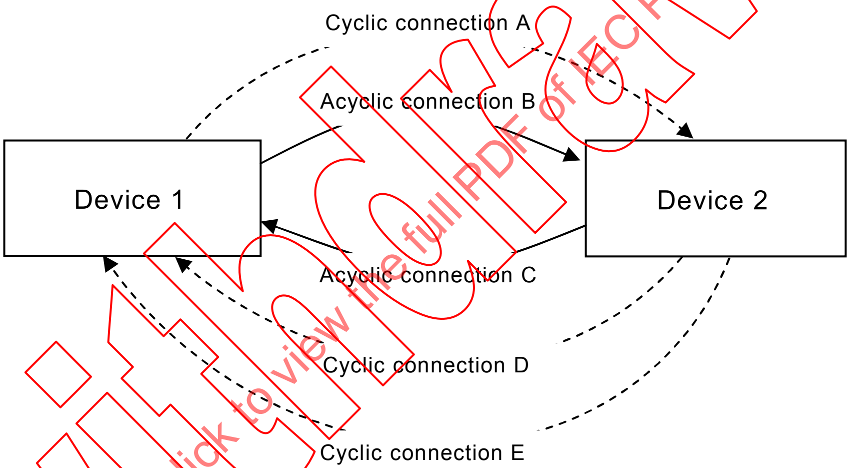


Figure 5 – Communication relationship RTFN device

6.2 Device synchronization

6.2.1 Communication model RTFL – precise clock synchronization

Precise clock synchronization (PCS) is used to synchronize devices. PCS describes a mechanism to maintain synchronized clocks within a Type SNpTYPE RTFL network. Since each device introduces a delay in the forward and backward direction (within the device and on the physical link), the propagation delay time between the global time base and the respective device clock shall be considered during the synchronization of the clocks.

The master clock (MC) within a Type SNpTYPE segment is the global time base. Its clock is used to synchronize the clocks of the other devices. The MC can be externally synchronized according to IEC 61588. It can be integrated into the root device, an ordinary device or incorporated as a stand-alone ordinary device. If the MC is a stand-alone device or an ordinary device, it shall be the first device after the root device.

The master clock shall transmit the system time in each MSCL DLPDU to all slaves. Each OD stores the time when each MSCL DLPDU passes the TSU in forward direction and in backward direction. The difference between these times can be requested by the RD.

Furthermore each OD shall read the system time in forward direction out of the MSCL DLPDU.

The root device shall calculate the network delays during network initialization and operation and take these into account to configure the clock adjustment within ordinary devices. After completion of the delay measurement and the successful configuration of the clock adjustment each OD corrects its time based on the received system time. Furthermore, the RD configures an average time for each OD. If the current difference significantly differs from the average value during normal operation, the OD shall react in sending an error message or in ignoring the current value.

6.2.2 Communication model RTFN

For the necessity of device synchronization, synchronization services according to IEC 61588 shall be used to synchronize RTFN devices. In the case of the necessity for device synchronization, RTFN devices shall act as one of the two basic types of PTP devices:

- ordinary clock; or
- boundary clock.

Additionally, the management node PTP device type may be supported. It can be combined with any of the two PTP device types ordinary clock or boundary clock or it can be integrated within a non-synchronized RTFN device.

7 Type SNpTYPE protocol machines

7.1 RTFL device protocol machines

7.1.1 Overview

Figure 6 depicts the general protocol machine structure within a Type SNpTYPE RTFL device by showing its protocol machines and their interaction.

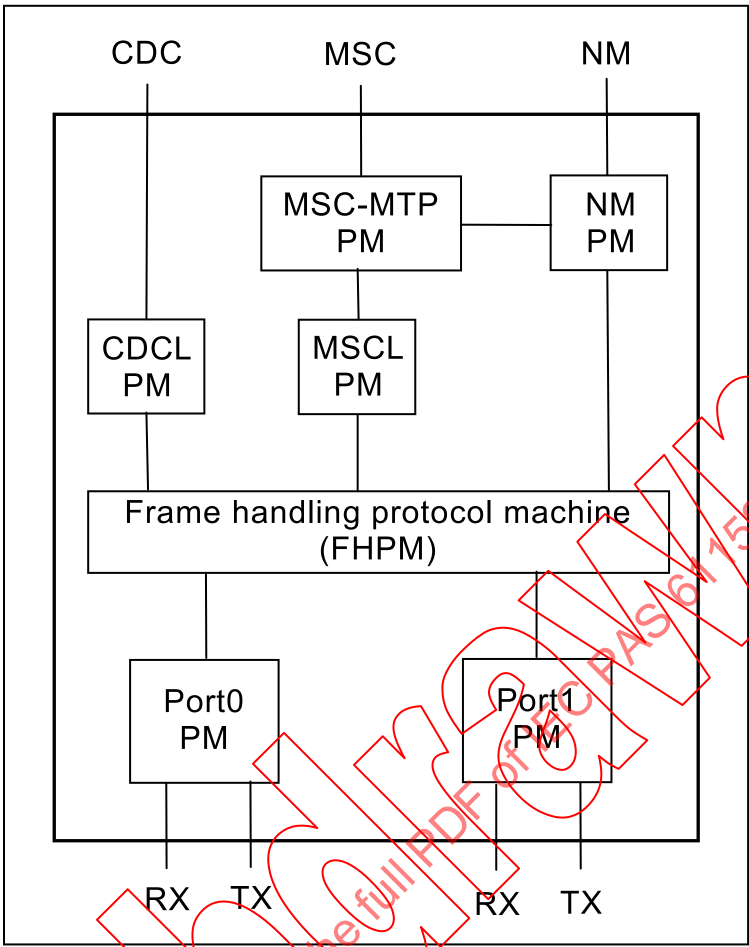


Figure 6 – Overview RTFL device protocol machines

7.1.2 PortX protocol machine (PortX PM)

The PortX PM provides the interconnection between frame handling protocol machine (FHPM) and the reconciliation sublayer and media independent interface of the physical layer according to ISO/IEC 8802-3 for one designated port of a RTFL device. There exists no explicit protocol machine for ports as it follows the rules defined for ports in ISO/IEC 8802-3.

7.1.3 Frame handling protocol machine (FHPM)

The frame handling protocol machine processes the Ethernet frames. FHPM splits incoming frames up and extracts all Type SNpTYPE DLPDUs. It maps the different incoming Type SNpTYPE DLPDUs to the different protocol machines CDCLPM, MSCLPM and NMPM. Furthermore, the arrangement of Type SNpTYPE DLPDUs within outgoing Ethernet frames issued by the protocol machines CDCLPM, MSCLPM, NMPM and PCSPM is handled.

FHPM consists of two independent sub-PMs, each responsible for the frame processing for one logical processing direction (i.e. forward direction for data writing, backward direction for data extraction) and therefore interacting with its corresponding PortX PM. Figure 7 illustrates the protocol machine for sending of Type SNpTYPE DLPDUs.

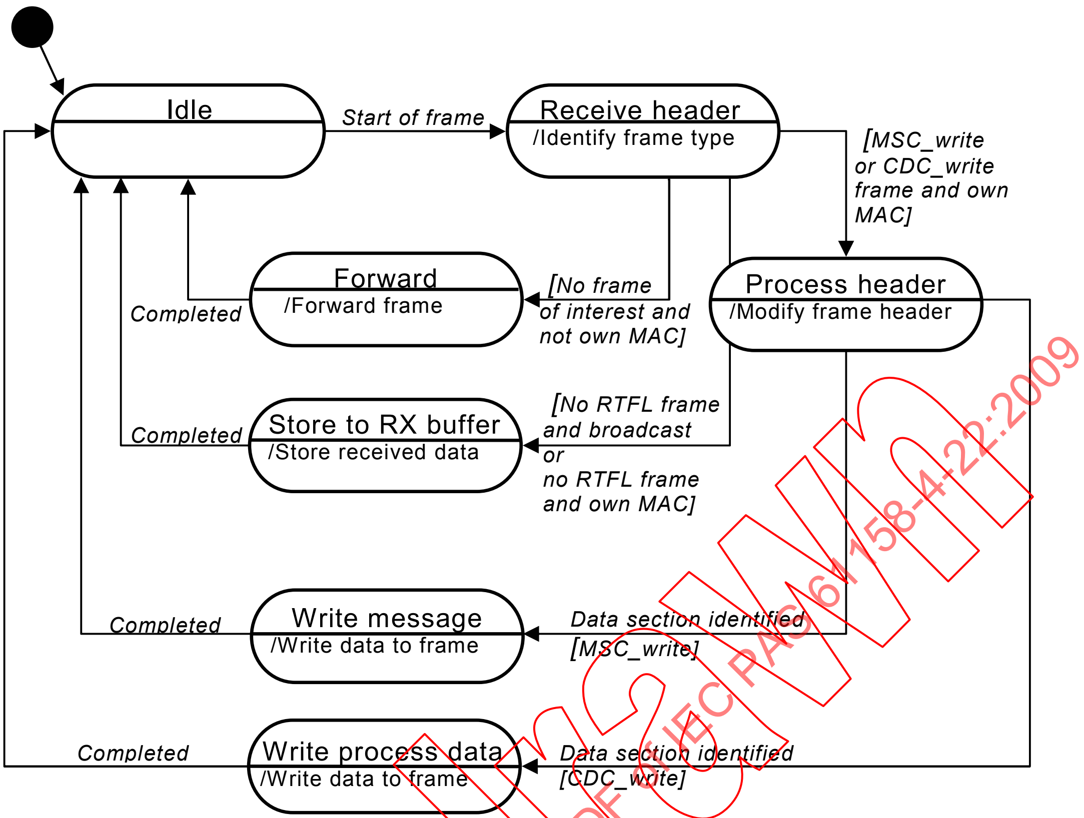


Figure 7 – Protocol machine send DLPDU procedure

Figure 8 illustrates the protocol machine for the receipt of Type SNpTYPE DLPDUs.

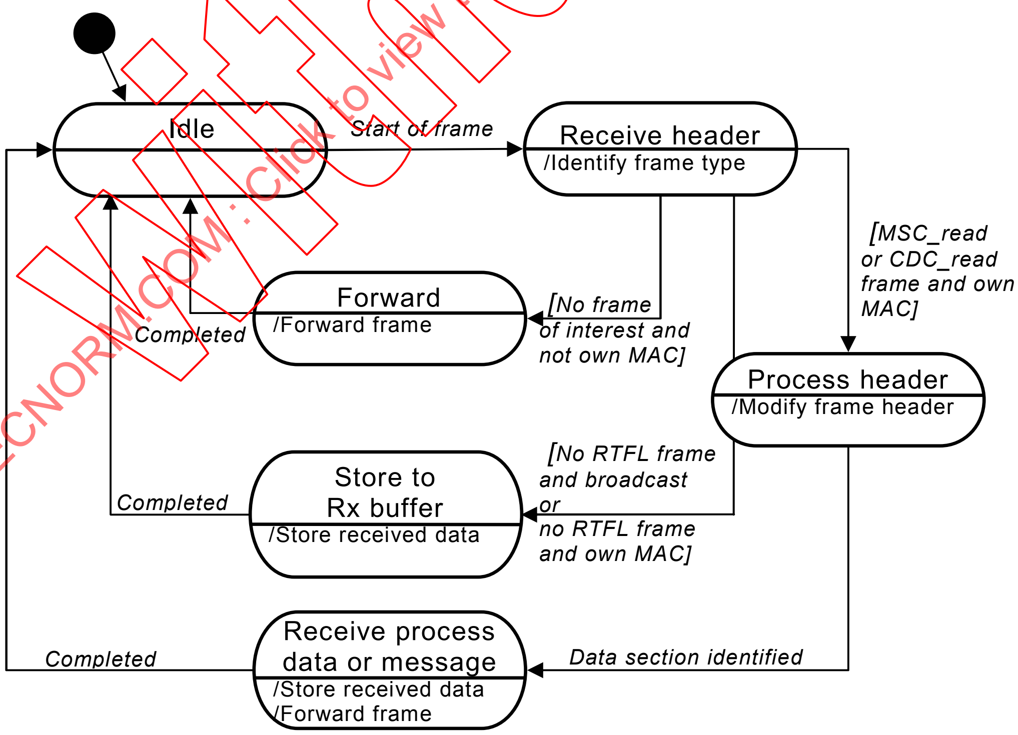


Figure 8 – Protocol machine receive DLPDU procedure

7.1.4 Cyclic data channel line protocol machine (CDCLPM)

7.1.4.1 Overview

CDCL protocol machine handles the exchange of process data objects between DLS-user and FHPM. The CDCLPM combines or extracts process data objects according to the CDCL protocol specified within this part of IEC 61158-4 and forwards the service requests to the FHPM or to the DLS-user.

7.1.4.2 CDCL send sequence

Figure 9 depicts the sequence of necessary actions and operations to send Type SNpTYPE CDC DLPDUs.

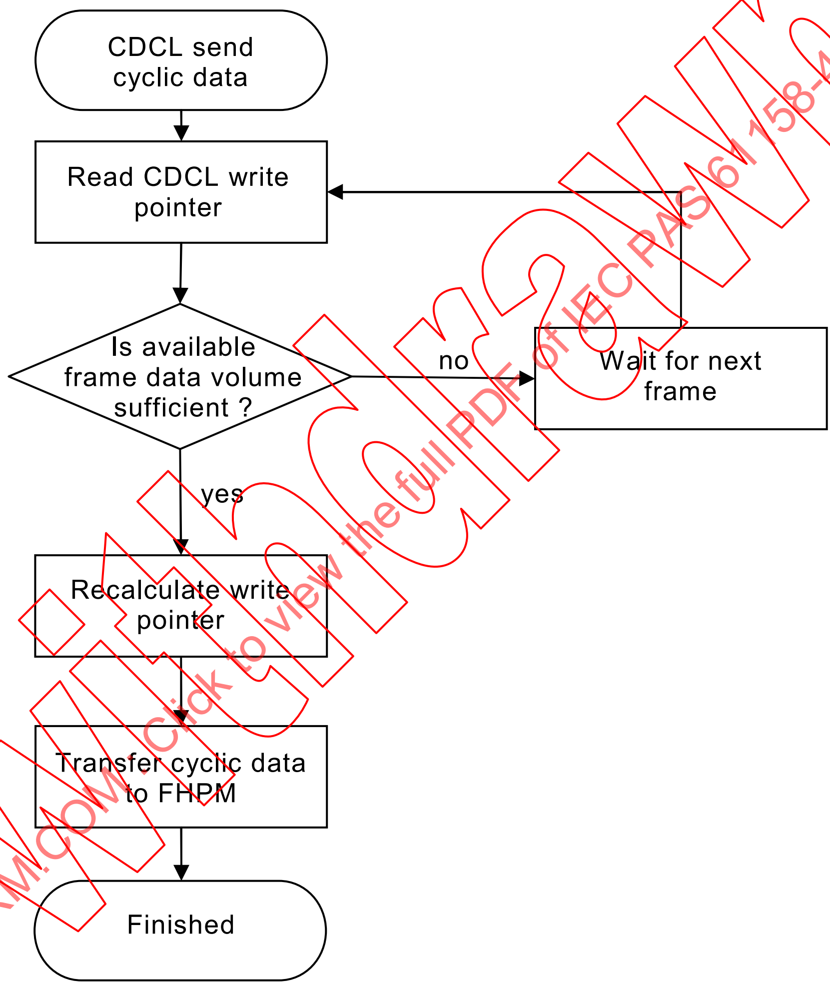
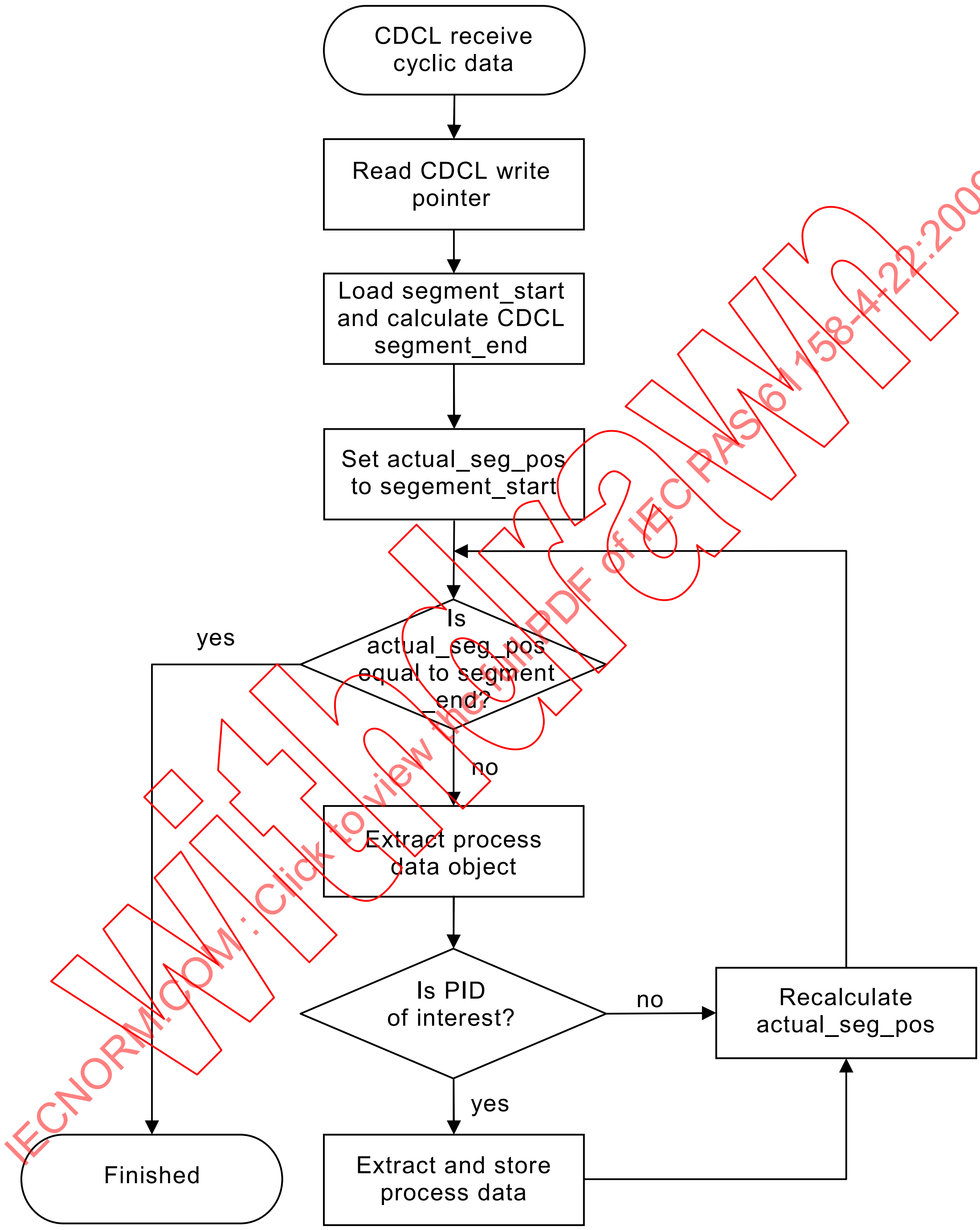


Figure 9 – CDCL send cyclic data sequence

7.1.4.3 CDCL receive sequence

Figure 10 depicts the sequence of necessary actions and operations to receive Type SNpTYPE CDC DLPDUs.



NOTE segment_end, segment_start and actual_seg_pos are symbolic expressions and are used to describe the CDC data section within a CDCL DLPDU as specified in 5.6.1 and the position within this data section

Figure 10 – CDCL receive cyclic data sequence

7.1.5 Message channel line protocol machine (MSCLPM)

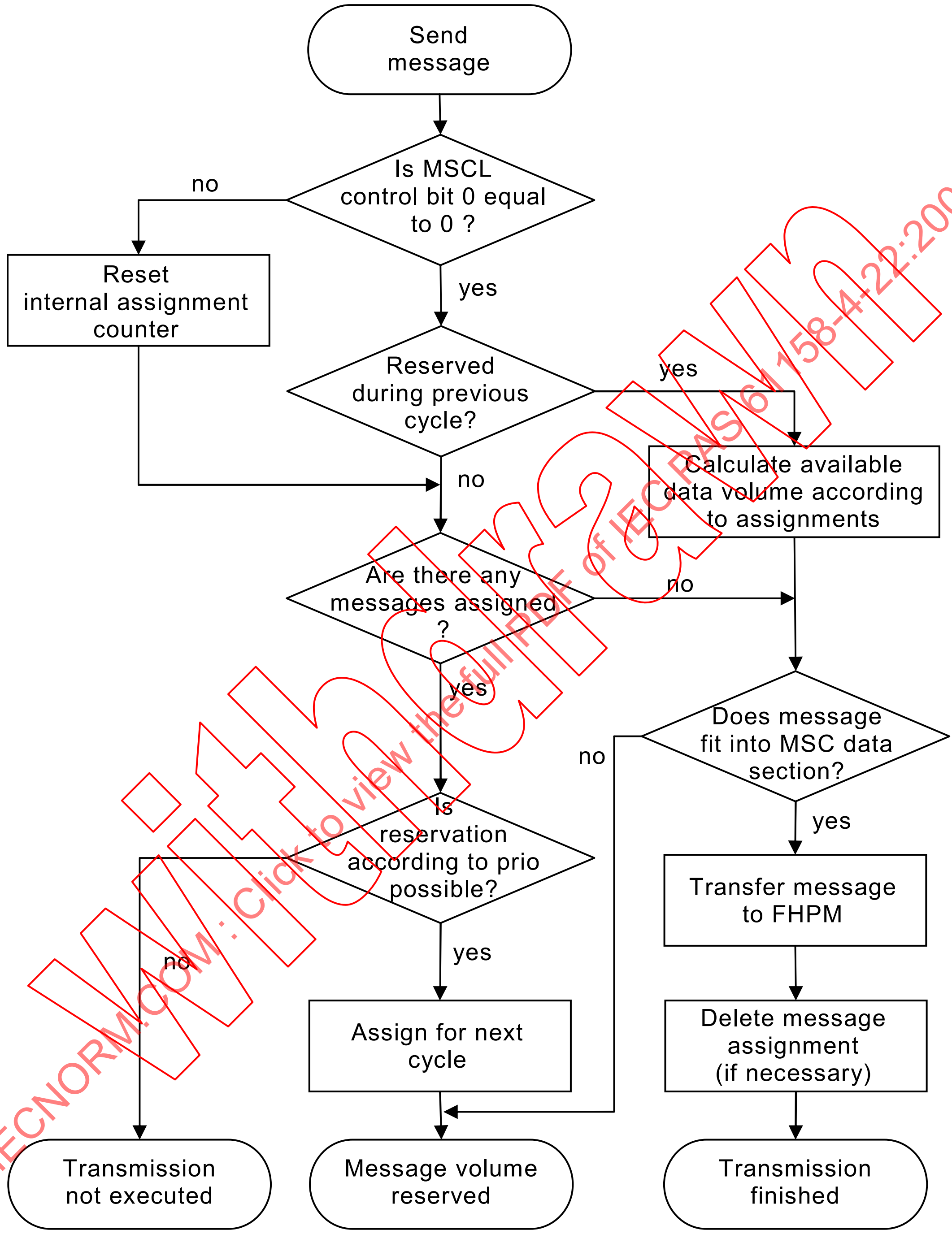
7.1.5.1 Overview

MSCL protocol machine handles the exchange of acyclic message data between MSC-MTP PM and FHPM. The MSCLPM combines or extracts MSC DLPDU data objects according to the MSCL protocol specified within this part of IEC 61158-4 and forwards the service requests and responses to the MSC-MTP PM.

The sending and receiving of MSC DLPDU data objects follows the send and receive sequences depicted in 7.1.5.2 and 7.1.5.3.

7.1.5.2 MSCL send sequence

Figure 11 illustrates the MSCL send sequence used for the transmission of MSC DLPDU data objects within a Type SNpTYPE RTFL device.

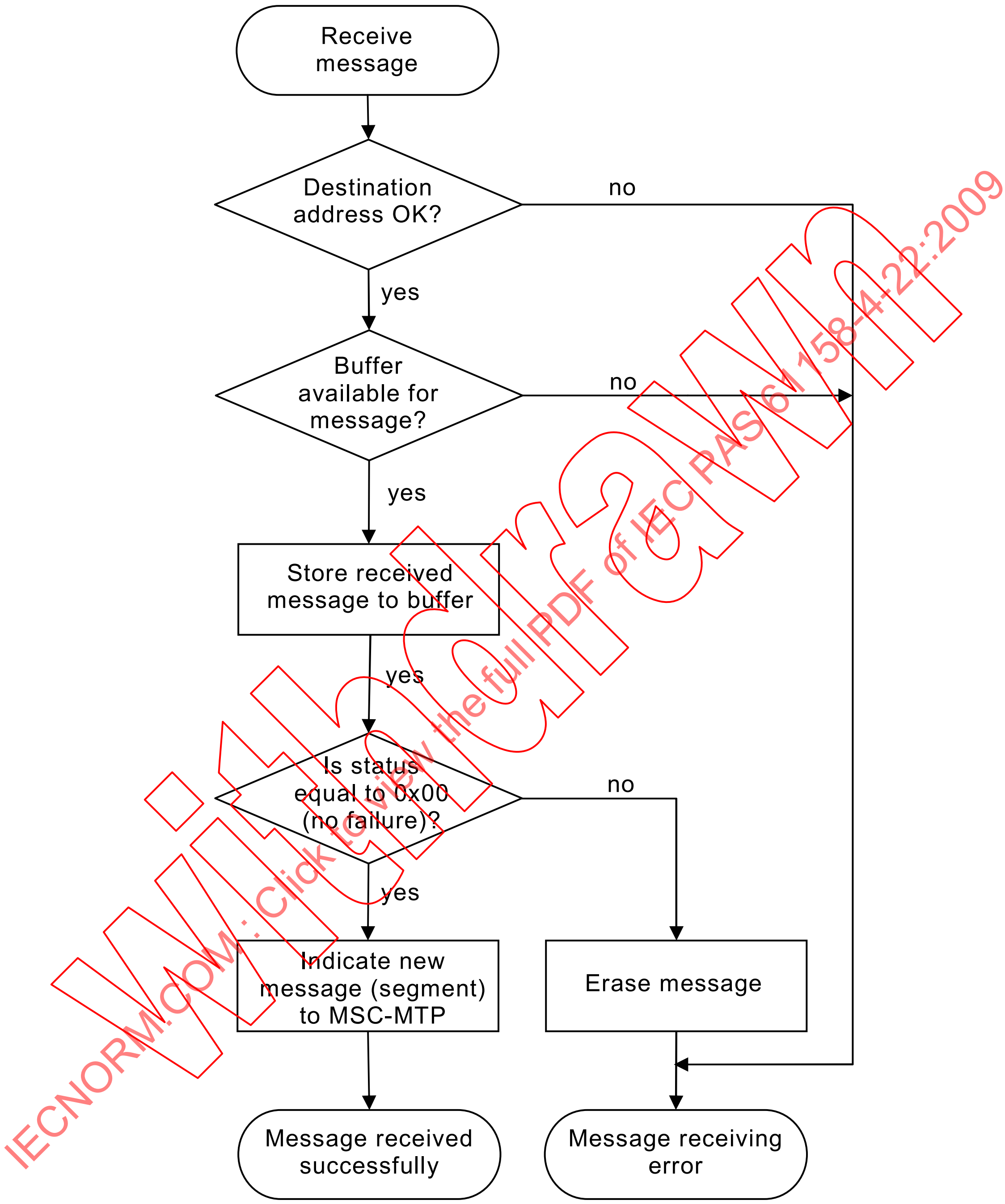


NOTE MSCL control is a particular field of the MSCL DLPDU.

Figure 11 – MSCL send sequence

7.1.5.3 MSCL receive sequence

Figure 12 illustrates the MSCL receive sequence used for the receipt of MSC DLPDU data objects within a Type SNpTYPE RTFL device.



NOTE Status is a particular field of the MSCL DLPDU.

Figure 12 – MSCL receive sequence

7.1.6 Message channel message transfer protocol protocol machine (MSC-MTP PM)

As specified in 7.3.