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Telecommunications and information exchange between information technology systems — Requirements for local and metropolitan area networks —

Part 1CM: **Time-sensitive networking for fronthaul**

AMENDMENT 1: Enhancements to fronthaul profiles to support new fronthaul interface, synchronization, and syntonization standards

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

Partie 1CM: Réseaux à temps critique pour fronthaul

AMENDEMENT 1: Perfectionnement des profils fronthaul pour la prise en charge de la nouvelle interface fronthaul, normes de synchronisation et de recherche

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IEEE Std 802.1CMde™-2020
(Amendment to IEEE Std 802.1CM™-2018)

IEEE Standard for
Local and metropolitan area networks—

Time-Sensitive Networking for Fronthaul

Amendment 1: Enhancements to Fronthaul Profiles to Support New Fronthaul Interface, Synchronization, and Syntonization Standards

Developed by the

LAN/MAN Standards Committee
of the
IEEE Computer Society

Approved 4 June 2020

IEEE SA Standards Board

Abstract: Enhancements to fronthaul profiles are defined in this amendment to IEEE Std 802.1CM™-2018 in order to address new developments in fronthaul interface standards and in related synchronization and syntonization standards.

Keywords: amendment, bridged network, CPRI, eCPRI, F1, fronthaul, IEEE 802®, IEEE 802.1™, IEEE 802.1CM™, IEEE 802.1CMde™, synchronization, time-sensitive networking, TSN, Virtual Local Area Network, VLAN, VLAN Bridge

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Introduction

> This introduction is not part of IEEE Std 802.1CMde-2020, IEEE Standard for local and metropolitan area networks—Time-Sensitive Networking for Fronthaul—Amendment 1: Enhancements to Fronthaul Profiles to Support New Fronthaul Interface, Synchronization, and Syntonization Standards.

This amendment to IEEE Std 802.1CM-2018 defines enhancements to fronthaul profiles in order to address new developments in fronthaul interface standards and in related synchronization and syntonization standards.

The standard contains state-of-the-art material. The area covered by this standard is undergoing evolution. Revisions are anticipated within the next few years to clarify existing material, to correct possible errors, and to incorporate new related material. Information on the current revision state of this and other IEEE 802® standards may be obtained from

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IEEE Standard for
Local and metropolitan area networks—

Time-Sensitive Networking for Fronthaul

Amendment 1: Enhancements to Fronthaul Profiles to Support New Fronthaul Interface, Synchronization, and Syntonization Standards

The amendment is based on IEEE Std 802.1CM-2018.

NOTE—The editing instructions contained in this amendment define how to merge the material contained therein into the existing base standard and its amendments to form the comprehensive standard.

The editing instructions are shown in ***bold italic***. Four editing instructions are used: change, delete, insert, and replace. ***Change*** is used to make corrections in existing text or tables. The editing instruction specifies the location of the change and describes what is being changed by using ~~strikethrough~~ (to remove old material) and underscore (to add new material). ***Delete*** removes existing material. ***Insert*** adds new material without disturbing the existing material. Deletions and insertions may require renumbering. If so, renumbering instructions are given in the editing instruction. ***Replace*** is used to make changes in figures or equations by removing the existing figure or equation and replacing it with a new one. Editing instructions, change markings, and this NOTE will not be carried over into future editions because the changes will be incorporated into the base standard.[1]

1. Overview

1.3 Introduction

Change the dashed list of the second paragraph in 1.3 as shown (text of footnote 3 remains unchanged):

— Virtual Local Area Network (VLAN) Bridge specification in IEEE Std 802.1Q™.[3]
— MAC service specifications in IEEE Std 802.1AC™.
— MAC/PHY technology specifications in IEEE Std 802.3™.
— Interspersing express traffic specification in IEEE Std 802.3~~br~~™.
— Frame preemption specification in IEEE Std 802.1Q.
— Time synchronization and Precision Time Protocol (PTP) specifications in IEEE Std 1588™.
— Telecom profile specification in ITU-T G.8275.1, which is based on IEEE Std 1588.
— Synchronous Ethernet specification in ITU-T G.8261, G.8262, G.8262.1, and G.8264.

[1] Notes in text, tables, and figures of a standard are given for information only and do not contain requirements needed to implement this standard.

2. Normative references

Delete* IEEE Std 802.3br™ *("IEEE ... Ethernet—Amendment 5: ....") from the list of normative references in Clause 2.

Change the following references in Clause 2 as shown (text of footnote 7 remains unchanged):

ITU-T G.8262, Timing characteristics of a synchronous ~~Ethernet~~ equipment slave clock.

MEF 10.~~3~~4, Subscriber Ethernet Service Attributes~~ Phase 3~~.[7]

Insert the following reference into Clause 2 in alphanumeric order:

ITU-T G.8262.1, Timing characteristics of an enhanced synchronous equipment slave clock.

3. Definitions

Change the following definition and footnote in Clause 3 as shown:

Synchronous Ethernet: A method to distribute frequency synchronization over the Ethernet physical layer according to IEEE Std 802.3 and ITU-T Recommendations G.8261, G.8262, G.8262.1, and G.8264.[10]

[10] Synchronous Ethernet has been defined to be fully conformant to IEEE Std 802.3 as documented in the relevant ITU-T Recommendations (G.8261, G.8262, G.8262.1, and G.8264).

4. Acronyms and abbreviations

Delete* TAI *("Temps ... Time") from the list of abbreviations in Clause 4.

Insert the following abbreviation into Clause 4 in alphanumeric order:

NR New Radio access technology (for 5G)

5. Conformance

5.3 Bridge requirements

5.3.1 Common bridge requirements

Change item p) in the lettered list of 5.3.1 as shown:

p) Support flow metering (8.6.5 of IEEE Std 802.1Q-2018) with the token bucket bandwidth profile specified in MEF 10.~~3~~4;

5.4 Bridge options

Change item a) in the lettered list in the introductory text of 5.4 as shown:

a) Support MEF 10.~~3~~4 token sharing for the token bucket bandwidth profile, which is used for flow metering [item p) in 5.3.1; 8.6.5 of IEEE Std 802.1Q-2018];

5.4.1 Bridge requirements for Profile B

Change item b) in the lettered list of 5.4.1 as shown:

b) Support Frame Preemption, i.e.,
   1) Support item ad) in 5.4.1 of IEEE Std 802.1Q-2018 (see also 7.3);
   2) Support Interspersing Express Traffic (Clause 99 of IEEE Std 802.3~~br~~-2018, see also 7.3)~~[13]~~;
   ~~3) Support Frame Preemption and Interspersing Express Traffic on each port whose data rate is not higher than 10Gbps;~~
   3) ~~4)~~ Support the configuration of 64-octet fragment size for Interspersing Express Traffic at each port for which Interspersing Express Traffic is enabled.

5.4.2 Bridge requirements for synchronization

Change items b) and c) in the lettered list of 5.4.2 as shown:

b) Support the ITU-T G.8275.1 telecom profile (full timing support from the network) and one or more of the related clocks:
   1) ~~Support~~ Telecom-Boundary Clock (ITU-T G.8273.2) Class A, B, or C, or
   2) ~~Support~~ Telecom-Transparent Clock (ITU-T G.8273.3), or
   3) ~~Support~~ Primary Reference Time Clock or enhanced Primary Reference Time Clock, and Grandmaster functionality (ITU-T G.8272 or ITU-T G.8272.1);

c) Support Synchronous Ethernet functions ~~(ITU-T G.8264)~~ including the Ethernet Synchronization Messaging Channel (ESMC) (ITU-T G.8264), and the related clock specification, i.e.,
   1) Synchronous Ethernet ~~slave~~equipment clock (ITU-T G.8262), or
   2) Enhanced synchronous Ethernet equipment clock (ITU-T G.8262.1).

~~[13]At the time of publication of this standard, the relevant content of IEEE Std 802.3 was separately published as IEEE Std 802.3br™-2016.~~

5.6 End station options

Change item b) in the lettered list in the introductory text of 5.6 as shown:

b) Support Synchronous Ethernet functions ~~(ITU-T G.8264)~~ including the ESMC (ITU-T G.8264), and the related clock specification, i.e.,
   1) Synchronous Ethernet ~~slave~~equipment clock (ITU-T G.8262), or
   2) Enhanced synchronous Ethernet equipment clock (ITU-T G.8262.1).

5.6.1 End station requirements for time synchronization

Change the introductory text of item b) and the text of item b)1) in the lettered list of 5.6.1 as shown:

b) Support ITU-T G.8275.1 telecom profile (full timing support from the network) and the functionality of one or more of the related clocks that allow the requirements of 6.4 to be met, ~~i.~~e.g.,
   1) Support ~~Telecom-~~Time Slave Clock functionality~~or Telecom-Boundary Clock~~ (e.g., ITU-T G.8273.2), or

6. Fronthaul

Change the first item in the dashed list in the introductory text of Clause 6 as shown:

— Provides background information on aspects of the ~~Evolved Universal Terrestrial R~~radio ~~A~~access ~~(E-UTRA) (3GPP TS 36.211 [B3])~~ technolog~~y~~ies supported by the fronthaul standards that are closely related to this standard (6.1).

Change the title and text of 6.1 as shown:

6.1 ~~Evolved Universal Terrestrial~~ Radio ~~A~~access technology background

The Evolved Universal Terrestrial Radio Access (E-UTRA) specifications (e.g., 3GPP TS 36.211 [B3]) and the New Radio (NR) access technology for 5G specifications (e.g., 3GPP TS 38.211 [B3b]) define precise time intervals for data transmission. ~~E-UTRA time intervals are defined as multiples of the basic time unit: $T_s = 1/(15000 \times 2048)$ s.~~ E-UTRA and NR use~~s~~ Orthogonal Frequency Division Multiplexing (OFDM) where an OFDM symbol is the smallest element of an E-UTRA or NR frame. NR supports a wider range of OFDM numerologies than E-UTRA. In either case, data transmission timing is based on t~~T~~he OFDM symbol time~~ to carry data is $2048 \times T_s$~~. ~~In addition, the full OFDM symbol time includes the time of the cyclic prefix (T_{CP}). In case of normal cyclic prefix, $T_{CP} = 160 \times T_s$ for the first symbol and $T_{CP} = 144 \times T_s$ for the following six symbols. In case of extended cyclic prefix, $T_{CP} = 512 \times T_s$ for each symbol~~.

The timing of packet transmission at an eRE/RE and an eREC/REC in a fronthaul interface supporting E-UTRA or NR is related to the given OFDM symbol times~~ explained above~~. A timing example is shown in Figure 38 in the eCPRI Interface Specification V2.0 [B5].

NOTE—Frame refers to Ethernet frame in this document. ~~OFDM~~E-UTRA frame and NR frame refer~~s~~ to the ~~OFDM~~ frame structure specified by 3GPP standards (see 3GPP TS 36.211 [B3] and 3GPP TS 38.211 [B3b], respectively).

6.2 Class 1 requirements

6.2.3 IQ data requirements

6.2.3.1 Latency

Change 6.2.3.1 as shown:

The maximum end-to-end one-way latency is 100 µs for IQ data between an edge port connected to an REC and another edge port connected to an RE. This maximum end-to-end latency includes the propagation delay of the links between the bridges of the fronthaul bridged network, and internal delays in these bridges. The end-to-end one-way latency is measured from the ~~arrival~~reception of the ~~last~~first bit at the ingress edge port of the bridged network to the transmission of the last bit by the egress edge port of the bridged network (see ~~Annex L.3 of IEEE Std 802.1Q-2018~~ 8.8.1.5 in MEF 10.4).

~~NOTE 1—MEF 10.3 defines one-way frame delay from first bit to last bit (8.8.1 in MEF 10.3).~~

NOTE~~—2~~—No requirement on frame delay variation has been specified; see the CPRI functional decomposition requirements [B7].

6.3 Class 2 requirements

Change 6.3 as shown:

Class 2 refers to fronthaul interfaces where the functional decomposition of an E-UTRA BS (see 3GPP TS 36.104 [B1]) or an NR BS (see 3GPP TS 38.104 [B3a]) into eRE and eREC is inside the radio physical layer (PHY) as specified by the eCPRI Interface Specification [B5]. eCPRI bit rates corresponding to the same end-user data rates are smaller than Common Public Radio Interface Specification [B4] bit rates due to the flexible functional decomposition provided by eCPRI. In the case of Class 2, the eCPRI protocol is used between the eRE and the eREC, and they are connected by a bridged network as described in Clause 8.

6.3.1 eCPRI background

Change the first paragraph of 6.3.1 as shown (text of footnote 19 remains unchanged):

The eCPRI functional decomposition positions the split point inside the radio physical layer (PHY) when dividing a BS into eRE and eREC. The eCPRI Interface Specification [B5] functional split is more flexible than the Common Public Radio Interface Specification [B4] functional split. The fronthaul bridged network connects the eRE and the eREC regardless of the functional decomposition selected for a specific implementation. The intra-PHY splits introduced by eCPRI are called Split $\{I_D;II_D;I_U\}$ (see 6.1.1 in the eCPRI Interface Specification V~~1.1~~2.0 [B5]), which include multiple options.[19]

Change the last paragraph of 6.3.1 as shown:

When used for an E-UTRA or NR BS, eCPRI timing is related to the E-UTRA ~~OFDM~~or NR frame structure and timing described in 6.1.

6.3.2 User Plane data requirements

Change the introductory text of 6.3.2 as shown:

This subclause describes Class 2 User Plane information flows and their requirements. The timing of the transmission of User Plane data by an eRE and an eREC is aligned with E-UTRA or NR OFDM timing (see 6.1), which is periodic. That is, the time windows when one or more packets of a User Plane data flow can be sent are aligned with the given OFDM timing. The traffic of a User Plane data flow carrying user data is correlated with the user data traffic of the corresponding UE (i.e., eRE and eREC exchange user data only when there is user data exchange between UE and BS). Thus, a User Plane data flow can have time windows with no packet. There is a maximum amount of data in a time window for a User Plane data flow. The requirements for User Plane data flows are described in the Requirements for the eCPRI Transport Network V1.2 [B6].

6.3.2.1 Latency

Change 6.3.2.1 as shown (including the addition of a new Table 6-1):

~~The maximum end-to-end one-way latency is 100 µs for the majority of User Plane data between an edge port connected to an eREC and another edge port connected to an eRE. This~~ User Plane (fast) data ~~belongs to the high priority traffic class in~~ has the most stringent latency requirement according to Table 1 in the Requirements for the eCPRI Transport Network V1.~~1~~2 [B6], where this data belongs to the 'High' traffic class. Four latency classes for this data are specified for different use cases in Table 1A in the Requirements for the eCPRI Transport Network V1.2 [B6], a subset of which is listed in Table 6-1. Each corresponds to the maximum end-to-end one-way latency between an edge port connected to an eREC and another edge port connected to an eRE for a given use case. The value 100 µs of the High100 latency class enables full E-UTRA and NR performance.

Table 6-1—Subset of latency classes for the 'High' traffic class

Latency class	Maximum one-way latency
High100	100 µs
High200	200 µs
High500	500 µs

NOTE 1—The High25 latency class for ultra-low latency performance in Table 1A in the Requirements for the eCPRI Transport Network V1.2 [B6] is primarily, but not only, for direct point-to-point fronthaul connections.

The maximum end-to-end latency includes the propagation delay of the links between the bridges of the fronthaul bridged network, and internal delays in these bridges. The end-to-end one-way latency is measured from the ~~arrival~~reception of the ~~last~~first bit at the ingress edge port of the bridged network to the transmission of the last bit by the egress edge port of the bridged network (see ~~Annex L.3 of IEEE Std 802.1Q-2018~~8.8.1.5 in MEF 10.4).

~~NOTE 1—MEF 10.3 defines one-way frame delay from first bit to last bit (8.8.1 in MEF 10.3).~~

NOTE 2—No requirement on frame delay variation has been specified; see the Requirements for the eCPRI Transport Network V1.2 [B6].

The latency requirement is not that strict for User Plane (slow) data, as shown in Table 1 in the Requirements for the eCPRI Transport Network V1.~~1~~2 [B6]. The maximum end-to-end one-way latency from edge port to edge port is 1 ms for User Plane (slow), which belongs to the medium priority traffic class in Table 1 in the Requirements for the eCPRI Transport Network V1.~~1~~2 [B6].

6.3.3 Control and Management Plane data requirements

6.3.3.1 Latency

Change 6.3.3.1 as shown:

According to the Requirements for the eCPRI Transport Network V1.2 [B6], C&M information flows are not as time-critical as the high-priority User Plane (fast) data flows ~~with 100 µs latency budget~~ (6.3.2.1).

The maximum end-to-end one-way latency is 100 ms for the majority of C&M Plane data between an edge port connected to an eREC and another edge port connected to an eRE. This C&M Plane data belongs to the low-priority traffic class in Table 1 in the Requirements for the eCPRI Transport Network V1.~~1~~2 [B6].

The latency requirement is stricter for C&M Plane (fast) in Table 1 in the Requirements for the eCPRI Transport Network V1.~~1~~2 [B6]. The maximum end-to-end one-way latency from edge port to edge port is 1 ms for C&M Plane (fast), i.e., the same as for User Plane (slow) (see 6.3.2.1). Therefore, similarly to User Plane (slow), C&M Plane (fast) also belongs to the medium priority traffic class in Table 1 in the Requirements for the eCPRI Transport Network V1.~~1~~2 [B6].

6.3.3.2 Frame Loss Ratio

Change 6.3.3.2 as shown:

The maximum FLR that the majority of C&M Plane data flows can tolerate is 10^{-6}. This C&M Plane data belongs to the low-priority traffic class in Table 1 in the Requirements for the eCPRI Transport Network V1.~~1~~2 [B6].

The FLR tolerance requirement is stricter for C&M Plane (fast) data flows in Table 1 in the Requirements for the eCPRI Transport Network V1.~~1~~2 [B6], where C&M Plane (fast) belongs to the medium priority traffic class. The maximum tolerable FLR between edge ports of a fronthaul bridged network for a C&M Plane (fast) data flow is 10^{-7}, which is the same as for a User Plane data flow (6.3.2.2).

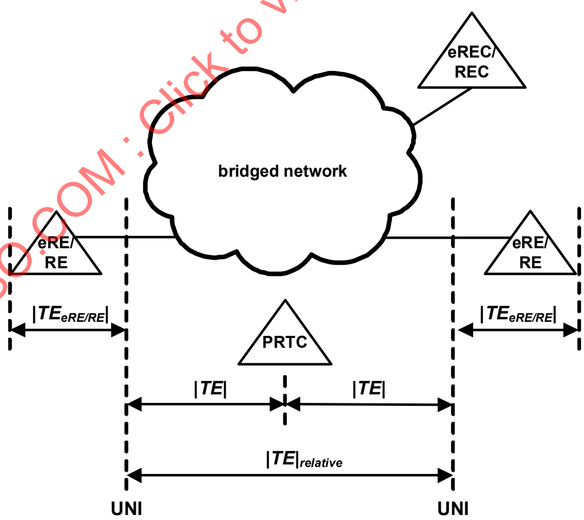
6.4 Synchronization requirements

6.4.1 Time synchronization requirements

Change 6.4.1 as shown (including the deletion of the original Table 6-1):

If the bridged network provides time synchronization, then the following timing accuracy requirements apply. Three~~Four~~ different Categories are defined and distinguished by the Requirements for the eCPRI Transport Network V1.2 [B6] with respect to time synchronization requirements; they are described in 6.4.1.1, 6.4.1.2, and 6.4.1.3~~, and 6.4.1.4~~. Different timing Categories are applicable for different 3GPP features; an example is given for each Category.

Based on ITU-T G.8271.1, synchronization accuracy is specified here using maximum absolute TE (max|TE|) values when the requirement is expressed with respect to an internationally recognized time reference ~~[e.g., the Temps Atomique International (TAI)]~~ or maximum absolute relative TE (max|TE|$_{relative}$) values when the requirement is expressed between two reference points. The subclauses contained herein define the requirements at the input of the eRE/RE. Time ~~e~~Errors (TEs) introduced by the link connected to the eRE/RE are not part of the budget for eRE/RE internal Time Error (|$TE_{eRE/RE}$|) but are included in the max|TE| budget. The different TEs are illustrated in Figure 6-3.



Legend:

PRTC: Primary Reference Time Clock
eRE: eCPRI Radio Equipment
eREC: eCPRI Radio Equipment Control
RE: Radio Equipment
REC: Radio Equipment Control
TE: Time Error
UNI: User Network Interface

Figure 6-3—Time ~~e~~Errors

NOTE 1—Figure 6-3 is based on Figure 7 of the eCPRI transport requirements specification (Requirements for the eCPRI Transport Network V1.~~1~~2 [B6]), which uses the User Network Interface (UNI) definition of MEF 10.~~3~~4.

The following interface condition cases are distinguished:

- Case 1: The Telecom Time Slave Clock (T-TSC) is integrated in eRE/RE, i.e., PTP termination is in eRE/REs. Thus, the eRE/RE has two time budgets: eRE/RE internal TE and integrated T-TSC TE. Case 1 corresponds to deployment case 1 of Figure 7-1 of ITU-T G.8271.1 (10/2017) (illustrated in Figure 6-4). Case 1 includes two sub-cases:
  - Case 1.1: The performance of an integrated T-TSC ~~requirements are the same as~~is assumed to be similar to that of a standalone T-TSC Class B as specified in ITU-T G.8273.2.
  - Case 1.2: ~~Enhanced~~An integrated T-TSC ~~requirements~~is assumed to contribute with a total maximum absolute TE of 15 ns. (See Note 5 in section 4.2 in the Requirements for the eCPRI Transport Network V1.2 [B6].)

NOTE 2—There is no specific requirement for the integrated T-TSC TE and eRE/RE internal TE in Case 1.1 and Case 1.2. The combined TE is what matters.

- Case 2: The T-TSC is not integrated in eRE/REs, i.e., PTP termination is in T-TSC at the edge port, and the phase/time reference is delivered from the T-TSC to the co-located eRE/REs via a phase/time synchronization distribution interface (e.g., 1 PPS and Time of Day). Case 2 corresponds to deployment case 2 of Figure 7-1 of ITU-T G.8271.1 (10/2017) (illustrated in Figure 6-4).

~~According to the Requirements for the eCPRI Transport Network [B6], the budget for eRE/RE internal Time Error (|*TEeRE/RE*|) depends on the Case and the Category as shown in Table 6-1.~~

~~Table 6-1—Budget for eRE/RE internal absolute Time Error~~

	~~Category A+ (6.4.1.1)~~	~~Category A (6.4.1.2)~~	~~Category B (6.4.1.3)~~	~~Category C (6.4.1.4)~~
~~Case 1 (1.1 & 1.2)~~	~~N/A~~	~~20 ns~~	~~20 ns~~	~~20 ns~~
~~Case 2~~	~~22.5 ns~~	~~30 ns~~	~~30 ns~~	~~30 ns~~

~~Category A+ (6.4.1.1),~~ Category A (~~6.4.1.2~~6.4.1.1)~~,~~ and Category B (~~6.4.1.3~~6.4.1.2) requirements are expressed as relative requirements between two points at the edge of the bridged network (instead of relative to a common clock reference). Category C (~~6.4.1.4~~6.4.1.3) requirements are expressed as an absolute requirement at the edge of the bridged network as in ITU-T G.8271.1. Category C (~~6.4.1.4~~6.4.1.3) network limits are not derived from 3GPP requirements, but network limits specified for reference point C in 7.3 of ITU-T G.8271.1 (10/2017) are used (see reference point C in Figure 6-4). Considerations on how to measure network limits on a packet-based interface (e.g., PTP) are provided in Appendix III of ITU-T G.8271.1 (10/2017). The ITU-T has defined individual clock specifications for time distribution to address Category C (~~6.4.1.4~~6.4.1.3) requirements. Their use for other Categories is discussed in 7.4.

NOTE ~~2~~3—eRE/RE clock specification is in scope of the specifications of CPRI Cooperation; it is out of the scope of ITU-T and out of the scope of this document. The budget of the bridged network is important for this document.

NOTE ~~3~~4—ITU-T recommendations under development are expected to support the requirements of Case 1.2 in Categories A and B, and Case 2 in Category~~ies A+ and~~ A.

FLR requirement for PTP is not specified by this standard. Requirements on PTP are described in IEEE Std 1588 and requirements for the PTP telecom profile for phase/time synchronization with full timing support from the network in ITU-T G.8275.1. These requirements do not include explicit requirements on PTP FLR; however, they provide indications on expected FLR levels that can impact PTP performance [see the requirements on message rates as specified in 6.2.8 of ITU-T G.8275.1 (06/2016)].

The requirements for the different Categories are explained in the following subclauses; they are also summarized in Table 2 in the Requirements for the eCPRI Transport Network V1.~~1~~2 [B6].

Category A (6.4.1.1) and Category B (6.4.1.2) requirements are relevant for carrier aggregation radio access technologies (used between two cooperating eRE/REs); see Table II.2 in ITU-T G.8271 (03/2020 [B14a].

Delete 6.4.1.1 ["Category A+," including Equation (6-1)], and renumber the successive subclauses of 6.4.1 accordingly.

6.4.1.1 ~~6.4.1.2~~ Category A

Change the new 6.4.1.1 as shown:

Category A is applicable to Case 1.2 and Case 2. The maximum relative TE can be determined as shown by ~~Equation (6-2)~~ Equation (6-1) and ~~Equation (6-3)~~ Equation (6-2) for the applicable cases:

Case 1.2: $\max|TE|_{relative} = 130\text{ ns} - 2 \times |TE_{eRE/RE}| - 2 \times |TE_{T\text{-}TSC}| \cancel{= 60\text{ ns}}$ ~~(6-2)~~(6-1)

Case 2: $\max|TE|_{relative} = 130\text{ ns} - 2 \times |TE_{eRE/RE}| \cancel{= 70\text{ ns}}$ ~~(6-3)~~(6-2)

where

$|TE_{eRE/RE}|$	is the budget for all respective internal eRE/RE TE
$|TE_{T\text{-}TSC}|$	is the budget for T-TSC TE

~~Equation (6-2)~~ Equation (6-1) and ~~Equation (6-3)~~ Equation (6-2) are derived from section 6.5.3.1 of 3GPP TS 36.104~~-2018~~ v15.4.0 [B1]. The maximum Time Alignment Error is 130 ns.

For example:

— In Case 1.2, a 60 ns budget remains for the maximum relative TE ~~of the bridged network as~~at the input of the eRE/REs if $|TE_{eRE/RE}|$ is 20 ns ~~(see Table 6-1)~~ and $|TE_{T\text{-}TSC}|$ is 15 ns. ($|TE_{T\text{-}TSC}| = 15$ *ns* could be considered similar to the value for an ITU-T G.8273.2 Class C Telecom Time Slave Clock; see section 4.2 in the Requirements for the eCPRI Transport Network V1.2 [B6].)~~.~~

— In Case 2, a 70 ns budget remains for the maximum relative TE ~~of the bridged network as~~at the input of the eRE/REs if $|TE_{eRE/RE}|$ is 30 ns ~~(see Table 6-1)~~.

~~Category A requirements are relevant, e.g., for intra-band contiguous carrier aggregation radio access technology (used between two cooperating eRE/REs).~~

6.4.1.2 ~~6.4.1.3~~ Category B

Change the new 6.4.1.2 as shown:

Category B is applicable to Case 1.1, Case 1.2, and Case 2. The maximum relative TE can be determined as shown by ~~Equation (6-4)~~Equation (6-3), ~~Equation (6-5)~~Equation (6-4), and ~~Equation (6-6)~~ Equation (6-5) for the different cases:

Case 1.1: $\max|TE|_{relative} = 260\text{ ns} - 2 \times |TE_{eRE/RE}| - 2 \times |TE_{T\text{-}TSC}|$~~ = 100 ns~~ ~~(6-4)~~(6-3)

Case 1.2: $\max|TE|_{relative} = 260\text{ ns} - 2 \times |TE_{eRE/RE}| - 2 \times |TE_{T\text{-}TSC}|$~~ = 190 ns~~ ~~(6-5)~~(6-4)

Case 2: $\max|TE|_{relative} = 260\text{ ns} - 2 \times |TE_{eRE/RE}|$~~ = 200 ns~~ ~~(6-6)~~(6-5)

where

$|TE_{eRE/RE}|$ is the budget for all respective internal eRE/RE TE
$|TE_{T\text{-}TSC}|$ is a budget for T-TSC TE

~~Equation (6-4)~~Equation (6-3), ~~Equation (6-5)~~Equation (6-4), and ~~Equation (6-6)~~ Equation (6-5) are derived from section 6.5.3.1 of 3GPP TS 36.104 v15.4.0 [B1]. The maximum Time Alignment Error is 260 ns.

For example:

— In Case 1.1, a 100 ns budget remains for the maximum relative TE ~~of the bridged network as~~at the input of the eRE/REs if $|TE_{eRE/RE}|$ is 20 ns ~~(see Table 6-1)~~ and $|TE_{T\text{-}TSC}|$ is 60 ns. ($|TE_{T\text{-}TSC}|$ = 60 ns is on the order of the value for an ITU-T G.8273.2 Class B Telecom Time Slave Clock, where $|TE_{T\text{-}TSC}| = |cTE_{T\text{-}TSC}| + |dTE_{T\text{-}TSC}|$ = 20 ns + 40 ns = 60 ns, ~~according to ITU-T G.8273.2 Class B Telecom Time Slave Clock, where~~ cTE is constant TE, and dTE is dynamic TE.)~~.~~
— In Case 1.2, a 190 ns budget remains for the maximum relative TE ~~of the bridged network as~~at the input of the eRE/REs if $|TE_{eRE/RE}|$ is 20 ns ~~(see Table 6-1)~~ and $|TE_{T\text{-}TSC}|$ is 15 ns. ($|TE_{T\text{-}TSC}|$ = 15 ns could be considered similar to the value for an ITU-T G.8273.2 Class C Telecom Time Slave Clock, see section 4.2 in the Requirements for the eCPRI Transport Network V1.2 [B6].)~~.~~
— In Case 2, a 200 ns budget remains for the maximum relative TE ~~of the bridged network as~~at the input of the eRE/REs if $|TE_{eRE/RE}|$ is 30 ns ~~(see Table 6-1)~~.

~~Category B requirements are relevant, e.g., for intra-band non-contiguous and inter-band carrier aggregation radio access technologies (used between two cooperating eRE/REs).~~

6.4.2 Frequency synchronization requirements

Change the first and second paragraphs of 6.4.2 as shown (text of footnote 20 remains unchanged):

The frequency synchronization requirements are based on 3GPP TS 36.104 [B1]. As applied to the bridged network, they are related to the need for the eRE/RE to recover a timing signal that meets the applicable synchronization requirements on the radio interface. In particular, ±50 ppb (on the short term of a 1 ms observation window) is required on the radio air interface (3GPP TS 36.104 [B1]) at the output of the eRE/RE. In worst case, the network should deliver at least ±16 ppb (on the long term) at the input of the eRE/RE.[20] The use of PTP and (optionally) Synchronous Ethernet by eRE/RE is possible only if the eRE/RE can filter network noise so that the total of all frequency errors is less than the 3GPP limit of ±50 ppb (on the short term).

When frequency synchronization is recovered via Synchronous Ethernet (ITU-T G.8262) or enhanced Synchronous Ethernet (ITU-T G.8262.1), the applicable requirements at the input of the eRE/RE are defined by the Synchronous Ethernet network limits in 9.2.1 of ITU-T G.8261 (08/2019).

7. Bridge and synchronization functions

7.3 Frame preemption

Change 7.3 as shown:

Frame preemption is the suspension of the transmission of a preemptable frame to allow one or more express frames to be transmitted before the transmission of the preemptable frame is resumed. IEEE Std 802.3~~br~~ specifies the MAC Merge sublayer, which supports interspersing express traffic with preemptable traffic.~~[21]~~ The MAC Merge sublayer supports two ways to hold the transmission of preemptable traffic in the presence of express traffic (until subsequent release): the MAC Merge sublayer can preempt (interrupt) preemptable traffic being currently transmitted, and the MAC Merge sublayer can prevent starting the transmission of preemptable traffic (see 99.1 of IEEE Std 802.3~~br~~-201~~6~~8). The IEEE 802.1Q bridge forwarding process optionally supports frame preemption. The benefits provided by frame preemption decrease as the data rate of a bridge port increases.

Frame preemption takes some time; the express frame cannot be transmitted immediately. If frame preemption is possible, then the express frame can be transmitted only after the transmission of the current fragment of the preemptable frame including the Cyclic Redundancy Check (CRC) of the frame and the Inter Packet Gap (IPG). Preemption occurs only if at least 60 octets of the preemptable frame have been transmitted and at least 64 octets (including the frame CRC) remain to be transmitted. The earliest starting position of preemption is controlled by the addFragSize variable, which is a 2-bit integer value indicating, in units of 64 octets, the minimum number of octets over 64 octets required in non-final fragments by the receiver (see 99.4.4 and 79.3.7 of IEEE Std 802.3~~br~~-201~~6~~8). Preemption happens within $(1240 + 512 \times \text{addFragSize})$ bit times. That is, the worst case is 1240 bit times when addFragSize = 0, which is used for the worst-case calculations in this document.

If PTP messages are carried by express frames or by frames that are smaller than 124 octets, then they are not preempted.

7.4 Network synchronization

Change item a)3) in the lettered list in the introductory text of 7.4 as shown (Figure 7-2 and NOTE 1 remain unchanged):

3) *Timing distribution to a cluster of eRE/REs from the nearest common master / boundary clock.* An example is shown in Figure 7-2, where the nearest common master / boundary clock is implemented in Node *n*, which is the starting point from where the relative phase deviation can be calculated. This allows for a relatively short synchronization chain, with target performance in terms of maximum absolute TE, relative to Node *n*, depending on the length of the chain and the characteristics of the PTP clocks. As an example, 100 ns can be met in a short chain (e.g., two hops) with properly performing clocks (e.g., Class B or Class C of ITU-T G.8273.2).

Change item a)4) in the lettered list in the introductory text of 7.4 as shown (Figure 7-3 and NOTE 2 remain unchanged):

4) *General deployment* as described by an appropriate PTP profile, e.g., as described by the time synchronization architecture as per ITU-T G.8275 [B16], the telecom profile as per ITU-T G.8275.1 with network characteristics as per ITU-T G.8271.1 and clocks as per ITU-T G.8273.2

~~[21]At the time of publication of this standard, the relevant content of IEEE Std 802.3 was separately published as IEEE Std 802.3br-2016.~~

[Telecom-Boundary Clock (T-BC)] and ITU-T G.8273.3 [Telecom-Transparent Clock (T-TC)]; see example in Figure 7-3. In this case, the target performance in terms of maximum absolute TE relative to an internationally recognized time reference ~~(e.g., TAI)~~ is 1.1 µs at the input of the end station in order to meet 1.5 µs at the output of the end station (including some budget for synchronization network rearrangements).

Change item b) in the lettered list in the introductory text of 7.4 as shown (NOTE 3 remains unchanged):

b) *Physical layer frequency synchronization* (e.g., SyncE). This is specified by ITU-T (G.8261, G.8262, G.8262.1, and G.8264) as a way to deliver frequency synchronization over the physical layer. Synchronous Ethernet support of PTP operations is assumed in ITU-T G.8275.1 based networks (and ITU-T G.8273.2 clocks); an end station can use it for the purpose of frequency synchronization and/or to support PTP operations.

Change item c) in the lettered list in the introductory text of 7.4 as shown (NOTE 4 remains unchanged):

c) *Global Navigation Satellite System (GNSS) or Regional Navigation Satellite System at the eRE/REs*. Examples of satellite systems are Global Positioning System (GPS), Global Navigation Satellite System (GLONASS), Galileo, BeiDou Navigation Satellite System (BDS), Indian Regional Navigation Satellite System (IRNSS), and ~~Galileo~~Quasi-Zenith Satellite System (QZSS). The expected accuracy in typical installations is of the order of 100 ns. As a reference, ITU-T G.8272 (PRTC specification) specifies 100 ns, and ITU-T G.8272.1 specifies 30 ns for enhanced PRTC in a central location.

8. Fronthaul profiles

Change the second paragraph of the introductory text of Clause 8 as shown:

Profile A (8.1) and Profile B (8.2) are applicable to both Class 1 (6.2) and Class 2 (6.3) because the two Classes have similar requirements. Three types of fronthaul flows can be distinguished based on their requirements. Based on Table 1 in the Requirements for the eCPRI Transport Network V1.~~1~~2 [B6], this document refers to the three types of fronthaul flows and corresponding fronthaul traffic classes as follows:

Change item a) and item b) in the lettered list in the introductory text of Clause 8 as shown:

a) High Priority Fronthaul (HPF) data, which includes Class 1 IQ data (6.2.3) and Class 2 User Plane (fast) data (see Table 1 and Table 1A in the Requirements for the eCPRI Transport Network V1.2 [B6] and 6.3.2)~~ with 100 µs maximum end-to-end one-way latency~~;

b) Medium Priority Fronthaul (MPF) data, which has 1 ms maximum end-to-end one-way latency, thus includes Class 2 User Plane (slow) data and Class 2 C&M Plane (fast) data (see Table 1 in the Requirements for the eCPRI Transport Network V1.~~1~~2 [B6], and 6.3.2.1 and 6.3.3, respectively);

Change the third paragraph in the introductory text of Clause 8 as shown:

As Class 1 IQ data [item a) in 6.2.1] and Class 2 User Plane data [item a) in 6.3.1] belong to HPF [preceding item a)], they are treated the same way in Profile A (8.1) and Profile B (8.2). Thus, Class 2 User Plane data flows are considered as if they were CBR data flows, i.e., a User Plane data flow had the same amount of data in each time window (6.3.2). There are Class 2 User Plane data flows that do not use all the bandwidth allocated in the bridged network due to the time windows with no packet (6.3.1). This unused bandwidth can be used by any other traffic, whether fronthaul or not.

Change the fourth paragraph in the introductory text of Clause 8 as shown:

Class 2 User Plane (slow) data and Class 2 C&M Plane (fast) data belong to MPF [preceding item b)] because they have similar requirements (see Table 1 in the Requirements for the eCPRI Transport Network V1.~~1~~2 [B6]).

8.1 Profile A

8.1.3 Meeting latency targets

Change the third paragraph of 8.1.3 as shown:

The propagation delay [$t_{Propagation}$, item d) in 7.1] can be a significant part of the end-to-end latency. For instance, if the distance between eRE/RE and eREC/REC is 10 km, then the propagation delay is roughly 50 µs, which is half of the 100 µs end-to-end one-way latency budget of ~~HPF data~~the High100 latency class (~~6.2.3.1, ~~6.3.2.1).

Change the last two paragraphs of 8.1.3 as shown (text of footnote 22 remains unchanged):

In order to avoid ingress traffic exceeding the amount considered during network design, flow metering (8.6.5 of IEEE Std 802.1Q-2018) with the MEF 10.~~3~~4 bandwidth profile per traffic class is used at the ingress of the bridged network. Therefore, edge bridges of a fronthaul bridged network shall implement the

MEF 10.~~3~~4 token bucket bandwidth profile, which is configured such that excess HPF traffic is discarded in order to meet the HPF requirements. That is, the ingress HPF traffic is limited to the amount that is considered during network design, e.g., for worst-case delay calculations.

The network is configured to avoid starvation of MPF and LPF traffic taking into account their bandwidth requirements.[22] Furthermore, the bandwidth design is enforced with MEF 10.~~3~~4 bandwidth profile per traffic class at the ingress of the bridged network. That is, bandwidth profile is configured to limit ingress HPF, MPF, and LPF traffic to the amount that is considered during network design. Excess HPF and MPF traffic is configured to be discarded in order to avoid starvation of LPF. Excess LPF traffic can be allowed. The bandwidth profile can be configured such that unused bandwidth assigned to HPF and MPF is available to lower priority traffic classes. That is, token sharing may be enabled from HPF and MPF to lower priority traffic classes (see ~~Annex C~~Appendix D in MEF 10.~~3~~4). For instance, non-fronthaul traffic can use the bandwidth not used by fronthaul traffic.

8.2 Profile B

8.2.3 Meeting latency targets

Change the last paragraph of 8.2.3 as shown:

The worst-case queuing delay for HPF is as explained in 8.1.3 because MPF and LPF are not preemptable. That is, the total worst-case end-to-end latency for an HPF data information flow can be calculated according to Equation (8-1) as explained in 8.1.3. MEF 10.~~3~~4 bandwidth profile per traffic class is used at the ingress of the bridged network in order to meet the latency targets of fronthaul traffic. Bandwidth profiles are configured as described in 8.1.3.