

IEEE Standard for Local and metropolitan area networks— Time-Sensitive Networking for Fronthaul

IEEE Computer Society

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LAN/MAN Standards Committee

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USA

IEEE Std 802.1CM™-2018

**IEEE Standard for
Local and metropolitan area networks—**

Time-Sensitive Networking for Fronthaul

Sponsor

**LAN/MAN Standards Committee
of the
IEEE Computer Society**

Approved 7 May 2018

IEEE-SA Standards Board

Abstract: This standard defines profiles that select features, options, configurations, defaults, protocols, and procedures of bridges, stations, and LANs that are necessary to build networks that are capable of transporting fronthaul streams, which are time sensitive.

Keywords: bridged network, fronthaul, IEEE 802[®], IEEE 802.1[™], IEEE 802.1CM[™], 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 802.1CM-2018, IEEE Standard for Local and metropolitan area networks—Time-Sensitive Networking for Fronthaul.

This standard defines profiles that select features, options, configurations, defaults, protocols and procedures of bridges, stations, and LANs that are necessary to build networks that are capable of transporting fronthaul streams, which are time-sensitive.

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IEEE Standard for Local and metropolitan area networks—

Time-Sensitive Networking for Fronthaul

1. Overview

1.1 Scope

This standard defines profiles that select features, options, configurations, defaults, protocols and procedures of bridges, stations, and LANs that are necessary to build networks that are capable of transporting fronthaul streams, which are time-sensitive.

NOTE—Stream and flow are used as synonyms in this document.¹

1.2 Purpose

The purpose of this standard is to specify defaults and profiles that enable the transport of time-sensitive fronthaul streams in Ethernet bridged networks.

1.3 Introduction

Fronthaul provides connectivity between functional blocks of a cellular base station (BS). The fronthaul flows between these functional blocks have stringent quality of service requirements. The successful support of fronthaul flows in a bridged network requires the selection of specific features and options that are specified in a number of different standards, some developed by IEEE Project 802[®], and others (in particular, those that relate to functionality in OSI layer 3 and above; ISO/IEC 7498:1994 [B11]) developed by other standards organizations.²

This standard selects features and options that support OSI layers 1 and 2 in bridges and end stations from the following specifications:

- Virtual Local Area Network (VLAN) Bridge specification in IEEE Std 802.1QTM.³
- MAC service specifications in IEEE Std 802.1ACTM.

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

²The numbers in brackets correspond to those of the bibliography in Annex C

³Information on references can be found in Clause 2.

- MAC/PHY technology specifications in IEEE Std 802.3™.
- Interspersing express traffic specification in IEEE Std 802.3br™.
- 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, and G.8264.

To specify and explain the selection of features and options, this standard:

- a) Describes fronthaul requirements (Clause 6), specifying two classes of requirements (6.2, 6.3) that depend on the BS functional decomposition, and specifying synchronization requirements (6.4) that apply to both classes.
- b) Describes how the operation of bridges and bridged networks affects the quality of service provided by the fronthaul bridged network (Clause 7), providing details to assist in the calculation of latency (7.1, 7.2, 7.3), the selection of network synchronization methods (7.4), and the potential impact of the use of flow control (7.5) and Energy Efficient Ethernet (EEE, 7.6).
- c) Specifies two bridge profiles (Clause 8) that support the construction of bridged networks meeting fronthaul requirements. Profile A (8.1) is applicable to bridges that do not support frame preemption (7.3), while Profile B (8.2) involves frame preemption to accommodate larger non-fronthaul flows and frame sizes while preserving fronthaul traffic guarantees.
- d) Discusses the applicability (Clause 9) of the synchronization methods described in 7.4 to the time synchronization categories defined in 6.4.1.
- e) Defines fronthaul profile conformance requirements (Clause 5) for bridges meeting either Profile A or Profile B requirements, for end stations and for synchronization.
- f) Provides a Profile Conformance Statement (PCS, Annex A) to support clear detailed statements of equipment conformance to fronthaul profile requirements.

2. Normative references

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

IEEE Std 802[®], IEEE Standard for Local and Metropolitan Area Networks—Overview and Architecture.^{4, 5}

IEEE Std 802.1AC[™], IEEE Standard for Local and Metropolitan Area Networks—Media Access Control (MAC) Service Definition.

IEEE Std 802.1Q[™], IEEE Standard for Local and Metropolitan Area Networks—Bridges and Bridged Networks.

IEEE Std 802.3[™], IEEE Standard for Ethernet.

IEEE Std 802.3br[™], IEEE Standard for Ethernet—Amendment 5: Specification and Management Parameters for Interspersing Express Traffic.

IEEE Std 1588[™], IEEE Standard for a Precision Clock Synchronization Protocol for Networked Measurement and Control Systems.

ITU-T G.8261, Timing and synchronization aspects in packet networks.⁶

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

ITU-T G.8264, Distribution of timing information through packet networks.

ITU-T G.8271.1, Network limits for time synchronization in packet networks.

ITU-T G.8272, Timing characteristics of primary reference time clocks.

ITU-T G.8272.1, Timing characteristics of enhanced primary reference time clocks.

ITU-T G.8273.2, Timing characteristics of telecom boundary clocks and telecom time slave clocks.

ITU-T G.8273.3, Timing characteristics of telecom transparent clocks.

ITU-T G.8275.1, Precision time protocol telecom profile for phase/time synchronization with full timing support from the network.

MEF 10.3, Ethernet Services Attributes Phase 3.⁷

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⁷MEF technical specifications are available from the MEF Forum (<https://www.mef.net/>).

3. Definitions

For the purposes of this document, the following terms and definitions apply. *The IEEE Standards Dictionary Online* should be consulted for terms not defined in this clause.⁸

This standard makes use of the following terms defined in IEEE Std 802:

- bridge
- end station
- Ethernet
- forwarding
- frame
- Local Area Network (LAN)

This standard makes use of the following terms defined in IEEE Std 802.1Q:

- bridged network
- latency
- port
- priority-tagged frame
- traffic class
- untagged frame
- Virtual Local Area Network (VLAN)
- VLAN Bridge
- VLAN-tagged frame

The following terms are specific to this standard:

Category: An identifier of time synchronization requirements.⁹

NOTE—See 6.4.1.

Class: A collective term for fronthaul interfaces that applies a particular functional decomposition of a cellular base station and a particular treatment of fronthaul information flows.

NOTE—See 6.2 and 6.3.

fronthaul: The connectivity between the functional blocks (e.g., baseband processing and radio frequency blocks) of a cellular base station.

periodic: Repeating continuously, with a constant time (the period) between each occurrence.

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.8264.¹⁰

time window: A time interval (among back-to-back time intervals of the same duration), within which packets of a specified flow can be sent.

⁸IEEE Standards Dictionary Online is available at: <http://dictionary.ieee.org>.

⁹The Categories used in this standard are defined by the Requirements for the eCPRI Transport Network [B6].

¹⁰Synchronous 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.8264.

4. Acronyms and abbreviations

3GPP	3rd Generation Partnership Project
BC	boundary clock
BS	base station
C&M	Control and Management
CBR	Constant Bit Rate
CPRI	Common Public Radio Interface
CRC	Cyclic Redundancy Check
cTE	constant Time Error
C-VLAN	Customer VLAN
dTE	dynamic Time Error
eRE	eCPRI Radio Equipment ¹¹
eREC	eCPRI Radio Equipment Control
EEE	Energy Efficient Ethernet
EISS	Enhanced Internal Sublayer Service
ESMC	Ethernet Synchronization Messaging Channel
E-UTRA	Evolved Universal Terrestrial Radio Access
FID	Filtering Identifier
FLR	Frame Loss Ratio
GM	Grandmaster
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
HPF	High Priority Fronthaul
IET	Interspersing Express Traffic
IPG	Inter Packet Gap
IQ	In-phase and Quadrature modulation
ISS	Internal Sublayer Service
LAN	Local Area Network
LPF	Low Priority Fronthaul
LPI	Low Power Idle
MAC	Medium Access Control

¹¹eCPRI is not an acronym; eCPRI is specified by the eCPRI Interface Specification [B5].

$\max TE $	maximum absolute Time Error
$\max TE _{relative}$	maximum absolute relative Time Error
MPF	Medium Priority Fronthaul
OFDM	Orthogonal Frequency Division Multiplexing
PCS	Profile Conformance Statement
PDU	Protocol Data Unit
PHY	physical layer
PICS	Protocol Implementation Conformance Statement
PRTC	Primary Reference Time Clock
PTP	Precision Time Protocol
PVID	Port VID
RE	Radio Equipment
REC	Radio Equipment Control
RSTP	Rapid Spanning Tree Protocol
SC	Slave Clock
SFD	Start Frame Delimiter
SyncE	Synchronous Ethernet
TAI	Temps Atomique International—International Atomic Time
T-BC	Telecom Boundary Clock
TC	transparent clock
TE	Time Error
TDM	Time Division Multiplexing
T-GM	Telecom Grandmaster
TSN	Time-Sensitive Networking
T-TC	Telecom Transparent Clock
T-TSC	Telecom Time Slave Clock
UE	User Equipment
UNI	User Network Interface
VID	VLAN Identifier
VLAN	Virtual LAN

5. Conformance

A claim of conformance to this standard is a claim that the behavior of an implementation of a bridge (5.3, 5.4) or of an end station (5.5, 5.6) meets the mandatory requirements of this standard and may support options identified in this standard.

5.1 Requirements terminology

For consistency with existing IEEE and IEEE 802.1™ standards, requirements placed upon conformant implementations of this standard are expressed using the following terminology:

- a) **Shall** is used for mandatory requirements;
- b) **May** is used to describe implementation or administrative choices (“may” means “is permitted to,” and hence, “may” and “may not” mean precisely the same thing);
- c) **Should** is used for recommended choices (the behaviors described by “should” and “should not” are both permissible but not equally desirable choices).

The Profile Conformance Statement (PCS) proformas (see Annex A) reflect the occurrences of the words “shall,” “may,” and “should” within the standard.

The standard avoids needless repetition and apparent duplication of its formal requirements by using **is**, **is not**, **are**, and **are not** for definitions and the logical consequences of conformant behavior. Behavior that is permitted but is neither always required nor directly controlled by an implementer or administrator, or whose conformance requirement is detailed elsewhere, is described by **can**. Behavior that never occurs in a conformant implementation or system of conformant implementations is described by **cannot**. The word **allow** is used as a replacement for the phrase “support the ability for,” and the word **capability** means “can be configured to.”

5.2 Profile Conformance Statement (PCS)

The supplier of an implementation that is claimed to conform to this standard shall provide the information necessary to identify both the supplier and the implementation, and shall complete a copy of the PCS proforma provided in Annex A.

5.3 Bridge requirements

This subclause defines the conformance requirements for bridge implementations claiming conformance to this standard. Each bridge implementation supports one or more profiles defined in this standard. Each profile includes the common bridge requirements (5.3.1). A bridge implementation that conforms to the provisions of this standard shall support Profile A requirements (5.3.2).

5.3.1 Common bridge requirements

A minimum set of features specified in IEEE Std 802.1Q are required for a bridge to support this standard. That is, the bridge shall be a VLAN Bridge supporting the minimum set of features identified in this subclause. The requirements of this subclause do not imply that a VLAN Bridge implementation that conforms to the provisions of this standard has to support options specified in IEEE Std 802.1Q-2018 other than those identified in this subclause.

A bridge implementation that conforms to the provisions of this standard shall:

- a) Conform to the relevant standard for the MAC technology implemented at each port in support of the MAC Internal Sublayer Service (ISS), as specified in IEEE Std 802.1AC;
- b) Implement full duplex IEEE 802.3 MAC with data rate of 1 Gbps or greater on each port;
- c) Support the capability of 2000 octets maximum size MAC Protocol Data Unit (PDU) on each port;
- d) Support the capability to disable MAC control PAUSE if it is implemented;
- e) Support the capability not to assert Low Power Idle (LPI) on each port that supports Energy Efficient Ethernet (EEE, specified in IEEE Std 802.3);
- f) Meet the VLAN Bridge requirements stated in items a) through f) in 5.4 of IEEE Std 802.1Q-2018;
- g) Support an active topology enforcement mechanism;
- h) Meet the VLAN Bridge requirements stated in items g) and h) in 5.4 of IEEE Std 802.1Q-2018 if the supported active topology enforcement mechanism is the Rapid Spanning Tree Protocol (RSTP);
- i) Meet the VLAN Bridge requirements stated in items i) through n) in 5.4 of IEEE Std 802.1Q-2018;
- j) Support at least the Acceptable Frame Types parameter value of Admit All frames on each port [see item l) in 5.4 of IEEE Std 802.1Q-2018];
- k) Support the use of at least one VLAN Identifier (VID);
- l) Meet the VLAN Bridge requirements stated in items p) through r) in 5.4 of IEEE Std 802.1Q-2018;
- m) Support the ability to allocate the Port VID (PVID) and all other VIDs to the single Filtering Identifier (FID) if only a single FID is supported [item q) in 5.4 of IEEE Std 802.1Q-2018], i.e., support shared VLAN learning (8.8.8 of IEEE Std 802.1Q-2018);
- n) Support a minimum of three traffic classes (3.268 of IEEE Std 802.1Q-2018) on all ports;
- o) Support the strict priority algorithm for transmission selection (8.6.8.1 of IEEE Std 802.1Q-2018) on each port for each traffic class;
- p) Support flow metering (8.6.5 of IEEE Std 802.1Q-2018) with the token bucket bandwidth profile specified in MEF 10.3;
- q) Support the capability to disable Priority-based flow control if it is implemented (Clause 36 of IEEE Std 802.1Q-2018).

5.3.2 Bridge requirements for Profile A

A bridge implementation for which a claim of conformance to Profile A (8.1) is made, shall support items a) through q) of the common bridge requirements (5.3.1).

5.4 Bridge options

A bridge implementation that conforms to the provisions of this standard may:

- a) Support MEF 10.3 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];
- b) Support Profile B (5.4.1, 8.2);
- c) Support synchronization in the bridged network (5.4.2, Clause 9).¹²

5.4.1 Bridge requirements for Profile B

A bridge implementation for which a claim of conformance to Profile B (8.2) is made, shall:

¹²Support of synchronization in the bridged network is optional if methods [items c) and d) in 7.4] that put no requirements on the bridged network are available to be used to support synchronization.

- a) Support items a) through q) of the common bridge requirements (5.3.1);
- 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 (IEEE Std 802.3br, see also 7.3)¹³;
 - 3) Support Frame Preemption and Interspersing Express Traffic on each port whose data rate is not higher than 10Gbps;
 - 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

A bridge implementation for which a claim of conformance to support synchronization in the bridged network (Clause 9) is made, shall:

- a) Support untagged frames on all ports;
- 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), 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), and the related clock specification, i.e., Synchronous Ethernet slave clock (ITU-T G.8262).

NOTE—Untagged frames can be used for packet timing [item a) in 7.4] and physical layer frequency synchronization [item b) in 7.4]. The untagged frame is defined by 3.281 of IEEE Std 802.1Q-2018.

5.5 End station requirements

This subclause defines the conformance requirements for end station implementations claiming conformance to this standard. An end station implementation that conforms to the provisions of this standard shall:

- a) Support priority-tagged (see 3.184 of IEEE Std 802.1Q-2018) or VLAN-tagged frames on all ports;
- b) Support a minimum of three traffic classes on all ports.

5.6 End station options

An end station implementation that conforms to the provisions of this standard may:

- a) Support time synchronization via the bridged network (5.6.1);
- b) Support Synchronous Ethernet functions (ITU-T G.8264) including the ESMC, and the related clock specification, i.e., Synchronous Ethernet slave clock (ITU-T G.8262).

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