Draft IEEE Standard for Local and metropolitan area networks—

Cut-Through Forwarding Bridges and Bridged Networks

Unapproved draft, prepared by the
Time-Sensitive Networking (TSN) Task Group of IEEE 802.1

Sponsored by the
LAN/MAN Standards Committee
of the
IEEE Computer Society

DRAFT STATUS:
Draft for first Task Group Ballot.

This and the following cover pages are not part of the draft. They provide revision and other information for IEEE 802.1 Working Group members and participants in the IEEE Standards Association ballot process, and will be updated as convenient. New participants: Please read these cover pages, they contain information that should help you contribute effectively to this standards development project. Blank pages allow for the addition of cross-references to changed text without forcing renumbering of all pages in the draft. Pages are numbered from 1 (including cover pages) for the convenience of reviewers whose PDF viewers do not easily accommodate different numbering sequences. Pages will of course be renumbered prior to publication.The text proper of this draft begins with the Title page.

Editors' Foreword

<<Throughout this document, all notes such as this one, presented between angle braces, are temporary notes inserted by the Editors for a variety of purposes. Certain text is also highlighted to attract the attention of reviewers. These notes and highlights, the temporary Annex Z (if present) containing some discussion of issues, the Editors' Foreword and Introduction to the current draft, and the preceding cover pages, will be removed prior to Sponsor Ballot and publication and are not part of the normative text. The records of participants in the development of the standard will be added at an appropriate time. >>

Participation in 802.1 standards development

All participants in the standardization activities of IEEE 802.1 should be aware of the Working Group Policies and Procedures, and the fact that they have obligations under the IEEE Patent Policy, the IEEE Standards Association (SA) Copyright Policy, and the IEEE SA Participation Policy. For information on these policies see 1.ieee802.org/rules/ and the slides presented at the beginning of each of our Working Group and Task Group meeting.

As part of our IEEE 802® process, the text of the PAR (Project Authorization Request) and CSD (Criteria for Standards Development) of each project is reviewed regularly to ensure their continued validity. The PAR is summarized in these cover pages and a links are provided to the full text of both PAR and CSD. A vote of "Approve" on this draft is also an affirmation that the PAR and CSD for this project are still valid.

Comments on this draft are encouraged. NOTE: All issues related to IEEE standards presentation style, formatting, spelling, etc. are routinely handled between the 802.1 Editor and the IEEE Staff Editors prior to publication, after balloting and the process of achieving agreement on the technical content of the standard is complete. Readers are urged to devote their valuable time and energy only to comments that materially affect either the technical content of the document or the clarity of that technical content. Comments should not simply state what is wrong, but also what might be done to fix the problem.

Full participation in the work of IEEE 802.1 requires attendance at IEEE 802 meetings. Information on 802.1 activities, working papers, and email distribution lists etc. can be found on the 802.1 Website:

http://ieee802.org/1/

Use of the email distribution list is not presently restricted to 802.1 members, and the working group has a policy of considering comments from all who are interested and willing to contribute to the development of the draft. Individuals not attending meetings have helped to identify sources of misunderstanding and ambiguity in past projects. The email lists exist primarily to allow the members of the working group to develop standards, and are not a general forum. All contributors to the work of 802.1 should familiarize themselves with the IEEE patent policy and anyone using the email distribution list will be assumed to have done so. Information can be found at http://standards.ieee.org/db/patents/

Comments on this draft may be sent to the 802.1 email exploder, to the Editor, or to the Chairs of the 802.1 Working Group and Time-Sensitive Networking (TSN) Task Group.

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As part of our IEEE 802 process, the text of the PAR and CSD (Criteria for Standards Development, formerly referred to as the 5 Criteria or 5C's) is reviewed on a regular basis in order to ensure their continued validity. A vote of "Approve" on this draft is also an affirmation by the balloter that the PAR is still valid.

Draft development

During the early stages of draft development, 802.1 editors have a responsibility to attempt to craft technically coherent drafts from the resolutions of ballot comments and from the other discussions that take place in the working group meetings. Preparation of drafts often exposes inconsistencies in editor's instructions or exposes the need to make choices between approaches that were not fully apparent in the meeting. Choices and requests by the editors' for contributions on specific issues will be found in the editors' Introduction to the current draft and at appropriate points in the draft.

The ballot comments received on each draft, and the editors' proposed and final disposition of comments on working group drafts, are part of the audit trail of the development of the standard and are available, along with all the revisions of the draft on the 802.1 website (for address see above).

During the early stages of draft development the proposed text can be moved around a great deal, and even minor rearrangement can lead to a lot of 'change', not all of which is noteworthy from the point of the reviewer, so the use of automatic change bars is not very effective. In early drafts change bars may be omitted or applied manually, with a view to drawing the readers attention to the most significant areas of change. Readers interested in viewing every change are encouraged to use Adobe Acrobat to compare the document with their selected prior draft. Note that the FrameMaker change bar feature is useless when it comes to indicating changes to Figures.

iPAR (Project Authorization Request) and CSD

Extracts from the PAR, as approved by IEEE NesCom 5th June 2023:

https://development.standards.ieee.org/myproject-web/public/view.html#pardetail/9744

and the CSD (Criteria for Standards Development):

https://mentor.ieee.org/802-ec/dcn/23/ec-23-0076-00-ACSD-p802-1du.pdf

follow.

PAR Scope:

This standard specifies Cut-Through Forwarding (CTF) Bridges based on the IEEE 802.1Q Bridge architecture, including protocols, procedures, and managed objects. CTF Bridges interconnect individual local area networks (LANs) using different or identical media access control (MAC) methods with and without support for CTF. This standard also details the usage of CTF Bridges in Bridged networks.

PAR Purpose:

This standard enables lower latency communication compared to what is achievable without CTF and reduces the dependency of end-to-end latency on frame length, while allowing interoperable interconnection of individual LANs with and without support for CTF.

PAR Need for the Project:

The lower latency achievable in Bridged networks with CTF enables the applicability of bridging in certain applications, including use cases in industrial automation, professional audio-video and data centers. This project addresses the unmet needs of these applications for interoperable equipment that has lower latency.

CSD broad market potential [extract]

Proprietary implementations of Cut-Through Forwarding (CTF) are already widely used in industrial automation installations and data center networks. Standardizing CTF can be an enabling technology for a wide range of professional audio-video applications.

Existing proprietary implementations by Bridge vendors support CTF, but interoperability is limited. Standardizing CTF is an opportunity for deployment of IEEE 802 technology in existing and new use cases in industrial automation systems, data centers, and professional audio-video applications.

Additional material:
https://mentor.ieee.org/802.1/dcn/21/1-21-0037-00-ICne-ieee-802-tutorial-cut-through-forwarding-ctf-among-ethernet-networks.pdf

CSD compatability [extract]

The project will comply with IEEE Std 802, IEEE Std 802.1AC, and IEEE Std 802.1Q.

Introduction to the current draft

This introduction is not part of the draft, and will be revised for SA ballot. A set of cover pages will be retained for use during SA ballot.

The current draft is for Task Group balloting, based on the final comment dispositions against the previous draft. The previous draft, the final comment dispositions against the previous draft, and further information on project P802.1DU can be found at https://1.ieee802.org/tsn/802-1du/.

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P802.1DU/D0.3

July 3, 2024

Draft IEEE Standard for Local and metropolitan area networks—

Cut-Through Forwarding Bridges and Bridged Networks

Unapproved draft, prepared by the

Time-Sensitive Networking (TSN) Task Group of IEEE 802.1

Sponsored by the

LAN/MAN Standards Committee
of the
IEEE Computer Society

IEEE Standards Activities Department
445 Hoes Lane
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Abstract: This standard specifies Cut-Through Forwarding Bridges and Bridged networks.

Keywords: Cut-Through Forwarding, Store and Forward, Bridged Network, IEEE 802.1AC™, IEEE 802.1Q™, IEEE 802.1CB™, Local Area Network, LAN, virtual LAN, VLAN Bridge

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3. Available at: https://ieeexplore.ieee.org/browse/standards/collection/ieee.
4. Available at: https://standards.ieee.org/standard/index.html.
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Participants

<<The following lists will be updated in the usual way prior to publication>>

At the time this standard was completed, the IEEE 802.1 working group had the following membership:

Glenn Parsons, *Chair*
Jessy Rouyer, *Vice Chair*
Janos Farkas, *TSN Task Group Chair*
Johannes Specht, *Editor*

The following members of the individual balloting committee voted on this standard. Balloters may have voted for approval, disapproval, or abstention.

A.N. Other

<<The above lists will be updated in the usual way prior to publication>>

When the IEEE-SA Standards Board approved this standard on <dd> <month> <year>, it had the following membership:

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Vice-Chair
Past Chair
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<<The above lists will be updated in the usual way prior to publication>>

Introduction

This introduction is not part of IEEE Std 802.1DU-20XX, IEEE Standard for Local and metropolitan area networks—Cut-Through Forwarding Bridges and Bridged Networks

This standard specifies Cut-Through Forwarding Bridges and Bridged Networks.

This standard was first published as IEEE Std 802.1DU-20XX.

This 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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Cut-Through Forwarding Bridges and Bridged Networks

1. Overview

1.1 Scope

This standard specifies Cut-Through Forwarding (CTF) Bridges based on the IEEE 802.1Q Bridge architecture, including protocols, procedures, and managed objects. CTF Bridges interconnect individual local area networks (LANs) using different or identical media access control (MAC) methods with and without support for CTF. This standard also details the usage of CTF Bridges in Bridged networks.

1.2 Purpose

This standard enables lower latency communication compared to what is achievable without CTF and reduces the dependency of end-to-end latencyon frame length, while allowing interoperable interconnection of individual LANs with and without support for CTF.

1.3 Introduction

The standardization of Ethernet communication technology in IEEE Std 802.3™[B8], specifying transmission over the physical media of individual Local Area Networks (LANs), and in IEEE Std 802.1Q™, specifying Bridges that interconnect IEEE 802® LANs,[1] has facilitated widespread deployment of networks that connect significantly more end stations, with significantly greater bandwidth, and at significantly reduced cost compared to prior technology. All these metrics have been improved by several orders of magnitude—reducing costs through the multi-vendor provision of common components (Bridges, end station interfaces, integrated circuit and circuit designs, connectors, and software) for a wide range of network applications.

The use of Ethernet communication technology in networks with high-reliability and deterministic latency requirements is further supported by Time-Sensitive Networking (TSN) provisions in IEEE Std 802.1Q, IEEE Std 802.1AS, IEEE Std 802.1CB, and the security provisions in IEEE Std 802.1AE and IEEE Std 802.1X. The provisions in these standards can be used in various ways, and include options that address different network requirements and parameters that vary by network and application scale. Network design, time to deploy, and component development, selection, validation, and configuration for a particular network can all benefit from consistent choices, across similar networks and network applications, of the provisions, parameters, and options specified in the relevant standards.

This standard specifies provisions for CTF in Bridges and Bridged networks, consistent with the aforesaid IEEE 802 standards in form of a separate IEEE 802.1 base standard, allowing the aforesaid IEEE 802 standards to remain unaltered. It specifies Bridges with support for CTF based on the existing Bridge architecture of IEEE Std 802.1Q, maintains the traditional MAC demarcation between IEEE 802.1 and other IEEE 802 working groups, provides support for mixes of Store and Forward (S&F) and CTF MAC methods, and provides connectivity in networks comprising Bridges with and without support for CTF.

To this end, this standard

a) Specifies the architecture of Bridges with support for CTF (CTF Bridges).
b) Establishes modeling principles for the specification of CTF.
c) Defines interfaces for supporting a broad variety of Internal Sublayer Service (ISS) providers that support CTF, including MAC methods with support for CTF.

[1] IEEE and IEEE 802 are registered trademarks in the U.S. Patent & Trademark Office, owned by The Institute of Electrical and Electronics Engineers, Incorporated.

d) Selects and extends existing functionality of IEEE Std 802.1Q, IEEE Std 802.1CB and IEEE Std 802.1AC supporting CTF.

e) Establishes compatibility with functionality from IEEE Std 802.1Q, IEEE Std 802.1CB and IEEE Std 802.1AC not supporting CTF.

f) Provides management means for controlling CTF in Bridges.

<<Editor’s Note: Extend as appropriate>>

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.

ANSI X3.159, American National Standards for Information Systems—Programming Language—C.[2]

IEEE Std 802®, IEEE Standard for Local and metropolitan area networks: Overview and Architecture.[3,4]

IEEE Std 802d™-2017, IEEE Standard for Local and Metropolitan Area Networks: Overview and Architecture—Amendment 1: Allocation of Uniform Resource Name (URN) Values in IEEE 802® Standards.

IEEE Std 802.1AB™, IEEE Standard for Local and metropolitan area networks—Station and Media Access Control Connectivity Discovery.

IEEE Std 802.1AC™, IEEE Standard for Local and metropolitan area networks—Media Access Control (MAC) Service Definition.

IEEE Std 802.1AE™, IEEE Standard for Local and metropolitan area networks—Media Access Control (MAC) Security.

IEEE Std 802.1AS™, IEEE Standard for Local and metropolitan area networks—Timing and Synchronization for Time-Sensitive Applications in Bridged Local Area Networks.

IEEE Std 802.1AX™, IEEE Standard for Local and metropolitan area networks—Link Aggregation.

IEEE Std 802.1CB™, IEEE Standard for Local and metropolitan area networks—Frame Replication and Elimination for Reliability.

IEEE Std 802.1Q™, IEEE Standard for Local and metropolitan area networks—Bridges and Bridged Networks.

IEEE Std 802.1X™, IEEE Standards for Local and metropolitan area networks—Port Based Network Access Control.

IETF RFC 2119 (BCP 14), Key Words for Use in RFCs to Indicate Requirement Levels, March 1997.[5]

IETF RFC 4122, A Universally Unique IDentifier (UUID) URN Namespace, July 2005.

IETF RFC 7950, The YANG 1.1 Data Modeling Language, August 2016.

IETF RFC 8343, A YANG Data Model for Interface Management, March 2018.

ISO/IEC 7498-1, Information processing systems — Open Systems Interconnection — Basic Reference Model—Part 1: The Basic Model.[6]

[2] ANSI publications are available from the American National Standards Institute (https://www.ansi.org/).
[3] IEEE publications are available from The Institute of Electrical and Electronics Engineers (https://standards.ieee.org/).
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[5] IETF documents (i.e., RFCs) are available from the Internet Engineering Task Force (https://tools.ietf.org/html/).

ITU-T Recommendation G.8013/Y.1731, Operation, administration and maintenance (OAM) functions and mechanisms for Ethernet-based Networks.

MEF Technical Specification 10.3 (MEF 10.3), Ethernet Service Attributes Phase 3, October 2013.

[6] ISO and ISO/IEC documents are available from the International Organization for Standardization (https://www.iso.org/). ISO/IEC publications are also available in the United States from Global Engineering Documents (https://global.ihs.com/). Electronic copies are available in the United States from the American National Standards Institute (https://www.ansi.org/)

3. Definitions

<<Editor's Note: This clause contains some definitions from other IEEE 802 and IEEE 802.1 standards with their copied definition text. A future version may limit on listing particular definition without that text. This clause is in an intermediate state and additional discussion is needed for proceeding.>>

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.[7]

The following terms are specific to this standard:

Cut-Through Forwarding (CTF): A relaying principle that allows externally visible frame transmission to start before associated externally visible frame receptions were completed.

Cut-Through Forwarding (CTF) Bridge: A Bridge supporting Cut-Through Forwarding.

frame under reception: A frame that is being serially received from LAN for which reception began but did not finish.

frame under transmission: A frame that is being serially transmitted to a LAN for which transmission began but did not finish.

late error: An error condition associated with a frame under reception that is identified after further processing of such frame already began.

processing stall: A temporal operation in the model of a CTF Bridge intended to defer processing of a frame under reception until a certain condition, typically the availability of data, is satisfied.

received frame: A frame that was serially received from a LAN that has finished reception.

Store and Forward(S&F): A relaying principle that allows externally visible frame transmission to only start after associated externally visible frame receptions were completed.

Store and Forward (S&F) Bridge: A Bridge not supporting for Cut-Through Forwarding.

transmitted frame: A frame that was serially transmitted to a LAN that has finished transmission.

This standard makes use of the following term defined in IEEE Std 802:[8]

end station

This standard makes use of the following terms defined in IEEE Std 802.1Q:[9]

Bridge: A system that includes Media Access Control (MAC) Bridge or Virtual Local Area Network (VLAN) Bridge component functionality.

Bridge Port: A Service Access Point (SAP) that provides the Enhanced Internal Sublayer Service (EISS) to the Media Access Control (MAC) Relay Entity of a Virtual Local Area Network (VLAN) Bridge component, or that provides the Internal Sublayer Service (ISS) to the MAC Relay Entity of a MAC Bridge, and the interface stack that supports that SAP.

[7] *IEEE Standards Dictionary Online* is available at https://dictionary.ieee.org.
[8] This definition is from IEEE Std 802-2014. Notes to definitions are particular to this standard.
[9] These definitions are from IEEE Std 802.1Q-2022. Notes to definitions are particular to this standard.

Bridged Network: A concatenation of individual IEEE 802 Local Area Networks (LANs) interconnected by Bridges.

Customer Virtual Local Area Network (C-VLAN): A Virtual Local Area Network (VLAN) identified by a C-VLAN Identifier (C-VID).

NOTE—The use of 'Customer' in the context of VLAN identification is not to be confused with any business relationships or role responsibilities in the context of this standard or its use.

Customer Virtual Local Area Network (C-VLAN) Bridge: A system comprising a single C-VLAN component.

Customer Virtual Local Area Network (C-VLAN) component: A Virtual Local Area Network (VLAN) Bridge component with each Port supported by an instance of the Enhanced Internal Sublayer Service (EISS) that can recognize, insert, and remove C-VLAN tags (C-TAGs).

Customer Virtual Local Area Network [C-VLAN] Identifier (C-VID): A Virtual Local Area Network (VLAN) Identifier (VID) conveyed in a C-VLAN tag (C-TAG).

Customer Virtual Local Area Network [C-VLAN] tag (C-TAG): A Virtual Local Area Network (VLAN) tag with a Tag Protocol Identification value allocated for "802.1Q Tag Protocol EtherType."

Frame: A unit of data transmission on an IEEE 802 Local Area Network (LAN) that conveys a Media Access Control (MAC) Protocol Data Unit (MPDU).

IEEE 802 Local Area Network [LAN] (IEEE 802 LAN): LAN technologies that provide a Media Access Control (MAC) Service equivalent to the MAC Service defined in IEEE Std 802.1AC.

Media Access Control (MAC) Bridge: A Bridge that does not recognize Virtual Local Area Network (VLAN) tagged frames.

Multicast:

a) A group Media Access Control (MAC) address (noun).
b) To transmit a frame using a group MAC address as the destination address (verb).
c) Containing a group MAC address as the destination address (adjective).

packet: A protocol data unit, comprising data, addressing, and protocol identification information, sent by an instance of an identified class of protocol entities and transmitted in one or more frames (e.g., an IPv6 packet).

Port: A Service Access Point (SAP) and the interface stack supporting that SAP.

preemption: The suspension of the transmission of a preemptible frame to allow one or more express frames to be transmitted before transmission of the preemptible frame is resumed.

Priority-tagged frame: A tagged frame whose tag header carries priority information but carries no Virtual Local Area Network (VLAN) identification information.

Service Access Point (SAP): The point at which a service is offered.

NOTE—In this standard, any given SAP provides access to either the Internal Sublayer Service (ISS, IEEE Std 802.1AC) or the Enhanced Internal Sublayer Service (EISS, IEEE Std 802.1Q). The abbreviation SAP (without a preceding ISS or EISS) is used where the nature of the service is clear.

shim: A protocol entity that uses the same service as it provides.

NOTE—Shims specified or referenced in this standard make use of the Internal Sublayer Service (ISS) or the Enhanced Internal Sublayer Service (EISS). They secure the ISS, enhance privacy, or provide multiplexing over separate instances of the ISS.

Stream: A unidirectional flow of data (e.g., audio and/or video) from a Talker to one or more Listeners.

StreamID: A 64-bit field that uniquely identifies a stream.

Tag header: A header that allows priority information, and optionally, Virtual Local Area Network (VLAN) identification information, to be associated with a frame.

Tagged frame: A frame that contains a tag header immediately following the Source MAC Address field of the frame.

Talker: The end station that is the source or producer of a stream.

time-aware: An adjective to describe use of time that is synchronized with other stations using a protocol (e.g., IEEE Std 802.1AS).

time-sensitive stream: A stream of data frames that are required to be delivered with a bounded latency.

traffic class: A classification used to expedite transmission of frames generated by critical or time-sensitive services.

transmission gate: A gate that connects or disconnects the transmission selection function of the forwarding process from the queue, allowing or preventing it from selecting frames from that queue. The gate has two states, Open and Closed.

unicast:

a) An individual Media Access Control (MAC) address (noun).
b) To transmit a frame using an individual MAC address as the destination address (verb).
c) Containing an individual MAC address as the destination address (adjective).

Untagged frame: A frame that does not contain a tag header immediately following the Source MAC Address field of the frame.

Virtual Bridged Network: A concatenation of individual IEEE 802 Local Area Networks (LANs) interconnected by Bridges, including Virtual Local Area Network (VLAN) Bridges.

Virtual Local Area Network (VLAN): The closure of a set of Media Access Control (MAC) Service Access Points (MSAPs) such that a data request in one MSAP in the set is expected to result in a data indication in another MSAP in the set.

Virtual Local Area Network (VLAN) Bridge: A system comprising a single VLAN Bridge component implemented in accordance with Clause 5 of IEEE Std 802.1Q-2021.

Virtual Local Area Network (VLAN) Bridge component: The media access method-independent functionality supporting an instance of the Enhanced Internal Sublayer Service (EISS) at each Bridge Port that can recognize, insert, and remove VLAN tags, and the functionality that relays frames between Bridge Ports.

Virtual Local Area Network (VLAN) Bridged Network: A Virtual Bridged Network.

Virtual Local Area Network (VLAN) tagged frame: A tagged frame whose tag header carries both VLAN identification and priority information.

This standard makes use of the following terms defined in IEEE Std 802.1AE:[10]

[10] These definitions are from IEEE Std 802.1AE-2018 as amended by IEEE Std 802.1AEdk-202X. Notes to definitions are particular to this standard.

express frame: A frame that a protocol entity identifies as a candidate for early transmission using **preemption** capabilities.

NOTE—Not all protocol entities that forward a given frame need to identify that frame as an express frame or a preemptable frame. Preemption is specified in IEEE Std 802.3.

preemptable frame: A frame that a protocol entity identifies as a candidate for suspension by **preemption** capabilities, so as to allow the earlier transmission of an **express frame**.

preemption: The temporary suspension of the transmission (or encoding for transmission) of a **preemptable frame** to allow the earlier transmission of an **express frame**.

NOTE—The preemption capabilities specified by IEEE Std 802.3 can be used to expedite the transmission of an **express frame** that becomes available for transmission after transmission of a **preemptable frame** has begun.

traffic: A sequence of frames forwarded in a network.

4. Abbreviations and acronyms

The following abbreviations and acronyms are used in this standard:

CTF	Cut-Through Forwarding
ISS	Internal Sublayer Service
EISS	Enhanced Internal Sublayer Service
MAC	Medium Access Control
S&F	Store and Forward

<<Editor’s Note: Extended as appropriate>>

5. Conformance

5.1 Overview

This clause specifies mandatory and optional capabilities provided by implementations conformant to this standard. An implementation can:

a) Compose all or part of the functionality of a CTF Bridge
b) Provide, as specified by this standard, one or more instances of the MAC Service to other functional entities whose specification is outside the scope of this standard.
c) Provide, as specified by this standard, one or more instance of the Internal Sublayer Service (ISS) to other implementations or instances of the same implementation that conform to this standard.

<<Editor's Note: Items a), b) and c) were taken from 802.1Q-2022 as starting point with smaller modifications for P802.1DU. As of now, there are contributions on required differences for CTF in end stations (compared to end stations as already specified).>>

5.2 Requirements terminology

For consistency with existing IEEE and IEEE 802.1™ standards, requirements are expressed using the following terminology: [11]

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).

Protocol Implementation Conformance Statements (PICS) 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."

5.3 Protocol Conformance Statement (PCS)

A claim of conformance specifies implementation of a specific CTF Bridge, a C-VLAN component with support for CTF, or a VLAN-unaware MAC Bridge component with support for CTF as specified in this standard.

<<Editor's Note: Extending beyond the aforesaid needs to be discussed.>>

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 relevant

[11] Originally derived from ISO/IEC style requirements, and consistent with the terminology specified in the ISO/IEC Directives Part 2:2021, Clause 7 (http://www.iec.ch/members_experts/refdocs).

PCS proforma provided in Annex A for that specific Bridge component or station together with the Protocol Implementation Conformance Statements (PICS) for the herein referenced protocols and procedures from other IEEE 802.1 standards.

5.4 CTF Bridge requirements

5.4.1 VLAN unaware conformance

<<Editor’s Note: Placeholder>>

5.4.2 VLAN aware conformance

<<Editor’s Note: Placeholder>>

5.5 CTF Bridge options

5.5.1 VLAN unaware conformance

<<Editor’s Note: Placeholder>>

5.5.2 VLAN aware conformance

<<Editor’s Note: Placeholder>>

<<Editor’s Note: The above are structural placeholders. The intended content is a combination of references to conformance in existing 802.1 Stds and references within P802.1DU for additional functionality. Contents are planned for a later stage (i.e., once there is certain consensus on the technical operation.>>

Further major items that may (or may not) be part of the conformance clause are the following (for consideration/discussion):

1) ISS provider conformance (outer interfaces) with and without support for CTF

2) Conformant networks

>>

6. Architecture

This standard specifies the operation of Bridges, similar to IEEE Std 802.1Q [B1] and associated IEEE standards (e.g., IEEE Std 802.1CB). For differentiation between Bridges with support for CTF in the present standard and Bridges according to IEEE Std 802.1Q and associated IEEE Stds, the term *S&F Bridge* is used for referring to Bridges according to IEEE Std 802.1Q and associated IEEE standards, and the term *CTF Bridge* is used for referring to Bridges defined in this standard.

Similar to S&F Bridges, CTF Bridges may or may not support Virtual Local Area Networks (VLANs), and therefore terms VLAN-aware and VLAN-unaware are used to distinguish between Bridges with and without support for VLANs.

The architecture of CTF Bridges is shown in Figure 6-1 in a compact form, and is aligned with that of S&F Bridges (see also Figure 8-2, Figure 8-3, Figure 8-4, ff. of IEEE Std 802.1Q).

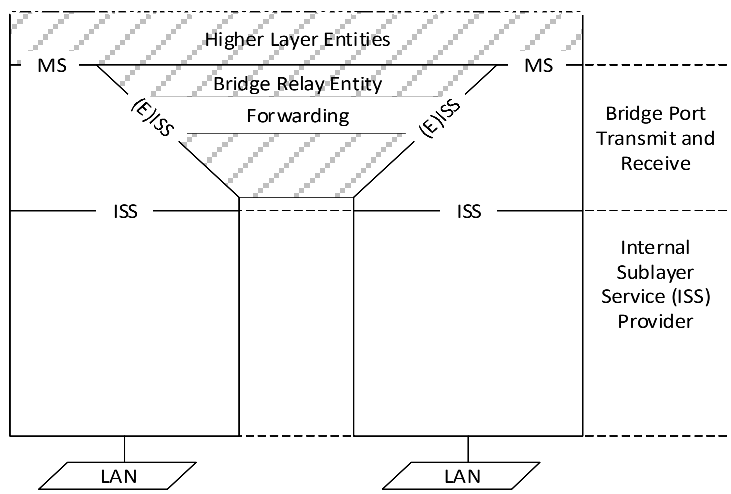

Figure 6-1—Architecture of a Cut-Through Forwarding (CTF) Bridge.

This architecture includes the following elements:

a) Higher layer entities using the MAC Service (MS) via the MAC Service interface defined in clause 14 of IEEE Std 802.1AC [B2].

b) Two or more Internal Sublayer Service (ISS) providers (Clause 8), where at least one ISS provider supports CTF (8.3).

c) Bridge Port transmit and receive operations (Clause 9) per Bridge port that transform and transfer service primitive invocations between the Bridge relay entity, higher layer entities and ISS providers.

d) A Bridge relay entity (Clause 10) that relays frames between different Bridge Ports.

This standard excludes several details on higher layer entities above the MAC service interface and elements of the Bridge relay entity other than the forwarding process:

e) For frames to and from higher layer entities, the Bridge port transmit and receive operations of a CTF Bridge establish the behavior of S&F Bridge at the MAC service interface (9.5), allowing higher layer entities to operate according to the behavior specified in IEEE 802.1 Standards unaltered.

f) The forwarding process of a CTF Bridge (re-)establishes the behavior of an S&F Bridge at interaction points with other elements of the Bridge relay entity.

NOTE 1—Examples for higher layer entities are Spanning Tree Protocols and Multiple Registration Protocols, supported by LLC entities above the MAC service interface [see also item c) in 8.2 and item b) in 8.3 of IEEE Std 802.1Q].

NOTE 2—An example element of the Bridge relay entity other than the forwarding process is the learning process [see also item c) in 8.2 and item b) in 8.3 of IEEE Std 802.1Q].

ISS providers according to the present standard can support CTF or not. Bridges according to the present standard comprise at least one ISS provider with support for CTF. Bridges that comprise no ISS provider with support for CTF are specified in IEEE Std 802.1Q.

7. Modeling principles

7.1 Overview

This clause (Clause 7) specifies principles for modeling the operation of a CTF Bridge. An exemplary illustration for those principles and elements thereof is shown in Figure 7-1.

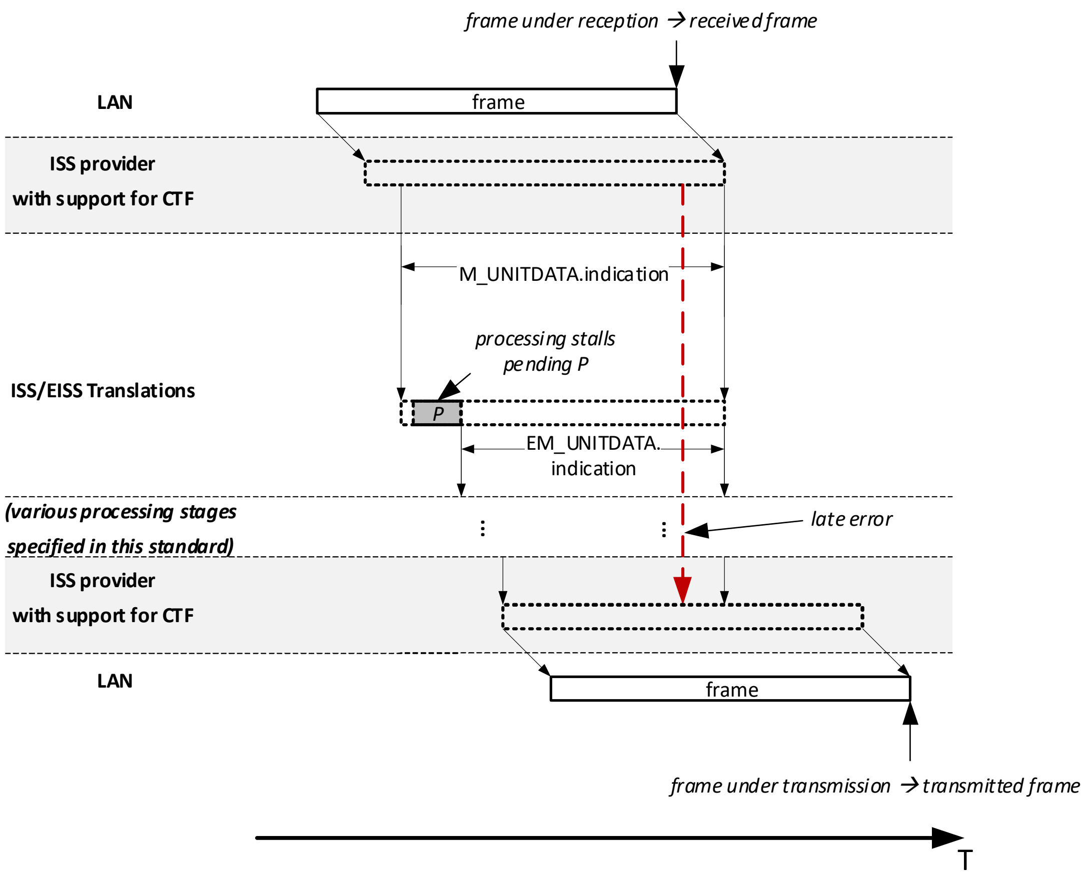

Figure 7-1—Exemplary illustration of modeling principles and elements.

7.2 Frame types

If necessary, distinct terms are used for frames or describing their current state, as follows:

a) **frame under reception:** A frame that is being serially received from LAN for which reception began but did not finish.
b) **received frame:** A frame that was serially received from a LAN that has finished reception.
c) **frame under transmission:** A frame that is being serially transmitted to a LAN for which transmission began but did not finish.
d) **transmitted frame:** A frame that was serially transmitted to a LAN that has finished transmission.

7.3 Modeling of service primitives

All invocations of service primitives in this standard are atomic. That is, each invocation is non-decomposable (see also 7.2 of IEEE Std 802.1AC and [B4]). Semantics of the ISS (Clause 8) and EISS (9.4) in terms of service primitives, their parameters, etc. are refined in this standard for the CTF operation, allowing for accurate description of operations within a CTF Bridge.

This detailed model comprises the following:

a) The values of parameters and potential sub-parameters during invocations of a service primitive are passed according to a call-by-reference scheme.
b) A service primitive has two attributes, 'start and 'end. These attributes are used in subsequent descriptions to indicate the temporal start and the end of the indication, respectively.
c) The parameters of a service primitive could often be modeled explicitly as bit arrays that are filled incrementally [e.g., the destination_address parameter of M_UNITDATA.indication in 8.3)]. However, this standard uses parameter-based modeling (7.4) in conjunction with the temporal control elements (7.5) for description of the CTF operation.

NOTE—The concept of attributes is inspired by the Very High Speed Integrated Circuits Hardware Description Language, VHDL [B5], which provides predefined attributes (e.g., 'transaction) that allow modeling over multiple VHDL simulation cycles at the same instant of simulated time.

In a series of sequential processing stages (e.g., a sub-process of the forwarding process in 10.1), this model allows later processing stages to access contents in service primitive parameters that are incrementally added by an earlier processing stage.

The 'start and ‘end attributes can, but are not required to, be in temporal relationship with the duration of frames on the physical layer.

In a simplified model, ‘start is followed by ‘end instantaneously (see also 7.5.4), with all parameters being available at that instant of time. Such simplified service primitive invocations are denoted as *instantaneous invocations*. Where sufficient, this model is used in this Standard.

7.4 Parameter-based modeling

Processing of frames by CTF Bridges is modeled at parameter level accuracy. The purpose of this model is to

a) provide means for compact description of temporal control (7.5) in and across processing stages,
b) enable re-use of existing data transformation rules from IEEE 802.1 Stds, and
c) avoid low level details that would not provide value to the clarity of descriptions.

The parameter-based modeling uses the resolution of symbolic and/or numeric parameters. On the receive path, high-level parameters can be derived from (a subset of) information contained in the service primitive parameters of the associated unit-data indication and/or out-of-band information (e.g., management parameters). On the transmit path, service primitive parameters of unit-data requests can be constructed from high-level parameters and/or out-of-band information (e.g., management configuration parameters). The translations between high-level parameters and service primitive parameters are as specified in IEEE Stds 802.1Q, 802.1AC and 802.1CB.

A parameter is said to be complete at the earliest instant of time between ‘start and ‘end at which the minimal information is available to unambiguously determine the parameter's value within the valid value range of such parameter. High-level parameters derived from information contained in service primitive parameters of unit-data indications are completed later than ‘start of the associated unit-data service primitive invocation. High-level parameters solely based on out-of-band information are completed at ‘start.

As an example, the vlan_identifier parameter of EM_UNITDATA.indication (9.4) invocations can be derived from the subset of information in the mac_service_data_unit of an M_UNITDATA.indication (Clause 8) located in a VLAN Tag (9.6 of IEEE Std 802.1Q) according to the specification of the Support for the EISS defined in item e) in 6.9.1 of IEEE Std 802.1Q, or originate from out-of-band information like a configured per-Port PVID parameter [item d) in 6.9, item f) in 6.9.1 and 12.10.1.2 of IEEE Std 802.1Q]. If the VLAN tag is required to unambiguously determine the vlan_identifier parameter, the parameter is complete when all bits of the VID parameter in the VLAN Tag are available in the mac_service_data_unit parameter.

NOTE—The bits and potential out-of-band information form the minimal information, and exclude any redundant information, most prominently the (in-band) redundant encoding of the VID parameter in the frame's FCS parameter.

7.5 Temporal control

7.5.1 Processing stalls

Parameter-based modeling is used for convenient formulation of temporal control statements in processing stages. A processing stage (7.3) may stall further processing of a frame under reception, including (but not limited to) passing this frame to a subsequent processing stage, until one or more parameters are complete (7.4), subject to the implicit discarding due to late errors (7.5.2). Most processing stalls are given due to the data dependencies already specified in IEEE 802.1 Standards (e.g., Ingress Filtering as part of the forwarding process in 8.6.2 of IEEE Std 802.1Q depends on the availability of a frame's VID, which therefore implicitly requires completion of the vlan_identifier parameter of EM_UNITDATA.indication invocations), however, explicit modeling of processing stalls may be expressed by formulations in natural language.

Example formulations:

a) “Processing **stalls** pending the **vlan_identifier** parameter.”
*b) “Further execution in a CTF Bridge is **stalled** pending the **destination address** of a frame under reception prior to the filtering database lookup of the destination ports.”*

A processing stall does not become effective if all associated parameters of a frame are complete at the point where the processing stall is defined.

7.5.2 Late errors

In a sequence of processing stages, an earlier processing stage may discover an error in a frame under reception and then notify all subsequent (not antecedent) processing stages, which may then implement error handling upon this such notification. This is termed as a late error, which is raised by the earlier processing stage and associated with a particular frame under reception. If any of the subsequent stage stalls processing pending one or more parameters of the associated frame under reception when the error is raised, the frame is discarded in the subsequent stage and thereby neither further processed nor passed to any other following processing stage.)

Late errors can be indicated by ISS providers with support for CTF (8.3) and processing stages specified in other clauses of this standard.

7.5.3 Fall-backs to S&F

The descriptions of the processing stages use fall back to S&F as a modeling shortcut to summarize the following sequence:

a) Processing of a frame under reception stalls pending the frame's end of reception, which is a shortcut by itself for stalling processing pending all parameters of a frame under reception, including the FCS.
b) Dependent on whether or not a late error was indicated by an earlier processing stage for that frame while processing stalls, processing continues or the frame is discarded:

1) **Late error indicated:** The frame is discarded prior to any further processing by any stage.
2) **No Late error indicated:** Processing of the frame continues through subsequent processing steps and stages according to the standardized behavior of an S&F Bridge.

7.5.4 Instantaneous processing

In absence of processing stalls, processing stages in this standard perform their operations instantaneously. Purpose of this temporal behavior is to model data dependencies, late error handling and the resulting externally visible behavior. Additional delays (e.g., real world implementations starting transmissions on a physical medium later than the model) are not described by the model, but could be determined by observation/measurement and are available as management parameters (11.3).

NOTE—Idealized instantaneous operations, in terms of 0-delay at an infinite high resolution, are not possible in real world implementations. The model is not intended to specify upper bounds for delays of real world implementations.

8. Internal Sublayer Service (ISS) providers

8.1 Overview

Bridges with support for CTF contain two or more Internal Sublayer Service (ISS) providers for connecting with individual LANs. Two types of ISS providers are specified by the present standard:

a) ISS providers without support for CTF (8.2)
b) ISS providers with support for CTF (8.3)

8.2 ISS providers without support for CTF

ISS providers without support for CTF provide the service primitives and parameters as specified in IEEE Std 802.1AC. The two unit-data primitives of such providers are M_UNITDATA.indication, which corresponds to the receipt of an error-free frame from an individual LAN, and M_UNITDATA.request, which corresponds to transmission of a frame to an individual LAN.

```
M_UNITDATA.indication          (
                               destination_address,
                               source_address,
                               mac_service_data_unit,
                               priority,
                               drop_eligible,
                               frame_check_sequence,
                               service_access_point_identifier,
                               connection_identifier
                               )

M_UNITDATA.request             (
                               destination_address,
                               source_address,
                               mac_service_data_unit,
                               priority,
                               drop_eligible,
                               frame_check_sequence,
                               service_access_point_identifier,
                               connection_identifier
                               )
```

NOTE 1—The service primitives from IEEE Std 802.1AC are repeated in this standard for reference.

Invocations of M_UNITDATA.indication and M_UNITDATA.requests are modeled as instantaneous invocations (7.3). An invocation of M_UNITDATA.indication occurs after reception of the associated frame from the individual LAN finished, and an invocation of M_UNITDATA.request occurs before transmission of the associated frame to the individual LAN starts.

8.3 ISS providers with support for CTF

ISS providers with support for CTF are as specified in 8.2 with the following modifications:

a) A detailed temporal behavioral for M_UNITDATA.indication and M_UNITDATA.request is defined.
b) A frame_handle parameter is associated with each M_UNITDATA.indication and M_UNITDATA.request invocation.
c) Two additional service primitives, M_LATEERROR.indication and M_LATEERROR.request, are provided by ISS providers with support for CTF.

The temporal behavior of M_UNITDATA.indication and M_UNITDATA.request is defined as follows:

d) M_UNITDATA.indication'end occurs after reception of the associated frame from the individual LAN finished.
e) M_UNITDATA.indication'start occurs earliest when reception of the associated frame to the individual LAN started, and latest at the instant of time of M_UNITDATA.indication'end. The exact positioning in this range is defined by the ISS provider.
f) M_UNITDATA.request'start occurs at the time when the associated frame for transmission is passed towards to individual LAN by a Bridge port (9.2).
g) M_UNITDATA.request'end occurs at the time when the associated frame under transmission is completed:
    1) If the frame under transmission originates from frame under reception from a different Bridge port, the frame completes at the time of M_UNITDATA.indication'end of the frame under reception.
    2) If the frame under transmission originates from a higher layer entity (9.5), the frame completes at the time of M_UNITDATA.indication'end of the associated ISS service primitive invocation from that entity.

The frame_handle parameter is passed as subparameter of the connection_identifier parameter. This parameter identifies the associated frame in a Bridge with support for CTF. The frame_handle parameter is unique for a particular frame within a Bridge from the time the reception of that frame starts until that frame can no longer be transmitted by that Bridge.

NOTE—This standard does not define an explicit encoding of the frame_handle parameter. Any encoding that satisfies the above uniqueness criterion is valid.

During frame reception and transmission, the frame_handle parameter is determined by the ISS provider prior to or at the time of M_UNITDATA.indication'start, and passed to the ISS provider at the time of M_UNITDATA.request'start, respectively.

An M_LATEERROR.indication primitive is invoked for indicating a later error in a frame under reception, including (but not limited to) an inconsistent FCS. An M_LATEERROR.request primitive may be invoked for requesting late error handling by the ISS provider for a frame under reception.

```
M_LATEERROR.indication      (
                            frame_handle,
                            marked_error
                            )

M_LATEERROR.request         (
                            frame_handle,
                            marked_error
                            )
```

Invocations of M_LATERROR.indication and M_LATERROR.request are modeled as instantaneous invocations (7.3). An ISS provider can invoke M_LATEERROR.indication between M_UNITDATA.indication’start and M_UNITDATA.indication’end of the M_UNITDATA.indication invocation that carries the same frame_handle value as subparameter of connection_identifier. A M_LATEERROR.request primitive can be invoked between M_UNITDATA.request’start and M_UNITDATA.request’end of the M_UNITDATA.request invocation associated with the same frame_handle value.

An ISS provider with support for CTF can handle late errors upon M_LATEERROR.request invocation by marking erroneous frames under transmission, truncating frames under transmission, combinations thereof, or other means. The exact operation is dependent on the ISS provider and not specified in this Standard in detail.

In general, marking erroneous frames under transmission assigns a externally visible indicator to such frames, usually at the end of frame transmission. The marked_error parameter is a Boolean for identifying and controlling such markings. On invocations of M_LATEERROR.indication, marked_error is used for distinguishing between late errors that where discovered and marked by the sending ISS provider upstream (TRUE), and late errors that were discovered the first time by the receiving ISS provider (FALSE). ISS providers not supporting marking always set this parameter to FALSE. On invocations of M_LATERROR.request, the value marked_error is always TRUE.

NOTE—It is assumed that there is a variety of options for implementing frame marking mechanisms. For example, by using physical layer symbols (1.121 through 1.126 of [B7]) or special frame check sequences (p.54 of [B6]). The description permits any marking mechanism, but the associated error counters (11.4) are only consistent in LANs with homogeneous ISS providers with support for CTF, and may be inconsistent in heterogeneous settings.

<<Editor’s Note: Parameter frame_handle may be moved to a higher position in the stack (e.g., CTF sublayer). The resulting externally visible behavior would be the same. Parameter marked_error in M_LATEERROR.request may be removed in future unless there are cases where erroneous frames under transmission should not be marked.>>

9. Bridge port transmit and receive operations

9.1 Overview

The architecture of the Bridge Port transmit and receive operations in CTF Bridges is based on the architecture found in S&F Bridges with additions for CTF. The architecture in CTF Bridges is shown in Figure 9-1 and Figure 9-2 for VLAN-unaware and VLAN-aware CTF Bridges, respectively.

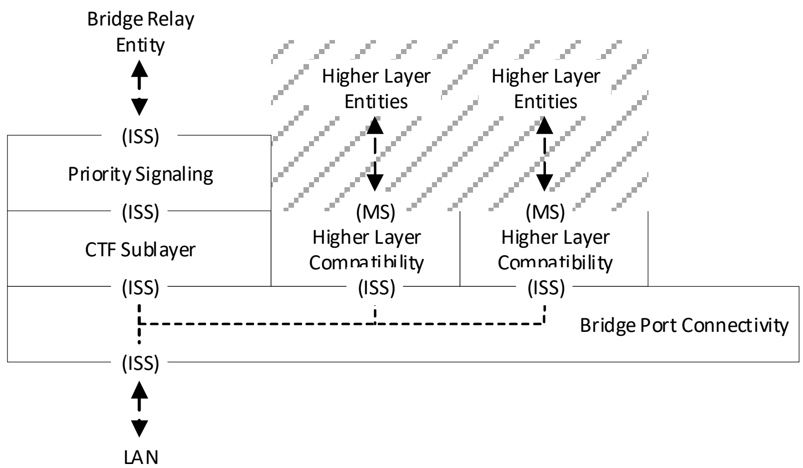

Figure 9-1—Bridge Port Transmit and Receive (VLAN-unaware).

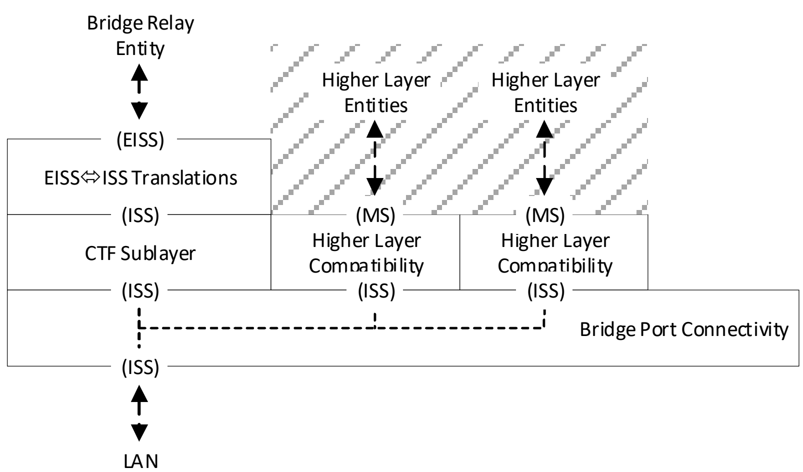

Figure 9-2—Bridge Port Transmit and Receive (VLAN-aware).

The elements contained are as follows:

a) Bridges Port Connectivity (9.2) between the access points of the ISS.
b) Priority Signaling in VLAN-unaware CTF Bridges (9.3).
c) Translations between ISS and EISS in VLAN-aware CTF Bridges (9.4).
d) Higher Layer Compatibility (9.5).
e) CTF Sublayer (9.6).

9.2 Bridge port connectivity

Bridge Port connectivity in CTF Bridges is as specified for S&F Bridges specified in 8.5.1 of IEEE Std 802.1Q with the additional definitions as follows.

For frames under reception originating from the LAN, a copy of such frames for each upper access point is created prior to passing each copy towards the respective upper access point. Frames from the upper access points are passed towards the LAN instantaneously. The multiplexing rules towards the LAN are identical to those of S&F Bridges with the addition that frames under reception originating from the Bridge relay entity are treated as received frames.

9.3 Priority signaling

9.3.1 Receive path operations

VLAN-unaware CTF Bridges may implement a shim for support of the ISS with signaled priority, as specified in 6.20 of IEEE Std 802.1Q, to determine values of the drop_eligible and priority parameters (Clause 8) from frames destined towards the Bridge relay entity that contain a C-Tag (Customer VLAN Tag) or S-Tag (Service VLAN Tag or Backbone VLAN Tag).

If the shim is not implemented, frames under reception are passed towards the Bridge relay entity instantaneously.

If the shim is implemented, the following additional definitions for frames under reception apply.

Frames under reception are stalled pending the initial four octets of the mac_service_data_unit parameter. If the first two octets indicate a C-Tag (Table 9-1 of IEEE Std 802.1Q), the priority and drop_eligible parameters are decoded from the Tag's Control Information (9.6 of IEEE Std 802.1Q) in the subsequent two octets prior to passing the frame towards the Bridge relay entity instantaneously. For any other VLAN Tag (Table 9-1 of IEEE Std 802.1Q), processing falls back to S&F. In absence of any VLAN Tag, the frame is passed towards the Bridge relay entity instantaneously.

For frames under reception, the invocation of M_UNITDATA.indication (M_UNITDATA.indication'start) towards the Bridge relay entity starts when the frame is passed to the Bridge relay entity according to the aforesaid definitions, and ends when the originating invocation of M_UNITDATA.indication ends (M_UNITDATA.indication'end).

NOTE—This definition is intended to support the understanding of temporal relationships (e.g., distinction between *frame under reception* and *received frame*).

9.3.2 Transmit path operations

All frames originating from the Bridge relay entity are passed towards Bridge Port connectivity (9.2) instantaneously.

9.4 Translations between Internal Sublayer Service (ISS) and Enhanced Internal Sublayer Service (EISS)

9.4.1 Receive path operations

The translations from ISS to EISS can extract and decode C-Tags from the mac_service_data_unit parameter and discard tagged or untagged frames dependent on management parameters. The operations are as specified in 9.6.1 of IEEE Std 802.1Q, with the following additional definitions for frames under reception.

Frames under reception are stalled pending the initial four octets of the mac_service_data_unit parameter. The frame is then discarded according to the rules specified in 6.9.1 of IEEE Std 802.1Q, or further processed as follows:

a) If the first two octets indicate a C-Tag (Table 9-1 of IEEE Std 802.1Q), the vlan_identifier, priority and drop_eligible parameters are decoded from the Tag's Control Information (9.6 of IEEE Std 802.1Q) in the subsequent two octets, the first four octets are removed from mac_service_data_unit parameter, and the frame is passed towards the Bridge relay entity instantaneously in this order.
b) If the first two octets indicate a VLAN Tag other than a C-Tag, processing falls back to S&F.
c) In all other cases, the frame is passed towards the Bridge relay entity instantaneously.

For frames under reception, the invocation of EM_UNITDATA.indication (EM_UNITDATA.indication'start) towards the Bridge relay entity starts when the frame is passed to the Bridge relay entity according to the aforesaid definitions, and ends when the originating invocation of M_UNITDATA.indication ends (EM_UNITDATA.indication'end).

9.4.2 Transmit path operations

The translations from EISS to ISS on the transmit path of S&F Bridges can discard, encode and insert C-Tags into the mac_service_data_unit parameter. The operations are as specified in 9.6.2 of IEEE Std 802.1Q.

NOTE—Modifications of the mac_service_data_unit parameter in accordance with ISO/IEC 11802-5, IETF RFC 1042 (1988) and IETF RFC 1390 (9.6.2 of IEEE Std 802.1Q) are incorporated into the queuing decision logic (10.12).

9.5 Higher layer compatibility

9.5.1 Receive path operations

On the receive path, higher layer compatibility ensures that only frames from ISS providers are passed via the MAC Service Interface to higher layer entities in absence of late errors. A CTF Bridge falls back to S&F prior to passing copies of frames under reception towards higher layer entities and performs the translation between the service primitives of the ISS and the MAC Service as defined in Clause 14 of IEEE Std 802.1 AC.

9.5.2 Transmit path operations

On the transmit path from higher layer entities towards ISS providers, higher layer compatibility falls back to S&F prior to passing frames, unless such frames are passed by the higher layer according to the instantaneous invocation model (7.3).

<<Editor’s Note: The intention of this description is to avoid limiting the temporal behavior of higher layer entities while ensuring that ISS providers without support for CTF can handle frames from any higher layer entity.>>

9.6 Cut-Through Forwarding (CTF) sublayer

9.6.1 Receive path operations

For frames under reception destined towards the Bridge relay, the CTF sublayer can emit late errors and fall back to S&F based on the CTFReceptionEnable parameter (11.2.4) and dependent on whether or not the ISS provider associated with the Bridge Port supports CTF or not, as reflected by the CTFReceptionSupported parameter (11.2.3).

If CTFReceptionEnable is TRUE and CTFReceptionSupported is TRUE, a frame under reception is passed towards the relay (9.3 and 9.4) instantaneously. The receive path operations of the CTF sublayer maintains reference to such frames. If a M_LATERROR.indication (8.3) occurs afterwards and prior to M_UNIDATA.indication'end, a late error associated with that frame is raised and an error counter is increased (9.6.3).

If CTFReceptionEnable is FALSE and CTFReceptionSupported is TRUE, processing of a frame under reception is stalled pending all parameters of this frame. The frame is passed towards the Bridge relay instantaneously if no M_LATERROR.indication (8.3) occurred prior to M_UNIDATA.indication'end and discarded otherwise.

If CTFReceptionSupported is FALSE, only received frames are visible to the CTF sublayer (8.2), and are passed towards the Bridge relay instantaneously.

9.6.2 Transmit path operations

The transmit path of the CTF sublayer passes frames from the Bridge relay entity towards the LAN instantaneously. For any frame that is a frame under transmission AND a frame under reception (i.e., Cut-Through), the transmit path operations of the CTF sublayer maintains reference to such frames and invokes one M_LATEERROR.request (8.3) per frame if a late error has been raised by an earlier stage. Such earlier stages include the CTF sublayer receive path (9.6.1) and other processing stages in the Bridge relay entity (Clause 10).

9.6.3 Error counters

Handling of inconsistent frames can increase diagnostic error counters on the receive path (9.6.1), CTFReceptionDiscoveredErrors (11.4.1) and CTFReceptionUndiscoveredErrors (11.4.2), as follows:

— If the first_error parameter of an M_LATEERROR.indication invocation is FALSE, CTFReceptionDiscoveredErrors is increased.
— If the first_error parameter of an M_LATEERROR.indication invocation is TRUE, CTFReceptionUndiscoveredErrors is increased.

10. Bridge relay operations

10.1 Overview

The structure of the Bridge relay entity of CTF Bridges is aligned with that of an S&F Bridge. Additional definitions for supporting frames under reception for Cut-Through exist primarily in the forwarding process (see also Clause 6).

The structure of the forwarding process in CTF Bridges, in terms of processing stages passed by frames, is likewise aligned with that of S&F Bridges. It comprises processing stages symmetrical to those found in S&F Bridges (8.6 and Figure 8-12 of IEEE Std 802.1Q) with incorporated processing stages for FRER (8.1 and Figure 8-2 of IEEE Std 802.1CB). The given subset is intended to provide the minimum for having stream_handle and sequence_number parameters. The forwarding process of a CTF Bridge, additional elements in the Bridge relay and indicated interactions between them are shown in Figure 10-1.

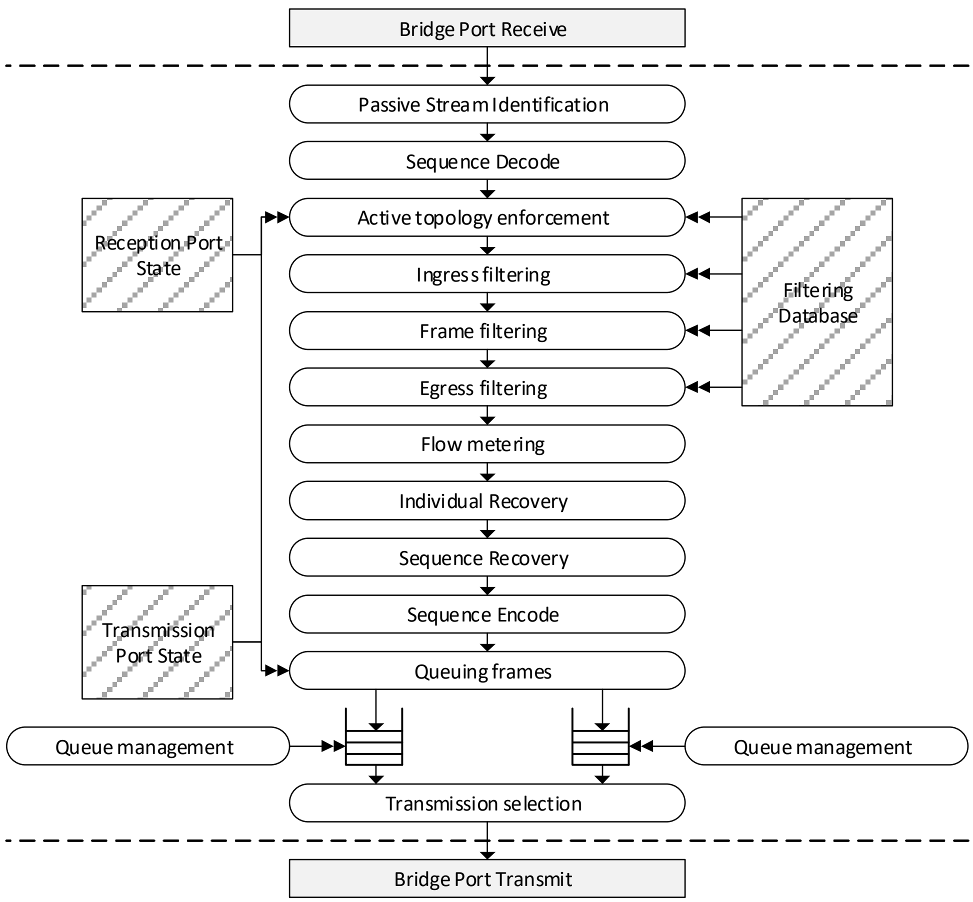

Figure 10-1—Forwarding process of a CTF Bridge.

The processing stages and their subsections are as follows:

a) Passive Stream Identification (10.2)
b) Sequence Decode (10.3)
c) Active topology enforcement (10.4)
d) Ingress filtering (10.5)
e) Frame filtering (10.6)

f) Egress filtering (10.7)
g) Flow classification and metering (10.8)
h) Individual recovery (10.9)
i) Sequence recovery (10.10)
j) Sequence encode (10.11)
k) Queuing frames (10.12), and associated additional definitions for queue management (10.13)
l) Transmission selection (10.14)

The sections of the processing stages are written in a manner that avoids replicating contents of the corresponding sections in the published IEEE 802.1 standards. The sections provide reference to the corresponding section(s) in the published standards, followed by additional definitions for processing frames under reception. While the emphasis is on processing frames under reception, the stages are equally capable for processing received frames.

<<Editor’s Note: The FRER stages used in this version limit to a subset of those described in IEEE Std 802.1CB when the FRER functions are integrated into the forwarding process. For example, active stream identification is not present.>>

10.2 Passive stream identification

The passive stream identification stage can determine a stream_handle parameter and associate it with a frame. The passive stream identification stage is not present in CTF Bridges without support for IEEE Std 802.1CB. If present, the operation of this stage is as specified in 6.2, 6.4, 6.5, 8.1 and Figure 8-2 of IEEE Std 802.1CB with the additional definitions for frames under reception described in the following.

Whether or not a frame under reception can be subject to passive stream identification is dependent on the associated management parameters (Clause 9 of IEEE Std 802.1CB), and can depend a variable set of per-frame parameters of a frame under reception. Processing of such frame stalls pending all necessary parameters of the frame that are required to determine the following:

a) Whether or not one or more stream identification function instance matches the frame, and
b) in case of multiple matching stream identification function instance, to the resolve ambiguity as defined in IEEE Std 802.1CB.

The exact set of parameters required to satisfy the aforesaid conditions is dependent on the stream identification function instances that are actually set in the stream identity table (9.1 of IEEE Std 802.1CB) and the parameters of the underlying stream identification functions (Clause 6 of IEEE Std 802.1CB). If a stream identification function instance matches, a stream_handle parameter is associated to the frame before the frame is passed to the next processing stage instantaneously.

NOTE—The stall operation in this clause does not become effective (7.5.1) if all necessary parameters are already available when a frame under reception reaches the passive stream identification stage.

10.3 Sequence decode

The sequence decode stage is not present in CTF Bridges without support for FRER. The stage can extract redundancy tags (7.8 of IEEE Std 802.1CB) from frames, decode therein contained sequence_number parameters (item b) in 6.1 of IEEE Std 802.1CB), and assign these parameters to frames. The operation of this stage is as specified in 7.6 of IEEE Std 802.1CB with the additional definitions for frames under reception described in the following.

<<Editor’s Note: Consideration of tags other than R-Tag is excluded in this version.>>

If a frame under reception has no associated stream_handle parameter (10.2), the frame is passed to the next processing stage (10.4) instantaneously. If a frame under reception has an associated stream_handle parameter, processing stalls pending the initial six octets in the mac_service_data_unit parameter. If the first two octets indicate an R-Tag (Table 7-1 of IEEE Std 802.1CB), the sequence_number parameter is decoded from the 5th and 6th octet, the first six octets are removed from the mac_service_data_unit parameter, and the frame is passed to the next processing stage instantaneously.

10.4 Active topology enforcement

10.4.1 Overview

The active topology enforcement stage can determine if frames from reception Ports are submitted to learning, and determines the initial set of potential transmission Ports for each frame. Both operations are as specified in 8.6.1 of IEEE Std 802.1Q in CTF Bridges, with the additions described in the following for learning (10.4.2) and the initial set of potential transmission Ports (10.4.3) separately.

<<Editor’s Note: To my surprise, I could not find a statement in 8.4 or 8.6.1 of IEEE Std 802.1Q indicating that frames would be discarded by active topology enforcement if the forwarding control in 8.6.1 is FALSE.>>

10.4.2 Learning

Learning is based on the source_address (VLAN-unaware and VLAN-aware CTF Bridges) and VID (VLAN-aware CTF Bridges) parameters of frames for adding dynamic entries in the forwarding database (FDB) as specified in 8.7 of IEEE Std 802.1Q. The parameters are submitted to learning only if the following conditions are satisfied:

a) A frame under reception associated with the parameters reached the end of reception.
b) This frame's FCS is consistent.
c) All conditions of an S&F Bridge for using the parameters for learning are satisfied (8.4 and 8.6.1 of IEEE Std 802.1Q).

10.4.3 Initial set of potential transmission ports

The initial set of potential transmission Ports is determined by CTF Bridges as specified in 8.6.1 of IEEE Std 802.1Q.

10.5 Ingress filtering

The ingress filtering stage is not present in VLAN-unaware CTF Bridges. The stage discards frames originating from reception Ports based on per frame VID parameters, if present. The conditions under which a frame is discarded by a CTF Bridge are identical to those specified in 8.6.2 of IEEE Std 802.1Q. Non-discarded frames are passed to the next processing stage (10.6) instantaneously.

10.6 Frame filtering

The frame filtering stage reduces the set of potential transmission Ports (10.4) associated with a frame based on the destination_address (VLAN-unaware and VLAN-aware CTF Bridges) and VID (VLAN-aware CTF Bridges only) parameters, entries in the FDB, and management parameters. The operation of this stage is as specified in 8.6.3 of IEEE Std 802.1Q with the additional definitions for frames under reception as follows.

When a frame under reception reaches frame filtering, processing stalls pending a frame's destination_address parameter before performing an FDB query for this frame (8.8.9 of IEEE Std 802.1Q). Dependent on a query's result by the FDB, processing of the frame under reception falls back to S&F or passes the frame to the next stage instantaneously as follows:

— Whenever the query evaluation by the FDB results in flooding (i.e., query evaluation hits an "ELSE Forward" branch in 8.8.9 of IEEE Std 802.1Q), processing of the frame falls back to S&F.
— In all other cases, a frame under reception is passed to the next processing stage instantaneously.

NOTE 1—The specified fall-back to S&F is intended to reduce the cases for circulation of inconsistent frames in topological loops, assuming that the performance benefits of CTF in presence of flooding are negligible in most use-cases.

NOTE 2—The above processing stall may rarely become effective (7.5.1) in VLAN-aware CTF bridges because the frame filtering stage cannot be reached prior to evaluation of VLAN information in frames under reception by earlier stages.

<<Editor's Note: flow_hash [item c) in 8.6.3 of IEEE Std 802.1Q] is not considered in this version of this document.>>

10.7 Egress filtering

The egress filtering stage is only present in VLAN-aware CTF Bridges. The stage reduces the set of potential transmission Ports (10.4) associated with a frame based on this frame's VID parameter. The rules under which transmission Ports are removed from this set are identical to those specified in 8.6.4 of IEEE Std 802.1Q.

10.8 Flow classification and metering

10.8.1 Overview

The flow classification and metering stage can apply flow classification and metering to frames that are received on a Bridge Port and have one or more potential transmission ports. The stage is structured into multiple internal (sub)stages in CTF Bridges, identical to the structure specified in 8.6.5 of IEEE Std 802.1Q. The internal stages and their relationships are shown in Figure 10-2.

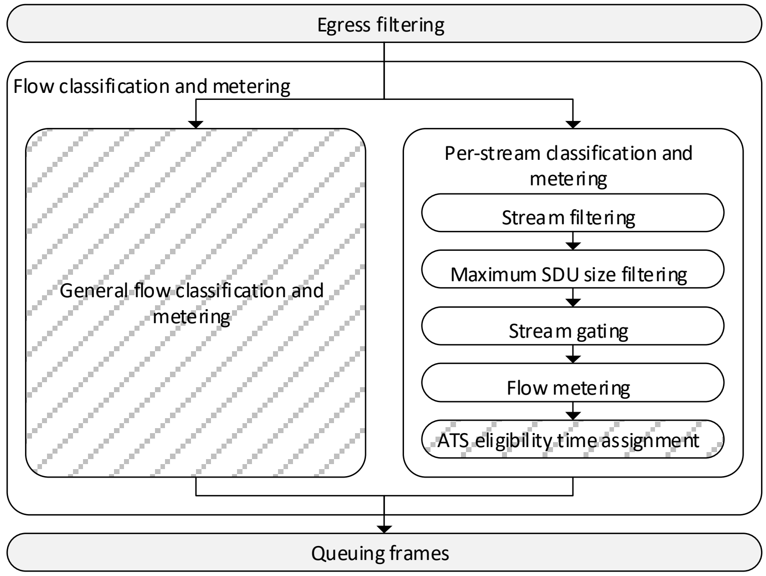

Figure 10-2—Flow classification and metering.

Support for frames under reception is provided by CTF Bridges for the following internal stages:

a) Stream filtering
b) Maximum SDU size filtering
c) Stream gating
d) Flow metering

Processing in CTF Bridges falls back to S&F immediately if a frame under reception reaches any other internal stage of flow classification and metering prior to being processed by that other internal stage.

The operation of stages with support for frames under reception is described in 10.8.2, 10.8.3, 10.8.4 and 10.8.5. All of these stages process frames under reception instantaneously (i.e., stall-free operation).

10.8.2 Stream filtering

The operation of stream filtering for frames under reception is as specified in 8.6.5.3 of IEEE Std 802.1Q.

10.8.3 Maximum SDU size filtering

The operation of maximum SDU size filtering for frames under reception is as specified in 8.6.5.3.1 of IEEE Std 802.1Q with the following additional definitions for frames under reception.

When a frame under reception reaches maximum SDU size filtering, an initial number of octets of this frame is already received. This number of octets is used by maximum SDU size filtering for the decision on whether or not this frame is passed to a subsequent processing stage or discarded. If a frame under reception already passed frame maximum SDU size filtering and the associated maximum SDU size limit is exceeded prior to the frame's end of reception, a late error for that frame is indicated for handling by subsequent processing stages in a CTF Bridge.

10.8.4 Stream gating

The operation of stream gates for frames under reception is as specified in 8.6.5.4 of IEEE Std 802.1Q with the following additional definitions for frames under reception.

When a frame under reception reaches a stream gate, this frame is only passed to the next processing stage if the gate is in an open state. The frame is discarded otherwise prior to being passed to the next processing stage. If a stream gate closes prior to the end of the frame under reception, a late error for this frame is indicated immediately for handling by subsequent processing stages in a CTF Bridge.

10.8.5 Flow metering

The operation of stream gates for frames under reception is as specified in 8.6.5.5 of IEEE Std 802.1Q with the following additional definitions for frames under reception.

When a frame under reception reaches flow metering, an initial number of octets of this frame is already received. This number of octets is used by the associated flow meter for the decision on whether or not this frame is passed to a subsequent processing stage or discarded. If a frame under reception already passed flow metering and the limit of the flow meter is subsequently exceeded prior to the frame's end of reception, a late error for this frame is indicated for handling by subsequent processing stages in a CTF Bridge.

10.9 Individual recovery

The individual recovery stage is not present in CTF Bridges without support for FRER. If present, the stage can associate frames belonging to individual Member streams (7.4.2 of IEEE Std 802.1CB) with therefore configured instances of the Base recovery function (7.4.3 of IEEE Std 802.1CB), which then discard frames with repeating sequence_number parameters (10.3) on a per Member stream resolution. The operation of the individual recovery stage is as specified in 7.5 of IEEE Std 802.1CB, with the following additions for CTF Bridges.

If frames under reception are associated with a Base recovery function for individual recovery, processing falls back to S&F prior to performing individual recovery.

NOTE—Falling back to S&F ensures that individual recovery does not falsely discard a frame with correct sequence_number parameter (and consistent FCS) after accepting a frame with incorrect but identical sequence_number (and inconsistent FCS) earlier. The same rationale applies in 10.10.

10.10 Sequence recovery

The sequence recovery stage is not present in CTF Bridges without support for FRER. If present, the stage can associate frames belonging to sets of Member streams with therefore configured instances of the Base recovery function (7.4.3 of IEEE Std 802.1CB), which then remove frames with repeating sequence_number parameters [item b) in 6.1 of IEEE Std 802.1CB] on a per Member stream set resolution. The operation of the sequence recovery stage is as specified in IEEE Std 802.1CB (7.4.2 of IEEE Std 802.1CB), with the following additions for CTF Bridges.

If frames under reception are associated with a Base recovery function for sequence recovery, processing falls back to S&F prior to performing sequence recovery.

10.11 Sequence encode

The sequence recovery stage is not present in CTF Bridges without support for FRER. If it is present, the stage can encode and insert R-Tags into the mac_service_data_unit parameter based on the sequence_number parameter associated with these frames. The operation of the sequence encode stage for frames under reception is as specified in 7.6 and 7.8 of IEEE Std 802.1CB.

10.12 Queuing frames

The queuing frames stage queues each received frame to a per-traffic class queue of each remaining potential transmission Port associated with the frame (10.4, 10.6 and 10.7). The stage operates as specified in 8.6.6 of IEEE Std 802.1Q with the following additional definitions for frames under reception.

Before a frame under reception is queued, a per-queue copy of a frame is created before queuing and considered separately according to the following algorithm:

```
IF
        (the associated CTFTransmissionEnable parameter [11.2.2] is FALSE)
        OR
        (the associated transmission selection algorithm is not strict priority [8.6.8.1 of IEEE Std 802.1Q])
THEN
        Processing falls back to S&F before queuing the frame instantaneously.
ELSE IF
        (CTFInconsistencyCondition is TRUE)
THEN
        IF
                (the associated CTFInconsistencyFallbackEnable parameter [11.2.6] is TRUE)
        THEN
                Processing falls back to S&F before queuing the frame instantaneously.
        ELSE
                The frame is discarded before queuing.
        END IF
ELSE
        The frame is queued instantaneously.
END IF

CTFInconsistencyCondition :=
        (transmission link speed of the frame > reception link speed of the frame)
        OR
        (mac_service_data_unit modification required in accordance with
        ISO/IEC 11802-5, IETF RFC 1042 (1988) and IETF RFC 1390)
```

NOTE— When 'ELSE IF (CTFInconsistencyCondition is TRUE)' is reached, the associated CTFTransmissionEnable parameter is always TRUE.

<<Editor’s Note: TBD: Put a reference after (CTFInconsistencyCondition) - AND modification of the mac_service_data_unit according to 6.9.2 of 802.1Q cannot be precluded>>

10.13 Queue management

The rules for removing frames from 8.6.7 of IEEE Std 802.1Q remain unaltered in CTF Bridges.

In addition, CTF Bridges may remove a frame from a queue if all of the following conditions are satisfied:

a) The frame was queued while it was under reception.
b) A processing stage before queuing (10.12) raised a late error for that frame.
c) The end of reception of the frame was reached before the frame was selected for transmission (10.14).

NOTE—Erroneous frames removed according to this additional rule will not become visible on the LAN of an associated transmission Port, because such frames can be removed before being selected by transmission selection.

10.14 Transmission selection

Transmission selection determines whether frames in per traffic class queues are available for transmission, determines transmission ordering and transmission times of queued frames, de-queues frames for transmission and initiates transmission. Transmission selection in CTF Bridges is as specified in 8.6.8 of IEEE Std 802.1Q.

11. Management parameters

11.1 Overview

The management parameters for CTF fall into three categories:

a) Control Parameters (11.2)
b) Timing Parameters (11.3)
c) Error Counters (11.4)

The control parameters allow to (i) determine whether CTF is supported on a per Port and per Port per Traffic Class resolution, and if CTF is supported, to (ii) enable and disable CTF on these resolutions. These parameters are available in reception Ports and transmission Ports. For a pair of Bridge ports, frames can only be subject to the CTF operation if CTF is supported and enabled on both Ports.

The timing parameters expose the delays experienced by frames passing from a particular reception Port to another transmission Port. These parameters are primarily intended for automated network and traffic configuration, for example, by a Centralized Network Controller (CNC) using the associated mechanisms from Clause 46 of IEEE Std 802.1Q.

The error counters expose information on frames that were subject to the CTF operation in a Bridge, even though such frames have consistency errors (i.e., a frame check sequence inconsistent with the remaining contents of that frame) during reception by this Bridge. These counters are primarily intended for manual diagnostic purposes to support identifying erroneous links or stations, for example, by a human network administrator.

11.2 Control parameters

11.2.1 CTFTransmissionSupported

A Boolean read-only parameter that indicates whether CTF on transmission is supported (TRUE) or not (FALSE). There is one CTFTransmissionSupported parameter for each traffic class of each transmission Port. This parameter is always FALSE for all traffic classes of a Port if the underlying ISS provider does not support CTF (8.2).

11.2.2 CTFTransmissionEnable

A Boolean parameter to enable (TRUE) and disable (FALSE) CTF on transmission. There is one CTFTransmissionEnable parameter for each traffic class of each transmission Port. The default value of the CTFTransmissionEnable parameter is FALSE for all traffic classes of all transmission Ports. It is an error if a CTFTransmissionEnable is set to TRUE if the associated CTFTransmissionSupported parameter is FALSE.

11.2.3 CTFReceptionSupported

A Boolean read-only parameter that indicates whether CTF on reception is supported (TRUE) or not (FALSE). There is one CTFReceptionSupported parameter for each reception Port. This parameter is always FALSE for a Port if the underlying ISS provider does not support CTF (8.2).

11.2.4 CTFReceptionEnable

A Boolean parameter to enable (TRUE) and disable (FALSE) CTF on reception. There is one CTFReceptionEnable parameter for each reception Port. The default value of the CTFReceptionEnable parameter is FALSE for all reception Ports. It is an error if a CTFReceptionEnable is set to TRUE if the associated CTFReceptionSupported parameter is FALSE.

11.2.5 CTFInconsistencyFallbackSupported

A Boolean read-only parameter that indicates whether falling back to S&F prior to queuing inconsistent frames is supported (TRUE) or not (FALSE). There is one CTFInconsistencyFallbackSupported parameter for each transmission Port.

11.2.6 CTFInconsistencyFallbackEnable

A Boolean parameter to enable (TRUE) and disable (FALSE) falling back to S&F prior to queuing inconsistent frames. There is one CTFInconsistencyFallbackEnable parameter for each transmission Port. The default value of the CTFInconsistencyFallbackEnable parameter is FALSE for all transmission Ports. It is an error if a CTFInconsistencyFallbackEnable is set to TRUE if the associated CTFInconsistencyFallbackSupported parameter is FALSE.

11.3 Timing parameters

11.3.1 CTFDelayMin and CTFDelayMax

A pair of unsigned integer read-only parameters, in units of nanoseconds, describing the delay range for frames that are subject to the CTF operation and encounter zero delay for transmission selection (8.6.8 of IEEE Std 802.1Q). This occurs when the queue for the frame's traffic class is empty, the frame's traffic class has permission to transmit, and the egress Port is idle (i.e., not transmitting another frame). There is one pair of CTFDelayMin and CTFDelayMax parameters per reception Port per transmission Port traffic class pair.

<<Editor's Note: This version does not contain parameters for frame truncation.>>

11.4 Error counters

11.4.1 CTFReceptionDiscoveredErrors

An integer counter, counting the number of received frames with already discovered consistency errors. There is one CTFReceptionDiscoveredErrors parameter for each reception Port.

A frame with discovered consistency errors is a frame with consistency errors discovered by the present Bridge, and has already been identified as such by a Bridge on the upstream path.

Determination on whether or not inconsistency errors where already discovered by an upstream Bridge relies on an implementation-dependent marking mechanism for such frames (see also 8.3). If the present Bridge discovers such marking, then CTFReceptionDiscoveredErrors is increased by one.

The CTFReceptionDiscoveredErrors counter the CTFReceptionUndiscoveredErrors counter (11.4.2) are related to each other, and the interpretation of both coutners is dependent on the marking mechanisms present in a network:

a) If all Bridges of a network use the identical marking mechanisms, the values of CTFReceptionDiscoveredErrors and CTFReceptionUndiscoveredErrors can be interpreted individually.
b) If the Bridges of a network use different marking machnisms, including cases where some Bridge not use any marking mechanism, the sum of both counters can be interpreted as number of received

frames with consistency errors discovered by the present Bridge, but irrespectively on whether or not a potential Bridge on the upstream path already discovered these errors.

11.4.2 CTFReceptionUndiscoveredErrors

An integer counter, counting the number of received frames with yet undiscovered consistency errors. There is one CTFReceptionUndiscoveredErrors parameter for each reception Port.

A frame with undiscovered consistency errors is a frame with consistency errors discovered by the present Bridge, and has not been identified as such by a Bridge on the upstream path.

This counter is increased by one if a frame with consistency errors is received at the associated reception Port and CTFReceptionDiscoveredErrors (11.4.1) is not increased.

12. YANG

12.1 YANG framework

<<Editor's Note: Placeholder>>

12.2 Structure of the YANG modules

<<Editor's Note: Placeholder>>

12.3 Security considerations

<<Editor's Note: Placeholder>>

12.4 YANG schema tree definitions

<<Editor's Note: Placeholder>>

12.5 YANG modules

<<Editor's Note: Placeholder>>

13. Cut-Through Forwarding (CTF) in Bridged networks

<<Editor’s Note: Placeholder for:

- Describing forwarding to unintended ports and or traffic classes of frames under reception due to header corruption,

- Qualitative analysis of the impact,

- Mitigations, and

- Recommendations for networks.

>>

Annex A

(normative)

PICS proforma—Cut-Through Forwarding (CTF) Bridges[12]

<<Editor’s Note: The remaining contents of Annex A are as found in the FrameMaker template and will be adjusted in a later stage (i.e., do not review/comment now).

A.1 Introduction

The supplier of a protocol implementation that is claimed to conform to this standard shall complete the following Protocol Implementation Conformance Statement (PICS) proforma.

A completed PICS proforma is the PICS for the implementation in question. The PICS is a statement of which capabilities and options of the protocol have been implemented. The PICS can have a number of uses, including use

a) By the protocol implementer, as a checklist to reduce the risk of failure to conform to the standard through oversight.
b) By the supplier and acquirer—or potential acquirer—of the implementation, as a detailed indication of the capabilities of the implementation, stated relative to the common basis for understanding provided by the standard PICS proforma.
c) By the user—or potential user—of the implementation, as a basis for initially checking the possibility of interworking with another implementation (note that, while interworking can never be guaranteed, failure to interwork can often be predicted from incompatible PICSs).
d) By a protocol tester, as the basis for selecting appropriate tests against which to assess the claim for conformance of the implementation.

A.2 Abbreviations and special symbols

A.2.1 Status symbols

M	mandatory
O	optional
O.n	optional, but support of at least one of the group of options labeled by the same numeral n is required
X	prohibited
pred:	conditional-item symbol, including predicate identification: see A.3.4
¬	logical negation, applied to a conditional item’s predicate

A.2.2 General abbreviations

N/A	not applicable
PICS	Protocol Implementation Conformance Statement

[12] *Copyright release for PICS proformas:* Users of this standard may freely reproduce the PICS proforma in this annex so that it can be used for its intended purpose and may further publish the completed PICS.

A.3 Instructions for completing the PICS proforma

A.3.1 General structure of the PICS proforma

The first part of the PICS proforma, implementation identification and protocol summary, is to be completed as indicated with the information necessary to identify fully both the supplier and the implementation.

The main part of the PICS proforma is a fixed-format questionnaire, divided into several subclauses, each containing a number of individual items. Answers to the questionnaire items are to be provided in the rightmost column, either by simply marking an answer to indicate a restricted choice (usually Yes or No) or by entering a value or a set or range of values. (Note that there are some items where two or more choices from a set of possible answers can apply; all relevant choices are to be marked.)

Each item is identified by an item reference in the first column. The second column contains the question to be answered; the third column records the status of the item—whether support is mandatory, optional, or conditional: see also A.3.4. The fourth column contains the reference or references to the material that specifies the item in the main body of this standard, and the fifth column provides the space for the answers.

A supplier may also provide (or be required to provide) further information, categorized as either Additional Information or Exception Information. When present, each kind of further information is to be provided in a further subclause of items labeled Ai or Xi, respectively, for cross-referencing purposes, where i is any unambiguous identification for the item (e.g., simply a numeral). There are no other restrictions on its format and presentation.

A completed PICS proforma, including any Additional Information and Exception Information, is the Protocol Implementation Conformation Statement for the implementation in question.

NOTE—Where an implementation is capable of being configured in more than one way, a single PICS may be able to describe all such configurations. However, the supplier has the choice of providing more than one PICS, each covering some subset of the implementation's configuration capabilities, in case that makes for easier and clearer presentation of the information.

A.3.2 Additional information

Items of Additional Information allow a supplier to provide further information intended to assist the interpretation of the PICS. It is not intended or expected that a large quantity will be supplied, and a PICS can be considered complete without any such information. Examples might be an outline of the ways in which a (single) implementation can be set up to operate in a variety of environments and configurations, or information about aspects of the implementation that are outside the scope of this standard but that have a bearing on the answers to some items.

References to items of Additional Information may be entered next to any answer in the questionnaire and may be included in items of Exception Information.

A.3.3 Exception information

It may occasionally happen that a supplier will wish to answer an item with mandatory status (after any conditions have been applied) in a way that conflicts with the indicated requirement. No preprinted answer will be found in the Support column for this item. Instead, the supplier shall write the missing answer into the Support column, together with an *Xi* reference to an item of Exception Information, and shall provide the appropriate rationale in the Exception item itself.

An implementation for which an Exception item is required in this way does not conform to this standard.

NOTE—A possible reason for the situation described previously is that a defect in this standard has been reported, a correction for which is expected to change the requirement not met by the implementation.

A.3.4 Conditional status

A.3.4.1 Conditional items

The PICS proforma contains a number of conditional items. These are items for which both the applicability of the item itself, and its status if it does apply—mandatory or optional—are dependent on whether certain other items are supported.

Where a group of items is subject to the same condition for applicability, a separate preliminary question about the condition appears at the head of the group, with an instruction to skip to a later point in the questionnaire if the "Not Applicable" answer is selected. Otherwise, individual conditional items are indicated by a conditional symbol in the Status column.

A conditional symbol is of the form "**pred:** S" where **pred** is a predicate as described in A.3.4.2 below, and S is a status symbol, M or O.

If the value of the predicate is true (see A.3.4.2), the conditional item is applicable, and its status is indicated by the status symbol following the predicate: The answer column is to be marked in the usual way. If the value of the predicate is false, the "Not Applicable" (N/A) answer is to be marked.

A.3.4.2 Predicates

A predicate is one of the following:

a) An item-reference for an item in the PICS proforma: The value of the predicate is true if the item is marked as supported and is false otherwise.

b) A predicate-name, for a predicate defined as a boolean expression constructed by combining item-references using the boolean operator OR: The value of the predicate is true if one or more of the items is marked as supported.

c) The logical negation symbol "¬" prefixed to an item-reference or predicate-name: The value of the predicate is true if the value of the predicate formed by omitting the "¬" symbol is false, and vice versa.

Each item whose reference is used in a predicate or predicate definition, or in a preliminary question for grouped conditional items, is indicated by an asterisk in the Item column.

A.4 PICS proforma—Cut-Through Forwarding (CTF) Bridges

A.4.1 Implementation identification

Supplier	
Contact point for queries about the PICS	
Implementation Name(s) and Version(s)	
Other information necessary for full identification, e.g., name(s) and version(s) of machines and/or operating system names	
NOTE 1—Only the first three items are required for all implementations; other information may be completed as appropriate in meeting the requirement for full identification. NOTE 2—The terms “Name” and “Version” should be interpreted appropriately to correspond with a supplier’s terminology (e.g., Type, Series, Model).	

A.4.2 Protocol summary

Identification of protocol specification	<tbs>
Identification of amendments and corrigenda to the PICS proforma that have been completed as part of the PICS	Amd. : Corr. : Amd. : Corr. :
Have any Exception items been required? (See A.3.3: the answer “Yes” means that the implementation is not conformant).	No [ ] Yes [ ]

Date of Statement	

Annex B

(informative)

Bibliography

Bibliographical references are resources that provide additional or helpful material but do not need to be understood or used to implement this standard. Reference to these resources is made for informational use only.

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Annex Z

(informative)

Commentary

<<Editor’s Note: Placeholder, for collecting open issues during the development.>>