P802.1DC/Draft 2.1

May 2023

Draft Standard for Local and metropolitan area networks—

Quality of Service Provision by Network Systems

Developed by the

LAN/MAN Standards Committee
of the
IEEE Computer Society

Unapproved draft

Prepared by the Security Task Group of IEEE 802.1

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.

The text proper of this draft begins with the Title page.

Editors' Foreword

All material in this document preceding the Title page.will be replaced prior to SA Ballot and are not part of the normative text. To avoid gratuitous changes to page numbering between final WG ballot and initial SA Ballot, the number of cover pages will remain unchanged, with pages intentionally left bank marked as such. The SA ballot cover pages may contain information for the stages of that ballot (including, if appropriate, cross-references to text changed in the course of SA balloting). The records of participants in the development of the standard will be added pre-publication.

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.

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http://ieee802.org/1/

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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 TSNTask 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.

Introductory notes to P802.1DC Draft 2.2

Draft 2.2 was prepared by Norman Finn for Working Group recirculation ballot as a result of the resolution of Working Group recirculation ballot comments on Draft 2.1, conducted in an IEEE 802.1 TSN teleconference on June 26, 2023. Revision bars in D2.2 are relative to D2.1. Significant changes from D2.1 include:

a) Definitions that were copies from IEEE Std 802 and IEEE Std 802.1Q were deleted from Clause 3.
b) Two comment resolutions, inadvertently left out of D2.1, were implemented.
c) Annex Z removed.

Introductory notes to P802.1DC Draft 2.1

Draft 2.1 was prepared by Norman Finn for Working Group recirculation ballot as a result of the resolution of first Working Group ballot comments on Draft 2.0, conducted as part of the March, 2023 IEEE 802 plenary in Atlanta. Revision bars in D2.1 are relative to D2.0. Significant changes from D2.‘ include:

a) Deletion of editor’s notes.
b) References to other documents cleaned up.
c) Editorial improvements and corrections.
d) Treatment of IPV vs. priority corrected.
e) Proper text for 802.1-standard YANG clause fleshed out.
f) YANG modules brought up to current YANGsters conventions.

Introductory notes to P802.1DC Draft 2.0

Draft 2.0 was prepared by Norman Finn for Working Group balloting as a result of the resolution of Task Group ballot comments on Draft 1.4, conducted as part of the November, 2022 IEEE 802 plenary in Bangkok. Revision bars in D2.0 are relative to D1.3. Significant changes from D2.0 include:

a) Minor editorial corrections..

Introductory notes to P802.1DC Draft 1.4

Draft 1.4 was prepared by Norman Finn for Task Group balloting after the Draft 1.3 YANG modules were revised during the September, 2022, IEEE 802.1 interim meeting. Draft 1.3 was not balloted. Revision bars in D1.4 are relative to D1.2. Significant changes from D1.3 include:

a) YANG modules were corrected to be able to compile (Clause 9).

Introductory notes to P802.1DC Draft 1.3

Draft 1.3 was prepared by Norman Finn for Task Group balloting as a result of the resolution of Task Group ballot comments on Draft 1.2, conducted as part of the March, 2022 IEEE 802 virtual plenary. Revision bars in D1.3 are relative to D1.2. Significant changes from D1.2 include:

a) YANG modules have been added (Clause 9).
b) .IEEE Std 802.1Qcw and IEEE Std 802.1Qcz have been added as normative references, both for changes to Asynchronous Traffic Shaping and for YANG.
c) A clear list of features provided has been added (6.2) and Clause 7 has been shuffled somewhat to be organized around that list.
d) In order to clarify the document, references in Clause 5 are now to subclauses in Clause 7, and Clause 7 contains the normative references to other documents.

Introductory notes to P802.1DC Draft 1.2

Draft 1.2 was prepared by Norman Finn for Task Group balloting as a result of the resolution of Task Group ballot comments on Draft 1.1, conducted at the IEEE 802.1 plenary meeting in Waikoloa, Hawaii, USA, November 11-14, 2019, and in subsequent virtual meetings of the TSN Task Group. Revision bars in D1.2 are relative to D1.1. Significant changes from D1.1 include:

a) All mention of Congestion Notification removed.
b) Shifted base from IEEE Std 802.1Q-2018 to IEEE Std 802.1Q-2022, and therefore eliminated references to IEEE Std 802.1Qcr.
c) Minor clarifications.

Introductory notes to P802.1DC Draft 1.1

Draft 1.1 was prepared by Norman Finn for Task Group balloting as a result of the resolution of Task Group ballot comments on Draft 1.0, conducted at the IEEE 802.1 interim meeting in Edinburgh, Scotland, September 16-20, 2019. Revision bars in D1.1 are relative to D1.0. Major changes from D1.0 include:

a) Changed “DCQoS” to “GFQoS”.
b) Changed “relay system” to “forwarding system”.
c) Changed “support for VLAN tagging” to “support for the EISS”.
d) Extracted support for preemption into a new clause 7.3.7.
e) Explained that VLAN tags can be seen as part of the mac_service_data_unit.
f) Made the requirements for in-order delivery more clear (7.3.4).

Introductory notes to P802.1DC Draft 1.0

Draft 1.0 was prepared by Norman Finn for Task Group balloting as a result of informal discussions about Draft 0.1, conducted at the IEEE 802.1 interim meeting in Hiroshima, Japan, January 14-18, 2019. No revision bars are present in D1.0. Major changes from D0.1 include:

a) YANG and MIB clauses (9 and 10) deleted.

b) References to SNMP/MIB RFCs deleted from Clause 2.
c) Clause 7 has been much reduced in scope, as little was required.
d) “QoS system” changed to “DCQoS system”.
e) The PICs proforma (Annex A) has been supplied.
f) The editor believes that D1.0 is essentially complete.

Introductory notes to P802.1DC Draft 0.1

Draft 0.1 was prepared by Norman Finn for a first Task Group ballot. Everything in this draft can be considered a contribution to the Time-Sensitive Networking Task Group by the editor; nothing has been approved by the Task Group or Working Group.

Project Authorization Request, Scope, Purpose, and Criteria for Standards Development (CSD)

The complete PAR, as approved by IEEE NesCom 14 May 2018, can be found at:

https://development.standards.ieee.org/myproject-web/public/view.html#pardetail/6449

and the CSD (Criteria for Standards Development) at:

https://mentor.ieee.org/802-ec/dcn/18/ec-18-0091-00-ACSD-802-1dc.pdf

extracts of relevant material from the PAR and CSD follow.

PAR Scope and Need

Scope:

This standard specifies Bridges that interconnect individual LANs, each supporting the IEEE 802 MAC Service using a different or identical media access control method, to provide Bridged Networks and VLANs.

Scope of the Project:

This standard specifies procedures and managed objects for Quality of Service (QoS) features specified in IEEE Std 802.1Q, such as per-stream filtering and policing, queuing, transmission selection, flow control and preemption, in a network system which is not a bridge.

Need for the Project:

IEEE Std 802.1Q specifies Quality of Service (QoS) features for bridges. These features are perfectly applicable to other devices, e.g. end stations, routers, or firewall appliances. In IEEE Std 802.1Q, the specifications of these features are scattered, and coupled tightly to the operation of a bridge. There is a need for simple reference points to these QoS specifications that are usable for non-bridge systems, and for managed objects for these features that are not specific to bridges.

CSD broad market potential

IEEE Std 802.1Q Time-Sensitive Networking (TSN) features have been steadily gaining market acceptance. Such networks are limited in size, and thus applicability, by limitations in the size of a bridged network. The proposed project will allow other Standards Development Organizations (SDOs), for example, the Deterministic Networking Working Group of the Internet Engineering Task Force (IETF DetNet), to standardize routers, hosts, or network address translation appliances that provide the same QoS functions as IEEE 802.1Q bridges, including queuing, shaping, transmission selection, and policing functions. Supporting larger networks will increase the proven applicability of IEEE 802 devices.

The interest from users has led a number of vendors to participate in the development of the project. Additional vendors and users are participating in IETF DetNet, demonstrating support for the expansion of these features.

CSD technical feasibility

No new QoS mechanisms are being defined in the proposed project. The feasibility of deploying these technologies in devices that are not IEEE Std 802.1Q bridges has been proven by the implementation of these mechanisms in millions of devices.

Introduction to the current draft

This is a draft of P802.1DC for working group ballot.

P802.1DC/Draft 2.1

May 2023

Draft Standard for Local and metropolitan area networks—

Quality of Service Provision by Network Systems

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
Piscataway, NJ 08854, USA

Abstract: This standard specifies procedures and managed objects for Quality of Service (QoS) features specified in IEEE Std 802.1Q, such as per-stream filtering and policing, queuing, transmission selection, stream control and preemption, in a network system which is not a bridge.

Keywords: CQF, IEEE 802.1Q™, LAN, local area network, Time-Sensitive Networking, TSN, Virtual Bridged Network, virtual LAN, VLAN Bridge, Quality of Service, priority, credit-based shaper, scheduled traffic, asynchronous traffic shaping, cyclic queuing and forwarding, per-Stream filtering and policing, preemption.

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1. Available at: https://development.standards.ieee.org/myproject-web/public/view.html#landing.
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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*
János Farkas, *TSN Task Group Chair*
Norman Finn, *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:

Chair
Vice-Chair
Past Chair
Secretary

*Member Emeritus

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

Introduction

This introduction is not part of P802.1DC/Draft 2.1, Draft Standard for Local and metropolitan area networks—Quality of Service Provision by Network Systems

This Standard specifies Quality of Service Provision by Network Systems.

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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Contents

IEEE P802.1DC™/D2.0

Draft Standard for
Local and metropolitan area networks—

Quality of Service Provision by Network Systems

1. Overview

1.1 Scope

This standard specifies procedures and managed objects for Quality of Service (QoS) features specified in IEEE Std 802.1Q, such as per-stream filtering and policing, queuing, transmission selection, stream control and preemption, in a network system which is not a bridge.

1.2 Need

IEEE Std 802.1Q specifies Quality of Service (QoS) features for bridges. These features are perfectly applicable to other devices, e.g. end stations, routers, or firewall appliances. In IEEE Std 802.1Q, the specifications of these features are scattered, and coupled tightly to the operation of a bridge. There is a need for simple reference points to these QoS specifications that are usable for non-bridge systems, and for managed objects for these features that are not specific to bridges.

1.3 Specification model

The model of operation documented by this standard is simply a basis for describing the functionality of a compliant equipment. Implementations can adopt any internal model of operation compatible with the externally visible behavior that this standard specifies. Conformance of equipment to this standard is purely in respect of observable protocol.

1.4 Specification precedence

If any conflict among parts of this standard become apparent, information in normative Tables takes precedence over other parts of the standard, followed by that in normative text, followed by that in normative Figures. Non-normative Tables, Figures, and text are in Annexes and are clearly marked as such.

1.5 Introduction

IEEE Std 802.1Q™ specifies the operation of Bridges and Bridged Networks, as well as certain end station behaviors. Parts of that standard can be classified as describing Quality of Service functions (QoS). QoS functions are those that affect the following parameters:

a) Latency: The time required to forward a frame[1] from source to destination through a Bridged Network.

b) Frame loss probability: The likelihood of losing a frame, rather than forwarding it, due to various events occurring between the source and destination.

c) Variability of the above parameters.

These parameters can be applied to individual frames, or to collections of frames, such as a single stream of frames from one source application instance to another, all frames sharing the same priority value, or all frames bound for a particular destination. Minimums, maximums, averages, or other mathematical functions can be applied to the parameters of a collection.

In defining QoS, IEEE Std 802.1Q-2022 makes normative references to IEEE Std 802.1CB, and IEEE Std 802.1AC.

The present standard specifies General Frame QoS (GFQoS), the IEEE Std 802.1DC Quality of Service. It specifies the behavior of two kinds of systems, a GFQoS end system and a GFQoS forwarding system, each of which supplies the GFQoS.

The referenced IEEE 802 standards specify many non-QoS functions that are of no concern to the present standard. For example, there are many functions that are performed by an IEEE Std 802.1Q Bridge, or by a GFQoS forwarding system, that are *not* a part of GFQoS:

d) Frame forwarding, in the sense of choosing the output port(s), to which a given frame is forwarded by a GFQoS forwarding system.

e) Transformations that frames may undergo as they are forwarded due to forwarding decisions, e.g adding VLAN (Virtual Local Area Network) tags or updating fields in an IPv6 header [B9].

f) Frame Replication and Elimination for Reliability. (See 6.5.3 for an explanation why.)

g) Various control protocols, including resource reservation protocols (e.g. Stream Reservation Protocol, SRP, Clause 35 of IEEE Std 802.1Q-2022, or Resource ReSerVation Protocol, RSVP, IETF RFC 2205[B7]) that can be used to control GFQoS functions. (See 6.5.4 for an explanation why.)

Clauses 2, 3, and 4 contain the normative references, definitions, and abbreviations used in this standard, respectively. Clause 5 specifies the requirements for various types of systems to claim compliance to this standard. It is the starting point to answer the question, “What must a compliant implementation do?” Clause 6 introduces the specifications for GFQoS functions specified in IEEE Std 802.1Q, and IEEE Std

1. Bridges, by definition, receive, transmit, and forward “frames”, as specified in IEEE Std 802. Other standards from IEEE and other organizations use the term “packet” for a unit of transmitted data. This standard uses “frame” exclusively, as it indicates the unit of transmission on a port, which is the most useful unit for this standard.

802.1CB, including, in 6.2, a complete list of GFQoS functions. Clause 7 contains the specifications for certain of the GFQoS functions that cannot be specified, in Clause 5, simply as references to other IEEE 802.1 standards. Clause 8 specifies the managed objects required to control the GFQoS functions.

1.6 Reference conventions

Because the present standard makes frequent references to specific subclauses in IEEE Std 802.1Q-2022 and its amendments, IEEE Std 802.1AC-2016, and IEEE Std 802.1CB-2017, as well as to subclauses within the present standard, the following conventions are used:

- A reference to "subclause *x.y* in IEEE Std 802.1Q-2022" is of the form: "[Q] *x.y*".
- A reference to "subclause *x.y* in IEEE Std 802.1CB-2017" is of the form: "[CB] *x.y*".
- A reference to "subclause *x.y* in IEEE Std 802.1AC-2016" is of the form "[AC] *x.y*".
- A reference to "subclause *x.y* in IEEE Std 802.1Qcw-2023" is of the form "[Qcw] *x.y*".
- A reference to "subclause *x.y* in IEEE Std 802.1Qcz-2023" is of the form "[Qcz] *x.y*".
- A reference to subclause *x.y* in the present standard has no prefix: "*x.y*".

2. Normative references

The following referenced documents are indispensable for the application of this document (i.e., they must be understood and used). Each referenced document is cited in 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. Non-normative references (i.e., that provide additional information not required for the application of this document) are given in Annex B.

NOTE—The inclusion of a document in this list of normative references indicates that certain information in that document is necessary to implement the present standard. It does not imply that any other part of that referenced document is to be implemented by a system conformant to the present standard.

IEEE Std 802™, IEEE Standards for Local and Metropolitan Area Networks: Overview and Architecture.[1, 2]

IEEE Std 802.1AC™-2016, IEEE Standard for Local and metropolitan area networks—Media Access Control (MAC) Service Definition.

IEEE Std 802.1Q™-2022, IEEE Standard for Local and metropolitan area networks—Bridges and Bridged Networks.

IEEE Std 802.1Qcw™-2023, IEEE Standard for Local and metropolitan area networks—Bridges and Bridged Networks—Amendment: YANG Data Models for Scheduled Traffic, Frame Preemption, and Per-Stream Filtering and Policing.

IEEE Std 802.1Qcz™-2023, IEEE Standard for Local and metropolitan area networks—Bridges and Bridged Networks—Amendment: Congestion Isolation.

IEEE Std 802.1CB™-2017, IEEE Standard for Local and metropolitan area networks—Frame Replication and Elimination for Reliability.

OMG Unified Modeling Language (OMG UML), Version 2.5, March 2015.[3]

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3. Definitions

For the purposes of this document, the following terms and definitions apply. The *IEEE Standards Dictionary Online* should be consulted for terms not defined in this clause.[1]

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

— end station
— frame

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

— bit time
— Bridge
— Listener
— Stream
— Talker

NOTE 1—The IEEE Get program[2] provides certain IEEE standards, including IEEE Std 802 and IEEE Std 802.1Q, at no charge, after a waiting period following publication.

The following terms are specific to this standard:

end system: In this standard, a system attached to a network that is an initial source or a final destination of data transmitted across that network.

NOTE 2—The term “end system” is often used in this document in places where the reader of IEEE 802 standards would expect the term, “end station,” in order to avoid confusion caused by standards relating to routers. For example, a router, as defined by IETF, is an IEEE 802 “end station,” but not an “end system.” Where this standard specifically refers to the use of IEEE 802 services, the term “end station” is used. Where it refers to more generalized instances of associationless services, the term “end system” is used.

forwarding system: In this standard, a router, security appliance, address translation appliance, or any other device that forwards a frame from one port to another, such that the frame is, in some useful sense, identifiable to other systems as being the same frame. In this standard, an IEEE Std 802.1Q Bridge is not considered a forwarding system because an IEEE Std 802.1Q Bridge and its forwarding behavior are specified by IEEE Std 802.1Q.

General Frame QoS: The kinds and levels of Quality of Service functions specified by the present standard.

GFQoS end system: In this standard, an end system that is a GFQoS system.

GFQoS forwarding system: In this standard, a forwarding system that is a GFQoS system.

GFQoS system: In this standard, an end system or a forwarding system that conforms to this standard.

system: In this standard, a functional unit. No relationship between physical implementation and logical function is implied by the term, “system”; a chassis can be composed of multiple systems, and a system can be spread over multiple chassis.

1. *IEEE Standards Dictionary Online* is available at https://dictionary.ieee.org.
2. https://standards.ieee.org/products-programs/ieee-get-program/

4. Abbreviations

This standard contains the following abbreviations:

CQF	Cyclic Queuing and Forwarding
GFQoS	General Frame Quality of Service
DSCP	Differentiated Services Code Point
EISS	Enhanced Internal Sublayer Service
FQTSS	Forwarding and Queuing enhancements for Time-Sensitive Streams
IPV	Internal priority value specification
ISS	Internal Sublayer Service
PSFP	Per-Stream Filtering and Policing
QoS	Quality of Service
TSN	Time-Sensitive Networking
UML	Unified Modeling Language

5. Conformance

This clause specifies the mandatory and optional capabilities provided by conformant implementations of this standard. Three terms are used for systems compliant to this standard:

a) **GFQoS system:** A GFQoS system provides the GFQoS, and is either a GFQoS end system or a GFQoS forwarding system. Common required behaviors for all GFQoS systems are given in 5.4, and optional behaviors in 5.5.

b) **GFQoS end system:** A GFQoS end system provides the GFQoS on one or more ports for the purpose of sourcing or sinking streams. Required behaviors are given in 5.6, and optional behaviors in 5.7.

c) **GFQoS forwarding system:** GFQoS forwarding system provides the GFQoS when forwarding frames from one port to another. Required behaviors are given in 5.8, and optional behaviors are given in 5.9.

5.1 Protocol Implementation Conformance Statement (PICS)

A claim of conformance specifies implementation of a GFQoS end system or a GFQoS forwarding system. A GFQoS system can support multiple claims for a range of possible behaviors. 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 PICS proforma provided in Annex A for that specific system implementation.

5.2 Requirements terminology

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

a) Shall is used for mandatory requirements;

b) May is used to describe implementation or administrative choices. “May” means “is permitted to,” and hence, “may” and “may not” mean precisely the same thing;

c) Should is used for recommended choices. The behaviors described by “should” and “should not” are both permissible but not equally desirable choices.

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

The standard avoids needless repetition and apparent duplication of its formal requirements by using is, is not, are, and are not for definitions and the logical consequences of conformant behavior. Behavior that is permitted but is neither always required nor directly controlled by an implementor 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.”

Where the present standard states that “a conformant system shall” support (conform to, provide, etc.) some part of some other IEEE 802 standard, this means that the “shall,” “may,” and “should” terms in the referenced standard apply in the manner described, in that referenced standard, to the conformant system; it does not mean that a “may” or “should” in the referenced standard are promoted to a “shall” for the present standard. Where the present standard states that “a conformant system may” support (conform to, provide,

etc.) some part of some other IEEE 802 standard, this means that the “shall,” “may,” and “should” terms in the referenced standard are all to be interpreted as “may”.

5.3 Interpreting IEEE Std 802.1Q and IEEE Std 802.1CB for GFQoS systems

IEEE Std 802.1Q-2022 is the standard that specifies Bridges and end stations. In order to apply this standard to GFQoS systems, the following systematic substitutions are to be made when reading those standards:

Bridge: For “Bridge”, read “GFQoS forwarding system”.
MAC Relay: For “MAC Relay”, read “GFQoS forwarding system”.
Bridge Port: For “Bridge Port”, read “port”.
End station: For “end station”, read “GFQoS end system”.

These transformations apply only to clauses called out in this standard as applying to GFQoS system. No “shall”, “should”, or “may” in IEEE Std 802.1Q is a requirement on a GFQoS system except as called out in the present standard.

For the purposes of the present standard, the term, “relay system” used in IEEE Std 802.1CB is equivalent to the term, “forwarding system” in the present standard. (“Relay system” is a subset of “forwarding system,” in that a “forwarding system” cannot be an IEEE Std 802.1Q Bridge.)

5.4 GFQoS system required behaviors

Any system conformant to this standard shall:

a) Support the GFQoS provision model (7.2).
b) Conform to the relevant standard for the MAC technology implemented at each port in support of the MAC Internal Sublayer Service (ISS), as specified in [AC] 11.1.
c) Support transmission selection by strict priority (7.3.1, [Q] 8.6.8.1).

5.5 GFQoS system optional behaviors

Any system conformant to this standard may:

a) Support the Enhanced Internal Sublayer Service (EISS), as specified in 7.3.2.
b) Support for priority-based flow control ([Q] 5.11).
c) Support transmission selection by enhanced transmission selection ([Q] 5.4.1.6, [Q] 8.6.8.3), except that support for DCBX (Data Center Bridging eXchange Protocol) ([Q] 5.4.1.6:e, [Q] Clause 38) is not required.

NOTE— [Q] 5.4.1.6 applies only to Bridges, not to end systems. The present standard allows GFQoS end systems to claim support for enhanced transmission selection.

d) Support enhancements for scheduled traffic ([Q] 8.6.8.4, [Q] 8.6.9).
e) Support management of the system using the YANG modules specified in Clause 9.

5.6 GFQoS end system required behaviors

An end system conformant to this standard shall, on one or more ports:

a) Support all of the items listed in 5.4.

5.7 GFQoS end system optional behaviors

An end system conformant to this standard may, on at least one port:

a) Support any of the items listed in 5.5.
b) Support Forwarding and Queuing enhancements for Time-Sensitive Streams (FQTSS, [Q] 5.20).
c) Support Per-Stream Filtering and Policing (PSFP, [Q] 5.27).
d) Support transmission selection by Asynchronous Traffic Shaping (ATS, [Q] 5.31).
e) Support cyclic queuing and forwarding (CQF, [Q] 5.28).
f) Support Talker end system required ([CB] 5.6), recommended ([CB] 5.7), and/or optional ([CB] 5.8) behaviors for Frame Replication and Elimination for Reliability.
g) Support Listener end system required ([CB] 5.9), recommended ([CB] 5.10), and/or optional ([CB] 5.11) behaviors for Frame Replication and Elimination for Reliability.
h) Support frame preemption ([Q] 5.26).

5.8 GFQoS forwarding system required behaviors

A forwarding system conformant to this standard shall, on more than one port:

a) Support all of the items listed in 5.4.

5.9 GFQoS forwarding system optional behaviors

A forwarding system conformant to this standard may, on more than one port:

a) Support any of the items listed in 5.5.
b) Support Forwarding and Queuing enhancements for Time-Sensitive Streams (FQTSS, [Q] 5.4.1.5).
c) Support Per-Stream Filtering and Policing (PSFP, [Q] 5.4.1.8).
d) Support transmission selection by Asynchronous Traffic Shaping (ATS, [Q] 5.4.1.10).
e) Support cyclic queuing and forwarding (CQF, [Q] 5.4.1.9).
f) Conform to forwarding system required ([CB] 5.12), recommended ([CB] 5.13), and/or optional ([CB] 5.14) behaviors for Frame Replication and Elimination for Reliability.
g) Support frame preemption (7.3.3).
h) Support General flow classification and metering ([Q] 8.6.5.1).

6. IEEE Std 802.1Q Quality of Service provision

6.1 Introduction

The purpose of this Clause 6 is to introduce the model for Quality of Service (QoS) provision in IEEE Std 802.1Q-2022. This clause lists the QoS functions, gives some clue to their relationships, and provides references to the clauses in IEEE Std 802.1Q-2022 and its amendments that specify the operation of these functions.

The remainder of this clause includes:

a) In 6.2, a list of GFQoS functions provided in the present standard;

b) In 6.3, a list of the subclauses of IEEE 802.1Q-2022 that are relevant to GFQoS;

c) In 6.4, a list of functions in IEEE 802.1Q-2022 that can affect GFQoS, but are not strictly GFQoS functions, and are not addressed in the present standard; and

d) In 6.5, a list of QoS mechanisms in IEEE 802.1Q-2022 that are not included in the present standard.

6.2 List of GFQoS functions

Following is a list of the functions that can be provided by GFQoS systems. For each, a reference is given to the requirements in Clause 5 for conformance for that function.

6.2.1 Basic GFQoS functionality

This specifies the reference model with respect to which the various functions are specified. (5.4:a, 5.4:b)

6.2.2 Strict priority

The output queues on a port are ranked by priority. The highest priority output queue that is eligible for selection is the one from which the next frame is transmitted. (5.4:c)

6.2.3 Extended Internal Sublayer Service (EISS)

The EISS is a MAC service interface defined in IEEE Std 802.1Q Bridges to handle VLAN tagging. (5.5:a)

6.2.4 Priority-based Flow Control (PFC)

PFC allows a receiver to pause the transmission of frames from a queue serving a particular layer 2 priority level in the attached transmitter. (5.5:b)

6.2.5 Frame preemption

Preemption is the process whereby the transmission of a frame can be interrupted one or more times in order to allow the transmission of frames with more critical requirements on delivery time. (5.7:h, 5.9:g)

6.2.6 Frame Replication and Elimination for Reliability

IEEE Std 802.1CB specifies mechanisms for sequence numbering and then replicating the frames of a stream, sending those replicated streams along multiple disjoint paths through the network, and recombining the streams, eliminating the duplicates, at one or more other points in the network. (5.7:g, 5.9:f)

6.2.7 General flow classification and metering

This provides mechanisms for discarding and/or marking frames for reduced probability of delivery based on source MAC address, destination MAC addresses, VID or priority. (5.9:h)

6.2.8 Per-Stream Filtering and Policing (PSFP)

PSFP supports the identification of streams or set of streams for specific treatment based on the contents of the frame, including timed input gates, assignment to specific classes of service, discard based on frame size, flow metering. (5.9:c)

6.2.9 Enhanced Transmission Selection (ETS)

ETS limits the percentage of an output port's bandwidth that can be taken up by a priority level or set of priority levels. (5.5:c)

6.2.10 Scheduled Traffic

The Scheduled Traffic function provides schedule for an output port that repeats at a fixed frequency. Each entry in the schedule enables and/or disables specific output queues. (5.5:d)

6.2.11 Forwarding and Queuing enhancements for Time-Sensitive Streams (FQTSS)

This function employs the credit-based shaper to pace (shape) the output from a queue in order to make possible the calculation of worst-case delivery times for classes of flows. (5.7:b, 5.9:b)

6.2.12 Cyclic Queuing and Forwarding (CQF)

CQF applies the scheduled traffic (6.2.10) and stream gate (6.2.8) functions to alternate two queues between the filling and transmitting states, with ports in all Bridges in a network switching queues synchronously, thus progressing frames at a predictable rate through the network. (5.7:e, 5.9:e)

6.2.13 Asynchronous Traffic Shaping (ATS)

ATS assigns a state machine to each stream or set of streams of interest to a Bridge. That state machine uses the time of arrival of each identified frame to assign a transmission time to the frame. Frames are output in order of transmission time, with no frame transmitted before its time. This function allows the accurate computation of the worst-case time required for a frame belonging to an ATS stream to traverse the network. (5.7:d, 5.9:d)

6.3 IEEE Std 802.1Q-2022 clauses defining GFQoS

In IEEE Std 802.1Q-2022, the subclauses relevant to GFQoS are the following:

a) [Q] Clause 6 "Support of the MAC service" describes the MAC service, offered by a Bridged network or VLAN Bridged Network, that an IEEE 802.1Q Bridge participates in offering.
   1) Subclause [Q] 6.5 "Quality of service (QoS) maintenance" contains useful definitions and explanations of the GFQoS parameters.
   2) Subclauses [Q] 6.7.1 and [Q] 6.7.2 describe frame preemption. (See also [B1].)
   3) Subclauses [Q] 6.8 and [Q] 6.9 specify support for the Enhanced Internal Sublayer Service (EISS) and the use of VLAN tags.

b) [Q] Clause 8 "Principles of Bridge operation", specifies the core operations of a Bridge.

1) [Q] 8.2 “Bridge architecture” provides a necessary context for the discussion of the functions specific to GFQoS.

2) [Q] 8.6 “The forwarding process” describes the operation of a Bridge, including many of the GFQoS mechanisms, in a “day in the life of a frame” linear order. [Q] Clause 34.6 “End station behavior” adds end station considerations to this model.

c) Specific GFQoS functions specified in Clause 7 are described in various places in IEEE Std 802.1Q-2022. The functions that occur between input and placing the frames in queues include:

1) Flow classification and metering, [Q] 8.6.5, 7.2.1 (which contains normative references to IEEE Std 802.1CB-2017), includes the prioritization, identification, and rate marking of specific streams. Both general flow classification and metering (7.2.1.1) and per-stream classification and metering (7.2.1.2) are covered in this subclause.

2) Stream gate control, [Q] 8.6.10, is a mechanism for admitting or discarding specific streams’ frames, and for using stream identification information to assign a frame to a specific class of service. These decisions can be based on a synchronized time schedule. Stream gate control is a part of Per-Stream Filtering and Policing (PSFP), the definition of which is in several subclauses within [Q] 8.6.

3) Queuing frames, [Q] 8.6.6, assigns frames to a queue, based on the class of service. The selection of an output port, described in other subclauses of IEEE Std 802.1Q-2022, is not relevant to the present standard.

4) Queue management, [Q] 8.6.7, includes provision for dropping frames to be placed in a queue because of maximum forwarding time, red/yellow/green marking, or a full queue.

d) Having placed the frames in queues, a number of GFQoS functions are described for selecting which frame to transmit next:

1) Strict priority, [Q] 8.6.8.1, is the simplest selection method. The highest priority frame is transmitted.

2) Forwarding and Queuing enhancements for Time-Sensitive Streams (FQTSS, the credit-based shaper), [Q] 8.6.8.2 and [Q] Annex L (informative), limits the bandwidth of a queue to a specific maximum value.

3) Enhanced transmission selection (ETS), [Q] 8.6.8.3 and [Q] Clause 37, allow a group of queues to share the available bandwidth, so that each queue is assured of a specific minimum percentage of the bandwidth available to the group.

4) Enhancements for scheduled traffic, [Q] 8.6.8.4, [Q] 8.6.9, and [Q] Annex Q (informative), specify a set of gates, one per queue, that open and close on a repeating schedule that is tied to a clock that can be synchronized with other Bridges (forwarding systems) and end stations (end systems) in the network.

5) Cyclic queuing and forwarding, [Q] Annex T, describes a specific use case of the other functions which, taken together, provide a double buffering scheme for a traffic class that provides streams an assured maximum per-hop latency that is easy to calculate and enforce.

6) The Asynchronous traffic shaper, [Q] 8.6.11 and [Q] Clause 47, uses more complex queues and a token bucket shaping algorithm in order to provide an assured maximum end-to-end latency without requiring a synchronized clock.

7) Priority flow control, [Q] Clause 36, allows a receiver at one end of a point-to-point LAN to throttle the transmitter on a per-priority basis.

The rest of this Clause 6 contains further text that will be helpful to a reader of IEEE Std 802.1Q and IEEE Std 802.1CB.

6.4 Other Bridge functions relevant to GFQoS provision

6.4.1 Link Aggregation

IEEE Std 802.1AX [B2] specifies Link Aggregation, wherein multiple physical ports can be aggregated together to appear, to the upper layers (e.g. a Bridge Port) to be a single physical port. This allows one to increase the bandwidth and reliability of a link between two systems.

IEEE Std 802.1Q-2022 does not specify where the queues that are referenced by [Q] 8.6.6, [Q] 8.6.7, and [Q] 8.6.8 physically reside. The first paragraph of [Q] 8.6.6 implies that there is a set of queues attached to each “transmission Port,” not to each “Bridge Port.” Thus, in the case of Link Aggregation, IEEE Std 802.1Q-2022 does not specify whether the queues are associated with the Aggregator Port (the simulated combined port, which is associated with the Bridge Port, and can be the transmission Port) or the Aggregation Port (the physical port, which can also be a transmission Port). When designing or configuring a network, some GFQoS functions behave very differently, depending on whether the queues are associated with the Aggregator Port or an Aggregation Port.

6.4.2 MAC Security entity

MAC security, specified in IEEE Std 802.1AE-2006 [B3], can cause some or all of the frames passing into or out of a given port to undergo a cryptographic transformation, which takes a finite, sometimes variable, amount of time. This of course, affects the GFQoS that a system can offer. However, MAC security is not strictly a GFQoS function, and is not addressed further in the present standard.

6.4.3 Priority / DSCP regeneration

IEEE Std 802.1Q-2022 Bridges have the capability of altering the priority parameter of a forwarded frame in various ways. Similarly, an IETF router can alter the value of the Differentiated Services Code Point (DSCP). Such actions affect the GFQoS offered, but such actions are too closely connected to the forwarding functions of these devices to specify in the present standard.

Priority regeneration can be critical, for example to protect the network against the input of frames that have the priority or DSCP of a time-sensitive stream, but which do not, in fact, belong to a reserved stream (see [Q] 6.9.4).

6.5 GFQoS functions not specified

6.5.1 Congestion notification

The present standard does not specify any functions for congestion notification, which is specified in IEEE Std 801.Q-2022 in Clauses [Q] 30, [Q] 31, [Q] 32, and [Q] 33.

6.5.2 Media QoS capabilities

Although some media (e.g. IEEE Std 802.11) offer a QoS capability, the present standard specifies GFQoS functions only for end systems and forwarding systems, and not the QoS functions of specific media.

6.5.3 Frame replication and elimination for reliability

Frame replication and elimination for reliability is described in IEEE Std 802.1CB. The probability of frame loss is a GFQoS concern. However, the replication, sequencing, and elimination methods described in IEEE Std 802.1CB are described for end systems and forwarding systems, not just for Bridges. IEEE Std 802.1CB is applicable to GFQoS systems without further elaboration, so its functions need not be included in the

present standard. The present standard does make normative references to IEEE Std 802.1CB solely for stream identification for other GFQoS purposes.

6.5.4 Control protocols

Resources in a network have to be reserved for the use of specific streams or for classes of streams before the transmission of the streams begin, in order to obtain the benefits of certain GFQoS functions. For this reason, [Q] 35 specifies the Stream Reservation Protocol. IETF RFC 2205[B7] specifies the Resource ReSerVation Protocol (RSVP) for a similar purpose. These protocols make assumptions about the forwarding system used, either a bridge or a router; they are not a suitable subject for the present standard, which makes no such assumptions.

7. GFQoS systems

7.1 GFQoS end systems, GFQoS forwarding systems, and streams

The GFQoS provision model (7.2) is concerned with providing GFQoS to classes of frames and to streams of frames. A stream is a set of frames from a single Talker (source end system) to one (unicast) or one or more (multicast) Listeners (destination end systems). Multiple streams can flow from one Talker A to a Listener B. A class of frames is not limited to a single source. The user responsible for each stream or class has some expectation of GFQoS from the network. A stream is unidirectional, in the sense that there is no association, as far as the GFQoS provision model data plane is concerned, between the frames received by and transmitted from an end system.

The GFQoS provision model (7.2) specifies two kinds of GFQoS systems: GFQoS end systems and GFQoS forwarding systems. A GFQoS end system applies the GFQoS provision model (7.2) to frames transmitted and received on one or more ports.

A GFQoS forwarding system has two or more ports, and transfers frames from one reception port to one or more transmission ports in a manner such that each transmitted frame is, in some useful sense, identifiable as being the same as, or a copy, perhaps modified, of the received frame. We can thus speak of a frame's path through a network, or of the time taken for a frame to traverse the network. A GFQoS forwarding system applies the GFQoS provision model to the frames that it forwards.

A GFQoS end system does not forward frames. A GFQoS forwarding system, or part of a GFQoS forwarding system, can also be a Talker or a Listener, and thus act as a GFQoS end system for the purposes of this standard.

All GFQoS systems implement the GFQoS provision model (7.2). There are a number of GFQoS functions that can optionally be implemented, as listed in 7.3.

7.2 GFQoS provision model

Figure 7-1, below, is based on [Q] Figure 8-12 in [Q] 8.6. It illustrates the operation of the forwarding process in a single instance of a frame forwarded between the ports of a GFQoS forwarding system with two ports. It illustrates just those parts of the forwarding process ([Q] 8.6) that are relevant to a GFQoS forwarding system. The functions are shown in sequence from the top, where a frame is received on the reception port, through the various functions, to the transmission port at the bottom of the figure. Not shown in Figure 7-1 are functions in [Q] Figure 8-12 that only apply to a Bridge, e.g. Egress filtering ([Q] 8.6.4). In particular, there is no function in Figure 7-1 that determines the set of transmission ports on which a given received frame is to be sent. The behavior of any such function, or its relationship to the GFQoS functions shown in Figure 7-1, is not specified in the present standard.

Figure 7-2, below, illustrates the parts of the IEEE Std 802.1Q forwarding process that are relevant to a GFQoS end system. It is based upon [Q] Figure 8-12, and upon [Q] Figure 34-1 in [Q] 34.6.1. [Q] 34.6.1 adds a layer of queuing and selection to the basic model of [Q] Figure 8-11. This is the maximum amount of functionality that this standard requires of a GFQoS end system, if it implements certain of the GFQoS functions listed as optional in Clause 5; not all GFQoS functions require two layers of queues. Figure 7-2 is slightly more complex than [Q] Figure 34-1, so that all of the functions relevant to a GFQoS end system, and not just Forwarding and Queuing for Time Sensitive Streams (FQTSS, the subject of [Q] Clause 34), can be specified by the present standard.

The models illustrated in Figure 7-1, Figure 7-2, [Q] 8.6.6, and [Q] Figure 22-4 each have a set of queues, and that set is associated with a a specific output Bridge Port. As stated in 1.3 and [Q] 8.3, this is a

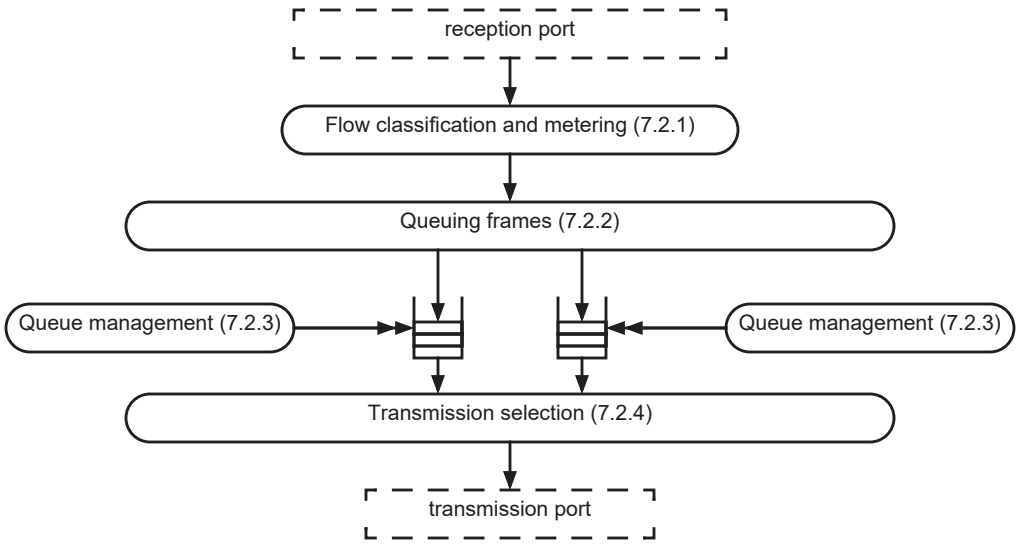

Figure 7-1—GFQoS forwarding system forwarding process functions

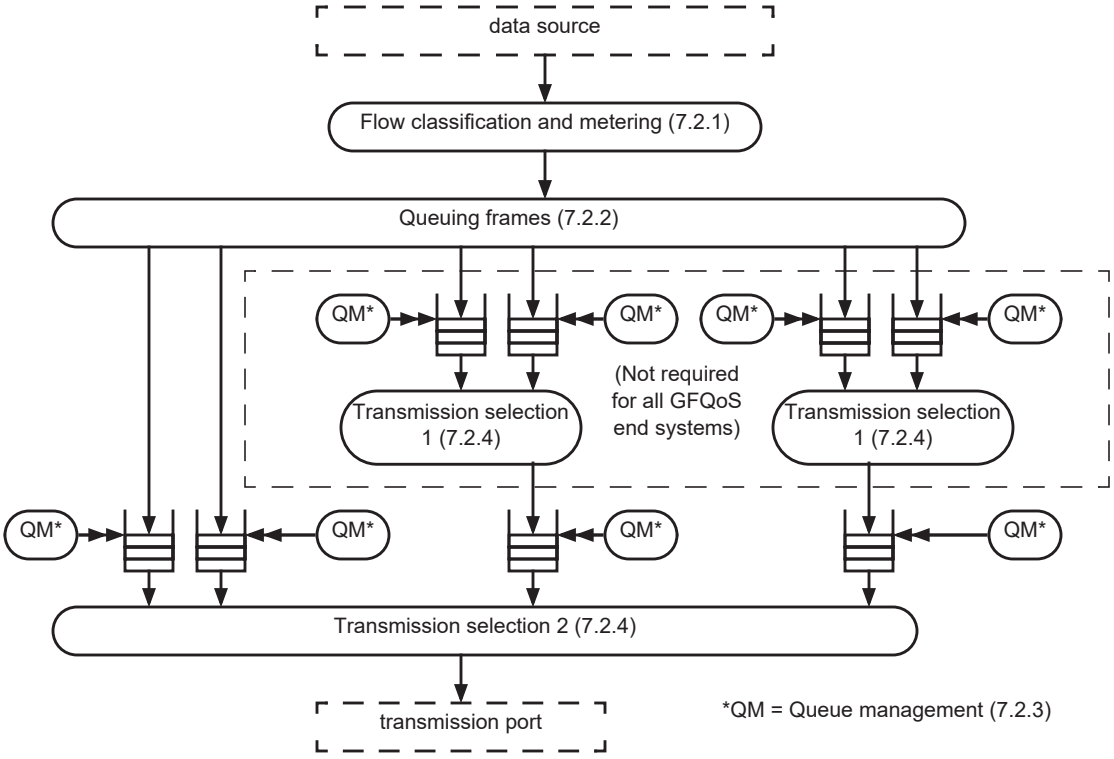

Figure 7-2—GFQoS end system forwarding process functions

behavioral model, not the design of a specific implementation, and does not preclude an implementation from employing queues on input ports, virtual queues, or queues on the physical ports comprising an IEEE Std 802.1AX aggregation. A number of figures in IEEE Std 802.1Q-2022 show that frames to be output on a physical port, e.g. those from the “LLC” function in [Q] Figure 22-8, can bypass the output queues entirely. Such behavior would adversely impact some GFQoS functions. IEEE Std 802.1Q does not prohibit

implementing its QoS functions in other ways, including placing the queuing functions near the MAC layer in individual physical ports.

7.2.1 Flow classification and metering

Flow classification and metering is illustrated in [Q] Figure 8-13. It comprises functions that are associated with an input port, There are two types of flow classification and metering specified by IEEE Std 802.1Q, General flow classification and metering (7.2.1.1) and Per-Stream classification and metering (7.2.1.2).

NOTE—In [Q] 8.6.5.3.1, “Maximum SDU size” is the maximum size of the mac_service_data_unit parameter of the ISS ([AC] 11.1) or EISS ([Q] 6.8.1).

7.2.1.1 General flow classification and metering

General flow classification and metering is illustrated in [Q] Figure 8-13 and specified in [Q] 8.6.5.1. It provides for discarding and/or marking frames for reduced probability of delivery based on source MAC address, destination MAC address, VID or priority. See 5.9:h for normative requirements.

7.2.1.2 Per-Stream classification and metering

Per-Stream classification and metering includes a number of optional functions that are performed and controlled per input port. Per-Stream classification and metering is specified in [Q] 8.6.5 and its subclauses. It includes stream filtering ([Q] 8.6.5.3), maximum SDU size filtering ([Q] 8.6.5.3.1), stream gating ([Q] 8.6.5.4), flow metering ([Q] 8.6.5.5), and Asynchronous Traffic Shaping (ATS) Eligibility Time Assignment ([Q] 8.6.5.6). For the purposes of the present standard, these functions are grouped into two optional functions, Per-Stream Filtering and Policing (5.9:c) and ATS (5.7:d, 5.9:d).

7.2.2 Queuing frames

In a GFQoS system, each frame is assigned to a queue according to the class of service selected by the Flow classification and metering function (7.2.1). A GFQoS system shall perform the queuing frames functions specified in [Q] 8.6.6, with the following exception:

a) The in-order delivery requirements for an IEEE Std 802.1Q Bridge are listed in bullets a) and b) of [Q] 8.6.6. For GFQoS, these requirements are modified to say that the order of frames received on the same input port of a GFQoS forwarding system shall be preserved for:
   1) Unicast frames traversing the same path, at the same quality of service, between the same source and destination addresses.
   2) Multicast frames traversing the same path, at the same quality of service, and addressed to the same destination.

7.2.3 Queue management

A GFQoS system shall perform the queue management functions as described in [Q] 8.6.7, with the following exception:

a) The Bridge transit delay ([Q] 6.5.6) requirement applies only to an IEEE Std 802.1Q Bridge. However, a GFQoS forwarding system may discard frames from a queue to meet a similar requirement for a maximum transit delay across the GFQoS forwarding system.

7.2.4 Transmission selection

A GFQoS system shall perform the transmission selection functions as described in [Q] 8.6.8. There are optional capabilities within [Q] 8.6.8.

7.2.5 Parameterization of frames

As explained in [AC] Clause 7, frames are not modeled as passing from layer to layer in the protocol stack as a simple octet string. The MAC service offered by IEEE Std 802.3 Ethernet [B1], for example, passes a frame as a sequence of four parameters, destination_address, source_address, mac_service_data_unit, and frame_check_sequence. IEEE Std 802.1Q-2022 makes use of the Internal Sublayer Service (ISS) specified in [AC] Clause 11. The ISS is a medium-independent abstraction of the MAC services specified by the various IEEE 802 media. It has parameters, such as "priority", that are used by some media (e.g. IEEE 802.11 Wireless [B4]), but not others (e.g. IEEE 802.3 Ethernet). The ISS provides a convenient model for describing the reception and transmission of frames, and is required of all systems ([AC] 11.1).

IEEE Std 802.1Q-2022 specifies an Enhanced Internal Sublayer Service (EISS, [Q] 6.8) which extends the ISS parameter list. Among other tasks, the Support of the EISS function [Q] 6.9 extracts the VLAN tag information (the EISS parameters vlan_identifier, priority, and drop_eligible) from the ISS mac_service_data_unit of a received frame, and packs these parameters back into the mac_service_data_unit on a transmitted frame. Support of the EISS is optional for a GFQoS system.

Table 7-1 extends this model all the way through TCP/UDP headers ([B5], [B11]), and summarizes the list of parameters that are directly relevant to the GFQoS provision model.

Table 7-1—Parameter use by the GFQoS provision model

parameter	specified in	port selection[1]	GFQoS differentiation without flow classification[2]	stream/ GFQoS differentiation with flow classification[3]	modifiable by GFQoS[4]
destination_address	ISS ([AC] 11)	Yes	no	Yes	no
source_address	ISS ([AC] 11)	Yes	no	Yes	no
mac_service_data_unit	ISS ([AC] 11) and EISS ([Q] 6.8)	no	no	Yes	no
frame size	ISS ([AC] 11.1)[5] and EISS ([Q] 6.8)	no	Yes	Yes	Yes
priority	ISS ([AC] 11) and EISS ([Q] 6.8)	no	Yes	Yes	Yes
drop_eligible	ISS ([AC] 11) and EISS ([Q] 6.8)	no	Yes	Yes	Yes
vlan_identifier	EISS ([Q] 6.8)	Yes	no	Yes	no
frame_check_sequence	ISS ([AC] 11)	Yes	no	no	no

Table 7-1—Parameter use by the GFQoS provision model

parameter	specified in	port selection[1]	GFQoS differentiation without flow classification[2]	stream/ GFQoS differentiation with flow classification[3]	modifiable by GFQoS[4]
service_access_point_identifier	ISS ([AC] 11)	Yes	no	no	no
connection_identifier					
stream_handle	[CB] 6	no	no	Yes	no
other uses of connection_identifier	ISS ([AC] 11)	Yes	no	no	no
flow_hash	EISS ([Q] 6.8)	Yes	no	no	no
time_to_live	EISS ([Q] 6.8)	Yes	no	no	no
internal priority value specification (IPV)	PSFP ([Q] 8.6.5, [Q] 8.6.10)	no	no	Yes	Yes
IP source address[6]	[CB] 6.7	Yes[7]	no	Yes	no
IP destination address[6]	[CB] 6.7	Yes[7]	no	Yes	no
IP differentiated services code point[6]	[CB] 6.7	Yes[7]	no	Yes	no
IP next protocol[6]	[CB] 6.7	Yes[7]	no	Yes	no
IP transport source port number[6]	[CB] 6.7	Yes[7]	no	Yes	no
IP transport destination port number[6]	[CB] 6.7	Yes[7]	no	Yes	no

1 Parameter is used by an IEEE 802.1Q Bridge to determine the set of transmission ports to which the frame is to be forwarded.
2 Parameter can be used by an IEEE 802.1Q Bridge for GFQoS purposes, without flow classification and metering (7.2.1).
3 Parameter can be used to identify a particular stream or set of streams for GFQoS purposes using flow classification and metering (7.2.1).
4 Parameter can be modified by GFQoS.
5 "Frame size" is not a separate parameter in [AC] 11.1; it is an implied characteristic of the mac_service_data_unit parameter.
6 These parameters are specified in IETF RFCs, including [B5], [B6], [B11], [B9], [B8], and [B10]. Their use in the context of the present standard is described in [CB] 6.7.
7 In IEEE Std 802.1Q, this parameter is part of the mac_service_data_unit, and is not used by an IEEE Std 802.1Q Bridge for selecting output ports. A Bridge can use these parameters, via [CB] Clause 6, for stream identification.

The use of the mac_service_data_unit for GFQoS purposes is not limited to VLAN tagging and removal. Stream identification based on the examination of the mac_service_data_unit is not precluded, just as forwarding based on the mac_service_data_unit is not precluded. (See, e.g. [Q] 6.12 Protocol VLAN classification.)

7.3 Quality of service functions

7.3.1 Transmission by priority

IEEE Std 802.1Q provides eight levels of priority and two levels of drop eligibility to be assigned to a frame. These parameters can be carried in a VLAN tag or by other means specified by certain media (e.g. some specified by IEEE Std 802.11). The present standard considers the reception, manipulation, and transmission of priority and drop eligibility values to be specific to Bridges, and does not address these functions.

This does not mean that priority is irrelevant to the present standard. [Q] 8.6.6 specifies the Internal Priority Value (IPV). The Stream Gate function [Q] 8.6.5.4 can assign an IPV to a frame. This IPV overrides the priority in determining in which of the output queues that frame is placed when assigned to a port for transmission. One queue may serve more than one IPV/priority value. Frames with a given IPV/priority are always assigned to the same queue.

Although the allowed range for the IPV parameter is not specified explicitly in IEEE Std 802.1Q, the managed objects specified in that standard effectively limit an implementation to eight classes of service, and thus eight output queues per port. In practice, Bridges (and many other devices) use a number of methods to assign a frame an IPV/priority, and thus to an output queue, including the recognition of particular layer 2 or layer 3 protocols, IP DIFFSERV code points, etc. The present standard does not restrict such behavior by forwarding systems.

Strict priority is the basis of all IEEE Std 802.1Q QoS functions, and therefore of GFQoS. *The queues on a port are served strictly according to priority, no matter what GFQoS techniques are applied.* However, any given queue can be made eligible or not eligible for the priority competition, according to Stream Gates, shaper state machines, priority flow control, and a number of mechanisms. Thus, a low-priority queue can transmit frames, even if higher-priority queues are not empty, but only if those higher-priority queues are all rendered ineligible for transmission by some GFQoS mechanism. If no GFQoS functions are enabled, strict priority remains to control the queues.

A GFQoS system shall support transmission selection by strict priority ([Q] 8.6.8.1.

7.3.2 Enhanced Internal Sublayer Service

A GFQoS system may support the Enhanced Internal Sublayer Service (EISS), which is described in [Q] 6.8, [Q] 6.9, and supported by [Q] Clause 9. A GFQoS system that supports the EISS shall:

a) Implement the EISS as specified in [Q] 6.8.

b) Implement the support of the EISS as specified in [Q] 6.9, with the following exceptions:

   1) The GFQoS system may implement the Acceptable Frame Types parameter.

   2) The GFQoS system may implement the PVID and VID Set and/or the default PVID.

   3) The GFQoS system may implement the VID translation table and/or the Egress VID translation table.

   4) The GFQoS system may discard a frame as described in item b) of [Q] 6.9.1.

   5) The GFQoS system may provide only a fixed Priority Code Point Encoding Table ([Q] 6.9.3) that leaves the priority and drop_eligible parameters unchanged

   6) The GFQoS system may provide priority regeneration [Q] 6.9.4.

c) Support either a C-TAG or an S-TAG on each port, as specified in [Q] 6.9 and supported by [Q] Clause 9.

d) Conform to the format and encoding in [Q] Clause 9 for tags supported by the GFQoS system.

NOTE 1—The present standard is concerned solely with QoS issues. The use of the EISS priority and drop_eligible parameters are of obvious relevance to QoS. The EISS vlan_identifier field is of concern only for stream identification purposes, not for forwarding purposes.

NOTE 2—The option for support of the EISS is specified so that the vlan_identifier of a received frame can be determined in exactly the same manner as an IEEE Std 802.1Q VLAN-aware Bridge, including, for example, the port VLAN identifier (PVID, [Q] 6.9). Alternatively, in the present standard, VLAN tags (or other tags) can be accessed as part of the mac_service_data_unit parameter (see 7.2.5), without implementing the EISS.

7.3.3 Frame preemption

A GFQoS forwarding system that supports frame preemption shall:

a) Implement frame preemption as described in [Q] 6.7.2,
b) Conform to those portions of [Q] 6.7.1 and [Q] 8.6.8 that are specified as requirements for frame preemption.

8. Managed Objects

Managed objects and the MIB modules to access them, for all of the GFQoS functions in the present standard, are specified in IEEE Std 802.1Q-2022 and its amendments, and in IEEE Std 802.1CB-2017. The managed objects and MIB modules in IEEE Std 802.1CB-2017 are directly applicable to the present standard, because they are not tied to the IEEE 802.1Q Bridge functions. Some of the managed objects in IEEE Std 802.1Q, however, are tied to IEEE Std 802.1Q Bridge functionality, and to Bridge Ports ([Q] 8.2), in particular.

See Clause 9 for YANG modules for managing the IEEE Std 802.1Q managed objects relevant to GFQoS in a manner independent of the Bridge functionality specified in IEEE Std 802.1Q. The present standard does not specify any MIB modules.

9. YANG Data Model

This clause specifies YANG data modules that provide control and status monitoring of systems and system components that implement the functionality specified in this standard. These data models are based on the set of managed objects and their functionality specified in Clause 8.

This clause:

a) Introduces the YANG framework that governs the naming and hierarchy of configuration and operational data structures in the data models, and the modeling of network interfaces (9.1),
b) Describes each of the data models and its relationship to the operational processes and managed objects specified in the other clauses of this standard (9.2),
c) Describes the structure of the data models (9.3),
d) Reviews security considerations (9.4),
e) Provides a schema tree as an overview of the YANG module (9.5),
f) Specifies the YANG modules (9.6).

9.1 YANG framework

In order to make certain YANG modules that control features in IEEE Std 802.1Q-2022 and its amendments easy to incorporate into both IEEE 802.1Q Bridges and IEEE 802.1Q end stations, those YANG modules are defined in pairs, one pair for each feature. One module of each pair defines groupings that control the feature. The other module augments either a Bridge component or a Bridge Port with that first module's groupings. The present standard takes advantage of this structure. The modules defined in the present clause use the modules that control IEEE 802.1Q features required for GFQoS to augment systems and/or interfaces, instead of Bridge components and/or Bridge Ports.

9.2 IEEE 802.1DC YANG modules

Table 9-1 shows the modules, specified in IEEE Std 802.1Q-2022 and its amendments, that can be used to control GFQoS functions in GFQoS systems. As shown in 9.3, these modules can be adapted for use in GFQoS systems by means of YANG `augment` statements.

Table 9-1—YANG modules specified IEEE Std 802.1Q-2022 and amendments, and relevant to GFQoS systems

Function	Module name	Specified in[1]
Scheduled Transmission	ieee802-dot1q-sched	[Qcw] 48.6.17
Asynchronous Traffic Shaping	ieee802-dot1q-ats ieee802-dot1q-stream-filters-gates	[Qcz] 48.6.18 [Qcz] 48.6.14
Frame preemption	ieee802-dot1q-preemption	[Qcw] 48.6.19
Per-Stream Filtering and Policing	ieee802-dot1q-psfp	[Qcw] 48.6.21

1 See 1.6 "Reference conventions".

9.3 Structure of the YANG modules

The YANG modules specified by this standard use the YANG modules summarized in Table 9-2.

Table 9-2—Summary of GFQoS functions and their YANG modules

Module	References	Managed functionality	Notes
		Basic functionality 6.2.1	No YANG modules are provided for basic functionality; there are no managed objects to control that are independent of the functions of an IEEE 802.1Q Bridge.
		Strict priority 6.2.2	No YANG modules are provided for strict priority; there are no managed objects to control that are independent of the functions of an IEEE 802.1Q Bridge.
ieee802-dot1dc-gfqos	9.6.3	EISS 6.2.3	The managed objects and YANG modules for managing the Extended Internal Sublayer Service (EISS) are specified in IEEE Std 802.1Q as part of the modules that control a Bridge component and a Bridge Port. These have been adapted for use by GFQoS systems in the present standard (6.2.3).
		PFC 6.2.4	At the time of this writing, there is no published IEEE 802.1 standard for a YANG module to control Priority Flow Control.
ieee802-dot1dc-preemption-if	9.6.1	Frame preemption 6.2.5	Augments an interface using ieee802-dot1q-preemption [Qcw] 48.6.19
		FRER 6.2.6	Frame Replication and Elimination for Reliability (FRER) is managed by YANG modules specified in IEEE Std 802.1CB and its amendments.
		General flow classification and metering 6.2.7	No YANG modules are provided for general flow classification and metering; there are no managed objects specified by IEEE 802.1 to control this function.
ieee802-dot1dc-psfp-sys	9.6.2	PSFP 6.2.8	Augments a system using ieee802-dot1q-psfp [Qcw] 48.6.21
ieee802-dot1dc-gfqos	9.6.3	ETS 6.2.9	Enhanced Transmission Selection is managed using YANG modules specified in [Qcz] D.6.5.3, which are included by reference through ieee802-dot1dc-gfqos (9.6.3).
ieee802-dot1dc-sched-if	9.6.4	Scheduled traffic 6.2.10	Augments an interface using ieee802-dot1q-sched [Qcw] 48.6.17
		FQTSS 6.2.11	At the time of this writing, there is no published IEEE 802.1 standard for a YANG module to control Forwarding and Queuing enhancements for Time-Sensitive Streams.
		CQF 6.2.12	No YANG modules are provided specifically for cyclic queuing and forwarding. Control of CQF is accomplished by managing PSFP (6.2.8) and scheduled transmissions (6.2.10), as described in [Q] Annex T
ieee802-dot1dc-ats-if	9.6.5	ATS 6.2.13	Augments an interface using ieee802-dot1q-ats [Qcz] 48.6.18 and ieee802-dot1q-stream-filters-gates [Qcz] 48.6.14

9.4 Security considerations

See [Qcw] 48.4 and [Qcz] 48.4 for a review of security considerations relevant to the IEEE 802.1DC YANG modules.

9.5 YANG Schema tree definitions

See [Qcw] 48.5 and [Qcz] 48.5 for a schema tree definitions of the IEEE 802.1DC YANG modules, except for the ieee802-dot1dc-gfqos module, below (9.5.1).

9.5.1 Tree diagram for ieee802-dot1dc-gfqos

```
module: ieee802-dot1dc-gfqos

  augment /if:interfaces/if:interface:
    +--rw gfqos-ifc
       +--rw pvid?                                      dot1qtypes:vlan-index-type
{eiss}?
       +--rw acceptable-frame?                           enumeration {eiss}?
       +--rw transmission-selection-algorithm-table
       |  +--rw transmission-selection-algorithm-map* [traffic-class]
       |     +--rw traffic-class                         traffic-class-type
       |     +--rw transmission-selection-algorithm?     identityref
       +--ro media-dependent-overhead?                   uint8
       +--ro statistics
          +--ro delay-exceeded-discards?          yang:counter64
          +--ro mtu-exceeded-discards?            yang:counter64
          +--ro frame-rx?                         yang:counter64
          +--ro octets-rx?                        yang:counter64
          +--ro frame-tx?                         yang:counter64
          +--ro octets-tx?                        yang:counter64
          +--ro discard-inbound?                  yang:counter64
          +--ro forward-outbound?                 yang:counter64
          +--ro discard-lack-of-buffers?          yang:counter64
          +--ro discard-transit-delay-exceeded?   yang:counter64
          +--ro discard-on-error?                 yang:counter64
          +--ro discard-on-ingress-filtering?     yang:counter64 {dot1q:ingress-
filtering}?
```

9.6 YANG modules

9.6.1 YANG module for Preemption

```
module ieee802-dot1dc-preemption-if {
  yang-version "1.1";
  namespace urn:ieee:std:802.1Q:yang:ieee802-dot1dc-preemption-if;
  prefix preempt-if;

  import ietf-interfaces {
    prefix if;
  }
  import ieee802-dot1q-preemption {
    prefix q-preempt;
  }

```

```
  organization
    "Institute of Electrical and Electronics Engineers";
  contact
    "WG-URL: http://ieee802.org/1/
     WG-EMail: stds-802-1-l@ieee.org
       Contact: IEEE 802.1 Working Group Chair
       Postal: C/O IEEE 802.1 Working Group
       IEEE Standards Association
            445 Hoes Lane
            Piscataway
            NJ 08854
            USA

    E-mail: stds-802-1-chairs@ieee.org";

  description
    "This module provides for management of General Frame Quality of
    Service (GFQoS) systems that support Frame Preemption.

    Copyright (C) IEEE (2023).

    This version of this YANG module is part of IEEE Std 802.1DC;
    see the standard itself for full legal notices.";

  revision 2023-05-16 {
    description
      "Published as part of IEEE Std 802.1DC.

      The following reference statement identifies each referenced
      IEEE Standard as updated by applicable amendments.";

    reference
      "IEEE Std 802.1DC:
      IEEE Std 802.1DC - Quality of Service Provision by
      Network Systems.";
  }

  feature frame-preemption {
    description
      "Frame preemption supported.";
    reference
      "IEEE Std 802.1DC";
  }
  augment "/if:interfaces/if:interface" {
    if-feature "frame-preemption";
    description
      "Augment interface with Frame Preemption configuration.";
    uses q-preempt:preemption-parameters;
  }
}

```

9.6.2 YANG module for Per-Stream Filtering and Policing

```
module ieee802-dot1dc-psfp-sys {
  yang-version "1.1";
  namespace urn:ieee:std:802.1Q:yang:ieee802-dot1dc-psfp-sys;
  prefix psfp-sys;

  import ietf-system {
    prefix sys;
  }
  import ieee802-dot1q-psfp {
    prefix q-psfp;
  }

  organization
    "Institute of Electrical and Electronics Engineers";
  contact
    "WG-URL: http://ieee802.org/1/
     WG-EMail: stds-802-1-l@ieee.org
       Contact: IEEE 802.1 Working Group Chair
       Postal: C/O IEEE 802.1 Working Group
       IEEE Standards Association
            445 Hoes Lane
            Piscataway
            NJ 08854
            USA

    E-mail: stds-802-1-chairs@ieee.org";

  description
    "This module provides management of General Frame Quality of
    Service (GFQoS) systems that support IEEE Std 802.1Q Per
    Stream Filtering and Policing (PSFP).

    Copyright (C) IEEE (2023).

    This version of this YANG module is part of IEEE Std 802.1DC;
    see the standard itself for full legal notices.";

  revision 2023-05-16 {
    description
      "Published as part of IEEE Std 802.1DC.

      The following reference statement identifies each referenced
      IEEE Standard as updated by applicable amendments.";

    reference
      "IEEE Std 802.1DC:
      IEEE Std 802.1DC - Quality of Service Provision by
      Network Systems.";
  }

  feature psfp {
    description
```

```
      "Per Stream Filtering and Policing supported.";
    reference
      "IEEE Std 802.1DC";
  }

  augment "/sys:system" {
    description
      "Augment system with Per-Stream Filtering and Policing
      configuration";
    uses q-psfp:psfp-parameters;
  }
}
```

9.6.3 YANG module for GFQoS interface

```
module ieee802-dot1dc-gfqos {
  yang-version "1.1";
  namespace urn:ieee:std:802.1Q:yang:ieee802-dot1dc-gfqos;
  prefix dot1dc;
  import ietf-yang-types {
    prefix yang;
  }
  import ietf-interfaces {
    prefix if;
  }
  import ieee802-dot1q-types {
    prefix dot1qtypes;
  }
  import ieee802-dot1q-bridge {
    prefix dot1q;
  }

  organization
    "Institute of Electrical and Electronics Engineers";
  contact
    "WG-URL: http://ieee802.org/1/
     WG-EMail: stds-802-1-l@ieee.org
       Contact: IEEE 802.1 Working Group Chair
       Postal: C/O IEEE 802.1 Working Group
       IEEE Standards Association
            445 Hoes Lane
            Piscataway
            NJ 08854
            USA

    E-mail: stds-802-1-chairs@ieee.org";

  description
    "This module provides for management of General Frame Quality of
    Service (GFQoS) systems that support Extended Internal Sublayer
    Service (EISS).
```

```
  Copyright (C) IEEE (2023).

  This version of this YANG module is part of IEEE Std 802.1DC;
  see the standard itself for full legal notices.";

revision 2023-05-16 {
  description
    "Published as part of IEEE Std 802.1DC.

    The following reference statement identifies each referenced
    IEEE Standard as updated by applicable amendments.";

  reference
    "IEEE Std 802.1DC:
    IEEE Std 802.1DC - Quality of Service Provision by Network
    Systems.
    IEEE Std 802.1Q:
    IEEE Std 802.1Q-2022 Bridges and Bridged Networks.";
}

feature eiss {
  description
    "Each GFQoS interface may support the Extended Internal Sublayer
    Service (EISS). This is one useful method for dealing with VLAN
    tags.";
  reference
    "7.3.2 of IEEE Std 802.1DC";
}
augment "/if:interfaces/if:interface" {
  description
    "Augment the interface model with the GFQoS interface";
  container gfqos-ifc {
    description
      "GFQoS interface is an extension of the IETF Interfaces model
      (RFC7223).";
    leaf pvid {
      if-feature "eiss";
      type dot1qtypes:vlan-index-type;
      default "1";
      description
        "The primary (default) VID assigned to interface.";
      reference
        "12.10.1, item m) of 5.4 of IEEE Std 802.1Q";
    }
    leaf acceptable-frame {
      if-feature "eiss";
      type enumeration {
        enum admit-only-VLAN-tagged-frames {
          description
            "Admit only VLAN-tagged frames.";
        }
        enum admit-only-untagged-and-priority-tagged {
          description
            "Admit only untagged and priority-tagged frames.";
```

```
        }
        enum admit-all-frames {
          description
            "Admit all frames.";
        }
      }
      default "admit-all-frames";
      description
        "To configure the Acceptable Frame Types parameter associated
        with one or more GFQoS interfaces, only if EISS is supported";
      reference
        "12.10.1.3, 6.9 of IEEE Std 802.1Q";
    }
    container transmission-selection-algorithm-table {
      description
        "The Transmission Selection Algorithm Table for a given
        interface assigns, for each traffic class that the interface
        supports, the transmission selection algorithm that is to be
        used to select frames for transmission from the corresponding
        queue. Transmission Selection Algorithm Tables may be managed,
        and allow the identification of vendor-specific transmission
        selection algorithms. The transmission selection algorithms
        are identified in the Transmission Selection Algorithm Table
        by means of integer identifiers.";
      reference
        "12.20.2, 8.6.8 of IEEE Std 802.1Q";
      uses dot1qtypes:transmission-selection-table-grouping;
    }
    leaf media-dependent-overhead {
      type uint8;
      units "octets";
      config false;
      description
        "The portMediaDependentOverhead parameter provides the number
        of additional octets for media-dependent framing. The overhead
        includes all octets prior the first octet of the Destination
        Address field and all octets after the last octet of the frame
        check sequence.";
      reference
        "12.4.2 of IEEE Std 802.1Q";
    }
    container statistics {
      config false;
      description
        "Container of operational state node information associated
        with the GFQoS interface.";
      uses dot1qtypes:bridge-port-statistics-grouping;
      leaf discard-on-ingress-filtering {
        if-feature "dot1q:ingress-filtering";
        type yang:counter64;
        description
          "The number of frames that were discarded as a result of
          Ingress Filtering being enabled.
```

```
            Discontinuities in the value of this counter can occur at
            re-initialization of the management system, and at other
            times as indicated by the value of 'discontinuity-time'.";
          reference
            "12.6.1.1.3 of IEEE Std 802.1Q";
        }
      }
    }
  }
}
```

9.6.4 YANG module for Scheduled Transmissions

```
module ieee802-dot1dc-sched-if {
  yang-version "1.1";
  namespace urn:ieee:std:802.1Q:yang:ieee802-dot1dc-sched-if;
  prefix sched-if;

  import ietf-interfaces {
    prefix if;
  }
  import ieee802-dot1q-sched {
    prefix q-sched;
  }

  organization
    "Institute of Electrical and Electronics Engineers";
  contact
    "WG-URL: http://ieee802.org/1/
     WG-EMail: stds-802-1-l@ieee.org
       Contact: IEEE 802.1 Working Group Chair
       Postal: C/O IEEE 802.1 Working Group
       IEEE Standards Association
            445 Hoes Lane
            Piscataway
            NJ 08854
            USA

    E-mail: stds-802-1-chairs@ieee.org";

  description
    "This module provides for management of General Frame Quality of
    Service (GFQoS) systems that support Scheduled Traffic Enhancements.

    Copyright (C) IEEE (2023).

    This version of this YANG module is part of IEEE Std 802.1DC;
    see the standard itself for full legal notices.";

  revision 2023-05-16 {
    description
      "Published as part of IEEE Std 802.1DC.

```

```
      The following reference statement identifies each referenced
      IEEE Standard as updated by applicable amendments.";

    reference
      "IEEE Std 802.1DC:
      IEEE Std 802.1DC - Quality of Service Provision by
      Network Systems.";
  }

  augment "/if:interfaces/if:interface" {

    description
      "Augment interface with Scheduled Traffic configuration.";

   uses q-sched:sched-parameters;
  }
}
```

9.6.5 YANG module for Asynchronous Traffic Shaping

```
module ieee802-dot1dc-ats-if {
  yang-version "1.1";
  namespace urn:ieee:std:802.1Q:yang:ieee802-dot1dc-ats-if;
  prefix ats-if;
  import ietf-system {
    prefix sys;
  }
  import ietf-interfaces {
    prefix if;
  }
  import ieee802-dot1q-ats {
    prefix ats;
  }
  import ieee802-dot1q-stream-filters-gates {
    prefix sfsg;
  }

  organization
    "Institute of Electrical and Electronics Engineers";
  contact
    "WG-URL: http://ieee802.org/1/
     WG-EMail: stds-802-1-l@ieee.org
       Contact: IEEE 802.1 Working Group Chair
       Postal: C/O IEEE 802.1 Working Group
       IEEE Standards Association
            445 Hoes Lane
            Piscataway
            NJ 08854
            USA

    E-mail: stds-802-1-chairs@ieee.org";

  description
```

```
  "This module provides management of 802.1Q General Frame Quality of
  Service (GFQoS) systems that support Asynchronous Traffic Shaping
  (ATS).

  Copyright (C) IEEE (2023).

  This version of this YANG module is part of IEEE Std 802.1DC;
  see the standard itself for full legal notices.";

revision 2023-05-16 {
  description
    "Published as part of IEEE Std 802.1DC.

    The following reference statement identifies each referenced
    IEEE Standard as updated by applicable amendments.";

  reference
    "IEEE Std 802.1DC:
    IEEE Std 802.1DC - Quality of Service Provision by
    Network Systems.";
}

augment "/if:interfaces/if:interface" {
  description
    "Augments interfaces by ATS per-Port parameters.";
  uses ats:ats-port-parameters;
}
augment "/sys:system" {
  description
    "Augments the Bridge component with ATS parameters.";
  uses sfsg:sfsg-parameters {
    augment "stream-filters/stream-filter-instance-table" {
      description
        "Augments the Bridge component stream filter for ATS
        schedulers.";
      uses ats:ats-parameters;
      container scheduler {
        description
          "Enapsulates ATS scheduler nodes.";
        leaf scheduler-ref {
          type leafref {
            path
              '..'+
              '/..'+
              '/schedulers'+
              '/scheduler-instance-table'+
              '/scheduler-instance-id';
          }
          description
            "A reference to the ATS scheduler associated with this
            stream filter.";
        }
        leaf scheduler-enable {
          type boolean;
```

```
            default "false";
            description
              "If TRUE, this stream filter has an associated ATS
              scheduler referenced by scheduler-ref. If FALSE, no ATS
              scheduler is associated with this stream filter
              (scheduler-ref is ignored).";
          }
        }
      }
    }
  }
}
```

Annex A

(informative)

Protocol Implementation Conformance Statement (PICS) proforma

A.1 Introduction[1]

The supplier of an 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. A PICS is included at the end of each clause as appropriate. The PICS can be used for a variety of purposes by various parties, including the following:

a) As a checklist by the protocol implementor, to reduce the risk of failure to conform to the standard through oversight;

b) As a detailed indication of the capabilities of the implementation, stated relative to the common basis for understanding provided by the standard PICS proforma, by the supplier and acquirer, or potential acquirer, of the implementation;

c) As a basis for initially checking the possibility of interworking with another implementation by the user, or potential user, of the implementation (note that, while interworking can never be guaranteed, failure to interwork can often be predicted from incompatible PICS);

d) As the basis for selecting appropriate tests against which to assess the claim for conformance of the implementation, by a protocol tester.

A.1.1 Abbreviations and special symbols

The following symbols are used in the PICS proforma:

M	mandatory field/function
!	negation
O	optional field/function
O.<n>	optional field/function, but at least one of the group of options labeled by the same numeral <n> is required
O/<n>	optional field/function, but one and only one of the group of options labeled by the same numeral <n> is required
X	prohibited field/function
<item>:	simple-predicate condition, dependent on the support marked for <item>
<item1>*<item2>:	AND-predicate condition, the requirement must be met if both optional items are implemented
<item1>+<item2>:	OR-predicate condition, the requirement must be met if either of the optional items are implemented

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

A.1.2 Instructions for completing 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 subclauses, each containing a group of items. Answers to the questionnaire items are to be provided in the right-most column, either by simply marking an answer to indicate a restricted choice (usually Yes, No, or Not Applicable), 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 contains the reference or references to the material that specifies the item in the main body of the standard; the sixth column contains values and/or comments pertaining to the question to be answered. The remaining columns record the status of the items—whether the support is mandatory, optional or conditional—and provide the space for the answers.

The 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 A<i> or X<i>, 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 or presentation.

A completed PICS proforma, including any Additional Information and Exception Information, is the protocol implementation conformance statement for the implementation in question.

Note that where an implementation is capable of being configured in more than one way, according to the items listed under Major Capabilities/Options, 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, if that would make presentation of the information easier and clearer.

A.1.3 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 the 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 a brief rationale, based perhaps upon specific application needs, for the exclusion of functions that, although optional, are nonetheless commonly present in implementations.

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.1.4 Exceptional information

It may occasionally happen that a supplier will wish to answer an item with mandatory or prohibited 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; instead, the supplier is required to write into the Support column an X<i> reference to an item of Exception Information, and to 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 that a possible reason for the situation described above is that a defect in the standard has been reported, a correction for which is expected to change the requirement not met by the implementation.

A.1.5 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, optional, or prohibited—are dependent upon whether or not certain other items are supported.

Individual conditional items are indicated by a conditional symbol of the form "<item>:<s>" in the Status column, where "<item>" is an item reference that appears in the first column of the table for some other item, and "<s>" is a status symbol, M (Mandatory), O (Optional), or X (Not Applicable).

If the item referred to by the conditional symbol is marked as supported, then 1) the conditional item is applicable, 2) its status is given by "<s>", and 3) the support column is to be completed in the usual way. Otherwise, the conditional item is not relevant and the Not Applicable (N/A) answer is to be marked.

Each item whose reference is used in a conditional symbol is indicated by an asterisk in the Item column.

A.1.6 Identification

A.1.6.1 Implementation identification

Supplier (Note 1)	
Contact point for queries about the PICS (Note 1)	
Implementation Name(s) and Version(s) (Notes 1 and 3)	
Other information necessary for full identification—e.g., name(s) and version(s) of machines and/or operating system names (Note 2)	
NOTE 1—Required for all implementations. NOTE 2—May be completed as appropriate in meeting the requirements for the identification. NOTE 3—The terms Name and Version should be interpreted appropriately to correspond with a supplier's terminology (e.g., Type, Series, Model).	

A.1.6.2 Protocol summary

Identification of protocol specification	IEEE P802.1DC, Quality of Service Provision by Network Systems.
Identification of amendments and corrigenda to the PICS proforma that have been completed as part of the PICS	Amd : _____ Cor: _____ Amd : _____ Cor: _____
Have any exceptions been noted? (See A.1.4. The answer, "Yes" means that the implementation does not conform to IEEE P802.1DC.	Yes [ ] No [ ]

A.2 PICS proforma for Quality of Service Provision by Network Systems

A.2.1 Major capabilities/options

Item	Feature	Subclause	Value/Comment	Status	Support
END	Is the system a GFQoS end system?	5.4, 5.6	At least one of END or RLY must be marked, “Yes.”	O.1	Yes [ ] No [ ]
RLY	Is the system a GFQoS forwarding system?	5.4, 5.8		O.1	Yes [ ] No [ ]
MC1	Does the system support the GFQoS provision model?	5.4:a, 7.2		M	Yes [ ]
MC2	Does the system support the ISS?	5.4:b, [AC] 11.1		M	Yes [ ]
MC3	Does the system support transmission by strict priority?	5.4:c		M	Yes [ ]
MC4	Does the system support the EISS?	5.5:a, 7.3.2		O	Yes [ ] No [ ]
MC5	Does the system support priority flow control?	5.5:b		O	Yes [ ] No [ ]
MC6	Does the system support enhanced transmission selection?	5.5:c		O	Yes [ ] No [ ]
MC7	Does the system support enhancements for scheduled traffic?	5.5:d		O	Yes [ ] No [ ]
MC8	Does the system support management via YANG modules specified in Clause 9?	5.5:e, 9		O	Yes [ ] No [ ]

A.2.2 GFQoS end system capabilities/options

Item	Feature	Subclause	Value/Comment	Status	Support
ES9	Does the system support FQTSS?	5.7:b		END: O	Yes [ ] No [ ]
ES10	Does the system support PSFP?	5.7:c		END: O	Yes [ ] No [ ]
ES11	Does the system support CQF?	5.7:e		END: O	Yes [ ] No [ ]
ES12	Does the system support asynchronous traffic shaping?	5.7:d		END: O	Yes [ ] No [ ]

Item	Feature	Subclause	Value/Comment	Status	Support
ES13	Does the system support IEEE Std 802.1CB-2017 Talker end system behaviors?	5.7:f		END: O	Yes [ ] No [ ]
ES14	Does the system support IEEE Std 802.1CB-2017 Listener end system behaviors?	5.7:g		END: O	Yes [ ] No [ ]
ES15	Does the system support frame preemption?	5.7:h		END: O	Yes [ ] No [ ]

A.2.3 GFQoS forwarding system capabilities/options

Item	Feature	Subclause	Value/Comment	Status	Support
RS16	Does the system support CQF?	5.9:e		RLY: O	Yes [ ] No [ ]
RS17	Does the system support FQTSS?	5.9:b		RLY: O	Yes [ ] No [ ]
RS18	Does the system support general flow classification and metering?	5.9:h		RLY: O	Yes [ ] No [ ]
RS19	Does the system support PSFP?	5.9:c		RLY: O	Yes [ ] No [ ]
RS20	Does the system support asynchronous traffic shaping?	5.9:d		RLY: O	Yes [ ] No [ ]
RS21	Does the system support IEEE Std 802.1CB-2017 relay system behaviors?	5.9:f		RLY: O	Yes [ ] No [ ]
RS22	Does the system support frame preemption?	5.9:g		RLY: O	Yes [ ] No [ ]

Annex B

(informative)

Bibliography

[B1] IEEE Std 802.3™, IEEE Standard for Ethernet.

[B2] IEEE Std 802.1AX, IEEE Standard for Local and metropolitan area networks—Link Aggregation.

[B3] IEEE Std 802.1AE, IEEE Standard for Local and Metropolitan Area Networks: Media Access Control (MAC) Security.

[B4] IEEE Std 802.11, IEEE Standard for Information technology—Telecommunications and information exchange between systems Local and metropolitan area networks—Specific requirements Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications

[B5] IETF RFC 768, User Datagram Protocol, Postel, J., August 1980.6

[B6] IETF RFC 791, Internet Protocol, Postel, J., Ed., September 1981.

[B7] IETF RFC 2205, Resource ReSerVation Protocol (RSVP)—Version 1 Functional Specification, Braden, RT Ed., Zhang L, Berson S, Herzog S, Jamin S, September 1997

[B8] IETF RFC 2474, Definition of the Differentiated Services Field (DS Field) in the IPv4 and IPv6 Headers, Nichols, K., et al., December 1998.

[B9] IETF RFC 8200 (STD 86), Internet Protocol, Version 6 (IPv6) Specification, Deering, S., Hinden, R., July 2017.

[B10] IETF RFC 9260, Stream Control Transmission Protocol, Stewart, R., Tüxen, M., Nielsen, K., June 2022.

[B11] IETF RFC 9293 (STD 7), Transmission Control Protocol, Eddy, W., Ed., August 2022.