

IEEE Standard for Local and metropolitan area networks— Bridges and Bridged Networks

IEEE Computer Society

Developed by the
LAN/MAN Standards Committee

IEEE Std 802.1Q™-2022
(Revision of IEEE Std 802.1Q-2018)

STANDARDS

IEEE Standard for Local and metropolitan area networks— Bridges and Bridged Networks

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

Approved 21 September 2022
IEEE SA Standards Board

Abstract: This standard specifies how the Media Access Control (MAC) Service is supported by Bridged Networks, the principles of operation of those networks, and the operation of MAC Bridges and VLAN Bridges, including management, protocols, and algorithms.

Keywords: Bridged Network, IEEE 802.1Q™, LAN, local area network, MAC Bridge, metropolitan area network, MSTP, Multiple Spanning Tree Protocol, PBN, Provider Bridged Network, Rapid Spanning Tree Protocol, RSTP, Shortest Path Bridging Protocol, SPB Protocol, Time-Sensitive Networking, TSN, Virtual Bridged Network, virtual LAN, VLAN Bridge

The Institute of Electrical and Electronics Engineers, Inc.
3 Park Avenue, New York, NY 10016-5997, USA

Copyright © 2022 by the Institute of Electrical and Electronics Engineers, Inc.
All rights reserved. Published 22 December 2022. Printed in the United States of America.

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

PDF: ISBN 978-1-5044-9188-4 STD25783
Print: ISBN 978-1-5044-9189-1 STDPD25783

IEEE prohibits discrimination, harassment, and bullying.

For more information, visit <http://www.ieee.org/web/aboutus/whatis/policies/p9-26.html>.

No part of this publication may be reproduced in any form, in an electronic retrieval system or otherwise, without the prior written permission of the publisher.

Important Notices and Disclaimers Concerning IEEE Standards Documents

IEEE Standards documents are made available for use subject to important notices and legal disclaimers. These notices and disclaimers, or a reference to this page (<https://standards.ieee.org/ipr/disclaimers.html>), appear in all standards and may be found under the heading “Important Notices and Disclaimers Concerning IEEE Standards Documents.”

Notice and Disclaimer of Liability Concerning the Use of IEEE Standards Documents

IEEE Standards documents are developed within IEEE Societies and subcommittees of IEEE Standards Association (IEEE SA) Board of Governors. IEEE develops its standards through an accredited consensus development process, which brings together volunteers representing varied viewpoints and interests to achieve the final product. IEEE Standards are documents developed by volunteers with scientific, academic, and industry-based expertise in technical working groups. Volunteers are not necessarily members of IEEE or IEEE SA and participate without compensation from IEEE. While IEEE administers the process and establishes rules to promote fairness in the consensus development process, IEEE does not independently evaluate, test, or verify the accuracy of any of the information or the soundness of any judgments contained in its standards.

IEEE makes no warranties or representations concerning its standards, and expressly disclaims all warranties, express or implied, concerning this standard, including but not limited to the warranties of merchantability, fitness for a particular purpose and non-infringement. In addition, IEEE does not warrant or represent that the use of the material contained in its standards is free from patent infringement. IEEE standards documents are supplied “AS IS” and “WITH ALL FAULTS.”

Use of an IEEE standard is wholly voluntary. The existence of an IEEE Standard does not imply that there are no other ways to produce, test, measure, purchase, market, or provide other goods and services related to the scope of the IEEE standard. Furthermore, the viewpoint expressed at the time a standard is approved and issued is subject to change brought about through developments in the state of the art and comments received from users of the standard.

In publishing and making its standards available, IEEE is not suggesting or rendering professional or other services for, or on behalf of, any person or entity, nor is IEEE undertaking to perform any duty owed by any other person or entity to another. Any person utilizing any IEEE Standards document, should rely upon his or her own independent judgment in the exercise of reasonable care in any given circumstances or, as appropriate, seek the advice of a competent professional in determining the appropriateness of a given IEEE standard.

IN NO EVENT SHALL IEEE BE LIABLE FOR ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES (INCLUDING, BUT NOT LIMITED TO: THE NEED TO PROCURE SUBSTITUTE GOODS OR SERVICES; LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE PUBLICATION, USE OF, OR RELIANCE UPON ANY STANDARD, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE AND REGARDLESS OF WHETHER SUCH DAMAGE WAS FORESEEABLE.

Translations

The IEEE consensus development process involves the review of documents in English only. In the event that an IEEE standard is translated, only the English version published by IEEE is the approved IEEE standard.

Official statements

A statement, written or oral, that is not processed in accordance with the IEEE SA Standards Board Operations Manual shall not be considered or inferred to be the official position of IEEE or any of its committees and shall not be considered to be, nor be relied upon as, a formal position of IEEE. At lectures, symposia, seminars, or educational courses, an individual presenting information on IEEE standards shall make it clear that the presenter's views should be considered the personal views of that individual rather than the formal position of IEEE, IEEE SA, the Standards Committee, or the Working Group. Statements made by volunteers may not represent the formal position of their employer(s) or affiliation(s).

Comments on standards

Comments for revision of IEEE Standards documents are welcome from any interested party, regardless of membership affiliation with IEEE or IEEE SA. However, **IEEE does not provide interpretations, consulting information, or advice pertaining to IEEE Standards documents.**

Suggestions for changes in documents should be in the form of a proposed change of text, together with appropriate supporting comments. Since IEEE standards represent a consensus of concerned interests, it is important that any responses to comments and questions also receive the concurrence of a balance of interests. For this reason, IEEE and the members of its Societies and subcommittees of the IEEE SA Board of Governors are not able to provide an instant response to comments, or questions except in those cases where the matter has previously been addressed. For the same reason, IEEE does not respond to interpretation requests. Any person who would like to participate in evaluating comments or in revisions to an IEEE standard is welcome to join the relevant IEEE working group. You can indicate interest in a working group using the Interests tab in the Manage Profile & Interests area of the [IEEE SA myProject system](#).¹ An IEEE Account is needed to access the application.

Comments on standards should be submitted using the [Contact Us](#) form.²

Laws and regulations

Users of IEEE Standards documents should consult all applicable laws and regulations. Compliance with the provisions of any IEEE Standards document does not constitute compliance to any applicable regulatory requirements. Implementers of the standard are responsible for observing or referring to the applicable regulatory requirements. IEEE does not, by the publication of its standards, intend to urge action that is not in compliance with applicable laws, and these documents may not be construed as doing so.

Data privacy

Users of IEEE Standards documents should evaluate the standards for considerations of data privacy and data ownership in the context of assessing and using the standards in compliance with applicable laws and regulations.

¹ Available at: <https://development.standards.ieee.org/myproject-web/public/view.html#landing>.

² Available at: <https://standards.ieee.org/content/ieee-standards/en/about/contact/index.html>.

Copyrights

IEEE draft and approved standards are copyrighted by IEEE under US and international copyright laws. They are made available by IEEE and are adopted for a wide variety of both public and private uses. These include both use, by reference, in laws and regulations, and use in private self-regulation, standardization, and the promotion of engineering practices and methods. By making these documents available for use and adoption by public authorities and private users, neither IEEE nor its licensors waive any rights in copyright to the documents.

Photocopies

Subject to payment of the appropriate licensing fees, IEEE will grant users a limited, non-exclusive license to photocopy portions of any individual standard for company or organizational internal use or individual, non-commercial use only. To arrange for payment of licensing fees, please contact Copyright Clearance Center, Customer Service, 222 Rosewood Drive, Danvers, MA 01923 USA; +1 978 750 8400; <https://www.copyright.com/>. Permission to photocopy portions of any individual standard for educational classroom use can also be obtained through the Copyright Clearance Center.

Updating of IEEE Standards documents

Users of IEEE Standards documents should be aware that these documents may be superseded at any time by the issuance of new editions or may be amended from time to time through the issuance of amendments, corrigenda, or errata. An official IEEE document at any point in time consists of the current edition of the document together with any amendments, corrigenda, or errata then in effect.

Every IEEE standard is subjected to review at least every 10 years. When a document is more than 10 years old and has not undergone a revision process, it is reasonable to conclude that its contents, although still of some value, do not wholly reflect the present state of the art. Users are cautioned to check to determine that they have the latest edition of any IEEE standard.

In order to determine whether a given document is the current edition and whether it has been amended through the issuance of amendments, corrigenda, or errata, visit [IEEE Xplore](#) or [contact IEEE](#).³ For more information about the IEEE SA or IEEE's standards development process, visit the IEEE SA Website.

Errata

Errata, if any, for all IEEE standards can be accessed on the [IEEE SA Website](#).⁴ Search for standard number and year of approval to access the web page of the published standard. Errata links are located under the Additional Resources Details section. Errata are also available in [IEEE Xplore](#). Users are encouraged to periodically check for errata.

Patents

IEEE Standards are developed in compliance with the [IEEE SA Patent Policy](#).⁵

Attention is called to the possibility that implementation of this standard may require use of subject matter covered by patent rights. By publication of this standard, no position is taken by the IEEE with respect to the existence or validity of any patent rights in connection therewith. If a patent holder or patent applicant has

³ Available at: <https://ieeexplore.ieee.org/browse/standards/collection/ieee>.

⁴ Available at: <https://standards.ieee.org/standard/index.html>.

⁵ Available at: <https://standards.ieee.org/about/sasb/patcom/materials.html>.

filed a statement of assurance via an Accepted Letter of Assurance, then the statement is listed on the IEEE SA Website at <https://standards.ieee.org/about/sasb/patcom/patents.html>. Letters of Assurance may indicate whether the Submitter is willing or unwilling to grant licenses under patent rights without compensation or under reasonable rates, with reasonable terms and conditions that are demonstrably free of any unfair discrimination to applicants desiring to obtain such licenses.

Essential Patent Claims may exist for which a Letter of Assurance has not been received. The IEEE is not responsible for identifying Essential Patent Claims for which a license may be required, for conducting inquiries into the legal validity or scope of Patents Claims, or determining whether any licensing terms or conditions provided in connection with submission of a Letter of Assurance, if any, or in any licensing agreements are reasonable or non-discriminatory. Users of this standard are expressly advised that determination of the validity of any patent rights, and the risk of infringement of such rights, is entirely their own responsibility. Further information may be obtained from the IEEE Standards Association.

IMPORTANT NOTICE

IEEE Standards do not guarantee or ensure safety, security, health, or environmental protection, or ensure against interference with or from other devices or networks. IEEE Standards development activities consider research and information presented to the standards development group in developing any safety recommendations. Other information about safety practices, changes in technology or technology implementation, or impact by peripheral systems also may be pertinent to safety considerations during implementation of the standard. Implementers and users of IEEE Standards documents are responsible for determining and complying with all appropriate safety, security, environmental, health, and interference protection practices and all applicable laws and regulations.

Participants

At the time this standard was submitted to the IEEE-SA Standards Board for approval, the IEEE 802.1 Working Group had the following membership:

Glenn Parsons, *Chair*
Jessy V. Rouyer, *Vice Chair*
John Messenger, *Editor*
Mick Seaman, *Editor*

Astrit Ademaj
Venkat Arunarthi
Ralf Assmann
Huajie Bao
Rudy Belliardi
Christian Boiger
Paul Bottorff
Radhakrishna Canchi
Feng Chen
Abhijit Choudhury
Paul Congdon
Rodney Cummings
Josef Dorr
Hesham M. Elbakoury
Anna Engelmann
Thomas Enzinger
János Farkas
Donald W. Fedyk
Norman Finn
Geoffrey Garner
Amrit Gopal
Craig Gunther
Marina Gutierrez
Stephen Haddock
Mark Hantel

Jerome Henry
Marc Holness
Daniel Hopf
Woojung Huh
Satoko Itaya
Yoshihiro Ito
Michael Karl
Stephan Kehrer
Randy Kelsey
Marcel Kiessling
Gavin Lai
Joao Lopes
Lily Lv
Christophe Mangin
Scott Mansfield
Olaf Mater
David McCall
Larry McMillan
Hiroki Nakano
Don Pannell
Razvan Petre
Michael Potts
Dieter Proell
Karen Randall
Maximilian Riegel

Silvana Rodrigues
Atsushi Sato
Frank Schewe
Maik Seewald
Ramesh Sivakolundu
Johannes Specht
Marius Stanica
Guenter Steindl
Nemanja Stamenic
Karim Traore
Max Turner
Balazs Varga
Ganesh Venkatesan
Xinyuan Wang
Tongtong Wang
Karl Weber
Leon Wessels
Ludwig Winkel
Jordon Woods
Takahiro Yamaura
Yue Yin
Uwe Zeier
Nader Zein
William Zhao
Helge Zinner

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

Robert Aiello	Raj Jain	R. K. Rannow
Thomas Alexander	Pranav Jha	Alon Regev
Harry Bims	Lokesh Kabra	Maximilian Riegel
Christian Boiger	Piotr Karocki	Jessy V. Rouyer
Rich Boyer	Stephan Kehrer	Peter Saunderson
Vern Brethour	Randy Kelsey	Frank Schewe
William Byrd	Stuart Kerry	Mick Seaman
Paul Cardinal	Evgeny Khorov	Johannes Specht
Juan Carreon	Yongbum Kim	Gunter Steindl
Pin Chang	Jeff Koftinoff	Eugene Stoudenmire
Diego Chiozzi	Gavin Lai	Walter Struppler
Paul Congdon	Hyeong Ho Lee	Mitsutoshi Sugawara
Michael Cowan	James Lepp	Bo Sun
János Farkas	Joseph Levy	David Tepen
Avraham Freedman	Christophe Mangin	David Tremblay
Craig Gunther	Scott Mansfield	Max Turner
Stephen Haddock	Roger Marks	John Vergis
Mark Hantel	Stephen McCann	Stephen Webb
Jerome Henry	Jonathon McLendon	Karl Weber
Marco Hernandez	Satoshi Obara	Scott Willy
Werner Hoelzl	Glenn Parsons	Andreas Wolf
Oliver Holland	Arumugam Paventhan	Dayin Xu
Marc Holness	Clinton Powell	Yu Yuan
Yoshihiro Ito	Dieter Proell	Oren Yuen

When the IEEE SA Standards Board approved this standard on 21 September 2022, it had the following membership:

David J. Law, *Chair*
Ted Burse, *Vice Chair*
Gary Hoffman, *Past Chair*
Konstantinos Karachalios, *Secretary*

Edward A. Addy	Johnny Daozhuang Lin	Mark Siira
Ramy Ahmed Fathy	Kevin Lu	Dorothy V. Stanley
J. Travis Griffith	Daleep C. Mohla	Lei Wang
Guido R. Hiertz	Andrew Myles	F. Keith Waters
Yousef Kimiagar	Damir Novosel	Karl Weber
Joseph L. Koepfinger*	Annette D. Reilly	Sha Wei
Thomas Koshy	Robby Robson	Philip B. Winston
John D. Kulick	Jon Walter Rosdahl	Daidi Zhong

*Member Emeritus

Historical participants

Since the initial publication, many IEEE standards have added functionality or provided updates to material included in this standard. The following is a historical list of participants who have dedicated their valuable time, energy, and knowledge to the creation of this material:

IEEE 802.1Q Standard	Date approved by IEEE	Officers at the time of Working Group Ballot
IEEE Std 802.1Q-1998	8 December 1998	William P. Lidinsky , <i>Chair</i> Mick Seaman , <i>Chair, Interworking Task Group</i> Tony Jeffree , <i>Coordinating Editor</i> Anil Rijasinghani, Richard Hausmann, Michele Wright, Paul Langille, P. J. Singh , <i>Editorial Team</i>
IEEE Std 802.1u-2001	17 March 2001	Tony Jeffree , <i>Chair</i> Neil Jarvis , <i>Vice Chair</i> Mick Seaman , <i>Chair, Interworking Task Group</i>
IEEE Std 802.1v-2001	17 March 2001	Tony Jeffree , <i>Chair</i> Neil Jarvis , <i>Vice Chair</i> Mick Seaman , <i>Chair, Interworking Task Group</i> David Delany , <i>Editor</i> Andrew Smith , <i>Editor</i>
IEEE Std 802.1s-2002	11 December 2002	Tony Jeffree , <i>Chair</i> Neil Jarvis , <i>Vice Chair</i> Mick Seaman , <i>Chair, Interworking Task Group</i> Norman W. Finn , <i>Editor</i>
IEEE Std 802.1ad-2005	28 March 2005	Tony Jeffree , <i>Chair</i> Paul Congdon , <i>Vice Chair</i> Mick Seaman , <i>Chair, Interworking Task Group</i> Stephen R. Haddock , <i>Editor</i>
IEEE Std 802.1Q-2005	7 December 2005	Tony Jeffree , <i>Chair and Editor</i> Paul Congdon , <i>Vice Chair</i> Mick Seaman , <i>Chair, Interworking Task Group</i>
IEEE Std 802.1ak-2007	22 March 2007	Tony Jeffree , <i>Chair and Editor</i> Paul Congdon , <i>Vice Chair</i> Mick Seaman , <i>Chair, Interworking Task Group</i>
IEEE Std 802.1ag-2007	27 September 2007	Tony Jeffree , <i>Chair</i> Paul Congdon , <i>Vice Chair</i> Stephen R. Haddock , <i>Chair, Interworking Task Group</i> Norman W. Finn , <i>Editor-in-Chief</i> David V. Elie-Dit-Cosaque, Dinesh Mohan, Oscar Rodriguez, Ali Sajassi , <i>Assistant Editors</i>

IEEE 802.1Q Standard	Date approved by IEEE	Officers at the time of Working Group Ballot
IEEE Std 802.1ah-2008	12 June 2008	Tony Jeffree , <i>Chair</i> Paul Congdon , <i>Vice Chair</i> Stephen R. Haddock , <i>Chair, Interworking Task Group</i> Paul Bottorff , Stephen Haddock , and Muneyoshi Suzuki , <i>Editors</i>
IEEE Std 802.1Q-2005/Cor-1-2008	26 September 2008	Tony Jeffree , <i>Chair and Editor</i> Paul Congdon , <i>Vice Chair</i> Stephen R. Haddock , <i>Chair, Interworking Task Group</i>
IEEE Std 802.1ap-2008	10 December 2008	Tony Jeffree , <i>Chair</i> Paul Congdon , <i>Vice Chair</i> Stephen R. Haddock , <i>Chair, Interworking Task Group</i> Glenn Parsons , <i>Editor</i> David Levi , <i>Assistant Editor</i>
IEEE Std 802.1Qaw-2009	17 June 2009	Tony Jeffree , <i>Chair</i> Paul Congdon , <i>Vice Chair</i> Stephen R. Haddock , <i>Chair, Interworking Task Group</i> Linda Dunbar , <i>Editor</i>
IEEE Std 802.1Qay-2009	17 June 2009	Tony Jeffree , <i>Chair</i> Paul Congdon , <i>Vice Chair</i> Stephen R. Haddock , <i>Chair, Interworking Task Group</i> Panagiotis Saltsidis , <i>Editor</i>
IEEE Std 802.1aj-2009	9 December 2009	Tony Jeffree , <i>Chair</i> Paul Congdon , <i>Vice Chair</i> Stephen R. Haddock , <i>Chair, Interworking Task Group</i> John Messenger , <i>Editor</i> Brian Hassink , <i>MIB Editor</i>
IEEE Std 802.1Qav-2009	9 November 2009	Tony Jeffree , <i>Chair and Editor</i> Paul Congdon , <i>Vice Chair</i> Michael Johas Teener , <i>Chair, Audio Video Bridging Task Group</i>
IEEE Std 802.1Qau-2010	25 March 2010	Tony Jeffree , <i>Chair</i> Paul Congdon , <i>Vice Chair</i> Patricia Thaler , <i>Chair, Data Center Bridging Task Group</i> Norman W. Finn , <i>Editor</i>
IEEE Std 802.1Qat-2010	30 September 2010	Tony Jeffree , <i>Chair</i> Paul Congdon , <i>Vice Chair</i> Michael Johas Teener , <i>Chair, Audio Video Bridging Task Group</i> Craig Gunther , <i>Editor</i>

IEEE 802.1Q Standard	Date approved by IEEE	Officers at the time of Working Group Ballot
IEEE Std 802.1Q-2011	16 May 2011	Tony Jeffree , <i>Chair and Editor</i> Paul Congdon , <i>Vice Chair</i> Stephen Haddock , <i>Chair, Interworking Task Group</i>
IEEE Std 802.1Qbc-2011	16 June 2011	Tony Jeffree , <i>Chair</i> Paul Congdon , <i>Vice Chair</i> Stephen Haddock , <i>Chair, Interworking Task Group</i> Norman Finn , <i>Editor</i>
IEEE Std 802.1Qbc-2011	16 June 2011	Tony Jeffree , <i>Chair</i> Paul Congdon , <i>Vice Chair</i> Stephen Haddock , <i>Chair, Interworking Task Group</i> Thomas Mack-Crane , <i>Editor</i>
IEEE Std 802.1Qbb-2011	16 June 2011	Tony Jeffree , <i>Chair</i> Paul Congdon , <i>Vice Chair</i> Patricia Thaler , <i>Chair, Data Center Bridging Task Group</i> Claudio DeSanti , <i>Editor</i>
IEEE Std 802.1Qaz-2011	16 June 2011	Tony Jeffree , <i>Chair</i> Paul Congdon , <i>Vice Chair</i> Patricia Thaler , <i>Chair, Data Center Bridging Task Group</i> Craig W. Carlson , <i>Editor</i>
IEEE Std 802.1Qbf-2011	7 December 2011	Tony Jeffree , <i>Chair</i> Paul Congdon , <i>Vice Chair</i> Stephen Haddock , <i>Chair, Interworking Task Group</i> Robert Sultan , <i>Editor</i>
IEEE Std 802.1aq-2012	29 March 2012	Tony Jeffree , <i>Chair</i> Glenn Parsons , <i>Vice Chair</i> Stephen Haddock , <i>Chair, Interworking Task Group</i> Donald Fedyk , Mick Seaman , <i>Editors</i>
IEEE Std 802.1Qbg-2012	14 May 2012	Tony Jeffree , <i>Chair and Editor</i> Paul Congdon , <i>Vice Chair</i> Patricia Thaler , <i>Chair, Data Center Bridging Task Group</i> Paul Bottorff , <i>Editor, Clauses 12 and 17</i>
IEEE Std 802.1Q-2011/Cor-2-2012	19 October 2012	Tony Jeffree , <i>Chair and Editor</i> Glenn Parsons , <i>Vice Chair and Chair, Maintenance Task Group</i>
IEEE Std 802.1Qbp-2014	27 March 2014	Tony Jeffree , <i>Chair</i> Glenn Parsons , <i>Vice Chair</i> Stephen Haddock , <i>Chair, Interworking Task Group</i> Ben Mack-Crane , <i>Editor</i>

IEEE 802.1Q Standard	Date approved by IEEE	Officers at the time of Working Group Ballot
IEEE Std 802.1D-2004	9 February 2004	Tony Jeffree , <i>Chair and Editor</i> Paul Congdon , <i>Vice Chair</i> Mick Seaman , <i>Chair, Interworking Task Group and Editor</i>
IEEE Std 802.1D-2004	3 November 2014	Glenn Parsons , <i>Chair</i> John Messenger , <i>Vice-Chair</i> Tony Jeffree , <i>Editor</i> Stephen Haddock , <i>Chair, Interworking Task Group</i>
IEEE Std 802.1Qcd-2015	16 February 2015	Glenn Parsons , <i>Chair</i> John Messenger , <i>Vice Chair</i> Patricia Thaler , <i>Chair, Data Center Bridging Task Group</i> Eric Multanen , <i>Editor</i>
IEEE Std 802.1Qca-2015	3 September 2015	Glenn Parsons , <i>Chair</i> John Messenger , <i>Vice-Chair</i> János Farkas , <i>Editor</i> Stephen Haddock , <i>Chair, Interworking Task Group</i>
IEEE Std 802.1Q-2014/Cor 1-2015	5 December 2015	Glenn Parsons , <i>Chair</i> John Messenger , <i>Vice-Chair and Chair, Maintenance Task Group</i> Tony Jeffree , <i>Editor</i>
IEEE Std 802.1Qbv-2015	5 December 2015	Glenn Parsons , <i>Chair</i> John Messenger , <i>Vice-Chair</i> Michael Johas Teener , <i>Chair, Time-Sensitive Networking Task Group</i> Tony Jeffree , <i>Editor</i>
IEEE Std 802.1Qbu-2016	30 June 2016	Glenn Parsons , <i>Chair</i> John Messenger , <i>Vice-Chair</i> Michael Johas Teener , <i>Chair, Time-Sensitive Networking Task Group</i> Tony Jeffree , <i>Editor</i>
IEEE Std 802.1Qbz-2016	30 June 2016	Glenn Parsons , <i>Chair</i> John Messenger , <i>Vice-Chair</i> Michael Johas Teener , <i>Chair, Time-Sensitive Networking Task Group</i> Norm Finn , <i>Editor</i>
IEEE Std 802.1Qci-2017	14 February 2017	Glenn Parsons , <i>Chair</i> John Messenger , <i>Vice-Chair</i> János Farkas , <i>Chair, Time-Sensitive Networking Task Group</i> Tony Jeffree , <i>Editor</i>
IEEE Std 802.1Qch-2017	15 May 2017	Glenn Parsons , <i>Chair</i> John Messenger , <i>Vice-Chair</i> János Farkas , <i>Chair, Time-Sensitive Networking Task Group</i> Tony Jeffree , <i>Editor</i>

IEEE 802.1Q Standard	Date approved by IEEE	Officers at the time of Working Group Ballot
IEEE Std 802.1Qcc-2018	14 June 2018	Glenn Parsons , <i>Chair</i> John Messenger , <i>Vice Chair and Acting Chair</i> Jessy V. Rouyer , <i>Acting Vice Chair</i> János Farkas , <i>Chair, Time-Sensitive Networking Task Group</i> Rodney Cummings , <i>Editor</i>
IEEE Std 802.1Qcp-2018	14 June 2018	Glenn Parsons , <i>Chair</i> John Messenger , <i>Vice Chair and Acting Chair</i> Jessy V. Rouyer , <i>Acting Vice Chair</i> János Farkas , <i>Chair, Time-Sensitive Networking Task Group</i> Marc Holness , <i>Editor</i>
IEEE Std 802.1Qcy-2019	21 March 2019	Glenn Parsons , <i>Chair</i> John Messenger , <i>Vice Chair and Acting Chair</i> Jessy V. Rouyer , <i>Acting Vice Chair</i> János Farkas , <i>Chair, Time-Sensitive Networking Task Group</i> Yizhou Li , <i>Editor</i> Paul Bottorff , <i>Editor</i>
IEEE Std 802.1Qcx-2020	4 June 2020	Glenn Parsons , <i>Chair</i> John Messenger , <i>Vice Chair</i> János Farkas , <i>Chair, Time-Sensitive Networking Task Group</i> Marc Holness , <i>Editor</i>
IEEE Std 802.1Qcr-2020	24 September 2020	Glenn Parsons , <i>Chair</i> John Messenger , <i>Vice Chair</i> Jessy V. Rouyer , <i>Secretary</i> János Farkas , <i>Chair, Time-Sensitive Networking Task Group</i> Craig Gunther , <i>Vice Chair, Time-Sensitive Networking Task Group</i> Johannes Specht , <i>Editor</i>

Osama Aboul-Magd
Steve Adams
Stephen Ades
Fumio Akashi
Zehavit Alon
Ken Alonge
Ann Ambler
Paul D. Amer
Yafan An
Ting Ao
Charles Arnold
Peter Ashwood-Smith
Siamack Ayandeh
Floyd Backes
Ann Ballard
Richard Bantel
John Bartlett
Sy Bederman
Alexei Beliaev
Les Bell
Amatzia Ben-Artzi
Avner Ben-Dor
Michael Berger
Caitlin Bestler
Jan Bialkowski
James S. Binder
Robert Bledsoe
Rob Boatright
Kwami Boakaye
Christian Boiger
Brad Booth
Jean-Michel Bonnamy
Mike Borza
Paul Bottorff
David Brady
Rudolf Brandner
Martin Brewer
Frank Bruns
Juan Bulnes
Bill Bunch
Jim Burns
Peter Carbone
Bob Cardinal
Craig W. Carlson
Paul Carroll
Marco Carugi
Jeffrey Catlin
Dennis Cave
Dirceu Cavendish
Alan Chambers
Steve Chan
David W. Chang
Xin Chang
Frank Chao
Ken Chapman
Alice Chen
David Chen
Feng Chen
Weiyang Cheng
Rao Cherukuri
Taesik Cheung
Jade Chien
Hon Wah Chin

Chi Chong
Jin-Seek Choi
Chris Christ
Marc Cochran
Paul Congdon
Glenn Connery
Alex Conta
Jim Corrigan
Diego Crupnicoff
David Cullerot
Rodney Cummings
Uri Cummings
Ted Davies
Andy Davis
Peter Dawe
Stan Degen
Arjan de Heer
Frank Deignan
David Delaney
Prakash Desai
Claudio DeSanti
Ron Dhondy
Patrick Diamond
Aboubacar Kader Diarra
Jeffrey Dietz
Russell Dietz
Zheming Ding
Kurt Dobbins
Eiji Doi
Barbara J. Don Carlos
Linda Dunbar
Craig Easley
Donald Eastlake, III
Peter Ecclesine
J. J. Ekstrom
Anush Elangovan
Hesham M. Elbakoury
Walter Eldon
David Elie-Dit-Cosaque
János Farkas
Donald W. Fedyk
Eldon D. Feist
Felix Feifei Feng
Norman Finn
Len Fishler
Kevin Flanagan
Yishai Fraenkel
Paul Frantz
David Frattura
Robert Frazier
Lars Henrik Frederiksen
Andre Fredette
John Fuller
Ilango Ganga
Geoffrey Garner
Anoop Ghanwani
Franz Goetz
Pat Gonia
Gerrard Goubert
Richard Graham
Mark Gravel
Michael A. Gravel
Eric W. Gray

Karanvir Grewal
John Grinham
Yingjie Gu
Craig Gunther
Mitch Gusat
Stephen Haddock
Sharam Hakimi
Mogens Hansen
Mark Hantel
Harold Harrington
John Hart
Scott Harvell
Mike Harvey
Takashi Hasegawa
Brian Hassink
Wayne Hathaway
Brian Hausauer
Richard Hausman
Hitoshi Hayakawa
Vic Hayes
Asif Hazarika
David Head
Gaby Hecht
Deepak Hegde
Ariel Hendel
Bob Herbst
John Hickey
Jeremy Hitt
David Hollender
Marc Holness
Steve Horowitz
Bob Hott
Michelle Hsiung
Charles Hudson
Jack R. Hung
Rita Hunt
David Husak
Altaf Hussain
Rahil Hussain
Thomas Hytry
Romain Insler
Ran Ish-Shalom
Jay Israel
Atsushi Iwata
Vipin K. Jain
Neil Jarvis
Tony Jeffree
Paul Hongkyu Jeong
Pankaj Jha
Markus Jochim
Michael Johas Teener
Girault Jones
Peter Jones
Shyam Kaluve
Daya Kamath
Abhay Karandikar
Allen Kasey
Prakash Kashyap
Toyayuki Kato
Manu Kaycee
Hal Keen
Srikanth Keesara
Stephan Kehler

Daniel Kelley
Kevin Ketchum
Keti Kilcrease
Doyeon Kim
Yongbum Kim
Alan Kirby
Kimberly Kirkpatrick
Keith Klamm
Steve Kleiman
Philippe Klein
Oliver Kleinberg
Marcel Kiessling
Yongbum Kim
Philippe Klein
Bruce Kling
Walter Knitl
Mike Ko
Raghu Kondapalli
Jouni Korhonen
Michael Krause
Dan Krent
James Kristof
Vinod Kumar
Paul Kummer
Bruce Kwan
Paul Lachapelle
Kari Laihonen
Ashvin Lakshmikantha
Bill Lane
Paul Langille
Roger Lapuh
H. Eugene Latham
Loren Larsen
Yannick Le Goff
Marcus Leech
John Lemon
Michael Lerer
Lin Li
Bing Liao
George Lin
William P. Lidinsky
Johann Lindmeyr
Marina Lipshteyn
Gary Littleton
Robert D. Love
Yuanqui Luo
Andy Luque
Jeff Lynch
Gael Mace
Thomas Mack-Crane
Phillip Magnuson
Christophe Mangin
Mahalingam Mani
David Martin
Peter Martini
Riccardo Martinotti
Marco Mascitto
Tom McBeath
Keith McCloghrie
Bruce McClure
Tom McGowan
Alan McGuire
James McIntosh

Martin McNealis
Menucher Menuchery
Milan Merhar
Margaret A. Merrick
John Messenger
Colin Mick
Amol Mitra
Dinesh Mohan
Gabriel Montenegro
Jim Montrose
Matthew Mora
John Morris
Bob Moskowitz
Eric Multanen
Yaron Nachman
Yukihiro Nakagawa
Hiroki Nakano
Krishna Narayanaswamy
Lawrence Ng
Henry Ngai
Paul Nikolich
Kevin Nolith
Bob Noseworthy
Don O'Connor
Karen O'Donoghue
Jerry O'Keefe
Eugene O'Neil
Satoshi Obara
Hiroshi Ohta
David Olsen
Toshio Ooka
Jörg Ottensmeyer
Shlomo Ovadia
Vijoy Pandey
Don Pannell
Luc Pariseau
Glenn Parsons
Richard Patti
Ken Patton
Mark Pearson
Joseph Pelissier
Yonadav Perry
David Peterson
Roger Pfister
Thomas L. Phinney
John Pickens
Walter Pieniciak
Daniel Pitt
Hayim Porat
Gideon Prat
Kirk Preiss
Ron L. G. Prince
Max Pritikin
Ray Qiu
Rene Raeber
Ananda Rajagopal
Steve Ramberg
Nigel Ramsden
Karen Randall
Shlomo Reches
Frank Reichstein
Dick Reohr
Trudy Reusser

James Richmond
Maximilian Riegel
Anil Rijisinghani
Robert Roden
Edouard Rocher
Gunter Roeck
John J. Roesse
Josef Roesse
Derek J. Rohde
Allyn Romanow
Dan Romascanu
Paul Rosenblum
Moran Roth
Jessy V. Rouyer
Doug Ruby
Eric Ryu
Jonathan Sadler
Ali Sajassi
Dolors Sala
Joseph Salowey
John Salter
Panagiotis Saltsidis
Sam Sambasivan
Ray Samora
Behcet Sarikaya
Alan Sarsby
Satish Sathe
John M. Sauer
Ayman Sayed
Susan Schanning
Ted Schroeder
Benjamin Schultz
Mick Seaman
Gerry Segal
Rich Seifert
Lee Sendelbach
Koichiro Seto
Daniel Sexton
Himanshu Shah
Rakesh Sharma
Ravi Shenoy
Howard Sherry
K. Karl Shimada
Fred Shu
Wu-Shi Shung
Taeshi Shimizu
Phil Simmons
Curtis Simonson
Paramjeet Singh
Rosemary V. Slager
Alexander Smith
Andrew Smith
Michel Soerensen
M. Soha
Stuart Soloway
Johannes Specht
Nurit Sprecher
Kevin B. Stanton
Larry Stefani
Wilfried Steiner
Dan Stokesberry
Sundar Subramaniam
Robert Sultan

Muneyoshi Suzuki
Yoshihiro Suzuki
George Swallow
Lennart Swartz
Richard Sweatt
Vahid Tabatabaee
Attila Takacs
Kenta Takumi
Francois Tallet
Robin Tasker
Angus Telfer
John Terry
Patricia A. Thaler
Jonathan Thatcher
Dave Thompson
Geoff Thompson
David Thornburg
Oliver Thorp
Michel Thorsen
Fouad Tobagi
Nathan Tobol
Jeremy Touve
Naoki Tsukutari
Fred Tuck
Chait Tumuluri

Wendell Turner
Paul Unbehagen
Dhadesugoor Vaman
Steve Van Seters
Dono van-Mierop
Peter Videcranz
John Viega
Maarten Vissers
Dennis Volpano
Manoj Wadekar
Paul Wainwright
Scott Wasson
Daniel Watts
Yuehua Wei
John Wakerly
Peter Wang
Philip Wang
Y. C. Wang
Yan Wang
Trevor Warwick
Bob Watson
Karl Weber
Yuehua Wei
Brian Weis
Alan Weissberger

Glenn Wenig
Martin White
Bert Wijnen
Deborah Wilbert
Keith Willette
Robert Williams
Val Wilson
Ludwig Winkel
Robert Winter
Michael Witkowski
Edward Wong
Jordon Woods
Michael D. Wright
Michele Wright
Chien-Hsien Wu
Min Xiao
Ken Young
Allen Yu
Wayne Zakowski
Igor Zhovnirovsky
Carolyn Zimmer
Helge Zinner
Glen Zorn
Nick Zuccherro
Juan-Carlos Zuniga

Introduction

This introduction is not part of IEEE Std 802.1Q™-2022, IEEE Standard for Local and metropolitan area networks—Bridges and Bridged Networks.

IEEE Std 802.1Q™-2022 incorporates the text of the following amendments into IEEE Std 802.1Q™-2018.

IEEE Std 802.1Qcc™-2018	Stream Reservation Protocol (SRP) Enhancements and Performance Improvements
IEEE Std 802.1Qcp™-2018	YANG Data Model
IEEE Std 802.1Qcy™-2019	Virtual Station Interface (VSI) Discovery and Configuration Protocol (VDP) Extension to Support Network Virtualization Overlays Over Layer 3 (NVO3)
IEEE Std 802.1Qcx™-2020	YANG Data Model for Connectivity Fault Management
IEEE Std 802.1Qcr™-2020	Asynchronous Traffic Shaping

The 2018 revision of this standard incorporated the text of the following amendments into IEEE Std 802.1Q-2014.

IEEE Std 802.1Qcd™-2015	Application Virtual Local Area Network (VLAN) Type, Length, Value (TLV)
IEEE Std 802.1Qca™-2015	Path Control and Reservation
IEEE Std 802.1Q-2014 Cor 1-2015	Technical and editorial corrections
IEEE Std 802.1Qbv™-2015	Enhancements for scheduled traffic
IEEE Std 802.1Qbu™-2016	Frame preemption
IEEE Std 802.1Qbz™-2016	Enhancements to Bridging of IEEE 802.11 Media
IEEE Std 802.1Qci™-2017	Per-Stream Filtering and Policing
IEEE Std 802.1Qch™-2017	Cyclic Queuing and Forwarding

The 2014 revision of this standard incorporated the text of the following amendments into IEEE Std 802.1Q-2011.

IEEE Std 802.1Qbe™-2011	Multiple I-SID Registration Protocol
IEEE Std 802.1Qbc™-2011	Provider Bridging—Remote Customer Service Interfaces
IEEE Std 802.1Qbb™-2011	Priority-based Flow Control
IEEE Std 802.1Qaz™-2011	Enhanced Transmission Selection for Bandwidth Sharing Between Traffic Classes
IEEE Std 802.1Qbf™-2011	PBB-TE Infrastructure Segment Protection
IEEE Std 802.1Qbg™-2012	Edge Virtual Bridging
IEEE Std 802.1aq™-2012	Shortest Path Bridging
IEEE Std 802.1Q-2011/Cor 2-2012	Technical and editorial corrections
IEEE Std 802.1Qbp™-2014	Equal Cost Multiple Paths (ECMP)

The 2011 revision of this standard incorporated the text of the following amendments into IEEE Std 802.1Q-2005.

IEEE Std 802.1ad™-2005	Provider Bridges
IEEE Std 802.1ak™-2007	Multiple Registration Protocol
IEEE Std 802.1ag™-2007	Connectivity Fault Management
IEEE Std 802.1ah™-2008	Provider Backbone Bridges
IEEE Std 802-1Q-2005/Cor-1-2008	Corrections to the Multiple Registration Protocol

IEEE Std 802.1ap™-2008	Management Information Base (MIB) Definitions for VLAN Bridges
IEEE Std 802.1Qaw™-2009	Management of Data Driven and Data Dependent Connectivity Faults
IEEE Std 802.1Qay™-2009	Provider Backbone Bridge Traffic Engineering
IEEE Std 802.1aj™-2009	Two-Port Media Access Control (MAC) Relay
IEEE Std 802.1Qav™-2009	Forwarding and Queuing Enhancements for Time-Sensitive Streams
IEEE Std 802.1Qau™-2010	Congestion Notification
IEEE Std 802.1Qat™-2010	Stream Reservation Protocol

Clause 13 of IEEE Std 802.1Q-2011 was also revised to include an updated specification of the Rapid Spanning Tree Algorithm and Protocol (RSTP), superseding references to IEEE Std 802.1D™-2004 [B12].⁶

The 2005 revision of this standard incorporated the text of the following amendments into IEEE Std 802.1Q-1998.

IEEE Std 802.1u™-2001	Technical and Editorial Corrections
IEEE Std 802.1v™-2001	VLAN Classification by Protocol and Port
IEEE Std 802.1s™-2002	Multiple Spanning Trees

This standard was first published as IEEE Std 802.1Q-1998, making use of the concepts and mechanisms of LAN Bridging that were introduced by IEEE Std 802.1D and defining additional mechanisms to allow the implementation of Virtual Bridged Networks.

For an introduction to this standard that details each of the provisions introduced by amendments and revisions throughout its development, refer to 1.3.

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

Secretary, IEEE-SA Standards Board
445 Hoes Lane
Piscataway, NJ 08854-4141
USA

⁶ The numbers in brackets correspond to those of the bibliography in Annex W.

Contents

1.	Overview.....	74
1.1	Scope.....	74
1.2	Purpose.....	74
1.3	Introduction.....	75
2.	Normative references.....	83
3.	Definitions	87
4.	Abbreviations.....	109
5.	Conformance.....	115
5.1	Requirements terminology.....	115
5.2	Conformant components and equipment	115
5.3	Protocol Implementation Conformance Statement (PICS).....	116
5.4	VLAN Bridge component requirements.....	116
5.4.1	VLAN Bridge component options	117
5.4.2	Multiple VLAN Registration Protocol (MVRP) requirements	123
5.4.3	VLAN Bridge requirements for congestion notification	123
5.4.4	Multiple Stream Registration Protocol (MSRP) requirements	124
5.4.5	Shortest Path Bridging (SPB) operation (optional)	124
5.4.6	Path Control and Reservation (PCR) (optional)	125
5.5	C-VLAN component conformance.....	126
5.5.1	C-VLAN component options	126
5.5.2	TE-MSTID (optional)	126
5.6	S-VLAN component conformance	127
5.6.1	S-VLAN component options	127
5.6.2	S-VLAN component requirements for Provider Backbone Bridge Traffic Engineering (PBB-TE)	127
5.6.3	S-VLAN component requirements for PBB-TE IPS	128
5.6.4	S-VLAN component requirements for ECMP with flow filtering	128
5.7	I-component conformance	128
5.7.1	I-component options	128
5.8	B-component conformance.....	129
5.8.1	B-component options	129
5.8.2	B-component requirements for PBB-TE	129
5.8.3	B-component requirements for PBB-TE IPS	130
5.8.4	B-component requirements for ECMP with flow filtering	130
5.9	C-VLAN Bridge conformance.....	130
5.9.1	C-VLAN Bridge options	130
5.10	Provider Bridge conformance.....	130
5.10.1	S-VLAN Bridge conformance	131
5.10.2	Provider Edge Bridge conformance	131
5.11	System requirements for Priority-based Flow Control (PFC)	131
5.12	Backbone Edge Bridge (BEB) conformance.....	131
5.12.1	BEB requirements for PBB-TE	132
5.13	MAC Bridge component requirements.....	132
5.13.1	MAC Bridge component options	132
5.14	MAC Bridge conformance.....	133
5.14.1	MAC Bridge options	133

5.15	TPMR component conformance.....	134
5.15.1	TPMR component options	134
5.16	TPMR conformance.....	134
5.16.1	TPMR options	135
5.17	T-component conformance	135
5.17.1	T-component options	135
5.18	End station requirements for MMRP, MVRP, and MSRP	135
5.18.1	MMRP requirements and options	135
5.18.2	MVRP requirements and options	136
5.18.3	MSRP requirements and options	136
5.19	VLAN-aware end station requirements for CFM	137
5.20	End station requirements—FQTSS	137
5.21	End station requirements for congestion notification	138
5.22	MAC-specific bridging methods	138
5.23	EVB Bridge requirements.....	139
5.24	EVB station requirements.....	139
5.24.1	Edge relay (ER) requirements	140
5.25	End station requirements—enhancements for scheduled traffic	141
5.26	End station requirements—enhancements for frame preemption.....	142
5.27	End station requirements—PSFP	142
5.28	End station requirements—Cyclic queuing and forwarding.....	142
5.29	TSN CNC station requirements	142
5.30	VDP-NVO3 requirements.....	143
5.30.1	VDP-NVO3 nNVE requirements	143
5.30.2	VDP-NVO3 tNVE requirements	143
5.31	End station requirements—ATS.....	143
6.	Support of the MAC Service	144
6.1	Basic architectural concepts and terms	145
6.2	Provision of the MAC Service.....	145
6.2.1	Point-to-point, multipoint-to-multipoint, and rooted-multipoint connectivity ...	146
6.3	Support of the MAC Service	146
6.4	Preservation of the MAC Service	147
6.5	Quality of service (QoS) maintenance.....	147
6.5.1	Service availability	147
6.5.2	Frame loss	148
6.5.3	Frame misordering	148
6.5.4	Frame duplication	149
6.5.5	Transit delay	150
6.5.6	Frame lifetime	150
6.5.7	Undetected frame error rate	151
6.5.8	Maximum Service Data Unit Size	151
6.5.9	Priority	151
6.5.10	Throughput	152
6.6	Internal Sublayer Service (ISS)	153
6.7	Support of the ISS by specific MAC procedures.....	153
6.7.1	Support of the ISS by IEEE Std 802.3 (Ethernet)	153
6.7.2	Frame preemption	153
6.8	Enhanced Internal Sublayer Service (EISS)	154
6.8.1	Service primitives	154
6.8.2	Status parameters	155
6.8.3	Point-to-point parameters	155
6.8.4	Control primitives and parameters	155

6.9	Support of the EISS	156
6.9.1	Data indications	157
6.9.2	Data requests	158
6.9.3	Priority Code Point encoding	158
6.9.4	Regenerating priority	160
6.10	Support of the ISS/EISS by PIPs	161
6.10.1	Data indications	163
6.10.2	Data requests	164
6.10.3	Priority Code Point encoding	164
6.11	Support of the EISS by CBPs	165
6.11.1	Data indications	166
6.11.2	Data requests	167
6.11.3	Priority Code Point decoding	168
6.11.4	Regenerating priority	168
6.12	Protocol VLAN classification.....	168
6.12.1	Protocol Templates	170
6.12.2	Protocol Group Identifiers	170
6.12.3	Protocol Group Database	170
6.13	Support of the ISS for attachment to a PBN	171
6.13.1	Data requests	172
6.13.2	Data indications	172
6.14	Support of the ISS within a system.....	173
6.15	Support of the ISS by additional technologies.....	173
6.16	Filtering services in Bridged Networks	173
6.16.1	Purpose(s) of filtering service provision	174
6.16.2	Goals of filtering service provision	174
6.16.3	Users of filtering services	174
6.16.4	Basis of service	174
6.16.5	Categories of service	175
6.16.6	Service configuration	175
6.16.7	Service definition for Extended Filtering Services	175
6.17	EISS Multiplex Entity.....	177
6.18	Backbone Service Instance Multiplex Entity.....	178
6.18.1	Demultiplexing direction	179
6.18.2	Multiplexing direction	180
6.18.3	Priority Code Point encoding	180
6.18.4	Status parameters	180
6.19	TESI Multiplex Entity	181
6.20	Support of the ISS with signaled priority	182
6.20.1	Data indications	182
6.20.2	Data requests	183
6.21	Infrastructure Segment Multiplex Entity	183
6.22	PDU and protocol discrimination and media.....	184
7.	Principles of Virtual Bridged Network operation.....	185
7.1	Network overview.....	185
7.2	Use of VLANs	186
7.3	Active topology.....	186
7.4	VLAN topology	187
7.5	Locating end stations	188
7.6	Ingress, forwarding, and egress rules.....	189

8.	Principles of Bridge operation	190
8.1	Bridge operation	190
8.1.1	Relay	190
8.1.2	Filtering and relaying information	191
8.1.3	Duplicate frame prevention	191
8.1.4	Traffic segregation	191
8.1.5	Traffic reduction	192
8.1.6	Traffic expediting	192
8.1.7	Conversion of frame formats	192
8.2	Bridge architecture.....	193
8.3	Model of operation.....	195
8.4	Active topologies, learning, and forwarding	199
8.5	Bridge Port Transmit and Receive.....	200
8.5.1	Bridge Port connectivity	200
8.5.2	TPMR Port connectivity	201
8.5.3	Support of Higher Layer Entities	202
8.6	The Forwarding Process	202
8.6.1	Active topology enforcement	203
8.6.2	Ingress filtering	205
8.6.3	Frame filtering	205
8.6.4	Egress filtering	208
8.6.5	Flow classification and metering	208
8.6.6	Queuing frames	217
8.6.7	Queue management	218
8.6.8	Transmission selection	219
8.6.9	Scheduled traffic state machines	225
8.6.10	Stream gate control state machines	232
8.6.11	ATS Scheduler state machines	234
8.7	The Learning Process.....	238
8.7.1	Default filtering utility criteria	238
8.7.2	Enhanced filtering utility criteria	238
8.7.3	Ageing of Dynamic Filtering Entries	239
8.8	The Filtering Database (FDB)	239
8.8.1	Static Filtering Entries	242
8.8.2	Static VLAN Registration Entries	243
8.8.3	Dynamic Filtering Entries	244
8.8.4	MAC Address Registration Entries	245
8.8.5	Dynamic VLAN Registration Entries	245
8.8.6	Default Group filtering behavior	246
8.8.7	Dynamic Reservation Entries	247
8.8.8	Allocation of VIDs to FIDs	247
8.8.9	Querying the FDB	248
8.8.10	Determination of the member set for a VID	252
8.8.11	Permanent Database	252
8.8.12	Connection_Identifier	252
8.9	MST, SPB, and ESP configuration information.....	253
8.9.1	MST Configuration Table	254
8.9.2	MST configuration identification	254
8.9.3	FID to MSTI Allocation Table	254
8.9.4	SPT Configuration Identification	254
8.10	Spanning Tree Protocol Entity.....	255
8.11	MRP entities	255
8.12	Bridge Management Entity.....	256

8.13	Addressing	256
8.13.1	End stations	256
8.13.2	Bridge Ports	256
8.13.3	Use of LLC by Spanning Tree Protocol Entities	257
8.13.4	Reserved MAC addresses	257
8.13.5	Group MAC addresses for spanning tree entity	257
8.13.6	Group MAC addresses for MRP Applications	259
8.13.7	Bridge Management Entities	260
8.13.8	Unique identification of a Bridge	260
8.13.9	Points of attachment and connectivity for Higher Layer Entities	260
8.13.10	VLAN attachment and connectivity for Higher Layer Entities	264
8.13.11	CFM entities	265
9.	Tagged frame format	267
9.1	Purpose of tagging	267
9.2	Representation and encoding of tag fields	267
9.3	Tag format.....	268
9.4	TPID formats	268
9.5	Tag Protocol identification	268
9.6	VLAN Tag Control Information (TCI).....	269
9.7	Backbone Service Instance Tag Control Information (I-TAG TCI).....	270
10.	Multiple Registration Protocol (MRP) and Multiple MAC Registration Protocol (MMRP)	272
10.1	MRP overview	272
10.2	MRP architecture	275
10.3	MRP Attribute Propagation (MAP).....	276
10.3.1	MAP Context	277
10.4	Requirements to be met by MRP	278
10.5	Requirements for interoperability between MRP Participants	278
10.6	Protocol operation.....	280
10.7	Protocol specification	284
10.7.1	Notational conventions and abbreviations	285
10.7.2	Registrar Administrative Controls	286
10.7.3	Applicant Administrative Controls	287
10.7.4	Protocol timers	287
10.7.5	Protocol event definitions	288
10.7.6	Protocol Action definitions	290
10.7.7	Applicant state machine	292
10.7.8	Registrar state machine	292
10.7.9	LeaveAll state machine	292
10.7.10	PeriodicTransmission state machine	295
10.7.11	Timer values	295
10.7.12	Operational reporting and statistics	296
10.7.13	Interoperability considerations	296
10.7.14	External control	297
10.8	Structure and encoding of Multiple Registration Protocol Data Units (MRPDUs)	297
10.8.1	Structure	297
10.8.2	Encoding of MRPDUs parameters	299
10.8.3	Packing and parsing MRPDUs	302
10.9	Multiple MAC Registration Protocol (MMRP)—Purpose	304

10.10	MMRP Model of operation.....	305
10.10.1	Propagation of Group Membership information	306
10.10.2	Propagation of Group service requirement information	307
10.10.3	Source pruning	307
10.10.4	Use of Group service requirement registration by end stations	307
10.11	Default Group filtering behavior and MMRP propagation	307
10.12	Definition of the MMRP application	309
10.12.1	Definition of MRP elements	309
10.12.2	Provision and support of Extended Filtering Services	311
10.12.3	Use of “new” declaration capability	313
10.12.4	Attribute value support requirements	313
10.12.5	Registrar Administrative Controls	313
11.	VLAN topology management.....	314
11.1	Static and dynamic VLAN configuration	314
11.2	Multiple VLAN Registration Protocol (MVRP)	315
11.2.1	MVRP overview	315
11.2.2	VLAN registration service definition	317
11.2.3	Definition of the MVRP application	318
11.2.4	VID translation table	321
11.2.5	Use of “new” declaration capability	321
11.2.6	New-Only Participant and Registrar Administrative Controls	321
11.2.7	Attribute value support requirements	321
12.	Bridge management	322
12.1	Management functions.....	322
12.1.1	Configuration Management	322
12.1.2	Fault Management	323
12.1.3	Performance Management	323
12.1.4	Security Management	323
12.1.5	Accounting Management	323
12.2	VLAN Bridge objects	323
12.3	Data types	324
12.4	Bridge Management Entity	325
12.4.1	Bridge Configuration	325
12.4.2	Port configuration	328
12.5	MAC entities.....	330
12.5.1	ISS Port Number table managed object (optional)	330
12.6	Forwarding process.....	331
12.6.1	The Port Counters	331
12.6.2	Priority handling	332
12.6.3	Traffic Class Table	339
12.7	Filtering Database (FDB).....	340
12.7.1	The Filtering Database object	340
12.7.2	A Static Filtering Entry object	341
12.7.3	A Dynamic Filtering Entry object	341
12.7.4	A MAC Address Registration Entry object	342
12.7.5	A VLAN Registration Entry object	342
12.7.6	Permanent Database object	342
12.7.7	General FDB operations	343
12.8	Bridge Protocol Entity	345
12.8.1	The Protocol Entity	345
12.8.2	Bridge Port	348

12.9	MRP Entities.....	352
12.9.1	The MRP Timer object	352
12.9.2	The MRP Attribute Type object	353
12.9.3	Periodic state machine objects	354
12.10	Bridge VLAN managed objects.....	354
12.10.1	Bridge VLAN Configuration managed object	355
12.10.2	VLAN Configuration managed object	360
12.10.3	The VID to FID allocation managed object	361
12.11	MMRP entities	363
12.11.1	MMRP Configuration managed object	363
12.12	MST configuration entities	365
12.12.1	The MSTI List	365
12.12.2	The FID to MSTID Allocation Table	366
12.12.3	The MST Configuration Table	367
12.13	Provider Bridge management	369
12.13.1	Provider Bridge Port Type managed object	370
12.13.2	Customer Edge Port Configuration managed object	371
12.13.3	Remote Customer Access managed object	374
12.14	CFM entities	376
12.14.1	Maintenance Domain list managed object	376
12.14.2	CFM Stack managed object	378
12.14.3	Default MD Level managed object	379
12.14.4	Configuration Error List managed object	380
12.14.5	Maintenance Domain managed object	381
12.14.6	Maintenance Association managed object	383
12.14.7	Maintenance association Endpoint managed object	386
12.15	Backbone Core Bridge (BCB) management.....	393
12.16	Backbone Edge Bridge (BEB) management	393
12.16.1	BEB configuration managed object	395
12.16.2	BEB/PB/VLAN Bridge Port configuration managed object	399
12.16.3	VIP configuration managed object	399
12.16.4	PIP configuration managed object	400
12.16.5	CBP Configuration managed object	407
12.17	DDCFM entities.....	410
12.17.1	DDCFM Stack managed object	410
12.17.2	Reflection Responder managed object	410
12.17.3	RFM Receiver managed object	414
12.17.4	Decapsulator Responder managed object	415
12.17.5	SFM Originator managed object	417
12.18	PBB-TE Protection Switching managed objects	420
12.18.1	TE protection group list managed object	420
12.18.2	TE protection group managed object	421
12.19	TPMR managed objects.....	423
12.19.1	TPMR management entity	424
12.19.2	MAC and PHY entities	426
12.19.3	Forwarding Process	426
12.19.4	MAC Status Propagation Entity (MSPE)	431
12.20	Management entities for FQTSS	433
12.20.1	The Bandwidth Availability Parameter Table	433
12.20.2	The Transmission Selection Algorithm Table	434
12.20.3	The Priority Regeneration Override Table	434
12.20.4	SR Class to Priority Mapping Table	434

12.21	Congestion Notification managed objects	435
12.21.1	CN component managed object	435
12.21.2	CN component priority managed object	435
12.21.3	CN Port priority managed object	437
12.21.4	Congestion Point managed object	438
12.21.5	Reaction Point port priority managed object	438
12.21.6	Reaction Point group managed object	439
12.22	Stream Reservation Protocol (SRP) entities	439
12.22.1	SRP Bridge Base Table	440
12.22.2	SRP Bridge Port Table	440
12.22.3	SRP Latency Parameter Table	441
12.22.4	SRP Stream Table	441
12.22.5	SRP Reservations Table	441
12.22.6	SRP Stream Preload Table	442
12.22.7	SRP Reservations Preload Table	442
12.23	Priority-based Flow Control objects	444
12.24	1:1 PBB-TE IPS managed objects	444
12.24.1	IPG list managed object	444
12.24.2	IPG managed object	446
12.25	Shortest Path Bridging managed objects	448
12.25.1	The SPB System managed object	449
12.25.2	The SPB MTID Static managed object	451
12.25.3	The SPB Topology Instance Dynamic managed object	453
12.25.4	The SPB ECT Static Entry managed object	453
12.25.5	The SPB ECT Dynamic Entry managed object	455
12.25.6	The SPB Adjacency Static Entry managed object	456
12.25.7	The SPB Adjacency Dynamic Entry managed object	457
12.25.8	The SPBM BSI Static Entry managed object	457
12.25.9	The SPB Topology Node Table managed object	459
12.25.10	The SPB Topology ECT Table managed object	460
12.25.11	The SPB Topology Edge Table managed object	460
12.25.12	The SPBM Topology Service Table managed object	461
12.25.13	The SPBV Topology Service Table managed object	462
12.25.14	The ECMP ECT Static Entry managed object	463
12.26	Edge Virtual Bridging (EVB) management.....	464
12.26.1	EVB system base table	467
12.26.2	SBP table entry	469
12.26.3	VSI table entry	470
12.26.4	S-channel configuration and management	471
12.26.5	ER management	473
12.27	Edge Control Protocol (ECP) management.....	474
12.27.1	ECP table entry	474
12.28	Path Control and Reservation (PCR) management.....	475
12.28.1	The PCR ECT Static Entry managed object	476
12.28.2	The PCR Topology ECT Table managed object	478
12.29	Managed objects for scheduled traffic.....	479
12.29.1	The Gate Parameter Table	479
12.29.2	Timing points for scheduled traffic	481
12.30	Managed objects for frame preemption.....	482
12.30.1	Frame Preemption Parameter table	482

12.31	Managed objects for per-stream classification and metering	484
12.31.1	The Stream Parameter Table	484
12.31.2	The Stream Filter Instance Table	485
12.31.3	The Stream Gate Instance Table	487
12.31.4	The Flow Meter Instance Table	490
12.31.5	The Scheduler Instance Table	490
12.31.6	The Scheduler Group Instance Table	491
12.31.7	The Scheduler Port Parameter Table	492
12.31.8	The Scheduler Timing Characteristics Table	492
12.32	Stream reservation remote management.....	494
12.32.1	Bridge Delay	494
12.32.2	Propagation Delay	496
12.32.3	Static Trees	496
12.32.4	MRP External Control	497
13.	Spanning tree protocols	501
13.1	Protocol design requirements.....	502
13.2	Protocol support requirements	503
13.2.1	MSTP support requirements	503
13.2.2	SPB support requirements	503
13.3	Protocol design goals	504
13.4	RSTP overview	504
13.4.1	Computation of the active topology	505
13.4.2	Example topologies	506
13.5	MSTP overview	509
13.5.1	Example topologies	510
13.5.2	Relationship of MSTP to RSTP	513
13.5.3	Modeling an MST or SPT Region as a single Bridge	513
13.6	SPB overview	514
13.7	Compatibility and interoperability	515
13.7.1	Designated Port selection	515
13.7.2	Force Protocol Version	515
13.8	MST Configuration Identifier (MCID).....	516
13.9	Spanning tree priority vectors.....	517
13.10	CIST Priority Vector calculations.....	519
13.11	MST Priority Vector calculations	521
13.12	Port Role assignments.....	523
13.13	Stable connectivity.....	524
13.14	Communicating spanning tree information	525
13.15	Changing spanning tree information.....	526
13.16	Changing Port States with RSTP or MSTP.....	527
13.16.1	Subtree connectivity and priority vectors	528
13.16.2	Root Port transition to Forwarding	528
13.16.3	Designated Port transition to Forwarding	528
13.16.4	Master Port transition to Forwarding	530
13.17	Changing Port States with SPB	532
13.17.1	Agreement Digest	534
13.18	Managing spanning tree topologies	535
13.19	Updating learned station location information	536
13.20	Managing reconfiguration.....	538
13.21	Partial and disputed connectivity	539
13.22	In-service upgrades	539
13.23	Fragile Bridges.....	541

13.24	Spanning tree protocol state machines.....	541
13.25	State machine timers.....	543
13.25.1	edgeDelayWhile	544
13.25.2	fdWhile	544
13.25.3	helloWhen	544
13.25.4	mdelayWhile	544
13.25.5	rbWhile	544
13.25.6	rcvdInfoWhile	544
13.25.7	rrWhile	545
13.25.8	tcDetected	545
13.25.9	tcWhile	545
13.25.10	pseudoInfoHelloWhen	545
13.26	Per Bridge variables.....	545
13.26.1	agreementDigest	546
13.26.2	BridgeIdentifier	546
13.26.3	BridgePriority	546
13.26.4	BridgeTimes	546
13.26.5	ForceProtocolVersion	547
13.26.6	MigrateTime	547
13.26.7	MstConfigId	547
13.26.8	AuxMstConfigId	547
13.26.9	rootPortId	547
13.26.10	rootPriority	547
13.26.11	rootTimes	547
13.26.12	TxHoldCount	547

13.27	Per port variables	547
13.27.1	AdminEdge	550
13.27.2	ageingTime	550
13.27.3	agree	550
13.27.4	agreed	550
13.27.5	agreedAbove	550
13.27.6	agreedDigest	550
13.27.7	agreedDigestValid	550
13.27.8	agreeDigest	550
13.27.9	agreeDigestValid	550
13.27.10	agreedMisorder	551
13.27.11	agreedN	551
13.27.12	agreedND	551
13.27.13	agreedPriority	551
13.27.14	agreedTopology	551
13.27.15	agreementOutstanding	551
13.27.16	agreeN	551
13.27.17	agreeND	551
13.27.18	AutoEdge	551
13.27.19	AutoIsolate	552
13.27.20	designatedPriority	552
13.27.21	designatedTimes	552
13.27.22	disputed	552
13.27.23	enableBPDUrx	552
13.27.24	enableBPDUtx	552
13.27.25	ExternalPortPathCost	552
13.27.26	isL2gp	552
13.27.27	isolate	553
13.27.28	fdbFlush	553
13.27.29	forward	553
13.27.30	forwarding	553
13.27.31	infoInternal	553
13.27.32	infoIs	553
13.27.33	InternalPortPathCost	553
13.27.34	learn	554
13.27.35	learning	554
13.27.36	master	554
13.27.37	mastered	554
13.27.38	mcheck	554
13.27.39	msgPriority	554
13.27.40	msgTimes	554
13.27.41	neighbourPriority	555
13.27.42	newInfo	555
13.27.43	newInfoMsti	555
13.27.44	operEdge	555
13.27.45	portEnabled	555
13.27.46	portId	555
13.27.47	portPriority	555
13.27.48	portTimes	556
13.27.49	proposed	556
13.27.50	proposing	556
13.27.51	pseudoRootId	556
13.27.52	rcvdBPDU	556
13.27.53	rcvdInfo	556

13.27.54	rcvdInternal	556
13.27.55	rcvdMsg	556
13.27.56	rcvdRSTP	556
13.27.57	rcvdSTP	556
13.27.58	rcvdTc	556
13.27.59	rcvdTcAck	556
13.27.60	rcvdTen	557
13.27.61	reRoot	557
13.27.62	reselect	557
13.27.63	restrictedDomainRole	557
13.27.64	restrictedRole	557
13.27.65	restrictedTen	557
13.27.66	role	557
13.27.67	selected	557
13.27.68	selectedRole	557
13.27.69	sendRSTP	558
13.27.70	sync	558
13.27.71	synced	558
13.27.72	tcAck	558
13.27.73	tcProp	558
13.27.74	tick	558
13.27.75	txCount	558
13.27.76	updtInfo	558
13.28	State machine conditions and parameters	558
13.28.1	allSptAgree	559
13.28.2	allSynced	559
13.28.3	allTransmitReady	559
13.28.4	BestAgreementPriority	559
13.28.5	cist	559
13.28.6	cistRootPort	559
13.28.7	cistDesignatedPort	560
13.28.8	EdgeDelay	560
13.28.9	forwardDelay	560
13.28.10	FwdDelay	560
13.28.11	HelloTime	560
13.28.12	MaxAge	560
13.28.13	msti	560
13.28.14	mstiDesignatedOrTCpropagatingRootPort	560
13.28.15	mstiMasterPort	560
13.28.16	operPointToPoint	560
13.28.17	rcvdAnyMsg	560
13.28.18	rcvdCistMsg	560
13.28.19	rcvdMstiMsg	561
13.28.20	reRooted	561
13.28.21	rstpVersion	561
13.28.22	spt	561
13.28.23	stpVersion	561
13.28.24	updtCistInfo	561
13.28.25	updtMstiInfo	561

13.29	State machine procedures	561
13.29.1	betterorsameInfo(newInfoIs)	562
13.29.2	clearAllRcvdMsgs()	562
13.29.3	clearReselectTree()	562
13.29.4	disableForwarding()	563
13.29.5	disableLearning()	563
13.29.6	enableForwarding()	563
13.29.7	enableLearning()	563
13.29.8	fromSameRegion()	563
13.29.9	newTcDetected()	563
13.29.10	newTcWhile()	563
13.29.11	pseudoRcvMsgs()	564
13.29.12	rcvInfo()	564
13.29.13	rcvMsgs()	565
13.29.14	rcvAgreements()	565
13.29.15	recordAgreement()	565
13.29.16	recordDispute()	566
13.29.17	recordMastered()	566
13.29.18	recordPriority()	566
13.29.19	recordProposal()	566
13.29.20	recordTimes()	566
13.29.21	setReRootTree()	567
13.29.22	setSelectedTree()	567
13.29.23	setSyncTree()	567
13.29.24	setTcFlags()	567
13.29.25	setTcPropTree()	567
13.29.26	syncMaster()	567
13.29.27	txConfig()	567
13.29.28	txRstp()	568
13.29.29	txTcn()	568
13.29.30	updtAgreement()	568
13.29.31	updtBPDUVersion()	569
13.29.32	updtDigest()	569
13.29.33	updtRcvdInfoWhile()	570
13.29.34	updtRolesTree()	571
13.29.35	uptRolesDisabledTree()	572
13.30	The Port Timers state machine	572
13.31	Port Receive state machine	573
13.32	Port Protocol Migration state machine	574
13.33	Bridge Detection state machine	574
13.34	Port Transmit state machine	575
13.35	Port Information state machine.....	576
13.36	Port Role Selection state machine	577
13.37	Port Role Transitions state machine	577
13.38	Port State Transition state machine	582
13.38.1	Port State transitions for the CIST and MSTIs	583
13.38.2	Port State transitions for SPTs	583
13.39	Topology Change state machine.....	584
13.40	Layer 2 Gateway Port Receive state machine	585

13.41	CEP spanning tree operation.....	585
13.41.1	PEP operPointToPointMAC and operEdge	585
13.41.2	updtRolesTree()	586
13.41.3	setReRootTree(), setSyncTree(), setTePropTree()	586
13.41.4	allSynced, reRooted	586
13.41.5	Configuration parameters	586
13.42	Virtual Instance Port (VIP) spanning tree operation	587
14.	Encoding of Bridge Protocol Data Units (BPDUs)	588
14.1	BPDU Structure	588
14.1.1	Transmission and representation of octets	588
14.1.2	Common BPDU fields	588
14.2	Encoding of parameter types	590
14.2.1	Encoding of Protocol Identifiers	590
14.2.2	Encoding of Protocol Version Identifiers	590
14.2.3	Encoding of BPDU types	590
14.2.4	Encoding of flags	590
14.2.5	Encoding of Bridge Identifiers	590
14.2.6	Encoding of External Root Path Cost and Internal Root Path Cost	591
14.2.7	Encoding of Port Identifiers	591
14.2.8	Encoding of Timer Values	591
14.2.9	Encoding of Port Role values	591
14.2.10	Encoding of Length Values	592
14.2.11	Encoding of Hop Counts	592
14.3	Transmission of BPDUs	592
14.4	Encoding and decoding of STP Configuration, RST, MST, and SPT BPDUs.....	592
14.4.1	MSTI Configuration Messages	594
14.5	Validation of received BPDUs	595
14.6	Validation and interoperability	596
15.	Support of the MAC Service by PBNs	597
15.1	Service transparency	597
15.2	Customer service interfaces	598
15.3	Port-based service interface	598
15.4	C-tagged service interface	599
15.5	S-tagged service interface	600
15.6	Remote customer service interfaces (RCSIs)	601
15.7	Service instance segregation	604
15.8	Service instance selection and identification	604
15.9	Service priority selection	605
15.10	Service access protection	605
16.	Principles of Provider Bridged Network (PBN) operation	606
16.1	PBN overview	606
16.2	Provider Bridged Network (PBN)	607
16.3	Service instance connectivity.....	610
16.4	Service provider learning of customer end station addresses	611
16.5	Detection of connectivity loops through attached networks.....	611
16.6	Network management	612
17.	Management Information Base (MIB)	613
17.1	Internet Standard Management Framework	613

17.2	Structure of the MIB	613
17.2.1	Structure of the IEEE8021-TC-MIB	615
17.2.2	Structure of the IEEE8021-BRIDGE-MIB	616
17.2.3	Structure of the IEEE8021-SPANNING-TREE MIB	620
17.2.4	Structure of the IEEE8021-Q-BRIDGE-MIB	623
17.2.5	Structure of the IEEE8021-PB-MIB	628
17.2.6	Structure of the IEEE8021-MSTP-MIB	630
17.2.7	Structure of the IEEE8021-CFM-MIB	633
17.2.8	Structure of the IEEE8021-PBB-MIB	639
17.2.9	Structure of the IEEE8021-DDCFM-MIBs	642
17.2.10	Structure of the IEEE8021-PBBTE-MIB	644
17.2.11	Structure of the TPMR MIB	647
17.2.12	Structure of the IEEE8021-FQTSS-MIB	649
17.2.13	Structure of the IEEE8021-CN-MIB	650
17.2.14	Structure of the IEEE8021-SRP-MIB	652
17.2.15	Structure of the IEEE8021-MVRPX-MIB	654
17.2.16	Structure of the IEEE8021-MIRP-MIB	654
17.2.17	Structure of the IEEE8021-PFC-MIB	655
17.2.18	Structure of the IEEE8021-TEIPS-MIB	655
17.2.19	Structure of the IEEE8021-SPB-MIB	657
17.2.20	Structure of the IEEE8021-EVB-MIB	662
17.2.21	Structure of the IEEE8021-ECMP-MIB	666
17.2.22	Structure of the IEEE8021-ST-MIB	667
17.2.23	Structure of the IEEE8021-Preemption-MIB	668
17.2.24	Structure of the IEEE8021-PSFP-MIB	668
17.2.25	Structure of the IEEE8021-TSN-REMOTE-MANAGEMENT-MIB	671
17.3	MIB module relationships	673
17.3.1	Relationship of the IEEE8021-TC-MIB to other MIB modules	673
17.3.2	Relationship of the IEEE8021-BRIDGE-MIB to other MIB modules	673
17.3.3	Relationship of the IEEE8021-RSTP MIB to other MIB modules	676
17.3.4	Relationship of the IEEE8021-Q-BRIDGE-MIB to other MIB modules	676
17.3.5	Relationship of the IEEE8021-PB-BRIDGE MIB to other MIB modules	678
17.3.6	Relationship of the IEEE8021-MSTP-MIB to other MIB modules	678
17.3.7	Relationship of the IEEE8021-CFM-MIB to other MIB modules	678
17.3.8	Relationship of the IEEE8021-PBB-MIB to other MIB modules	679
17.3.9	Relationship of the IEEE8021-DDCFM to other MIB modules	680
17.3.10	Relationship of the IEEE8021-PBBTE-MIB to other MIB modules	680
17.3.11	Relationship of the IEEE8021-TPMR MIB to other MIB modules	681
17.3.12	Relationship of the IEEE8021-FQTSS-MIB to other MIB modules	681
17.3.13	Relationship of the IEEE8021-CN-MIB to other MIB modules	681
17.3.14	Relationship of the IEEE8021-SRP-MIB to other MIB modules	682
17.3.15	Relationship of the IEEE8021-MVRPX-MIB to other MIB modules	682
17.3.16	Relationship of the IEEE8021-MIRP-MIB to other MIB modules	682
17.3.17	Relationship of the IEEE8021-PFC-MIB to other MIB modules	682
17.3.18	Relationship of the IEEE8021-TEIPS-MIB to other MIB modules	683
17.3.19	Relationship of the IEEE8021-SPB-MIB to other MIB modules	683
17.3.20	Relationship of the IEEE8021-EVB-MIB to other MIB modules	683
17.3.21	Relationship of the IEEE8021-ECMP-MIB to other MIB modules	683
17.3.22	Relationship of the IEEE8021-ST-MIB to other MIB modules	683
17.3.23	Relationship of the IEEE8021-Preemption-MIB to other MIB modules	684
17.3.24	Relationship of IEEE8021-PSFP-MIB to other MIB modules	684
17.3.25	Relationship of IEEE8021-TSN-REMOTE-MANAGEMENT-MIB to other MIB modules	684

17.4	Security considerations	684
17.4.1	Security considerations of the IEEE8021-TC-MIB	684
17.4.2	Security considerations of the IEEE8021-BRIDGE-MIB	685
17.4.3	Security considerations of the IEEE8021-SPANNING-TREE MIB	686
17.4.4	Security considerations of the IEEE8021-Q-BRIDGE-MIB	686
17.4.5	Security considerations of the IEEE8021-PB-MIB	687
17.4.6	Security considerations of the IEEE8021-MSTP-MIB	687
17.4.7	Security considerations of the IEEE8021-CFM-MIB	688
17.4.8	Security considerations of the IEEE8021-PBB-MIB	690
17.4.9	Security considerations of the IEEE8021-DDCFM-MIB	691
17.4.10	Security considerations of the IEEE8021-PBBTE-MIB	691
17.4.11	Security considerations of the IEEE8021-TPMR-MIB	692
17.4.12	Security considerations of the IEEE8021-FQTSS-MIB	692
17.4.13	Security considerations of the IEEE8021-CN-MIB	693
17.4.14	Security considerations of the IEEE8021-SRP-MIB	695
17.4.15	Security considerations of the IEEE8021-MVRPX-MIB	695
17.4.16	Security considerations of the IEEE8021-MIRP-MIB	696
17.4.17	Security considerations of the IEEE8021-PFC-MIB	696
17.4.18	Security considerations of the IEEE8021-TEIPS-MIB	696
17.4.19	Security considerations of the IEEE8021-SPB-MIB	697
17.4.20	Security considerations of the IEEE8021-EVB-MIB	697
17.4.21	Security considerations of the IEEE8021-ECMP-MIB	699
17.4.22	Security considerations of the IEEE8021-ST-MIB	699
17.4.23	Security considerations of the IEEE8021-Preemption-MIB	700
17.4.24	Security considerations of the IEEE8021-PSFP-MIB	700
17.4.25	Security considerations of the IEEE8021-TSN-REMOTE-MANAGEMENT-MIB 702	
17.5	Dynamic component and Port creation.....	703
17.5.1	Overview of the dynamically created Bridge entities	703
17.5.2	Component creation	704
17.5.3	Port creation	705
17.6	MIB operations for service interface configuration.....	715
17.6.1	Provisioning PBN service interfaces	715
17.6.2	Provisioning Backbone Bridged Network service interfaces	718

17.7	MIB modules	724
17.7.1	Definitions for the IEEE8021-TC-MIB module	724
17.7.2	Definitions for the IEEE8021-BRIDGE-MIB module	733
17.7.3	Definitions for the IEEE8021-SPANNING-TREE-MIB module	766
17.7.4	Definitions for the IEEE8021-Q-BRIDGE-MIB module	781
17.7.5	Definitions for the IEEE8021-PB-MIB module	819
17.7.6	Definitions for the IEEE8021-MSTP-MIB module	834
17.7.7	Definitions for the CFM MIB modules	858
17.7.8	Definitions for the IEEE8021-PBB-MIB module	926
17.7.9	Definitions for the IEEE8021-DDCFM-MIB module	945
17.7.10	Definitions for the IEEE8021-PBBTE-MIB module	960
17.7.11	Definitions for the IEEE8021-TPMR-MIB module	974
17.7.12	Definitions for the IEEE8021-FQTSS-MIB module	986
17.7.13	Definitions for the IEEE8021-CN-MIB module	998
17.7.14	Definitions for the IEEE8021-SRP-MIB module	1028
17.7.15	Definitions for the IEEE8021-MVRPX-MIB module	1046
17.7.16	Definitions for the IEEE8021-MIRP-MIB module	1050
17.7.17	Definitions for the IEEE8021-PFC-MIB module	1055
17.7.18	Definitions for the IEEE8021-TEIPS-V2-MIB module	1058
17.7.19	Definitions for the IEEE8021-SPB-MIB module	1070
17.7.20	Definitions for the IEEE8021-EVB-MIB module	1106
17.7.21	Definitions for the IEEE8021-ECMP-MIB module	1130
17.7.22	Definitions for the IEEE8021-ST-MIB module	1137
17.7.23	Definitions for the IEEE8021-Preemption-MIB module	1148
17.7.24	Definitions for the IEEE8021-PSFP-MIB module	1153
17.7.25	Definitions for the IEEE8021-TSN-REMOTE-MANAGEMENT-MIB module	1173
18.	Principles of Connectivity Fault Management operation	1182
18.1	Maintenance Domains and DoSAPs.....	1183
18.2	Service instances and MAs	1185
18.3	Maintenance Domain Levels	1186
19.	CFM entity operation.....	1190
19.1	Maintenance Points (MPs).....	1190

19.2	MA Endpoints (MEPs)	1190
19.2.1	MEP identification	1190
19.2.2	MEP functions	1192
19.2.3	MEP architecture	1192
19.2.4	MP Type Demultiplexer	1194
19.2.5	MP Multiplexer	1194
19.2.6	MP Level Demultiplexer	1194
19.2.7	MP OpCode Demultiplexer	1194
19.2.8	MEP Continuity Check Receiver	1194
19.2.9	MEP Continuity Check Initiator	1195
19.2.10	MP Loopback Responder	1195
19.2.11	MEP Loopback Initiator	1196
19.2.12	MEP Linktrace Initiator	1196
19.2.13	MEP LTI SAP	1196
19.2.14	MEP Linktrace SAP	1196
19.2.15	MEP CCM Database	1196
19.2.16	MEP Fault Notification Generator	1196
19.2.17	MEP Decapsulator Responder (DR)	1196
19.2.18	MEP RFM Receiver	1197
19.3	MIP Half Function	1197
19.3.1	MHF identification	1197
19.3.2	MHF functions	1197
19.3.3	MHF architecture	1198
19.3.4	MHF Level Demultiplexer	1198
19.3.5	MHF Type Demultiplexer	1199
19.3.6	MHF OpCode Demultiplexer	1199
19.3.7	MHF Multiplexer	1199
19.3.8	MHF Loopback Responder	1199
19.3.9	MHF Continuity Check Receiver	1199
19.3.10	MIP CCM Database	1199
19.3.11	MHF Linktrace SAP	1199
19.3.12	MHF DR	1199
19.3.13	MHF RFM Receiver	1199
19.4	MP addressing.....	1200
19.5	Linktrace Output Multiplexer (LOM).....	1200
19.6	Linktrace Responder	1201
20.	CFM protocols	1203
20.1	Continuity Check protocol.....	1204
20.1.1	MAC status reporting in the CCM	1206
20.1.2	Defects and Fault Alarms	1206
20.1.3	CCM reception	1206
20.2	Loopback protocol	1207
20.2.1	LBM transmission	1207
20.2.2	LBM reception and LBR transmission	1208
20.2.3	LBR reception	1209
20.3	Linktrace protocol.....	1209
20.3.1	LTM origination	1210
20.3.2	LTM reception, forwarding, and replying	1211
20.3.3	LTR reception	1212
20.4	CFM state machines.....	1213

20.5	CFM state machine timers	1213
20.5.1	LTFwhile	1213
20.5.2	CCIwhile	1213
20.5.3	errorCCMwhile	1214
20.5.4	xconCCMwhile	1215
20.5.5	LBIwhile	1215
20.5.6	FNGwhile	1215
20.5.7	mmCCMwhile	1215
20.5.8	mmLocwhile	1215
20.5.9	mmFNGwhile	1215
20.5.10	rMEPwhile	1215
20.6	CFM procedures	1215
20.6.1	CCMtime()	1215
20.7	Maintenance Domain variable	1216
20.7.1	mdLevel	1216
20.8	MA variables.....	1216
20.8.1	CCMinterval	1216
20.9	MEP variables.....	1216
20.9.1	MEPactive	1217
20.9.2	enableRmepDefect	1217
20.9.3	MAdefectIndication	1217
20.9.4	allRMEPsDead	1218
20.9.5	lowestAlarmPri	1218
20.9.6	presentRDI	1218
20.9.7	MEPprimaryVID	1218
20.9.8	presentTraffic	1218
20.9.9	presentmmLoc	1218
20.9.10	ISpresentTraffic	1218
20.9.11	ISpresentmmLoc	1218
20.9.12	EpMEP	1219
20.10	MEP Continuity Check Initiator variables.....	1219
20.10.1	CCIenabled	1219
20.10.2	CCIsentCCMs	1219
20.10.3	MACstatusChanged	1219
20.10.4	Npaths	1219
20.10.5	flowHash[]	1219
20.10.6	pathN	1219
20.10.7	CCMcnt	1220
20.11	MEP Continuity Check Initiator procedures	1220
20.11.1	xmitCCM()	1220
20.12	MEP Continuity Check Initiator state machine	1221
20.13	MHF Continuity Check Receiver variables.....	1221
20.13.1	MHFrecvvCCM	1221
20.13.2	MHFCCMPDU	1221
20.14	MHF Continuity Check Receiver procedures.....	1222
20.14.1	MHFprocessCCM()	1222
20.15	MHF Continuity Check Receiver state machine	1222

20.16	MEP Continuity Check Receiver variables	1222
20.16.1	CCMreceivedEqual	1223
20.16.2	CCMequalPDU	1223
20.16.3	CCMreceivedLow	1223
20.16.4	CCMlowPDU	1223
20.16.5	recvdMacAddress	1223
20.16.6	recvdRDI	1223
20.16.7	recvdInterval	1223
20.16.8	recvdPortState	1223
20.16.9	recvdInterfaceStatus	1223
20.16.10	recvdSenderId	1224
20.16.11	recvdFrame	1224
20.16.12	CCMsequenceErrors	1224
20.16.13	rcvdTrafficBit	1224
20.17	MEP Continuity Check Receiver procedures	1224
20.17.1	MEPprocessEqualCCM()	1224
20.17.2	MEPprocessLowCCM()	1225
20.18	MEP Continuity Check Receiver state machine.....	1225
20.19	Remote MEP variables	1225
20.19.1	rMEPCCMdefect	1226
20.19.2	rMEPlastRDI and rMEPlastRDI[i]	1226
20.19.3	rMEPlastPortState	1226
20.19.4	rMEPlastInterfaceStatus	1226
20.19.5	rMEPlastSenderId	1227
20.19.6	rCCMreceived	1227
20.19.7	rMEPmacAddress	1227
20.19.8	rMEPportStatusDefect	1227
20.19.9	rMEPinterfaceStatusDefect	1227
20.19.10	lastPathN	1227
20.20	Remote MEP state machine.....	1227
20.21	Remote MEP Error variables.....	1227
20.21.1	errorCCMreceived	1228
20.21.2	errorCCMlastFailure	1228
20.21.3	errorCCMdefect	1229
20.22	Remote MEP Error state machine	1229
20.23	MEP Cross Connect variables	1229
20.23.1	xconCCMreceived	1229
20.23.2	xconCCMlastFailure	1229
20.23.3	xconCCMdefect	1230
20.24	MEP Cross Connect state machine.....	1230
20.25	MEP Mismatch variables.....	1230
20.25.1	mmCCMreceived	1230
20.25.2	mmCCMdefect	1231
20.25.3	mmCCMTime	1231
20.25.4	disableLocdefect	1231
20.25.5	mmLocdefect	1231
20.26	MEP Mismatch state machines.....	1231
20.27	MP Loopback Responder variables	1231
20.27.1	LBMreceived	1231
20.27.2	LBMPDU	1232
20.28	MP Loopback Responder procedures	1233
20.28.1	ProcessLBM()	1233
20.28.2	xmitLBR()	1233
20.29	MP Loopback Responder state machine.....	1234

20.30	MEP Loopback Initiator variables	1234
20.30.1	LBMstosend	1235
20.30.2	nextLBMtransID	1235
20.30.3	expectedLBRtransID	1235
20.30.4	LBIactive	1235
20.30.5	xmitReady	1235
20.30.6	LBRreceived	1235
20.30.7	LBRPDU	1235
20.31	MEP Loopback Initiator transmit procedures	1235
20.31.1	xmitLBM()	1236
20.32	MEP Loopback Initiator transmit state machine	1236
20.33	MEP Loopback Initiator receive procedures	1236
20.33.1	ProcessLBR()	1237
20.34	MEP Loopback Initiator receive state machine	1238
20.35	MEP Fault Notification Generator variables	1238
20.35.1	fngPriority	1238
20.35.2	fngDefect	1238
20.35.3	fngAlarmTime	1238
20.35.4	fngResetTime	1239
20.35.5	someRMEPCCMdefect	1239
20.35.6	someMACstatusDefect	1239
20.35.7	someRDIdefect	1239
20.35.8	highestDefectPri	1239
20.35.9	highestDefect	1239
20.36	MEP Fault Notification Generator procedures	1239
20.36.1	xmitFaultAlarm()	1240
20.37	MEP Fault Notification Generator state machine	1240
20.38	MEP Mismatch Fault Notification Generator variables	1240
20.38.1	mfngAllowed	1241
20.38.2	mmdefectIndication	1241
20.38.3	mfngAlarmTime	1241
20.38.4	mfngResetTime	1241
20.39	MEP Mismatch Fault Notification Generator procedures	1241
20.39.1	xmitFaultAlarm()	1241
20.40	MEP Mismatch Fault Notification Generator state machine	1241
20.41	MEP Linktrace Initiator variables	1241
20.41.1	nextLTMtransID	1242
20.41.2	ltmReplyList	1242
20.42	MEP Linktrace Initiator procedures	1244
20.42.1	xmitLTM()	1244
20.43	MEP Linktrace Initiator receive variables	1245
20.43.1	LTRreceived	1245
20.43.2	LTRPDU	1245
20.44	MEP Linktrace Initiator receive procedures	1245
20.44.1	ProcessLTR()	1246
20.45	MEP Linktrace Initiator receive state machine	1246
20.46	Linktrace Responder variables	1246
20.46.1	nPendingLTRs	1246
20.46.2	LTMreceived	1247
20.46.3	LTMPDU	1247

20.47	LTM Receiver procedures	1247
20.47.1	ProcessLTM()	1247
20.47.2	clearPendingLTRs()	1251
20.47.3	ForwardLTM()	1251
20.47.4	enqueueLTR()	1252
20.48	LTM Receiver state machine	1254
20.49	LTR Transmitter procedure	1254
20.49.1	xmitOldestLTR()	1254
20.50	LTR Transmitter state machine	1254
20.51	CFM PDU validation and versioning	1254
20.51.1	Goals of CFM PDU versioning	1255
20.51.2	PDU transmission	1255
20.51.3	PDU validation	1256
20.51.4	Validation pass	1256
20.51.5	Execution pass	1257
20.51.6	Future extensions	1258
20.52	PDU identification	1258
20.53	Use of transaction IDs and sequence numbers	1258
21.	Encoding of CFM PDUs.....	1260
21.1	Structure, representation, and encoding.....	1260
21.2	CFM encapsulation	1260
21.3	CFM request and indication parameters	1261
21.3.1	destination_address parameter	1261
21.3.2	source_address parameter	1261
21.4	Common CFM Header.....	1261
21.4.1	MD Level	1261
21.4.2	Version	1261
21.4.3	OpCode	1262
21.4.4	Flags	1262
21.4.5	First TLV Offset	1263
21.5	TLV format	1263
21.5.1	General format for CFM TLVs	1263
21.5.2	Organization-Specific TLV	1263
21.5.3	Sender ID TLV	1265
21.5.4	Port Status TLV	1266
21.5.5	Interface Status TLV	1267
21.5.6	Data TLV	1268
21.5.7	End TLV	1268
21.6	CCM format.....	1268
21.6.1	Flags	1269
21.6.2	First TLV Offset	1270
21.6.3	Sequence Number	1270
21.6.4	Maintenance association Endpoint Identifier	1270
21.6.5	Maintenance Association Identifier	1270
21.6.6	Defined by ITU-T G.8013/Y.1731	1273
21.6.7	Optional CCM TLVs	1273
21.7	LBM and LBR formats.....	1273
21.7.1	Flags	1274
21.7.2	First TLV Offset	1274
21.7.3	Loopback Transaction Identifier	1274
21.7.4	Additional LBM/LBR TLVs	1274
21.7.5	PBB-TE MIP TLV	1274

21.8	LTM format	1275
21.8.1	Flags	1276
21.8.2	First TLV Offset	1276
21.8.3	LTM Transaction Identifier	1276
21.8.4	LTM TTL	1276
21.8.5	Original MAC Address	1276
21.8.6	Target MAC Address	1276
21.8.7	Additional LTM TLVs	1277
21.8.8	LTM Egress Identifier TLV	1277
21.9	LTR format	1277
21.9.1	Flags	1277
21.9.2	First TLV Offset	1278
21.9.3	LTR Transaction Identifier	1278
21.9.4	Reply TTL	1278
21.9.5	Relay Action	1279
21.9.6	Additional LTR TLVs	1279
21.9.7	LTR Egress Identifier TLV	1279
21.9.8	Reply Ingress TLV	1280
21.9.9	Reply Egress TLV	1281
22.	CFM in systems	1283
22.1	CFM shims in Bridges	1283
22.1.1	Preliminary positioning of MPs	1283
22.1.2	CFM and the Forwarding Process	1284
22.1.3	Up/Down separation of MPs	1286
22.1.4	Service instances over multiple Bridges	1288
22.1.5	Multiple VID service instances	1290
22.1.6	Untagged CFM PDUs	1290
22.1.7	MPs and non-VLAN-aware Bridges	1290
22.1.8	MPs and other standards	1291
22.1.9	CFM and IEEE 802.3 OAM	1293
22.2	Maintenance Entity creation	1293
22.2.1	Creating Maintenance Domains and MAs	1294
22.2.2	Creating MEPs	1294
22.2.3	Creating MIPs	1296
22.2.4	CFM configuration errors	1297
22.3	MPs, Ports, and MD Level assignment.....	1298
22.4	Stations and CFM	1298
22.5	Scalability of CFM.....	1299
22.6	CFM in Provider Bridges.....	1300
22.6.1	MPs and C-VLAN components	1300
22.6.2	Maintenance C-VLAN on a Port-based service interface	1300
22.6.3	Maintenance C-VLAN on a C-tagged service interface	1302
22.6.4	MPs and Port-mapping S-VLAN components	1302
22.7	Management Port MEPs and CFM in the enterprise environment.....	1304
22.8	Implementing CFM on Bridges that implement earlier revisions of IEEE Std 802.1Q	1306
23.	MAC status propagation	1307
23.1	Model of operation.....	1309
23.1.1	MAC Status Shim (MSS)	1310
23.1.2	Relationship of CFM to the MSS	1310
23.2	MAC Status Protocol (MSP) overview	1310
23.3	MSP state machines.....	1315

23.4	State machine timers	1316
23.4.1	linkNotifyWhen	1316
23.4.2	linkNotifyWhile	1316
23.4.3	macNotifyWhile	1316
23.4.4	macRecoverWhile	1316
23.5	MSP performance parameters	1316
23.5.1	LinkNotify	1317
23.5.2	LinkNotifyWait	1317
23.5.3	LinkNotifyRetry	1317
23.5.4	MACNotify	1317
23.5.5	MACNotifyTime	1317
23.5.6	MACRecoverTime	1317
23.6	State machine variables	1317
23.6.1	BEGIN	1317
23.6.2	addConfirmed	1317
23.6.3	disableMAC	1317
23.6.4	disabledMAC	1317
23.6.5	disableMSS	1317
23.6.6	lossConfirmed	1317
23.6.7	macOperational	1318
23.6.8	mssOperational	1318
23.6.9	prop	1318
23.6.10	rxAck	1318
23.6.11	rxAdd	1318
23.6.12	rxAddConfirm	1318
23.6.13	rxLoss	1318
23.6.14	rxLossConfirm	1318
23.6.15	txAck	1318
23.6.16	txAdd	1318
23.6.17	txAddConfirm	1318
23.6.18	txLoss	1318
23.6.19	txLossConfirm	1318
23.7	State machine procedures	1319
23.8	Status Transition state machine (STM)	1319
23.9	Status Notification state machine (SNM)	1319
23.10	Receive Process	1319
23.11	Transmit Process	1319
23.12	Management of MSP	1320
23.13	MSPDU transmission, addressing, and protocol identification	1321
23.13.1	Destination MAC Address	1321
23.13.2	Source MAC Address	1321
23.13.3	Priority	1321
23.13.4	EtherType use and encoding	1321
23.14	Representation and encoding of octets	1322
23.15	MSPDU structure	1322
23.15.1	Protocol Version	1322
23.15.2	Packet Type	1322
23.16	Validation of received MSPDUs	1323
23.17	Other MSP participants	1323
24.	Bridge performance	1324
24.1	Guaranteed Port Filtering Rate	1324
24.2	Guaranteed Bridge Relaying Rate	1324

24.3	RSTP performance requirements	1324
25.	Support of the MAC Service by PBBNs	1326
25.1	Service transparency	1328
25.2	Customer service interface.....	1328
25.3	Port-based service interface.....	1329
25.4	S-tagged service interface.....	1330
25.5	I-tagged service interface.....	1332
25.6	Service instance segregation.....	1334
25.7	Service instance selection and identification.....	1334
25.8	Service priority and drop eligibility selection.....	1334
25.9	Service access protection	1335
25.9.1	Class II redundant LANs access protection	1337
25.9.2	Class III simple redundant LANs and nodes access protection	1337
25.10	Support of the MAC Service by a PBB-TE Region	1338
25.10.1	Provisioning TESI.....	1339
25.10.2	ESP forwarding behavior	1341
25.11	Transparent service interface.....	1342
26.	Principles of Provider Backbone Bridged Network (PBBN) operation	1344
26.1	PBBN overview	1344
26.2	PBBN example	1345
26.3	B-VLAN connectivity.....	1347
26.4	Backbone addressing	1347
26.4.1	Learning individual backbone addresses at a PIP	1348
26.4.2	Translating backbone destination addresses at a CBP	1349
26.4.3	Backbone addressing considerations for CFM MPs	1349
26.5	Detection of connectivity loops through attached networks.....	1350
26.6	Scaling of PBBs	1350
26.6.1	Hierarchical PBBNs	1350
26.6.2	Peer PBBNs	1351
26.7	Network management.....	1351
26.8	CFM in PBBs.....	1351
26.8.1	CFM over Port-based and S-tagged service interfaces	1356
26.8.2	CFM over I-tagged Service Interfaces	1357
26.8.3	CFM over hierarchical E-NNI	1357
26.8.4	CFM over peer E-NNI	1358
26.9	CFM in a PBB-TE Region.....	1358
26.9.1	Addressing PBB-TE MEPs	1359
26.9.2	TESI identification	1359
26.9.3	PBB-TE MEP placement in a Bridge Port	1359
26.9.4	PBB-TE MIP placement in a Bridge Port	1360
26.9.5	TESI Maintenance Domains	1360
26.9.6	PBB-TE enhancements of the CFM protocols	1360
26.9.7	Addressing Infrastructure Segment MEPs	1362
26.9.8	Infrastructure Segment identification	1363
26.9.9	Infrastructure Segment MEP placement in a Bridge Port	1363
26.9.10	Infrastructure Segment Maintenance Domains	1365
26.9.11	IPS extensions to Continuity Check operation	1365
26.10	Protection switching for point-to-point TESI.....	1365
26.10.1	Introduction	1365
26.10.2	1:1 point-to-point TESI protection switching	1366
26.10.3	Protection Switching state machines	1369

26.11	IPS in PBB-TE Region	1375
26.11.1	Infrastructure Segment monitoring	1376
26.11.2	1:1 IPS	1376
26.11.3	IPS Control entity	1379
26.11.4	1:1 IPS state machines	1380
26.11.5	M:1 IPS	1381
26.12	Mismatch defect.....	1386
26.13	Signaling VLAN registrations among I-components	1387
27.	Shortest Path Bridging (SPB)	1388
27.1	Protocol design requirements.....	1390
27.2	Protocol support.....	1391
27.3	Protocol design goals	1392
27.4	ISIS-SPB VLAN configuration	1392
27.4.1	SPT Region and ISIS-SPB adjacency determination	1393
27.5	ISIS-SPB information	1395
27.6	Calculating CIST connectivity.....	1396
27.7	Connectivity between regions in the same domain	1397
27.8	Calculating SPT connectivity	1397
27.8.1	ISIS-SPB overload	1398
27.9	Loop prevention	1398
27.10	SPVID and SPSourceID allocation.....	1398
27.11	Allocation of VIDs to FIDs	1400
27.12	SPBV SPVID translation	1401
27.13	VLAN topology management.....	1401
27.14	Individual addresses and SPBM	1402
27.14.1	Loop mitigation	1403
27.14.2	Loop prevention	1403
27.15	SPBM group addressing	1403
27.16	Backbone service instance topology management	1405
27.17	Equal cost shortest paths, ECTs, and load spreading	1406
27.18	Connectivity Fault Management for SPBM	1406
27.18.1	SPBM MA types	1406
27.18.2	SPBM MEP placement in a Bridge Port	1407
27.18.3	SPBM MIP placement in a Bridge Port	1408
27.18.4	SPBM modifications of the CFM protocols	1408
27.19	Using SPBV and SPBM modes	1409
27.19.1	Shortest Path Bridging—VID	1409
27.19.2	Shortest Path Bridging—MAC	1410
27.20	Security considerations	1412
28.	ISIS-SPB Link State Protocol.....	1413
28.1	ISIS-SPB control plane MAC.....	1413
28.2	Formation and maintenance of ISIS-SPB adjacencies	1414
28.3	Loop prevention	1415
28.4	The Agreement Digest	1415
28.4.1	Agreement Digest Format Identifier	1415
28.4.2	Agreement Digest Format Capabilities	1416
28.4.3	Agreement Digest Convention Identifier	1416
28.4.4	Agreement Digest Convention Capabilities	1416
28.4.5	Agreement Digest Edge Count	1417
28.4.6	The Computed Topology Digest	1417
28.5	Symmetric shortest path tie breaking.....	1418

28.6	Symmetric ECT framework.....	1419
28.7	Symmetric ECT	1420
28.8	Symmetric ECT Algorithm details	1421
28.9	ECT Migration.....	1422
28.9.1	Use of a new ECT Algorithm in SPBV	1422
28.9.2	Use of a new ECT Algorithm in SPBM	1423
28.10	MAC address registration	1424
28.11	Circuit IDs and Port Identifiers.....	1424
28.12	ISIS-SPB TLVs.....	1424
28.12.1	MT-Capability TLV	1425
28.12.2	SPB MCID sub-TLV	1425
28.12.3	SPB Digest sub-TLV	1426
28.12.4	SPB Base VLAN-Identifiers sub-TLV	1427
28.12.5	SPB Instance sub-TLV	1428
28.12.6	SPB Instance Opaque ECT Algorithm sub-TLV	1429
28.12.7	SPB Link Metric sub-TLV	1431
28.12.8	SPB Adjacency Opaque ECT Algorithm sub-TLV	1431
28.12.9	SPBV MAC address sub-TLV	1432
28.12.10	SPBM Service Identifier and Unicast Address (ISID-ADDR) sub-TLV	1433
29.	DDCFM operations and protocols.....	1436
29.1	Principles of DDCFM operation.....	1436
29.1.1	Data-driven and data-dependent faults (DDFs)	1436
29.1.2	Basic principle to diagnose and isolate DDFs	1436
29.2	DDCFM Entity operation	1439
29.2.1	DDCFM implementation	1439
29.2.2	FPT RR	1440
29.2.3	RR-related parameters	1441
29.2.4	Reflection Target and RFM Receiver	1442
29.2.5	RPT-related parameters	1442
29.2.6	Decapsulator Responder (DR)	1443
29.2.7	SFM Originator	1444
29.3	DDCFM protocols	1444
29.3.1	RR variables	1444
29.3.2	RR Filter procedures	1446
29.3.3	RR Encapsulation procedures	1447
29.3.4	RR Transmit procedure	1448
29.3.5	RR-related state machines	1449
29.3.6	RFM Receiver variables	1450
29.3.7	RFM Receiver procedure	1451
29.3.8	DR variables	1452
29.3.9	DR procedures	1452
29.3.10	Decapsulator Responder state machine	1454
29.4	Encoding of DDCFM PDUs.....	1454
29.4.1	RFM and SFM Header	1454
29.4.2	RFM format	1454
29.4.3	SFM format	1455
30.	Principles of congestion notification	1457
30.1	Congestion notification design requirements	1457

30.2	Quantized Congestion Notification protocol (QCN)	1459
30.2.1	The CP algorithm	1460
30.2.2	Basic RP algorithm	1461
30.2.3	RP algorithm with timer	1462
30.3	Congestion Controlled Flow (CCF).....	1463
30.4	Congestion Notification Priority Value (CNPV).....	1464
30.5	Congestion Notification tag (CN-TAG)	1464
30.6	Congestion Notification Domain (CND).....	1464
30.7	Multicast data.....	1465
30.8	Congestion notification and additional tags.....	1465
31.	Congestion notification entity operation.....	1467
31.1	Congestion-aware Bridge Forwarding Process.....	1467
31.1.1	Congestion Point (CP)	1468
31.1.2	CP ingress multiplexer	1468
31.2	Congestion-aware end station functions.....	1468
31.2.1	Output flow segregation	1470
31.2.2	Per-CNPV station function	1470
31.2.3	Flow Select Database	1472
31.2.4	Flow multiplexer	1472
31.2.5	CNM demultiplexer	1472
31.2.6	Input flow segregation	1473
31.2.7	End station input queue	1473
31.2.8	Reception selection	1473
32.	Congestion notification protocol	1474
32.1	CND operations	1474
32.1.1	CND defense	1474
32.1.2	Automatic CND recognition	1476
32.1.3	Variables controlling CND defense	1476
32.2	CN component variables.....	1477
32.2.1	cngMasterEnable	1478
32.2.2	cngCnmTransmitPriority	1478
32.2.3	cngDiscardedFrames	1478
32.2.4	cngErroredPortList	1478
32.3	Congestion notification per-CNPV variables	1478
32.3.1	cncpDefModeChoice	1478
32.3.2	cncpAlternatePriority	1479
32.3.3	cncpAutoAltPri	1479
32.3.4	cncpAdminDefenseMode	1479
32.3.5	cncpCreation	1479
32.3.6	cncpLldpInstanceChoice	1479
32.3.7	cncpLldpInstanceSelector	1479

32.4	CND defense per-Port per-CNPV variables	1480
32.4.1	cnpdDefModeChoice	1480
32.4.2	cnpdAdminDefenseMode	1480
32.4.3	cnpdAutoDefenseMode	1481
32.4.4	cnpdLldpInstanceChoice	1481
32.4.5	cnpdLldpInstanceSelector	1481
32.4.6	cnpdAlternatePriority	1481
32.4.7	cnpdXmitCnpvCapable	1481
32.4.8	cnpdXmitReady	1481
32.4.9	cncpDoesEdge	1482
32.4.10	cnpdAcceptsCnTag	1482
32.4.11	cnpdRcvdCnpv	1482
32.4.12	cnpdRcvdReady	1482
32.4.13	cnpdIsAdminDefMode	1482
32.4.14	cnpdDefenseMode	1482
32.5	CND defense procedures	1483
32.5.1	DisableCnpvRemapping()	1483
32.5.2	TurnOnCnDefenses()	1483
32.5.3	TurnOffCnDefenses()	1483
32.6	CND defense state machine.....	1483
32.7	Congestion notification protocol	1484
32.8	CP variables	1485
32.8.1	cpMacAddress	1486
32.8.2	cpId	1486
32.8.3	cpQSp	1486
32.8.4	cpQLen	1486
32.8.5	cpQLenOld	1486
32.8.6	cpW	1486
32.8.7	cpQOffset	1486
32.8.8	cpQDelta	1486
32.8.9	cpFb	1486
32.8.10	cpEnqueued	1487
32.8.11	cpSampleBase	1487
32.8.12	cpDiscardedFrames	1487
32.8.13	cpTransmittedFrames	1487
32.8.14	cpTransmittedCnms	1487
32.8.15	cpMinHeaderOctets	1487
32.9	CP procedures	1487
32.9.1	Random	1487
32.9.2	NewCpSampleBase()	1487
32.9.3	EM_UNITDATA.request (parameters)	1488
32.9.4	GenerateCnmPdu()	1488
32.10	RP per-Port per-CNPV variables	1489
32.10.1	rpppMaxRps	1489
32.10.2	rpppCreatedRps	1489
32.10.3	rpppRpCentiseconds	1490

32.11	RP group variables	1490
32.11.1	rpEnable	1490
32.11.2	rpTimeReset	1490
32.11.3	rpByteReset	1490
32.11.4	rpThreshold	1491
32.11.5	rpMaxRate	1491
32.11.6	rpAiRate	1491
32.11.7	rpHaiRate	1491
32.11.8	rpGd	1491
32.11.9	rpMinDecFac	1491
32.11.10	rpMinRate	1491
32.12	RP timer	1491
32.12.1	RpWhile	1491
32.13	RP variables	1492
32.13.1	rpEnabled	1492
32.13.2	rpByteCount	1492
32.13.3	rpByteStage	1492
32.13.4	rpTimeStage	1492
32.13.5	rpTargetRate	1492
32.13.6	rpCurrentRate	1492
32.13.7	rpFreeze	1492
32.13.8	rpLimiterRate	1493
32.13.9	rpFb	1493
32.14	RP procedures	1493
32.14.1	ResetCnm	1493
32.14.2	TestRpTerminate	1493
32.14.3	TransmitDataFrame	1493
32.14.4	ReceiveCnm	1494
32.14.5	ProcessCnm	1494
32.14.6	AdjustRates	1494
32.15	RP rate control state machine	1495
32.16	Congestion notification and encapsulation interworking function	1497
33.	Encoding of congestion notification PDUs	1499
33.1	Structure, representation, and encoding	1499
33.2	CN-TAG format	1499
33.2.1	Flow Identifier	1500
33.3	Congestion Notification Message (CNM)	1500
33.4	Congestion Notification Message PDU format	1500
33.4.1	Version	1500
33.4.2	ReservedV	1500
33.4.3	Quantized Feedback	1501
33.4.4	Congestion Point Identifier	1501
33.4.5	cnmQOffset	1501
33.4.6	cnmQDelta	1501
33.4.7	Encapsulated priority	1502
33.4.8	Encapsulated destination MAC address	1502
33.4.9	Encapsulated MSDU length	1502
33.4.10	Encapsulated MSDU	1502
33.4.11	CNM Validation	1502
34.	Forwarding and Queuing Enhancements for time-sensitive streams (FQTSS)	1503
34.1	Overview	1503

34.2	Detection of SRP domains	1503
34.3	The bandwidth availability parameters	1504
34.3.1	deltaBandwidth when lockClassBandwidth is false	1504
34.3.2	deltaBandwidth when lockClassBandwidth is true	1505
34.3.3	Bandwidth availability parameter management	1505
34.4	Deriving actual bandwidth requirements from the size of the MSDU	1506
34.5	Default SR class configuration	1507
34.6	Transmission selection	1508
34.6.1	Credit-based shaper	1509
34.6.2	Strict priority	1510
34.6.3	Scheduled traffic	1511
35.	Stream Reservation Protocol (SRP)	1512
35.1	Multiple Stream Registration Protocol (MSRP)	1513
35.1.1	MSRP and Shared Media	1514
35.1.2	Behavior of end stations	1515
35.1.3	Behavior of Bridges	1517
35.1.4	SRP domains and status parameters	1517
35.2	Definition of the MSRP application	1518
35.2.1	Definition of internal state variables	1518
35.2.2	Definition of MRP elements	1520
35.2.3	Provision and support of Stream registration service	1544
35.2.4	MSRP Attribute Propagation	1549
35.2.5	Operational reporting and statistics	1558
35.2.6	Encoding	1558
35.2.7	Attribute value support requirements	1559
36.	Priority-based Flow Control (PFC)	1560
36.1	PFC operation	1560
36.1.1	Overview	1560
36.1.2	PFC primitives	1561
36.1.3	Detailed specification of PFC operation	1562
36.2	PFC-aware system queue functions	1563
36.2.1	PFC Initiator	1563
36.2.2	PFC Receiver	1563
37.	Enhanced Transmission Selection (ETS)	1566
37.1	Overview	1566
37.1.1	Relationship to other transmission selection algorithms	1566
37.2	ETS configuration parameters	1566
37.3	ETS algorithm	1566
37.4	Legacy configuration	1567
38.	Data Center Bridging eXchange protocol (DCBX)	1568
38.1	Overview	1568
38.2	Goals	1568
38.3	Types of DCBX attributes	1568
38.3.1	Informational attributes	1568
38.4	DCBX and LLDP	1568
38.4.1	Asymmetric attribute passing	1569
38.4.2	Symmetric attribute passing	1570