

INTERNATIONAL
STANDARD

ISO/IEC/
IEEE
8802-1CB

First edition
2019-02

**Information technology —
Telecommunications and information
exchange between systems — Local
and metropolitan area networks —
Specific requirements —**

**Part 1CB:
Frame replicaton and elimination for
reliability**

*Technologies de l'information — Télécommunications et échange
d'information entre systèmes — Réseaux locaux et métropolitains —
Exigences spécifiques —*

Partie 1CB: Duplication de trame et son élimination pour la fiabilité



Reference number
ISO/IEC/IEEE 8802-1CB:2019(E)

© IEEE 2017



COPYRIGHT PROTECTED DOCUMENT

© IEEE 2017

All rights reserved. Unless otherwise specified, or required in the context of its implementation, no part of this publication may be reproduced or utilized otherwise in any form or by any means, electronic or mechanical, including photocopying, or posting on the internet or an intranet, without prior written permission. Permission can be requested from either ISO or IEEE at the respective address below or ISO's member body in the country of the requester.

ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Fax: +41 22 749 09 47
Email: copyright@iso.org
Website: www.iso.org

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

Email: stds.ipr@ieee.org
Website: www.ieee.org

Published in Switzerland

Foreword

ISO (the International Organization for Standardization) and IEC (the International Electrotechnical Commission) form the specialized system for worldwide standardization. National bodies that are members of ISO or IEC participate in the development of International Standards through technical committees established by the respective organization to deal with particular fields of technical activity. ISO and IEC technical committees collaborate in fields of mutual interest. Other international organizations, governmental and non-governmental, in liaison with ISO and IEC, also take part in the work. In the field of information technology, ISO and IEC have established a joint technical committee, ISO/IEC JTC 1.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted (see www.iso.org/directives).

IEEE Standards documents are developed within the IEEE Societies and the Standards Coordinating Committees of the IEEE Standards Association (IEEE-SA) Standards Board. The IEEE develops its standards through a consensus development process, approved by the American National Standards Institute, which brings together volunteers representing varied viewpoints and interests to achieve the final product. Volunteers are not necessarily members of the Institute and serve without compensation. While the IEEE administers the process and establishes rules to promote fairness in the consensus development process, the IEEE does not independently evaluate, test, or verify the accuracy of any of the information contained in its standards.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO and IEC shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

ISO/IEC/IEEE 8802-1CB was prepared by the LAN/MAN of the IEEE Computer Society (as IEEE Std 802.1CB-2017) and drafted in accordance with its editorial rules. It was adopted, under the "fast-track procedure" defined in the Partner Standards Development Organization cooperation agreement between ISO and IEEE, by Joint Technical Committee ISO/IEC JTC 1, *Information technology*, Subcommittee SC6, *Telecommunications and information exchange between systems*.

A list of all parts in the ISO/IEC/IEEE 8802 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

IEEE Std 802.1CB™-2017

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

Frame Replication and Elimination for Reliability

Sponsor

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

Approved 28 September 2017

IEEE-SA Standards Board

Abstract: This standard specifies procedures, managed objects, and protocols for bridges and end systems that provide identification and replication of packets for redundant transmission, identification of duplicate packets, and elimination of duplicate packets. It is not concerned with the creation of the multiple paths over which the duplicates are transmitted.

Keywords: Bridged Local Area Networks, Bridges, Bridging, Frame Elimination, Frame Replication, IEEE 802[®], IEEE 802.1CB[™], IEEE 802.1Q[™], local area networks (LANs), MAC Bridges, Redundancy, Time-Sensitive Networking, TSN, Virtual Bridged Local Area Networks (virtual LANs)

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

Copyright © 2017 by The Institute of Electrical and Electronics Engineers, Inc.
All rights reserved. Published 27 October 2017. 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.

Print: ISBN 978-1-5044-4297-8 STD22761
PDF: ISBN 978-1-5044-4298-5 STDPD22761

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 documents are made available for use subject to important notices and legal disclaimers. These notices and disclaimers, or a reference to this page, appear in all standards and may be found under the heading “Important Notices and Disclaimers Concerning IEEE Standards Documents.” They can also be obtained on request from IEEE or viewed at <http://standards.ieee.org/IPR/disclaimers.html>.

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

IEEE Standards documents (standards, recommended practices, and guides), both full-use and trial-use, are developed within IEEE Societies and the Standards Coordinating Committees of the IEEE Standards Association (“IEEE-SA”) Standards Board. IEEE (“the Institute”) develops its standards through a consensus development process, approved by the American National Standards Institute (“ANSI”), which brings together volunteers representing varied viewpoints and interests to achieve the final product. IEEE Standards are documents developed through scientific, academic, and industry-based technical working groups. Volunteers in IEEE working groups are not necessarily members of the Institute 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 Standards do not guarantee or ensure safety, security, health, or environmental protection, or ensure against interference with or from other devices or networks. 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.

IEEE does not warrant or represent the accuracy or content of the material contained in its standards, and expressly disclaims all warranties (express, implied and statutory) not included in this or any other document relating to the standard, including, but not limited to, the warranties of: merchantability; fitness for a particular purpose; non-infringement; and quality, accuracy, effectiveness, currency, or completeness of material. In addition, IEEE disclaims any and all conditions relating to: results; and workmanlike effort. 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: PROCUREMENT OF 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 should be considered 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, or 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 his or her views should be considered the personal views of that individual rather than the formal position of IEEE.

Comments on standards

Comments for revision of IEEE Standards documents are welcome from any interested party, regardless of membership affiliation with IEEE. However, IEEE does not provide 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 Standards Coordinating Committees 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 revisions to an IEEE standard is welcome to join the relevant IEEE working group.

Comments on standards should be submitted to the following address:

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

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 imply 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.

Copyrights

IEEE draft and approved standards are copyrighted by IEEE under U.S. 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, IEEE does not waive any rights in copyright to the documents.

Photocopies

Subject to payment of the appropriate fee, 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. 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 ten years. When a document is more than ten 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 the IEEE-SA Website at <http://ieeexplore.ieee.org> or contact IEEE at the address listed previously. For more information about the IEEE SA or IEEE's standards development process, visit the IEEE-SA Website at <http://standards.ieee.org>.

Errata

Errata, if any, for all IEEE standards can be accessed on the IEEE-SA Website at the following URL: <http://standards.ieee.org/findstds/errata/index.html>. Users are encouraged to check this URL for errata periodically.

Patents

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 filed a statement of assurance via an Accepted Letter of Assurance, then the statement is listed on the IEEE-SA Website at <http://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.

Participants

At the time of approval of this standard, the IEEE 802.1 Working Group had the following membership:

Glenn Parsons, Chair
John Messenger, Vice Chair
János Farkas, Chair, Time-Sensitive Networking Task Group
Norman Finn, Editor

Ralf Assmann	Mark Hantel	Maximilian Riegel
Shenghua Bao	Patrick Heffernan	Jessy Rouyer
Jens Bierschenk	Marc Holness	Eero Ryytty
Steinar Bjornstad	Hal Keen	Soheil Samii
Christian Boiger	Stephan Kehrer	Frank Schewe
Paul Bottorff	Jouni Korhonen	Michael Seaman
David Chen	Hajime Koto	Johannes Specht
Feng Chen	Yizhou Li	Patricia Thaler
Weiyang Cheng	Christophe Mangin	Paul Unbehagen
Rodney Cummings	James McIntosh	Hao Wang
Mickael Fontaine	Robert Moskowitz	Tongtong Wang
Geoffrey Garner	Tero Mustala	Xinyuan Wang
Eric W. Gray	Donald R. Pannell	Karl Weber
Craig Gunther	Walter Pienciak	Brian Weis
Marina Gutierrez	Michael Potts	Jordon Woods
Stephen Haddock	Karen Randall	Nader Zein

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

Thomas Alexander	Marco Hernandez	Satoshi Obara
Richard Alfvén	Guido Hiertz	David Olsen
Butch Anton	Werner Hoelzl	Glenn Parsons
Stefan Aust	Noriyuki Ikeuchi	Bansi Patel
Steinar Bjornstad	Osamu Ishida	Arumugam Paventhan
Christian Boiger	Atsushi Ito	Adee Ran
David Brandt	Raj Jain	Alon Regev
Nancy Bravin	Anthony Jeffree	Maximilian Riegel
Ashley Butterworth	SangKwon Jeong	Robert Robinson
William Byrd	Michael Johas Teener	Benjamin Rolfe
Yesenia Cevallos	Peter Jones	Dan Romascanu
Keith Chow	Piotr Karocki	Jessy Rouyer
Charles Cook	Stuart Kerry	Osman Sakr
Rodney Cummings	Yongbum Kim	Bartien Sayogo
Patrick Diamond	Jeff Koftinoff	Frank Schewe
Richard Doyle	Jouni Korhonen	Michael Seaman
Sourav Dutta	Hyeong Ho Lee	Veselin Skendzic
Richard Edgar	John Lemon	Ju-Hyung Son
Marc Emmelmann	Joseph Levy	Kevin Stanton
János Farkas	Arthur H. Light	Thomas Starai
Norman Finn	Elvis Maculuba	Eugene Stoudenmire
Michael Fischer	Roger Marks	Walter Struppler
Yukihiro Fujimoto	Arthur Marris	Patricia Thaler
Devon Gayle	Richard Mellitz	Dmitri Varsanofiev
Joel Goergen	Charles Moorwood	Prabodh Varshney
Eric W. Gray	Henry Muysshondt	George Vlantis
Randall Groves	Charles Ngethe	Khurram Waheed
Craig Gunther	Nick S. A. Nikjoo	Karl Weber
Stephen Haddock	Paul Nikolich	Oren Yuen
Mark Hantel	Saad Nsaif	Zhen Zhou

When the IEEE-SA Standards Board approved this standard on 28 September 2017, it had the following membership:

Jean-Philippe Faure, *Chair*
Gary Hoffman, *Vice Chair*
John D. Kulick, *Past Chair*
Konstantinos Karachalios, *Secretary*

Chuck Adams
Masayuki Ariyoshi
Ted Burse
Stephen Dukes
Doug Edwards
J. Travis Griffith
Michael Janezic

Thomas Koshy
Joseph L. Koepfinger*
Kevin Lu
Daleep Mohla
Damir Novosel
Ronald C. Petersen
Annette D. Reilly

Robby Robson
Dorothy Stanley
Adrian Stephens
Mehmet Ulema
Phil Wennblom
Howard Wolfman
Yu Yuan

*Member Emeritus

Introduction

This introduction is not part of IEEE Std 802.1CB-2017, IEEE Standard for Local and metropolitan area networks—
Frame Replication and Elimination for Reliability.

This standard defines Frame Replication and Elimination for Reliability.

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 can be obtained from

Secretary, IEEE-SA Standards Board
445 Hoes Lane
P.O. Box 1331
Piscataway, NJ 08855-1331
USA

Contents

1.	Overview	16
1.1	Scope	16
1.2	Rationale	16
1.3	State diagram conventions	16
1.4	Specification model	16
1.5	Specification precedence	17
1.6	Introduction	17
2.	Normative references	18
3.	Definitions	19
4.	Acronyms and abbreviations	21
5.	Conformance	22
5.1	Requirements terminology	22
5.2	Conformant components and equipment	22
5.3	Stream identification component required behaviors	22
5.4	Stream identification component recommended behavior	23
5.5	Stream identification component optional behaviors	23
5.6	Talker end system required behaviors	23
5.7	Talker end system recommended behaviors	23
5.8	Talker end system optional behaviors	23
5.9	Listener end system required behaviors	24
5.10	Listener end system recommended behavior	24
5.11	Listener end system optional behaviors	24
5.12	Relay system required behaviors	24
5.13	Relay system recommended behaviors	25
5.14	Relay system optional behaviors	25
5.15	FRER C-component required and optional behaviors	25
6.	Stream identification	26
6.1	Stream service subparameters	27
6.2	Stream identification function	28
6.3	Stream identification in systems	29
6.4	Null Stream identification	30
6.5	Source MAC and VLAN Stream identification	31
6.6	Active Destination MAC and VLAN Stream identification	31
6.7	IP Stream identification	32
7.	Frame Replication and Elimination for Reliability	33
7.1	Overview of Frame Replication and Elimination for Reliability	33
7.1.1	Goals and objectives	33
7.2	Use of the term Stream	35
7.3	Frame Replication and Elimination for Reliability functions	35
7.4	Sequencing function	36
7.4.1	Sequence generation function	36
7.4.1.1	Events for sequence generation	37
7.4.1.2	Variables for sequence generation	37

7.4.1.2.1	GenSeqSpace	37
7.4.1.2.2	GenSeqNum	37
7.4.1.3	SequenceGenerationReset	37
7.4.1.4	SequenceGenerationAlgorithm	37
7.4.2	Sequence recovery function	38
7.4.3	Base recovery function	38
7.4.3.1	Events for sequence recovery	39
7.4.3.2	Variables for sequence recovery	39
7.4.3.2.1	RecovSeqSpace	39
7.4.3.2.2	SequenceHistory	40
7.4.3.2.3	RecovSeqNum	40
7.4.3.2.4	RemainingTicks	40
7.4.3.2.5	TicksPerSecond	40
7.4.3.2.6	TakeAny	40
7.4.3.3	SequenceRecoveryReset	40
7.4.3.4	VectorRecoveryAlgorithm	41
7.4.3.5	MatchRecoveryAlgorithm	43
7.4.3.6	ShiftSequenceHistory	44
7.4.4	Latent error detection function	45
7.4.4.1	Events for latent error detection	45
7.4.4.2	Variables for latent error detection	46
7.4.4.2.1	CurBaseDifference	46
7.4.4.3	LatentErrorReset	46
7.4.4.4	LatentErrorTest	46
7.5	Individual recovery function	47
7.6	Sequence encode/decode function	47
7.7	Stream splitting function	47
7.8	Redundancy tag	48
7.8.1	Redundancy tag EtherType	49
7.8.2	Redundancy tag information	49
7.9	HSR sequence tag	49
7.10	PRP sequence trailer	50
7.11	Autoconfiguration	51
7.11.1	Introduction to autoconfiguration	51
7.11.2	Creating autoconfigured Stream identity table entries	52
8.	Frame Replication and Elimination for Reliability in Bridges	56
8.1	Limiting options	56
8.2	FRER C-component input transformations	58
8.3	Frame Replication and Elimination for Reliability and VLAN tags	58
8.4	Configuring Frame Replication and Elimination for Reliability in Bridges	59
9.	Stream Identification Management	61
9.1	Stream identity table	61
9.1.1	tsnStreamIdEntry	61
9.1.1.1	tsnStreamIdHandle	61
9.1.1.2	tsnStreamIdInFacOutputPortList	61
9.1.1.3	tsnStreamIdOutFacOutputPortList	61
9.1.1.4	tsnStreamIdInFacInputPortList	62
9.1.1.5	tsnStreamIdOutFacInputPortList	62
9.1.1.6	tsnStreamIdIdentificationType	62
9.1.1.7	tsnStreamIdParameters	62
9.1.2	Managed objects for Null Stream identification	62

9.1.2.1	tsnCpeNullDownDestMac	62
9.1.2.2	tsnCpeNullDownTagged	63
9.1.2.3	tsnCpeNullDownVlan	63
9.1.3	Managed objects for Source MAC and VLAN Stream identification	63
9.1.3.1	tsnCpeSmacVlanDownSrcMac	63
9.1.3.2	tsnCpeSmacVlanDownTagged	63
9.1.3.3	tsnCpeSmacVlanDownVlan	63
9.1.4	Managed objects for Active Destination MAC and VLAN Stream identifications	63
9.1.4.1	tsnCpeDmacVlanDownDestMac	63
9.1.4.2	tsnCpeDmacVlanDownTagged	64
9.1.4.3	tsnCpeDmacVlanDownVlan	64
9.1.4.4	tsnCpeDmacVlanDownPriority	64
9.1.4.5	tsnCpeDmacVlanUpDestMac	64
9.1.4.6	tsnCpeDmacVlanUpTagged	64
9.1.4.7	tsnCpeDmacVlanUpVlan	65
9.1.4.8	tsnCpeDmacVlanUpPriority	65
9.1.5	Managed objects for IP Stream identification	65
9.1.5.1	tsnCpeIpIdDestMac	65
9.1.5.2	tsnCpeIpIdTagged	65
9.1.5.3	tsnCpeIpIdVlan	65
9.1.5.4	tsnCpeIpIdIpSource	65
9.1.5.5	tsnCpeIpIdIpDestination	65
9.1.5.6	tsnCpeIpIdDscp	65
9.1.5.7	tsnCpeIpIdNextProtocol	66
9.1.5.8	tsnCpeIpIdSourcePort	66
9.1.5.9	tsnCpeIpIdDestinationPort	66
9.2	Operational per-port per-Stream Stream identification counters	66
9.2.1	tsnCpsSidInputPackets	66
9.2.2	tsnCpsSidOutputPackets	66
9.3	Operational per-port Stream identification counters	66
9.3.1	tsnCpSidInputPackets	66
9.3.2	tsnCpSidOutputPackets	66
10.	Frame Replication and Elimination for Reliability management	67
10.1	Counter behavior	67
10.2	Additional tsnStreamIdEntry managed objects	67
10.2.1	tsnStreamIdAutoconfigured	68
10.2.2	tsnStreamIdLanPathId	68
10.3	Sequence generation table	68
10.3.1	frerSeqGenEntry	68
10.3.1.1	frerSeqGenStreamList	68
10.3.1.2	frerSeqGenDirection	68
10.4	Sequence recovery table	68
10.4.1	frerSeqRcvyEntry	68
10.4.1.1	frerSeqRcvyStreamList	68
10.4.1.2	frerSeqRcvyPortList	69
10.4.1.3	frerSeqRcvyDirection	69
10.4.1.4	frerSeqRcvyReset	69
10.4.1.5	frerSeqRcvyAlgorithm	69
10.4.1.6	frerSeqRcvyHistoryLength	69
10.4.1.7	frerSeqRcvyResetMSec	69
10.4.1.8	frerSeqRcvyInvalidSequenceValue	69
10.4.1.9	frerSeqRcvyTakeNoSequence	70

10.4.1.10	frerSeqRcvyIndividualRecovery	70
10.4.1.11	frerSeqRcvyLatentErrorDetection	70
10.4.1.12	Latent error detection managed objects	70
10.4.1.12.1	frerSeqRcvyLatentErrorDifference	70
10.4.1.12.2	frerSeqRcvyLatentErrorPeriod	70
10.4.1.12.3	frerSeqRcvyLatentErrorPaths	70
10.4.1.12.4	frerSeqRcvyLatentResetPeriod	71
10.5	Sequence identification table	71
10.5.1	frerSeqEncEntry	71
10.5.1.1	frerSeqEncStreamList	71
10.5.1.2	frerSeqEncPort	71
10.5.1.3	frerSeqEncDirection	71
10.5.1.4	frerSeqEncActive	71
10.5.1.5	frerSeqEncEncapsType	71
10.5.1.6	frerSeqEncPathIdLanId	71
10.6	Stream split table	72
10.6.1	frerSplitEntry	72
10.6.1.1	frerSplitPort	72
10.6.1.2	frerSplitDirection	72
10.6.1.3	frerSplitInputIdList	72
10.6.1.4	frerSplitOutputIdList	72
10.7	Managed objects for autoconfiguration	72
10.7.1	Sequence autoconfiguration table	72
10.7.1.1	frerAutSeqEntry	73
10.7.1.1.1	frerAutSeqSeqEncaps	73
10.7.1.1.2	frerAutSeqReceivePortList	73
10.7.1.1.3	frerAutSeqTagged	73
10.7.1.1.4	frerAutSeqVlan	73
10.7.1.1.5	frerAutSeqRecoveryPortList	73
10.7.1.1.6	frerAutSeqDestructMSec	73
10.7.1.1.7	frerAutSeqResetMSec	73
10.7.1.1.8	frerAutSeqAlgorithm	73
10.7.1.1.9	frerAutSeqHistoryLength	74
10.7.1.1.10	frerAutSeqCreateIndividual	74
10.7.1.1.11	frerAutSeqCreateRecovery	74
10.7.1.1.12	frerAutSeqLatErrDetection	74
10.7.1.1.13	frerAutSeqLatErrDifference	74
10.7.1.1.14	frerAutSeqLatErrPeriod	74
10.7.1.1.15	frerAutSeqLatErrResetPeriod	74
10.7.2	Output autoconfiguration table	74
10.7.2.1	frerAutOutEntry	74
10.7.2.1.1	frerAutOutPortList	74
10.7.2.1.2	frerAutOutEncaps	75
10.7.2.1.3	frerAutOutLanPathId	75
10.8	Operational per-port and per-Stream FRER counters	75
10.8.1	Per-Stream vs. per-Stream-per-port counters	75
10.8.2	frerCpsSeqGenResets	75
10.8.3	frerCpsSeqRcvyOutOfOrderPackets	75
10.8.4	frerCpsSeqRcvyRoguePackets	76
10.8.5	frerCpsSeqRcvyPassedPackets	76
10.8.6	frerCpsSeqRcvyDiscardedPackets	76
10.8.7	frerCpsSeqRcvyLostPackets	76
10.8.8	frerCpsSeqRcvyTaglessPackets	76
10.8.9	frerCpsSeqRcvyResets	76

10.8.10	frerCpsSeqRcvyLatentErrorResets	76
10.8.11	frerCpsSeqEncErroredPackets	76
10.9	Operational per-port FRER counters	76
10.9.1	frerCpSeqRcvyPassedPackets	77
10.9.2	frerCpSeqRcvyDiscardPackets	77
10.9.3	frerCpSeqEncErroredPackets	77
Annex A (normative) Protocol Implementation Conformance Statement (PICS) proforma		78
A.1	Introduction	78
A.1.1	Abbreviations and special symbols	78
A.1.2	Instructions for completing the PICS proforma	79
A.1.3	Additional information	79
A.1.4	Exceptional information	79
A.1.5	Conditional items	80
A.1.6	Identification	80
A.2	PICS proforma for Frame Replication and Elimination for Reliability	81
A.2.1	Major capabilities/options	81
A.2.2	Stream identification component	81
A.2.3	Talker end system	82
A.2.4	Listener end system	83
A.2.5	Relay system	84
A.2.6	FRER 802.1Q C-component	86
A.2.7	Common requirements	86
Annex B (informative) Interoperability with other standards		87
B.1	Sequence number size	87
B.2	Per-Stream versus per-source sequencing	87
Annex C (informative) Frame Replication and Elimination for Reliability in systems		88
C.1	Example 1: End-to-end FRER	88
C.2	Example 2: Various stack positions	89
C.3	Example 3: Ladder redundancy	92
C.4	Example 4: Multicast trees	93
C.5	Example 5: Protocol interworking	93
C.6	Example 6: Chained two-port end systems	94
C.7	Cautions	95
C.8	Balancing tag insertion and removal	95
C.9	FRER and reserved bandwidth	95
C.10	Use of the Individual recovery function	97
C.11	Use of autoconfiguration	97
C.11.1	Routing and labeling Member Streams	97
C.11.2	Recognizing packets that trigger autoconfiguration	98
C.11.3	Per-port packet decoding and encoding	99
C.11.4	Individual and Sequence recovery functions	99
Annex D (informative) Bibliography		100

List of figures

Figure 6-1—Stream identification service.....	26
Figure 6-2—A Stream with three Listeners.....	26
Figure 6-3—Stream identification function: single upper SAP.....	28
Figure 6-4—Stream identification function: array of upper SAPs.....	28
Figure 6-5—Stream functions in a relay system (three views of same system).....	29
Figure 6-6—In- and out-facing functions.....	30
Figure 7-1—Compound Stream built from four Member Streams.....	33
Figure 7-2—Frame Replication and Elimination for Reliability functions.....	35
Figure 7-3—Sequence recovery functions and Individual recovery functions.....	47
Figure 7-4—R-TAG format.....	48
Figure 8-1—FRER functions in an FRER C-component.....	56
Figure 8-2—Augmented Forwarding Process does sequence recovery.....	57
Figure 8-3—Example Ethernet frame format.....	59
Figure C-1—Dual-homed end systems using Link Aggregation.....	88
Figure C-2—Protocol stack for End System B in Figure C-1.....	89
Figure C-3—Protocol stack for End System G in Figure C-1 and Figure C-4.....	89
Figure C-4—Frame Replication and Elimination for Reliability flexible positioning.....	90
Figure C-5—Protocol stack for relay system B, proxying for End System A, in Figure C-4.....	91
Figure C-6—Protocol stack for relay system C in Figure C-4.....	91
Figure C-7—Protocol stack for relay system F in Figure C-4.....	92
Figure C-8—Ladder redundancy.....	92
Figure C-9—Multicast trees.....	93
Figure C-10—Protocol interworking.....	93
Figure C-11—Dual-homed end systems using 3-port bridge.....	94
Figure C-12—Protocol stacks for Systems B and G in Figure C-11.....	94
Figure C-13—Explicit path causing a loop.....	95
Figure C-14—Example of Long and short paths.....	96
Figure C-15—Autoconfiguration example.....	98

List of tables

Table 6-1—Stream identification functions	27
Table 7-1—R-TAG EtherType	49
Table 8-1—Managed objects for FRER in an FRER C-component	59
Table 9-1—Stream identification types	62
Table 10-1—Enumerated values for frerSeqRcvyAlgorithm	69
Table 10-2—Sequence Encode/Decode types	72

IEEE Standard for Local and metropolitan area networks—

Frame Replication and Elimination for Reliability

1. Overview

1.1 Scope

This standard specifies procedures, managed objects, and protocols for bridges and end systems that provide identification and replication of packets for redundant transmission, identification of duplicate packets, and elimination of duplicate packets. It is not concerned with the creation of the multiple paths over which the duplicates are transmitted.

1.2 Rationale

The reason for Frame Replication and Elimination for Reliability (FRER) is to increase the probability that a given packet will be delivered. It is expected that, in many applications, other means to increase the probability of delivery are likely to be used as well. When FRER is used over paths that are fixed to a specific topology, and that are protected against congestion loss (e.g., by using techniques described by IEEE Std 802.1BA™ [B1]), FRER can substantially reduce the probability of packet loss due to equipment failures.¹

1.3 State diagram conventions

This document uses the programming language C (ISO/IEC 9899:2011) to document the operation of conformant systems.² C functions are distinguished with `this special fixed-width font` (e.g., 7.4.3.3). Each C function is executed when a given event occurs, as described for that code segment or in the accompanying text. Events are assumed to take place sequentially, not simultaneously, and code routines execute instantaneously.

1.4 Specification model

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

¹The numbers in brackets correspond to those of the bibliography in Annex D.

²Information on references can be found in Clause 2.

1.5 Specification precedence

If any conflict among parts of this standard become apparent, C functions (see 1.3) take precedence over other parts of the standard, followed by information in normative tables, followed by that in normative text, followed by that in normative figures. Non-normative tables, figures, and text are in annexes and are clearly marked as such.

1.6 Introduction

This standard is one of a number of IEEE 802.1™ and other standards suitable for Time-Sensitive Networking (TSN) that together have the overall goal of providing extremely low packet loss rates and finite, low, and stable end-to-end latencies. TSN supports unicast and multicast Streams of packets that implement a wide range of demanding real-time applications including audio/video studios, industrial processes, and the control of machines and vehicles. The TSN goals are not achieved at the expense of hampering the ability of the network to carry traffic for non-time-critical applications.

At the highest level, this standard posits the existence of one Talker end system and one or more Listener end systems per Stream. A Stream is characterized by a maximum packet size and number of packets transmitted per time interval. Because the Stream's maximum throughput is known, the resources, including link bandwidth, buffer space, and control parameters, required at every hop along the Stream's path to guarantee that Stream zero congestion loss and finite latency, can be provided (by other standards, e.g., Clause 35 of IEEE Std 802.1Q™-2014). This provisioned path carrying the Stream is called a *Reservation*.

On the assumption that the time required for a dynamic network control protocol to recover from an equipment failure is unacceptable in certain applications, this standard defines Frame Replication and Elimination for Reliability (FRER), which divides a Stream into one or more linked Member Streams, thus making the original Stream a Compound Stream. It replicates the packets of the Stream, splitting the copies into the multiple Member Streams, and then rejoins those Member Streams at one or more other points, eliminates the replicates, and delivers the reconstituted Stream from those points.

In order to accommodate existing applications and to promote interoperability with similar standards, this standard defines a number of schemes for identifying packets belonging to Streams and distinguishing them from other packets.

2. Normative references

The following referenced documents are indispensable for the application of this document (i.e., they must be understood and used, so each referenced document is cited in text and its relationship to this document is explained). For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies. Non-normative references (i.e., that provide additional information not required for the application of this document) are given in Annex D.

IEC 62439-3:2016, Industrial communication networks—High availability automation networks—Part 3: Parallel Redundancy Protocol (PRP) and High-availability Seamless Redundancy (HSR).³

IEEE Std 802[®], IEEE Standard for Local and metropolitan area networks: Overview and Architecture.^{4, 5}

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

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

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

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

IETF RFC 793, Transmission Control Protocol, Postel, J., Ed., September 1981.

IETF RFC 2460, Internet Protocol, Version 6 (IPv6) Specification, Deering, S. and R. Hinden, December 1998.

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

IETF RFC 4960, Stream Control Transmission Protocol, Stewart, R., Ed., September 2007.

ISO/IEC 9899:2011, Information technology—Programming languages—C.⁷

³IEC publications are available from the International Electrotechnical Commission (<http://www.iec.ch>) and the American National Standards Institute (<http://www.ansi.org/>).

⁴The IEEE standards or products referred to in Clause 2 are trademarks owned by The Institute of Electrical and Electronics Engineers, Incorporated.

⁵IEEE publications are available from The Institute of Electrical and Electronics Engineers (<http://standards.ieee.org>).

⁶IETF documents (i.e., RFCs) are available for download at <http://www.rfc-archive.org/>.

⁷ISO/IEC publications are available from the International Organization for Standardization (<http://www.iso.org/>) and the American National Standards Institute (<http://www.ansi.org/>).