

IEEE Standard for Local and metropolitan area networks— Link Aggregation

IEEE Computer Society

Sponsored by the
LAN/MAN Standards Committee

IEEE Std 802.1AX™-2014

(Revision of
IEEE Std 802.1AX-2008)

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

Sponsor

LAN/MAN Standards Committee

of the

IEEE Computer Society

Approved 10 December 2014

IEEE SA-Standards Board

Abstract: MAC-independent Link Aggregation capability and general information relevant to specific MAC types are defined in this standard. Link Aggregation allows parallel full-duplex point-to-point links to be used as if they were a single link and also supports the use of multiple links as a resilient load sharing interconnect between multiple nodes in two separately administered networks.

Keywords: Aggregated Link, Aggregator, Distributed Resilient Network Interconnect, DRNI, IEEE 802[®], IEEE 802.1AX[™], interconnect, Link Aggregation, Link Aggregation Group, local area network, management, Network-Network Interface, NNI

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

Copyright © 2014 by The Institute of Electrical and Electronics Engineers, Inc.
All rights reserved. Published 30 December 2014. 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 978-0-7381-9448-6 STD20052
PDF: ISBN 978-0-7381-9449-3 STDPD20052

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 Notice” or “Important Notices and Disclaimers Concerning IEEE Standards Documents.”

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. Volunteers 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 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/expel/standards.jsp> or contact IEEE at the address listed previously. For more information about the IEEE-SA or IOWA'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

The following individuals were officers and members of the Higher Layer LAN Protocols Working Group at the beginning of the Working Group ballot. Individuals may have not voted, voted for approval, disapproval, or abstained on this standard.

Glenn Parsons, *Working Group Chair*
John Messenger, *Working Group Vice Chair*
Stephen Haddock, *Chair, Interworking Task Group*
Michael Seaman, *Chair, Security Task Group*
Michael Johas Teener, *Chair, Time Sensitive Networking Task Group*
Pat Thaler, *Chair, Data Center Bridging Task Group*
Maximilian Riegel, *Chair, OmniRAN Task Group*
Eric Gray, *Recording Secretary*

Ting Ao
Christian Boiger
Paul Bottorff
David Chen
Feng Chen
Weiyang Cheng
Diego Crupnicoff
Rodney Cummings
Patrick Diamond
Aboubacar Kader Diarra
Janos Farkas
Norman Finn
Geoffrey Garner
Anoop Ghanwani
Mark Gravel
Craig Gunther

Hitosh Hayakawa
Jeremy Hitt
Rahil Hussain
Anthony Jeffree
Peter Jones
Hal Keen
Marcel Kiessling
Yongbum Kim
Philippe Klein
Jouni Korhonen
Jeff Lynch
Ben Mack-Crane
Christophe Mangin
James McIntosh
Eric Multanen
Donald Pannell

Karen Randall
Dan Romascanu
Jessy V. Rouyer
Panagiotis Saltsidis
Behcet Sarikaya
Daniel Sexton
Johannes Specht
Kevin B. Stanton
Wilfried Steiner
Vahid Tabatabaee
Jeremy Touve
Karl Weber
Yuehua Wei
Brian Weis
Jordon Woods
Juan-Carlos Zuniga

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

Thomas Alexander
Richard Alfvin
Butch Anton
Jacob Ben Ary
Nancy Bravin
William Byrd
Juan Carreon
Keith Chow
Charles Cook
Patrick Diamond
Yezid Donoso
Sourav Dutta
Donald Eastlake, 3rd
Richard Edgar
Andrew Fieldsend
Yukihiro Fujimoto
Devon Gayle
Anoop Ghanwani
Randall Groves
Chris Guy
Stephen Haddock
Werner Hoelzl
Rita Horner
Victor Hou
Noriyuki Ikeuchi

James Innis
Osamu Ishida
Akio Iso
Atsushi Ito
Raj Jain
Anthony Jeffrey
Michael Johas Teener
Peter Jones
Shinkyō Kaku
Piotr Karocki
Stuart Kerry
Yongbum Kim
Bruce Kraemer
Geoff Ladwig
Mark Laubach
John Lemon
Ru Lin
Elvis Maculuba
Roger Marks
Jeffery Masters
Brett Mcclellan
Jonathon Mclendon
Richard Mellitz
John Messenger
Charles Moorwood
Jose Morales

Michael Newman
Nick S.A. Nikjoo
Paul Nikolich
Satoshi Obara
Maximilian Riegel
Dan Romascanu
Jessy V. Rouyer
Panagiotis Saltsidis
Peter Saunderson
Michael Seaman
Kapil Sood
Thomas Starai
Rene Struik
Walter Struppler
William Taylor
Dmitri Varsanofiev
Prabodh Varshney
George Vlantis
Hung-Yu Wei
Andreas Wolf
Chun Yu
Charles Wong
Michael Wright
Oren Yuen
Daidi Zhong

When the IEEE-SA Standards Board approved this standard on 10 December 2014, it had the following membership:

John Kulick, *Chair*
Jon Walter Rosdahl, *Vice Chair*
Richard H. Hulett, *Past Chair*
Konstantinos Karachalios, *Secretary*

Peter Balma
Farooq Bari
Ted Burse
Clint Chaplain
Stephen Dukes
Jean-Phillippe Faure
Gary Hoffman

Michael Janezic
Jeffrey Katz
Joseph L. Koepfinger*
David J. Law
Hung Ling
Oleg Logvinov
T. W. Olsen
Glenn Parsons

Ron Peterson
Adrian Stephens
Peter Sutherland
Yatin Trivedi
Phil Winston
Don Wright
Yu Yuan

*Member Emeritus

Also included are the following nonvoting IEEE-SA Standards Board liaisons:

Richard DeBlasio, *DOE Representative*
Michael Janezic, *NIST Representative*

Michelle Turner
IEEE-SA Content Publishing

Kathryn Bennett
IEEE-SA Technical Community Programs

Introduction

This introduction is not part of IEEE Std 801.AX™-2014, IEEE Standard for Local and metropolitan area networks—Link Aggregation.

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.....	1
1.1	Scope.....	1
1.2	Purpose.....	1
1.3	State diagram conventions.....	2
2.	Normative references.....	3
3.	Definitions.....	4
4.	Acronyms and abbreviations.....	7
5.	Conformance.....	8
5.1	Requirements terminology.....	8
5.2	Protocol Implementation Conformance Statement.....	8
5.3	Link Aggregation requirements.....	8
5.3.1	Link Aggregation options.....	9
5.4	Distributed Resilient Network Interconnect requirements.....	9
5.4.1	Distribution Resilient Network Interconnect options.....	9
6.	Link Aggregation.....	11
6.1	Overview.....	11
6.1.1	Goals and objectives.....	11
6.1.2	Positioning of Link Aggregation within the IEEE 802 architecture.....	12
6.1.3	LLDP Parser/Multiplexer.....	13
6.1.3.1	LLDP Parser state diagram.....	14
6.1.3.1.1	LLDP Parser Function.....	14
6.1.3.1.2	Constants.....	14
6.1.3.1.3	Variables.....	14
6.1.3.1.4	State diagram.....	14
6.2	Link Aggregation operation.....	15
6.2.1	Principles of Link Aggregation.....	15
6.2.2	Service interfaces.....	16
6.2.3	Frame Collector.....	17
6.2.3.1	Frame Collector state diagram.....	17
6.2.3.1.1	Constants.....	17
6.2.3.1.2	Variables.....	17
6.2.3.1.3	Messages.....	17
6.2.3.1.4	State diagram.....	17
6.2.4	Frame Distributor.....	18
6.2.4.1	Frame Distributor state diagram.....	19
6.2.4.1.1	Variables.....	19
6.2.4.1.2	Messages.....	19
6.2.4.1.3	State diagram.....	19
6.2.5	Marker Generator/Receiver (optional).....	19
6.2.6	Marker Responder.....	20
6.2.7	Protocol Parser/Multiplexer.....	20
6.2.7.1	Protocol Parser state diagram.....	20
6.2.7.1.1	Functions.....	20

	6.2.7.1.2	Variables	21
	6.2.7.1.3	Messages	21
	6.2.7.1.4	State diagram	21
6.2.8	Aggregator Parser/Multiplexer		22
	6.2.8.1	Aggregator Parser state diagram	22
	6.2.8.1.1	Constants	22
	6.2.8.1.2	Variables	22
	6.2.8.1.3	Messages	23
	6.2.8.1.4	State Diagram	23
6.2.9	Aggregator		24
6.2.10	Control Parser/Multiplexer		24
	6.2.10.1	Control Parser state diagram	24
	6.2.10.1.1	Control Parser Function	24
	6.2.10.1.2	Constants	24
	6.2.10.1.3	Variables	25
6.2.11	Addressing		25
	6.2.11.1	Source address (SA)	25
	6.2.11.2	Destination address	25
6.3	Link Aggregation Control		26
6.3.1	Characteristics of Link Aggregation Control		27
6.3.2	System identification		28
6.3.3	Aggregator identification		28
6.3.4	Port identification		28
6.3.5	Capability identification		29
6.3.6	Link Aggregation Group identification		30
	6.3.6.1	Construction of the Link Aggregation Group Identifier	30
	6.3.6.2	Representation of the Link Aggregation Group Identifier	31
6.3.7	Selecting a Link Aggregation Group		31
6.3.8	Agreeing on a Link Aggregation Group		32
6.3.9	Attaching a link to an Aggregator		32
6.3.10	Signaling readiness to transfer user data		32
6.3.11	Enabling the Frame Collector and Frame Distributor		33
6.3.12	MAC_Operational status		33
6.3.13	Monitoring the membership of a Link Aggregation Group		33
6.3.14	Detaching a link from an Aggregator		34
6.3.15	Configuration and administrative control of Link Aggregation		34
6.3.16	Link Aggregation Control state information		34
6.4	Link Aggregation Control Protocol		35
6.4.1	LACP design elements		35
6.4.2	LACPDU structure and encoding		35
	6.4.2.1	Transmission and representation of octets	35
	6.4.2.2	Encapsulation of LACPDUs in frames	36
	6.4.2.3	LACPDU structure	36
	6.4.2.4	Version 2 TLVs	40
	6.4.2.4.1	Port Algorithm TLV	40
	6.4.2.4.2	Port Conversation ID Digest TLV	41
	6.4.2.4.3	Port Conversation Mask TLVs	41
	6.4.2.4.4	Port Conversation Service Mapping TLV	44
6.4.3	LACP state machine overview		44
6.4.4	Constants		46
6.4.5	Variables associated with the System		46
6.4.6	Variables associated with each Aggregator		47
6.4.7	Variables associated with each Aggregation Port		48
6.4.8	Variables used for managing the operation of the state machines		50

6.4.9	Functions.....	52
6.4.10	Timers	54
6.4.11	Messages.....	54
6.4.12	Receive machine	54
6.4.13	Periodic Transmission machine	56
6.4.14	Selection Logic	57
	6.4.14.1 Selection Logic—Requirements	58
	6.4.14.2 Selection Logic—Recommended default operation	59
6.4.15	Mux machine	60
6.4.16	Transmit machine	64
6.4.17	Churn Detection machines.....	64
6.4.18	Long LACPDU machine	65
6.5	Marker protocol	67
	6.5.1 Introduction.....	67
	6.5.2 Sequence of operations	67
	6.5.3 Marker and Marker Response PDU structure and encoding	68
	6.5.3.1 Transmission and representation of octets.....	68
	6.5.3.2 Encapsulation of Marker and Marker Response PDU in frames.....	68
	6.5.3.3 Marker and Marker Response PDU structure.....	68
	6.5.4 Protocol definition	70
	6.5.4.1 Operation of the marker protocol.....	70
	6.5.4.2 Marker Responder state diagram	70
	6.5.4.2.1 Variables.....	70
	6.5.4.2.2 Messages.....	71
6.6	Conversation-sensitive frame collection and distribution	71
	6.6.1 Conversation-sensitive collection and distribution state diagrams.....	72
	6.6.1.1 Conversion-sensitive collection state diagram	72
	6.6.1.1.1 Variables.....	72
	6.6.1.1.2 Variables associated with each Aggregation Port	73
	6.6.1.1.3 Functions	73
	6.6.1.1.4 Messages.....	73
	6.6.1.1.5 State diagram	73
	6.6.2 Conversation-sensitive LACP state diagrams.....	74
	6.6.2.1 Per-Aggregator Variables	74
	6.6.2.2 Variables associated with each Aggregation Port.....	76
	6.6.2.3 Variables used for managing the operation of the state diagrams	78
	6.6.2.4 Functions.....	78
	6.6.2.5 Timers	81
	6.6.2.6 Messages	81
	6.6.2.7 State diagrams.....	81
6.7	Configuration capabilities and restrictions	87
	6.7.1 Use of system and port priorities	87
	6.7.2 Dynamic allocation of operational Keys	87
	6.7.3 Link Aggregation on shared-medium links	88
	6.7.4 Selection Logic variants.....	88
	6.7.4.1 Reduced reconfiguration.....	88
	6.7.4.2 Limited Aggregator availability.....	89
7.	Management.....	90
	7.1 Overview.....	90
	7.1.1 Systems management overview.....	90
	7.1.2 Management model.....	91
	7.2 Managed objects	91

7.2.1	Introduction.....	91
7.2.2	Overview of managed objects.....	92
7.2.2.1	Text description of managed objects	92
7.2.3	Containment.....	93
7.2.4	Naming.....	93
7.2.5	Capabilities	94
7.3	Management for Link Aggregation	98
7.3.1	Aggregator managed object class	98
7.3.1.1	Aggregator attributes	99
7.3.1.1.1	aAggID	99
7.3.1.1.2	aAggDescription	99
7.3.1.1.3	aAggName	100
7.3.1.1.4	aAggActorSystemID	100
7.3.1.1.5	aAggActorSystemPriority	100
7.3.1.1.6	aAggAggregateOrIndividual	100
7.3.1.1.7	aAggActorAdminKey.....	100
7.3.1.1.8	aAggActorOperKey.....	101
7.3.1.1.9	aAggMACAddress	101
7.3.1.1.10	aAggPartnerSystemID	101
7.3.1.1.11	aAggPartnerSystemPriority	101
7.3.1.1.12	aAggPartnerOperKey	102
7.3.1.1.13	aAggAdminState	102
7.3.1.1.14	aAggOperState.....	102
7.3.1.1.15	aAggTimeOfLastOperChange.....	102
7.3.1.1.16	aAggDataRate.....	103
7.3.1.1.17	aAggOctetsTxOK	103
7.3.1.1.18	aAggOctetsRxOK	103
7.3.1.1.19	aAggFramesTxOK.....	103
7.3.1.1.20	aAggFramesRxOK	104
7.3.1.1.21	aAggMulticastFramesTxOK	104
7.3.1.1.22	aAggMulticastFramesRxOK	104
7.3.1.1.23	aAggBroadcastFramesTxOK.....	104
7.3.1.1.24	aAggBroadcastFramesRxOK	105
7.3.1.1.25	aAggFramesDiscardedOnTx	105
7.3.1.1.26	aAggFramesDiscardedOnRx	105
7.3.1.1.27	aAggFramesWithTxErrors	105
7.3.1.1.28	aAggFramesWithRxErrors	106
7.3.1.1.29	aAggUnknownProtocolFrames	106
7.3.1.1.30	aAggPortList.....	106
7.3.1.1.31	aAggLinkUpDownNotificationEnable.....	106
7.3.1.1.32	aAggCollectorMaxDelay.....	106
7.3.1.1.33	aAggPortAlgorithm	107
7.3.1.1.34	aAggPartnerAdminPortAlgorithm.....	107
7.3.1.1.35	aAggConversationAdminLink[]	107
7.3.1.1.36	aAggPartnerAdminPortConversationListDigest	107
7.3.1.1.37	aAggAdminDiscardWrongConversation.....	108
7.3.1.1.38	aAggAdminServiceConversationMap[]	108
7.3.1.1.39	aAggPartnerAdminConvServiceMappingDigest	108
7.3.1.2	Aggregator Notifications	108
7.3.1.2.1	nAggLinkUpNotification.....	108
7.3.1.2.2	nAggLinkDownNotification.....	109
7.3.2	Aggregation Port managed object class.....	109
7.3.2.1	Aggregation Port Attributes.....	109
7.3.2.1.1	aAggPortID.....	109

	7.3.2.1.2	aAggPortActorSystemPriority	109
	7.3.2.1.3	aAggPortActorSystemID	109
	7.3.2.1.4	aAggPortActorAdminKey	110
	7.3.2.1.5	aAggPortActorOperKey	110
	7.3.2.1.6	aAggPortPartnerAdminSystemPriority	110
	7.3.2.1.7	aAggPortPartnerOperSystemPriority	110
	7.3.2.1.8	aAggPortPartnerAdminSystemID	110
	7.3.2.1.9	aAggPortPartnerOperSystemID	111
	7.3.2.1.10	aAggPortPartnerAdminKey	111
	7.3.2.1.11	aAggPortPartnerOperKey	111
	7.3.2.1.12	aAggPortSelectedAggID	111
	7.3.2.1.13	aAggPortAttachedAggID	111
	7.3.2.1.14	aAggPortActorPort	112
	7.3.2.1.15	aAggPortActorPortPriority	112
	7.3.2.1.16	aAggPortPartnerAdminPort	112
	7.3.2.1.17	aAggPortPartnerOperPort	112
	7.3.2.1.18	aAggPortPartnerAdminPortPriority	112
	7.3.2.1.19	aAggPortPartnerOperPortPriority	113
	7.3.2.1.20	aAggPortActorAdminState	113
	7.3.2.1.21	aAggPortActorOperState	113
	7.3.2.1.22	aAggPortPartnerAdminState	113
	7.3.2.1.23	aAggPortPartnerOperState	114
	7.3.2.1.24	aAggPortAggregateOrIndividual	114
	7.3.2.1.25	aAggPortOperConversationPasses	114
	7.3.2.1.26	aAggPortOperConversationCollected	114
	7.3.2.1.27	aAggPortLinkNumberID	114
	7.3.2.1.28	aAggPortPartnerAdminLinkNumberID	115
	7.3.2.1.29	aAggPortWTRTime	115
	7.3.2.2	Aggregation Port Extension Attributes	115
	7.3.2.2.1	aAggPortProtocolDA	115
7.3.3		Aggregation Port Statistics managed object class	115
	7.3.3.1	Aggregation Port Statistics attributes	116
	7.3.3.1.1	aAggPortStatsID	116
	7.3.3.1.2	aAggPortStatsLACPDU Rx	116
	7.3.3.1.3	aAggPortStatsMarkerPDU Rx	116
	7.3.3.1.4	aAggPortStatsMarkerResponsePDU Rx	116
	7.3.3.1.5	aAggPortStatsUnknownRx	116
	7.3.3.1.6	aAggPortStatsIllegalRx	117
	7.3.3.1.7	aAggPortStatsLACPDU Tx	117
	7.3.3.1.8	aAggPortStatsMarkerPDU Tx	117
	7.3.3.1.9	aAggPortStatsMarkerResponsePDU Tx	117
7.3.4		Aggregation Port Debug Information managed object class	117
	7.3.4.1	Aggregation Port Debug Information attributes	117
	7.3.4.1.1	aAggPortDebugInformationID	117
	7.3.4.1.2	aAggPortDebugRxState	118
	7.3.4.1.3	aAggPortDebugLastRxTime	118
	7.3.4.1.4	aAggPortDebugMuxState	118
	7.3.4.1.5	aAggPortDebugMuxReason	119
	7.3.4.1.6	aAggPortDebugActorChurnState	119
	7.3.4.1.7	aAggPortDebugPartnerChurnState	119
	7.3.4.1.8	aAggPortDebugActorChurnCount	119
	7.3.4.1.9	aAggPortDebugPartnerChurnCount	120
	7.3.4.1.10	aAggPortDebugActorSyncTransitionCount	120
	7.3.4.1.11	aAggPortDebugPartnerSyncTransitionCount	120

	7.3.4.1.12	aAggPortDebugActorChangeCount	120
	7.3.4.1.13	aAggPortDebugPartnerChangeCount	120
	7.3.4.1.14	aAggPortDebugActorCDSChurnState	120
	7.3.4.1.15	aAggPortDebugPartnerCDSChurnState	121
	7.3.4.1.16	aAggPortDebugActorCDSChurnCount	121
	7.3.4.1.17	aAggPortDebugPartnerCDSChurnCount	121
7.4		Management for Distributed Resilient Network Interconnect	121
	7.4.1	Distributed Relay Managed Object Class	121
	7.4.1.1	Distributed Relay Attributes	122
	7.4.1.1.1	aDrniID	122
	7.4.1.1.2	aDrniDescription	122
	7.4.1.1.3	aDrniName	122
	7.4.1.1.4	aDrniPortalAddr	122
	7.4.1.1.5	aDrniPortalPriority	122
	7.4.1.1.6	aDrniThreePortalSystem	123
	7.4.1.1.7	aDrniPortalSystemNumber	123
	7.4.1.1.8	aDrniIntraPortalLinkList	123
	7.4.1.1.9	aDrniAggregator	123
	7.4.1.1.10	aDrniConvAdminGateway[]	123
	7.4.1.1.11	aDrniNeighborAdminConvGatewayListDigest	124
	7.4.1.1.12	aDrniNeighborAdminConvPortListDigest	124
	7.4.1.1.13	aDrniGatewayAlgorithm	124
	7.4.1.1.14	aDrniNeighborAdminGatewayAlgorithm	124
	7.4.1.1.15	aDrniNeighborAdminPortAlgorithm	125
	7.4.1.1.16	aDrniNeighborAdminDRCPState	125
	7.4.1.1.17	aDrniEncapsulationMethod	125
	7.4.1.1.18	aDrniIPLEncapMap	125
	7.4.1.1.19	aDrniNetEncapMap	126
	7.4.1.1.20	aDrniDRPortConversationPasses	126
	7.4.1.1.21	aDrniDRGatewayConversationPasses	126
	7.4.1.1.22	aDrniPSI	126
	7.4.1.1.23	aDrniPortConversationControl	127
	7.4.1.1.24	aDrniIntraPortalPortProtocolDA	127
	7.4.2	IPP Managed Objects Class	127
	7.4.2.1	IPP Attributes	127
	7.4.2.1.1	aIPPID	127
	7.4.2.1.2	aIPPPortConversationPasses	127
	7.4.2.1.3	aIPPGatewayConversationDirection	128
	7.4.2.1.4	aIPPAdminState	128
	7.4.2.1.5	aIPPOperState	128
	7.4.2.1.6	aIPPTimeOfLastOperChange	128
	7.4.3	IPP Statistics managed object class	129
	7.4.3.1	IPP Statistics attributes	129
	7.4.3.1.1	aIPPStatsID	129
	7.4.3.1.2	aIPPStatsDRCPDUsRx	129
	7.4.3.1.3	aIPPStatsIllegalRx	129
	7.4.3.1.4	aIPPStatsDRCPDUsTx	129
	7.4.4	IPP Debug Information managed object class	129
	7.4.4.1	IPP Debug Information attributes	130
	7.4.4.1.1	aIPPDebugInformationID	130
	7.4.4.1.2	aIPPDebugDRCPRxState	130
	7.4.4.1.3	aIPPDebugLastRxTime	130
	7.4.4.1.4	aIPPDebugDifferPortalReason	130

8.	Frame distribution and collection algorithms	131
8.1	Conversation Identifiers	131
8.2	Per-service frame distribution	131
8.2.1	Goals and objectives	131
8.2.2	Overview	131
8.2.3	Port Conversation Identifiers	132
9.	Distributed Resilient Network Interconnect	133
9.1	Goals and objectives	133
9.2	Distributed Relay	134
9.3	Distributed Relay operation and procedures	136
9.3.1	Portal Topology	139
9.3.2	Intra-Portal Link	140
9.3.2.1	Network / IPL sharing by time	140
9.3.2.2	Network / IPL sharing by tag	141
9.3.2.3	Network / IPL sharing by encapsulation	141
9.3.3	Protocol Identification	142
9.3.4	DR Function state machines	142
9.3.4.1	Service interfaces	143
9.3.4.2	Per-DR Function variables	143
9.3.4.3	Per-IPP Intra-Portal Port variables	144
9.3.4.4	Functions	144
9.3.4.5	Messages	145
9.3.4.6	DR Function: Aggregator Port reception state machine	145
9.3.4.7	DR Function: Gateway distribution state machine	145
9.3.4.8	DR Function: IPP N reception state machine	146
9.4	Distributed Relay Control Protocol	147
9.4.1	Establishing the Portal and Distributed Relay	149
9.4.2	DRCPDU transmission, addressing, and protocol identification	149
9.4.2.1	Destination MAC Address	149
9.4.2.2	Source MAC Address	150
9.4.2.3	Priority	150
9.4.2.4	Encapsulation of DRCPDUs in frames	150
9.4.3	DRCPDU structure and encoding	150
9.4.3.1	Transmission and representation of octets	150
9.4.3.2	DRCPDU structure	151
9.4.3.3	Conversation Vector TLVs	158
9.4.3.3.1	2P Gateway Conversation Vector TLV	158
9.4.3.3.2	3P Gateway Conversation Vector-1 TLV	159
9.4.3.3.3	3P Gateway Conversation Vector-2 TLV	159
9.4.3.3.4	2P Port Conversation Vector TLV	160
9.4.3.3.5	3P Port Conversation Vector-1 TLV	160
9.4.3.3.6	3P Port Conversation Vector-2 TLV	161
9.4.3.4	Network/IPL sharing TLVs	161
9.4.3.4.1	Network/IPL Sharing Method TLV	162
9.4.3.4.2	Network/IPL Sharing Encapsulation TLV	163
9.4.3.5	Organization-Specific TLV	163
9.4.4	DRCP Control Parser/Multiplexer	164
9.4.4.1	Control Parser state diagram	164
9.4.4.1.1	Control Parser Function	164
9.4.4.1.2	Constants	164
9.4.4.1.3	Variables	164

9.4.5	DRCP state machine overview	165
9.4.6	Constants	166
9.4.7	Variables associated with the Distributed Relay	167
9.4.8	Per-DR Function variables	167
9.4.9	Per-IPP Intra-Portal Port variables	170
9.4.10	Variables used for managing the operation of the state machines	176
9.4.11	Functions	178
9.4.12	Timers	191
9.4.13	Messages	191
9.4.14	DRCPDU Receive machine	191
9.4.15	DRCP Periodic Transmission machine	194
9.4.16	Portal System machine	195
9.4.17	DRNI Gateway and Aggregator machines	196
9.4.18	DRNI IPP machines	197
9.4.19	DRCPDU Transmit machine	198
9.4.20	Network/IPL sharing machine	199
Annex A (normative) Protocol Implementation Conformance Statement (PICS) proforma		201
A.1	Introduction	201
A.1.1	Abbreviations and special symbols	201
A.1.2	Instructions for completing the PICS proforma	202
A.1.3	Additional information	202
A.1.4	Exceptional information	202
A.1.5	Conditional items	203
A.1.6	Identification	203
A.1.6.1	Implementation identification	203
A.1.6.2	Protocol summary	203
A.2	PICS proforma for Clause 6	204
A.2.1	Major capabilities/options	204
A.2.2	LLDP Port connectivity	205
A.2.3	Protocol Parser/Multiplexer support	205
A.2.4	Frame Collector	205
A.2.5	Frame Distributor	206
A.2.6	Marker protocol	206
A.2.7	Aggregator Parser/Multiplexer	206
A.2.8	Control Parser/Multiplexer	207
A.2.9	System identification	207
A.2.10	Aggregator identification	207
A.2.11	Port identification	208
A.2.12	Capability identification	208
A.2.13	Link Aggregation Group identification	208
A.2.14	Detaching a link from an Aggregator	208
A.2.15	LACPDU structure	209
A.2.16	Version 2 LACPDU	209
A.2.17	State machine variables	209
A.2.18	Receive machine	210
A.2.19	Periodic Transmission machine	210
A.2.20	Selection Logic	210
A.2.21	Mux machine	211
A.2.22	Transmit machine	211
A.2.23	Churn Detection machines	212
A.2.24	Marker protocol	212
A.2.25	Management	214

A.2.26	Per-Service Frame Distribution.....	217
A.2.27	Conversation-sensitive frame collection and distribution.....	218
A.2.28	Configuration capabilities and restrictions.....	218
A.2.29	Link Aggregation on shared-medium links.....	219
A.2.30	Distributed Resilient Network Interconnect.....	219
A.2.31	DRCPDU structure.....	220
A.2.32	Bridge specific support.....	221
Annex B (informative)	Collection and distribution algorithms.....	222
B.1	Introduction.....	222
B.2	Port selection.....	223
B.3	Dynamic reallocation of conversations to different Aggregation Ports.....	223
B.4	Topology considerations in the choice of distribution algorithm.....	224
Annex C (informative)	LACP standby link selection and dynamic Key management.....	226
C.1	Introduction.....	226
C.2	Goals.....	226
C.3	Standby link selection.....	227
C.4	Dynamic Key management.....	227
C.5	A dynamic Key management algorithm.....	227
C.6	Example 1.....	229
C.7	Example 2.....	229
Annex D (normative)	SMIPv2 MIB definitions for Link Aggregation.....	231
D.1	Introduction.....	231
D.2	SNMP Management Framework.....	231
D.3	Security considerations.....	231
D.4	Structure of the MIB module.....	232
D.4.1	Relationship to the managed objects defined in Clause 7.....	233
D.4.2	MIB Subtrees.....	238
D.4.2.1	The dot3adAgg Subtree.....	238
D.4.2.2	The dot3adAggPort Subtree.....	238
D.4.2.3	The dot3adAggNotifications Subtree.....	238
D.4.2.4	The dot3adDrni Subtree.....	238
D.4.2.5	The dot3adIPP Subtree.....	238
D.5	Relationship to other MIBs.....	238
D.5.1	Relationship to the Interfaces MIB.....	238
D.5.2	Layering model.....	239
D.5.3	ifStackTable.....	239
D.5.4	ifRevAddressTable.....	239
D.6	Definitions for Link Aggregation MIB.....	239
Annex E (informative)	Distributed Bridge.....	306
E.1	Distributed VLAN Bridge.....	306
E.2	Higher Layer Entities in a Distributed Bridge.....	310

Annex F (normative) Link Layer Discovery Protocol TLVs	311
F.1 Link Aggregation TLV	311
F.1.1 aggregation status	311
F.1.2 aggregated Port ID	312
F.1.3 Link Aggregation TLV usage rules	312
F.1.4 Use of other TLVs on an Aggregator or Aggregation Link	312
Annex G (normative) Network / IPL sharing by time—MAC Address synchronization	314
G.1 Address synchronization—design goals	315
G.2 Address synchronization—non-goals	315
G.3 Protocol summary	315
G.4 Address Synchronization Description	315
G.5 ASPDU transmission, addressing, and protocol identification	317
G.5.1 Destination MAC Address	317
G.5.2 Source MAC Address	317
G.5.3 Priority	317
G.5.4 Encapsulation of ASPDUs in frames	317

IEEE Standard for Local and metropolitan area networks— Link Aggregation

IMPORTANT NOTICE: IEEE Standards documents are not intended to ensure safety, health, or environmental protection, or ensure against interference with or from other devices or networks. Implementers 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.

This IEEE document is made available for use subject to important notices and legal disclaimers. These notices and disclaimers appear in all publications containing this document and may be found under the heading “Important Notice” or “Important Notices and Disclaimers Concerning IEEE Documents.” They can also be obtained on request from IEEE or viewed at <http://standards.ieee.org/IPR/disclaimers.html>.

1. Overview

1.1 Scope

Link Aggregation provides protocols, procedures, and managed objects that allow the following:

- One or more parallel instances of full-duplex point-to-point links to be aggregated together to form a Link Aggregation Group (LAG), such that a MAC Client can treat the LAG as if it were a single link.
- A resilient interconnect using multiple full-duplex point-to-point links among one to three nodes in a network and one to three nodes in another, separately administered, network, along with a means to ensure that frames belonging to any given service will use the same physical path in both directions between the two networks.

This standard defines the MAC-independent Link Aggregation capability and general information relevant to specific MAC types that support Link Aggregation. The capabilities defined are compatible with previous versions of this standard.

1.2 Purpose

Link Aggregation allows the establishment of full-duplex point-to-point links that have a higher aggregate bandwidth than the individual links that form the aggregation, and the use of multiple systems at each end of the aggregation. This allows improved utilization of available links in bridged local area network (LAN) environments, along with improved resilience in the face of failure of individual links or systems. In