

IEEE Standard for Ethernet

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Abstract: Ethernet local area network operation is specified for selected speeds of operation from 1 Mb/s to 100 Gb/s using a common media access control (MAC) specification and management information base (MIB). The Carrier Sense Multiple Access with Collision Detection (CSMA/CD) MAC protocol specifies shared medium (half duplex) operation, as well as full duplex operation. Speed specific Media Independent Interfaces (MIIs) allow use of selected Physical Layer devices (PHY) for operation over coaxial, twisted-pair or fiber optic cables. System considerations for multisegment shared access networks describe the use of Repeaters that are defined for operational speeds up to 1000 Mb/s. Local Area Network (LAN) operation is supported at all speeds. Other specified capabilities include various PHY types for access networks, PHYs suitable for metropolitan area network applications, and the provision of power over selected twisted-pair PHY types.

Keywords: 10BASE; 100BASE; 1000BASE; 10GBASE; 40GBASE; 100GBASE; 10 Gigabit Ethernet; 40 Gigabit Ethernet; 100 Gigabit Ethernet; attachment unit interface; AUI; Auto Negotiation; Backplane Ethernet; data processing; DTE Power via the MDI; EPON; Ethernet; Ethernet in the First Mile; Ethernet passive optical network; Fast Ethernet; Gigabit Ethernet; GMII; information exchange; IEEE 802.3; local area network; management; medium dependent interface; media independent interface; MDI; MIB; MII; PHY; physical coding sublayer; Physical Layer; physical medium attachment; PMA; Power over Ethernet; repeater; type field; VLAN TAG; XGMII

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Participants

The following individuals were officers of the IEEE 802.3 working group at the beginning of the working group ballot of this revision:

David J. Law, *Working Group Chair*
Wael William Diab, *Working Group Vice-Chair*
Adam Healey, *Working Group Secretary*
Steven B. Carlson, *Working Group Executive Secretary*
Valerie Maguire, *Working Group Treasurer*

Wael William Diab, *IEEE P802.3 (802.3bh) Task Force Chair and Chief Editor*
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Peter Anslow, *IEEE P802.3 (802.3bh) Task Force Section Editor*
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Historical participants

The following individuals participated in the IEEE 802.3 working group during various stages of the standard's development. Since the initial publication, many IEEE standards have added functionality or provided updates to material included in this standard. Included is a historical list of participants who have dedicated their valuable time, energy, and knowledge to the creation of this material:

IEEE Std 802.3 document	Date approved by IEEE and ANSI	Officers at the time of working group ballot
IEEE Std 802.3-1985, Original 10 Mb/s standard, MAC, PLS, AUI, 10BASE5	23 June 1983 (IEEE) 31 December 1984 (ANSI)	Donald C. Loughry , <i>Working Group Chair</i>
IEEE Std 802.3a-1988 (Clause 10), 10 Mb/s MAU 10BASE2	15 November 1985 (IEEE) 28 December 1987 (ANSI)	Donald C. Loughry , <i>Working Group Chair</i> Alan Flatman , <i>Task Force Chair</i>
IEEE Std 802.3b-1985 (Clause 11), 10 Mb/s Broad-band MAU, 10BROAD36	19 September 1985 (IEEE) 28 February 1986 (ANSI)	Donald C. Loughry , <i>Working Group Chair</i> Menachem Abraham , <i>Task Force Chair</i>
IEEE Std 802.3c-1985 (9.1–9.8), 10 Mb/s Baseband Repeater	12 December 1985 (IEEE) 4 June 1986 (ANSI)	Donald C. Loughry , <i>Working Group Chair</i> Geoffrey O. Thompson , <i>Task Force Chair</i>
IEEE Std 802.3d-1987 (9.9), 10 Mb/s Fiber MAU, FOIRL	10 December 1987 (IEEE) 9 February 1989 (ANSI)	Donald C. Loughry , <i>Working Group Chair</i> Steven Moustakas , <i>Task Force Chair</i>
IEEE Std 802.3e-1987 (Clause 12), 1 Mb/s MAU and Hub 1BASE5	11 June 1987 (IEEE) 15 December 1987 (ANSI)	Donald C. Loughry , <i>Working Group Chair</i> Robert Galin , <i>Task Force Chair</i>
IEEE Std 802.3h-1990 (Clause 5), 10 Mb/s Layer Management, DTEs	28 September 1990 (IEEE) 11 March 1991 (ANSI)	Donald C. Loughry , <i>Working Group Chair</i> Andy J. Luque , <i>Task Force Chair</i>
IEEE Std 802.3i-1990 (Clauses 13 and 14), 10 Mb/s UTP MAU, 10 BASE-T	28 September 1990 (IEEE) 11 March 1991 (ANSI)	Donald C. Loughry , <i>Working Group Chair</i> Patricia Thaler , <i>Task Force Chair (initial)</i> Richard Anderson , <i>Task Force Chair (final)</i>

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IEEE Std 802.3j-1993 (Clauses 15–18), 10 Mb/s Fiber MAUs 10BASE-FP, 10BASE-FB, and 10BASE-FL	15 September 1993 (IEEE) 15 March 1994 (ANSI)	Patricia Thaler , <i>Working Group Chair</i> Keith Amundsen , <i>Task Force Chair (initial)</i> Frederick Scholl , <i>Task Force Chair (final)</i> Michael E. Lee , <i>Technical Editor</i>
IEEE Std 802.3k-1993 (Clause 19), 10 Mb/s Layer Management, Repeaters	17 September 1992 (IEEE) 8 March 1993 (ANSI)	Patricia Thaler , <i>Working Group Chair</i> Joseph S. Skorupa , <i>Task Force Chair</i> Geoffrey O. Thompson , <i>Vice Chair and Editor</i>
IEEE Std 802.3l-1992 (14.10), 10 Mb/s PICS Proforma 10BASE-T MAU	17 September 1992 (IEEE) 23 February 1993 (ANSI)	Patricia Thaler , <i>Working Group Chair</i> Mike Armstrong , <i>Task Force Chair and Editor</i> Paul Nikolich , <i>Vice Chair</i> William Randle , <i>Editorial Coordinator</i>
IEEE Std 802.3m-1995, Maintenance 2	21 September 1995 (IEEE) 16 July 1996 (ANSI)	Patricia Thaler , <i>Working Group Chair</i> Gary Robinson , <i>Maintenance Chair</i>
IEEE Std 802.3n-1995, Maintenance 3	21 September 1995 (IEEE) 4 April 1996 (ANSI)	Patricia Thaler , <i>Working Group Chair</i> Gary Robinson , <i>Maintenance Chair</i>
IEEE Std 802.3p-1993 (Clause 20), Management, 10 Mb/s Integrated MAUs	17 June 1993 (IEEE) 4 January 1994 (ANSI)	Patricia Thaler , <i>Working Group Chair</i> Joseph S. Skorupa , <i>Task Force Chair</i> Geoffrey O. Thompson , <i>Vice Chair and Editor</i>
IEEE Std 802.3q-1993 (Clause 5), 10 Mb/s Layer Management, GDMO Format	17 June 1993 (IEEE) 4 January 1994 (ANSI)	Patricia Thaler , <i>Working Group Chair</i> Joseph S. Skorupa , <i>Task Force Chair</i> Geoffrey O. Thompson , <i>Vice Chair and Editor</i>
IEEE Std 802.3r-1996 (8.8), Type 10BASE5 Medium Attachment Unit PICS proforma	29 July 1996 (IEEE) 6 January 1997 (ANSI)	Patricia Thaler , <i>Working Group Chair</i> Imre Juhász , <i>Task Force Chair</i> William Randle , <i>Task Force Editor</i>
IEEE Std 802.3s-1995, Maintenance 4	21 September 1995 (IEEE) 8 April 1996 (ANSI)	Geoffrey O. Thompson , <i>Working Group Chair</i> Gary Robinson , <i>Maintenance Chair</i>
IEEE Std 802.3t-1995, 120 Ω informative annex to 10BASE-T	14 June 1995 (IEEE) 12 January 1996 (ANSI)	Geoffrey O. Thompson , <i>Working Group Chair</i> Jacques Christ , <i>Task Force Chair</i>
IEEE Std 802.3u-1995 (Clauses 21–30), Type 100BASE-T MAC param- eters, Physical Layer, MAUs, and Repeater for 100 Mb/s Operation	14 June 1995 (IEEE) 4 April 1996 (ANSI)	Geoffrey O. Thompson , <i>Working Group Chair</i> Peter Tarrant , <i>Task Force Chair (Phase 1)</i> Howard Frazier , <i>Task Force Chair (Phase 2)</i> Paul Sherer , <i>Task Force Editor-in-Chief (Phase 1)</i> Howard Johnson , <i>Task Force Editor-in-Chief (Phase 2)</i> Colin Mick , <i>Task Force Comment Editor</i>
IEEE Std 802.3v-1995, 150 Ω informative annex to 10BASE-T	12 December 1995 (IEEE) 16 July 1996 (ANSI)	Geoffrey O. Thompson , <i>Working Group Chair</i> Larry Nicholson , <i>Task Force Chair</i>
IEEE Std 802.3x-1997 and IEEE Std 802.3y-1997 (Revi- sions to IEEE Std 802.3, Clauses 31 and 32), Full- Duplex Operation and Type 100BASE-T2	20 March 1997 (IEEE) 5 September 1997 (ANSI)	Geoffrey O. Thompson , <i>Working Group Chair</i> David J. Law , <i>Working Group Vice Chair</i> Rich Seifert , <i>Task Force Chair and Editor (802.3x)</i> J. Scott Carter , <i>Task Force Chair (802.3y)</i> Colin Mick , <i>Task Force Editor (802.3y)</i>
IEEE Std 802.3z-1998 (Clauses 34–39, 41–42), Type 1000BASE-X MAC Param- eters, Physical Layer, Repeater, and Management Parameters for 1000 Mb/s Operation	25 June 1998 (IEEE)	Geoffrey O. Thompson , <i>Working Group Chair</i> David J. Law , <i>Working Group Vice Chair</i> Howard M. Frazier, Jr. , <i>Task Force Chair</i> Howard W. Johnson , <i>Task Force Editor</i>
IEEE Std 802.3aa-1998, Maintenance 5	25 June 1998 (IEEE)	Geoffrey O. Thompson , <i>Working Group Chair</i> Colin Mick , <i>Task Force Editor</i>

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IEEE Std 802.3ab-1999 (Clause 40), Physical Layer Parameters and Specifications for 1000 Mb/s Operation Over 4 Pair of Category 5 Balanced Copper Cabling, Type 1000BASE-T	26 June 1999 (IEEE)	Geoffrey O. Thompson , <i>Working Group Chair</i> David J. Law , <i>Working Group Vice Chair</i> Robert M. Grow , <i>Working Group Secretary</i> George Eisler , <i>Task Force Chair</i> Colin Mick , <i>Task Force Editor</i>
IEEE Std 802.3ac-1998, Frame Extensions for Virtual Bridged Local Area Network (VLAN) Tagging on IEEE 802.3 Networks	16 September 1998 (IEEE)	Geoffrey O. Thompson , <i>Working Group Chair</i> David J. Law , <i>Working Group Vice Chair</i> Andy J. Luque , <i>Working Group Secretary</i> Ian Crayford , <i>Task Force Chair</i> Rich Seifert , <i>Task Force Editor</i>
IEEE Std 802.3ad-2000 (Clause 43), Aggregation of Multiple Link Segments	30 March 2000 (IEEE)	Geoffrey O. Thompson , <i>Working Group Chair</i> David J. Law , <i>Working Group Vice Chair</i> Robert M. Grow , <i>Working Group Secretary</i> Steven Haddock , <i>Task Force Chair</i> Tony Jeffree , <i>Task Force Co-Editor</i> Rich Seifert , <i>Task Force CoEditor</i>
IEEE Std 802.3-2002 (IEEE 802.3ag, Maintenance 6, Revision of the base), Carrier Sense Multiple Access with Collision Detection (CSMA/CD) access method and Physical Layer specifications	14 January 2002 (IEEE)	Geoffrey O. Thompson , <i>Working Group Chair</i> David J. Law , <i>Working Group Vice Chair</i> Robert M. Grow , <i>Working Group Secretary</i>
IEEE Std 802.3ae-2002, (Clauses 44–53) Media Access Control (MAC) Parameters, Physical Layers, and Management Parameters for 10 Gb/s Operation	13 June 2002 (IEEE)	Geoffrey O. Thompson , <i>Working Group Chair</i> David J. Law , <i>Working Group Vice Chair</i> Robert M. Grow , <i>Working Group Secretary</i> R. Jonathan Thatcher , <i>Task Force Chair</i> Stephen Haddock , <i>Task Force Vice Chair</i> Bradley J. Booth , <i>Task Force Editor</i> Lacreshia Laningham , <i>Task Force Assistant Editor</i> Benjamin Brown , <i>Logic Track Chair</i> Walter Thirion , <i>Optical Track Chair</i>
IEEE Std 802.3af-2003, (Clause 33) Data Terminal Equipment (DTE) Power via Media Dependent Interface (MDI)	12 June 2003 (IEEE)	Geoffrey O. Thompson , <i>Working Group Chair (Phase 1)</i> Robert M. Grow , <i>Working Group Chair (Phase 2)</i> David J. Law , <i>Working Group Vice Chair</i> Robert M. Grow , <i>Working Group Secretary (Phase 1)</i> Steven B. Carlson , <i>Working Group Secretary (Phase 2)</i> Steven B. Carlson , <i>Task Force Chair</i> Michael S. McCormack , <i>Task Force Editor (Phase 1)</i> John J. Jetzt , <i>Task Force Editor (Phase 2)</i> Chad M. Jones , <i>Task Force Comment Editor</i>
IEEE Std 802.3ah-2004, Media Access Control Parameters, Physical Layers, and Management Parameters for Subscriber Access Networks	6 April 2005 (IEEE)	Robert M. Grow , <i>Working Group Chair</i> David J. Law , <i>Working Group Vice Chair</i> Steven B. Carlson , <i>Working Group Secretary</i> Howard Frazier , <i>Task Force Chair</i> Wael W. Diab , <i>Task Force Editor-in-Chief</i> Hugh Barrass , <i>Task Force Vice-Chair</i> Scott Simon , <i>Task Force Recording Secretary</i> Behrooz Rezvani , <i>Task Force Executive Secretary</i>
IEEE Std 802.3aj-2003, Maintenance 7	11 September 2003 (IEEE)	Robert M. Grow , <i>Working Group Chair</i> David J. Law , <i>Working Group Vice Chair, Task Force Chair</i> Steven B. Carlson , <i>Working Group Secretary</i> Catherine K. N. Berger , <i>Task Force Editor</i>
IEEE Std 802.3ak-2004, Physical Layer and Management Parameters for 10Gb/s Operation, Type 10GBASE-CX4	9 February 2004 (IEEE)	Robert M. Grow , <i>Working Group Chair</i> David J. Law , <i>Working Group Vice Chair</i> Steven B. Carlson , <i>Working Group Secretary</i> Daniel J. Dove , <i>Task Force Chair</i> Howard A. Baumer , <i>Task Force Editor</i>

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IEEE Std 802.3-2005 (IEEE 802.3REVam, Revision of the base), Carrier Sense Multiple Access with Collision Detection (CSMA/CD) access method and Physical Layer specifications	9 June 2005 (IEEE)	Robert M. Grow , <i>Working Group Chair</i> David J. Law , <i>Working Group Vice Chair</i> Wael W. Diab , <i>Secretary</i> Steven B. Carlson , <i>Working Group Executive Secretary</i> Piers Dawe , <i>Review Editor</i>
IEEE Std 802.3an-2006, Physical Layer and Management Parameters for 10 Gb/s Operation, Type 10GBASE-T	8 June 2006 (IEEE)	Robert M. Grow , <i>Working Group Chair</i> David J. Law , <i>Working Group Vice Chair</i> Wael William Diab , <i>Working Group Secretary</i> Steven B. Carlson , <i>Working Group Executive Secretary</i> Bradley Booth , <i>Task Force Chair</i> Sanjay Kasturia , <i>Task Force Editor-in-Chief</i> George Eisler , <i>Task Force Recording Secretary</i>
IEEE Std 802.3ap-2007, Ethernet Operation over Electrical Backplanes	22 March 2007 (IEEE)	Robert M. Grow , <i>Working Group Chair</i> David J. Law , <i>Working Group Vice-Chair</i> Wael W. Diab , <i>Working Group Secretary</i> Steven B. Carlson , <i>Working Group Executive Secretary</i> Bradley Booth , <i>Working Group Treasurer</i> Adam Healey , <i>Task Force Chair</i> John D'Ambrosia , <i>Task Force Secretary</i> Schelto vanDoorn , <i>Task Force Editor-in-Chief (Phase 1)</i> Ilango S. Ganga , <i>Task Force Editor-in-Chief (Phase 2)</i>
IEEE Std 802.3aq-2006, Physical Layer and Management Parameters for 10 Gb/s Operation, Type 10GBASE-LRM	15 September 2006 (IEEE)	Robert M. Grow , <i>Working Group Chair</i> David J. Law , <i>Working Group Vice Chair</i> Wael William Diab , <i>Working Group Secretary</i> Steven B. Carlson , <i>Working Group Executive Secretary</i> David G. Cunningham , <i>Task Force Chair</i> Nick Weiner , <i>Task Force Editor</i> Piers Dawe , <i>Task Force Contributing Editor</i>
IEEE Std 802.3as-2006, Frame format extensions	15 September 2006 (IEEE)	Robert M. Grow , <i>Working Group Chair</i> David J. Law , <i>Working Group Vice Chair</i> Wael William Diab , <i>Working Group Secretary</i> Steven B. Carlson , <i>Working Group Executive Secretary</i> Kevin Q Daines , <i>Task Force Chair</i> Glenn W. Parsons , <i>Task Force Editor</i>
IEEE Std 802.3-2005/Cor 1-2006 (IEEE 802.3au), DTE Power via MDI Isolation corrigendum	8 June 2006 (IEEE)	Robert M. Grow , <i>Working Group Chair</i> David J. Law , <i>Working Group Vice Chair, Task Force Editor</i> Wael W. Diab , <i>Working Group Secretary</i> Steven B. Carlson , <i>Working Group Executive Secretary</i>
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IEEE Std 802.3-2008 (IEEE 802.3ay), Maintenance #9 (Revision of the base), Carrier Sense Multiple Access with Collision Detection (CSMA/CD) access method and Physical Layer specifications	26 September 2008 (IEEE)	Robert M. Grow , <i>Working Group Chair</i> David J. Law , <i>Working Group Vice Chair, Task Force Editor</i> Wael William Diab , <i>Working Group Secretary</i> Steven B. Carlson , <i>Working Group Executive Secretary</i> Bradley Booth , <i>Working Group Treasurer</i>
IEEE Std 802.3at-2009 Data Terminal Equipment (DTE) Power via the Media Dependent Interface (MDI) Enhancements	11 September 2009 (IEEE)	David J. Law , <i>Working Group Chair</i> Wael William Diab , <i>Working Group Vice Chair</i> Adam Healey , <i>Working Group Secretary</i> Steven B. Carlson , <i>Working Group Executive Secretary</i> Bradley Booth , <i>Working Group Treasurer</i> Mike McCormack , <i>Task Force Chair</i> D. Matthew Landry , <i>Task Force Chief Editor</i> Chad Jones , <i>Task Force Comment Editor</i>

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IEEE Std 802.3av-2009 Physical Layer Specifications and Management Parameters for 10 Gb/s Passive Optical Networks	11 September 2009 (IEEE)	David J. Law , <i>Working Group Chair</i> Wael William Diab , <i>Working Group Vice Chair</i> Adam Healey , <i>Working Group Secretary</i> Steven B. Carlson , <i>Working Group Executive Secretary</i> Bradley Booth , <i>Working Group Treasurer</i> Glen Kramer , <i>Task Force Chair</i> Duane Remein , <i>Task Force Chief Editor</i> Marek Hajduczenia , <i>Task Force Assistant Editor</i>
IEEE Std 802.3az-2010 Media Access Control Parameters, Physical Layers, and Management Parameters for Energy-Efficient Ethernet	30 September 2010 (IEEE)	David J. Law , <i>Working Group Chair</i> Wael William Diab , <i>Working Group Vice Chair</i> Steven B. Carlson , <i>Working Group Executive Secretary</i> Adam Healey , <i>Working Group Secretary</i> Bradley Booth , <i>Working Group Treasurer</i> Michael Bennett , <i>Task Force Chair</i> Sanjay Kasturia , <i>Task Force Editor-in-Chief</i>
IEEE Std 802.3ba Media Access Control Parameters, Physical Layers, and Management Parameters for 40 Gb/s and 100 Gb/s Operation	17 June 2010 (IEEE)	David J. Law , <i>Working Group Chair</i> Wael William Diab , <i>Working Group Vice-Chair</i> Steven B. Carlson , <i>Working Group Executive Secretary</i> Adam Healey , <i>Working Group Secretary</i> Bradley Booth , <i>Working Group Treasurer</i> John D'Ambrosia , <i>Task Force Chair</i> Ilango S. Ganga , <i>Task Force Editor-in-Chief</i>
IEEE Std 802.3-2008/Cor 1-2009 (IEEE 802.3bb) Pause Reaction Delay Corrigendum.	9 December 2009 (IEEE)	David J. Law , <i>Working Group Chair</i> Wael William Diab , <i>Working Group Vice-Chair</i> Steven B. Carlson , <i>Working Group Executive Secretary</i> Adam Healey , <i>Working Group Secretary</i> Bradley Booth , <i>Working Group Treasurer</i>
IEEE Std 802.3bc-2009 Ethernet Organizationally Specific Type, Length, Value (TLVs)	11 September 2009 (IEEE)	David J. Law , <i>Working Group Chair and Task Force Editor</i> Wael W. Diab , <i>Working Group Vice Chair; Task Force Chair</i> Steven B. Carlson , <i>Working Group Executive Secretary</i> Adam Healey , <i>Working Group Secretary</i> Bradley Booth , <i>Working Group Treasurer</i>
IEEE Std 802.3bd-2011 MAC Control Frame for Priority-based Flow Control	16 June 2011 (IEEE)	Tony Jeffree , <i>IEEE 802.1 Working Group Chair</i> Paul Congdon , <i>IEEE 802.1 Working Group Vice Chair</i> David J. Law , <i>IEEE 802.3 Working Group Chair</i> Wael W. Diab , <i>IEEE 802.3 Working Group Vice Chair</i> Pat Thaler , <i>Data Center Bridging Task Group Chair</i>
IEEE Std 802.3bf-2011 Media Access Control (MAC) Service Interface and Management Parameters to Support Time Synchronization Protocols	16 May 2011 (IEEE)	David J. Law , <i>Working Group Chair</i> Wael William Diab , <i>Working Group Vice-Chair</i> Adam Healey , <i>Working Group Secretary</i> Steven B. Carlson , <i>Working Group Executive Secretary</i> Valerie Maguire , <i>Working Group Treasurer</i> Steven B. Carlson , <i>Task Force Chair</i> Marek Hajduczenia , <i>Task Force Editor-in-Chief</i>
IEEE Std 802.3bg-2011 Physical Layer and Management Parameters for Serial 40 Gb/s Ethernet Operation Over Single-Mode Fiber	31 March 2011 (IEEE)	David J. Law , <i>Working Group Chair</i> Wael William Diab , <i>Working Group Vice-Chair</i> Adam Healey , <i>Working Group Secretary</i> Steven B. Carlson , <i>Working Group Executive Secretary</i> Valerie Maguire , <i>Working Group Treasurer</i> Mark Nowell , <i>Task Force Chair</i> Pete Anslow , <i>Task Force Editor-in-Chief</i>

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Introduction

This introduction is not part of IEEE Std 802.3-2012, IEEE Standard for Ethernet.

IEEE Std 802.3 was first published in 1985. Since the initial publication, many projects have added functionality or provided maintenance updates to the specifications and text included in this standard. Each IEEE 802.3 project/amendment is identified with a suffix (e.g., IEEE Std 802.3ba™-2010). A historical listing of all projects that have added to or modified IEEE Std 802.3 follows as a part of this introductory material. The listing is in chronological order of project initiation and for each project describes: subject, clauses added (if any), approval dates, and committee officers.

The Media Access Control (MAC) protocol specified in IEEE Std 802.3 is Carrier Sense Multiple Access with Collision Detection (CSMA/CD). This MAC protocol was included in the experimental Ethernet developed at Xerox Palo Alto Research Center. While the experimental Ethernet had a 2.94 Mb/s data rate, IEEE Std 802.3-1985 specified operation at 10 Mb/s. Since 1985, new media options, new speeds of operation, and new capabilities have been added to IEEE Std 802.3.

Some of the major additions to IEEE Std 802.3 are identified in the marketplace with their project number. This is most common for projects adding higher speeds of operation or new protocols. For example, IEEE Std 802.3u™ added 100 Mb/s operation (also called Fast Ethernet), IEEE Std 802.3x specified full duplex operation and a flow control protocol, IEEE Std 802.3z added 1000 Mb/s operation (also called Gigabit Ethernet), IEEE Std 802.3ae added 10 Gb/s operation (also called 10 Gigabit Ethernet), IEEE Std 802.3ah™ specified access network Ethernet (also called Ethernet in the First Mile) and IEEE Std 802.3ba added 40 Gb/s operation (also called 40 Gigabit Ethernet) and 100 Gb/s operation (also called 100 Gigabit Ethernet). These major additions are all now included in and are superseded by IEEE Std 802.3-2012 and are not maintained as separate documents.

IEEE Std 802.3-2012

Section One—Includes Clause 1 through Clause 20 and Annex A through Annex H and Annex 4A. Section One includes the specifications for 10 Mb/s operation and the MAC, frame formats and service interfaces used for all speeds of operation.

Section Two—Includes Clause 21 through Clause 33 and Annex 22A through Annex 33E. Section Two includes management attributes for multiple protocols and speed of operation as well as specifications for providing power over twisted-pair cabling for multiple operational speeds. It also includes general information on 100 Mb/s operation as well as most of the 100 Mb/s Physical Layer specifications.

Section Three—Includes Clause 34 through Clause 43 and Annex 36A through Annex 43C. Section Three includes general information on 1000 Mb/s operation as well as most of the 1000 Mb/s Physical Layer specifications.

Section Four—Includes Clause 44 through Clause 55 and Annex 44A through Annex 55B. Section Four includes general information on 10 Gb/s operation as well as most of the 10 Gb/s Physical Layer specifications.

Section Five—Includes Clause 56 through Clause 77 and Annex 57A through Annex 76A. Clause 56 through Clause 67 and Clause 75 through Clause 77, as well as associated annexes, specify subscriber access and other Physical Layers and sublayers for operation from 512 kb/s to 10 Gb/s, and defines services and protocol elements that enable the exchange of IEEE Std 802.3 format frames between stations in a subscriber access network. Clause 68 specifies a 10 Gb/s Physical Layer specification.

Clause 69 through Clause 74 and associated annexes specify Ethernet operation over electrical backplanes at speeds of 1000 Mb/s and 10 Gb/s.

Section Six—Includes Clause 78 through Clause 90 and Annex 83A through Annex 86A. Clause 78 specifies Energy-Efficient Ethernet. Clause 79 specifies IEEE 802.3 Organizationally Specific Link Layer Discovery Protocol (LLDP) type, length, and value (TLV) information elements. Clause 80 through Clause 89 and associated annexes includes general information on 40 Gb/s and 100 Gb/s operation as well the 40 Gb/s and 100 Gb/s Physical Layer specifications. Clause 90 specifies Ethernet support for time synchronization protocols.

IEEE Std 802.3 will continue to evolve. New Ethernet capabilities are anticipated to be added within the next few years as amendments to this standard.

List of special symbols

For the benefit of users who have received this document by electronic means, what follows is a list of special symbols and operators. If any of these symbols or operators fail to print out correctly, the editors apologize and hope that this table will at least help to sort out the meaning of the resulting funny-shaped blobs and strokes.

Special symbols and operators

Printed character	Meaning	Font
*	Boolean AND	Symbol
+	Boolean OR, arithmetic addition	Symbol
^	Boolean XOR	Times New Roman
!	Boolean NOT	Symbol
×	Multiplication	Symbol
<	Less than	Symbol
≤	Less than or equal to	Symbol
>	Greater than	Symbol
≥	Greater than or equal to	Symbol
=	Equal to	Symbol
≈	Approximately equal to	Symbol
≠	Not equal to	Symbol
←	Assignment operator	Symbol
∈	Indicates membership	Symbol
∉	Indicates nonmembership	Symbol
±	Plus or minus (a tolerance)	Symbol
°	Degrees	Symbol
Σ	Summation	Symbol
√	Square root	Symbol
—	Big dash (em dash)	Times New Roman
–	Little dash (en dash), subtraction	Times New Roman
	Vertical bar	Times New Roman
†	Dagger	Times New Roman
‡	Double dagger	Times New Roman
α	Lower case alpha	Symbol
β	Lower case beta	Symbol
γ	Lower case gamma	Symbol
δ	Lower case delta	Symbol
ε	Lower case epsilon	Symbol
λ	Lower case lambda	Symbol
μ	Lower case mu	Times New Roman
Π	Upper case pi	Symbol
Ω	Upper case omega	Symbol

IEEE Standard for Ethernet

SECTION ONE

This section includes Clause 1 through Clause 20, Annex A through Annex H, and Annex 4A.

Contents

1. Introduction.....	1
1.1 Overview.....	1
1.1.1 Scope.....	1
1.1.2 Basic concepts.....	2
1.1.2.1 Half duplex operation	2
1.1.2.2 Full duplex operation	2
1.1.3 Architectural perspectives.....	2
1.1.3.1 Architectural rationale	3
1.1.3.2 Compatibility interfaces.....	3
1.1.4 Layer interfaces.....	6
1.1.5 Application areas	6
1.2 Notation	6
1.2.1 State diagram conventions	6
1.2.2 Service specification method and notation	7
1.2.2.1 Classification of service primitives.....	8
1.2.3 Physical Layer and media notation	8

1.2.4	Physical Layer message notation	9
1.2.5	Hexadecimal notation	9
1.2.6	Accuracy and resolution of numerical quantities	9
1.3	Normative references	9
1.4	Definitions	16
1.5	Abbreviations	44
2.	Media Access Control (MAC) service specification	49
2.1	Scope and field of application	49
2.2	Overview of the service	49
2.2.1	General description of services provided by the layer	49
2.2.2	Model used for the service specification	49
2.2.3	Overview of interactions	49
2.2.4	Basic services	50
2.3	Detailed service specification	50
2.3.1	MA_DATA.request	50
2.3.1.1	Function	50
2.3.1.2	Semantics of the service primitive	50
2.3.1.3	When generated	50
2.3.1.4	Effect of receipt	50
2.3.1.5	Additional comments	50
2.3.2	MA_DATA.indication	51
2.3.2.1	Function	51
2.3.2.2	Semantics of the service primitive	51
2.3.2.3	When generated	51
2.3.2.4	Effect of receipt	52
2.3.2.5	Additional comments	52
3.	Media Access Control (MAC) frame and packet specifications	53
3.1	Overview	53
3.1.1	Packet format	53
3.1.2	Service interface mappings	54
3.2	Elements of the MAC frame and packet	54
3.2.1	Preamble field	54
3.2.2	Start Frame Delimiter (SFD) field	54
3.2.3	Address fields	54
3.2.3.1	Address designation	55
3.2.4	Destination Address field	55
3.2.5	Source Address field	56
3.2.6	Length/Type field	56
3.2.7	MAC Client Data field	56
3.2.8	Pad field	57
3.2.9	Frame Check Sequence (FCS) field	57
3.2.10	Extension field	57
3.3	Order of bit transmission	58
3.4	Invalid MAC frame	58
4.	Media Access Control	59
4.1	Functional model of the MAC method	59
4.1.1	Overview	59
4.1.2	CSMA/CD operation	60

4.1.2.1	Normal operation	60
4.1.2.1.1	Transmission without contention	60
4.1.2.1.2	Reception without contention	61
4.1.2.2	Access interference and recovery	61
4.1.3	Relationships to the MAC client and Physical Layers	62
4.2	CSMA/CD Media Access Control (MAC) method: Precise specification	62
4.2.1	Introduction	62
4.2.2	Overview of the procedural model	62
4.2.2.1	Ground rules for the procedural model	63
4.2.2.2	Use of Pascal in the procedural model	63
4.2.2.3	Organization of the procedural model	64
4.2.2.4	Layer management extensions to procedural model	64
4.2.3	Packet transmission model	64
4.2.3.1	Transmit data encapsulation	65
4.2.3.2	Transmit media access management	70
4.2.3.2.1	Deference	70
4.2.3.2.2	Interpacket gap	70
4.2.3.2.3	Collision handling (half duplex mode only)	71
4.2.3.2.4	Collision detection and enforcement (half duplex mode only)	71
4.2.3.2.5	Collision backoff and retransmission (half duplex mode only)	71
4.2.3.2.6	Full duplex transmission	72
4.2.3.2.7	Packet bursting (half duplex mode only)	72
4.2.3.3	Minimum frame size	72
4.2.3.4	Carrier extension (half duplex mode only)	73
4.2.4	Frame reception model	73
4.2.4.1	Receive data decapsulation	73
4.2.4.1.1	Address recognition	73
4.2.4.1.2	Frame check sequence validation	74
4.2.4.1.3	Frame disassembly	74
4.2.4.2	Receive media access management	74
4.2.4.2.1	Framing	74
4.2.4.2.2	Collision filtering	74
4.2.5	Preamble generation	75
4.2.6	Start frame sequence	75
4.2.7	Global declarations	75
4.2.7.1	Common constants, types, and variables	75
4.2.7.2	Transmit state variables	77
4.2.7.3	Receive state variables	78
4.2.7.4	State variable initialization	78
4.2.8	Frame transmission	79
4.2.9	Frame reception	86
4.2.10	Common procedures	89
4.3	Interfaces to/from adjacent layers	90
4.3.1	Overview	90
4.3.2	MAC service	90
4.3.2.1	MAC client transmit interface state diagram	90
4.3.2.1.1	Variables	90
4.3.2.1.2	Functions	91
4.3.2.1.3	Messages	91
4.3.2.1.4	MAC client transmit interface state diagram	91
4.3.2.2	MAC client receive interface state diagram	92
4.3.2.2.1	Variables	92
4.3.2.2.2	Functions	92
4.3.2.2.3	Messages	92

4.3.2.2.4	MAC client receive interface state diagram	93
4.3.3	Services required from the Physical Layer	93
4.4	Specific implementations.....	95
4.4.1	Compatibility overview	95
4.4.2	MAC parameters.....	96
4.4.3	Configuration guidelines.....	97
5.	Layer Management	99
5.1	Introduction.....	99
5.1.1	Systems Management overview	99
5.1.2	Layer Management model	99
5.1.3	Packages.....	100
5.1.4	Conformance requirements.....	100
5.2	Management facilities.....	100
5.2.1	Introduction.....	100
5.2.2	DTE MAC Sublayer Management facilities	100
5.2.2.1	DTE MAC sublayer attributes	102
5.2.2.1.1	aMACID	102
5.2.2.1.2	aFramesTransmittedOK	102
5.2.2.1.3	aSingleCollisionFrames	102
5.2.2.1.4	aMultipleCollisionFrames	102
5.2.2.1.5	aFramesReceivedOK	103
5.2.2.1.6	aFrameCheckSequenceErrors	103
5.2.2.1.7	aAlignmentErrors.....	103
5.2.2.1.8	aOctetsTransmittedOK	103
5.2.2.1.9	aFramesWithDeferredXmissions.....	104
5.2.2.1.10	aLateCollisions	104
5.2.2.1.11	aFramesAbortedDueToXSColls	104
5.2.2.1.12	aFramesLostDueToIntMACXmitError	104
5.2.2.1.13	aCarrierSenseErrors	105
5.2.2.1.14	aOctetsReceivedOK.....	105
5.2.2.1.15	aFramesLostDueToIntMACRcvError	105
5.2.2.1.16	aPromiscuousStatus	105
5.2.2.1.17	aReadMulticastAddressList	106
5.2.2.1.18	aMulticastFramesXmittedOK	106
5.2.2.1.19	aBroadcastFramesXmittedOK	106
5.2.2.1.20	aFramesWithExcessiveDeferral.....	106
5.2.2.1.21	aMulticastFramesReceivedOK	107
5.2.2.1.22	aBroadcastFramesReceivedOK	107
5.2.2.1.23	aInRangeLengthErrors.....	107
5.2.2.1.24	aOutOfRangeLengthField.....	107
5.2.2.1.25	aFrameTooLongErrors.....	108
5.2.2.1.26	aMACEnableStatus.....	108
5.2.2.1.27	aTransmitEnableStatus	108
5.2.2.1.28	aMulticastReceiveStatus	108
5.2.2.1.29	aReadWriteMACAddress	109
5.2.2.1.30	aCollisionFrames	109
5.2.2.2	DTE MAC Sublayer actions	109
5.2.2.2.1	acInitializeMAC.....	109
5.2.2.2.2	acAddGroupAddress.....	109
5.2.2.2.3	acDeleteGroupAddress	110
5.2.2.2.4	acExecuteSelfTest.....	110
5.2.2.3	ResourceTypeID Managed Object Class	110

5.2.2.3.1	ResourceTypeID	110
5.2.3	DTE Physical Sublayer Management facilities	110
5.2.3.1	DTE Physical Sublayer attributes	110
5.2.3.1.1	aPHYID	110
5.2.3.1.2	aSQETestErrors	110
5.2.4	DTE Management procedural model	111
5.2.4.1	Common constants and types	111
5.2.4.2	Transmit variables and procedures	111
5.2.4.3	Receive variables and procedures	113
5.2.4.4	Common procedures	115
6.	Physical Signaling (PLS) service specifications	117
6.1	Scope and field of application	117
6.2	Overview of the service	117
6.2.1	General description of services provided by the layer	117
6.2.2	Model used for the service specification	117
6.2.3	Overview of interactions	117
6.2.4	Basic services and options	118
6.3	Detailed service specification	118
6.3.1	Peer-to-peer service primitives	118
6.3.1.1	PLS_DATA.request	118
6.3.1.1.1	Function	118
6.3.1.1.2	Semantics of the service primitive	118
6.3.1.1.3	When generated	118
6.3.1.1.4	Effect of receipt	118
6.3.1.2	PLS_DATA.indication	119
6.3.1.2.1	Function	119
6.3.1.2.2	Semantics of the service primitive	119
6.3.1.2.3	When generated	119
6.3.1.2.4	Effect of receipt	119
6.3.2	Sublayer-to-sublayer service primitives	119
6.3.2.1	PLS_CARRIER.indication	119
6.3.2.1.1	Function	119
6.3.2.1.2	Semantics of the service primitive	119
6.3.2.1.3	When generated	119
6.3.2.1.4	Effect of receipt	119
6.3.2.2	PLS_SIGNAL.indication	120
6.3.2.2.1	Function	120
6.3.2.2.2	Semantics of the service primitive	120
6.3.2.2.3	When generated	120
6.3.2.2.4	Effect of receipt	120
6.3.2.3	PLS_DATA_VALID.indication	120
6.3.2.3.1	Function	120
6.3.2.3.2	Semantics of the service primitive	120
6.3.2.3.3	When generated	120
6.3.2.3.4	Effect of receipt	120
7.	Physical Signaling (PLS) and Attachment Unit Interface (AUI) specifications	121
7.1	Scope	121
7.1.1	Definitions	121
7.1.2	Summary of major concepts	121
7.1.3	Application	122

7.1.4	Modes of operation	122
7.1.5	Allocation of function	122
7.2	Functional specification	122
7.2.1	PLS–PMA (DTE–MAU) Interface protocol	122
7.2.1.1	PLS to PMA messages	123
7.2.1.1.1	output message	123
7.2.1.1.2	output_idle message	124
7.2.1.1.3	normal message	124
7.2.1.1.4	isolate message (optional)	124
7.2.1.1.5	mau_request message (optional)	124
7.2.1.2	PMA to PLS interface	126
7.2.1.2.1	input message	126
7.2.1.2.2	input_idle message	128
7.2.1.2.3	signal_quality_error message	128
7.2.1.2.4	mau_available message	128
7.2.1.2.5	mau_not_available message (optional)	128
7.2.2	PLS interface to MAC and management entities	129
7.2.2.1	PLS–MAC interface	129
7.2.2.1.1	OUTPUT_UNIT	129
7.2.2.1.2	OUTPUT_STATUS	129
7.2.2.1.3	INPUT_UNIT	129
7.2.2.1.4	CARRIER_STATUS	129
7.2.2.1.5	SIGNAL_STATUS	130
7.2.2.1.6	DATA_VALID_STATUS	130
7.2.2.2	PLS–management entity interface	130
7.2.2.2.1	RESET_REQUEST	130
7.2.2.2.2	RESET_RESPONSE	131
7.2.2.2.3	MODE_CONTROL	131
7.2.2.2.4	SQE_TEST	131
7.2.3	Frame structure	131
7.2.3.1	Silence	132
7.2.3.2	Preamble	132
7.2.3.3	Start of Frame Delimiter (SFD)	132
7.2.3.4	Data	132
7.2.3.5	End of transmission delimiter	132
7.2.4	PLS functions	132
7.2.4.1	Reset and Identify function	133
7.2.4.2	Mode function	133
7.2.4.3	Output function	134
7.2.4.4	Input function	134
7.2.4.5	Error Sense function	134
7.2.4.6	Carrier Sense function	135
7.3	Signal characteristics	135
7.3.1	Signal encoding	135
7.3.1.1	Data encoding	135
7.3.1.2	Control encoding	139
7.3.2	Signaling rate	140
7.3.3	Signaling levels	140
7.4	Electrical characteristics	140
7.4.1	Driver characteristics	140
7.4.1.1	Differential output voltage, loaded	140
7.4.1.2	Requirements after idle	142
7.4.1.3	AC common-mode output voltage	142
7.4.1.4	Differential output voltage, open circuit	142

7.4.1.5	DC common-mode output voltage	142
7.4.1.6	Fault tolerance	143
7.4.2	Receiver characteristics	143
7.4.2.1	Receiver threshold levels	143
7.4.2.2	AC differential input impedance	144
7.4.2.3	AC common-mode range	144
7.4.2.4	Total common-mode range	144
7.4.2.5	Idle input behavior	145
7.4.2.6	Fault tolerance	145
7.4.3	AUI cable characteristics	145
7.4.3.1	Conductor size	146
7.4.3.2	Pair-to-pair balanced crosstalk	146
7.4.3.3	Differential characteristic impedance	146
7.4.3.4	Transfer impedance	146
7.4.3.5	Attenuation	146
7.4.3.6	Timing jitter	146
7.4.3.7	Delay	146
7.5	Functional description of interchange circuits	147
7.5.1	General	147
7.5.2	Definition of interchange circuits	147
7.5.2.1	Circuit DO—Data Out	148
7.5.2.2	Circuit DI—Data In	148
7.5.2.3	Circuit CO—Control Out (optional)	148
7.5.2.4	Circuit CI—Control In	148
7.5.2.5	Circuit VP—Voltage Plus	149
7.5.2.6	Circuit VC—Voltage Common	149
7.5.2.7	Circuit PG—Protective Ground	149
7.5.2.8	Circuit shield terminations	149
7.6	Mechanical characteristics	149
7.6.1	Definition of mechanical interface	149
7.6.2	Line interface connector	149
7.6.3	Contact assignments	150
8.	Medium Attachment Unit and baseband medium specifications, type 10BASE5	153
8.1	Scope	153
8.1.1	Overview	153
8.1.1.1	Medium Attachment Unit	153
8.1.1.2	Repeater unit	154
8.1.2	Definitions	154
8.1.3	Application perspective: MAU and MEDIUM objectives	154
8.1.3.1	Object	154
8.1.3.2	Compatibility considerations	154
8.1.3.3	Relationship to PLS and AU interface	155
8.1.3.4	Modes of operation	155
8.2	MAU functional specifications	155
8.2.1	MAU Physical Layer functions	155
8.2.1.1	Transmit function requirements	155
8.2.1.2	Receive function requirements	156
8.2.1.3	Collision Presence function requirements	157
8.2.1.4	Monitor function requirements (optional)	157
8.2.1.5	Jabber function requirements	158
8.2.2	MAU interface messages	158
8.2.2.1	DTE Physical Layer to MAU Physical Layer messages	158

8.2.2.2	MAU Physical Layer to DTE Physical Layer	159
8.2.2.2.1	input message.....	159
8.2.2.2.2	input_idle message.....	159
8.2.2.2.3	mau_available message.....	159
8.2.2.2.4	signal_quality_error message	159
8.2.3	MAU state diagrams	160
8.3	MAU—medium electrical characteristics	160
8.3.1	MAU-to-coaxial cable interface	160
8.3.1.1	Input impedance.....	160
8.3.1.2	Bias current.....	161
8.3.1.3	Coaxial cable signaling levels.....	161
8.3.1.4	Transmit output levels symmetry	167
8.3.1.5	Collision detect thresholds.....	167
8.3.2	MAU electrical characteristics.....	167
8.3.2.1	Electrical isolation	167
8.3.2.2	Power consumption.....	168
8.3.2.3	Reliability.....	168
8.3.3	MAU—DTE electrical characteristics.....	168
8.3.4	MAU—DTE mechanical connection.....	168
8.4	Characteristics of the coaxial cable	168
8.4.1	Coaxial cable electrical parameters	168
8.4.1.1	Characteristic impedance.....	168
8.4.1.2	Attenuation.....	168
8.4.1.3	Velocity of propagation	169
8.4.1.4	Edge jitter, untapped cable.....	169
8.4.1.5	Transfer impedance.....	169
8.4.1.6	Cable dc loop resistance	169
8.4.2	Coaxial cable properties.....	170
8.4.2.1	Mechanical requirements	170
8.4.2.1.1	General construction	170
8.4.2.1.2	Center conductor	170
8.4.2.1.3	Dielectric material.....	170
8.4.2.1.4	Shielding system	170
8.4.2.1.5	Overall jacket.....	170
8.4.2.2	Jacket marking	171
8.4.3	Total segment dc loop resistance	171
8.5	Coaxial trunk cable connectors.....	171
8.5.1	Inline coaxial extension connector	171
8.5.2	Coaxial cable terminator.....	172
8.5.2.1	Termination.....	172
8.5.2.2	Earthing.....	172
8.5.3	MAU-to-coaxial cable connection.....	172
8.5.3.1	Electrical requirements	172
8.5.3.2	Mechanical requirements	173
8.5.3.2.1	Connector housing	173
8.5.3.2.2	Contact reliability	173
8.5.3.2.3	Shield probe characteristics	174
8.6	System considerations.....	174
8.6.1	Transmission system model.....	174
8.6.2	Transmission system requirements	175
8.6.2.1	Cable sectioning.....	175
8.6.2.2	MAU placement.....	175
8.6.2.3	Trunk cable system grounding.....	175
8.6.3	Labeling	176

8.7	Environmental specifications.....	176
8.7.1	General safety requirements	176
8.7.2	Network safety requirements	176
8.7.2.1	Installations	176
8.7.2.2	Grounding	177
8.7.2.3	Safety	177
8.7.2.4	Breakdown path	177
8.7.2.5	Isolation boundary	177
8.7.2.6	Installation and maintenance guidelines	177
8.7.3	Electromagnetic environment	178
8.7.3.1	Susceptibility levels	178
8.7.3.2	Emission levels	178
8.7.4	Temperature and humidity	178
8.7.5	Regulatory requirements.....	178
8.8	Protocol implementation conformance statement (PICS) proforma for Clause 8, Medium Attachment Unit and baseband medium specifications, type 10BASE5.....	179
8.8.1	Overview.....	179
8.8.2	Abbreviations and special symbols.....	179
8.8.2.1	Status symbols	179
8.8.2.2	Abbreviations.....	179
8.8.3	Instructions for completing the PICS proforma.....	179
8.8.3.1	General structure of the PICS proforma	179
8.8.3.2	Additional information	180
8.8.3.3	Exception information	180
8.8.3.4	Conditional items	180
8.8.4	Identification	181
8.8.4.1	Implementation identification.....	181
8.8.4.2	Protocol summary.....	181
8.8.5	Global statement of conformance	181
8.8.6	PICS proforma tables for MAU	182
8.8.6.1	MAU compatibility.....	182
8.8.6.2	Transmit function	182
8.8.6.3	Receive function	183
8.8.6.4	Collision function	184
8.8.6.5	Monitor function	184
8.8.6.6	Jabber function	185
8.8.6.7	MAU to coaxial cable interface	186
8.8.6.8	MAU electrical characteristics	187
8.8.6.9	MAU-DTE requirements	187
8.8.6.10	MAU to coaxial cable connection	188
8.8.6.11	Safety requirements	188
8.8.7	PICS proforma tables for MAU AUI characteristics.....	189
8.8.7.1	Signal characteristics	189
8.8.7.2	DI and CI driver characteristics	189
8.8.7.3	DO receiver characteristics	190
8.8.7.4	CO receiver characteristics	191
8.8.7.5	Circuit termination.....	191
8.8.7.6	Mechanical characteristics	192
8.8.8	PICS proforma tables for 10BASE5 coaxial cable.....	193
8.8.8.1	10BASE5 coaxial cable characteristics	193
9.	Repeater unit for 10 Mb/s baseband networks.....	195
9.1	Overview.....	195

9.2	References	196
9.3	Definitions	196
9.4	Compatibility interface	196
9.4.1	AUI compatibility	196
9.4.2	Mixing segment compatibility	196
9.4.2.1	Direct coaxial cable attachment compatibility	196
9.4.2.2	“N” connector compatibility	196
9.4.2.3	BNC compatibility	196
9.4.2.4	BFOC/2.5 (10BASE-FP) compatibility	196
9.4.3	Link segment compatibility	197
9.4.3.1	Vendor-dependent IRL	197
9.4.3.2	Fiber optic FOIRL compatibility	197
9.4.3.3	Twisted-pair jack compatibility	197
9.4.3.4	Fiber optic 10BASE-FB and 10BASE-FL compatibility	197
9.5	Basic functions	197
9.5.1	Repeater set network properties	197
9.5.2	Signal amplification	197
9.5.3	Signal symmetry	197
9.5.4	Signal retiming	198
9.5.5	Data handling	198
9.5.5.1	Start-of-packet propagation delays	198
9.5.5.2	Start-of-packet variability	198
9.5.6	Collision handling	199
9.5.6.1	Collision presence	199
9.5.6.2	Jam generation	199
9.5.6.3	Collision-jam propagation delays	199
9.5.6.4	Transmit recovery time	200
9.5.6.5	Carrier recovery time	200
9.5.7	Electrical isolation	200
9.6	Detailed repeater functions and state diagrams	201
9.6.1	State diagram notation	201
9.6.2	Data and collision handling	204
9.6.3	Preamble regeneration	204
9.6.4	Fragment extension	204
9.6.5	MAU Jabber Lockup Protection	205
9.6.6	Auto-Partitioning/Reconnection (optional)	205
9.6.6.1	Overview	205
9.6.6.2	Detailed auto-partition/reconnection algorithm state diagram	205
9.7	Electrical isolation	208
9.7.1	Environment A requirements	208
9.7.2	Environment B requirements	208
9.8	Reliability	208
9.9	Medium attachment unit and baseband medium specification for a vendor-independent FOIRL	209
9.9.1	Scope	209
9.9.1.1	Overview	209
9.9.1.2	Application perspective: FOMAU and medium objectives	211
9.9.1.3	Compatibility considerations	211
9.9.1.4	Relationship to AUI	211
9.9.1.5	Mode of operation	211
9.9.2	FOMAU functional specifications	211
9.9.2.1	Transmit function requirements	212
9.9.2.2	Receive function requirements	213
9.9.2.3	Collision Presence function requirements	213

9.9.2.4	Jabber function requirements.....	214
9.9.2.5	Low Light Level Detection function requirements.....	214
9.9.2.6	Repeater Unit to FOMAU Physical Layer messages.....	215
9.9.2.7	FOMAU Physical Layer to repeater unit messages.....	215
9.9.2.7.1	input message.....	215
9.9.2.7.2	input_idle message.....	215
9.9.2.7.3	fomau_available message	215
9.9.2.7.4	signal_quality_error message	215
9.9.2.8	FOMAU state diagrams	216
9.9.3	FOMAU electrical characteristics	217
9.9.3.1	Electrical isolation	217
9.9.3.2	Power consumption.....	217
9.9.3.3	Reliability.....	218
9.9.3.4	FOMAU/Repeater unit electrical characteristics	218
9.9.3.5	FOMAU/Repeater unit mechanical connection.....	218
9.9.4	FOMAU/Optical medium interface	218
9.9.4.1	Transmit optical parameters.....	218
9.9.4.1.1	Wavelength	218
9.9.4.1.2	Spectral width	218
9.9.4.1.3	Optical modulation	218
9.9.4.1.4	Optical idle signal	218
9.9.4.1.5	Transmit optical logic polarity.....	218
9.9.4.1.6	Optical rise and fall times	220
9.9.4.1.7	Transmit optical pulse edge jitter.....	220
9.9.4.1.8	Peak coupled optical power	221
9.9.4.2	Receive optical parameters	221
9.9.4.2.1	Receive peak optical power range	221
9.9.4.2.2	Receive optical pulse edge jitter	221
9.9.4.2.3	Receive optical logic polarity	221
9.9.5	Characteristics of the optical fiber cable link segment.....	221
9.9.5.1	Optical fiber medium	222
9.9.5.2	Optical medium connector plug and socket.....	222
9.9.6	System requirements.....	222
9.9.6.1	Optical transmission system considerations	222
9.9.6.2	Timing considerations.....	223
9.9.7	Environmental specifications.....	224
9.9.7.1	Safety requirements	224
9.9.7.1.1	Electrical safety.....	224
9.9.7.1.2	Optical source safety.....	224
9.9.7.2	Electromagnetic environment.....	224
9.9.7.2.1	Susceptibility levels	224
9.9.7.2.2	Emission levels	224
9.9.7.3	Temperature and humidity	225
10.	Medium attachment unit and baseband medium specifications, type 10BASE2	227
10.1	Scope.....	227
10.1.1	Overview.....	227
10.1.1.1	Medium attachment unit (normally contained within the data terminal equipment [DTE]).....	228
10.1.1.2	Repeater unit	228
10.1.2	Definitions	228
10.1.3	Application perspective: MAU and medium objectives.....	228
10.1.3.1	Object.....	228

10.1.3.2	Compatibility considerations	229
10.1.3.3	Relationship to PLS and AUI	229
10.1.3.4	Mode of operation.....	229
10.2	References.....	229
10.3	MAU functional specifications	229
10.3.1	MAU Physical Layer functional requirements	230
10.3.1.1	Transmit function requirements.....	230
10.3.1.2	Receive function requirements	231
10.3.1.3	Collision Presence function requirements	231
10.3.1.4	Jabber functional requirements.....	232
10.3.2	MAU interface messages	232
10.3.2.1	DTE to MAU messages	232
10.3.2.2	MAU to DTE messages	232
10.3.2.2.1	input message.....	234
10.3.2.2.2	input_idle message.....	234
10.3.2.2.3	mau_available message.....	234
10.3.2.2.4	signal_quality_error (SQE) message	234
10.3.3	MAU state diagrams	234
10.4	MAU–medium electrical characteristics	235
10.4.1	MAU-to-coaxial cable interface	235
10.4.1.1	Input impedance.....	235
10.4.1.2	Bias current.....	235
10.4.1.3	Coaxial cable signaling levels.....	235
10.4.1.4	Transmit output levels symmetry	237
10.4.1.5	Collision detect thresholds.....	237
10.4.2	MAU electrical characteristics.....	237
10.4.2.1	Electrical isolation	237
10.4.2.2	Power consumption.....	237
10.4.2.3	Reliability.....	238
10.4.3	MAU–DTE electrical characteristics.....	238
10.5	Characteristics of coaxial cable system	238
10.5.1	Coaxial cable electrical parameters	238
10.5.1.1	Characteristic impedance	238
10.5.1.2	Attenuation.....	238
10.5.1.3	Velocity of propagation	238
10.5.1.4	Edge jitter; entire segment without DTEs attached	238
10.5.1.5	Transfer impedance.....	239
10.5.1.6	Cable dc loop resistance	239
10.5.2	Coaxial cable physical parameters.....	239
10.5.2.1	Mechanical requirements	239
10.5.2.1.1	General construction	240
10.5.2.1.2	Center conductor	240
10.5.2.1.3	Dielectric material.....	240
10.5.2.1.4	Shielding system	240
10.5.2.1.5	Overall jacket.....	240
10.5.2.2	Jacket marking	240
10.5.3	Total segment dc loop resistance	240
10.6	Coaxial trunk cable connectors.....	241
10.6.1	In-line coaxial extension connector	241
10.6.2	Coaxial cable terminator.....	242
10.6.3	MAU-to-coaxial cable connection.....	242
10.7	System considerations.....	242
10.7.1	Transmission system model.....	242
10.7.2	Transmission system requirements	244

10.7.2.1	Cable sectioning.....	244
10.7.2.2	MAU placement.....	244
10.7.2.3	Trunk cable system earthing	244
10.7.2.4	Static discharge path	244
10.7.2.4.1	Installation environment	244
10.8	Environmental specifications.....	245
10.8.1	Safety requirements	245
10.8.1.1	Installations	245
10.8.1.2	Earthing.....	245
10.8.2	Electromagnetic environment	245
10.8.2.1	Susceptibility levels	245
10.8.2.2	Emission levels	245
10.8.3	Regulatory requirements.....	245
11.	Broadband medium attachment unit and broadband medium specifications, type 10BROAD36	247
11.1	Scope.....	247
11.1.1	Overview.....	247
11.1.2	Definitions	249
11.1.3	MAU and medium objectives	249
11.1.4	Compatibility considerations	250
11.1.5	Relationship to PLS and AUI	250
11.1.6	Mode of operation.....	250
11.2	MAU functional specifications	250
11.2.1	MAU functional requirements	250
11.2.1.1	Transmit function requirements.....	250
11.2.1.2	Receive function requirements	251
11.2.1.3	Collision Detection function requirements	251
11.2.1.3.1	Collision enforcement transmitter requirements.....	252
11.2.1.3.2	Collision enforcement detection requirements	252
11.2.1.4	Jabber function requirements.....	252
11.2.2	DTE PLS to MAU and MAU to DTE PLS messages	253
11.2.2.1	DTE Physical Layer to MAU Physical Layer messages	253
11.2.2.2	MAU Physical Layer to DTE Physical Layer messages	253
11.2.2.2.1	input message.....	253
11.2.2.2.2	input_idle message.....	253
11.2.2.2.3	mau_available message.....	253
11.2.2.3	signal_quality_error message	253
11.2.3	MAU state diagrams	254
11.2.3.1	MAU state diagram messages.....	254
11.2.3.2	MAU state diagram signal names	254
11.3	MAU characteristics	257
11.3.1	MAU-to-coaxial cable interface	257
11.3.1.1	Receive interface.....	257
11.3.1.1.1	Receive input impedance	257
11.3.1.1.2	Receiver squelch requirements	257
11.3.1.1.3	Receive level requirements.....	258
11.3.1.1.4	Receiver selectivity and linearity requirements.....	258
11.3.1.1.5	Receive input mechanical requirements	258
11.3.1.2	Transmit interface	258
11.3.1.2.1	Transmit output impedance	258
11.3.1.2.2	Transmitted RF packet format	258
11.3.1.2.3	Transmit spectrum and group delay characteristics.....	259
11.3.1.2.4	Transmit out-of-band spectrum	261

11.3.1.2.5	Transmit level requirements	261
11.3.1.2.6	Nontransmitting signal leakage requirement	261
11.3.1.2.7	Transmit spurious output requirement	261
11.3.1.2.8	Collision enforcement signal leakage requirement	262
11.3.1.2.9	Transmit output mechanical requirements	262
11.3.2	MAU frequency allocations	262
11.3.2.1	Single-cable systems frequency allocations	262
11.3.2.2	Dual-cable systems frequency allocations	263
11.3.3	AUI electrical characteristics	263
11.3.3.1	Electrical isolation requirements	263
11.3.3.2	Current consumption	263
11.3.3.3	Driver and receiver requirements	264
11.3.3.4	AUI mechanical connection	264
11.3.4	MAU transfer characteristics	264
11.3.4.1	AUI to coaxial cable framing characteristics	264
11.3.4.1.1	Scrambler and differential encoding requirements	265
11.3.4.2	Coaxial cable to AUI framing characteristics	266
11.3.4.3	Circuit DO to circuit DI framing characteristics	267
11.3.4.4	AUI to coaxial cable delay characteristics	267
11.3.4.4.1	Circuit DO to RF data signal delay	267
11.3.4.4.2	Circuit DO to CE RF output delay	267
11.3.4.4.3	Transmit postamble to SQE test signal delay	267
11.3.4.4.4	SQE test signal length	267
11.3.4.5	Coaxial cable to AUI delay characteristics	267
11.3.4.5.1	Received RF to circuit DI delay	268
11.3.4.5.2	Received RF to CE RF output and circuit CI delay	268
11.3.4.5.3	Collision enforcement to circuit CI delay	268
11.3.4.5.4	Receive data to SQE test delay	268
11.3.4.6	Delay from circuit DO to circuit DI	269
11.3.4.7	Interpacket gap requirement	270
11.3.4.8	Bit error ratio	270
11.3.5	Reliability	270
11.4	System considerations	271
11.4.1	Delay budget and network diameter	271
11.4.2	MAU operation with packets shorter than 512 bits	271
11.5	Characteristics of the coaxial cable system	272
11.5.1	Electrical requirements	272
11.5.2	Mechanical requirements	272
11.5.3	Delay requirements	272
11.6	Frequency translator requirements for the single-cable version	273
11.6.1	Electrical requirements	273
11.6.2	Mechanical requirements	273
11.7	Environmental specifications	273
11.7.1	Safety requirements	273
11.7.2	Electromagnetic environment	274
11.7.2.1	Susceptibility levels	274
11.7.2.2	Emission levels	274
11.7.3	Temperature and humidity	274
12.	Physical signaling, medium attachment, and baseband medium specifications, type 1BASE5	275
12.1	Introduction	275
12.1.1	Overview	275

12.1.2	Scope.....	275
12.1.3	Definitions	275
12.1.4	General characteristics	275
12.1.5	Compatibility	276
12.1.6	Objectives of type 1BASE5 specification	276
12.2	Architecture	276
12.2.1	Major concepts.....	276
12.2.2	Application perspective	277
12.2.3	Packet structure.....	277
12.2.3.1	Silence.....	278
12.2.3.2	Preamble	278
12.2.3.3	Start-of-frame delimiter	279
12.2.3.4	Data	279
12.2.3.5	End-of-transmission delimiter	279
12.3	DTE physical signaling (PLS) specification.....	280
12.3.1	Overview.....	280
12.3.1.1	Summary of major concepts	280
12.3.1.2	Application perspective	280
12.3.2	Functional specification	281
12.3.2.1	PLS-PMA interface.....	281
12.3.2.1.1	output message.....	281
12.3.2.1.2	output_idle message.....	281
12.3.2.1.3	input message.....	281
12.3.2.1.4	input_idle message.....	281
12.3.2.2	PLS-MAC interface	282
12.3.2.2.1	OUTPUT_UNIT	282
12.3.2.2.2	OUTPUT_STATUS.....	282
12.3.2.2.3	INPUT_UNIT	282
12.3.2.2.4	CARRIER_STATUS	282
12.3.2.2.5	SIGNAL_STATUS.....	282
12.3.2.3	PLS functions.....	283
12.3.2.3.1	State diagram variables	283
12.3.2.3.2	Output function	283
12.3.2.3.3	Input function.....	284
12.3.2.3.4	Error Sense function	284
12.3.2.3.5	Carrier Sense function	285
12.3.2.4	Signal encoding.....	285
12.3.2.4.1	Data transmission rate.....	285
12.3.2.4.2	Data symbol encoding	285
12.3.2.4.3	Collision presence encoding	285
12.3.2.4.4	Idle line encoding.....	286
12.4	Hub specification	287
12.4.1	Overview.....	287
12.4.1.1	Summary of major concepts	288
12.4.1.2	Application perspective	288
12.4.2	Hub structure.....	288
12.4.2.1	Upward side.....	288
12.4.2.2	Downward side	288
12.4.3	Hub PLS functional specification	289
12.4.3.1	Hub PLS to PMA interface	289
12.4.3.2	Hub PLS functions.....	289
12.4.3.2.1	State diagram variables	289
12.4.3.2.2	Upward Signal Transfer function	290
12.4.3.2.3	Jabber function.....	290

12.4.3.2.4	Downward Signal Transfer function.....	291
12.4.3.2.5	Retiming (jitter removal)	293
12.4.3.2.6	Header hub wrap-around	293
12.4.3.2.7	Collision presence startup	293
12.4.3.3	Reliability.....	294
12.5	Physical medium attachment (PMA) specification	294
12.5.1	Overview.....	294
12.5.2	PLS–PMA interface.....	294
12.5.3	Signal characteristics	295
12.5.3.1	Transmitter characteristics	295
12.5.3.1.1	Differential output voltage.....	295
12.5.3.1.2	Output timing jitter	298
12.5.3.1.3	Transmitter impedance balance	298
12.5.3.1.4	Common-mode output voltage	299
12.5.3.1.5	Common-mode tolerance.....	299
12.5.3.1.6	Transmitter fault tolerance.....	300
12.5.3.2	Receiver characteristics	300
12.5.3.2.1	Differential input voltage.....	300
12.5.3.2.2	Input timing jitter	300
12.5.3.2.3	Idle input behavior	300
12.5.3.2.4	Differential input impedance	301
12.5.3.2.5	Common-mode rejection	301
12.5.3.2.6	Noise immunity.....	302
12.5.3.2.7	Receiver fault tolerance	302
12.6	Medium Dependent Interface (MDI) specification	302
12.6.1	Line interface connector	302
12.6.2	Connector contact assignments.....	303
12.6.3	Labeling	303
12.7	Cable medium characteristics	304
12.7.1	Overview.....	304
12.7.2	Transmission parameters	304
12.7.2.1	Attenuation.....	304
12.7.2.2	Differential characteristic impedance	304
12.7.2.3	Medium timing jitter.....	304
12.7.2.4	Dispersion	305
12.7.3	Coupling parameters	305
12.7.3.1	Pair-to-pair crosstalk.....	305
12.7.3.2	Multiple-disturber crosstalk.....	305
12.7.3.3	Balance.....	306
12.7.4	Noise environment.....	306
12.7.4.1	Impulse noise	306
12.7.4.2	Crosstalk	307
12.8	Special link specification	307
12.8.1	Overview.....	307
12.8.2	Transmission characteristics	307
12.8.3	Permitted configurations.....	307
12.9	Timing.....	307
12.9.1	Overview.....	307
12.9.2	DTE timing	308
12.9.3	Medium timing	308
12.9.4	Special link timing	308
12.9.5	Hub timing	308
12.10	Safety	309
12.10.1	Isolation	309

12.10.2	Telephony voltages	310
13.	System considerations for multisegment 10 Mb/s baseband networks	311
13.1	Overview	311
13.1.1	Repeater usage	312
13.2	Definitions	312
13.3	Transmission System Model 1	312
13.4	Transmission System Model 2	319
13.4.1	Round-trip collision delay	319
13.4.1.1	Worst-case path delay value (PDV) selection	319
13.4.1.2	Worst-case PDV calculation	319
13.4.2	Interpacket gap (IPG) shrinkage	320
13.4.2.1	Worst-case path variability value (PVV) selection	321
13.4.2.2	Worst-case path variability value (PVV) calculation	321
13.5	Full duplex topology limitations	321
14.	Twisted-pair medium attachment unit (MAU) and baseband medium, type 10BASE-T including type 10BASE-Te	323
14.1	Scope	323
14.1.1	Overview	323
14.1.1.1	Medium Attachment Unit (MAU)	323
14.1.1.2	Repeater unit	324
14.1.1.3	Twisted-pair media	324
14.1.2	Definitions	324
14.1.3	Application perspective	325
14.1.3.1	Objectives	325
14.1.3.2	Compatibility considerations	326
14.1.3.3	Modes of operation	326
14.1.4	Relationship to PLS and AUI	326
14.2	MAU functional specifications	326
14.2.1	MAU functions	327
14.2.1.1	Transmit function requirements	328
14.2.1.2	Receive function requirements	328
14.2.1.3	Loopback function requirements (half duplex mode only)	329
14.2.1.4	Collision Presence function requirements (half duplex mode only)	329
14.2.1.5	signal_quality_error Message (SQE) Test function requirements	329
14.2.1.6	Jabber function requirements	329
14.2.1.7	Link Integrity Test function requirements	330
14.2.1.8	Auto-Negotiation	331
14.2.2	PMA interface messages	331
14.2.2.1	PLS to PMA messages	331
14.2.2.1.1	PMA to PLS messages	331
14.2.2.2	PMA to twisted-pair link segment messages	332
14.2.2.3	Twisted-pair link segment to PMA messages	332
14.2.2.4	Interface message time references	332
14.2.3	MAU state diagrams	332
14.2.3.1	State diagram variables	332
14.2.3.2	State diagram timers	338
14.3	MAU electrical specifications	338
14.3.1	MAU-to-MDI interface characteristics	338
14.3.1.1	Isolation requirement	338
14.3.1.2	Transmitter specifications	339

14.3.1.2.1	Differential output voltage	340
14.3.1.2.2	Transmitter differential output impedance	343
14.3.1.2.3	Output timing jitter	344
14.3.1.2.4	Transmitter impedance balance	344
14.3.1.2.5	Common-mode output voltage	344
14.3.1.2.6	Transmitter common-mode rejection.....	345
14.3.1.2.7	Transmitter fault tolerance.....	345
14.3.1.3	Receiver specifications	346
14.3.1.3.1	Receiver differential input signals	346
14.3.1.3.2	Receiver differential noise immunity	346
14.3.1.3.3	Idle input behavior	347
14.3.1.3.4	Receiver differential input impedance.....	347
14.3.1.3.5	Common-mode rejection	347
14.3.1.3.6	Receiver fault tolerance	347
14.3.2	MAU-to-AUI specification.....	347
14.3.2.1	MAU-AUI electrical characteristics	347
14.3.2.2	MAU–AUI mechanical connection	348
14.3.2.3	Power consumption.....	348
14.4	Characteristics of the simplex link segment	349
14.4.1	Overview.....	349
14.4.2	Transmission parameters	349
14.4.2.1	Insertion loss	349
14.4.2.2	Differential characteristic impedance	349
14.4.2.3	Medium timing jitter	349
14.4.2.4	Delay	350
14.4.3	Coupling parameters	350
14.4.3.1	Differential near-end crosstalk (NEXT) loss	350
14.4.3.1.1	Twenty-five-pair cable and twenty-five-pair binder groups.....	350
14.4.3.1.2	Four-pair cable.....	350
14.4.3.1.3	Other cables	350
14.4.3.2	Multiple-disturber NEXT (MDNEXT) loss	350
14.4.4	Noise environment.....	351
14.4.4.1	Impulse noise	351
14.4.4.2	Crosstalk noise.....	351
14.5	MDI specification	351
14.5.1	MDI connectors	351
14.5.2	Crossover function.....	352
14.6	System considerations.....	353
14.7	Environmental specifications.....	354
14.7.1	General safety	354
14.7.2	Network safety	354
14.7.2.1	Installation	354
14.7.2.2	Grounding	354
14.7.2.3	Installation and maintenance guidelines	354
14.7.2.4	Telephony voltages	354
14.7.3	Environment.....	355
14.7.3.1	Electromagnetic emission	355
14.7.3.2	Temperature and humidity	355
14.8	MAU labeling	355
14.9	Timing summary.....	356
14.10	Protocol implementation conformance statement (PICS) proforma for Clause 14, Twisted-pair medium attachment unit (MAU) and baseband medium, type 10BASE-T and type 10BASE-Te	357
14.10.1	Introduction.....	357

14.10.1.1	Scope.....	357
14.10.1.2	Reference	357
14.10.1.3	Definitions	357
14.10.1.4	Conformance.....	357
14.10.2	Identification of implementation	358
14.10.2.1	Supplier information	358
14.10.2.2	Implementation information	358
14.10.3	Identification of the protocol	358
14.10.4	PICS proforma for 10BASE-T	359
14.10.4.1	Abbreviations.....	359
14.10.4.2	PICS Completion instructions and implementation statement	359
14.10.4.3	Additional information	359
14.10.4.4	References.....	359
14.10.4.5	PICS proforma tables for MAU	360
14.10.4.5.1	MAU functions	360
14.10.4.5.2	Transmit function.....	361
14.10.4.5.3	Receive function	361
14.10.4.5.4	Loopback function	362
14.10.4.5.5	Collision Detect function	362
14.10.4.5.6	signal_quality_error Message Test function.....	363
14.10.4.5.7	Jabber function.....	363
14.10.4.5.8	Link Integrity Test function	364
14.10.4.5.9	MAU state diagram requirements.....	365
14.10.4.5.10	AUI requirements	365
14.10.4.5.11	Isolation requirements.....	365
14.10.4.5.12	Transmitter specification	366
14.10.4.5.13	Receiver specification.....	367
14.10.4.5.14	MDI requirements.....	368
14.10.4.5.15	Safety requirements	368
14.10.4.6	PICS proforma tables for MAU AUI characteristics.....	369
14.10.4.6.1	Signal characteristics	369
14.10.4.6.2	DI and CI driver characteristics	369
14.10.4.6.3	DO receiver characteristics.....	370
14.10.4.6.4	Power consumption.....	370
14.10.4.6.5	Circuit termination	371
14.10.4.6.6	Mechanical characteristics.....	371
14.10.4.7	PICS proforma tables for 10BASE-T link segment.....	372
14.10.4.7.1	10BASE-T link segment characteristics.....	372
14.10.4.8	PICS proforma tables for Auto-Negotiation able MAUs	373
15.	Fiber optic medium and common elements of medium attachment units and star, type 10BASE-F.....	375
15.1	Scope.....	375
15.1.1	Overview.....	375
15.1.1.1	Fiber optic medium attachment units (MAUs).....	375
15.1.1.2	Fiber optic passive star	375
15.1.1.3	Repeater unit	376
15.1.2	Definitions	377
15.1.3	Applications perspective: MAUs, stars, and fiber optic medium	377
15.1.3.1	Objectives	377
15.1.3.2	Compatibility considerations	377
15.1.3.3	Relationship to PLS and AUI	378
15.1.3.4	Guidelines for implementation of systems	379

15.1.3.5	Modes of operation	379
15.2	MDI optical characteristics	380
15.2.1	Transmit optical parameters	380
15.2.1.1	Center wavelength	380
15.2.1.2	Spectral width	380
15.2.1.3	Optical modulation extinction ratio	380
15.2.1.4	Optical Idle Signal amplitude	380
15.2.1.5	Optical transmit pulse logic polarity	380
15.2.1.6	Optical transmit pulse rise and fall times	380
15.2.1.7	Optical transmit pulse overshoot and undershoot	380
15.2.1.8	Optical transmit pulse edge jitter	380
15.2.1.9	Optical transmit pulse duty cycle distortion	382
15.2.1.10	Optical transmit average power range	382
15.2.1.11	Optical transmit signal templates	382
15.2.1.11.1	10BASE-FP optical transmit signal template	383
15.2.1.11.2	10BASE-FB optical transmit signal template	384
15.2.1.11.3	10BASE-FL Optical transmit signal template	386
15.2.2	Receive optical parameters	387
15.2.2.1	Optical receive average power range	387
15.2.2.2	Optical receive pulse edge jitter	387
15.2.2.3	Optical receive pulse logic polarity	388
15.2.2.4	Optical receive pulse rise and fall times	388
15.3	Characteristics of the fiber optic medium	388
15.3.1	Optical fiber and cable	388
15.3.1.1	Attenuation	388
15.3.1.2	Modal bandwidth	388
15.3.1.3	Propagation delay	388
15.3.2	Optical medium connector plug and socket	389
15.3.2.1	Optical connector insertion loss	389
15.3.2.2	Optical connector return loss	389
15.3.3	Fiber optic medium insertion loss	390
15.3.3.1	10BASE-FP segment insertion loss	390
15.3.3.2	10BASE-FB and 10BASE-FL segment insertion loss	390
15.3.4	Electrical isolation	390
15.4	MAU reliability	390
15.5	MAU–AUI specification	390
15.5.1	MAU–AUI electrical characteristics	390
15.5.2	MAU–AUI mechanical connections	391
15.5.3	Power consumption	391
15.5.4	MAU–AUI messages	391
15.5.4.1	PLS to PMA messages	391
15.5.4.2	PMA to PLS messages	391
15.5.4.2.1	signal_quality_error message	391
15.6	Environmental specifications	392
15.6.1	Safety requirements	392
15.6.2	Electromagnetic environment	392
15.6.3	Other environmental requirements	393
15.7	MAU labeling	393
15.7.1	10BASE-FP star labeling	393
15.8	Protocol implementation conformance statement (PICS) proforma for Clause 15, Fiber optical medium and common elements of medium attachment units and star, type 10BASE-F	394
15.8.1	Introduction	394
15.8.2	Abbreviations and special symbols	394

15.8.2.1	Status symbols	394
15.8.2.2	Abbreviations	394
15.8.3	Instructions for completing the pics proforma	394
15.8.3.1	General structure of the PICS proforma	394
15.8.3.2	Additional information	395
15.8.3.3	Exception information	395
15.8.3.4	Conditional items	396
15.8.4	Identification	396
15.8.4.1	Implementation identification	396
15.8.4.2	Protocol summary	396
15.8.5	Major capabilities/options	397
15.8.6	PICS Proforma for the fiber optic medium	397
15.8.6.1	Characteristics of the fiber optic medium	397
15.8.6.2	Optical medium connector plug and socket	398
15.8.6.3	Fiber optic medium insertion loss	398
15.8.6.4	Electrical isolation requirements	398
16.	Fiber optic passive star and medium attachment unit, type 10BASE-FP	399
16.1	Scope	399
16.1.1	Overview	399
16.1.1.1	10BASE-FP medium attachment unit	399
16.1.1.2	10BASE-FP Star	399
16.1.1.3	Repeater unit	399
16.2	PMA interface messages	400
16.2.1	PMA-to-MDI interface signal encodings	400
16.2.2	PMA-to-MDI OTD messages	400
16.2.2.1	OTD_output	400
16.2.2.2	OTD_idle	400
16.2.2.3	OTD_manch_violation	401
16.2.3	MDI ORD-to-PMA messages	401
16.2.3.1	ORD_input	401
16.2.3.2	ORD_idle	402
16.2.3.3	ORD_crv	402
16.3	10BASE-FP MAU functional specifications	402
16.3.1	Transmit function requirements	402
16.3.1.1	Preamble encoding	403
16.3.1.1.1	Synchronization pattern	403
16.3.1.1.2	Packet header code rule violation	403
16.3.1.1.3	Unique word	403
16.3.1.2	Data transmit	403
16.3.1.3	Collision encoding (unique word jam)	404
16.3.2	Receive function requirements	404
16.3.2.1	Preamble reconstruction and alignment	404
16.3.2.2	Data receive	404
16.3.2.3	Signal presence during collision	404
16.3.3	Loopback function requirements	404
16.3.4	Collision presence function requirements	405
16.3.4.1	CI Circuit signaling	405
16.3.4.2	Collision detection	405
16.3.4.3	End of collision	406
16.3.5	signal_quality_error Message (SQE) Test function requirements	406
16.3.6	Jabber function requirements	406
16.3.7	Link fault detection and low light function requirements	407

16.3.8	Interface message time references	408
16.3.9	MAU state diagram.....	408
16.3.9.1	MAU state diagram variables	408
16.3.9.2	MAU state diagram timers.....	410
16.3.9.3	MAU state diagram counters	411
16.4	Timing summary.....	416
16.5	10BASE-FP Star functional specifications.....	416
16.5.1	Star functions	416
16.5.1.1	Number of ports	416
16.5.1.2	Optical power division.....	416
16.5.1.3	Configuration.....	417
16.5.1.4	Reliability.....	417
16.5.2	Star optical characteristics	417
16.5.2.1	Star insertion loss.....	417
16.5.2.2	Star single output port uniformity.....	417
16.5.2.3	Star directivity.....	417
16.6	Protocol implementation conformance statement (PICS) proforma for Clause 16, Fiber optic passive star and medium attachment unit, type 10BASE-FP	418
16.6.1	Introduction.....	418
16.6.2	Abbreviations and special symbols.....	418
16.6.2.1	Status symbols	418
16.6.2.2	Abbreviations.....	418
16.6.3	Instructions for completing the PICS proforma.....	418
16.6.3.1	General structure of the PICS proforma	418
16.6.3.2	Additional information	419
16.6.3.3	Exception information	419
16.6.3.4	Conditional items	420
16.6.4	Identification	420
16.6.4.1	Implementation identification.....	420
16.6.4.2	Protocol summary	420
16.6.5	Major capabilities/options.....	421
16.6.6	PICS proforma for the type 10BASE-FP MAU	421
16.6.6.1	Compatibility considerations	421
16.6.6.2	Optical transmit parameters.....	422
16.6.6.3	Optical receive parameters.....	423
16.6.6.4	Optical medium connector plug and socket.....	423
16.6.6.5	MAU functions	423
16.6.6.6	PMA interface messages.....	423
16.6.6.7	PMA to MDI OTD messages.....	424
16.6.6.8	MDI ORD to PMA messages	424
16.6.6.9	Transmit functions	424
16.6.6.10	Collision Encoding (Unique Word Jam) function	425
16.6.6.11	Receive functions.....	425
16.6.6.12	Preamble reconstruction and alignment function	426
16.6.6.13	Data receive function	426
16.6.6.14	Signal presence during collision.....	426
16.6.6.15	Loopback function	427
16.6.6.16	Collision presence function	427
16.6.6.17	signal_quality_error Message (SQE) test function	428
16.6.6.18	Jabber function.....	428
16.6.6.19	Link Fault Detect function	428
16.6.6.20	MAU state diagram requirements	429
16.6.6.21	MAU-to-AUI signal characteristics.....	429
16.6.6.22	MAU-to-AUI DI and CI driver characteristics	429

16.6.6.23	AUI-to-MAU DO receiver characteristics.....	430
16.6.6.24	MAU-to-AUI circuit termination.....	430
16.6.6.25	MAU-to-AUI mechanical connections.....	431
16.6.6.26	MAU reliability.....	431
16.6.6.27	Power consumption.....	432
16.6.6.28	PLS-PMA requirements.....	432
16.6.6.29	signal_quality_error message (SQE)	432
16.6.6.30	Environmental requirements.....	433
16.6.6.31	MAU labeling	433
16.6.7	PICS proforma tables for 10BASE-FP stars.....	433
16.6.7.1	Star basic functions.....	433
16.6.7.2	Star optical characteristics	434
16.6.7.3	Star environmental requirements	434
16.6.7.4	10BASE-FP star labeling.....	434
17.	Fiber optic medium attachment unit, type 10BASE-FB.....	435
17.1	Scope.....	435
17.1.1	Overview.....	435
17.1.1.1	Medium attachment unit	435
17.1.1.2	Relationship to repeater	435
17.1.1.3	Remote diagnostic messages	435
17.1.2	Relationship to AUI.....	435
17.2	PMA interface messages.....	436
17.2.1	PMA-to-MDI interface signal encodings	436
17.2.2	PMA-to-MDI OTD messages.....	436
17.2.2.1	OTD_output.....	437
17.2.2.2	OTD_sync_idle.....	437
17.2.2.3	OTD_remote_fault.....	437
17.2.3	MDI ORD-to-PMA messages.....	437
17.2.3.1	Status decoding	437
17.2.3.2	ORD_input.....	437
17.2.3.3	ORD_sync_idle.....	437
17.2.3.4	ORD_remote_fault.....	438
17.2.3.5	ORD_invalid_data	438
17.2.4	Transitions between signals.....	438
17.2.5	Signaling rate	438
17.3	MAU functional specifications.....	438
17.3.1	Transmit function requirements.....	438
17.3.1.1	Data transmit.....	439
17.3.1.2	Synchronous idle.....	439
17.3.1.3	Fault signaling.....	439
17.3.2	Receive function requirements	439
17.3.2.1	Data receive	439
17.3.2.2	Remote status message handling	439
17.3.3	Collision function requirements.....	439
17.3.3.1	Collision detection	439
17.3.3.2	End of collision.....	440
17.3.4	Loopback function requirements	440
17.3.5	Fault-handling function requirements.....	440
17.3.6	Jabber function requirements.....	440
17.3.7	Low light level detection function requirements	441
17.3.8	Synchronous qualification function requirements	441
17.3.9	Interface message time references	442

17.3.10	MAU state diagrams	442
17.3.10.1	MAU state diagram variables	442
17.3.10.2	MAU state diagram timers	443
17.4	Timing summary	446
17.5	Protocol implementation conformance statement (PICS) proforma for Clause 17, Fiber optical medium attachment unit, type 10BASE-FB	447
17.5.1	Introduction	447
17.5.2	Abbreviations and special symbols	447
17.5.2.1	Status symbols	447
17.5.2.1.1	Abbreviations	447
17.5.3	Instructions for completing the PICS proforma	447
17.5.3.1	General structure of the PICS proforma	447
17.5.3.2	Additional information	448
17.5.3.3	Exception information	448
17.5.3.4	Conditional items	449
17.5.4	Identification	449
17.5.4.1	Implementation identification	449
17.5.4.2	Protocol summary	449
17.5.5	PICS proforma for the type 10BASE-FB MAU	449
17.5.6	PICS proforma for the type 10BASE-FB MAU	450
17.5.6.1	Compatibility considerations	450
17.5.6.2	Optical transmit parameters	450
17.5.6.3	Optical receive parameters	451
17.5.6.4	Optical medium connector plug and socket	451
17.5.6.5	MAU functions	452
17.5.6.6	PMA-to-MDI OTD messages and signaling	452
17.5.6.7	MDI ORD-to-PMA messages and signaling	453
17.5.6.8	Transitions between signals	453
17.5.6.9	Signaling rate	453
17.5.6.10	Transmit functions	454
17.5.6.11	Receive functions	454
17.5.6.12	Data receive function	455
17.5.6.13	Remote status message handling	455
17.5.6.14	Collision function requirements	455
17.5.6.15	End of collision	456
17.5.6.16	Loopback function	456
17.5.6.17	Fault-handling function	456
17.5.6.18	Jabber-handling function	457
17.5.6.19	Low light detection	457
17.5.6.20	Synchronous qualification	458
17.5.6.21	MAU state diagram requirements	458
17.5.6.22	MAU reliability	458
17.5.6.23	PLS-PMA requirements	459
17.5.6.24	signal_quality_error message (SQE)	459
17.5.6.25	Environmental requirements	459
17.5.6.26	MAU labeling	459
18.	Fiber optic medium attachment unit, type 10BASE-FL	461
18.1	Scope	461
18.1.1	Overview	461
18.1.1.1	10BASE-FL medium attachment unit (MAU)	461
18.1.1.2	Repeater unit	461
18.2	PMA interface messages	461

18.2.1	PMA to fiber optic link segment messages	462
18.2.1.1	OTD_output	462
18.2.1.2	OTD_idle	462
18.2.2	Fiber optic link segment to PMA messages.....	462
18.2.2.1	ORD_input.....	462
18.2.2.2	ORD_idle.....	462
18.2.3	Interface message time references	463
18.3	MAU functional specifications	463
18.3.1	MAU functions	463
18.3.1.1	Transmit function requirements.....	464
18.3.1.2	Receive function requirements	465
18.3.1.3	Loopback function requirements (half duplex mode only)	465
18.3.1.4	Collision Presence function requirements (half duplex mode only).....	465
18.3.1.5	signal_quality_error Message (SQE) Test function requirements.....	466
18.3.1.6	Jabber function requirements.....	466
18.3.1.7	Link Integrity Test function requirements	466
18.3.1.8	Auto-Negotiation	467
18.3.2	MAU state diagrams	467
18.3.2.1	MAU state diagram variables	467
18.3.2.2	MAU state diagram timers.....	469
18.4	Timing summary.....	474
18.5	Protocol implementation conformance statement (PICS) proforma for Clause 18, Fiber optic medium attachment unit, type 10BASE-FL	475
18.5.1	Introduction.....	475
18.5.2	Abbreviations and special symbols.....	475
18.5.2.1	Status symbols	475
18.5.2.2	Abbreviations.....	475
18.5.3	Instructions for completing the PICS proforma.....	476
18.5.3.1	General structure of the PICS proforma	476
18.5.3.2	Additional information	476
18.5.3.3	Exception information	476
18.5.3.4	Conditional items	477
18.5.4	Identification	477
18.5.4.1	Implementation identification.....	477
18.5.4.2	Protocol summary	477
18.5.5	Major capabilities/options.....	478
18.5.6	PICS proforma tables for the type 10BASE-FL MAU.....	478
18.5.6.1	Compatibility considerations	478
18.5.6.2	Optical transmit parameter	479
18.5.6.3	Optical receive parameters	480
18.5.6.4	Optical medium connector plug and socket.....	480
18.5.6.5	MAU functions	481
18.5.6.6	PMA interface messages.....	481
18.5.6.7	PMA-to-MDI OTD messages.....	481
18.5.6.8	MDI ORD-to-PMA messages.....	481
18.5.6.9	Transmit function	482
18.5.6.10	Receive function	482
18.5.6.11	Loopback function	483
18.5.6.12	Collision Presence function	483
18.5.6.13	signal_quality_error Message (SQE) Test function.....	483
18.5.6.14	Jabber function.....	484
18.5.6.15	Link Integrity Test function.....	484
18.5.6.16	MAU state diagram requirements.....	486
18.5.6.17	MAU-to-AUI signal characteristics.....	486

18.5.6.18	MAU-to-AUI DI and CI driver characteristics	487
18.5.6.19	AUI-to-MAU DO receiver characteristics	487
18.5.6.20	AUI circuit termination	488
18.5.6.21	MAU-to-AUI mechanical connections	488
18.5.6.22	MAU reliability	489
18.5.6.23	Power consumption	489
18.5.6.24	PLS-PMA requirements	489
18.5.6.25	signal_quality_error message (SQE)	489
18.5.6.26	Environmental requirements	490
18.5.6.27	MAU labeling	490
19.	Layer Management for 10 Mb/s baseband repeaters	491
19.1	Introduction	491
19.1.1	Scope	491
19.1.2	Relationship to objects in IEEE Std 802.1F-1993	491
19.1.3	Definitions	491
19.1.4	Symbols and abbreviations	491
19.1.5	Management model	492
19.2	Managed objects	493
19.2.1	Introduction	493
19.2.2	Overview of managed objects	493
19.2.2.1	Text description of managed objects	493
19.2.2.2	Port functions to support management	493
19.2.2.3	Containment	495
19.2.2.4	Naming	496
19.2.2.5	Packages and capabilities	496
19.2.3	Repeater managed object class	498
19.2.3.1	Repeater attributes	498
19.2.3.1.1	aRepeaterID	498
19.2.3.1.2	aRepeaterGroupCapacity	498
19.2.3.1.3	aGroupMap	498
19.2.3.1.4	aRepeaterHealthState	498
19.2.3.1.5	aRepeaterHealthText	499
19.2.3.1.6	aRepeaterHealthData	499
19.2.3.1.7	aTransmitCollisions	499
19.2.3.2	Repeater actions	499
19.2.3.2.1	acResetRepeater	499
19.2.3.2.2	acExecuteNonDisruptiveSelfTest	500
19.2.3.3	Repeater notifications	500
19.2.3.3.1	nRepeaterHealth	500
19.2.3.3.2	nRepeaterReset	501
19.2.3.3.3	nGroupMapChange	501
19.2.4	ResourceTypeID Managed Object Class	501
19.2.5	Group managed object class	501
19.2.5.1	Group attributes	501
19.2.5.1.1	aGroupID	501
19.2.5.1.2	aGroupPortCapacity	502
19.2.5.1.3	aPortMap	502
19.2.5.2	Group Notifications	502
19.2.5.2.1	nPortMapChange	502
19.2.6	Port managed object class	502
19.2.6.1	Port Attributes	502
19.2.6.1.1	aPortID	502

19.2.6.1.2	aPortAdminState	503
19.2.6.1.3	aAutoPartitionState	503
19.2.6.1.4	aReadableFrames	503
19.2.6.1.5	aReadableOctets	503
19.2.6.1.6	aFrameCheckSequenceErrors	504
19.2.6.1.7	aAlignmentErrors	504
19.2.6.1.8	aFramesTooLong	504
19.2.6.1.9	aShortEvents	504
19.2.6.1.10	aRuns	505
19.2.6.1.11	aCollisions	505
19.2.6.1.12	aLateEvents	505
19.2.6.1.13	aVeryLongEvents	506
19.2.6.1.14	aDataRateMismatches	506
19.2.6.1.15	aAutoPartitions	506
19.2.6.1.16	aLastSourceAddress	506
19.2.6.1.17	aSourceAddressChanges	507
19.2.6.2	Port Actions	507
19.2.6.2.1	acPortAdminControl	507
20.	Layer Management for 10 Mb/s baseband medium attachment units	509
20.1	Introduction	509
20.1.1	Scope	509
20.1.2	Management model	509
20.2	Managed objects	509
20.2.1	Text description of managed objects	509
20.2.1.1	Naming	509
20.2.1.2	Containment	510
20.2.1.3	Packages	510
20.2.2	MAU Managed object class	511
20.2.2.1	MAU attributes	511
20.2.2.1.1	aMAUID	511
20.2.2.1.2	aMAUType	511
20.2.2.1.3	aMediaAvailable	512
20.2.2.1.4	aLoseMediaCounter	512
20.2.2.1.5	aJabber	512
20.2.2.1.6	aMAUAdminState	513
20.2.2.1.7	aBbMAUXmitRcvSplitType	513
20.2.2.1.8	aBroadbandFrequencies	513
20.2.2.2	MAU actions	514
20.2.2.2.1	acResetMAU	514
20.2.2.2.2	acMAUAdminControl	514
20.2.2.3	MAU notifications	514
20.2.2.3.1	nJabber	514
Annex A (informative)	Bibliography	515
Annex B (informative)	System guidelines	519
B.1	Baseband system guidelines and concepts, 10 Mb/s	519
B.1.1	Overall system objectives	519
B.1.2	Analog system components and parameter values	519
B.1.3	Minimum frame length determination	521
B.1.4	System jitter budgets	522

B.1.4.1	Nominal jitter values	522
B.1.4.2	Decoder evaluation	523
B.1.5	Systems consideration calculations	524
B.1.5.1	Overview	524
B.1.5.2	Maximum collision fragment size	524
B.1.5.2.1	Left-end base SDV	525
B.1.5.2.2	Mid-base SDV	526
B.1.5.2.3	Right-end base SDV	526
B.1.5.3	Interpacket Gap (IPG) shrinkage	527
B.1.5.3.1	Transmitting end segment variability value	527
B.1.5.3.2	Mid-segment variability value	528
B.1.5.4	Timing parameters for round-trip delay and variability calculations	528
B.1.5.4.1	MAU parameters	528
B.1.5.4.2	Repeater parameters	529
B.1.5.4.3	Media parameters	529
B.1.5.4.4	DTE parameters	529
B.2	System parameters and budgets for 1BASE5	531
B.2.1	Delay budget	531
B.2.2	Minimum frame length determination	532
B.2.3	Jitter budget	533
B.3	Example crosstalk computation for multiple disturbers, balanced-pair cable	534
B.4	10BASE-T guidelines	536
B.4.1	System jitter budget	536
B.4.2	Filter characteristics	536
B.4.3	Notes for conformance testing	536
B.4.3.1	Notes for 14.3.1.2.1 on differential output voltage	536
B.4.3.2	Note for 14.3.1.2.2 on transmitter differential output impedance	537
B.4.3.3	Note for 14.3.1.2.3 on output timing jitter	537
B.4.3.4	General note on common-mode tests	538
B.4.3.5	Note for 14.3.1.3.4 on receiver differential input impedance	538
B.4.3.6	Note for 14.3.1.3.3 on receiver idle input behavior	538
B.4.3.7	Note for 14.3.1.3.5 on receiver common-mode rejection	538
B.5	10BASE-F	539
B.5.1	System jitter budget	539
B.5.2	10BASE-FP fiber optic segment loss budget	539
Annex C (informative)	State diagram, MAC sublayer	542
Annex D (informative)	Application context, selected medium specifications	543
D.1	Introduction	543
D.2	Type 10BASE5 applications	543
D.3	Type 10BASE2 applications	543
D.4	Type FOIRL and 10BASE-F applications; alternative fiber optic medium applications	544
D.4.1	Alternative fiber types	544
D.4.1.1	Theoretical coupling losses	544
D.4.1.2	Maximum launch power	545
D.4.2	Type 10BASE-FP applications using 50/125 μm fiber	546
D.4.2.1	Coupled transmit power	546
D.4.2.2	Star coupler loss	546
D.4.2.3	Collision detection	547
D.5	10BASE-T use of cabling systems with a nominal differential characteristic impedance of 120 Ω	547

D.6	10BASE-T use of cabling systems with a nominal differential characteristic impedance of 150 Ω	548
Annex E (informative)	Receiver wavelength design considerations (FOIRL).....	550
Annex F (normative)	Additional attributes required for systems	551
F.1	Introduction	551
F.1.1	Scope.....	551
F.2	Objects/Attributes/Actions/Notifications	551
F.2.1	TimeSinceSystemReset attribute	551
F.2.2	RepeaterResetTimeStamp attribute	552
F.2.3	ResetSystemAction action	552
Annex G (normative)	Additional material required for conformance testing	553
G.1	Introduction	553
G.1.1	Material in support of the aDataRateMismatches attribute	553
Annex H (normative)	GDMO specifications for CSMA/CD managed objects	554
Annex 4A (informative)	Simplified full duplex media access control.....	555
4A.1	Functional model of the MAC method	555
4A.1.1	Overview.....	555
4A.1.2	Full duplex operation	556
4A.1.2.1	Transmission	556
4A.1.2.2	Reception	556
4A.1.3	Relationships to the MAC client and Physical Layers	557
4A.2	Media access control (MAC) method: precise specification	557
4A.2.1	Introduction.....	557
4A.2.2	Overview of the procedural model	557
4A.2.2.1	Ground rules for the procedural model.....	557
4A.2.2.2	Use of Pascal in the procedural model.....	558
4A.2.2.3	Organization of the procedural model	558
4A.2.2.4	Layer management extensions to procedural model.....	563
4A.2.3	Packet transmission model.....	563
4A.2.3.1	Transmit data encapsulation	563
4A.2.3.2	Transmit media access management.....	563
4A.2.3.2.1	Deference	563
4A.2.3.2.2	Interpacket gap.....	564
4A.2.3.2.3	Transmission	564
4A.2.3.2.4	Minimum frame size	564
4A.2.4	Frame reception model	564
4A.2.4.1	Receive data decapsulation	564
4A.2.4.1.1	Address recognition	564
4A.2.4.1.2	Frame check sequence validation	565
4A.2.4.1.3	Frame disassembly.....	565
4A.2.4.2	Receive media access management	565
4A.2.5	Preamble generation	565
4A.2.6	Start frame sequence	565
4A.2.7	Global declarations	566
4A.2.7.1	Common constants, types, and variables	566
4A.2.7.2	Transmit state variables	567

4A.2.7.3	Receive state variables	567
4A.2.7.4	State variable initialization	567
4A.2.8	Frame transmission	568
4A.2.9	Frame reception	571
4A.2.10	Common procedures	574
4A.3	Interfaces to/from adjacent layers	574
4A.3.1	Overview	574
4A.3.2	MAC service	574
4A.3.2.1	MAC client transmit interface state diagram	574
4A.3.2.1.1	Variables	574
4A.3.2.1.2	Functions	575
4A.3.2.1.3	Messages	575
4A.3.2.1.4	MAC client transmit interface state diagram	575
4A.3.2.2	MAC client receive interface state diagram	575
4A.3.2.2.1	Variables	576
4A.3.2.2.2	Functions	576
4A.3.2.2.3	Messages	576
4A.3.2.2.4	MAC client receive interface state diagram	576
4A.3.3	Services required from the Physical Layer	578
4A.4	Specific implementations	579
4A.4.1	Compatibility overview	579
4A.4.2	MAC parameters	579

3. Media Access Control (MAC) frame and packet specifications

3.1 Overview

This clause defines the mapping between MAC service interface primitives and Ethernet packets, including the syntax and semantics of the various fields of MAC frames and the fields used to form those MAC frames into packets.

During Ethernet's history, capabilities have been added to allow data link layer (layer 2) protocol encapsulations within the MAC Client Data field. As a result, there are now more than one type of MAC frame.

The frame format specified in this clause includes the following three types of MAC frames:

- a) A basic frame
- b) A Q-tagged frame
- c) An envelope frame

All three frame types use the same Ethernet frame format.

3.1.1 Packet format

Figure 3–1 shows the fields of a packet: the Preamble, Start Frame Delimiter (SFD), the addresses of the MAC frame's destination and source, a length or type field to indicate the length or protocol type of the following field that contains the MAC client data, a field that contains padding if required, and the Frame Check Sequence (FCS) field containing a cyclic redundancy check value to detect errors in a received MAC frame. An Extension field is added, if required (for 1000 Mb/s half duplex operation only). Of these fields, all are of fixed size except for the MAC Client Data, Pad and Extension fields, which may contain an integer number of octets between the minimum and maximum values that are determined by the specific implementation of the MAC. See 4.4 for particular MAC parameters.

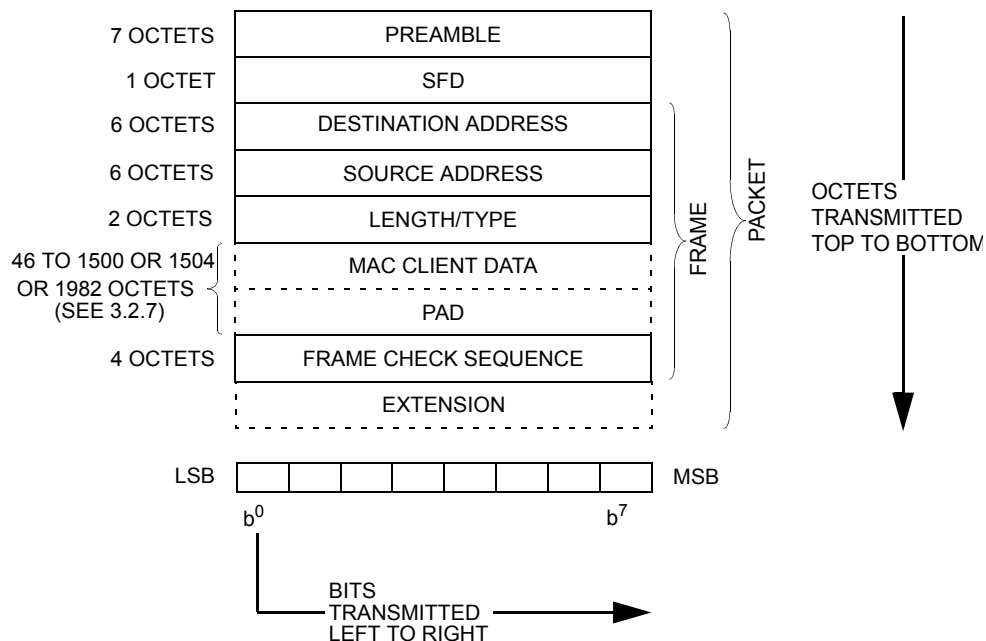


Figure 3–1—Packet format

The minimum and maximum MAC frame size limits in 4.4 refer to that portion of the packet from the dDestination Address field through the Frame Check Sequence field, inclusive (i.e., the MAC frame).

Relative to Figure 3–1, the octets of a packet are transmitted from top to bottom, and the bits of each octet are transmitted from left to right.

3.1.2 Service interface mappings

Figure 3–2 shows the mapping of service interface parameters to the fields of a MAC frame within a packet. The MAC client may or may not supply Pad and FCS. For this reason the mappings for Pad and FCS are shown with dashed lines.

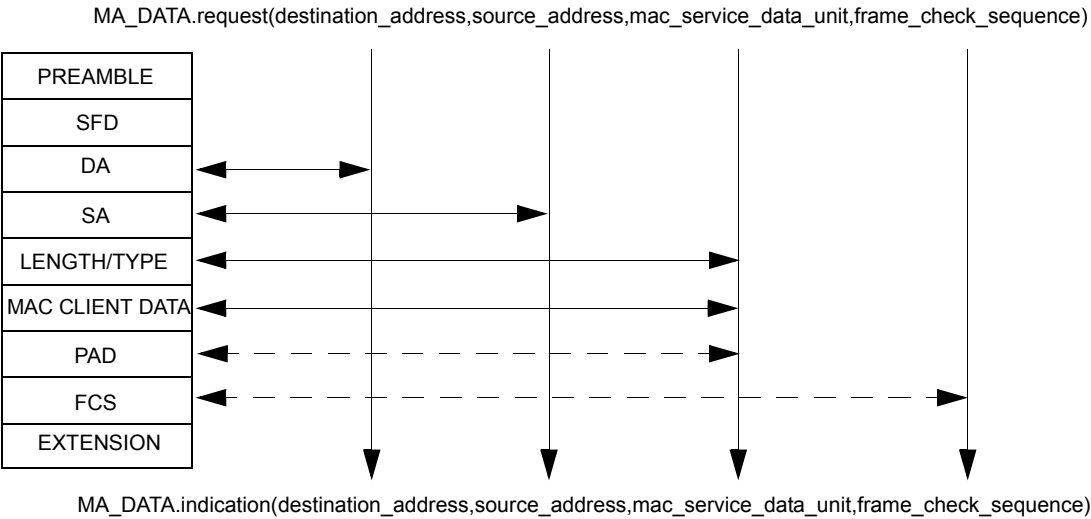


Figure 3–2—Service primitive mappings

3.2 Elements of the MAC frame and packet

A MAC frame is encapsulated in a packet by the MAC. This subclause describes in detail the fields of the MAC frame and the additional fields that the MAC creates to encapsulate the MAC frame. These fields are described in order of transmission.

3.2.1 Preamble field

The Preamble field is a 7-octet field that is used to allow the PLS circuitry to reach its steady-state synchronization with the received packet’s timing (see 4.2.5).

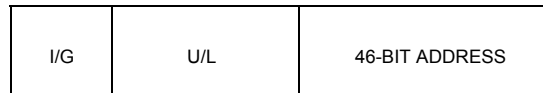
3.2.2 Start Frame Delimiter (SFD) field

The SFD field is the sequence 10101011. It immediately follows the preamble pattern. A MAC frame starts immediately after the SFD.

3.2.3 Address fields

Each MAC frame shall contain two address fields: the Destination Address field and the Source Address field, in that order. The Destination Address field shall specify the destination addressee(s) for which the MAC frame is intended. The Source Address field shall identify the station from which the MAC frame was initiated. The representation of each address field shall be as follows (see Figure 3–3):

- a) Each address field shall be 48 bits in length.
- b) The first bit (LSB) shall be used in the Destination Address field as an address type designation bit to identify the Destination Address either as an individual or as a group address. If this bit is 0, it shall indicate that the address field contains an individual address. If this bit is 1, it shall indicate that the address field contains a group address that identifies none, one or more, or all of the stations connected to the LAN. In the Source Address field, the first bit is reserved and set to 0.
- c) The second bit shall be used to distinguish between locally or globally administered addresses. For globally administered (or U, universal) addresses, the bit is set to 0. If an address is to be assigned locally, this bit shall be set to 1. Note that for the broadcast address, this bit is also a 1.
- d) Each octet of each address field shall be transmitted least significant bit first.



I/G = 0 INDIVIDUAL ADDRESS
 I/G = 1 GROUP ADDRESS
 U/L = 0 GLOBALLY ADMINISTERED ADDRESS
 U/L = 1 LOCALLY ADMINISTERED ADDRESS

Figure 3–3—Address field format

3.2.3.1 Address designation

A MAC sublayer address is one of two types:

- a) *Individual Address*. The address associated with a particular station on the network.
- b) *Group Address*. A multdestination address, associated with one or more stations on a given network. There are two kinds of multicast addresses:
 - 1) *Multicast-Group Address*. An address associated by higher-level convention with a group of logically related stations.
 - 2) *Broadcast Address*. A distinguished, predefined multicast address that always denotes the set of all stations on a given LAN.

All 1's in the Destination Address field shall be predefined to be the Broadcast Address. This group shall be predefined for each communication medium to consist of all stations actively connected to that medium; it shall be used to broadcast to all the active stations on that medium. All stations shall be able to recognize the Broadcast Address. It is not necessary that a station be capable of generating the Broadcast Address.

The address space shall also be partitioned into locally administered and globally administered addresses. The nature of a body and the procedures by which it administers these global (U) addresses is beyond the scope of this standard.²¹

3.2.4 Destination Address field

The Destination Address field specifies the station(s) for which the MAC frame is intended. It may be an individual or multicast (including broadcast) address.

²¹For information on how to use MAC addresses, see IEEE Std 802-2001, Overview and Architecture. To apply for an Organizationally Unique Identifier for building a MAC address, contact the Registration Authority, IEEE Standards Department, P.O. Box 1331, 445 Hoes Lane, Piscataway, NJ 08855-1331, USA; +1 732 562 3813; fax +1 732 562 1571. URL: <http://standards.ieee.org/develop/regauth/>

3.2.5 Source Address field

The Source Address field specifies the station sending the MAC frame. The Source Address field is not interpreted by the MAC sublayer.

3.2.6 Length/Type field

This two-octet field takes one of two meanings, depending on its numeric value. For numerical evaluation, the first octet is the most significant octet of this field.

- a) If the value of this field is less than or equal to 1500 decimal (05DC hexadecimal), then the Length/Type field indicates the number of MAC client data octets contained in the subsequent MAC Client Data field of the basic frame (Length interpretation).
 - b) If the value of this field is greater than or equal to 1536 decimal (0600 hexadecimal), then the Length/Type field indicates the Ethertype of the MAC client protocol (Type interpretation).²²
- The Length and Type interpretations of this field are mutually exclusive.

When used as a Type field, it is the responsibility of the MAC client to ensure that the MAC client operates properly when the MAC sublayer pads the supplied MAC Client data, as discussed in 3.2.7.

Regardless of the interpretation of the Length/Type field, if the length of the MAC Client Data field is less than the minimum required for proper operation of the protocol, a Pad field (a sequence of octets) will be added after the MAC Client Data field but prior to the FCS field, specified below. The procedure that determines the size of the Pad field is specified in 4.2.8. The Length/Type field is transmitted and received with the high order octet first.

NOTE—Clause 2 of IEEE Std 802 defines a set of Ethertype values and associated mechanisms for use in prototype and vendor-specific protocol development.

3.2.7 MAC Client Data field

The MAC Client Data field contains a sequence of octets. Full data transparency is provided in the sense that any arbitrary sequence of octet values may appear in the MAC Client Data field up to a maximum field length determined by the particular implementation.

Ethernet implementations shall support at least one of three maximum MAC Client Data field sizes defined as follows:

- a) 1500 decimal—basic frames (see 1.4.102)
- b) 1504 decimal—Q-tagged frames (see 1.4.334)
- c) 1982 decimal—envelope frames (see 1.4.184)

If layer management is implemented, frames with a MAC Client Data field larger than the supported maximum MAC Client Data field size are counted. It is recommended that new implementations support the transmission and reception of envelope frames, item c) above.

NOTE 1—The envelope frame is intended to allow inclusion of additional prefixes and suffixes required by higher layer encapsulation protocols (see 1.4.180) such as those defined by the IEEE 802.1 working group (such as Provider Bridges and MAC Security), ITU-T or IETF (such as MPLS). The original MAC Client Data field maximum remains 1500 octets while the encapsulation protocols may add up to an additional 482 octets. Use of these extra octets for other purposes is not recommended, and may result in MAC frames being dropped or corrupted as they may violate maximum MAC frame size restrictions if encapsulation protocols are required to operate on them.

²²Ethertype assignments are administered by the Registration Authority, IEEE Standards Department, P.O. Box 1331, 445 Hoes Lane, Piscataway, NJ 08855-1331, USA; +1 732 562 3813; fax +1 732 562 1571. URL: <http://standards.ieee.org/develop/regauth/>.

NOTE 2—All IEEE 802.3 MAC frames share a common format. The processing of the three types of MAC frames is not differentiated within the IEEE 802.3 MAC, except for management. However, they may be distinguished within the MAC client.

NOTE 3—All Q-tagged frames are envelope frames, but not all envelope frames are Q-tagged frames.

See 4.4 for a discussion of MAC parameters; see 4.2.3.3 for a discussion of the minimum frame size and minFrameSize.

3.2.8 Pad field

A minimum MAC frame size is required for correct CSMA/CD protocol operation (see 4.2.3.3 and 4.4). If necessary, a Pad field (in units of octets) is appended after the MAC Client Data field prior to calculating and appending the FCS field. The size of the Pad, if any, is determined by the size of the MAC Client Data field supplied by the MAC client and the minimum MAC frame size and address size MAC parameters (see 4.4).

The length of the Pad field required for MAC Client Data that is clientDatasize/8 octets long is $\max [0, \text{minFrameSize} - (\text{clientDatasize} + 2 \times \text{addressSize} + 48)]$ bits.

3.2.9 Frame Check Sequence (FCS) field

A cyclic redundancy check (CRC) is used by the transmit and receive algorithms to generate a CRC value for the FCS field. The FCS field contains a 4-octet (32-bit) CRC value. This value is computed as a function of the contents of the protected fields of the MAC frame: the Destination Address, Source Address, Length/Type field, MAC Client Data, and Pad (that is, all fields except FCS). The encoding is defined by the following generating polynomial.

$$G(x) = x^{32} + x^{26} + x^{23} + x^{22} + x^{16} + x^{12} + x^{11} + x^{10} + x^8 + x^7 + x^5 + x^4 + x^2 + x + 1$$

Mathematically, the CRC value corresponding to a given MAC frame is defined by the following procedure:

- The first 32 bits of the frame are complemented.
- The n bits of the protected fields are then considered to be the coefficients of a polynomial $M(x)$ of degree $n - 1$. (The first bit of the Destination Address field corresponds to the $x^{(n-1)}$ term and the last bit of the MAC Client Data field (or Pad field if present) corresponds to the x^0 term.)
- $M(x)$ is multiplied by x^{32} and divided by $G(x)$, producing a remainder $R(x)$ of degree ≤ 31 .
- The coefficients of $R(x)$ are considered to be a 32-bit sequence.
- The bit sequence is complemented and the result is the CRC.

The 32 bits of the CRC value are placed in the FCS field so that the x^{31} term is the left-most bit of the first octet, and the x^0 term is the right most bit of the last octet. (The bits of the CRC are thus transmitted in the order $x^{31}, x^{30}, \dots, x^1, x^0$.) See Hammond, et al. [B36].

3.2.10 Extension field

The Extension field follows the FCS field, and is made up of a sequence of extension bits, which are readily distinguished from data bits. The length of the field is in the range of zero to (slotTime–minFrameSize) bits, inclusive. The contents of the Extension field are not included in the FCS computation.

The Extension field may have a length of greater than zero under the conditions that are described in 4.2.3.4. The length of the Extension field will be zero under all other conditions. Implementations defined in 4.4.2 may ignore this field altogether if the number of bit times in the slotTime parameter is equal to the number of bits in the minFrameSize parameter.

3.3 Order of bit transmission

Each octet of the MAC frame, with the exception of the FCS, is transmitted least significant bit first.

3.4 Invalid MAC frame

An invalid MAC frame shall be defined as one that meets at least one of the following conditions:

- a) The frame length is inconsistent with a length value specified in the length/type field. If the length/type field contains a type value as defined by 3.2.6, then the frame length is assumed to be consistent with this field and should not be considered an invalid frame on this basis.
- b) It is not an integral number of octets in length.
- c) The bits of the incoming frame (exclusive of the FCS field itself) do not generate a CRC value identical to the one received.

The contents of invalid MAC frames shall not be passed to the LLC or MAC Control sublayers.²³ The occurrence of invalid MAC frames may be communicated to network management.

²³Invalid MAC frames may be ignored, discarded, or used in a private manner by MAC clients other than LLC or MAC control. The use of such frames is beyond the scope of this standard.