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Telecommunications and exchange between information technology systems — Requirements for local and metropolitan area networks —

Part 3:
Standard for Ethernet

Télécommunications et échange entre systèmes informatiques — Exigences pour les réseaux locaux et métropolitains —

Partie 3: Norme pour Ethernet

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ISO/IEC/IEEE 8802-3 was prepared by the LAN/MAN of the IEEE Computer Society (as IEEE Std 8802-3: 2018) and drafted in accordance with its editorial rules. It was adopted, under the “fast-track procedure” defined in the Partner Standards Development Organization cooperation agreement between ISO and IEEE, by Joint Technical Committee ISO/IEC JTC 1, *Information technology*, Subcommittee SC 6, *Telecommunications and information exchange between systems*.

This third edition cancels and replaces the second edition (ISO/IEC/IEEE 8802-3:2017), which has been technically revised. It also incorporates the Amendments ISO/IEC/IEEE 8802-3:2017/Amd 1:2017, ISO/IEC/IEEE 8802-3:2017/Amd 2:2017, ISO/IEC/IEEE 8802-3:2017/Amd 3:2017, ISO/IEC/IEEE 8802-3:2017/Amd 4:2017, ISO/IEC/IEEE 8802-3:2017/Amd 5:2017, ISO/IEC/IEEE 8802-3:2017/Amd 6:2018, ISO/IEC/IEEE 8802-3:2017/Amd 7:2017, ISO/IEC/IEEE 8802-3:2017/Amd 8:2018, ISO/IEC/IEEE 8802-3:2017/Amd 9:2018, ISO/IEC/IEEE 8802-3:2017/Amd 9:2018, ISO/IEC/IEEE 8802-3:2017/Amd 10:2019, ISO/IEC/IEEE 8802-3:2017/Amd 11:2019 and the Technical Corrigendum ISO/IEC/IEEE 8802-3:2017/Cor 1:2018.

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Abstract: Ethernet local area network operation is specified for selected speeds of operation from 1 Mb/s to 400 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, or electrical backplanes. 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: 2.5 Gigabit Ethernet; 5 Gigabit Ethernet; 10 Gigabit Ethernet; 25 Gigabit Ethernet; 40 Gigabit Ethernet; 100 Gigabit Ethernet; 200 Gigabit Ethernet; 400 Gigabit Ethernet; attachment unit interface; AUI; Auto-Negotiation; Backplane Ethernet; data processing; DTE Power via the MDI; Energy Efficient Ethernet; EPoC; EPON; EPON Protocol over Coax; Ethernet; Ethernet in the First Mile; Ethernet passive optical network; express traffic; Fast Ethernet; Gigabit Ethernet; IEEE 802.3™; information exchange; LAN; local area network; management; MDI; medium dependent interface; media independent interface; MIB; MII; MPMC; multi-point MAC control; PCS; PHY; physical coding sublayer; Physical Layer; physical medium attachment; physical medium dependent; PMA; PMD; PoDL; Power over Data Lines; Power over Ethernet; reconciliation sublayer; repeater; RS; type field; VLAN tag

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Pete Anslow, *IEEE 802.3 Working Group Secretary*
Steven B. Carlson, *IEEE 802.3 Working Group Executive Secretary*
Valerie Maguire, *IEEE 802.3 Working Group Treasurer*

Adam Healey, *IEEE P802.3 (IEEE 802.3cj) Task Force Chair* and *Editor-in-Chief*
Pete Anslow, *IEEE P802.3 (IEEE 802.3cj) Task Force Section Editor*
Marek Hajduczenia, *IEEE P802.3 (IEEE 802.3cj) Task Force Section Editor*

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	Working Group officers, Task Force Chair, and Task Force Editors as listed in the document
IEEE Std 802.3-1985, Original 10 Mb/s standard, MAC, PLS, AUI, 10BASE5	23 June 1983	**Donald C. Loughry,** *Working Group Chair*
IEEE Std 802.3b-1985 (Clause 11), 10 Mb/s Broadband MAU, 10BROAD36	19 September 1985	**Donald C. Loughry,** *Working Group Chair* **Menachem Abraham,** *Task Force Chair*
IEEE Std 802.3a-1988 (Clause 10), 10 Mb/s MAU 10BASE2	15 November 1985	**Donald C. Loughry,** *Working Group Chair* **Alan Flatman,** *Task Force Chair*
IEEE Std 802.3c-1985 (9.1–9.8), 10 Mb/s Baseband Repeater	12 December 1985	**Donald C. Loughry,** *Working Group Chair* **Geoffrey O. Thompson,** *Task Force Chair*
IEEE Std 802.3e-1987 (Clause 12), 1 Mb/s MAU and Hub 1BASE5	11 June 1987	**Donald C. Loughry,** *Working Group Chair* **Robert Galin,** *Task Force Chair*
IEEE Std 802.3d-1987 (9.9), 10 Mb/s Fiber MAU, FOIRL	10 December 1987	**Donald C. Loughry,** *Working Group Chair* **Steven Moustakas,** *Task Force Chair*
IEEE Std 802.3h-1990 (Clause 5), 10 Mb/s Layer Management, DTEs	28 September 1990	**Donald C. Loughry,** *Working Group Chair* **Andy J. Luque,** *Task Force Chair*
IEEE Std 802.3i-1990 (Clauses 13 and 14), 10 Mb/s UTP MAU, 10 BASE-T	28 September 1990	**Donald C. Loughry**, *Working Group Chair* **Patricia Thaler,** *Task Force Chair (initial)* **Richard Anderson,** *Task Force Chair (final)*
IEEE Std 802.3k-1993 (Clause 19), 10 Mb/s Layer Management, Repeaters	17 September 1992	**Patricia Thaler,** *Working Group Chair* **Joseph S. Skorupa,** *Task Force Chair* **Geoffrey O. Thompson,** *Vice Chair* and *Editor*
IEEE Std 802.3*l*-1992 (14.10), 10 Mb/s PICS Proforma 10BASE-T MAU	17 September 1992	**Patricia Thaler,** *Working Group Chair* **Mike Armstrong,** *Task Force Chair* and *Editor* **Paul Nikolich,** *Vice Chair* **William Randle,** *Editorial Coordinator*

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IEEE Std 802.3p-1993 (Clause 20), Management, 10 Mb/s Integrated MAUs	17 June 1993	**Patricia Thaler,** *Working Group Chair* **Joseph S. Skorupa,** *Task Force Chair* **Geoffrey O. Thompson,** *Vice Chair* and *Editor*
IEEE Std 802.3q-1993 (Clause 5), 10 Mb/s Layer Management, GDMO Format	17 June 1993)	**Patricia Thaler,** *Working Group Chair* **Joseph S. Skorupa,** *Task Force Chair* **Geoffrey O. Thompson,** *Vice Chair* and *Editor*
IEEE Std 802.3j-1993 (Clauses 15–18), 10 Mb/s Fiber MAUs 10BASE-FP, 10BASE-FB, and 10BASE-FL	15 September 1993	**Patricia Thaler,** *Working Group Chair* **Keith Amundsen,** *Task Force Chair (initial)* **Frederick Scholl,** *Task Force Chair (final)* **Michael E. Lee,** *Technical Editor*
IEEE Std 802.3t-1995, 120 Ω informative annex to 10BASE-T	14 June 1995	**Geoffrey O. Thompson,** *Working Group Chair* **Jacques Christ,** *Task Force Chair*
IEEE Std 802.3u-1995 (Clauses 21–30), Type 100BASE-T MAC parameters, Physical Layer, MAUs, and Repeater for 100 Mb/s Operation	14 June 1995	**Geoffrey O. Thompson,** *Working Group Chair* **Peter Tarrant,** *Task Force Chair (Phase 1)* **Howard Frazier,** *Task Force Chair (Phase 2)* **Paul Sherer,** *Task Force Editor-in-Chief (Phase 1)* **Howard Johnson,** *Task Force Editor-in-Chief (Phase 2)*
IEEE Std 802.3m-1995, Maintenance 2	21 September 1995	**Patricia Thaler,** *Working Group Chair* **Gary Robinson,** *Maintenance Chair*
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IEEE Std 802.3s-1995, Maintenance 4	21 September 1995	**Geoffrey O. Thompson,** *Working Group Chair* **Gary Robinson,** *Maintenance Chair*
IEEE Std 802.3v-1995, 150 Ω informative annex to 10BASE-T	12 December 1995	**Geoffrey O. Thompson,** *Working Group Chair* **Larry Nicholson,** *Task Force Chair*
IEEE Std 802.3r-1996 (8.8), Type 10BASE5 Medium Attachment Unit PICS proforma	29 July 1996	**Patricia Thaler,** *Working Group Chair* **Imre Juhász**, *Task Force Chair* **William Randle,** *Task Force Editor*
IEEE Std 802.3x-1997 and IEEE Std 802.3y-1997 (Revisions to IEEE Std 802.3, Clauses 31 and 32), Full-Duplex Operation and Type 100BASE-T2	20 March 1997	**Geoffrey O. Thompson,** *Working Group Chair* **David J. Law,** *Working Group Vice Chair* **Rich Seifert,** *Task Force Chair* and *Editor (802.3x)* **J. Scott Carter,** *Task Force Chair (802.3y)* **Colin Mick**, *Task Force Editor (802.3y)*
IEEE Std 802.3z-1998 (Clauses 34–39, 41–42), Type 1000BASE-X MAC Parameters, Physical Layer, Repeater, and Management Parameters for 1000 Mb/s Operation	25 June 1998	**Geoffrey O. Thompson,** *Working Group Chair* **David J. Law,** *Working Group Vice Chair* **Howard M. Frazier, Jr.,** *Task Force Chair* **Howard W. Johnson,** *Task Force Editor*
IEEE Std 802.3aa-1998, Maintenance 5	25 June 1998	**Geoffrey O. Thompson,** *Working Group Chair* **Colin Mick**, *Task Force Editor*
IEEE Std 802.3ac-1998, Frame Extensions for Virtual Bridged Local Area Network (VLAN) Tagging on IEEE 802.3 Networks	16 September 1998	**Geoffrey O. Thompson,** *Working Group Chair* **David J. Law,** *Working Group Vice Chair* **Andy J. Luque,** *Working Group Secretary* **Ian Crayford,** *Task Force Chair* **Rich Seifert,** *Task Force Editor*
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	**Geoffrey O. Thompson,** *Working Group Chair* **David J. Law,** *Working Group Vice Chair* **Robert M. Grow,** *Working Group Secretary* **George Eisler**, *Task Force Chair* **Colin Mick**, *Task Force Editor*

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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	**Geoffrey O. Thompson,** *Working Group Chair* **David J. Law,** *Working Group Vice Chair* **Robert M. Grow,** *Working Group Secretary*
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	**Geoffrey O. Thompson,** *Working Group Chair* **David J. Law,** *Working Group Vice Chair* **Robert M. Grow,** *Working Group Secretary* **R. Jonathan Thatcher,** *Task Force Chair* **Stephen Haddock,** *Task Force Vice Chair* **Bradley J. Booth,** *Task Force Editor*
IEEE Std 802.3af-2003, (Clause 33) Data Terminal Equipment (DTE) Power via Media Dependent Interface (MDI)	12 June 2003	**Geoffrey O. Thompson,** *Working Group Chair (Phase 1)* **Robert M. Grow,** *Working Group Chair (Phase 2)* **David J. Law,** *Working Group Vice Chair* **Robert M. Grow,** *Working Group Secretary (Phase 1)* **Steven B. Carlson,** *Working Group Secretary (Phase 2)* **Steven B. Carlson,** *Task Force Chair* **Michael S. McCormack,** *Task Force Editor (Phase 1)* **John J. Jetzt,** *Task Force Editor (Phase 2)*
IEEE Std 802.3aj-2003, Maintenance 7	11 September 2003	**Robert M. Grow,** *Working Group Chair* **David J. Law,** *Working Group Vice Chair, Task Force Chair* **Steven B. Carlson,** *Working Group Secretary* **Catherine K. N. Berger,** *Task Force Editor*
IEEE Std 802.3ak-2004, Physical Layer and Management Parameters for 10Gb/s Operation, Type 10GBASE-CX4	9 February 2004	**Robert M. Grow,** *Working Group Chair* **David J. Law,** *Working Group Vice Chair* **Steven B. Carlson,** *Working Group Secretary* **Daniel J. Dove,** *Task Force Chair* **Howard A. Baumer,** *Task Force Editor*
IEEE Std 802.3ah-2004, Media Access Control Parameters, Physical Layers, and Management Parameters for Subscriber Access Networks	6 April 2005	**Robert M. Grow,** *Working Group Chair* **David J. Law,** *Working Group Vice Chair* **Steven B. Carlson,** *Working Group Secretary* **Howard Frazier,** *Task Force Chair* **Wael W. Diab,** *Task Force Editor-in-Chief* **Hugh Barrass,** *Task Force Vice-Chair*
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	**Robert M. Grow,** *Working Group Chair* **David J. Law,** *Working Group Vice Chair, Task Force Chair, Task Force Chief Editor* **Wael W. Diab,** *Working Group Secretary* **Steven B. Carlson,** *Working Group Executive Secretary*
IEEE Std 802.3an-2006, Physical Layer and Management Parameter for 10 Gb/s Operation, Type 10GBASE-T	8 June 2006	**Robert M. Grow,** *Working Group Chair* **David J. Law,** *Working Group Vice Chair* **Wael William Diab,** *Working Group Secretary* **Steven B. Carlson,** *Working Group Executive Secretary* **Bradley Booth,** *Task Force Chair* **Sanjay Kasturia,** *Task Force Editor-in-Chief*
IEEE Std 802.3-2005/Cor 1-2006 (IEEE 802.3au), DTE Power via MDI Isolation corrigendum	8 June 2006	**Robert M. Grow,** *Working Group Chair* **David J. Law,** *Working Group Vice Chair, Task Force Chair,* and *Task Force Editor* **Wael W. Diab**, *Working Group Secretary* **Steven B. Carlson,** *Working Group Executive Secretary*

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IEEE Std 802.3aq-2006, Physical Layer and Management Parameters for 10 Gb/s Operation, Type 10GBASE-LRM	15 September 2006	**Robert M. Grow,** *Working Group Chair* **David J. Law,** *Working Group Vice Chair* **Wael William Diab,** *Working Group Secretary* **Steven B. Carlson,** *Working Group Executive Secretary* **David G. Cunningham,** *Task Force Chair* **Nick Weiner,** *Task Force Editor*
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IEEE Std 802.3-2005/Cor 2-2007 (IEEE 802.3aw), 10GBASE-T corrigendum	7 June 2007	**Robert M. Grow,** *Working Group Chair* **David J. Law,** *Working Group Vice Chair, Task Force Chair,* and *Task Force Editor* **Wael W. Diab,** *Working Group Secretary* **Steven B. Carlson,** *Working Group Executive Secretary* **Bradley Booth,** *Working Group Treasurer*
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	**Robert M. Grow,** *Working Group Chair* **David J. Law,** *Working Group Vice Chair, Task Force Chair,* and *Task Force Editor* **Wael William Diab,** *Working Group Secretary* **Steven B. Carlson,** *Working Group Executive Secretary* **Bradley Booth,** *Working Group Treasurer*
IEEE Std 802.3at-2009 Data Terminal Equipment (DTE) Power via the Media Dependent Interface (MDI) Enhancements	11 September 2009	**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* **Bradley Booth,** *Working Group Treasurer* **Mike McCormack,** *Task Force Chair* **D. Matthew Landry,** *Task Force Chief Editor*
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IEEE Std 802.3bc-2009 Ethernet Organizationally Specific Type, Length, Value (TLVs)	11 September 2009	**David J. Law,** *Working Group Chair* and *Task Force Editor* **Wael W. Diab,** *Working Group Vice Chair* and *Task Force Chair* **Steven B. Carlson,** *Working Group Executive Secretary* **Adam Healey,** *Working Group Secretary* **Bradley Booth,** *Working Group Treasurer*
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IEEE Std 802.3 document	Date approved by IEEE	Working Group officers, Task Force Chair, and Task Force Editors as listed in the document
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	**David J. Law,** *Working Group Chair* **Wael William Diab,** *Working Group Vice-Chair* **Steven B. Carlson,** *Working Group Executive Secretary* **Adam Healey,** *Working Group Secretary* **Bradley Booth,** *Working Group Treasurer* **John D'Ambrosia,** *Task Force Chair* **Ilango S. Ganga,** *Task Force Editor-in-Chief*
IEEE Std 802.3az-2010 Media Access Control Parameters, Physical Layers, and Management Parameters for Energy-Efficient Ethernet	30 September 2010	**David J. Law,** *Working Group Chair* **Wael William Diab,** *Working Group Vice Chair* **Steven B. Carlson,** *Working Group Executive Secretary* **Adam Healey,** *Working Group Secretary* **Bradley Booth,** *Working Group Treasurer* **Michael Bennett,** *Task Force Chair* **Sanjay Kasturia,** *Task Force Editor-in-Chief*
IEEE Std 802.3bg-2011 Physical Layer and Management Parameters for Serial 40 Gb/s Ethernet Operation Over Single-Mode Fiber	31 March 2011	**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* **Mark Nowell,** *Task Force Chair* **Pete Anslow,** *Task Force Editor-in-Chief*
IEEE Std 802.3bf-2011 Media Access Control (MAC) Service Interface and Management Parameters to Support Time Synchronization Protocols	16 May 2011	**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* **Steven B. Carlson,** *Task Force Chair* **Marek Hajduczenia,** *Task Force Editor-in-Chief*
IEEE Std 802.3bd-2011 MAC Control Frame for Priority-based Flow Control	16 June 2011	**Tony Jeffree,** *IEEE 802.1 Working Group Chair* **Paul Congdon,** *IEEE 802.1 Working Group Vice Chair* **David J. Law,** *IEEE 802.3 Working Group Chair* **Wael W. Diab,** *IEEE 802.3 Working Group Vice Chair* **Pat Thaler,** *Data Center Bridging Task Group Chair*
IEEE Std 802.3-2012 (IEEE 802.3ah), Maintenance #10 (Revision of the base), Standard for Ethernet	28 December 2012	**David J. Law,** *Working Group Chair* **Wael William Diab,** *Working Group Vice-Chair, Task Force Chair,* and *Task Force Editor-in-Chief* **Adam Healey,** *Working Group Secretary* **Steven B. Carlson,** *Working Group Executive Secretary* **Valerie Maguire,** *Working Group Treasurer*
IEEE Std 802.3bk-2013 Physical Layer Specifications and Management Parameters for Extended Ethernet Passive Optical Networks	23 August 2013	**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* **Marek Hajduczenia,** *Task Force Chair* **Susumu Nishihara,** *Task Force Editor-in-Chief*
IEEE Std 802.3bj-2014 Physical Layer Specifications and Management Parameters for 100 Gb/s Operation Over Backplanes and Copper Cables	12 June 2014	**David J. Law,** *Working Group Chair* **Wael William Diab,** *Working Group Vice-Chair (initial)* **Adam Healey,** *Working Group Secretary, (initial), Task Force Editor-in-Chief (initial), Working Group Vice-Chair (final),* and *Task Force Chair (final)* **Peter Anslow,** *Working Group Secretary (final)* **Steven B. Carlson,** *Working Group Executive Secretary* **Valerie Maguire,** *Working Group Treasurer* **John D'Ambrosia,** *Task Force Chair (initial)* **Matthew Brown,** *Task Force Editor-in-Chief (final)*
IEEE Std 802.3bm-2015 Physical Layer Specifications and Management Parameters for 40 Gb/s and 100 Gb/s Operation Over Fiber Optic Cables	16 February 2015	**David J. Law,** *Working Group Chair* **Adam Healey,** *Working Group Vice-Chair* **Pete Anslow,** *Working Group Secretary* and *Task Force Editor-in-Chief* **Steven B. Carlson,** *Working Group Executive Secretary* **Valerie Maguire,** *Working Group Treasurer* **Dan Dove,** *Task Force Chair* **Kapil Shrikhande,** *Task Force Vice-Chair*

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IEEE Std 802.3-2015 (IEEE 802.3bx), Maintenance #11 (Revision of the base), Standard for Ethernet	3 September 2015	**David J. Law,** *Working Group Chair* **Adam Healey,** *Working Group Vice-Chair, Task Force Chair,* and *Task Force Editor-in-Chief* **Pete Anslow,** *Working Group Secretary* **Steven B. Carlson,** *Working Group Executive Secretary* **Valerie Maguire,** *Working Group Treasurer*
IEEE Std 802.3bw-2015 Physical Layer Specifications and Management Parameters for 100 Mb/s Operation over a Single Balanced Twisted Pair Cable (100BASE-T1)	26 October 2015	**David J. Law,** *Working Group Chair* **Adam Healey,** *Working Group Vice-Chair* **Pete Anslow,** *Working Group Secretary* **Steven B. Carlson,** *Working Group Executive Secretary* and *Task Force Chair, Phase 2* **Valerie Maguire,** *Working Group Treasurer* **Thomas Hogenmüller**, *Task Force Chair, Phase 1* **Mehmet Tazebay**, *Task Force Vice-Chair* **Curtis Donahue**, *Task Force Editor-in-Chief*
IEEE Std 802.3by-2016 Media Access Control Parameters, Physical Layers, and Management Parameters for 25 Gb/s Operation	30 June 2016	**David J. Law,** *Working Group Chair* **Adam Healey,** *Working Group Vice-Chair* **Pete Anslow,** *Working Group Secretary* **Steven B. Carlson,** *Working Group Executive Secretary* **Valerie Maguire,** *Working Group Treasurer* **Mark Nowell**, *Task Force Chair* **Matthew Brown**, *Task Force Editor-in-Chief*
IEEE Std 802.3bq-2016 Physical Layers and Management Parameters for 25 Gb/s and 40 Gb/s Operation, Types 25GBASE-T and 40GBASE-T	30 June 2016	**David J. Law,** *Working Group Chair* **Adam Healey,** *Working Group Vice-Chair* **Pete Anslow,** *Working Group Secretary* **Steven B. Carlson,** *Working Group Executive Secretary* **Valerie Maguire,** *Working Group Treasurer* **David Chalupsky**, *Task Force Chair* **George Zimmerman**, *Task Force Editor-in-Chief*
IEEE Std 802.3bp-2016 Physical Layer Specifications and Management Parameters for 1 Gb/s Operation over a Single Twisted-Pair Copper Cable	30 June 2016	**David J. Law,** *Working Group Chair* **Adam Healey,** *Working Group Vice-Chair* **Pete Anslow,** *Working Group Secretary* **Steven B. Carlson,** *Working Group Executive Secretary* and *Task Force Chair* **Valerie Maguire,** *Working Group Treasurer* **Marek Hajduczenia**, *Task Force Editor-in-Chief*
IEEE Std 802.3br-2016 Specification and Management Parameters for Interspersing Express Traffic	30 June 2016	**David J. Law,** *Working Group Chair* **Adam Healey,** *Working Group Vice-Chair* **Pete Anslow,** *Working Group Secretary* **Steven B. Carlson,** *Working Group Executive Secretary* **Valerie Maguire,** *Working Group Treasurer* **Ludwig Winkel**, *Task Force Chair* **Patricia Thaler**, *Task Force Editor-in-Chief*
IEEE Std 802.3bn-2016 Physical Layer Specifications and Management Parameters for Ethernet Passive Optical Networks Protocol over Coax	22 September 2016	**David J. Law,** *Working Group Chair* **Adam Healey,** *Working Group Vice-Chair* **Pete Anslow,** *Working Group Secretary* **Steven B. Carlson,** *Working Group Executive Secretary* **Valerie Maguire,** *Working Group Treasurer* **Mark Laubach**, *Task Force Chair* **Duane Remein**, *Task Force Editor-in-Chief*
IEEE Std 802.3bz-2016 Media Access Control Parameters, Physical Layers, and Management Parameters for 2.5 Gb/s and 5 Gb/s Operation, Types 2.5GBASE-T and 5GBASE-T	22 September 2016	**David J. Law,** *Working Group Chair* **Adam Healey,** *Working Group Vice-Chair* **Pete Anslow,** *Working Group Secretary* **Steven B. Carlson,** *Working Group Executive Secretary* **Valerie Maguire,** *Working Group Treasurer* **David Chalupsky**, *Task Force Chair* **George Zimmerman**, *Task Force Editor-in-Chief*
IEEE Std 802.3bu-2016 Physical Layer and Management Parameters for Power over Data Lines (PoDL) of Single Balanced Twisted-Pair Ethernet	7 December 2016	**David J. Law,** *Working Group Chair* **Adam Healey,** *Working Group Vice-Chair* **Pete Anslow,** *Working Group Secretary* **Steven B. Carlson,** *Working Group Executive Secretary* **Valerie Maguire,** *Working Group Treasurer* **Dave Dwelley,** *Task Force Chair, Phase 1* **Dan Dove,** *Task Force Chair, Phase 2* **Andy Gardner**, *Task Force Editor-in-Chief*

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IEEE Std 802.3bv-2017 Physical Layer Specifications and Management Parameters for 1000 Mb/s Operation Over Plastic Optical Fiber	14 February 2017	**David J. Law,** *Working Group Chair* **Adam Healey,** *Working Group Vice-Chair* **Pete Anslow,** *Working Group Secretary* **Steven B. Carlson,** *Working Group Executive Secretary* **Valerie Maguire,** *Working Group Treasurer* **Robert M. Grow,** *Task Force Chair* **Rubén Pérez-Aranda***, Task Force Editor-in-Chief*
IEEE Std 802.3-2015/Cor 1-2017 (IEEE 802.3ce) Multilane Timestamping	23 March 2017	**David J. Law,** *Working Group Chair* **Adam Healey,** *Working Group Vice-Chair, Task Force Chair,* and *Task Force Editor-in-Chief* **Pete Anslow,** *Working Group Secretary* **Steven B. Carlson,** *Working Group Executive Secretary* **Valerie Maguire,** *Working Group Treasurer*
IEEE Std 802.3bs-2017 Media Access Control Parameters, Physical Layers, and Management Parameters for 200 Gb/s and 400 Gb/s Operation	6 December 2017	**David J. Law,** *Working Group Chair* **Adam Healey,** *Working Group Vice-Chair* **Pete Anslow,** *Working Group Secretary* and *Task Force Editor-in-Chief* **Steven B. Carlson,** *Working Group Executive Secretary* **Valerie Maguire,** *Working Group Treasurer* **John D'Ambrosia,** *Task Force Chair*
IEEE Std 802.3cc-2017 Physical Layer and Management Parameters for Serial 25 Gb/s Ethernet Operation Over Single-Mode Fiber	6 December 2017	**David J. Law,** *Working Group Chair* **Adam Healey,** *Working Group Vice-Chair* **Pete Anslow,** *Working Group Secretary* **Steven B. Carlson,** *Working Group Executive Secretary* **Valerie Maguire,** *Working Group Treasurer* **David Lewis,** *Task Force Chair* **Kohichi R. Tamura,** *Task Force Editor-in-Chief*

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When the IEEE-SA Standards Board approved this standard on 14 June 2018, it had the following membership:

Introduction

This introduction is not part of IEEE Std 802.3-2018, 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 the standard. Each IEEE 802.3 project/amendment is identified with a suffix (e.g., IEEE Std 802.3ba™-2010).

The half duplex Media Access Control (MAC) protocol specified in IEEE Std 802.3-1985 is Carrier Sense Multiple Access with Collision Detection (CSMA/CD). This MAC protocol was key to the experimental Ethernet developed at Xerox Palo Alto Research Center, which had a 2.94 Mb/s data rate. Ethernet at 10 Mb/s was jointly released as a public specification by Digital Equipment Corporation (DEC), Intel and Xerox in 1980. Ethernet at 10 Mb/s was approved as an IEEE standard by the IEEE Standards Board in 1983 and subsequently published in 1985 as IEEE Std 802.3-1985. Since 1985, new media options, new speeds of operation, and new capabilities have been added to IEEE Std 802.3. A full duplex MAC protocol was added in 1997.

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 802.3z 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 802.3-2015 and are not maintained as separate documents.

At the date of IEEE Std 802.3-2018 publication, IEEE Std 802.3 is composed of the following documents:

IEEE Std 802.3-2018

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 95 and Annex 83A through Annex 93C. 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 95 and associated annexes include general information on 40 Gb/s and 100 Gb/s operation as well as 40 Gb/s and 100 Gb/s Physical Layer specifications. Clause 90 specifies Ethernet support for time synchronization protocols.

Section Seven—Includes Clause 96 through Clause 115 and Annex 97A through Annex 115A. Clause 96 through Clause 98, Clause 104, and associated annexes, specify Physical Layers and optional features for 100 Mb/s and 1000 Mb/s operation over a single twisted pair. Clause 100 through Clause 103, as well as associated annexes, specify Physical Layers for the operation of the EPON protocol over coaxial distribution networks. Clause 105 through Clause 114 and associated annexes include general information on 25 Gb/s operation as well as 25 Gb/s Physical Layer specifications. Clause 99 specifies a MAC merge sublayer for the interspersing of express traffic. Clause 115 and its associated annex specify a Physical Layer for 1000 Mb/s operation over plastic optical fiber.

Section Eight—Includes Clause 116 through Clause 126 and Annex 119A through Annex 120E. Clause 116 through Clause 124 and associated annexes include general information on 200 Gb/s and 400 Gb/s operation as well as 200 Gb/s and 400 Gb/s Physical Layer specifications. Clause 125 and Clause 126 include general information on 2.5 Gb/s and 5 Gb/s operation as well as 2.5 Gb/s and 5 Gb/s Physical Layer specifications.

A companion document IEEE Std 802.3.1 describes Ethernet management information base (MIB) modules for use with the Simple Network Management Protocol (SNMP). IEEE Std 802.3.1 is updated to add management capability for enhancements to IEEE Std 802.3 after approval of the enhancements.

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.

Acknowledgments

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IEEE Standard for Ethernet

SECTION ONE

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

Contents

IEEE Standard for Ethernet

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

1. Introduction

1.1 Overview

This is an international standard for Local and Metropolitan Area Networks (LANs and MANs), employing CSMA/CD as the shared media access method and the IEEE 802.3 (Ethernet) protocol and frame format for data communication. This international standard is intended to encompass several media types and techniques for a variety of MAC data rates as shown in Figure 1–1 and in 4.4.2.

1.1.1 Scope

This standard defines Ethernet local area, access and metropolitan area networks. Ethernet is specified at selected speeds of operation; and uses 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) provide an architectural and optional implementation interface to selected Physical Layer entities (PHY). The Physical Layer encodes frames for transmission and decodes received frames with the modulation specified for the speed of operation, transmission medium and supported link length. Other specified capabilities include: control and management protocols, and the provision of power over selected twisted pair PHY types.

1.1.2 Basic concepts

This standard provides for two distinct modes of operation: half duplex and full duplex. A given IEEE 802.3 instantiation operates in either half or full duplex mode at any one time. The term "CSMA/CD MAC" is used throughout this standard synonymously with "802.3 MAC," and may represent an instance of either a half duplex or full duplex mode data terminal equipment (DTE), even though full duplex mode DTEs do not implement the CSMA/CD algorithms traditionally used to arbitrate access to shared-media LANs.

1.1.2.1 Half duplex operation

In half duplex mode, the CSMA/CD media access method is the means by which two or more stations share a common transmission medium. To transmit, a station waits (defers) for a quiet period on the medium (that is, no other station is transmitting) and then sends the intended message in bit-serial form. If, after initiating a transmission, the message collides with that of another station, then each transmitting station intentionally transmits for an additional predefined period to ensure propagation of the collision throughout the system. The station remains silent for a random amount of time (backoff) before attempting to transmit again. Each aspect of this access method process is specified in detail in subsequent clauses of this standard.

Half duplex operation can be used with certain media types and configurations as defined by this standard. For allowable configurations, see 4.4.2.

1.1.2.2 Full duplex operation

Full duplex operation allows simultaneous communication between a pair of stations using point-to-point media (dedicated channel). Full duplex operation does not require that transmitters defer, nor do they monitor or react to receive activity, as there is no contention for a shared medium in this mode. Full duplex mode can only be used when all of the following are true:

a) The physical medium is capable of supporting simultaneous transmission and reception without interference.
b) There are exactly two stations connected with a full duplex point-to-point link. Since there is no contention for use of a shared medium, the multiple access (i.e., CSMA/CD) algorithms are unnecessary.
c) Both stations on the LAN are capable of, and have been configured to use, full duplex operation.

The most common configuration envisioned for full duplex operation consists of a central bridge (also known as a switch) with a dedicated LAN connecting each bridge port to a single device. Repeaters as defined in this standard are outside the scope of full duplex operation.

Full duplex operation constitutes a proper subset of the MAC functionality required for half duplex operation.

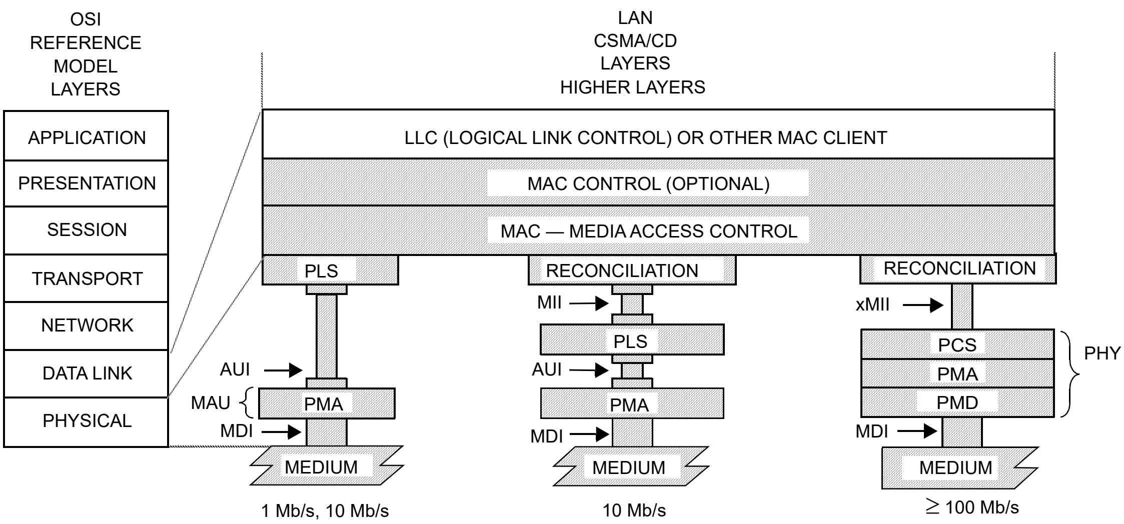
1.1.3 Architectural perspectives

There are two important ways to view network design corresponding to the following:

a) *Architecture.* Emphasizing the logical divisions of the system and how they fit together.
b) *Implementation.* Emphasizing actual components, their packaging, and interconnection.

This standard is organized along architectural lines, emphasizing the large-scale separation of the system into two parts: the Media Access Control (MAC) sublayer of the Data Link Layer and the Physical Layer. These layers are intended to correspond closely to the lowest layers of the ISO/IEC Model for Open Systems Interconnection (see Figure 1–1). (See ISO/IEC 7498-1:1994.[1]) The Logical Link Control (LLC) sublayer and MAC sublayer together encompass the functions intended for the Data Link Layer as defined in the OSI model.

[1]For information about references, see 1.3.



AUI = ATTACHMENT UNIT INTERFACE
MAU = MEDIUM ATTACHMENT UNIT
MDI = MEDIUM DEPENDENT INTERFACE
MII = MEDIA INDEPENDENT INTERFACE
PCS = PHYSICAL CODING SUBLAYER
PHY = PHYSICAL LAYER DEVICE
PLS = PHYSICAL LAYER SIGNALING
PMA = PHYSICAL MEDIUM ATTACHMENT
PMD = PHYSICAL MEDIUM DEPENDENT

NOTE—In this figure, the xMII is used as a generic term for the Media Independent Interfaces for implementations of 100 Mb/s and above. For example: for 100 Mb/s implementations this interface is called MII; for 1 Gb/s implementations it is called GMII; for 10 Gb/s implementations it is called XGMII; etc.

Figure 1–1—IEEE 802.3 standard relationship to the ISO/IEC Open Systems Interconnection (OSI) reference model

1.1.3.1 Architectural rationale

An architectural organization of the standard has two main advantages:

a) *Clarity*. A clean overall division of the design along architectural lines makes the standard clearer.
b) *Flexibility*. Segregation of medium-dependent aspects in the Physical Layer allows the LLC and MAC sublayers to apply to a family of transmission media.

Partitioning the Data Link Layer allows various media access methods within the family of LAN standards.

The architectural model is based on a set of interfaces that may be different from those emphasized in implementations. One critical aspect of the design, however, shall be addressed largely in terms of the implementation interfaces: compatibility.

1.1.3.2 Compatibility interfaces

The following important compatibility interfaces are defined within what is architecturally the Physical Layer.

a) *Medium Dependent Interfaces (MDI)*. To communicate in a compatible manner, all stations shall adhere rigidly to the exact specification of physical media signals defined in the appropriate clauses in this standard, and to the procedures that define correct behavior of a station. The medium-independent aspects of the LLC sublayer and the MAC sublayer should not be taken as detracting from this point; communication in an Ethernet Local Area Network requires complete compatibility at the Physical Medium interface (that is, the physical cable interface).

b) *Attachment Unit Interface (AUI).* Some DTEs are located some distance from their connection to the physical cable. A small amount of circuitry will exist in the Medium Attachment Unit (MAU) directly adjacent to the physical cable, while the majority of the hardware and all of the software will be placed within the DTE. The AUI is defined as a second compatibility interface. While conformance with this interface is not strictly necessary to ensure communication, it is recommended, since it allows maximum flexibility in intermixing MAUs and DTEs. The AUI may be optional or not specified for some implementations of this standard that are expected to be connected directly to the medium and so do not use a separate MAU or its interconnecting AUI cable. The PLS and PMA are then part of a single unit, and no explicit AUI implementation is required.

c) *Media Independent Interface (MII).* It is anticipated that some DTEs will be connected to a remote PHY, and/or to different medium dependent PHYs. The MII is defined as a third compatibility interface. While conformance with implementation of this interface is not strictly necessary to ensure communication, it is recommended, since it allows maximum flexibility in intermixing PHYs and DTEs. The MII is optional.

d) *Gigabit Media Independent Interface (GMII).* The GMII is designed to connect a 1 Gb/s capable MAC or repeater unit to a 1 Gb/s PHY. While conformance with implementation of this interface is not strictly necessary to ensure communication, it is recommended, since it allows maximum flexibility in intermixing PHYs and DTEs at 1 Gb/s speeds. The GMII is intended for use as a chip-to-chip interface. No mechanical connector is specified for use with the GMII. The GMII is optional.

e) *Ten-bit Interface (TBI).* The TBI is provided by the 1000BASE-X PMA sublayer as a physical instantiation of the PMA service interface. The TBI is recommended for 1000BASE-X systems, since it provides a convenient partition between the high-frequency circuitry associated with the PMA sublayer and the logic functions associated with the PCS and MAC sublayers. The TBI is intended for use as a chip-to-chip interface. No mechanical connector is specified for use with the TBI. The TBI is optional.

f) *10 Gigabit Media Independent Interface (XGMII).* The XGMII is designed to connect a 2.5 Gb/s, 5 Gb/s, or 10 Gb/s capable MAC to a PHY of the same rate. While conformance with implementation of this interface is not necessary to ensure communication, it allows maximum flexibility in intermixing PHYs and DTEs at 2.5 Gb/s, 5 Gb/s, and 10 Gb/s speeds. The XGMII is intended for use as a chip-to-chip interface. No mechanical connector is specified for use with the XGMII. The XGMII is optional.

g) *10 Gigabit Attachment Unit Interface (XAUI).* The XAUI is designed to extend the connection between a 10 Gb/s capable MAC and a 10 Gb/s PHY. While conformance with implementation of this interface is not necessary to ensure communication, it is recommended, since it allows maximum flexibility in intermixing PHYs and DTEs at 10 Gb/s speeds. The XAUI is intended for use as a chip-to-chip interface. No mechanical connector is specified for use with the XAUI. The XAUI is optional.

h) *10 Gigabit Sixteen-Bit Interface (XSBI).* The XSBI is provided as a physical instantiation of the PMA service interface for 10GBASE-R and 10GBASE-W PHYs. While conformance with implementation of this interface is not necessary to ensure communication, it provides a convenient partition between the high-frequency circuitry associated with the PMA sublayer and the logic functions associated with the PCS and MAC sublayers. No mechanical connector is specified for use with the XSBI. The XSBI is optional.

i) *25 Gigabit Media Independent Interface (25GMII).* The 25GMII is designed to connect a 25 Gb/s capable MAC to a 25 Gb/s PHY. While conformance with implementation of this interface is not necessary to ensure communication, it allows flexibility in intermixing PHYs and DTEs at 25 Gb/s speeds. The 25GMII is a logical interconnection intended for use as an intra-chip interface. No mechanical connector is specified for use with the 25GMII. The 25GMII is optional.

j) *25 Gigabit Attachment Unit Interface (25GAUI).* The 25GAUI is a physical instantiation of the PMA service interface to extend the connection between 25 Gb/s capable PMAs. While conformance with implementation of this interface is not necessary to ensure communication, it is recommended, since it allows maximum flexibility in intermixing PHYs and DTEs at 25 Gb/s speeds. The 25GAUI is intended for use as a chip-to-chip or a chip-to-module interface. No mechanical connector is specified for use with the 25GAUI. The 25GAUI is optional.

k) *40 Gb/s Media Independent Interface (XLGMII).* The XLGMII is designed to connect a 40 Gb/s capable MAC to a 40 Gb/s PHY. While conformance with implementation of this interface is not necessary to ensure communication, it allows flexibility in intermixing PHYs and DTEs at 40 Gb/s speeds. The XLGMII is a logical interconnection intended for use as an intra-chip interface. No mechanical connector is specified for use with the XLGMII. The XLGMII is optional.

l) *40 Gb/s Attachment Unit Interface (XLAUI).* The XLAUI is a physical instantiation of the PMA service interface to extend the connection between 40 Gb/s capable PMAs. While conformance with implementation of this interface is not necessary to ensure communication, it is recommended, since it allows maximum flexibility in intermixing PHYs and DTEs at 40 Gb/s speeds. The XLAUI is intended for use as a chip-to-chip or a chip-to-module interface. No mechanical connector is specified for use with the XLAUI. The XLAUI is optional.

m) *40 Gb/s Parallel Physical Interface (XLPPI)*. The XLPPI is provided as a physical instantiation of the PMD service interface for 40GBASE-SR4 and 40GBASE-LR4 PMDs. The XLPPI has four lanes. While conformance with implementation of this interface is not necessary to ensure communication, it allows flexibility in connecting the 40GBASE-SR4 or 40GBASE-LR4 PMDs. The XLPPI is intended for use as a chip-to-module interface. No mechanical connector is specified for use with the XLPPI. The XLPPI is optional.

n) *100 Gb/s Media Independent Interface (CGMII).* The CGMII is designed to connect a 100 Gb/s capable MAC to a 100 Gb/s PHY. While conformance with implementation of this interface is not necessary to ensure communication, it allows flexibility in intermixing PHYs and DTEs at 100 Gb/s speeds. The CGMII is a logical interconnection intended for use as an intra-chip interface. No mechanical connector is specified for use with the CGMII. The CGMII is optional.

o) *100 Gb/s Attachment Unit Interface (CAUI-n).* The CAUI-n is a physical instantiation of the PMA service interface to extend the connection between 100 Gb/s capable PMAs. While conformance with implementation of this interface is not necessary to ensure communication, it is recommended, since it allows maximum flexibility in intermixing PHYs and DTEs at 100 Gb/s speeds. The CAUI-n is intended for use as a chip-to-chip or a chip-to-module interface. Two widths of CAUI-n are defined: a ten-lane version (CAUI-10) in Annex 83A and Annex 83B, and a four-lane version (CAUI-4) in Annex 83D and Annex 83E. No mechanical connector is specified for use with the CAUI-n. The CAUI-n is optional.

p) *100 Gb/s Parallel Physical Interface (CPPI)*. The CPPI is provided as a physical instantiation of the PMD service interface for 100GBASE-SR10 PMDs. The CPPI has ten lanes. While conformance with implementation of this interface is not necessary to ensure communication, it allows flexibility in connecting the 100GBASE-SR10 PMDs. The CPPI is intended for use as a chip-to-module interface. No mechanical connector is specified for use with the CPPI. The CPPI is optional.

q) *200 Gb/s Media Independent Interface (200GMII).* The 200GMII is designed to connect a 200 Gb/s capable MAC to a 200 Gb/s PHY. While conformance with implementation of this interface is not necessary to ensure communication, it allows flexibility in intermixing PHYs and DTEs at 200 Gb/s speeds. The 200GMII is a logical interconnection intended for use as an intra-chip interface. No mechanical connector is specified for use with the 200GMII. The 200GMII is optional.

r) *200 Gb/s Attachment Unit Interface (200GAUI-n).* The 200GAUI-n is a physical instantiation of the PMA service interface to extend the connection between 200 Gb/s capable PMAs. While conformance with implementation of this interface is not necessary to ensure communication, it is recommended, since it allows maximum flexibility in intermixing PHYs and DTEs at 200 Gb/s speeds. The 200GAUI-n is intended for use as a chip-to-chip or a chip-to-module interface. Two widths of 200GAUI-n are defined: an eight-lane version (200GAUI-8) in Annex 120B and Annex 120C, and a four-lane version (200GAUI-4) in Annex 120D and Annex 120E. No mechanical connector is specified for use with the 200GAUI-n. The 200GAUI-n is optional.

s) *400 Gb/s Media Independent Interface (400GMII).* The 400GMII is designed to connect a 400 Gb/s capable MAC to a 400 Gb/s PHY. While conformance with implementation of this interface is not necessary to ensure communication, it allows flexibility in intermixing PHYs and DTEs at 400 Gb/s speeds. The 400GMII is a logical interconnection intended for use as an intra-chip interface. No mechanical connector is specified for use with the 400GMII. The 400GMII is optional.

t) *400 Gb/s Attachment Unit Interface (400GAUI-n).* The 400GAUI-n is a physical instantiation of the PMA service interface to extend the connection between 400 Gb/s capable PMAs. While conformance with implementation of this interface is not necessary to ensure communication, it is recommended, since it allows maximum flexibility in intermixing PHYs and DTEs at 400 Gb/s speeds. The 400GAUI-n is intended for use as a chip-to-chip or a chip-to-module interface. Two widths of 400GAUI-n are defined: a sixteen-lane version (400GAUI-16) in Annex 120B and Annex 120C, and an eight-lane version (400GAUI-8) in Annex 120D and Annex 120E. No mechanical connector is specified for use with the 400GAUI-n. The 400GAUI-n is optional.

1.1.4 Layer interfaces

In the architectural model used here, the layers interact by way of well-defined interfaces, providing services as specified in Clause 2 and Clause 6. In general, the interface requirements are as follows:

a) The interface between the MAC sublayer and its client includes facilities for transmitting and receiving frames, and provides per-operation status information for use by higher-layer error recovery procedures.

b) The interface between the MAC sublayer and the Physical Layer includes signals for framing (carrier sense, receive data valid, transmit initiation) and contention resolution (collision detect), facilities for passing a pair of serial bit streams (transmit, receive) between the two layers, and a wait function for timing.

These interfaces are described more precisely in 4.3. Additional interfaces are necessary to provide for MAC Control services, and to allow higher level network management facilities to interact with these layers to perform operation, maintenance, and planning functions. Network management functions are described in Clause 30.

1.1.5 Application areas

Use of this standard is not restricted to any specific environments or applications.

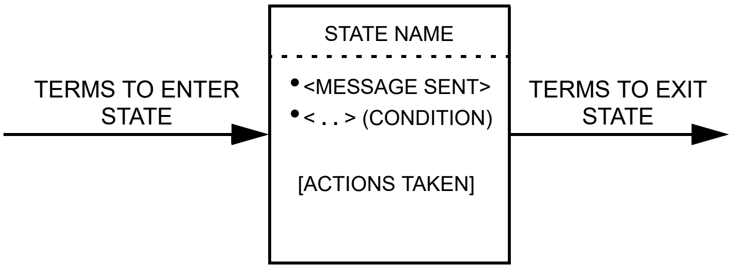
In the context of this standard, the term “LAN” is used to indicate all networks that utilize the IEEE 802.3 (Ethernet) protocol for communication. These may include (but are not limited to) LANs and MANs.

1.2 Notation

1.2.1 State diagram conventions

The operation of a protocol can be described by subdividing the protocol into a number of interrelated functions. The operation of the functions can be described by state diagrams. Each diagram represents the domain of a function and consists of a group of connected, mutually exclusive states. Only one state of a function is active at any given time (see Figure 1–2).

Each state that the function can assume is represented by a rectangle. These are divided into two parts by a horizontal line. In the upper part the state is identified by a name in capital letters. The lower part contains the name of any ON signal that is generated by the function. Actions are described by short phrases and enclosed in brackets.



Key: ( ) = condition, for example, (if no_collision)
[ ] = action, for example, [reset PLS functions]
* = logical AND
+ = logical OR, arithmetic addition
Tw = Wait Time, implementation dependent
Td = Delay Timeout
Tb = Backoff Timeout
UCT = unconditional transition

Figure 1–2—State diagram notation example

All permissible transitions between the states of a function are represented graphically by arrows between them. A transition that is global in nature (for example, an exit condition from all states to the IDLE or RESET state) is indicated by an open arrow. Labels on transitions are qualifiers that must be fulfilled before the transition will be taken. The label UCT designates an unconditional transition. Qualifiers described by short phrases are enclosed in parentheses.

State transitions and sending and receiving of messages occur instantaneously. When a state is entered and the condition to leave that state is not immediately fulfilled, the state executes continuously, sending the messages and executing the actions contained in the state in a continuous manner.

Some devices described in this standard (e.g., repeaters) are allowed to have two or more ports. State diagrams that are capable of describing the operation of devices with an unspecified number of ports require a qualifier notation that allows testing for conditions at multiple ports. The notation used is a term that includes a description in parentheses of which ports must meet the term for the qualifier to be satisfied (e.g., ANY and ALL). It is also necessary to provide for term-assignment statements that assign a name to a port that satisfies a qualifier. The following conventions are used to describe a term-assignment statement that is associated with a transition:

a) The character ":" (colon) is a delimiter used to denote that a term assignment statement follows.
b) The character "⇐" (left arrow) denotes assignment of the value following the arrow to the term preceding the arrow.

The state diagrams contain the authoritative statement of the functions they depict; when apparent conflicts between descriptive text and state diagrams arise, the state diagrams are to take precedence. This does not override, however, any explicit description in the text that has no parallel in the state diagrams.

The models presented by state diagrams are intended as the primary specifications of the functions to be provided. It is important to distinguish, however, between a model and a real implementation. The models are optimized for simplicity and clarity of presentation, while any realistic implementation may place heavier emphasis on efficiency and suitability to a particular implementation technology. It is the functional behavior of any unit that must match the standard, not its internal structure. The internal details of the model are useful only to the extent that they specify the external behavior clearly and precisely.

1.2.2 Service specification method and notation

The service of a layer or sublayer is the set of capabilities that it offers to a user in the next higher (sub)layer. Abstract services are specified here by describing the service primitives and parameters that characterize each service. This definition of service is independent of any particular implementation (see Figure 1–3).

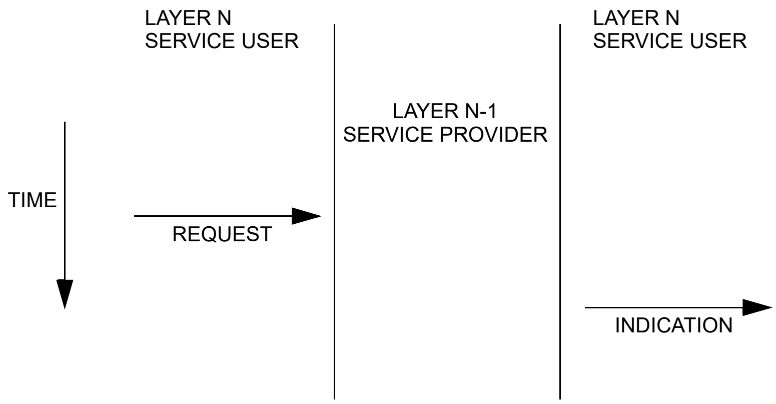


Figure 1–3—Service primitive notation

Specific implementations may also include provisions for interface interactions that have no direct end-to-end effects. Examples of such local interactions include interface flow control, status requests and indications, error notifications, and layer management. Specific implementation details are omitted from this service specification both because they will differ from implementation to implementation and because they do not impact the peer-to-peer protocols.

1.2.2.1 Classification of service primitives

Primitives are of two generic types:

a) REQUEST. The request primitive is passed from layer N to layer N-1 to request that a service be initiated.
b) INDICATION. The indication primitive is passed from layer N-1 to layer N to indicate an internal layer N-1 event that is significant to layer N. This event may be logically related to a remote service request, or may be caused by an event internal to layer N-1.

The service primitives are an abstraction of the functional specification and the user-layer interaction. The abstract definition does not contain local detail of the user/provider interaction. For instance, it does not indicate the local mechanism that allows a user to indicate that it is awaiting an incoming call. Each primitive has a set of zero or more parameters, representing data elements that shall be passed to qualify the functions invoked by the primitive. Parameters indicate information available in a user/provider interaction; in any particular interface, some parameters may be explicitly stated (even though not explicitly defined in the primitive) or implicitly associated with the service access point. Similarly, in any particular protocol specification, functions corresponding to a service primitive may be explicitly defined or implicitly available.

1.2.3 Physical Layer and media notation

Users of this standard need to reference which particular implementation is being used or identified. Therefore, a means of identifying each implementation is given by a simple, three-field, type notation that is explicitly stated at the beginning of each relevant clause. In general, the Physical Layer type is specified by these fields:

<data rate> <modulation type> <additional distinction>

The data rate, if only a number, is in Mb/s, and if suffixed by a "G", is in Gb/s. The modulation type (e.g., BASE) indicates how encoded data is transmitted on the medium. The additional distinction may identify characteristics of transmission or medium and, in some cases, the type of PCS encoding used (examples of additional distinctions are "T" for twisted pair, "B" for bidirectional optics, and "X" for a block PCS coding used for that speed of operation). Expansions for defined Physical Layer types are included in 1.4.

1.2.4 Physical Layer message notation

Messages generated within the Physical Layer, either within or between PLS and the MAU (that is, PMA circuitry), are designated by an italic type to designate either form of physical or logical message used to execute the Physical Layer signaling process (for example, *input_idle* or *mau_available*).

1.2.5 Hexadecimal notation

Numerical values designated by the 0x prefix indicate a hexadecimal interpretation of the corresponding number. For example: 0x0F represents an 8-bit hexadecimal value of the decimal number 15; 0x00000000 represents a 32-bit hexadecimal value of the decimal number 0; etc.

Numerical values designated with a 16 subscript indicate a hexadecimal interpretation of the corresponding number. For example: $0F_{16}$ represents an 8-bit hexadecimal value of the decimal number 15.

1.2.6 Accuracy and resolution of numerical quantities

Unless otherwise stated, numerical limits in this standard are to be taken as exact, with the number of significant digits and trailing zeros having no significance.

1.2.7 Qm.n number format

The Qm.n number format is a fixed-point number format where the number of fractional bits is specified by n and optionally the number of integer bits is specified by m. For example, a Q14 number has 14 fractional bits; a Q2.14 number has 2 integer bits and 14 fractional bits. Preceding the "Q" with a "U" indicates an unsigned number.

1.2.8 Em dash (—) in a table cell

A table cell containing an em-dash (—) indicates a lack of data for that cell, or:

- For a units cell, that there is no unit for that parameter
- For a maximum cell, that there is no requirement on the maximum value of that parameter
- For a minimum cell, that there is no requirement on the minimum value of that parameter

1.3 Normative references

The following standards contain provisions that, through reference in this text, constitute provisions of this standard. Standards may be subject to revision, and parties subject to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid international standards. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.

ANSI INCITS 230-1994 (R1999), Information Technology—Fibre Channel—Physical and Signaling Interface (FC-PH) [formerly ANSI X3.230-1994 (R1999)].[2]

ANSI INCITS 263-1995 (S2010), Fibre Distributed Data Interface (FDDI)—Token Ring Twisted Pair Physical Layer Medium Dependent (TP-PMD) [formerly INCITS 263-1995 (R2005)].

ANSI/TIA-568-C.0 (February 2009), Generic Telecommunications Cabling for Customer Premises.[3]

ANSI/TIA-568-C.2-1 (July 2016), Balanced Twisted-Pair Telecommunications Cabling and Components Standard, Addendum 1: Specifications for 100 Ω Next Generation Cabling.

ANSI/TIA-568-C.2 (August 2009), Commercial Building Telecommunications Cabling Standard Part 2: Balanced Twisted-Pair Cabling Components.

ANSI/TIA-568-C.3 (June 2008), Optical Fiber Cabling Components Standard.

ANSI/TIA-604-18:2015, FOCIS 18—Fiber Optic Connector Intermateability Standard—Type MPO-16.

ANSI/TIA/EIA-455-175A-92, Chromatic Dispersion Measurement of Single-Mode Optical Fibers by the Differential Phase-Shift Method.

ANSI/TIA/EIA-455-203-2001, Launched Power Distribution Measurement Procedure for Graded-Index Multimode Transmitters.

ANSI/TIA/EIA-455-204-2000, Measurement of Bandwidth on Multimode Fiber.

ANSI/TIA/EIA-568-A-1995, Commercial Building Telecommunications Cabling Standard.

ASTM D4728, Standard Test Method for Random Vibration Testing of Shipping Containers.[4]

ATIS-0300269.2006(S2016), Structure and Representation of Trace Message Formats for Information Exchange.[5]

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[13]IEEE Std 802.1F-1993 has been withdrawn; however, copies can be obtained from Global Engineering, 15 Inverness Way East, Englewood, CO 80112-5704, USA, tel. (303) 792-2181 (http://global.ihs.com/).
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NOTE—Local and national standards such as those supported by ANSI, EIA, MIL, NFPA, and UL are not a formal part of this standard except where no international standard equivalent exists. A number of local and national standards are referenced as resource material; these bibliographical references are located in the bibliography in Annex A.[24]