

INTERNATIONAL STANDARD

ISO/IEC
8802-3

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Std 802.3

Fifth edition
1996-07-29

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

Part 3:

Carrier sense multiple access with collision
detection (CSMA/CD) access method and
physical layer specifications

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

*Partie 3: Accès multiple par surveillance du signal et détection de collision
(CSMA/CD) et spécifications pour la couche physique*



Reference number
ISO/IEC 8802-3:1996(E)
ANSI/IEEE
Std 802.3-1996 Edition



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Abstract: This Local and Metropolitan Area Network standard, ISO/IEC 8802-3: 1996 [ANSI/IEEE Std 802.3, 1996 Edition], specifies the media access control characteristics for the Carrier Sense Multiple Access with Collision Detection (CSMA/CD) access method. It also specifies the media, Medium Attachment Unit (MAU) and physical layer repeater unit for 10 Mb/s baseband and broadband systems, and it provides a 1 Mb/s baseband implementation. Specifications for MAU types 10BASE5, 10BASE2, FOIRL (fiber optic inter-repeater link), 10BROAD36, 1BASE5, 10BASE-T, and 10BASE-F are included. System considerations for multisegment 10 Mb/s baseband networks are provided. Layer and sublayer interface specifications are aligned to the ISO/IEC Open Systems Interconnection Basic Reference Model and 8802 models. The 8802-3 internal model is defined and used.

Keywords: attachment unit interface (AUI), data processing, Ethernet, information interchange, local area networks; local area networks, management; mode of data transmission, network interconnection, models, repeater

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ANSI/IEEE Std 802.3, 1996 Edition

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

**Part 3: Carrier sense multiple access
with collision detection (CSMA/CD)
access method and physical layer
specifications**

Sponsor

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



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and by the
International Electrotechnical Commission



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International Standard ISO/IEC 8802-3: 1996

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In the field of information technology, ISO and IEC have established a joint technical committee, ISO/IEC JTC 1. Draft International Standards adopted by the joint technical committee are circulated to national bodies for voting. Publication as an International Standard requires approval by at least 75% of the national bodies casting a vote.

The first international edition of this standard was published as ISO 8802-3 : 1989. New editions were published in 1990, 1992, and 1993.

This fifth edition cancels and replaces the fourth edition (ISO/IEC 8802-3: 1993), which has been technically revised.

For the purpose of assigning organizationally unique identifiers, the Institute of Electrical and Electronics Engineers, Inc., USA, has been designated by the ISO Council as the Registration Authority. Communications on this subject should be addressed to

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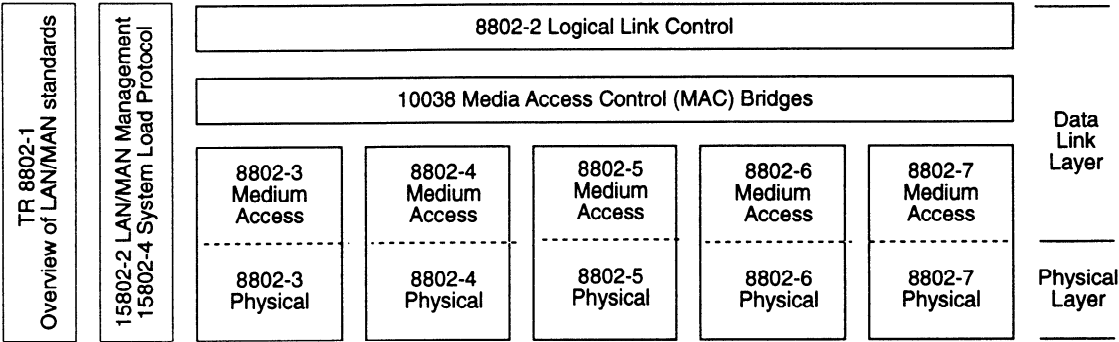
Xerox Corporation
P.O. Box 1600
Stamford, CT 06904, USA



International Organization for Standardization/International Electrotechnical Commission
Case postale 56 • CH-1211 Genève 20 • Switzerland

Foreword to International Standard ISO/IEC 8802-3: 1996

This International Standard is part of a family of International Standards for Local and Metropolitan Area Networks. The relationship between this International Standard and the other members of the family is shown below. (The numbers in the figure refer to ISO Standard numbers.)



This family of International Standards deals with the Physical and Data Link layers as defined by the ISO/IEC Open Systems Interconnection Basic Reference Model (ISO/IEC 7498-1: 1994). The access standards define five types of medium access technologies and associated physical media, each appropriate for particular applications or system objectives. Other types are under investigation.

The International Standards defining the access technologies are as follows:

- a) ISO/IEC 8802-3 [ANSI/IEEE Std 802.3, 1996 Edition], a bus utilizing CSMA/CD as the access method.
- b) ISO/IEC 8802-4 [ANSI/IEEE Std 802.4-1990], a bus utilizing token passing as the access method.
- c) ISO/IEC 8802-5 [ANSI/IEEE Std 802.5-1992], a ring utilizing token passing as the access method.
- d) ISO/IEC 8802-6 [ANSI/IEEE Std 802.6, 1994 Edition], a dual bus utilizing distributed queuing as the access method.
- e) ISO 8802-7, a ring utilizing slotted ring as the access method.

ISO/IEC TR 8802-1 provides an overview of the LAN/MAN standards, along with details of their document numbering.

ISO/IEC 8802-2 [ANSI/IEEE Std 802.2, 1994 Edition], *Logical Link Control*, is used in conjunction with the medium access standards to provide the data link layer service to network layer protocols.

ISO/IEC 10038 [ANSI/IEEE Std 802.1D, 1993 Edition], *Media Access Control (MAC) bridges*, specifies an architecture and protocol for the interconnection of IEEE 802 LANs below the level of the logical link control protocol.

ISO/IEC 15802-2 [ANSI/IEEE Std 802.1B, 1995 Edition], *LAN/MAN Management*, defines an Open Systems Interconnection (OSI) management-compatible architecture, and services and protocol elements for use in a LAN/MAN environment for performing remote management.

ISO/IEC 15802-4 [ANSI/IEEE Std 802.1E, 1994 Edition], *System Load Protocol*, specifies a set of services and protocol for those aspects of management concerned with the loading of systems in ISO/IEC LAN/MAN environments.

The main body of the International Standard serves for both the ISO/IEC 8802-3: 1996 and IEEE Std 802.3, 1996 Edition standards. ISO and IEEE each have a unique foreword.

ANSI/IEEE Std 8802-3, 1996 Edition

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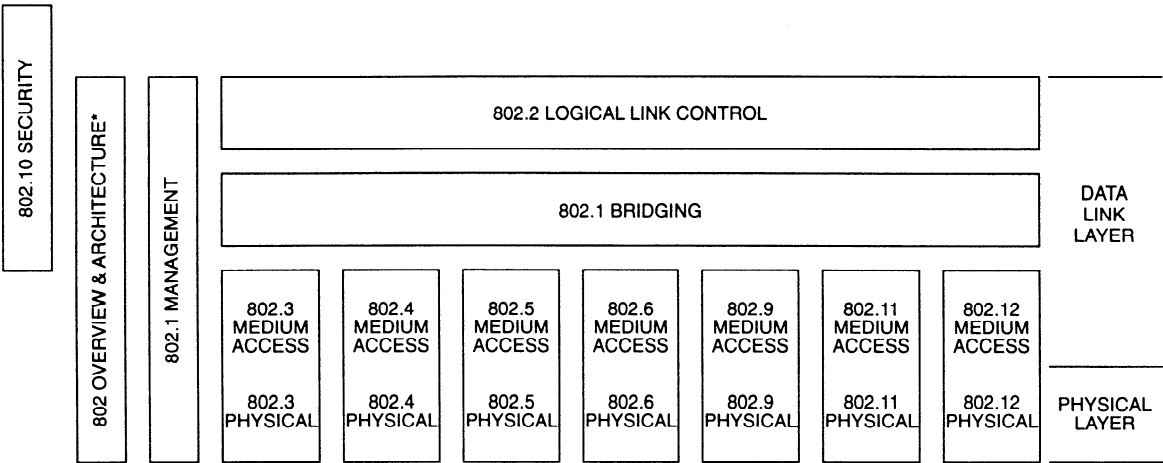
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Foreword to ANSI/IEEE Std 8803-3, 1996 Edition

This standard is part of a family of standards for local and metropolitan area networks. The relationship between the standard and other members of the family is shown below. (The numbers in the figure refer to IEEE standard numbers.)



* Formerly IEEE Std 802.1A.

This family of standards deals with the Physical and Data Link layers as defined by the International Organization for Standardization/International Electrotechnical Commission (ISO/IEC) Open Systems Interconnection Basic Reference Model (ISO/IEC 7498-1: 1994). The access standards define several types of medium access technologies and associated physical media, each appropriate for particular applications or system objectives. Other types are under investigation.

The standards defining the technologies noted above are as follows:

- IEEE Std 802 *Overview and Architecture.* This standard provides an overview to the family of IEEE 802 Standards. This document forms part of the 802.1 scope of work.
- ANSI/IEEE Std 802.1B and 802.1k [ISO/IEC 15802-2] *LAN/MAN Management.* Defines an Open Systems Interconnection (OSI) management-compatible architecture, and services and protocol elements for use in a LAN/MAN environment for performing remote management.
- ANSI/IEEE Std 802.1D [ISO/IEC 10038] *MAC Bridging.* Specifies an architecture and protocol for the interconnection of IEEE 802 LANs below the MAC service boundary.
- ANSI/IEEE Std 802.1E [ISO/IEC 15802-4] *System Load Protocol.* Specifies a set of services and protocol for those aspects of management concerned with the loading of systems on IEEE 802 LANs.
- ANSI/IEEE Std 802.2 [ISO/IEC 8802-2] *Logical Link Control*
- ANSI/IEEE Std 802.3 [ISO/IEC 8802-3] *CSMA/CD Access Method and Physical Layer Specifications*
- ANSI/IEEE Std 802.4 [ISO/IEC 8802-4] *Token Passing Bus Access Method and Physical Layer Specifications*

- ANSI/IEEE Std 802.5 [ISO/IEC 8802-5] *Token Ring Access Method and Physical Layer Specifications*
- ANSI/IEEE Std 802.6 [ISO/IEC 8802-6] *Distributed Queue Dual Bus Access Method and Physical Layer Specifications*
- ANSI/IEEE Std 802.9 [ISO/IEC DIS 8802-9] *Integrated Services (IS) LAN Interface at the Medium Access Control (MAC) and Physical (PHY) Layers*
- ANSI/IEEE Std 802.10 *Interoperable LAN/MAN Security*
- ANSI/IEEE Std 802.12 *Demand Priority Access Method, Physical Layer and Repeater Specifications*

In addition to the family of standards, the following is a recommended practice for a common Physical Layer technology:

- IEEE Std 802.7 *IEEE Recommended Practice for Broadband Local Area Networks*

The following additional working groups have authorized standards projects under development:

- IEEE 802.11 *Wireless LAN Medium Access Control (MAC) Sublayer and Physical Layer Specifications*
- IEEE 802.14 *Standard Protocol for Cable-TV Based Broadband Communication Network*

The reader of this standard is urged to become familiar with the complete family of standards.

Conformance test methodology

An additional standards series, identified by the number 1802, has been established to identify the conformance test methodology documents for the 802 family of standards. Thus the conformance test documents for 802.3 are numbered 1802.3, the conformance test documents for 802.5 will be 1802.5, and so on. Similarly, ISO will use 18802 to number conformance test standards for 8802 standards.

ANSI/IEEE Std 802.3, 1996 Edition

This standard contains state-of-the-art material. The area covered by this standard is undergoing evolution. Revisions are anticipated to this standard within the next few years to clarify existing material, to correct possible errors, and to incorporate new related material. Details on the contents of this standard are provided on the following pages.

The IEEE 802.3 Working Group acknowledges and appreciates that many concepts embodied in this standard are based largely upon the CSMA/CD access method earlier described in *The Ethernet* specification as written jointly by individuals from Xerox Corporation, Digital Equipment Corporation, and Intel Corporation. Appreciation is also expressed to Robert M. Metcalfe and David R. Boggs for their pioneering work in establishing the original concepts.

Participants

Working group members

The following individuals participated in the 802.3 working group during various stages of the standard's development. The superscripted letters by each name indicate the document(s) each participant worked on (a = 802.3a, b = 802.3b, etc.). The superscripted letter "o" indicates the original standard (ANSI/IEEE Std 802.3-1985). Complete identification of the documents is included in the officer listing on pages x–xi. Note that working group participation for IEEE Std 802.3r-1995 or 802.3u-1995 is not included in this edition, nor for the maintenance revisions 2, 3, or 4 (802.3m, n, and s).

Fazal Abbas^{tv}
Menachem Abraham^{acdehi}
Martin Adams^{tv}
Luc Adriaenssensⁱ
Don Aelmore^{tv}
John R. Agee^{hi}
Paul Ahrensⁱ
Alan Albrecht^{tv}
Keith Albright^{bcd}
John Allenⁱ
Karen Amavisca^{jkpq}
Nitish Amin^{iv}
Keith Amundsen^{dehijkl}
Paul Anderson^{iv}
Richard Anderson^{hijkl}
Stephen J. Anderson^{ijkl}
Jack S. Andresen^k
Ekkehard Antz^{hijk}
Mike Armstrong^{klpqtv}
Susie Armstrong^{hi}
Phil L. Arst^o
Jean-Pierre Astorg^{de}
R. V. Balakrishnan^{abcdehi}
Mogens Cash Balsby^{jkpq}
Ian Barker^c
Yoram Barzilai^v
Denis Beaudoin^v
William Belknap^{ac}
Richard Bennett^{bcd}
Roberto Bertoldiⁱ
Dave Bethuneⁱ
Larry Birenbaum^{tv}
Mark Bohrer^{hiltv}
Samuel Bourche^v
David Bourque^v
Sidney Bouzaglo^v
Richard Bowers^{klpqv}
Richard Brand^{hijklpqtv}
Richard S. Brehove^{ijkl}
Robert F. Bridge^o
Charles Brill^{oabcdetv}
Jack Brown^{jkpqt}

Suzy Brown^{ijkl}
Juan Bulnes^{abcde}
Thomas T. Butler^{hijkl}
Luca Cafiero^{hit}
Peter Campbell^v
Robert R. Campbell^{dil}
Luigi Canavese^{dehijkl}
Kiwon Chang^v
Samuel Chang^v
Howard Charney^{tv}
Hon Wah Chin^v
Jacques Christ^{htv}
Yue-Der Chzh^v
Albert Claessen^{de}
G. J. Clancy^o
Brice Clark^{tv}
Michael Coden^{ci}
Kevin Coneⁱ
Patrick Conlon^{tv}
Robert Conte^{hi}
Ronald J. Cooper^{tv}
Stephen Cooper^{abc}
Neil Cooteⁱ
Ronald Crane^{abtv}
Ian Crayford^{hikltv}
Bill Cronin^{ehi}
Peter Cross^{hijkl}
David Cullerot^{tv}
David Cunningham^{tv}
Joe Curcio^{itv}
Robert A. Curtis^{ijklv}
Saleem Dahmouh^v
Bernard Daines^v
Nabil Damouny^{hi}
Mark Darbyⁱ
John Davidson^{oab}
Peter Dawe^{de}
John DeCramer^{hil}
Kathryn de Graaf^{fkpq}
Gerald de Grace^v
Ralph DeMent^o
Tazio M. DeNicolo^{il}

Peter Desaulniers^{de}
Mark Devon^{ab}
Sanjay Dhawan^{hijklpq}
Sean Dingman^v
Thuyen Dinh^{tv}
Hank (H. N.) Dorris^o
Dan Dove^{tv}
James Doyle^v
Scott Dredge^{ijkl}
Raymond S. Duley^{deh}
Paul Eastman^{bch}
Jeff Ebeling^{de}
Peter Ecclesine^{tv}
Phil Edholm^{abc}
Tom Edsallⁱ
Dean Edwards^v
George Eisler^v
Paul "Skip" Elyⁱ
Richard Ely^{hijklv}
Gregory Ennis^{abc}
Gianfranco Enrico^{de}
Norman Erbacher^{hiki}
Nick Esser^{tv}
Judith Estrin^{oab}
Steve Evitts^{hijklpq}
Richard Fabbri^o
Eldon Feistⁱ
Severn Ferdun^{jk}
Dave Fifield^t
Juan Figueroa^{tv}
David Fischer^{tv}
Alan V. Flatman^{abcdehiv}
Steve Flickinger^{klpq}
Christian G. Folting^v
Richard Fransen^{abcde}
Howard Frazier^{tv}
Ingrid Fromm^{oabcdei}
Atsuhisa Fukuoka^{tv}
Mel Gable^{hil}
Robert Galin^{abcdehi}
Sharad Gandhi^{bc}
Clete Gardenhour^{tv}

Mark Gerhold^{deijkl}
 Adi Golbert^{de}
 Steve Goody^{tv}
 Rich Graham^{abcch}
 Robert Gudzt^{tv}
 Andreas Gulle^{hi}
 Karunakar Gulukota^v
 Richard Gumpertz^{bcdehi}
 Sudhir Gupta^l
 Stephen Haddock^v
 Clive Hallatt^{hi}
 Kevin Hamilton^h
 Benny Hanigal^{hijkl}
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 Hacene Hariti^{bcde}
 Guy Harkins^{abc}
 Milton C. Harper^o
 G. R. Hartley^{ijkl}
 Lloyd Hasley^{deh}
 W. B. Hatfield^{hil}
 Stephen Haughey^{hi}
 Haw Ming Haung^{de}
 Carl G. Hayssen^{hil}
 Chris Heegard^{ijklpq}
 Wolfgang Heidasch^{jkpqtv}
 Ariel Hendel^h
 Chip Hicks^h
 William Hingston^h
 Charles Hoffner^{deh}
 Bryan Hoover^o
 Gregory Hopkins^{ab}
 Steven E. Horowitz^{jkpq}
 Fred Huang^b
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 George D. Jelatis^o
 Ernie Jensen^{hitv}
 Clarence Joh^{hijklpqtv}
 Richard John^{klv}
 Donald C. Johnson^{bcdehil}
 Howard Johnson^{tv}
 Mize Johnson^{dehi}
 Nick Jones^v
 Anthony Jordan^v
 Imre Juhasz^{ijklpq}
 Kwi-Yung Jung^{bcde}
 Dieter W. Junkers^{hijklpqtv}
 Jayant Kadambi^{tv}
 Omer Kal^{tv}
 Joel S. Kalmanⁱ
 Matt Kaltenbach^{de}
 Ron Kao^v
 Rainer Kaps^{ijkl}

Harold W. Katz^o
 Paul Kellam^{bcde}
 Joe Kennedy^{ab}
 Scott Kesler^{deh}
 Gary Kidwell^v
 Bob Kilgore^{hi}
 Yongbum Kim^{hijkltv}
 John Kincaid^{hi}
 Bill Kind^{htv}
 Tadayoshi Kitayama^{hi}
 Hiroshi Kobayashi^{abcde}
 Steven Koller^{il}
 Paul Kopera^{hi}
 Leonid Koshevoyⁱ
 Donald E. Kotas^o
 William F. Kous^l
 Joseph Kozilek^{tv}
 George Kubovcik^{tv}
 Ted Kummertⁱ
 David Kung^{hi}
 Jeffrey Kuo^v
 David Kurcharczyk^{ijkl}
 Hidetsune Kurokawa^{de}
 Lee LaBarre^{bcde}
 Adel Henry Labib^{ik}
 Hans Lackner^{ijklpqtv}
 Ed Lare^{bd}
 Tony Lauck^{abc}
 David Law^{jkpqtv}
 John Laynor^{bc}
 My Le^v
 Michael Lebar^{ijklpqtv}
 Jack Lee^{tv}
 Michael Lee^{ehijklpq}
 Richard Lefkowitz^{ijkl}
 Richard Lena^{hil}
 Sam Liang^v
 William P. Lidinsky^o
 Chan-De Lin^v
 Yoseph L. Linde^{hijklpqt}
 Wayne Lindquist^{dh}
 Laurie Lindsey^o
 Chang-Chi Liu^v
 William D. Livingston^{oabc}
 Terry Lockyer^{bcdehijkltv}
 Hugh Logan^{ab}
 Leland Long^{ab}
 Sherry J. Lorei^l
 Don Loughry^{oacdehi}
 James A. Lucas^{bcdeh}
 Andy J. Luque^{oabcdehijklpqtv}
 Mark Lynn^{ijkl}
 Ian Lyon^h
 Brian MacLeod^{tv}

Kenneth MacLeod^{hitv}
 Sam Madani^{tv}
 Randall Maglioizzi^l
 Daniel Maltbie^{oabc}
 Bob Marchetti^v
 Luciano Marchitto^{ehi}
 Charles Marsh^{hijkl}
 Robert Marshall^v
 Bob Matthys^h
 Bret A. Matz^{ijkl}
 Joseph Mazor^{btv}
 Mike McConnell^v
 John McCool^v
 Andy McDonald^v
 Jerry McDowell^o
 Keith McKechnie^{tv}
 Donna McMaster^{ijklpq}
 Tim McShane^{tv}
 Mukesh Mehta^v
 Avraham Menachem^v
 Mark Merrill^{ijklpq}
 C. Kenneth Miller^o
 Ray Mompoin^{ijkl}
 Robert L. Morrell^o
 Jack Moses^{tv}
 Steven Moustakas^{abcdehi}
 Shimon Muller^{tv}
 Narayan Murthy^{bhiv}
 Samba Murthy^v
 Wendell Nakamine^{oab}
 W. P. Neblett^o
 Darcy Nelson^{hi}
 James Nelson^o
 Thinh Nguyenphu^l
 Henry T. Nicholas^v
 Larry Nicholson^{tv}
 Paul Nikolich^{ijklpqtv}
 Bob Norton^{hi}
 J. Michael O'Connor^{hilv}
 Chris Oliver^{hijpq}
 Lloyd Oliver^{abcdehikl}
 Keith Onodera^{hi}
 Pat Overs^{tv}
 Kazuyuki Ozawa^{hijkl}
 Charles Palanzoⁱ
 Jerry Pate^{tv}
 Sandeep Patel^v
 Aidan Paul^{bcd}
 Prasun K. Paul^{adjklpq}
 John Payne^{tv}
 Tony Peatfield^{hijklpqtv}
 Anthony Peck^{ijkl}
 Jim Pelster^t
 Brian Peterson^v

Thomas L. Phinney^o
Roy Pierce^{de}
David Poisner^{ijkl}
Bill Poston^c
David Potter^{oabc}
Kimberly Pottratz^{tv}
Gideon Prat^{tv}
Robert S. Printis^o
William Quackenbush^v
Tomas J. Quigley^v
Mohammad Rajabzadeh^v
Shlomo Rakib^v
Brian Ramelson^{pqtv}
Brian Ramsey^{jkpqt}
William Randle^{lpqt}
Peter Rautenberg^{hijklpqtv}
Eric Rawson^{bcde}
Ivan Reede^l
Dennis Rehm^v
Eugene Reilly^{ab}
Jim Reinstedler^{ijklpq}
Andreas Rendel^{kl}
Victor Renteria^v
Bill Reysen^{hi}
Joseph Rickert^{abcde}
Sean Riley^v
Paul Rivett^l
Anthony Rizzolo^b
Gary S. Robinson^{oabcdehijklpqtv}
Steven Robinson^{hijkl}
Timothy Rock^{bcde}
A. Rodriguez^v
David Roos^{bcde}
Robert Rosenthal^{oabc}
Floyd Ross^{tv}
Michael Rothenberg^{ijklpqtv}
Paul F. Russoⁱ
Khosrow Sadeghi^{tv}
Joseph St. Amand^{abc}
Ed Sakaguchi^e
Moni Samaan^{hi}
Fred Sammartino^h
Henry Samueli^v
F. Sarles^{hi}
Stan Sassower^{hi}
Dieter W. Schicketanz^{ijklpq}
Ronald Schmidt^{hi}
Tom Schmitt^{hil}
Frederick Scholl^{hijklpq}

Walter Schreuer^{abcde}
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Anthony Seaman^{tv}
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Richard Seifert^{tv}
Koichiro Seto^v
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Som Sikdar^{tv}
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Paramjeet (P. J.) Singh^{tv}
Semir Sirazi^{bcdeh}
Joseph Skorupa^{hijklpqtv}
James P. Skoutas^v
Dinah Sloan^{jkpqt}
Tom Slykhouse^{tv}
David A. Smith^{bcdehijklpq}
Michael Smith^{tv}
Robert Smith^v
Robert W. Smith^{hiv}
Steve Smith^{hi}
Robert Snyder^{hi}
Dror Sofer^{tv}
Walter Sotelo^{tv}
Stephen Soto^{abc}
Gary Spencer^{ab}
Michael Spratt^{tv}
Graham Starkins^{hijkl}
Peter Staub^{tv}
David E. Stein^{hijkpq}
Gary Stephens^o
Daniel P. Stokesberry^o
Steve Storozum^{jkpqt}
Ron Sulyma^v
Robert Summers^{abcde}
Ken F. Sumner^o
Daniel Sze^{ov}
Andre Szezepanek^v
Martin Takessian^v
Wen-Tsung Tang^v
Sandray Tarana^{tv}
Victor J. Tarassov^o
Peter Tarrant^{ehikltv}
Mark Taylor^{ehijkl}
Tim Teckman^v

Pat Thaler^{abcdehijklpqtv}
Douglas Thompson^{hiltv}
Geoffrey O. Thompson^{abcdehijklpqtv}
Nathan Tobol^{bdehijklpq}
John Todd^v
Carlos A. Tomaszewski^{dehil}
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Herbert Uhl^{hi}
Jayshree Ullal^e
Steven Ulrich^h
Robert Verne^{tv}
Nader Vjeh^{ijklpqtv}
John Visser^{hi}
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John von Voros^v
William Wager^{il}
P. E. Wainwright^o
Ikuo Wakayama^{pqtv}
Chang Jung Wang^{tv}
Yun-Che Wang^{tv}
Marc Warshaw^{bc}
Robert Watson^{ijkltv}
Lyle Weiman^o
Andrew Weitzner^v
Jim Welch^{tv}
Alan Wetzcl^{ijkl}
David White^{ab}
Hugh E. White^o
Lawrence White^a
Joseph A. Wiencko, Jr.^{dehil}
Bruce Williams^{deh}
Richard Williams^{ahi}
Roger Wilmarth^{hi}
Izumi Wilson^l
Mike Wincn^{hi}
Mark Wingrove^{hi}
Andrew Witzner^t
Don Wong^{tv}
Paul Woodruff^{gijklpq}
Choa-Ping Wu^o
Shuntaro Yamazaki^{tv}
Howard Yang^v
Ronald Yara^{ac}
Nobushige Yokota^{hil}
Nariman Yousefi^{tv}
Hong Yu^{lv}
Nick Zades^o
Jamie Zartman^v
Mo R. Zonoun^{oab}

Additional individuals who contributed actively in the development of the original standard (ANSI/IEEE Std 802.3-1985) throughout its elaboration were

Juan Bulnes	Tony Lauck	Mark Townsend
Ronald Crane	Dean Lindsay	Roger Van Brunt
Dane Elliot	Then T. Liu	Bo Vicklund
Alan V. Flatman	Robert Moles	Chris Wargo
Maris Graube	Joseph St. Amand	Richard Williams
Guy Harkins	Richard Seifert	Ronald Yara
	Nathan Tobol	

The ECMA TC24 Committee on Communication Protocols also provided helpful input in the development of the original standard. The IEC TC83 Committee on Information Technology Equipment also provided very helpful input to the development of the FOIRL standard (802.3d-1987, 9.9).

Officers

The following individuals served as officers of IEEE 802.3 during the development of the standard:

ANSI/IEEE Std 802.3 document	Date approved by IEEE and ANSI	Officers at the time of working group ballot
802.3-1985, Original 10 Mb/s standard, MAC, PLS, AUI, 10BASE5	23 June 1983 (IEEE) 31 December 1984 (ANSI)	Donald C. Loughry, Working Group Chair
802.3a-1988 (clause 10), 10 Mb/s MAU 10BASE2	15 November 1985 (IEEE) 28 December 1987 (ANSI)	Donald C. Loughry, Working Group Chair Alan Flatman, Task Force Chair
802.3b-1985 (clause 11), 10 Mb/s Broadband MAU, 10BROAD36	19 September 1985 (IEEE) 28 February 1986 (ANSI)	Donald C. Loughry, Working Group Chair Menachem Abraham, Task Force Chair
802.3c-1985 (9.1–9.8), 10 Mb/s Baseband Repeater	12 December 1985 (IEEE) 4 June 1986 (ANSI)	Donald C. Loughry, Working Group Chair Geoffrey O. Thompson, Task Force Chair
802.3d-1987 (9.9), 10 Mb/s Fiber MAU, FOIRL	10 December 1987 (IEEE) 9 February 1989 (ANSI)	Donald C. Loughry, Working Group Chair Steven Moustakas, Task Force Chair
802.3e-1987 (clause 12), 1 Mb/s MAU and Hub 1BASE5	11 June 1987 (IEEE) 15 December 1987 (ANSI)	Donald C. Loughry, Working Group Chair Robert Galin, Task Force Chair
802.3h-1990 (clause 5), 10 Mb/s Layer Management, DTEs	28 September 1990 (IEEE) 11 March 1991 (ANSI)	Donald C. Loughry, Working Group Chair Andy J. Luque, Task Force Chair
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, Working Group Chair Patricia Thaler, Task Force Chair (initial) Richard Anderson, Task Force Chair (final)
802.3j-1993 (clauses 15–18), 10 Mb/s Fiber MAUs 10BASE-FP, FB, and FL	15 September 1993 (IEEE) 15 March 1994 (ANSI)	Patricia Thaler, Working Group Chair Keith Amundsen, Task Force Chair (initial) Frederick Scholl, Task Force Chair (final) Michael E. Lee, Technical Editor
802.3k-1993 (clause 19), 10 Mb/s Layer Management, Repeaters	17 September 1992 (IEEE) 8 March 1993 (ANSI)	Patricia Thaler, Working Group Chair Joseph S. Skorupa, Task Force Chair Geoffrey O. Thompson, Vice Chair and Editor

ANSI/IEEE Std 802.3 document	Date approved by IEEE and ANSI	Officers at the time of working group ballot
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>
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>
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>
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>
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>
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>
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>
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>

Two other supplements, IEEE Std 802.3u-1995, *Media Access Control (MAC) Parameters, Physical Layer, Medium Attachment Units, and Repeater for 100 Mb/s Operation, Type 100BASE-T* and 802.3r-1995, *Protocol Implementation Conformance Statement (PICS) Proforma, Type 10BASE5 MAU*, have been approved by IEEE but are not included in this edition.

Balloting group members

On the following pages, members of balloting groups for the parts of IEEE Std 802.3 included in this edition are listed. Note that balloting groups for maintenance revisions 2, 3, and 4 (802.3m, n, and s) are not included.

802.3-1985

W. Adamis	J. Fletcher	V. Lasker	L. Rich
R. Appleby	W. Franta	N. Lau	D. Rine
G. Arnold	R. Gagliano	R. Laughlin	R. Rosenthal
Y. Baeg	D. Gan	F. Lim	P. Ruosadri
E. Beauregard	M. Graube	T. Liu	S. Samoylenko
J. Becker	M. Greene	J. Loo	B. Sashi
E. Bergaimini	R. Gustin	K. Loughner	A. Sauer
Boorstyn	K. Harbaugh	D. Loughry	N. Schneidewind
A. Carrato	G. Harkins	T. Louhenkillbi	O. Serlin
G. Carson	R. Harrington	D. Manchester	D. Shepard
S. Chakradarti	H. Heilborn	M. Marco	D. Sloyer
S. Chandra	L. Heselton	D. Matters	H. Solomon
F. Chang	D. Hislop	D. McInode	G. Stephens
C. Chao	C. Hobbs	D. Michels	C. Stillebroer
C. Chen	S. Hollander	L. Moraes	K. Sumner
P. Chen	P. Hutton	D. Morriss	E. Sykas
K. Chon	P. Induiago	J. Murayama	A. Tantawi
R. Chow	T. Ishida	R. Nelson	D. Tether
G. Clinque	J. Jelemenshy	D. Ofsevit	J. Turret
I. Cotton	O. Kahn	C. Ostereicher	K. Tu
D. Cox	S. Kak	M. Papa	D. Umbaugh
R. DeJardins	K. Katzeff	S. Peter	J. Vorhies
D. Dickel	C. Kessler	D. Phuoc	A. Weissberger
C. Eldridge	D. Kirschner	T. Phinney	W. Wenker
P. Enslow	R. Kolm	G. Power	T. Wicklund
J. Fendrich	T. Kuki	A. Reddi	T. Wolf
M. Figuerea	R. Kunkel	M. Repko	F. Wolff
D. Fisher	W. Lai	F. Restivo	R. Young

802.3a-1988

Marshall Abrams	Keith W. Harbaugh	Patrick S. McIntosh	R. M. Simmons
John Adams	S. M. Harris	Marco Meli	David W. Sloyer
William B. Adams	J. Scott Haugdahl	David S. Millman	Stephen Soto
S. R. Ahuja	Sharon Healy	Aditya N. Mishra	Tom Stack
Kit Athul	C. W. Hobbs	Richard J. Moff	Carel M. Stillebroer
William Ayen	Jim P. Hong	David E. Morgan	Fred Strauss
Yong-Myung Baeg	Paul L. Hutton	Mike Morganti	Bart W. Stuck
Wesley A. Ballenger, Jr.	Richard Iliff	Kinji Mori	Tatsuya Suda
Edwardo W. Bergamini	George D. Jelatis	D. J. Morris	Peter Sugar
Henk F. Boley	Guy Juanole	H. T. Mouftah	Efstathios D. Sykas
Betty Brannick	Siegel L. Junker	Dale A. Murray	Daniel T. W. Sze
George S. Carson	Karl H. Kellermayr	Ruth Nelson	Ahmed N. Tantaui
Po Chen	Mladen Kezunovic	J. Duane Northcutt	Alexander Thomasian
L. Y. Cheung	Samuel Kho	Charles Ostereicher	Mario Tokoro
Kilnam Chon	David Kollm	David Ofsevit	H. C. Tornig
T. Ricky Chow	Sastri L. Kota	Young Oh	Donald F. Towsley
David Cohen	Hirayr M. Kudyan	George Parowski	Wei-Tek Tsai
Allen F. Conrad	Takahiko Kuki	Thomas L. Phinney	M. Tsuchiya
Ira W. Cotton	Lee LaBarre	Nikitas Pimopoulos	Richard Tung
Robert S. Crowder	Wai-Sum Lai	David Potter	Stanko Turk
Michel Diaz	Valerie Lasker	John Potvcek	L. David Umbaugh
Mitchell G. Duncan	Lanse M. Leach	Gary S. Robinson	James Vorhies
Philip H. Enslow, Jr.	Edward Y. S. Lee	Marya Repko	Pearl S. C. Wang
Judith Estrin	Stephen E. Levin	Robert Rosenthal	Don Weir
John W. Fendrich	F. C. Lim	Gian Paolo Rossi	Alan J. Weissberger
Harvey A. Freeman	Don C. Loughry	David J. Rypka	Willaim J. Wenker
Patrick Gonia	Joseph F. P. Luhukay	S. I. Samoylenko	Earl J. Whitaker
Ambuj Goyal	Wo-Shun Luk	Norman F. Schneidewind	Bryan S. Whittle
Michael D. Graebner	Marco Marsan	Oscar Sepulveda	Michael Willett
Maris Graube	Joseph Massi	Omri Serlin	Donald Wittman
Nobuhiro Hamada	Darrell B. McIndoe	D. Sheppard	George R. Wood
Joseph L. Hammond			Tsong-Ho Wu

802.3b-1985

Marshall Abrams	Ambuj Goyal	Valerie Lasker	Young Oh
John Adams	Michael D. Graebner	Lanse M. Leach	George Parowski
William B. Adams	Maris Graube	Edward Y. S. Lee	Thomas L. Phinney
S. R. Ahuja	Nobuhiro Hamada	Stephen E. Levin	Nikitas Pimopoulos
Kit Athul	Joseph L. Hammond	F. C. Lim	Efstathios D. Sykas
William Ayen	Keith W. Harbaugh	Don C. Loughry	Daniel T. W. Sze
Yong-Myung Baeg	S. M. Harris	Joseph F. P. Luhukay	Ahmed N. Tantaui
Wesley A. Ballenger, Jr.	J. Scott Haugdahl	Wo-Shun Luk	Mario Tokoro
Edwardo W. Bergamini	Sharon Healy	Marco Marsan	H. C. Tornig
Henk F. Boley	C. W. Hobbs	Joseph Massi	Donald F. Towsley
George S. Carson	Jim P. Hong	Darrell B. McIndoe	Wei-Tek Tsai
Po Chen	Paul L. Hutton	Patrick S. McIntosh	M. Tsuchiya
L. Y. Cheung	Richard Iliff	Marco Meli	Richard Tung
Kilnam Chon	George D. Jelatis	David S. Millman	Stanko Turk
T. Ricky Chow	E. Douglas Jensen	Aditya N. Mishra	L. David Umbaugh
David Cohen	Guy Juanole	Richard J. Moff	James Vorhies
Allen F. Conrad	Siegel L. Junker	David E. Morgan	Pearl S. C. Wang
Ira W. Cotton	Karl H. Kellermayr	Mike Morganti	Don Weir
Robert S. Crowder	Mladen Kezunovic	Kinji Mori	Alan J. Weissberger
Michel Diaz	Samuel Kho	D. J. Morris	William J. Wenker
Mitchell G. Duncan	David Kollm	H. T. Mouftah	Earl J. Whitaker
Philip H. Enslow, Jr.	Sastri L. Kota	Dale A. Murray	Bryan S. Whittle
Judith Estrin	Hirayr M. Kudyan	Ruth Nelson	Michael Willett
John W. Fendrich	Takahiko Kuki	J. Duane Northcutt	Donald Wittman
Harvey A. Freeman	Lee LaBarre	Charles Oestereicher	George R. Wood
Patrick Gonia	Wai-Sum Lai	David Ofsevit	Tsong-Ho Wu

802.3c-1985

Marshall Abrams	Michael D. Graebner	Marco Marsan	D. Sheppard
John Adams	Maris Graube	Joseph Massi	R. M. Simmons
William B. Adams	Nobushiro Hamada	Darrell B. McIndoe	L. Sintonen
S. R. Ahuja	Joseph L. Hammond	Patrick S. McIntosh	David W. Sloyer
P. D. Amer	S. M. Harris	David S. Millman	Stephen Soto
Kit Athul	J. Scott Haugdahl	Aditya N. Mishra	Fred Strauss
William Ayen	C. W. Hobbs	David E. Morgan	Bart W. Stuck
Yong-Myung Baeg	Jim P. Hong	Mike Morganti	Tatsuya Suda
Wesley A. Ballenger, Jr.	Paul L. Hutton	Kinji Mori	Efstathios D. Sykas
Edwardo W. Bergamini	Richard Iliff	D. J. Morris	Daniel T. W. Sze
H. F. Boley	George D. Jelatis	H. T. Mouftah	Ahmed N. Tantaui
Paul W. Campbell, Jr.	E.D. Jensen	Dale A. Murray	Mario Tokoro
George S. Carson	Guy Juanole	Ruth Nelson	H. C. Tornig
Po Chen	Karl H. Kellermayr	J. Duane Northcutt	Donald F. Towsley
L. Y. Cheung	Mladen Kozunovic	Charles Oestereicher	Wei-Tek Tsai
Kilnam Chon	Samuel Kho	Young Oh	M. Tsuchiya
T. Ricky Chow	David Kollm	George Parowski	Richard Tung
W. F. Chow	Sastri L. Kota	Thomas L. Phinney	Stanko Turk
David Cohen	Hirayr M. Kudyan	David Potter	L. David Umbaugh
Allen F. Conrad	Takahiko Kuki	John Potvcek	James Vorhies
Robert S. Crowder	Lee LaBarre	Gary S. Robinson	Pearl S. C. Wang
Michel Diaz	Wai-Sum Lai	Marya Repko	Don Weir
Philip H. Enslow, Jr.	Lanse M. Leach	Robert Rosenthal	Alan J. Weissberger
Judith Estrin	Stephen E. Levin	Gian Paolo Rossi	William J. Wenker
John W. Fendrich	F. C. Lim	David J. Rypka	Earl J. Whitaker
Harvey A. Freeman	William Livingston	S. I. Samoylenko	Michael Willett
R. J. Gagliano	Don C. Loughry	Norman F. Schneidewind	Tsong-Ho Wu
Patrick Gonia	Joseph F. P. Luhukay	Oscar Sepulveda	Oren Yuen
Ambuj Goyal	Meli Marco	Omri Serlin	

802.3d-1987

William B. Adams	Stephen Harris	Darrel B. McIndoe	Ron Simmons
S. R. Ahuja	J. Scott Haugdahl	P. S. McIntosh	J. B. Sinclair
Kit Athul	C. W. Hobbs	David S. Millman	L. Sintonen
William Ayen	Paul Hutton	Aditya N. Mishra	Tom Stack
Eduardo W. Bergamini	Richard Illif	David E. Morgan	Carel M. Stillebroer
Paul W. Campbell, Jr.	E. D. Jenson	Mike Morganti	Fred Strauss
George S. Carson	Guy Juanole	Kanji Mori	Tatsuya Suda
Po Chen	Karl H. Kellermayr	David Morris	P. Sugar
L. Y. Cheung	M. Kezunovic	H. H. T. Mouftah	Efstathios D. Sykas
Kilnam Chon	Samuel Kno	Dale N. Murray	Daniel T. W. Sze
W. F. Chow	S. E. Kille	R. R. Nelson	Ahmed N. Tantawi
Michael Coden	David Kollm	J. D. Northcut	H. C. Tornig
A. F. Conrad	Takahiko Kuki	Charles Oestereicher	D. F. Towsley
Robert S. Crowder	Lee LaBarre	Young Oh	Wei-Tek Tsai
Michel Diaz	Wai-Sum Lai	George Parowski	Stanko Turk
N. I. Dimopoulos	Lanse M. Leach	Thomas L. Phinney	L. David Umbaugh
M. G. Duncan	Edward Y. Lee	J. M. Potucek	J. T. Vorhies
Philip H. Enslow, Jr.	R. C. Lightburn	Marya Repko	Pearl S. C. Wang
Judith Estrin	F. C. Lim	Gary S. Robinson	Don Weir
John W. Fendrich	William D. Livingston	Robert Rosenthal	Alan J. Weissburger
Harvey A. Freeman	Don C. Loughry	Gian Paolo Rossi	W. J. Wenker
Patrick S. Gonia	Joseph F. P. Luhukay	David J. Rypka	Earl J. Whitaker
R. L. Gordon	Wo-Shun Luk	S. I. Samaylenko	Bryan Whittle
A. Goyal	Marco Ajmone Marsan	Norman F. Schneidewind	Michael Willett
M. D. Graebner	Joseph Massi	Omri Serlin	David C. Wood
Maris Graube	Marco Meli	D. Sheppard	Tsong-Hu Wu
Joseph L. Hammond			Oren Yuen

802.3e-1987

William B. Adams	Stephen Harris	Darrel B. McIndoe	Ron Simmons
S. R. Ahuja	J. Scott Haugdahl	P. S. McIntosh	J. B. Sinclair
Kit Athul	C. W. Hobbs	David S. Millman	L. Sintonen
William Ayen	Paul Hutton	Aditya N. Mishra	Tom Stack
Eduardo W. Bergamini	Richard Illif	David E. Morgan	Carel M. Stillebroer
Paul W. Campbell, Jr.	E. D. Jenson	Mike Morganti	Fred Strauss
George S. Carson	Guy Juanole	Kanji Mori	Tatsuya Suda
Po Chen	Karl H. Kellermayr	David Morris	P. Sugar
L. Y. Cheung	M. Kezunovic	H. H. T. Mouftah	Efstathios D. Sykas
Kilnam Chon	Samuel Kno	Dale N. Murray	Daniel T. W. Sze
W. F. Chow	S. E. Kille	R. R. Nelson	Ahmed N. Tantawi
Michael Coden	David Kollm	J. D. Northcut	H. C. Tornig
A. F. Conrad	Takahiko Kuki	Charles Oestereicher	D. F. Towsley
Robert S. Crowder	Lee LaBarre	Young Oh	Wei-Tek Tsai
Michel Diaz	Wai-Sum Lai	George Parowski	Stanko Turk
N. I. Dimopoulos	Lanse M. Leach	Thomas L. Phinney	L. David Umbaugh
M. G. Duncan	Edward Y. Lee	J. M. Potucek	J. T. Vorhies
Philip H. Enslow, Jr.	R. C. Lightburn	Marya Repko	Pearl S. C. Wang
Judith Estrin	F. C. Lim	Gary S. Robinson	Don Weir
John W. Fendrich	William D. Livingston	Robert Rosenthal	Alan J. Weissburger
Harvey A. Freeman	Don C. Loughry	Gian Paolo Rossi	W. J. Wenker
Patrick S. Gonia	Joseph F. P. Luhukay	David J. Rypka	Earl J. Whitaker
R. L. Gordon	Wo-Shun Luk	S. I. Samaylenko	Bryan Whittle
A. Goyal	Marco Ajmone Marsan	Norman F. Schneidewind	Michael Willett
M. D. Graebner	Joseph Massi	Omri Serlin	David C. Wood
Maris Graube	Marco Meli	D. Sheppard	Tsong-Hu Wu
Joseph L. Hammond			Oren Yuen

802.3h-1990

William Adams
Kit Athul
William E. Ayen
Ali Bahrololoomi
George S. Carson
Chih-Tsai M. Chen
Michael H. Coden
R. A. Conser
R. S. Crowder
Andrew Davidson
Luis F. M. De Moraes
N. I. Dimopoulos
Mitchell Duncan
John E. Emrich
John W. Fendrich
Harold C. Folts
Harvey Freeman
Ingrid Fromm
D. G. Gan
Patrick Gonia
Julio Gonzalez Sanz
Michael Graebner

Maris Graube
Joseph L. Hammond
Stephen Harris
J. Scott Haugdahl
C.W.L. Hobbs
Chris Hsieh
Richard J. Iliff
Raj Jain
M. Kezunovic
Samuel Kho
Tom Kurihara
Lee Labarre
Anthony B. Lake
Mike Lawler
Jaiyong Lee
F. C. Lim
Randolph S. Little
William Livingston
Joseph Loo
Donald C. Loughry
Andy J. Luque
Kelly C. McDonald

Darrell B. McIndoe
Richard H. Miller
David S. Millman
Aditya Mishra
John E. Montague
M. A. F. Morganti
Kinji Mori
D. J. Morris
M. T. Mouftah
Arne A. Nilsson
Charles Oestereicher
Young Oh
Thomas L. Phinney
Rafat Pirzada
Udo Pooch
Robert S. Printis
Marya S. Repko
John P. Riganati
Gary S. Robinson
N. F. Schneidewind
Manfred H. Seifert
D. A. Sheppard

Glen Sherwood
R. M. Simmons
Leo Sintonen
Harry P. Solomon
Robert K. Southard
John Spragins
C. M. Stillebroer
Frank J. Strauss
E. D. Sykas
A. N. Tantawi
Nathan Tobol
Twi-Tek Tsai
David L. Umbaugh
T. A. Varetoni
James Vorhies
Don Weir
A. P. Wheeler
Earl J. Whitaker
D. C. Wood
George B. Wright
Oren Yuen

802.3i-1990

Bandula W. Abeyesundara
William B. Adams
Don Aelmore
Hasan S. Alkhatib
Jonathan Allan
Sule Arslander
Kit Athul
Michael Atkinson
William E. Ayen
Yong Myung Baeg
Subhash Bhatia
Asa O. Bishop
Alan L. Bridges
Richard Caasi
Mehmet U. Caglayan
Anthony L. Carrato
George S. Carson
Brian J. Casey
George C. Chachis
Chih-Tsai Chen
Gerald W. Cichanowski
Michael H. Coden
Keith Collins
Rodney A. Conser
Robert Crowder
Jose A. Cucto
F. Deravi
Ashwani K. Dhawan
Siyi Terry Dong
Mitchell G. Duncan
Andrew M. Dunn
Sourav Dutta
Ted Dzik
Hans Eklund
John E. Emrich
Richard G. Estock
Changxin Fan
John W. Fendrich
John N. Ferguson
Samuel Fineberg
Ernest L. Fogle
Harold C. Folts
Sandra J. Fomey
Harvey A. Freeman
Ingrid Fromm
Eithan Froumine

Robert Gagliano
Isaac Ghansah
Patrick Gonia
Michael D. Graebner
Maris Graube
Abraham Grund
Crag Guarnieri
Sandor V. Halasz
Joseph L. Hammond
Clark M. Hay
Lee A. Hollaar
Marsha D. Hopwood
Anne B. Horton
Genesio L. Hubscher
Wing Huen
Bob Jacobsen
Raj Jain
Gerrit K. Janssen
Jack R. Johnson
Reijo Juvonen
Richard H. Karpinski
Julian Kateley
Gary C. Kessler
Samuel Kho
Jens Kolind
Vijaya Konangi
Peter Kornerup
Jon Kramp
Stephen B. Kruger
Thomas M. Kurihara
Anthony B. Lake
Lak Ming Lam
Glen Langdon
Mike Lawler
Lanse M. Leach
John E. Lecky
Jaiyong Lee
Michael E. Lee
Lewis E. Leinenweber
Kin Fun Le
F. C. Lim
Ping Lin
Randolph S. Little
William D. Livingston
Mauro Lolli
Wayne M. Loucks

Donald Loughry
Nam C. Low
Andy J. Luque
Carl R. Manson
Eduardo G. Marmol
Gerald M. Masson
Richard McBride
Kelly C. McDonald
William McDonald
Darrell B. McIndoe
Richard H. Miller
David S. Millman
C. B. M. Mishra
Wen Hsien Lim Moh
John E. Montague
Kinji Mori
Gerald Moseley
H. H. T. Mouftah
K. R. S. Murthy
Charles E. Neblock
Ruth Nelson
Arne A. Nilsson
Donal O'Mahony
Frederic Oakland
Charles Oestereicher
Attila Ozgit
Richard J. Paroline
Thomas E. Phillips
Art J. Pina
Rafat Pirzada
Udo W. Pooch
Hardy J. Pottinger
Andris Putnins
Thad L. D. Regulinski
Francisco J. Retivo
John R. Riganati
Saber Rizk
Philip T. Robinson
Gary S. Robinson
Robert Rosenthal
Daniel Rosich
Floyd E. Ross
Victor Rozentouler
Chiseki Sagawa
Mark S. Sanders
Ravi Sankar

Julio Gonzalez Sanz
Ambatipudi Sastry
Vidyadhar S. Savant
Manoj Kumar Saxena
Lorne Schachter
Norman Schneidewind
Jeffrey R. Schwab
A. D. Sheppard
Glen Sherwood
William T. Smith
I. A. Soceanu
Robert K. Southard
Charles Spurgeon
Michael Stephenson
Fred J. Strauss
Efsthathios D. Sykas
Roy S. Syler
Gregory M. Sylvain
Daniel Sze
Nhi P. Ta
Hassan Tabaic
Hao Tang
Ahmed N. Tantawi
Steven R. Taylor
James N. Thomas
Geoffrey O. Thompson
Nathal Tobol
Robert Tripi
L. David Umbaugh
Thomas A. Varetoni
James T. Vorhies
Barry Vornbrock
Clarence M. Weaver
Zhao Wei
Donald F. Weir
Alan J. Weissberger
Raymond Wenig
William J. Wenker
Earl J. Whitaker
Thomas P. Wigen
Michael Willett
Paul A. Willis
George B. Wright
Jen-Kun Yang
Oren Yuen
William H. Yundt

William B. Adams	Craig Guarnieri	Andy J. Luque	Chiseki Sagawa
Don Aelmore	Sandor V. Halasz	Carl R. Manson	Julio Gonzalez Sanz
Hasan S. Alkhatib	Joseph L. Hammond	Eduardo G. Marmol	Ambatipudi R. Sastry
Kit Athul	Clark M. Hay	Richard McBride	Manoj Kumar Saxena
William E. Ayen	C. W. L. Hobbs	Kelly C. McDonald	Lorne H. Schachter
Subhash Bhatia	Lee A. Hollaar	William McDonald	Norman Schneidewind
Alan L. Bridges	Marsha D. Hopwood	Darrell B. McIndoe	Jeffrey R. Schwab
Richard Caasi	Genesio L. Hubscher	Richard H. Miller	Donald A. Sheppard
Mehmet U. Caglayan	Paul L. Hutton	David S. Millman	R. M. Simmons
Anthony L. Carrato	Richard J. Iliff	Wen-Hsien Moh	William T. Smith
George Carson	Bob Jacobsen	John E. Montague	Robert K. Southard
George C. Chachis	Raj Jain	M. A. F. Morganti	Charles Spurgeon
Gerald W. Cichanowski	Jack R. Johnson	Kinji Mori	Michael Stephenson
Michael H. Coden	Reijo Juvonen	David J. Morris	Carel M. Stillebroer
Keith Collins	Gary C. Kessler	Gerald Moseley	Fred J. Strauss
Rodney A. Conser	Mladen Kezunovic	Hussein H. T. Mouftah	Efstathios D. Sykas
Robert Crowder	Jens Kolind	Charles E. Neblock	Daniel Sze
Ashwani K. Dhawan	Vijaya Konangi	Ruth Nelson	Nhi P. Ta
N. I. Dimopoulos	Peter Komerup	Arne A. Nilsson	Ahmed N. Tantawi
Mitchell G. Duncan	Jon Kramp	Donal O'Mahony	Steven R. Taylor
Andrew M. Dunn	Stephen B. Kruger	Charles Oestereicher	Patricia Thaler
Sourav K. Dutta	Lak Ming Lam	Young Oh	Geoffrey O. Thompson
Ted Dzik	Michael Lawler	Thomas E. Phillips	Robert Tripi
Paul Eastman	Lanse M. Leach	Thomas L. Phinney	Wei-Tek Tsai
Hans Eklund	John E. Lecky	Philip K. Piele	Mark-Rene Uchida
John E. Emrich	Jai Yong Lee	Art J. Pina	L. David Umbaugh
Changxin Fan	Michael E. Lee	Rafat Pirzada	James T. Vorhies
John W. Fendrich	Lewis E. Leinenweber	Udo W. Pooch	Barry Vormbrock
John N. Ferguson	Kin Fun Li	Hardy J. Pottinger	Clarence M. Weaver, Jr.
Samuel Fineberg	F. C. Lim	Robert S. Printis	Donald F. Weir
Harold C. Folts	Ping Lin	Andris Putnins	Raymond Wenig
Sandra J. Forney	Randolph S. Little	Eugene J. Reilly	William J. Wenker
Harvey A. Freeman	William D. Livingston	John P. Riganati	Earl J. Whitaker
Ingrid Fromm	Mauro Lolli	Gary S. Robinson	Michael Willett
Robert Gagliano	Joseph Loo	Philip T. Robinson	Paul A. Willis
D. G. Gan	Donald C. Loughry	Robert Rosenthal	George B. Wright
Isaac Ghansah	Nam C. Low	Daniel Rosich	Jerry A. Wyatt
Patrick Gonia	Joseph F. P. Luhukay	Floyd E. Ross	Oren Yuen
Abraham Grund			William H. Yundt

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W. B. Adams	S. J. Forney	L. M. Lam	G. Moseley	R. M. Simmons
D. Aeolmore	H. A. Freeman	M. Lawler	H. H. T. Mouftah	W. T. Smith
H. S. Alkhatib	I. Fromm	L. M. Leach	C. E. Neblock	R. K. Southard
K. Athus	R. Gagliano	J. E. Lecky	R. Nelson	C. Spurgeon
W. E. Ayen	D. G. Gan	M. E. Lee	A. A. Nilsson	M. Stephenson
S. Bhatia	I. Ghansah	Jai Yong Lee	D. O'Mahony	C. M. Stillebroer
A. L. Bridges	P. Gonia	L. E. Leinenweber	C. Oestereicher	F. J. Strauss
R. Caasi	J. Gonzalez-Sanz	Kin Fun Li	Y. Oh	E. Sykas
M. U. Caglayan	A. Grund	F. C. Lim	T. E. Phillis	D. Sze
A. L. Carrato	C. Guarnieri	Ping Lin	T. L. Phinney	N. P. Ta
G. Carson	S. V. Halaxz	R. S. Little	P. K. Piele	A. N. Tantawi
G. C. Chachis	J. L. Hammond	W. D. Livingston	A. J. Pina	S. R. Taylor
G. W. Cichanowski	C. M. Hay	M. Lolli	R. Pirzada	P. Taler
M. H. Coden	C. W. L. Hobbs	J. Loo	U. W. Pooch	G. O. Thompson
K. Collins	L. A. Hollaar	D. C. Loughry	H. J. Pottinger	R. Tripi
R. A. Conser	M. D. Hopwood	N. C. Low	R. S. Printis	Wei-Tek Tsai
R. Crosder	C. Hsieh	J. F. P. Luhukay	A. Putnins	M. Uchida
A. K. Dhawan	G. L. Hubscher	A. J. Luque	E. J. Reilly	L. D. Umbaugh
N. I. DiMopoulos	P. L. Hutton	C. R. Manson	J. P. Riganati	J. T. Vorhies
M. G. Duncan	R. J. Iliff	E. G. Marmol	P. T. Robinson	B. Vornbrock
A. M. Dunn	R. Jacobsen	R. McBride	G. S. Robinson	C. M. Weaver
S. Dutta	R. Jain	K. C. McDonald	R. Rosenthal	D. F. Weir
T. Dzik	J. R. Johnson	W. McDonald	D. Rosich	R. Wenig
P. Eastman	R. Juvonen	D. B. McIndoe	F. E. Ross	E. J. Whitaker
H. Eklund	G. C. Kessler	R. H. Miller	C. Sagawa	M. Willett
J. E. Emrich	M. Kezunovic	D. S. Millman	A. Sastry	P. A. Willis
C. Fan	J. Kolind	H. L. Wen Moh	M. K. Saxena	G. B. Wright
J. W. Fendrich	V. Konangi	J. E. Montague	L. H. Schacter	J. A. Wyatt
J. N. Ferguson	P. Kornerup	M. A. F. Morganti	N. Schneidewind	O. Yuen
S. Fineberg	J. Kramp	K. Mori	J. R. Schwab	W. H. Yundt
H. C. Folts	S. B. Kruger	D. J. Morris	D. A. Sheppard	

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W. B. Adams	J. N. Ferguson	P. Kornerup	K. Mori	R. M. Simmons
D. Aelmore	S. Fineberg	J. Kramp	D. A. J. Morris	W. T. Smith
H. S. Alkhatib	H. C. Folts	S. B. Kruger	G. Moseley	R. K. Southard
K. Athul	S. J. Forney	A. B. Lake	H. H. T. Mouftah	C. Spurgeon
W. E. Ayen	H. A. Freeman	L. M. Lam	C. E. Neblock	M. Stephenson
S. Bhatia	I. Fromm	G. Langdon	R. Nelson	C. M. Stillebroer
A. O. Bishop, Jr.	R. Gagliano	M. Lawler	A. A. Nilsson	F. J. Strauss
A. L. Bridges	D. G. Gan	L. M. Leach	D. O'Mahony	E. Sykas
R. Caasi	I. Ghansah	J. Y. Lee	C. Oestereicher	D. Sze
M. U. Caglayan	P. Gonia	M. E. Lee	Y. Oh	N. P. Ta
A. L. Carrato	A. Grund	K. F. Li	T. E. Phillips	A. N. Tantawy
G. Carson	C. Guarnieri	F. C. Lim	T. L. Phinney	S. R. Taylor
B. J. Casey	S. V. Halasz	P. Lin	A. J. Pina	P. Thaler
G. C. Chachis	J. L. Hammond	R. S. Little	R. Pirzada	G. O. Thompson
G. W. Cichanowski	S. Harris	W. D. Livingston	U. W. Pooch	R. Tripi
M. H. Coden	C. M. Hay	M. Lolli	H. J. Pottinger	Wei-Tek Tsai
K. Collins	C. W. L. Hobbs	J. Loo	R. S. Printis	M. Uchida
R. A. Conser	L. A. Hollaar	D. C. Loughry	A. Putnins	L. D. Umbaugh
R. Crowder	M. D. Hopwood	N. C. Low	E. J. Reilly	J. T. Vorhies
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T. Dzik	R. Juvonen	D. B. McIndoe	J. G. Sanz	G. B. Wright
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H. Eklund	G. C. Kessler	D. S. Millman	M. K. Saxena	J. Yang
J. E. Emrich	M. Kezunovic	A. N. Mishra	N. Schneidewind	O. Yuen
C. Fan	J. Kolind	H. L. W. Moh	J. R. Schwab	W. H. Yundt
J. W. Fendrich	V. Konangi	M. A. F. Morganti	D. A. Sheppard	

802.3p-1993

William B. Adams	Isaac Ghansah	William McDonald	Floyd E. Ross
Don Aelmore	Patrick Gonia	David S. Millman	Manoj Kumar Saxena
Hasan S. Alkhatib	Julio Gonzalez-Sanz	John E. Montague	Norman Schneidewind
Kit Athul	Craig Guarnieri	Kinji Mori	Donald A. Sheppard
Michael Benedek	Richard J. Iliff	David J. Morris	Joseph S. Skorupa
Paul W. Campbell	Anthony A. Jeffree	Ellis S. Nolley	Saragur M. Srinidhi
George Carson	Gary C. Kessler	Donal O'Mahony	Carel M. Stillebroer
Robert Crowder	Mladen Kezunovic	Art J. Pina	Fred J. Strauss
Paul Eastman	Youngeum Kim	R. I. Prince	Efstathios D. Sykas
Hans Eklund	Jens Kolind	Vikram Punj	Hao Tang
John E. Emrich	Lanse M. Leach	Andris Putnins	Geoffrey O. Thompson
Philip H. Enslow	Michael E. Lee	Yang Qianli	Robert Tripi
Changxin Fan	Randolph S. Little	Brian Ramelson	Mark-Rene Uchida
John W. Fendrich	Joseph F. P. Luhukay	John P. Riganati	Barry Vornbrock
Harvey A. Freeman	Andy J. Luque	Gary S. Robinson	Raymond Wenig
Ingrid Fromm	Kelly C. McDonald	Daniel Rosich	Oren Yuen

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William B. Adams	Patrick Gonia	William McDonald	Floyd E. Ross
Don Aelmore	Julio Gonzalez-Sanz	David S. Millman	Manoj Kumar Saxena
Hasan S. Alkhatib	Craig Guarnieri	W. Melody Moh	Norman Schneidewind
Kit Athul	Richard J. Iliff	John E. Montague	Donald A. Sheppard
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George Carson	Gary C. Kessler	Ellis S. Nolley	Saragur M. Srinidhi
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Hans Eklund	Lanse M. Leach	Vikram Punj	Efstathios D. Sykas
John E. Emrich	Michael E. Lee	Andris Putnins	Hao Tang
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Harvey A. Freeman	Andy J. Luque	Gary S. Robinson	Barry Vornbrock
Ingrid Fromm	Kelly C. McDonald	Daniel Rosich	Raymond Wenig
Isaac Ghansah			Oren Yuen

802.3t-1995

Don Aelmore	Raj Jain	David S. Millman	Floyd E. Ross
Kit Athulathmu	Howard Johnson	W. Melody Moh	Frederick E. Sauer
Peter K. Campbell	Omer Kal	Kinji Mori	James F. Schooler
James T. Carlo	Gary C. Kessler	David J. Morris	Gregory D. Schumacher
Robert S. Crowder	Youngeum Kim	Wayne D. Moyers	Michael A. Smith
Paul S. Eastman	David Law	Paul Nikolich	Efstathios D. Sykas
Philip H. Enslow	Lanse M. Leach	Ellis S. Nolley	Geoffrey O. Thompson
John W. Fendrich	Sam Liang	Donal O'Mahony	Robert C. Tripi
David Fifield	Yoseph L. Linde	Kirk Preiss	Mark-Rene Uchida
Harvey A. Freeman	Randolph S. Little	Robert S. Printis	Barry M. Vornbrock
Robert J. Gagliano	Donald C. Loughry	Andris Putnins	Ikuo Wakayama
Craig Guarnieri	Robert D. Love	Brian Ramelson	Raymond P. Wenig
Karunakar Gulukota	Andy J. Luque	Eugene J. Reilly	Paul A. Willis
Ulrich Hartmann	Colin K. Mick	Gary S. Robinson	Jerry A. Wyatt
Clark M. Hay	Richard H. Miller	Daniel Rosich	Oren Yuen
Paul L. Hutton			

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Don Aelmore
Kit Athulathmu
Peter K. Campbell
James T. Carlo
Robert S. Crowder
Paul S. Eastman
John W. Fendrich
David Fifield
Harvey A. Freeman
Robert J. Gagliano
Craig Guarnieri
Karunakar Gulukota
Ulrich Hartmann
Clark M. Hay
Paul L. Hutton

Raj Jain
Howard Johnson
Omer Kal
Gary C. Kessler
Yongbum Kim
David Law
Lanse M. Leach
Sam Liang
Yoseph L. Linde
Randolph S. Little
Donald C. Loughry
Robert D. Love
Andy J. Luque
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Richard H. Miller

David S. Millman
W. Melody Moh
Kinji Mori
David J. Morris
Wayne D. Moyers
Paul Nikolich
Ellis S. Nolley
Donal O'Mahony
Kirk Preiss
Robert S. Printis
Andris Putnins
Brian Ramelson
Eugene J. Reilly
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Floyd E. Ross
Frederick E. Sauer
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Gregory D. Schumacher
Michael A. Smith
Efsthathios D. Sykas
Geoffrey O. Thompson
Robert C. Tripi
Mark-Rene Uchida
Barry M. Vornbrock
Ikuo Wakayama
Raymond P. Wenig
Paul A. Willis
Jerry A. Wyatt
Oren Yuen

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Information technology—

Telecommunications and information exchange between systems—

Local and metropolitan area networks—Specific requirements—

Part 3: Carrier Sense Multiple Access with Collision Detection (CSMA/CD) access method and physical layer specifications

1. Introduction

1.1 Overview

1.1.1 Basic concepts

The Carrier Sense Multiple Access with Collision Detection (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 sends a few additional bytes 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 International Standard.

This is a comprehensive International Standard for Local Area Networks (LANs) employing CSMA/CD as the access method. This International Standard is intended to encompass several media types and techniques for signal rates of from 1 Mb/s to 20 Mb/s. This edition of the International Standard provides the necessary specifications for 10 Mb/s baseband and broadband systems, a 1 Mb/s baseband system, and a repeater unit.

NOTE—Additional specifications for a 100 Mb/s system have been approved by the IEEE and are being considered by ISO/IEC at the time of publication of this International Standard.

1.1.2 Architectural perspectives

There are two important ways to view local area network (LAN) design corresponding to

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

This International 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 Model for Open Systems Interconnection (see Figure 1-1). See ISO/IEC 7498-1: 1994. 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.

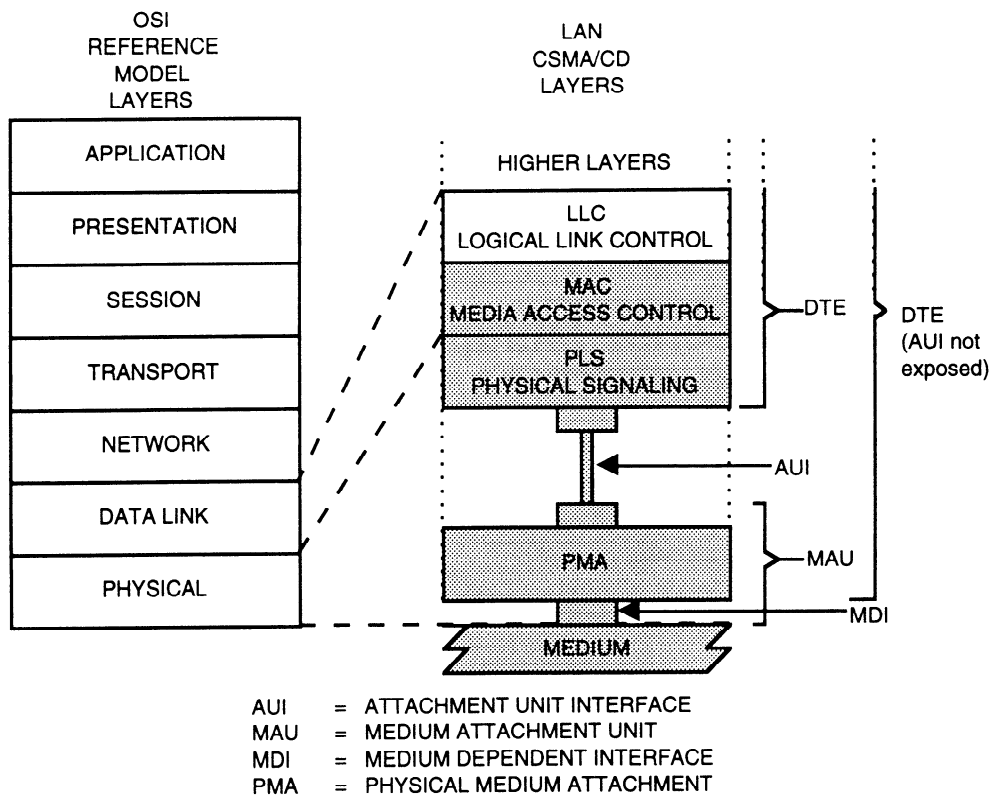


Figure 1-1—ISO/IEC 8802-3 relationship to the ISO/IEC Open Systems Interconnection (OSI) reference model

1.1.2.1 Architectural rationale

An architectural organization of the International Standard has two main advantages:

- Clarity.* A clean overall division of the design along architectural lines makes the standard clearer.
- 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.

1.1.2.2 Compatibility interfaces

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

- Medium-Dependent Interface (MDI).* To communicate in a compatible manner, all stations shall adhere rigidly to the exact specification of physical media signals defined in clause 8 (and beyond) in this International 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 by way of the ISO/IEC 8802-3 [ANSI/IEEE 802.3] LAN

requires complete compatibility at the Physical Medium interface (that is, the coaxial cable interface).

- b) *Attachment Unit Interface (AUI)*. It is anticipated that most DTEs will be located some distance from their connection to the coaxial cable. A small amount of circuitry will exist in the Medium Attachment Unit (MAU) directly adjacent to the coaxial 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 highly recommended, since it allows maximum flexibility in intermixing MAUs and DTEs. The AUI may be optional or not specified for some implementations of this International 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 specification is required.

1.1.3 Layer interfaces

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

- a) The interface between the MAC sublayer and the LLC sublayer 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, 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 allow higher level network management facilities to interact with these layers to perform operation, maintenance, and planning functions. Network management functions will be discussed in clause 5.

1.1.4 Application areas

The applications environment for the LAN is intended to be commercial and light industrial. Use of CSMA/CD LANs in home or heavy industrial environments, while not precluded, is not considered within the scope of this International Standard.

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.

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

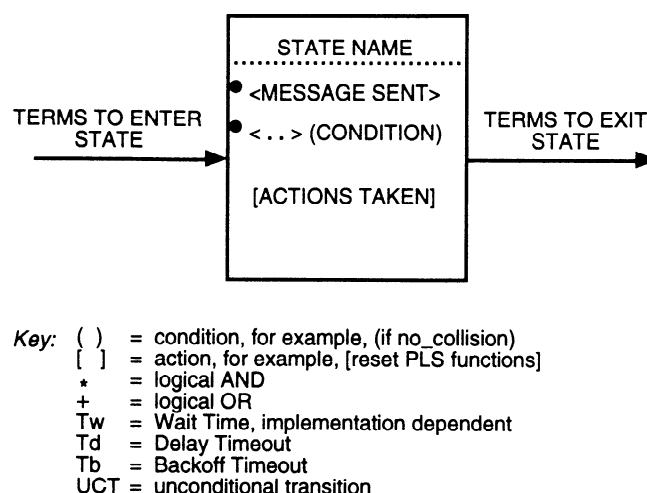


Figure 1-2—State diagram notation example

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 International Standard (e.g., repeaters) are allowed to have two or more ports. State diagrams capable of describing the operation of devices with an unspecified number of ports, required 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 convention is 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 International 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).

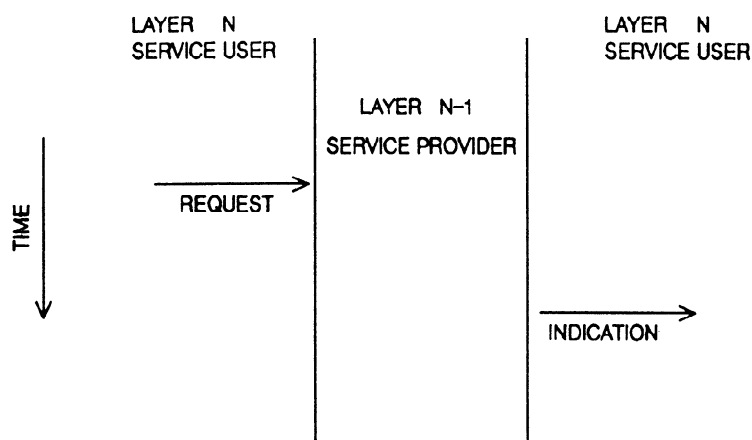


Figure 1-3—Service primitive notation

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 International 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 in Mb/s> <medium type> <maximum segment length (× 100 m)>

For example, the International Standard contains a 10 Mb/s baseband specification identified as “TYPE 10BASE5,” meaning a 10 Mb/s baseband medium whose maximum segment length is 500 m. Each successive Physical Layer specification will state its own unique TYPE identifier along similar lines.

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*).

1.3 References

The following standards contain provisions which, through references in this text, constitute provisions of this International Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the standards listed below. Local and national standards such as those supported by ANSI, EIA, IEEE, MIL, NFPA and UL are not a formal part of the ISO/IEC 8802-3 standard except where equivalent International Standards do not exist.

Reference to local or national standards that may be useful resource material are identified by a bracketed number and located in Annex A.

CISPR 22: 1993, Limits and Methods of Measurement of Radio Interference Characteristics of Information Technology Equipment.¹

IEC 60, High-voltage test techniques.²

IEC 68, Basic environmental testing procedures.

IEC 96-1: 1986, Radio-frequency cables, Part 1: General requirements and measuring methods and Amendment No. 2 (1993).

IEC 169-8 and -16, Radio-frequency connectors, Part 8: Radio-frequency coaxial connectors with inner diameter of outer conductor 6.5 mm (0.256 in) with bayonet lock—Characteristic impedance 50 ohms (Type BNC); Part 16: Radio-frequency coaxial connectors with inner diameter of outer conductor 7 mm (0.276 in) with screw coupling—Characteristic impedance 50 ohms (75 ohms) (Type N).

IEC 380, Safety of electrically energized office machines.

IEC 435, Safety of data processing equipment.

IEC 793-1: 1992, Optical fibres—Part 1: Generic specification.

IEC 793-2: 1992, Optical fibres—Part 2: Product specifications.

IEC 794-1: 1993, Optical fibre cables—Part 1: Generic specification.

¹CISPR documents are available from the International Electrotechnical Commission, 3 rue de Varembé, Case Postale 131, CH 1211, Genève 20, Switzerland/Suisse. CISPR documents are also available in the United States from the Sales Department, American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036, USA.

²IEC publications are available from IEC Sales Department, Case Postale 131, 3 rue de Varembé, CH-1211, Genève 20, Switzerland/Suisse. IEC publications are also available in the United States from the Sales Department, American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036, USA.

IEC 794-2: 1989, Optical fibre cables—Part 2: Product specifications.

IEC 807-2: 1992, Rectangular connectors for frequencies below 3 MHz, Part 2: Detail specification for a range of connectors with assessed quality, with trapezoidal shaped metal shells and round contacts—Fixed solder contact types.

IEC 825: 1993, Safety of laser products—Part 1: Equipment classification, requirements and user's guide.

IEC 874-1: 1993, Connectors for optical fibres and cables—Part 1: Generic specification.

IEC 874-2: 1993, Connectors for optical fibres and cables—Part 2: Sectional specification for fibre optic connector type F-SMA.

IEC 874-10: 1992, Connectors for optical fibres and cables—Part 10: Sectional specification, Fibre optic connector type BFOC/2,5.

IEC 950: 1991, Safety of Information Technology Equipment, Including Electrical Business Equipment.

IEEE Std 802-1990, IEEE Standards for Local and Metropolitan Area Networks: Overview and Architecture (ANSI).³

IEEE Std 802.1F-1993, IEEE Standards for Local and Metropolitan Area Networks: Common Definitions and Procedures for IEEE 802 Management Information (ANSI).

ISO 2382-9: 1984, Data processing—Vocabulary—Part 09: Data communication.⁴

ISO/IEC 7498-1: 1994, Information technology—Open Systems Interconnection—Basic Reference Model: The Basic Model.

ISO/IEC 7498-4: 1989, Information processing systems—Open Systems Interconnection—Basic Reference Model—Part 4: Management Framework.

ISO/IEC 8824: 1990, Information technology—Open Systems Interconnection—Specification of Abstract Syntax Notation One (ASN.1).

ISO/IEC 8825: 1990, Information technology—Open Systems Interconnection—Specification of basic encoding rules for Abstract Syntax Notation One (ASN.1).

ISO/IEC 8877: 1992, Information technology—Telecommunications and information exchange between systems—Interface connector and contact assignments for ISDN Basic Access Interface located at reference points S and T.

ISO/IEC 9595: 1991, Information technology—Open Systems Interconnection—Common management information service definition.

ISO/IEC 9596-1: 1991, Information technology—Open Systems Interconnection—Common management information protocol—Part 1: Specification.

³IEEE publications are available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA.

⁴ISO publications are available from the ISO Central Secretariat, Case Postale 56, 1 rue de Varembé, CH-1211, Genève 20, Switzerland/Suisse. ISO publications are also available in the United States from the Sales Department, American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036, USA.

ISO/IEC 9646-1: 1994, Information technology—Open Systems Interconnection—Conformance testing methodology and framework—Part 1: General concepts.

ISO/IEC 9646-2: 1994, Information technology—Open Systems Interconnection—Conformance testing methodology and framework—Part 2: Abstract test suite specification.

ISO/IEC 10040: 1992, Information technology—Open Systems Interconnection—Systems management overview.

ISO/IEC 10164-1: 1992, Information technology—Open Systems Interconnection—Systems management—Part 1: Object Management Function.

ISO/IEC 10165-1: 1993, Information technology—Open Systems Interconnection—Management information services—Structure of management information—Part 1: Management Information Model.

ISO/IEC 10165-2: 1992, Information technology—Open Systems Interconnection—Management information services—Structure of management information—Part 2: Definition of management information.

ISO/IEC 10165-4: 1992, Information technology—Open Systems Interconnection—Management information services—Structure of management information—Part 4: Guidelines for the definition of managed objects.

ISO/IEC 10742: 1994, Information technology—Telecommunications and information exchange between systems—Elements of management information related to OSI Data Link Layer standards.

ISO/IEC 11801: 1995, Information technology—Generic cabling for customer premises.

ISO/IEC 15802-2: 1995 [ANSI/IEEE Std 802.1B-1992 and IEEE Std 802.1k-1993], Information technology—Telecommunications and information exchange between systems—Local and metropolitan area networks—Common specifications—Part 2: LAN/MAN Management.

1.4 Definitions

The definitions used in this International Standard are consistent with ISO 2382-9: 1984.

EDITORIAL NOTE—A more specific part 25 pertaining to LAN systems has been approved since the definitions in this International Standard were established. This International Standard is ISO/IEC 2382-25: 1992, Information technology—Vocabulary—Part 25: Local area networks.

2. Media Access Control (MAC) service specification

2.1 Scope and field of application

This clause specifies the services provided by the Media Access Control (MAC) sublayer to the Logical Link Control (LLC) sublayer for the ISO/IEC LAN International Standard (see Figure 2-1). The services are described in an abstract way and do not imply any particular implementation, or any exposed interface. There is not necessarily a one-to-one correspondence between the primitives and the formal procedures and interfaces described in 4.2 and 4.3.

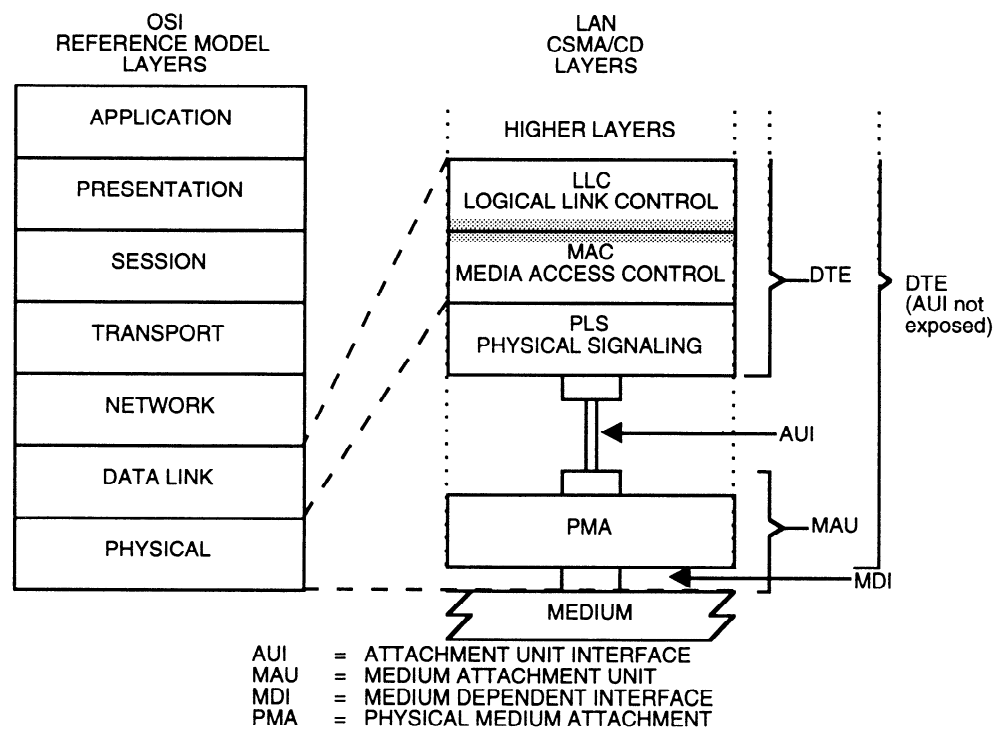


Figure 2-1—Service specification relation to the LAN model

2.2 Overview of the service

2.2.1 General description of services provided by the layer

The services provided by the MAC sublayer allow the local LLC sublayer entity to exchange LLC data units with peer LLC sublayer entities. Optional support may be provided for resetting the MAC sublayer entity to a known state.

2.2.2 Model used for the service specification

The model used in this service specification is identical to that used in 1.2.

2.2.3 Overview of interactions

MA_DATA.request
MA_DATA.indication

2.2.4 Basic services and options

The MA_DATA.request and MA_DATA.indication service primitives described in this clause are considered mandatory.

2.3 Detailed service specification

2.3.1 MA_DATA.request

2.3.1.1 Function

This primitive defines the transfer of data from a local LLC sublayer entity to a single peer LLC entity or multiple peer LLC entities in the case of group addresses.

2.3.1.2 Semantics of the service primitive

The semantics of the primitive are as follows:

```
MA_DATA.request      (  
    destination_address,  
    m_sdu,  
    service_class  
)
```

The destination_address parameter may specify either an individual or a group MAC entity address. It must contain sufficient information to create the DA field that is appended to the frame by the local MAC sublayer entity and any physical information. The m_sdu parameter specifies the MAC service data unit to be transmitted by the MAC sublayer entity. There is sufficient information associated with m_sdu for the MAC sublayer entity to determine the length of the data unit. The service_class parameter indicates a quality of service requested by LLC or higher layer (see 2.3.1.5).

2.3.1.3 When generated

This primitive is generated by the LLC sublayer entity whenever data shall be transferred to a peer LLC entity or entities. This can be in response to a request from higher protocol layers or from data generated internally to the LLC sublayer, such as required by Type 2 service.

2.3.1.4 Effect of receipt

The receipt of this primitive will cause the MAC entity to append all MAC specific fields, including DA, SA, and any fields that are unique to the particular media access method, and pass the properly formed frame to the lower protocol layers for transfer to the peer MAC sublayer entity or entities.

2.3.1.5 Additional comments

The CSMA/CD MAC protocol provides a single quality of service regardless of the service_class requested.

3.2 Elements of the MAC frame

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 frame 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 and indicates the start of a frame.

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 frame is intended. The Source Address field shall identify the station from which the frame was initiated. The representation of each address field shall be as follows (see Figure 3-2):

- a) Each address field shall contain either 16 bits or 48 bits. However, at any given time, the Source and Destination Address size shall be the same for all stations on a particular LAN.
- b) The support of 16 or 48 bit address length for Source and Destination Address shall be left to the manufacturer as an implementation decision. There is no requirement that manufacturers support both sizes.
- c) 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. In the Source Address field, the first bit is reserved and set to 0. 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.
- d) For 48 bit addresses, 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.
- e) Each octet of each address field shall be transmitted least significant bit first.

48 BIT ADDRESS FORMAT

I/G	U/L	46 BIT ADDRESS
-----	-----	----------------

16 BIT ADDRESS FORMAT

I/G	15 BIT ADDRESS
-----	----------------

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

Figure 3-2—Address field format

3.2.3.1 Address designation

A MAC sublayer address is of one of two types:

- a) *Individual Address*. The address associated with a particular station on the network.
- b) *Group Address*. A multidestination address, associated with one or more stations on a given network. There are two kinds of multicast address:
 - 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 (for 16 or 48 bit address size LANs) 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 International Standard.⁵

3.2.4 Destination Address field

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

3.2.5 Source Address field

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

3.2.6 Length field

The Length field is a 2-octet field whose value⁶ indicates the number of LLC data octets in the data field. If the value is less than the minimum required for proper operation of the protocol, a PAD field (a sequence of octets) will be added at the end of the 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 field is transmitted and received with the high order octet first.

3.2.7 Data and PAD fields

The data field contains a sequence of *n* octets. Full data transparency is provided in the sense that any arbitrary sequence of octet values may appear in the data field up to a maximum number specified by the implementation of this International Standard that is used. A minimum frame size is required for correct CSMA/CD protocol operation and is specified by the particular implementation of the International Standard. If necessary, the data field is extended by appending extra bits (that is, a pad) in units of octets after the LLC

⁵For information on how to use MAC addresses, see IEEE Std 802-1990, 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; (908) 562-3813; fax (908) 562-1571.

⁶Packets with a length field value greater than those specified in 4.4.2 may be ignored, discarded, or used in a private manner. The use of such packets is beyond the scope of this International Standard.

data field but prior to calculating and appending the FCS. The size of the pad, if any, is determined by the size of the data field supplied by LLC and the minimum frame size and address size parameters of the particular implementation. The maximum size of the data field is determined by the maximum frame size and address size parameters of the particular implementation.

The length of PAD field required for LLC data that is n octets long is $\max(0, \text{minFrameSize} - (8 \times n + 2 \times \text{addressSize} + 48))$ bits. The maximum possible size of the LLC data field is $\text{maxFrameSize} - (2 \times \text{addressSize} + 48)/8$ octets. See 4.4 for a discussion of implementation parameters; see 4.2.3.3 for a discussion of the minFrameSize .

3.2.8 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) cyclic redundancy check (CRC) value. This value is computed as a function of the contents of the source address, destination address, length, LLC data and pad (that is, all fields except the preamble, SFD, and 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 frame is defined by the following procedure:

- The first 32 bits of the frame are complemented.
- The n bits of the frame 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 data field 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 frame check sequence 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 reference [A23].

3.3 Order of bit transmission

Each octet of the MAC frame, with the exception of the FCS, is transmitted low-order 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:

- The frame length is inconsistent with the length field.
- It is not an integral number of octets in length.
- 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 LLC. The occurrence of invalid MAC frames may be communicated to network management.

4. Media Access Control

4.1 Functional model of the MAC method

4.1.1 Overview

The architectural model described in clause 1 is used in this clause to provide a functional description of the LAN CSMA/CD MAC sublayer.

The MAC sublayer defines a medium-independent facility, built on the medium-dependent physical facility provided by the Physical Layer, and under the access-layer-independent LAN LLC sublayer. It is applicable to a general class of local area broadcast media suitable for use with the media access discipline known as Carrier Sense Multiple Access with Collision Detection (CSMA/CD).

The LLC sublayer and the MAC sublayer together are intended to have the same function as that described in the OSI model for the Data Link Layer alone. In a broadcast network, the notion of a data link between two network entities does not correspond directly to a distinct physical connection. Nevertheless, the partitioning of functions presented in this International Standard requires two main functions generally associated with a data link control procedure to be performed in the MAC sublayer. They are as follows:

- a) Data encapsulation (transmit and receive)
 - 1) Framing (frame boundary delimitation, frame synchronization)
 - 2) Addressing (handling of source and destination addresses)
 - 3) Error detection (detection of physical medium transmission errors)
- b) Media Access Management
 - 1) Medium allocation (collision avoidance)
 - 2) Contention resolution (collision handling)

The remainder of this clause provides a functional model of the CSMA/CD MAC method.

4.1.2 CSMA/CD operation

This clause provides an overview of frame transmission and reception in terms of the functional model of the architecture. This overview is descriptive, rather than definitional; the formal specifications of the operations described here are given in 4.2 and 4.3. Specific implementations for CSMA/CD mechanisms that meet this International Standard are given in 4.4. Figure 4-1 provides the architectural model described functionally in the subclauses that follow.

The Physical Layer Signaling (PLS) component of the Physical Layer provides an interface to the MAC sublayer for the serial transmission of bits onto the physical media. For completeness, in the operational description that follows some of these functions are included as descriptive material. The concise specification of these functions is given in 4.2 for the MAC functions and in clause 7 for PLS.

Transmit frame operations are independent from the receive frame operations. A transmitted frame addressed to the originating station will be received and passed to the LLC sublayer at that station. This characteristic of the MAC sublayer may be implemented by functionality within the MAC sublayer or full duplex characteristics of portions of the lower layers.