

INTERNATIONAL STANDARD

ISO/IEC
8802-3
ANSI/IEEE
Std 802.3

Second edition
1990-09-21

Information processing systems — Local area networks —

Part 3 :

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

Systèmes de traitement de l'information — Réseaux locaux —

*Partie 3 : Accès multiple par surveillance du signal et détection de collision et
spécifications pour la couche physique*



Reference number
ISO/IEC 8802-3 : 1990 (E)
ANSI/IEEE
Std 802.3 1990 Edition



Documents

Document Sharing Hub

Abstract: This Local Area Network (LAN) standard, ISO/IEC 8802-3 : 1990 [ANSI/IEEE Std 802.3-1990 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 systems. Specifications for MAU types 10BASE5, 10BASE2, and FOIRL (fiber optic inter-repeater link) are included. Layer and sublayer interface specifications are aligned to the ISO Open Systems Interconnection Basic Reference Model and 8802 models. The 8802-3 internal model is defined and used.

First Printing

ISBN 1-55937-049-1

Library of Congress Catalog Card Number 90-083842

Copyright © 1990 by

The Institute of Electrical and Electronics Engineers, Inc
345 East 47th Street, New York, NY 10017, USA

*No part of this publication may be reproduced in any form,
in an electronic retrieval system or otherwise,
without the prior written permission of the publisher.*

September 21, 1990

SH13482

**International Standard ISO/IEC 8802-3 : 1990
ANSI/IEEE Std 802.3-1990 Edition**

**(This edition contains ANSI/IEEE Std 802.3-1988,
ANSI/IEEE Std 802.3c-1985, and ANSI/IEEE Std 802.3d-1987)**

Information processing systems— Local area networks—

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

**Correction Sheet
September 18, 1990**

This correction sheet indicates an editorial change only.

Page 27 (Footnote 4) should be corrected as follows: Change "[23]" to "[14]."

Page 171 (Footnote 11) should be corrected as follows: Change "[23]" to "[14]."

Page 194 (Footnote 14) should be corrected as follows: Change "[A14]" to "[A12]."

Page 196 (Footnote 15) should be corrected as follows: Change "See footnote 12" to "See footnote 14."

Copyright © 1990 by

**The Institute of Electrical and Electronics Engineers, Inc
345 East 47th Street, New York, NY 10017-2394, USA**

*No part of this publication may be reproduced in any form,
in an electronic retrieval system or otherwise,
without the prior written permission of the publisher.*



Documents

Document Sharing Hub

**International Standard ISO/IEC 8802-3 : 1990
ANSI/IEEE Std 802.3-1990 Edition**

(This edition contains ANSI/IEEE Std 802.3-1988,
ANSI/IEEE Std 802.3c-1985, and ANSI/IEEE Std 802.3d-1987)

Information processing systems— Local area networks—

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

Sponsor

**Technical Committee on Computer Communications
of the
IEEE Computer Society**

Approved June 9, 1988 (ANSI/IEEE Std 802.3-1988)
Approved October 20, 1988 (ANSI/IEEE Std 802.3a-1988)
Approved December 12, 1985 (ANSI/IEEE Std 802.3c-1985)
Approved December 10, 1987 (ANSI/IEEE Std 802.3d-1987)

IEEE Standards Board

Approved January 12, 1989 (ANSI/IEEE Std 802.3-1988 and 802.3a-1988)
Approved June 4, 1986 (ANSI/IEEE Std 802.3c-1985)
Approved February 9, 1989 (ANSI/IEEE Std 802.3d-1987)

American National Standards Institute

Approved 1990 by the

**International Organization for Standardization
and by the
International Electrotechnical Commission**



Adopted as an International Standard by the
International Organization for Standardization
and by the
International Electrotechnical Commission



Published by
The Institute of Electrical and Electronics Engineers, Inc.



International Standard ISO/IEC 8802-3 : 1990

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

In the field of information technology, ISO and IEC have established a joint technical committee, ISO/IEC JTC 1. Draft International Standards adopted by the joint technical committee are circulated to the national bodies for approval before their acceptance as International Standards. They are approved in accordance with procedures requiring at least 75 % approval by the national bodies voting.

In 1985, IEEE Standard 802.3-1985 was adopted by ISO Technical Committee 97, *Information processing systems*, as draft International Standard ISO/DIS 8802-3. Following the procedures described above, the Standard was subsequently approved by ISO and published as ISO 8802-3:1989, incorporating ISO 8802-3/DAD 1 which had resulted from the adoption by ISO in 1987 of ANSI/IEEE Std 802.3a.

This new edition incorporates Addendum 2, *Repeater set and repeater unit specification for use with 10BASE5 and 10BASE2 networks*, which was approved in 1988, and Addendum 5, *Medium attachment unit and baseband medium specification for a vendor independent fibre optic inter repeater link (FOIRL)*, which was approved in 1989.

For the purpose of assigning global addresses, 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

Registration Authority for ISO/IEC 8802-3
c/o The Institute of Electrical and Electronics Engineers, Inc.
445 Hoes Lane
PO Box 1331
Piscataway, NJ 08855-1331
USA

During the preparation of this International Standard, information was gathered on patents upon which application of the standard might depend. Relevant patents were identified as belonging to Xerox Corporation. However, ISO and IEC cannot give authoritative or comprehensive information about evidence, validity or scope of patent and like rights. The patent-holder has stated that licences will be granted under reasonable terms and conditions and communications on this subject should be addressed to

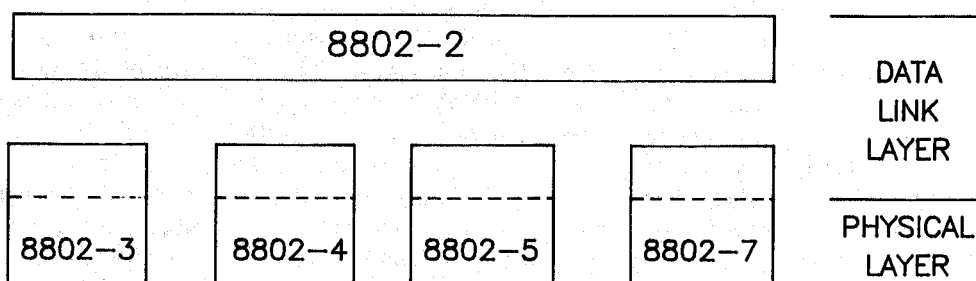
Xerox Corporation
PO Box 1600
Stamford, CT 06904
USA



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

Foreword to International Standard ISO/IEC 8802-3 : 1990

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



This family of standards deals with the physical and data link layers as defined by the ISO Open Systems Interconnection Basic Reference Model (ISO 7498 : 1984). The access standards define four types of medium access technologies and associated physical media, each appropriate for particular applications or system objectives. The standards defining these technologies are

- (1) ISO/IEC 8802-3 [ANSI/IEEE Std 802.3-1990 Edition], a bus utilizing CSMA/CD as the access method,
- (2) ISO/IEC 8802-4 [ANSI/IEEE Std 802.4-1990], a bus utilizing token passing as the access method,
- (3) ISO 8802-7, a ring utilizing slotted ring as the access method.

ISO 8802-2 [ANSI/IEEE Std 802.2-1989], Logical Link Control protocol, is used in conjunction with the medium access standards.

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

The main body of this standard serves for both the ISO 8802-3 : 1989 and IEEE 802.3-1990 standards. ISO and IEEE each have unique foreword sections. The Annex applies to the IEEE standard only. The Appendixes serve as useful reference material to both standards.

ANSI/IEEE Std 802.3-1990 Edition

IEEE Standards documents are developed within the Technical Committees of the IEEE Societies and the Standards Coordinating Committees of the IEEE Standards Board. Members of the committees serve voluntarily and without compensation. They are not necessarily members of the Institute. The standards developed within IEEE represent a consensus of the broad expertise on the subject within the Institute as well as those activities outside of IEEE which have expressed an interest in participating in the development of the standard.

Use of an IEEE Standard is wholly voluntary. The existence of an IEEE Standard does not imply that there are no other ways to produce, test, measure, purchase, market, or provide other goods and services related to the scope of the IEEE Standard. Furthermore, the viewpoint expressed at the time a standard is approved and issued is subject to change brought about through developments in the state of the art and comments received from users of the standard. Every IEEE Standard is subjected to review at least once every five years for revision or reaffirmation. When a document is more than five years old, and has not been reaffirmed, it is reasonable to conclude that its contents, although still of some value, do not wholly reflect the present state of the art. Users are cautioned to check to determine that they have the latest edition of any IEEE Standard.

Comments for revision of IEEE Standards are welcome from any interested party, regardless of membership affiliation with IEEE. Suggestions for changes in documents should be in the form of a proposed change of text, together with appropriate supporting comments.

Interpretations: Occasionally questions may arise regarding the meaning of portions of standards as they relate to specific applications. When the need for interpretations is brought to the attention of IEEE, the Institute will initiate action to prepare appropriate responses. Since IEEE Standards represent a consensus of all concerned interests, it is important to ensure that any interpretation has also received the concurrence of a balance of interests. For this reason IEEE and the members of its technical committees are not able to provide an instant response to interpretation requests except in those cases where the matter has previously received formal consideration.

Comments on standards and requests for interpretations should be addressed to:

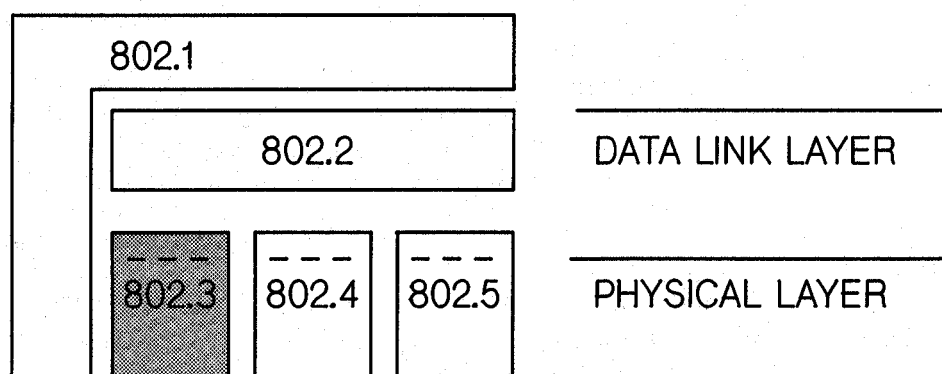
Secretary, IEEE Standards Board
345 East 47th Street
New York, NY 10017
USA

IEEE Standards documents are adopted by the Institute of Electrical and Electronics Engineers without regard to whether their adoption may involve patents on articles, materials, or processes. Such adoptions does not assume any liability to any patent owner, nor does it assume any obligation whatever to parties adopting the standards documents.

Foreword to ANSI/IEEE Std 802.3-1990 Edition
(This edition contains ANSI/IEEE Std 802.3-1988,
ANSI/IEEE Std 802.3c-1985, and ANSI/IEEE Std 802.3d-1987)

(This Foreword is not a part of this International Standard or of ANSI/IEEE Std 802.3-1990 Edition.)

This standard is part of a family of standards for Local Area Networks (LANs). The relationship between this standard and other members of the family is shown below. (The numbers in the figure refer to IEEE standard numbers.)



This family of standards deals with the Physical and Data Link Layers as defined by the ISO Open Systems Interconnection Basic Reference Model (ISO 7498 : 1984). The access standards define three types of medium access technologies and associated physical media, each appropriate for particular applications or system objectives. The standards defining these technologies are

- (1) ANSI/IEEE Std 802.3-1990 Edition [ISO/IEC 8802-3], a bus utilizing CSMA/CD as the access method,
- (2) ANSI/IEEE Std 802.4-1990 [ISO/IEC 8802-4], a bus utilizing token passing as the access method,
- (3) ANSI/IEEE Std 802.5-1989, a ring utilizing token passing as the access method.

Other access methods (for example, metropolitan area networks and integrated voice-data networks) are under investigation.

ANSI/IEEE Std 802.2-1989 [ISO 8802-2], the Logical Link Control standard, is used in conjunction with the medium access standards.

IEEE 802.1* (a series of related standards) describes the relationship

* IEEE Std 802.1A-1990, Overview and Architecture of Network Standards; IEEE Std 802.1D-1990, MAC (Media Access Control) Bridges; and IEEE Std 802.1E-1990, System Load Protocol have been approved as IEEE Standards, but are not yet published. Other projects in the 802.1 series are currently under development.

among the family of 802 standards and their relationship to the ISO Open Systems Interconnection Basic Reference Model in more detail. IEEE 802.1 will also contain networking management standards and information on internetworking.

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

The local area network access mechanism specified by this standard may include patented matter. The IEEE Standards Office calls attention to the fact that it is claimed that the process of the local area network access mechanism described throughout this standard is the subject of United States patent numbers 4 063 220 and 4 099 024 and corresponding patents of foreign countries owned by the Xerox Corporation. Although these patents appear to cover the access mechanism subject in this standard, the IEEE takes no position with respect to patent validity. The Xerox Corporation has assured the IEEE that it is willing to grant a license under these patents on reasonable and nondiscriminatory terms and conditions to anyone wishing to obtain such a license. The Xerox Corporation's undertakings in this respect are on file with the IEEE Standards Office and the license details may be obtained from the Office of General Counsel of Xerox Corporation, whose address is Post Office Box 1600, Stamford, Connecticut 06904, USA.

This edition of the standard defines a 10 Mb/s baseband implementation of the Physical Layer using the CSMA/CD access method. It is anticipated that future editions of the standard may provide additional implementations of the physical layer to support different needs (for example, media, and data rates).

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.

Readers wishing to know the state of revisions should contact

Secretary
IEEE Standards Board
Institute of Electrical and Electronics Engineers, Inc
PO Box 1331, 445 Hoes Lane
Piscataway, NJ 08855-1331

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.

When the IEEE 802.3 Working Group approved the original standard (ANSI/IEEE Std 802.3-1985) in 1983, it had the following membership:

Donald C. Loughry, *Chair*

Phil L. Arst
Robert F. Bridge
Charles Brill
G. J. Clancy
John Davidson
Ralph DeMent
Hank (H. N.) Dorris
Judith Estrin
Richard Fabbri
Ingrid Fromm
Milton C. Harper
Bryan Hoover
George D. Jelatis
Harold W. Katz

Donald E. Kotas
William P. Lidinsky
Laurie Lindsey
William D. Livingston
Andy Luque
Daniel Maltbie
Jerry McDowell
C. Kenneth Miller
Robert L. Morrell
Wendell Nakamine
W. P. Neblett
James Nelson
Thomas L. Phinney
David Potter

Robert S. Printis
Gary S. Robinson
Robert Rosenthal
Gary Stephens
Daniel P. Stokesberry
Ken. F. Sumner
Daniel Sze
Victor J. Tarassov
P. E. Wainwright
Lyle Weiman
Hugh E. White
Choa-Ping Wu
Nick Zades
Mo R. Zonoun

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

Juan Bulnes
Ron Crane
Dane Elliot
Alan Flatman
Maris Graube
Guy Harkins

Dean Lindsay
Then. T. Liu
Robert Moles
Tony Lauck
Joseph St. Amand
Richard Seifert
Nathan Tobol

Mark Townsend
Roger Van Brunt
Bo Vicklund
Chris Wargo
Richard Williams
Ron Yara

The ECMA TC24 Committee on Communication Protocols also provided helpful input in the development of this standard.

When the IEEE 802.3 Working Group approved ANSI/IEEE Std 802.3a-1988 (Section 10) in November 1984, it had the following membership:

Donald C. Loughry, *Chair*

Alan Flatman, *Chair, Type 10BASE2 Task Force*

Menachem Abraham
R. V. Balakrishnan
William Belknap
Charles Brill
Juan Bulnes
Stephen Cooper
Ronald Crane
John Davidson
Mark Devon
Phil Edholm
Gregory Ennis
Judy Estrin
Richard Fransen
Ingrid Fromm
Robert Galin
Rich Graham

Guy Harkins
Greg Hopkins
Joe Kennedy
Hiroshi Kobayashi
Tony Lauck
William Livingston
Hugh Logan
Leland Long
Andy Lague
Daniel Maltbie
Steven Moustakas
Wendell Nakamine
Lloyd Oliver
Aidan Paul
David Potter
Eugene Reilly

Joseph Rickert
Gary Robinson
Robert Rosenthal
Joseph St. Amand
Walter Schreuer
Stephen Soto
Gary Spencer
Robert Summers
Pat Thaler
Geoff Thompson
Wendell Turner
David White
Lawrence White
Rich Williams
Ronald Yara
Mo Zonoun

The following persons were on the balloting committee that approved
ANSI/IEEE Std 802.3-1985 for submission to the IEEE Standards Board:

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

The following persons were on the balloting committee that approved ANSI/IEEE Std 802.3a-1988 (Section 10) for submission to the IEEE Standards Board:

Marshall Abrams	Keith W. Harbaugh	Marco Meli
John Adams	S. M. Harris	David S. Millman
William B. Adams	J. Scott Haugdahl	Aditya N. Mishra
S. R. Ahuja	Sharon Healy	Richard J. Moff
Kit Athul	C. W. Hobbs	David E. Morgan
William Ayen	Jim P. Hong	Mike Morganti
Yong-Myung Baeg	Paul L. Hutton	Kinji Mori
Wesley A. Ballenger, Jr.	Richard Iliff	D. J. Morris
Edwardo W. Bergamini	George D. Jelatis	H. T. Mouftah
Henk F. Boley	Guy Juanole	Dale A. Murray
Betty Brannick	Siegel L. Junker	Ruth Nelson
George S. Carson	Karl H. Kellermayr	J. Duane Northcutt
Po Chen	Mladen Kezunovic	Charles Ostereicher
L. Y. Cheung	Samuel Kho	David Ofsevit
Kilnam Chon	David Kollm	Young Oh
T. Ricky Chow	Sastri L. Kota	George Parowski
David Cohen	Hirayr M. Kudyan	Thomas L. Phinney
Allen F. Conrad	Takahiko Kuki	Nikitas Pimopoulos
Ira W. Cotton	Lee LaBarre	David Potter
Robert S. Crowder	Wai-Sum Lai	John Potvcek
Michel Diaz	Valerie Lasker	Gary S. Robinson
Mitchell G. Duncan	Lanse M. Leach	Marya Repko
Philip H. Enslow, Jr.	Edward Y. S. Lee	Robert Rosenthal
Judith Estrin	Stephen E. Levin	Gian Paolo Rossi
John W. Fendrich	F. C. Lim	David J. Rypka
Harvey A. Freeman	Don C. Loughry	S. I. Samoylenko
Patrick Gonia	Joseph F. P. Luhukay	Norman F. Schneidewind
Ambuj Goyal	Wo-Shun Luk	Oscar Sepulveda
Michael D. Graebner	Marco Marsan	Omri Serlin
Maris Graube	Joseph Massi	D. Sheppard
Nobuhiro Hamada	Darrell B. McIndoe	R. M. Simmons
Joseph L. Hammond	Patrick S. McIntosh	David W. Sloyer

When the IEEE Standards Board approved ANSI/IEEE Std 802.3-1988 on June 9, 1988, and ANSI/IEEE Std 802.3a-1988 on October 20, 1988, it had the following membership:

Donald C. Fleckenstein, *Chair*

Marco Migliaro, *Vice Chair*

Andrew G. Salem, *Secretary*

Arthur A. Blaisdell	John W. Horch	L. Bruce McClung
Fletcher J. Buckley	Jack M. Kinn	Donald T. Michael*
James M. Daly	Frank D. Kirschner	Richard E. Mosher
Stephen R. Dillon	Frank C. Kitzantides	L. John Rankine
Eugene P. Fogarty	Joseph L. Koepfinger*	Gary S. Robinson
Jay Forster*	Irving Kolodny	Frank L. Rose
Thomas L. Hannan	Edward Lohse	Helen M. Wood
Kenneth D. Hendrix	John E. May, Jr.	Karl H. Zaininger
Theodore W. Hissey, Jr.	Lawrence V. McCall	Donald W. Zipse

*Member emeritus

When the IEEE 802.3 Working Group approved ANSI/IEEE Std 802.3c-1985 (9.1–9.8) in July 1985, it had the following membership:

Donald C. Loughry, *Chair*
Geoffrey O. Thompson, *Chair, Repeater Task Force*

Menachem Abraham
Keith Albright
R. V. Balakrishnan
William Belknap
Richard Bennett
Charles Brill
Juan Bulnes
Stephen Cooper
Paul Eastman
Phil Edholm
Gregory Ennis
Alan Flatman
Richard Fransen
Ingrid Fromm
Robert Galin
Sharad Gandhi
Rich Graham
Richard Gumpertz

Hacene Hariti
Guy Harkins
Fred Huang
Stephen Janshego
Donald Johnson
Kwi-Yung Jung
Paul Kellam
Joe Kennedy
Hiroshi Kobayashi
Lee LaBarre
Tony Lauck
John Laynor
William Livingston
Terry Lockyer
James Lucas
Andy Luque
Daniel Maltbie
Steven Moustakas
Lloyd Oliver

Aidan Paul
David Potter
Eric Rawson
Joseph Rickert
Gary Robinson
Timothy Rock
David Roos
Robert Rosenthal
Joseph St. Amand
Walter Schreuer
Semir Sirazi
David Smith
Stephen Soto
Robert Summers
Pat Thaler
Wendell Turner
Marc Warshaw
Ronald Yara

The following persons were on the balloting committee that approved ANSI/IEEE Std 802.3c-1985 (9.1-9.8) for submission to the IEEE Standards Board:

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

When the IEEE Standards Board approved ANSI/IEEE Std 802.3c-1985 (9.1-9.8) on December 12, 1985, it had the following membership:

John E. May, *Chair*

John P. Riganati, *Vice Chair*

Sava I. Sherr, *Secretary*

James H. Beall
Fletcher J. Buckley
Rene Castenschiold
Edward Chelotti
Edward J. Cohen
Paul G. Cummings
Donald C. Fleckenstein

Jay Forster
Daniel L. Goldberg
Kenneth D. Hendrix
Irvin N. Howell
Jack Kinn
Joseph L. Koepfinger*
Irving Kolodny
R. F. Lawrence

Lawrence V. McCall
Donald T. Michael*
Frank L. Rose
Clifford O. Swanson
J. Richard Weger
W. B. Wilkens
Charles J. Wylie

*Member emeritus

When the IEEE 802.3 Working Group approved ANSI/IEEE Std 802.3d-1987 (9.9), it had the following membership:

Donald C. Loughry, *Chair*
Steven Moustakas, *Chair, Task Force*

Menachem Abraham
Keith Albright
Keith Amundsen
Jean-Pierre Astorg
R. V. Balakrishnan
Richard Bennett
Charles Brill
Juan Bulnes
Robert Campbell
Luigi Canavese
Albert Claessen
Peter Dawe
Peter Desaulniers
Raymond Duley
Jeff Ebeling
Gianfranco Enrico
Alan Flatman
Richard Fransen
Ingrid Fromm
Robert Galin
Mark Gerhold
Adi Golbert
Rich Graham
Rich Gumpertz
Hacene Hariti

Lloyd Hasley
Hawming Haung
Charles Hoffner
Michael Hughes
Donald Johnson
Mze Johnson
Kwi-Yung Jung
Matt Kaltenbach
Paul Kellam
Scott Kesler
Hiroshi Kobayashi
Hidetsune Kurokawa
Lee LaBarre
Ed Lare
Wayne Lindquist
Terry Lockyer
Don Loughry
James Lucas
Andy Luque
Lloyd Oliver
Aidan Paul
Roy Pierce
Eric Rawson
Joseph Rickert
Gary Robinson

Timothy Rock
David Roos
Walter Schruer
Semir Sirazi
David Smith
Robert Summers
Pat Thaler
Geoff Thompson
Nathan Tobol
Carlos Tomaszewski
Wendell Turner
Joseph Wiencko
Bruce Williams

OBSERVERS

Allen Cherin
John Decramer
Paul Eastman
Shinji Emori
Jiro Kashio
Michael Lee
Luciano Marchitto
Jim Montrose
Peter Tarrant

The IEC TC83 Committee on Information Technology Equipment also provided very helpful input to the development of the FOIRL Standard (9.9).

The following persons were on the balloting committee that approved ANSI/IEEE Std 802.3d-1987 (9.9) for submission to the IEEE Standards Board:

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

When the IEEE Standards Board approved ANSI/IEEE Std 802.3d-1987 (9.9) on December 12, 1985, it had the following membership:

Donald C. Fleckenstein, *Chair*

Marco Migliaro, *Vice Chair*

Andrew G. Salem, *Secretary*

James H. Beall	Leslie R. Kerr	Donald T. Michael*
Dennis Bodson	Jack Kinn	L. John Rankine
Marshall L. Cain	Irving Kolodny	John P. Riganati
James M. Daly	Joseph L. Koepfinger*	Gary S. Robinson
Stephen R. Dillon	Edward Lohse	Frank L. Rose
Eugene P. Fogarty	John May	Robert E. Rountree
Jay Forster	Lawrence V. McCall	William R. Tackaberry
Kenneth D. Hendrix	L. Bruce McClung	William B. Wilkens
Irvin N. Howell		Helen M. Wood

*Member emeritus

Contents

SECTION	PAGE
1. Introduction.....	21
1.1 Overview.....	21
1.1.1 Basic Concepts.....	21
1.1.2 Architectural Perspectives.....	21
1.1.3 Layer Interfaces	23
1.1.4 Application Areas.....	23
1.2 Notation	23
1.2.1 State Diagram Conventions.....	23
1.2.2 Service Specification Method and Notation.....	25
1.2.3 Physical Layer and Media Notation	26
1.2.4 Physical Layer Message Notation	26
1.3 References	27
1.4 Definitions.....	28
2. MAC Service Specification.....	29
2.1 Scope and Field of Application.....	29
2.2 Overview of the Service.....	29
2.2.1 General Description of Services Provided by the Layer.....	29
2.2.2 Model Used for the Service Specification.....	30
2.2.3 Overview of Interaction.....	30
2.2.4 Basic Services and Options.....	30
2.3 Detailed Service Specification.....	30
2.3.1 MA_DATA.request.....	30
2.3.2 MA_DATA.indication.....	31
3. Media Access Control Frame Structure.....	33
3.1 Overview.....	33
3.1.1 MAC Frame Format.....	33
3.2 Elements of the MAC Frame.....	34
3.2.1 Preamble Field.....	34
3.2.2 Start Frame Delimiter (SFD) Field.....	34
3.2.3 Address Fields.....	34
3.2.4 Destination Address Field.....	35
3.2.5 Source Address Field.....	36
3.2.6 Length Field.....	36
3.2.7 Data and PAD Fields.....	36
3.2.8 Frame Check Sequence Field	36
3.3 Order of Bit Transmission.....	37
3.4 Invalid MAC Frame.....	37
4. Media Access Control Method.....	39
4.1 Functional Model of the Media Access Control Method.....	39
4.1.1 Overview.....	39
4.1.2 CSMA/CD Operation	39
4.1.3 Relationships to LLC Sublayer and Physical Layer.....	42

SECTION	PAGE
4.1.4 CSMA/CD Access Method Functional Capabilities.....	42
4.2 CSMA/CD Media Access Control Method (MAC): Precise Specification	44
4.2.1 Introduction	44
4.2.2 Overview of the Procedural Model.....	44
4.2.3 Frame Transmission Model.....	47
4.2.4 Frame Reception Model.....	51
4.2.5 Preamble Generation	52
4.2.6 Start Frame Sequence.....	53
4.2.7 Global Declarations.....	53
4.2.8 Frame Transmission.....	56
4.2.9 Frame Reception.....	61
4.2.10 Common Procedures	64
4.3 Interfaces to/from Adjacent Layers.....	64
4.3.1 Overview.....	64
4.3.2 Services Provided by the MAC Sublayer	64
4.3.3 Services Required from the Physical Layer.....	65
4.4 Specific Implementations.....	67
4.4.1 Compatibility Overview.....	67
4.4.2 Allowable Implementations.....	67
5. Network Management.....	69
6. PLS Service Specifications.....	71
6.1 Scope and Field of Application.....	71
6.2 Overview of the Service.....	72
6.2.1 General Description of Services Provided by the Layer.....	72
6.2.2 Model Used for the Service Specification.....	72
6.2.3 Overview of Interactions.....	72
6.2.4 Basic Services and Options.....	72
6.3 Detailed Service Specification.....	72
6.3.1 Peer-to-Peer Service Primitives.....	72
6.3.2 Sublayer-to-Sublayer Service Primitives.....	73
7. Physical Signaling (PLS) and Attachment Unit Interface (AUI) Specifications	75
7.1 Scope	75
7.1.1 Definitions	76
7.1.2 Summary of Major Concepts	76
7.1.3 Application	77
7.1.4 Modes of Operation	77
7.1.5 Allocation of Function	77
7.2 Functional Specification.....	77
7.2.1 PLS-PMA (DTE-MAU) Interface Protocol.....	77
7.2.2 PLS Interface to MAC and Management Entities.....	84
7.2.3 Frame Structure.....	86
7.2.4 PLS Functions.....	87

SECTION	PAGE
7.3 Signal Characteristics.....	90
7.3.1 Signal Encoding.....	90
7.3.2 Signaling Rate.....	95
7.3.3 Signaling Levels.....	95
7.4 Electrical Characteristics.....	95
7.4.1 Driver Characteristics.....	96
7.4.2 Receiver Characteristics.....	99
7.4.3 AUI Cable Characteristics.....	101
7.5 Functional Description of Interface Circuits.....	103
7.5.1 General.....	103
7.5.2 Definition of Interchange Circuits.....	104
7.6 Mechanical Characteristics.....	107
7.6.1 Definition of Mechanical Interface.....	107
7.6.2 Line Interface Connector.....	107
7.6.3 Contact Assignments.....	108
8. Medium Attachment Unit and Baseband Medium Specifications, Type 10BASE5.....	111
8.1 Scope.....	111
8.1.1 Overview.....	111
8.1.2 Definitions.....	112
8.1.3 Application Perspective: MAU and MEDIUM Objectives...	113
8.2 MAU Functional Specifications.....	114
8.2.1 MAU Physical Layer Functions.....	115
8.2.2 MAU Interface Messages.....	117
8.2.3 MAU State Diagrams.....	119
8.3 MAU-Medium Electrical Characteristics.....	120
8.3.1 MAU-to-Coaxial Cable Interface.....	120
8.3.2 MAU Electrical Characteristics.....	125
8.3.3 MAU-DTE Electrical Characteristics.....	126
8.3.4 MAU-DTE Mechanical Connection.....	126
8.4 Characteristics of the Coaxial Cable.....	126
8.4.1 Coaxial Cable Electrical Parameters.....	126
8.4.2 Coaxial Cable Properties.....	127
8.4.3 Total Segment DC Loop Resistance.....	129
8.5 Coaxial Trunk Cable Connectors.....	129
8.5.1 Inline Coaxial Extension Connector.....	129
8.5.2 Coaxial Cable Terminator.....	129
8.5.3 MAU-to-Coaxial Cable Connector.....	130
8.6 System Considerations.....	131
8.6.1 Transmission System Model.....	131
8.6.2 Transmission System Requirements.....	133
8.6.3 Labeling.....	136
8.7 Environmental Specifications.....	136
8.7.1 General Safety Requirements.....	136

SECTION	PAGE
8.7.2 Network Safety Requirements.....	137
8.7.3 Electromagnetic Environment	138
8.7.4 Temperature and Humidity.....	139
8.7.5 Regulatory Requirements	139
9. Repeater Unit for 10 Mb/s Baseband Networks	141
9.1 Overview.....	141
9.2 Definitions.....	142
9.3 References	143
9.4 Compatibility Interface.....	143
9.4.1 AUI Compatibility	143
9.4.2 Direct Cable Compatibility.....	143
9.4.3 IRL Compatibility.....	144
9.5 Basic Functions	144
9.5.1 Repeater Set Network Properties	144
9.5.2 Signal Amplification	144
9.5.3 Signal Symmetry.....	144
9.5.4 Signal Retiming.....	144
9.5.5 Data Handling.....	145
9.5.6 Collision Handling	145
9.6 Detailed Repeater Functions and State Diagrams	146
9.6.1 State Diagram Notation	146
9.6.2 Data and Collision Handling.....	152
9.6.3 Preamble Regeneration.....	152
9.6.4 Fragment Extension	152
9.6.5 MAU Jabber Lockup Protection.....	152
9.6.6 Auto-Partitioning/Reconnection (Optional).....	152
9.7 Electrical Isolation.....	155
9.7.1 Environment A Requirements.....	155
9.7.2 Environment B Requirements.....	155
9.8 Reliability.....	155
9.9 Medium Attachment Unit and Baseband Medium Specification for a Vendor-Independent FIORL.....	156
9.9.1 Scope.....	156
9.9.2 FOMAU Functional Specifications.....	158
9.9.3 FOMAU Electrical Characteristics.....	168
9.9.4 FOMAU/Optical Medium Interface.....	169
9.9.5 Characteristics of the Optical Fiber Cable Link Segment...	170
9.9.6 System Requirements.....	171
9.9.7 Environmental Specifications.....	173
10. Medium Attachment Unit and Baseband Medium Specifications, Type 10BASE2.....	175
10.1 Scope	175
10.1.1 Overview.....	175
10.1.2 Definitions	176

SECTION	PAGE
10.1.3 Application Perspective: MAU and Medium Objectives	177
10.2 References	178
10.3 MAU Functional Specifications.....	178
10.3.1 MAU Physical Layer Functional Requirements	179
10.3.2 MAU Interface Messages	182
10.3.3 MAU State Diagrams.....	184
10.4 MAU-Medium Electrical Characteristics.....	185
10.4.1 MAU-to-Coaxial Cable Interface.....	185
10.4.2 MAU Electrical Characteristics	187
10.4.3 MAU-DTE Electrical Characteristics.....	188
10.5 Characteristics of Coaxial Cable System	188
10.5.1 Coaxial Cable Electrical Parameters	188
10.5.2 Coaxial Cable Physical Parameters.....	189
10.5.3 Total Segment DC Loop Resistance	191
10.6 Coaxial Trunk Cable Connectors	191
10.6.1 In-Line Coaxial Extension Connector	191
10.6.2 Coaxial Cable Terminator.....	191
10.6.3 MAU-to-Coaxial Cable Connection.....	191
10.7 System Considerations	193
10.7.1 Transmission System Model	193
10.7.2 Transmission System Requirements.....	194
10.8 Environmental Specifications	196
10.8.1 Safety Requirements	196
10.8.2 Electromagnetic Environment	197
10.8.3 Regulatory Requirements	197
11. Broadband Medium Specifications, Type 10BROAD36 [under consideration].....	199
12. Baseband Medium Specifications, Type 1BASE5 [under consideration].....	199

FIGURES

Fig 1-1 LAN Standard Relationship to the OSI Reference Model.....	22
Fig 1-2 State Diagram Notation Example.....	24
Fig 1-3 Service Primitive Notation	26
Fig 2-1 Service Specification Relation to the LAN Model	29
Fig 3-1 MAC Frame Format	33
Fig 3-2 Address Field Format.....	34
Fig 4-1 MAC Sublayer Partitioning, Relationship to OSI Reference Model.....	40
Fig 4-2 CSMA/CD Media Access Control Functions.....	43
Fig 4-3 Relationship Among CSMA/CD Procedures.....	46
Fig 4-4 Control Flow Summary	48
Fig 4-5 Control Flow: MAC Sublayer.....	49
Fig 6-1 Service Specification Relationship to the LAN Model	72

FIGURES	PAGE
Fig 7-1 Physical Layer Partitioning, Relationship to OSI Reference Model.....	75
Fig 7-2 Generalized MAU Model.....	78
Fig 7-3 PLS Reset and Identify Function.....	80
Fig 7-4 PLS Mode Function.....	81
Fig 7-5 PLS Output Function.....	82
Fig 7-6 PLS Input Function.....	88
Fig 7-7 PLS Error Sense Function.....	89
Fig 7-8 PLS Carrier Sense Function.....	91
Fig 7-9 Interface Function for MAU with Conditioning.....	92-93
Fig 7-10 Examples of Manchester Waveforms.....	94
Fig 7-11 Differential Output Voltage, Loaded.....	97
Fig 7-12 Generalized Driver Waveform.....	98
Fig 7-13 Common-Mode Output Voltage.....	99
Fig 7-14 Driver Fault Conditions.....	100
Fig 7-15 Common-Mode Input Test.....	101
Fig 7-16 Receiver Fault Conditions.....	102
Fig 7-17 Common-Mode Transfer Impedance.....	103
Fig 7-18 Connector Locking Posts.....	106
Fig 7-19 Connector Slide Latch.....	107
Fig 7-20 Connector Hardware and AUI Cable Configuration.....	108
Fig 8-1 Physical Layer Partitioning, Relationship to the ISO Open System Interconnection Reference Model.....	111
Fig 8-2 Interface Function: Simple MAU without Isolate Capability.....	120
Fig 8-3 Interface Function: Simple MAU with Isolate Capability.....	121
Fig 8-4 Jabber Function.....	122
Fig 8-5 Recommended Driver Current Signal Levels.....	124
Fig 8-6 Typical Coaxial Trunk Cable Signal Waveform.....	124
Fig 8-7 Maximum Coaxial Cable Transfer Impedance.....	127
Fig 8-8 Coaxial Tap Connector Configuration Concepts.....	132
Fig 8-9 Typical Coaxial Tap Connection Circuit.....	132
Fig 8-10 Maximum Transmission Path.....	133
Fig 8-11 Minimal System Configuration.....	134
Fig 8-12 Minimal System Configuration Requiring a Repeater Set.....	134
Fig 8-13 An Example of a Large System with Maximum Transmission Paths.....	135
Fig 8-14 An Example of a Large Point-to-Point Link System (5140 ns).....	135
Fig 9-1 Repeater Set, Coax-to-Coax Configuration.....	141
Fig 9-2 Repeater Unit State Diagram.....	150
Fig 9-3 Transmit Timer State Diagram for Port X.....	151
Fig 9-4 Tw2 State Diagram.....	151
Fig 9-5 MAU Jabber Lockup Protection State Diagram.....	151
Fig 9-6 Partitioning State Diagram for Port X.....	154
Fig 9-7 Schematic of the Vendor-Independent FOIRL and Its Relationship to the Repeater Unit.....	157

FIGURES	PAGE
Fig 9-8 FOMAU Transmit, Receive, and Collision Functions State Diagram	166
Fig 9-9 FOMAU Jabber Function State Diagram.....	167
Fig 9-10 Low Light Level Detection Function State Diagram	167
Fig 10-1 Physical Layer Partitioning; Relationship to the ISO Open System Interconnection (OSI) Reference Model	175
Fig 10-2 MAU Interface Function	180
Fig 10-3 Jabber Function State Diagram	183
Fig 10-4 Driver Current Signal Levels	186
Fig 10-5 Coaxial Trunk Cable Waveform	187
Fig 10-6 Maximum Coaxial Cable Transfer Impedance.....	190
Fig 10-7 Examples of Insulated Connector Cover.....	192
Fig 10-8 Maximum Transfer Path.....	193
Fig 10-9 The Minimum System Configuration.....	195
Fig 10-10 The Minimum System Configuration Requiring a Repeater Set .	195
Fig 10-11 An Example of a Large Hybrid System.....	196
TABLES	
Table 8-1 Generation of Collision Presence Signal	117
Table 9-1 Maximum Allowable Timing Budget Contributions to the FOIRL System Timing Budget.....	172
Table 10-1 Generation of Collision Presence Signal	181
ANNEX	
Additional Reference Material	201
APPENDIXES	
A System Guidelines.....	203
B State Diagram, MAC Sublayer	211
C Application Context, Selected Medium Specifications.....	217
D Receiver Wavelength Design Considerations.....	219
APPENDIX FIGURES	
Fig A1 Maximal System Configuration Bit Budget Apportionments.....	205
Fig A2 Typical Signal Waveforms	208
Fig A3 Worst-Case Signal Waveform Variations.....	208
Fig B1 Transmit Component State Diagram.....	212
Fig B2 Receive Component State Diagram.....	215
APPENDIX TABLES	
Table B1 Transmit Component State Transmission.....	213
Table B2 Receive Component State Transmission.....	215

Information processing systems— Local area networks—

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 sections of this standard.

This is a comprehensive standard for Local Area Networks employing CSMA/CD as the access method. This 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 standard provides the necessary specification and related parameter values for 10 Mb/s baseband implementations.

1.1.2 Architectural Perspectives. There are two important ways to view local area network design corresponding to

(1) *Architecture.* Emphasizing the logical divisions of the system and how they fit together.

(2) *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 Model for

Open Systems Interconnection (see Fig 1-1). See ISO 7498:1984 [10].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.

1.1.2.1 An architectural organization of the standard has two main advantages:

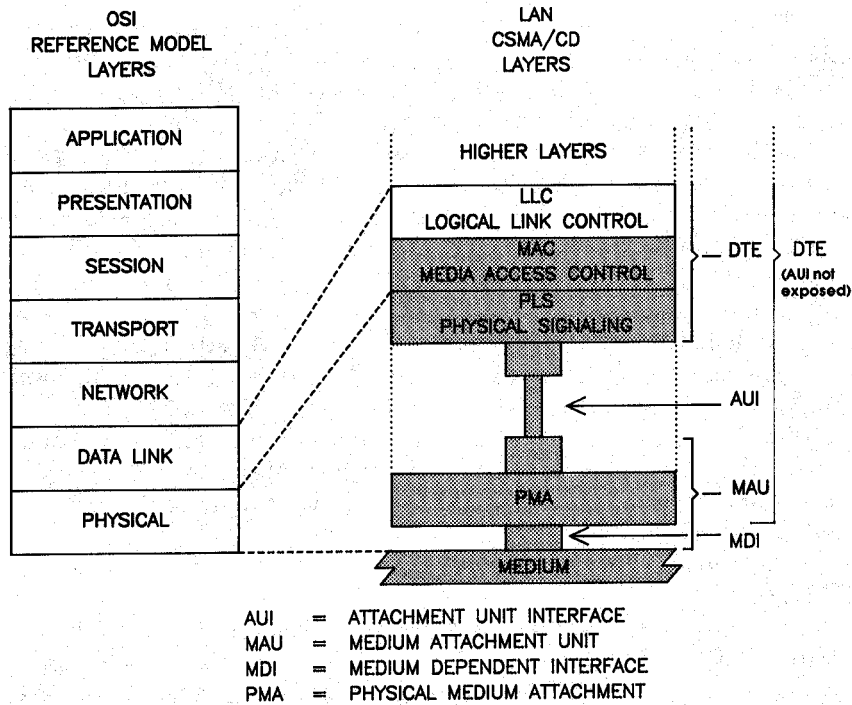
(1) *Clarity*. A clean overall division of the design along architectural lines makes the standard clearer.

(2) *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 Local Area Network 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,

Fig 1-1
LAN Standard Relationship to the
OSI Reference Model



¹ The numbers in brackets correspond to those of the references listed in 1.3; when preceded by A, they correspond to those listed in the Annex.

however, shall be addressed largely in terms of the implementation interfaces: compatibility.

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

(1) *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 Section 8 (and beyond) 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 by way of the ISO 8802-3 [IEEE 802.3] Local Area Network requires complete compatibility at the Physical Medium interface (that is, the coaxial cable interface).

(2) *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 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 Sections 2 and 6. In general, the interface requirements are as follows:

(1) 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.

(2) 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 Section 5.

1.1.4 Application Areas. The applications environment for the Local Area Network 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 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 Fig 1-2).

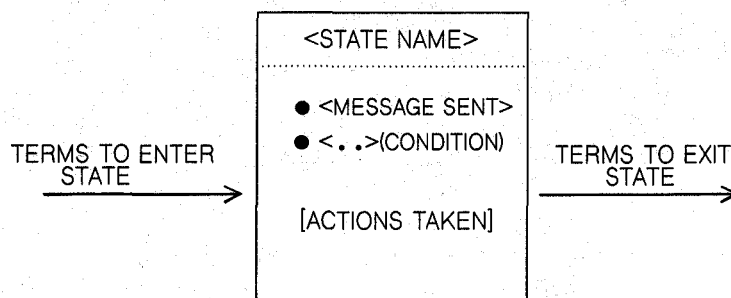
Each state that the function can assume is represented by a rectangle. These are divided into two parts by a horizontal line. In the upper part the state is identified by a name in capital letters. The lower part contains the name of any ON signal that is generated by the function. Actions are described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

Fig 1-2
State Diagram Notation Example



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

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:

- (1) The character ":" (colon) is a delimiter used to denote that a term assignment statement follows.
- (2) 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 Fig 1-3).

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:

- (1) REQUEST. The request primitive is passed from layer N to layer N-1 to request that a service be initiated.
- (2) 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

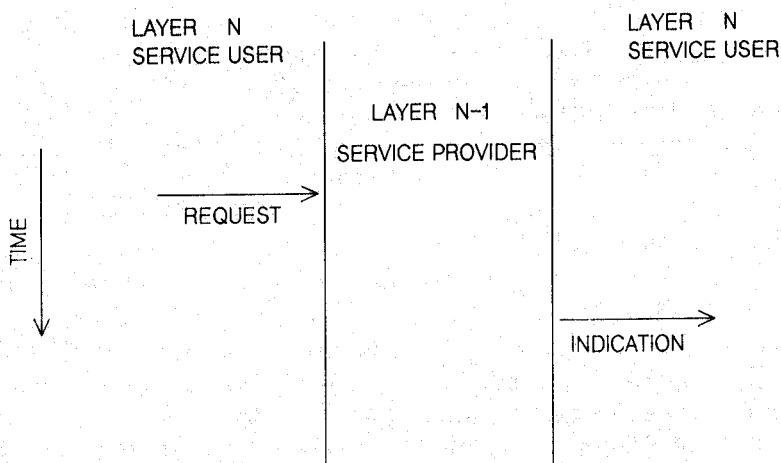


Fig 1-3
Service Primitive Notation

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 section. In general, the Physical Layer type is specified by these fields:

<data rate in Mb/s> <medium type> <maximum segment length (x 100 m)>

For example, the 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

- [1] CISPR Publication 22 (1985), Limits and Methods of Measurement of Radio Interference Characteristics of Information Technology Equipment.²
- [2] IEC Publication 96-1, Radio-frequency cables, Part 1: General requirements and measuring methods.
- [3] IEC Publication 96-1A, 1st Supplement to Radio-frequency cables, Part 1: Appendix Section 5.4, Terminated triaxial test method for transfer impedance up to 100 MHz.
- [4] IEC Publication 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).
- [5] IEC Publication 380, Safety of electrically energized office machines.
- [6] IEC Publication 435, Safety of data processing equipment.
- [7] IEC Publication 807-2, Rectangular connectors for frequencies below 3 MHz, Part 2: Detail specification for a range of connectors with round contacts—Fixed solder contact types.
- [8] IEC Publication 950, Safety of Information Technology Equipment, Including Electrical Business Equipment.
- [9] ISO 2382-9 : 1984, Data processing—Vocabulary—Part 09: Data communication.³
- [10] ISO 7498 : 1984, Information processing systems—open systems interconnection—Basic reference model.
- [11] IEC Publication 60, High-voltage test techniques.
- [12] IEC Publication 68, Environmental testing.
- [13] IEC Publication 793-1, Optical fibres, Part 1: Generic specification.
- [14] IEC Publication 793-2, Optical fibres, Part 2: Product specifications.⁴

² CISPR and IEC documents are available in the US from the Sales Department, American National Standards Institute, 1430 Broadway, New York, NY 10018, USA. These documents are also available from International Electrotechnical Commission, 3 rue de Varembe, Case Postale 131, CH-1211, Genève 20, Switzerland/Suisse.

³ ISO documents are available in the US from the Sales Department, American National Standards Institute, 1430 Broadway, New York, NY 10018, USA. ISO documents are also available from ISO member bodies and from ISO Central Secretariat, 1 rue de Varembe, Case Postale 56, CH-1211, Genève 20, Switzerland/Suisse.

⁴ Subsection 9.9 is to be read with the understanding that the following changes to IEC Publication 793-2 [23] have been requested:

- (1) Correction of the numerical aperture tolerance in Table III to ± 0.015 .
- (2) Addition of another bandwidth category, of ≥ 150 MHz referred to 1 km, for the type A1b fiber in Table III.

- [15] IEC Publication 794-1, Optical fibre cables, Part 1: Generic specification.
- [16] IEC Publication 794-2, Optical fibres cables, Part 2: Product specifications.
- [17] IEC Publication 825, Radiation safety of laser products, equipment classification, requirements, and user's guide.
- [18] IEC Publication 874-1, Connectors for optical fibres and cables, Part 1: Generic specification.
- [19] IEC Publication 874-2, Connectors for optical fibres and cables, Part 2: Sectional specification for fibre optic connector type F-SMA.

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. Reference to such local or national standards may be useful resource material and are identified by a bracketed number beginning with the letter A and located in Annex A.

1.4 Definitions. The definitions used in this standard are consistent with ISO 2382-9:1984 [9]. A more specific Part 25, pertaining to LAN systems, is in development.

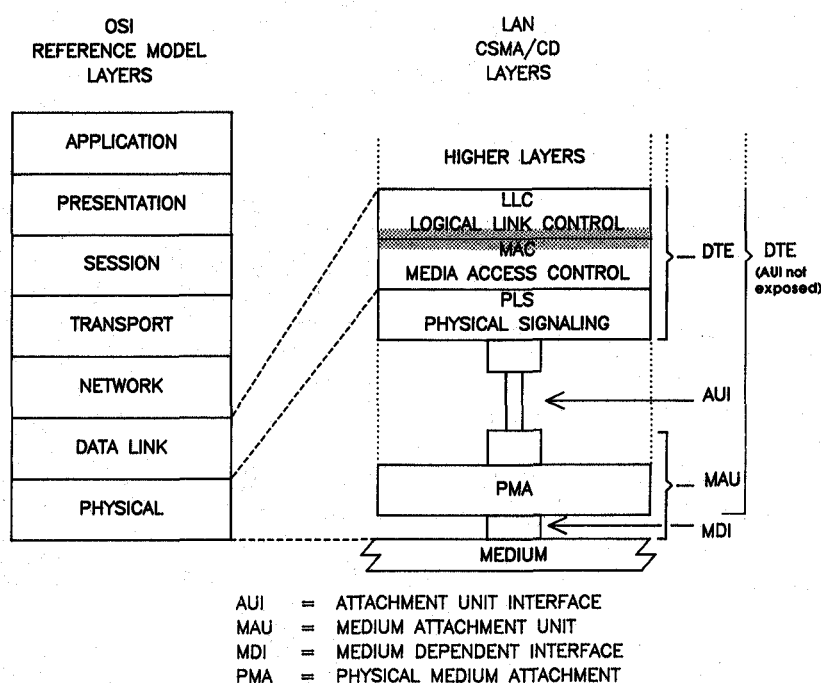
2. MAC Service Specification

2.1 Scope and Field of Application. This section specifies the services provided by the Media Access Control (MAC) sublayer to the Logical Link Control (LLC) sublayer for the ISO [IEEE] Local Area Network standard (see Fig 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.

2.2 Overview of the Service

2.2.1 General Description of Services Provided by the Layer. The services

Fig 2-1
Service Specification Relation to the LAN Model



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 section 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.

2.3.2 MA_DATA.indication

2.3.2.1 Function. This primitive defines the transfer of data from the MAC sublayer entity to the LLC sublayer entity or entities in the case of group addresses.

2.3.2.2 Semantics of the Service Primitive. The semantics of the primitive are as follows:

```
MA_DATA.indication (
    destination_address,
    source_address,
    m_sdu,
    reception_status
)
```

The destination_address parameter may be either an individual or a group address as specified by the DA field of the incoming frame. The source_address parameter is an individual address as specified by the SA field of the incoming frame. The m_sdu parameter specifies the MAC service data unit as received by the local MAC entity. The reception_status parameter is used to pass status information to the peer LLC sublayer entity.

2.3.2.3 When Generated. The MA_DATA.indication is passed from the MAC sublayer entity to the LLC sublayer entity or entities to indicate the arrival of a frame to the local MAC sublayer entity. Such frames are reported only if they are validly formed, received without error, and their destination address designates the local MAC entity.

2.3.2.4 Effect of Receipt. The effect of receipt of this primitive by the LLC sublayer is unspecified.

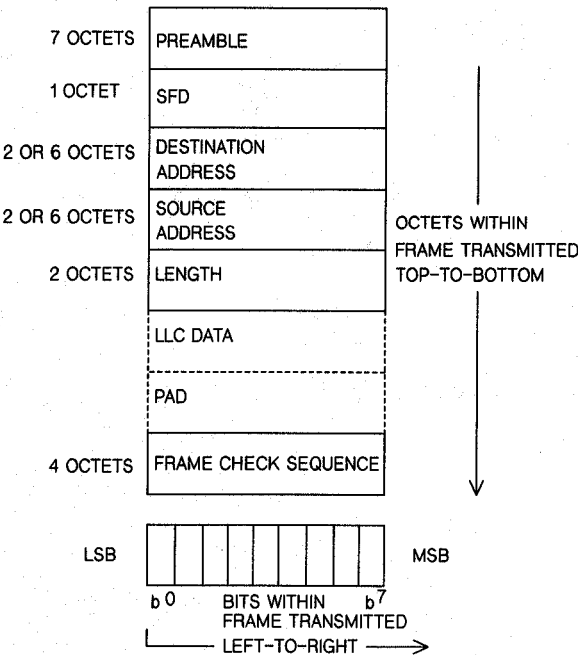
2.3.2.5 Additional Comments. If the local MAC sublayer entity is designated by the destination_address parameter of an MA_DATA.request, the indication primitive will also be invoked by the MAC entity to the local LLC entity. This full duplex characteristic of the MAC sublayer may be due to unique functionality within the MAC sublayer or full duplex characteristics of the lower layers (for example, all frames transmitted to the broadcast address will invoke MA_DATA.indication at all stations in the network including the station that generated the request).

3. Media Access Control Frame Structure

3.1 Overview. This section defines in detail the frame structure for data communication systems using local area network MAC procedures. It defines the relative positions of the various components of the MAC frame. It defines the method for representing station addresses. It defines a partition of the address space into individual (single station) and group (multicast or multi-station) addresses, and into user administered and globally administered addresses.

3.1.1 MAC Frame Format. Figure 3-1 shows the eight fields of a frame: the preamble, Start Frame Delimiter (SFD), the addresses of the frame's source and destination, a length field to indicate the length of the following field

Fig 3-1
MAC Frame Format



containing the LLC data to be transmitted, a field that contains padding if required, and the frame check sequence field containing a cyclic redundancy check value to detect errors in received frames. Of these eight fields, all are of fixed size except the LLC data and PAD fields, which may contain any integer number of octets between the minimum and maximum values determined by the specific implementation of the CSMA/CD Media Access mechanism. See 4.4 for particular implementations.

The minimum and maximum frame size limits in 4.4 refer to that portion of the frame from the destination address field through the frame check sequence field, inclusive.

Relative to Fig 3-1, the octets of a frame are transmitted from top to bottom, and the bits of each octet are transmitted from left to right.

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 Fig 3-2):

(1) Each address field shall contain either 16 bits or 48 bits. However, at any

Fig 3-2
Address Field Format

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

given time, the Source and Destination Address size shall be the same for all stations on a particular local area network.

(2) 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.

(3) 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 local area network.

(4) 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.

(5) Each octet of each address field shall be transmitted least significant bit first.

3.2.3.1 Address Designation. A MAC sublayer address is of one of two types:

(1) *Individual Address.* The address associated with a particular station on the network.

(2) *Group Address.* A multidestination address, associated with one or more stations on a given network. There are two kinds of multicast address:

(a) *Multicast-Group Address.* An address associated by higher-level convention with a group of logically related stations.

(b) *Broadcast Address.* A distinguished, predefined multicast address that always denotes the set of all stations on a given local area network.

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 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.

⁵ Information concerning the Registration Authority and its procedures may be obtained on request to the Secretary General, ISO Central Secretariat, Case Postale 56, CH-1211 Genève, Switzerland, quoting the number of this International Standard. The ISO Global (U) address administration has been delegated to the Secretary, IEEE Standards Board, 345 East 47 Street, New York, NY 10017.

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 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 standard. If necessary, the data field is extended by appending extra bits (that is, a pad) in units of octets after the LLC 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 Field. A cyclic redundancy check (CRC) is used by the transmit and receive algorithms to generate a CRC value for the FCS field. The frame check sequence (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:

- (1) The first 32 bits of the frame are complemented.
- (2) 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 cor-

⁶ Packets 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 standard.

responds to the $x^{(n-1)}$ term and the last bit of the data field corresponds to the x^0 term.)

(3) $M(x)$ is multiplied by x^{32} and divided by $G(x)$, producing a remainder $R(x)$ of degree <31 .

(4) The coefficients of $R(x)$ are considered to be a 32-bit sequence.

(5) 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 [A18].

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:

(1) The frame length is inconsistent with the length field.

(2) It is not an integral number of octets in length.

(3) 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 Media Access Control Method

4.1.1 Overview. The architectural model described in Section 1 is used in this section to provide a functional description of the Local Area Network 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 local area network 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 standard requires two main functions generally associated with a data link control procedure to be performed in the MAC sublayer. They are as follows:

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

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

4.1.2 CSMA/CD Operation. This section 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 standard are given in 4.4. Figure 4-1 provides the architectural model described functionally in the sections 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

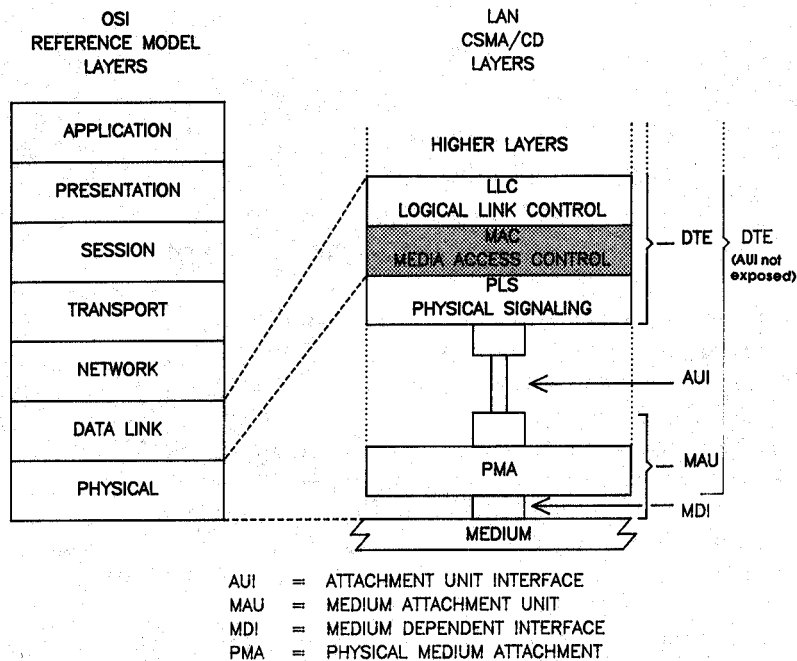


Fig 4-1
MAC Sublayer Partitioning, Relationship to
OSI Reference Model

concise specification of these functions is given in 4.2 for the MAC functions and in Section 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.

4.1.2.1 Normal Operation

4.1.2.1.1 Transmission Without Contention. When a LLC sublayer requests the transmission of a frame, the Transmit Data Encapsulation component of the CSMA/CD MAC sublayer constructs the frame from the LLC-supplied data. It appends a preamble and a start of frame delimiter to the beginning of the frame. Using information passed by the LLC sublayer, the CSMA/CD MAC sublayer also appends a PAD at the end of the MAC information field of sufficient length to ensure that the transmitted frame length satisfies a minimum frame size requirement (see 4.2.3.3). It also appends destination and source addresses, a length count field, and a frame check sequence to provide for error detection. The frame is then handed to the Transmit Media Access Management component in the MAC sublayer for transmission.

Transmit Media Access Management then attempts to avoid contention with other traffic on the medium by monitoring the carrier sense signal provided by the Physical Layer Signaling (PLS) component and deferring to passing traffic. When the medium is clear, frame transmission is initiated (after a brief interframe delay to provide recovery time for other CSMA/CD MAC sublayers and for the physical medium). The MAC sublayer then provides a serial stream of bits to the PLS interface for transmission.

The PLS performs the task of actually generating the electrical signals on the medium that represent the bits of the frame. Simultaneously, it monitors the medium and generates the collision detect signal, which, in the contention-free case under discussion, remains off for the duration of the frame. A functional description of the Physical Layer is given in Sections 7 and beyond.

When transmission has completed without contention, the CSMA/CD MAC sublayer so informs the LLC sublayer using the LLC to MAC interface and awaits the next request for frame transmission.

4.1.2.1.2 Reception Without Contention. At each receiving station, the arrival of a frame is first detected by the PLS, which responds by synchronizing with the incoming preamble, and by turning on the carrier sense signal. As the encoded bits arrive from the medium, they are decoded and translated back into binary data. The PLS passes subsequent bits up to the MAC sublayer, where the leading bits are discarded, up to and including the end of the preamble and Start Frame Delimiter.

Meanwhile, the Receive Media Access Management component of the MAC sublayer, having observed carrier sense, has been waiting for the incoming bits to be delivered. Receive Media Access Management collects bits from the PLS as long as the carrier sense signal remains on. When the carrier sense signal is removed, the frame is truncated to an octet boundary, if necessary, and passed to Receive Data Decapsulation for processing.

Receive Data Decapsulation checks the frame's Destination Address field to decide whether the frame should be received by this station. If so, it passes the Destination Address (DA), the Source Address (SA), and the LLC data unit (LLCDU) to the LLC sublayer along with an appropriate status code indicating `reception_complete` or `reception_too_long`. It also checks for invalid MAC frames by inspecting the frame check sequence to detect any damage to the frame enroute, and by checking for proper octet-boundary alignment of the end of the frame. Frames with a valid FCS may also be checked for proper octet boundary alignment.

4.1.2.2 Access Interference and Recovery. If multiple stations attempt to transmit at the same time, it is possible for them to interfere with each other's transmissions, in spite of their attempts to avoid this by deferring. When transmissions from two stations overlap, the resulting contention is called a collision. A given station can experience a collision during the initial part of its transmission (the collision window) before its transmitted signal has had time to propagate to all stations on the CSMA/CD medium. Once the collision window has passed, a transmitting station is said to have acquired the

medium; subsequent collisions are avoided since all other (properly functioning) stations can be assumed to have noticed the signal (by way of carrier sense) and to be deferring to it. The time to acquire the medium is thus based on the round-trip propagation time of the physical layer whose elements include the PLS, PMA, and physical medium.

In the event of a collision, the transmitting station's Physical Layer initially notices the interference on the medium and then turns on the collision detect signal. This is noticed in turn by the Transmit Media Access Management component of the MAC sublayer, and collision handling begins. First, Transmit Media Access Management enforces the collision by transmitting a bit sequence called jam. In 4.4 an implementation that uses this enforcement procedure is provided. This ensures that the duration of the collision is sufficient to be noticed by the other transmitting station(s) involved in the collision. After the jam is sent, Transmit Media Access Management terminates the transmission and schedules another transmission attempt after a randomly selected time interval. Retransmission is attempted again in the face of repeated collisions. Since repeated collisions indicate a busy medium, however, Transmit Media Access Management attempts to adjust to the medium load by backing off (voluntarily delaying its own retransmissions to reduce its load on the medium). This is accomplished by expanding the interval from which the random retransmission time is selected on each successive transmit attempt. Eventually, either the transmission succeeds, or the attempt is abandoned on the assumption that the medium has failed or has become overloaded.

At the receiving end, the bits resulting from a collision are received and decoded by the PLS just as are the bits of a valid frame. Fragmentary frames received during collisions are distinguished from valid transmissions by the MAC sublayer's Receive Media Access Management component.

4.1.3 Relationships to LLC Sublayer and Physical Layer. The CSMA/CD MAC sublayer provides services to the LLC sublayer required for the transmission and reception of frames. Access to these services is specified in 4.3. The CSMA/CD MAC sublayer makes a best effort to acquire the medium and transfer a serial stream of bits to the PLS. Although certain errors are reported to the LLC, error recovery is not provided by MAC. Error recovery may be provided by the LLC or higher (sub)layers.

4.1.4 CSMA/CD Access Method Functional Capabilities. The following summary of the functional capabilities of the CSMA/CD MAC sublayer is intended as a quick reference guide to the capabilities of the standard, as depicted in Fig 4-2:

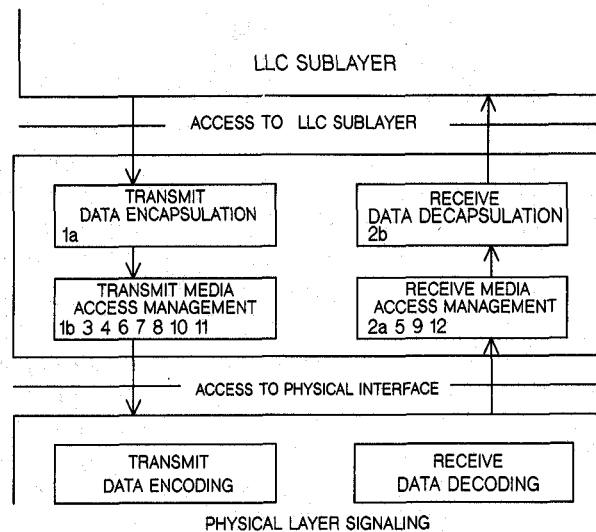
(1) For Frame Transmission

- (a) Accepts data from the LLC sublayer and constructs a frame
- (b) Presents a bit-serial data stream to the physical layer for transmission on the medium

NOTE: Assumes data passed from the LLC sublayer are octet multiples.

(2) For Frame Reception

- (a) Receives a bit-serial data stream from the physical layer



NOTE: Numbers refer to functions listed in 4.1.4.

Fig 4-2
CSMA/CD Media Access Control Functions

(b) Presents to the LLC sublayer frames that are either broadcast frames or directly addressed to the local station

(c) Discards or passes to Network Management all frames not addressed to the receiving station

(3) Defers transmission of a bit-serial stream whenever the physical medium is busy

(4) Appends proper FCS value to outgoing frames and verifies full octet boundary alignment

(5) Checks incoming frames for transmission errors by way of FCS and verifies octet boundary alignment

(6) Delays transmission of frame bit stream for specified interframe gap period

(7) Halts transmission when collision is detected

(8) Schedules retransmission after a collision until a specified retry limit is reached

(9) Enforces collision to ensure propagation throughout network by sending jam message

(10) Discards received transmissions that are less than a minimum length

(11) Appends preamble, Start Frame Delimiter, DA, SA, length count, and FCS to all frames, and inserts pad field for frames whose LLC data length is less than a minimum value

(12) Removes preamble, Start Frame Delimiter, DA, SA, length count, FCS and pad field (if necessary) from received frames

4.2 CSMA/CD Media Access Control Method (MAC): Precise Specification

4.2.1 Introduction. A precise algorithmic definition is given in this section, providing procedural model for the CSMA/CD MAC process with a program in the computer language Pascal. See references [A2] and [A17] for resource material. Note whenever there is any apparent ambiguity concerning the definition of some aspect of the CSMA/CD MAC method, it is the Pascal procedural specification in 4.2.7 through 4.2.10 which should be consulted for the definitive statement. Sections 4.2.2 through 4.2.6 provide, in prose, a description of the access mechanism with the formal terminology to be used in the remaining subsections.

4.2.2 Overview of the Procedural Model. The functions of the CSMA/CD MAC method are presented below, modeled as a program written in the computer language Pascal. This procedural model is intended as the primary specification of the functions to be provided in any CSMA/CD MAC sublayer implementation. It is important to distinguish, however, between the model and a real implementation. The model is optimized for simplicity and clarity of presentation, while any realistic implementation shall place heavier emphasis on such constraints as efficiency and suitability to a particular implementation technology or computer architecture. In this context, several important properties of the procedural model shall be considered.

4.2.2.1 Ground Rules for the Procedural Model

(1) First, it shall be emphasized that *the description of the MAC sublayer in a computer language is in no way intended to imply that procedures shall be implemented as a program executed by a computer.* The implementation may consist of any appropriate technology including hardware, firmware, software, or any combination.

(2) Similarly, it shall be emphasized that it is the behavior of any MAC sublayer implementations that shall match the standard, not their internal structure. The internal details of the procedural model are useful only to the extent that they help specify that behavior clearly and precisely.

(3) The handling of incoming and outgoing frames is rather stylized in the procedural model, in the sense that frames are handled as single entities by most of the MAC sublayer and are only serialized for presentation to the Physical Layer. In reality, many implementations will instead handle frames serially on a bit, octet or word basis. This approach has not been reflected in the procedural model, since this only complicates the description of the functions without changing them in any way.

(4) The model consists of algorithms designed to be executed by a number of concurrent processes; these algorithms collectively implement the CSMA/CD procedure. The timing dependencies introduced by the need for concurrent activity are resolved in two ways:

(a) *Processes Versus External Events.* It is assumed that the algorithms are executed "very fast" relative to external events, in the sense that a process never falls behind in its work and fails to respond to an external event in a timely manner. For example, when a frame is to be received, it is assumed

that the Media Access procedure `ReceiveFrame` is always called well before the frame in question has started to arrive.

(b) *Processes Versus Processes*. Among processes, no assumptions are made about relative speeds of execution. This means that each interaction between two processes shall be structured to work correctly independent of their respective speeds. Note, however, that the timing of interactions among processes is often, in part, an indirect reflection of the timing of external events, in which case appropriate timing assumptions may still be made.

It is intended that the concurrency in the model reflect the parallelism intrinsic to the task of implementing the LLC and MAC procedures, although the actual parallel structure of the implementations is likely to vary.

4.2.2.2 Use of Pascal in the Procedural Model. Several observations need to be made regarding the method with which Pascal is used for the model. Some of these observations are as follows:

(1) Some limitations of the language have been circumvented to simplify the specification:

(a) The elements of the program (variables and procedures, for example) are presented in logical groupings, in top-down order. Certain Pascal ordering restrictions have thus been circumvented to improve readability.

(b) The *process* and *cycle* constructs of the Pascal derivative. Concurrent Pascal have been introduced to indicate the sites of autonomous concurrent activity. As used here, a process is simply a parameterless procedure that begins execution at "the beginning of time" rather than being invoked by a procedure call. A cycle statement represents the main body of a process and is executed repeatedly forever.

(c) The lack of variable array bounds in the language has been circumvented by treating frames as if they are always of a single fixed size (which is never actually specified). The size of a frame depends on the size of its data field, hence the value of the "pseudo-constant" `frameSize` should be thought of as varying in the long-term, even though it is fixed for any given frame.

(d) The use of a variant record to represent a frame (as fields and as bits) follows the spirit but not the letter of the Pascal Report, since it allows the underlying representation to be viewed as two different data types.

(2) The model makes no use of any explicit interprocess synchronization primitives. Instead, all interprocess interaction is done by way of carefully stylized manipulation of shared variables. For example, some variables are set by only one process and inspected by another process in such a manner that the net result is independent of their execution speeds. While such techniques are not generally suitable for the construction of large concurrent programs, they simplify the model and more nearly resemble the methods appropriate to the most likely implementation technologies (microcode, hardware state-machines, etc.)

4.2.2.3 Organization of the Procedural Model. The procedural model used here is based on five cooperating concurrent processes. Three are actually defined in the MAC sublayer. The remaining two processes are provided by the clients of the MAC sublayer (which may include the LLC sublayer) and utilize

the interface operations provided by the MAC sublayer. The five processes are thus:

- (1) Frame Transmitter Process
- (2) Frame Receiver Process
- (3) Bit Transmitter Process
- (4) Bit Receiver Process
- (5) Deference Process

This organization of the model is illustrated in Fig 4-3 and reflects the fact that the communication of entire frames is initiated by the client of the MAC sublayer; while the timing of collision backoff and of individual bit transfers

Fig 4-3
Relationship Among CSMA/CD Procedures

