

Supplement to Information technology— Local and metropolitan area networks— Specific requirements—Part 12: Demand- priority access method, physical layer and repeater specifications:

Full-Duplex Operation

Sponsor

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

Approved 25 March 1998

IEEE-SA Standards Board

Abstract: Optional MAC capabilities are defined to allow direct link connection between two end nodes with provision for both half-duplex and full-duplex operation; burst-mode packet transmission from an end node to a repeater where the end node may send one or more packets each time it is granted permission to transmit; and implementation of the MAC Control sublayer to allow the exchange of control requests between peer MAC entities across the network when in ISO/IEC 8802-3 compatibility mode. Full interoperability is maintained with existing ISO/IEC 8802-12 products.

Keywords: burst mode, demand-priority access method, direct connect, flow control, full duplex, local area networks, MAC Control, management, media access control, repeater

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

Copyright © 1998 by the Institute of Electrical and Electronics Engineers, Inc.
All rights reserved. Published 1998. Printed in the United States of America.

ISBN 0-7381-0177-X

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.

IEEE Standards documents are developed within the IEEE Societies and the Standards Coordinating Committees of the IEEE Standards Association (IEEE-SA) 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 that 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 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 societies and Standards Coordinating 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-SA Standards Board
445 Hoes Lane
P.O. Box 1331
Piscataway, NJ 08855-1331
USA

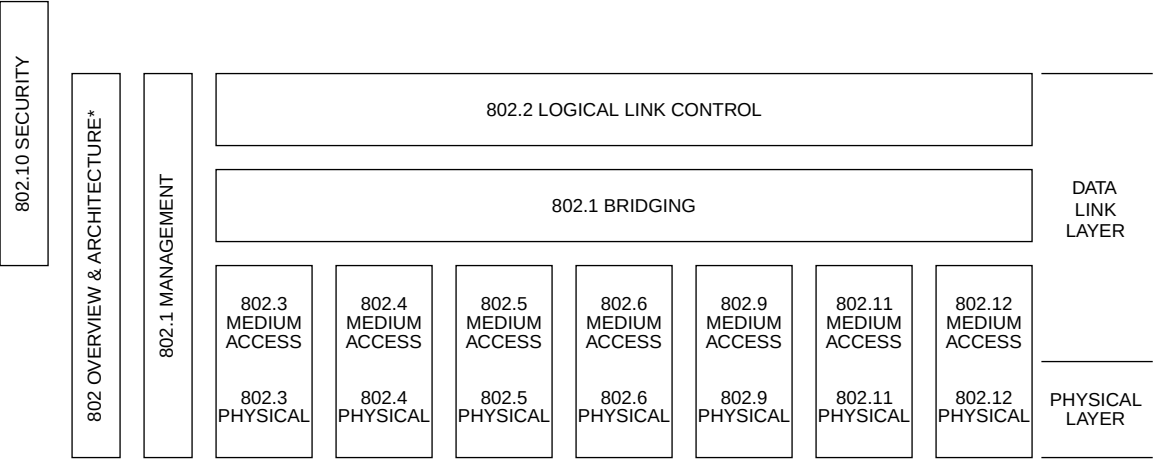
Note: Attention is called to the possibility that implementation of this standard may require use of subject matter covered by patent rights. By publication of this standard, no position is taken with respect to the existence or validity of any patent rights in connection therewith. The IEEE shall not be responsible for identifying patents for which a license may be required by an IEEE standard or for conducting inquiries into the legal validity or scope of those patents that are brought to its attention.

Authorization to photocopy portions of any individual standard for internal or personal use is granted by the Institute of Electrical and Electronics Engineers, Inc., provided that the appropriate fee is paid to Copyright Clearance Center. To arrange for payment of licensing fee, please contact Copyright Clearance Center, Customer Service, 222 Rosewood Drive, Danvers, MA 01923 USA; (978) 750-8400. Permission to photocopy portions of any individual standard for educational classroom use can also be obtained through the Copyright Clearance Center.

Introduction

(This introduction is not part of IEEE Std 802.12c-1998, Supplement to Information technology—Local and metropolitan area networks—Specific requirements—Part 12: Demand-priority access method, physical layer and repeater specifications: Full-Duplex Operation.)

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



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

The standards defining the access technologies are as follows:

- IEEE Std 802 *Overview and Architecture.* This standard provides an overview to the family of IEEE 802 Standards.
- ANSI/IEEE Std 802.1B and 802.1k [ISO/IEC 15802-2] *LAN/MAN Management.* Defines an OSI management-compatible architecture, and services and protocol elements for use in a LAN/MAN environment for performing remote management.
- ANSI/IEEE Std 802.1D [ISO/IEC 10038] *Media Access Control (MAC) Bridges.* Specifies an architecture and protocol for the interconnection of IEEE 802 LANs below the MAC service boundary.
- ANSI/IEEE Std 802.1E [ISO/IEC 15802-4] *System Load Protocol.* Specifies a set of services and protocol for those aspects of management concerned with the loading of systems on IEEE 802 LANs.
- ANSI/IEEE Std 802.1G [ISO/IEC 15802-5] *Remote Media Access Control (MAC) Bridging.* Specifies extensions for the interconnection, using non-LAN communication technologies, of geographically separated IEEE 802 LANs below the level of the logical link control protocol.
- ANSI/IEEE Std 802.2 [ISO/IEC 8802-2] *Logical Link Control*

- ANSI/IEEE Std 802.3 [ISO/IEC 8802-3] *CSMA/CD Access Method and Physical Layer Specifications*
- ANSI/IEEE Std 802.4 [ISO/IEC 8802-4] *Token Passing Bus Access Method and Physical Layer Specifications*
- ANSI/IEEE Std 802.5 [ISO/IEC 8802-5] *Token Ring Access Method and Physical Layer Specifications*
- ANSI/IEEE Std 802.6 [ISO/IEC 8802-6] *Distributed Queue Dual Bus Access Method and Physical Layer Specifications*
- ANSI/IEEE Std 802.9 [ISO/IEC 8802-9] *Integrated Services (IS) LAN Interface at the Medium Access Control (MAC) and Physical (PHY) Layers*
- ANSI/IEEE Std 802.10 *Interoperable LAN/MAN Security*
- ANSI/IEEE Std 802.11 [ISO/IEC 8802-11] *Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications*
- ANSI/IEEE Std 802.12 [ISO/IEC 8802-12] *Demand-Priority Access Method, Physical Layer and Repeater Specifications*

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

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

The following additional working group has authorized standards projects under development:

- IEEE 802.14 *Standard Protocol for Cable-TV Based Broadband Communication Network*

Conformance test methodology

An additional standards series, identified by the number 1802, has been established to identify the conformance test methodology documents for the 802 family of standards. Thus the conformance test documents for 802.3 are numbered 1802.3.

IEEE Std 802.12c-1998

The purpose of this supplement to ISO/IEC 8802-12: 1998 is to define optional MAC capabilities that will allow the following:

- Direct link connection between two end nodes with provision for both half-duplex and full-duplex modes. Half-duplex mode allows packet transmission in either direction, but in only one direction at a time. Full-duplex mode allows simultaneous packet transmission in both directions.
- Burst-mode packet transmission from an end node to a repeater where the end node is allowed to send one or more packets each time it is granted permission to send.
- Implementation of the MAC Control sublayer to allow the exchange of control requests between peer MAC entities across the network when in ISO/IEC 8802-3 compatibility mode.

Full interoperability is maintained with existing ISO/IEC 8802-12 products.

These revisions to ISO/IEC 8802-12: 1998 contain technical and editorial changes and additions to clauses 1–4, 6–7, 10–14, 16–17, and to annexes A, C, D, and E. Technical changes for the individual purposes include the following:

- a) Full- and half-duplex operation between directly connected end nodes:
 - 1) The training frame configuration field formats in 10.6.2 and 10.6.3 have been revised to include full-duplex capability. Full-duplex (FD) bits have been added to figures 10-16 and 10-17, and their associated descriptions are now included in 10.6.2.5 and 10.6.3.5.
 - 2) Clause 11 has been extensively revised. The order of 11.3 and 11.4 has been interchanged, two optional state machines and an optional fifth autonomous process have been added to the MAC logical structure, and the description of the various operational modes has been expanded to include state machine interaction and synchronization.

Most of the figures have been revised and a number of new figures have been added. New type values, variables, and timers have been added to support several new procedures and functions as well as to support the new state machines. Pseudo-code additions have also been made to a number of the existing functions and procedures and to several states of the MAC state machine.
 - 3) New network management objects have been added to figure 13-4 in 13.1.2.2, and to the attribute lists in 13.1.3.2. The associated object attributes have been described in 13.2.5.2.1 and GDMO attribute definitions have been added to C.2.1.1 and C.2.1.2. ASN.1 types have been added to C.4 and object identifier values have been included in D.4.
 - 4) A requirement for a selectable copper-media crossover function has been defined for 4-UTP links in 16.10.4 and for STP links in 17.10.3.
 - 5) The notes for table 14-1 (14.3.1) and table 14-2 (14.3.2) have been revised to account for the expanded control function interpretation during operation between two directly connected end nodes.
 - 6) The tables in A.5.1, A.5.2, A.5.4, A.7.2, and A.7.3 of the PICS proforma have been revised to include direct end-node-to-end-node link capability queries.
 - 7) A 4-UTP cable restriction for full-duplex operation has been added to E.3.
- b) Burst-mode transmission:
 - 1) The training frame configuration field formats in 10.6.2 and 10.6.3 have been revised to include burst-mode capability. Burst-mode (B) bits have been added to figures 10-16 and 10-17, and their associated descriptions are now included in 10.6.2.4 and 10.6.3.4.
 - 2) The control state definitions in 11.2.2.3, 11.2.2.4, and 11.3.1.3 have been expanded and a tenth state has been added to the MAC state machine (figure 11-3.1). Burst-mode transmission restrictions have been defined in 11.4.3.3 and their associated timers and timer values have been added to 11.5.2 and 11.5.2.2. New type values and variables have been added to 5.4 and 5.5. Pseudo-code additions are included in the procedures and functions in 11.5.6.4, 11.5.6.10, 11.5.7.1, and 11.5.7.4, and in the MAC state machine in 11.6.3, 11.6.6, 11.6.7, and 11.7.10. A new function has also been defined in 11.5.7.3.
 - 3) New timer values, types, and variables have been added to 12.5.1, 12.5.2, and 12.5.3.1. Figure 12-19 has been revised and pseudo-code additions have been made to 12.6.3.4, 12.7.8, and 12.7.10. The frame transmission definition in 12.9.7.3 has been revised to allow for burst-mode time-out errors and a new figure 12-42.1 has been included in 12.9.8.2 to define the repeater response to a B bit in the requested-configuration field of a lower port training frame.

- 4) New network management objects have been added to figures 13-3 and 13-4 in 13.1.2.2 and to the attribute lists in 13.1.3.1.3 and 13.1.3.2. The associated object attributes have been described in 13.2.4.5.1 and 13.2.5.2.1, and GDMO attribute definitions have been added to C.1.4.1, C.1.4.2, C.2.1.1, and C.2.1.2. Object identifier values have been included in D.3 and D.4.
 - 5) The tables in A.5.1, A.5.2, A.5.4, A.6.1, and A.6.3 of the PICS proforma have been revised to include burst-mode capability queries.
 - 6) A 4-UTP bundled cable restriction for burst-mode operation has been added to E.3.1.
- c) MAC Control:
- 1) Figure 7-1 has been revised to include the optional MAC Control sublayer in the LAN model, and two MA_CONTROL primitives have been added to 7.3.
 - 2) The ISO/IEC 8802-3 compatibility-mode frame-format Length field description in 10.2.2 has been expanded to allow Type field interpretation, the invalid MAC frame definition has been expanded to exempt Type-field values greater than minTypeFieldLength, and a new subclause (10.8) has been added to define the MAC Control frame format.
 - 3) The end-node LAN model (figure 11-1) in 11.1 has been revised. New type values have been added to 11.5.4; new variables have been added to 11.5.5; and new pseudo code has been added to the procedure in 11.5.6.6 and to the function in 11.5.7.1. Two new functions (11.5.7.6 and 11.5.7.8) have been defined and new pseudo code has been also added to the MAC state machine (11.6.3 and 11.6.6) and to the TX state machine (11.8.1 and 11.8.2).
 - 4) A new network management object has been defined and has been included in figure 13-4 and in subclauses 13.1.3.2 and 13.2.5.1. GDMO code for the object attribute has been added to C.2.1.2 and an allocation for the object identifier value has been included in D.4.
 - 5) The tables in A.5.1 and A.5.2 of the PICS proforma have been revised to include direct MAC Control capability queries.

The parameter lists for the M_UNITDATA.request and M_UNITDATA.indication primitives in 7.4 have also been expanded and the MAC services to upper sublayers in 11.2.1 have been clarified to make them consistent with ISO/IEC DIS 15802-3 [IEEE P802.1D, D16, March 19, 1998].

This standard contains state-of-the-art material. The area covered by this standard is undergoing evolution. Revisions are possible within the next few years to clarify existing material, to correct possible errors, and to incorporate new related material. Information on the current revision state of this and other IEEE 802 standards may be obtained from

Secretary, IEEE-SA Standards Board
 445 Hoes Lane
 P.O. Box 1331
 Piscataway, NJ 08855-1331
 USA

IEEE 802 committee working documents are available from

IEEE Document Distribution Service
 AlphaGraphics #35 Attn: P. Thrush
 10201 N. 35th Avenue
 Phoenix, AZ 85051
 USA

Participants

The following is a list of participants in the IEEE 802.12 Working Group at the time this supplement was approved.

Pat Thaler, *Chair*
William G. Lane, *Technical Editor*

Alan Albrecht
Dan Dove
Alvin Eng

Bob Faulk
Josef Kozilek
Robert H. Leonowich
Henry Ngai

K. Karl Shimada
Greg Watson
James Young

The following persons were on the balloting committee:

William B. Adams
Alan Albrecht
Jack S. Andresen
Kit Athul
Thomas W. Bailey
Peter K. Campbell
James T. Carlo
David E. Carlson
Alan M. Chambers
Robert S. Crowder
Christos Douligeris
Edward A. Dunlop
Sourav K. Dutta
Paul S. Eastman
Jean Paul Emard
Philip H. Enslow
Changxin Fan
Robert L. Faulk
John W. Fendrich
Howard M. Frazier
Gautam Garai

Julio Gonzalez-Sanz
Raj Jain
Peter M. Kelly
Edward R. Kelly
Gary C. Kessler
Stephen Barton Kruger
William G. Lane
Jai Yong Lee
Walter Levy
Randolph S. Little
Peter Martini
John L. Messenger
Bennett Meyer
David S. Millman
Warren Monroe
John E. Montague
Shimon Muller
Paul Nikolich
Robert O'Hara
Donal O'Mahony
Charles Oestereich
John M. Osepchuk

Roger Pandanda
Lalit M. Patnaik
Lucy W. Person
Ronald C. Petersen
Vikram Punj
Andris Putnins
Edouard Y. Rocher
James W. Romlein
Floyd E. Ross
Norman Schneidewind
Donald A. Sheppard
William R. Smith
Efsthathios D. Sykas
Patricia Thaler
Geoffrey O. Thompson
Mark-Rene Uchida
John Viaplana
Barry M. Vornbrock
Yun-Che Wang
Qian-li Yang
Oren Yuen

The final conditions for approval of this supplement were met on 25 March 1998. This supplement was conditionally approved by the IEEE-SA Standards Board on 19 March 1998, with the following membership:

Richard J. Holleman, *Chair*

Donald N. Heirman, *Vice Chair*

Judith Gorman, *Secretary*

Satish K. Aggarwal
Clyde R. Camp
James T. Carlo
Gary R. Engmann
Harold E. Epstein
Jay Forster*
Thomas F. Garrity
Ruben D. Garzon

James H. Gurney
Jim D. Isaak
Lowell G. Johnson
Robert Kennelly
E. G. "Al" Kiener
Joseph L. Koepfinger*
Stephen R. Lambert
Jim Logothetis
Donald C. Loughry

L. Bruce McClung
Louis-François Pau
Ronald C. Petersen
Gerald H. Peterson
John B. Posey
Gary S. Robinson
Hans E. Weinrich
Donald W. Zipse

*Member Emeritus

Valerie E. Zelenty
IEEE Standards Project Editor

Contents

1.	Overview	1
1.2	Purpose	1
2.	Normative references	1
3.	Definitions.....	2
4.	Abbreviations and acronyms.....	2
6.	Introduction to the protocol	2
6.1	Network topology	2
6.1.1	Network components	2
6.1.2	Network structure.....	3
6.1.3	Link configuration	3
6.1.4	Link media	4
6.2	Basic operational concepts.....	4
6.2.1	Round-robin polling.....	4
6.2.2	Data transmission.....	4
6.2.3	Round-robin transmission example	6
6.4	Link training.....	7
6.7	Architectural relationship to the ISO/IEC and IEEE standards	7
6.7.1	End-node architecture	7
6.7.3	MAC functions.....	8
6.8	Items for future study	8
7.	Medium Access Control (MAC) service definitions	8
7.1	Scope	8
7.4	MAC services to a bridge	9
7.5	MAC services to the MAC Control entity	9
7.5.1	MA_CONTROL.request.....	10
7.5.2	MA_CONTROL.indication	10
10.	Medium Access Control (MAC) frame format structure.....	10
10.2	Elements of the ISO/IEC 8802-12 MAC frame format— ISO/IEC 8802-3 compatibility mode	10
10.2.2	Length/Type (L) field	10
10.6	Elements of the ISO/IEC 8802-12 training frame	11
10.6.1	Address fields.....	11
10.6.2	Requested-configuration field format	12
10.6.3	Allowed-configuration field format	14
10.8	MAC Control frame format	16
10.8.1	Destination address (DA) field	16
10.8.2	Source address (SA) field	17
10.8.3	Length/Type (L) field	17
10.8.4	MAC Control opcode field	17
10.8.5	MAC Control parameters field	17
10.8.6	Reserved field	17
10.8.7	MAC Control frame FCS field	17
11.	Medium Access Control (MAC) protocol	18
11.1	Scope	18

11.2	Overview of the MAC operations.....	19
11.2.1	MAC services to upper sublayers	19
11.2.2	Link control.....	20
11.2.3	Internal control.....	23
11.3	The MAC logical structure	23
11.3.1	Autonomous processes.....	25
11.3.2	State machines	29
11.4	MAC operational modes	31
11.4.1	DCMAC mode arbitration	33
11.4.2	Training mode.....	34
11.4.3	Active mode.....	43
11.4.4	Retrain_Delay mode	57
11.5	State machine global definitions	58
11.5.1	Counters	58
11.5.2	Timers	58
11.5.3	Constants.....	61
11.5.4	Types.....	62
11.5.5	Variables	66
11.5.6	Procedures.....	69
11.5.7	Functions.....	77
11.6	MAC state machine state definitions	82
11.6.1	MAC1 : MAC1_REQUEST_TRAINING.....	82
11.6.2	MAC2 : MAC2_REMOVE_CONTROL_SIGNAL.....	84
11.6.3	MAC3 : MAC3_IDLE_OR_REQUEST.....	85
11.6.4	MAC4 : MAC4_WAIT_FOR_START_MAC_FRAME	90
11.6.5	MAC5 : MAC5_READ_FRAME.....	92
11.6.6	MAC6 : MAC6_TRANSMIT_FRAME	95
11.6.7	MAC7 : MAC7_WAIT_FOR_PMI_TRANSMIT_INDICATION.....	96
11.6.8	MAC8 : MAC8_ACQUIRE_CONTROL_SIGNAL	98
11.6.9	MAC9 : MAC9_RETRAIN_DELAY	99
11.6.10	MAC10 : MAC10_BURST_DELAY.....	100
11.7	The arbitration state machine state definitions	101
11.7.1	ARB1_Begin_Next_Arbitration_Cycle.....	103
11.7.2	ARB2r_Blind_RCS_Monitor_RMode	103
11.7.3	ARB3r_Wait_For_Training_Up.....	103
11.7.4	ARB4r_Wait_For_Request_Or_Idle	103
11.7.5	ARB2e_Blind_RCS_Monitor.....	104
11.7.6	ARB3e_Request_Training.....	104
11.7.7	ARB4e_Continue_Request_Training	104
11.7.8	ARB5e_Test_Idle	104
11.7.9	ARB6e_Initiate_Training	104
11.8	The TX state machine state definitions.....	104
11.8.1	TX3_IDLE.....	105
11.8.2	TX6_TRANSMIT_FRAME	109
11.8.3	TX7_WAIT_FOR_PMI_TRANSMIT_INDICATION	110
11.9	DCMAC copper link-media crossover requirement.....	111
12.	Repeater Medium Access Control (RMAC) protocol	111
12.2	RMAC packet monitoring and network control overview	111
12.3	Control state definitions.....	111
12.3.1	Transmit Control States	111
12.5	State machine constants, variables, and types	112
12.5.1	Global constants.....	112
12.5.2	Types.....	112

12.6 Functions and procedures	112
12.6.3 Function definitions	112
12.7 Receive State Machine (RSM).....	114
12.7.6 RX6 : RX6_EXPECT_IDLE_OR_REQ.....	115
12.7.7 RX7 : RX7_EXPECT_FRAME_FROM_BELOW	117
12.7.8 RX8 : RX8_RECEIVING_FRAME_FROM_BELOW	119
12.7.10 RX10 : RX10_WAIT_FRAME_FROM_LOCAL_PORT_REPEATED	120
12.9 The Buffer Control and Address Lookup Logic (BCALL) state machine	120
12.9.2 BCALL control registers.....	120
12.9.7 Control of frame transmission	120
12.9.8 Local port training.....	120
13. Layer management functions and services	125
13.1 Introduction.....	125
13.1.2 Layer management model.....	125
13.1.3 Packages.....	127
13.2.4 Repeater management facilities	128
13.2.5 End-node management facilities.....	129
14. Physical Medium Independent (PMI) specifications.....	132
14.3 Control functions	132
14.3.1 TCS transfer function.....	132
14.3.2 RCS transfer function	133
16. 4-UTP Physical Medium Dependent (PMD) sublayer, Medium Dependent Interface (MDI), and link specifications.....	133
16.10 MDI specification	133
16.10.4 DCMAC crossover function	133
17. Dual-simplex STP Physical Medium Dependent (PMD) sublayer, Medium Dependent Interface (MDI), and link specifications	134
17.10 MDI specification	134
17.10.3 DCMAC crossover function	134
Annex A (normative) Protocol Implementation Conformance Statement (PICS) proforma	134
A.5 End-node PICS proforma.....	134
A.5.1 End-node: Major capabilities	134
A.5.2 Support for MAC functions	136
A.5.4 MAC timer support	137
A.6 Repeater PICS proforma	138
A.6.1 Repeater: Major capabilities	138
A.6.3 RMAC timer support	140
A.7 Physical Layer items	141
A.7.2 PMD/MDI for 4-UTP links.....	141
A.7.3 PMD/MDI for dual-simplex STP links.....	142
Annex C (normative) GDMO specifications for demand-priority managed objects	144
C.1 Repeater GDMO specification.....	144
C.1.4 Port managed object class	144
C.2 End-node GDMO specification	144
C.2.1 End-node MAC managed object class	144
C.4 ASN.1 module for demand-priority managed objects	148

Annex D (normative) Allocation of object-identifier values.....	149
D.3 Repeater object identifiers	149
D.4 End-node object identifiers	149
Annex E (normative) Network topology rules	150
E.3 4-UTP cable	150
E.3.1 4-UTP bundled-cable restrictions.....	150

Supplement to Information technology—Local and metropolitan area networks—Specific requirements—Part 12: Demand-priority access method, physical layer and repeater specifications:

Full-Duplex Operation

Revisions to ISO/IEC 8802-12:1998

Editing instructions for incorporating the revisions defined by this supplement into the indicated subclauses of ISO/IEC 8802-12:1998 (ANSI/IEEE Std 802.12-1995 and ANSI/IEEE Std 802.12d-1997) are shown in ***bold italic*** type. New figures are numbered with the number of the immediately previous figure in the base standard followed by a decimal fraction (e.g., n-xx.1 indicates the new figure is to be added after figure n-xx, figure n-xx.2 indicates the figure is to be added after figure n-xx.1, etc.). New footnotes and equations are identified with a similar numbering scheme.

1. Overview

1.2 Purpose

Add the following text to the end of this subclause:

- o) Allow direct-link connection between two end nodes.
- p) Support burst-mode transmission between an end node and a repeater.
- q) Support the exchange of MAC Control requests when in ISO/IEC 8802-3 compatibility mode.

2. Normative references

Add the following references to the proper alphabetical location in this clause:

IEEE Std 610.7-1995, IEEE Standard Glossary of Computer Networking Terminology.

IEEE Std 802.3x-1997, Supplement to ISO/IEC 8802-3: 1996: Specification for 802.3 Full Duplex Operation.

ISO/IEC DIS 15802-3 [IEEE P802.1D, D16, March 19, 1998], Information technology—Telecommunications and information exchange between systems—Local and metropolitan area networks—Common specifications—Part 3: Media Access Control (MAC) Bridges.^{8.1}

^{8.1} IEEE P802.1D, D16, dated March 19, 1998, is available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA. Please note that this draft will be superseded by ISO/IEC 15802-3 when the standard becomes available.

3. Definitions

Add the following definitions to the proper alphabetical location in this clause:

bridge: A layer 2 interconnection device that conforms to ISO/IEC DIS 15802-3.

burst mode: An operational mode in which an end node may send one or more packets each time it is granted permission to transmit.

direct-connect end node: An end-node configuration that allows the node to be directly connected to another end node in a two-node, repeaterless network. A direct-connect node may be connected to another direct-connect node (allowing either full- or half-duplex packet transmission), to an end node without direct-connect capability (allowing half-duplex packet transmission), or to a repeater (allowing half-duplex packet transmission as an ordinary end node).

flow control: An operational capability that allows a peer MAC client entity to cause a temporary delay in further packet transmission from the MAC to that entity.

full-duplex operation: A mode of operation in a network link that supports duplex transmission as defined in IEEE Std 610.7-1995. Within the scope of this standard, this mode allows for simultaneous data communication between two end nodes, provided that the Physical Layer is capable of supporting simultaneous data transmission and reception without interference.

4. Abbreviations and acronyms

Add the following abbreviations and acronyms to the proper alphabetical locations in this clause:

DCMAC	MAC with direct-connect capability
EMode	DCMAC end-node mode
RMode	DCMAC repeater mode

6. Introduction to the protocol

6.1 Network topology

6.1.1 Network components

Replace the text in this subclause with the following:

The demand-priority LAN architecture utilizes three principal structural components: end nodes, repeaters, and network links.

- a) End nodes are typically personal or larger computers, user workstations, peripherals, or file servers. They might also be special devices (such as LAN analyzers), or they might be switches or bridges to other LANs.
- b) Repeaters are the network controllers and are configured with two or more local ports to allow connection to end nodes or other repeaters. They can also be configured with an optional cascade port, which is reserved for connection to repeaters only.

- c) Link segments provide the interconnection medium between a repeater and its connected end nodes or other repeaters, or between two direct-connect end nodes.

6.1.2 Network structure

Replace the text in this subclause with the following:

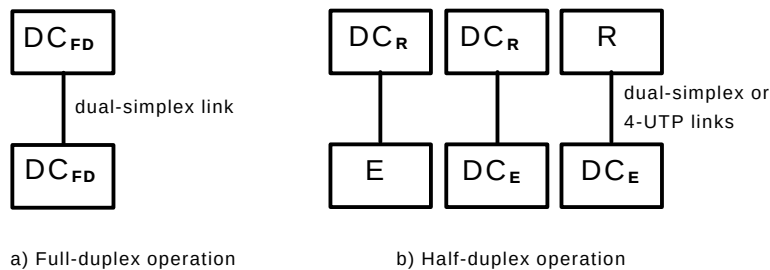
The network can be structured with single or multiple repeater levels or, in the case of two end nodes that are connected directly together, with no repeater at all.

Add a new subclause 6.1.2.4 after subclause 6.1.2.3 with the following::

6.1.2.4 Direct end-node-to-end-node connection

An optional configuration is provided to allow direct-link connection between two end nodes in either of the following two transmission modes:

- a) *Full-duplex mode* supports simultaneous, two-way data transmission between two end nodes, such as a user station and a switch, a user station and a network server, or a network server and a switch. Full-duplex operation requires the following:
 - 1) There are exactly two end nodes on the LAN as shown in figure 6-3.1a).
 - 2) Both end nodes have direct-connect capability.
 - 3) The link supports full-duplex packet transmission.
- b) *Half-duplex mode* restricts data transmission to one direction at a time. A direct-connect node can appear to the entity at the other end of the link as either an end node with a basic MAC (EMode) or as a repeater (RMode). A direct-connect node may be connected to an end node without direct-connect capability, to another direct-connect end node, or to a repeater as shown in figure 6-3.1b).



DC_{FD} = direct-connect end node with full-duplex operation
 DC_E = direct-connect end node with half-duplex EMode operation
 DC_R = direct-connect end node with half-duplex RMode operation
 R = repeater (local port)
 E = end node without direct-connect capability

NOTE—Full-duplex operation cannot be supported over 4-UTP link media.

Figure 6-3.1 Allowable direct-connect node configurations

6.1.3 Link configuration

Add the following sentences to the end of this subclause:

Promiscuous mode has no meaning and is not allowed in links between two directly connected end nodes. The network, in this case, consists of only two nodes. Any packet transmitted on the network will be sent by one node and will be received by the other.

6.1.4 Link media

Replace the text in this subclause with the following:

The links between repeater local ports and their connected end nodes or between directly connected end nodes can be 4-pair 100 Ω balanced cable (4-UTP), 2-pair 150 Ω balanced cable (STP), or two optical fibres. STP and optical fibre cables can be used for all links in single and multiple repeater networks and for all link configurations and operational modes between directly connected end nodes.

For 4-UTP links, the recommended configuration is 4-pair cable. 4-UTP links may be used for all half-duplex configurations of directly connected end nodes, but must not be used for full-duplex operation.

4-UTP bundled cable (25-pair binder-groups) is allowed for repeater-to-end-node links, but requires repeaters with privacy-mode and store-and-forward capability because excessive crosstalk could occur with simultaneous transmission of a packet to multiple ports on the same bundled cable as the sending end node. Bundled cable must not be used in the following:

- 1) Repeater-to-repeater links.
- 2) Repeater-to-end-node links where the end node is operating in promiscuous mode or is permitted to transmit in burst mode.
- 3) Links between directly connected end nodes.

See annex E for additional network configuration information and topology rules for ISO/IEC 8802-12 networks.

6.2 Basic operational concepts

6.2.1 Round-robin polling

Replace the first paragraph in this subclause with the following:

Round-robin polling in the repeater provides all end nodes with access to the network during each round-robin cycle. The repeater maintains two next-port pointers, one for normal-priority and one for high-priority requests, that keep track of the next ports to be serviced. All ports are polled at least once per packet transmission to determine which have requests pending. End nodes may transmit packets in either of the following two modes:

- a) In the single-packet mode, an end node may send only one packet each time it is granted permission to transmit.
- b) In the optional burst mode, an end node may send one or more packets each time it is granted permission to transmit.

Burst-mode transmission sequences are subject to a time constraint to ensure that transmission times do not become excessive. Individual packets that are transmitted in one burst sequence may have the same or different destination addresses.

6.2.2 Data transmission

Replace this subclause with the following, including new subclauses 6.2.2.1 and 6.2.2.2:

Packet transmission depends on whether the end node is connected to a repeater or to a direct-connect end node.

6.2.2.1 Data transmission in repeater-connected end nodes

Packet transmission follows a request/grant sequence in which the request is initiated by the sending end node and the issuance of the grant is controlled by the repeater. When packet transmission is occurring:

- a) The repeater polls all local ports to determine which end nodes or lower-level repeaters are requesting to send a packet and whether the request is normal priority or high priority. If an end node has a packet ready to send, it transmits either a Request_Normal or Request_High control signal. Otherwise, the end node transmits the Idle_Up control signal.
- b) Once the repeater has finished transmitting the packet, it selects the next end node with a request pending (the next port closest to the next-port pointer value) by sending Grant to the selected end node. Packet transmission begins when the end node detects the grant.
- c) The repeater alerts all end nodes on the network (other than the sender) of a possible incoming packet (by transmitting an Incoming control signal) and decodes the destination address as it is being received.
- d) When an end node receives the Incoming control signal, it prepares to receive a packet.
- e) After the repeater has decoded the destination address, the packet is sent to the addressed end node(s) and to any promiscuous ports. Communication to non-addressed, non-promiscuous ports is inhibited during packet transmission (the repeater sends Idle_Down to these ports during packet transmission).

Figure 6-4 shows a conceptual time-space diagram of a transmission (from an end node connected to port 8 to an end node connected to port 3) in a single-level repeater topology. Elasticity buffering of the packet is provided in the repeater to compensate for delays required to decode the destination address and to begin packet retransmission to the designated end node.

6.2.2.2 Data transmission in directly connected end nodes

Packet transmission between two directly connected end nodes depends on the configuration of each end node that is established at the end of the training sequence as follows:

- a) Full-duplex mode is allowed between two directly connected end nodes if they are both configured to support full-duplex operation. Full-duplex data transmission does not follow the request-grant sequence since round-robin polling is not required. Either node may initiate packet transmission at any time it is not sending a packet. The Incoming control signal is sent for a short duration to alert the other entity to prepare to receive a packet, and then packet transmission will begin.
- b) Half-duplex mode is allowed between two end nodes if at least one is a direct-connect node configured in RMode. The other may be either a basic end node or another direct-connect node configured in EMode. The transmission sequence is controlled by the RMode-configured node. If both nodes need to send a packet, the node with the highest priority request will be allowed to send first. If the priorities at both nodes are the same, the nodes will alternate sending packets. The RMode-configured node first determines which node should be next to send.

- 1) If the other node is next to send, the RMode-configured end node will send the Grant control signal (indicating permission to send).
- 2) If the RMode-configured node is next to send, it will send the Incoming control signal for a short duration to alert the other node to prepare to receive a packet, and then packet transmission will begin.

6.2.3 Round-robin transmission example

Replace the text in this subclause with the following:

Figure 6-5 shows an example that would result with round-robin polling in an 8-station, single-repeater network, assuming that the network was idle at $t = 0$. The normal-priority request from port 2 is selected by the repeater's RMAC and the packet transmission begins. During this time, high-priority requests are received from ports 5 and 1, but they are not acted upon until the current packet transmission is complete. The repeater then selects and processes the high-priority request with the closest port in port order to the high-priority next-port pointer (port 1 in this example). The high-priority request from port 5 is serviced next. Since there are no additional high-priority requests pending after port 5, the repeater returns to normal-priority requests and processes these, in port order (ports 3, 6, and 7), as indicated by the normal-request next-port pointer. Another high-priority request is received from port 1 during port 7's normal-priority burst-mode sequence. Since burst-mode transmissions are not interrupted in mid-sequence by high-priority requests, Port 1's high-priority request must wait until the burst sequence is complete. The high-priority request is serviced and the remaining normal-priority requests are then processed in the order indicated by the normal-priority next-port pointer.

Replace figure 6-5 with the following:

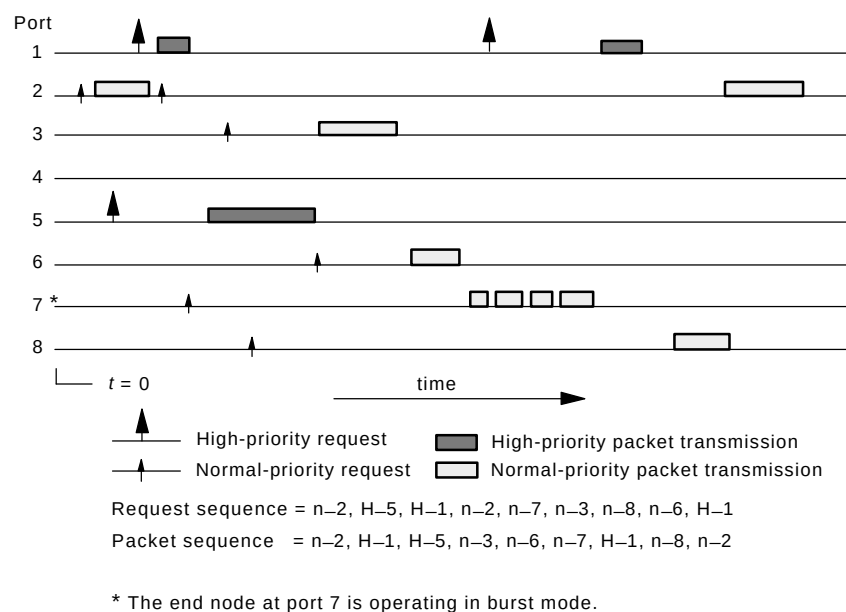


Figure 6-5—Packet transmission time-space diagram

6.4 Link training

Add the following sentences to the end of this subclause:

Link training for direct-connect nodes is always conducted in half-duplex mode. It is preceded by an arbitration sequence that is used to determine the type of the entity at the other end of the link and to negotiate the training mode (EMode or RMode) of the local node before any training packets are exchanged. Training can result in either half-duplex or full-duplex active operation.

6.7 Architectural relationship to the ISO/IEC and IEEE standards

6.7.1 End-node architecture

Replace this subclause with the following:

The five sublayers of the reference model for the demand-priority end node correspond to the two lower layers of the ISO 7498-1:1984 model for Open Systems Interconnection (OSI). A depiction of this relationship is presented in figure 6-8.

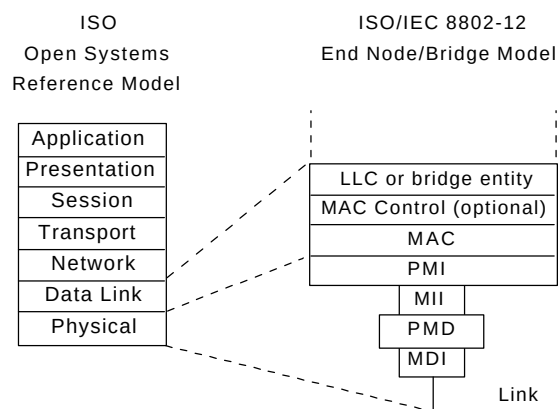


Figure 6-8—Demand-priority end node/bridge model

The upper sublayer in the end node is typically an ISO/IEC 8802-2 Class I LLC supporting Type 1 unacknowledged, connectionless-mode transmission, or an ISO/IEC 8802-2 Class II LLC supporting Type 2, connection-mode transmission, or similar protocol instance. The upper sublayer may also be a bridge entity.

The MAC sublayer is compatible with the following two MAC formats and interfaces:

- The MAC-frame format and MAC/LLC interface of ISO/IEC 8802-3:1996
- The MAC-frame format and MAC/LLC interface of ISO/IEC 8802-5:1995

The MAC Control sublayer provides an optional additional service for controlling MAC operation while in the ISO/IEC 8802-3 compatibility mode. It may be used to provide flow control between peer MAC client entities across the underlying channel. MAC Control is not defined for the ISO/IEC 8802-5 compatibility mode.

The MAC will also support an Ethernet frame within the ISO/IEC 8802-3 compatible MAC-frame format, where a type field is used in place of the length field. MAC Control frames are treated as Ethernet frames and are distinguished by their Length/Type field identifier.

The functions intended for the ISO Physical Layer are encompassed by the PMI and PMD sublayers. The MII is defined as a logical interface between the PMI and the PMD. An optional physical definition of the MII allows the interchange of PMDs supporting different physical links.

The MDI is usually a fully specified, physically exposed connection between the PMD and the link medium. However, in some cases, a MAC is embedded in another device without an exposed MDI. For instance, a MAC supporting network management protocols in a repeater might not have an exposed MDI. In that case, the Physical Layer functions are logically, but not physically, present.

6.7.3 MAC functions

Replace this subclause with the following:

The MAC accepts transmit requests and provides receive indications for packet traffic between the end node and the repeater or between the end node and a direct-connect end node.

- a) A basic MAC controls frame format composition and decomposition, checks for transmission errors in received frames, and initiates control requests to the PMI.
- b) A DCMAC performs all the functions of a basic MAC and also provides single-port network control similar to an RMAC when it is the controlling entity in a directly connected link between two end nodes.

The MAC service specifications, formats, and protocol are defined in clauses 7, 10, and 11, respectively.

6.8 Items for future study

Delete this subclause.

7. Medium Access Control (MAC) service definitions

7.1 Scope

Replace this subclause with the following:

This clause specifies the services provided by the MAC sublayer to the local LLC sublayer and the optional MAC Control sublayer in an end node, to the internal relay entity in a bridge, and to the repeater's local LME entity (see figure 7-1). MAC services to the LLC are defined in ISO/IEC 15802-1:1995. MAC services to the optional MAC Control sublayer are defined in IEEE Std 802.3x-1997. MAC services to a bridge are defined in ISO/IEC DIS 15802-3. The MAC interfaces to an LLC are described in 7.3; the MAC interfaces to a bridge are described in 7.4. The MAC services to the optional MAC Control sublayer are described in 7.5. These descriptions indicate MAC operation; no particular implementation of the MAC sublayer is implied.

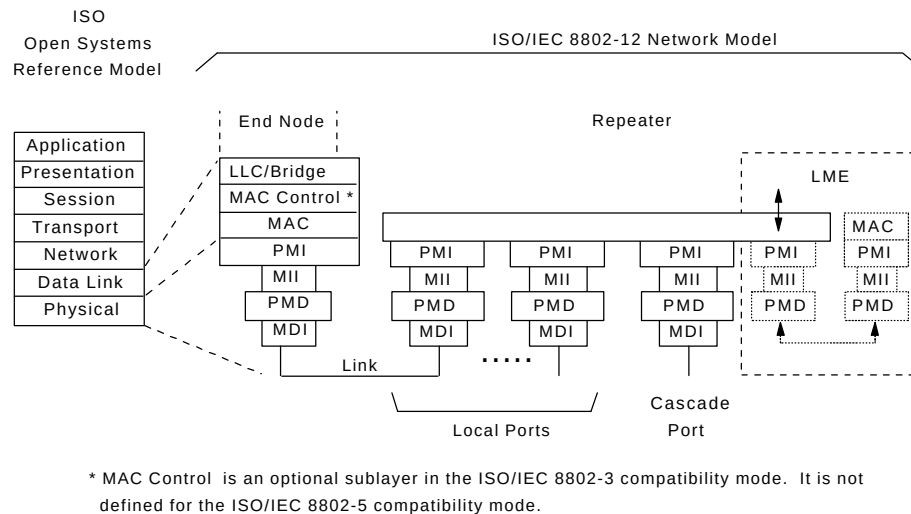


Figure 7-1—Relationship to the LAN model

7.4 MAC services to a bridge

Replace this subclause with the following:

Two service primitives are defined for the bridge interface:

- a) M_UNITDATA.request
- b) M_UNITDATA.indication

The formats for M_UNITDATA.indications and M_UNITDATA.requests are the same as the formats for MA_UNITDATA.indications and MA_UNITDATA.requests, except for the addition of an optional parameter for the FCS and two parameters that indicate the frame_type and the requested mac_action. The FCS parameter may be used to preserve the FCS value when bridging between LANs using like formats. The frame_type and mac_action parameters are not explicitly encoded in the MAC frames, but are included as constants in bridging service requests and indications as specified in ISO/IEC DIS 15802-3, subclause 2.5.6.

Add a new subclause 7.5, including 7.5.1 and 7.5.2, after 7.4 as follows:

7.5 MAC service to the MAC Control entity

This subclause defines the MAC Control sublayer interface for the ISO/IEC 8802-3 compatibility mode. The MAC Control sublayer is not defined for the ISO/IEC 8802-5 compatibility mode. Two primitives are defined for the MAC Control interface:

- a) MA_CONTROL.request
- b) MA_CONTROL.indication

The MA_CONTROL.request and MA_CONTROL.indication primitives are completely specified in subclauses 2.3.3 and 2.3.4 of IEEE Std 802.3x-1997. Abbreviated descriptions of these two primitives are included here for information only.

7.5.1 MA_CONTROL.request

This primitive defines the transfer of control requests from the MAC client to the MAC Control sublayer. Implementation of the MA_CONTROL.request primitive is mandatory if the optional MAC Control sublayer is implemented.

```
MA_CONTROL.request ( destination_address,  
                    opcode,  
                    request_operand_list )
```

The destination_address parameter may specify either an individual or group MAC entity address. It must contain sufficient information to create the DA field that is prepended to the frame by the local MAC sublayer entity. The opcode specifies the control operation requested by the MAC client entity. The request_operand_list is an opcode-specific set of parameters.

7.5.2 MA_CONTROL.indication

This primitive defines the transfer of control status indications from the MAC Control sublayer to the MAC client. Implementation of the MA_CONTROL.indication primitive is mandatory if the optional MA Control sublayer is implemented.

```
MA_CONTROL.indication ( opcode,  
                      indication_operand_list )
```

The indication_operand_list is an opcode-specific set of parameters.

10. Medium Access Control (MAC) frame format structure

10.2 Elements of the ISO/IEC 8802-12 MAC frame format—ISO/IEC 8802-3 compatibility mode

Revise the title of 10.2 as shown above and replace figure 10-3 with the following:

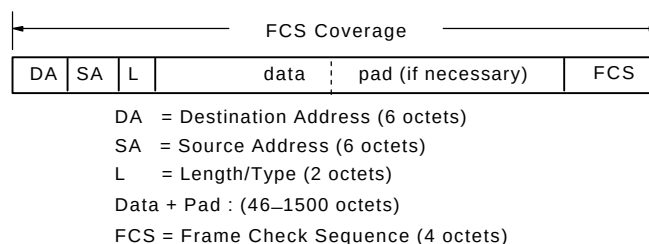


Figure 10-3—ISO/IEC 8802-3 MAC frame format

10.2.2 Length/Type (L) field

Revise the title of 10.2.2 as shown above and replace the text in this subclause with the following:

The L field is a two-octet field that takes one of two meanings, depending on its numeric value. For numerical evaluation, the first octet is the most significant octet of this field. If the value of this field is:

- Less than or equal to maxDataFieldLength, it indicates the number of LLC data octets in the data field.

- b) Equal to or greater than minTypeFieldLength, it indicates the nature of the MAC client protocol (Type interpretation).¹⁷
- c) Equal to macControlLengthValue, it indicates that this frame is a MAC Control frame.

Length and Type interpretations of this field are mutually exclusive. When this field is used as a Type field, it is the responsibility of the MAC client to ensure that the total data plus pad field length fall within the limits of 10.2.3. Values for maxDataFieldLength, minTypeFieldLength, and macControlLengthValue are defined in 11.5.3.

10.6 Elements of the ISO/IEC 8802-12 training frame

Revise the title of 10.6 as shown above and replace this entire subclause, including subclauses 10.6.1 through 10.6.3.8 with the following:

Training frames are special MAC frames that are used only during link initialization. Training frames are initially constructed by the training initiator at the lower end of a link (the MAC or DCMAC in an end node or the RMAC cascade port in a repeater). Training frames shall be forwarded to all network repeaters. The ISO/IEC 8802-12 training frame format is shown in figure 10-14.

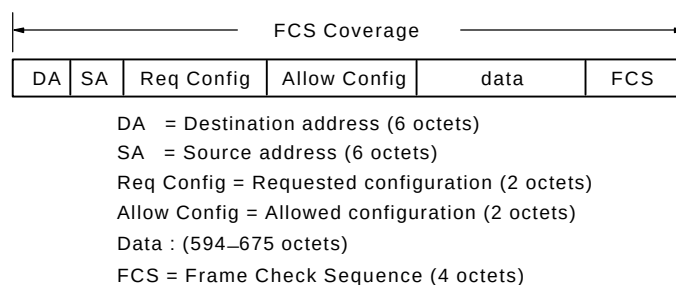


Figure 10-14—ISO/IEC 8802-12 training frame format

10.6.1 Address fields

Each frame contains two address fields: the Destination Address and the Source Address, in that order. The format of the address fields is shown in figure 10-15. Each address field shall contain 48 bits.

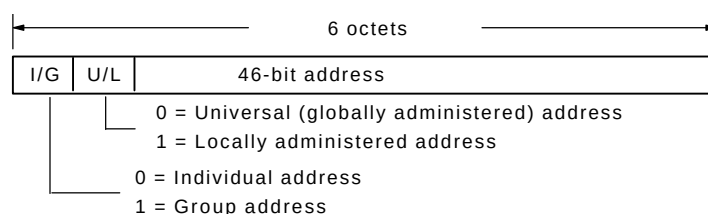


Figure 10-15—ISO/IEC 8802-12 training frame address field format

¹⁷ Type field assignments are administered by the Registration Authority, IEEE Standards Department, P.O. Box 1331, 445 Hoes Lane, Piscataway, NJ 08855-1331, USA, tel (732) 562-3813; fax (732) 562-1571. URL: <http://standards.ieee.org/>

10.6.1.1 Destination address

Because training is a procedure that directly involves only the training initiator at the lower end of the link and the training responder at the upper end of the link, the destination address shall be the null address.

10.6.1.2 Source address

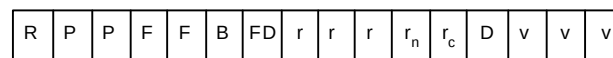
Part of the link initialization process is to establish the network address of the training initiator as follows:

- a) If the training initiator is an end node, the Source Address shall be the individual address of the end node unless a non-null individual address has not yet been assigned to the end node. In the latter case, the link may be tested by training with the null address. The end node shall not be allowed to join the network until a non-null address is assigned.
- b) If the training initiator is a repeater, the Source Address shall normally be the null address. If the repeater contains an integrated LME with an assigned non-null individual address, the repeater may train with that address.

An end node may train with a null address to verify link operability, but training will not be successfully complete until the end node has trained with an assigned individual address.

10.6.2 Requested-configuration field format

The requested-configuration field allows the training initiator to inform the training responder about itself and to request a port configuration. Figure 10-16 shows the requested-configuration field format. The training-response packet from the training responder shall contain the training initiator's requested configuration.



- R = repeater bit
 PP = promiscuous bits
 FF = format bits
 B = burst-mode bit
 FD = full-duplex bit
 rrr = reserved bits (set to 000)
 r_n = access-not-allowed bit (used in allowed-configuration field, set to 0)
 r_c = configuration bit (used in allowed-configuration field, set to 0)
 D = duplicate (redundant) uplink bit
 vvv = version bits

Figure 10-16—ISO/IEC 8802-12 training frame requested-configuration field format

10.6.2.1 Repeater (R) bit

The R bit allows the training initiator to inform the training responder whether it is a repeater or an end node. An end node may be any MAC-based device such as a user station, a bridge, or a LAN analyzer.

- R = 0, the training initiator is an end node.
 R = 1, the training initiator is a repeater.

If the training initiator is a direct-connect end node, the R bit shall be set to zero, regardless of the desired training mode (see 11.9).

10.6.2.2 Promiscuous (PP) bits

The PP bits allow the training initiator to request the class of unicast addressed packets it wishes to receive:

- a) PP = 00, receive only unicast packets specifically addressed to this end node.
- b) PP = 01, reserved for future standardization.
- c) PP = 10, receive all packets forwarded by the local training responder (promiscuous mode).
- d) PP = 11, reserved for future standardization.

Repeaters, bridges, and network analyzers shall always request that all packets be forwarded by the local repeater (promiscuous mode). Group-addressed packets shall be forwarded to all active ports regardless of the PP configuration.

10.6.2.3 Format (FF) bits

The FF bits allow the training initiator to request the operational format it wishes to use.

- a) FF = 00, ISO/IEC 8802-3 format is requested.
- b) FF = 01, reserved for future standardization.
- c) FF = 10, ISO/IEC 8802-5 format is requested.
- d) FF = 11, either ISO/IEC 8802-3 or ISO/IEC 8802-5 format is acceptable.

10.6.2.4 Burst-mode (B) bit

The B bit indicates the requested transmission mode for the training initiator:

- a) B = 0, normal (single packet) transmission is requested.
- b) B = 1, burst-mode (multiple packet) transmission is requested.

The B bit is reserved for end-node training when the end node is connected to a repeater local port. If the training initiator is a direct-connect end node and the FD bit is one, or if the training initiator is a repeater, this bit shall be set to zero.

10.6.2.5 Full-duplex (FD) bit

The FD bit indicates the requested operational mode of the training initiator:

- a) FD = 0, full-duplex operation is not requested.
- b) FD = 1, full-duplex operation is requested.

The FD bit is reserved for use in training direct-connect end nodes to operate in full-duplex mode. If the training initiator does not support full-duplex operation, this bit shall be set to zero.

10.6.2.6 Reserved (r) bits

The r bits are reserved for future standardization. All r bits, including r_n and r_c , shall be transmitted as zero and ignored by the receiver.

10.6.2.7 Duplicate uplink (D) bit

The duplicate uplink bit indicates whether or not a lower entity is training this link as the secondary link.

- a) D = 0, the link is being trained as the primary link.
- b) D = 1, the link is being trained as the secondary link.

The D bit is used by the training initiator to request the higher-level entity to disable duplicate-address checking for that local port. A D bit value of one in the requested-configuration field of the training request frame shall cause a repeater with local-port-redundant-link capability to ignore the MAC address attribute of this port when performing duplicate-address checks. A D bit value of one shall also cause a repeater with local-port-redundant-link capability to generate a value of zero for the D bit in the allowed-configuration field of the training-response frame, regardless of the value of the network management aCentralMgmtDetectedDupAddr attribute. The D bit is informational for network management.

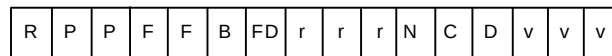
10.6.2.8 Version (vvv) bits

The vvv bits identify the version of the ISO/IEC 8802-12 MAC/RMAC training protocol with which the training initiator is compliant. The current version shall be numbered 001.

10.6.3 Allowed-configuration field format

The allowed-configuration field allows the training responder to indicate the configuration that will be allowed. Figure 10-17 shows the allowed-configuration field format. The training initiator (the lower entity) shall set the contents of the allowed-configuration field to zero. If the training responder is:

- a) A DCMAC, it shall set the bits of the allowed-configuration field as defined in 11.4.2.3.2.
- b) An RMAC, it shall set the bits of the allowed-configuration field as defined in 12.9.8.



R = repeater bit	r = reserved bit (set to 0)
PP = promiscuous bits	N = access-not-allowed bit
FF = format bits	C = configuration bit
B = burst-mode bit	D = duplicate-address bit
FD = full-duplex bit	vvv = version bits

Figure 10-17—ISO/IEC 8802-12 training frame allowed-configuration field format

10.6.3.1 Repeater (R) bit

Replace the text in this subclause with the following:

The R bit allows the training responder to indicate how the training initiator will be treated.

- a) R = 0, requested access as an end node is allowed.
- b) R = 1, requested access as a repeater is allowed.

10.6.3.2 Promiscuous (PP) bits

Replace the text in this subclause with the following:

The PP bits provide a means for the training responder to indicate the class of unicast addressed packets the training initiator will receive.

- a) PP = 00, the training initiator will receive only unicast packets specifically addressed to it.
- b) PP = 01, reserved for future standardization.
- c) PP = 10, the training initiator will receive all packets forwarded by the local repeater.
- d) PP = 11, reserved for future standardization.

10.6.3.3 Format (FF) bits

Replace the text in this subclause with the following:

The FF bits allow the training responder to indicate the operational format that is allowed.

- a) FF = 00, ISO/IEC 8802-3 format will be used.
- b) FF = 01, reserved for future standardization.
- c) FF = 10, ISO/IEC 8802-5 format will be used.
- d) FF = 11, reserved for future standardization.

10.6.3.4 Burst-mode (B) bit

The B bit indicates the transmission mode that will be allowed. If the training initiator is an end node, and:

- a) B = 0, burst-mode transmission will not be allowed.
- b) B = 1, burst-mode transmission will be allowed.

If the training initiator is a repeater, or if the training responder is a direct-connect end node, this bit shall be set to zero.

10.6.3.5 Full-duplex (FD) bit

The FD bit indicates the allowed operational mode that will be allowed.

- a) FD = 0, Full-duplex operation is not allowed.
- b) FD = 1, Full-duplex operation is allowed.

10.6.3.6 Reserved (r) bits

The r bits are reserved for future standardization and shall be set to zero.

10.6.3.7 Access-not-allowed (N) bit

The access-not-allowed bit is provided for private use to allow the training responder to indicate that the training initiator will be denied access to the network for reasons other than configuration (e.g., because of security restrictions).

- a) N = 0, access will be allowed if the configuration is compatible with the network.
- b) N = 1, access will not be allowed (even if the configuration is compatible).

Use of the N bit is optional. If the N bit is not used, it shall be set to zero.

10.6.3.8 Configuration (C) bit

The configuration bit indicates whether or not the requested basic configuration is compatible with the network.

- a) C = 0, the basic configuration is compatible with the network.

- b) $C = 1$, the basic configuration is not compatible with the network.¹⁸ In this case, the FF, PP, and R bits shall indicate the basic configuration that would be allowed (providing $N = 0$).

10.6.3.9 Duplicate address (D) bit

The duplicate address bit indicates whether or not a duplicate address has been detected in the repeater's port address list or if network management has set the aCentralMgmtDetectedDupAddr attribute to true. A duplicate address will also be detected in a direct-connect end node training in RMode if both entities have the same assigned address.

- a) $D = 0$, no duplicate address has been detected.
b) $D = 1$, a duplicate address has been detected.

If both links are connected to local ports on the same higher-level repeater and that repeater is not equipped with local-port-redundant-link training capability, the D bit in the requested-configuration field will be ignored and a duplicate address may be detected. In this case, it will be necessary for the training initiator to train at least one link with the null address.

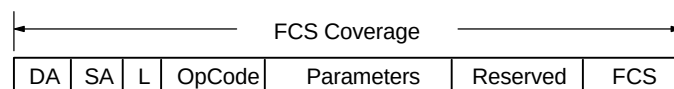
10.6.3.10 Version (vvv) Bits

The vvv bits identify the version of the ISO/IEC 8802-12 MAC/RMAC training protocol with which the training responder is compliant. The current version shall be numbered 001.

10.8 MAC Control frame format

Add new subclauses 10.8 through 10.8.7 at the end of clause 10 as follows:

The MAC Control frame format is required only if the optional MAC Control entity is implemented. This subclause defines the ISO/IEC 8802-12 MAC Control frame format and identifies the fields required for the ISO/IEC 8802-3 compatibility mode (see figure 10-17.1). Field descriptions are specified by IEEE Std 802.3x-1997 and are included here for information only. All fields are fixed size, except for the parameters and reserved fields, which can contain any integral number of octets between the minimum and maximum defined values. MAC Control is not defined for ISO/IEC 8802-5 compatibility mode.



DA = Destination Address (6 octets)
SA = Source Address (6 octets)
L = Length/Type (2 octets)
OpCode = MAC Control OpCode (2 octets)
Parameters = OpCode Parameters (0–44 octets)
Reserved = fill (transmitted as zeros), where
Parameters length + Reserved length = 44 octets
FCS = Frame Check Sequence (4 octets)

Figure 10-17.1—MAC Control frame format

¹⁸ An incompatible basic configuration may be caused by a mismatch between the requested and allowed R, PP, FF, or vvv fields, or by a duplicate or null address in an end node. The B, Fd, and D bits in the requested-configuration field represent optional capabilities that are not considered when determining the value of the C bit in the allowed-configuration field.

10.8.1 Destination address (DA) field

The destination address field of a MAC Control frame contains the 48-bit address of the station(s) for which the frame is intended. It may be an individual or multicast (including broadcast) address. Permitted values for the destination address field may be specified separately for each MAC Control opcode defined in the annexes to clause 31 of IEEE Std 802.3x-1997.

10.8.2 Source address (SA) field

The source address field of a MAC Control frame contains the 48-bit individual address of the station sending the frame.

10.8.3 Length/Type (L) field

The length/type field of a MAC Control frame is a 2-octet field which contains the value `macControlLengthValue`. This value carries the type interpretation (see 10.2.2), and has been universally assigned for MAC Control of ISO/IEC 8802-3 compatible LANs.

10.8.4 MAC Control opcode field

The MAC Control opcode field contains a 2-octet operation code indicating the MAC Control function. It defines the semantics of the MAC Control parameters field specified in 31.4.1.5 of IEEE Std 802.3x-1997. Annex 31A of that standard contains the list of defined MAC Control opcodes and interpretations.

A MAC Control frame contains exactly one MAC Control opcode.

10.8.5 MAC Control parameters field

The MAC Control parameters field contains the MAC Control opcode-specific parameters. This field may contain none, one, or more parameters as defined in the normative annex that defines the particular MAC Control function (see IEEE Std 802.3x-1997, annex 31A and indicated normative annexes).

The MAC Control parameters field contains an integral numbers of octets. The length of the parameters field varies from a minimum of 0 to a maximum of `parameterAndReservedLength` octets (see 11.5.3).

10.8.6 Reserved field

The reserved field is used when the MAC Control parameters do not fill the fixed length MAC Control frame. The size of the reserved field is determined by the size of the MAC Control parameters field supplied for the particular MAC control.

The reserved field length for a parameters field of n octets is $(\text{parameterAndReservedLength} - n)$. The reserved field is transmitted as all zeros.

10.8.7 MAC Control frame FCS field

A CRC procedure is used to generate a CRC value for insertion into the FCS field prior to transmission. The CRC value is computed as a function of the DA, SA, L, Opcode, Parameters, and Reserved fields. The encoding is defined by the generating polynomial:

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

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

- a) The first 32 bits of the frame are complemented.
- b) 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 DA field corresponds to the $x^{(n-1)}$ term and the last bit of the data field corresponds to the x^0 term.]
- c) $M(x)$ is multiplied by x^{32} and divided by $G(x)$, producing a remainder $R(x)$ of degree ≤ 31 .
- d) The coefficients of $R(x)$ are considered to be a 32-bit sequence.
- e) The bit sequence is complemented and the result is the CRC (see [B5]).

The 32 bits of the CRC value are placed in the FCS field such that the x^{31} term is the leftmost bit of the first octet, and the x^0 term is the rightmost bit of the last octet, as shown in figure 10-5. The FCS shall be transferred commencing with the coefficient of the x^{31} term and proceeding in sequence to the coefficient of the x^0 term.

11. Medium Access Control (MAC) protocol

Replace the entire contents of this clause with the following:

11.1 Scope

The MAC is the primary control layer in an end node. This clause describes the data functions and control operations of the MAC sublayer (see figure 11-1). The descriptions are provided as state diagrams, supplemented by prose annotations, with state definitions in pseudo code. All are normative. Should differences be perceived in interpretation, pseudo code definitions shall take precedence. No particular physical implementation is implied.

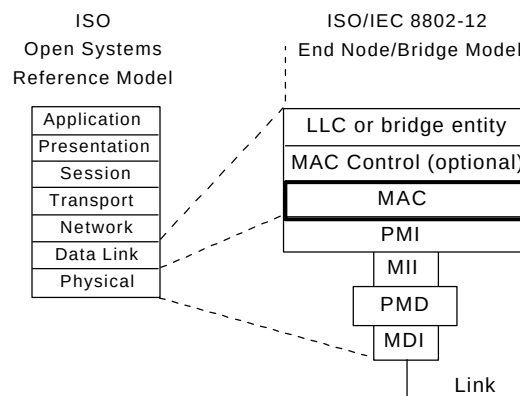


Figure 11-1—Relationship to the LAN model

An end node shall be equipped with a basic MAC and may be equipped with one or more of the following optional capabilities:

- a) A second MAC and a second (redundant) link to maintain network connectivity in case of link or repeater failure.
- b) Burst-mode capability to allow transmission of one or more packets each time it is granted permission to send.

- c) Direct-connect capability to allow direct communication with another end node in either half- or full-duplex mode. A MAC equipped with direct-connect capability is a DCMAC.
- d) A MAC Control entity to allow the peer-to-peer exchange of MAC Control requests.

Recommendations for connecting redundant-link end nodes in an ISO/IEC 8802-12 network are given in E.5. The definition of redundant links for end nodes and the manner in which reception of duplicate packets is resolved if both links are simultaneously active are implementation issues and are beyond the scope of this standard.

The MAC Control entity is defined in clause 31 of IEEE Std 802.3x-1997.

11.2 Overview of the MAC operations

11.2.1 MAC services to upper sublayers

The MAC sublayer provides end-node access control to the link medium for data transmission and reception and for control signal exchange with the repeater's RMAC or with a direct-connect end node's DCMAC.

11.2.1.1 MA_UNITDATA.request and MA_UNITDATA.indication primitives

The MAC accepts MA_UNITDATA.request (DA, SA, Routing Information, msdu, priority) primitives from the LLC, and constructs an appropriate MAC frame for transmission in either ISO/IEC 8802-3 or ISO/IEC 8802-5 format.

- a) The MAC adds its own address as the source address if the source address is not provided by the LLC.
- b) The MAC computes a CRC value and inserts it into the FCS field.
- c) If the MAC is a basic MAC or a DCMAC operating in EMode (end-node mode), it:
 - 1) Issues a PMI_CONTROL.request (Request_Normal or Request_High), based on the priority level indicated by the LLC.
 - 2) Issues a PMI_UNITDATA.request to initiate packet transmission after a Grant (to send) has been received from the controlling entity (repeater or DCMAC in RMode).
- d) If the MAC is a DCMAC operating in RMode (half-duplex repeater mode), autonomous process 5 monitors MA_UNITDATA.requests from the LLC and compares them with requests from the other entity. When this process indicates that an MA_UNITDATA.request from the LLC is to be honored, the MAC issues a PMI_CONTROL.request for a short burst of Incoming to alert the other entity to prepare to receive a packet, and then issues a PMI_UNITDATA.request to initiate packet transmission.
- e) If the MAC is a DCMAC operating in full-duplex mode, MA_UNITDATA.requests from the LLC are honored immediately or as soon as any current transmission is complete. The MAC issues a PMI_CONTROL.request for a short burst of Incoming to alert the other entity to prepare to receive a packet, and then issues a PMI_UNITDATA.request to initiate packet transmission.

The MAC also reacts to control signals from a repeater or a DCMAC (in either RMode or full-duplex mode) indicating a possible incoming packet by requesting the physical sublayers to switch to the receive mode. When data packets are received, the MAC verifies the destination address, performs an FCS check on the received frame, and checks whether any other transmission errors have been detected, or if an IPM has been received. If all error checks are negative in an end node, the MAC frame is converted back to

LLC frame format and an MA_UNITDATA.indication (DA, SA, Routing Information, msdu, priority)²⁰ is made to the LLC.

11.2.1.2 MA_CONTROL.request and MA_CONTROL.indication primitives

If the MAC is configured for the ISO/IEC 8802-3 compatibility mode and the optional MAC Control sublayer is implemented, the MAC will accept an MA_CONTROL.request (DA, op_code, request_operand_list) from the MAC Control sublayer, construct a MAC Control frame, and then transmit the MAC Control frame in the same manner as a high-priority data frame from the LLC (11.2.1.1).

On receipt of a MAC Control frame (distinguished from an LLC MAC frame by the value of the length/type field), the MAC verifies the destination address, performs an FCS check on the received frame, and checks whether any other transmission errors have been detected, or if an IPM has been received. If all error checks are negative, the MAC frame is converted to MAC Control frame format and an MA_CONTROL.indication (opcode, indication_operand_list) is made to the MAC Control sublayer. MAC Control frames are not passed to the LLC sublayer.

Currently, the only use for MA_CONTROL.request and MA_CONTROL.indication primitives is for the PAUSE opcode (which is only defined for full-duplex operation).

11.2.1.3 M_UNITDATA.request and M_UNITDATA.indication primitives

If the MAC is connected to a bridge, the MAC will accept an M_UNITDATA.request (frame_type, mac_action, DA, SA, Routing Information, msdu, user_priority, FCS), and will construct an appropriate MAC frame for transmission in either ISO/IEC 8802-3 or ISO/IEC 8802-5 format. It then:

- a) Computes a CRC value (if needed) and inserts it into the FCS field.²¹
- b) Initiates packet transmission, based on the priority level indicated by the user_priority parameter, in the same manner as for an MA_UNITDATA.request from the LLC (11.2.1.1).

When data packets are received, the MAC verifies the destination address, performs an FCS check on the received frame, and checks whether any other transmission errors have been detected, or if an IPM has been received. If all error checks are negative, the MAC makes an M_UNITDATA.indication (frame_type, mac_action, DA, SA, Routing Information, msdu, user_priority, FCS)²² to the bridge entity.

The definition of the MAC sublayer in the remainder of this clause is based on service to an LLC sublayer. If the upper sublayer is a bridge entity, the MA_UNITDATA.request and MA_UNITDATA.indication primitives shall be replaced by the appropriate M_UNITDATA.request or M_UNITDATA.indication primitives (with additional parameters as indicated in 7.4) in the following subclauses:

- a) 11.3.1.1 [autonomous process 1: Wait for transmission request].
- b) 11.5.7.1 [FUNCTION Build_Frame].
- c) 11.5.6.6 [PROCEDURE Process_Received_MAC_Frame].

²⁰ The Routing Information field in an MA_UNITDATA.indication is only applicable to the ISO/IEC 8802-5 format (see 7.3, figures 7-2 and 7-3).

²¹ When bridging between like formats, the FCS value may be included with the received frame. An indicator is provided within the parameter space of the FCS parameter to indicate the presence or absence of an FCS value.

²² The frame_type and mac_action parameters are encoded as constants. The Routing Information field in an M_UNITDATA.indication is only applicable to the ISO/IEC 8802-5 format (see 7.4).

11.2.2 Link control

Arbitration and control of data traffic are accomplished through peer level exchange of control request and indication primitives between the MAC sublayer in the end node and the RMAC sublayer in the repeater as shown in figure 11-2:

- Outgoing control requests are specified in the transmit_control_state parameter value of the PMI_CONTROL.request primitives generated by the MAC.
- Incoming control signals are indicated in the receiver_control_state and grant_state parameters of the PMI_CONTROL.indication primitives generated by the PMI.

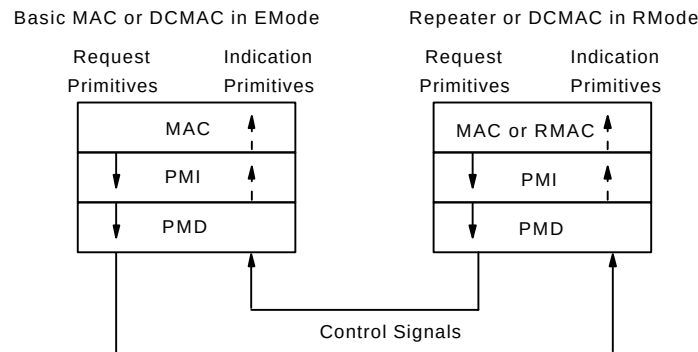


Figure 11-2—Link control

11.2.2.1 Control state definitions

The transmit control states provide a means for the MAC to request, via the PMI, a particular control action to be taken (or control signal to be sent) by the PMD sublayer. The grant state and receiver control states provide a means for the PMD to indicate that a link condition or control signal has been received. The grant state indicates when packet transmission may proceed.

11.2.2.2 Transmit control states

A new TCS may be requested by the MAC while the outgoing frame is being transferred to the PMI, but the equivalent control signals will not be sent by the PMD until after packet transmission is fully complete. The TCS definitions are as follows:

Grant: This state is used by DCMACs operating in RMode to indicate that the other entity is being granted permission to send a packet.

Idle_Down: This state is used by DCMACs operating in either RMode or full-duplex mode to indicate that this DCMAC is in the idle state and does not need to send a packet.

Idle_Up: This state indicates that the end node is in the idle state and is not requesting to send a packet.

Request_High, Request_Normal: These states are used by the end node to inform the repeater or the other entity's DCMAC that it wishes to send a packet:

- Request_High indicates that a high-priority packet needs to be sent.
- Request_Normal indicates that a normal-priority packet needs to be sent.

Training_Down: This state indicates that the DCMAC is either arbitrating or allowing training to continue in RMode.

Training_Up: This state indicates that link training is desired or is continuing.

TxDisable: This state allows the MAC to request that the PMD's transmitters be disabled.

11.2.2.3 Receiver control states

RCSs indicate either the current or previous RCS, depending on the grant state:

- a) If grant_state = 0, the RCS represented by the RCS code value indicates the current control state received at the MDI.
- b) If grant_state = 1, the RCS represented by the RCS code value indicates the control state received at the MDI prior to grant_state being decoded.

The RCS definitions are as follows:

Data_on_Link: This state is used by the PMD to indicate that data streams (rather than control signals) are being received from the link.

Enable_High_Only: An RCS that may be received by the end node during a burst-mode packet transmission sequence indicating that the repeater has high-priority requests pending. If the end node is equipped with burst-mode capability, this control state is ignored by the MAC. If it does not have burst-mode capability, Enable_High_Only is an invalid control state.

Grant: This state indicates that the end node has been granted permission to send one or more packets. If the granting entity is:

- a) A repeater and burst mode is not enabled, this end node may send only one packet.
- b) A repeater and burst mode is enabled, this end node may send one or more packets.
- c) A DCMAC operating in RMode, this end node may send only one packet.

Grant is a separate code used in conjunction with the RCS.

Idle_Down: This state indicates that the repeater or other end node (a DCMAC operating in RMode) currently has no packet that is destined for this end node.

Idle_Up: This state indicates that the other entity is in the idle state and is not requesting to send a packet.

Incoming: This state is used by the controlling entity (a repeater or DCMAC) to alert the end node that a packet may be incoming.

Link_Warning: This state is used by the PMD to indicate a condition that may require the link to be retrained.

Mode Transition: This state is used by the PMD to indicate that the signals on the link are in transition between data and control modes.

Request_High: An RCS that may be received by a DCMAC operating in RMode. Request_High indicates that the entity at the other end of a direct-connect link is requesting permission to send a high-

priority packet. If the end node is not equipped with DCMAC capability, Request_High is an invalid control state.

Request_Normal: An RCS that may be received by a DCMAC operating in RMode. Request_Normal indicates that the entity at the other end of a direct-connect link is requesting permission to send a normal-priority packet. If the end node is equipped with a basic MAC or is equipped with a DCMAC that is operating in EMode, Request_Normal is interpreted as Incoming.

Training_Down: This state indicates that training may proceed.

Training_Up: This state indicates that link training is desired or is continuing.

11.2.2.4 Grant state coding

A grant_state = 1 indicates that the end node may send one or more packets:

- a) If burst mode is not enabled, the end node may send one packet only.
- b) If burst mode is enabled, the end node may send one or more packets.

A grant_state = 0 indicates that a packet may not be sent.

11.2.3 Internal control

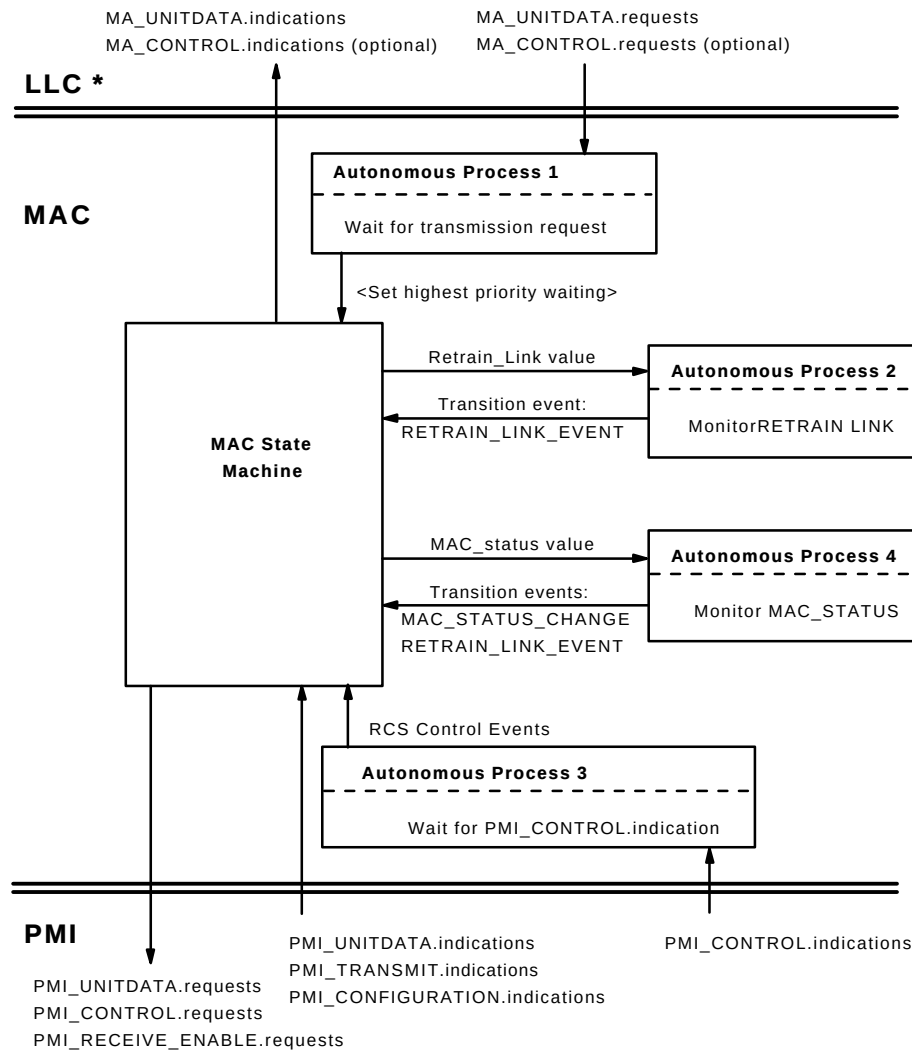
Control requests for, and indications of, actions that are internal to the end node are also defined by the following PMI primitives:

- a) PMI_TRANSMIT.indication allows the PMI to inform the MAC when packet transmission is complete²³ (see 8.6).
- b) PMI_RECEIVE_ENABLE.request defines when the physical sublayers are to switch to the data reception mode (see 8.8).

11.3 The MAC logical structure

The logical structure of the basic MAC consists of the MAC state machine and four autonomous processes as shown in figure 11-3. The MAC must support two logical interfaces: to the LLC (defined by the service primitives described in clause 7), and to the PMI (defined by the service primitives described in clause 8). It may also support an additional logical interface to the optional MAC Control sublayer (defined by the service primitives described in clause 7).

²³ Because start-of-stream and end-of-stream sequences are generated by the PMI rather than the MAC, the PMI_TRANSMIT.indication (transmit_complete) occurs a number of clock cycles after the transfer of octets from the MAC to the PMI is complete.



* The upper sublayer may be the optional MAC Control sublayer

Figure 11-3—Basic MAC logical structure

The logical structure of the DCMAC is an expansion of the logical structure of the basic MAC as shown in figure 11-4. It contains three additional logical elements and the additional data path shown in bold: an operational mode-arbitration state machine, a separate transmit (TX) state machine, and an additional autonomous process 5 to reconcile the frame waiting events from autonomous process 1, and the RCS control events from autonomous process 3. The additional data path from the MAC state machine to the TX state machine is used during RMode training as a return path for the training-response frame.

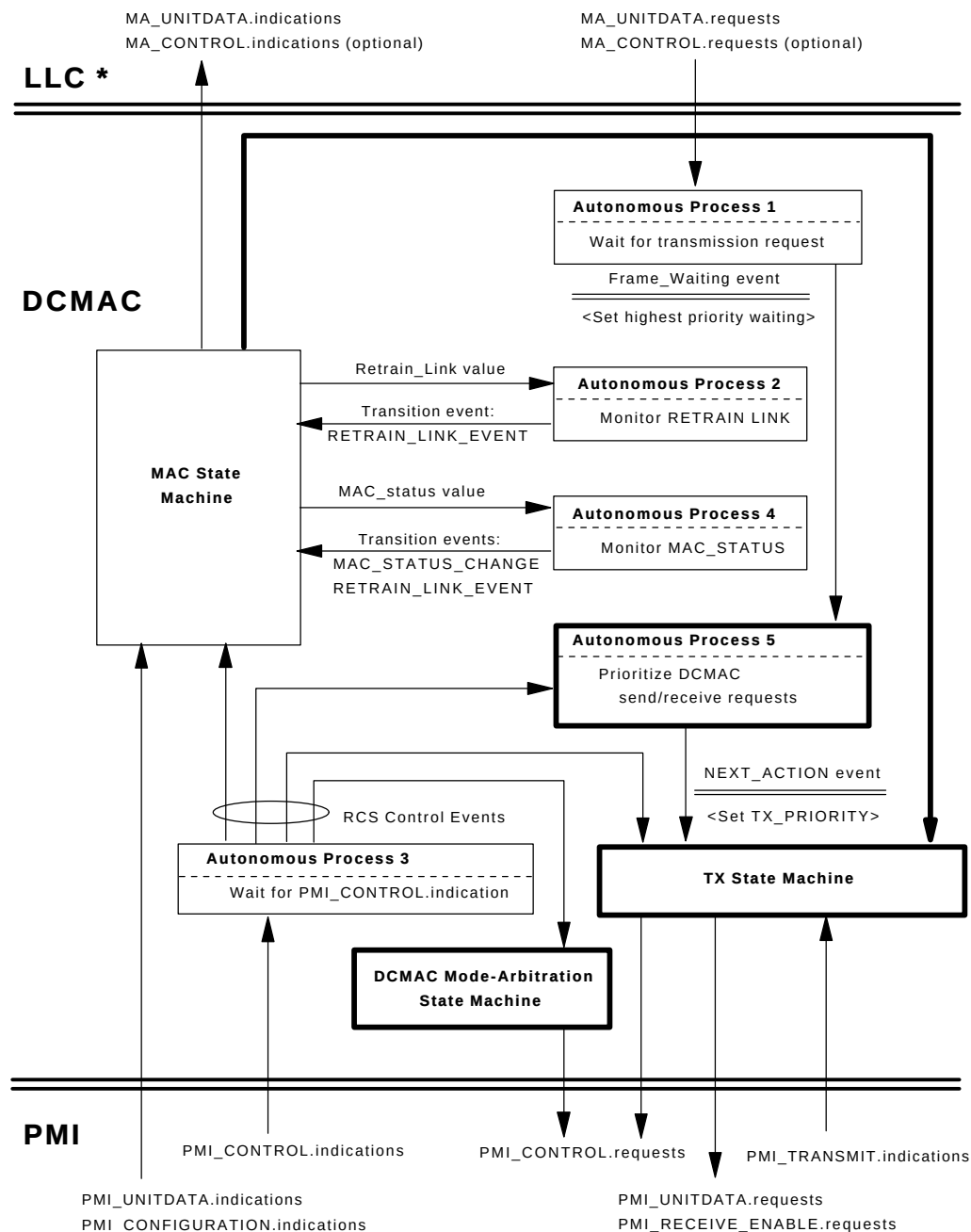


Figure 11-4—DCMAC logical structure

11.3.1 Autonomous processes

All autonomous processes shall generate the appropriate event on each cycle of the PMI transmit clock (TxClk).

This process waits for an MA_UNITDATA.request or an MA_CONTROL.request and updates the MAC state machine variable HIGHEST_PRIORITY_WAITING to indicate the priority of the highest priority packet that is waiting to be transmitted. The parameters of the MA_UNITDATA.request are used by the function Build_Frame to construct the outgoing frame.

- a) For ISO/IEC 8802-3 frames, the transmission priority shall be either “normal” or “high.” If no priority level is indicated in the MA_UNITDATA.request priority parameter, the default priority level should be “normal.”
- b) For ISO/IEC 8802-5 frames, the priority parameter range is 0 to 7. The default levels should be:
 - 1) Normal-priority for priority parameter values of 0 to 4.
 - 2) High-priority for priority parameter values of 5 to 7.

This process examines the variable RETRAIN_LINK and generates RETRAIN_LINK_EVENT whenever the variable RETRAIN_LINK is found to be true. RETRAIN_LINK_EVENT is a case variable used in MAC3_IDLE_OR_REQUEST.

- The MAC state machine in a basic MAC.
- The MAC state machine, the TX state machine, and the arbitration state machine in a DCMAC.

```

Begin
  If (BURST_MODE_ENABLED = True) Then
    receiver_control_state := RCS_IS_ENABLE_HIGH_ONLY;
  Else

```

```

        receiver_control_state := RCS_IS_ILLEGAL;
    End { Enable_High_Only }

```

Request_Normal : { **Request_Normal will be interpreted as Incoming by all MAC configurations except a DCMAC in RMode**}

```

    Begin
        If (DCMAC_MODE = RMode) Then
            receiver_control_state := RCS_IS_REQUEST_NORMAL;
        Else
            receiver_control_state := RCS_IS_INCOMING;
        End { Request_Normal }

```

Request_High : { **Request_High will be interpreted as Request_High by a DCMAC operating in RMode.**

Request_High will be interpreted as Enable_High_Only by basic

MACs

and DCMACs during active operation in EMode, only if BURST_MODE_ENABLED is true.

Request_High will be interpreted as invalid otherwise. }

```

    Begin
        If (DCMAC_MODE = RMode) Then
            receiver_control_state := RCS_IS_REQUEST_HIGH;
        Else
            If ( BURST_MODE_ENABLED = True) Then
                receiver_control_state := Enable_High_Only;
            Else
                receiver_control_state := RCS_IS_ILLEGAL;
            End { Request_High }

```

Training_Down : RCS_IS_TRAINING_DOWN; { **Training_Down is interpreted as Training_Up by DCMACs during RMode operation. }**

```

Training_Up   : RCS_IS_TRAINING_UP;
Data_on_Link  : {not used};
Link_Warning  : RCS_IS_LINK_WARNING;
default      : RCS_IS_ILLEGAL;

```

End {**Case**}

11.3.1.4 Autonomous process 4 : Monitor MAC_STATUS

This process examines the variable MAC_STATUS and the network management actions **acClose** and **acOpen**. This process:

- Generates an event MAC_STATUS_CHANGE whenever the variable MAC_STATUS is set to “closed” or whenever it changes from “closed” to some other value.
- Generates an event RETRAIN_LINK_EVENT whenever MAC_STATUS is set to “closed” by a network management **acClose** action—this will force the link to go to, and to remain in, the Retrain_Delay mode.
- Sets MAC_STATUS to “opening” whenever a network management **acOpen** action is received—this will allow the MAC to exit the Retrain_Delay mode.

11.3.1.5 Autonomous process 5: Prioritize DCMAC send/receive requests

This process is only active when MAC_STATUS is either “opening” or “opened” and the DCMAC is in either RMode or in full-duplex mode. It is not required in a basic MAC.

The process monitors the requested priorities of frame waiting events (MA_UNITDATA.request or MA_CONTROL.request) from autonomous process 1 (Wait for transmission request) and RCS control events from autonomous process 3 (Wait for PMI_CONTROL.indication) and maintains values for THIS_ENTITY_PRIORITY and OTHER_ENTITY_PRIORITY for both the LLC and the other entity to identify whether either needs to send a packet and to indicate the priority level being requested.

If the frame waiting event from autonomous process 1 is an MA_CONTROL.request, this process will set the variable NEXT_ACTION to SEND_FRAME and will pass the MA_CONTROL.request to the TX state machine for frame construction and transmission. Otherwise:

- a) If the DCMAC is in RMode, this process determines the order of packet transmissions from this node and from the other entity:
 - 1) If neither entity needs to send a packet (both priority values are “none”), this process will set the variable NEXT_ACTION to IDLE to indicate that the TX state machine should send Idle_Down.
 - 2) If only the other entity needs to send a packet (the priority values are “none” for the LLC and either “normal” or “high” for the other entity), this process will set NEXT_ACTION to RECEIVE_FRAME to indicate that the TX state machine should send Grant.
 - 3) If only this node needs to send a packet (the priority values are either “normal” or “high” for the LLC and “none” for the other entity), this process will set TX_PRIORITY to the value of HIGHEST_PRIORITY_WAITING and NEXT_ACTION to the value of SEND_FRAME. It will then pass the MA_UNITDATA.request to the TX state machine for frame construction and transmission.
 - 4) If both entities need to send a packet and:
 - i) The priority levels are different, this process will select the higher priority source, will set TX_PRIORITY to the selected priority, and will set NEXT_ACTION to either RECEIVE_FRAME or SEND_FRAME as required by the selection. If NEXT_ACTION is SEND_FRAME, it will also pass the MA_UNITDATA.request to the TX state machine for frame construction and transmission.
 - ii) The priority levels are the same, this process will alternate between setting NEXT_ACTION to RECEIVE_FRAME (indicating that the TX state machine should send Grant) and to SEND_FRAME (indicating that the TX state machine should send a frame).
- b) If the DCMAC is in full-duplex mode, data transmission and data reception operations can occur simultaneously. On receipt of a frame waiting event, this process will immediately set NEXT_ACTION to SEND_FRAME and will set TX_PRIORITY to the appropriate level, and will then pass the associated MA_UNITDATA.request to the TX state machine. Data reception is controlled by the MAC state machine.

This process may optionally include a packet promotion timer that raises the priority of either a normal-priority MA_UNITDATA.request from the LLC or PMI_CONTROL.request (Request_Normal) from the other entity that has been blocked because of an extended series of high-priority packets. The packet promotion timer, if implemented, should expire in 200–300 ms.

11.3.2 State machines

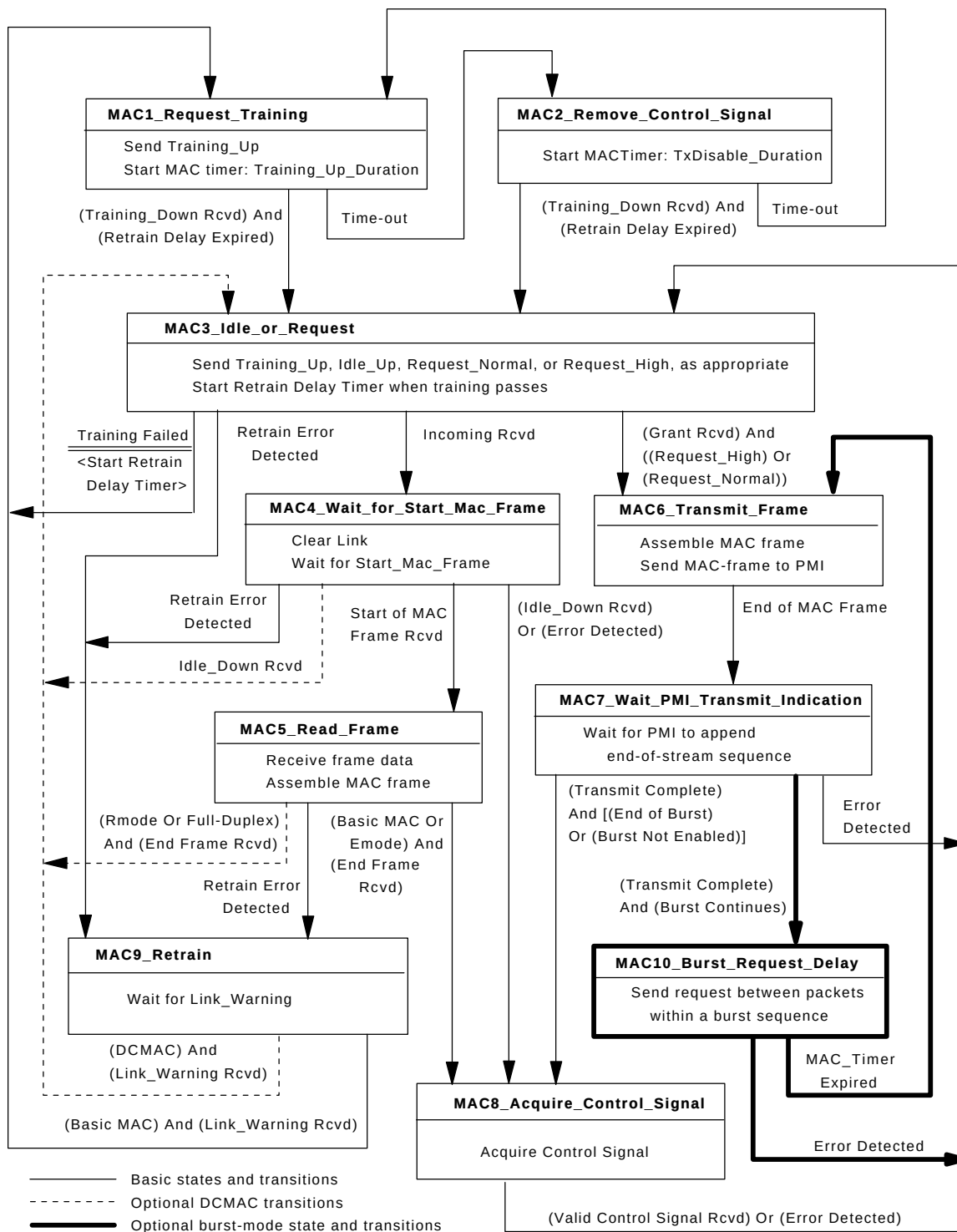
11.3.2.1 MAC state machine

The structure of the MAC state machine is shown in figure 11-5. It is used by both basic MACs and DCMACs. Entry to the MAC state machine after power on is controlled by the PROCEDURE goto_REQUEST_TRAINING in a basic MAC and by the PROCEDURE goto_ARBITRATION in a DCMAC. The MAC state machine is defined in 11.6.

- a) Training is initiated in States 1 and 2. The actual training process is accomplished in States 3 through 8.
- b) The active mode supports three activities (packet transmission, packet reception, and idle) and involves States 3 through 8 and 10:
 - 1) When the MAC receives a frame, it cycles through the state sequence:
 - i) MAC3_IDLE_OR_REQUEST
 - ii) MAC4_WAIT_FOR_START_MAC_FRAME
 - iii) MAC5_READ_FRAME
 - iv) MAC8_ACQUIRE_CONTROL_SIGNAL
 - 2) When the MAC sends a frame in single-packet transmission mode, it cycles through the state sequence:
 - i) MAC3_IDLE_OR_REQUEST
 - ii) MAC6_TRANSMIT_FRAME
 - iii) MAC7_WAIT_FOR_PMI_TRANSMIT_INDICATION
 - iv) MAC8_ACQUIRE_CONTROL_SIGNAL
 - 3) Burst-mode transmission requires an additional state, MAC10_BURST_DELAY. During burst-mode transmission, the MAC cycles through the sequence:
 - i) States MAC3, MAC6, MAC7, and MAC10 for the first frame.
 - ii) States MAC6, MAC7, and MAC10 for all intermediate frames
 - iii) States MAC 6, MAC 7, and MAC 8 for the last frame.
 - 4) When the MAC is idle, it remains in State 3.
- c) The Retrain_Delay mode is defined by State 9. This state is used when an error occurs.

The MAC state machine is only used for packet reception in a DCMAC operating in full-duplex mode or RMode. When the MAC receives a frame, it cycles through the state sequence:

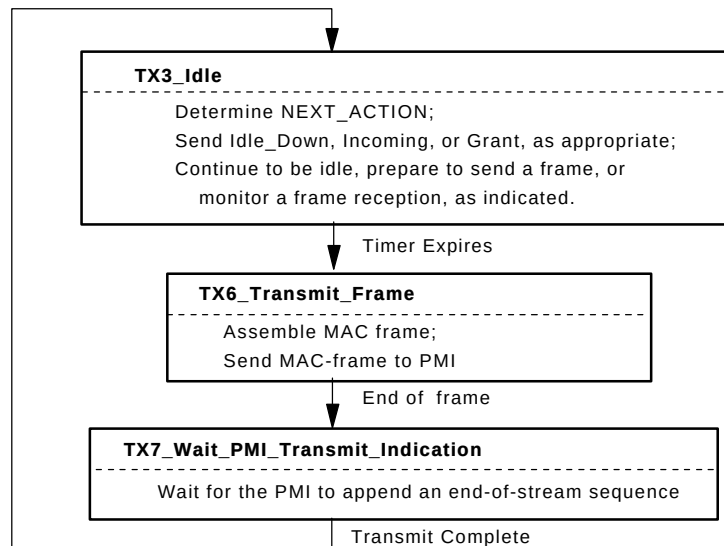
- a) MAC3_IDLE_OR_REQUEST
- b) MAC4_WAIT_FOR_START_MAC_FRAME
- c) MAC5_READ_FRAME

**Figure 11-5—The MAC state machine**

11.3.2.2 TX state machine

The DCMAC TX state machine is shown in figure 11-6. It is similar to the TX state machine in a repeater and is used when the DCMAC is either in RMode or in full-duplex mode. The TX state machine initiates

all transmit control states and controls all frame transmissions. Entry to the TX state machine after power on is controlled by the PROCEDURE `goto_ARBITRATION`. The TX state machine is defined in 11.8.



NOTE—The TX state machine is only active during operation in Rmode and full-duplex mode.

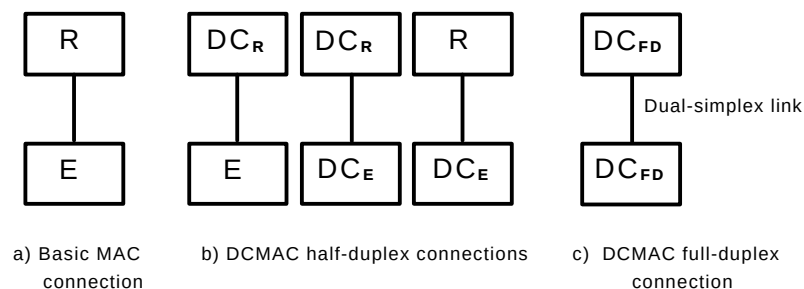
Figure 11-6—The TX state machine

11.3.2.3 DCMAC Mode-Arbitration state machine

The arbitration state machine is only used by the DCMAC, and only for negotiating whether training will be in RMode or EMode. The arbitration state machine is defined in 11.7.

11.4 MAC operational modes

End nodes may be connected in any of the five network configurations shown in figure 11-7, depending on the type of MAC that is installed in the node.



DC_{FD} = direct-connect end node with full-duplex operation
 DC_E = direct-connect end node with half-duplex Emode operation
 DC_R = direct-connect end node with half-duplex Rmode operation
 R = repeater (local port)
 E = basic end node

Figure 11-7 Allowable end-node network connections

At the conceptual level, a basic MAC can be viewed as being in any of the three meta-states shown in figure 11-8:

- a) Training—initializing the link in preparation to join the network.
- b) Active—able to communicate with peer entities elsewhere on the network.
- c) Retrain_Delay—not yet able to complete training and waiting to join the network.

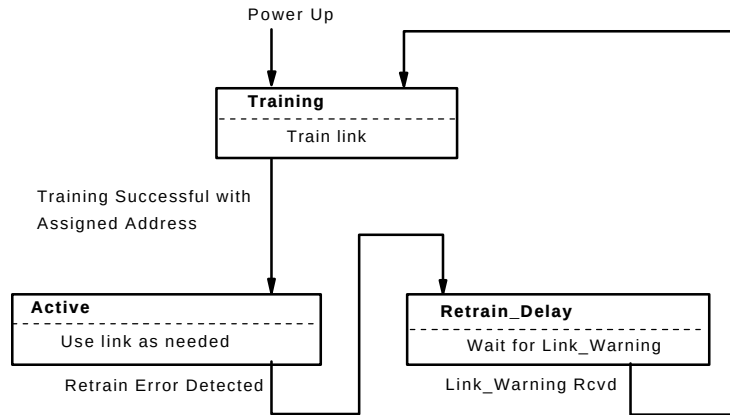


Figure 11-8—Basic MAC meta-state diagram

The DCMAC can support either full- or half-duplex packet transmission and reception, and can appear to the entity at the other end of the link either as a repeater (RMode) or as a basic MAC (EMode). Because of this, the DCMAC needs the additional arbitration meta-state shown in figure 11-9 to determine the type of device at the other end of the link and to negotiate the training mode that it will use.

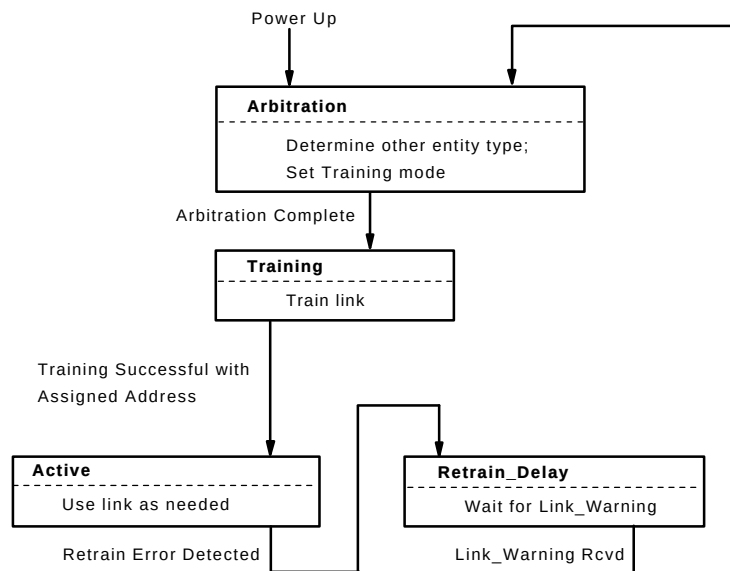


Figure 11-9—DCMAC meta-state diagram

11.4.1 DCMAC mode arbitration

The purpose of the mode-arbitration sequence is to agree upon a compatible mode-configuration pair. Arbitration is conducted by exchanging control signals between the two directly connected entities at each end of the link and requires only the logical elements and control paths shown in bold in figure 11-10.

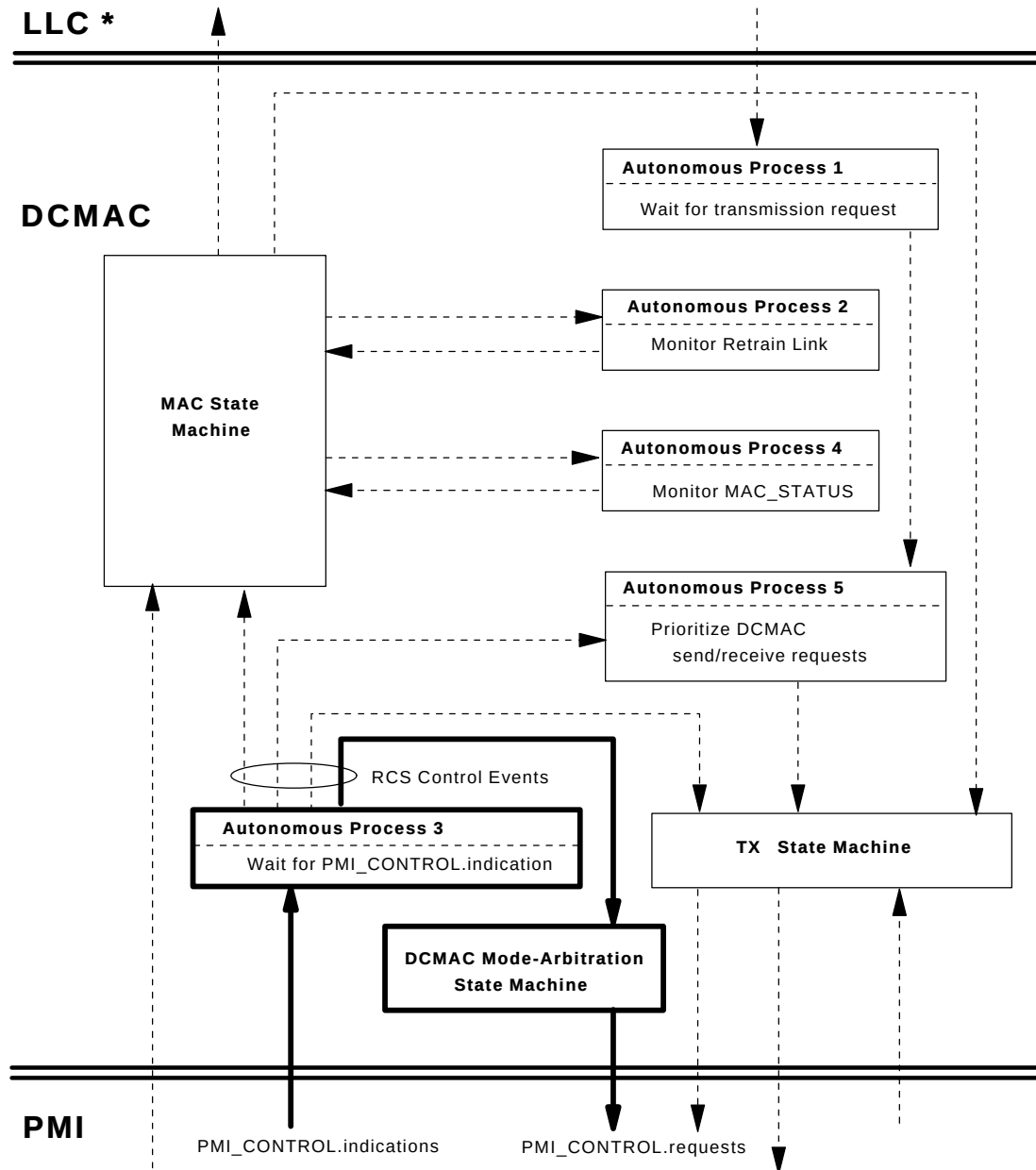


Figure 11-10—Logical elements and control paths required for DCMAC arbitration

Arbitration allows a DCMAC to negotiate whether training will be conducted in EMode or RMode. Conceptually, the DCMAC should only need to try first one mode (either EMode or RMode) and then the other, as shown in the expanded meta-state diagram in figure 11-11, until a compatible mode pair has

been established or an invalid link connection (e.g., a repeater cascade port connected to a DCMAC) has been identified.

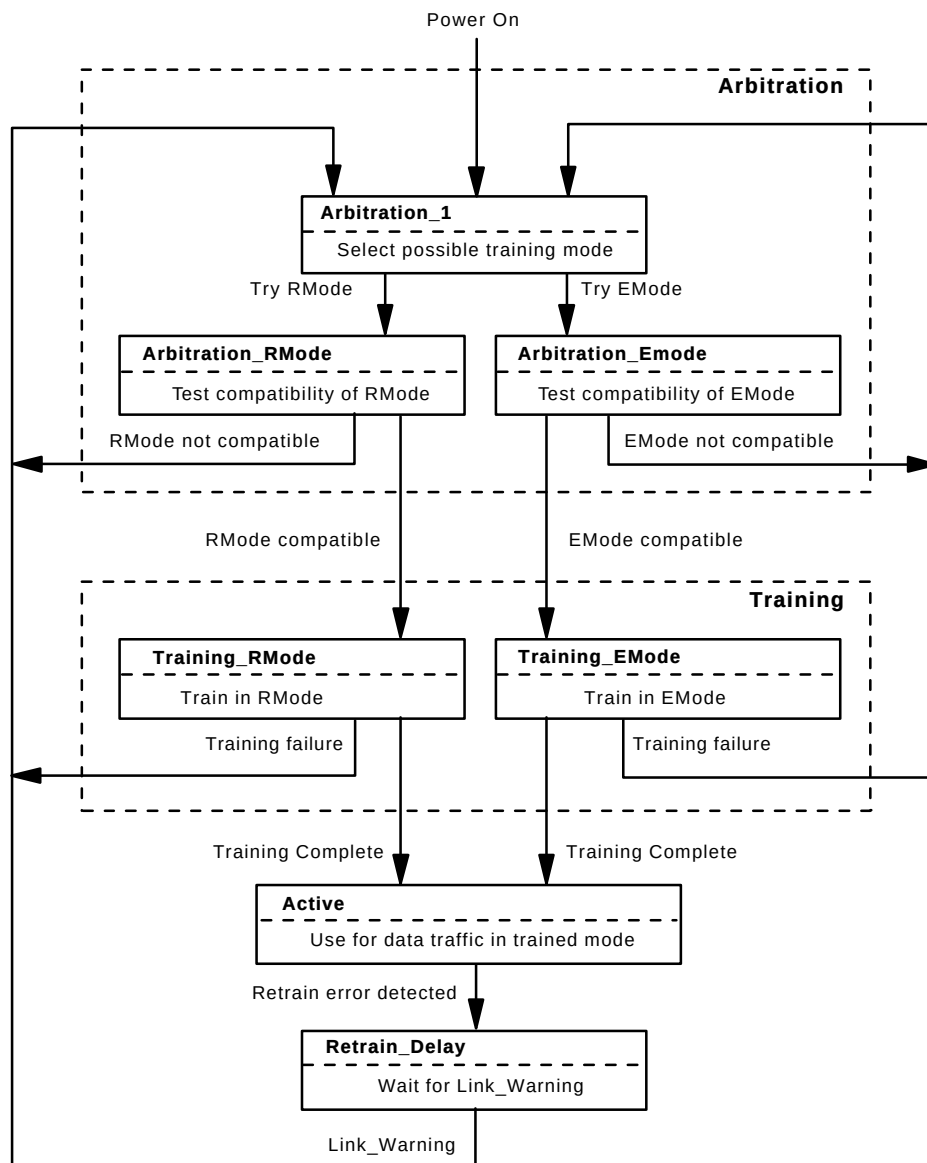


Figure 11-11 Expanded DCMAC meta-state diagram

A problem arises, however, when the other entity is also a DCMAC. In this case, both entities could be trying the same mode during each arbitration cycle and might never settle into a compatible mode pair. State 1 of the arbitration state machine uses a mode selection procedure that guarantees one DCMAC will eventually try EMode at the same time the other tries RMode, and will do so in a bounded length of time.

11.4.2 Training mode

The link must be initialized each time the end node is powered up or whenever an error condition indicates that the link may not be operating correctly. Training is always done in half-duplex mode and

requires two separate procedures. The training procedure for a basic MAC and for a DCMAC in EMode is essentially the same. Training a DCMAC in RMode is similar to training for a local port in a repeater.

11.4.2.1 Basic MAC training

Training in a basic MAC requires the MAC state machine states shown in bold in figure 11-12. Training is initiated in States 1 and 2. The MAC will alternate between these states until the training responder indicates that it will allow training to proceed. The actual training process is accomplished in States 3 through 8.

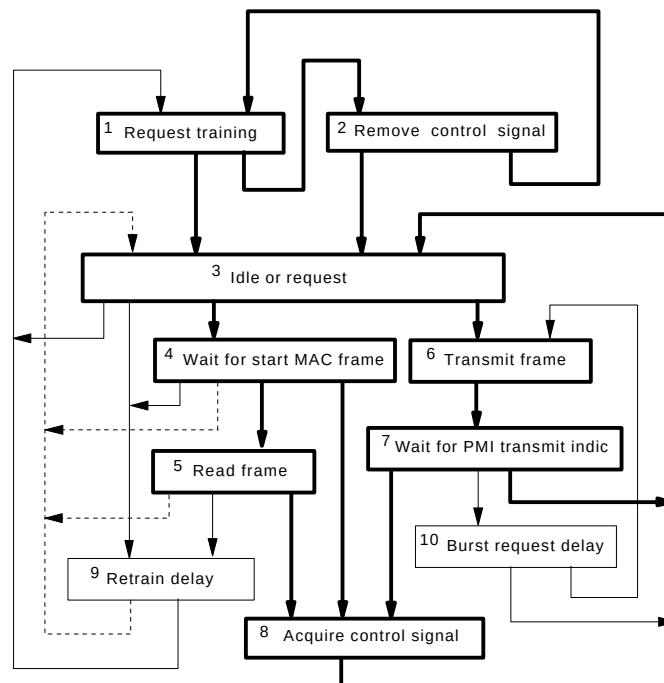
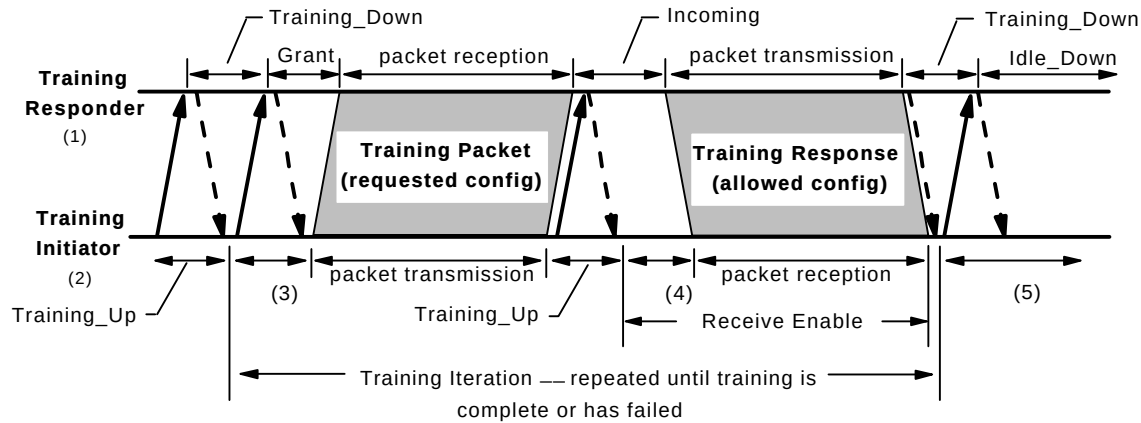


Figure 11-12 MAC state machine states and transitions required for basic MAC and DCMAC/EMode training

Training is initiated by the end node and is accomplished by the successful exchange of training frames with the repeater as depicted in the time-space diagram in figure 11-13.



NOTES

- 1—The training responder may be either a repeater or a DCMAC in half-duplex RMode.
- 2—The training initiator may be either a basic MAC or a DCMAC in half-duplex EMode.
- 3—Request_Normal.
- 4—The control signal sent after receipt of Incoming depends on the PMD/Link configuration:
 - a) In half-duplex links, the link is cleared of outgoing control signals to prepare for incoming data.
 - b) In dual-simplex links, Training_Up shall continue to be sent during the entire time RxEn is asserted.
- 5—Idle_Up if training is complete, Training_Up if training has failed.

Figure 11-13—Link training time-space diagram

The training process begins with the end node requesting training by generating a PMI_CONTROL.request (Training_Up) primitive. Training begins with the receipt of a PMI_CONTROL.indication (Training_Down) primitive and continues until a series of consecutive training frames (the training iteration sequence in figure 11-13) have been successfully exchanged:

- a) If 24 consecutive packets are received without error and in the 24th packet, the C and N bits are zero; the bits in the requested-configuration field are consistent with the bits in the allowed-configuration field;^{23.1} and the MAC has trained with an assigned address; then the MAC indicates success by generating a PMI_CONTROL.request (Idle_Up) primitive [rather than PMI_CONTROL.request (Request_Normal)] after the last received training packet. It transitions to the active state upon receipt of a PMI_CONTROL.indication (Idle_Down or Incoming) primitive.
- b) If training fails, the MAC waits for a 1–2 s delay and then initiates a new training sequence.

The end node shall neither send nor receive normal data traffic while training is in progress.

11.4.2.2 DCMAC EMode training

EMode training in a DCMAC is essentially the same as training in a basic MAC. The only difference is that the requests to send a training frame are initiated with a PMI_CONTROL.request (Request_High) rather than a PMI_CONTROL.request (Request_Normal) to avoid having the other entity, if it is a basic MAC, misinterpret the request as Incoming.

^{23.1} Not all options defined by the bits in the requested configuration field (the B, Fd, and D bits) are checked by the RMAC to determine the value of the C bit in the allowed configuration field (see 12.9.8.1). The MAC is responsible for checking these option bits to determine compatibility with the network (e.g., if the B bit in the requested configuration field is one but the B bit in the allowed configuration field is zero, burst-mode operation will not be allowed).

11.4.2.3 DCMAC RMode training

RMode training in a DCMAC is similar to local port training in a repeater. It requires both the MAC and TX state machines and the control/data paths shown in figure 11-14.

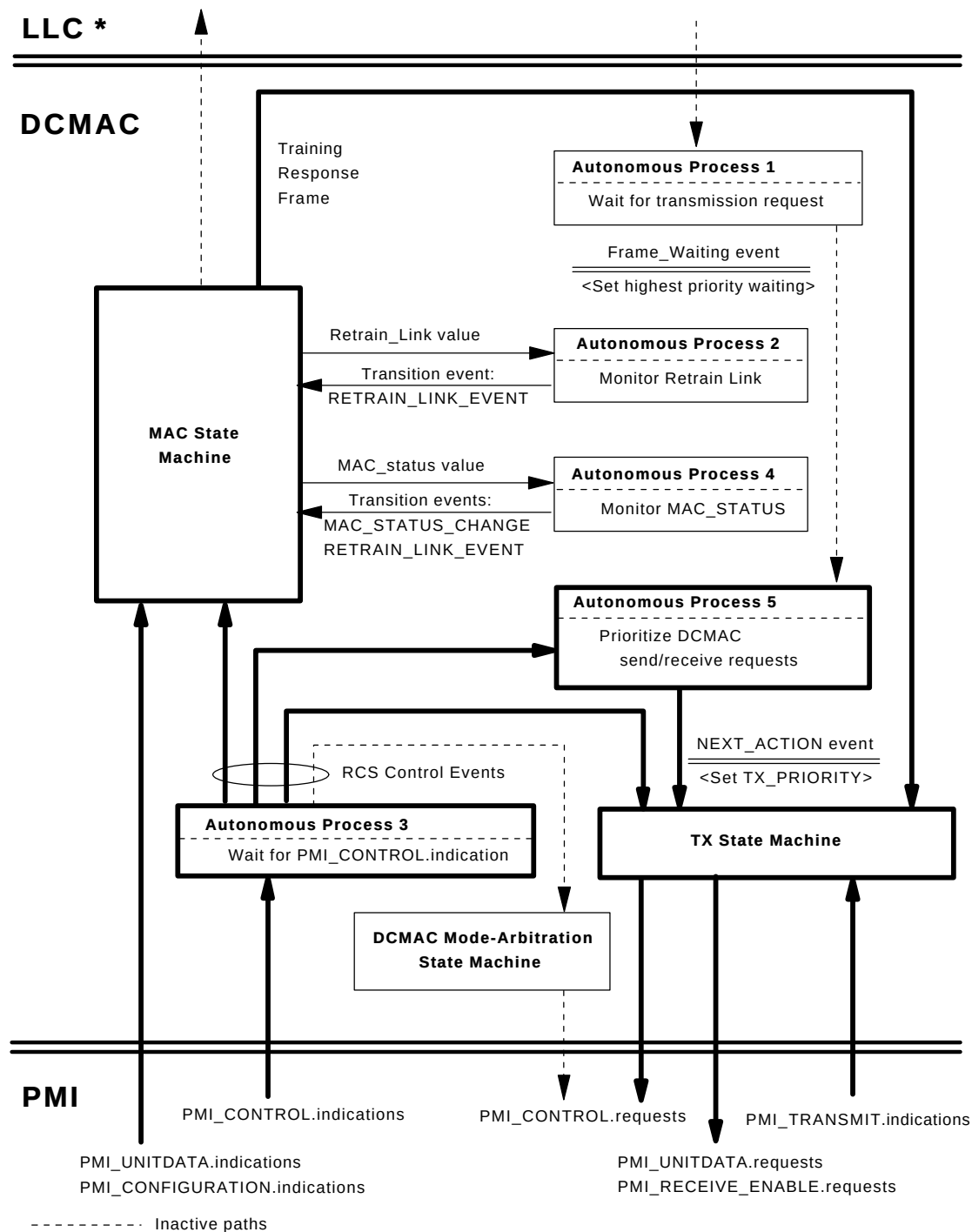


Figure 11-14—Logical elements and control/data paths required for DCMAC RMode training

The MAC state machine is effectively much smaller when the DCMAC is operating in RMode since it is only used for frame reception and requires only the three states shown in bold in figure 11-15.

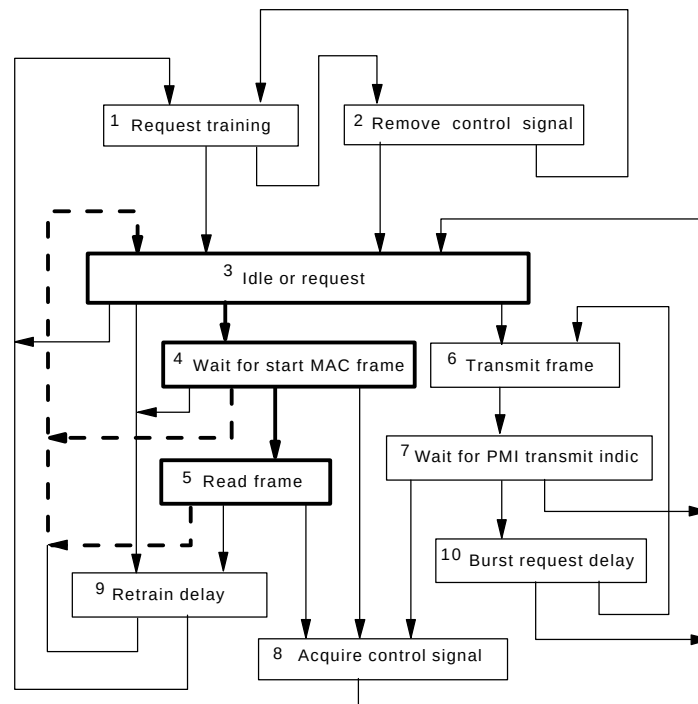


Figure 11-15—The MAC state machine states and transitions required for DCMAC RMode operations

Frame transmission is controlled by the separate TX state machine shown in figure 11-16. The three states are similar, but expanded in function, to the equivalently numbered states in the MAC state machine (see figure 11-5).

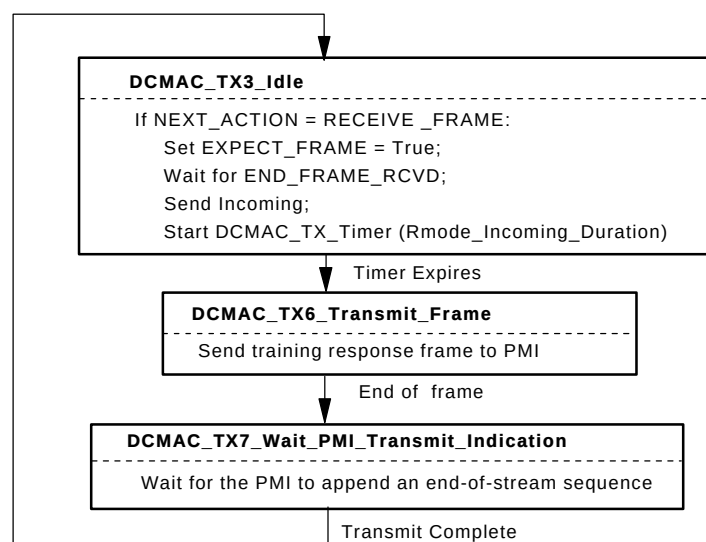


Figure 11-16—The effective TX state machine during RMode training

Synchronization of the MAC and TX state machines is accomplished through the exchange of variables as shown in figure 11-17. During training:

- A PMI_CONTROL.indication (Request_Normal or Request_High) is translated by autonomous process 3 into an RCS_IS_REQUEST_NORMAL or an RCS_IS_REQUEST_HIGH event which is used by autonomous process 5 to set NEXT_ACTION to RECEIVE_FRAME, which tells TX3 to send Grant.
- As soon as Grant has been sent, TX3 sets the variable EXPECT_FRAME to True, telling the MAC state machine to assert Receive Enable. EXPECT_FRAME is interpreted by the MAC state machine as equivalent to receipt of Incoming from a repeater local port.
- START_FRAME_RCVD is set in MAC4 when the start-of-frame indication has been detected. It tells the TX state machine to ignore the MAC_Receive_Retrain_Duration timer.
- END_FRAME_RCVD is set in MAC5_READ_FRAME when the end-of-frame indication has been detected. It tells the TX state machine that the training-response frame is now ready to be returned to the training initiator.

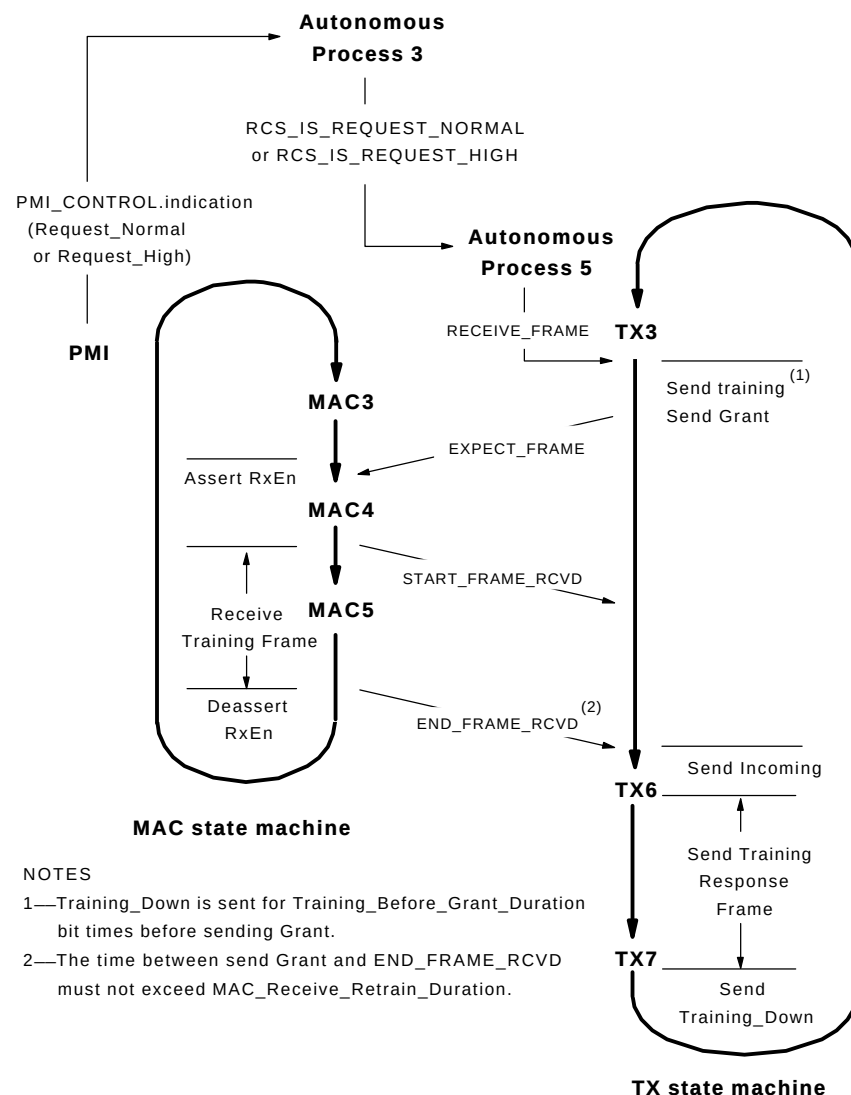


Figure 11-17—MAC/TX state machine synchronization during RMode training