802.3av™

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

Part 3: Carrier Sense Multiple Access with Collision Detection (CSMA/CD) Access Method and Physical Layer Specifications

Amendment 1: Physical Layer Specifications and Management Parameters for 10 Gb/s Passive Optical Networks

IEEE Computer Society

Sponsored by the
LAN/MAN Standards Committee

IEEE
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IEEE Std 802.3av™-2009
(Amendment of
IEEE Std 802.3™-2008)

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Approved 11 September 2009
IEEE-SA Standards Board

Abstract: This amendment to IEEE Std 802.3-2008 extends Ethernet Passive Optical Networks (EPONs) operation to 10 Gb/s providing both symmetric, 10 Gb/s downstream and upstream, and asymmetric, 10 Gb/s downstream and 1 Gb/s upstream, data rates. It specifies the 10 Gb/s EPON Reconciliation Sublayer, 10GBASE-PR symmetric and 10/1GBASE-PRX Physical Coding Sublayers (PCSs) and Physical Media Attachments (PMAs), and Physical Medium Dependent sublayers (PMDs) that support both symmetric and asymmetric data rates while maintaining complete backward compatibility with already deployed 1 Gb/s EPON equipment. The EPON operation is defined for distances of at least 10 km and at least 20 km, and for split ratios of 1:16 and 1:32.

An additional MAC Control opcode is also defined to provide organization specific extension operation.

Keywords: 10 Gb/s Ethernet Passive Optical Networks (10G-EPON), forward error correction (FEC), Multi-Point MAC Control (MPMC), Physical Coding Sublayer (PCS), Physical Media Attachment (PMA), Physical Medium Dependent (PMD), PON, Point to Multipoint (P2MP), Reconciliation Sublayer (RS)

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Introduction

This introduction is not part of IEEE Std 802.3av-2009, IEEE Standard for Information technology—Telecommunications and information exchange between systems—Local and metropolitan area networks—Specific requirements, Part 3: CSMA/CD Access Method and Physical Layer Specifications, Amendment 1: Physical Layer Specifications and Management Parameters for 10 Gb/s Passive Optical Networks.

IEEE Std 802.3™ was first published in 1985. Since the initial publication, many projects have added functionality or provided maintenance updates to the specifications and text included in the standard. Each IEEE 802.3 project/amendment is identified with a suffix (e.g., IEEE Std 802.3av-2009).

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

Some of the major additions to IEEE Std 802.3 are identified in the marketplace with their project number. This is most common for projects adding higher speeds of operation or new protocols. For example, IEEE Std 802.3u™ added 100 Mb/s operation (also called Fast Ethernet), IEEE Std 802.3x™ specified full duplex operation and a flow control protocol, IEEE Std 802.3z™ added 1000 Mb/s operation (also called Gigabit Ethernet), IEEE Std 802.3ae™ added 10 Gb/s operation (also called 10 Gigabit Ethernet) and IEEE Std 802.3ah™ specified access network Ethernet (also called Ethernet in the First Mile). These major additions are all now included in, and are superseded by, IEEE Std 802.3-2008 and are not maintained as separate documents.

At the date of IEEE Std 802.3av-2009 publication, IEEE Std 802.3 is comprised of the following documents:

IEEE Std 802.3-2008

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

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

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

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

Section Five—Includes Clause 56 through Clause 74 and Annex 57A through Annex 74A. Clause 56 through Clause 67 and associated annexes specify subscriber access and other Physical Layers and sublayers for operation from 512 kb/s to 1000 Mb/s, and defines services and protocol elements that enable the exchange of IEEE Std 802.3 format frames between stations in a subscriber access network. Clause 68 specifies a 10 Gb/s Physical Layer specification. Clause 69 through Clause 74 and associated annexes specify Ethernet operation over electrical backplanes at speeds of 1000 Mb/s and 10 Gb/s.

IEEE Std 802.3av-2009

This amendment includes changes to IEEE Std 802.3-2008 and adds Clause 75 through Clause 77 and Annex 75A through Annex 76A. This amendment adds new Physical Layers for 10 Gb/s operation on point-to-multipoint passive optical networks.

IEEE Std 802.3bc™-2009

This amendment includes changes to IEEE Std 802.3-2008 and adds Clause 79. This amendment moves the Ethernet Organizationally Specific Type, Length, Value (TLV) information elements that were specified in IEEE Std 802.1AB to IEEE Std 802.3.

IEEE Std 802.3at™-2009

This amendment includes changes to IEEE Std 802.3-2008. This amendment augments the capabilities of IEEE Std 802.3-2008 with higher power levels and improved power management information.

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

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Contents

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

Special symbols and operators

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

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[This amendment is based on IEEE Std 802.3-2008.]

NOTE—The editing instructions contained in this amendment define how to merge the material contained therein into the existing base standard and its amendments to form the comprehensive standard.

The editing instructions are shown in ***bold italic***. Four editing instructions are used: change, delete, insert, andreplace. ***Change*** is used to make corrections in existing text or tables. The editing instruction specifies the location of the change and describes what is being changed by using ~~strikethrough~~ (to remove old material) and underscore (to add new material). ***Delete*** removes existing material. ***Insert*** adds new material without disturbing the existingmaterial. Insertions may require renumbering. If so, renumbering instructions are given in the editing instruction. ***Replace*** is used to make changes in figures or equations by removing the existing figure or equation and replacing it with a new one. Editing instructions, change markings, and this NOTE will not be carried over into future editions because the changes will be incorporated into the base standard.[1]

[1]Notes in text, tables, and figures are given for information only and do not contain requirements needed to implement the standard.

1. Introduction

1.3 Normative references

Change the following reference as follows:

ITU-T Recommendation G.652, ~~2000~~2005—Characteristics of a single-mode optical fibre cable.

Insert the following new references in alphanumerical order:

IEC 61280-4-2:2000, Fibre optic communication subsystem basic test procedures; Fibre optic cable plant; Single-mode fibre optic cable plant attenuation.

ITU-T Recommendation G.650.1, 2004—Transmission media characteristics - Optical fibre cables.

ITU-T Recommendation G.671 am 1, 2006—Transmission characteristics of optical components and subsystems, Amendment 1.

ITU-T Recommendation G.657, 2006—Characteristics of a bending loss insensitive single mode optical fibre and cable for the access network.

ITU-T Recommendation G.983.1, 2005—Broadband optical access systems based on Passive Optical Networks (PON).

ITU-T Recommendation G.984.3, 2008—Gigabit-capable Passive Optical Networks (G-PON): Transmission convergence layer specification.

TIA-455-127-A:2006 FOTP-127-A Basic Spectral Characterization of Laser Diodes.

1.4 Definitions

Insert the following after 1.4.39 10GBASE-LX4 and renumber as appropriate:

1.4.40 10GBASE-PR: IEEE 802.3 Physical Layer specification for a 10 Gb/s (10/10G-EPON) point-to-multipoint link over one single-mode optical fiber.

NOTE—See IEEE 802.3 Clause 75, Clause 76, and Clause 77.

1.4.41 10/1GBASE-PRX: IEEE 802.3 Physical Layer specification for a 10 Gb/s downstream, 1 Gb/s upstream (10/1G-EPON) point-to-multipoint link over one single-mode optical fiber.

NOTE—See IEEE 802.3 Clause 75, Clause 76, and Clause 77.

Insert the following after 1.4.46 10GBASE-X and renumber as appropriate:

1.4.47 1G-EPON: An EPON architecture operating at 1 Gb/s in both downstream and upstream directions.

1.4.48 10G-EPON: An EPON architecture operating at 10 Gb/s in either downstream or both downstream and upstream directions. This term collectively refers to 10/10G-EPON and 10/1G-EPON architectures.

1.4.49 10/1G-EPON: An EPON architecture operating at 10 Gb/s in downstream direction and at 1 Gb/s data rate in upstream direction (asymmetric rate).

1.4.50 10/10G-EPON: An EPON architecture operating at 10 Gb/s in both downstream and upstream directions (symmetric rate).

Change subclause 1.4.95 as follows:

1.4.95 channel insertion loss: As used in IEEE 802.3 ~~Clause 38~~ for fiber optic links, the static loss of light through a link between a transmitter and receiver. It includes the loss of the fiber, connectors, and splices and, for EPON links, optional power splitter/combiner.

Insert the following after 1.4.253 ordered_set and renumber as appropriate:

1.4.254 Organizationally Unique Identifier: A unique number that defines a manufacturer or other organization.

NOTE—See http://standards.ieee.org/regauth/index.html.

Insert the following after 1.4.269 pause and renumber as appropriate:

1.4.270 pause_quantum: The unit of measurement for pause time specified; 512 MAC bit times.

NOTE—See IEEE Std 802.3, Annex 31B.

Insert the following after 1.4.342 ternary symbol and renumber as appropriate:

1.4.343 time_quantum: The unit of measurement for time related parameters specified in Multipoint MAC Control.

NOTE—See Clause 64 and Clause 77. The value of time_quantum is defined in 64.2.2.1.

1.5 Abbreviations

Insert the following new abbreviations in alphabetical order:

DFB	distributed feedback
EOB	end of burst delimiter
EPON	Ethernet Passive Optical Network
OUI	Organizationally Unique Identifier
SLD	Start of LLID Delimiter
TDMA	time division multiple access
TQ	time_quantum
WDM	wavelength division multiplexing

30. Management

30.2.2.1 Text description of managed objects

Insert new managed object oEXTENSION in 30.2.2.1 with the following definition, placing it between oGroup and oMACControlEntity managed object definitions:

oEXTENSION If implemented, oEXTENSION is contained within oMACControlEntity. The oEXTENSION managed object class provides the management controls necessary to allow an instance of the MAC Control EXTENSION function to be managed.

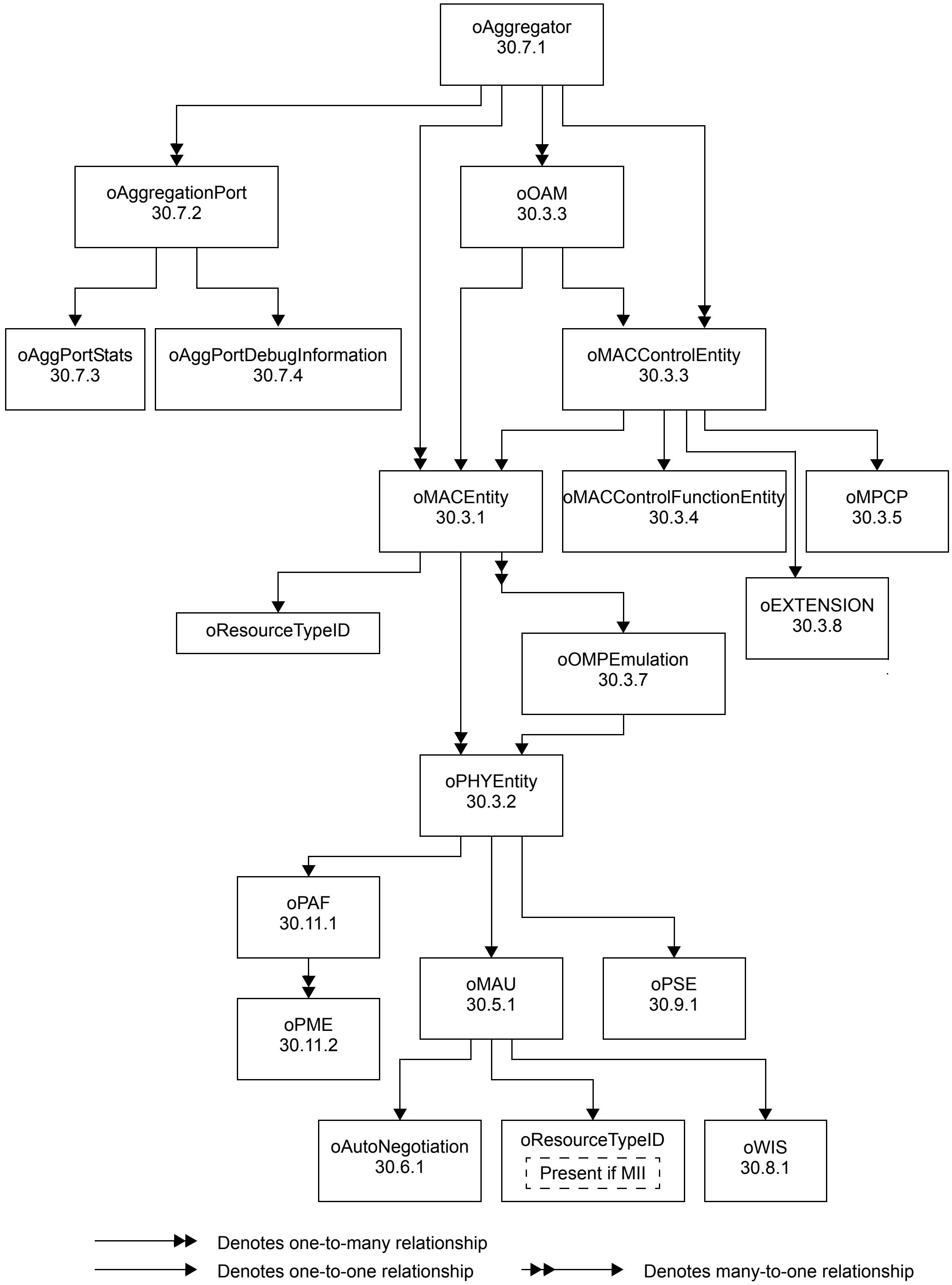
30.2.5 Capabilities

Change Table 30–1c, placing a new block of rows below oMACControlFunctionEntity block, as presented below:

Table 30–1c—Capabilities

			DTE								Repeater					MAU						
			Basic Package (mandatory)	Mandatory Package (mandatory)	Recommended Package (optional)	Optional Package (optional)	Array Package (optional)	Excessive Deferral Package (optional)	Multiple PHY Package (optional)	PHY Error Monitor Capability (optional)	Basic Control Capability (mandatory)	Performance Monitor Capability (optional)	Address Tracking Capability (optional)	100/1000 Mb/s Monitor Capability (optional)	1000 Mb/s Burst Monitor Capability (optional)	Basic Package (mandatory)	MAU Control Package (optional)	Media Loss Tracking Package (conditional)	Broadband DTE MAU Package (conditional)	MII Capability (conditional)	PHY Error Monitor Capability (optional)	Auto-Negotiation Package (mandatory)
All the cells above without any changes																						
aPAUSEMACCtrlFramesReceived	ATTRIBUTE	GET			X																	
oEXTENSION managed object class (30.3.8)																						
aEXTENSIONMACCtrlFramesTransmitted	ATTRIBUTE	GET			X																	
aEXTENSIONMACCtrlFramesReceived	ATTRIBUTE	GET			X																	
oRepeater managed object class (30.4.1)																						
All the cells below without any changes																						

Replace Figure 30–3 with that presented below:



NOTE—The objects oAggregator, oAggregationPort, oAggPortStats, and oAggPortDebugInformation are deprecated by IEEE Std 802.1AX-2008.

Figure 30–3— DTE System entity relationship diagram

30.3.1.1.2 aFramesTransmittedOK

Change first sentence under APPROPRIATE SYNTAX: to read as follows:

Generalized nonresettable counter.

30.3.2.1.2 aPhyType

Insert a new entry as follows:

10GBASE–PR Clause 76 10/10G-EPON 10 Gb/s 64B/66B
10/1GBASE–PRX Clause 76 10/1G-EPON 10 Gb/s 64B/66B downstream and 1 Gb/s 8B/10B upstream

30.3.2.1.3 aPhyTypeList

Insert a new entry as follows:

10GBASE–PR Clause 76 10/10G-EPON 10 Gb/s 64B/66B
10/1GBASE–PRX Clause 76 10/1G-EPON 10 Gb/s 64B/66B downstream and 1 Gb/s 8B/10B upstream

30.3.5.1.2 aMPCPAdminState

Change the behaviour definition to read as follows:

A read–only value that identifies the operational state of the Multipoint MAC Control sublayer. An interface which can provide the Multipoint MAC Control sublayer functions specified in Clause 64 or Clause 77 ~~will be~~ is enabled to do so when this attribute has the enumeration “enabled”. When this attribute has the enumeration “disabled” the interface ~~will~~ acts as it would if it had no Multipoint MAC Control sublayer. The operational state of the Multipoint MAC Control sublayer can be changed using the acMPCPAdminControl action.;

30.3.5.1.3 aMPCPMode

Change the behaviour definition to read as follows:

A read–only value that identifies the operational mode of the Multipoint MAC Control sublayer. An interface which can provide the Multipoint MAC Control sublayer functions specified in Clause 64 and Clause 77 ~~will~~ operates as an OLT when this attribute has the enumeration “OLT”. When this attribute has the enumeration “ONU” the interface ~~will~~ acts as an ONU.;

30.3.5.1.4 aMPCPLinkID

Change the behaviour definition to read as follows:

A read–only value that identifies the Logical Link identity (LLID) associated with the MAC port as specified in ~~65.1.2.3.2~~65.1.3.2.2 or 76.2.6.1.3.2, as appropriate.;

30.3.7.1.2 aOMPEmulationType

Change the behaviour definition to read as follows:

A read–only value that indicates ~~that~~ the mode of operation of the Reconciliation Sublayer for Point to Point Emulation (see 65.1.3.1 or 76.2.6.1.1, as appropriate).;

30.3.7.1.3 aSLDErrors

Change the behaviour definition to read as follows:

A count of frames received that do not contain a valid SLD field as defined in 65.1.3.3.1 or 76.2.6.1.3.1, as appropriate.;

30.3.7.1.4 aCRC8Errors

Change the behaviour definition to read as follows:

A count of frames received that contain a valid SLD field, as defined in 65.1.3.3.1 or 76.2.6.1.3.1, as appropriate, but do not pass the CRC–8 check as defined in 65.1.3.3.3 or 76.2.6.1.3.3, as appropriate.;

30.3.7.1.5 aGoodLLID

Change the behaviour definition to read as follows:

A count of frames received that contain a valid SLD field, as defined in 65.1.3.3.1 or 76.2.6.1.3.1, as appropriate, and pass the CRC–8 check as defined in 65.1.3.3.3 or 76.2.6.1.3.3, as appropriate.;

30.3.7.1.6 aONUPONcastLLID

Change the behaviour definition to read as follows:

~~A count of frames received that contain a valid SLD field in an ONU, as defined in 65.1.3.3.1, passes the CRC-8 check, as defined in 65.1.3.3.3, and the frame meets the rule for acceptance defined in 65.1.3.3.2.;~~

A count of frames received that: 1) contain a valid SLD field in an ONU, 2) meet the rules for frame acceptance, and 3) pass the CRC-8 check. The SLD is defined in 65.1.3.3.1 or 76.2.6.1.3.1, as appropriate. The rules for LLID acceptance are defined in 65.1.3.3.2 or 76.2.6.1.3.2, as appropriate. The CRC-8 check is defined in 65.1.3.3.3 or 76.2.6.1.3.3, as appropriate.;

30.3.7.1.7 aOLTPONcastLLID

Change the behaviour definition to read as follows:

A count of frames received that contain a valid SLD field in an ONU, as defined in 65.1.3.3.1 or 76.2.6.1.3.1, as appropriate, and pass the CRC–8 check, as defined in 65.1.3.3.3 or 76.2.6.1.3.3, as appropriate, and meet the rule for acceptance defined in 65.1.3.3.2 or 76.2.6.1.3.2, as appropriate.;

30.3.7.1.8 aBadLLID

Change the behaviour definition to read as follows:

~~A count of frames received that contain a valid SLD field in an OLT, as defined in 65.1.3.3.1, and pass the CRC-8 check, as defined in 65.1.3.3.3, but are discarded due to the LLID check as defined in 65.1.3.3.2.;~~

A count of frames received that contain a valid SLD field in an OLT, and pass the CRC-8 check, but are discarded due to the LLID check. The SLD is defined in 65.1.3.3.1 or 76.2.6.1.3.1, as appropriate. The CRC-8 check is defined in 65.1.3.3.3 or 76.2.6.1.3.3, as appropriate. The LLID check is defined in 65.1.3.3.2 or 76.2.6.1.3.2, as appropriate.;

Insert a new subclause 30.3.8, renumbering subsequent subclauses as appropriate, with the following contents:

30.3.8 EXTENSION entity managed object class

This subclause formally defines the behaviours for the oEXTENSION managed object class attributes.

30.3.8.1 aEXTENSIONMACCtrlFramesTransmitted

ATTRIBUTE

APPROPRIATE SYNTAX:

Generalized nonresettable counter. This counter has a maximum increment rate of 1 600 000 counts per second at 1000 Mb/s

BEHAVIOUR DEFINED AS:

A count of EXTENSION frames passed to the MAC sublayer for transmission. This counter is incremented when a MA_CONTROL.request primitive is generated within the MAC Control sublayer with an opcode indicating the EXTENSION operation.;

30.3.8.2 aEXTENSIONMACCtrlFramesReceived

ATTRIBUTE

APPROPRIATE SYNTAX:

Generalized nonresettable counter. This counter has a maximum increment rate of 1 600 000 counts per second at 1000 Mb/s

BEHAVIOUR DEFINED AS:

A count of MAC Control frames passed by the MAC sublayer to the MAC Control sublayer. This counter is incremented when a ReceiveFrame function call returns a valid frame with: (1) a lengthOrType field value equal to the reserved Type for 802.3_MAC_Control as specified in 31.4.1.3, and (2) an opcode indicating the EXTENSION operation.;

30.5.1.1.2 aMAUType

Insert the following between 10GBASE–T and 802.9a:

10/1GBASE–PRX–D1	One single-mode fiber 10.3125 GBd continuous downstream / 1.25 GBd burst mode upstream OLT PHY as specified in Clause 75
10/1GBASE–PRX–D2	One single-mode fiber 10.3125 GBd continuous downstream / 1.25 GBd burst mode upstream OLT PHY as specified in Clause 75
10/1GBASE–PRX–D3	One single-mode fiber 10.3125 GBd continuous downstream / 1.25 GBd burst mode upstream OLT PHY as specified in Clause 75
10/1GBASE–PRX–U1	One single-mode fiber 10.3125 GBd continuous downstream / 1.25 GBd burst mode upstream ONU PHY as specified in Clause 75
10/1GBASE–PRX–U2	One single-mode fiber 10.3125 GBd continuous downstream / 1.25 GBd burst mode upstream ONU PHY as specified in Clause 75
10/1GBASE–PRX–U3	One single-mode fiber 10.3125 GBd continuous downstream / 1.25 GBd burst mode upstream ONU PHY as specified in Clause 75
10GBASE–PR–D1	One single-mode fiber 10.3125 GBd continuous downstream / burst mode upstream OLT PHY as specified in Clause 75
10GBASE–PR–D2	One single-mode fiber 10.3125 GBd continuous downstream / burst mode upstream OLT PHY as specified in Clause 75
10GBASE–PR–D3	One single-mode fiber 10.3125 GBd continuous downstream / burst mode upstream OLT PHY as specified in Clause 75
10GBASE–PR–U1	One single-mode fiber 10.3125 GBd continuous downstream / burst mode upstream ONU PHY as specified in Clause 75
10GBASE–PR–U3	One single-mode fiber 10.3125 GBd continuous downstream / burst mode upstream ONU PHY as specified in Clause 75

30.5.1.1.15 aFECCorrectedBlocks

Change the behaviour definition to read as follows:

For 1000BASE–PX~~ PHYs or~~, 10GBASE–R, 10GBASE–PR or 10/1GBASE–PRX PHYs, a count of corrected FEC codewords. This counter ~~will~~does not increment for other PHY types.

Increment the counter by one for each received block that is corrected by the FEC function in the PHY.

If a Clause 45 MDIO Interface to the PCS is present, then this attribute ~~will~~ maps to the FEC corrected codewords counter (see 45.2.7.5 and 45.2.1.86 for 10GBASE–R, 45.2.3.32 for 10GBASE–PR and 10/1GBASE–PRX).;

30.5.1.1.16 aFECUncorrectableBlocks

Change the behaviour definition to read as follows:

For 1000BASE–PX~~ PHYs or~~, 10GBASE–R, 10GBASE–PR or 10/1GBASE–PRX PHYs, a count of uncorrectable FEC codewords. This counter ~~will~~does not increment for other PHY types.

Increment the counter by one for each received block that is determined to be uncorrectable by the FEC function in the PHY.

If a Clause 45 MDIO Interface to the PCS is present, then this attribute ~~will~~ maps to the FEC uncorrectable codewords counter (see 45.2.7.5 and 45.2.1.87 for 10GBASE–R, 45.2.3.33 for 10GBASE–PR and 10/1GBASE–PRX).;

Annex 31A

(normative)

MAC Control opcode assignments

Change Table 31A–1 as follows:

Table 31A–1—MAC Control opcodes

Opcode (hexadecimal)	MAC Control function	Specified in	Value/Comment	Timestamp[a]
00-00	Reserved			
00-01	PAUSE	Annex 31B	Requests that the recipient stop transmitting non-control frames for a period of time indicated by the parameters of this function.	No
00-02	GATE	Clause 64 Clause 77	Request that the recipient allow transmission of frames at a time, and for a period of time indicated by the parameters of this function.	Yes
00-03	REPORT	Clause 64 Clause 77	Notify the recipient of pending transmission requests as indicated by the parameters of this function.	Yes
00-04	REGISTER_REQ	Clause 64 Clause 77	Request that the station be recognized by the protocol as participating in a gated transmission procedure as indicated by the parameters of this function.	Yes
00-05	REGISTER	Clause 64 Clause 77	Notify the recipient that the station is recognized by the protocol as participating in a gated transmission procedure as indicated by the parameters of this function.	Yes
00-06	REGISTER_ACK	Clause 64 Clause 77	Notify the recipient that the station acknowledges participation in a gated transmission procedure.	Yes
00-07 through FF-F~~F~~D	Reserved			
FF–FE	EXTENSION	Annex 31C	This frame is used for Organization–Specific Extension. Upon reception of this message, the MAC Control generates MA_CONTROL.Indication informing the MAC Control Client to perform the relevant action.	No
FF–FF	Reserved			

[a]The timestamp field is generated by MAC Control and is not exposed through the client interface.

Insert a new row to Table 31A-3 at the end of the table, as presented below:

Table 31A–3—GATE MAC Control indications

discoveryInformation[a]	16 bits	See Table 77–3 for the internal structure of the discoveryInformation field.

[a]Only present in 10G–EPON GATE MAC Control indication (Clause 77).

Insert three new rows to Table 31A-5 at the end of the table, as presented below:

Table 31A–5—REGISTER_REQ MAC Control indications

laserOnTime[a]	8 bits	Indicates the Laser On Time characteristic for the given ONU transmitter, expressed in the units of time_quanta.
laserOffTime[a]	8 bits	Indicates the Laser Off Time characteristic for the given ONU transmitter, expressed in the units of time_quanta.
discoveryInformation[a]	16 bits	See Table 77–7 for the internal structure of the discoveryInformation field.

[a]Only present in 10G–EPON REGISTER_REQ MAC Control indication (Clause 77).

Insert two new rows to Table 31A-6 at the end of the table, as presented below:

Table 31A–6—REGISTER MAC Control indications

laserOnTime[a]	8 bits	Indicates the Laser On Time characteristic for the given ONU transmitter, expressed in the units of time_quanta.
laserOffTime[a]	8 bits	Indicates the Laser Off Time characteristic for the given ONU transmitter, expressed in the units of time_quanta.

[a]Only present in 10G–EPON REGISTER MAC Control indication (Clause 77).

Add a new Table 31A–8 after Table 31A–7 with the description of EXTENSION frame with the following contents:

Table 31A–8—EXTENSION MAC Control indications

EXTENSION (opcode 0xFFFE)		
indication_operand_list element	**Value**	**Interpretation**
OUI	24 bits	Organizationally-Unique Identifier that determines the format and semantics of the Value field and its subfields, if any are defined.
Value	Variable	Organization-specific value, distinguished by the OUI.

Insert a new annex as follows:

Annex 31C

(normative)

MAC Control organization specific extension operation

31C.1 Organization specific extension description

The extension operation is used to provide a standardized means for other standards development organizations, in particular ITU-T, to define their own MAC Control protocols outside the scope of this standard. The first application of this is to enable Physical Layer Operations, Administration, and Management (PLOAM) messages related to protection switching, low-level performance monitoring, and management channel set-up (see ITU-T G.984 and ITU-T G.983). The requirements defined in Clause 31 apply to these protocols.

31C.2 Transmission of Extension MAC Control frame

Upon receipt of a MA_CONTROL.request primitive containing the EXTENSION opcode from a MAC client, the MAC control sublayer calls the MAC sublayer MAC:MA_DATA.request service primitive with the following parameters:

a) The destination_address is set equal to the destination_address parameter of the MA_CONTROL.request primitive. This parameter is currently restricted to either the value 01–80–C2–00–00–01 or to the 48 bit individual address of the destination station.
b) The source_address is set equal to the 48 bit individual address of the station.
c) The length/type field (i.e., the first two octets) within the mac_service_data_unit parameter is set to the IEEE 802.3 MAC Control type value assigned in 31.4.1.3.
d) The remainder of the mac_service_data_unit is set to the concatenation of the Extension Opcode, ITU-T's Organizationally Unique Identifier[2] (00-19-A7), and the organization-specific data.
e) The frame_check_sequence is omitted.

31C.3 Receive operation

The opcode–independent MAC Control sublayer Receive state diagram accepts and parses valid frames received from the MAC sublayer. MAC Control sublayer entities that implement the EXTENSION operation shall implement the Receive state diagram specified in this subclause. The functions specified in this subclause are performed upon receipt of a valid Control frame containing the EXTENSION opcode and define the function called by the INITIATE MAC CONTROL FUNCTION state of Figure 31–4 (see 31.5.3).

[2]Details defining the format of OUIs can be found in IEEE Std 802-2001 Clause 9. Interested applicants should contact the IEEE Standards Department, Institute of Electrical and Electronics Engineers, http://standards.ieee.org/regauth/index.html, 445 Hoes Lane, Piscataway, NJ 08854, USA.

31C.3.1 Receive state diagram (INITIATE MAC CONTROL FUNCTION) for EXTENSION operation

Figure 31C–2 depicts the INITIATE MAC CONTROL FUNCTION for the EXTENSION operation (see 31.5.3). Upon reception of EXTENSION frames, the frame is sent to the MAC CONTROL client.

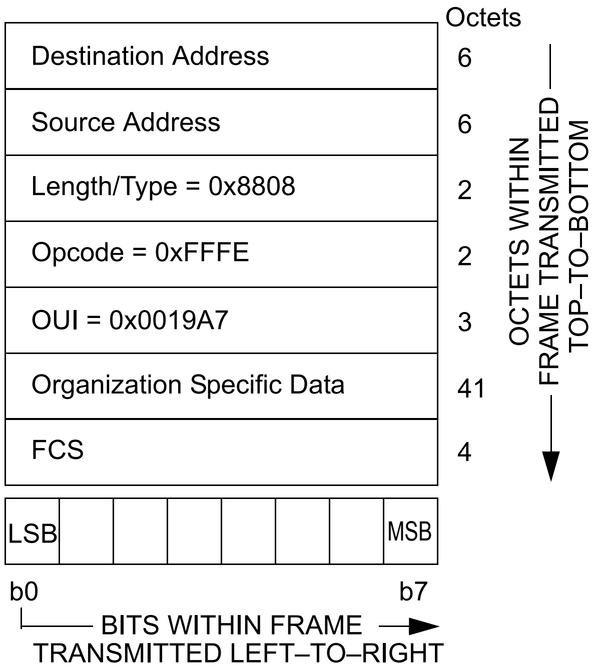


Figure 31C–1—MAC Control EXTENSION Frame

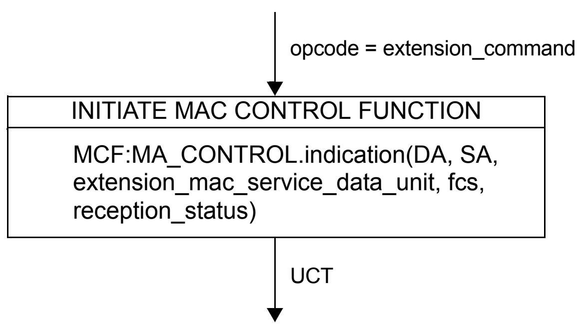


Figure 31C–2—EXTENSION receive function

31C.4 Protocol implementation conformance statement (PICS) proforma for MAC Control organization specific extension operation[3]

31C.4.1 Introduction

The supplier of a protocol implementation that is claimed to conform to Annex 31C, MAC Control organization specific extension operation, shall complete the following PICS proforma in addition to the PICS of Clause 31.

A detailed description of the symbols used in the PICS proforma, along with instructions for completing the PICS proforma, can be found in Clause 21.

31C.4.2 Identification

31C.4.2.1 Implementation identification

Supplier	
Contact point for queries about the PICS	
Implementation Name(s) and Version(s)	
Other information necessary for full identification—e.g., name(s) and version(s) for machines and/or operating systems; System Name(s)	
NOTE 1—Only the first three items are required for all implementations, other information may be completed as appropriate in meeting the requirements for the identification. NOTE 2—The terms Name and Version should be interpreted appropriately to correspond with a supplier's terminology (e.g., Type, Series, Model).	

31C.4.2.2 Protocol summary

Identification of protocol specification	IEEE Std 802.3av-2009, Annex 31C, MAC Control organization specific extension operation
Identification of amendments and corrigenda to this PICS proforma that have been completed as part of this PICS	
Have any Exception items been required? No [ ] Yes [ ] (See Clause 21; The answer Yes means that the implementation does not conform to IEEE Std 802.3av-2009)	

Date of Statement	

[3]*Copyright release for PICS proformas:* Users of this standard may freely reproduce the PICS proforma in this annex so that it can be used for its intended purpose and may further publish the completed PICS.

31C.4.3 EXTENSION command state diagram requirements

Item	Feature	Subclause	Value/Comment	Status	Support
ESD1	Receive state diagram for EXTENSION operation	31C.3	Meets requirements of Figure 31C–2	M	Yes [ ]

45. Management Data Input/Output (MDIO) Interface

45.2.1 PMA/PMD registers

Change Table 45-3 as follows:

Table 45–3—PMA/PMD registers

Register address	Register name	Subclause
~~1.12, 1.13~~	~~Reserved~~	
1.12	P2MP ability register	45.2.1.11
1.13	Reserved	N/A

45.2.1.1.4 PMA loopback (1.0.0)

Change first sentence in second paragraph as follows:

The loopback function is mandatory for the 1000BASE-KX, 10GBASE-KR, and 10GBASE-X port type and optional for all other port types, except 2BASE-TL, ~~and~~ 10PASS-TS, and 10/1GBASE-PRX, which do not support loopback.

45.2.1.4 PMA/PMD speed ability (Register 1.4)

Change Table 45-6 as follows (the entire table is not shown):

Table 45–6—PMA/PMD speed ability register bit definitions

Bit(s)	Name	Description	R/W[a]
1.4.15:~~7~~8	Reserved for future speeds	Value always 0, writes ignored	RO
1.4.7	10/1G capable	1 = PMA/PMD is capable of operating at 10 Gb/s downstream and 1 Gb/s upstream 0 = PMA/PMD is not capable of operating at 10 Gb/s downstream and 1 Gb/s upstream.	RO
1.4.6	10M capable	1 = PMA/PMD is capable of operating at 10 Mb/s 0 = PMA/PMD is not capable of operating as 10 Mb/s	RO

[a]RO = Read only

Insert new subclause 45.2.1.4.1 as below renumbering remaining subclauses:

45.2.1.4.1 10/1G capable (1.4.7)

When read as a one, bit 1.4.7 indicates that the PMA/PMD is able to operate at a data rate of 10 Gb/s in the downstream direction and 1 Gb/s in the upstream direction. When read as a zero, bit 1.4.7 indicates that the PMA/PMD is not able to operate at a data rate of 10 Gb/s in the downstream direction and 1 Gb/s in the upstream direction.

Change Table 45-7 as follows:

45.2.1.6 PMA/PMD control 2 register (Register 1.7)

Table 45–7—PMA/PMD control 2 register bit definitions

Bit(s)	Name	Description	R/W[a]
1.7.15:~~4~~5	Reserved	Value always 0, writes ignored	R/W
1.7.~~3~~4:0	PMA/PMD type selection	4 3 2 1 0 1 1 1 x x = reserved 1 1 0 1 1 = reserved 1 1 0 1 0 = 10GBASE-PR-U3 1 1 0 0 1 = 10GBASE-PR-U1 1 1 0 0 0 = 10/1GBASE-PRX-U3 1 0 1 1 1 = 10/1GBASE-PRX-U2 1 0 1 1 0 = 10/1GBASE-PRX-U1 1 0 1 0 1 = 10GBASE-PR-D3 1 0 1 0 0 = 10GBASE-PR-D2 1 0 0 1 1 = 10GBASE-PR-D1 1 0 0 1 0 = 10/1GBASE-PRX-D3 1 0 0 0 1 = 10/1GBASE-PRX-D2 1 0 0 0 0 = 10/1GBASE-PRX-D1 0 1 1 1 1 = 10BASE-T PMA/PMD ~~type~~ 0 1 1 1 0 = 100BASE-TX PMA/PMD ~~type~~ 0 1 1 0 1 = 1000BASE-KX PMA/PMD ~~type~~ 0 1 1 0 0 = 1000BASE-T PMA/PMD ~~type~~ 0 1 0 1 1 = 10GBASE-KR PMA/PMD ~~type~~ 0 1 0 1 0 = 10GBASE-KX4 PMA/PMD ~~type~~ 0 1 0 0 1 = 10GBASE-T PMA ~~type~~ 0 1 0 0 0 = 10GBASE-LRM PMA/PMD ~~type~~ 0 0 1 1 1 = 10GBASE-SR PMA/PMD ~~type~~ 0 0 1 1 0 = 10GBASE-LR PMA/PMD ~~type~~ 0 0 1 0 1 = 10GBASE-ER PMA/PMD ~~type~~ 0 0 1 0 0 = 10GBASE-LX4 PMA/PMD ~~type~~ 0 0 0 1 1 = 10GBASE-SW PMA/PMD ~~type~~ 0 0 0 1 0 = 10GBASE-LW PMA/PMD ~~type~~ 0 0 0 0 1 = 10GBASE-EW PMA/PMD ~~type~~ 0 0 0 0 0 = 10GBASE-CX4 PMA/PMD ~~type~~	R/W

[a]R/W = Read/Write

45.2.1.6.1 PMA/PMD type selection (1.7.~~3~~4:0)

The PMA/PMD type of the PMA/PMD shall be selected using bits ~~3 through~~ 4 to 0.

45.2.1.10 PMA/PMD extended ability register (Register 1.11)

Change Table 45–11 as follows:

Table 45–11—PMA/PMD Extended ability register bit definitions

Bit(s)	Name	Description	R/W[a]
1.11.15:10 ~~9~~	Reserved	Ignore on read	RO
1.11.9	P2MP ability	1 = PMA/PMD has P2MP abilities listed in register 1.12 0 = PMA/PMD does not have P2MP abilities	RO
1.11.8	10BASE-T ability	1 = PMA/PMD is able to perform 10BASE-T 0 = PMA/PMD is not able to perform 10BASE-T	RO
1.11.7	100BASE-TX ability	1 = PMA/PMD is able to perform 100BASE-TX 0 = PMA/PMD is not able to perform 100BASE-TX	RO
1.11.6	1000BASE-KX ability	1 = PMA/PMD is able to perform 1000BASE-KX 0 = PMA/PMD is not able to perform 1000BASE-KX	RO
1.11.5	1000BASE-T ability	1 = PMA/PMD is able to perform 1000BASE-T 0 = PMA/PMD is not able to perform 1000BASE-T	RO
1.11.4	10GBASE-KR ability	1 = PMA/PMD is able to perform 10GBASE-KR 0 = PMA/PMD is not able to perform 10GBASE-KR	RO
1.11.3	10GBASE-KX4 ability	1 = PMA/PMD is able to perform 10GBASE-KX4 0 = PMA/PMD is not able to perform 10GBASE-KX4	RO
1.11.2	10GBASE-T ability	1 = PMA/PMD is able to perform 10GBASE-T 0 = PMA/PMD is not able to perform 10GBASE-T	RO
1.11.1	10GBASE-LRM ability	1 = PMA/PMD is able to perform 10GBASE-LRM 0 = PMA/PMD is not able to perform 10GBASE-LRM	RO
1.11.0	10GBASE-CX4 ability	1 = PMA/PMD is able to perform 10GBASE-CX4 0 = PMA/PMD is not able to perform 10GBASE-CX4	RO

[a]RO = Read only

Insert the following new subclause prior to 45.2.1.10.1 and renumber remaining subclauses in 45.2.1.10 as appropriate:

45.2.1.10.1 P2MP ability (1.11.9)

When read as a one, bit 1.11.9 indicates that the PMA/PMD has P2MP abilities listed in register 1.12. When read as a zero, bit 1.11.9 indicates that the PMA/PMD does not have P2MP abilities.

Insert new subclause 45.2.1.11 and Table 45-12 as follows; renumber succeeding paragraphs and tables.

45.2.1.11 10G-EPON PMA/PMD ability register (Register 1.12)

The assignment of bits in the 10G-EPON PMA/PMD ability register is shown in Table 45–12. All of the bits in the 10G-EPON PMA/PMD ability register are read only; a write to the 10G-EPON PMA/PMD ability register shall have no effect.

Table 45–12—10G-EPON PMA/PMD ability register bit definitions

Bit(s)	Name	Description	R/W[a]
1.12.15:11	Reserved	Ignore on read	RO
1.12.10	10/1GBASE-PRX-D1 ability	1 = PMA/PMD is able to perform 10/1GBASE-PRX-D1 0 = PMA/PMD is not able to perform 10/1GBASE-PRX-D1	RO
1.12.9	10/1GBASE-PRX-D2 ability	1 = PMA/PMD is able to perform 10/1GBASE-PRX-D2 0 = PMA/PMD is not able to perform 10/1GBASE-PRX-D2	RO
1.12.8	10/1GBASE-PRX-D3 ability	1 = PMA/PMD is able to perform 10/1GBASE-PRX-D3 0 = PMA/PMD is not able to perform 10/1GBASE-PRX-D3	RO
1.12.7	10GBASE-PR-D1 ability	1 = PMA/PMD is able to perform 10GBASE-PR-D1 0 = PMA/PMD is not able to perform 10GBASE-PR-D1	RO
1.12.6	10GBASE-PR-D2 ability	1 = PMA/PMD is able to perform 10GBASE-PR-D2 0 = PMA/PMD is not able to perform 10GBASE-PR-D2	RO
1.12.5	10GBASE-PR-D3 ability	1 = PMA/PMD is able to perform 10GBASE-PR-D3 0 = PMA/PMD is not able to perform 10GBASE-PR-D3	RO
1.12.4	10/1GBASE-PRX-U1 ability	1 = PMA/PMD is able to perform 10/1GBASE-PRX-U1 0 = PMA/PMD is not able to perform 10/1GBASE-PRX-U1	RO
1.12.3	10/1GBASE-PRX-U2 ability	1 = PMA/PMD is able to perform 10/1GBASE-PRX-U2 0 = PMA/PMD is not able to perform 10/1GBASE-PRX-U2	RO
1.12.2	10/1GBASE-PRX-U3 ability	1 = PMA/PMD is able to perform 10/1GBASE-PRX-U3 0 = PMA/PMD is not able to perform 10/1GBASE-PRX-U3	RO
1.12.1	10GBASE-PR-U1 ability	1 = PMA/PMD is able to perform 10GBASE-PR-U1 0 = PMA/PMD is not able to perform 10GBASE-PR-U1	RO
1.12.0	10GBASE-PR-U3 ability	1 = PMA/PMD is able to perform 10GBASE-PR-U3 0 = PMA/PMD is not able to perform 10GBASE-PR-U3	RO

[a]RO = Read only

45.2.1.11.1 10/1GBASE-PRX-D1 ability (1.12.10)

When read as a one, bit 1.12.10 indicates that the PMA/PMD is able to operate as a 10/1GBASE-PRX-D1 PMA/PMD type. When read as a zero, bit 1.12.10 indicates that the PMA/PMD is not able to operate as a 10/1GBASE-PRX-D1 PMA/PMD type.

45.2.1.11.2 10/1GBASE-PRX-D2 ability (1.12.9)

When read as a one, bit 1.12.9 indicates that the PMA/PMD is able to operate as a 10/1GBASE-PRX-D2 PMA/PMD type. When read as a zero, bit 1.12.9 indicates that the PMA/PMD is not able to operate as a 10/1GBASE-PRX-D2 PMA/PMD type.

45.2.1.11.3 10/1GBASE-PRX-D3 ability (1.12.8)

When read as a one, bit 1.12.8 indicates that the PMA/PMD is able to operate as a 10/1GBASE-PRX-D3 PMA/PMD type. When read as a zero, bit 1.12.8 indicates that the PMA/PMD is not able to operate as a 10/1GBASE-PRX-D3 PMA/PMD type.

45.2.1.11.4 10GBASE-PR-D1 ability (1.12.7)

When read as a one, bit 1.12.7 indicates that the PMA/PMD is able to operate as a 10GBASE-PR-D1 PMA/PMD type. When read as a zero, bit 1.12.7 indicates that the PMA/PMD is not able to operate as a 10GBASE-PR-D1 PMA/PMD type.

45.2.1.11.5 10GBASE-PR-D2 ability (1.12.6)

When read as a one, bit 1.12.6 indicates that the PMA/PMD is able to operate as a 10GBASE-PR-D2 PMA/PMD type. When read as a zero, bit 1.12.6 indicates that the PMA/PMD is not able to operate as a 10GBASE-PR-D2 PMA/PMD type.

45.2.1.11.6 10GBASE-PR-D3 ability (1.12.5)

When read as a one, bit 1.12.5 indicates that the PMA/PMD is able to operate as a 10GBASE-PR-D3 PMA/PMD type. When read as a zero, bit 1.12.5 indicates that the PMA/PMD is not able to operate as a 10GBASE-PR-D3 PMA/PMD type.

45.2.1.11.7 10/1GBASE-PRX-U1 ability (1.12.4)

When read as a one, bit 1.12.4 indicates that the PMA/PMD is able to operate as a 10/1GBASE-PRX-U1 PMA/PMD type. When read as a zero, bit 1.12.4 indicates that the PMA/PMD is not able to operate as a 10/1GBASE-PRX-U1 PMA/PMD type.

45.2.1.11.8 10/1GBASE-PRX-U2 ability (1.12.3)

When read as a one, bit 1.12.3 indicates that the PMA/PMD is able to operate as a 10/1GBASE-PRX-U2 PMA/PMD type. When read as a zero, bit 1.12.3 indicates that the PMA/PMD is not able to operate as a 10/1GBASE-PRX-U2 PMA/PMD type.

45.2.1.11.9 10/1GBASE-PRX-U3 ability (1.12.2)

When read as a one, bit 1.12.2 indicates that the PMA/PMD is able to operate as a 10/1GBASE-PRX-U3 PMA/PMD type. When read as a zero, bit 1.12.2 indicates that the PMA/PMD is not able to operate as a 10/1GBASE-PRX-U3 PMA/PMD type.

45.2.1.11.10 10GBASE-PR-U1 ability (1.12.1)

When read as a one, bit 1.12.1 indicates that the PMA/PMD is able to operate as a 10GBASE-PR-U1 PMA/PMD type. When read as a zero, bit 1.12.1 indicates that the PMA/PMD is not able to operate as a 10GBASE-PR-U1 PMA/PMD type.

45.2.1.11.11 10GBASE-PR-U3 ability (1.12.0)

When read as a one, bit 1.12.0 indicates that the PMA/PMD is able to operate as a 10GBASE-PR-U3 PMA/PMD type. When read as a zero, bit 1.12.0 indicates that the PMA/PMD is not able to operate as a 10GBASE-PR-U3 PMA/PMD type.

45.2.3 PCS registers

Change last rows of Table 45-82:

Register address	Register name
3.74	10GBASE-PR and 10/1GBASE-PRX FEC ability register
3.75	10GBASE-PR and 10/1GBASE-PRX FEC control register
3.76, 3.77	10/1GBASE-PRX and 10GBASE-PR corrected FEC codewords counter
3.78, 3.79	10/1GBASE-PRX and 10GBASE-PR uncorrected FEC codewords counter
3.80	10GBASE-PR and 10/1GBASE-PRX BER monitor timer control
3.81	10GBASE-PR and 10/1GBASE-PRX BER monitor status
3.82	10GBASE-PR and 10/1GBASE-PRX BER monitor threshold control
~~3.74~~ 3.83 through 3.32 767	Reserved
3.32 768 through 3.65 535	Vendor specific

Change row 8 (not including header) of Table 45-83 as follows:

3.0.5:2	Speed selection	5 4 3 2 1 x x x = Reserved x 1 x x = Reserved x x 1 ~~x~~1 = Reserved 0 0 1 0 = 10/1 Gb/s 0 0 0 1 = 10PASS-TS/2BASE-TL 0 0 0 0 = 10 Gb/s	R/W

Insert the following new subclause after subclause 45.2.3.28:

45.2.3.29 10GBASE-PR and 10/1GBASE-PRX FEC ability register (Register 3.74)

The assignment of bits in the 10GBASE-PR and 10/1GBASE-PRX FEC ability register is shown in Table 45–107.

Table 45–107—10GBASE-PR and 10/1GBASE-PRX FEC ability register bit definitions

Bit(s)	Name	Description	R/W[a]
3.74.15:1	Reserved	Value always zero, writes ignored	RO
3.74.0	10 Gb/s FEC ability	A read of 1 in this bit indicates that the PCS supports the 10/1GBASE-PRX or 10GBASE-PR 10 Gb/s FEC (always reads as 1 for 10/1GBASE-PRX or 10GBASE-PR).	RO

[a]RO = Read only

45.2.3.30 10GBASE-PR and 10/1GBASE-PRX FEC control register (Register 3.75)

The assignment of bits in the 10GBASE-PR FEC control register is shown in Table 45–108.

Table 45–108—10GBASE-PR and 10/1GBASE-PRX FEC control register bit definitions

Bit(s)	Name	Description	R/W[a]
3.75.15:2	Reserved	Value always zero, writes ignored	RO
3.75.1	Enable FEC error indication	A write of 1 to this bit configures the 10 Gb/s FEC decoder to indicate uncorrectable codeword errors to the higher layer. In a 10/1GBASE-PRX OLT, this bit is undefined.	R/W
3.75.0	10 Gb/s FEC enable	Always reads as 1 for 10/1GBASE-PRX or 10GBASE-PR since 10 Gb/s FEC is always enabled	RO

[a]RO = Read only, R/W = Read/Write

45.2.3.30.1 FEC enable error indication (3.75.1)

This bit instructs the 10 Gb/s FEC decoder component of the 10GBASE-PR and 10/1GBASE-PRX PCS to indicate decoding errors to the upper layers (see 45.2.3.30 and 76.3.3.3).

When written as a one, the receiving PCS invalidates 66 bit blocks received in uncorrectable FEC codewords. As a consequence, the receiving MAC discards any packet which includes data that was received in an uncorrectable FEC codeword (even though the packet itself might or might not contain errors).

When written as a zero, the receiving PCS does not modify 66 bit blocks received in uncorrectable FEC codewords. As a consequence, the receiving MAC performs regular processing on a packet that includes data that was received in an uncorrectable FEC codeword (though the packet itself may contain errors which might or might not be detected by the MAC FCS)

45.2.3.30.2 10 Gb/s FEC Enable (3.75.0)

This bit indicates whether 10 Gb/s FEC is enabled in the 10GBASE-PR and 10/1GBASE-PRX PCS and always reads as one.

The register for enabling and disabling forward error correction in the 10/1GBASE-PRX upstream is specified in 45.2.8.3.

45.2.3.31 10/1GBASE-PRX and 10GBASE-PR corrected FEC codewords counter (Register 3.76, 3.77)

The assignment of bits in the 10/1GBASE-PRX and 10GBASE-PR corrected FEC codewords counter register is shown in Table 45–109. See 76.3.3.3.2 for a definition of this counter. These bits shall be reset to all zeros when the register is read by the management function or upon PCS reset. These bits shall be held at all ones in the case of overflow.

Table 45–109—10GBASE-PR corrected FEC codewords counter register bit definitions

Bit(s)	Name	Description	R/W[a]
3.76.15:0	corrected FEC codewords lower	corrected_FEC_codewords_counter[15:0]	RO, MW, NR
3.77.15:0	corrected FEC codewords upper	corrected_FEC_codewords_counter[31:16]	RO, MW, NR

[a]RO = Read only, MW = Multi-word, NR = Non Roll-over

45.2.3.32 10/1GBASE-PRX and 10GBASE-PR uncorrected FEC codewords counter (Register 3.78, 3.79)

The assignment of bits in the 10/1GBASE-PRX and 10GBASE-PR uncorrected FEC codewords counter register is shown in Table 45–110. See 76.3.3.3.2 for a definition of this counter. These bits shall be reset to all zeros when the register is read by the management function or upon PCS reset. These bits shall be held at all ones in the case of overflow.

Table 45–110—10GBASE-PR uncorrected FEC codewords counter register bit definitions

Bit(s)	Name	Description	R/W[a]
3.78.15:0	uncorrected FEC codewords lower	uncorrected_FEC_codewords_counter[15:0]	RO, MW, NR
3.79.15:0	uncorrected FEC codewords lower	uncorrected_FEC_codewords_counter[32:16]	RO, MW, NR

[a]RO = Read only, MW = Multi-word, NR = Non Roll-over

45.2.3.33 10GBASE-PR and 10/1GBASE-PRX BER monitor timer control register (Register 3.80)

The assignment of bits in the 10GBASE-PR and 10/1GBASE-PRX BER monitor timer control register is shown in Table 45–111. This register is defined only when 10GBASE-PR or 10/1GBASE-PRX ONU capability is supported. The 10G-EPON BER monitor is described in 76.3.3.4.

Table 45–111—10GBASE-PR and 10/1GBASE-PRX BER monitor timer control register bit definitions

Bit(s)	Name	Description	R/W[a]
3.80.7:0	10G-EPON BER monitor timer	Duration (in units of 5 microseconds) of the timer used by the 10G-EPON BER monitor function. Default value is 25 (i.e., 125 microseconds). A value of 0 indicates that the BER monitor function is disabled.	R/W

[a]R/W = Read/Write

45.2.3.34 10GBASE-PR and 10/1GBASE-PRX BER monitor status (Register 3.81)

The assignments of bits in the 10GBASE-PR and 10/1GBASE-PRX BER monitor status register is shown in Table 45–112. This register is defined only when 10GBASE-PR or 10/1GBASE-PRX ONU capability is supported.

Table 45–112—10GBASE-PR and 10/1GBASE-PRX BER monitor status Register

Bit(s)	Name	Description	R/W[a]
3.81.7:2	Reserved	Value always zero, writes ignored	RO
3.81.1	Latched high BER	1 = 10GBASE-PR or 10/1GBASE-PRX PCS reported a high BER. 0 = 10GBASE-PR or 10/1GBASE-PRX PCS did not report a high BER.	RO, LH
3.81.0	high BER	1 = 10GBASE-PR or 10/1GBASE-PRX PCS reporting a high BER. 0 = 10GBASE-PR or 10/1GBASE-PRX PCS not reporting a high BER.	RO

[a]RO Read only, LH = Latching high

45.2.3.34.1 10GBASE-PR and 10/1GBASE-PRX PCS high BER (3.81.0)

In the 10GBASE-PR and 10/1GBASE-PRX PCS, when read as a one, bit 3.81.0 indicates that the receiver is detecting a BER greater than the configurable threshold (high BER state). When read as a zero, bit 3.81.0 indicates that the receiver is detecting a BER lower than the configurable threshold (low BER state). This bit mirrors the state of the hi_ber variable, defined in 76.3.3.4.

45.2.3.34.2 10GBASE-PR and 10/1GBASE-PRX PCS latched high BER (3.81.1)

In the 10GBASE-PR and 10/1GBASE-PRX PCS, when read as a one, bit 3.81.1 indicates that the receiver detected a BER greater than the configurable threshold (high BER state). When read as a zero, bit 3.81.1 indicates that the receiver detected BER lower than the configurable threshold (low BER state).

This bit is a latching high version of the 10GBASE-PR and 10/1GBASE-PRX high BER status bit (3.81.0).

45.2.3.35 10GBASE-PR and 10/1GBASE-PRX BER monitor threshold control (Register 3.82)

The assignment of bits in the 10GBASE-PR and 10/1GBASE-PRX BER monitor threshold control register is shown in Table 45–113. This register is defined only when 10GBASE-PR or 10/1GBASE-PRX ONU capability is supported. The 10G-EPON BER monitor is described in 76.3.3.4.

Table 45–113—10GBASE-PR and 10/1GBASE-PRX BER monitor threshold control register bit definitions

Bit(s)	Name	Description	R/W[a]
3.82.15:0	10G-EPON BER monitor threshold	Number of sync header errors within a timer interval that triggers a high BER condition for the 10G-EPON BER monitor function. Default value is 1600. A value of 0 indicates that the BER monitor function is disabled.	R/W

[a]R/W = Read/Write

45.5 Protocol implementation conformance statement (PICS) proforma for Clause 45, MDIO interface

Insert the following row at the end of table 45.5.3.3 PMA/PMD management functions:

Item	Feature	Subclause	Value/Comment	Status	Support
MM119	Writes to this register have no effect	45.2.1.11		PMA:M	Yes [ ] No [ ] N/A [ ]

Insert the following row at the end of table 45.5.3.6 PCS options:

Item	Feature	Subclause	Value/Comment	Status	Support
*CPR	Implementation of 10GBASE-PR or 10/1GBASE-PRX PCS	45.2.3		PCS:O	Yes [ ] No [ ] N/A [ ]

Insert the following rows at the end of table 45.5.3.7 PCS management functions:

Item	Feature	Subclause	Value/Comment	Status	Support
RM79	corrected FEC codeword counter is reset when read or upon PHY reset.	45.2.3.31		CPR:M	Yes [ ] No [ ] N/A [ ]
RM80	corrected FEC codeword counter is held at all ones in the case of overflow	45.2.3.31		CPR:M	Yes [ ] No [ ] N/A [ ]
RM81	uncorrected FEC codeword counter is reset when read or upon PHY reset.	45.2.3.32		CPR:M	Yes [ ] No [ ] N/A [ ]
RM82	uncorrected FEC codeword counter is held at all ones in the case of overflow	45.2.3.32		CPR:M	Yes [ ] No [ ] N/A [ ]

56. Introduction to Ethernet for subscriber access networks

56.1 Overview

Change the first paragraphs as follows:

Ethernet for subscriber access networks, also referred to as “Ethernet in the First Mile,” or EFM, combines a minimal set of extensions to the IEEE 802.3 Media Access Control (MAC) and MAC Control sublayers with a family of Physical Layers. These Physical Layers include optical fiber and voice grade copper cable Physical Medium Dependent sublayers (PMDs) for point-to-point (P2P) connections in subscriber access networks. EFM also introduces the concept of Ethernet Passive Optical Networks (EPONs), in which a point-to-multipoint (P2MP) network topology is implemented with passive optical splitters, along with extensions to the MAC Control sublayer and Reconciliation Sublayer as well as optical fiber PMDs to support this topology. In addition, a mechanism for network Operations, Administration, and Maintenance (OAM) is included to facilitate network operation and troubleshooting. 100BASE-LX10 extends the reach of 100BASE-X to achieve 10 km over conventional single-mode two-fiber cabling. The relationships between these EFM elements and the ISO/IEC Open System Interconnection (OSI) reference model are shown in Figure 56–1 for point-to-point topologies, ~~and~~ Figure 56–2 for 1G-EPON ~~point-to-multipoint~~ topologies, Figure 56-3 for 10/10G-EPON topologies, and Figure 56–4 for 10/1G-EPON topologies.

An important characteristic of EFM is that only full duplex links are supported. A simplified full duplex MAC is defined in Annex 4A for use in EFM networks. P2MP applications use this simplified full duplex MAC. EFM Copper applications may use either this simplified full duplex MAC or the Clause 4 MAC operating in half duplex mode as described in 61.1.4.1.2. All other EFM P2P applications may use either this simplified full duplex MAC or the Clause 4 MAC operating in full duplex mode.

The EFM architecture is extended in Clause 75 and Clause 76 by the addition of 10G–EPON. 10G–EPON includes the 10/10G-EPON (10 Gb/s downstream and 10 Gb/s upstream) as well as 10/1G-EPON (10 Gb/s downstream and 1 Gb/s upstream) PONs.

Replace Figure 56-2 with the following:

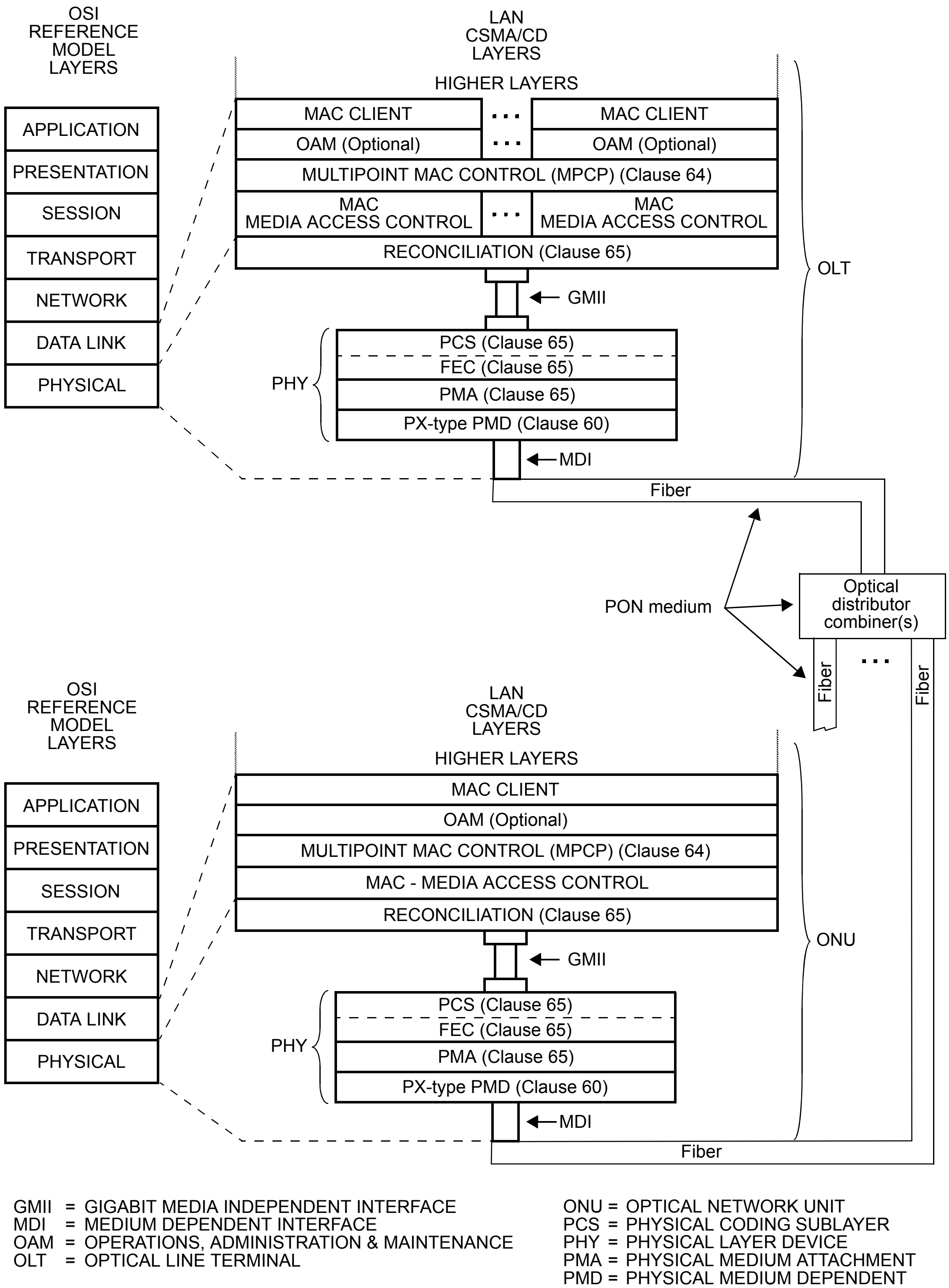
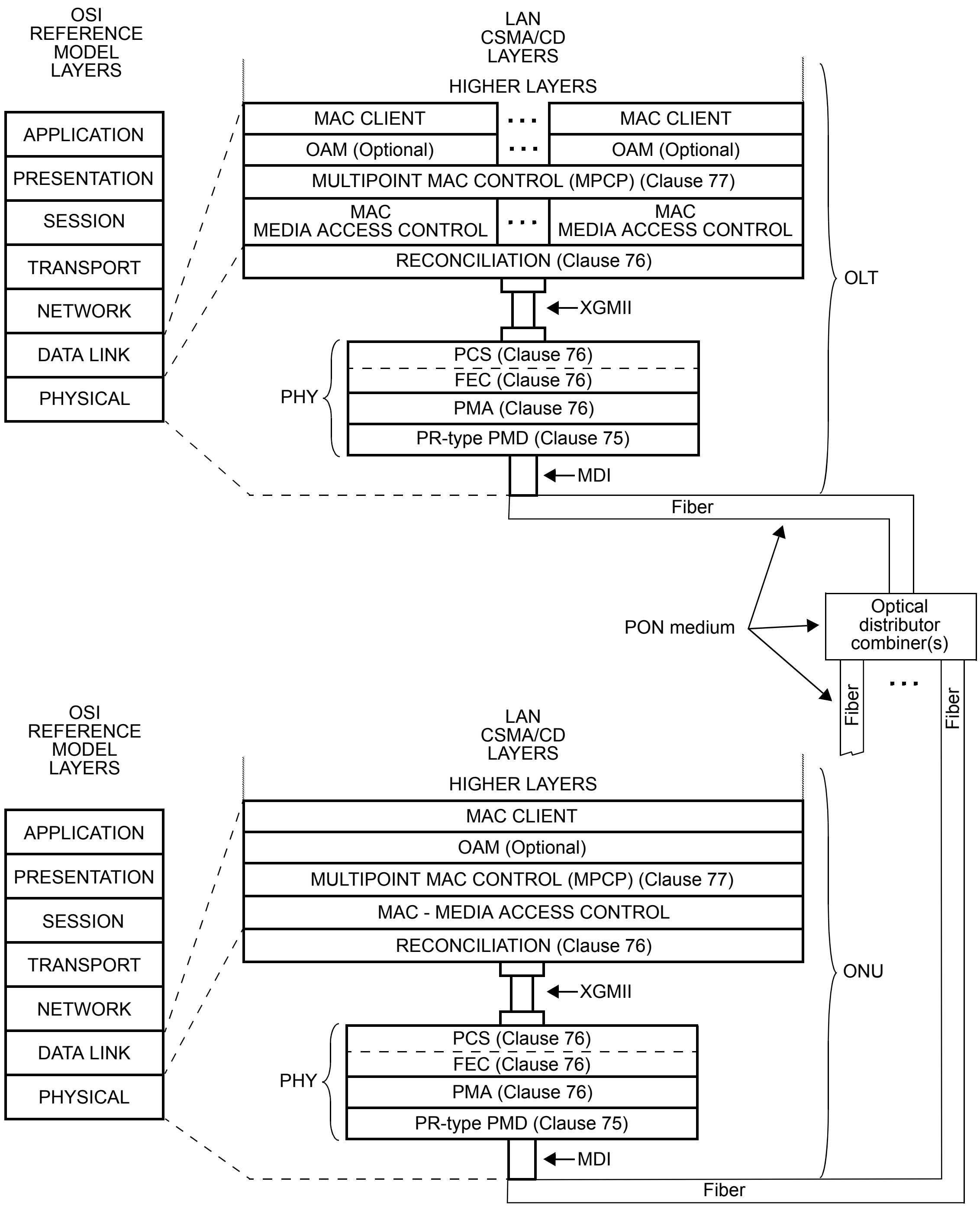


Figure 56–2—Architectural positioning of EFM: P2MP 1G-EPON architecture (1 Gb/s downstream, 1 Gb/s upstream)

Insert Figure 56-3 and 56-4, renumbering subsequent figures as appropriate.



XGMII= 10 GIGABIT MEDIA INDEPENDENT INTERFACE
MDI = MEDIUM DEPENDENT INTERFACE
OAM = OPERATIONS, ADMINISTRATION & MAINTENANCE
OLT = OPTICAL LINE TERMINAL
ONU = OPTICAL NETWORK UNIT
PCS = PHYSICAL CODING SUBLAYER
PHY = PHYSICAL LAYER DEVICE
PMA = PHYSICAL MEDIUM ATTACHMENT
PMD = PHYSICAL MEDIUM DEPENDENT

Figure 56–3—Architectural positioning of EFM: P2MP 10/10G–EPON architecture (10 Gb/s downstream, 10 Gb/s upstream)

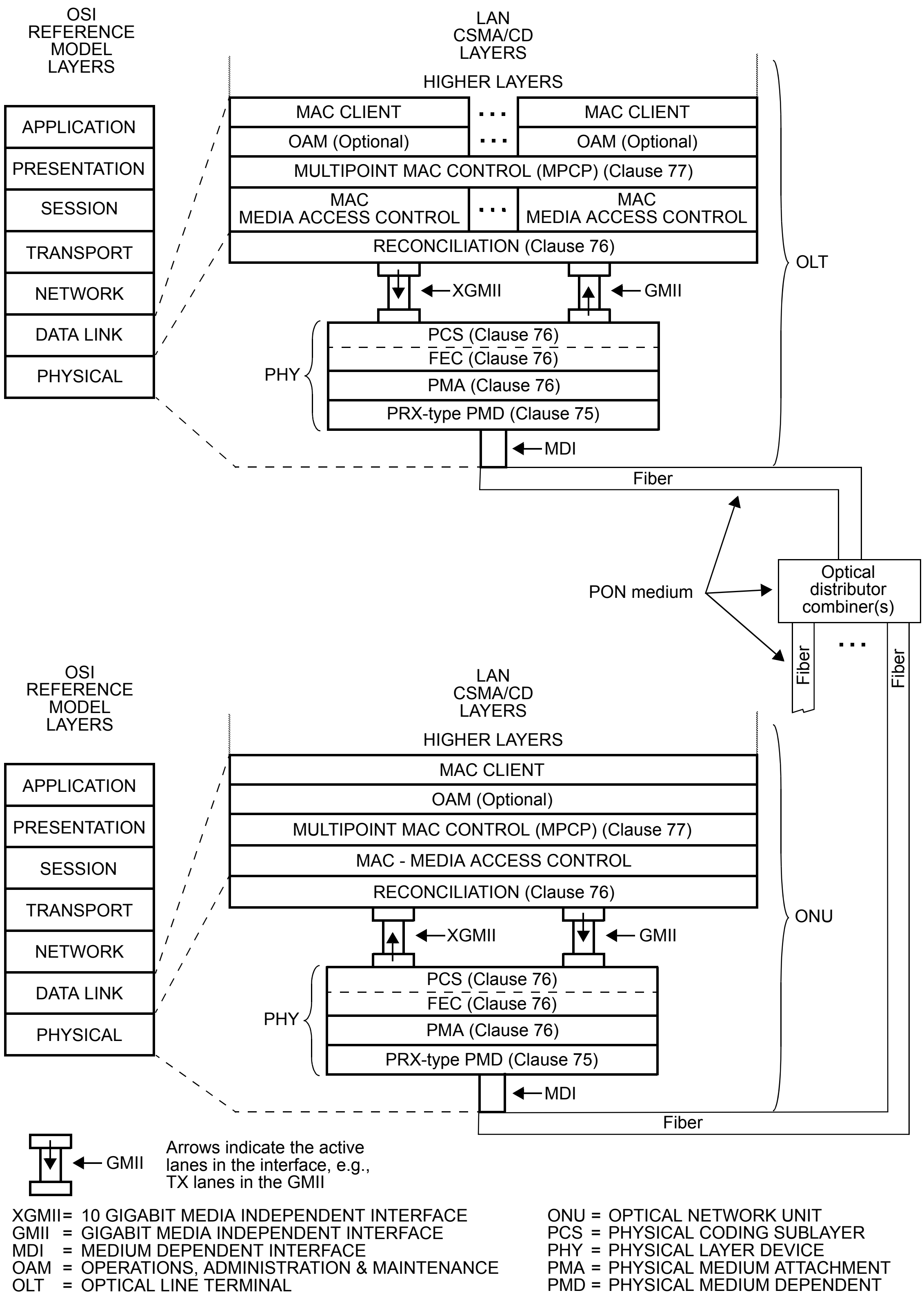


Figure 56–4—Architectural positioning of EFM: P2MP 10/1G–EPON architecture (10 Gb/s downstream, 1 Gb/s upstream)

Change 56.1.2 as follows:

56.1.2 Summary of P2MP sublayers

~~For P2MP optical fiber topologies, EFM supports a nominal bit rate of 1000 Mb/s, shared amongst the population of Optical Network Units (ONUs) attached to the P2MP topology. The P2MP PHYs use the 1000BASE-X Physical Coding Sublayer (PCS), the Physical Medium Attachment (PMA) sublayer defined in Clause 65, and an optional FEC function defined in Clause 65.~~

For P2MP optical fiber topologies, EFM supports two systems:

a) PON with a nominal bit rate of 1000 Mb/s in both downstream and upstream directions (1G-EPON), shared amongst the population of Optical Network Units (ONUs) attached to the P2MP topology. The P2MP PHYs use the 1000BASE-PX Physical Coding Sublayer (PCS), the Physical Medium Attachment (PMA) sublayer defined in Clause 65 and an optional forward error correction (FEC) function defined in Clause 65.

b) PON with a nominal bit rate of 10 Gb/s in both the downstream and upstream directions (10/10G–EPON) as well as PON with a nominal bit rate of 10 Gb/s in the downstream direction and 1 Gb/s in the upstream direction (10/1G–EPON), shared amongst the population of ONUs attached to the P2MP topology. The P2MP PHYs for the 10/10G–EPON use the 10GBASE-PR PCS and PMA (see Clause 75). The P2MP PHYs for 10/1G-EPON use the 10GBASE-PRX PCS and PMA (see Clause 76). EPONs using a nominal 10 Gb/s bit rate use a mandatory FEC function defined in Clause 76 in any direction running at the 10 Gb/s bit rate.

56.1.2.1 Multipoint MAC Control Protocol (MPCP)

The Multipoint MAC Control Protocol (MPCP) for 1G-EPON uses messages, state diagrams, and timers, as defined in Clause 64, to control access to a P2MP topology, while Clause 77 defines the messages, state diagrams, and timers required to control access to a P2MP topology in 10G-EPON. The issues related to coexistence of 1G-EPON and 10G-EPON on the same fiber plant are described in 77.4.

Every P2MP topology consists of one Optical Line Terminal (OLT) plus one or more ONUs, as shown in Figure 56–2, Figure 56–3 and Figure 56–4, for 1G-EPON, 10/10G-EPON and 10/1G-EPON, respectively. One of several instances of the MPCP in the OLT communicates with the instance of the MPCP in the ONU. A pair of MPCPs that communicate between the OLT and ONU are a distinct and associated pair.

56.1.2.2 Reconciliation Sublayer (RS) and media independent interfaces

The Clause 22 RS and MII, ~~and~~ Clause 35 RS and GMII, and Clause 46 RS and XGMII are ~~both~~ all employed for the same purpose in EFM, that being the interconnection between the MAC sublayer and the PHY sublayers. Extensions to the Clause 35 RS for P2MP topologies are described in Clause 65, while the RS for 10G-EPON P2MP topologies is described in Clause 76.

The combination of MPCP and the extension of the Reconciliation Sublayer (RS) for P2P Emulation allows an underlying P2MP network to appear as a collection of point-to-point links to the higher protocol layers (at and above the MAC Client).

The MPCP achieves this by ~~prepending~~ providing a Logical Link Identification (LLID) in ~~to the beginning of~~ each packet~~,~~ by replacing two octets of the preamble.

This is described in Clause 65 for EPON and in Clause 76 for 10G–EPON. EFM Copper links use the MII of Clause 22 operating at 100 Mb/s. This is described in 61.1.4.1.2.

56.1.3 Physical Layer signaling systems

Insert the following below the third paragraph:

Additionally, EFM introduces a family of Physical Layer signaling systems which are derived from 10GBASE–R, but which include RS, PCS and PMA sublayers adapted for 10G-EPON, along with a mandatory FEC capability, as defined in Clause 76. All of these systems employ the PMD defined in Clause 75. The family of P2MP Physical Layer signaling systems utilizes 10GBASE-R signaling for the downstream direction while supporting both 10GBASE-R and 1000BASE-X upstream signaling in the following series of PMD combinations:

a) 10GBASE–PR–D1 and 10GBASE–PR–U1, creating a PR10 power budget, with 10 Gb/s downstream and 10 Gb/s upstream data rates, supporting a reach of at least 10 km and a split ratio of at least 1:16.
b) 10GBASE–PR–D2 and 10GBASE–PR–U1, creating a PR20 power budget, with 10 Gb/s downstream and 10 Gb/s upstream data rates, supporting a reach of at least 20 km and a split ratio of at least 1:16 or the reach of at least 10 km and the split ratio of at least 1:32.
c) 10GBASE–PR–D3 and 10GBASE–PR–U3, creating a PR30 power budget, with 10 Gb/s downstream and 10 Gb/s upstream data rates, supporting a reach of at least 20 km and a split ratio of at least 1:32.
d) 10/1GBASE–PRX–D1 and 10/1GBASE–PRX–U1, creating a PRX10 power budget, with 10 Gb/s downstream and 1 Gb/s upstream data rates, supporting a reach of at least 10 km and a split ratio of at least 1:16.
e) 10/1GBASE–PRX–D2 and 10/1GBASE–PRX–U2, creating a PRX20 power budget, with 10 Gb/s downstream and 1 Gb/s upstream data rates, supporting a reach of at least 20 km and a split ratio of at least 1:16.
f) 10/1GBASE–PRX–D3 and 10/1GBASE–PRX–U3, creating a PRX30 power budget, with 10 Gb/s downstream and 1 Gb/s upstream data rates, supporting a reach of at least 20 km and a split ratio of at least 1:32.

All 10G–EPON PMDs are defined in Clause 75.

Change Table 56-1 as follows:

Table 56–1—Summary of EFM Physical Layer signaling systems

Name	Location	Rate [a] ~~(Mb/s)~~	Nominal reach (km)	Medium	Clause
100BASE-LX10	ONU/OLT [b]	100 Mb/s	10	Two single-mode fibers	58
100BASE-BX10-D	OLT	100 Mb/s	10	One single-mode fiber	58
100BASE-BX10-U	ONU				
1000BASE-LX10	ONU/OLT [b]	1000 Mb/s	10 0.55	Two single-mode fibers Two multimode fibers	59
1000BASE-BX10-D	OLT	1000 Mb/s	10	One single-mode fiber	59
1000BASE-BX10-U	ONU				
1000BASE-PX10-D	OLT	1000 Mb/s	10	One single-mode fiber PON	60
1000BASE-PX10-U	ONU				

Table 56–1—Summary of EFM Physical Layer signaling systems *(continued)*

1000BASE-PX20-D	OLT	1000 Mb/s	20	One single-mode fiber PON	60
1000BASE-PX20-U	ONU				
10/1GBASE-PRX-D1	OLT	10 Gb/s (tx) 1000 Mb/s (rx)	10	One single-mode fiber PON	75
10/1GBASE-PRX-U1	ONU	1000 Mb/s (tx) 10 Gb/s (rx)			
10/1GBASE-PRX-D2	OLT	10 Gb/s (tx) 1000 Mb/s (rx)	20	One single-mode fiber PON	75
10/1GBASE-PRX-U2	ONU	1000 Mb/s (tx) 10 Gb/s (rx)			
10/1GBASE-PRX-D3	OLT	10 Gb/s (tx) 1000 Mb/s (rx)	20	One single-mode fiber PON	75
10/1GBASE-PRX-U3	ONU	1000 Mb/s (tx) 10 Gb/s (rx)			
10GBASE-PR-D1	OLT	10 Gb/s	10	One single-mode fiber PON	75
10GBASE-PR-U1	ONU				
10GBASE-PR-D2	OLT	10 Gb/s	20	One single-mode fiber PON	75
10GBASE-PR-U2	ONU				
10GBASE-PR-D3	OLT	10 Gb/s	20	One single-mode fiber PON	75
10GBASE-PR-U3	ONU				
10PASS-TS-O	CO [c]	10 Mb/s [d]	0.75 [e]	One or more pairs of voice grade copper cable	62
10PASS-TS-R	Subscriber [c]				
2BASE-TL-O	CO [c]	2 Mb/s [f]	2.7 [g]	One or more pairs of voice grade copper cable	63
2BASE-TL-R	Subscriber [c]				

[a]For 10/1G-EPON Physical layer signaling systems transmit rate is denoted with the abbreviation “(tx)” to the location whereas the receive rate is denoted with the abbreviation “(rx)”.
[b]Symmetric
[c]In private networks, the network administrator ~~will~~ designates one end of each link as the network end.
[d]Nominal rate stated at the nominal reach. Rate may vary depending on plant. Refer to Annex 62B for more information.
[e]Reach may vary depending on plant. Refer to Annex 62B for further information.
[f]Nominal rate stated at the nominal reach. Rate may vary depending on plant. Refer to Annex 63B for more information.
[g]Reach may vary depending on plant. Refer to Annex 63B for further information.

Change paragraph below Table 56-1 as follows:

Table 56–2 specifies the correlation between nomenclature and clauses for P2P systems, while Table 56–3 specifies the correlation between nomenclature and clauses for P2MP systems. A complete implementation conforming to one or more nomenclatures meets the requirements of the corresponding clauses.

Change Table 56-2 as shown below (removing column 12 “P2MP MPMC”, column 13 “P2MP RS, PCS, PMA”, column 14” FEC, and last 4 rows).

Table 56–2—Nomenclature and clause correlation

Nomenclature	Clause														
	57	58		59		60		61	62	63	~~64~~	~~65~~		66	
	OAM	100BASE-LX10 PMD	100BASE-BX10 PMD	1000BASE-LX10 PMD	1000BASE-BX10 PMD	1000BASE-PX10 PMD	1000BASE-PX20 PMD	Cu PCS	10PASS-TS PMA & PMD	2BASE-TL PMA & PMD	~~P2MP MPMC~~	~~P2MP RS, PCS, PMA~~	~~FEC~~	100BASE-X PCS, PMA	1000BASE-X PCS, PMA
2BASE-TL	O[a]							M		M					
10PASS-TS	O							M	M						
100BASE-LX10	O	M												M	
100BASE-BX10	O		M											M	
1000BASE-LX10	O			M											M
1000BASE-BX10	O				M										M
~~1000BASE-PX10-D~~	~~O~~					~~M~~					~~M~~	~~M~~	~~O~~		~~M~~
~~1000BASE-PX10-U~~	~~O~~					~~M~~					~~M~~	~~M~~	~~O~~		
~~1000BASE-PX20-D~~	~~O~~						~~M~~				~~M~~	~~M~~	~~O~~		~~M~~
~~1000BASE-PX20-U~~	~~O~~						~~M~~				~~M~~	~~M~~	~~O~~		

[a]O = Optional, M = Mandatory

Insert Table 56-3 as follows and renumber remaining tables.

Table 56–3—Nomenclature and clause correlation for P2MP systems[a]

Nomenclature	Clause 57	Clause 60		Clause 64	Clause 65		Clause 66	Clause 75	Clause 76	Clause 77
	OAM	1000BASE-PX10 PMD	1000BASE-PX20 PMD	P2MP MPMC	P2MP RS, PCS, PMA	FEC	1000BASE-X PCS, PMA	10/1GBASE–PRX or 10GBASE-PR PMDs	P2MP RS, PCS, PMA, FEC	10G-EPON P2MP MPMC
1000BASE-PX10-D	O	M		M	M	O	M			
1000BASE-PX10-U	O	M		M	M	O				
1000BASE-PX20-D	O		M	M	M	O	M			
1000BASE-PX20-U	O		M	M	M	O				
10/1GBASE-PRX-D1	O			M				M	M	M
10/1GBASE-PRX-U1	O			M				M	M	M
10/1GBASE-PRX-D2	O			M				M	M	M
10/1GBASE-PRX-U2	O			M				M	M	M
10/1GBASE-PRX-D3	O			M				M	M	M
10/1GBASE-PRX-U3	O			M				M	M	M
10GBASE-PR-D1	O							M	M	M
10GBASE-PR-U1	O							M	M	M
10GBASE-PR-D2	O							M	M	M
10GBASE-PR-D3	O							M	M	M
10GBASE-PR-U3	O							M	M	M

[a]O = Optional, M = Mandatory

66. Extensions of the 10 Gb/s Reconciliation Sublayer (RS), 100BASE–X PHY, and 1000BASE–X PHY for unidirectional transport

Change title of subclause 66.3 by inserting "P2P" as shown below.

66.3 Modifications to the reconciliation sublayer (RS) for <u>P2P</u> 10 Gb/s operation

66.3.1 Overview

Change the paragraph by inserting "P2P" as follows:

This subclause specifies the 10 Gb/s RS for support of <u>P2P</u> subscriber access networks.

Insert new subclause 66.4 as follows. Renumber subsequent paragraphs as required.

66.4 Modifications to the RS for P2MP 10 Gb/s operation

66.4.1 Overview

This subclause specifies the 10 Gb/s RS for support of P2MP subscriber access networks.

66.4.2 Functional specifications

The 10 Gb/s RS for P2MP subscriber access networks shall conform to the requirements of the 10 Gb/s RS specified in Clause 46 with the following exception: The 10 Gb/s RS for P2MP subscriber access networks may have the ability to transmit data regardless of whether the PHY has determined that a valid link has been established. The following are the detailed changes to Clause 46 in order to support this additional ability.

66.4.2.1 Link fault signaling

The description of the link fault signaling functional specification is changed to include the contribution of the new unidirectional_enable variable. The second paragraph of 46.3.4 is changed to read (~~strikethroughs~~ show deleted text and <u>underscores</u> show inserted text):

Sublayers within the PHY are capable of detecting faults that render a link unreliable for communication. <u>The nature of the P2MP link allows for some of these fault conditions to be ignored.</u> Upon recognition of a fault condition a PHY sublayer indicates Local Fault status on the data path. When this Local Fault status reaches an RS, the RS <u>tests the unidirectional_enable variable. If this variable is FALSE, the RS</u> stops sending MAC data, and continuously generates ~~a Remote Fault status~~ <u>Idle control characters</u> on the transmit data path (possibly truncating a MAC frame being transmitted). <u>If this variable is TRUE, the RS continues to allow the transmissions of MAC data.</u> When Remote Fault status is received by an RS, the RS <u>tests the unidirectional_enable variable. If this variable is FALSE, the RS</u> stops sending MAC data, and continuously generates Idle control characters. <u>If this variable is TRUE, the RS continues to allow the transmission of MAC data.</u> When the RS no longer receives fault status messages, it returns to normal operation, sending MAC data.

66.4.2.2 Variables

Insert a new variable among those already described in 46.3.4.2:

unidirectional_enable
A control variable that enables the unidirectional mode of operation.

Values: FALSE; Unidirectional capability is not enabled
TRUE; Unidirectional capability is enabled

66.4.2.3 State Diagram

The description of what the RS outputs onto TXC<3:0> and TXD<31:0> is changed to include the contribution of the new unidirectional_enable variable. The lettered list of 46.3.4.3 is changed to read (~~strikethroughs~~ show deleted text and underscores show inserted text):

a) link_fault = OK
The RS shall send MAC frames as requested through the PLS service interface. In the absence of MAC frames, the RS shall generate Idle control characters.

b) link_fault = Local Fault
If unidirectional_enable = FALSE, t~~T~~he RS shall continuously generate Idle control characters~~Remote Fault Sequence ordered_sets~~.
If unidirectional_enable = TRUE, the RS shall send MAC frames as requested through the PLS service interface. In the absence of MAC frames, the RS shall generate Idle control characters.

c) link_fault = Remote Fault
If unidirectional_enable = FALSE, t~~T~~he RS shall continuously generate Idle control characters.
If unidirectional_enable = TRUE, the RS shall send MAC frames as requested through the PLS service interface. In the absence of MAC frames, the RS shall generate Idle control characters.

Change PICS subclause to number 66.5:

66.5 Protocol implementation conformance statement (PICS) proforma for Clause 66, Extensions of the 10 Gb/s Reconciliation Sublayer (RS), 100BASE–X PHY, and 1000BASE–X PHY for unidirectional transport

66.5.3 Major capabilities/options

Insert item to end of PICS (table heading shown for clarity):

Item	Feature	Subclause	Value/Comment	Status	Support
*XP2MP	10 Gb/s P2MP operation	66.4	Device supports 10 Gb/s P2MP operation	O	Yes [ ] No [ ]

Add "P2P" to subclause 66.5.4.4 title as follows:

66.5.4.4 Extensions of the 10 Gb/s P2P RS

Insert subclause 66.5.4.5 and table as follows:

66.5.4.5 Extensions of the 10 Gb/s P2MP RS

Item	Feature	Subclause	Value/Comment	Status	Support
PF1	Integrates 10 Gb/s P2MP RS	66.4.2	See Clause 76.	PUNI * XP2MP:M	Yes [ ]
PF2	link_fault = OK and MAC frames	66.4.2.3	RS services MAC frame transmission requests.	PUNI * XP2MP:M	Yes [ ] No [ ]
PF3	link_fault = OK and no MAC frames	66.4.2.3	In absence of MAC frames, RS transmits Idle control characters.	PUNI * XP2MP:M	Yes [ ] No [ ]
PF4	link_fault = Local Fault and unidirectional_enable = FALSE	66.4.2.3	RS transmits continuous Idle control characters.	PUNI * XP2MP:M	Yes [ ] No [ ]
PF5	link_fault = Local Fault and unidirectional_enable = TRUE and MAC frames	66.4.2.3	RS services MAC frame transmission requests.	PUNI * XP2MP:M	Yes [ ] No [ ]
PF6	link_fault = Local Fault and unidirectional_enable = TRUE and no MAC frames	66.4.2.3	In absence of MAC frames, RS transmits Idle control characters.	PUNI * XP2MP:M	Yes [ ] No [ ]
PF7	link_fault = Remote Fault and unidirectional_enable = FALSE	66.4.2.3	RS transmits continuous Idle control characters.	PUNI * XP2MP:M	Yes [ ] No [ ]
PF8	link_fault = Remote Fault and unidirectional_enable = TRUE and no MAC frames	66.4.2.3	RS services MAC frame transmission requests.	PUNI * XP2MP:M	Yes [ ] No [ ]
PF9	link_fault = Remote Fault and unidirectional_enable = TRUE and no MAC frames	66.4.2.3	In absence of MAC frames, RS transmits Idle control characters.	PUNI * XP2MP:M	Yes [ ] No [ ]

67. System considerations for Ethernet subscriber access networks

Change the second sentence in 67.6.3 as follows:

67.6.3 Link status signaling in P2MP networks

This is achieved by mapping the local_link_status parameter to variable 'registered' defined in 64.3.3.2 for 1 Gb/s P2MP links and in 77.3.3.2 for 10 Gb/s links as follows:

Insert the following new clauses and corresponding annexes after Clause 74:

75. Physical Medium Dependent (PMD) sublayer and medium for passive optical networks, type 10GBASE–PR and 10/1GBASE–PRX

75.1 Overview

Clause 75 describes Physical Medium dependent (PMD) sublayer for Ethernet Passive Optical Networks operating at the line rate of 10.3125 GBd in either downstream or in both downstream and upstream directions.

75.1.1 Terminology and conventions

The following list contains references to terminology and conventions used in Clause 75:

Basic terminology and conventions, see 1.1 and 1.2.

Normative references, see 1.3.

Definitions, see 1.4.

Abbreviations, see 1.5.

Informative references, see Annex A.

Introduction to 1000 Mb/s baseband networks, see Clause 34.

Introduction to 10 Gb/s baseband network, see Clause 44.

Introduction to Ethernet for subscriber access networks, see Clause 56.

EPONs operate over a point-to-multipoint (P2MP) topology, also called a tree or trunk-and-branch topology. The device connected at the root of the tree is called an Optical Line Terminal (OLT) and the devices connected as the leaves are referred to as Optical network Units (ONUs). The direction of transmission from the OLT to the ONUs is referred to as the *downstream* direction, while the direction of transmission from the ONUs to the OLT is referred to as the *upstream* direction.

75.1.2 Goals and objectives

The following are the PMD objectives fulfilled by Clause 75:

a) Support subscriber access networks using point-to-multipoint topologies on optical fiber.
b) Provide physical layer specifications:
   1) PHY for PON, 10 Gb/s downstream / 1 Gb/s upstream, on a single SMF
   2) PHY for PON, 10 Gb/s downstream / 10 Gb/s upstream, on a single SMF
c) PHY(s) to have a BER better than or equal to 10^{-12} at the PHY service interface.
d) Define up to three optical power budgets that support split ratios of at least 1:16 and at least 1:32, and distances of at least 10 km and at least 20 km.

75.1.3 Power budget classes

To support the above-stated objectives, Clause 75 defines the following three power budget classes:

— *Low power budget class* supports P2MP media channel insertion loss of ≤ 20 dB e.g., a PON with the split ratio of at least 1:16 and the distance of at least 10 km.

— *Medium power budget class* supports P2MP media channel insertion loss of ≤ 24 dB e.g., a PON with the split ratio of at least 1:16 and the distance of at least 20 km or a PON with the split ratio of at least 1:32 and the distance of at least 10 km.
— *High power budget class* supports P2MP media channel insertion loss of ≤ 29 dB e.g., a PON with the split ratio of at least 1:32 and the distance of at least 20 km.

75.1.4 Power budgets

Each power budget class is represented by PRX-type power budget and PR-type power budget as follows:

— PRX–type power budget describes asymmetric-rate PHY for PON operating at 10 Gb/s downstream and 1 Gb/s upstream over a single SMF [see objective b 1) in 75.1.2].
— PR–type power budget describes symmetric-rate PHY for PON operating at 10 Gb/s downstream and 10 Gb/s upstream over a single SMF [see objective b 2) in 75.1.2].

Each power budget is further identified with a numeric representation of its class, where a value of 10 represents low power budget, a value of 20 represents medium power budget, and a value of 30 represents high power budget. Thus, the following power budgets are defined in Clause 75:

— PRX10: asymmetric-rate, low power budget, compatible with PX10 power budget defined in Clause 60.
— PRX20: asymmetric-rate, medium power budget, compatible with PX20 power budget defined in Clause 60.
— PRX30: asymmetric-rate, high power budget.
— PR10: symmetric-rate, low power budget, compatible with PX10 power budget defined in Clause 60.
— PR20: symmetric-rate, medium power budget, compatible with PX20 power budget defined in Clause 60.
— PR30: symmetric-rate, high power budget.

Table 75–1 shows the primary attributes of all power budget types defined in Clause 75.

Table 75–1—Power budgets

Description	Low Power Budget		Medium Power Budget		High Power Budget		Units
	PRX10	PR10	PRX20	PR20	PRX30	PR30	
Number of fibers	1						–
Nominal downstream line rate	10.3125						GBd
Nominal upstream line rate	1.25	10.3125	1.25	10.3125	1.25	10.3125	GBd
Nominal downstream wavelength	1577						nm
Downstream wave-length tolerance	–2, +3						nm
Nominal upstream wavelength	1310	1270	1310	1270	1310	1270	nm
Upstream wavelength tolerance	±50	±10	±50	±10	±50	±10	nm
Maximum reach[a]	≥10		≥20		≥20		km
Maximum channel insertion loss	20		24		29		dB
Minimum channel insertion loss	5		10		15		dB

[a]A compliant system may exceed the maximum reach designed for given power budget as long as optical power budget and other mandatory optical layer specifications are met.

75.1.5 Positioning of PMD sublayer within the IEEE 802.3 architecture

Figure 75–1 and Figure 75–2 depict the relationships of the symmetric-rate (10/10G–EPON) and asymmetric-rate (10/1G–EPON) PMD sublayer (shown hatched) with other sublayers and the ISO/IEC Open System Interconnection (OSI) reference model.

75.2 PMD types

Similarly to power budget classes, asymmetric-rate and symmetric-rate PMDs are identified by PRX and PR designations, respectively.

The characteristics of the P2MP topology result in significantly different ONU and OLT PMDs. For example, the OLT PMD operates in a continuous mode in the transmit direction (downstream), but uses a burst mode in the receive direction (upstream). On the other hand, the ONU PMD receives data in a continuous mode, but transmits in a burst mode. To differentiate OLT PMDs from ONU PMDs, the OLT PMD name has a suffix “D” appended to it, where D stands for downstream–facing PMD, e.g., 10GBASE–PR–D1. ONU PMDs have suffix “U” for upstream–facing PMD, e.g., 10GBASE–PR–U1.

In the downstream direction, the signal transmitted by the D-type PMD is received by all U-type PMDs. In the upstream direction, the D-type PMD receives data bursts from each of the U-type PMDs.

Clause 75 defines several D-type and several U-type PMDs, that differ in their receive and/or transmit characteristics. Such PMDs are further distinguished by appending a digit after the suffix D or U, e.g., 10GBASE–PR–D1 or 10GBASE–PR–D2.

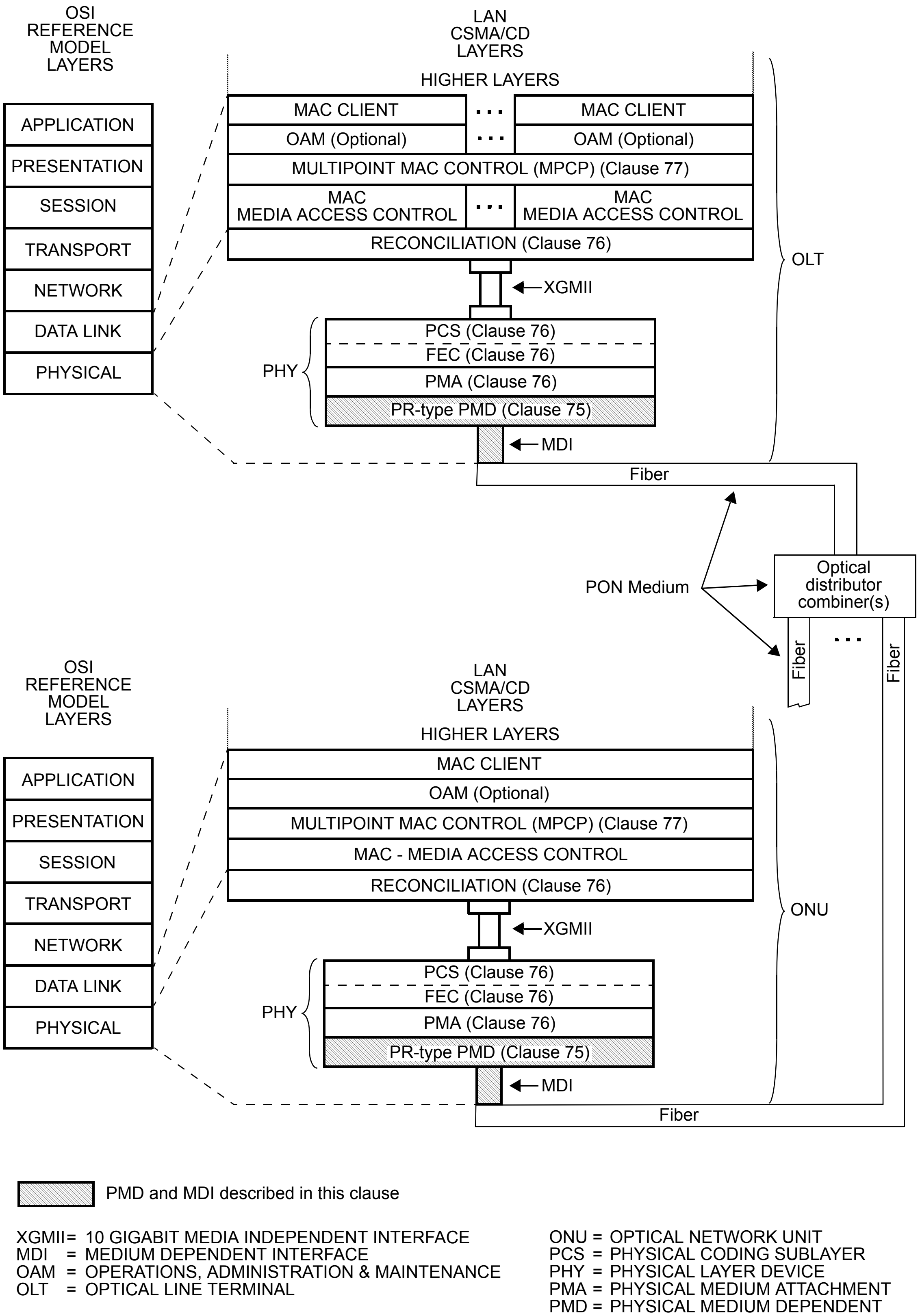


Figure 75–1—Relationship of 10/10G–EPON P2MP PMD to the ISO/IEC OSI reference model and the IEEE 802.3 CSMA/CD LAN model

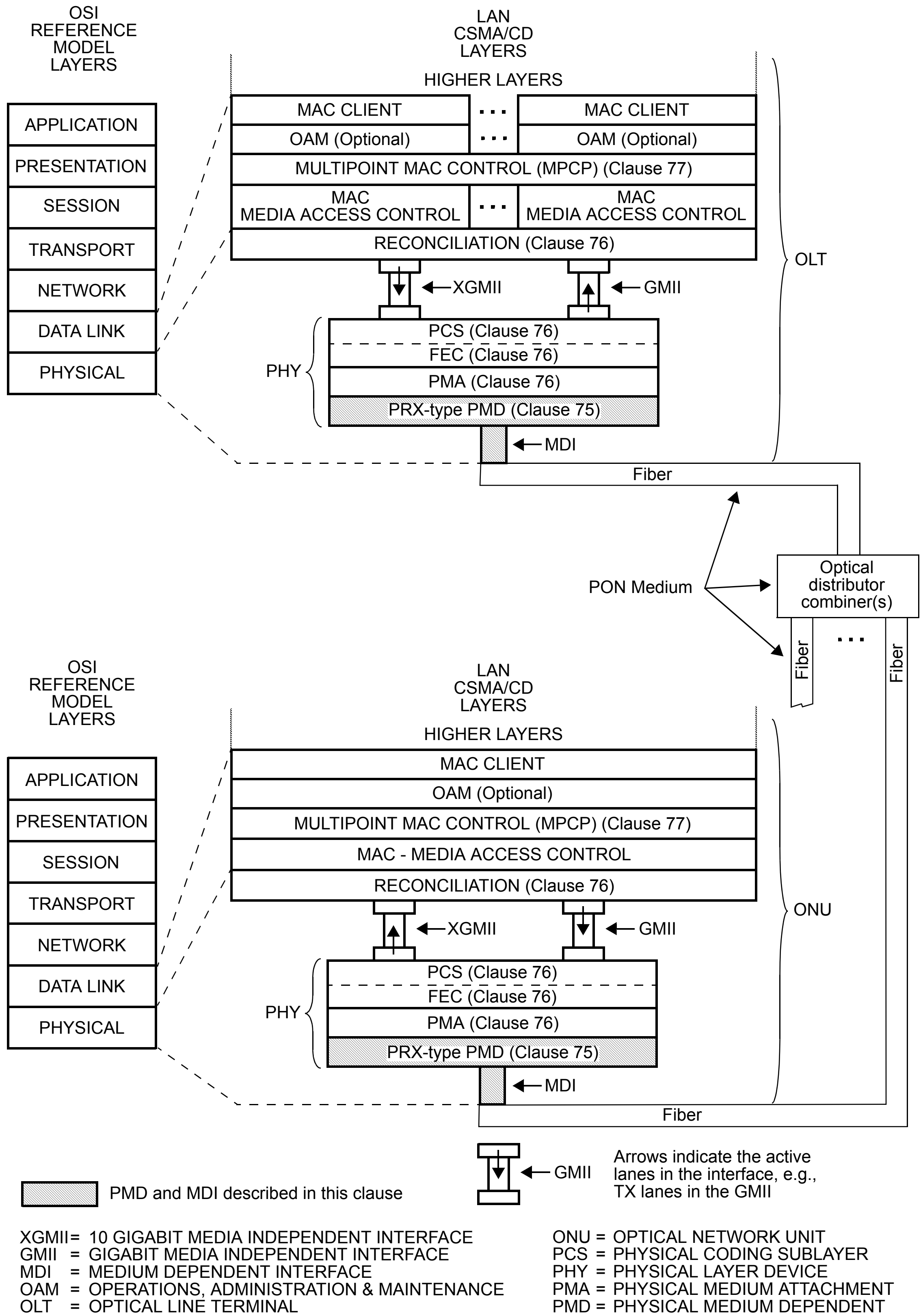


Figure 75–2—Relationship of 10/1G–EPON P2MP PMD to the ISO/IEC OSI reference model and the IEEE 802.3 CSMA/CD LAN model

The following OLT PMDs (D-type) are defined in this subclause:

a) Asymmetric-rate D-type PMDs (collectively referred to as 10/1GBASE–PRX–D), transmitting at 10.3125 GBd continuous mode and receiving at 1.25 GBd burst mode:
   1) 10/1GBASE–PRX–D1
   2) 10/1GBASE–PRX–D2
   3) 10/1GBASE–PRX–D3
b) Symmetric-rate D-type PMDs (collectively referred to as 10GBASE–PR–D), transmitting at 10.3125 GBd continuous mode and receiving at 10.3125 GBd burst mode:
   1) 10GBASE–PR–D1
   2) 10GBASE–PR–D2
   3) 10GBASE–PR–D3

The following ONU PMDs (U-type) are defined in this subclause:

c) Asymmetric-rate U-type PMDs (collectively referred to as 10/1GBASE–PRX–U), transmitting at 1.25 GBd burst mode and receiving at 10.3125 GBd continuous mode:
   1) 10/1GBASE–PRX–U1
   2) 10/1GBASE–PRX–U2
   3) 10/1GBASE–PRX–U3
d) Symmetric-rate U-type PMDs (collectively referred to as 10GBASE–PR–U), transmitting at 10.3125 GBd burst mode and receiving at 10.3125 GBd continuous mode:
   1) 10GBASE–PR–U1
   2) 10GBASE–PR–U3

A specific power budget is achieved by combining an OLT PMD (D-type) with an ONU PMD (U-type) as shown in 75.2.1. Detailed PMD receive and transmit characteristics for D-type PMDs are given in 75.4 and characteristics for U-type PMDs are presented in 75.5. Every PMD has non-overlapping transmit and receive wavelength bands and operates over a single SMF (see 75B.2).

75.2.1 Mapping of PMDs to power budgets

The power budget is determined by the PMDs located at the ends of the physical media. This subclause describes how PMDs may be combined to achieve the power budgets listed in Table 75–1.

75.2.1.1 Asymmetric-rate, 10 Gb/s downstream and 1 Gb/s upstream power budgets (PRX type)

Table 75–2 illustrates recommended pairings of asymmetric-rate ONU PMDs with asymmetric-rate OLT PMDs to achieve the power budgets shown in Table 75–1.

Table 75–2—PMD – power budget mapping for asymmetric-rate PRX–type power budgets

		OLT PMDs		
		10/1GBASE–PRX–D1	**10/1GBASE–PRX–D2**	**10/1GBASE–PRX–D3**
ONU PMDs	**10/1GBASE–PRX–U1**	PRX10	N/A	N/A
	10/1GBASE–PRX–U2	N/A	PRX20	N/A
	10/1GBASE–PRX–U3	N/A	N/A	PRX30

75.2.1.2 Symmetric-rate, 10 Gb/s power budgets (PR type)

Table 75–3 illustrates recommended pairings of symmetric-rate ONU PMDs with symmetric-rate OLT PMDs to achieve the power budgets as shown in Table 75–1.

Table 75–3—PMD – power budget mapping for symmetric-rate PR–type power budgets

		OLT PMDs		
		10GBASE–PR–D1	**10GBASE–PR–D2**	**10GBASE–PR–D3**
ONU PMDs	**10GBASE–PR–U1**	PR10	PR20	N/A
	10GBASE–PR–U3	N/A	N/A	PR30

75.3 PMD functional specifications

The 10GBASE–PR and 10/1GBASE–PRX type PMDs perform the transmit and receive functions that convey data between the PMD service interface and the MDI.

75.3.1 PMD service interface

The following specifies the services provided by Clause 75 PMDs. These PMD sublayer service interfaces are described in an abstract manner and do not imply any particular implementation.

The PMD Service Interface supports the exchange of a continuous stream of bits, representing either 64B/66B blocks (the transmit and receive paths in 10GBASE–PR PMDs, transmit path in 10/1GBASE–PRX–D PMDs) or 8B/10B blocks (transmit path in 10/1GBASE–PRX–U PMDs, receive path in 10/1GBASE–PRX–D PMDs), between the PMA and PMD entities. The PMD translates the serialized data received from the compatible PMA to and from signals suitable for the specified medium. The following primitives are defined:

— PMD_UNITDATA.request
— PMD_UNITDATA.indication
— PMD_SIGNAL.request
— PMD_SIGNAL.indication

75.3.1.1 Delay constraints

The PMD shall introduce a transmit delay of not more than 4 time_quanta with the variability of no more than 0.5 time_quanta, and a receive delay of not more than 4 time_quanta with the variability of no more than 0.5 time_quanta. A description of the overall system delay constraints can be found in 76.1.2 and the definition for the time_quantum can be found in 77.2.2.1.

75.3.1.2 PMD_UNITDATA.request

This primitive defines the transfer of a serial data stream from the Clause 65 or Clause 76 PMA to the PMD.

The semantics of the service primitive are PMD_UNITDATA.request(tx_bit). The data conveyed by PMD_UNITDATA.request is a continuous stream of bits. The tx_bit parameter can take one of two values: ONE or ZERO. The Clause 76 PMA continuously sends the appropriate stream of bits to the PMD for transmission on the medium, at a nominal signaling speed of 10.3125 GBd in the case of 10/10G–EPON OLT, 10/10G–EPON ONU, and 10/1G–EPON OLT PMDs. The Clause 65 PMA continuously sends the appropriate stream of bits to the PMD for transmission on the medium, at a nominal signaling speed of 1.25 GBd in the case of 10/1G–EPON ONU PMDs. Upon the receipt of this primitive, the PMD converts the specified stream of bits into the appropriate signals at the MDI.

75.3.1.3 PMD_UNITDATA.indication

This primitive defines the transfer of data from the PMD to the Clause 65 or Clause 76 PMA.

The semantics of the service primitive are PMD_UNITDATA.indication(rx_bit). The data conveyed by PMD_UNITDATA.indication is a continuous stream of bits. The rx_bit parameter can take one of two values: ONE or ZERO. The PMD continuously sends a stream of bits to the Clause 76 PMA corresponding to the signals received from the MDI, at the nominal signaling speed of 10.3125 GBd in the case of 10/10G–EPON OLT, 10/10G–EPON ONU, and 10/1G–EPON ONU PMDs or to the Clause 65 PMA at the nominal signaling speed of 1.25 GBd in the case of 10/1G–EPON OLT PMDs.

75.3.1.4 PMD_SIGNAL.request

In the upstream direction, this primitive is generated by the Clause 76 PMA to turn on and off the transmitter according to the granted time. A signal for laser control is generated as described in 76.4.1.1 for the Clause 76 PCS.

The semantics of the service primitive are PMD_SIGNAL.request(tx_enable). The tx_enable parameter can take on one of two values: ENABLE or DISABLE, determining whether the PMD transmitter is on (enabled) or off (disabled). The Clause 76 PMA generates this primitive to indicate a change in the value of tx_enable. Upon the receipt of this primitive, the PMD turns the transmitter on or off as appropriate.

75.3.1.5 PMD_SIGNAL.indication

This primitive is generated by the PMD to indicate the status of the signal being received from the MDI.

The semantics of the service primitive are PMD_SIGNAL.indication(SIGNAL_DETECT). The SIGNAL_DETECT parameter can take on one of two values: OK or FAIL, indicating whether the PMD is detecting light at the receiver (OK) or not (FAIL). When SIGNAL_DETECT = FAIL, PMD_UNITDATA.indication(rx_bit) is undefined. The PMD generates this primitive to indicate a change in the value of SIGNAL_DETECT. If the MDIO interface is implemented, then PMD_global_signal_detect shall be continuously set to the value of SIGNAL_DETECT.

NOTE—SIGNAL_DETECT = OK does not guarantee that PMD_UNITDATA.indication(rx_bit) is known good. It is possible for a poor quality link to provide sufficient light for a SIGNAL_DETECT = OK indication and still not meet the specified bit error ratio. PMD_SIGNAL.indication(SIGNAL_DETECT) has different characteristics for upstream and downstream links, see 75.3.5.

75.3.2 PMD block diagram

The PMD sublayer is defined at the eight reference points shown in Figure 75–3 for 10GBASE–PR and 10/1GBASE–PRX PMDs.

For 10GBASE–PR and 10/1GBASE–PRX PMDs, test points TP1 through TP4 refer to the downstream channel, while test points TP5 through TP8 refer to the upstream channel. In the downstream channel, TP2 and TP3 are compliance points, while in the upstream channel TP6 and TP7 are compliance points. TP1, TP4, TP5, and TP8 are reference points for use by implementers. The optical transmit signal is defined at the output end of a patch cord (TP2 for the downstream channel and TP6 for the upstream channel), between 2 m and 5 m in length, of a fiber type consistent with the link type connected to the transmitter. Unless specified otherwise, all transmitter measurements and tests defined in 75.7 are made at TP2 or TP6, while tests defined in 60.7 are made at TP6. The optical receive signal is defined at the output of the fiber optic cabling (TP3 for the downstream channel and TP7 for the upstream channel) connected to the receiver. Unless specified otherwise, all receiver measurements and tests defined in 75.7 are made at TP3 or TP7.

The electrical specifications of the PMD service interface (TP1 and TP4 for the downstream channel and TP5 and TP8 for the upstream channel) are not system compliance points (these are not readily testable in a system implementation).

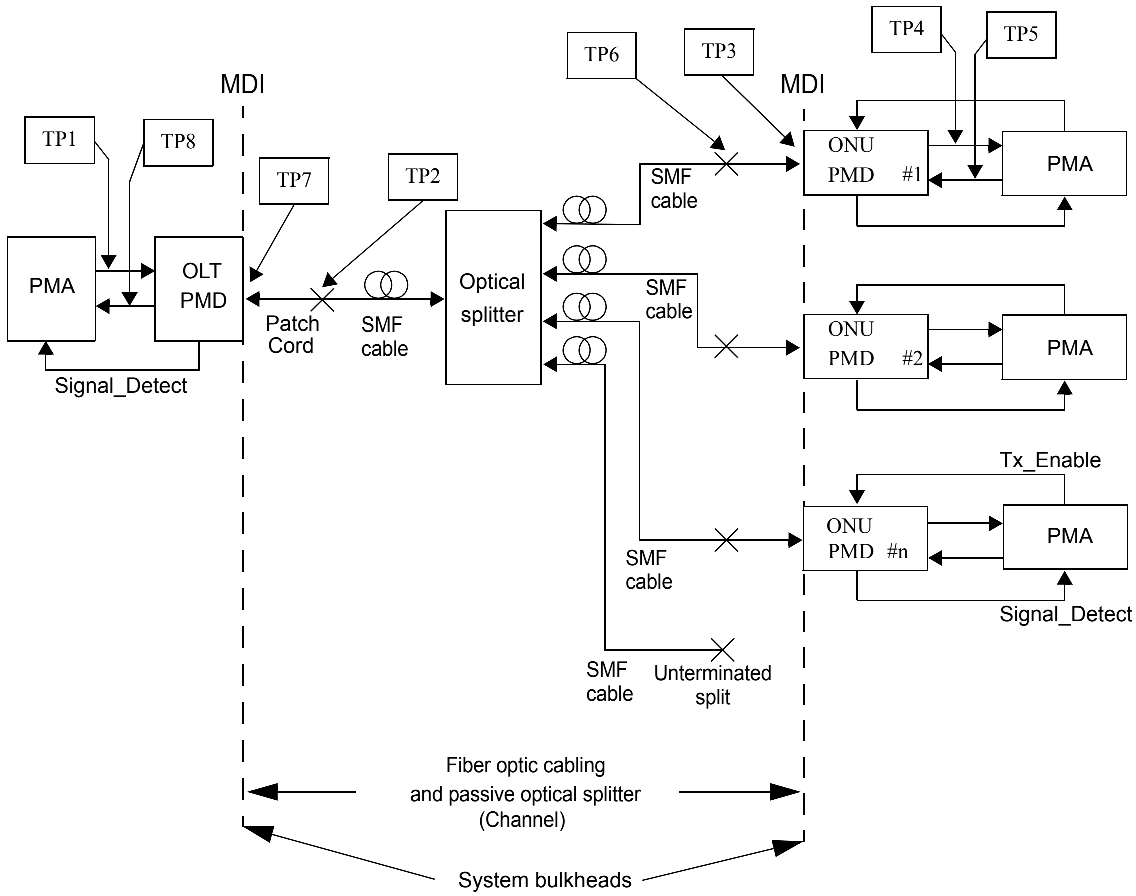


Figure 75–3—10GBASE–PR and 10/1GBASE–PRX block diagram

75.3.3 PMD transmit function

The PMD Transmit function shall convey the bits requested by the PMD service interface message PMD_UNITDATA.request(tx_bit) to the MDI according to the optical specifications in Clause 75.

In the upstream direction, the flow of bits is interrupted according to PMD_SIGNAL.request(tx_enable). This implies three optical levels, 1, 0, and dark, the latter corresponding to the transmitter being in the OFF state. The higher optical power level shall correspond to tx_bit = ONE.

75.3.4 PMD receive function

The PMD Receive function shall convey the bits received from the MDI according to the optical specifications in Clause 75 to the PMD service interface using the message PMD_UNITDATA.indication(rx_bit). The higher optical power level shall correspond to rx_bit = ONE.

75.3.5 PMD signal detect function

75.3.5.1 ONU PMD signal detect

The PMD Signal Detect function for the continuous mode downstream signal shall report to the PMD service interface, using the message PMD_SIGNAL.indication(SIGNAL_DETECT), which is signaled continuously. PMD_SIGNAL.indication is intended to be an indicator of the presence of the optical signal.

The value of the SIGNAL_DETECT parameter shall be generated according to the conditions defined in Table 75–4 for 10GBASE–PR and 10/1GBASE–PRX type PMDs. The ONU PMD receiver is not required to verify whether a compliant 10GBASE–PR signal is being received.

75.3.5.2 OLT PMD signal detect

The response time for the PMD Signal Detect function for the burst mode upstream signal may be longer or shorter than a burst length; thus, it may not fulfill the traditional requirements placed on Signal Detect. PMD_SIGNAL.indication is intended to be an indicator of optical signal presence. The signal detect function in the OLT may be realized in the PMD or the Clause 76 PMA sublayer.

The value of the SIGNAL_DETECT parameter shall be generated according to the conditions defined in Table 75–4 for PMDs defined in Clause 75. The 10GBASE–PR–D PMD receiver is not required to verify whether a compliant 10GBASE–PR signal is being received. Similarly, the 10/1GBASE–PRX–D PMD receiver is not required to verify whether a compliant 1000BASE–PX signal is being received.

75.3.5.3 10GBASE–PR and 10/1GBASE–PRX Signal detect functions

The Signal Detect value definitions for Clause 75 PMDs are shown in Table 75–4.

Table 75–4—SIGNAL_DETECT value definitions for Clause 75 PMDs

Receive conditions			Signal_detect value
10GBASE–PR–D1, 10GBASE–PR–D2, 10GBASE–PR–D3	**10GBASE–PR–U1, 10GBASE–PR–U3, 10/1GBASE–PRX–U1, 10/1GBASE–PRX–U2, 10/1GBASE–PRX–U3**	**10/1GBASE–PRX–D1, 10/1GBASE–PRX–D2, 10/1GBASE–PRX–D3**	
Average input optical power ≤ Signal Detect Threshold (min) in Table 75–6 at the specified receiver wavelength	Average input optical power ≤ Signal Detect Threshold (min) in Table 75–11 at the specified receiver wavelength	Average input optical power ≤ Signal Detect Threshold (min) in Table 75–7 at the specified receiver wavelength	FAIL
Average input optical power ≥ Receive sensitivity (max) in Table 75–6 with a compliant 10GBASE–PR signal input at the specified receiver wavelength	Average input optical power ≥ Receive sensitivity (max) in Table 75–11 with a compliant 10GBASE–PR signal input at the specified receiver wavelength	Average input optical power ≥ Receive sensitivity (max) in Table 75–7 with a compliant 1000BASE–PX signal input at the specified receiver wavelength	OK
All other conditions	All other conditions	All other conditions	Unspecified

75.3.6 PMD transmit enable function for ONU

PMD_SIGNAL.request(tx_enable) is defined for all ONU PMDs specified in Clause 75. PMD_SIGNAL.request(tx_enable) is asserted prior to data transmission by the ONU PMDs.

75.4 PMD to MDI optical specifications for 10/10G–EPON and 10/1G–EPON OLT PMDs

This subclause details the PMD to MDI optical specifications for 10/10G–EPON and 10/1G–EPON OLT PMDs, as specified in 75.2. Specifically, 75.4.1 defines the OLT transmit parameters, while 75.4.2 defines the OLT receive parameters.

The operating ranges for PR and PRX power budget classes are defined in Table 75–1. A PR or PRX compliant transceiver operates over the media types listed in Table 75–14 according to the specifications described in 75.9. A transceiver which exceeds the operational range requirement while meeting all other optical specifications is considered compliant.

NOTE—The specifications for OMA have been derived from extinction ratio and average launch power (minimum) or receiver sensitivity (maximum). The calculation is defined in 58.7.6.

75.4.1 Transmitter optical specifications

The signaling speed, operating wavelength, side mode suppression ratio, average launch power, extinction ratio, return loss tolerance, OMA, eye, and Transmitter and Dispersion Penalty (TDP) for transmitters making part of the 10/10G–EPON and 10/1G–EPON OLT PMDs (as specified in 75.2) shall meet the specifications defined in Table 75–5 per measurement techniques described in 75.7. Their $RIN_{15}OMA$ should meet the value listed in Table 75–5 per measurement techniques described in 75.7.8. Note that there are only two groups of transmit parameters. The first group is shared by 10GBASE–PR–D1, 10/1GBASE–PRX–D1, 10GBASE–PR–D3, and 10/1GBASE–PRX–D3. The second group is shared by 10GBASE–PR–D2 and 10/1GBASE–PRX–D2.

Table 75–5—PR and PRX type OLT PMD transmit characteristics

Description	10GBASE–PR–D1, 10GBASE–PR–D3, 10/1GBASE–PRX–D1, 10/1GBASE–PRX–D3	10GBASE–PR–D2, 10/1GBASE–PRX–D2	Unit
Signaling speed (range)	10.3125 ± 100 ppm	10.3125 ± 100 ppm	GBd
Wavelength (range)	1575 to 1580	1575 to 1580	nm
Side Mode Suppression Ratio (min)[a]	30	30	dB
Average launch power (max)	5	9	dBm
Average launch power (min)[b]	2	5	dBm
Average launch power of OFF transmitter (max)	–39	–39	dBm
Extinction ratio (min)	6	6	dB
$RIN_{15}OMA$ (max)	–128	–128	dB/Hz
Launch OMA (min)[b]	3.91 (2.46)	6.91 (4.91)	dBm (mW)
Transmitter eye mask definition {X1, X2, X3, Y1, Y2, Y3}[c]	{0.25, 0.40, 0.45, 0.25, 0.28, 0.40}	{0.25, 0.40, 0.45, 0.25, 0.28, 0.40}	UI
Optical return loss tolerance (max)	15	15	dB
Transmitter reflectance (max)	–10	–10	dB
Transmitter and dispersion penalty (max)	1.5	1.5	dB
Decision timing offset for transmitter and dispersion penalty	±0.05	±0.05	UI

[a]Transmitter is a single longitudinal mode device. Chirp is allowed such that the total optical path penalty does not exceed that found in Table 75B–2.
[b]Minimum average launch power and minimum launch OMA are valid for ER = 9 dB (see Figure 75–4 for details)
[c]As defined in Figure 75–8.

The relationship between OMA, extinction ratio, and average power is described in 58.7.6 and illustrated in Figure 75–4 for a compliant transmitter. Note that the OMA_{min} and AVP_{min} are calculated for ER = 9 dB, where AVP_{min} represents the Average launch power (min) as presented in Table 75–5. The transmitter specifications are further relaxed by allowing lower ER = 6 dB while maintaining the OMA_{min} and AVP_{min} constant. The shaded area indicates a compliant part.

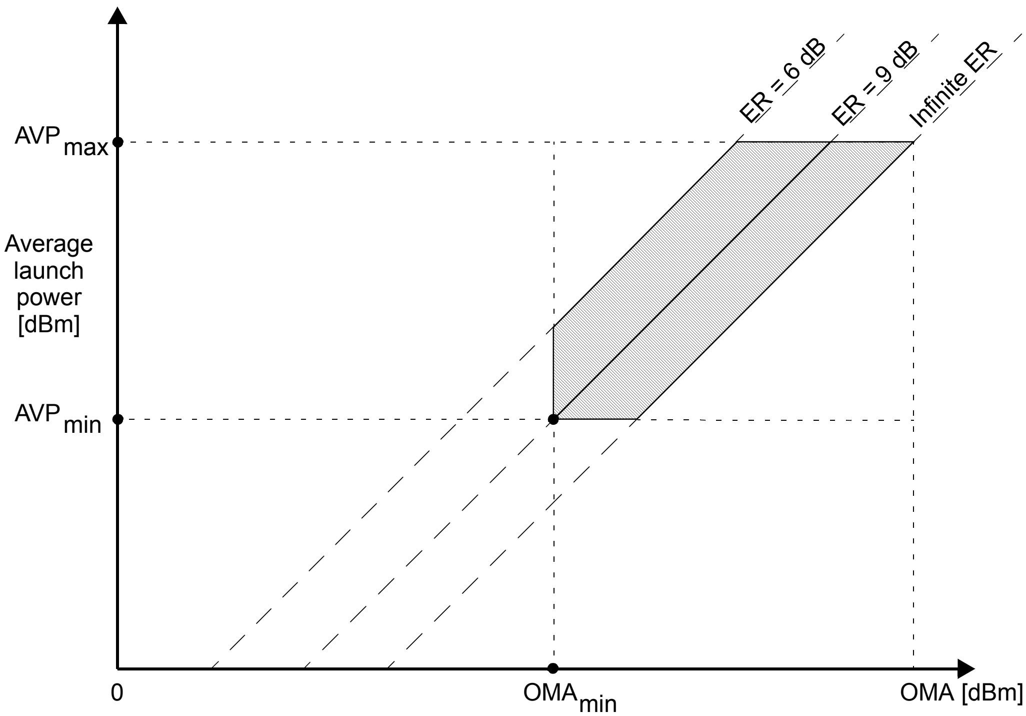


Figure 75–4—Graphical representation of region of PR–D type transmitter compliance

75.4.2 Receiver optical specifications

The signaling speed, operating wavelength, overload, stressed sensitivity, reflectivity, and signal detect for receivers forming part of the 10/10G–EPON and 10/1G–EPON OLT PMDs (as specified in 75.2) shall meet the specifications defined in Table 75–6 for 10/10G–EPON OLT PMDs and in Table 75–7 for 10/1G–EPON OLT PMDs, per measurement techniques defined in 75.7. Their unstressed receive characteristics should meet the values listed in Table 75–6 and Table 75–7 per measurement techniques described in 75.7.11. Either the damage threshold included in Table 75–6 or Table 75–7 shall be met, or the receiver shall be labeled to indicate the maximum optical input power level to which it can be continuously exposed without damage.

The damage threshold included in Table 75–6 and Table 75–7 does not guarantee direct ONU–OLT connection, which may result in damage of the receiver. If direct ONU–OLT connection is necessary, optical attenuators and/or equivalent loss components should be inserted to decrease receive power below the damage threshold.

Table 75–6—PR type OLT PMD receive characteristics

Description	10GBASE–PR–D1	10GBASE–PR–D2, 10GBASE–PR–D3	Unit
Signaling speed (range)	10.3125 ± 100 ppm	10.3125 ± 100 ppm	GBd
Wavelength (range)	1260 to 1280	1260 to 1280	nm
Bit error ratio (max)[a]	10^{-3}	10^{-3}	–
Average receive power (max)	–1	–6	dBm
Damage threshold (max)[b]	0	–5	dBm
Receiver sensitivity (max)	–24	–28	dBm
Receiver sensitivity OMA (max)	–23.22 (4.77)	–27.22 (1.90)	dBm (μW)
Signal detect threshold (min)	–45	–45	dBm
Receiver reflectance (max)	–12	–12	dB
Stressed receive sensitivity (max)[c]	–21	–25	dBm
Stressed receive sensitivity OMA (max)	–20.22 (9.51)	–24.22 (3.79)	dBm (μW)
Vertical eye–closure penalty[d]	2.99	2.99	dB
$T_{receiver\_settling}$ (max)[e]	800	800	ns
Stressed eye jitter	0.3	0.3	UI pk to pk
Jitter corner frequency for a sinusoidal jitter	4	4	MHz
Sinusoidal jitter limits for stressed receiver conformance test (min, max)	(0.05, 0.15)	(0.05, 0.15)	UI

[a]The BER of 10^{-12} is achieved by the utilization of FEC as described in 76.3.
[b]Direct ONU–OLT connection may result in damage of the receiver.
[c]The stressed receiver sensitivity is mandatory.
[d]Vertical eye closure penalty and the jitter specifications are test conditions for measuring stressed receiver sensitivity. They are not required characteristics of the receiver.
[e]$T_{receiver\_settling}$ represents an upper bound. Optics with better performance may be used in compliant implementations, since the OLT notifies the ONUs of its requirements in terms of the $T_{receiver\_settling}$ time via the SYNCTIME parameter (see 77.3.3.2).

Table 75–7—PRX type OLT PMD receive characteristics

Description	10/1GBASE –PRX–D1	10/1GBASE –PRX–D2	10/1GBASE –PRX–D3	Unit
Signaling speed (range)	same as 1000BASE–PX10–D receive parameters (see Table 60–5)	same as 1000BASE–PX20–D receive parameters (see Table 60–8)	1.25 ± 100 ppm	GBd
Wavelength (range)			1260 to 1360	nm
Bit error ratio (max)			10^{-12}	
Average receive power (max)			–9.38	dBm
Damage threshold (max)			–5.00	dBm
Receiver sensitivity (max)			–29.78	dBm
Receiver sensitivity OMA (max)			–29.00 (1.26)	dBm (μW)
Signal detect threshold (min)			–45	dBm
Receiver reflectance (max)			–12	dB
Stressed receive sensitivity (max)			–28.38[a]	dBm
Stressed receive sensitivity OMA (max)			–27.60 (1.74)	dBm (μW)
Vertical eye–closure penalty[b]			1.4	dB
$T_{receiver\_settling}$ (max)[c]			400	ns
Stressed eye jitter			0.28	UI pk to pk
Jitter corner frequency for a sinusoidal jitter			637	kHz
Sinusoidal jitter limits for stressed receiver conformance test (min, max)			(0.05, 0.15)	UI

[a]The stressed receiver sensitivity is mandatory.
[b]Vertical eye closure penalty and the jitter specifications are test conditions for measuring stressed receiver sensitivity. They are not required characteristics of the receiver.
[c]$T_{receiver\_settling}$ represents an upper bound. Optics with better performance may be used in compliant implementations, since the OLT notifies the ONUs of its requirements in terms of the $T_{receiver\_settling}$ time via the SYNCTIME parameter (see 77.3.3.2).

75.5 PMD to MDI optical specifications for 10/10G–EPON and 10/1G–EPON ONU PMDs

This subclause details the PMD to MDI optical specifications for 10/10G–EPON and 10/1G–EPON ONU PMDs, as specified in 75.2. Specifically, 75.5.1 defines the ONU transmit parameters, while 75.5.2 defines the ONU receive parameters.

The operating ranges for PR and PRX power budget classes are defined in Table 75–1. A PR or PRX compliant transceiver operates over the media types listed in Table 75–14 according to the specifications described in 75.9. A transceiver which exceeds the operational range requirement while meeting all other optical specifications is considered compliant.

NOTE—The specifications for OMA have been derived from extinction ratio and average launch power (minimum) or receiver sensitivity (maximum). The calculation is defined in 58.7.6.

75.5.1 Transmitter optical specifications

The signaling speed, operating wavelength, spectral width (for 10/1G–EPON ONU PMDs) or side mode suppression ratio (for 10/10G–EPON ONU PMDs), average launch power, extinction ratio, return loss tolerance, OMA, eye and TDP for transmitters forming part of the 10/10G–EPON and 10/1G–EPON ONU PMDs (as specified in 75.2) shall meet the specifications defined in Table 75–8 for 10/10G–EPON ONU PMDs and in Table 75–9 for 10/1G–EPON ONU PMDs, per measurement techniques described in 75.7. Their $RIN_{15}OMA$ should meet the value listed in Table 75–8 or Table 75–9, as appropriate, per measurement techniques described in 75.7.8.

Table 75–8—PR type ONU PMD transmit characteristics

Description	10GBASE –PR–U1	10GBASE –PR–U3	Unit
Signaling speed (range)	10.3125 ± 100 ppm	10.3125 ± 100 ppm	GBd
Wavelength (range)	1260 to 1280	1260 to 1280	nm
Side Mode Suppression Ratio (min)[a]	30	30	dB
Average launch power (max)	4	9	dBm
Average launch power (min)[b]	–1	4	dBm
Average launch power of OFF transmitter (max)	–45	–45	dBm
Extinction ratio (min)	6	6	dB
$RIN_{15}OMA$ (max)	–128	–128	dB/Hz
Launch OMA (min)[b]	–0.22 (0.95)	4.78 (3.01)	dBm (mW)
Transmitter eye mask definition {X1, X2, X3, Y1, Y2, Y3}[c]	{0.25, 0.40, 0.45, 0.25, 0.28, 0.40}	{0.25, 0.40, 0.45, 0.25, 0.28, 0.40}	UI
T_{on} (max)	512	512	ns
T_{off} (max)	512	512	ns
Optical return loss tolerance (max)	15	15	dB
Transmitter reflectance (max)	–10	–10	dB
Transmitter and dispersion penalty (max)[d]	3.0	3.0	dB
Decision timing offset for transmitter and dispersion penalty	±0.0625	±0.0625	UI

[a]Transmitter is a single longitudinal mode device. Chirp is allowed such that the total optical path penalty does not exceed that found in Table 75B–2.
[b]Minimum average launch power and minimum launch OMA are valid for ER = 6 dB (see Figure 75–5 for details).
[c]As defined in Figure 75–8.
[d]If a transmitter has a lower TDP, the minimum transmitter launch OMA (OMA_{min}) and average minimum launch power (AVP_{min}) may be relaxed by the amount 3.0 dB – TDP.

The relationship between OMA, extinction ratio and average power is described in 58.7.6 and illustrated in Figure 75–5 for a compliant transmitter. Note that the OMA_{min} and AVP_{min} are calculated for ER = 6 dB. The transmitter average launch power specifications are further relaxed by allowing ER higher than 6 dB while maintaining the OMA_{min} constant. The shaded area indicates a compliant part.

Table 75–9—PRX type ONU PMD transmit characteristics

Description	10/1GBASE –PRX–U1	10/1GBASE –PRX–U2	10/1GBASE –PRX–U3	Unit
Signaling speed (range)	same as 1000BASE–PX10–U transmit parameters (see Table 60–3)	same as 1000BASE–PX20–U transmit parameters (see Table 60–6)	1.25 ± 100 ppm	GBd
Wavelength[a] (range)			1260 to 1360	nm
RMS spectral width (max)			see [b]	nm
Average launch power (max)			5.62	dBm
Average launch power (min)[c]			0.62	dBm
Average launch power of OFF transmitter (max)			–45	dBm
Extinction ratio (min)			6	dB
$RIN_{15}OMA$ (max)			–115	dB/Hz
Launch OMA (min)[c]			1.40 (1.38)	dBm (mW)
Transmitter eye mask definition {X1, X2, Y1, Y2, Y3}[d]			{0.22, 0.375, 0.20, 0.20, 0.30}	UI
T_{on} (max)			512	ns
T_{off} (max)			512	ns
Optical return loss tolerance (max)			15	dB
Transmitter reflectance (max)			–10	dB
Transmitter and dispersion penalty (max)			1.4	dB
Decision timing offset for transmitter and dispersion penalty			±0.125	UI

[a]This represents the range of center wavelength ±1σ of the rms spectral width.
[b]If the transmitter employs a Fabry–Perot laser, the RMS spectral width shall comply with Table 75–10. If the transmitter employs a DFB laser, the side mode suppression ratio (min) shall be 30 dB.
[c]Minimum average launch power and minimum launch OMA are valid for ER = 6 dB.
[d]As defined in Figure 75–7.

The maximum RMS spectral width vs. wavelength for 10/1GBASE–PRX–U1, 10/1GBASE–PRX–U2 and 10/1GBASE–PRX–U3 PMDs are shown, respectively, in Table 60–4, Table 60–7 and Table 75–10. The equation used to generate these values is included in 60.7.2.

75.5.2 Receiver optical specifications

The signaling speed, operating wavelength, overload, stressed sensitivity, reflectivity, and signal detect for receivers forming part of the 10/10G–EPON ONU and 10/1G–EPON ONU PMDs (as specified in 75.2) shall meet the specifications defined in Table 75–11 for Clause 75 ONU PMDs, per measurement techniques defined in 75.7. Their unstressed receive characteristics should meet the values listed in Table 75–11 per measurement techniques described in 75.7.11. Either the damage threshold included in Table 75–11 shall be met, or the receiver shall be labeled to indicate the maximum optical input power level to which it can be continuously exposed without damage.

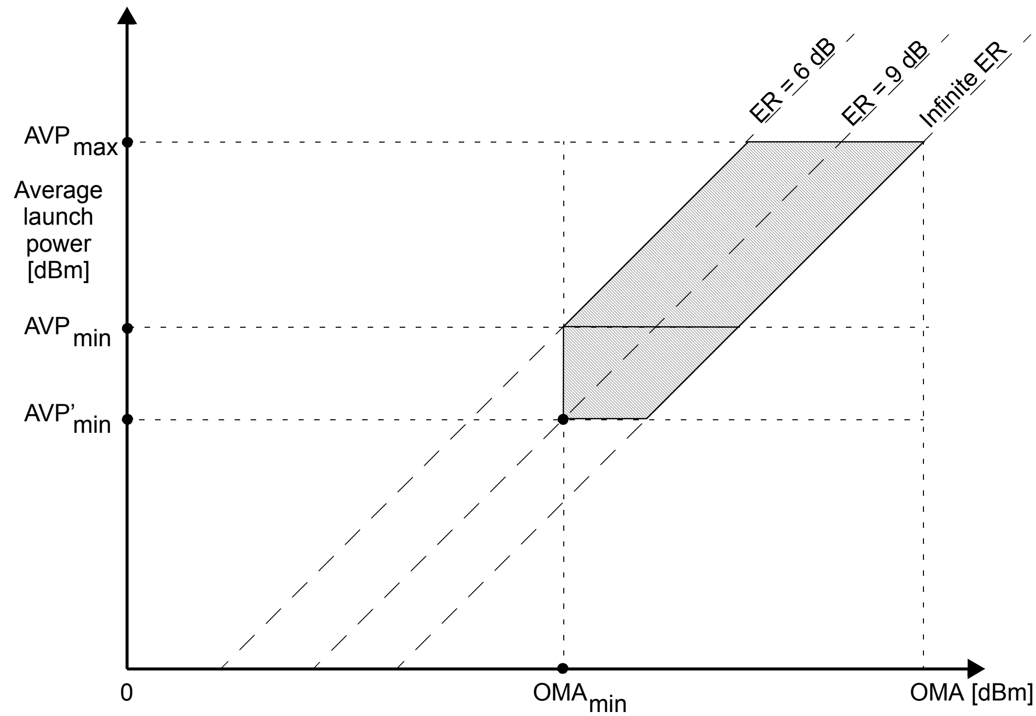


Figure 75–5—Graphical representation of region of PR–U type transmitter compliance

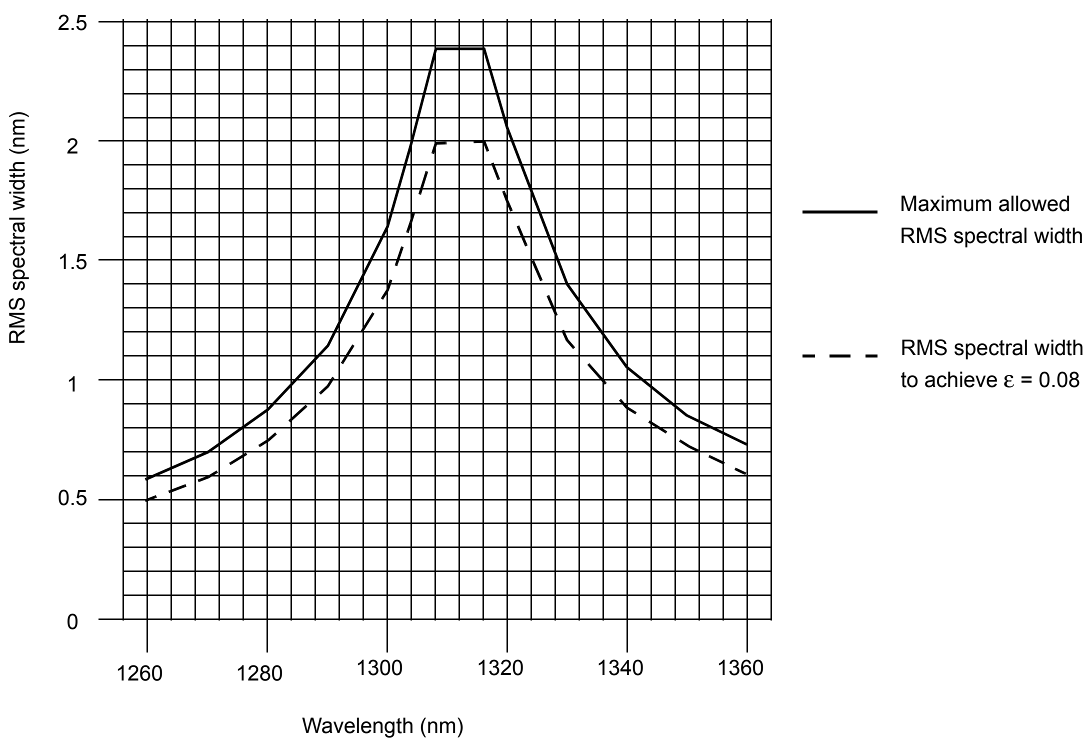


Figure 75–6—10/1GBASE–PRX–U3 transmitter spectral limits

The damage threshold included in Table 75–11 does not guarantee direct ONU–OLT connection, which may result in damage of the receiver. If direct ONU–OLT connection is necessary, optical attenuators and/or equivalent loss components should be inserted to decrease receive power below damage threshold.

Table 75–10—10/1GBASE–PRX–U3 transmitter spectral limits

Center Wavelength	RMS spectral width (max)[a]	RMS spectral width to achieve epsilon ε <=0.08 (informative)
nm	nm	nm
1260	0.59	0.5
1270	0.7	0.59
1280	0.87	0.74
1290	1.14	0.97
1300	1.64	1.39
1304	1.98	1.67
1305	2.09	1.77
1308	2.4	2
1317	2.4	2
1320	2.07	1.75
1321	1.98	1.67
1330	1.4	1.18
1340	1.06	0.89
1350	0.86	0.72
1360	0.72	0.61

[a] These limits for the 10/1GBASE–PRX–U3 transmitter are illustrated in Figure 75–6. The equation used to calculate these values is detailed in 60.7.2. Limits at intermediate wavelengths may be found by interpolation.

Table 75–11—PR and PRX type ONU PMD receive characteristics

Description	10GBASE–PR–U1, 10/1GBASE–PRX–U1, 10/1GBASE–PRX–U2	10GBASE–PR–U3, 10/1GBASE–PRX–U3	Unit
Signaling speed (range)	10.3125 ± 100 ppm	10.3125 ± 100 ppm	GBd
Wavelength (range)	1575 to 1580	1575 to 1580	nm
Bit error ratio (max)[a]	10^{-3}	10^{-3}	—
Average receive power (max)	0	–10	dBm
Damage threshold (max)[b]	1	–9	dBm
Receiver sensitivity (max)	–20.50	–28.50	dBm
Receiver sensitivity OMA (max)	–18.59 (13.84)	–26.59 (2.19)	dBm (μW)
Signal detect threshold (min)	–44	–44	dBm
Receiver reflectance (max)	–12	–12	dB
Stressed receive sensitivity (max)[c]	–19	–27	dBm

Table 75–11—PR and PRX type ONU PMD receive characteristics *(continued)*

Description	10GBASE–PR–U1, 10/1GBASE–PRX–U1, 10/1GBASE–PRX–U2	10GBASE–PR–U3, 10/1GBASE–PRX–U3	Unit
Stressed receive sensitivity OMA (max)	–17.09 (19.55)	–25.09 (3.10)	dBm (μW)
Vertical eye–closure penalty[d]	1.5	1.5	dB
Stressed eye jitter (min)	0.3	0.3	UI pk to pk
Jitter corner frequency for a sinusoidal jitter	4	4	MHz
Sinusoidal jitter limits for stressed receiver conformance test (min, max)	(0.05, 0.15)	(0.05, 0.15)	UI

[a]The BER of 10^{-12} is achieved by the utilization of FEC as described in 76.3.
[b]Direct ONU–OLT connection may result in damage of the receiver.
[c]The stressed receiver sensitivity is mandatory over the entire PR–D transmitter compliance region, as illustrated in Figure 75–4.
[d]Vertical eye closure penalty and the jitter specifications are test conditions for measuring stressed receiver sensitivity. They are not required characteristics of the receiver.

75.6 Dual-rate (coexistence) mode

To support coexistence of 10G–EPON and 1G–EPON ONUs on the same outside plant, the OLT may be configured to use a dual-rate mode. Dual-rate mode supports transmission and/or reception of both 10 Gb/s and 1 Gb/s data rates, and can be introduced as options for 10G–EPON OLTs, functionally combining PMDs supporting 10 Gb/s and 1 Gb/s data rates.

Table 75–12 depicts PMD coexistence mapping for dual-rate mode options.

Table 75–12—PMD coexistence mapping for dual-rate mode option[a]

Direction of dual-rate operation	OLT PMD combination	ONU PMDs coexisting on the same ODN
Downstream	1000BASE–PX–D 10/1GBASE–PRX–D	(1) 1000BASE–PX–U (2) 10/1GBASE–PRX–U
Upstream	10GBASE–PR–D 10/1GBASE–PRX–D	(1) 10GBASE–PR–U (2) 10/1GBASE–PRX–U
Downstream and upstream	1000BASE–PX–D 10GBASE–PR–D	(1) 1000BASE–PX–U (2) 10/1GBASE–PRX–U (3) 10GBASE–PR–U

[a]Only PMDs with compatible power budgets can be connected to the same ODN.

75.6.1 Downstream dual-rate operation

When the downstream dual-rate operation is enabled, the OLT transmits both 10 Gb/s and 1 Gb/s downstream signals in a WDM manner. The OLT should meet both 10 Gb/s and 1 Gb/s specifications defined in Table 75–5 (10GBASE–PR–D transmit characteristics) and in Table 60–3 or Table 60–6 (1000BASE–PX–D transmit characteristics).

75.6.2 Upstream dual-rate operation

When the upstream dual-rate operation is enabled, the OLT receives both 10 Gb/s and 1 Gb/s upstream signals in a TDMA manner. Further implementation details are described in Annex 75A. The OLT should meet both 10 Gb/s and 1 Gb/s specifications defined in Table 75–6 (10GBASE–PR–D receive characteristics), and in Table 60–5, Table 60–8 (1000BASE–PX–D receive characteristics), and Table 75–7 (10/1GBASE–PRX–D receive characteristics).

NOTE—The damage threshold values in Table 60–5, Table 60–8, and Table 75–7 are considerably higher than those in Table 75–6; the dual-rate PMD should be labeled appropriately.

75.7 Definitions of optical parameters and measurement methods

When measuring jitter at TP1 and TP5, it is recommended that jitter contributions at frequencies below receiver corner frequencies (i.e., 4 MHz for 10.3125 GBd receiver and 637 kHz for 1.25 GBd receiver) are filtered at the measurement unit. The following subclauses describe definitive patterns and test procedures for certain PMDs of this standard. Implementers using alternative verification methods should ensure adequate correlation and allow adequate margin such that specifications are met by reference to the definitive methods. All optical measurements, except TDP and $RIN_{15}OMA$ shall be made through a short patch cable between 2 m and 5 m in length.

75.7.1 Insertion loss

Insertion loss for SMF fiber optic cabling (channel) is defined at 1270 nm, 1310 nm, or 1577 nm, depending on the particular PMD. A suitable test method is described in ITU–T G.650.1.

75.7.2 Allocation for penalties in 10G–EPON PMDs

All the receiver types specified in Clause 75 are required to tolerate a path penalty not exceeding 1 dB to account for total degradations due to reflections, intersymbol interference, mode partition noise, laser chirp and detuning of the central wavelength, including chromatic dispersion penalty. All the transmitter types specified in Clause 75 introduce less than 1 dB of optical path penalty over the channel. The path penalty is a component of transmitter and dispersion penalty (TDP), which is specified in Table 75–5, Table 75–8, and Table 75–9 and described in 58.7.9.

75.7.3 Test patterns

Two types of test patterns are used for testing of 10 Gb/s optical PMDs: square wave (52.9.1.2) and patterns 1, 2, or 3 (52.9.1.1). These 10 Gb/s test patterns for 10GBASE–PR and 10/1GBASE–PRX are in Table 75–13. Two types of test frames [random and jitter (59.7.1)] are used for 1 Gb/s tests relevant to the 10/1GBASE–PRX PHY. All test patterns are listed in Table 75–13.

Table 75–13—Test patterns

Test	10 Gb/s pattern[a]	1 Gb/s pattern	Related subclause
Average optical power	1 or 3	Valid 8B/10B	75.7.5
OMA (modulated optical power)	Square	Idles	75.7.7
Extinction ratio	1 or 3	Idles	75.7.6
Transmit eye	1 or 3	Valid 8B/10B	75.7.7
$RIN_{15}OMA$	Square	Idles	75.7.8
Wavelength, spectral width	1 or 3	Valid 8B/10B	75.7.4
Side mode suppression ratio	1 or 3	Valid 8B/10B	—
VECP calibration	2 or 3	Jitter frame	75.7.12
Receiver sensitivity	1 or 3	Random frame	75.7.11
Receiver overload	1 or 3	Valid 8B/10B	—
Stressed receive sensitivity	2 or 3	Random frame	75.7.12
Transmitter and dispersion penalty	2 or 3	Random frame	75.7.10
Jitter	2 or 3	Jitter frame	75.7.13
Laser On/Off	1 or 3	Valid 8B/10B	75.7.14
Receiver settling	1 or 3	Valid 8B/10B	75.7.15

[a]Individual 10 Gb/s test patterns are described in 52.9.1.2 for a square wave and 52.9.1.1 for test patterns represented by numbers.

75.7.4 Wavelength and spectral width measurement

The center wavelength and spectral width (RMS) shall meet the specifications when measured according to TIA-455-127-A under modulated conditions using an appropriate PRBS or a valid 10GBASE–PR signal, 1000BASE–X signal, or another representative test pattern.

NOTE—The allowable range of central wavelengths is narrower than the operating wavelength range by the actual RMS spectral width at each extreme.

75.7.5 Optical power measurements

Optical power shall meet specifications according to the methods specified in ANSI/EIA-455-95. A measurement may be made with the port transmitting any valid encoded 8B/10B or 64B/66B data stream.

75.7.6 Extinction ratio measurements

The extinction ratio shall meet the specifications when measured according to IEC 61820-2-2 with the port transmitting a repeating idle pattern /I2/ ordered_set (see 36.2.4.12) or valid 10GBASE–PR signal, and with minimal back reflections into the transmitter, lower than –20 dB. The test receiver has the frequency response as specified for the transmitter optical waveform measurement.

75.7.7 Optical modulation amplitude (OMA) test procedure

A description of OMA measurements for 1 Gb/s PHYs is found in 58.7.5. The OMA measurements for 10 Gb/s PHYs shall be compliant with the description found in 52.9.5.

75.7.8 Relative intensity noise optical modulation amplitude (RIN_xOMA) measuring procedure

This procedure describes a component test that may not be appropriate for a system level test depending on the implementation. If used, the procedure shall be performed as described in 52.9.6 for 10 Gb/s PHYs and in 58.7.7 for 1 Gb/s PHYs.

75.7.9 Transmit optical waveform (transmit eye)

The required transmitter pulse shape characteristics are specified in the form of a mask of the transmitter eye diagram as shown in Figure 75–7 for upstream direction of 10/1GBASE–PRX PMD and Figure 75–8 for downstream direction of 10/1GBASE–PRX PMD and both directions of 10GBASE–PR PMD.

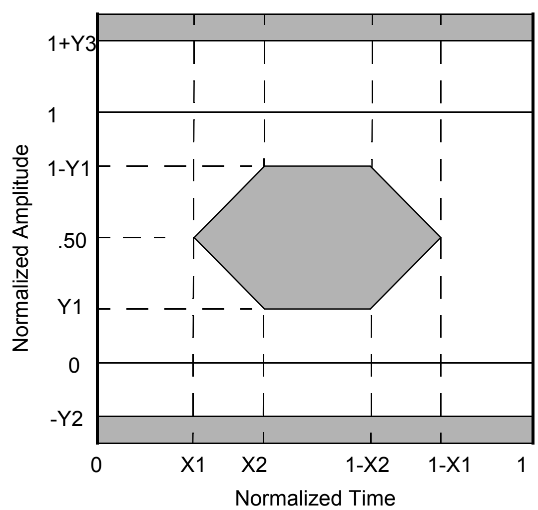


Figure 75–7—Transmitter eye mask definition for upstream direction of 10/1GBASE–PRX PMD

The measurement procedure is described in 58.7.8 for 1 Gb/s PHYs and 52.9.7 for 10 Gb/s PHYs and references therein. The eye shall comply to the mask of the eye using a fourth-order Bessel-Thomson receiver response as defined in 60.7.8 for 1 Gb/s PMD transmitters and 52.9.7 for 10 Gb/s PMD transmitters.

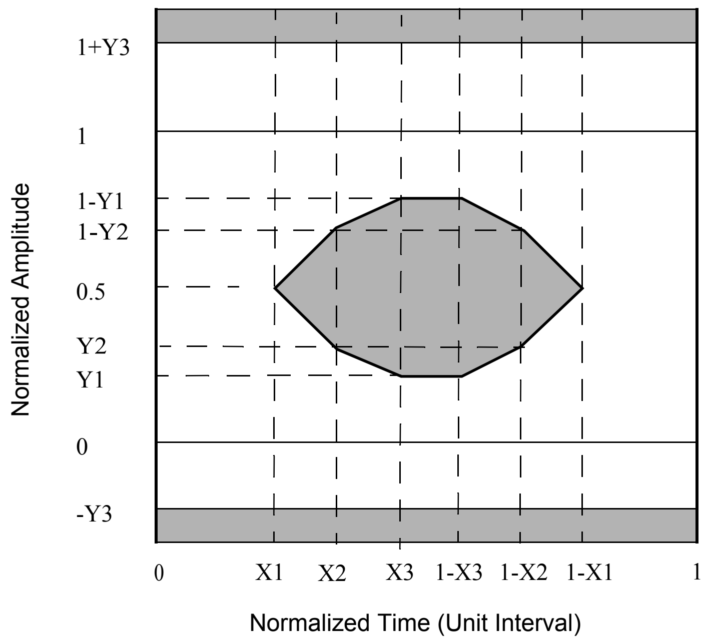


Figure 75–8—Transmitter eye mask definition for downstream direction of 10/1GBASE–PRX PMD and both directions of 10GBASE–PR PMD

75.7.10 Transmitter and dispersion penalty (TDP)

TDP measurement tests transmitter impairments, including chromatic dispersion effects, due to signal propagation in SMF used in PON. Possible causes of impairment include intersymbol interference, jitter, and RIN. Meeting the separate requirements (e.g., eye mask, spectral characteristics) does not in itself guarantee the TDP. The TDP limit shall be met. See 58.7.9 for details of the measurement for 1 Gb/s PHYs and 52.9.10 for 10 Gb/s PHYs.

75.7.11 Receive sensitivity

Receiver sensitivity is defined for the random pattern test frame, or test pattern 1, or test pattern 3, and an ideal input signal quality with the specified extinction ratio. The measurement procedure is described in 58.7.10 for 1 Gb/s PHYs and 52.9.8 for 10 Gb/s PHYs. The sensitivity shall be met for the bit error ratio defined in Table 75–6, Table 75–7, or Table 75–11 as appropriate.

75.7.12 Stressed receiver conformance test

Compliance with stressed receiver sensitivity is mandatory for the following PMDs: 10GBASE–PR–D1, 10GBASE–PR–D2, 10GBASE–PR–D3, 10GBASE–PR–U1, 10GBASE–PR–U3, 10/1GBASE–PRX–D3, 10/1GBASE–PRX–U1, 10/1GBASE–PRX–U2, and 10/1GBASE–PRX–U3. The stressed receiver conformance test is intended to screen against receivers with poor frequency response or timing characteristics that could cause errors when combined with a distorted but compliant signal. To be compliant with stressed receiver sensitivity, the receiver shall meet the specified bit error ratio at the power level and signal quality defined in Table 75–6, Table 75–7, or Table 75–11 as appropriate, according to the measurement procedures of 58.7.11 for 1 Gb/s PHYs and 52.9.9 for 10 Gb/s PHYs.

75.7.13 Jitter measurements

Jitter measurements for 1 Gb/s are described in 58.7.12. Jitter measurements for 10 Gb/s are described in 52.8.1.

75.7.14 Laser on/off timing measurement

The laser on/off timing measurement procedure is described in 60.7.13.1 with the following changes:

a) T_{on} is defined in 60.7.13.1.1, and its value is less than 512 ns (defined in Table 75–8 and Table 75–9).
b) $T_{receiver\_settling}$ is defined in 60.7.13.2.1, and its value is defined in Table 75–6 and Table 75–7.
c) T_{CDR} is defined in 76.4.2.1, and its value is less than 400 ns.
d) $T_{code\_group\_align}$ is defined in 36.6.2.4, and its value is less than 4 ten bit code–groups for 1 Gb/s PHYs, and is defined as 0 for 10 Gb/s PHYs.
e) T_{off} is defined in 60.7.13.11.1, and its value is less than 512 ns (defined in Table 75–8 and Table 75–9).

75.7.15 Receiver settling timing measurement

75.7.15.1 Definitions

Denote $T_{receiver\_settling}$ as the time beginning from the time that the optical power in the receiver at TP7 reaches the conditions specified in 75.7.12 and ending at the time that the electrical signal after the PMD at TP8 reaches within 15% of its steady state parameter (average power, jitter) (see Table 75–6 for 10GBASE–PR–D1, 10GBASE–PR–D2, and 10GBASE–PR–D3, and Table 75–7 for 10/1GBASE–PRX–D1, 10/1GBASE–PRX–D2, and 10/1GBASE–PRX–D3). $T_{receiver\_settling}$ is presented in Figure 75–9. The data transmitted may be any valid 64B/66B symbols (or a specific power synchronization sequence). The optical signal at TP7, at the beginning of the locking, may have any valid 64B/66B pattern, optical power level, jitter, or frequency shift matching the standard specifications.

75.7.15.2 Test specification

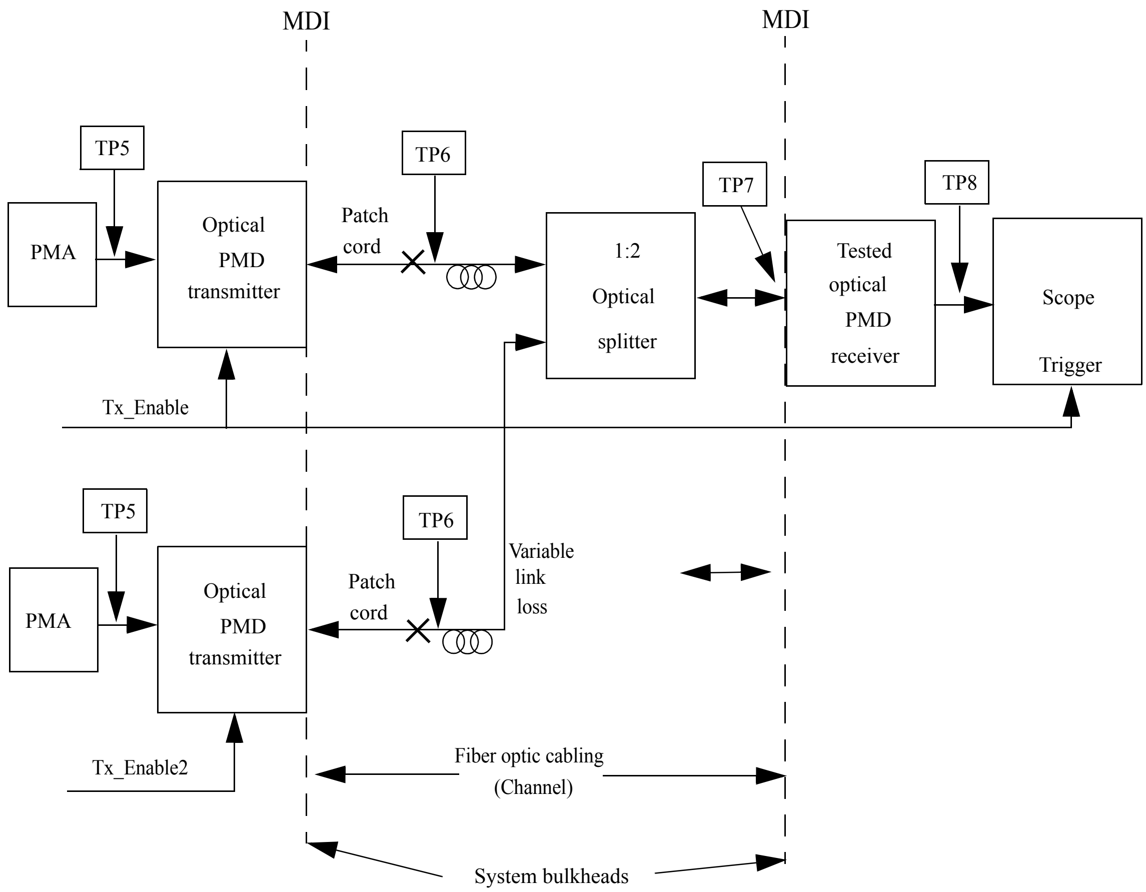


Figure 75–9—Receiver settling time measurement setup

Figure 75–9 illustrates the test setup for the OLT PMD receiver (upstream) $T_{receiver\_settling}$ time. The optical PMD transmitter has well–known parameters, with a fixed known T_{on} time. After T_{on} time the parameters of the reference transmitter, at TP6 and therefore at TP7, reach within 15% of its steady state values as specified in Table 75–8 for 10GBASE–PR–U1 and 10GBASE–PR–U3 and Table 75–9 for 10/1GBASE–PRX–U1, 10/1GBASE–PRX–U2 and 10/1GBASE–PRX–U3.

Define $T_{receiver\_settling}$ time as the time from the Tx_Enable assertion, minus the known T_{on} time, to the time the electrical signal at TP8 reaches within 15% of its steady state conditions.

Conformance should be assured for an optical signal at TP7 with any level of its specified parameters before the Tx_Enable assertion. Especially the $T_{receiver\_settling}$ time must be met in the following scenarios:

- — Switching from a ‘weak’ (minimal received power at TP7) ONU to a ‘strong’ (maximal received power at TP7) ONU, with minimal guard band between.
- — Switching from a ‘strong’ ONU to a ‘weak’ ONU, with minimal guard band between.
- — Switching from noise level, with maximal duration interval, to ‘strong’ ONU power level.

A non-rigorous way to describe this test setup would be (using a transmitter with a known T_{on}).

For a tested PMD receiver with a declared $T_{receiver\_settling}$ time, measure all PMD receiver electrical parameters at TP8 after $T_{receiver\_settling}$ from the TX_ENABLE trigger minus the reference transmitter T_{on}, reassuring conformance to within 15% of its specified steady state values.

75.8 Environmental, safety, and labeling

75.8.1 General safety

All equipment subject to this clause shall conform to IEC 60950–1.

75.8.2 Laser safety

10GBASE–PR and 10/1GBASE–PRX optical transceivers shall conform to Class 1 laser requirements as defined in IEC 60825–1 and IEC 60825–2, under any condition of operation. This includes single fault conditions whether coupled into a fiber or out of an open bore.

Conformance to additional laser safety standards may be required for operation within specific geographic regions.

Laser safety standards and regulations require that the manufacturer of a laser product provide information about the product's laser, safety features, labeling, use, maintenance, and service. This documentation explicitly defines requirements and usage restrictions on the host system necessary to meet these safety certifications.

75.8.3 Installation

It is recommended that proper installation practices, as defined by applicable local codes and regulation, be followed in every instance in which such practices are applicable.

75.8.4 Environment

The 10GBASE–PR and 10/1GBASE–PRX operating environment specifications are as defined in 52.11, as defined in 52.11.1 for electromagnetic emission, and as defined in 52.11.2 for temperature, humidity, and handling.

See Annex 67A for additional environmental information. Two optional temperature ranges are defined in Table 60–13. Implementations shall be declared as compliant over one or both complete ranges, or not so declared (compliant over parts of these ranges or another temperature range).

75.8.5 PMD labeling

The 10GBASE–PR and 10/1GBASE–PRX labeling recommendations and requirements are as defined in 52.12.

Defined PMDs are as follows:

— 10/1GBASE–PRX–D1
— 10/1GBASE–PRX–D2
— 10/1GBASE–PRX–D3
— 10GBASE–PR–D1
— 10GBASE–PR–D2
— 10GBASE–PR–D3
— 10/1GBASE–PRX–U1
— 10/1GBASE–PRX–U2
— 10/1GBASE–PRX–U3
— 10GBASE–PR–U1
— 10GBASE–PR–U3

Each field-pluggable component shall be clearly labeled with its operating temperature range over which compliance is ensured.

75.9 Characteristics of the fiber optic cabling

The 10GBASE–PR and 10/1GBASE–PRX fiber optic cabling shall meet the dispersion specifications defined in IEC 60793–2 and ITU–T G.652, as shown in Table 75–14. The fiber optic cabling consists of one or more sections of fiber optic cable and any intermediate connections required to connect sections together. It also includes a connector plug at each end to connect to the MDI. The fiber optic cabling spans from one MDI to another MDI, as shown in Figure 75–3.

75.9.1 Fiber optic cabling model

The fiber optic cabling model is shown in Figure 75–3.

NOTE—The optical splitter presented in Figure 75–3 may be replaced by a number of smaller 1:n splitters such that a different topology may be implemented while preserving the link characteristics and power budget as defined in Table 75B–1 and Table 75B–2.

The maximum channel insertion losses shall meet the requirements specified in Table 75–1. Insertion loss measurements of installed fiber cables are made in accordance with IEC 61280–4–2:2000. The fiber optic cabling model (channel) defined here is the same as a simplex fiber optic link segment. The term *channel* is used here for consistency with generic cabling standards.

75.9.2 Optical fiber and cable

The fiber optic cable requirements are satisfied by the fibers specified in IEC 60793–2 Type B1.1 (dispersion un–shifted SMF) and Type B1.3 (low water peak SMF), ITU–T G.652 and ITU–T G.657 (bend–insensitive SMF), as noted in Table 75–14.

75.9.3 Optical fiber connection

Table 75–14—Optical fiber and cable characteristics

Description[a]	IEC 60793–2 B1.1, B1.3 SMF, ITU–T G.652, G.657 SMF[b]				Unit
Nominal wavelength[c]	1270	1310	1550	1577	nm
Cable attenuation (max)[d]	0.44	0.4	0.35	0.35	dB/km
Zero dispersion wavelength[e]	$1300 \le \lambda_0 \le 1324$				nm
Dispersion slope (max)	0.093				$ps/nm^2 \cdot km$

[a]The fiber dispersion values are normative, all other values in the table are informative.
[b]Other fiber types are acceptable if the resulting ODN meets channel insertion loss and dispersion requirements.
[c]Wavelength specified is the nominal wavelength and typical measurement wavelength. Power penalties at other wavelengths are accounted for.
[d]Attenuation for single-mode optical fiber cables for 1310 nm and 1550 nm is defined in ITU–T G.652. The attenuation values in the 1270 nm and 1577 nm windows were calculated using spectral attenuation modelling method (5.4.4) included in G.650.1 (06/2004) and the matrix coefficients included in Appendix III therein. 1310 nm (0.4 dB/km), 1380 nm (0.5 dB/km) and 1550 nm (0.35 dB/km) attenuation values were used as the input for the predictor model.
[e]See IEC 60793 or ITU–T G.652.

An optical fiber connection as shown in Figure 75–3 consists of a mated pair of optical connectors. The 10GBASE–PR or 10/1GBASE–PRX PMD is coupled to the fiber optic cabling through an optical connection and any optical splitters into the MDI optical receiver, as shown in Figure 75–3. The channel insertion loss includes the loss for connectors, splices and other passive components such as splitters, see Table 75B–1 and Table 75B–2.

The channel insertion loss was calculated under the assumption of 14.5 dB loss for a 1:16 splitter/18.1 dB loss for a 1:32 splitter (ITU–T G.671 am 1). Unitary fiber attenuation for particular transmission wavelength is provided in Table 75–14. The number of splices/connectors is not predefined; the number of individual fiber sections between the OLT MDI and the ONU MDI is not defined. The only requirements are that the resulting channel insertion loss is within the limits specified in Table 75–1 and the maximum reach in Table 75–1 is not exceeded. Other fiber arrangements (e.g., increasing the split ratio while decreasing the fiber length) are supported as long as the limits for the channel insertion loss specified in Table 75–1 are observed.

The maximum discrete reflectance for single-mode connections shall be less than –26 dB.

75.9.4 Medium Dependent Interface (MDI)

The 10GBASE–PR or 10/1GBASE–PRX PMD is coupled to the fiber cabling at the MDI. The MDI is the interface between the PMD and the “fiber optic cabling” as shown in Figure 75–3. Examples of an MDI include the following:

a) Connectorized fiber pigtail
b) PMD receptacle

When the MDI is a remateable connection, it shall meet the interface performance specifications of IEC 61753–1. The MDI carries the signal in both directions for 10GBASE–PR or 10/1GBASE–PRX PMD and couples to a single fiber.

NOTE—Compliance testing is performed at TP2 and TP3 as defined in 75.3.2, not at the MDI.

75.10 Protocol implementation conformance statement (PICS) proforma for Clause 75, Physical Medium Dependent (PMD) sublayer and medium for passive optical networks, type 10GBASE–PR and 10/1GBASE–PRX[4]

75.10.1 Introduction

The supplier of a protocol implementation that is claimed to conform to Clause 75, Physical Medium Dependent (PMD) sublayer and medium for passive optical networks, type 10GBASE–PR and 10/1GBASE–PRX, shall complete the following protocol implementation conformance statement (PICS) proforma.

A detailed description of the symbols used in the PICS proforma, along with instructions for completing the PICS proforma, can be found in Clause 21.

75.10.2 Identification

75.10.2.1 Implementation identification

Supplier[1]	
Contact point for enquiries about the PICS[1]	
Implementation Name(s) and Version(s)[1,3]	
Other information necessary for full identification—e.g., name(s) and version(s) for machines and/or operating systems; System Name(s)[2]	
NOTE 1—Required for all implementations. NOTE 2—May be completed as appropriate in meeting the requirements for the identification. NOTE 3—The terms Name and Version should be interpreted appropriately to correspond with a supplier's terminology (e.g., Type, Series, Model).	

75.10.2.2 Protocol summary

Identification of protocol standard	IEEE Std 802.3av-2009, Clause 75, Physical Medium Dependent (PMD) sublayer and medium for passive optical networks, type 10GBASE–PR and 10/1GBASE–PRX
Identification of amendments and corrigenda to this PICS proforma that have been completed as part of this PICS	
Have any Exception items been required?	No [ ] Yes [ ]
(See Clause 21; the answer Yes means that the implementation does not conform to IEEE Std 802.3av-2009.)	

Date of Statement	

[4]*Copyright release for PICS proformas:* Users of this standard may freely reproduce the PICS proforma in this subclause so that it can be used for its intended purpose and may further publish the completed PICS.

75.10.3 Major capabilities/options

Item	Feature	Subclause	Value/Comment	Status	Support
DTX	Transmit delay	75.3.1.1	Delay of 4 TQ (max) with variability 0.5 TQ (max)	M	Yes [ ]
DRX	Receive delay	75.3.1.1	Delay of 4 TQ (max) with variability 0.5 TQ (max)	M	Yes [ ]
HT	High temperature operation	75.8.4	–5 ºC to 85 ºC	O	Yes [ ] No [ ]
LT	Low temperature operation	75.8.4	–40 ºC to 60 ºC	O	Yes [ ] No [ ]
*PR10U	10GBASE–PR–D1 or 10GBASE–PR–U1 PMD	75.4, 75.5	Maximum channel insertion loss of 20 dB	O/1	Yes [ ] No [ ]
*PR10D	10GBASE–PR–D1 or 10GBASE–PR–U1 PMD	75.4, 75.5	Maximum channel insertion loss of 20 dB	O/1	Yes [ ] No [ ]
*PR20U	10GBASE–PR–D2 or 10GBASE–PR–U1 PMD	75.4, 75.5	Maximum channel insertion loss of 24 dB	O/1	Yes [ ] No [ ]
*PR20D	10GBASE–PR–D2 or 10GBASE–PR–U1 PMD	75.4, 75.5	Maximum channel insertion loss of 24 dB	O/1	Yes [ ] No [ ]
*PR30U	10GBASE–PR–D3 or 10GBASE–PR–U3 PMD	75.4, 75.5	Maximum channel insertion loss of 29 dB	O/1	Yes [ ] No [ ]
*PR30D	10GBASE–PR–D3 or 10GBASE–PR–U3 PMD	75.4, 75.5	Maximum channel insertion loss of 29 dB	O/1	Yes [ ] No [ ]
*PRX10U	10/1GBASE–PRX–D1 or 10/1GBASE–PRX–U1 PMD	75.4, 75.5	Maximum channel insertion loss of 20 dB	O/1	Yes [ ] No [ ]
*PRX10D	10/1GBASE–PRX–D1 or 10/1GBASE–PRX–U1 PMD	75.4, 75.5	Maximum channel insertion loss of 20 dB	O/1	Yes [ ] No [ ]
*PRX20U	10/1GBASE–PRX–D2 or 10/1GBASE–PRX–U2 PMD	75.4, 75.5	Maximum channel insertion loss of 24 dB	O/1	Yes [ ] No [ ]
*PRX20D	10/1GBASE–PRX–D2 or 10/1GBASE–PRX–U2 PMD	75.4, 75.5	Maximum channel insertion loss of 24 dB	O/1	Yes [ ] No [ ]
*PRX30U	10/1GBASE–PRX–D3 or 10/1GBASE–PRX–U3 PMD	75.4, 75.5	Maximum channel insertion loss of 29 dB	O/1	Yes [ ] No [ ]
*PRX30D	10/1GBASE–PRX–D3 or 10/1GBASE–PRX–U3 PMD	75.4, 75.5	Maximum channel insertion loss of 29 dB	O/1	Yes [ ] No [ ]
*INS	Installation/Cable	75.4.1	Items marked with INS include installation practices and cable specifications not applicable to a PHY manufacturer	O	Yes [ ] No [ ]

75.10.4 PICS proforma tables for Physical Medium Dependent (PMD) sublayer and medium for passive optical networks, type 10GBASE–PR and 10/1GBASE–PRX

75.10.4.1 PMD functional specifications

Item	Feature	Subclause	Value/Comment	Status	Support
FN1	Transmit function	75.3.3	Conveys bits from PMD service interface to MDI	M	Yes [ ]
FN2	Transmitter optical signal	75.3.3	Higher optical power transmitted is a logic 1	M	Yes [ ]
FN3	Receive function	75.3.4	Conveys bits from MDI to PMD service interface	M	Yes [ ]
FN4	Receiver optical signal	75.3.4	Higher optical power received is a logic 1	M	Yes [ ]
FN5	ONU signal detect function	75.3.5.1	Mapping to PMD service interface	M	Yes [ ]
FN6	ONU signal detect parameter	75.3.5.1	Generated according to Table 75–4	M	Yes [ ]
FN7	OLT signal detect function	75.3.5.2	Mapping to PMD service interface	O/2	Yes [ ]
FN8	OLT signal detect function	75.3.5.2	Provided by higher layer	O/2	Yes [ ]
FN9	OLT signal detect parameter	75.3.5.1	Generated according to Table 75–4	O	Yes [ ]

75.10.4.2 PMD to MDI optical specifications for 10GBASE–PR–D1

Item	Feature	Subclause	Value/Comment	Status	Support
PRD1F1	10GBASE–PR–D1 transmitter	75.4.1	Meets specifications in Table 75–5	PRD1F1:M	Yes [ ] N/A [ ]
PRD1F2	10GBASE–PR–D1 receiver	75.4.2	Meets specifications in Table 75–6	PRD1F2:M	Yes [ ] N/A [ ]
PRD1F3	10GBASE–PR–D1 stressed receiver sensitivity	75.4.2	Meets specifications in Table 75–6	PRD1F3:O	Yes [ ] No [ ] N/A[ ]
PRD1F4	10GBASE–PR–D1 receiver damage threshold	75.4.2	If the receiver does not meet the damage requirements in Table 75–6 then label accordingly	PRD1F4:M	Yes [ ] N/A [ ]

75.10.4.3 PMD to MDI optical specifications for 10GBASE–PR–D2

Item	Feature	Subclause	Value/Comment	Status	Support
PRD2F1	10GBASE–PR–D2 transmitter	75.4.1	Meets specifications in Table 75–5	PRD2F1:M	Yes [ ] N/A [ ]
PRD2F2	10GBASE–PR–D2 receiver	75.4.2	Meets specifications in Table 75–6	PRD2F2:M	Yes [ ] N/A [ ]
PRD2F3	10GBASE–PR–D2 stressed receiver sensitivity	75.4.2	Meets specifications in Table 75–6	PRD2F3:O	Yes [ ] No [ ] N/A[ ]
PRD2F4	10GBASE–PR–D2 receiver damage threshold	75.4.2	If the receiver does not meet the damage requirements in Table 75–6 then label accordingly	PRD2F4:M	Yes [ ] N/A [ ]

75.10.4.4 PMD to MDI optical specifications for 10GBASE–PR–D3

Item	Feature	Subclause	Value/Comment	Status	Support
PRD3F1	10GBASE–PR–D3 transmitter	75.4.1	Meets specifications in Table 75–5	PRD3F1:M	Yes [ ] N/A [ ]
PRD3F2	10GBASE–PR–D3 receiver	75.4.2	Meets specifications in Table 75–6	PRD3F2:M	Yes [ ] N/A [ ]
PRD3F3	10GBASE–PR–D3 stressed receiver sensitivity	75.4.2	Meets specifications in Table 75–6	PRD3F3:O	Yes [ ] No [ ] N/A[ ]
PRD3F4	10GBASE–PR–D3 receiver damage threshold	75.4.2	If the receiver does not meet the damage requirements in Table 75–6 then label accordingly	PRD3F4:M	Yes [ ] N/A [ ]

75.10.4.5 PMD to MDI optical specifications for 10/1GBASE–PRX–D1

Item	Feature	Subclause	Value/Comment	Status	Support
PRXD1F1	10/1GBASE–PXR–D1 transmitter	75.4.1	Meets specifications in Table 75–5	PRXD1F1:M	Yes [ ] N/A [ ]
PRXD1F2	10/1GBASE–PRX–D1 receiver	75.4.2	Meets specifications in Table 75–7	PRXD1F2:M	Yes [ ] N/A [ ]
PRXD1F3	10/1GBASE–PRX–D1 stressed receiver sensitivity	75.4.2	Meets specifications in Table 75–7	PRXD1F3:O	Yes [ ] No [ ] N/A[ ]
PRXD1F4	10/1GBASE–PRX–D1 receiver damage threshold	75.4.2	If the receiver does not meet the damage requirements in Table 75–7 then label accordingly	PRXD1F4:M	Yes [ ] N/A [ ]

75.10.4.6 PMD to MDI optical specifications for 10/1GBASE–PRX–D2

Item	Feature	Subclause	Value/Comment	Status	Support
PRXD2F1	10/1GBASE–PXR–D2 transmitter	75.4.1	Meets specifications in Table 75–5	PRXD2F1:M	Yes [ ] N/A [ ]
PRXD2F2	10/1GBASE–PRX–D2 receiver	75.4.2	Meets specifications in Table 75–7	PRXD2F2:M	Yes [ ] N/A [ ]
PRXD2F3	10/1GBASE–PRX–D2 stressed receiver sensitivity	75.4.2	Meets specifications in Table 75–7	PRXD2F3:O	Yes [ ] No [ ] N/A[ ]
PRXD2F4	10/1GBASE–PRX–D2 receiver damage threshold	75.4.2	If the receiver does not meet the damage requirements in Table 75–7 then label accordingly	PRXD2F4:M	Yes [ ] N/A [ ]

75.10.4.7 PMD to MDI optical specifications for 10/1GBASE–PRX–D3

Item	Feature	Subclause	Value/Comment	Status	Support
PRXD3F1	10/1GBASE–PXR–D3 transmitter	75.4.1	Meets specifications in Table 75–5	PRXD3F1:M	Yes [ ] N/A [ ]
PRXD3F2	10/1GBASE–PRX–D3 receiver	75.4.2	Meets specifications in Table 75–7	PRXD3F2:M	Yes [ ] N/A [ ]
PRXD3F3	10/1GBASE–PRX–D3 stressed receiver sensitivity	75.4.2	Meets specifications in Table 75–7	PRXD3F3:O	Yes [ ] No [ ] N/A[ ]
PRXD3F4	10/1GBASE–PRX–D3 receiver damage threshold	75.4.2	If the receiver does not meet the damage requirements in Table 75–7 then label accordingly	PRXD3F4:M	Yes [ ] N/A [ ]

75.10.4.8 PMD to MDI optical specifications for 10GBASE–PR–U1

Item	Feature	Subclause	Value/Comment	Status	Support
PRU1F1	10GBASE–PR–U1 transmitter	75.5.1	Meets specifications in Table 75–8	PRU1F1:M	Yes [ ] N/A [ ]
PRU1F2	10GBASE–PR–U1 receiver	75.5.2	Meets specifications in Table 75–11	PRU1F2:M	Yes [ ] N/A [ ]
PRU1F3	10GBASE–PR–U1 stressed receiver sensitivity	75.5.2	Meets specifications in Table 75–11	PRU1F3:O	Yes [ ] No [ ] N/A[ ]
PRU1F4	10GBASE–PR–U1 receiver damage threshold	75.5.2	If the receiver does not meet the damage requirements in Table 75–11 then label accordingly	PRU1F4:M	Yes [ ] N/A [ ]

75.10.4.9 PMD to MDI optical specifications for 10GBASE–PR–U3

Item	Feature	Subclause	Value/Comment	Status	Support
PRU3F1	10GBASE–PR–U3 transmitter	75.5.1	Meets specifications in Table 75–8	PRU3F1:M	Yes [ ] N/A [ ]
PRU3F2	10GBASE–PR–U3 receiver	75.5.2	Meets specifications in Table 75–11	PRU3F2:M	Yes [ ] N/A [ ]
PRU3F3	10GBASE–PR–U3 stressed receiver sensitivity	75.5.2	Meets specifications in Table 75–11	PRU3F3:O	Yes [ ] No [ ] N/A[ ]
PRU3F4	10GBASE–PR–U3 receiver damage threshold	75.5.2	If the receiver does not meet the damage requirements in Table 75–11 then label accordingly	PRU3F4:M	Yes [ ] N/A [ ]

75.10.4.10 PMD to MDI optical specifications for 10/1GBASE–PRX–U1

Item	Feature	Subclause	Value/Comment	Status	Support
PRXU1F1	10/1GBASE–PRX–U1 transmitter	75.5.1	Meets specifications in Table 75–9	PRXU1F1:M	Yes [ ] N/A [ ]
PRXU1F2	10/1GBASE–PRX–U1 receiver	75.5.2	Meets specifications in Table 75–11	PRXU1F2:M	Yes [ ] N/A [ ]
PRXU1F3	10/1GBASE–PRX–U1 stressed receiver sensitivity	75.5.2	Meets specifications in Table 75–11	PRXU1F3:O	Yes [ ] No [ ] N/A[ ]
PRXU1F4	10/1GBASE–PRX–U1 receiver damage threshold	75.5.2	If the receiver does not meet the damage requirements in Table 75–11 then label accordingly	PRXU1F4:M	Yes [ ] N/A [ ]

75.10.4.11 PMD to MDI optical specifications for 10/1GBASE–PRX–U2

Item	Feature	Subclause	Value/Comment	Status	Support
PRXU2F1	10/1GBASE–PRX–U2 transmitter	75.5.1	Meets specifications in Table 75–9	PRXU2F1:M	Yes [ ] N/A [ ]
PRXU2F2	10/1GBASE–PRX–U2 receiver	75.5.2	Meets specifications in Table 75–11	PRXU2F2:M	Yes [ ] N/A [ ]
PRXU2F3	10/1GBASE–PRX–U2 stressed receiver sensitivity	75.5.2	Meets specifications in Table 75–11	PRXU2F3:O	Yes [ ] No [ ] N/A[ ]
PRXU2F4	10/1GBASE–PRX–U2 receiver damage threshold	75.5.2	If the receiver does not meet the damage requirements in Table 75–11 then label accordingly	PRXU2F4:M	Yes [ ] N/A [ ]

75.10.4.12 PMD to MDI optical specifications for 10/1GBASE–PRX–U3

Item	Feature	Subclause	Value/Comment	Status	Support
PRXU3F1	10/1GBASE–PRX–U3 transmitter	75.5.1	Meets specifications in Table 75–9	PRXU3F1:M	Yes [ ] N/A [ ]
PRXU3F2	10/1GBASE–PRX–U3 receiver	75.5.2	Meets specifications in Table 75–11	PRXU3F2:M	Yes [ ] N/A [ ]
PRXU3F3	10/1GBASE–PRX–U3 stressed receiver sensitivity	75.5.2	Meets specifications in Table 75–11	PRXU3F3:O	Yes [ ] No [ ] N/A[ ]
PRXU3F4	10/1GBASE–PRX–U3 receiver damage threshold	75.5.2	If the receiver does not meet the damage requirements in Table 75–11 then label accordingly	PRXU3F4:M	Yes [ ] N/A [ ]

75.10.4.13 Definitions of optical parameters and measurement methods

Item	Feature	Subclause	Value/Comment	Status	Support
OM1	Measurement cable	75.7.1	2 m to 5 m in length	M	Yes [ ]
OM2	Wavelength and spectral width	75.7.4	Per TIA–455–127–A under modulated conditions.	M	Yes [ ]
OM3	Average optical power	75.7.5	Per TIA/EIA–455–95.	M	Yes [ ]
OM4	Extinction ratio	75.7.6	Per ANSI/TIA/EIA–526–4A with minimal back reflections and fourth-order Bessel–Thomson receiver.	M	Yes [ ]
OM5	Optical modulation amplitude (OMA) test procedure	75.7.7	As described in 58.7.5 for 1 Gb/s PHY and in 52.9.5.6 for 10 Gb/s PHY.	M	Yes [ ]
OM6	RIN_xOMA	75.7.8	As described in 58.8.7.	M	Yes [ ]
OM7	Transmit optical waveform (transmit eye)	75.7.9	Per ANSI/TIA/EIA–526–4A with test pattern and fourth-order Bessel–Thomson receiver.	M	Yes [ ]
OM8	Transmitter and dispersion penalty	75.7.10	As described in 58.7.7 for 1 Gb/s PHY and in 52.9.6 for 10 Gb/s PHY.	M	Yes [ ]
OM9	Receive sensitivity	75.7.11	As described in 58.7.10 for 1 Gb/s PHY and in 52.9.8 for 10 Gb/s PHY. Values defined in Table 75–6, Table 75–7, or Table 75–11 as appropriate.	M	Yes [ ]
*OM10	Stressed receiver conformance test	75.7.12	As described in 58.7.11 for 1 Gb/s PHY and in 52.9.9 for 10 Gb/s PHY. Values defined in Table 75–6, Table 75–7, or Table 75–11 as appropriate.	O	Yes[ ] N/A[ ]
OM11	Jitter measurements	75.7.13	As described in 58.7.12 for 1 Gb/s PHY and in 52.8.1 for 10 Gb/s PHY.	M	Yes [ ]

Item	Feature	Subclause	Value/Comment	Status	Support
OM12	Laser On/Off timing measurement	75.7.14	As described in 60.7.13.1 for 1 Gb/s PHY and in 60.7.13.1 with modifications defined in 75.7.14 for 10 Gb/s PHY.	M	Yes [ ]
OM13	Receiver settling timing measurement	75.7.15	As described in 60.7.13.2 for 1 Gb/s and 10 Gb/s PHY.	O	Yes [ ] No [ ]

75.10.4.14 Characteristics of the fiber optic cabling and MDI

Item	Feature	Subclause	Value/Comment	Status	Support
FO1	Fiber optic cabling	75.9	Specified in Table 75–14	INS:M	Yes [ ] N/A[ ]
F02	End –to–end channel loss	75.9	Meeting the requirements of Table 75B–1 and Table 75B–2	INS:M	Yes [ ] N/A[ ]
FO3	Maximum discrete reflectance – single-mode fiber	75.9.3	Less than –26 dB	INS:M	Yes [ ] N/A [ ]
FO4	MDI requirements	75.9.4	Meet the interface performance specifications of IEC 61753–1, if remateable	INS:O	Yes [ ] No [ ] N/A [ ]

75.10.4.15 Environmental specifications

Item	Feature	Subclause	Value/Comment	Status	Support
ES1	General safety	75.8.1	Conforms to IEC–60950–1	M	Yes [ ]
ES2	Laser safety —IEC Class 1	75.8.1	Conform to Class 1 laser requirements defined in IEC 60825–1 and IEC 60825–2	M	Yes [ ]
ES3	Documentation	75.8.1	Explicitly defines requirements and usage restrictions to meet safety certifications	M	Yes [ ]
ES4	Operating temperature range labeling	75.8.5	If required	M	Yes [ ] N/A[ ]

Annex 75A

(informative)

Dual-rate receiver implementation

75A.1 Overview

The OLT receiver supports burst mode operation. If the OLT supports a single upstream data rate e.g., only 1 Gb/s or 10 Gb/s, the receiver can be designed to handle the designated upstream data rate and line code. However, if the OLT supports both 1 Gb/s and 10 Gb/s upstream data rates, the OLT receiver supports both data rates via TDMA.

From a topological point of view, the PMD has a single optical input, sensitive to 1260–1360 nm signal, and two corresponding derived electrical outputs: 1.25 GBd and 10.3125 GBd. Thus, at a certain point in the implementation it is necessary to introduce a signal split, where the location of such a signal split is an implementation choice. The incoming signal can be split in the optical domain and fed into two, independent photodetectors as shown in Figure 75A–1(a). Alternatively, the signal can be detected using a single photodetector as shown in Figure 75A–1(b) and then split in the electrical domain after the transimpedance amplifier (TIA) block.

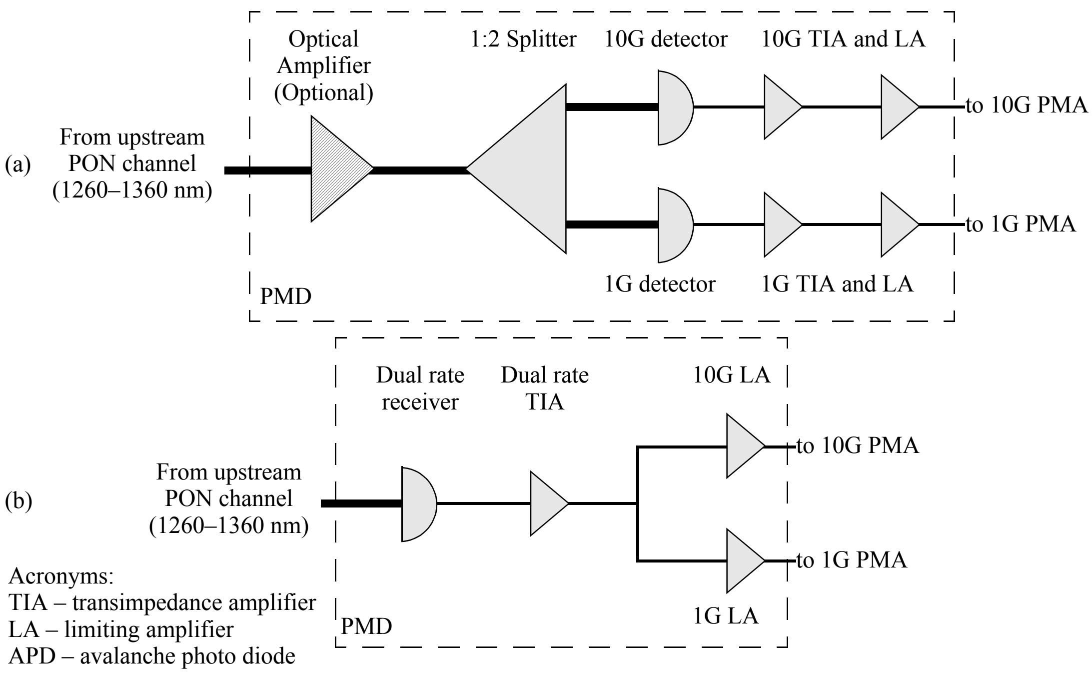


Figure 75A–1—Dual-rate PMD topologies with the split in the (a) optical domain, (b) electrical domain

When the incoming signal is split in the optical domain, it is possible to design each PMD channel specifically to match the signaling speed, offering optimum sensitivity for both 1 Gb/s and 10 Gb/s signals. However, the additional 1:2 optical splitter presented in Figure 75A–1(a) degrades the sensitivity of the

PMD by introducing additional loss and lowering the power of the optical signal. Such a sensitivity reduction may be tolerable in the PX10/PR10/PRX10 type PMDs, but the more stringent power budgets including PX20, PR20, PRX20, PR30, and PRX30 may be very challenging or even impossible to implement with such an additional loss on the OLT receiver side. This particular problem may be resolved via an additional, low-gain optical amplifier introduced in-line with the 1:2 optical splitter, as presented in Figure 75A–1(a), used to boost the power level of the incoming signal sufficiently to overcome the loss introduced by the 1:2 optical splitter.

When the incoming signal is split in the electrical domain, only one photodetector and one TIA unit is used. The resulting optical sensitivity theoretically can be maintained without the need for optical amplification, reducing the complexity of the OLT receiver. However, the photodetector and TIA cope with both data rates in quick succession, switching between 1 Gb/s and 10 Gb/s bursts during the guardband. The key aspect here is that the detector-TIA bandwidth directly affects the sensitivity. If the circuit parameters of the detector-TIA can be rapidly adapted to the correct value, optimum sensitivity can be maintained. There are several implementation choices in this regard, three examples of which are shown in Figure 75A–2(a)–(c):

a) This implementation fixes the detector parameters at some predefined value, resulting in the reduction of the OLT receiver sensitivity by approximately 2 dB. However, it should be noted that this penalty can be divided in such a way that both 1 Gb/s and 10 Gb/s sensitivities are 1 dB lower than their ideal values.
b) This implementation fixes the avalanche photo diode (APD) bias, but switches the TIA transimpedance depending on the target signaling speed for the given incoming burst, resulting in the reduction of the receiver sensitivity by approximately 1 dB. The said sensitivity penalty could be subdivided to both data rates by setting the APD bias to a compromise value.
c) This implementation switches both the APD bias and the TIA transimpedance depending on the signaling speed of the incoming burst. This results in ideal performance at both 1 Gb/s and 10 Gb/s data rates. However, it is the most complex implementation in terms of the number of elements and the control complexity.

In the case of dynamic detector designs, it is necessary to determine the data rate of the incoming burst before adjusting the dynamic detector to match the target data rate.

In general, the PMD layer does not have the a priori knowledge of which data rate is used in the given burst; such information is available only to the MAC Client and is not available to the PMD sublayer. Therefore, some sort of data rate detector circuit should be utilized. One of the simple methods is based on measuring the spectral energy content of the received signal at frequencies well above 1.25 GHz (e.g., in the range of 2–10 GHz). The 1 Gb/s signal has very little energy in this frequency range, while the 10 Gb/s signal has ample energy there. Thus, the presence of 5 GHz energy indicates that a 10 Gb/s signal is incident.

In the dual-rate PMD topologies with the split in the electrical domain, the 10 Gb/s detector and TIA are implemented for receiving both 1 Gb/s and 10 Gb/s signals. Therefore, the damage threshold (max) of the 1/10 Gb/s dual-rate receiver should comply with the 10 Gb/s receiver specification in Table 75–6. Those values for 1000BASE–PX10–D and 1000BASE–PX20–D in Table 60–5 and Table 60–8, and also those of 10/1GBASE–PRX–D1 and 10/1GBASE–PRX–D2 in Table 75–5 cannot be applied for dual-rate OLT receivers.

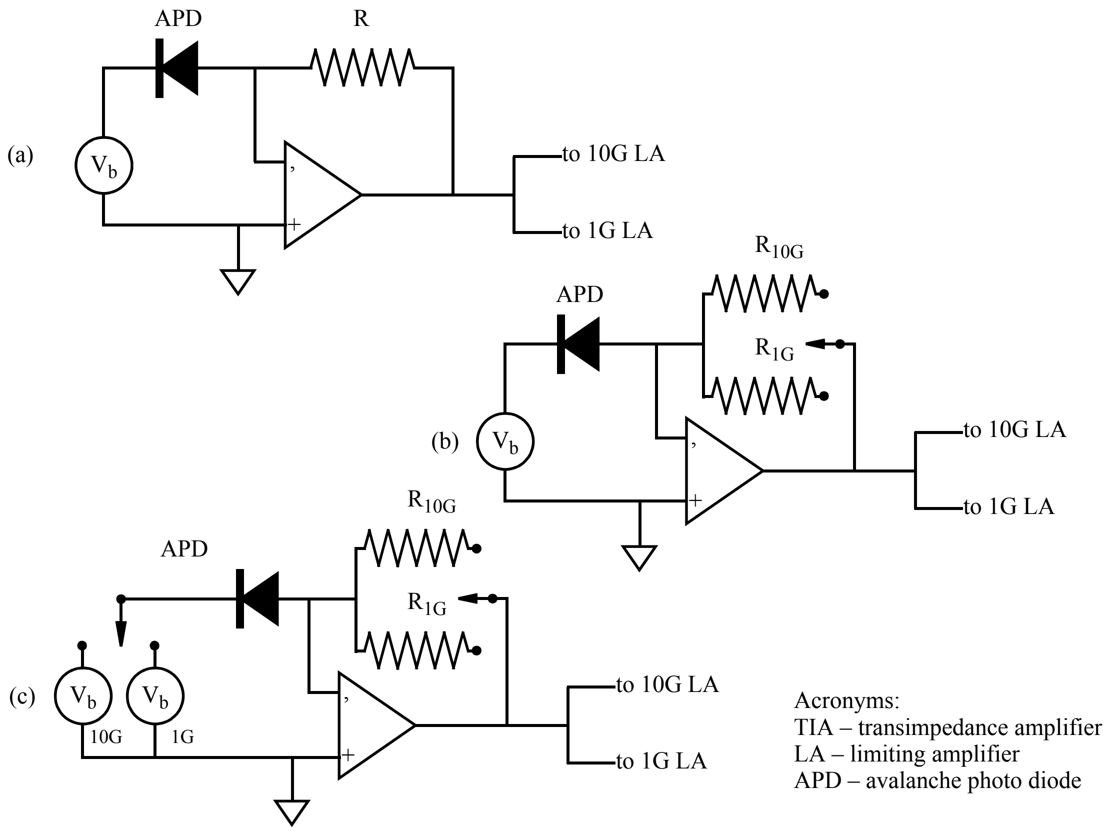


Figure 75A–2—Dual rate APD–TIA implementations: (a) static, (b) half–dynamic, (c) fully–dynamic

Annex 75B

(informative)

Illustrative channels and penalties for PR10, PR20, PR30, PRX10, PRX20, and PRX30 power budget classes

75B.1 Overview

Illustrative power budgets for PR10, PR20, and PR30 power budget classes are shown in Table 75B–1. Illustrative power budgets for PRX10, PRX20, and PRX30 power budget classes are shown in Table 75B–2.

NOTE—The budgets include an allowance for –12 dB reflection at the receiver.

75B.2 Wavelength allocation

The wavelength allocation plan for 10G–EPON systems is specified below.

75B.2.1 Downstream wavelength allocation

The 1 Gb/s downstream transmission uses the 1480–1500 nm wavelength band, as specified in Clause 60. The 10 Gb/s downstream transmission uses the 1575–1580 nm wavelength band, as specified in Clause 75. An OLT supporting both downstream channels may multiplex the output of the two transmitters using a WDM coupler, while the optical filters at an ONU are tuned to receive only one downstream wavelength.

Table 75B–1—Illustrative PR10, PR20 and PR30 channel insertion loss and penalties (symmetric-rate, 10 Gb/s power budget classes)

Description	PR10		PR20		PR30		Unit
	US[a]	DS[a]	US[a]	DS[a]	US[a]	DS[a]	
Fiber Type[b]	IEC 60793–2 B1.1, B1.3 SMF ITU–T G.652, G.657 SMF						
Measurement wavelength for fiber	1270	1577[c]	1270	1577[c]	1270	1577[c]	nm
Nominal distance[d]	10		20		20		km
Available power budget[e]	23	21.5	27	25.5	32	30.5	dB
Channel insertion loss (max)[f]	20		24		29		dB
Channel insertion loss (min)[g]	5		10		15		dB
Allocation for penalties[h]	3	2.5[i]	3	1.5	3	1.5	dB
Optical return loss of ODN (min)	20						dB

[a]US stands for Upstream, DS stands for Downstream.
[b]Other fiber types are acceptable if the resulting ODN meets channel insertion loss and dispersion requirements.
[c]The nominal transmit wavelength is 1577 nm.
[d]Nominal distance refers to the expected maximum distance a PMD is capable of achieving in a typical ODN. Numerous ODN implementation practices may result in longer or shorter distances being actually achievable in a user's network.
[e]The available power budget assumes a BER at the PMD service interface of 10^{-3}. The required BER of 10^{-12} at the PCS service interface is achieved by the FEC function of the PCS.
[f]The channel insertion loss is based on the cable attenuation at the target distance and nominal measurement wavelength. The channel insertion loss also includes the loss for connectors, splices and other passive components such as splitters.
[g]The power budgets for PR10, PR20 and PR30 power budget classes are such that a minimum insertion loss is assumed between transmitter and receiver. This minimum attenuation is required for PMD testing.
[h]The allocation for penalties is the difference between the available power budget and the channel insertion loss; insertion loss difference between nominal and worst case operating wavelength is considered a penalty. This allocation may be used to compensate for transmission related penalties. Further details are given in 75.7.2.
[i]The extra 1 dB of penalty here is to unify the downstream Tx and Rx specifications.

Table 75B–2—Illustrative PRX10, PRX20 and PRX30 channel insertion loss and penalties (asymmetric-rate, 10 Gb/s downstream, 1 Gb/s upstream power budget classes)

Description	PRX10		PRX20		PRX30		Unit
	US[a]	DS[a]	US[a]	DS[a]	US[a]	DS[a]	
Fiber Type[b]	IEC 60793–2 B1.1, B1.3 SMF ITU–T G.652, G.657 SMF						
Measurement wavelength for fiber	1310	1577[c]	1310	1577[c]	1310	1577[c]	nm
Nominal distance[d]	10		20		20		km
Available power budget	23.0	21.5[e]	26.0	25.5[e]	30.4	30.5[e]	dB
Channel insertion loss (max)[f]	20		24		29		dB
Channel insertion loss (min)[g]	5		10		15		dB
Allocation for penalties[h]	3	2.5[i]	2	1.5	1.4	1.5	dB
Optical return loss of ODN (min)	20						dB

[a]US stands for Upstream, DS stands for Downstream.
[b]Other fiber types are acceptable if the resulting ODN meets channel insertion loss and dispersion requirements.
[c]The nominal transmit wavelength is 1577 nm.
[d]Nominal distance refers to the expected maximum distance a PMD is capable of achieving in a typical ODN. Numerous ODN implementation practices may result in longer or shorter distances being actually achievable in a user's network.
[e]The available power budget assumes a BER at the PMD service interface of 10^{-3}. The required BER of 10^{-12} at the PCS service interface is achieved by the FEC function of the PCS.
[f]The channel insertion loss is based on the cable attenuation at the target distance and nominal measurement wavelength. The channel insertion loss also includes the loss for connectors, splices and other passive components such as splitters.
[g]The power budgets for PRX10, PRX20, and PRX30 power budget classes are such that a minimum insertion loss is assumed between transmitter and receiver. This minimum attenuation is required for PMD testing.
[h]The allocation for penalties is the difference between the available power budget and the channel insertion loss; insertion loss difference between nominal and worst case operating wavelength is considered a penalty. This allocation may be used to compensate for transmission related penalties. Further details are given in 75.7.2.
[i]The extra 1 dB of penalty here is to unify the downstream Tx and Rx specifications.

75B.2.2 Upstream wavelength allocation

The 1 Gb/s upstream transmission uses the 1260–1360 nm wavelength band, as specified in Clause 60. The 10 Gb/s upstream transmission uses the 1260–1280 nm wavelength band, as specified in Clause 75. The two wavelength bands overlap, thus WDM channel multiplexing cannot be used to separate the two data rates.

An OLT supporting both upstream data rates uses TDMA techniques to avoid collisions between transmissions originating from different ONUs, resulting in a dual-rate burst–mode reception as discussed in 75.6.

Annex 75C

(informative)

Jitter at TP1–TP8 for PR10, PR20, PR30, PRX10, PRX20, PRX30

75C.1 Overview

The jitter values at frequencies above 4 MHz are listed in Table 75C–1 for PR10, PR20, PR30, PRX10, PRX20, PRX30 downstream and in Table 75C–2 for PR10, PR20, PR30 upstream. Those in Table 75C–3 relate to the jitter frequencies above 637 kHz for PRX10, PRX20, PRX30 upstream.

Table 75C–1—PR10, PR20, PR30, PRX10, PRX20, PRX30 downstream jitter budgets

Reference point	DJ (UI p–p)	RJ (UI p–p)	TJ (UI p–p)
TP1	0.09	0.14	0.23
TP2	0.19	0.20	0.39
TP3	0.24	0.20	0.44
TP4	0.42	0.34	0.76

NOTE 1—Jitter measurements should be performed at nominal operating conditions.
NOTE 2—BER conditions for TP1, TP2, and TP3 are 10^{-12}, for TP4 is 10^{-3}.
NOTE 3—All jitter values relate to high frequency (>4 MHz) jitter.
NOTE 4—0.1 UI of sinusoidal jitter stress is assumed at the receiver.
NOTE 5—The Gaussian jitter is assumed to be a weak function of BER.

The upstream jitter transfer function is defined by Equation (75C–1). The jitter gain curve and the corresponding jitter gain values are shown in Figure 75C–1 where the jitter gain P and the jitter corner frequency fc are specified in Table 75C–4 for PR10, PR20 and PR30 and in Table 75C–5 for PRX10, PRX20, and PRX30, respectively.

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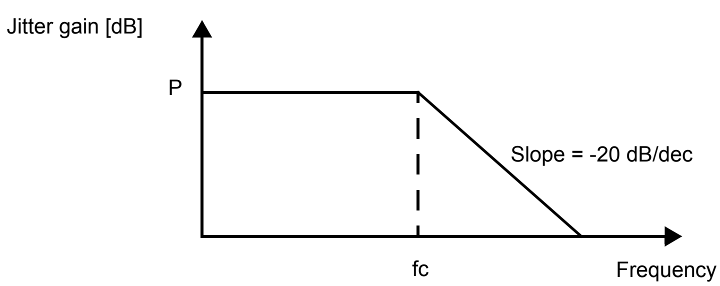


Figure 75C–1—Jitter gain curve values for PR10, PR20, PR30, PRX10, PRX20, and PRX30

Table 75C–2—PR10, PR20, PR30 upstream jitter budgets

Reference point	DJ (UI p–p)	RJ (UI p–p)	TJ (UI p–p)
TP5	0.12	0.16	0.28
TP6	0.30	0.21	0.51
TP7	0.35	0.21	0.56
TP8	0.53	0.23	0.76

NOTE 1—Jitter measurements should be performed at nominal operating conditions.
NOTE 2—BER conditions for TP5, TP6, and TP7 are 10^{-12}, for TP8 is 10^{-3}.
NOTE 3—All jitter values relate to high frequency (>4 MHz) jitter.
NOTE 4—0.1 UI of sinusoidal jitter stress is assumed at the receiver.
NOTE 5—The Gaussian jitter is assumed to be a weak function of BER.

Table 75C–3—PRX10, PRX20, PRX30 upstream jitter budgets

Reference point	Total jitter	
	UI	ps
TP5	0.24	192
TP6	0.40	320
TP7	0.49	392
TP8	0.67	536

Table 75C–4—Jitter gain curve values for PR10, PR20, and PR30

	Value	Unit
P	0.3	dB
fc	8	MHz

Table 75C–5—Jitter gain curve values for PRX10, PRX20, and PRX30

	Value	Unit
P	0.3	dB
fc	1274	kHz

$$\text{Jitter Transfer} = 20\log_{10}\left[\frac{\text{Jitter on upstream signal (UI)}}{\text{Jitter on downstream signal (UI)}} \times \frac{\text{downstream\_line\_rate}}{\text{upstream\_line\_rate}}\right] \quad (75C\text{-}1)$$

76. Reconciliation Sublayer, Physical Coding Sublayer, and Physical Media Attachment for 10G-EPON

76.1 Overview

This clause describes the Reconciliation Sublayer (RS), Physical Coding Sublayer (PCS) with FEC, and Physical Medium Attachment (PMA) used with 10GBASE-PR and 10/1GBASE-PRX point-to-multipoint (P2MP) networks. These are passive optical multipoint networks (PONs) that connect multiple DTEs using a single shared fiber. The architecture is asymmetric, based on a tree and branch topology utilizing passive optical splitters. This type of network requires that the Multipoint MAC Control sublayer exists above the MACs, as described in Clause 77.

76.1.1 Conventions

The notation used in the state diagrams in this clause follows the conventions in 21.5. Should there be a discrepancy between a state diagram and descriptive text, the state diagram prevails. The notation ++ after a counter indicates it is to be incremented by 1. The notation – – after a counter indicates it is to be decremented by 1. The notation –= after a counter indicates that the counter value is to be decremented by the following value. The notation += after a counter indicates that the counter value is to be incremented by the following value. Code examples given in this clause adhere to the style of the "C" programming language.

76.1.2 Delay constraints

The MPCP relies on strict timing based on the distribution of timestamps. The actual delay is implementation dependent but an implementation shall maintain a combined delay variation through RS, PCS, and PMA sublayers of no more than 1 time_quantum (see 77.2.2.1) so as not to interfere with the MPCP timing.

76.2 Reconciliation Sublayer (RS) for 10G-EPON

76.2.1 Overview

This subclause extends Clause 46 to enable multiple MACs to interface with a single Physical Layer, and to enable data links with one data rate (e.g., 10 Gb/s) in one direction but another (e.g., 1 Gb/s) in the opposite direction. The number of MACs supported is limited only by the implementation. It is acceptable for only one MAC to be connected to this Reconciliation Sublayer. Figure 76–1 and Figure 76–2 show the relationship between this RS and the ISO/IEC OSI reference model. The mapping of GMII/XGMII signals to PLS service primitives is described in 35.2.1 for GMII and 46.1.7 for XGMII with exceptions noted herein.

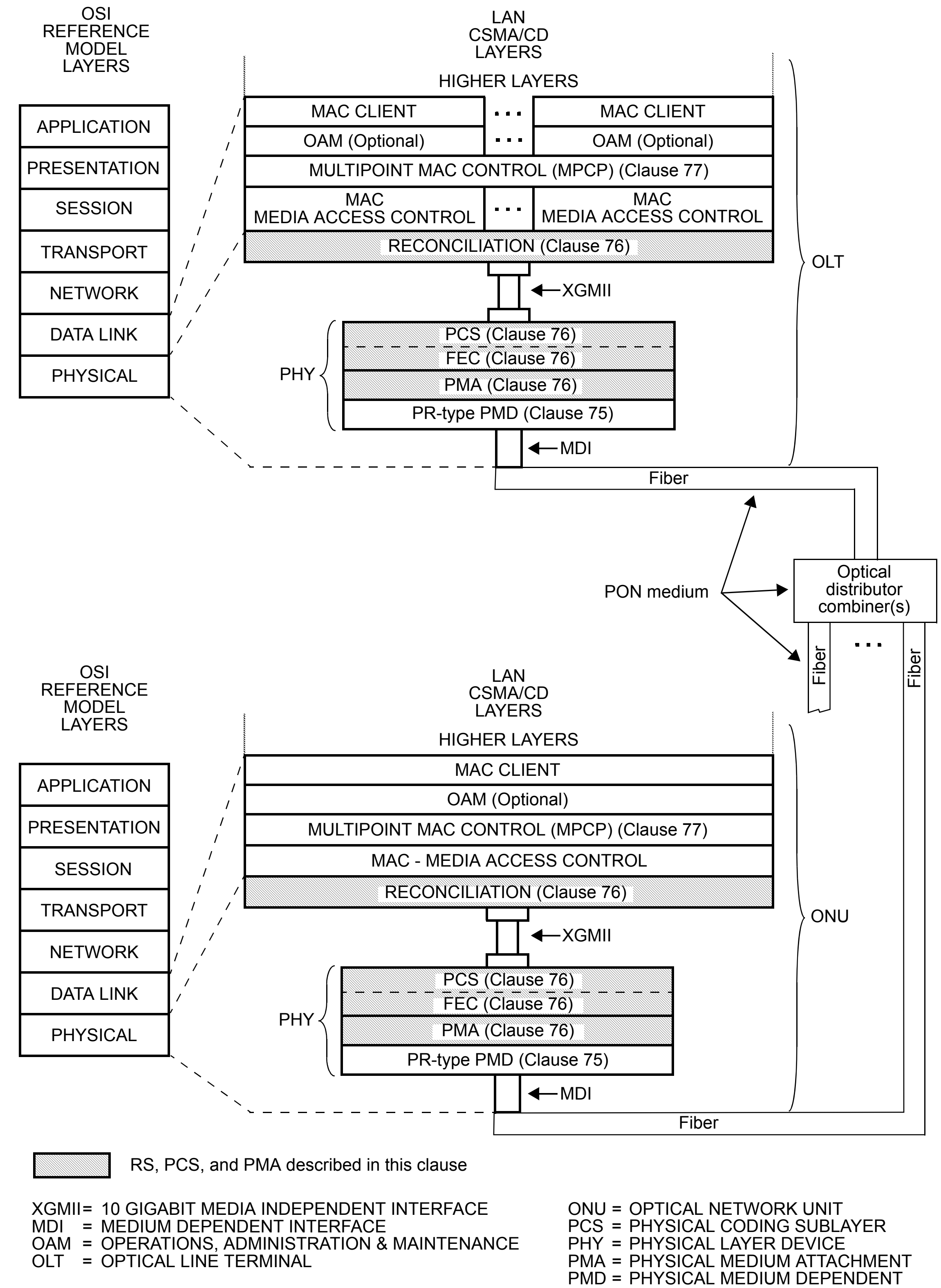
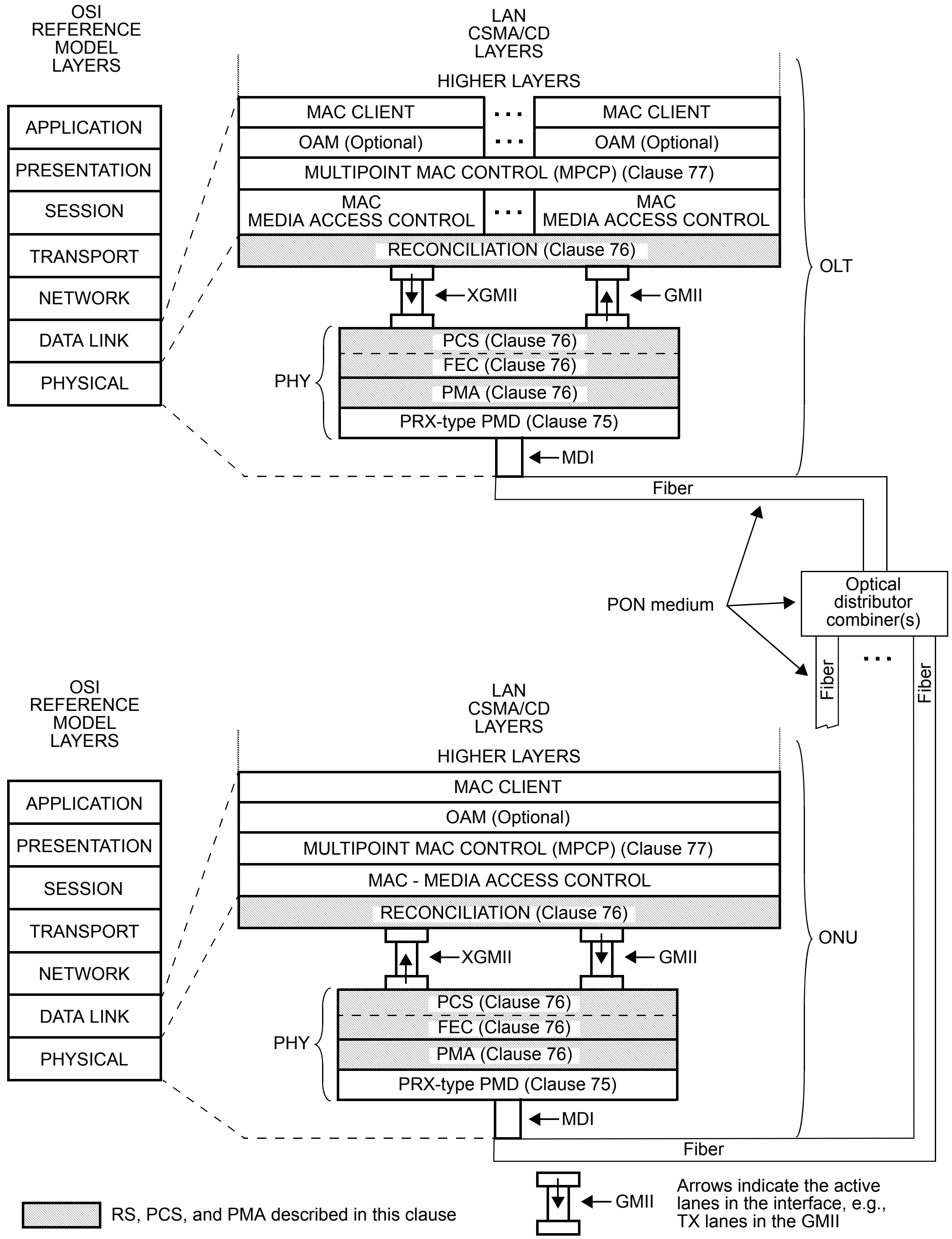


Figure 76–1—Relationship of 10/10G-EPON P2MP RS, PCS, and PMA to the ISO/IEC OSI reference model and the IEEE 802.3 CSMA/CD LAN model



XGMII = 10 GIGABIT MEDIA INDEPENDENT INTERFACE
GMII = GIGABIT MEDIA INDEPENDENT INTERFACE
MDI = MEDIUM DEPENDENT INTERFACE
OAM = OPERATIONS, ADMINISTRATION & MAINTENANCE
OLT = OPTICAL LINE TERMINAL
ONU = OPTICAL NETWORK UNIT
PCS = PHYSICAL CODING SUBLAYER
PHY = PHYSICAL LAYER DEVICE
PMA = PHYSICAL MEDIUM ATTACHMENT
PMD = PHYSICAL MEDIUM DEPENDENT

Figure 76–2—Relationship of 10/1G-EPON P2MP RS, PCS, and PMA to the ISO/IEC OSI reference model and the IEEE 802.3 CSMA/CD LAN model

76.2.2 Dual-speed Media Independent Interface

In 1G-EPON architectures, the GMII is the interface used to transfer data between the RS and the PCS. For 10/10G-EPON architectures, the XGMII is the interface used to transfer data between the RS and the PCS. When using a 10/1G-EPON architecture, a combination of both GMII and XGMII is needed in order to support transmission and reception at different speeds. Through the parallel use of the GMII and XGMII, the following modes are supported:

— Symmetric-rate 10 Gb/s operation for transmit and receive data paths, utilizing all of the functionality of the XGMII defined in Clause 46.
— Symmetric-rate 1 Gb/s operation for transmit and receive data paths, utilizing all of the functionality of the GMII defined in Clause 35.
— Asymmetric-rate operation for transmit and receive data paths at the OLT, utilizing transmit path functionality of the XGMII defined in Clause 46 and receive path functionality of the GMII defined in Clause 35.
— Asymmetric-rate operation for transmit and receive data paths at the ONU, utilizing transmit path functionality of the GMII defined in Clause 35 and receive path functionality of the XGMII defined in Clause 46.
— Coexistence of various ONU types by utilizing different data paths within the OLT.

76.2.2.1 10/10G-EPON

Figure 76–3(a) depicts the data paths used in 10/10G-EPON.

76.2.2.2 10/1G-EPON

At the OLT, the transmit path uses XGMII signals TXD<31:0>, TXC<3:0> and TX_CLK, while the receive path uses GMII signals RXD<7:0>, RX_ER, RX_CLK, and RX_DV. At the ONU, the transmit path uses GMII signals TXD<7:0>, TX_EN, TX_ER, and GTX_CLK, while the receive path uses XGMII signals RXD<31:0>, RXC<3:0> and RX_CLK.

Figure 76–3(b) depicts the data paths used in 10/1G-EPON.

76.2.2.3 Dual-rate mode

To support coexistence of 10/10G-EPON, 10/1G-EPON, and 1G-EPON ONUs on the same outside plant, the OLT may optionally support dual-rate mode. Dual-rate mode supports transmission and reception at both 10 Gb/s and 1 Gb/s. When operating in a dual-rate mode, a combination of XGMII and GMII data paths are used for transmission and reception. Figure 76–4 depicts the data paths used in an OLT operating in a dual-rate mode.

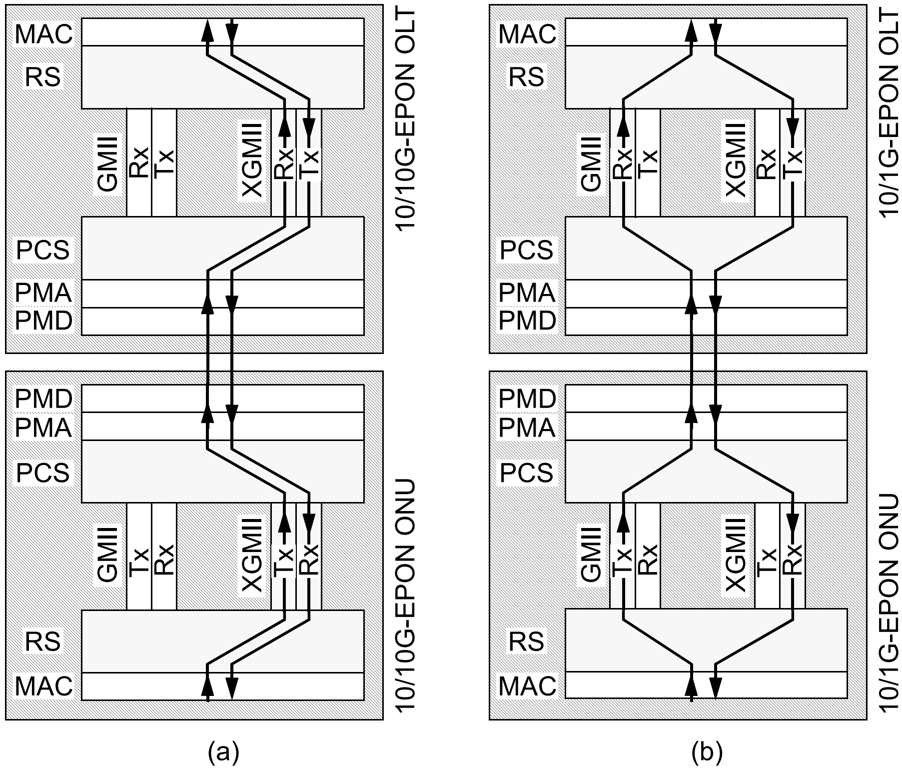


Figure 76–3—10/10G-EPON (a) and 10/1G-EPON (b) operation of OLT and ONU

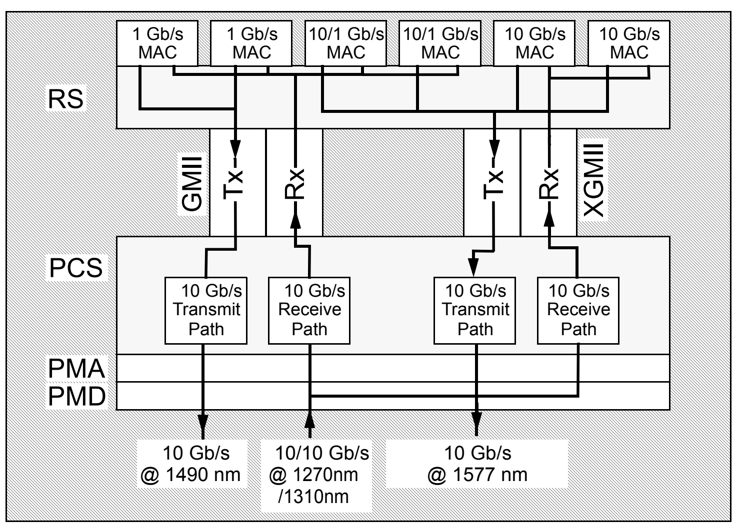


Figure 76–4—PCS and Reconciliation Sublayer for dual rate mode at OLT

76.2.2.4 Mapping of XGMII and GMII primitives

The mapping of XGMII/GMII signals to the PLS_DATA.request and PLS_DATA.indication primitives is described in 76.2.6. Additional details are provided in Table 76–1, which shows the mapping of PLS_DATA.request primitives to transmit interface signals for different types of OLTs and ONUs. Table 76–2 shows the mapping of PLS_DATA.indication primitives to receive interface signals for different types of OLTs and ONUs.

76.2.3 Summary of major concepts

A successful registration process, described in 77.3.3, results in the assignment of values to the MODE and LLID variables associated with a MAC. This may be one of many MACs in an OLT or a single MAC in an ONU. The MODE and LLID variables are used to identify a packet transmitted from that MAC and how received packets are directed to that MAC. The RS in the OLT shall operate in unidirectional mode as defined in 66.4.

As described in 77.1.2, multiple MACs within an OLT are bound to a single XGMII in the case of a 10/10G-EPON OLT, or to an XGMII transmit path and a GMII receive path in the case of a 10/1G-EPON OLT. Only one PLS_DATA.request primitive is active at any time.

At the ONU, the MAC is either bound to an XGMII in the case of a 10/10G-EPON ONU, or to an XGMII receive path and a GMII transmit path in case the of an 10/1G-EPON ONU.

In the transmit direction, the RS maps the active PLS_DATA.request to either the GMII signals (TXD<7:0>, TX_EN, TX_ER, and GTX_CLK) or the XGMII signals (TXD<31:0>, TXC<3:0>, and TX_CLK) according to the MAC instance generating the request. The RS replaces octets of preamble with the values of the transmitting MAC's MODE and LLID variables.

In the receive direction, the MODE and LLID values embedded within the preamble identify the MAC to which this packet should be directed. The RS establishes a temporal mapping of either the GMII signals (RXD<7:0>, RX_ER, RX_CLK, and RX_DV) or the XGMII signals (RXD<31:0>, RXC<3:0> and RX_CLK) to the correct PLS_DATA.indication and PLS_DATA_VALID.indication primitives.

76.2.3.1 Application

This subclause applies to the interface between the MAC and PHY in an OLT or an ONU. The physical implementation of the interface is primarily intended to be chip-to-chip, but may also be used as a logical interface between ASIC logic modules within an integrated circuit. These interfaces are used to provide media independence, so that an identical media access controller may be used with all 10GBASE-PR and 10/1GBASE-PRX PHY types.

76.2.4 GMII structure

See Clause 35.

76.2.5 XGMII structure

The XGMII structure is discussed in 46.1.6, and Figure 46-2 depicts a schematic view of the RS inputs and outputs.

76.2.6 Mapping of XGMII and GMII signals to PLS service primitives

Except as noted in Table 76–1 and Table 76–2, the mapping of the signals provided at the XGMII to the PLS service primitives is defined in 46.1.7.

Table 76–1—Mapping of PLS_DATA.request primitive

MAC location	MAC operating speed	Transmit interface	Signals
OLT	1G-EPON (Tx: 1 Gb/s)	GMII	TXD<7:0>, TX_EN, TX_ER, GTX_CLK
OLT	10/10G-EPON (Tx: 10 Gb/s)	XGMII	TXD<31:0>, TXC<3:0>, TX_CLK
OLT	10/1G-EPON (Tx: 10 Gb/s)	XGMII	TXD<31:0>, TXC<3:0>, TX_CLK
ONU	1G-EPON (Tx: 1 Gb/s)	GMII	TXD<7:0>, TX_EN, TX_ER, GTX_CLK
ONU	10/10G-EPON (Tx: 10 Gb/s)	XGMII	TXD<31:0>, TXC<3:0>, TX_CLK
ONU	10/1G-EPON (Tx: 1 Gb/s)	GMII	TXD<7:0>, TX_EN, TX_ER, GTX_CLK

Table 76–2—Mapping of PLS_DATA.indication primitive

MAC location	MAC operating speed	Receive interface	Signals
OLT	1G-EPON (Rx: 1 Gb/s)	GMII	RXD<7:0>, RX_ER, RX_DV, RX_CLK
OLT	10/10G-EPON (Rx: 10 Gb/s)	XGMII	RXD<31:0>, RXC<3:0>, RX_CLK
OLT	10/1G-EPON (Rx: 1 Gb/s)	GMII	RXD<7:0>,RX_ER,RX_DV,RX_CLK
ONU	1G-EPON (Rx: 1 Gb/s)	GMII	RXD<7:0>, RX_ER, RX_DV, RX_CLK
ONU	10/10G-EPON (Rx: 10 Gb/s)	XGMII	RXD<31:0>, RXC<3:0>, RX_CLK
ONU	10/1G-EPON (Rx: 10 Gb/s)	XGMII	RXD<31:0>, RXC<3:0>, RX_CLK

76.2.6.1 Functional specifications for multiple MACs

76.2.6.1.1 Variables

The variables of 65.1.3.1 are inherited except as shown below.

logical_link_id
Value: 15 bits
This variable shall be set to the broadcast value of 0x7FFE for the unregistered ONU MAC. Enabled OLT MACs may use any value for this variable. Registered ONU MACs may be assigned any value other than the reserved values listed in Figure 76–4 for this variable.

76.2.6.1.2 RS Transmit function

The transmit function is described in 65.1.3.2 except as noted below in Table 76–3, which shows the replacement mapping for 10G-EPON. The XGMII transmit function is described in 46.3.1.

Table 76–3—Preamble/SFD replacement mapping

Column	Lane	Field	Preamble/SFD	Modified preamble/SFD
0	0	—	0x55	Same
	1	—	0x55	Same
	2	SLD	0x55	0xd5
	3	—	0x55	Same
1	0	—	0x55	Same
	1	LLID[15:8]	0x55	<mode, logical_link_id[14:8]>[a]
	2	LLID[7:0]	0x55	<logical_link_id[7:0]>[b]
	3	CRC8	0xd5	The 8 bit CRC calculated over column 0 lane 2 through column 1 lane 2

[a]mode maps to TXD[15], logical_link_id[14] maps to TXD[14], logical_link_id[8] maps to TXD[8].
[b]logical_link_id[7] maps to TXD[23], logical_link_id[0] maps to TXD[16].

76.2.6.1.3 RS Receive function

The receive function is described in 65.1.3.3 except as noted below.

Table 65–2 is not applicable to 10G-EPON.

76.2.6.1.3.1 SLD

The 10 Gb/s RS transmit function maintains an alignment for its start control character to lane 0. The SLD is transmitted as the third octet and therefore is aligned to lane 2 in the same column containing the start control character. This is the only possibility considered when parsing the incoming octet stream for the SLD. If the SLD field is not found then the packet shall be discarded. If the packet is transferred, the SLD shall be replaced with a normal preamble octet and the two octets preceding the SLD and the one octet following the SLD are passed without modification. See Table 76–3.

76.2.6.1.3.2 LLID

This subclause supersedes the stipulations of 65.1.3.3.2.

The third and fourth octets following the SLD contain the mode and logical_link_id values. OLTs and ONUs act upon these values in a different manner.

If the device is an OLT, then the following comparison is made:

a) The received mode bit is ignored.
b) If the received logical_link_id value matches 0x7FFF or 0x7FFE and an enabled MAC exists with a logical_link_id variable with the same value, then the comparison is considered a match to that MAC.
c) If the received logical_link_id has a value other than 0x7FFF or 0x7FFE and an enabled MAC exists with a mode variable with a value of 0 and a logical_link_id variable matching the received logical_link_id value, then the comparison is considered a match to that MAC.

If the device is an ONU then the following comparison is made:

d) If the received mode bit is equal to 0 and the received logical_link_id value matches the logical_link_id variable, then the comparison is considered a match.

e) If the received mode bit is equal to 1 and the received logical_link_id value does not match the logical_link_id variable, or the received logical_link_id matches 0x7FFE, then the comparison is considered a match.

If no match is found, then the packet shall be discarded within the RS. If a match is found, then the packet is intended to be transferred. If the packet is transferred, then both octets of the LLID field shall be replaced with normal preamble octets.

If the packet is transferred, the one octet preceding the LLID is passed without modification. A number of LLIDs have been reserved (see Figure 76–4) for various purposes including downstream broadcast, discovery messages, and upstream registration request messages. An additional block of LLIDs has been set aside for future use and definition. A registered ONU shall not transmit frames with one of these reserved LLIDs.

Table 76–4—Reserved LLID values

LLID value	Used in RS	Purpose
0x7FFF	1000BASE-PX	Downstream: 1 Gb/s SCB Upstream: ONU registration at 1 Gb/s
0x7FFE	10/1GBASE-PRX	Downstream: 10 Gb/s SCB Upstream: ONU registration at 1 Gb/s
	10GBASE-PR	Downstream: 10 Gb/s SCB Upstream: ONU registration at 10 Gb/s
0x7FFD–0x7F00	—	Reserved for future use

76.2.6.1.3.3 CRC-8

The CRC-8 field is as described in 65.1.3.3.3.

76.3 Physical Coding Sublayer (PCS) for 10G-EPON

76.3.1 Overview

This subclause defines the physical coding sublayers 10GBASE-PR and 10/1GBASE-PRX, supporting burst mode operation over the point-to-multipoint physical medium. The 10GBASE-PR PCS is specified to support 10/10G EPON, where both the receive and transmit paths operate at 10 Gb/s rate. The 10/1GBASE-PRX PCS supports 10/1G-EPON, in which OLT transmit path and ONU receive path operate at 10 Gb/s, while the ONU transmit path and the OLT receive path operate at 1 Gb/s rate.

This subclause also specifies a forward error correction (FEC) mechanism to increase the optical link budget or the fiber distance. Figure 76–1 and Figure 76–2 show the relationship between the PCS sublayer and the ISO/IEC OSI reference model.

76.3.1.1 10/1GBASE-PRX PCS

Conceptually, the 10/1GBASE-PRX PCS represents a combination of transmit and receive functions defined in the 10GBASE-PR PCS (specified in this clause) and the 1000BASE-PX PCS (specified in Clause 65). At the OLT, the 10/1GBASE-PRX consists of the 10GBASE-PR transmit function and the 1000BASE-PX receive function (see Figure 76–5). Reciprocally, at the ONU, the 10/1GBASE-PRX PCS consists of the 10GBASE-PR receive function and the 1000BASE-PX transmit function (see Figure 76–6).

Deriving a specification for the 10/1GBASE-PRX PCS from the 10GBASE-PR PCS and the 1000BASE-PX PCS specifications as described previously is a straightforward process; therefore, no further explicit specification for the 10/1GBASE-PRX PCS is necessary.

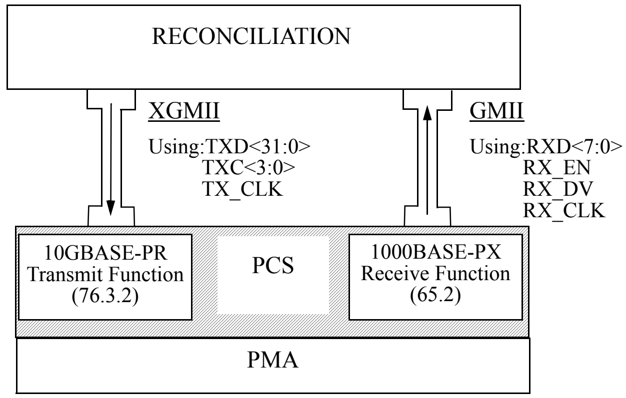


Figure 76–5—Conceptual diagram of 10/1GBASE-PRX PCS, OLT Side

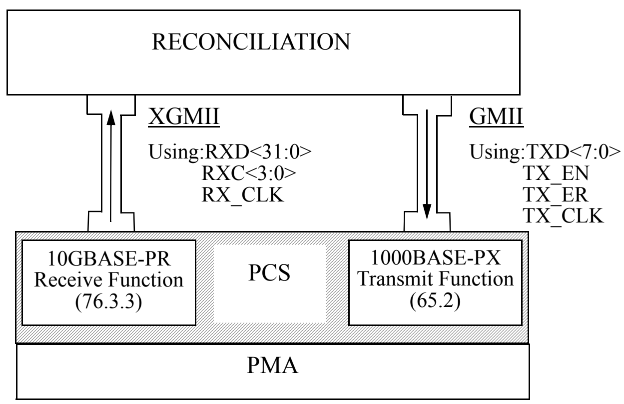


Figure 76–6—Conceptual diagram of 10/1GBASE-PRX PCS, ONU Side

76.3.1.2 10GBASE-PR PCS

The 10GBASE-PR PCS extends the physical coding sublayer described in Clause 49 to support burst mode operation over the point-to-multipoint physical medium. Figure 76–7 illustrates the functional block diagram of the downstream path and Figure 76–8 shows the functional block diagram of the upstream path.

76.3.2 PCS transmit function

This subclause defines the transmit direction of the physical coding sublayers for 10GBASE-PR and 10/1GBASE-PRX. In the OLT, the PCS transmit function operates at a 10 Gb/s rate in a continuous mode. In the ONU, the PCS transmit function may operate at a 10 Gb/s rate, as specified herein (10GBASE-PR), or at a 1 Gb/s rate, as specified in Clause 65 (10/1GBASE-PRX). For both 10GBASE-PR and 10/1GBASE-PRX, the ONU PCS always operates in a burst mode in the transmit direction. When operating at the 10 Gb/s rate, the PCS includes a mandatory FEC encoder. Figure 76–7 illustrates the transmit direction of OLT PCS. Figure 76–8 illustrates the transmit direction of the ONU PCS.

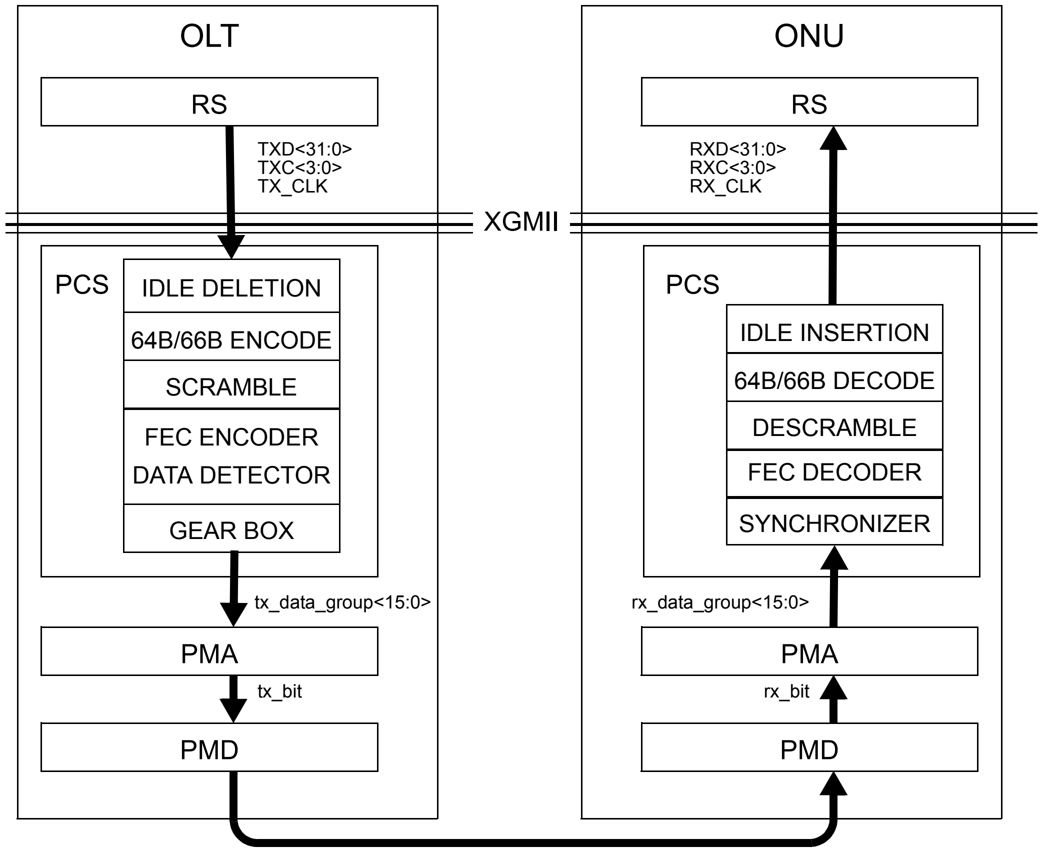


Figure 76–7—PCS functional block diagram, downstream path

76.3.2.1 Idle control character deletion

The Idle Deletion process is responsible for deleting excess Idle characters to allow the parity data to be inserted without increasing the PMD line rate. This process deletes four 72 bit vectors containing Idle characters per every thirty-one 72 bit vectors received from the XGMII. The MPCP function ensures that sufficient Idle characters occur so that the minimum IPG is always preserved between two adjacent packets.

The Idle Deletion process is depicted in Figure 76–9 for OLTs and in Figure 76–10 for ONUs.

76.3.2.1.1 Constants

FEC_DSize
TYPE: 16 bit unsigned
The number of 72 bit vectors constituting a payload of a FEC codeword. To normalize pre-FEC data rate, the Idle Deletion function removes FEC_PSize vectors per every FEC_DSize vectors transferred to the 64B/66B encoder.
Value: 27

FEC_PSize
TYPE: 16 bit unsigned
The number of 72 bit vectors constituting parity portion of a FEC codeword. To normalize pre-FEC data rate, the Idle Deletion function removes FEC_PSize vectors per every FEC_DSize vectors transferred to the 64B/66B encoder.
Value: 4

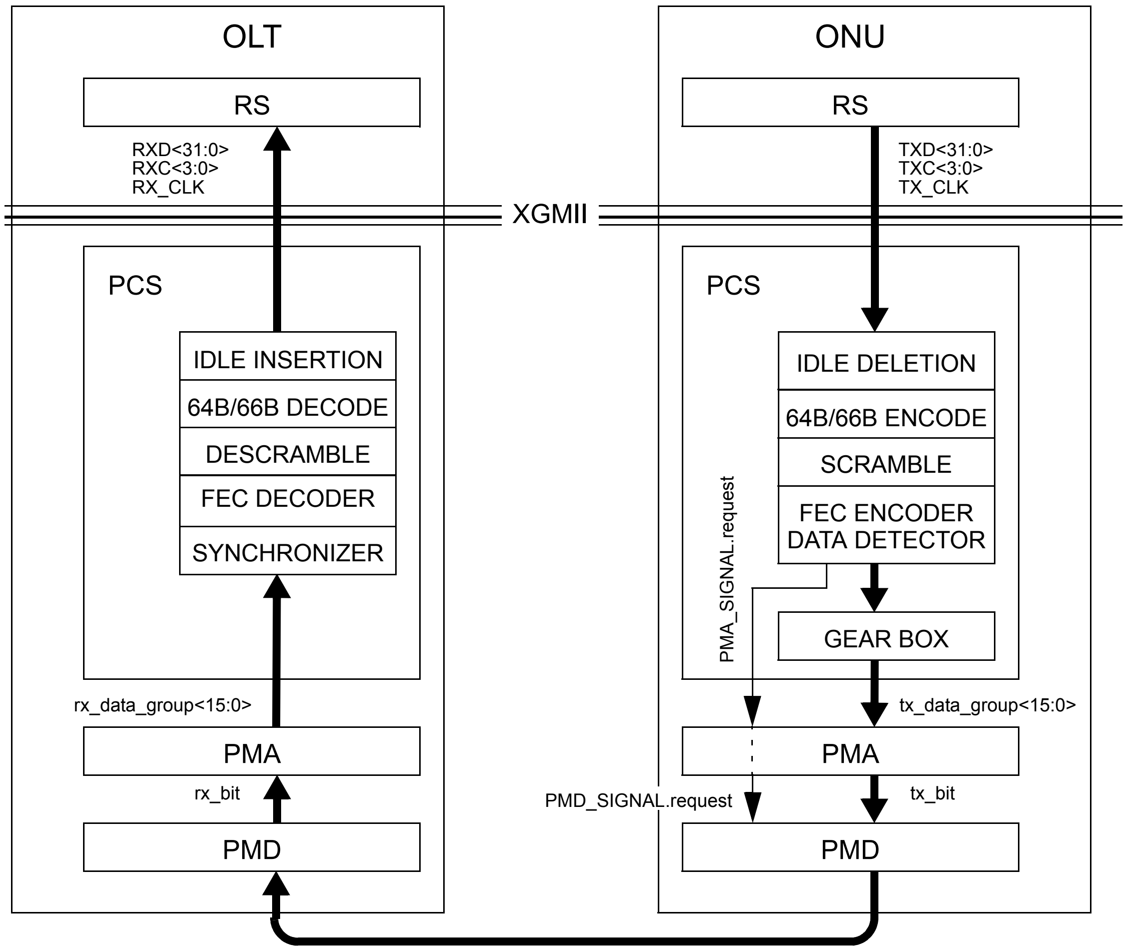


Figure 76–8—PCS functional block diagram, upstream path

76.3.2.1.2 Variables

BEGIN
TYPE: Boolean
This variable is used when initiating operation of the state diagram. It is set to true following initialization and every reset.

DelayBound
TYPE: 16 bit unsigned
This value represents the delay sufficient to initiate the laser and to stabilize the receiver at the OLT (i.e., the maximum FIFO size expressed in 66 bit blocks). The value includes LaserOnTime (77.3.3.2), $T_{receiver\_settling}$, T_{CDR}, Burst Delimiter, and the two 66 bit blocks containing Idles, that precede the first packet in the burst. This variable is used only by the ONU.

tx_raw<71:0>
This variable is defined in 49.2.13.2.2.

tx_raw_out<71:0>
72 bit vector sent from the output of the Idle Deletion function to the 64B/66B encoder. The vector contains two XGMII transfers mapped as shown for tx_raw<71:0>.

76.3.2.1.3 Functions

T_TYPE(tx_raw<71:0>)
    This function is defined in 49.2.13.2.3.

76.3.2.1.4 Counters

DelCount
    TYPE: 16 bit unsigned
    Counts the number of 72 bit vectors that need to be deleted.

IdleCount
    TYPE: 16 bit unsigned
    Counts the number of 72 bit vectors containing Idle control characters or other control vectors.

VectorCount
    TYPE: 16 bit unsigned
    Counts the number of 72 bit vectors transmitted.

76.3.2.1.5 State diagrams

The OLT PCS shall perform the Idle Deletion process as shown in Figure 76–9. The ONU PCS shall perform the Idle Deletion process as shown in Figure 76–10. Should there be a discrepancy between a state diagrams and descriptive text, the state diagrams prevail.

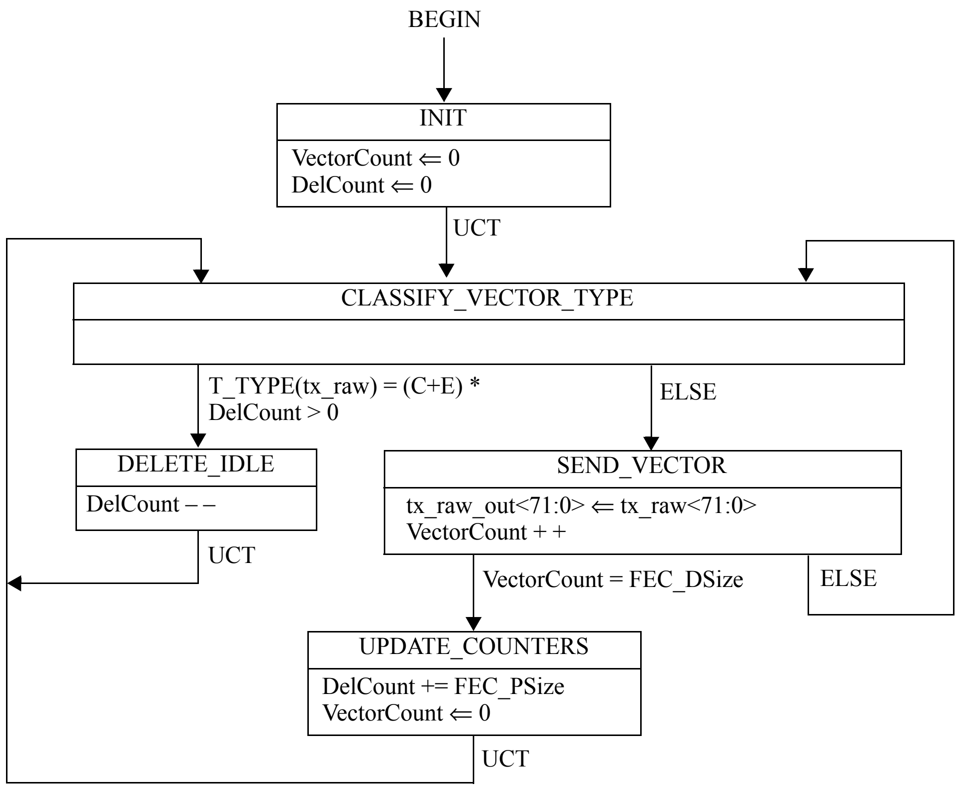


Figure 76–9—OLT Idle Deletion state diagram

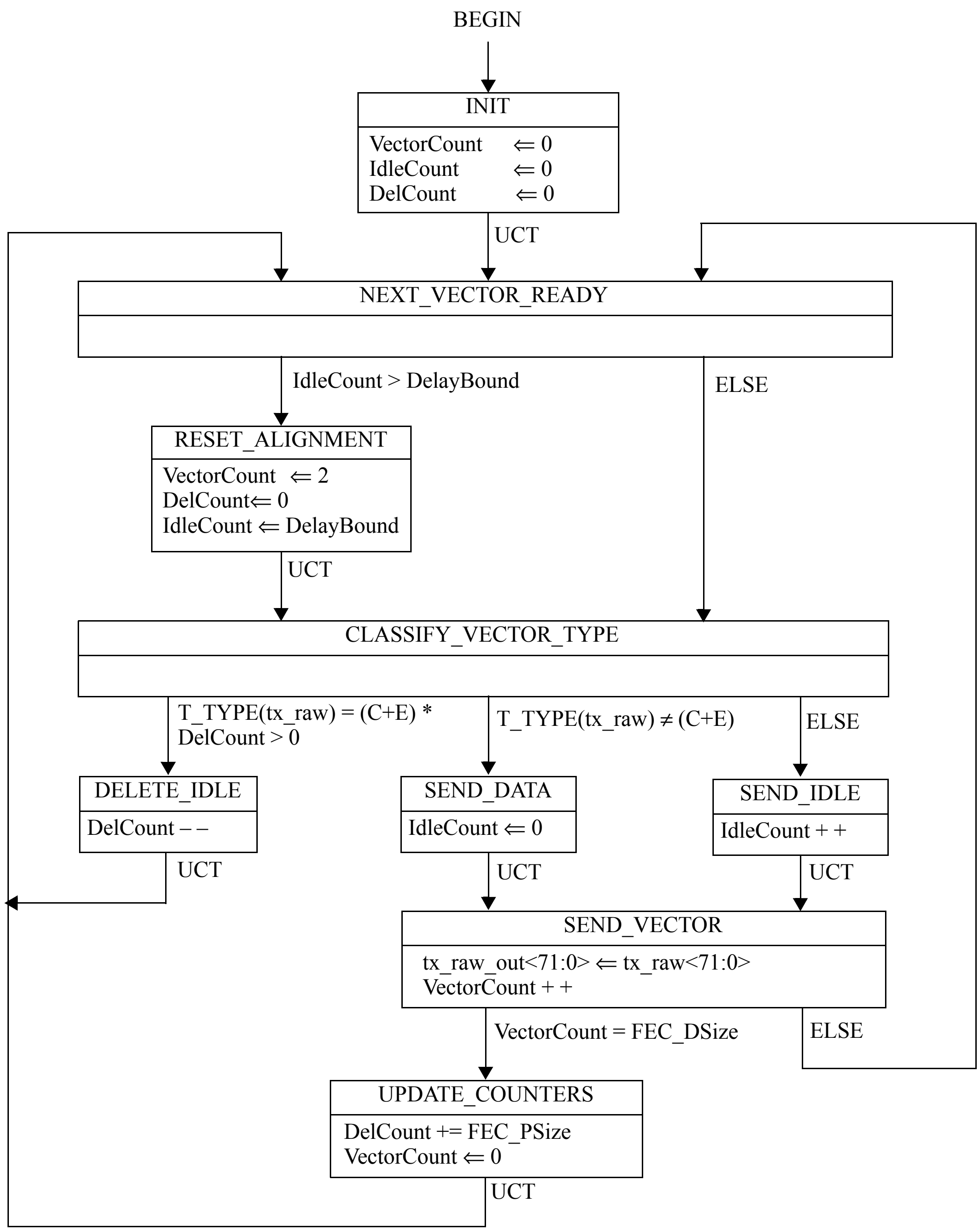


Figure 76–10—ONU Idle Deletion state diagram

76.3.2.2 64B/66B Encode

See 49.2.4 64B/66B transmission code. The encoder shall perform the functions specified in the state diagram shown in Figure 49–14.

76.3.2.3 Scrambler

See 49.2.6 Scrambler.

76.3.2.4 FEC encoding

The 10GBASE-PR-D, 10GBASE-PR-U, and 10/1GBASE-PRX-D PCS shall encode the transmitted data stream using Reed-Solomon code (255, 223). Annex 76A gives an example of RS(255,223) FEC Encoding.

76.3.2.4.1 FEC Algorithm [RS(255, 223)]

The FEC code used for 10GBASE-PR links is a linear cyclic block code—the Reed-Solomon code (255, 223) over the Galois Field of GF(2^8)—a code operating on 8 bit symbols. The code encodes 223 information symbols and adds 32 parity symbols. The code is systematic, meaning that the information symbols are not disturbed in any way in the encoder and the parity symbols are added separately to each block.

The code is based on the generating polynomial shown in Equation (76-1).

$$G(Z) = \prod_{i=0}^{31}(Z - \alpha^i) = A_{32}Z^{32} + A_{31}Z^{31} + \ldots + A_0Z^0 \tag{76-1}$$

where

α is a root of the binary primitive polynomial $x^8 + x^4 + x^3 + x^2 + 1$ and is represented as 0x02
A is a series representing the resulting polynomial coefficients of $G(Z)$, (A_{32} is equal to 0x01)
Z corresponds to an 8 bit GF(2^8) symbol
x corresponds to a bit position in a GF(2^8) symbol

The parity calculation shall produce the same result as the shift register implementation shown in Figure 76–11. Before calculation begins, the shift register shall be initialized to zero. The contents of the shift register are transmitted without inversion.

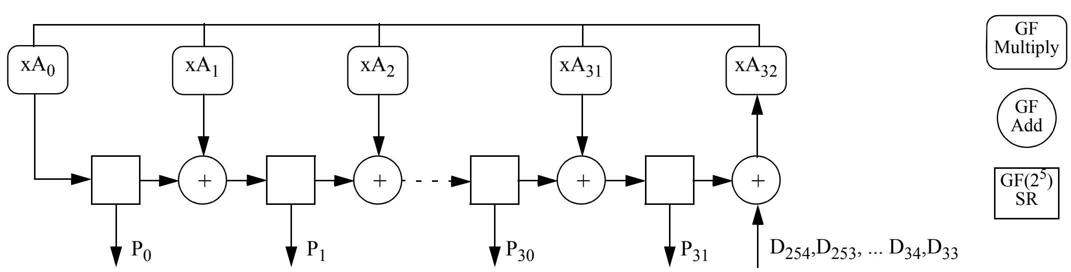


Figure 76–11—Circuit for generating FEC parity vector

A FEC parity vector is represented by Equation (76-2).

$$P(Z) = D(Z) \bmod G(Z) \tag{76-2}$$

where

$D(Z)$ is the data vector $D(Z) = D_{222}Z^{254} + D_{221}Z^{253} + \ldots + D_0Z^{32}$. D_{222} is the first data octet and D_0 is the last.

$P(Z)$ is the parity vector $P(Z) = P_{31}Z^{31} + P_{30}Z^{30} \ldots + P_0Z^0$. P_{31} is the first parity octet and P_0 is the last.

A data octet $(d_7, d_6, \ldots, d_1, d_0)$ is identified with the element: $d_7\alpha^7 + d_6\alpha^6 + \ldots + d_1\alpha^1 + d_0$ in GF(2^8), the finite field with 2^8 elements. The code has a correction capability of up to sixteen symbols.

NOTE—For the (255,223) Reed-Solomon code, the symbol size equals one octet. The d_0 is identified as the LSB and d_7 is identified as the MSB for all octets in accordance with the conventions of 3.1.1.

Bit ordering shall be as illustrated in Figure 76–12.

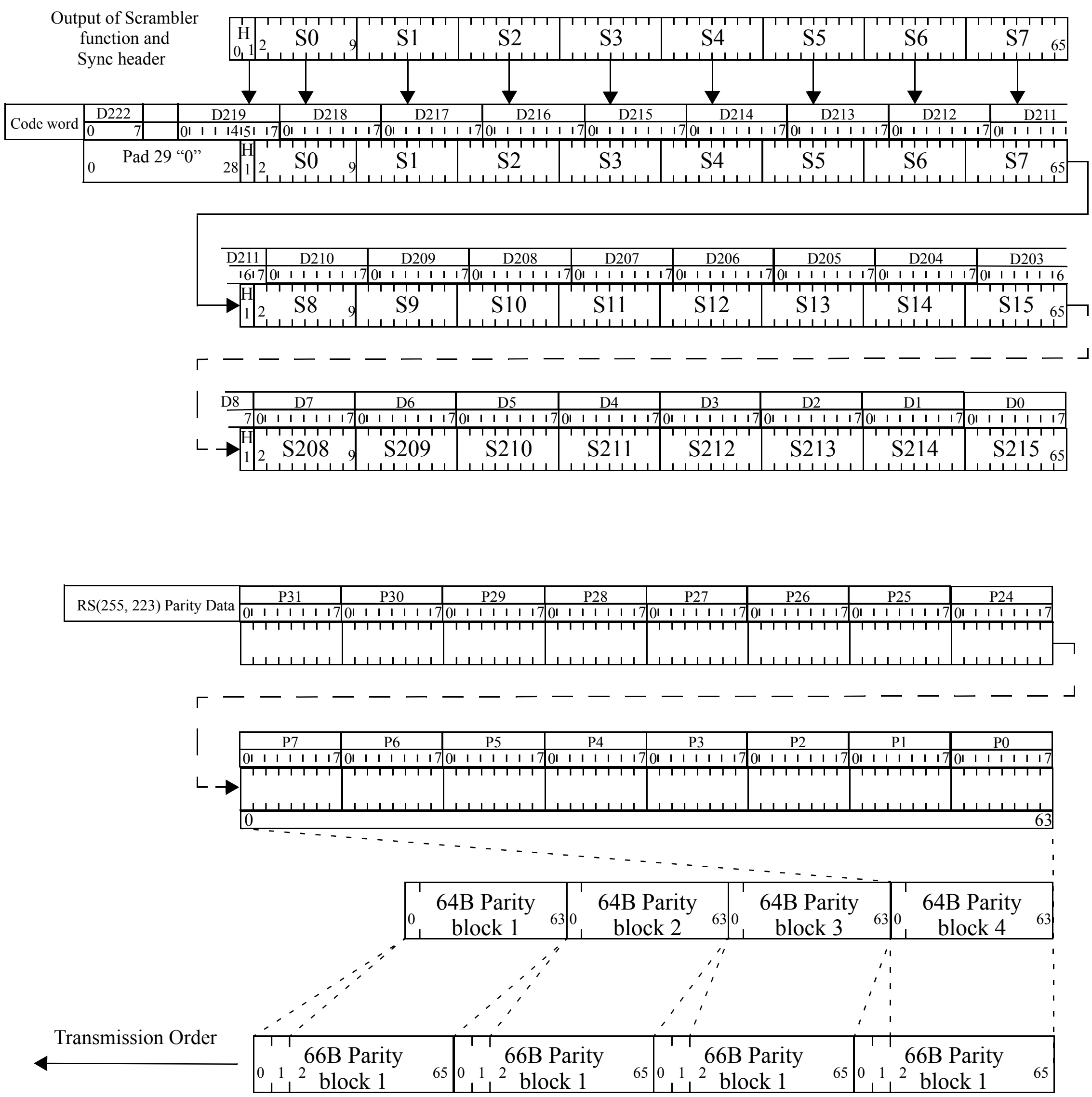


Figure 76–12—Bit ordering in FEC codeword generation

76.3.2.4.2 Parity calculation

Padding of FEC codewords and appending FEC parity octets in the 10GBASE-PR and 10/1GBASE-PRX OLT PCS transmitter is illustrated in Figure 76–13. The 64B/66B encoder and scrambler produce 66 bit blocks. The FEC encoder accumulates 27 of these 66 bit blocks to form the basis of an FEC codeword, removing the redundant first bit (i.e., sync header bit <0>) of each block (the first bit is guaranteed to be the complement of the second bit).

The FEC encoder then prepends 29 padding bits (binary 0) to the 27 blocks (65 bits each) to form the 223-octet payload portion of an FEC codeword. This data is then FEC-encoded, resulting in the 32-octet parity portion of the FEC codeword. The 223-octet payload portion and 32-octet parity portion combine to form the 255-octet Reed-Solomon codeword. The padding is used to generate the FEC codeword but is not transmitted.

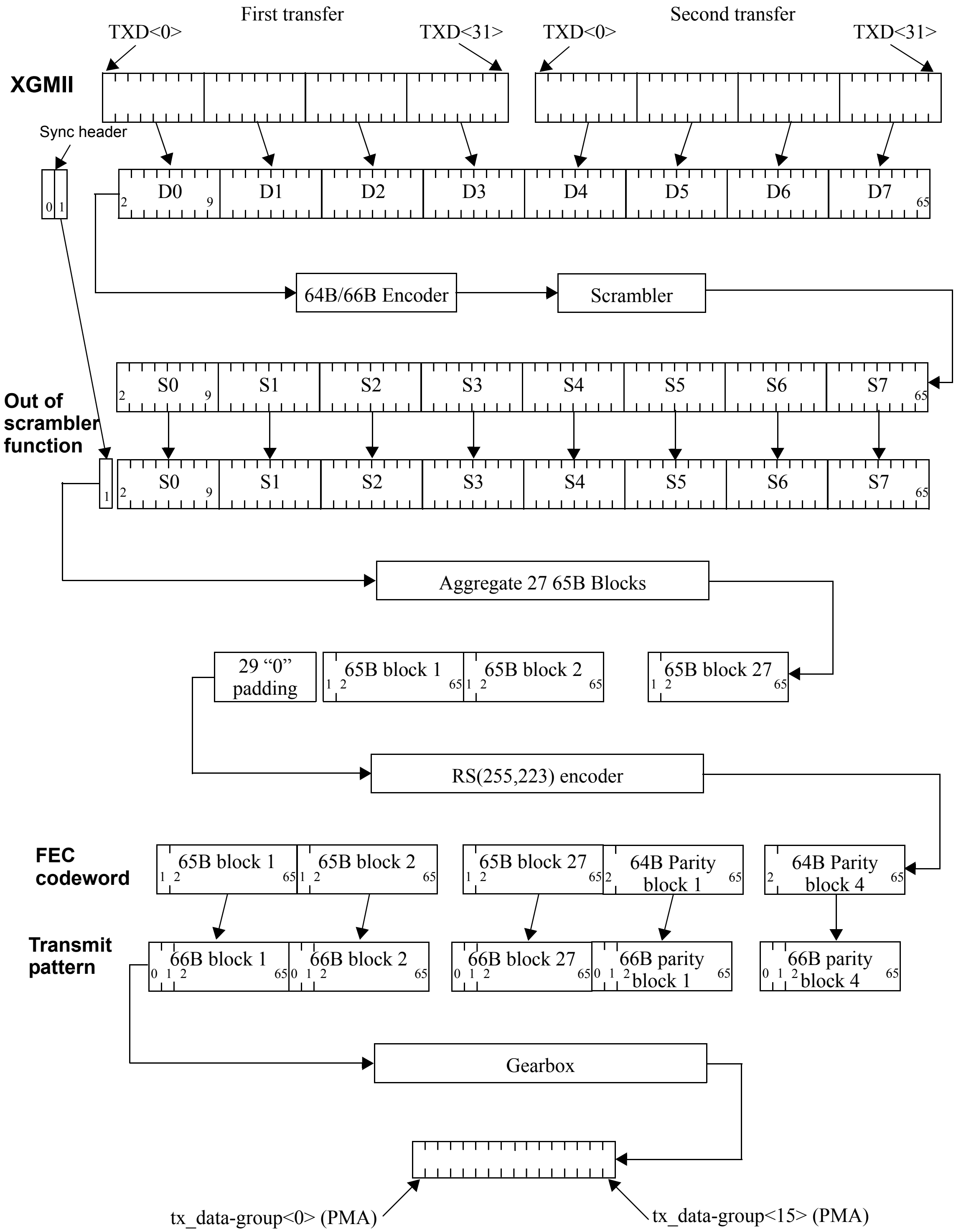


Figure 76–13—PCS Transmit bit ordering

76.3.2.4.3 FEC Transmission Block Formatting

As shown in Figure 76–13, after the Reed-Solomon codeword has been computed, the FEC encoder constructs the transmittable FEC codeword with the original sequence of twenty-seven 66 bit blocks (including the redundant sync bit, but not including the 29 “0” padding bits). The FEC encoder prepends a 2 bit sync header to each group of 64 parity bits to construct a properly formed 66 bit codeword, according to the predefined sync header pattern for the four 64 bit parity blocks: 00 11 11 00. Finally the four 66 bit parity blocks are appended following the twenty-seven 66 bit data blocks and transmitted to the PMA.

76.3.2.5 Data Detector

The 10GBASE-PR-D, 10GBASE-PR-U, and 10/1GBASE-PRX-D PCS transmit path includes the Data Detector process. This process contains a delay line (FIFO_DD buffer) that stores the 66 bit blocks to allow insertion of the FEC parity data into the transmitted data stream. The length of the FIFO_DD buffer should be large enough to hold the amount of data equal to the maximum amount of parity data that may be inserted within the transmission time of one packet of a maximum length (i.e., at most forty 66 bit blocks of parity data).

76.3.2.5.1 Burst Mode operation (ONU only)

In addition to inserting the parity data into the data stream, the Data Detector process in the 10GBASE-PR-U PCS generates the PMA_SIGNAL.request(tx_enable) primitive to turn the laser on and off at the correct times.

Upon initialization, the laser is turned off. When the first 66 bit block containing data arrives at the buffer, the Data Detector sets the PMA_SIGNAL.request(tx_enable) primitive to the value ON, instructing the PMD sublayer to start the process of turning the laser on.

When the buffer becomes empty (i.e., contains only 66 bit blocks with Idle characters), the Data Detector sends the End of Burst Delimiter and after that sets the PMA_SIGNAL.request(tx_enable) primitive to the value OFF, instructing the PMD sublayer to start the process of turning the laser off. Between packets, Idle blocks arrive at the buffer. If the number of these Idle blocks is insufficient to fill the buffer then the laser is not turned off.

The length of the FIFO_DD buffer at the ONU shall be chosen such that the delay introduced by the buffer together with any delay introduced by the PMA sublayer is long enough to turn the laser on and to allow a laser synchronization pattern, Burst Delimiter pattern, and a predefined number of Idle blocks to be transmitted. The laser synchronization pattern allows the receiving optical detector to adjust its gain ($T_{receiver\_settling}$) and synchronize its receive clock (T_{CDR}). The Burst Delimiter allows the receiver to easily identify the beginning of FEC protected portion of the ONU transmission. The Idle control characters are used to synchronize the descrambler and establish start-of-packet delineation.

Figure 76–14 illustrates the details of the ONU burst transmission. In particular, this figure shows the details of the synchronization time and the FEC protected portions of the burst transmission.

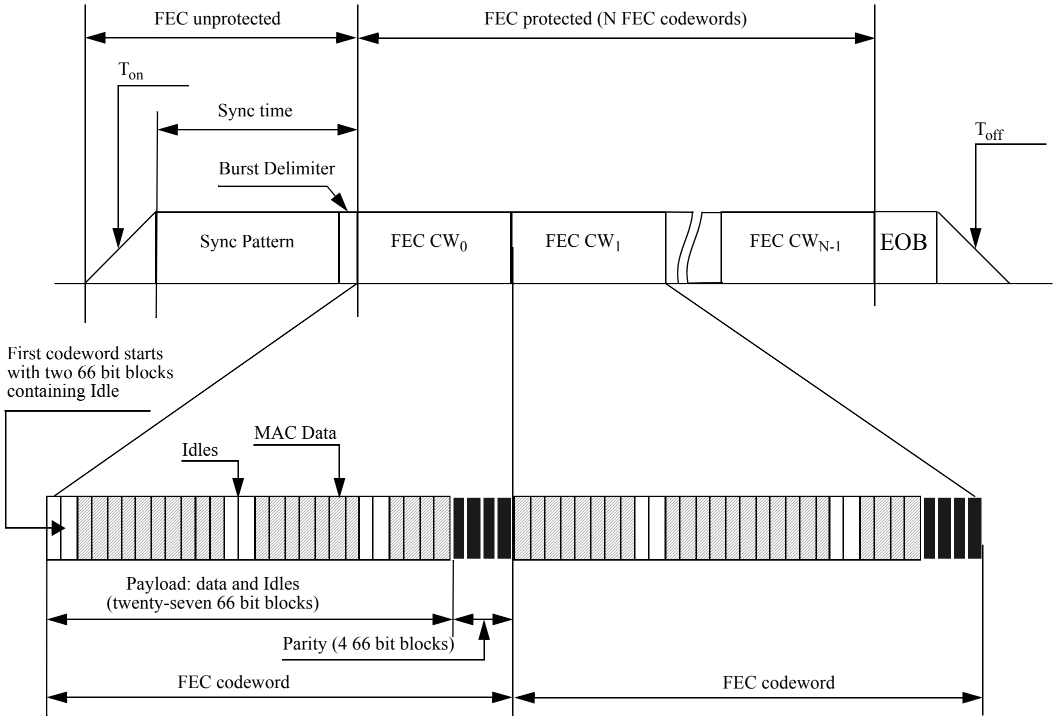


Figure 76–14—Details of burst composition

The ONU burst transmission begins with a Synchronization Pattern (see 76.3.2.5.2), which facilitates receiver clock recovery and gain control at the OLT. To facilitate FEC codeword synchronization, the ONU transmits a 66 bit BURST_DELIMITER (see Figure 76–15). When received at the OLT, the BURST_DELIMITER allows for FEC codeword alignment on the incoming data stream, even in the presence of bit errors. The BURST_DELIMITER is followed by two 66 bit blocks containing Idle codes. The first 66 bit block is used to synchronize the descrambler and a second 66 bit block is needed to provide packet delineation at the RS layer of the OLT. These two 66 bit Idle blocks are part of the first FEC codeword.

The ONU burst transmission ends with an END_BURST_DELIMITER (EOB) pattern of length TERMINATOR_LENGTH (see Figure 76–15). When received at the OLT, the burst terminator allows for the rapid reset of the OLT FEC synchronizer, so that it can search for the next burst. The burst terminator is not part of the last FEC codeword.

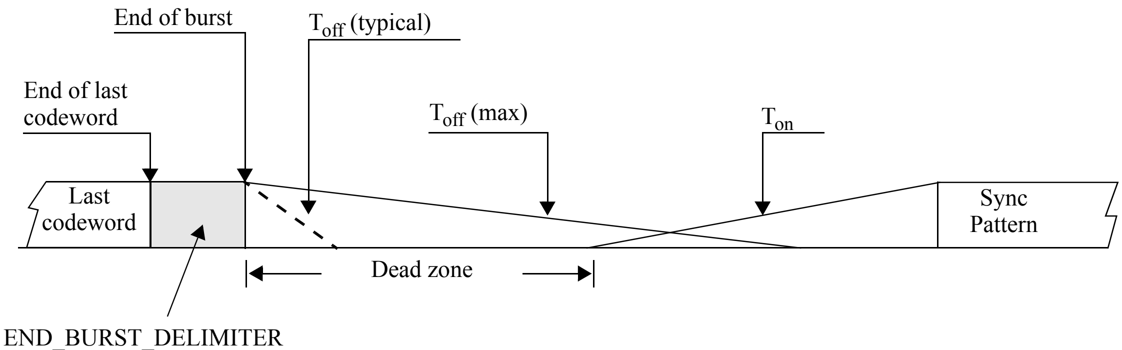


Figure 76–15—ONU burst transmission termination

The body of this subclause comprises state diagrams, including the associated definitions of variables, constants, and functions pertinent to the 10GBASE-PR and 10/1GBASE-PRX OLT PCS transmitters. Should there be a discrepancy between a state diagram and descriptive text, the state diagram prevails. The notation used in the state diagrams in this clause follows the conventions in 21.5. State diagram variables follow the conventions of 21.5.2 except when the variable has a default value.

76.3.2.5.2 Constants

BURST_DELIMITER
TYPE: 66 bit unsigned
A 66 bit value used to find the beginning of the first FEC codeword in the upstream burst.
Value: binary 01 followed by 0x 6B F8 D8 12 D8 58 E4 AB (transmission bit sequence: 01 1101 0110 0001 1111 0001 1011 0100 1000 0001 1011 0001 1010 0010 0111 1101 0101)

END_BURST_DELIMITER
TYPE: 66 bit unsigned
A 66 bit value used to identify the end of the upstream burst transmission.
Value: binary 10 followed by 0x 55 55 55 55 55 55 55 55 (transmission bit sequence of 10 1010 1010 1010 1010 1010 1010 1010 1010 1010 1010 1010 1010 1010 1010 1010 1010)

FEC_DSize
See 76.3.2.1.1.

FEC_PSize
See 76.3.2.1.1.

SP
Type: 66 bit unsigned
A 66 bit value used to for the burst mode synchronization pattern.
Value: binary 10 followed by 0x BF 40 18 E5 C5 49 BB 59 (transmission bit sequence 10 1111 1101 0000 0010 0001 1000 1010 0111 1010 0011 1001 0010 1101 1101 1001 1010)

TERMINATOR_LENGTH
Type: 8 bit unsigned
Number of END_BURST_DELIMITER blocks that are transmitted at the end of each burst.
Value: 3

76.3.2.5.3 Variables

CLK
TYPE: Boolean
This Boolean is true on every negative edge of TX_CLK (See 46.3.1) and represents instances of time at which a 66 bit block should be passed from Data Detector to the GearBox. This variable is reset to false upon read.

DelayBound
This variable is defined in 76.3.2.1.2.

FIFO_DD
TYPE: Array of 66 bit unsigned elements
A FIFO array used to store tx_coded<65:0> blocks while the parity is inserted and while burst preamble is generated (at the ONU only).

FifoSize
TYPE: 16 bit unsigned
Variable representing a number of elements stored in FIFO_DD.

SyncLength
TYPE: 16 bit unsigned
Required number of sync blocks per burst. The value of this variable is derived from the syncTime (excluding BURST_DELIMITER) and laserOnTime parameters defined in 77.3.3.

Transmitting
TYPE: Boolean
Boolean variable indicating whether the device is transmitting or not. At the ONU, the default value of Transmitting is false. At the OLT, this variable is always set to true.

tx_coded<65:0>
TYPE: 66 bit unsigned
66 bit block containing the output of the scrambler. The format for this vector is shown in Figure 49–7. The left-most bit in the figure is tx_coded<0> and the right-most bit is tx_coded<65>.

tx_coded_out<65:0>
TYPE: 66 bit unsigned
66 bit block containing the output of Data Detector being passed to the Gearbox. The format for this vector is shown in Figure 49–7. The left-most bit in the figure is tx_coded<0> and the right-most bit is tx_coded<65>.

76.3.2.5.4 Functions

RemoveFifoHead()
This function removes the first block in FIFO_DD and decrements the variable FifoSize by 1.

```
RemoveFifoHead()
   {
      // shift FIFO_DD forward
      FIFO_DD[0] = FIFO_DD[1]
      FIFO_DD[1] = FIFO_DD[2]
         ...
      FIFO_DD[FifoSize-2] = FIFO_DD[FifoSize-1]
      FifoSize --
   }
```

76.3.2.5.5 Messages

PMA_SIGNAL.request(tx_enable)
: This primitive is used to turn the laser on and off at the PMD sublayer. In the OLT, this primitive shall always take the value ON. In the ONU, the value of this variable is controlled by the Data detector state diagram (see Figure 76–17).

SCRAMBLER_UNITDATA.request(tx_coded<65:0>)
: A primitive generated by the SCRAMBLER transmit process conveying the next 66 bit block to be transmitted.

SUDR
: Alias for SCRAMBLER_UNITDATA.request(tx_coded<65:0>).

76.3.2.5.6 Counters

IdleBlockCount
: TYPE: 32 bit unsigned
: The number of consecutive non-data blocks ending with the most recently received block. The non-data blocks are represented by sync header 10 (binary).

ParityBlockCount
: TYPE: 8 bit unsigned
: The number of parity blocks transmitted in a current FEC codeword. After reaching the full parity size (FEC_PSize=4), this counter is reset to 0.

ProtectedBlockCount
: TYPE: 8 bit unsigned
: The number of blocks added to a payload of a current FEC codeword. After reaching the full payload size (FEC_DSize = 27), this counter is reset to 0.

SyncBlockCount
: TYPE: 16 bit unsigned
: The number of synchronization blocks transmitted in current burst.

76.3.2.5.7 State diagrams

The OLT and the ONU shall implement the Data Detector input process as depicted in Figure 76–16. The OLT shall implement the Data Detector output process as depicted in Figure 76–17(a). The ONU shall implement the Data Detector output process as depicted in Figure 76–17(b).

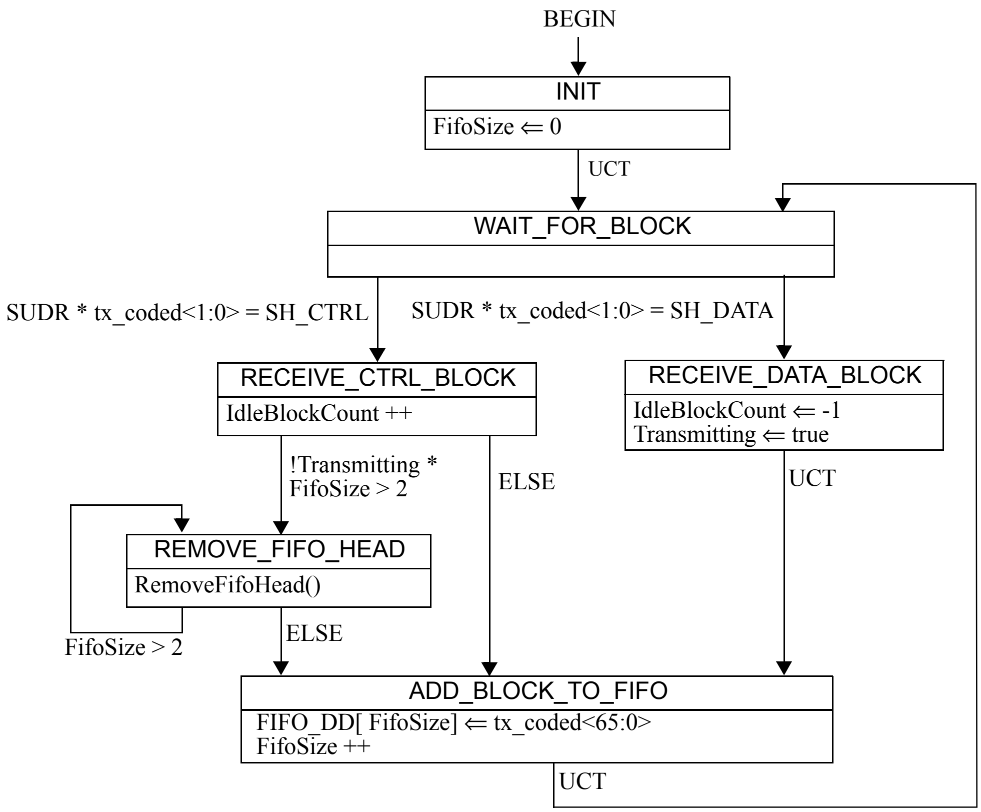
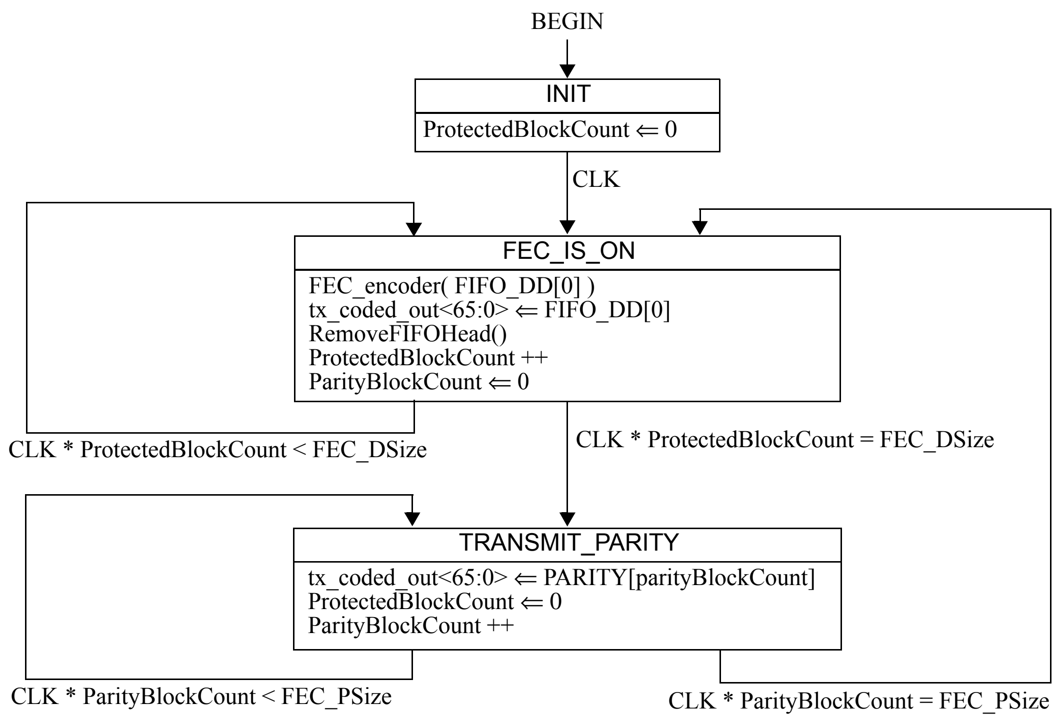


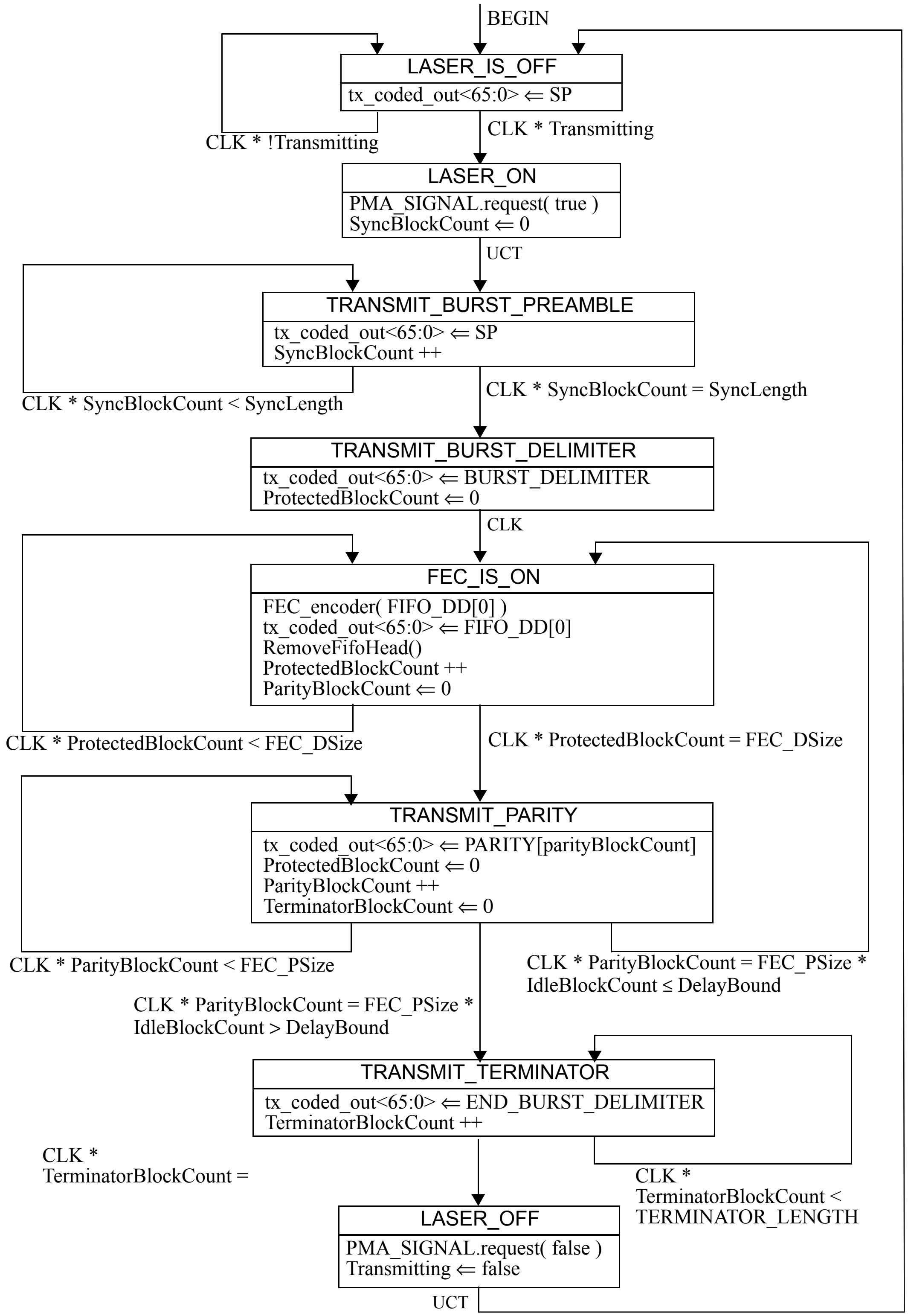
Figure 76–16—Data Detector, input process state diagram

76.3.2.6 Gearbox

See 49.2.7 Gearbox.



(a) OLT state diagram



(b) ONU state diagram

Figure 76–17—Data Detector, output process state diagram

76.3.3 PCS receive Function

This subclause defines the receive direction of physical coding sublayers for 10GBASE-PR and 10/1GBASE-PRX. In the ONU, the PCS operates at a 10 Gb/s rate in a continuous mode. In the OLT, the PCS may operate at a 10 Gb/s rate, as specified herein (10GBASE-PR), or at a 1 Gb/s rate, compliant with Clause 65 (10/1GBASE-PRX). For both 10GBASE-PR and 10/1GBASE-PRX, the OLT PCS always operates in burst mode. When operating at the 10 Gb/s rate, the PCS includes a mandatory FEC decoder. The receive direction of ONU PCS is illustrated in Figure 76–7 and receive direction for the OLT PCS is illustrated in Figure 76–8.

76.3.3.1 OLT synchronizer

The OLT codeword synchronization function receives data via the 16 bit PMA_UNITDATA.indication primitive.

The OLT synchronizer forms a bit stream from the primitives by concatenating requests with the bits of each primitive in order from rx_data-group<0> to rx_data-group<15> (see Figure 76–18). It obtains lock to the thirty-one 66 bit blocks in the bit stream by looking for the burst delimiter. Lock is obtained as specified in the codeword lock state diagram shown in Figure 76–18. While in codeword lock, the synchronizer copies the FEC-protected bits from each data block and the parity bits of the codeword into an input buffer. When the codeword is complete, the FEC decoder is triggered, and the input buffer is freed for the next codeword. When in codeword lock, the state diagram looks for the end of the burst. When this is observed, then the state diagram deasserts codeword lock. The state diagram then goes back to searching for the burst delimiter.

76.3.3.1.1 Variables

BD_valid
TYPE:Boolean
Indication that is set true if received block rx_coded matches the BURST_DELIMITER with less than 12 bits difference, and de-asserted otherwise.

cword_lock
TYPE: Boolean
Boolean variable that is set true when receiver acquires codeword delineation.

CurrentBlock<65:0>
TYPE: 66 bit vector
The last 66 bit block received. This variable has an initial value of 0.

decode_success
TYPE: Boolean
Indication that is set true if the codeword was successfully decoded by the FEC algorithm, and false otherwise.

EOB_valid
TYPE: Boolean
Indication that is set true if:

$$\mathrm{DistanceFromEob(CurrentBlock) + DistanceFromEob(PreviousBlock)} < 11$$

It is set to false otherwise.

inbuffer
TYPE: bit array
An array of 2040 bits that holds the input to the FEC decoder.

input_buffer_location
TYPE: integer
An integer that points to the next appending location in the input buffer.

persist_dec_fail
TYPE: Boolean
Indication that is set when three consecutive decoding failures have occurred.

PreviousBlock<65:0>
TYPE: 66 bit vector
The 66 bit block received previous to the current block. This variable has an initial value of 0.

reset
This variable is inherited from 49.2.13.2.2.

rx_coded<65:0>
This variable is inherited from 49.2.13.2.2.

signal_ok
This variable is inherited from 49.2.13.2.2.

76.3.3.1.2 Counters

decode_failures
TYPE:
Counter that holds the number of consecutive decoding failures.

sh_wndw_cnt
Count of the number of sync headers checked within the current 62-block window (composed of 2 codewords of 31 blocks each).

76.3.3.1.3 Functions

Append_inbuffer()
Appends the newly arrived 66 bit block into the input buffer of the FEC decoding algorithm, taking care to only insert the bits to be protected, and discarding the unwanted bits.

```
Append_inbuffer()
{
   BlockFromPMA()
   if (sh_wndw_cnt<27)
   {
      inbuffer[input_buffer_location]=rx_coded<1>
      input_buffer_location++
   }
   for(i=2, i<66, i++)
   {
      inbuffer[input_buffer_location]=rx_coded<i>
      input_buffer_location++
   }
}
```

BlockFromPMA()

Function that accepts the next received data from the PMA. Conceptually, this function serializes the 16 bit rx_data_group<15:0> to a bit stream at 10.3125 Gb/s, and then deserializes the resulting bit stream into a 66 bit wide rx_coded<65:0> block of data. It does not return until 66 bits have been transferred. Note that the internal design by which this function is accomplished is an implementation choice; however, the design operates such that a new 66 bit block is made available at the regular interval of 6.4 ns, and the transfers are made synchronous to the XGMII clock.

Decode()

Triggers the FEC decoding algorithm to accept the contents of the input buffer, and do its decoding work. Note that this function is not blocking, and returns immediately. It is assumed that the FEC decoding algorithm copies the input buffer contents into its own internal memory, so that the input buffer is released to accept the next codeword.

DecodeWhenReady()

Determines if the inbuffer contains a full codeword, and if so, it triggers the Decode function, and then clears the inbuffer for the next codeword.

```
DecodeWhenReady()
{
   if (sh_wndw_cnt=0 or sh_wndw_cnt=31)
   {
      if (cword_lock)
      {
         Decode();
      }
      Flush_inbuffer();
   }
}
```

DistanceFromEob(block<65:0>)

Returns the Hamming distance between the supplied block and the END_BURST_DELIMITER

Flush_inbuffer()

Flushes the input buffer of the FEC decoding algorithm block.

```
Flush_inbuffer()
{
   for(i=0, i<2040, i++)
   {
      inbuffer[i]=0
   }
   input_buffer_location = 29
}
```

SLIP_One_Bit

Causes the next candidate block sync position to be tested. The next candidate is exactly one bit later than the previous candidate – no burst alignments may be skipped. Following the conceptual model mentioned in “BlockFromPMA,” this function transfers one more bit from the 16 bit serializer to the 66 bit deserializer.

76.3.3.1.4 State diagram

The OLT Synchronizer shall implement the state diagram as depicted in Figure 76–18. Should there be a discrepancy between a state diagram and descriptive text, the state diagram prevails.

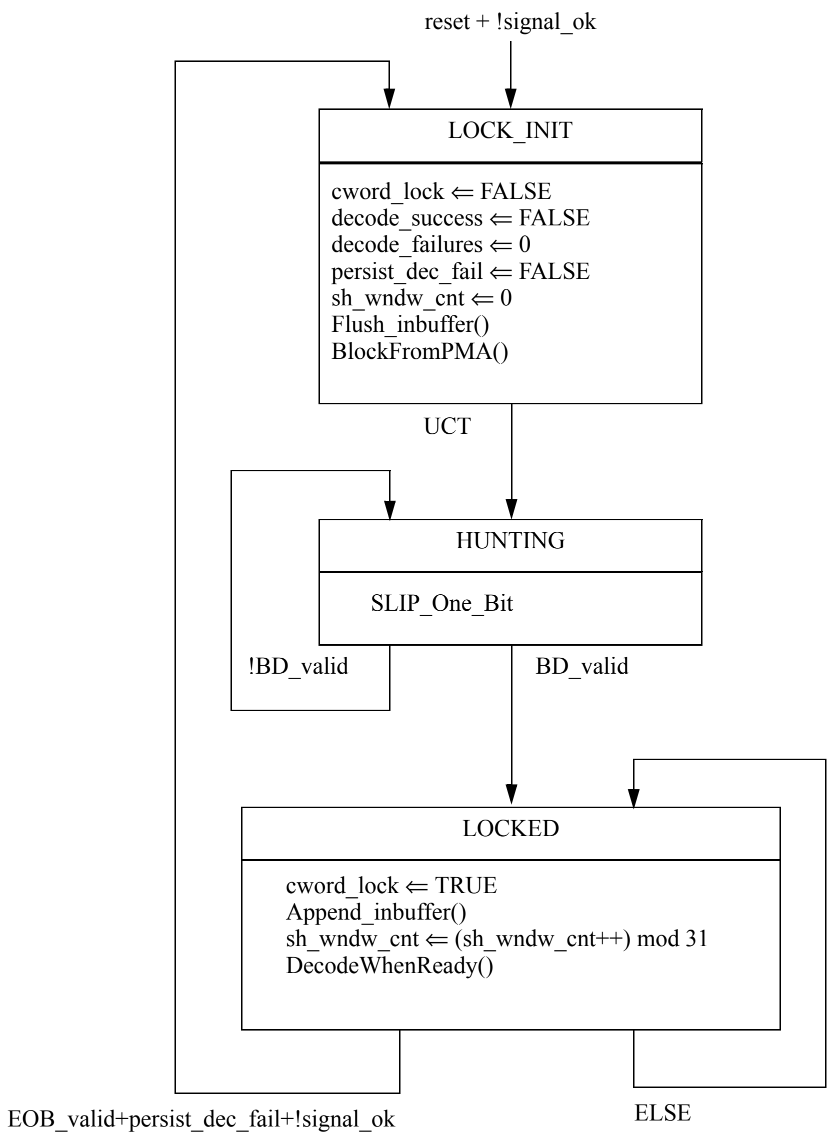


Figure 76–18—OLT Synchronizer state diagram

76.3.3.2 ONU Synchronizer

The codeword synchronization function receives data via the 16 bit PMA_UNITDATA.indication primitive.

The synchronizer forms a bit stream from the primitives by concatenating requests with the bits of each primitive in order from rx_data-group<0> to rx_data-group<15> (see Figure 76–19). It obtains lock to the thirty-one 66 bit blocks in the bit stream using the sync headers and outputs 2040 bit codewords to the FEC decoder function.

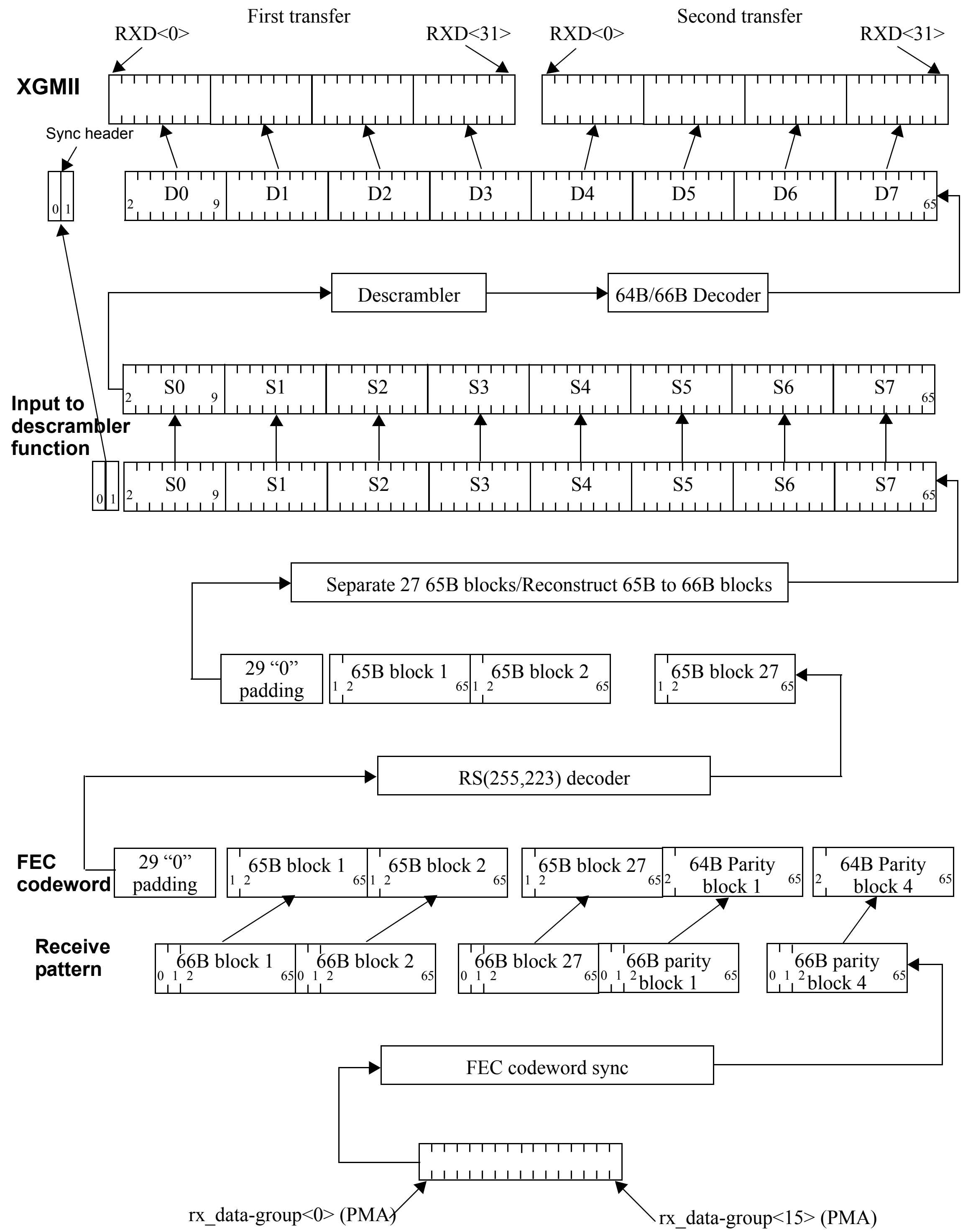


Figure 76–19—PCS Receive bit ordering

The incoming sync header pattern is 27 conventional (Clause 49) sync headers (binary 01 or 10), and then binary 00, 11, 11, and finally binary 00. The ONU synchronizer attempts to match this pattern to the received data stream, and when it finds a perfect match of two full codewords (62 blocks), it then asserts codeword lock.

While in codeword lock, the synchronizer copies the FEC-protected bits from each data block and the parity bits of the codeword into an input buffer. When the codeword is complete, the FEC decoder is triggered, and the input buffer is freed for the next codeword.

When in codeword lock, the state diagram continues to check for sync header validity. If 16 or more sync headers in a codeword pair (62 blocks) are invalid, then the state diagram deasserts codeword lock. In addition, if the persist_dec_fail signal becomes set, then codeword lock is deasserted (this check ensures that certain false-lock cases are not persistent.)

76.3.3.2.1 Constants

All the relevant constants defined in 49.2.13.2.1 are inherited. In addition, the following items are defined.

SH_CW_PATTERN
TYPE: array of 8 bit unsigned
31 element array of codeword sync header bit counts, where each element is set to the value 1 except for:
Value:
SH_CW_PATTERN[27]=0
SH_CW_PATTERN[28]=2
SH_CW_PATTERN[29]=2
SH_CW_PATTERN[30]=0

76.3.3.2.2 Variables

cword_lock
See 76.3.3.1.1.

decode_success
See 76.3.3.1.1.

persist_dec_fail
See 76.3.3.1.1.

reset
This variable is inherited from 49.2.13.2.2.

sh_valid
TYPE: Boolean array
Indication that is set true if received block rx_coded has valid sync header bits for the supposed current position in the FEC codeword. That is, sh_valid[i] is asserted if (rx_coded<0> + rx_coded<1>) = SH_CW_PATTERN[i mod 31] and de-asserted otherwise.

signal_ok
This variable is inherited from 49.2.13.2.2.

slip_done
This variable is inherited from 49.2.13.2.2.

test_sh
This variable is inherited from 49.2.13.2.2.

76.3.3.2.3 Counters

decode_failures
See 76.3.3.1.2.

FEC_cnt
TYPE: 8 bit unsigned
This counter keeps track of the parity sync header index that is currently being tested.

sh_wndw_cnt
See 76.3.3.1.2.

sh_valid_cnt
This counter is inherited from 49.2.13.2.4.

76.3.3.2.4 Functions

Append_inbuffer()
See 76.3.3.1.3.

DecodeWhenReady()
See 76.3.3.1.3.

SLIP
This function is inherited from 49.2.13.2.3.

76.3.3.2.5 State diagram

The ONU Synchronizer shall implement the state diagram as depicted in Figure 76–20. Should there be a discrepancy between a state diagram and descriptive text, the state diagram prevails.

76.3.3.3 FEC decoding process

The 10GBASE-PR-D, 10GBASE-PR-U, and 10/1GBASE-PRX-U PCS shall correct errors in the received data stream using Reed-Solomon code (255, 223). The FEC decoder corrects or confirms the correctness of the twenty-seven 66 bit blocks contained in the FEC codeword based on the four 66 bit blocks of parity information. The FEC decoding process then forwards the 66 bit data blocks to the descrambler and discards the parity blocks. The FEC decoding process is also responsible for setting bit 0 of the sync header to the inverse of bit 1 of the sync header. The handling of data leaving the FEC decoder and going to the descrambler is specified in the FEC decoding process state diagram shown in Figure 76–21. Implementations shall be capable of correcting up to 16 symbols in a codeword and detecting uncorrectable codewords.

The synchronizer state diagram accumulates a full codeword in a buffer. If the synchronizer is locked, then the FEC decoding process is triggered. The FEC algorithm then processes the buffer. The algorithm produces two outputs: the decode_success signal and (if successful) the corrected buffer. The data portion of the buffer is then read out to the descrambler logic in 66 bit blocks, as normal. Note that the rate of 66 bit transfers here is reduced due to the removal of the FEC parity blocks. This is corrected in the Idle Insertion step (see Figure 76–23).

If decode_success is false, then a counter is incremented (see 45.2.3.32). If there are three decoding failures in a row, then the Persist_dec_fail signal is asserted. This signal then resets the synchronizer.

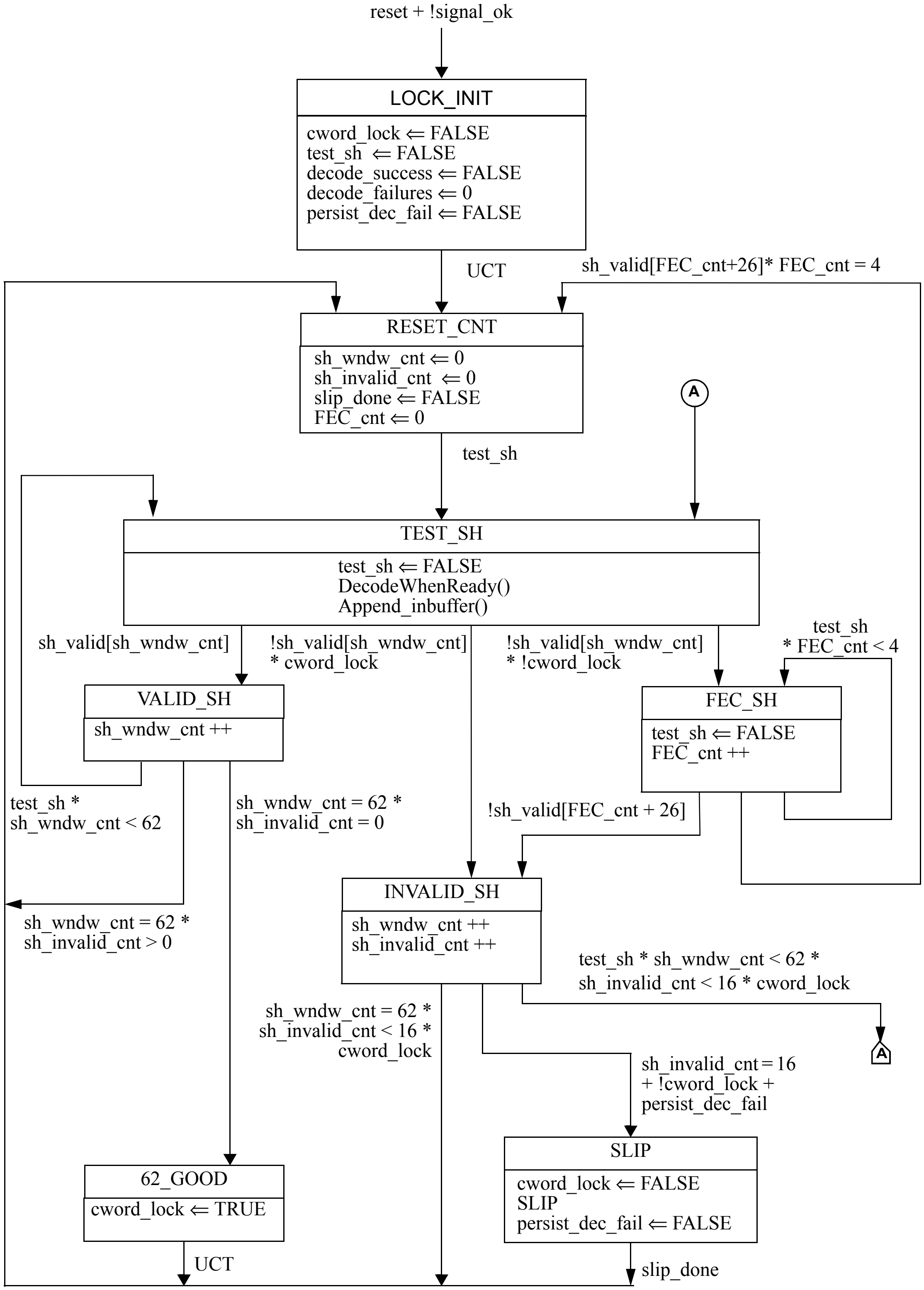


Figure 76–20—ONU Synchronizer state diagram

The FEC decoding process shall provide a user option to indicate an uncorrectable FEC codeword (due to an excess of symbols containing errors) to higher layers. If this option is set to be true, the FEC decoding process checks for the value of decode_success. If the variable decode_success is set to false, then each sync header of the received payload blocks in the FEC codeword is set to a value of binary 00. However, the data blocks are nevertheless passed to the descrambler to maintain descrambling synchronization. When this option is set to FALSE and decode_success is FALSE then each received payload block is passed unchanged.

76.3.3.3.1 Variables

decode_done
TYPE: Boolean
Indication that is transiently set when the FEC decoder algorithm has completed its processing and the corrected data is present in the output buffer.

decode_success
See 76.3.3.1.1.

mark_uncorrectable
TYPE: Boolean
Control variable that is set to true if the uncorrectable errors are to be marked.
Default: TRUE

outbuffer
TYPE: bit array
An array of 2040 bits that holds the output of the FEC decoder.

persist_dec_fail
See 76.3.3.1.1.

rx_code_corrected
Type: 66 bit vector
The next block of data to be sent to the scrambler.

76.3.3.3.2 Counters

decode_failures
See 76.3.3.1.2.

corrected_FEC_codewords_counter
A corrected block is an FEC codeword that was received with one or more errored symbols, and that has been corrected by the FEC decoder.
corrected_FEC_codewords_counter counts once for each corrected FEC codeword processed. This is a 32 bit counter. This variable is provided by a management interface that may be mapped to the 45.2.3.31 register (3.76, 3.77).

FEC_uncorrected_blocks_counter
An uncorrected block is an FEC codeword that was received with 17 or more errored symbols, and that has not been corrected by the FEC decoder.
FEC_uncorrected_blocks_counter counts once for each uncorrected FEC codeword processed. This is a 32 bit counter. This variable is provided by a management interface that may be mapped to the 45.2.3.32 register (3.78, 3.79).

76.3.3.3.3 Functions

All the relevant functions defined in 49.2.13.2.3 are inherited. In addition, the following items are defined.

BlockFromPMA()
: See 76.3.3.1.3.

BlockToDescrambler()
: Function that sends the next rx_coded_corrected<65:0> block to the descrambler. It does not return until the transfer is completed, and each transfer takes 6.4 ns and is synchronized to the XGMII clock.

Flush_inbuffer()
: See 76.3.3.1.3.

Read_outbuffer(i)
: Passes output buffer contents to the descrambler, with the appropriate format.

```
Read_outbuffer[i]
{
   int offset = 29+i*65
   for(j=0, j<65, j++)
   {
      rx_coded_corrected<j+1> = outbuffer[j+offset]
   }
   if (!decode_success AND mark_uncorrectable)
   {
      rx_coded_corrected<0> = 0
      rx_coded_corrected<1> = 0
   }
   else
   {
      rx_coded_corrected<0> = !rx_coded_corrected<1>
   }
   BlockToDescrambler()
}
```

SLIP
: This function is inherited from 49.2.13.2.3.

76.3.3.3.4 State diagrams

The body of this subclause comprises state diagrams, including the associated definitions of variables, constants, and functions pertinent to the 10GBASE-PR-D, 10GBASE-PR-U, and 10/1GBASE-PRX-U PCS receivers. Should there be a discrepancy between a state diagram and descriptive text, the state diagram prevails. The notation used in the state diagrams in this clause follows the conventions in 21.5.

The FEC decoding process shall be implemented in the PCS as depicted in Figure 76–21. Should there be a discrepancy between a state diagram and descriptive text, the state diagram prevails.

76.3.3.4 BER monitor

The BER monitor is described in Figure 76–22. This BER monitor function operates on the uncorrected incoming data stream.

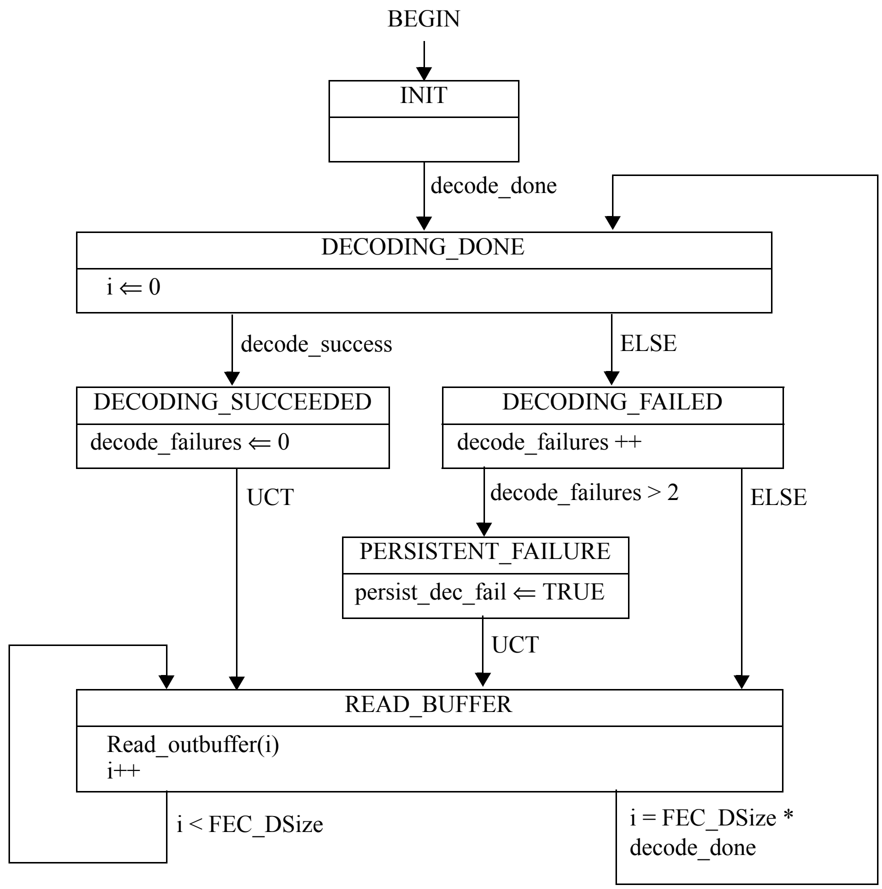


Figure 76–21—FEC decoding process state diagram

76.3.3.4.1 Variables

BER_Monitor_Interval

Indicates the time window associated with the BER monitor function. The timers in the BER monitor state diagram depend on this configurable variable. This value is reflected in MDIO register 3.80.

ber_test_sh

This variable is inherited from 49.2.13.2.2.

BER_Threshold

Indicates the threshold value of invalid sync headers associated with the BER monitor function. When BER_Threshold bad sync headers are encountered within the BER Monitor_Interval period, the BER monitor raises the hi_ber flag. When the number of bad sync headers encountered within the BER_Monitor_interval period less than the BER_Threshold, the hi_ber flag is turned off. This value is reflected in MDIO register 3.82.

hi_ber

This variable is inherited from 49.2.13.2.2.

reset

This variable is inherited from 49.2.13.2.2.

ber_test_sh
This variable is inherited from 49.2.13.2.2.

76.3.3.4.2 Timers

State diagram timers follow the conventions of 14.2.3.2.

interval_timer
Timer that is triggered every BER_monitor_interval us +1%, –25%.

76.3.3.4.3 Counters

ber_cnt
This counter is inherited from 49.2.13.2.4.

76.3.3.4.4 State diagrams

The BER monitor state diagram is present only in the ONU. It is shown in Figure 76–22.

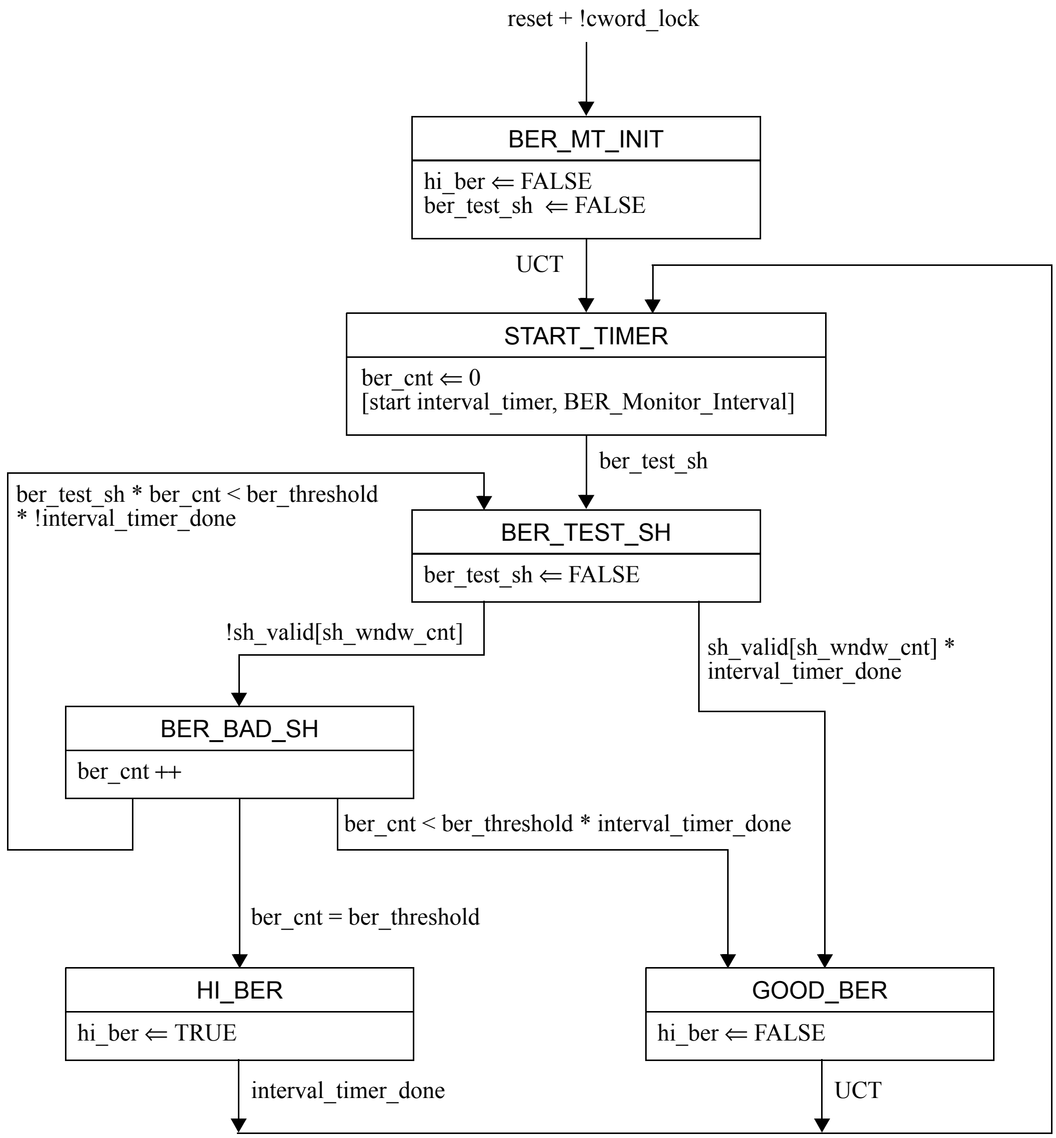


Figure 76–22—BER monitor state diagram (ONU only)

76.3.3.5 Descrambler

See 49.2.10 Descrambler.

76.3.3.6 66B/64B Decode

See 49.2.11 Receive process. The decoder shall perform functions specified in the state diagram shown in Figure 49–15.

76.3.3.7 Idle Insertion

The receiving PCS inserts the Idle control characters to compensate for the removed FEC parity octets. The Idle Insertion function (see Figure 76–23) receives 72 bit vectors from the 64B/66B decoder and writes them into the Idle Insertion FIFO (called FIFO_II) and reads 72 bit vectors from the FIFO_II and transfers them to the XGMII.

The Idle Insertion process receives 72 bit vectors at a slower rate than the nominal XGMII rate due to the fact that the FEC parity blocks are removed by the FEC decoder and not put through the descrambler and 64B/66B decoder. The Idle Insertion process outputs 72 bit vectors at the nominal XGMII rate. To match the input and output rates, the Idle Insertion process inserts additional 72 bit vectors containing Idle codes. The additional blocks are inserted between packets and not necessarily at the same locations where parity blocks have been removed.

The body of this subclause comprises state diagrams, including the associated definitions of variables, constants, and functions pertinent to the 10GBASE-PR-D, 10GBASE-PR-U and 10/1GBASE-PRX-U PCS receivers. Should there be a discrepancy between a state diagram and descriptive text, the state diagram prevails. The notation used in the state diagrams in this clause follows the conventions in 21.5.

76.3.3.7.1 Constants

FEC_DSize
    This constant is defined in 76.3.2.1.1.

FEC_PSize
    This constant is defined in 76.3.2.1.1.

FIFO_II_SIZE
    TYPE: 16 bit unsigned
    This constant represents the size of Idle Insertion FIFO buffer. This buffer should be able to accommodate the number of 66 bit blocks sufficient to fill the gap introduced by removing the parity blocks from a maximum size MAC frame.
    Value: 42

IDLE_VECTOR
    TYPE: 72 bit binary
    This constant represents a 72 bit vector containing Idle characters.

LBLOCK_R
    This constant is defined in 49.2.13.2.1.

76.3.3.7.2 Variables

FIFO_II
    TYPE: Array of 72 bit vectors received from 64B/66B decoder.
    This FIFO is internal to the Idle Insertion process. Upon initialization, all elements of this array are filled with IDLE_VECTORs. FIFO_II is a zero-based array of size FIFO_II_SIZE (see 76.3.3.7.1).

RX_CLK
    TYPE: Boolean
    This variable represents the RX_CLK signal defined in 46.3.2.1.

rx_raw_in<71:0>
    TYPE: 72 bit binary

Vector received from the output of the 64B/66B decoder. RXD<0> through RXD<31> for the second transfer are placed in rx_raw<40> through rx_raw<71>, respectively.

rx_raw_out<71:0>
TYPE: 72 bit binary
72 bit vector passed from the Idle Insertion process to XGMII. The vector is mapped to two XGMII transfers as follows:
Bits rx_raw<3:0> are mapped to RXC<3:0> for the first transfer;
Bits rx_raw<7:4> are mapped to RXC<3:0> for the second transfer;
Bits rx_raw<39:8> are mapped to RXD<31:0> for the first transfer;
Bits rx_raw<71:40> are mapped to RXD<31:0> for the second transfer.

VectorCount
TYPE: 16 bit unsigned
This variable tracks the number of 72 bit vectors stored in the FIFO_II.

76.3.3.7.3 Functions

T_TYPE(rx_raw)
This function is defined in 49.2.13.2.3.

76.3.3.7.4 Messages

DECODER_UNITDATA.indicate(rx_raw_in<71:0>)
A signal sent by the PCS Receive process conveying the next received 72 bit vector.

DUDI
Alias for DECODER_UNITDATA.indicate(rx_raw_in<71:0>).

76.3.3.7.5 State diagrams

The PCS Idle Insertion function shall implement the state diagram as shown in Figure 76–23. Should there be a discrepancy between a state diagram and descriptive text, the state diagram prevails.

76.4 10GBASE-PR and 10/1GBASE-PRX PMA

The 10GBASE-PR PMA is derived from the 10GBASE-R PMA defined in Clause 51. This clause specifies 10GBASE-R extensions necessary to support P2MP operation. The 10/1GBASE-PRX PMA conceptually consists of a combination of transmit and receive functions specified for 10GBASE-PR and 1000BASE-PX defined in 65.3.2, as shown in Table 76–5.

76.4.1 Extensions for 10GBASE-PR-U and 10/1GBASE-PRX-U

76.4.1.1 Physical Medium Attachment (PMA) sublayer interfaces

In addition to the primitives of Clause 51, the following primitive is defined:

PMA_SIGNAL.request(tx_enable)
This primitive is mapped to PMD_SIGNAL.request(tx_enable). It is generated by the PCS's Data Detector. The effect of reception of PMD_SIGNAL.request(tx_enable) is defined in 75.3.1.4.

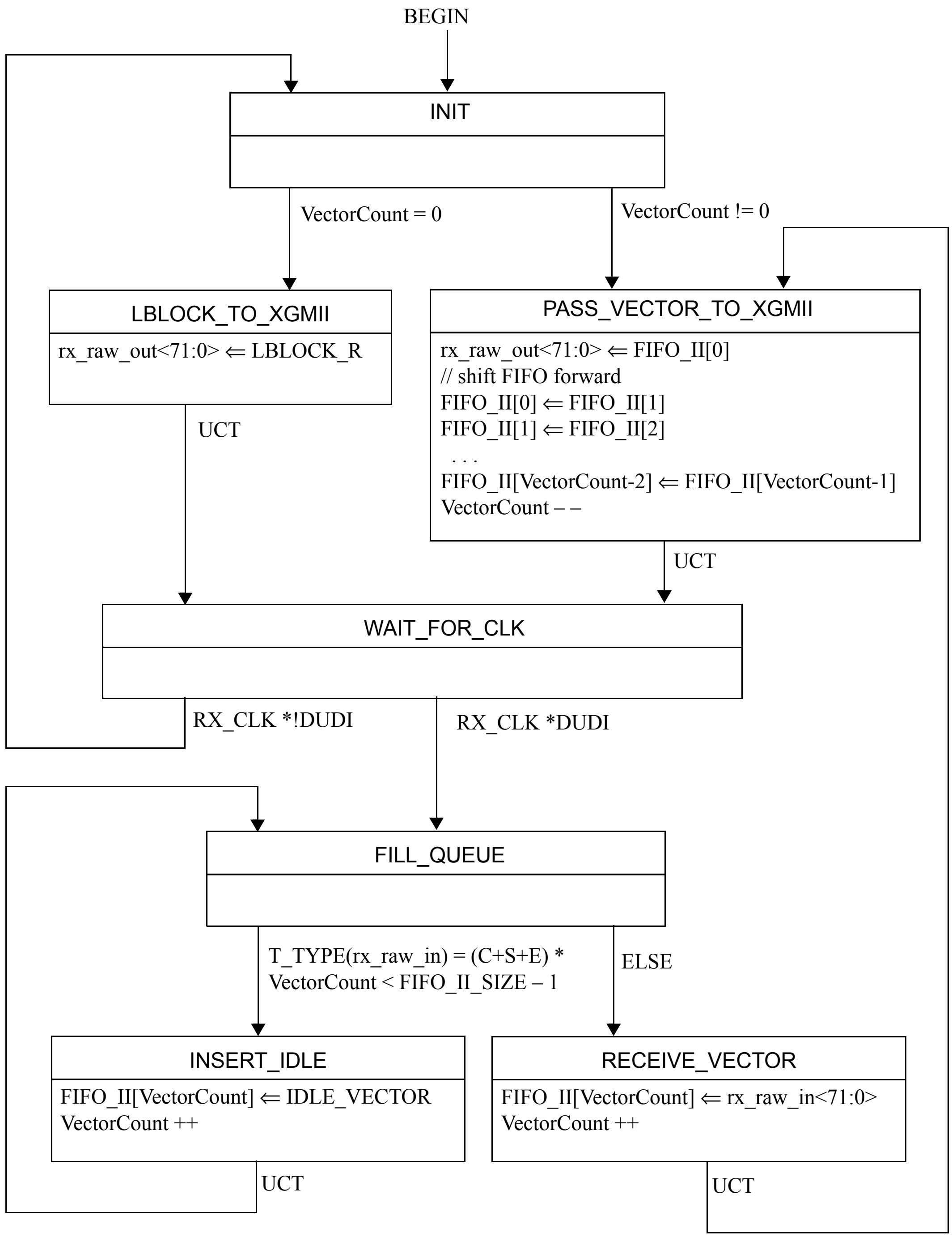


Figure 76–23—PCS Idle Insertion

tx_enable

The tx_enable parameter can take one of two values, ON or OFF.

Table 76–5—Derivation of PMA transmit and receive functions for 10GBASE-PR and 10/1GBASE-PRX

PMA	Transmit function	Receive function
10GBASE-PR-U	As specified in Clause 51 with extensions defined in 76.4.1.	
10/1GBASE-PRX-U	Identical to 1000BASE-PX-U. See 65.3.1.	Identical to 10GBASE-PR-U. See 76.4.1.
10GBASE-PR-D	As specified in Clause 51 with extensions defined in 76.4.2.	
10/1GBASE-PRX-D	Identical to 10GBASE-PR-D.	Identical to 1000BASE-PX-D. See 65.3.2.

76.4.1.2 Loop-timing specifications for ONUs

ONUs shall operate at the same time basis as the OLT, i.e., the ONU TX clock tracks the ONU RX clock, which in turn locks to OLT TX clock. Jitter transfer masks are defined in 75.7.

For the 10/1GBASE-PRX-U devices, the received clock PMA_RX_CLK is 644.53125 MHz (10.3125 GBd/16), however, the transmit clock PMA_TX_CLK is 125 MHz (1.25GBd/10). The loop timing is achieved by multiplying the PMA_RX_CLK by 32 and dividing by 165.

76.4.2 Extensions for 10GBASE-PR-D and 10/1GBASE-PRX-D

76.4.2.1 CDR lock timing measurement for the upstream direction

CDR lock time (denoted T_{CDR}) is defined as a time interval required by the receiver to acquire phase lock on the incoming data stream. T_{CDR} is measured as the time elapsed from the moment when the electrical signal after the PMD at TP8, as illustrated in Figure 75–3, reaches the conditions specified in 75.7.15 for receiver settling time to the moment when the signal phase is recovered and jitter is maintained for a network with BER of no more than 10^{-3}.

A PMA instantiated in an OLT becomes synchronized at the bit level within 400 ns (T_{CDR}) after the appearance of a valid synchronization pattern (as defined in 76.3.2.5.2) at TP8.

76.4.2.1.1 Test specification

The test of the OLT PMA receiver T_{CDR} time assumes that there is an optical PMD transmitter at the ONU with well known T_{on} time as defined in 75.7.14, and an optical PMD receiver at the OLT with well-known $T_{receiver\_settling}$ time as defined in 75.7.15. After T_{on} + $T_{receiver\_settling}$ time, the parameters at TP8 reach within 15% of their steady state values, measure T_{CDR} as the time from the TX_ENABLE assertion, minus the known T_{on} + $T_{receiver\_settling}$ time, to the time the electrical signal at the output of the receiving PMA reaches up to the phase difference from the input signal of the transmitting PMA assuring BER of 10^{-3}, and maintaining its jitter specifications. The signal throughout this test is the synchronization pattern, as illustrated in Figure 76–14.

76.5 Protocol implementation conformance statement (PICS) proforma for Clause 76, Reconciliation Sublayer, Physical Coding Sublayer, and Physical Media Attachment for 10G-EPON[5]

76.5.1 Introduction

The supplier of a protocol implementation that is claimed to conform to Clause 76, Reconciliation Sublayer, Physical Coding Sublayer and Physical Media Attachment for 10G-EPON, shall complete the following protocol implementation conformance statement (PICS) proforma.

A detailed description of the symbols used in the PICS proforma, along with instructions for completing the PICS proforma, can be found in Clause 21.

76.5.2 Identification

76.5.2.1 Implementation identification

Supplier	
Contact point for enquiries about the PICS	
Implementation Name(s) and Version(s)	
Other information necessary for full identification—e.g., name(s) and version(s) for machines and/or operating systems; System Name(s)	
NOTE 1—Only the first three items are required for all implementations; other information may be completed as appropriate in meeting the requirements for the identification. NOTE 2—The terms Name and Version should be interpreted appropriately to correspond with a supplier's terminology (e.g., Type, Series, Model).	

[5]*Copyright release for PICS proformas:* Users of this standard may freely reproduce the PICS proforma in this subclause so that it can be used for its intended purpose and may further publish the completed PICS.

76.5.2.2 Protocol summary

Identification of protocol standard	IEEE Std 802.3av-2009, Reconciliation Sublayer (RS), Physical Coding Sublayer (PCS), and Physical Media Attachment (PMA) for point-to-point media, types 10GBASE–PR and 10/1GBASE–PRX
Identification of amendments and corrigenda to this PICS proforma that have been completed as part of this PICS	
Have any Exception items been required? No [ ] Yes [ ] (See Clause 21; the answer Yes means that the implementation does not conform to IEEE Std 802.3av-2009)	
Date of Statement	

76.5.3 Major capabilities/options

Item	Feature	Subclause	Value/Comment	Status	Support
*OLT	OLT functionality	76.2.1	Device supports functionality required for OLT	O.1	Yes [ ] No [ ]
*ONU	ONU functionality	76.2.1	Device supports functionality required for ONU	O.1	Yes [ ] No [ ]

76.5.4 PICS proforma tables for Reconciliation Sublayer (RS), Physical Coding Sublayer (PCS), and Physical Media Attachment (PMA) for point-to-multipoint media, types 10GBASE–PR and 10/1GBASE–PRX

76.5.4.1 Operating modes of OLT MACs

Item	Feature	Subclause	Value/Comment	Status	Support
OM1	Unidirectional mode	76.2.3	Device operates in unidirectional transmission mode	OLT:M	Yes [ ]
OM2	Dual-rate mode	76.2.2.3	Device operates in dual-rate mode	OLT:O	Yes [ ] No [ ]

76.5.4.2 ONU and OLT variables

Item	Feature	Subclause	Value/Comment	Status	Support
FS1	enable variable	65.1.3.1	True for ONU MAC, TRUE for OLT MAC if enabled, FALSE for OLT MAC if not enabled	M	Yes [ ]
FS2	mode variable	65.1.3.1	0 for ONU MAC, 0 or 1 for enabled OLT MAC	M	Yes [ ]
FS3	logical_link_id variable	76.2.6.1.1	Set to 0x7FFE until ONU MAC is registered Set to any value for enabled OLT MAC. Set to any value other then 0x7FFE for registered ONU MAC	M	Yes [ ]

76.5.4.3 Preamble mapping and replacement

Item	Feature	Subclause	Value/Comment	Status	Support
PM1	CRC-8 generation	65.1.3.2	CRC calculation produces same result as serial implementation	M	Yes [ ] No [ ]
PM2	CRC-8 initial value	65.1.3.2	CRC shift register initialized to 0x00 before each new calculations	M	Yes [ ] No [ ]
PM3	SLD parsing	76.2.6.1.3.1	If SLD is not found then discard packet	M	Yes [ ] No[ ]
PM4	SLD replacement	76.2.6.1.3.1	Replace SLD with preamble	M	Yes [ ] No [ ]
PM5	LLID matching	76.2.6.1.3.2	If LLID does not match then discard packet	M	Yes [ ] No [ ]
PM6	LLID replacement	76.2.6.1.3.2	Replace LLID with preamble	M	Yes [ ] No [ ]
PM7	Reserved LLID	76.2.6.1.3.2	registered ONU shall not transmit frames with a reserved LLID	M	Yes [ ] No [ ]
PM8	CRC-8 checking	65.1.3.3.3	If CRC does not match then discard packet	M	Yes [ ] No [ ]
PM9	CRC-8 replacement	65.1.3.3.3	Replace CRC with preamble	M	Yes [ ] No [ ]

76.5.4.4 Coding Rules

Item	Feature	Subclause	Value/Comment	Status	Support
C1	Encoder implements the code as specified	76.3.2.2		M	Yes [ ] No [ ]
C2	Decoder implements the code as specified	76.3.3.6		M	Yes [ ] No [ ]

76.5.4.5 Data detection

Item	Feature	Subclause	Value/Comment	Status	Support
DD1	Buffer depth	76.3.2.5.1	Depth sufficient to turn on laser and send laser synchronization pattern, Burst Delimiter pattern and a predefined number of Idle control character (receiver settle).	ONU:M	Yes [ ] No [ ]
DD2	OLT laser control	76.3.2.5.5	Always takes the value ON	OLT:M	Yes [ ] No [ ]
DD3	ONU State diagrams	76.3.2.5.7	Meets the requirements of Figure 76–16 and Figure 76–17	ONU:M	Yes [ ] No[ ]
DD4	OLT State diagrams	76.3.2.5.7	Meets the requirements of Figure 76–16 and Figure 76–17	OLT:M	Yes [ ] No[ ]

76.5.4.6 Idle control character deletion

Item	Feature	Subclause	Value/Comment	Status	Support
AIC1	Idle Deletion function implementation in ONU	76.3.2.1.5	Meets the requirements of Figure 76–10	ONU:M	Yes [ ] No [ ]
AIC2	Idle Deletion function implementation in OLT	76.3.2.1.5	Meets the requirements of Figure 76–9	OLT:M	Yes [ ] No [ ]

76.5.4.7 FEC requirements

Item	Feature	Subclause	Value/Comment	Status	Support
FE1	FEC Encoder	76.3.2.4	RS(255,223)	M	Yes [ ] No [ ]
FE2	FEC Decoder	76.3.3.3	RS(255,223)	M	Yes [ ] No [ ]
FE3	Uncorrectable block indication	76.3.3.3	When activated, mark all 66 bit blocks in an uncorrectable block by setting all sync headers for the received payload blocks of the FEC codeword to the value of 00.	M	Yes [ ] No [ ]
FE4	Correctable codewords	76.3.3.3	Correct up to 16 symbols in a codeword and detect uncorrectable codewords	M	Yes [ ] No [ ]

76.5.4.8 FEC state diagrams

Item	Feature	Subclause	Value/Comment	Status	Support
SM1	Transmit	76.3.2.4.1	Meets the requirements of Figure 76–12	M	Yes [ ]
SM2	ONU synchronization	76.3.3.2.5	Meets the requirements of Figure 76–20	ONU:M	Yes [ ] No [ ]
SM3	OLT synchronization	76.3.3.1.4	Meets the requirements of Figure 76–18	OLT:M	Yes [ ] No [ ]
SM4	FEC decoding process	76.3.3.3.4	Meets the requirements of Figure 76–21	M	Yes [ ] No [ ]

76.5.4.9 PCS Idle Insertion

Item	Feature	Subclause	Value/Comment	Status	Support
PI1	Idle Insertion	76.3.3.7.5	Meets the requirements of Figure 76–23	M	Yes [ ] No [ ]

76.5.4.10 PMA

Item	Feature	Subclause	Value/Comment	Status	Support
BMC1	Loop timing	76.4.1.2	ONU RX clock tracks OLT TX clock	ONU:M	Yes [ ] No [ ]

76.5.4.11 Delay variation

Item	Feature	Subclause	Value/Comment	Status	Support
DV1	Delay variation	76.1.2	Combined delay variation through RS, PCS, and PMA sublayers is limited to 1 time_quantum	M	Yes [ ] No [ ]

Annex 76A

(informative)

FEC Encoding example

76A.1 Introduction and rationale

This Annex provides an example of FEC encoding with RS (255,223) code. See 76.3.2.4.3 for the format of the FEC codeword.[6]

76A.2 64B/66B block input

Table 76A–1 provides an example of a 64B/66B block stream received at the input to the RS (255,223) encoder. The example shows a stream of 27 scrambled 64B/66B blocks generated from the output of the PCS layer when the link was sending out Idles.

The 66 bit blocks in the Table 76A–1 are transmitted from left to right within each row and from top to bottom between rows. The 64 bit payload portion of the 66 bit block is described as a series of hexadecimal octets—the left-most octet of each payload portion is transmitted first. Bits within each octet of the payload are transmitted in least-significant bit-first order (i.e., the right-most bit of each octet is transmitted first). Thus, the first ten bits transmitted are: 10 0100 0000 …

[6]The tables in the clause are available at http://www.ieee802.org/3/av/online_resources/.

Table 76A–1—Example 64B/66B block stream at the input to FEC encode[a]

Sync [0:1]	**64 bit payload** [7:0]-[15:8]-[23:16]-[31:24]-[39:32]-[47:40]-[55:48]-[63:56]
10	02-57-78-EE-77-CB-80-37
10	B5-5A-DC-1F-B6-59-F3-3A
10	7B-AA-D3-A1-FB-F0-3E-05
10	67-33-FF-71-41-48-8D-63
10	6B-DC-63-C3-90-00-60-1C
10	0E-C7-0D-73-0C-07-92-BE
10	3B-B1-CF-78-C3-D5-22-89
10	66-DF-89-9C-13-38-CB-DE
10	AD-2E-EE-2B-0F-7A-6C-40
10	31-BF-92-0A-48-29-5E-8C
10	E7-EE-3E-0F-63-0B-46-01
10	22-4A-39-2F-2D-09-A0-14
10	A1-73-B8-E4-AE-50-6B-D8
10	A2-B6-3A-8E-2E-FC-3A-96
10	83-FD-46-A7-3B-2A-26-AD
10	3B-06-88-7D-7E-85-B7-2A
10	38-9F-34-A2-00-42-E5-FA
10	33-D2-29-70-F5-8C-02-DB
10	EE-DD-86-54-5E-FD-02-F8
10	43-B4-2C-78-09-2A-BA-19
10	73-B6-F5-F8-24-D1-BD-B6
10	BB-44-0B-CD-9F-AA-78-6B
10	EA-62-61-C3-9F-97-1C-19
10	74-4A-46-F1-52-48-41-73
10	4F-30-61-EB-98-22-55-8D
10	AA-C8-3C-C9-CC-01-51-34
10	58-15-A4-1B-1D-E8-DB-B2

[a]64 bit payload values are shown in hexadecimal notation.

76A.3 66 bit block input in binary format

Table 76A–2—Example 64B/66B block stream at the input to FEC encoder (binary)

Sync [0:1]	64 bit payload (transmitted from left to right)
10	0100 0000 1110 1010 0001 1110 0111 0111 1110 1110 1101 0011 0000 0001 1110 1100
10	1010 1101 0101 1010 0011 1011 1111 1000 0110 1101 1001 1010 1100 1111 0101 1100
10	1101 1110 0101 0101 1100 1011 1000 0101 1101 1111 0000 1111 0111 1100 1010 0000
10	1110 0110 1100 1100 1111 1111 1000 1110 1000 0010 0001 0010 1011 0001 1100 0110
10	1101 0110 0011 1011 1100 0110 1100 0011 0000 1001 0000 0000 0000 0110 0011 1000
10	0111 0000 1110 0011 1011 0000 1100 1110 0011 0000 1110 0000 0100 1001 0111 1101
10	1101 1100 1000 1101 1111 0011 0001 1110 1100 0011 1010 1011 0100 0100 1001 0001
10	0110 0110 1111 1011 1001 0001 0011 1001 1100 1000 0001 1100 1101 0011 0111 1011
10	1011 0101 0111 0100 0111 0111 1101 0100 1111 0000 0101 1110 0011 0110 0000 0010
10	1000 1100 1111 1101 0100 1001 0101 0000 0001 0010 1001 0100 0111 1010 0011 0001
10	1110 0111 0111 0111 0111 1100 1111 0000 1100 0110 1101 0000 0110 0010 1000 0000
10	0100 0100 0101 0010 1001 1100 1111 0100 1011 0100 1001 0000 0000 0101 0010 1000
10	1000 0101 1100 1110 0001 1101 0010 0111 0111 0101 0000 1010 1101 0110 0001 1011
10	0100 0101 0110 1101 0101 1100 0111 0001 0111 0100 0011 1111 0101 1100 0110 1001
10	1100 0001 1011 1111 0110 0010 1110 0101 1101 1100 0101 0100 0110 0100 1011 0101
10	1101 1100 0110 0000 0001 0001 1011 1110 0111 1110 1010 0001 1110 1101 0101 0100
10	0001 1100 1111 1001 0010 1100 0100 0101 0000 0000 0100 0010 1010 0111 0101 1111
10	1100 1100 0100 1011 1001 0100 0000 1110 1010 1111 0011 0001 0100 0000 1101 1011
10	0111 0111 1011 1011 0110 0001 0010 1010 0111 1010 1011 1111 0100 0000 0001 1111
10	1100 0010 0010 1101 0011 0100 0001 1110 1001 0000 0101 0100 0101 1101 1001 1000
10	1100 1110 0110 1101 1010 1111 0001 1111 0010 0100 1000 1011 1011 1101 0110 1101
10	1101 1101 0010 0010 1101 0000 1011 0011 1111 1001 0101 0101 0001 1110 1101 0110
10	0101 0111 0100 0110 1000 0110 1100 0011 1111 1001 1110 1001 0011 1000 1001 1000
10	0010 1110 0101 0010 0110 0010 1000 1111 0100 1010 0001 0010 1000 0010 1100 1110
10	1111 0010 0000 1100 1000 0110 1101 0111 0001 1001 0100 0100 1010 1010 1011 0001
10	0101 0101 0001 0011 0011 1100 1001 0011 0011 0011 1000 0000 1000 1010 0010 1100
10	0001 1010 1010 1000 0010 0101 1101 1000 1011 1000 0001 0111 1101 1011 0100 1101

76A.4 RS(255, 223) input buffer in Binary Format

The input buffer to the RS function begins with 29 ‘0’ bits followed by the 27 65 bit inputs as illustrated in Figure 76–12 and Figure 76–13.

Table 76A–3—Input buffer to the FEC encoder (binary)

0000	0000	0000	0000	0000	0000	0000	0001	0000	0011	1010	1000	0111	1001	1101	1111
1011	1011	0100	1100	0000	0111	1011	0001	0101	1010	1011	0100	0111	0111	1111	0000
1101	1011	0011	0101	1001	1110	1011	1000	1101	1110	0101	0101	1100	1011	1000	0101
1101	1111	0000	1111	0111	1100	1010	0000	0111	0011	0110	0110	0111	1111	1100	0111
0100	0001	0000	1001	0101	1000	1110	0011	0011	0101	1000	1110	1111	0001	1011	0000
1100	0010	0100	0000	0000	0001	1000	1110	0000	1110	0001	1100	0111	0110	0001	1001
1100	0110	0001	1100	0000	1001	0010	1111	1010	1101	1100	1000	1101	1111	0011	0001
1110	1100	0011	1010	1011	0100	0100	1001	0001	0011	0011	0111	1101	1100	1000	1001
1100	1110	0100	0000	1110	0110	1001	1011	1101	1010	1101	0101	1101	0001	1101	1111
0101	0011	1100	0001	0111	1000	1101	1000	0000	1001	0001	1001	1111	1010	1001	0010
1010	0000	0010	0101	0010	1000	1111	0100	0110	0010	1110	0111	0111	0111	0111	1100
1111	0000	1100	0110	1101	0000	0110	0010	1000	0000	0010	0010	0010	1001	0100	1110
0111	1010	0101	1010	0100	1000	0000	0010	1001	0100	0010	0001	0111	0011	1000	0111
0100	1001	1101	1101	0100	0010	1011	0101	1000	0110	1100	1000	1010	1101	1010	1011
1000	1110	0010	1110	1000	0111	1110	1011	1000	1101	0010	1100	0001	1011	1111	0110
0010	1110	0101	1101	1100	0101	0100	0110	0100	1011	0101	0110	1110	0011	0000	0000
1000	1101	1111	0011	1111	0101	0000	1111	0110	1010	1010	0000	0111	0011	1110	0100
1011	0001	0001	0100	0000	0001	0000	1010	1001	1101	0111	1101	1001	1000	1001	0111
0010	1000	0001	1101	0101	1110	0110	0010	1000	0001	1011	0110	0111	0111	1011	1011
0110	0001	0010	1010	0111	1010	1011	1111	0100	0000	0001	1111	0110	0001	0001	0110
1001	1010	0000	1111	0100	1000	0010	1010	0010	1110	1100	1100	0011	0011	1001	1011
0110	1011	1100	0111	1100	1001	0010	0010	1110	1111	0101	1011	0101	1011	1010	0100
0101	1010	0001	0110	0111	1111	0010	1010	1010	0011	1101	1010	1100	0101	0111	0100
0110	1000	0110	1100	0011	1111	1001	1110	1001	0011	1000	1001	1000	0001	0111	0010
1001	0011	0001	0100	0111	1010	0101	0000	1001	0100	0001	0110	0111	0011	1100	1000
0011	0010	0001	1011	0101	1100	0110	0101	0001	0010	1010	1010	1100	0100	1010	1010
0010	0110	0111	1001	0010	0110	0110	0111	0000	0001	0001	0100	0101	1000	0001	1010
1010	1000	0010	0101	1101	1000	1011	1000	0001	0111	1101	1011	0100	1101		

76A.5 RS(255, 223) input buffer

Table 76A–4 illustrates the 223 octets of the input buffer constructed by the RS(255, 223) encoder prior to computation of the parity octets. The octets of the buffer are formed from the input 66 bit blocks according to the procedure depicted in Figure 76–12 and Figure 76–13.

Note that in Figure 76–12 and Figure 76–13 the right-most bit of each formed octet is the most significant, whereas Table 76A–4 lists the octets in the more typical notation i.e., the least significant bit appears on the right.

Table 76A–4—223 octet input buffer within FEC encoder before computation of parity octets[a]

	Dn	Dn -1	Dn -2	Dn -3	Dn -4	Dn -5	Dn -6	Dn -7	Dn -8	Dn -9	Dn -10	Dn -11	Dn -12	Dn -13	Dn -14	Dn -15
n= 222	00	00	00	80	C0	15	9E	FB	DD	32	E0	8D	5A	2D	EE	0F
n= 206	DB	AC	79	1D	7B	AA	D3	A1	FB	F0	3E	05	CE	66	FE	E3
n= 190	82	90	1A	C7	AC	71	8F	0D	43	02	80	71	70	38	6E	98
n= 174	63	38	90	F4	B5	13	FB	8C	37	5C	2D	92	C8	EC	3B	91
n= 158	73	02	67	D9	5B	AB	8B	FB	CA	83	1E	1B	90	98	5F	49
n= 142	05	A4	14	2F	46	E7	EE	3E	0F	63	0B	46	01	44	94	72
n= 126	5E	5A	12	40	29	84	CE	E1	92	BB	42	AD	61	13	B5	D5
n= 110	71	74	E1	D7	B1	34	D8	6F	74	BA	A3	62	D2	6A	C7	00
n= 94	B1	CF	AF	F0	56	05	CE	27	8D	28	80	50	B9	BE	19	E9
n= 78	14	B8	7A	46	81	6D	EE	DD	86	54	5E	FD	02	F8	86	68
n= 62	59	F0	12	54	74	33	CC	D9	D6	E3	93	44	F7	DA	DA	25
n= 46	5A	68	FE	54	C5	5B	A3	2E	16	36	FC	79	C9	91	81	4E
n= 30	C9	28	5E	0A	29	68	CE	13	4C	D8	3A	A6	48	55	23	55
n= 14	64	9E	64	E6	80	28	1A	58	15	A4	1B	1D	E8	DB	B2	

[a]Dn octet values are shown in hexadecimal notation.

76A.6 Parity symbol output

Table 76A–5 illustrates the 32 parity octets computed by the RS(255, 223) encoder for the inputs given above.

Note that in Figure 76–12 and Figure 76–13 the right-most bit of each parity octet is the most significant, whereas Table 76A–5 lists the octets in the more typical notation i.e., the least significant bit is on the right.

Table 76A–5—32 parity octets computed by FEC encoder[a]

	Pn	Pn -1	Pn -2	Pn -3	Pn -4	Pn -5	Pn -6	Pn -7	Pn -8	Pn -9	Pn -10	Pn -11	Pn -12	Pn -13	Pn -14	Pn -15
n= 31	7E	62	35	FB	DB	9F	5E	8E	FD	B2	81	3E	F9	1D	9B	1A
n= 15	32	1E	70	CF	DD	C2	2C	54	43	F1	00	78	3C	4F	BD	F4

[a]Pn values are shown in hexadecimal notation.

76A.7 Parity symbols in binary format

As with the input buffer, this is written with least significant bit left most to correspond with Table 76A–6.

Table 76A–6—32 parity octets computed by FEC encoder (binary)

0111 1110 0100 0110 1010 1100 1101 1111 1101 1011 1111 1001 0111 1010 0111 0001
1011 1111 0100 1101 1000 0001 0111 1100 1001 1111 1011 1000 1101 1001 0101 1000
0100 1100 0111 1000 0000 1110 1111 0011 1011 1011 0100 0011 0011 0100 0010 1010
1100 0010 1000 1111 0000 0000 0001 1110 0011 1100 1111 0010 1011 1101 0010 1111

76A.8 64B/66B Parity Blocks for Transmit

Table 76A–7 illustrates the 64B/66B blocks carrying parity that are generated by the RS (255, 223) encoder for the input blocks in Table 76A–6 above. The RS (255, 223) encoder inserts the parity blocks into the transmission stream to the gearbox subsequent to its transmission of the corresponding input 66 bit blocks (as described in 76.3.2.4).

The 66 bit blocks in the Table 76A–7 are transmitted from left to right within each row and from top to bottom between rows. The 64 bit payload portion of the 66 bit block is described as a series of hexadecimal octets—the left-most octet of each payload portion is transmitted first. Bits within each octet of the payload are transmitted in least-significant bit-first order (i.e., the right-most bit of each octet is transmitted first).

Thus, the first 18 bits of the parity blocks transmitted are: 00 0111 1110 0100 0110 …

Table 76A–7—64B/66B blocks carrying 32 parity octets generated by FEC encoder

Sync [0:1]	64 bit payload [7:0]-[15:8]-[23:16]-[31:24]-[39:32]-[47:40]-[55:48]-[63:56]
00	7E-62-35-FB-DB-9F-5E-8E
11	FD-B2-81-3E-F9-1D-9B-1A
11	32-1E-70-CF-DD-C2-2C-54
00	43-F1-00-78-3C-4F-BD-F4

76A.9 Parity 66 bit blocks in binary format

Table 76A-8—64B/66B blocks carrying 32 parity octets generated by FEC encoder (binary)

Sync [0:1]	64 bit payload (transmitted from left to right)
00	0111 1110 0100 0110 1010 1100 1101 1111 1101 1011 1111 1001 0111 1010 0111 0001
11	1011 1111 0100 1101 1000 0001 0111 1100 1001 1111 1011 1000 1101 1001 0101 1000
11	0100 1100 0111 1000 0000 1110 1111 0011 1011 1011 0100 0011 0011 0100 0010 1010
00	1100 0010 1000 1111 0000 0000 0001 1110 0011 1100 1111 0010 1011 1101 0010 1111

77. Multipoint MAC Control for 10G–EPON

77.1 Overview

This clause deals with the mechanism and control protocols required in order to reconcile the 10 Gb/s P2MP topology into the Ethernet framework. The P2MP medium is a passive optical network (PON), an optical network with no active elements in the signal's path from source to destination. The only interior elements used in a PON are passive optical components, such as optical fiber, splices, and splitters. When combined with the Ethernet protocol, such a network is referred to as Ethernet passive optical network (EPON).

P2MP is an asymmetric medium based on a tree (or tree-and-branch) topology. The DTE connected to the trunk of the tree is called optical line terminal (OLT) and the DTEs connected at the branches of the tree are called optical network units (ONU). The OLT typically resides at the service provider's facility, while the ONUs are located at the subscriber premises.

In the downstream direction (from the OLT to an ONU), signals transmitted by the OLT pass through a 1:N passive splitter (or cascade of splitters) and reach each ONU. In the upstream direction (from the ONUs to the OLT), the signal transmitted by an ONU would only reach the OLT, but not other ONUs. To avoid data collisions and increase the efficiency of the subscriber access network, the ONU's transmissions are arbitrated. This arbitration is achieved by allocating a transmission window (grant) to each ONU. An ONU defers transmission until its grant arrives. When the grant arrives, the ONU transmits frames at wire speed during its assigned time slot.

A simplified P2MP topology example is depicted in Figure 77–1. Clause 67 provides additional examples of P2MP topologies.

Topics dealt with in this clause include allocation of upstream transmission resources to different ONUs, discovery and registration of ONUs into the network, and reporting of congestion to higher layers to allow for dynamic bandwidth allocation schemes and statistical multiplexing across the PON.

This clause does not deal with topics including bandwidth allocation strategies, authentication of end-devices, quality-of-service definition, provisioning, or management.

This clause specifies the multipoint control protocol (MPCP) to operate an optical multipoint network by defining a Multipoint MAC Control sublayer as an extension of the MAC Control sublayer defined in Clause 31, and supporting current and future operations as defined in Clause 31 and annexes.

Each PON consists of a node located at the root of the tree assuming the role of OLT, and multiple nodes located at the tree leaves assuming roles of ONUs. The network operates by allowing only a single ONU to transmit in the upstream direction at a time. The MPCP located at the OLT is responsible for timing the different transmissions. Reporting of congestion by the different ONUs may assist in optimally allocating the bandwidth across the PON.

Automatic discovery of end stations is performed, culminating in registration through binding of an ONU to an OLT port by allocation of a Logical Link ID (see LLID in 76.2.6.1.3.2), and dynamic binding to a MAC connected to the OLT.

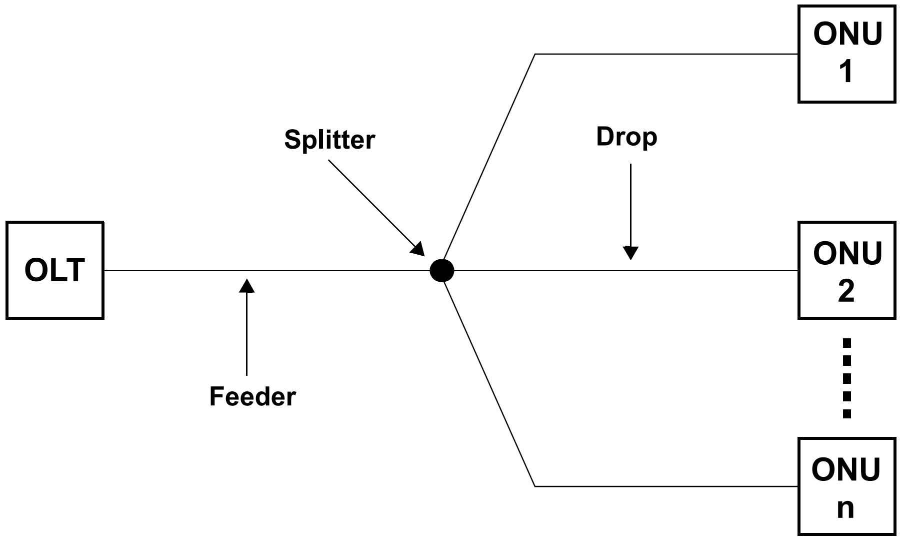


Figure 77–1—PON topology example

The Multipoint MAC Control functionality shall be implemented for subscriber access devices containing point-to-multipoint Physical Layer devices defined in Clause 75.

77.1.1 Goals and objectives

The goals and objectives of this clause are the definition of a point-to-multipoint Ethernet network utilizing an optical medium.

Specific objectives met include the following:

a) Support of point-to-point Emulation (P2PE) as specified
b) Support multiple LLIDs and MAC Clients at the OLT
c) Support a single LLID per ONU
d) Support a mechanism for single copy broadcast
e) Flexible architecture allowing dynamic allocation of bandwidth
f) Use of 32 bit timestamp for timing distribution
g) MAC Control based architecture
h) Ranging of discovered devices for improved network performance
i) Continuous ranging for compensating round trip time variation

77.1.2 Position of Multipoint MAC Control within the IEEE 802.3 hierarchy

Multipoint MAC Control defines the MAC control operation for optical point-to-multipoint networks. Figure 77–2 and Figure 77–3 depict the architectural positioning of the Multipoint MAC Control sublayer with respect to the MAC and the MAC Control client. The Multipoint MAC Control sublayer takes the place of the MAC Control sublayer to extend it to support multiple clients and additional MAC control functionality.

Multipoint MAC Control is defined using the mechanisms and precedents of the MAC Control sublayer. The MAC Control sublayer has extensive functionality designed to manage the real-time control and manipulation of MAC sublayer operation. This clause specifies the extension of the MAC Control mechanism to manipulate multiple underlying MACs simultaneously. This clause also specifies a specific protocol implementation for MAC Control.

The Multipoint MAC Control sublayer is specified such that it can support new functions to be implemented and added to this standard in the future. MultiPoint Control Protocol (MPCP), the management protocol for P2MP is one of these protocols. Non-real-time, or quasi-static control (e.g., configuration of MAC operational parameters) is provided by Layer Management. Operation of the Multipoint MAC Control sublayer is transparent to the MAC.

As depicted in Figure 77–2 and Figure 77–3, the layered system instantiates multiple MAC entities, using a single Physical Layer. The individual MAC instances offer a point-to-point emulation service between the OLT and the ONU. An additional MAC is instantiated to communicate to all 10G–EPON ONUs at once. This instance takes maximum advantage of the broadcast nature of the downstream channel by sending a single copy of a frame that is received by all 10G–EPON ONUs. This MAC instance is referred to as Single Copy Broadcast (SCB).

The ONU only requires one MAC instance since frame filtering operations are done at the RS layer before reaching the MAC. Therefore, MAC and layers above are emulation-agnostic at the ONU (see 76.2.6.1.3).

Although Figure 77–2 and Figure 77–3 and supporting text describe multiple MACs within the OLT, a single unicast MAC address may be used by the OLT. Within the EPON Network, MACs are uniquely identified by their LLIDs, which are dynamically assigned by the registration process.

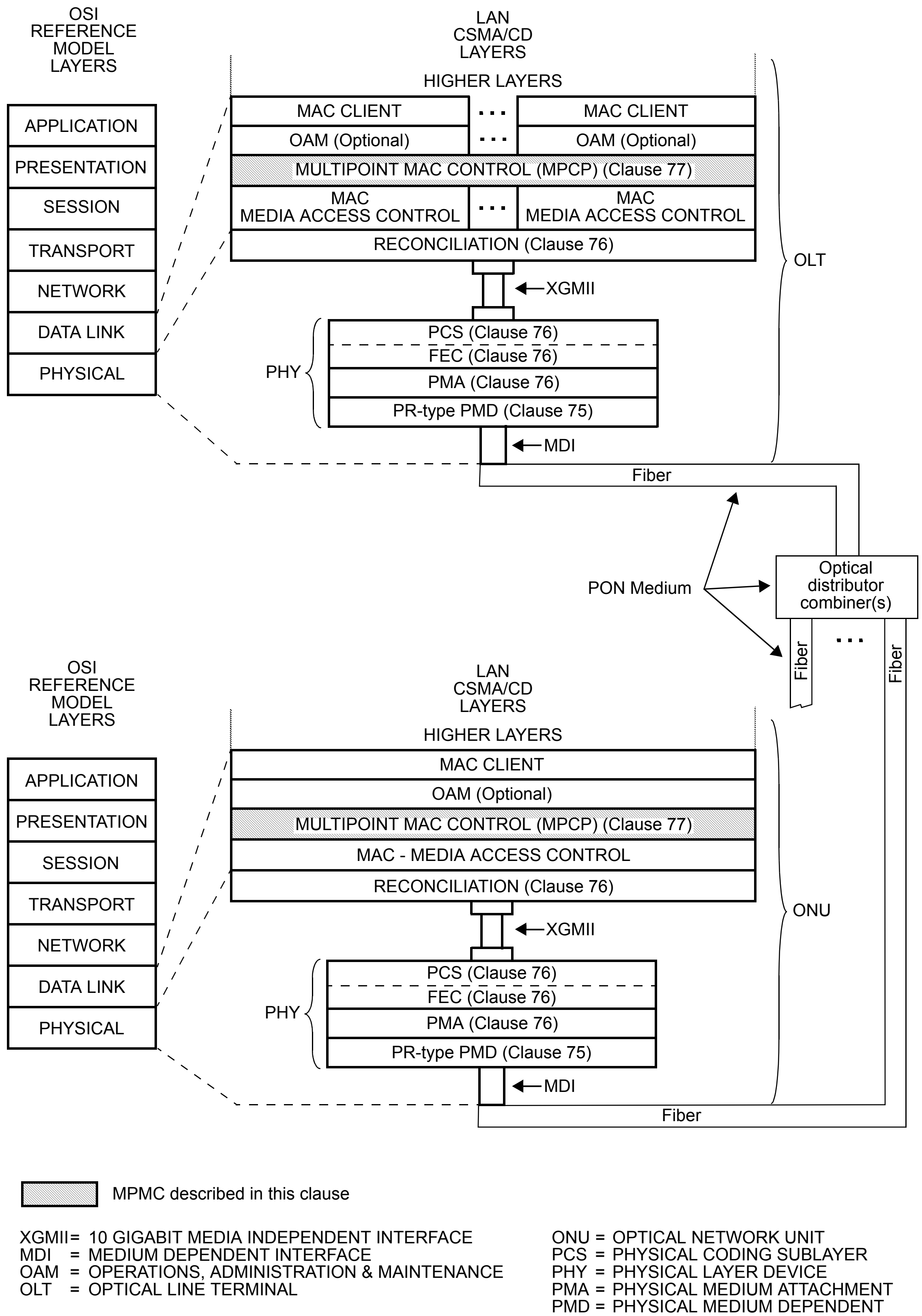


Figure 77–2—Relationship of Multipoint MAC Control and the OSI protocol stack for 10/10G–EPON (10 Gb/s downstream and 10 Gb/s upstream)

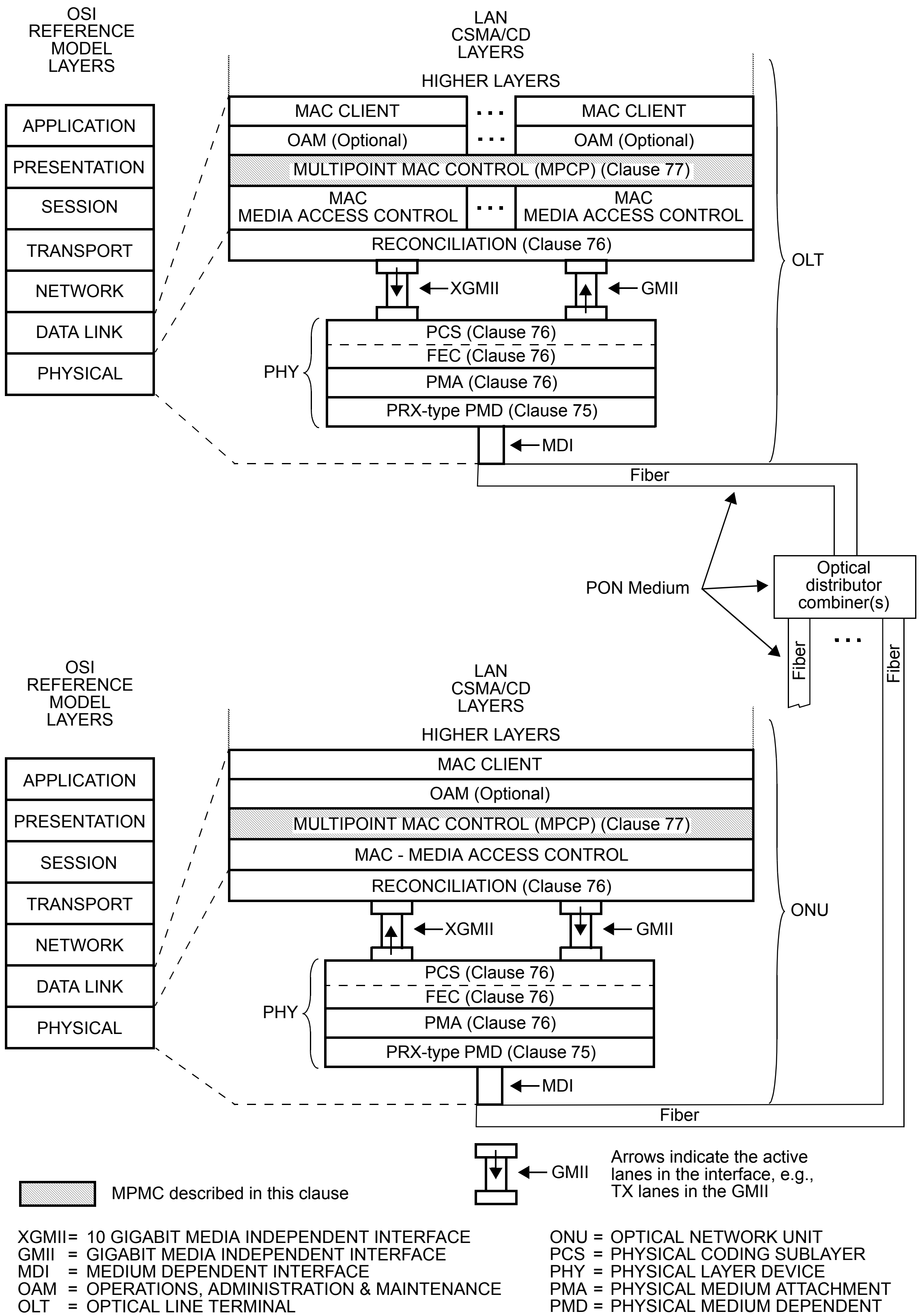


Figure 77–3—Relationship of Multipoint MAC Control and the OSI protocol stack for 10/1G–EPON (10 Gb/s downstream and 1 Gb/s upstream)

77.1.3 Functional block diagram

Figure 77–4 provides a functional block diagram of the Multipoint MAC Control architecture.

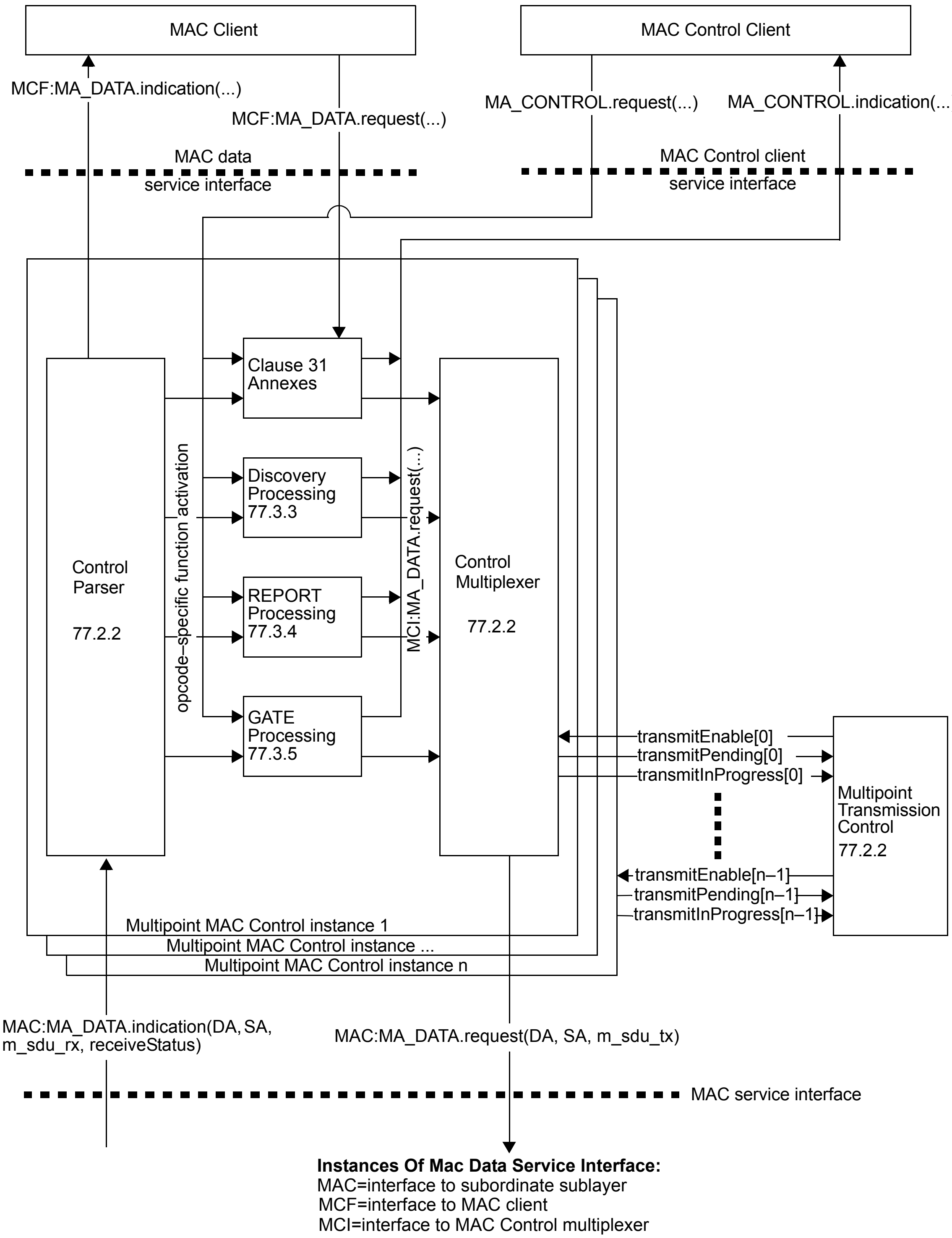


Figure 77–4—Multipoint MAC Control functional block diagram

77.1.4 Service interfaces

The MAC Client communicates with the Control Multiplexer using the standard service interface specified in 2.3. Multipoint MAC Control communicates with the underlying MAC sublayer using the standard service interface specified in Annex 4A.3.2. Similarly, Multipoint MAC Control communicates internally using primitives and interfaces consistent with definitions in Clause 31.

77.1.5 State diagram conventions

The body of this standard comprises state diagrams, including the associated definitions of variables, constants, and functions. Should there be a discrepancy between a state diagram and descriptive text, the state diagram prevails.

The notation used in the state diagrams follows the conventions of 21.5. State diagram timers follow the conventions of 14.2.3.2 augmented as follows:

a) [start x_timer, y] sets expiration of *y* to timer *x_timer*.
b) [stop x_timer] aborts the timer operation for *x_timer* asserting *x_timer_not_done* indefinitely.

The state diagrams use an abbreviation MACR as a shorthand form for MA_CONTROL.request and MACI as a shorthand form for MA_CONTROL.indication.

The vector notations used in the state diagrams for bit vector use 0 to mark the first received bit and so on (for example data[0:15]), following the conventions of 3.1 for bit ordering. When referring to an octet vector, 0 is used to mark the first received octet and so on (for example m_sdu[0..1]).

$a < b$: A function that is used to compare two (cyclic) time values. Returned value is true when b is larger than a allowing for wrap around of a and b. The comparison is made by subtracting b from a and testing the MSB. When MSB($a–b$) = 1 the value true is returned, else false is returned. In addition, the following functions are defined in terms of $a < b$:
$a > b$ is equivalent to $!(a < b$ or $a = b)$
$a \geq b$ is equivalent to $!(a < b)$
$a \leq b$ is equivalent to $!(a > b)$

77.2 Multipoint MAC Control operation

As depicted in Figure 77–4, the Multipoint MAC Control functional block comprises the following functions:

a) *Multipoint Transmission Control*. This block is responsible for synchronizing Multipoint MAC Control instances associated with the Multipoint MAC Control. This block maintains the Multipoint MAC Control state and controls the multiplexing functions of the instantiated MACs.
b) *Multipoint MAC Control Instance n*. This block is instantiated for each MAC and respective MAC and MAC Control clients associated with the Multipoint MAC Control. It holds all the variables and state associated with operating all MAC Control protocols for the instance.
c) *Control Parser*. This block is responsible for parsing MAC Control frames, and interfacing with Clause 31 entities, the opcode specific blocks, and the MAC Client.
d) *Control Multiplexer*. This block is responsible for selecting the source of the forwarded frames.
e) *Clause 31 annexes*. This block holds MAC Control actions as defined in Clause 31 annexes for support of legacy and future services.
f) *Discovery, Report, and Gate Processing*. These blocks are responsible for handling the MPCP in the context of the MAC.

77.2.1 Principles of Multipoint MAC Control

As depicted in Figure 77–4, Multipoint MAC Control sublayer may instantiate multiple Multipoint MAC Control instances in order to interface multiple MAC and MAC Control clients above with multiple MACs below. A unique unicast MAC instance is used at the OLT to communicate with each ONU. The individual MAC instances utilize the point-to-point emulation service between the OLT and the ONU as defined in 76.2.

At the ONU, a single MAC instance is used to communicate with a MAC instance at the OLT. In that case, the Multipoint MAC Control contains only a single instance of the Control Parser/Multiplexer function.

Multipoint MAC Control protocol supports several MAC and client interfaces. Only a single MAC interface and Client interface is enabled for transmission at a time. There is a tight mapping between a MAC service interface and a Client service interface. In particular, the assertion of the MAC:MA_DATA.indication primitive in MAC *j* leads to the assertion of the MCF:MA_DATA.indication primitive to Client *j*. Conversely, the assertion of the request service interface in Client *i* leads to the assertion of the MAC:MA_DATA.request primitive of MAC *i*. Note that the Multipoint MAC sublayer need not receive and transmit packets associated with the same interface at the same time. Thus the Multipoint MAC Control acts like multiple MAC Controls bound together with common elements.

The scheduling algorithm is implementation dependent, and is not specified for the case where multiple transmit requests happen at the same time.

The reception operation is as follows. The Multipoint MAC Control instances generate MAC:MA_DATA.indication service primitives continuously to the underlying MAC instances. Since these MACs are receiving frames from a single PHY only one frame is passed from the MAC instances to Multipoint MAC Control. The MAC instance responding to the MAC:MA_DATA.indication is referred to as the enabled MAC, and its service interface is referred to as the enabled MAC interface. The MAC passes to the Multipoint MAC Control sublayer all valid frames. Invalid frames, as specified in 3.4, are not passed to the Multipoint MAC Control sublayer in response to a MAC:MA_DATA.indication service primitive.

The enabling of a transmit service interface is performed by the Multipoint MAC Control instance in collaboration with the Multipoint Transmission Control. Frames generated in the MAC Control are given priority over MAC Client frames, in effect, prioritizing the MA_CONTROL primitive over the MCF:MA_DATA primitive, and for this purpose MCF:MA_DATA.request primitives may be delayed, discarded or modified in order to perform the requested MAC Control function. For the transmission of this frame, the Multipoint MAC Control instance enables forwarding by the MAC Control functions, but the MAC Client interface is not enabled. The reception of a frame in a MAC results in generation of the MAC:MA_DATA.indication primitive on that MAC's interface. Only one receive MAC interface is enabled at any given time since there is only one PHY interface.

The information of the enabled interfaces is stored in the controller state variables, and accessed by the Multiplexing Control block.

The Multipoint MAC Control sublayer uses the services of the underlying MAC sublayer to exchange both data and control frames.

Receive operation (MAC:MA_DATA.indication) at each instance:

a) A frame is received from the underlying MAC
b) The frame is parsed according to Length/Type field
c) MAC Control frames are demultiplexed according to opcode and forwarded to the relevant processing functions
d) Data frames (see 31.5.1) are forwarded to the MAC Client by asserting MCF:MA_DATA.indication primitives

Transmit operation (MAC:MA_DATA.request) at each instance:

e) The MAC Client signals a frame transmission by asserting MCF:MA_DATA.request, or
f) A protocol processing block attempts to issue a frame, as a result of a previous MA_CONTROL.request or as a result of an MPCP event that generates a frame.
g) When allowed to transmit by the Multipoint Transmission Control block, the frame is forwarded.

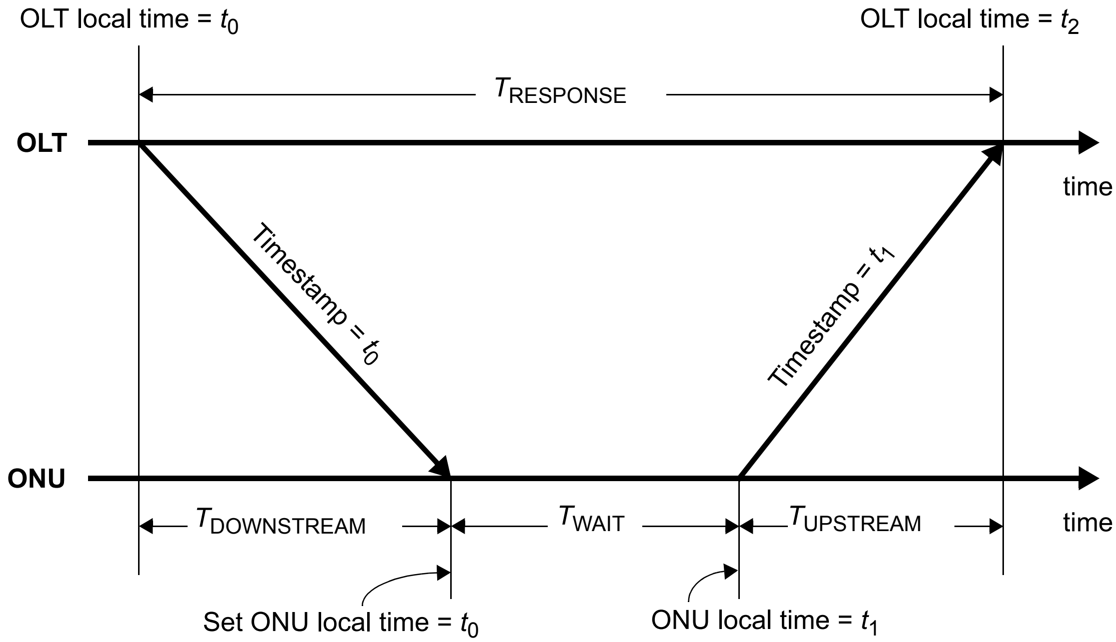
77.2.1.1 Ranging and timing process

Both the OLT and the ONU have 32 bit counters that increment every 16 ns. These counters provide a local time stamp. When either device transmits an MPCPDU, it maps its counter value into the timestamp field. The time of transmission of the first octet of the MPCPDU frame from the MAC Control to the MAC is taken as the reference time used for setting the timestamp value.

When the ONU receives MPCPDUs, it sets its counter according to the value in the timestamp field in the received MPCPDU.

When the OLT receives MPCPDUs, it uses the received timestamp value to calculate or verify a round trip time between the OLT and the ONU. The Round Trip Time (RTT) is equal to the difference between the timer value and the value in the timestamp field. The calculated RTT is notified to the client via the MA_CONTROL.indication primitive. The client can use this RTT for the ranging process.

A condition of *timestamp drift error* occurs when the difference between OLT's and ONU's clocks exceeds some predefined threshold. This condition can be independently detected by the OLT or an ONU. The OLT detects this condition when an absolute difference between new and old RTT values measured for a given ONU exceeds the value of guardThresholdOLT (see 77.2.2.1), as shown in Figure 77–11. An ONU detects the timestamp drift error condition when absolute difference between a timestamp received in an MPCPDU and the localTime counter exceeds guardThresholdONU (see 77.2.2.1), as is shown in Figure 77–12.



$T_{DOWNSTREAM}$ = downstream propagation delay

$T_{UPSTREAM}$ = upstream propagation delay

T_{WAIT} = wait time at ONU = $t_1 - t_0$

$T_{RESPONSE}$ = response time at OLT = $t_2 - t_0$

$$RTT = T_{DOWNSTREAM} + T_{UPSTREAM} = T_{RESPONSE} - T_{WAIT} = (t_2 - t_0) - (t_1 - t_0) = t_2 - t_1$$

Figure 77–5—Round trip time calculation

77.2.2 Multipoint transmission control, Control Parser, and Control Multiplexer

The purpose of the multipoint transmission control is to allow only one of the multiple MAC clients to transmit to its associated MAC and subsequently to the RS layer at one time by only asserting one transmitEnable signal at a time.

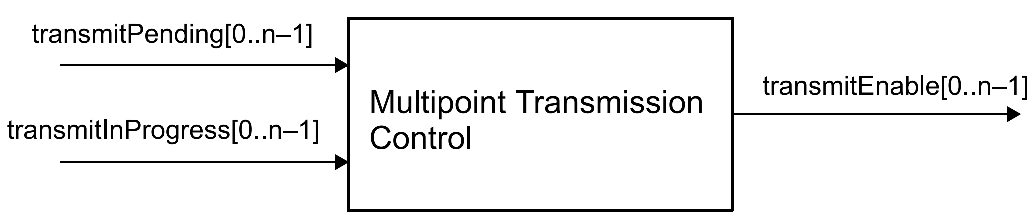


Figure 77–6—Multipoint Transmission Control service interfaces

Multipoint MAC Control Instance n function block communicates with the Multipoint Transmission Control using transmitEnable[n], transmitPending[n], and transmitInProgress[n] state variables (see Figure 77–4).

The Control Parser is responsible for opcode independent parsing of MAC frames in the reception path. By identifying MAC Control frames, demultiplexing into multiple entities for event handling is possible. Interfaces are provided to existing Clause 31 entities, functional blocks associated with MPCP, and the MAC Client.

The Control Multiplexer is responsible for forwarding frames from the MAC Control opcode-specific functions and the MAC Client to the MAC. Multiplexing is performed in the transmission direction. Given multiple MCF:MA_DATA.request primitives from the MAC Client, and MA_CONTROL.request primitives from the MAC Control Clients, a single MAC:MA_DATA.request service primitive is generated for transmission. At the OLT, multiple MAC instances share the same Multipoint MAC Control, as a result, the transmit block is enabled based on an external control signal housed in Multipoint Transmission Control for transmission overlap avoidance. At the ONU, the Gate Processing functional block interfaces for upstream transmission administration.

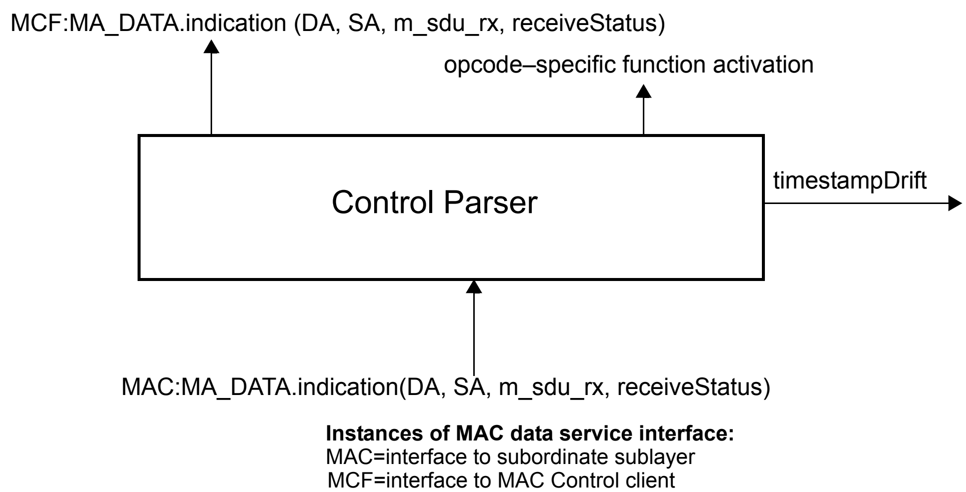
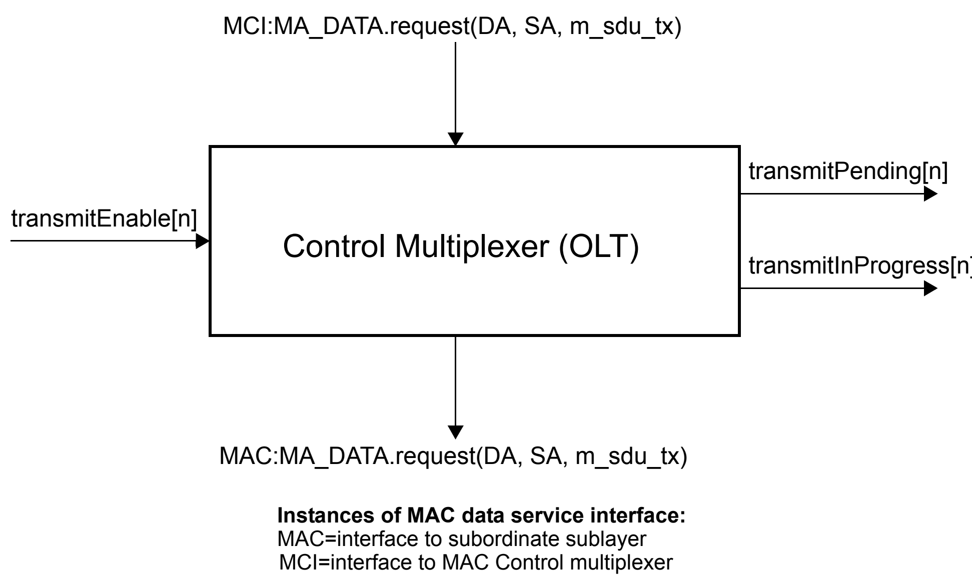
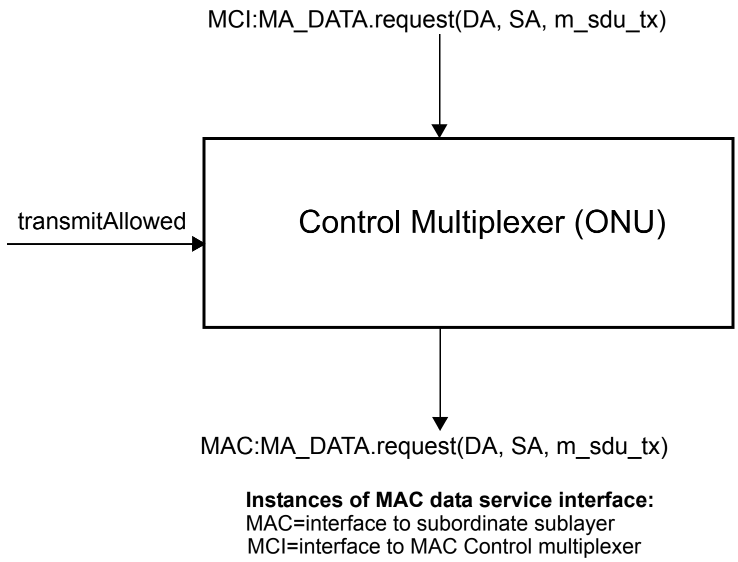


Figure 77–7—Control Parser service interfaces



NOTE—MAC:MA_DATA.request primitive may be issued from multiple MAC Control processing blocks.

Figure 77–8—OLT Control Multiplexer service interfaces



NOTE—MAC:MA_DATA.request primitive may be issued from multiple MAC Control processing blocks.

Figure 77–9—ONU Control Multiplexer service interfaces

77.2.2.1 Constants

FEC_CODEWORD_SIZE
TYPE: integer
This constant represents the size of FEC codeword in octets (FEC_PAYLOAD_SIZE + FEC_PARITY_SIZE).
Value: 248

FEC_PARITY_SIZE
TYPE: integer
This constant represents the size of FEC codeword parity field in octets.
Value: 32

FEC_PAYLOAD_SIZE
TYPE: integer
This constant represents the size of FEC codeword payload in octets.
VALUE: 216

guardThresholdOLT
TYPE: integer
This constant holds the maximum amount of drift allowed for a timestamp received at the OLT. This value is measured in units of time_quantum.
VALUE: 12

guardThresholdONU
TYPE: integer
This constant holds the maximum amount of drift allowed for a timestamp received at the ONU. This value is measured in units of time_quantum.
VALUE: 8

MAC_Control_type
TYPE: integer
The value of the Length/Type field as defined in 31.4.1.3.
VALUE: 0x8808

tailGuard
TYPE: integer
This constant holds the value used to reserve space at the end of the upstream transmission at the ONU in addition to the size of last MAC service data unit (m_sdu) in units of octets. Space is reserved for the MAC overheads including: preamble, SFD, DA, SA, Length/Type, FCS, and minimum inter–packet gap. The sizes of the above listed MAC overhead items are described in 3.1.1. The size of the minimum IPG is described in 4A.4.2.
VALUE: 38

time_quantum
This variable is defined in 64.2.2.1.

tqSize
TYPE: integer
This constant represents time_quantum in octet transmission times.
VALUE: 20

77.2.2.2 Counters

localTime
TYPE: 32 bit unsigned
This variable holds the value of the local timer used to control MPCP operation. This variable is advanced by a timer at 62.5MHz, and counts in time_quanta. At the OLT the counter shall track the transmit clock, while at the ONU the counter shall track the receive clock. For accuracy of receive clock see 76.4.1.2. It is reloaded with the received timestamp value (from the OLT) by the Control Parser (see Figure 77–12). Changing the value of this variable while running using Layer Management is highly undesirable and is unspecified.

77.2.2.3 Variables

BEGIN
TYPE: Boolean
This variable is used when initiating operation of the functional block state diagram. It is set to true following initialization and every reset.

fecOffset
TYPE: 32 bit unsigned
A variable that advances by 1 after every 8 bit times. After reaching the value of FEC_CODEWORD_SIZE, this variable is reset to zero. In the OLT, this variable is initialized to 0 at system initialization. In the ONU, this variable is assigned in the GATE Processing ONU Activation state diagram (see Figure 77–14).

NOTE—Notation fecOffset[1:0] refers to two least significant bits of this variable.

data_rx
TYPE: bit array
This variable represents a 0–based bit array corresponding to the payload of a received MPCPDU. This variable is used to parse incoming MPCPDU frames.

data_tx
TYPE: bit array
This variable represents a 0-based bit array corresponding to the payload of an MPCPDU being transmitted. This variable is used to access payload of outgoing MPCPDU frames, for example to set the timestamp value.

grantStart
TYPE: Boolean
This variable indicates beginning of a grant transmission. It is set to true in the GATE Processing ONU Activation state diagram (see Figure 77–30) when a new grant activates. It is reset to false after the transmission of the first frame in the grant (see Figure 77–14). This variable is defined in ONU only.

newRTT
TYPE: 16 bit unsigned
This variable temporary holds a newly–measured Round Trip Time to the ONU. The new RTT value is represented in units of time_quanta.

m_sdu_rx
TYPE: bit array
Equal to the concatenation of the Length/Type and data_rx variables.

m_sdu_tx
TYPE: bit array
Equal to the concatenation of the Length/Type and data_tx variables.

m_sdu_ctl
TYPE: bit array
Equal to the concatenation of the MAC_Control_type and data_tx variables.

OctetsRemaining
TYPE: 32 bit unsigned
This variable is an alias for the expression (((stopTime – localTime) × tqSize) – tqOffset). It denotes the number of octets that can be transmitted between the current time and the end of the grant.

OctetsRequired
TYPE: 16 bit unsigned
This variable represents a total transmission time of next packet and is used to check whether the next packet fits in the remainder of ONU's transmission window. The value of OctetsRequired includes packet transmission time, tailGuard defined in 77.2.2.1, and FEC parity data overhead. This variable is measured in units of octets.

opcode_rx
TYPE: 16 bit unsigned
This variable holds an opcode of the last received MPCPDU.

opcode_tx
TYPE: 16 bit unsigned
This variable holds an opcode of an outgoing MPCPDU.

packet_initiate_delay
TYPE: 16 bit unsigned

This variable is used to set the time–out interval for packet_initiate_timer defined in 77.2.2.5. The packet_initiate_delay value is represented in units of octets.

RTT
TYPE: 16 bit unsigned
This variable holds the measured Round Trip Time to the ONU. The RTT value is represented in units of time_quanta.

stopTime
TYPE: 32 bit unsigned
This variable holds the value of the localTime counter corresponding to the end of the nearest grant. This value is set by the Gate Processing function as described in 77.3.5.

timestamp
TYPE: 32 bit unsigned
This variable holds the value of timestamp of the last received MPCPDU frame.

timestampDrift
TYPE: Boolean
This variable is used to indicate whether an error is signaled as a result of uncorrectable timestamp drift.

tqOffset
TYPE: 8 bit unsigned
This variable denotes the offset (in octet times) of the current actual time from the localTime variable (which maintains the current time in units of time_quanta).

transmitAllowed
TYPE: Boolean
This variable is used to control PDU transmission at the ONU. It is set to true when the transmit path is enabled, and is set to false when the transmit path is being shut down. transmitAllowed changes its value according to the state of the Gate Processing functional block.

transmitEnable
TYPE: Boolean array
This array contains one element per each Multipoint MAC Control instance. Elements of this array are used to control the transmit path in the Multipoint MAC Control instance at the OLT. Setting an element to TRUE indicates that the selected instance is permitted to transmit a frame. Setting it to FALSE inhibits the transmission of frames in the selected instance. Only one element of transmitEnable should be set to TRUE at a time.

transmitInProgress
TYPE: Boolean array
This array contains one element per each Multipoint MAC Control instance. The element *j* of this array set to on indicates that the Multipoint MAC Control instance *j* is in the process of transmitting a frame.

transmitPending
TYPE: Boolean array
This array contains one element per each Multipoint MAC Control instance. The element *j* of this array set to on indicates that the Multipoint MAC Control instance *j* is ready to transmit a frame.

77.2.2.4 Functions

abs(n)
This function returns the absolute value of the parameter n.

Opcode–specific function(opcode)
Functions exported from opcode specific blocks that are invoked on the arrival of a MAC Control message of the appropriate opcode.

CheckGrantSize(length)
This function calculates the future time at which the transmission of the current frame (including the FEC parity overhead) is completed.

$$\text{CheckGrantSize(length)} = \left\lceil \frac{\text{fecOffset + length}}{\text{FEC\_PAYLOAD\_SIZE}} \right\rceil \times \text{FEC\_CODEWORD\_SIZE} - \text{fecOffset}$$

NOTE—The notation $\lceil x \rceil$ represents a *ceiling* function, which returns the value of its argument x rounded up to the nearest integer.

FEC_Overhead(length)
This function calculates the amount of time (in octet times) that the MPCP control multiplexer waits following transmission of a frame of size 'length' so as to allow the insertion of parity data into the frame by the PHY layer. As described in 76.3.2.4, FEC encoder adds 32 parity octets for each block of 216 data or control octets. FEC_Overhead() returns the number of octets that the PHY inserts during transmission of a particular packet and its subsequent IPG. Parameter 'length' represents the size of an entire frame including preamble, SFD, DA, SA, Length/Type, FCS, and IPG. The following formula is used to calculate the overhead:

$$\text{FEC\_Overhead(length)} = \text{length} + \text{FEC\_PARITY\_SIZE} \times \left\lfloor \frac{\text{fecOffset + length}}{\text{FEC\_PAYLOAD\_SIZE}} \right\rfloor$$

NOTE—The notation $\lfloor x \rfloor$ represents a *floor* function, which returns the value of its argument x rounded down to the nearest integer.

select()
This function selects the next Multipoint MAC Control instance allowed to initiate transmission of a frame. The function returns an index to the transmitPending array for which the value is not false. The selection criteria in the presence of multiple active elements in the list is implementation dependent.

SelectFrame()
This function enables the interface, which has a pending frame. If multiple interfaces have frames waiting at the same time, only one interface is enabled. The selection criteria is not specified, except for the case when some of the pending frames have Length/Type = MAC_Control. In this case, one of the interfaces with a pending MAC Control frame shall be enabled.

sizeof(sdu)
This function returns the size of the sdu in octets.

transmissionPending()
This function returns true if any of the Multipoint MAC Control instances has a frame waiting to be transmitted. The function can be represented as:

```
transmissionPending() =
   transmitPending[0] +
   transmitPending[1] +
```

```
... +
transmitPending[n-1]
```

where n is the total number of Multipoint MAC Control instances.

77.2.2.5 Timers

packet_initiate_timer

This timer is used to delay frame transmission from MAC Control to avoid variable MAC delay while MAC enforces IPG after a previous frame. In addition, this timer increases interframe spacing just enough to accommodate the extra parity data to be added by the FEC encoder.

77.2.2.6 Messages

MA_DATA.indication(DA, SA, m_sdu, receiveStatus)

The service primitive is defined in 2.3.2.

MA_DATA.request (DA, SA, m_sdu)

The service primitive is defined in 2.3.2.

77.2.2.7 State diagrams

The Multipoint transmission control function in the OLT shall implement state diagram shown in Figure 77–10. Control parser function in the OLT shall implement state diagram shown in Figure 77–11. Control parser function in the ONU shall implement state diagram shown in Figure 77–12. Control multiplexer function in the OLT shall implement state diagram shown in Figure 77–13. Control multiplexer function in the ONU shall implement state diagram shown in Figure 77–14.

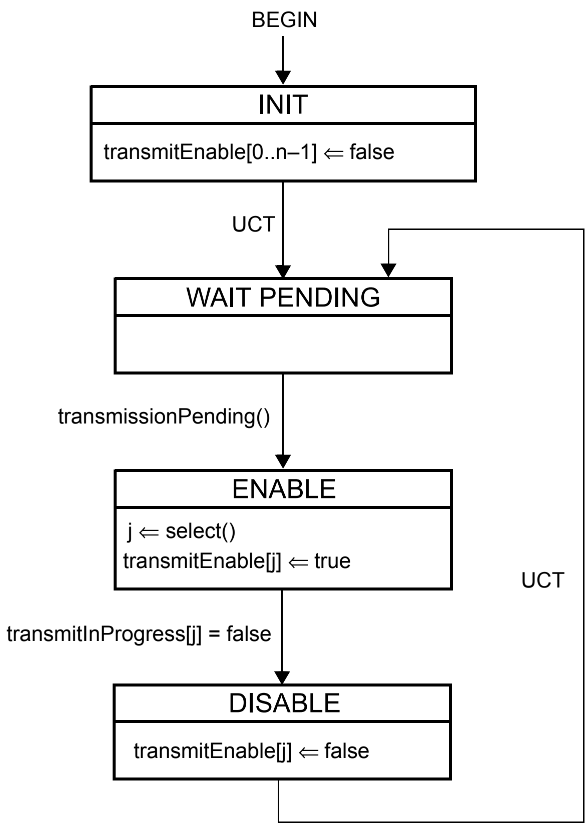


Figure 77–10—OLT Multipoint Transmission Control state diagram

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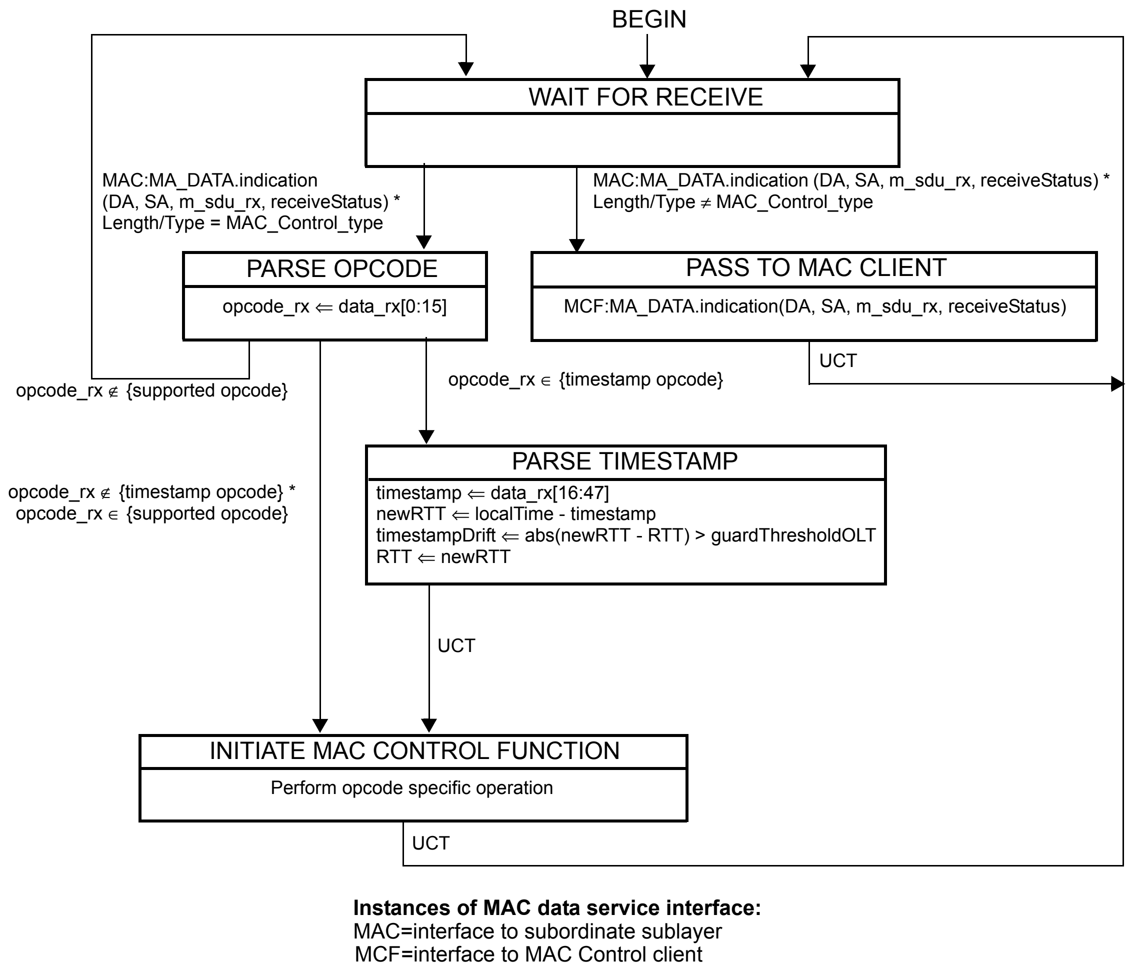
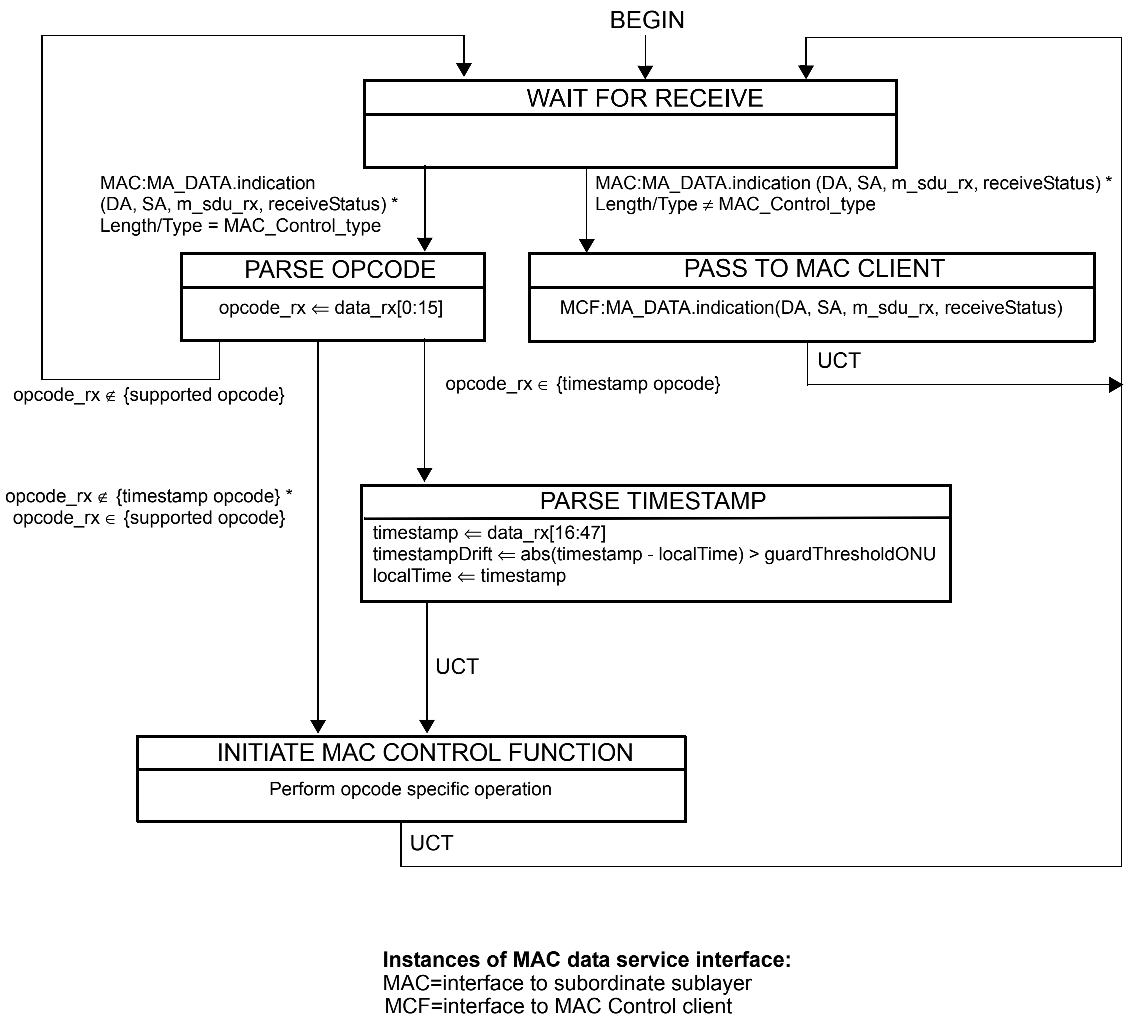


NOTE—The opcode–specific operation is launched as a parallel process by the MAC Control sublayer, and not as a synchronous function. Progress of the generic MAC Control Receive state diagram (as shown in this figure) is not implicitly impeded by the launching of the opcode specific function.

Refer to Annex 31A for list of supported opcodes and timestamp opcodes.

Figure 77–11—OLT Control Parser state diagram



NOTE—The opcode–specific operation is launched as a parallel process by the MAC Control sublayer, and not as a synchronous function. Progress of the generic MAC Control Receive state diagram (as shown in this figure) is not implicitly impeded by the launching of the opcode specific function.

Refer to Annex 31A for list of supported opcodes and timestamp opcodes.

Figure 77–12—ONU Control Parser state diagram

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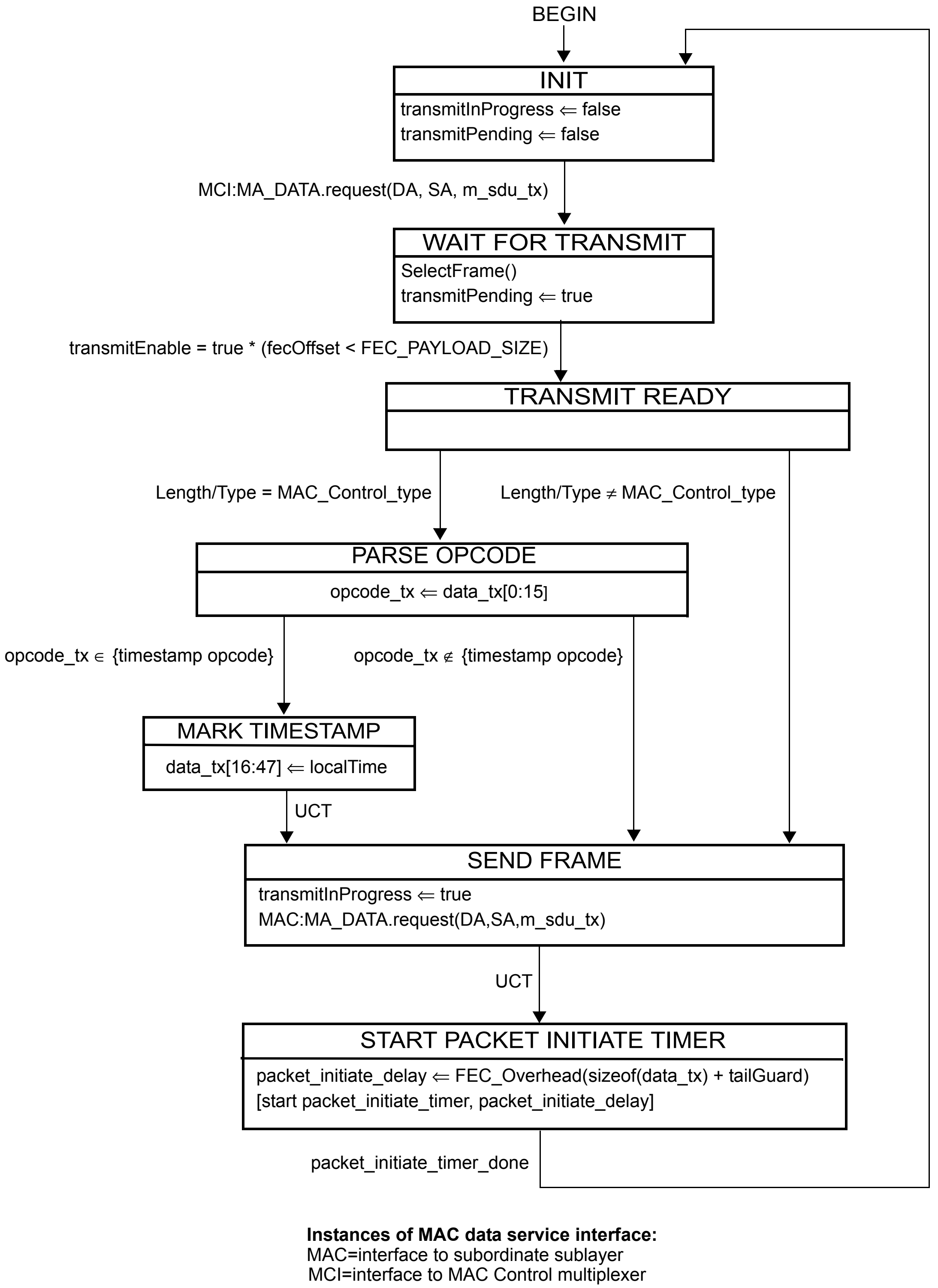
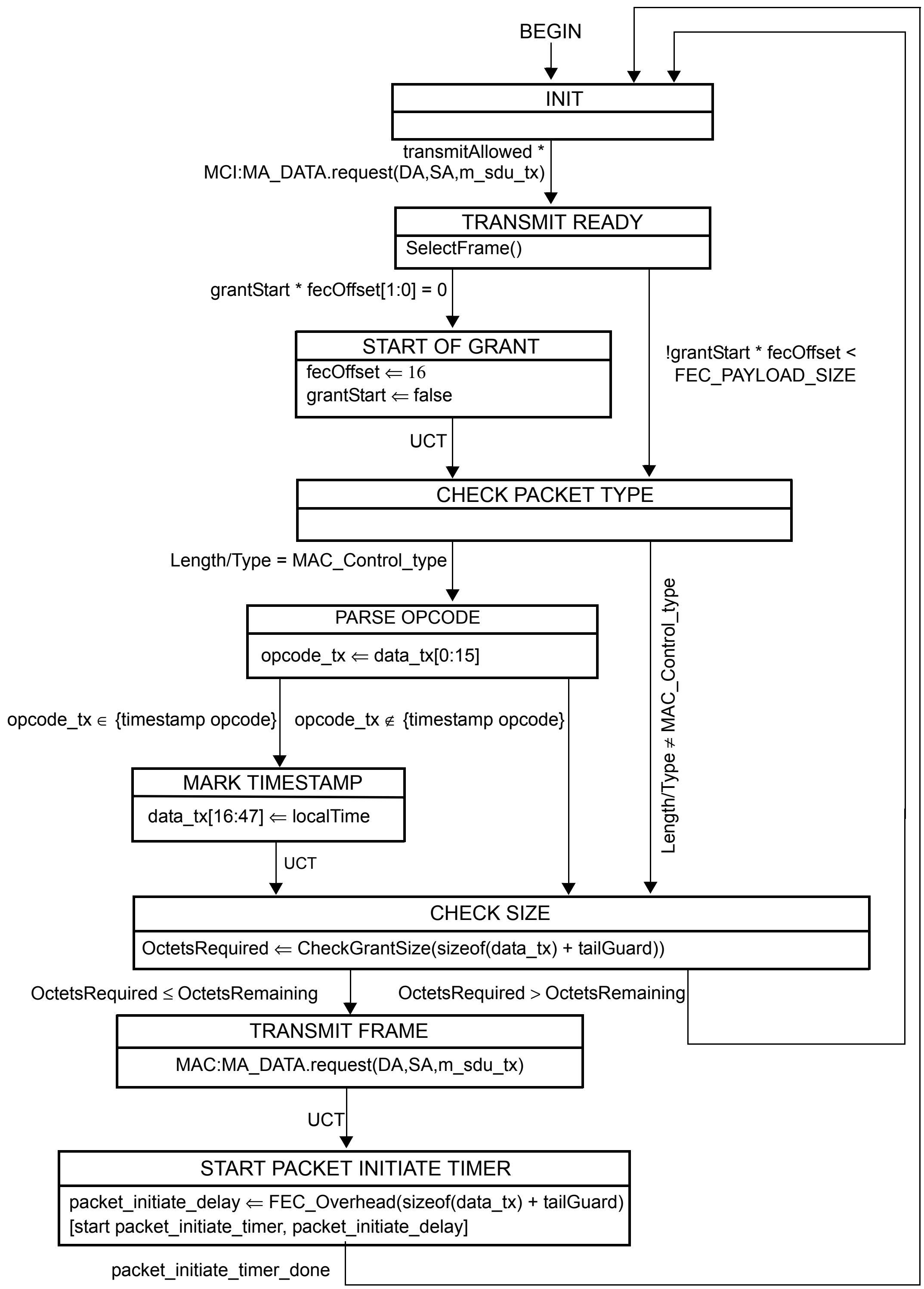


Figure 77–13—OLT Control Multiplexer state diagram



Instances of MAC data service interface:
MAC=interface to subordinate sublayer
MCI=interface to MAC Control multiplexer

Figure 77–14—ONU Control Multiplexer state diagram

77.3 Multipoint Control Protocol (MPCP)

As depicted in Figure 77–4, the Multipoint MAC Control functional block comprises the following functions:

a) *Discovery Processing*. This block manages the discovery process, through which an ONU is discovered and registered with the network while compensating for RTT.
b) *Report Processing*. This block manages the generation and collection of report messages, through which bandwidth requirements are sent upstream from the ONU to the OLT.
c) *Gate Processing*. This block manages the generation and collection of gate messages, through which multiplexing of multiple transmitters is achieved.

As depicted in Figure 77–4, the layered system may instantiate multiple MAC entities, using a single Physical Layer. Each instantiated MAC communicates with an instance of the opcode specific functional blocks through the Multipoint MAC Control. In addition some global variables are shared across the multiple instances. Common state control is used to synchronize the multiple MACs using MPCP procedures. Operation of the common state control is generally considered outside the scope of this document.

77.3.1 Principles of Multipoint Control Protocol

Multipoint MAC Control enables a MAC Client to participate in a point-to-multipoint optical network by allowing it to transmit and receive frames as if it was connected to a dedicated link. In doing so, it employs the following principles and concepts:

a) A MAC client transmits and receives frames through the Multipoint MAC Control sublayer.
b) The Multipoint MAC Control decides when to allow a frame to be transmitted using the client interface Control Multiplexer.
c) Given a transmission opportunity, the MAC Control may generate control frames that would be transmitted in advance of the MAC Client’s frames, utilizing the inherent ability to provide higher priority transmission of MAC Control frames over MAC Client frames.
d) Multiple MACs operate on a shared medium by allowing only a single MAC to transmit upstream at any given time across the network using a time-division multiple access (TDMA) method.
e) Such gating of transmission is orchestrated through the Gate Processing function.
f) New devices are discovered in the network and allowed transmission through the Discovery Processing function.
g) Fine control of the network bandwidth distribution can be achieved using feedback mechanisms supported in the Report Processing function.
h) The operation of P2MP network is asymmetric, with the OLT assuming the role of master, and the ONU assuming the role of slave.

77.3.2 Compatibility considerations

77.3.2.1 PAUSE operation

Even though MPCP is compatible with flow control, optional use of flow control may not be efficient in the case of large propagation delay. If flow control is implemented, then the timing constraints in Clause 31B supplement the constraints found at 77.3.2.4.

NOTE—MAC at an ONU can receive frames from unicast channel and SCB channel. If the SCB channel is used to broadcast data frames to multiple ONUs, the ONU’s MAC may continue receiving data frames from SCB channel even after the ONU has issued a PAUSE request to its unicast remote-end.

77.3.2.2 Optional Shared LAN emulation

By combining P2PE, suitable filtering rules at the ONU, and suitable filtering and forwarding rules at the OLT, it is possible to emulate an efficient shared LAN. Support for shared LAN emulation is optional, and requires an additional layer above the MAC, which is out of scope for this document. Thus, shared LAN emulation is introduced here for informational purposes only.

Specific behaviour of the filtering layer at the RS is specified in 76.2.6.1.3.2.

77.3.2.3 Multicast and single copy broadcast support

In the downstream direction, the PON is a broadcast medium. In order to make use of this capability for forwarding broadcast frames from the OLT to multiple recipients without frame duplication for each ONU, the SCB support is introduced.

The OLT has at least one MAC associated with every ONU. In addition one more MAC at the OLT is marked as the SCB MAC. The SCB MAC handles all downstream broadcast traffic, but is never used in the upstream direction for client traffic, except for client registration. Optional higher layers may be implemented to perform selective broadcast of frames. Such layers may require additional MACs (multicast MACs) to be instantiated in the OLT for some or all ONUs increasing the total number of MACs beyond the number of ONUs + 1.

When connecting the SCB MAC to an IEEE 802.1D bridge port it is possible that loops may be formed due to the broadcast nature. Thus it is recommended that this MAC not be connected to an IEEE 802.1D bridge port.

Configuration of SCB channels as well as filtering and marking of frames for support of SCB is defined in 76.2.6.1.3.2 for 10G–EPON compliant Reconciliation Sublayers.

77.3.2.4 Delay requirements

The MPCP protocol relies on strict timing based on distribution of timestamps. A compliant implementation needs to guarantee a constant delay through the MAC and PHY in order to maintain the correctness of the timestamping mechanism. The actual delay is implementation dependent; however, a complying implementation shall maintain a delay variation of no more than 1 time_quantum through the MAC.

The OLT shall not grant less than 1024 time_quanta into the future, in order to allow the ONU processing time when it receives a gate message. The ONU shall process all messages in less than this period. The OLT shall not issue more than one message every 1024 time_quanta to a single ONU. The unit of time_quantum is defined in 77.2.2.1.

77.3.3 Discovery processing

Discovery is the process whereby newly connected or off-line ONUs are provided access to the PON. The process is driven by the OLT, which periodically makes available Discovery Windows during which off-line ONUs are given the opportunity to make themselves known to the OLT. The periodicity of these windows is unspecified and left up to the implementor. The OLT signifies that a discovery period is occurring by broadcasting a discovery GATE MPCPDU, which includes the starting time and length of the discovery window, along with the Discovery Information flag field, as defined in 77.3.6.1. With the appropriate settings of individual flags contained in this 16 bit wide field, the OLT notifies all the ONUs about its upstream and downstream channel transmission capabilities. Note that the OLT may simultaneously support more than one data rate in the given transmission direction.

Off-line ONUs, upon receiving a Discovery GATE MPCPDU, wait for the period to begin and then transmit a REGISTER_REQ MPCPDU to the OLT. Discovery windows are unique in that they are the only times when multiple ONUs can access the PON simultaneously, and transmission overlap can occur. In order to reduce transmission overlaps, a contention algorithm is used by all ONUs. Measures are taken to reduce the probability for overlaps by artificially simulating a random distribution of distances from the OLT. Each ONU waits a random amount of time before transmitting the REGISTER_REQ MPCPDU that is shorter than the length of the discovery window. It should be noted that multiple valid REGISTER_REQ MPCPDUs can be received by the OLT during a single discovery window. Included in the REGISTER_REQ MPCPDU is the ONU's MAC address and number of maximum pending grants. Additionally, a registering ONU notifies the OLT of its transmission capabilities in the upstream and downstream channels by setting appropriately the flags in the Discovery Information field, as specified in 77.3.6.3.

Note that even though a compliant ONU is not prohibited from supporting more than one data rate in any transmission channel, it is expected that a single supported data rate for upstream and downstream channel is indicated in the Discovery Information field. Moreover, in order to assure maximum utilization of the upstream channel and to decrease the required size of the guard band between individual data bursts, the registering ONU notifies the OLT of the laser on/off times, by setting appropriate values in the Laser On Time and Laser Off Time fields, where both values are expressed in the units of time_quanta.

Upon receipt of a valid REGISTER_REQ MPCPDU, the OLT registers the ONU, allocating and assigning a new port identity (LLID), and bonding a corresponding MAC to the LLID.

The next step in the process is for the OLT to transmit a REGISTER MPCPDU to the newly discovered ONU, which contains the ONU's LLID, and the OLT's required synchronization time. Moreover, the OLT echoes the maximum number of pending grants. The OLT also sends the target value of laser on time and laser off time, which may be different than laser on time and laser off time delivered by the ONU in the REGISTER_REQ MPCPDU.

The OLT now has enough information to schedule the ONU for access to the PON and transmits a standard GATE message allowing the ONU to transmit a REGISTER_ACK. Upon receipt of the REGISTER_ACK, the discovery process for that ONU is complete, the ONU is registered and normal message traffic can begin. It is the responsibility of Layer Management to perform the MAC bonding, and start transmission from/to the newly registered ONU. The discovery message exchange is illustrated in Figure 77–15.

There may exist situations when the OLT requires that an ONU go through the discovery sequence again and reregister. Similarly, there may be situations where an ONU needs to inform the OLT of its desire to deregister. The ONU can then reregister by going through the discovery sequence. For the OLT, the REGISTER message may indicate a value, Reregister or Deregister, that if either is specified forces the receiving ONU into reregistering. For the ONU, the REGISTER_REQ message contains the Deregister bit that signifies to the OLT that this ONU should be deregistered.

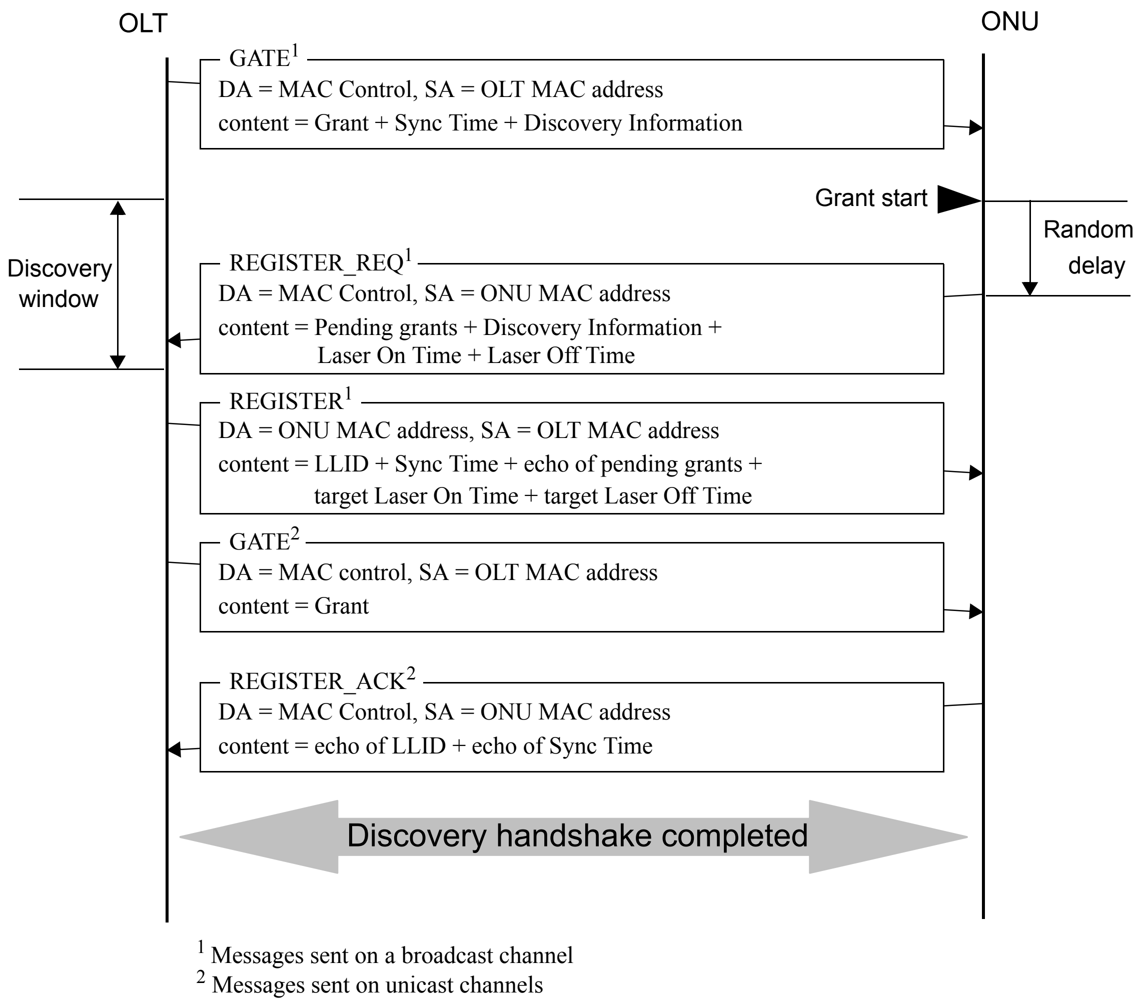


Figure 77–15—Discovery handshake message exchange

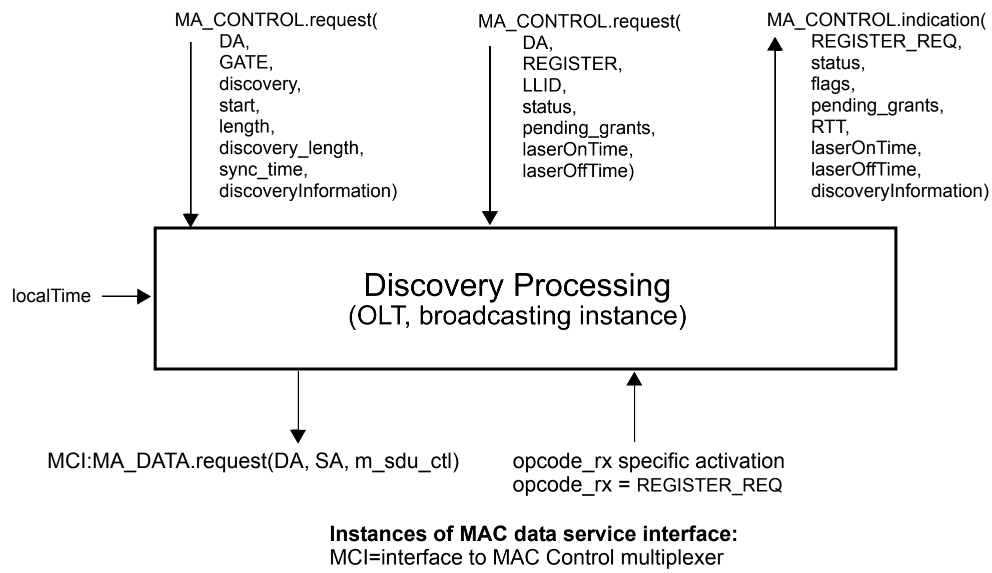


Figure 77–16—Discovery Processing service interfaces (OLT, broadcasting instance)

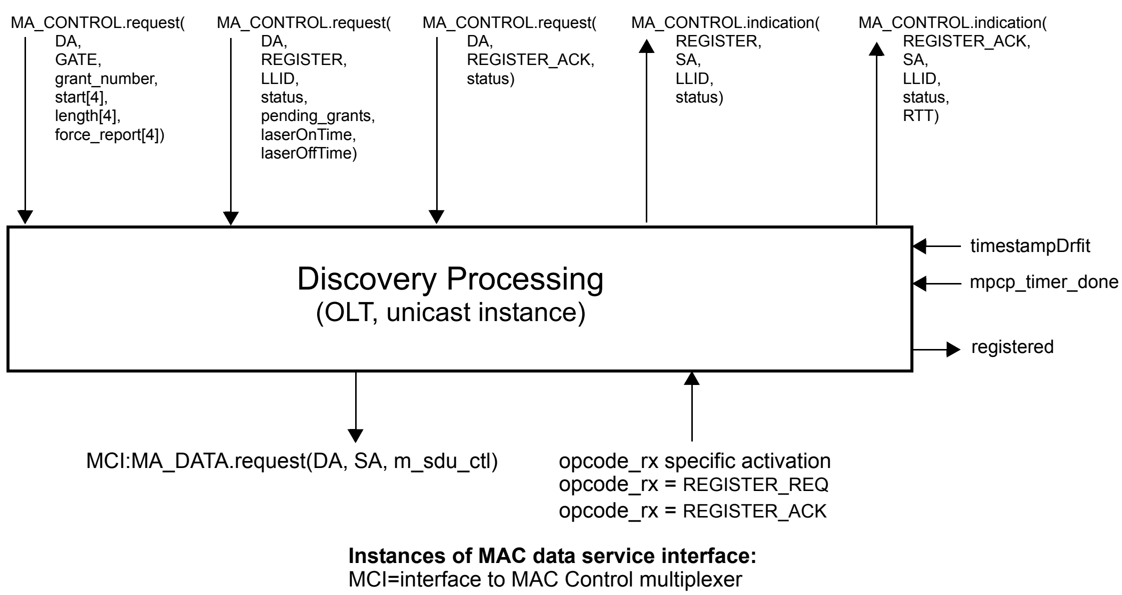


Figure 77–17—Discovery Processing service interfaces (OLT, unicasting instance)

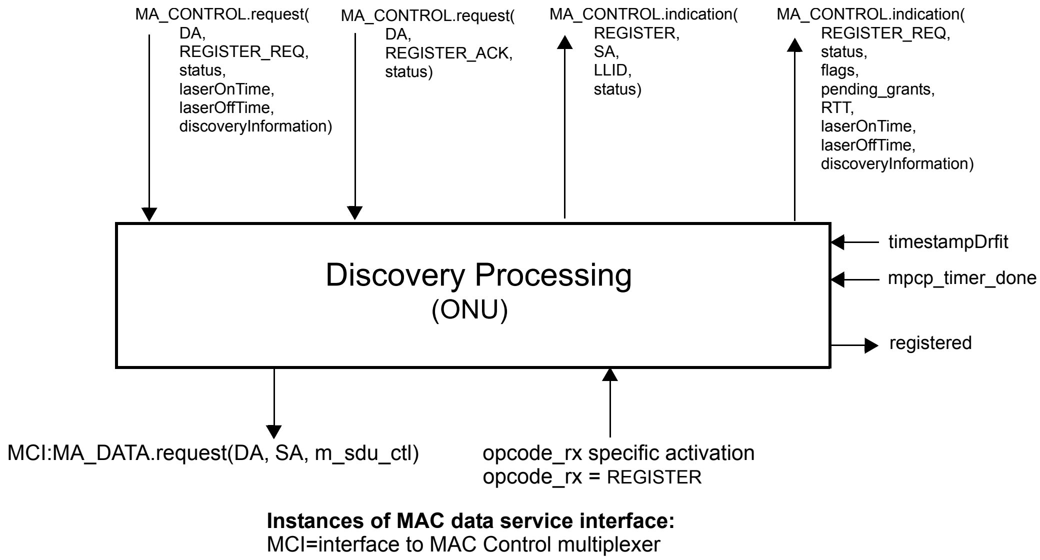


Figure 77–18—Discovery Processing service interfaces (ONU)

77.3.3.1 Constants

laserOffTimeCapability
TYPE: 8 bit unsigned
This constant represents the time required to terminate the laser, in units of time_quantum. While the default value corresponds to a maximum allowed T_{off} (as specified in Table 75–8 and Table 75–9), implementations may set it to the actual value time period required for turning off the PMD, as specified in 75.7.14.
VALUE: 0x20 (512 ns, default value)

laserOnTimeCapability
TYPE: 8 bit unsigned
This constant represents the time required to initialize the laser, in units of time_quantum. While the default value corresponds to a maximum allowed T_{on} (as specified in Table 75–8 and Table 75–9), implementations may set it to the actual value time period required for turning on the PMD, as specified in 75.7.14.
VALUE: 0x20 (512 ns, default value)

77.3.3.2 Variables

BEGIN
This variable is defined in 77.2.2.3.

data_rx
This variable is defined in 77.2.2.3.

data_tx
This variable is defined in 77.2.2.3.

grantEndTime
TYPE: 32 bit unsigned
This variable holds the time at which the OLT expects the ONU grant to complete. Failure of a

REGISTER_ACK message from an ONU to arrive at the OLT before grantEndTime is a fatal error in the discovery process, and causes registration to fail for the specified ONU, who may then retry to register. The value of grantEndTime is measured in units of time_quantum.

insideDiscoveryWindow
TYPE: Boolean
This variable holds the current status of the discovery window. It is set to true when the discovery window opens, and is set to false when the discovery window closes.

laserOffTime
TYPE: 8 bit unsigned
This variable holds the time required to terminate the laser. It counts in time_quanta units the time period required for turning off the PMD, as specified by the value of T_{off} in 75.7.14.
VALUE: laserOffTimeCapability (default value)

laserOnTime
TYPE: 8 bit unsigned
This variable holds the time required to initiate the PMD. It counts in time_quanta units the time period required for turning on the PMD, as specified by the value of T_{on} in 75.7.14.
VALUE: laserOnTimeCapability (default value)

localTime
This variable is defined in 77.2.2.2.

m_sdu_ctl
This variable is defined in 77.2.2.3.

opcode_rx
This variable is defined in 77.2.2.3.

pendingGrants
TYPE: 16 bit unsigned
This variable holds the maximum number of pending grants that an ONU is able to queue.

registered
TYPE: Boolean
This variable holds the current result of the Discovery Process. It is set to true once the discovery process is complete and registration is acknowledged.

syncTime
TYPE: 16 bit unsigned
This variable holds the time required to stabilize the receiver at the OLT. It counts time_quanta units from the point where transmission output is stable to the point where synchronization has been achieved. The value of syncTime includes gain adjustment interval ($T_{receiver\_settling}$), clock synchronization interval (T_{cdr}), and code–group alignment interval ($T_{code\_group\_align}$), as specified in 75.7.14. The OLT conveys the value of syncTime to ONUs in Discovery GATE and REGISTER messages. During the synchronization time a 10/1G–EPON ONU transmits only IDLE patterns, and a 10/10G–EPON ONU sends synchronization pattern (SP, see 76.3.2.5.2) followed by burst delimiter pattern (BURST_DELIMITER, see 76.3.2.5.2).

timestampDrift
This variable is defined in 77.2.2.3.

77.3.3.3 Functions

None.

77.3.3.4 Timers

discovery_window_size_timer
This timer is used to wait for the event signaling the end of the discovery window.
VALUE: The timer value is set dynamically based on the parameters received in a DISCOVERY GATE message.

mpcp_timer
This timer is used to measure the arrival rate of MPCP frames in the link. Failure to receive frames is considered a fatal fault and leads to deregistration.

77.3.3.5 Messages

MA_DATA.indication(DA, SA, m_sdu, receiveStatus)
The service primitive is defined in 2.3.2.

MA_DATA.request (DA, SA, m_sdu)
The service primitive is defined in 2.3.2.

MA_CONTROL.request(DA, GATE, discovery, start, length, discovery_length, sync_time, discoveryInformation)
The service primitive is used by the MAC Control client at the OLT to initiate the Discovery Process. This primitive takes the following parameters:

DA:	Multicast or unicast MAC address.
GATE:	Opcode for GATE MPCPDU as defined in Table 31A–1.
discovery:	Flag specifying that the given GATE message is to be used for discovery only.
start:	Start time of the discovery window.
length:	Length of the grant given for discovery.
discovery_length:	Length of the discovery window process.
sync_time:	The time interval required to stabilize the receiver at the OLT.
discoveryInformation:	This parameter represents the Discovery Information field in GATE MPCPDU as specified in 77.3.6.1, defining the speed(s) the OLT is capable of receiving and speed(s) at which the discovery window is opened for.

MA_CONTROL.request(DA, GATE, grant_number, start[4], length[4], force_report[4])
This service primitive is used by the MAC Control client at the OLT to issue the GATE message to an ONU. This primitive takes the following parameters:

DA:	Multicast MAC Control address as defined in Annex 31B.
GATE:	Opcode for GATE MPCPDU as defined in Table 31A–1.
grant_number:	Number of grants issued with this GATE message. The number of grants ranges from 0 to 4.
start[4]:	Start times of the individual grants. Only the first grant_number elements of the array are used.
length[4]:	Lengths of the individual grants. Only the first grant_number elements of the array are used.

force_report[4]: Flags indicating whether a REPORT message should be generated in the corresponding grant. Only the first grant_number elements of the array are used.

MA_CONTROL.request(DA, REGISTER_REQ, status, laserOnTime, laserOffTime, discoveryInformation)

The service primitive is used by a client at the ONU to request the Discovery Process to perform a registration. This primitive takes the following parameters:

DA: Multicast MAC Control address as defined in Annex 31B.
REGISTER_REQ: opcode for REGISTER_REQ MPCPDU as defined in Table 31A–1.
status: This parameter takes on the indication supplied by the flags field in the REGISTER_REQ MPCPDU as defined in Table 77–5.
laserOnTime: This parameter holds the laserOnTime value, expressed in units of time_quanta, as reported by MAC client and specified in 77.3.6.3.
laserOffTime: This parameter holds the laserOffTime value, expressed in units of time_quanta, as reported by MAC client and specified in 77.3.6.3.
discoveryInformation: This parameter represents the Discovery Information field, as specified in 77.3.6.3, defining the speed(s) the ONU is capable of transmitting and speed(s) at which the registration attempt is made.

MA_CONTROL.indication(REGISTER_REQ, status, flags, pending_grants, RTT, laserOnTime, laserOffTime, discoveryInformation)

The service primitive is issued by the Discovery Process to notify the client and Layer Management that the registration process is in progress. This primitive takes the following parameters:

REGISTER_REQ: Opcode for REGISTER_REQ MPCPDU as defined in Table 31A–1.
status: This parameter holds the values incoming or retry. Value incoming is used at the OLT to signal that a REGISTER_REQ message was received successfully. The value retry is used at the ONU to signal to the client that a registration attempt failed and needs to be repeated.
flags: This parameter holds the contents of the flags field in the REGISTER_REQ message. This parameter holds a valid value only when the primitive is generated by the Discovery Process in the OLT.
pending_grants: This parameter holds the contents of the pending_grants field in the REGISTER_REQ message. This parameter holds a valid value only when the primitive is generated by the Discovery Process in the OLT.
RTT: The measured round trip time to/from the ONU is returned in this parameter. RTT is stated in time_quanta units. This parameter holds a valid value only when the primitive is generated by the Discovery Process in the OLT.
laserOnTime: This parameter holds the contents of the laserOnTime field in the REGISTER_REQ message. This parameter holds a valid value only when the primitive is generated by the Discovery Process in the OLT.

laserOffTime: This parameter holds the contents of the laserOffTime field in the REGISTER_REQ message. This parameter holds a valid value only when the primitive is generated by the Discovery Process in the OLT.

discoveryInformation: This parameter holds the contents of the Discovery Information field in the REGISTER_REQ MPCPDU. This parameter holds a valid value only when the primitive is generated by the Discovery process in the OLT.

MA_CONTROL.request(DA, REGISTER, LLID, status, pending_grants, laserOnTime, laserOffTime)

The service primitive is used by the MAC Control client at the OLT to initiate acceptance of an ONU. This primitive takes the following parameters:

DA: Unicast MAC address or multicast MAC Control address as defined in Annex 31B.

REGISTER: Opcode for REGISTER MPCPDU as defined in Table 31A–1.

LLID: This parameter holds the logical link identification number assigned by the MAC Control client.

status: This parameter takes on the indication supplied by the flags field in the REGISTER MPCPDU as defined in Table 77–7.

pending_grants: This parameters echoes back the pending_grants field that was previously received in the REGISTER_REQ message.

laserOnTime: This parameter carries the target value of Laser On Time for the given ONU transmitter. This value may be different than the laserOnTime value carried in the REGISTER_REQ MPCPDU received from the corresponding ONU MAC during Discovery stage.

laserOffTime: This parameter carries the target value of Laser Off Time for the given ONU transmitter. This value may be different than the laserOffTime value carried in the REGISTER_REQ MPCPDU received from the corresponding ONU MAC during Discovery stage.

MA_CONTROL.indication(REGISTER, SA, LLID, status)

This service primitive is issued by the Discovery Process at the OLT or an ONU to notify the MAC Control client and Layer Management of the result of the change in registration status. This primitive takes the following parameters:

REGISTER: Opcode for REGISTER MPCPDU as defined in Table 31A–1.

SA: This parameter represents the MAC address of the OLT.

LLID: This parameter holds the logical link identification number assigned by the MAC Control client.

status: This parameter holds the value of accepted / denied / deregistered / reregistered.

MA_CONTROL.request(DA, REGISTER_ACK, status)

This service primitive is issued by the MAC Control clients at the ONU and the OLT to acknowledge the registration. This primitive takes the following parameters:

DA: Multicast MAC Control address as defined in Annex 31B.

REGISTER_ACK: Opcode for REGISTER_ACK MPCPDU as defined in Table 31A–1.

status: This parameter takes on the indication supplied by the flags field in the REGISTER MPCPDU as defined in Table 77–8.

MA_CONTROL.indication(REGISTER_ACK, SA, LLID, status, RTT)

This service primitive is issued by the Discovery Process at the OLT to notify the client and Layer Management that the registration process has completed. This primitive takes the following parameters:

REGISTER_ACK: Opcode for REGISTER_ACK MPCPDU as defined in Table 31A–1.

SA: This parameter represents the MAC address of the reciprocating device (ONU address at the OLT, and OLT address at the ONU).

LLID: This parameter holds the logical link identification number assigned by the MAC Control client.

status: This parameter holds the value of accepted/denied/reset/deregistered.

RTT: The measured round trip time to/from the ONU is returned in this parameter. RTT is stated in time_quanta units. This parameter holds a valid value only when the invoking Discovery Process in the OLT.

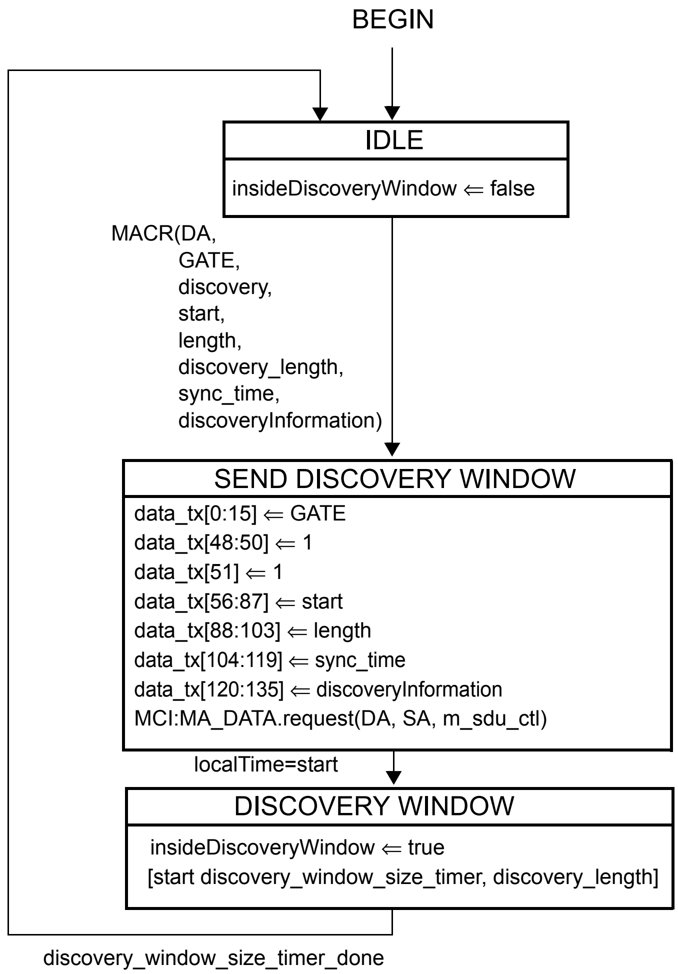
Opcode-specific function(opcode)

Functions exported from opcode specific blocks that are invoked on the arrival of a MAC Control message of the appropriate opcode.

77.3.3.6 State Diagrams

The Discovery Process in the OLT shall implement the discovery window setup state diagram shown in Figure 77–19, request processing state diagram as shown in Figure 77–20, register processing state diagram as shown in Figure 77–21, and final registration state diagram as shown in Figure 77–22. The discovery process in the ONU shall implement the registration state diagram as shown in Figure 77–23.

Instantiation of state diagrams as described in Figure 77–19, Figure 77–20, and Figure 77–21 is performed only at the Multipoint MAC Control instances attached to the broadcast LLID (0x7FFE). Instantiation of state diagrams as described in Figure 77–22 and Figure 77–23 is performed for every Multipoint MAC Control instance, except the instance attached to the broadcast channel.



Instances of MAC data service interface:
MCI=interface to MAC Control multiplexer

Figure 77–19—Discovery Processing OLT Window Setup state diagram

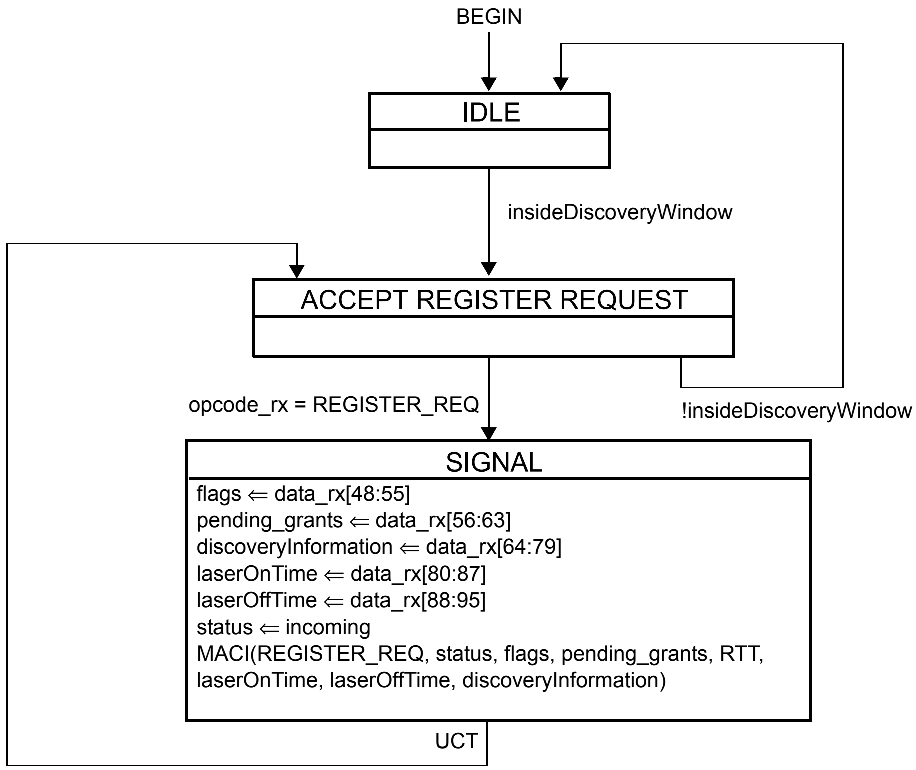
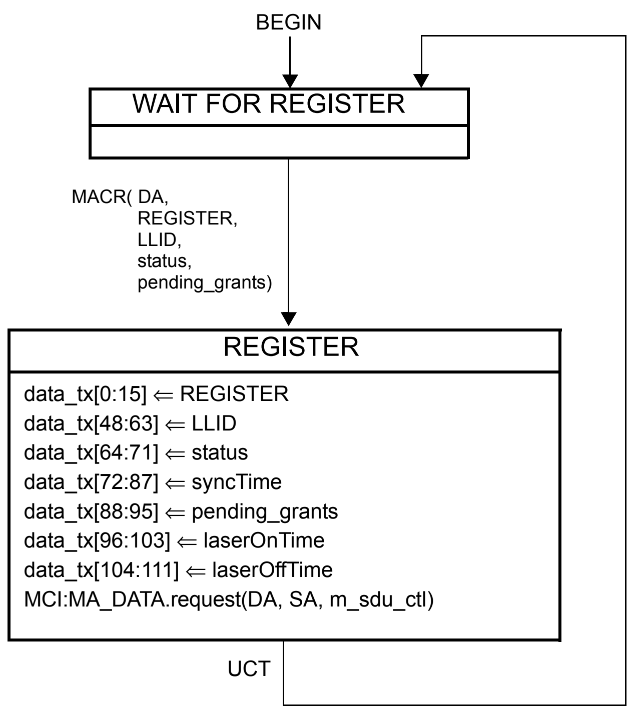
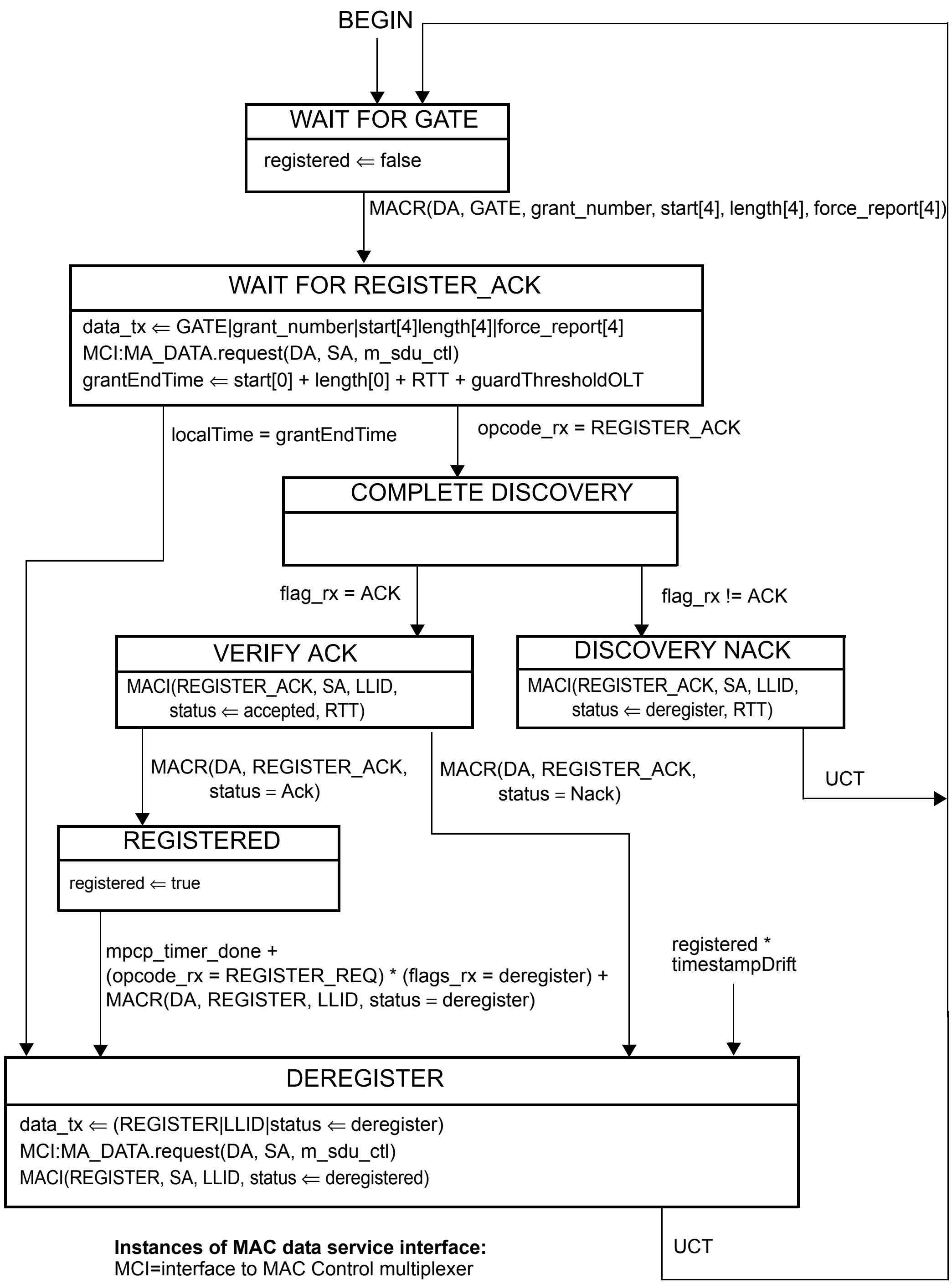


Figure 77–20—Discovery Processing OLT Process Requests state diagram



Instances of MAC data service interface:
MCI=interface to MAC Control multiplexer

Figure 77–21—Discovery Processing OLT Register state diagram



NOTE—The MAC Control Client issues the grant following the REGISTER message, taking the ONU processing delay of REGISTER message into consideration.

Figure 77–22—Discovery Processing OLT Final Registration state diagram

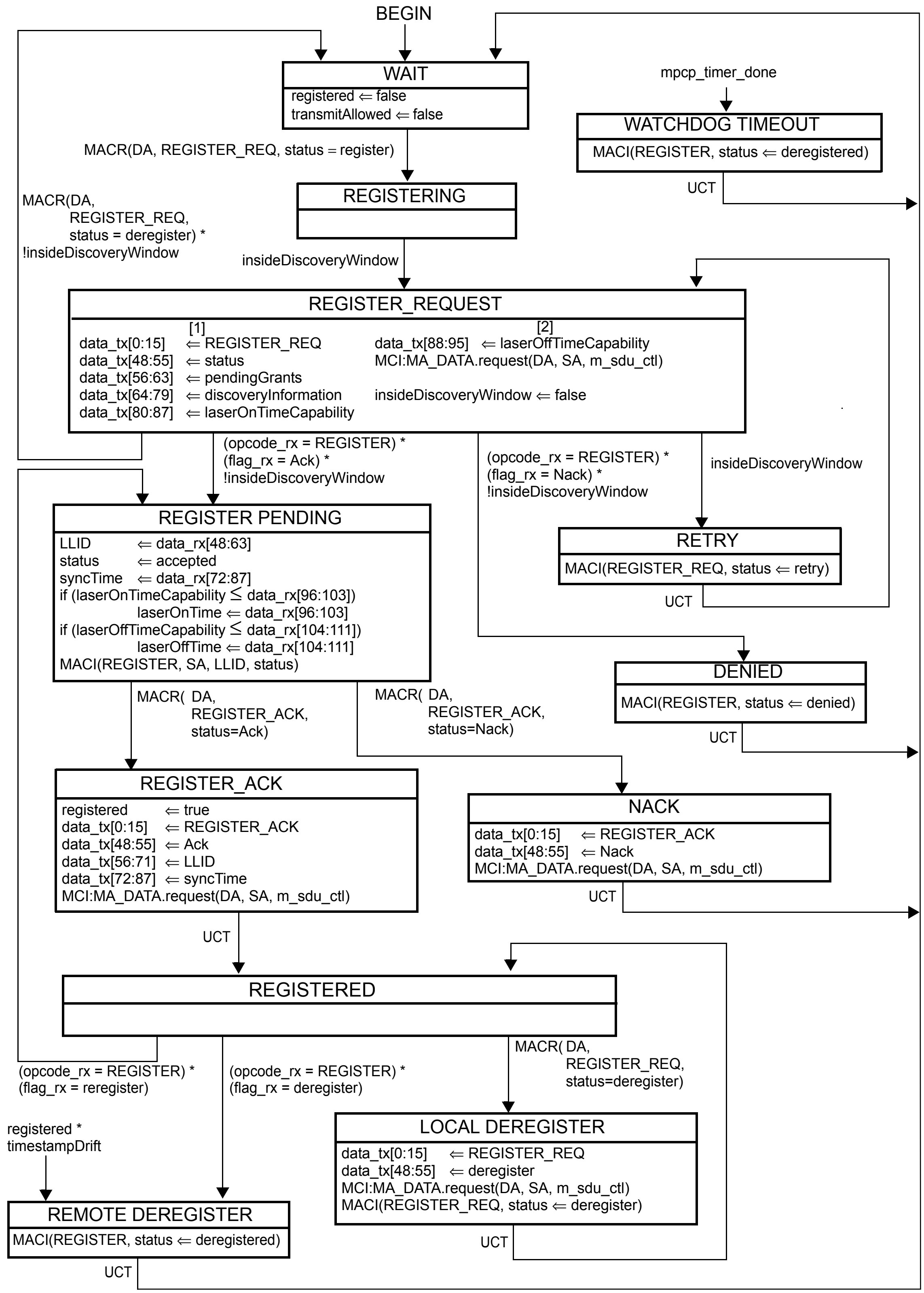


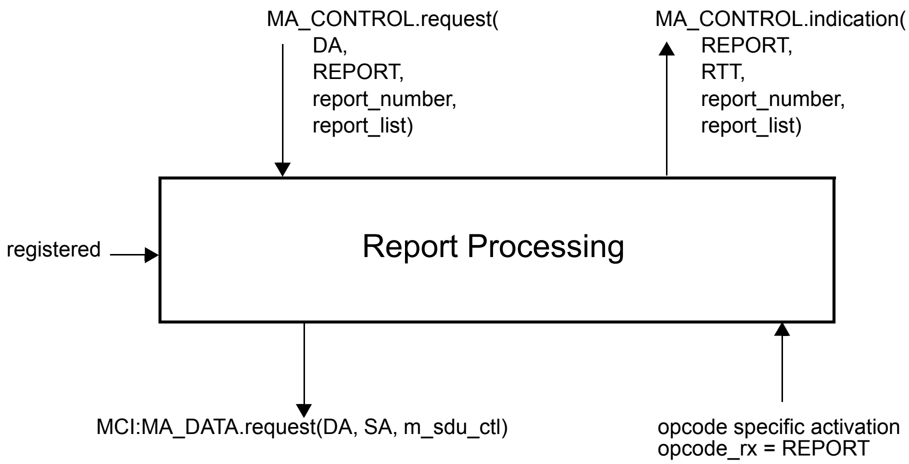
Figure 77–23—Discovery Processing ONU Registration state diagram

77.3.4 Report Processing

The Report Processing functional block has the responsibility of dealing with queue report generation and termination in the network. Reports are generated by higher layers and passed to the MAC Control sublayer by the MAC Control clients. Status reports are used to signal bandwidth needs as well as for arming the OLT watchdog timer.

Reports shall be generated periodically, even when no request for bandwidth is being made. This keeps a watchdog timer in the OLT from expiring and deregistering the ONU. For proper operation of this mechanism the OLT shall grant the ONU periodically.

The Report Processing functional block, and its MPCP protocol elements are designed for use in conjunction with an IEEE 802.1P capable bridge.



Instances of MAC data service interface:
MCI=interface to MAC Control multiplexer

Figure 77–24—Report Processing service interfaces

77.3.4.1 Constants

mpcp_timeout
TYPE: 32 bit unsigned
This constant represents the maximum allowed interval of time between two MPCPDU messages. Failure to receive at least one frame within this interval is considered a fatal fault and leads to deregistration.
VALUE: 0x03B9ACA0 (1 s)

report_timeout
TYPE: 32 bit unsigned
This constant represents the maximum allowed interval of time between two REPORT messages generated by the ONU.
VALUE: 0x002FAF08 (50 ms)

77.3.4.2 Variables

BEGIN
TYPE: Boolean

This variable is used when initiating operation of the functional block state diagram. It is set to true following initialization and every reset.

data_rx
This variable is defined in 77.2.2.3.

data_tx
This variable is defined in 77.2.2.3.

m_sdu_ctl
This variable is defined in 77.2.2.3.

opcode_rx
This variable is defined in 77.2.2.3.

registered
This variable is defined in 77.3.3.2.

77.3.4.3 Functions

None.

77.3.4.4 Timers

report_periodic_timer
ONUs are required to generate REPORT MPCPDUs with a periodicity of less than report_timeout value. This timer counts down time remaining before a forced generation of a REPORT message in an ONU.

mpcp_timer
This timer is defined in 77.3.3.4.

77.3.4.5 Messages

MA_DATA.request (DA, SA, m_sdu)
The service primitive is defined in 2.3.2.

MA_CONTROL.request(DA, REPORT, report_number, report_list)
This service primitive is used by a MAC Control client to request the Report Process at the ONU to transmit a queue status report. This primitive may be called at variable intervals, independently of the granting process, in order to reflect the time varying aspect of the network. This primitive uses the following parameters:

DA:	Multicast MAC Control address as defined in Annex 31B.
REPORT:	Opcode for REPORT MPCPDU as defined in Table 31A–1.
report_number:	The number of queue status report sets located in report list. The report_number value ranges from 0 to a maximum of 13.
report_list:	The list of queue status reports. A queue status report consists of two fields: valid and status. The parameter valid is a Boolean array of length of 8. The index of an element of this array reflects the numbered priority queue in the IEEE 802.1P nomenclature. An element with the value of '0' or false indicates that the corresponding status field is not present (the length of status field is 0),while '1' or true indicates that the

corresponding status field is present (the length of status field is 2 octets). The parameter status is an array of 16 bit unsigned integer values. This array consists only of entries whose corresponding bit in field valid is set to true.

MA_CONTROL.indication(REPORT, RTT, report_number, report_list)

The service primitive is issued by the Report Process at the OLT to notify the MAC Control client and higher layers the queue status of the MPCP link partner. This primitive may be called multiple times, in order to reflect the time–varying aspect of the network. This primitive uses the following parameters:

REPORT:	Opcode for REPORT MPCPDU as defined in Table 31A–1.
RTT:	This parameter holds an updated round trip time value that is recalculated following each REPORT message reception.
report_number:	The number of queue status report sets located in report list. The report_number value ranges from 0 to a maximum of 13.
report_list:	The list of queue status reports. A queue status report consists of two fields: valid and status. The parameter valid is a Boolean array of length of 8. The index of an element of this array reflects the numbered priority queue in the IEEE 802.1P nomenclature. An element with the value of '0' or false indicates that the corresponding status field is not present (the length of status field is 0),while '1' or true indicates that the corresponding status field is present (the length of status field is 2 octets). The parameter status is an array of 16 bit unsigned integer values. This array consists only of entries whose corresponding bit in field valid is set to true.

Opcode-specific function(opcode)

Functions exported from opcode specific blocks that are invoked on the arrival of a MAC Control message of the appropriate opcode.

77.3.4.6 State diagrams

The report process in the OLT shall implement the report processing state diagram as shown in Figure 77–25. The report process in the ONU shall implement the report processing state diagram as shown in Figure 77–26. Instantiation of state diagrams as described is performed for Multipoint MAC Control instances attached to unicast LLIDs only.

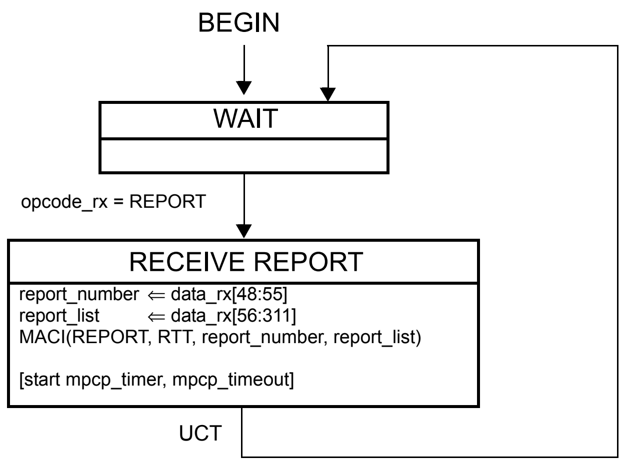
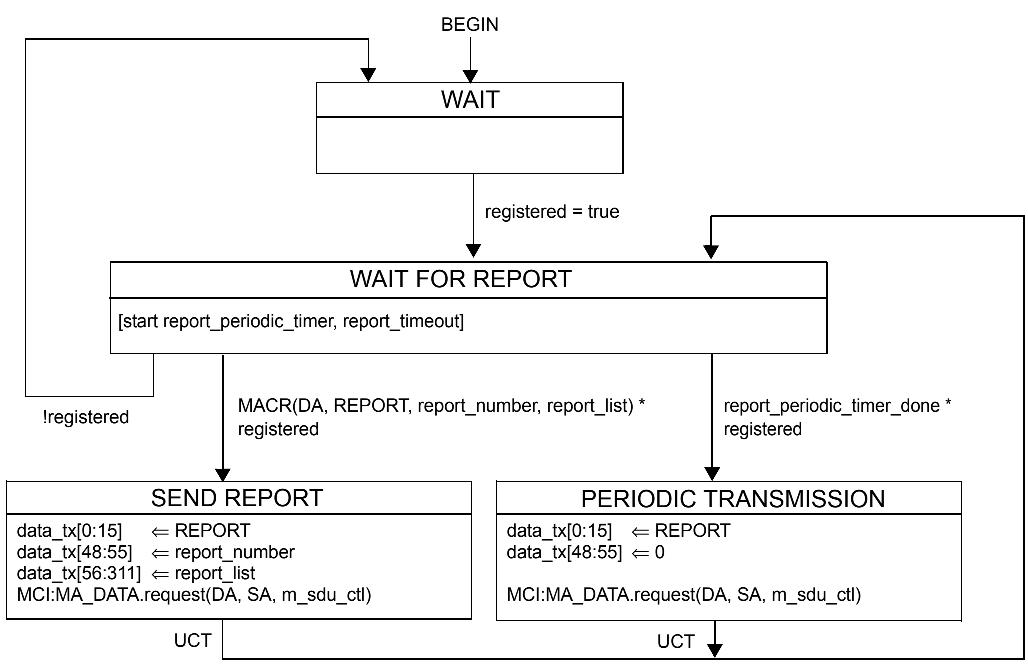


Figure 77–25—Report Processing state diagram at OLT



Instances of MAC data service interface:
MCI=interface to MAC Control multiplexer

Figure 77–26—Report Processing state diagram at ONU

77.3.5 Gate Processing

A key concept pervasive in Multipoint MAC Control is the ability to arbitrate a single transmitter out of a plurality of ONUs. The OLT controls an ONU’s transmission by the assigning of grants.

The transmitting window of an ONU is indicated in the GATE message where start time and length are specified. An ONU begins transmission when its localTime counter matches the start_time value indicated in the GATE message. An ONU concludes its transmission with sufficient margin to ensure that the laser is turned off before the grant length interval has elapsed.

Multiple outstanding grants may be issued to each ONU. The OLT shall not issue more than the maximum supported maximum outstanding grants as advertised by the ONU during registration (see pending grants in 77.3.6.3).

In order to maintain the watchdog timer at the ONU, grants are periodically generated. For this purpose empty GATE messages may be issued periodically.

When registered, the ONU ignores all gate messages where the Discovery flag is set.

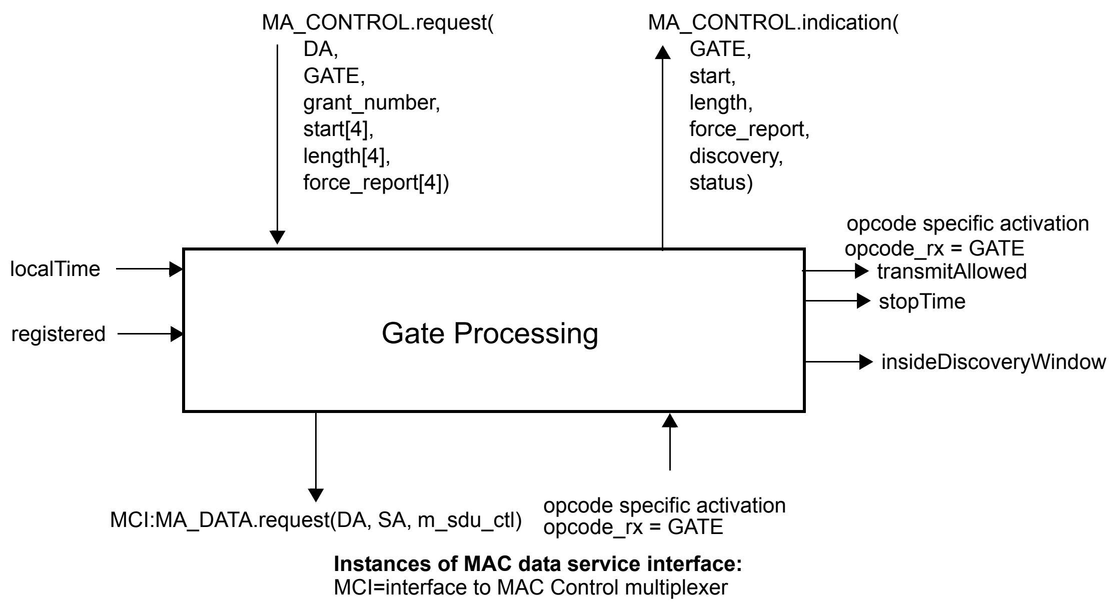


Figure 77–27—Gate Processing service interface

77.3.5.1 Constants

gate_timeout
    TYPE: 32 bit unsigned
    This constant represents the maximum allowed interval of time between two GATE messages generated by the OLT to the same ONU.
    VALUE: 0x002FAF08 (50 ms)

max_future_grant_time
    TYPE: 32 bit unsigned
    This constant holds the time limiting the future time horizon for a valid incoming grant.
    VALUE: 0x03B9ACA0 (1 s)

min_processing_time
    TYPE: 32 bit unsigned

This constant is the time required for the ONU processing time.
VALUE: 0x00000400 (16.384 μs)

minGrantLength
TYPE: 32 bit unsigned
This constant represents the minimum data portion of a grant. The minGrantLength is equal to one FEC codeword (see FEC_CODEWORD_SIZE in 77.2.2.1), less the initial 16 idle octets, expressed in units of time_quanta. The minimum grant length accepted by an ONU is equal to minGrantLength + BurstOverhead (see 77.3.5.2).
VALUE: 12

tqSize
This constant is defined in 77.2.2.1.

77.3.5.2 Variables

BEGIN
TYPE: Boolean
This variable is used when initiating operation of the functional block state diagram. It is set to true following initialization and every reset.

BurstOverhead
TYPE: integer
This variable represents the burst overhead and equals the sum of laserOnTime, laserOffTime, syncTime and an additional two time_quanta to account for END_BURST_DELIMITER and two leading IDLE vectors of the payload. This variable is expressed in units of time_quanta.

counter
TYPE: integer
This variable is used as a loop iterator counting the number of incoming grants in a GATE message.

currentGrant
TYPE:
structure
{
DA: 48 bit unsigned, a.k.a MAC address type
start 32 bit unsigned
length 16 bit unsigned
force_report Boolean
discovery Boolean
}
This variable is used for local storage of a pending grant state during processing. It is dynamically set by the Gate Processing functional block and is not exposed.
The state is a structure field composed of multiple subfields.

data_rx
This variable is defined in 77.2.2.3.

data_tx
This variable is defined in 77.2.2.3.

effectiveLength
TYPE: 32 bit unsigned
This variable is used for temporary storage of a normalized net time value. It holds the net effective

length of a grant normalized for elapsed time, and compensated for the periods required to turn the laser on and off, and waiting for receiver lock.

grantList
TYPE: list of elements having the structure define in currentGrant
This variable is used for storage of the list of pending grants. It is dynamically set by the Gate Processing functional block and is not exposed. Each time a grant is received it is added to the list. The list elements are structure fields composed of multiple subfields. The list is indexed by the start subfield in each element for quick searches.

grantStart
This variable is defined in 77.2.2.3.

insideDiscoveryWindow
This variable is defined in 77.3.3.2.

maxDelay
TYPE: 16 bit unsigned
This variable holds the maximum delay that can be applied by an ONU before sending the REGISTER_REQ MPCPDU. This delay is calculated such that the ONU would have sufficient time to transmit the REGISTER_REQ message and its associated overhead (FEC parity data, end-of-frame sequence, etc.) and terminate the laser before the end of the discovery grant.

m_sdu_ctl
This variable is defined in 77.2.2.3.

nextGrant
TYPE: element having same structure as defined in currentGrant
This variable is used for local storage of a pending grant state during processing. It is dynamically set by the Gate Processing functional block and is not exposed. The content of the variable is the next grant to become active.

nextStopTime
TYPE: 32 bit unsigned
This variable holds the value of the localTime counter corresponding to the end of the next grant.

opcode_rx
This variable is defined in 77.2.2.3.

registered
This variable is defined in 77.3.3.2.

stopTime
This variable is defined in 77.2.2.3.

syncTime
This variable is defined in 77.3.3.2.

transmitAllowed
This variable is defined in 77.2.2.3.

77.3.5.3 Functions

empty(list)
This function is use to check whether the list is empty. When there are no elements queued in the list, the function returns true. Otherwise, a value of false is returned.

confirmDiscovery(data)
This function is used to check whether the current Discovery Window is open for the given ONU (TRUE) or not (FALSE). This function returns values as shown in Table 77–1.

Table 77–1—Operation of the confirmDiscovery(data) function

OLT Discovery Information: Discovery Window		ONU Tx capability		confirmDiscovery(data) returns
1G	10G	1G	10G	
X	1	0	1	TRUE
1	X	1	0	TRUE
0	1	1	0	FALSE
1	0	0	1	FALSE
0	0	X	X	FALSE[a]

[a]These particular values for the Discovery Window fields should not be normally generated by the OLT.

InsertInOrder(sorted_list, inserted_element)
This function is used to queue an element inside a sorted list. The queuing order is sorted. In the condition that the list is full the element may be discarded. The length of the list is dynamic and it's maximum size equals the value advertised during registration as maximum number of pending grants.

IsBroadcast(grant)
This function is used to check whether its argument represents a broadcast grant, i.e., grant given to multiple ONUs. This is determined by the destination MAC address of the corresponding GATE message. The function returns the value true when MAC address is a global assigned MAC Control address as defined in Annex 31B, and false otherwise.

PeekHead(sorted_list)
This function is used to check the content of a sorted list. It returns the element at the head of the list without dequeuing the element.

Random(r)
This function is used to compute a random integer number uniformly distributed between 0 and r. The randomly generated number is then returned by the function.

RemoveHead(sorted_list)
This function is used to dequeue an element from the head of a sorted list. The return value of the function is the dequeued element.

77.3.5.4 Timers

gntWinTmr

This timer is used to wait for the event signaling the end of a grant window.
VALUE: The timer value is dynamically set according to the signaled grant length.

gate_periodic_timer

The OLT is required to generate GATE MPCPDUs with a periodicity of less than gate_timeout value. This timer counts down time remaining before a forced generation of a GATE message in the OLT.

mpcp_timer

This timer is defined in 77.3.3.4.

rndDlyTmr

This timer is used to measure a random delay inside the discovery window. The purpose of the delay is to a priori reduce the probability of transmission overlap during the registration process, and thus lowering the expectancy of registration time in the PON.
VALUE: A random value less than the net discovery window size less the REGISTER_REQ MPCPDU frame size less the idle period and laser turn on and off delays less the preamble size less the IFG size. The timer value is set dynamically based on the parameters passed from the client.

77.3.5.5 Messages

MA_DATA.request (DA, SA, m_sdu)

The service primitive is defined in 2.3.2.

MA_CONTROL.request(DA, GATE, grant_number, start[4], length[4], force_report[4])

This service primitive is defined in 77.3.3.5.

MA_CONTROL.indication(GATE, start, length, force_report, discovery, status)

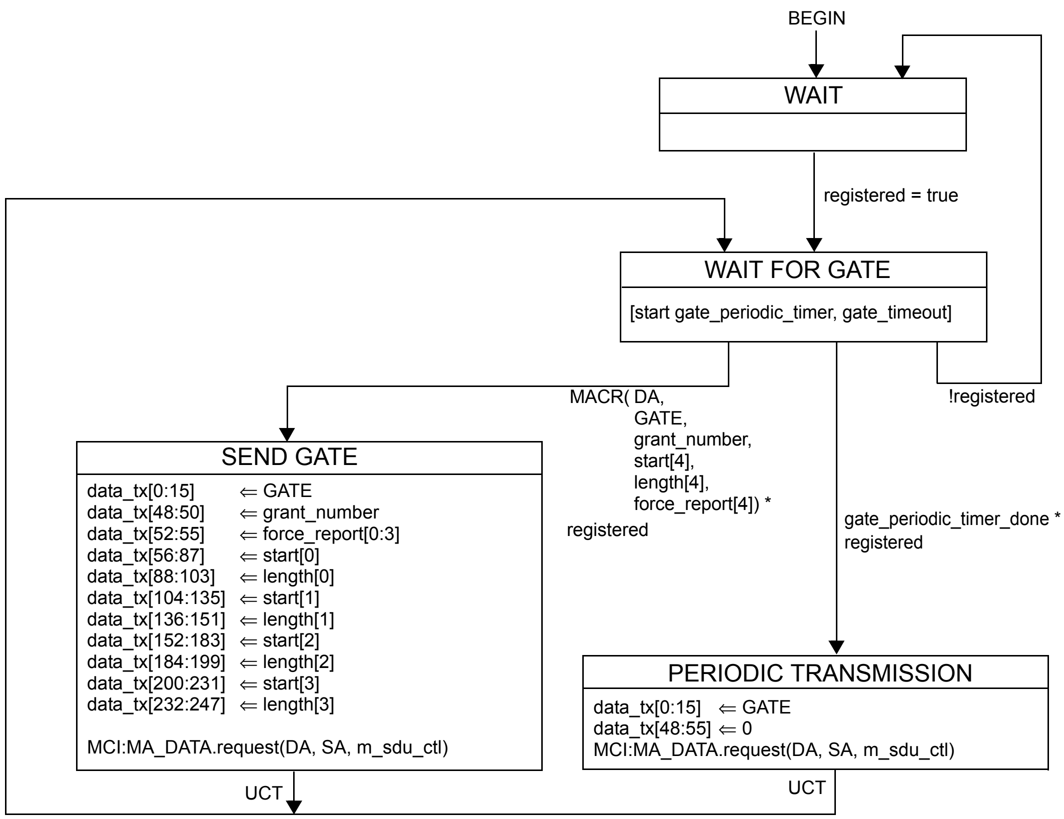
This service primitive issued by the Gate Process at the ONU to notify the MAC Control client and higher layers that a grant is pending. This primitive is invoked multiple times when a single GATE message arrives with multiple grants. It is also generated at the start and end of each grant as it becomes active. This primitive uses the following parameters:

GATE:	Opcode for GATE MPCPDU as defined in Table 31A–1.
start:	start time of the grant. This parameter is not present when the parameter *status* value is equal to *deactive*.
length:	Length of the grant. This parameter is not present when the parameter *status* value is equal to *deactive*.
force_report:	Flags indicating whether a REPORT message should be transmitted in this grant. This parameter is not present when the parameter *status* value is equal to *deactive*.
discovery:	This parameter holds the value true when the grant is to be used for the discovery process, and false otherwise. This parameter is not present when the parameter *status* value is equal to *deactive*.
status:	This parameter takes the value *arrive* on grant reception, *active* when a grant becomes active, and *deactive* at the end of a grant.

Opcode-specific function(opcode)
Functions exported from opcode specific blocks that are invoked on the arrival of a MAC Control message of the appropriate opcode.

77.3.5.6 State diagrams

The gating process in the OLT shall implement the Gate processing state diagram as shown in Figure 77–28. The gating process in the ONU shall implement the Gate processing state diagram as shown in Figure 77–29 and Figure 77–30. Instantiation of state diagrams as described is performed for all Multipoint MAC Control instances.



Instances of MAC data service interface:
MCI=interface to MAC Control multiplexer

Figure 77–28—Gate Processing state diagram at OLT

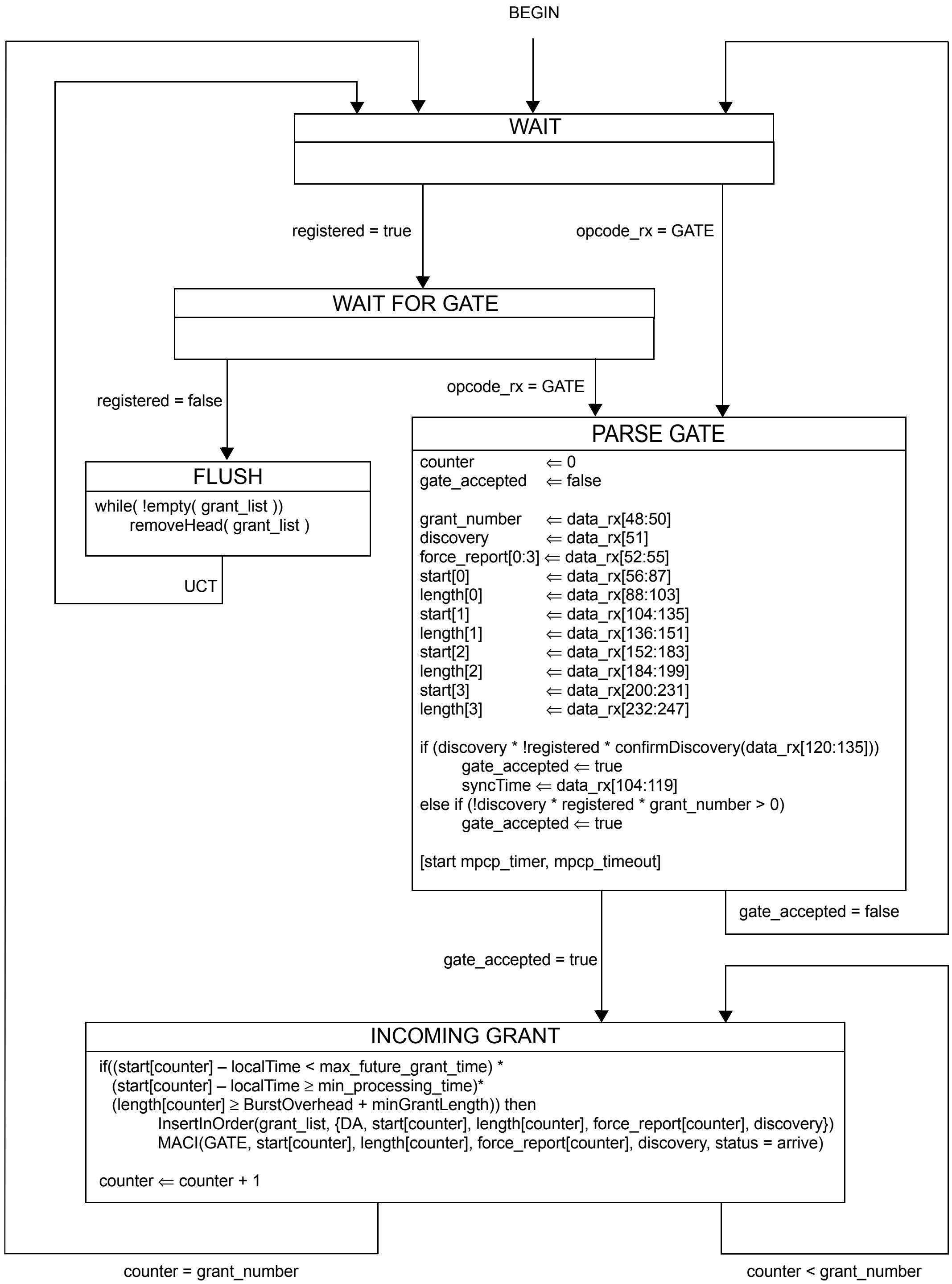


Figure 77–29—Gate Processing ONU Programing state diagram

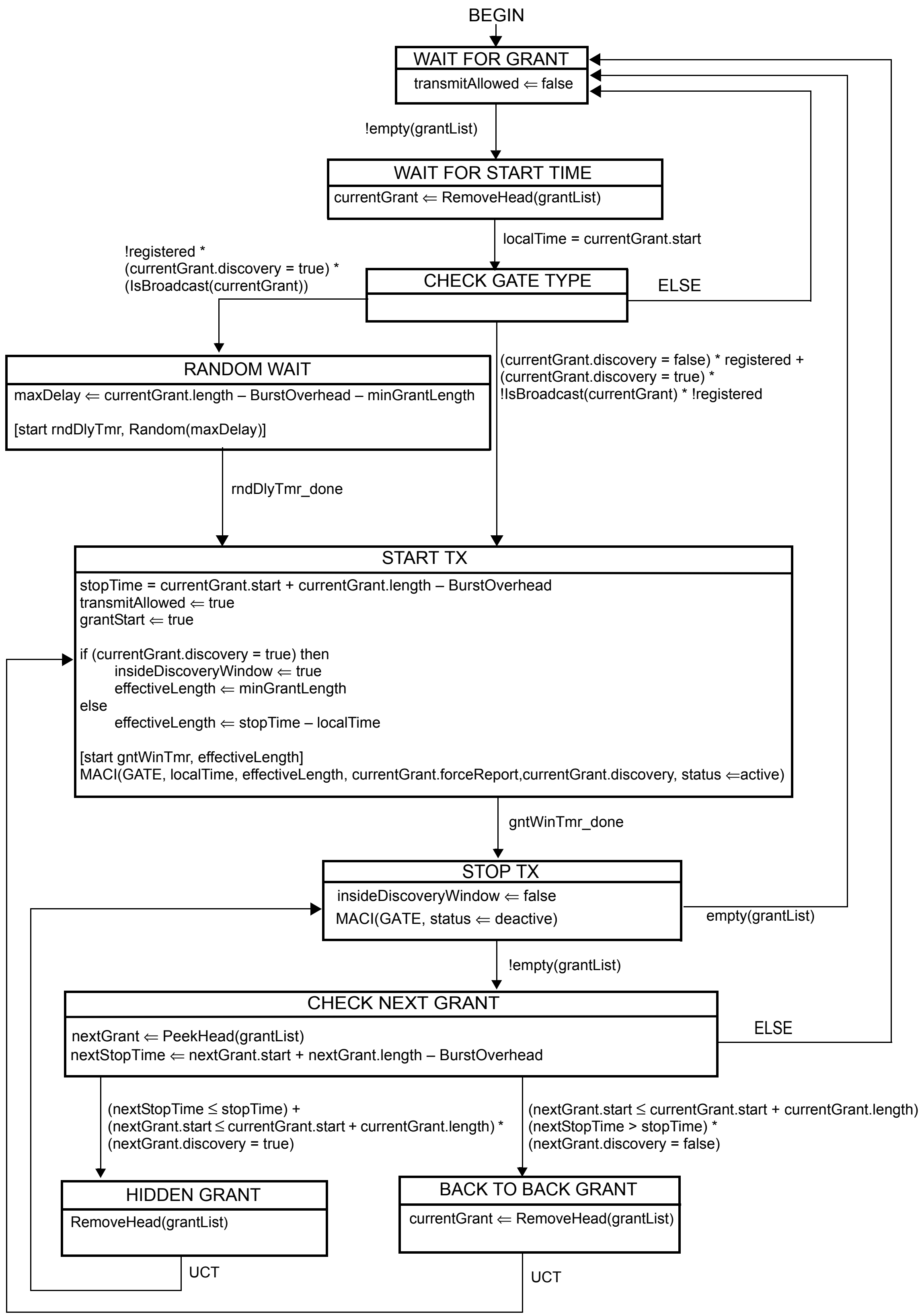


Figure 77–30—Gate Processing ONU Activation state diagram

77.3.6 MPCPDU structure and encoding

The MPCPDU structure shall be as shown in Figure 77–31, and is further defined in the following definitions:

a) Destination Address (DA). The DA in MPCPDU is the MAC Control Multicast address as specified in the annexes to Clause 31, or the individual MAC address associated with the port to which the MPCPDU is destined.

b) Source Address (SA). The SA in MPCPDU is the individual MAC address associated with the port through which the MPCPDU is transmitted. For MPCPDUs originating at the OLT end, this can be the address any of the individual MACs. These MACs may all share a single unicast address, as explained in 77.1.2.

c) Length/Type. MPCPDUs are always Type encoded, and carry the MAC_Control_Type field value as specified in 31.4.1.3.

d) Opcode. The opcode identifies the specific MPCPDU being encapsulated. Values are defined in Table 31A–1.

e) Timestamp. The timestamp field conveys the content of the localTime register at the time of transmission of the MPCPDUs. This field is 32 bits long and counts time in units of time_quanta.

f) Data/Reserved/PAD. These 40 octets are used for the payload of the MPCPDUs. When not used they would be filled with zeros on transmission, and be ignored on reception.

g) FCS. This field is the Frame Check Sequence, typically generated by the underlying MAC.
Based on the MAC instance used to generate the specific MPCPDU, the appropriate LLID shall be generated by the RS.

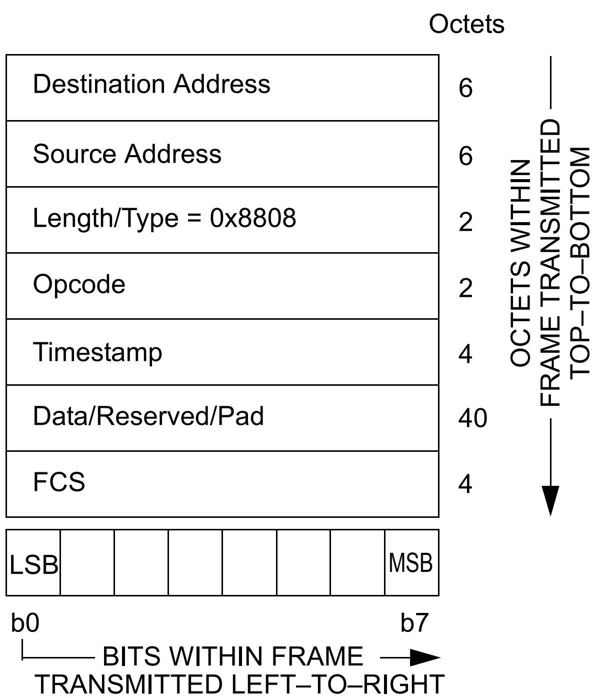


Figure 77–31—Generic MPCPDU

77.3.6.1 GATE description

The purpose of GATE message is to grant transmission windows to ONUs for both discovery messages and normal transmission. Up to four grants can be included in a single GATE message. The number of grants can also be set to zero for using the GATE message as an MPCP keep alive from OLT to the ONU.

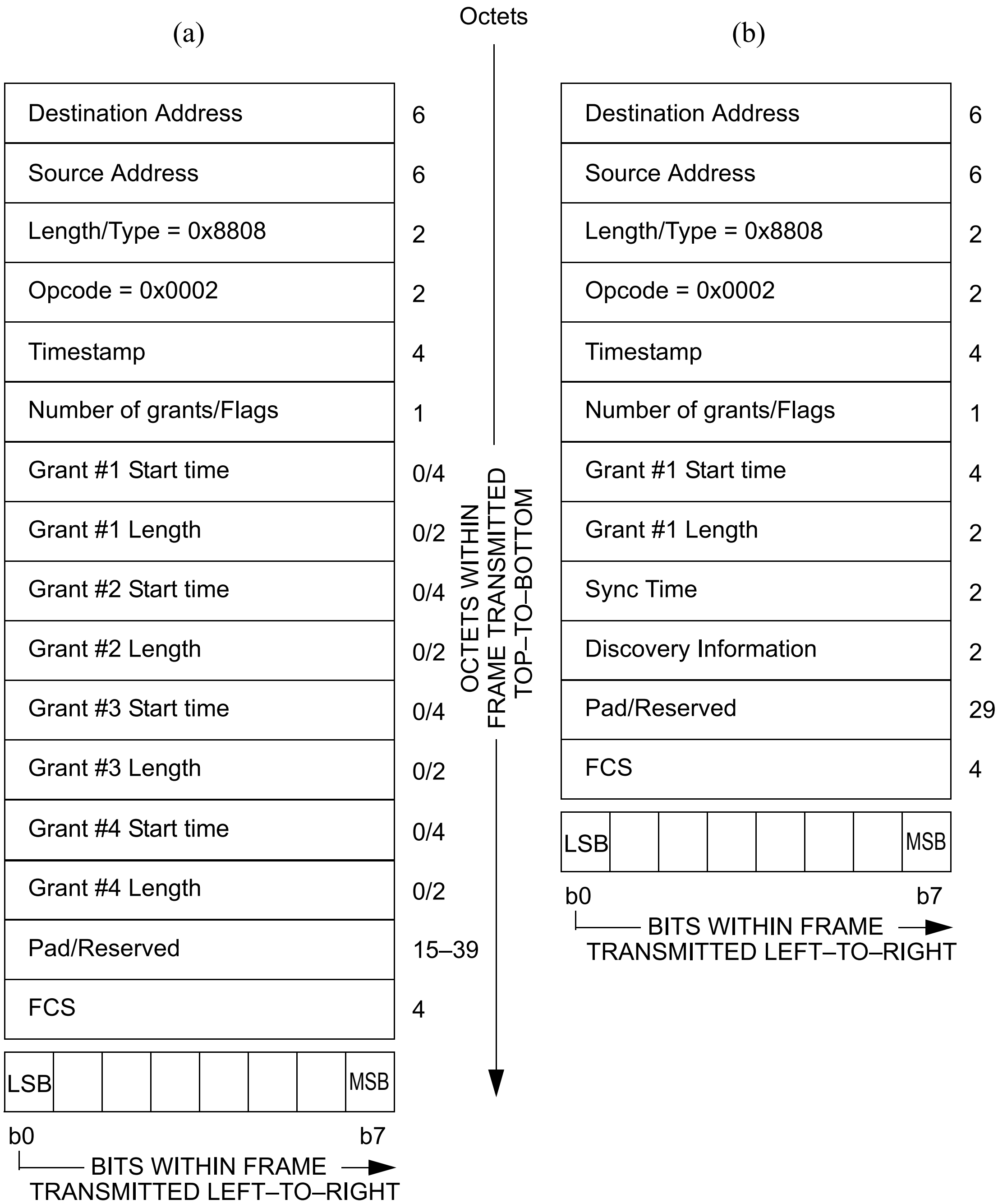


Figure 77–32—GATE MPCPDU: (a) normal GATE MPCPDU, (b) discovery GATE MPCPDU

The GATE MPCPDU is an instantiation of the Generic MPCPDU, and is further defined using the following definitions:

a) Opcode. The opcode for the GATE MPCPDU is 0x0002.
b) Flags. This is an 8 bit flag register that holds the following flags: As presented in Table 77–2, the Number of grants field contains the number of grants, composed of valid Length, Start Time pairs in this MPCPDU. This is a number between 0 and 4.

   NOTE—When Number of grants is set to 0, sole purpose of message is conveying of timestamp to ONU.

   The Discovery flag field indicates that the signaled grants would be used for the discovery process, in which case a single grant shall be issued in the GATE message.
   The Force Report flag fields ask the ONU to issue a REPORT message related to the corresponding grant number at the corresponding transmission opportunity indicated in this GATE.

Table 77–2—GATE MPCPDU Number of grants/flags fields

Bit	Flag field	Values
0–2	Number of grants	0 – 4
3	Discovery	0 – Normal GATE 1 – Discovery GATE
4	Force Report Grant 1	0 – No action required 1 – A REPORT frame should be issued at the corresponding transmission opportunity indicated in Grant 1
5	Force Report Grant 2	0 – No action required 1 – A REPORT frame should be issued at the corresponding transmission opportunity indicated in Grant 2
6	Force Report Grant3	0 – No action required 1 – A REPORT frame should be issued at the corresponding transmission opportunity indicated in Grant 3
7	Force Report Grant 4	0 – No action required 1 – A REPORT frame should be issued at the corresponding transmission opportunity indicated in Grant 4

c) Grant #n Start Time. This 32 bit unsigned field represents the start time of the grant. The start time is compared to the local clock, to correlate the start of the grant. Transmitted values shall satisfy the condition Grant #n Start Time < Grant #n+1 Start Time for consecutive grants within the same GATE MPCPDU.
d) Grant #n Length. This 16 bit unsigned field represents the length of the grant. The length is counted in 1 time_quantum increments. There are 4 Grants that are possibly packed into the GATE MPCPDU. The laserOnTime, syncTime, laserOffTime, two initial Idle blocks, FEC parity overhead, and burst terminator sequence (composed of three END_BURST_DELIMITER blocks) are included in and thus consume part of the Grant #n length.
e) Sync Time. This is an unsigned 16 bit value signifying the required synchronization time of the OLT receiver. The ONU calculates the effective grant length by subtracting the syncTime, laserOnTime, laserOffTime and END_BURST_DELIMITER from the grant length it received from the OLT. The value is counted in 1 time_quantum increments. The advertised value includes synchronization requirement on all receiver elements including PMD, PMA and PCS. This field is present only when the GATE is a discovery GATE, as signaled by the Discovery flag and is not present otherwise.
f) Discovery Information. This is a 16 bit flag register. This field is present only when the GATE is a discovery GATE, as signaled by the Discovery flag and is not present otherwise. Table 77–3 presents the internal structure of the Discovery Information flag field.
g) Pad/Reserved. This is an empty field that is transmitted as zeros, and ignored on reception. The size of this field depends on the used Grant #n Length/Start Time entry-pairs as well as the presence of the Sync Time and Discovery Information fields, and varies in length from 15–39 accordingly.

The GATE MPCPDU shall be generated by a MAC Control instance mapped to an active ONU, and as such shall be marked with a unicast type of LLID, except when the MPCPDU is a discovery GATE, as indicated by the Discovery flag being set to true. For the discovery procedure, a MAC Control instance is mapped to all ONUs, and therefore, the discovery GATE MPCPDU is marked with the appropriate broadcast LLID (see 77.3.2.3).

Table 77–3—GATE MPCPDU discovery information fields

Bit	Flag field	Values
0	OLT is 1G upstream capable	0 – OLT does not support 1 Gb/s reception 1 – OLT supports 1 Gb/s reception
1	OLT is 10G upstream capable	0 – OLT does not support 10 Gb/s reception 1 – OLT supports 10 Gb/s reception
2–3	Reserved	Ignored on reception
4	OLT is opening 1G discovery window	0 – OLT cannot receive 1 Gb/s data in this window 1 – OLT can receive 1 Gb/s data in this window
5	OLT is opening 10G discovery window	0 – OLT cannot receive 10 Gb/s data in this window 1 – OLT can receive 10 Gb/s data in this window
6–15	Reserved	Ignored on reception

77.3.6.2 REPORT description

REPORT messages have several functionalities. Time stamp in each REPORT message is used for round trip (RTT) calculation. In the REPORT messages ONUs indicate the upstream bandwidth needs they request per IEEE 802.1Q priority queue. REPORT messages are also used as keep–alives from ONU to OLT. ONUs issue REPORT messages periodically in order to maintain link health at the OLT as defined in 77.3.4. In addition, the OLT may specifically request a REPORT message.

The REPORT MPCPDU is an instantiation of the Generic MPCPDU, and is further defined using the following definitions:

a) Opcode. The opcode for the REPORT MPCPDU is 0x0003.
b) Number of Queue Sets. This field specifies the number of requests in the REPORT message. A REPORT frame may hold multiple sets of Report bitmap and Queue #n as specified in the Number of Queue Sets field.
c) Report bitmap. This is an 8 bit flag register that indicates which queues are represented in this REPORT MPCPDU—see Table 77–4.

Table 77–4—REPORT MPCPDU Report bitmap fields

Bit	Flag field	Values
0	Queue 0	0 – queue 0 report is not present; 1 – queue 0 report is present
1	Queue 1	0 – queue 1 report is not present; 1 – queue 1 report is present
2	Queue 2	0 – queue 2 report is not present; 1 – queue 2 report is present
3	Queue 3	0 – queue 3 report is not present; 1 – queue 3 report is present
4	Queue 4	0 – queue 4 report is not present; 1 – queue 4 report is present
5	Queue 5	0 – queue 5 report is not present; 1 – queue 5 report is present

Table 77–4—REPORT MPCPDU Report bitmap fields *(continued)*

Bit	Flag field	Values
6	Queue 6	0 – queue 6 report is not present; 1 – queue 6 report is present
7	Queue 7	0 – queue 7 report is not present; 1 – queue 7 report is present

d) Queue #n Report. This value represents the length of queue #n at time of REPORT message generation. The reported length shall be adjusted and rounded up to the nearest time_quantum to account for the necessary inter–frame spacing and preamble. FEC parity overhead is not included in the reported length. The Queue #n Report field is an unsigned 16 bit integer representing the transmission request in units of time_quanta. This field is present only when the corresponding flag in the Report bitmap is set.

e) Pad/Reserved. This is an empty field that is transmitted as zeros, and ignored on reception. The size of this field depends on the used Queue Report entries, and accordingly varies in length from 0 to 39.

The REPORT MPCPDU shall be generated by a MAC Control instance mapped to an active ONU, and as such shall be marked with a unicast type of LLID.

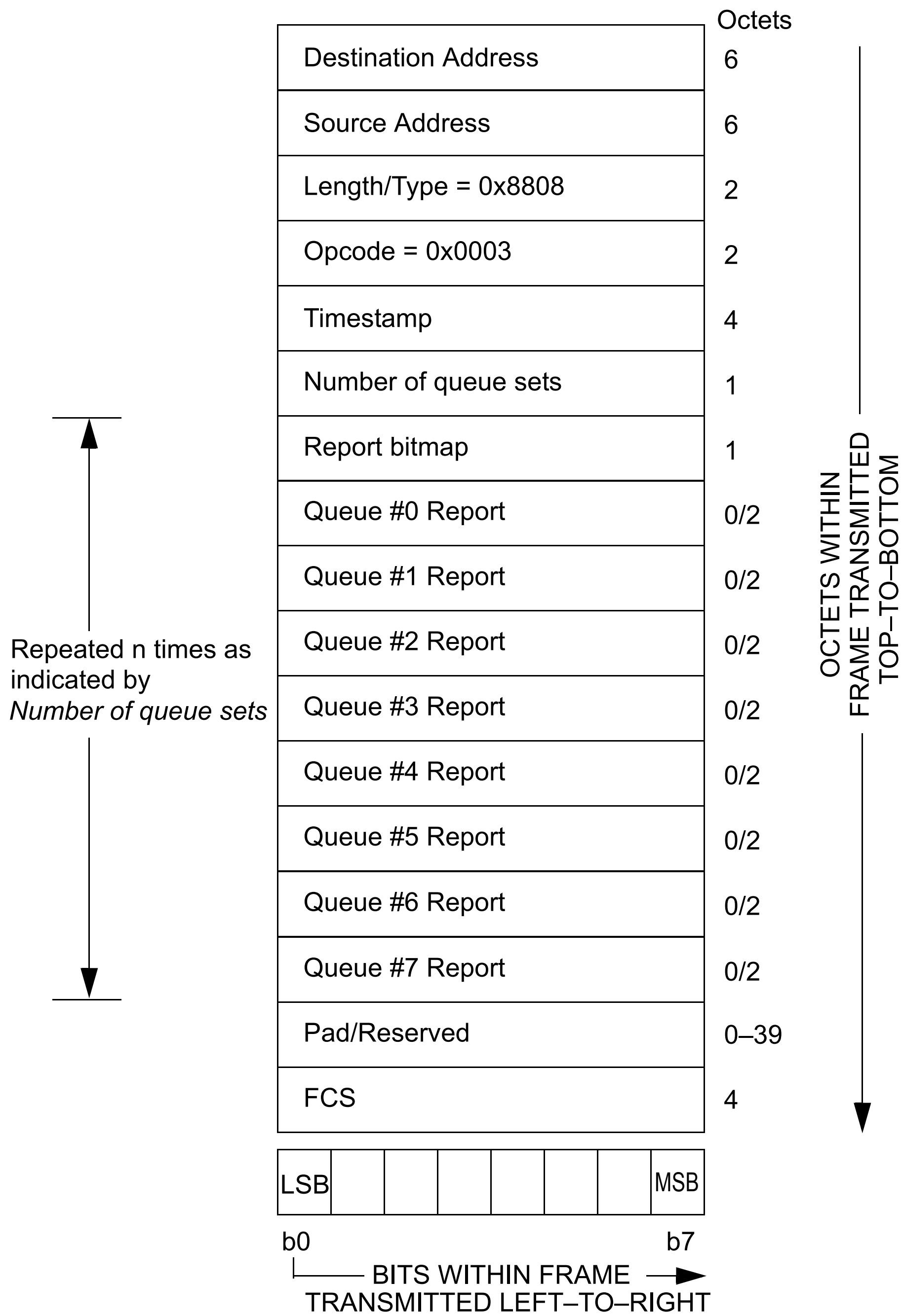


Figure 77–33—REPORT MPCPDU

77.3.6.3 REGISTER_REQ description

The REGISTER_REQ MPCPDU is an instantiation of the Generic MPCPDU, and is further defined using the following definitions:

a) Opcode. The opcode for the REGISTER_REQ MPCPDU is 0x0004.
b) Flags. This is an 8 bit flag register that indicates special requirements for the registration, as presented in Table 77–5.

Table 77–5—REGISTER_REQ MPCPDU Flags fields

Value	Indication	Comment
0	Reserved	Ignored on reception.
1	Register	Registration attempt for ONU.
2	Reserved	Ignored on reception.
3	Deregister	This is a request to deregister the ONU. Subsequently, the MAC is deallocated and the LLID may be reused.
4–255	Reserved	Ignored on reception.

c) Pending grants. This is an unsigned 8 bit value signifying the maximum number of future grants the ONU is configured to buffer. The OLT should not grant the ONU more than this maximum number of Pending grants vectors comprised of {start, length, force_report, discovery} into the future.
d) Discovery Information. This is a 16 bit flag register. Table 77–6 presents the structure of the Discovery Information flag.

Table 77–6—REGISTER_REQ MPCPDU Discovery Information Fields

Bit	Flag field	Values
0	ONU is 1G upstream capable	0 – ONU transmitter is not capable of 1 Gb/s 1 – ONU transmitter is capable of 1 Gb/s
1	ONU is 10G upstream capable	0 – ONU transmitter is not capable of 10 Gb/s 1 – ONU transmitter is capable of 10 Gb/s
2–3	Reserved	Ignored on reception
4	1G registration attempt	0 – 1 Gb/s registration is not attempted 1 – 1 Gb/s registration is attempted
5	10G registration attempt	0 – 10 Gb/s registration is not attempted 1 – 10 Gb/s registration is attempted
6–15	Reserved	Ignored on reception

e) Laser On Time. This field is 1 octet long and carries the Laser On Time characteristic for the given ONU transmitter. The value is expressed in the units of time_quanta.
f) Laser Off Time. This field is 1 octet long and carries the Laser Off Time characteristic for the given ONU transmitter. The value is expressed in the units of time_quanta.
g) Pad/Reserved. This is an empty field that is transmitted as zeros, and ignored on reception.

The REGISTER_REQ MPCPDU shall be generated by a MAC Control instance mapped to an undiscovered ONU, and as such shall be marked with a broadcast type of LLID (77.3.2.3).

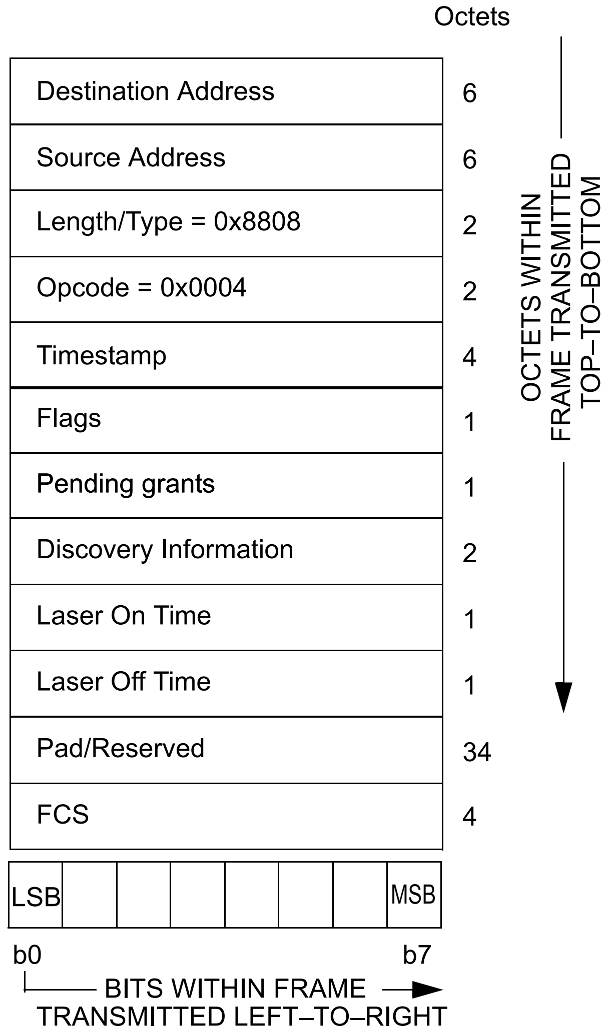


Figure 77–34—REGISTER_REQ MPCPDU

77.3.6.4 REGISTER description

The REGISTER MPCPDU is an instantiation of the Generic MPCPDU, and is further defined using the following definitions:

a) DA. The destination address used shall be an individual MAC address.
b) Opcode. The opcode for the REGISTER MPCPDU is 0x0005.
c) Assigned Port. This field holds a 16 bit unsigned value reflecting the LLID of the port assigned following registration.
d) Flags. this is an 8 bit flag register that indicates special requirements for the registration, as presented in Table 77–7.
e) Sync Time. This is an unsigned 16 bit value signifying the required synchronization time of the OLT receiver. The ONU calculates the effective grant length by subtracting the syncTime, laserOnTime, laserOffTime, and END_BURST_DELIMITER from the grant length it received from the OLT. The value is counted in 1 time_quantum increments. The advertised value includes synchronization requirement on all receiver elements including PMD, PMA, and PCS.

Table 77–7—REGISTER MPCPDU Flags field

Value	Indication	Comment
0	Reserved	Ignored on reception.
1	Reregister	The ONU is explicitly asked to re-register.
2	Deregister	This is a request to deallocate the port and free the LLID. Subsequently, the MAC is deallocated.
3	Ack	The requested registration is successful.
4	Nack	The requested registration attempt is denied by the MAC Control Client.
5–255	Reserved	Ignored on reception.

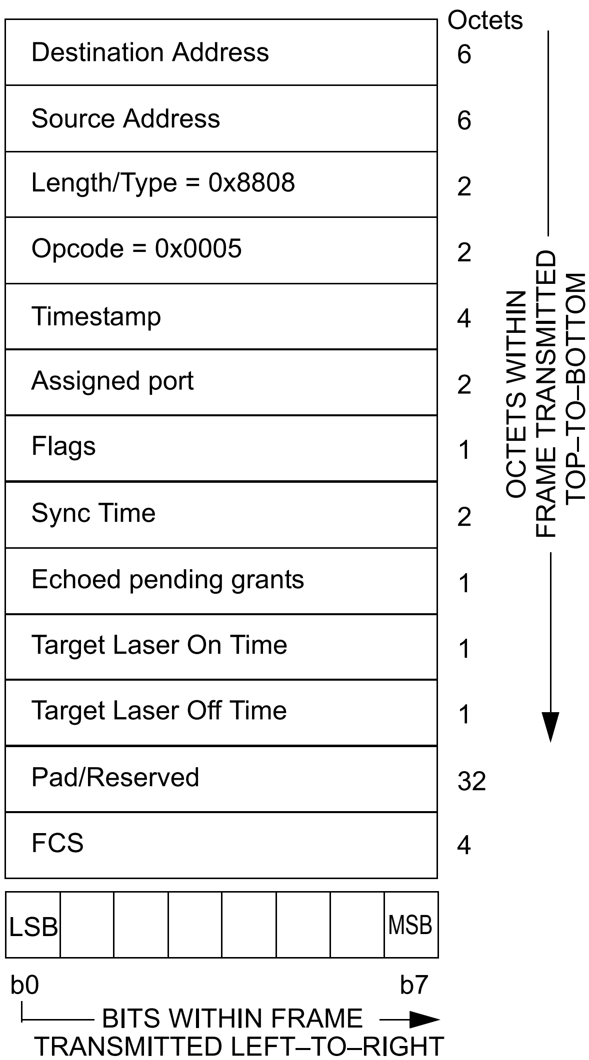


Figure 77–35—REGISTER MPCPDU

f) Echoed pending grants. This is an unsigned 8 bit value signifying the number of future grants the ONU may buffer before activating. The OLT should not grant the ONU more than this number of grants into the future.
g) Target Laser On Time. This is an unsigned 8 bit value, expressed in the units of time_quanta, signifying the Laser On Time for the given ONU transmitter. This value may be different from Laser On Time delivered by the ONU in the REGISTER_REQ MPCPDU during the Discovery process. The ONU updates the local laserOnTime variable per state diagram in Figure 77–23.
h) Target Laser Off Time. This is an unsigned 8 bit value, expressed in the units of time_quanta, signifying the Laser Off Time for the given ONU transmitter. This value may be different from Laser Off Time delivered by the ONU in the REGISTER_REQ MPCPDU during the Discovery process. The ONU updates the local laserOffTime variable per state diagram in Figure 77–23.
i) Pad/Reserved. This is an empty field that is transmitted as zeros, and ignored on reception.

The REGISTER MPCPDU shall be generated by a MAC Control instance mapped to all ONUs and such frame is marked by the broadcast LLID (77.3.2.3).

77.3.6.5 REGISTER_ACK description

The REGISTER_ACK MPCPDU is an instantiation of the Generic MPCPDU, and is further defined using the following definitions:

a) Opcode. The opcode for the REGISTER_ACK MPCPDU is 0x0006.
b) Flags. This is an 8 bit flag register that indicates special requirements for the registration, as presented in Table 77–8.
c) Echoed assigned port. This field holds a 16 bit unsigned value reflecting the LLID for the port assigned following registration.
d) Echoed Sync Time. This is an unsigned 16 bit value echoing the required synchronization time of the OLT receiver as previously advertised (77.3.6.4).
e) Pad/Reserved. This is an empty field that is transmitted as zeros, and ignored at reception.

Table 77–8—REGISTER_ACK MPCPDU Flags fields

Value	Indication	Comment
0	Nack	The requested registration attempt is denied by the MAC Control Client.
1	Ack	The registration process is successfully acknowledged.
2–255	Reserved	Ignored on reception.

The REGISTER_ACK MPCPDU shall be generated by a MAC Control instance mapped to an active ONU, and as such shall be marked with a unicast type of LLID.

77.4 Discovery Process in dual-rate systems

The enhancements introduced to the Clause 77 discovery process for EPONs facilitate the coexistence of 10G–EPON with 1G–EPON.

77.4.1 OLT speed-specific discovery

The discovery GATE MPCPDU is defined in Clause 64 for 1 Gb/s operation and in Clause 77 for 10 Gb/s operation. An additional field (Discovery Information field) was added to the 10 Gb/s discovery GATE MPCPDU. This field allows the OLT to relay speed-specific information regarding the discovery window to the different ONUs that may coexist in the same PON. The OLT has the ability to transmit common discovery GATE MPCPDUs on both the 1 Gb/s transmit path and 10 Gb/s transmit path, or it can send

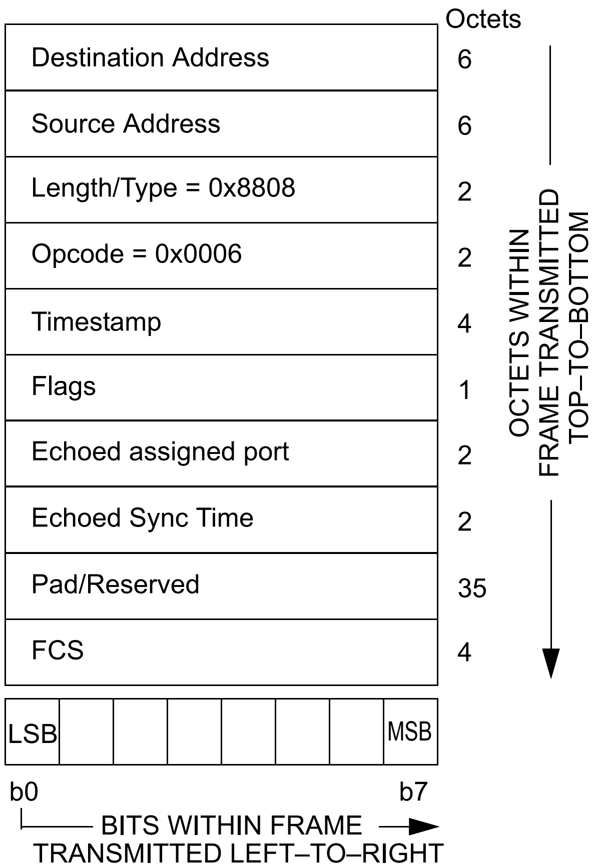


Figure 77–36—REGISTER_ACK MPCPDU

completely separate and independent GATE messages on these different paths. For each discovery window, the OLT is capable of opening windows for individual speeds or multiple speeds.

These different combinations allow the OLT MAC Control Client to open a number of discovery windows for all of the different ONU types. Table 77–9 shows the different types of windows that are possible, along with the necessary LLID and discovery information that also needs to be present in the discovery GATE MPCPDUs. For some combinations, it may be desirable for the OLT MAC Control Client to open overlapping discovery windows. It may do so by sending one discovery GATE MPCPDU on the 1 Gb/s downstream channel and a similar discovery GATE MPCPDU on the 10 Gb/s downstream channel; both discovery GATE MPCPDUs having the same Start Time value.

Figure 77–37 shows the three primary combinations of discovery windows and the different types of REGISTER_REQ MPCPDUs that may be received during the window. Figure 77–37(a) shows reception of messages from 1 Gb/s and 10/1 Gb/s ONUs. Figure 77–37(b) shows reception of messages from 10 Gb/s ONUs. Figure 77–37(c) shows reception of messages from all types of ONUs.

77.4.2 ONU speed-specific registration

A 1G–EPON ONU receives only discovery GATE messages transmitted by the OLT in the 1 Gb/s broadcast channel. Operation and registration of these ONUs is specified in Clause 64.

A 10/1G–EPON ONU is only capable of receiving discovery GATE MPCPDU transmitted by the OLT in the 10 Gb/s broadcast channel. These messages are parsed, and if a 1 Gb/s discovery window is opened, the ONU may attempt to register in the EPON.

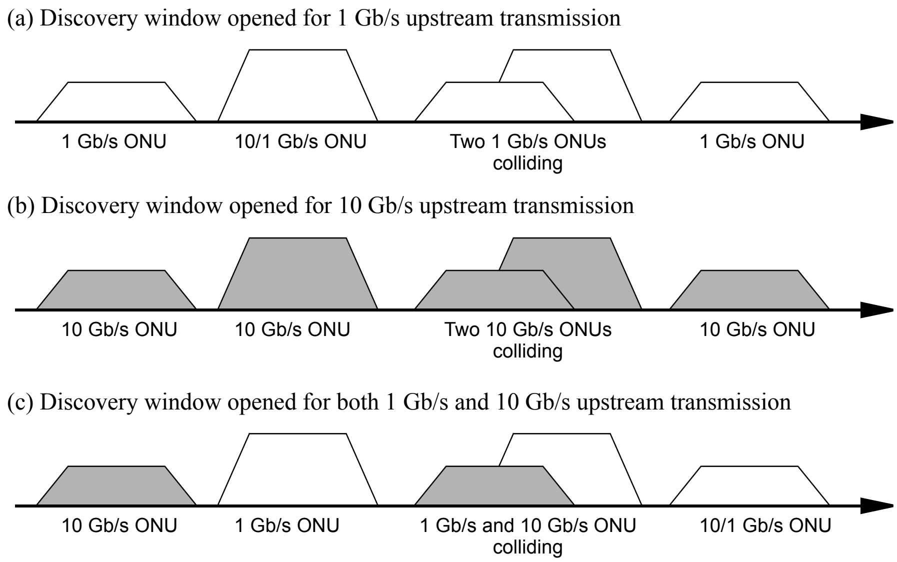


Figure 77–37—Combinations of REGISTER_REQ MPCPDUs during discovery window for 10G–EPON and 1G–EPON coexisting in the same PON

Table 77–9—Discovery GATE MPCPDUs for all ONU types

ONU types targeted by discovery GATE MPCPDU	LLID of discovery GATE(s)	Discovery information			
		Upstream capable		Discovery window	
		1G	10G	1G	10G
1G–EPON	0x7FFF	No Discovery Information field present			
10/1G–EPON	0x7FFE	1	0	1	0
1G–EPON and 10/1G–EPON	0x7FFF[a]	No Discovery Information field present			
	0x7FFE[a]	1	0	1	0
10/10G–EPON	0x7FFE	0	1	0	1
10/1G–EPON and 10/10G–EPON	0x7FFE	1	1	1	1
1G–EPON, 10/1G–EPON, and 10/10G–EPON	0x7FFF[a]	No Discovery Information field present			
	0x7FFE[a]	1	1	1	1

[a]Two discovery GATE MPCPDUs are transmitted in two separate downstream broadcast channels: one with the LLID of 0x7FFF transmitted in the 1 Gb/s downstream broadcast channel and another one the LLID of 0x7FFE transmitted in the 10 Gb/s downstream broadcast channel.

A 10/10G–EPON ONU is only capable of receiving discovery GATE MPCPDU transmitted by the OLT in the 10 Gb/s broadcast channel. These messages are parsed, and if a 10 Gb/s discovery window is opened, the ONU may attempt to register in the EPON.

A dual speed ONU capable of 10/1G–EPON operation or 10/10G–EPON operation is also only capable of receiving discovery GATE MPCPDU transmitted by the OLT in the 10 Gb/s broadcast channel. These messages need to be parsed, and the ONU makes the registration decision based on the available information. The ONU should attempt to register during the discovery window announced as supporting the highest speed common to both the OLT and ONU. Table 77–10 shows the action the ONU should take based on the ONU transmit capabilities and the received discovery information.

Table 77–10—ONU action during discovery window

OLT Discovery information				ONU Tx capability		ONU action
Upstream capable		Discovery window				
1G	10G	1G	10G	1G	10G	
1	0	1	0	1	X	Attempt 1G registration
1	X	1	X	1	0	Attempt 1G registration
X	1	X	1	X	1	Attempt 10G registration
1	1	0	1	1	0	Wait for 1G discovery window
1	1	1	0	X	1	Wait for 10G discovery window

The ONU generates the REGISTER_REQ MPCPDU with the same LLID as the discovery GATE MPCPDU it responds to, i.e., 1G–EPON ONU (per Clause 64) use LLID 0x7FFF, while the 10G–EPON ONUs use LLID 0x7FFE.

77.5 Protocol implementation conformance statement (PICS) proforma for Clause 77, Multipoint MAC Control[7]

77.5.1 Introduction

The supplier of a protocol implementation that is claimed to conform to Clause 77 Multipoint MAC Control, shall complete the following protocol implementation conformance statement (PICS) proforma.

A detailed description of the symbols used in the PICS proforma, along with instructions for completing the PICS proforma, can be found in Clause 21.

77.5.2 Identification

77.5.2.1 Implementation identification

Supplier	
Contact point for enquiries about the PICS	
Implementation Name(s) and Version(s)	
Other information necessary for full identification—e.g., name(s) and version(s) for machines and/or operating systems; System Name(s)	
NOTE 1—Only the first three items are required for all implementations; other information may be completed as appropriate in meeting the requirements for the identification. NOTE 2—The terms Name and Version should be interpreted appropriately to correspond with a supplier's terminology (e.g., Type, Series, Model).	

77.5.2.2 Protocol summary

Identification of protocol standard	IEEE Std 802.3av-2009, Clause 77, Multipoint MAC Control
Identification of amendments and corrigenda to this PICS proforma that have been completed as part of this PICS	
Have any Exception items been required? No [ ] Yes [ ] (See Clause 21; the answer Yes means that the implementation does not conform to IEEE Std 802.3av-2009.)	
Date of Statement	

[7]*Copyright release for PICS proformas:* Users of this standard may freely reproduce the PICS proforma in this subclause so that it can be used for its intended purpose and may further publish the completed PICS.

77.5.3 Major capabilities/options

Item	Feature	Subclause	Value/Comment	Status	Support
*OLT	OLT functionality	77.1	Device supports functionality required for OLT	O/1	Yes [ ] No [ ]
*ONU	ONU functionality	77.1	Device supports functionality required for ONU	O/1	Yes [ ] No [ ]

77.5.4 PICS proforma tables for Multipoint MAC Control

77.5.4.1 Compatibility considerations

Item	Feature	Subclause	Value/Comment	Status	Support
CC1	Delay through MAC	77.3.2.4	Maximum delay variation of 1 time_quantum	M	Yes [ ]
CC2	OLT grant time delays	77.3.2.4	Not grant nearer than 1024 time_quanta into the future	OLT:M	Yes [ ]
CC3	ONU processing delays	77.3.2.4	Process all messages in less than 1024 time_quanta	ONU:M	Yes [ ]
CC4	OLT grant issuance	77.3.2.4	Not grant more than one message every 1024 time_quanta to a single ONU	OLT:M	Yes [ ]

77.5.4.2 Multipoint MAC Control

Item	Feature	Subclause	Value/Comment	Status	Support
OM1	OLT localTime	77.2.2.2	Track transmit clock	OLT:M	Yes [ ]
OM2	ONU localTime	77.2.2.2	Track receive clock	ONU:M	Yes [ ]
OM3	Random wait for transmitting REGISTER_REQ messages	77.3.3	Shorter than length of discovery window	ONU:M	Yes [ ]
OM4	Periodic report generation	77.3.4	Reports are generated periodically	ONU:M	Yes [ ]
OM5	Periodic granting	77.3.4	Grants are issued periodically	OLT:M	Yes [ ]
OM6	Issuing of grants	77.3.5	Not issue more than maximum supported grants	OLT:M	Yes [ ]

77.5.4.3 State diagrams

Item	Feature	Subclause	Value/Comment	Status	Support
SM1	Multipoint Transmission Control	77.2.2.7	Meets the requirements of Figure 77–10	M	Yes [ ]
SM2	OLT Control Parser	77.2.2.7	Meets the requirements of Figure 77–11	M	Yes [ ]
SM3	ONU Control Parser	77.2.2.7	Meets the requirements of Figure 77–14	M	Yes [ ]
SM4	OLT Control Multiplexer	77.2.2.7	Meets the requirements of Figure 77–15	OLT:M	Yes [ ]
SM5	ONU Control Multiplexer	77.2.2.7	Meets the requirements of Figure 77–16	OLT:M	Yes [ ]
SM6	Discovery Processing OLT Window Setup	77.3.3.6	Meets the requirements of Figure 77–19	OLT:M	Yes [ ]
SM7	Discovery Processing OLT Process Requests	77.3.3.6	Meets the requirements of Figure 77–20	OLT:M	Yes [ ]
SM8	Discovery Processing OLT Register	77.3.3.6	Meets the requirements of Figure 77–21	ONU:M	Yes [ ]
SM9	Discovery Processing OLT Final Registration	77.3.3.6	Meets the requirements of Figure 77–22	OLT:M	Yes [ ]
SM10	Discovery Processing ONU Registration	77.3.3.6	Meets the requirements of Figure 77–23	ONU:M	Yes [ ]
SM11	Report Processing at OLT	77.3.4.6	Meets the requirements of Figure 77–25	OLT:M	Yes [ ]
SM12	Report Processing at ONU	77.3.4.6	Meets the requirements of Figure 77–26	ONU:M	Yes [ ]
SM13	Gate Processing at OLT	77.3.5.6	Meets the requirements of Figure 77–28	OLT:M	Yes [ ]
SM14	Gate Processing at ONU	77.3.5.6	Meets the requirements of Figure 77–29	ONU:M	Yes [ ]
SM15	Gate Processing ONU Activation	77.3.5.6	Meets the requirements of Figure 77–30	ONU:M	Yes [ ]

77.5.4.4 MPCP

Item	Feature	Subclause	Value/Comment	Status	Support
MP1	MPCPDU structure	77.3.6	As in Figure 77–31	M	Yes [ ]
MP2	LLID for MPCPDU	77.3.6	RS generates LLID for MPCPDU	M	Yes [ ]
MP3	Grants during discovery	77.3.6.1	Single grant in GATE message during discovery	OLT:M	Yes [ ]
MP4	Grant start time	77.3.6.1	Grants within one GATE MPCPDU are sorted by their Start time values	OLT:M	Yes [ ]
MP5	GATE generation	77.3.6.1	GATE generated for active ONU except during discovery	OLT:M	Yes [ ]
MP6	GATE LLID	77.3.6.1	Unicast LLID except for discovery	OLT:M	Yes [ ]
MP7	REPORT issuing	77.3.6.2	Issues REPORT periodically	ONU:M	Yes [ ]
MP8	REPORT generation	77.3.6.2	Generated by active ONU	ONU:M	Yes [ ]
MP9	REPORT LLID	77.3.6.2	REPORT has unicast LLID	ONU:M	Yes [ ]
MP10	REGISTER_REQ generation	77.3.6.3	Generated by undiscovered ONU	ONU:M	Yes [ ]
MP11	REGISTER_REQ LLID	77.3.6.3	Use broadcast LLID	ONU:M	Yes [ ]
MP12	REGISTER DA address	77.3.6.4	Use individual MAC address	OLT:M	Yes [ ]
MP13	REGISTER generation	77.3.6.4	Generated for all ONUs	OLT:M	Yes [ ]
MP14	REGISTER_ACK generation	77.3.6.5	Generated by active ONU	ONU:M	Yes [ ]
MP15	REGISTER_ACK LLID	77.3.6.5	Use unicast LLID	ONU:M	Yes [ ]