56. Introduction to Ethernet for subscriber access networks

56.1 Overview

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 MAC and MAC Control sublayers with a family of Physical Layers. These Physical Layers include optical fiber and voice grade copper cable PMDs for P2P connections in subscriber access networks. EFM also introduces the concept of Ethernet Passive Optical Networks (EPONs), in which a 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 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 OSI reference model are shown in Figure 56–1 for P2P topologies, Figure 56–2 for symmetric, 1 Gb/s EPON, Figure 56–3 for symmetric 10G–EPON and Figure 56–4 for asymmetric 10G–EPON topologies.

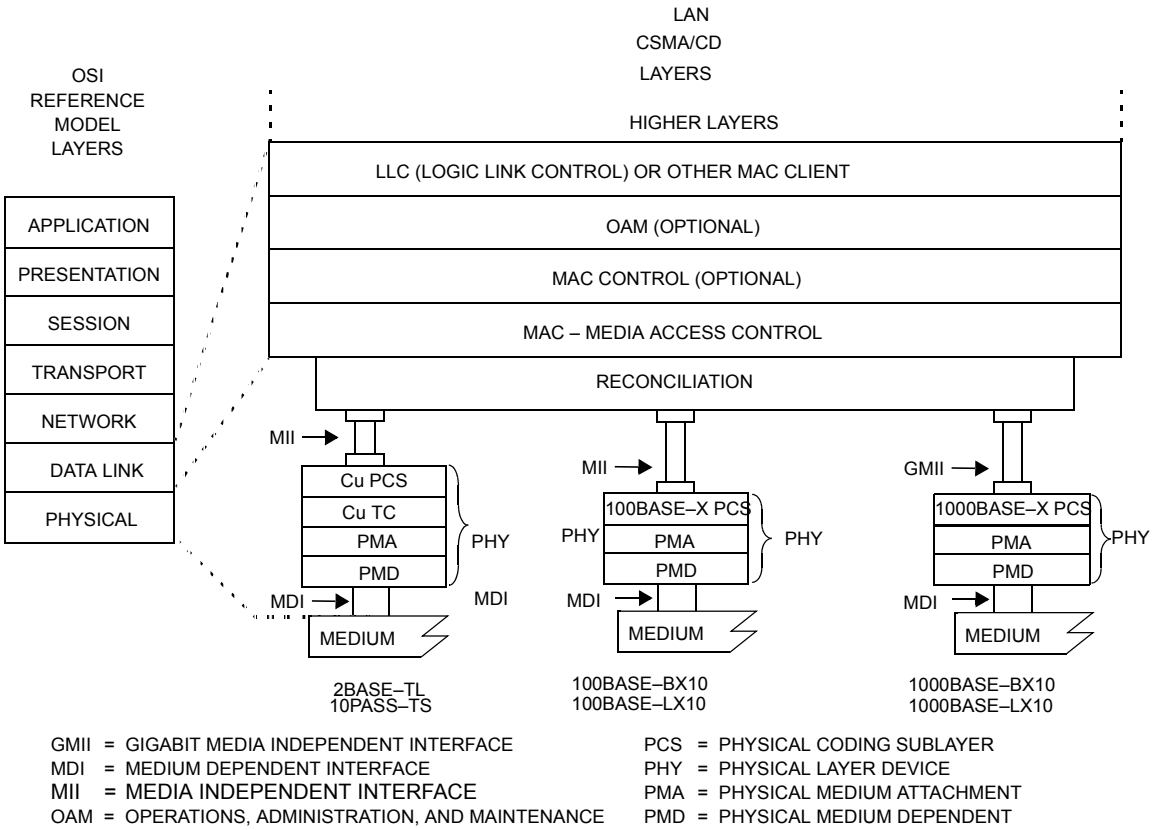


Figure 56–1—Architectural positioning of EFM: P2P Topologies

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 must 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.

EFM architecture is further extended in @@Clause 91@@ and @@Clause 92@@ by the addition of 10G–EPON. 10G–EPON extends the clauses of symmetric, 1 Gb/s EFM EPON to support symmetric (10 Gb/s

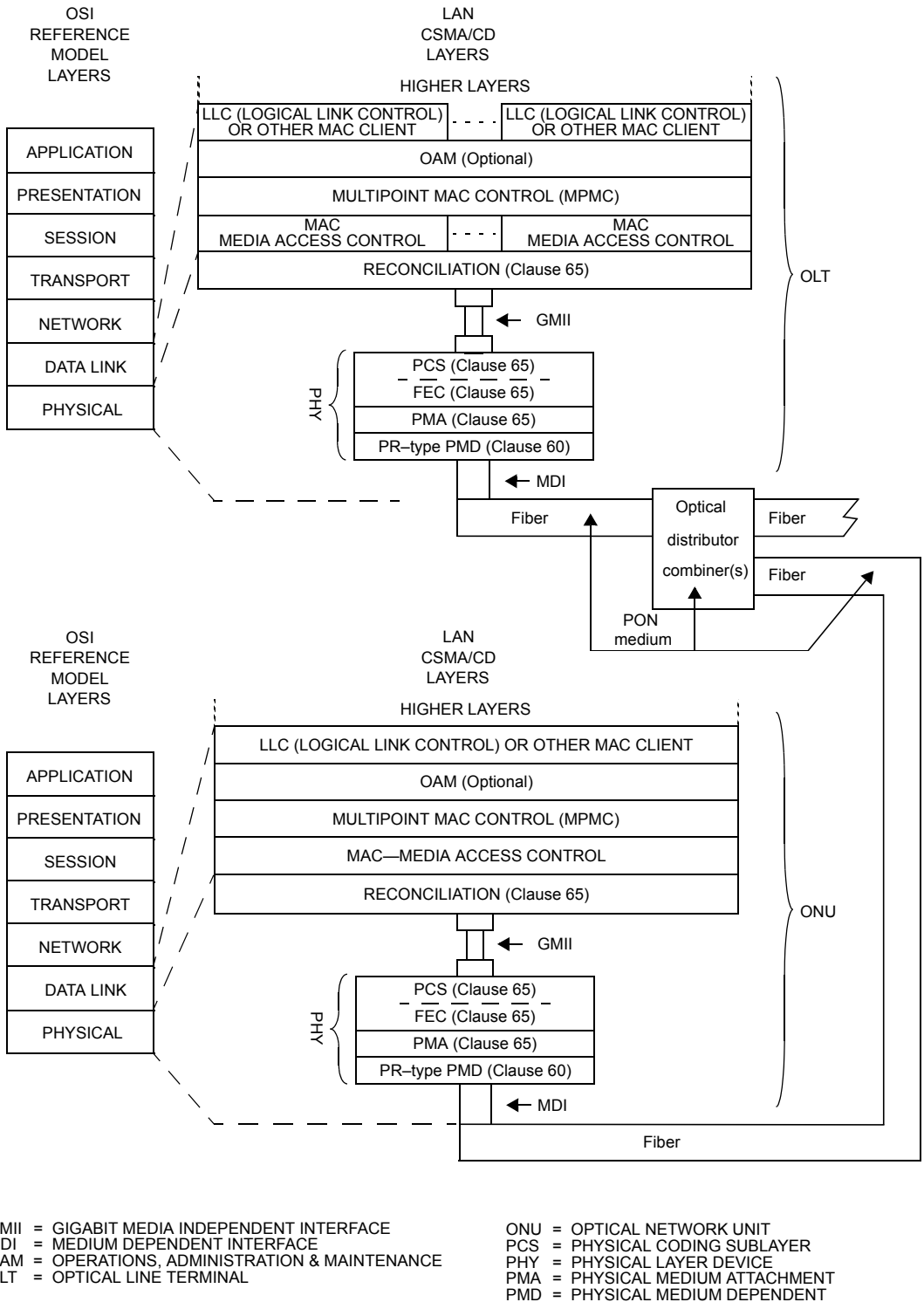
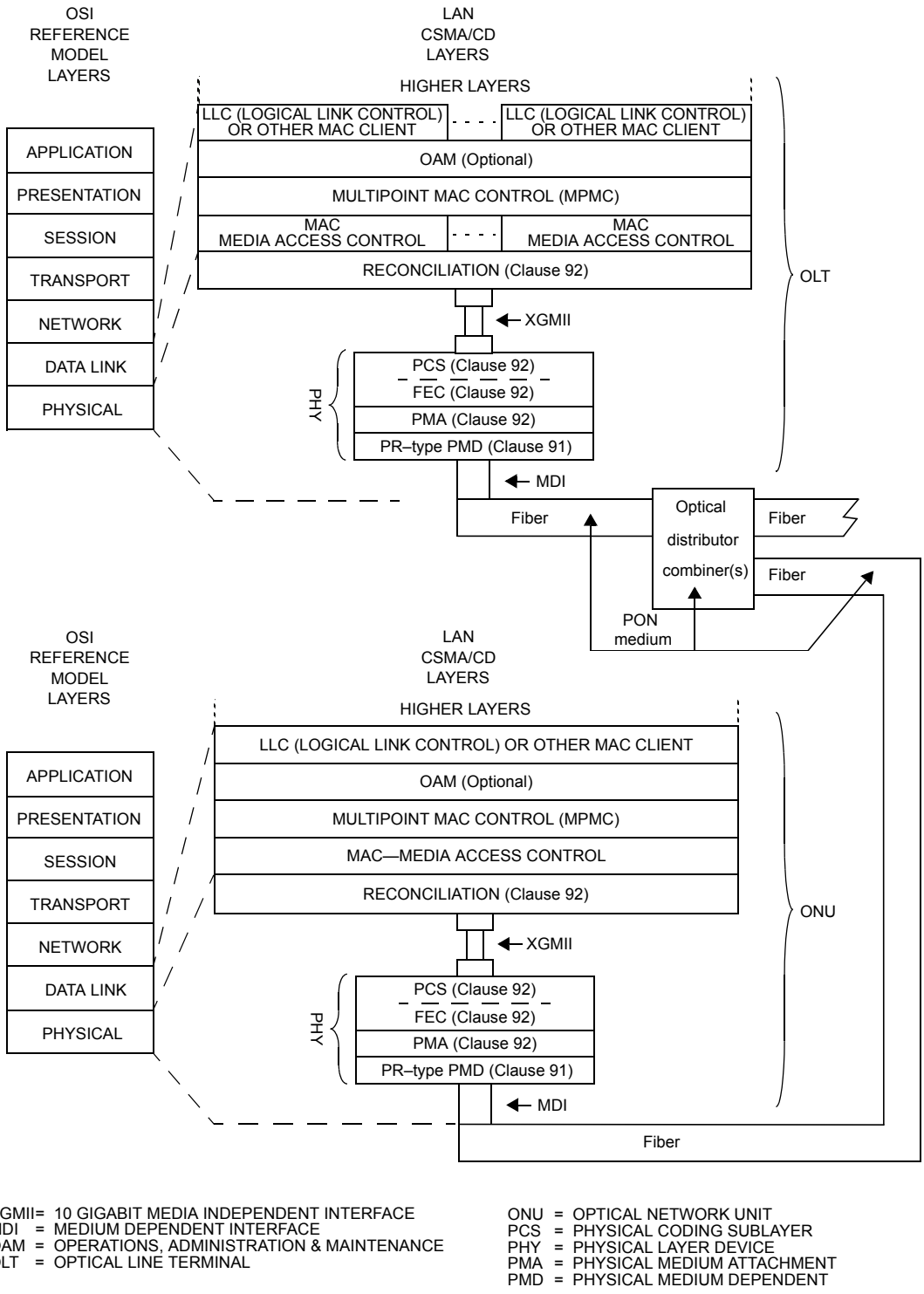


**Figure 56–2—Architectural positioning of EFM:
P2MP symmetric 1 Gb/s EPON architecture**



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 symmetric 10G–EPON architecture (10 Gb/s downstream, 10 Gb/s upstream)

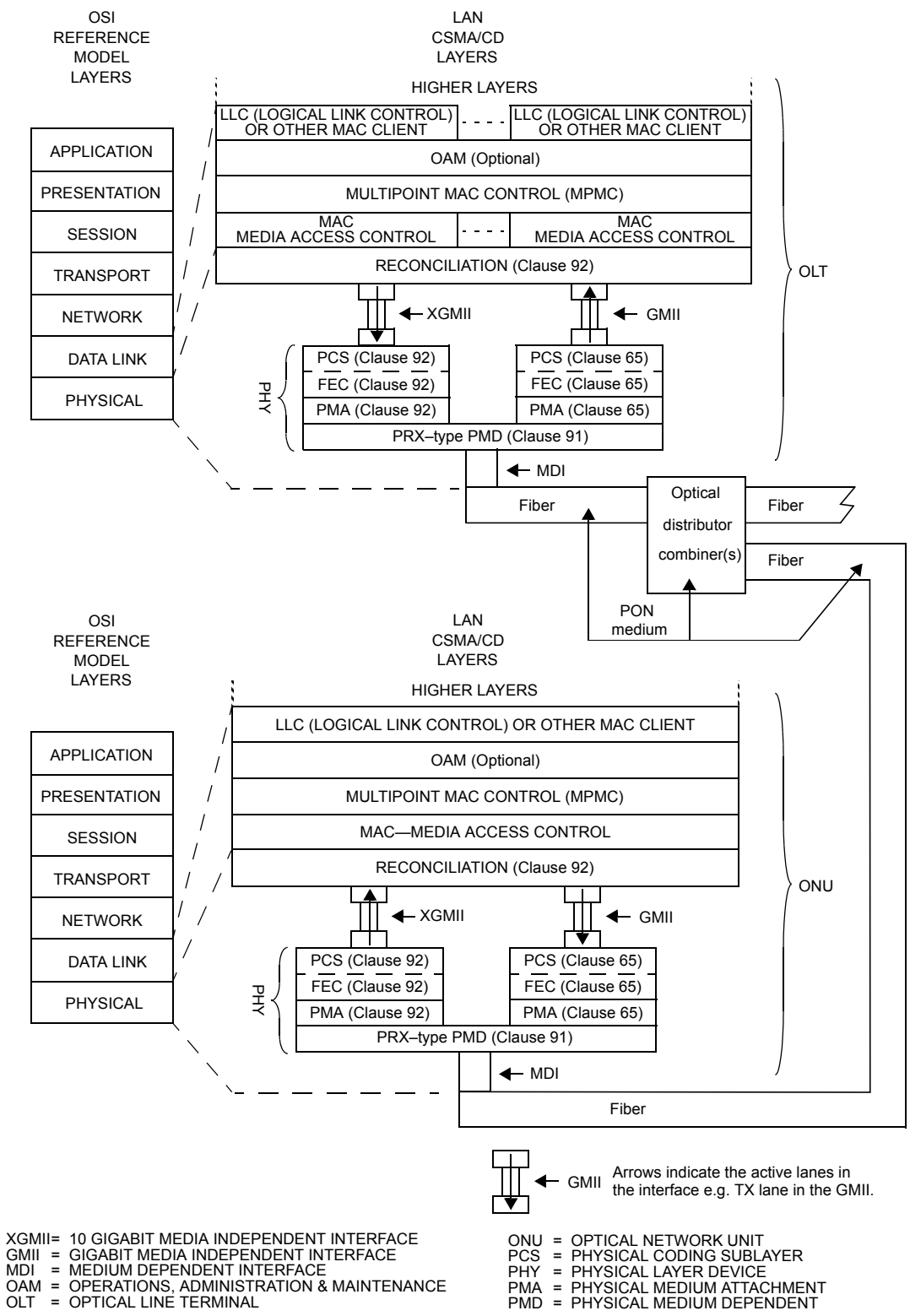


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Figure 56–4—Architectural positioning of EFM:
P2MP asymmetric 10G–EPON architecture (10 Gb/s downstream, 1 Gb/s upstream)

downstream and 10 Gb/s upstream) as well as asymmetric (10 Gb/s downstream and 1 Gb/s upstream) PONs. In the following clauses, the symmetric, 1 Gb/s EFM EPON will be referred as EPON, while symmetric (10 Gb/s downstream and 10 Gb/s upstream) as well as asymmetric (10 Gb/s downstream and 1 Gb/s upstream) EPONs will be referred to as 10G–EPON.

56.1.1 Summary of P2P sublayers

EFM P2P supports operation at several different bit rates, depending on the characteristics of the underlying medium. In the case of point–to–point optical fiber media, bit rates of 100 Mb/s and 1000 Mb/s are supported, using the 100BASE–X and 1000BASE–X Physical Coding Sublayer (PCS) and Physical Medium Attachment (PMA) sublayers defined in 66.1 and 66.2, respectively. In the case of point–to–point copper, EFM supports a variety of bit rates, depending on the span and the signal–to–noise ratio (SNR) characteristics of the medium as described in Clause 61 through Clause 63. 2BASE–TL supports a nominal bit rate of 2 Mb/s at a nominal reach of 2700 meters.[2] 10PASS–TS supports a nominal bit rate of 10 Mb/s at a nominal reach of 750 meters.[3]

56.1.2 Summary of P2MP sublayers

For P2MP optical fiber topologies, EFM supports currently two systems:

a) PON with a symmetric, nominal bit rate of 1 Gb/s, shared amongst the population of ONUs attached to the P2MP topology. The P2MP PHYs use the 1000BASE–X PCS, the PMA sublayer defined in @@Clause 60@@, and an optional FEC function defined in Clause 65;

b) PON with a nominal bit rate of 10 Gb/s in downstream and 10 Gb/s upstream (symmetric, 10G–EPON) as well as PON with a nominal bit rate of 10 Gb/s in downstream and 1 Gb/s upstream (asymmetric, 10G–EPON), shared amongst the population of ONUs attached to the P2MP topology. The P2MP PHYs use the 10GBASE–R PCS, the PMA sublayer defined in @@Clause 91@@, and an mandatory FEC function defined in @@Clause 92@@.

91.1.2.1 Multipoint MAC Control Protocol (MPCP)

The MPCP uses messages, state machines, and timers, as defined in Clause 64, to control access to a P2MP topology. Extensions to @@Clause 64@@ MPCP, required for proper operation of the 10G–EPON are included in @@Clause 93@@.

Editors' Note #1 (to be removed prior to release): Keep it updated as the Clause 64 option#2 ad hoc progresses.

The MPCP issues related with the coexistence of EPON and 10G–EPON on the same fibre plant are described in @@Annex 91A@@.

Every P2MP topology consists of one OLT plus one or more ONUs, as shown in Figure 56–2. 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.

91.1.2.2 Reconciliation Sublayer (RS) and media independent interfaces

The Clause 22 RS and MII, Clause 35 RS and GMII and @@Clause 46@@ RS and XGMII are 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 extensions to the @@Clause 46@@ RS for P2MP topologies are described in @@Clause 92@@. The combination of MPCP and the extension of the 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). It achieves this by prepending a LLID to the beginning of each data frame, replacing two octets of the preamble. This is

[2]Refer to Annex 63B for a more detailed discussion of bit rates and reach.
[3]Refer to Annex 62B for a more detailed discussion of bit rates and reach.

described in Clause 65 for EPON and in @@Clause 92@@ 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

EFM extends the family of 100BASE–X Physical Layer signaling systems to include 100BASE–LX10 (long wavelength), plus the combination of the 100BASE–BX10–D (Bidirectional long wavelength Downstream) and the 100BASE–BX10–U (Bidirectional long wavelength Upstream), as defined in Clause 58. All of these systems employ the 100BASE–X PCS and PMA as defined in Clause 66.

EFM also extends the family of 1000BASE–X Physical Layer signaling systems to include 1000BASE–LX10 (long wavelength), plus the combination of the 1000BASE–BX10–D (Bidirectional long wavelength Downstream) and the 1000BASE–BX10–U (Bidirectional long wavelength Upstream), as defined in Clause 59. All of these systems employ the 1000BASE–X PCS and PMA as defined in Clause 66. 1000BASE–LX10 is interoperable with 1000BASE–LX on single–mode and multimode fiber, and offers greater reach than 1000BASE–LX on single–mode fiber.

For P2MP topologies, EFM introduces a family of Physical Layer signaling systems which are derived from 1000BASE–X, but which include extensions to the RS, PCS and PMA, along with an optional FEC capability, as defined in Clause 65. The family of P2MP Physical Layer signaling systems includes the combination of 1000BASE–PX10–D (Passive Optical Network Downstream 10 km), plus 1000BASE–PX10–U (PON Upstream 10 km), and the combination of 1000BASE–PX20–D (PON Downstream 20 km) plus 1000BASE–PX20–U (PON Upstream 20 km), as defined in Clause 60.

Additionally, EFM introduces a family of Physical Layer signaling systems which are derived from 10GBASE–R, but which include extensions to the RS, PCS and PMA, along with a mandatory FEC capability, as defined in @@Clause 92@@. The family of P2MP Physical Layer signaling systems includes the following series of PMD combinations:

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

All 10G–EPON PMDs are defined in @@Clause 91@@.

For copper cabling, EFM introduces a family of Physical Layer signaling systems. There are two distinct signaling systems specified for copper cabling. Both of them share a set of common functions and interfaces as described in Clause 61. Clause 61 also includes an optional specification that supports combined operation on multiple copper pairs, affording greater data rate capability for a given link span. Underlying these functions, two Physical Layer signaling system specific PMAs and PMDs are described in Clause 62 and Clause 63. Non–loaded cable is a requirement of the signaling methods employed.

For high–speed applications, the 10PASS–TS signaling system is defined in Clause 62. 10PASS–TS relies on a technique referred to as Frequency Division Duplexing (FDD) to accomplish full duplex communication on a single wire pair. 10PASS–TS is a passband signaling system derived from the Very high–speed Digital Subscriber Line (VDSL) standard defined in American National Standard T1.424, using Multiple Carrier Modulation (MCM, also referred to as Discrete Multi–Tone or DMT). This PHY supports a nominal full duplex data rate of 10 Mb/s, hence the identifier 10PASS–TS. For the 10PASS–TS PHY, two subtypes are defined: 10PASS–TS–O and 10PASS–TS–R. A connection can be established only between a 10PASS–TS–O PHY on one end of the voice–grade copper line, and a 10PASS–TS–R PHY on the other end. In public networks, a 10PASS–TS–O PHY is used at a central office (CO), a cabinet, or other centralized distribution point; a 10PASS–TS–R PHY is used at the subscriber premises. In private networks, the network administrator will designate one end of each link as the network end. A PHY implementation may be equipped to support both subtypes and provide means to be configured as a 10PASS–TS–O or a 10PASS–TS–R.

For long distance applications, the 2BASE–TL signaling system is defined in Clause 63. 2BASE–TL is a baseband signaling system derived from the Single–Pair High–Speed Digital Subscriber Line (SHDSL) standards defined by ITU–T. The 2BASE–TL PMD supports a nominal full duplex data rate of approximately 2 Mb/s. As is the case with the 10PASS–TS PHY, the 2BASE–TL PHY consists of two subtypes: 2BASE–TL–O (network end) and 2BASE–TL–R (subscriber end).

System considerations for Ethernet subscriber access networks are described in Clause 67.

Specifications unique to the operation of each physical layer device are shown in Table 56–1.

Table 56–1—Summary of EFM physical layer signalling systems

Name	Location	Rate[a]	Nominal Reach (km)	Medium	Clause
100BASE–LX10	ONU/OLT[b]	100	10	Two SMFs	58
100BASE–BX10–D	OLT	100	10	One SMF	58
100BASE–BX10–U	ONU				
1000BASE–LX10	ONU/OLT[a]	1000	10 0.55	Two SMFs Two MMFs	59
1000BASE–BX10–D	OLT	1000	10	One SMF	59
1000BASE–BX10–U	ONU				
1000BASE–PX10–D	OLT	1000	10	One SMF PON	60
1000BASE–PX10–U	ONU				
1000BASE–PX20–D	OLT	1000	20	One SMF PON	60
1000BASE–PX20–U	ONU				
10GBASE–PR–D1	OLT	10 Gb/s	10	One SMF PON	91
10GBASE–PR–U1	ONU				
10GBASE–PR–D2	OLT	10 Gb/s	20	One SMF PON	91
10GBASE–PR–U1	ONU				
10GBASE–PR–D3	OLT	10 Gb/s	20	One SMF PON	91
10GBASE–PR–U3	ONU				
10/1GBASE–PRX–D1	OLT	10 Gb/s	10	One SMF PON	91
10/1GBASE–PRX–U1	ONU	1000			
10/1GBASE–PRX–D2	OLT	10 Gb/s	20	One SMF PON	91
10/1GBASE–PRX–U2	ONU	1000			
10/1GBASE–PRX–D3	OLT	10 Gb/s	20	One SMF PON	91
10/1GBASE–PRX–U3	ONU	1000			

Table 56–1—Summary of EFM physical layer signalling systems

10PASS–TS–O	CO[c]	10[d]	0.75[e]	One or more pairs of voice grade copper cable	62
10PASS–TS–R	Subscriber[b]				
2BASE–TL–O	CO[b]	2[f]	2.7[g]	One or more pairs of voice grade copper cable	63
2BASE–TL–R	Subscriber[b]				

[a]The data rate is expressed in Mb/s unless specifically stated otherwise in the given cell.
[b]Symmetric
[c]In private networks, the network administrator will designate 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.

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.

Table 56–2—Nomenclature and clause correlation for P2P systems[a]

Nomenclature	Clause									
	57	58		59		61	62	63	66	
	OAM	100BASE–LX10 PMD	100BASE–BX10 PMD	1000BASE–LX10 PMD	1000BASE–BX10 PMD	Cu PCS	10PASS–TS PMA, PMD	2BASE–TL PMA, PMD	100BASE–X PCS, PMA	1000BASE–X PCS, PMA
2BASE–TL	O					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

[a]O = Optional, M = Mandatory

56.1.4 Management

Managed objects, attributes, and actions are defined for all EFM components in Clause 30. Clause 30 consolidates all IEEE 802.3 management specifications so that agents can be managed by existing network management stations with little or no modification to the agent code, regardless of the operating speed of the network.

In addition to the management objects, attributes, and actions defined in Clause 30, EFM introduces OAM for subscriber access networks to Ethernet. OAM, as defined in Clause 57, includes a mechanism for communicating management information using OAM frames, as well as functions for performing low–level diagnostics on a per link basis in an Ethernet subscriber access network.

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

Nomenclature	Clause																						
	57	60		64	65		66		91												92		93
	OAM	1000BASE–PX10 PMD	1000BASE–PX20 PMD	P2MP MPCP	P2MP RS, PCS, PMA	FEC	100BASE–X PCS, PMA	1000BASE–X PCS, PMA	10GBASE–PR–D1	10GBASE–PR–U1	10GBASE–PR–D2	10GBASE–PR–D3	10GBASE–PR–U3	10/1GBASE–PRX–D1	10/1GBASE–PRX–U1	10/1GBASE–PRX–D2	10/1GBASE–PRX–U2	10/1GBASE–PRX–D3	10/1GBASE–PRX–U3	P2MP RS, PCS, PMA	FEC	P2MP MPCP for 10G–EPON
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																	
10GBASE–PR–D1	O			M					M												M	M	M
10GBASE–PR–U1	O			M						M											M	M	M
10GBASE–PR–D2	O			M							M										M	M	M
10GBASE–PR–D3	O			M								M									M	M	M
10GBASE–PR–U3	O			M									M								M	M	M
10/1GBASE–PRX–D1	O			M										M							M	M	M
10/1GBASE–PRX–U1	O			M											M						M	M	M
10/1GBASE–PRX–D2	O			M												M					M	M	M
10/1GBASE–PRX–U2	O			M													M				M	M	M
10/1GBASE–PRX–D3	O			M														M			M	M	M
10/1GBASE–PRX–U3	O			M															M		M	M	M

[a]O = Optional, M = Mandatory

56.1.5 Unidirectional transmission

In contrast to previous editions of IEEE Std 802.3, in certain circumstances a DTE is allowed to transmit frames while not receiving a satisfactory signal. It is necessary for a 1000BASE–PX–D OLT to do this to bring a PON into operation (although it is highly inadvisable for a 1000BASE–PX–U ONU to transmit without receiving). Clause 66 describes optional modifications to the 100BASE–X PHY, 1000BASE–X PHY and 10GBASE RS so that a DTE may signal remote fault using OAMPDUs. When unidirectional operation is not enabled, the sublayers in Clause 66 are precisely the same as their equivalents in Clause 24, Clause 36, and Clause 46.

56.2 State diagrams

State machine diagrams take precedence over text.

The conventions of 1.2 are adopted, along with the extensions listed in 21.5.

56.3 Protocol implementation conformance statement (PICS) proforma

The supplier of a protocol implementation that is claimed to conform to any part of IEEE 802.3, Clause 57 through Clause 66, demonstrates compliance by completing a protocol implementation conformance statement (PICS) proforma.

A completed PICS proforma is the PICS for the implementation in question. The PICS is a statement of which capabilities and options of the protocol have been implemented. A PICS is included at the end of each clause as appropriate. Each of the EFM PICS conforms to the same notation and conventions used in 100BASE–T (see 21.6).