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

SECTION FIVE: This section includes Clause 56 through Clause 67 and Annex 58A through Annex 67A.

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 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 point-to-multipoint 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.

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

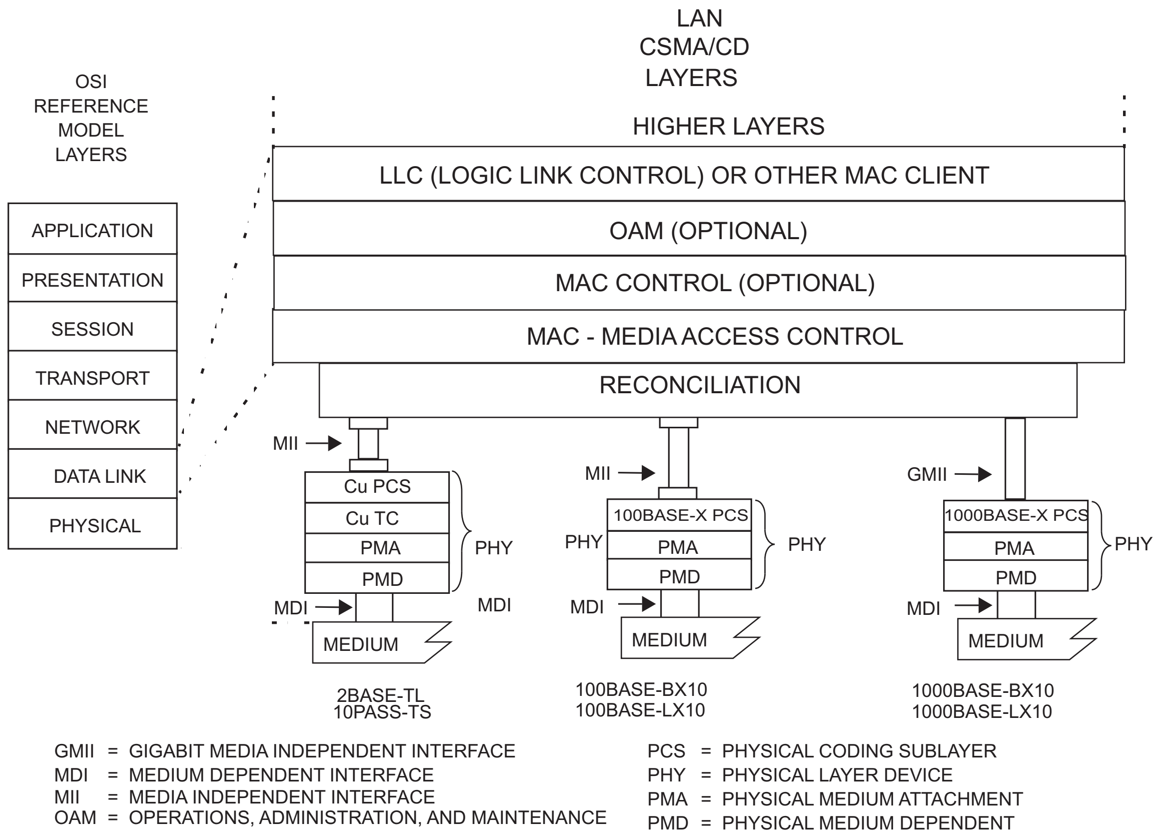


Figure 56–1—Architectural positioning of EFM: P2P Topologies

bit rate of 2 Mb/s at a nominal reach of 2700 meters.[1] 10PASS-TS supports a nominal bit rate of 10 Mb/s at a nominal reach of 750 meters.[2]

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.

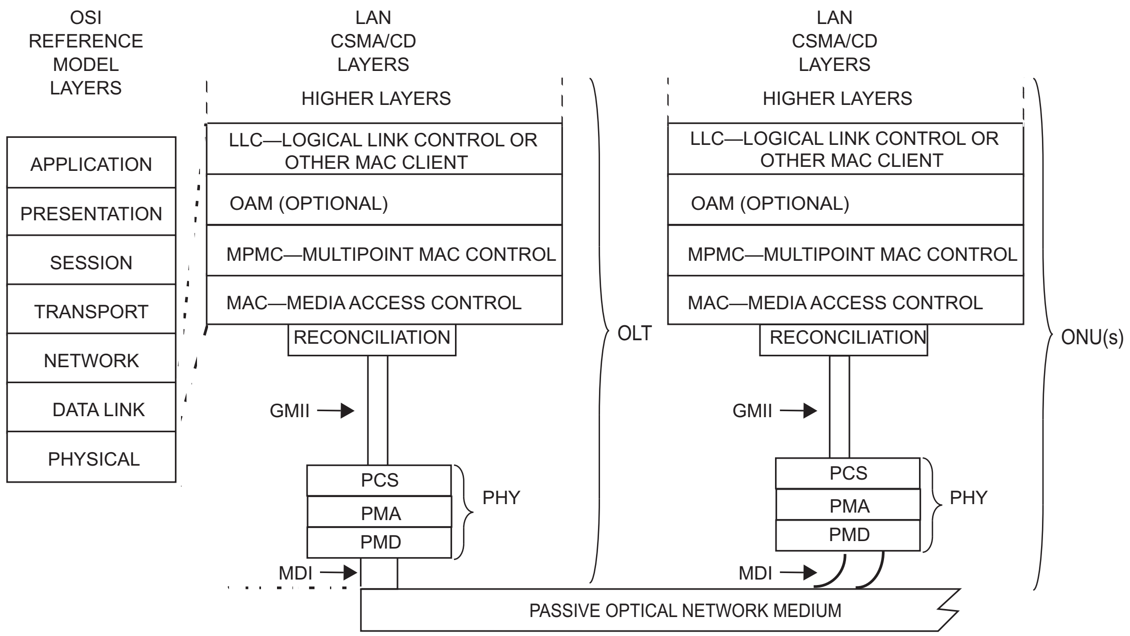
56.1.2.1 Multipoint MAC Control Protocol (MPCP)

The Multipoint MAC Control Protocol (MPCP) uses messages, state machines, and timers, as defined in Clause 64, to control access to a P2MP topology. Every P2MP topology consists of one Optical Line Terminal (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.

56.1.2.2 Reconciliation Sublayer (RS) and media independent interfaces

The Clause 22 RS and MII, and Clause 35 RS and GMII, are both employed for the same purpose in EFM, that being the interconnection between the MAC sublayer and the PHY sublayers. Extensions to the

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



GMII = GIGABIT MEDIA INDEPENDENT INTERFACE
MDI = MEDIUM DEPENDENT INTERFACE
OAM = OPERATIONS, ADMINISTRATION, AND 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 56–2—Architectural positioning of EFM: P2MP Topologies

Clause 35 RS for P2MP topologies are described in Clause 65. 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). It achieves this by prepending a Logical Link Identification (LLID) to the beginning of each data frame, replacing two octets of the preamble. This is described in Clause 65. 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 forward error correction (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.

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 signaling systems

Name	Location	Rate (Mb/s)	Nominal Reach (km)	Medium	Clause
100BASE-LX10	ONU/OLT[a]	100	10	Two single-mode fibers	58
100BASE-BX10-D	OLT	100	10	One single-mode fiber	58
100BASE-BX10-U	ONU				
1000BASE-LX10	ONU/OLT[a]	1000	10 0.55	Two single-mode fibers Two multimode fibers	59
1000BASE-BX10-D	OLT	1000	10	One single-mode fiber	59
1000BASE-BX10-U	ONU				
1000BASE-PX10-D	OLT	1000	10	One single-mode fiber PON	60
1000BASE-PX10-U	ONU				
1000BASE-PX20-D	OLT	1000	20	One single-mode fiber PON	60
1000BASE-PX20-U	ONU				

Table 56–1—Summary of EFM physical layer signaling systems *(continued)*

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

[a]Symmetric
[b]In private networks, the network administrator will designate one end of each link as the network end.
[c]Nominal rate stated at the nominal reach. Rate may vary depending on plant. Refer to Annex 62B for more information.
[d]Reach may vary depending on plant. Refer to Annex 62B for further information.
[e]Nominal rate stated at the nominal reach. Rate may vary depending on plant. Refer to Annex 63B for more information.
[f]Reach may vary depending on plant. Refer to Annex 63B for further information.

Table 56–2 specifies the correlation between nomenclature and clauses. A complete implementation conforming to one or more nomenclatures meets the requirements of the corresponding clauses.

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

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 Operations, Administration, and Maintenance (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.

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).

57. Operations, Administration, and Maintenance (OAM)

57.1 Overview

57.1.1 Scope

This clause defines the Operations, Administration, and Maintenance (OAM) sublayer, which provides mechanisms useful for monitoring link operation such as remote fault indication and remote loopback control. In general, OAM provides network operators the ability to monitor the health of the network and quickly determine the location of failing links or fault conditions. The OAM described in this clause provides data link layer mechanisms that complement applications that may reside in higher layers.

OAM information is conveyed in Slow Protocol frames (see Annex 43B) called OAM Protocol Data Units (OAMPDUs). OAMPDUs contain the appropriate control and status information used to monitor, test and troubleshoot OAM-enabled links. OAMPDUs traverse a single link, being passed between peer OAM entities, and as such, are not forwarded by MAC clients (e.g., bridges or switches).

OAM does not include functions such as station management, bandwidth allocation, or provisioning functions, which are considered outside the scope of this standard.

For the remainder of this clause, the term OAM is specific to the link level OAM described here.

57.1.2 Summary of objectives and major concepts

This subclause provides details and functional requirements for the OAM objectives:

a) Remote Failure Indication
   1) A mechanism is provided to indicate to a peer that the receive path of the local DTE is non-operational.
   2) Physical layer devices using Clause 66 may support unidirectional operation that allows OAM remote failure indication during fault conditions.
   3) Subscriber access physical layer devices using Clause 65 support unidirectional operation in the direction from OLT to ONU that allows OAM remote failure indication from OLT during fault conditions.
   4) Physical layer devices other than those listed above do not support unidirectional operation allowing OAM remote failure indication during fault conditions. Some physical layer devices have specific remote failure signaling mechanisms in the physical layer.
b) Remote Loopback—A mechanism is provided to support a data link layer frame-level loopback mode.
c) Link Monitoring
   1) A mechanism is provided to support event notification that permits the inclusion of diagnostic information.
   2) A mechanism is provided to support polling of any variable in the Clause 30 MIB.
d) Miscellaneous
   1) Implementation and activation of OAM is optional.
   2) A mechanism is provided that performs OAM capability discovery.
   3) An extension mechanism is provided and made available for higher layer management applications.

These objectives support a subset of the user-plane OAM requirements found in ITU-T Y.1730 [B34].

57.1.3 Summary of non-objectives

This subclause explicitly lists certain functions that are not addressed by OAM. These functions, while valuable, do not fall within the scope of this standard.

a) Management functions not pertaining to a single link such as protection switching and station management are not covered by this clause. Such functions could be addressed using the extension mechanism.
b) Provisioning and negotiation functions such as bandwidth allocation, rate adaptation and speed/duplex negotiation are not supported by OAM.
c) Issues related to privacy of OAM data and authentication of OAM entities are beyond the scope of this standard.
d) The ability to set/write remote MIB variables is not supported.

57.1.4 Positioning of OAM within the IEEE 802.3 architecture

OAM comprises an optional sublayer between a superior sublayer (e.g., MAC client or optional Link Aggregation) and a subordinate sublayer (e.g., MAC or optional MAC Control sublayer). Figure 57–1 shows the relationship of the OAM sublayer to the ISO/IEC (IEEE) OSI reference model.

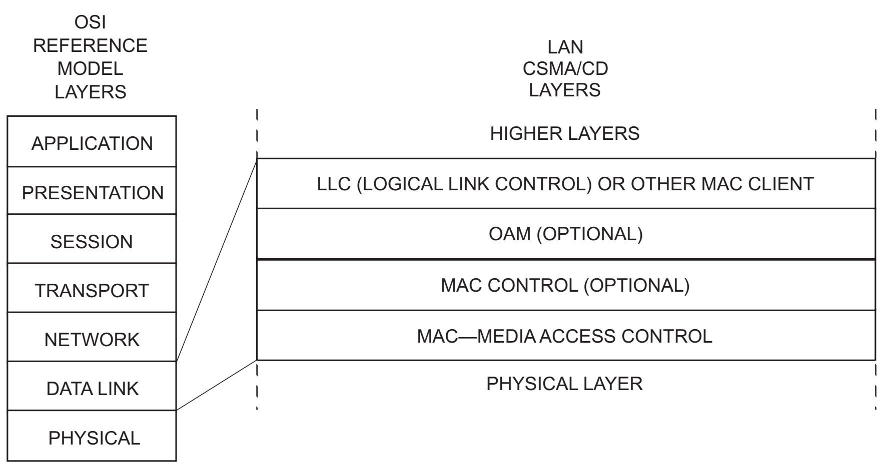


Figure 57–1—OAM sublayer relationship to the ISO/IEC Open Systems Interconnection (OSI) reference model and the IEEE 802.3 CSMA/CD LAN model

57.1.5 Compatibility considerations

57.1.5.1 Application

OAM is intended for point-to-point and emulated point-to-point IEEE 802.3 links. Implementation of OAM functionality is optional. A conformant implementation may implement the optional OAM sublayer for some ports within a system while not implementing it for other ports.

57.1.5.2 Interoperability between OAM capable DTEs

A DTE is able to determine whether or not a remote DTE has OAM functionality enabled. The OAM Discovery mechanism ascertains the configured parameters, such as maximum allowable OAMPDU size, and supported functions, such as OAM remote loopback, on a given link.

57.1.5.3 MAC Control PAUSE

MAC Control PAUSE, commonly referred to as Flow Control as defined in Annex 31B, inhibits the transmission of all MA_DATA.request service primitives, including OAMPDUs. This may delay or prevent the signaling of critical events such as unrecoverable failure conditions and link faults.

57.1.5.4 Interface to MAC Control client

MAC Control clients that generate MA_CONTROL.request service primitives (and which expect MA_CONTROL.indication service primitives in response) are not acted upon by the OAM sublayer. They communicate directly with the MAC Control entity as though no OAM sublayer exists.

57.1.5.5 Frame loss during OAM remote loopback

Invocations of OAM remote loopback may result in data frame loss. OAM remote loopback is an intrusive operation that prevents a link from passing frames between the MAC client of the local DTE and the MAC client of the remote DTE. Refer to 57.2.11 for a complete description of OAM remote loopback operation.

57.1.6 State diagram conventions

Many of the functions specified in this clause are presented in state diagram notation. All state diagrams contained in this clause use the notation and conventions defined in 21.5. In the event of a discrepancy between the text description and the state diagram formalization of a function, the state diagrams take precedence.

57.2 Functional specifications

57.2.1 Interlayer service interfaces

Figure 57–2 depicts the usage of interlayer interfaces by the OAM sublayer.

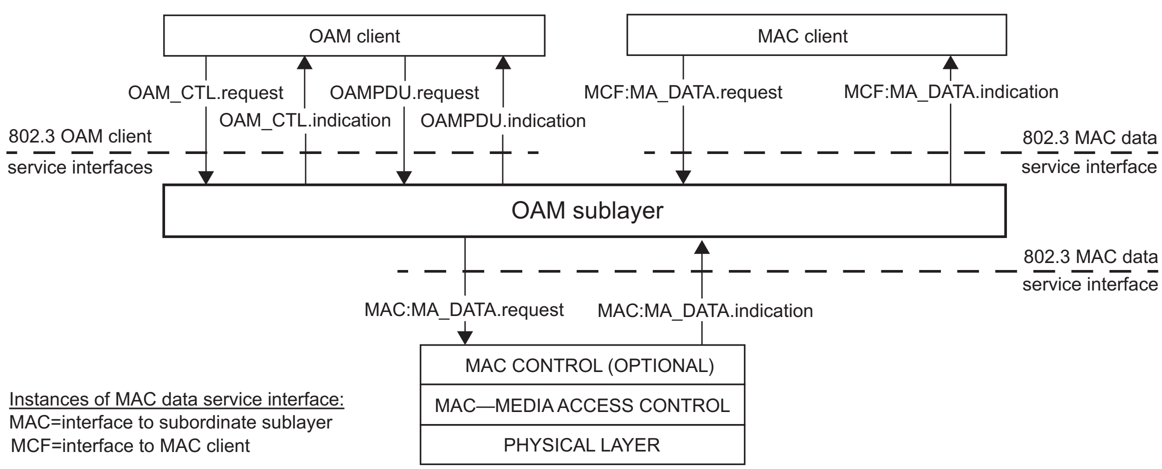


Figure 57–2—OAM sublayer support of interlayer service interfaces

57.2.2 Principles of operation

OAM employs the following principles and concepts:

a) The OAM sublayer presents a standard IEEE 802.3 MAC service interface to the superior sublayer. Superior sublayers include MAC client and Link Aggregation.
b) The OAM sublayer employs a standard IEEE 802.3 MAC service interface to the subordinate sublayer. Subordinate sublayers include MAC and MAC Control.
c) Frames from superior sublayers are multiplexed within the OAM sublayer with OAMPDUs.
d) The OAM sublayer parses received frames and passes OAMPDUs to the OAM client. In general, non-OAMPDUs are passed to the superior sublayer. When in OAM remote loopback mode, non-OAMPDUs are looped back to the subordinate sublayer. When the peer OAM entity is in OAM remote loopback mode, non-OAMPDUs are discarded by the OAM sublayer so that higher layer functions (e.g., bridging) do not process the looped back frames.
e) Knowledge of the underlying physical layer device is not required by the OAM sublayer.
f) OAMPDUs traverse a single link and are passed between OAM client entities or OAM sublayer entities. OAMPDUs are not forwarded by OAM clients.
g) OAM is extensible through the use of an Organization Specific OAMPDU, Organization Specific Information TLV, and Organization Specific Event TLV. These can be used for functions outside the scope of this standard.

57.2.3 Instances of the MAC data service interface

A superior sublayer such as the MAC client communicates with the OAM sublayer using the standard MAC data service interface specified in Clause 2. Similarly, the OAM sublayer communicates with a subordinate sublayer such as the MAC Control or MAC using the same standard service interfaces.

Since this clause uses two instances of the MAC data service interface, it is necessary to introduce a notation convention so that the reader can be clear as to which interface is being referred to at any given time. A prefix is therefore assigned to each service primitive, indicating which of the two interfaces is being invoked, as depicted in Figure 57–2. The prefixes are as follows:

a) MCF:, for primitives issued on the interface between the superior sublayer and the OAM sublayer (MCF is an abbreviation for MAC client frame)
b) MAC:, for primitives issued on the interface between the underlying subordinate sublayer (e.g., MAC) and the OAM sublayer

57.2.4 Responsibilities of OAM client

The OAM client plays an integral role in establishing and managing OAM on a link. The OAM client enables and configures the OAM sublayer entity. During the OAM Discovery process (see 57.3.2.1), the OAM client monitors received OAMPDUs from the remote DTE and based upon local and remote state and configuration settings allows OAM functionality to be enabled on the link.

After OAM has been established, the OAM client is responsible for adhering to the OAMPDU response rules. For example, the OAM client does not respond to illegal requests such as Variable Request and Loopback Control OAMPDUs from Passive DTEs. The OAM client is also expected to manage the OAM remote loopback mode (see 57.2.11). It does so by reacting to particular OAMPDUs and altering local configuration parameters.

Link events are signalled between peer OAM client entities. The OAM client transfers events by sending and receiving particular OAMPDUs. To increase the likelihood that a specific event is received by the remote DTE, the OAM client may send the event multiple times.

57.2.5 OAM client interactions

The OAM sublayer entity communicates with the OAM client using the following new interlayer service interfaces:

OAMPDU.request
OAMPDU.indication
OAM_CTL.request
OAM_CTL.indication

The OAMPDU.request, OAMPDU.indication, OAM_CTL.request and OAM_CTL.indication service primitives described in this subclause are mandatory.

57.2.5.1 OAMPDU.request

57.2.5.1.1 Function

This primitive defines the transfer of data from an OAM client entity to a peer OAM client entity.

57.2.5.1.2 Semantics of the service primitive

The semantics of the primitive are as follows:

```
OAMPDU.request          (
                        source_address,
                        flags,
                        code,
                        data
                        )
```

The source_address parameter specifies an individual MAC address. The flags parameter is used to create the Flags field within the OAMPDU to be transmitted. Only the indications corresponding to the Flags field bits 15:3 are contained in the flags parameter since the indications corresponding to Flags field bits 2:0 are contained in the OAM_CTL.request service primitive. The code parameter is used to create the Code field within the OAMPDU to be transmitted. The data parameter is used to create the Data field within the OAMPDU to be transmitted.

57.2.5.1.3 When generated

This primitive is generated by the OAM client entity whenever an OAMPDU is to be transferred to a peer entity. This can be in response to a request from the peer entity or from data generated internally to the OAM client.

57.2.5.1.4 Effect of receipt

The receipt of this primitive will cause the OAM sublayer entity to insert all OAMPDU specific fields, including DA, SA, Length/Type and Subtype, and pass the properly formed OAMPDU to the lower protocol layers for transfer to the peer OAM client entity according to the transmit rules as described in 57.3.2.2.6.

57.2.5.2 OAMPDU.indication

57.2.5.2.1 Function

This primitive defines the transfer of data from an OAM sublayer entity to an OAM client entity.

57.2.5.2.2 Semantics of the service primitive

The semantics of the primitive are as follows:

```
OAMPDU.indication        (
                         source_address,
                         flags,
                         code,
                         data
                         )
```

The source_address parameter is the MAC source address of the incoming OAMPDU. The flags parameter is the entire Flags field of the incoming OAMPDU. The code parameter is the Code field of the incoming OAMPDU. The data parameter is the Data field of the incoming OAMPDU.

57.2.5.2.3 When generated

This primitive is passed from the OAM sublayer entity to the OAM client entity to indicate the arrival of an OAMPDU to the local OAM sublayer entity that is destined for the OAM client. Such OAMPDUs are reported only if they are validly formed and received without error.

57.2.5.2.4 Effect of receipt

The effect of receipt of this primitive by the OAM client is unspecified.

57.2.5.3 OAM_CTL.request

57.2.5.3.1 Function

This primitive defines the transfer of control information from an OAM client entity to an OAM sublayer entity.

57.2.5.3.2 Semantics of the service primitive

The semantics of the primitive are as follows:

```
OAM_CTL.request          (
                         local_unidirectional,
                         local_link_status,
                         local_dying_gasp,
                         local_critical_event,
                         local_satisfied,
                         remote_state_valid,
                         remote_stable,
                         local_mux_action,
                         local_par_action,
                         information_data
                         )
```

When set, the local_unidirectional parameter is used to indicate the sending station supports transmission of OAMPDUs on unidirectional links as supported by some physical coding layers (see 57.2.12).

The local_link_status, local_dying_gasp, and local_critical_event parameters are used to indicate immediate event situations that should be transmitted to the peer OAM entity. The local_link_status parameter is used to convey the status of the link as determined by the underlying physical layer. When set to FAIL, the local_link_status parameter will cause the OAM sublayer entity to transmit an Information OAMPDU with the Link Fault bit of the Flags field set and no Information TLVs. The local_dying_gasp parameter is used to signal a local unrecoverable failure condition. When set, the local_dying_gasp parameter will cause the OAM sublayer to transmit an Information OAMPDU with the Dying Gasp bit of the Flags field set. The local_critical_event parameter is used to signal an unspecified critical link event condition. When set, the local_critical_event parameter will cause the OAM sublayer to transmit an Information OAMPDU with the Critical Event bit of the Flags field set.

The local_satisfied, remote_state_valid, and remote_stable parameters are used in the Discovery process. The local_satisfied parameter is set by the OAM client as a result of comparing its local configuration and the remote configuration found in the received Local Information TLV (see 57.3.2.1).

The local_mux_action and local_par_action parameters are used to control the state of the Multiplexer and Parser functions of the OAM sublayer (see 57.3.3 and 57.3.4).

The information_data parameter contains the Local Information TLV fields, and, if available, the Remote Information and Organization Specific Information TLV fields, to be included in Information OAMPDUs generated by the Transmit process (see 57.3.2.2).

57.2.5.3.3 When generated

This primitive is passed from the OAM client entity to the OAM sublayer to update control information.

57.2.5.3.4 Effect of receipt

The receipt of this primitive will cause the OAM sublayer to generate Information OAMPDUs or update specific fields of future Information OAMPDUs. Also, OAM functions will be re-evaluated based upon any changing control information.

57.2.5.4 OAM_CTL.indication

57.2.5.4.1 Function

This primitive defines the transfer of control information from an OAM sublayer entity to an OAM client entity.

57.2.5.4.2 Semantics of the service primitive

The semantics of the primitive are as follows:

```
OAM_CTL.indication          (
                            local_pdu,
                            local_stable,
                            local_lost_link_timer_done
                            )
```

The local_pdu and local_stable parameters are used by the OAM sublayer to indicate to the OAM client state information in the Discovery process (see 57.3.2.1). The local_lost_link_timer_done parameter is used to convey the expiration of the local_lost_link_timer.

57.2.5.4.3 When generated

This primitive is passed from the OAM sublayer entity to the OAM client entity to indicate local state information has changed.

57.2.5.4.4 Effect of receipt

The effect of receipt of this primitive by the OAM client is unspecified.

57.2.6 Instances of the OAM internal service interface

The OAM sublayer communicates internally using the OAM internal service interface. Since two instances of the OAM internal service interface are used, it is necessary to introduce a notation convention so that the reader can be clear as to which interface is being referred to at any given time. A prefix is therefore assigned to each service primitive, indicating which of the two interfaces is being invoked (see Figure 57–3). The prefixes are as follows:

a) LBF:, for primitives issued on the interface between the Parser and the Multiplexer (LBF is an abbreviation for Loopback frame).
b) CTL:, for primitives issued on the interface between the Control and other OAM functions (CTL is an abbreviation for Control function).

57.2.7 Internal block diagram

Figure 57–3 depicts the major blocks within the OAM sublayer and their interrelationships.

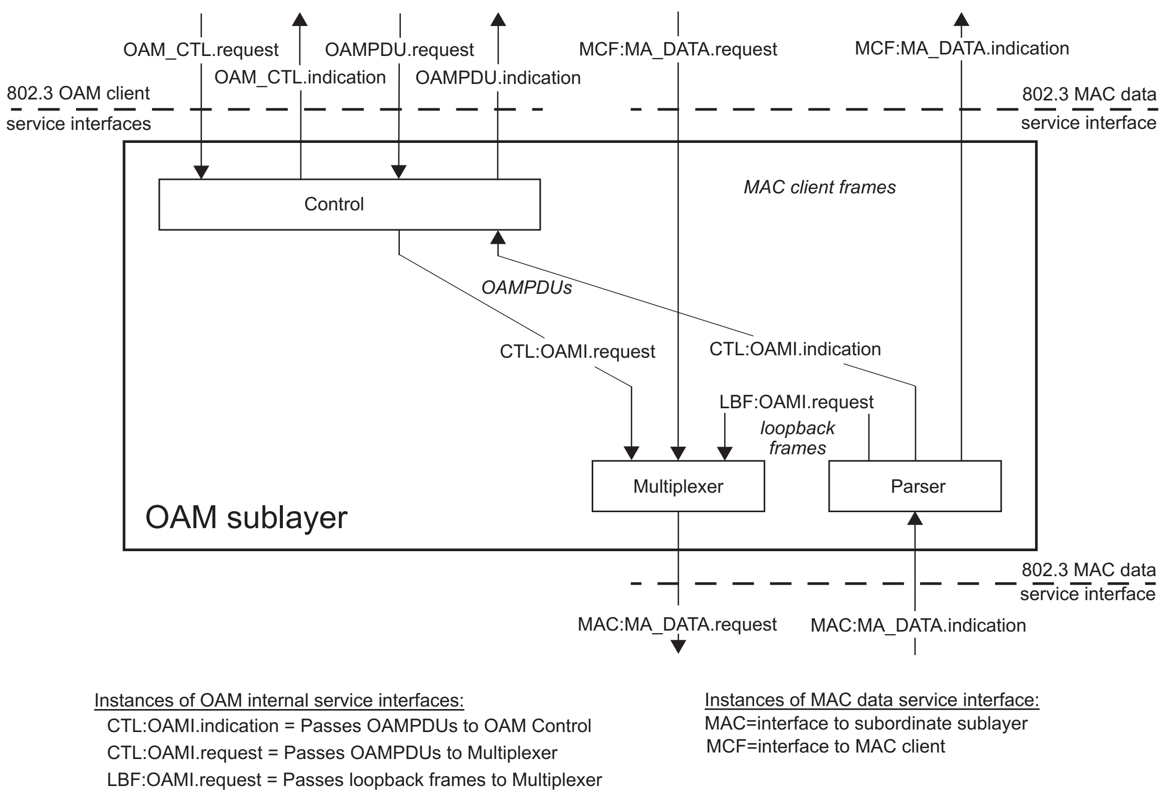


Figure 57–3—OAM sublayer block diagram

57.2.8 OAM internal interactions

The OAM sublayer entity employs the following new internal service interfaces:
OAMI.request
OAMI.indication

The OAMI.request and OAMI.indication service primitives described in this subclause are mandatory.

57.2.8.1 OAMI.request

57.2.8.1.1 Function

This primitive defines the transfer of frames to the Multiplexer function internal to the OAM sublayer.

57.2.8.1.2 Semantics of the service primitive

The semantics of the primitive are as follows:

```
OAMI.request          (
                      destination_address,
                      source_address,
                      oam_service_data_unit,
                      frame_check_sequence
                      )
```

The destination_address parameter specifies the Slow Protocols Multicast Address. The source_address parameter must specify an individual MAC address. The oam_service_data_unit parameter specifies the OAM service data unit to be transmitted within the OAM sublayer entity. This parameter includes the Length/Type, Subtype, Flags, Code and Data/Pad fields. There is sufficient information associated with the oam_service_data_unit for the OAM sublayer entity to determine the length of the data unit. The frame_check_sequence parameter, if present, must specify the frame check sequence field for the frame (see 3.2.8).

57.2.8.1.3 When generated

This primitive is generated by the Parser function whenever a frame is intended to be looped back to the remote DTE via the Multiplexer function. This primitive is also generated by the Control function whenever an OAMPDU is to be conveyed to the peer OAM entity via the Multiplexer function, internal to the OAM sublayer.

57.2.8.1.4 Effect of receipt

The receipt of this primitive will cause the Multiplexer function to pass the properly formed frame, subject to Figure 57–7, to the subordinate sublayer via the MAC data service interface (see 57.2.3).

57.2.8.2 OAMI.indication

57.2.8.2.1 Function

This primitive defines the transfer of frames to the Control function internal to the OAM sublayer.

57.2.8.2.2 Semantics of the service primitive

The semantics of the primitive are as follows:

```
OAMI.indication          (
                         destination_address,
                         source_address,
                         oam_service_data_unit,
                         frame_check_sequence,
                         reception_status
                         )
```

The destination_address parameter is the Slow Protocols Multicast Address as specified by the DA field of the incoming frame. The source_address parameter is an individual address as specified by the SA field of the incoming frame. The oam_service_data_unit parameter specifies the OAM service data unit as received by the internal OAM function. The frame_check_sequence parameter, if present, is the cyclic redundancy check value (see 3.2.8) as specified by the FCS field of the incoming frame. The reception_status parameter is used to pass status information to the internal OAM function. Values for the reception_status parameter can be found in 4.3.2.

57.2.8.2.3 When generated

This primitive is generated whenever the Parser function intends to pass a received OAMPDU to the Control function, internal to the OAM sublayer. Frames are reported only if they are validly formed and received without error.

57.2.8.2.4 Effect of receipt

The receipt of this primitive will cause the Control function to update internal state variables and pass the OAMPDU to the OAM client via the OAMPDU.indication service primitive (see 57.2.5.2).

57.2.9 Modes

DTEs incorporating the OAM sublayer support Active and/or Passive mode. When OAM is enabled, a DTE capable of both Active and Passive modes shall select either Active or Passive. Table 57–1 contains the behaviour of Active and Passive mode DTEs.

Table 57–1—Active and passive mode behaviour

Capability	Active DTE	Passive DTE
Initiates OAM Discovery process	Yes	No
Reacts to OAM Discovery process initiation	Yes	Yes
Required to send Information OAMPDUs	Yes	Yes
Permitted to send Event Notification OAMPDUs	Yes	Yes
Permitted to send Variable Request OAMPDUs	Yes	No
Permitted to send Variable Response OAMPDUs	Yes[a]	Yes
Permitted to send Loopback Control OAMPDUs	Yes	No
Reacts to Loopback Control OAMPDUs	Yes[a]	Yes
Permitted to send Organization Specific OAMPDUs	Yes	Yes

[a]Requires the peer DTE to be in Active mode.

57.2.9.1 Active mode

DTEs configured in Active mode initiate the exchange of Information OAMPDUs as defined by the Discovery state diagram (see Figure 57–5). Once the Discovery process completes, Active DTEs are permitted to send any OAMPDU while connected to a remote OAM peer entity in Active mode. Active DTEs operate in a limited respect if the remote OAM entity is operating in Passive mode (see Table 57–1). Active devices should not respond to OAM remote loopback commands and variable requests from a Passive peer.

57.2.9.2 Passive mode

DTEs configured in Passive mode do not initiate the Discovery process. Passive DTEs react to the initiation of the Discovery process by the remote DTE. This eliminates the possibility of passive to passive links. Passive DTEs shall not send Variable Request or Loopback Control OAMPDUs.

57.2.10 OAM events

OAM defines a set of events that may impact link operation. OAM contains mechanisms to communicate such events to the remote DTE. The following sections provide an overview of these events and mechanisms.

57.2.10.1 Critical link events

Table 57–2 lists the defined critical link events. Critical link events are carried within the Flags field of each OAMPDU. Refer to 57.4.2.1 for the definition and encoding of the Flags field.

Table 57–2—Critical link event

Critical link event	Description
Link fault	The PHY has determined a fault has occurred in the receive direction of the local DTE.
Dying gasp	An unrecoverable local failure condition has occurred.
Critical event	An unspecified critical event has occurred.

NOTE—The definition of the specific faults comprising the Critical Event, Dying Gasp, and Link Fault flags is implementation specific and beyond the scope of this standard.

57.2.10.2 Link events

Link events are signaled via Link Event TLVs that are defined in 57.5.3. Examples of link events include Errored Symbol Period Event and Errored Frame Event.

57.2.10.3 Local event procedure

Local events are communicated to the remote DTE via one of two mechanisms described below:

a) Critical link events, defined in 57.2.10.1, are communicated to the OAM sublayer via the OAM_CTL.request service primitive. The OAM sublayer shall respond to critical link events by setting or clearing the appropriate bits within the Flags field on any subsequently generated OAMPDUs of any type.
b) The OAM client sends an Event Notification OAMPDU (see 57.4.3.2) containing a Link Event TLV (see Table 57–12) for every event not yet signaled to the remote DTE. The OAM client uses the OAMPDU.request service primitive to send Event Notification OAMPDUs. The OAM client may send duplicate Event Notification OAMPDUs to increase the probability of reception at the remote DTE on deteriorating links.

57.2.10.4 Remote event procedure

Remote events are detected by the local OAM client via one of two mechanisms described below:

a) Critical link events, defined in 57.2.10.1, shall be detected by the local OAM sublayer via the Flags field of any received OAMPDU. The OAM sublayer signals the Flags field to the OAM client using the OAMPDU.indication service primitive. When receiving Information OAMPDUs indicating Link Fault from the remote DTE, it is recommended that the local OAM client set the local_link_status parameter in the OAM_CTL.request service primitive to OK. This avoids the situation where both ends of a link are in a deadlock condition where neither DTE will be capable of receiving frames.
b) All other link events shall be detected by the local OAM sublayer via the reception of an Event Notification OAMPDU and the subsequent passing of the OAMPDU to the OAM client via the OAMPDU.indication service primitive. The OAM client discards any duplicate received Event Notification OAMPDU.

57.2.11 OAM remote loopback

OAM provides an optional data link layer frame-level loopback mode, which is controlled remotely. OAM remote loopback can be used for fault localization and link performance testing. Statistics from both the local and remote DTE can be queried and compared at any time while the remote DTE is in OAM remote loopback mode. These queries can take place before, during or after loopback frames have been sent to the remote DTE. In addition, an implementation may analyze loopback frames within the OAM sublayer to determine additional information about the health of the link (i.e. determine which frames are being dropped due to link errors). Figure 57–4 shows the path of frames traversing the layer stack of both the local and remote DTEs.

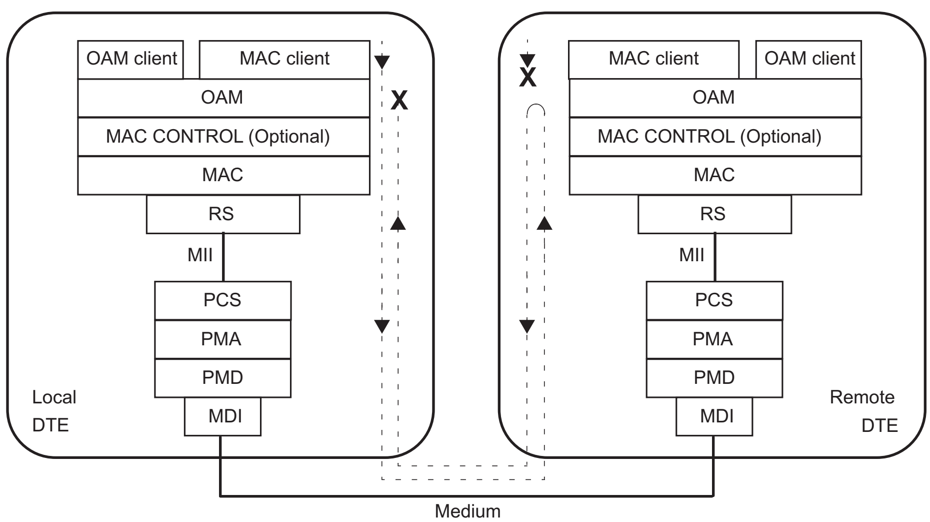


Figure 57–4—OAM remote loopback

57.2.11.1 Initiating OAM remote loopback

To initiate OAM remote loopback, the local OAM client sets its local_mux_action parameter to DISCARD and the local_par_action parameter to DISCARD via the OAM_CTL.request service primitive. The local OAM client sends a Loopback Control OAMPDU (see 57.4.3.5) with the Enable OAM Remote Loopback command. After receiving the Loopback Control OAMPDU, the remote OAM client first sets its local_par_action parameter to LB and its local_mux_action parameter to DISCARD via the OAM_CTL.request service primitive, and then sends an Information OAMPDU with updated state information reflecting its local_par_action set to LB and its local_mux_action parameter set to DISCARD. On the reception of an Information OAMPDU from the remote OAM client with updated state information, the local OAM client sets the local_mux_action to FWD.

If an OAM client has sent a Loopback Control OAMPDU and is waiting for the peer DTE to respond with an Information OAMPDU that indicates it is in OAM remote loopback mode, and that OAM client receives an OAM remote loopback command from the peer device, the following procedures are recommended:

a) If the local DTE has a higher source_address than the peer, it should enter OAM remote loopback mode at the command of its peer.
b) If the local DTE has a lower source_address than the peer, it should ignore the OAM remote loopback command from its peer and continue as if it were never received.

If OAM clients do not follow these guidelines, it may be possible for two OAM clients to issue simultaneous OAM remote loopback commands with indeterminate results.

57.2.11.2 During OAM remote loopback

This section elaborates on Figure 57–4 and describes the flow of frames within the local and remote DTEs and across the link during OAM remote loopback mode. While in OAM remote loopback mode:

a) The local DTE transmits frames from the MAC client and OAMPDUs from the local OAM client or OAM sublayer.
b) Within the remote OAM sublayer entity, every non-OAMPDU, including other Slow Protocol frames, is looped back without altering any field of the frame.
c) OAMPDUs received by the remote DTE are passed to the remote OAM client.
d) Both DTEs are required to send OAMPDUs to the peer DTE in order to keep the Discovery process from re-starting. Both are also permitted to send other OAMPDUs to the peer DTE.
e) Frames received by the local DTE are parsed by the OAM sublayer. OAMPDUs are passed to the OAM client and all other frames are discarded.

57.2.11.3 Exiting OAM remote loopback

When the local DTE wishes to end the OAM remote loopback test, the local OAM client sets its local_mux_action parameter to DISCARD. The local OAM client then sends a Loopback Control OAMPDU with the Disable OAM Remote Loopback command. After receiving a Loopback Control OAMPDU with the Disable OAM Remote Loopback command, the remote OAM client first sets the local_par_action and local_mux_action parameters to FWD via the OAM_CTL.request service primitive and then sends an Information OAMPDU with updated state information reflecting the local_par_action and local_mux_action parameters set to FWD. After receiving an Information OAMPDU with local_par_action and local_mux_action set to FWD, the local OAM client sets its local_par_action and local_mux_action parameters to FWD via the OAM_CTL.request service primitive. The remote Parser resumes passing received non-OAMPDUs up to the MAC client and the local Multiplexer resumes forwarding any frames sourced by the local MAC client.

57.2.11.4 Loss of OAMPDUs during OAM remote loopback

There is the possibility of OAMPDU loss before, during and after OAM remote loopback tests. Of particular interest to the operation of OAM remote loopback is the loss of Loopback Control OAMPDUs and Information OAMPDUs. The local OAM client is able to determine whether or not the remote OAM client received Loopback Control OAMPDUs by examining all received Information OAMPDUs. Since Information OAMPDUs are continually sent to keep the OAM Discovery process from re-starting, the occasional loss of an Information OAMPDU should not adversely impact the operation of OAM remote loopback mode.

57.2.11.5 Loss of frames during OAM remote loopback

While the link is operating in OAM remote loopback mode, MAC client frames originating from the remote DTE are not transmitted by the remote OAM sublayer entity. Depending upon the remote DTE's implementation of OAM remote loopback, not every frame received is guaranteed to be looped back to the local DTE. Clock differences between the local and remote DTEs may also be a source of lost frames, as the delta in the rate of frames transmitted and received may overrun buffers within either DTE. As always, frames that incur errors during transit will be dropped by the MAC sublayer receiving the frame. Also, OAMPDUs inserted by the remote DTE impacts the bandwidth available to loopback frames. Implementations should take into account the topology (e.g., emulated point-to-point, asymmetrical links) when determining the rate at which to send frames during OAM remote loopback. When a bidirectional link has asymmetric data rates, frame loss may occur if the receive bandwidth is less than the transmit bandwidth.

Loopback frames that are discarded by the OAM sublayer within the remote DTE are counted and, if Clause 30 is present, are reflected in 30.3.6.1.46. This helps determine the health of the link by distinguishing between frames discarded due to link errors and those discarded within the OAM sublayer.

57.2.11.6 Timing considerations for OAM remote loopback

For effective OAM remote loopback operation, it is necessary to place an upper bound on the response time of the remote OAM client after receiving Loopback Control OAMPDUs.

To ensure correct operation, the OAM client needs to, within one second of receiving a Loopback Control OAMPDU with the Enable OAM Remote Loopback command:

a) Set its local_par_action parameter to LB and the local_mux_action to DISCARD via the OAM_CTL.request service primitive.
b) Send an Information OAMPDU.

To ensure correct operation, the OAM client needs to, within one second of receiving a Loopback Control OAMPDU with the Disable OAM Remote Loopback command:

c) Set its local_par_action and local_mux_action parameters to FWD via the OAM_CTL.request service primitive.
d) Send an Information OAMPDU.

It is possible for the remote MAC client to send frames before the remote OAM client can send the Information OAMPDU instructing the local DTE to change its local_par_action variable. As a result these remote MAC client frames will be discarded by the local DTE.

57.2.12 Unidirectional OAM operation

OAM provides an OAMPDU-based mechanism to notify the remote DTE when one direction of a link is non-operational and therefore data transmission is disabled. The ability to operate a link in a unidirectional mode for diagnostic purposes supports the maintenance objective of failure detection and notification.

Some physical layer devices support Unidirectional OAM operation (see 22.2.4.1.12, 22.2.4.2.8, and Clause 66). When a link is operating in Unidirectional OAM mode, the OAM sublayer ensures that only Information OAMPDUs with the Link Fault critical link event indication set and no Information TLVs are sent once per second across the link.

57.3 Detailed functions and state diagrams

As depicted in Figure 57–3, the OAM sublayer comprises the following functions:

a) ***Multiplexer***. This function is responsible for passing frames received from the superior sublayer (e.g., MAC client sublayer), OAMPDUs from the Control function and loopback frames from the Parser, to the subordinate sublayer (e.g., MAC sublayer).
b) ***Parser***. This function distinguishes among OAMPDUs, MAC client frames and loopback frames and passes each to the appropriate entity (Control, superior sublayer and Multiplexer, respectively).
c) ***Control***. This function is responsible for providing the interface between the OAM client entity and the functions internal to the OAM sublayer. It incorporates the Discovery process which detects the existence and capabilities of OAM at the remote DTE. Also, it includes the Transmit process, which governs the transmission of OAMPDUs to the Multiplexer function and a set of Receive rules, which govern the reception of OAMPDUs.

57.3.1 State diagram variables

57.3.1.1 Constants

OAM_subtype
The value of the Subtype field for OAMPDUs (see Table 43B–3).

Slow_Protocols_Multicast
The value of the Slow Protocols Multicast Address. (see Table 43B–1.)

Slow_Protocols_Type
The value of the Slow Protocols Length/Type field. (see Table 43B–2.)

57.3.1.2 Variables

BEGIN
A variable that resets the functions within OAM.
Values: TRUE; when the OAM sublayer is reset, or when local_oam_enable is set to DISABLE.
FALSE; When (re-)initialization has completed and local_oam_enable is set to ENABLE.

ind_DA
ind_SA
ind_mac_service_data_unit
ind_reception_status
The parameters of the MA_DATA.indication service primitive, as defined in Clause 2.

ind_subtype
The value of the octet following the Length/Type field in a Slow Protocol frame (see Annex 43B).
Value: Integer

local_critical_event
A parameter of the OAM_CTL.request service primitive, as defined in 57.2.5.3. This indicates the DTE has experienced an unspecified critical event condition.
Values: FALSE; A critical event condition has not occurred.
TRUE; A critical event condition has occurred.

local_dying_gasp
A parameter of the OAM_CTL.request service primitive, as defined in 57.2.5.3. This indicates the DTE has experienced an unrecoverable failure condition.
Values: FALSE; An unrecoverable local failure condition has not occurred.
TRUE; An unrecoverable local failure condition has occurred.

local_link_status
A parameter of the OAM_CTL.request service primitive, as defined in 57.2.5.3. This indicates the status of the established link (see 67.6.3).
Values: FAIL; A link fault condition does exist.
OK; A link fault condition does not exist.

local_lost_link_timer_done
A parameter of the OAM_CTL.indication service primitive, as defined in 57.2.5.4. This is used to indicate the local_lost_link_timer has expired.
Values: TRUE; local_lost_link_timer has expired.
FALSE; local_lost_link_timer has not expired.

local_mux_action
A parameter of the OAM_CTL.request service primitive, as defined in 57.2.5.3. This governs the flow of frames from the MAC client through the Multiplexer function (see 57.3.3).
Values: FWD; Multiplexer passes MAC client frames to subordinate sublayer.
DISCARD; Multiplexer discards MAC client frames.

local_oam_enable
Used to enable and disable the OAM sublayer entity. If Clause 30 is present, this maps to 30.3.6.1.2 aOAMAdminState.
Values: DISABLE; The interface acts as it would if it had no OAM sublayer.
ENABLE; The interface employs the OAM sublayer and its functions.

local_oam_mode
Used to configure the OAM sublayer entity in either Active or Passive mode. If Clause 30 is present, this maps to 30.3.3.2 aOAMMode.
Values: PASSIVE; The OAM sublayer entity is configured in Passive mode.
ACTIVE; The OAM sublayer entity is configured in Active mode.

local_par_action
A parameter of the OAM_CTL.request service primitive, as defined in 57.2.5.3. This governs the flow of non-OAMPDUs through the Parser function (see 57.3.4).
Values: FWD; Parser passes received non-OAMPDUs to superior sublayer.
LB; Parser passes received non-OAMPDUs to Multiplexer during remote loopback test.
DISCARD; Parser discards received non-OAMPDUs.

local_pdu
This is used to govern the transmission and reception of OAMPDUs as part of the Discovery process (see 57.3.2.1).
Values: LF_INFO; Only Information OAMPDUs with the Link Fault critical link event set and without Information TLVs are allowed to be transmitted; only Information OAMPDUs are allowed to be received.
RX_INFO; No OAMPDUs are allowed to be transmitted; only Information OAMPDUs are allowed to be received.
INFO; Only Information OAMPDUs are allowed to be transmitted and received.
ANY; Any permissible OAMPDU is allowed to be transmitted and received (see Table 57–1).

local_satisfied
A parameter of the OAM_CTL.request service primitive, as defined in 57.2.5.3. This indicates the OAM client finds the local and remote OAM configuration settings are agreeable.
Values: FALSE; OAM client either has not seen or is not satisfied with local and remote settings.
TRUE; OAM client is satisfied with local and remote settings.

local_stable

A variable set by the Discovery state diagram (see Figure 57–5). This is used to indicate local OAM client acknowledgment of and satisfaction with remote OAM state information.

Values: FALSE; Indicates that local DTE either has not seen or is unsatisfied with remote state information.
TRUE; Indicates that local DTE has seen and is satisfied with remote state information.

local_unidirectional

A parameter of the OAM_CTL.request service primitive, as defined in 57.2.5.3. This indicates the DTE is capable of sending OAMPDUs when the link in the receive direction is not operational.

Values: FALSE; DTE is unable to send OAMPDUs when receive path is not operational.
TRUE; DTE is capable of sending OAMPDUs when receive path is not operational.

pdu_req

This represents a request to send an OAMPDU and is used within the Transmit state diagram (see Figure 57–6).

Values: NONE: No OAMPDU.request
CRITICAL: OAMPDU.request with one or more critical link event OAM_CTL.request parameters set (local_dying_gasp, local_link_status, local_critical_event).
NORMAL: OAMPDU.request with no critical link event(s) set

remote_stable

A parameter of the OAM_CTL.request service primitive, as defined in 57.2.5.3. OAM client extracts remote state information from received OAMPDUs. This is used to indicate remote OAM client acknowledgment of and satisfaction with local OAM state information.

Values: FALSE; Indicates that remote DTE either has not seen or is unsatisfied with local state information.
TRUE; Indicates that remote DTE has seen and is satisfied with local state information.

remote_state_valid

A parameter of the OAM_CTL.request service primitive, as defined in 57.2.5.3. This is used to indicate OAM client has received remote state information found within Local Information TLVs of received Information OAMPDUs.

Values: FALSE; Indicates that OAM client has not seen remote state information.
TRUE; Indicates that OAM client has seen remote state information.

req_DA
req_SA
req_mac_service_data_unit
req_frame_check_sequence

The parameters of the MA_DATA.request service primitive, as defined in Clause 2.

57.3.1.3 Messages

CTL:OAMI.indication

The service primitive used to pass a received frame to an internal OAM function with the specified parameters.

CTL:OAMI.request
LBF:OAMI.request

The service primitives used to transmit a frame with the specified parameters.

MAC:MA_DATA.indication

MCF:MA_DATA.indication
The service primitives used to pass a received frame to a client with the specified parameters.

MAC:MA_DATA.request
MCF:MA_DATA.request
The service primitives used to transmit a frame with the specified parameters.

MADI
Alias for
MA_DATA.indication(ind_DA, ind_SA, ind_mac_service_data_unit, ind_reception_status)

MADR
Alias for
MA_DATA.request(req_DA, req_SA, req_mac_service_data_unit, req_frame_check_sequence)

OAMII
Alias for
OAMI.indication(DA, SA, oam_service_data_unit, frame_check_sequence, reception_status)

OAMIR
Alias for
OAMI.request(DA, SA, oam_service_data_unit, frame_check_sequence)

RxOAMPDU
Alias for ind_DA = Slow_Protocols_Multicast * ind_Length/Type = Slow_Protocols_Type * ind_subtype = OAM_subtype

rxOK
Alias for ind_reception_status = receiveOK

valid_pdu_req
Alias for the following term:
(local_pdu≠RX_INFO * pdu_req=NORMAL * pdu_cnt≠0)
+ (local_pdu=ANY * pdu_req=CRITICAL)

57.3.1.4 Counters

pdu_cnt
This counter is used to limit the number of OAMPDUs transmitted per second and ensure at least one OAMPDU is sent each second within the Transmit state diagram (see Figure 57–6).

57.3.1.5 Timers

All timers operate in the manner described in 14.2.3.2 with the following addition. A timer is reset and stops counting upon entering a state where 'stop x_timer' is asserted.

local_lost_link_timer
Timer used to reset the Discovery state diagram (see Figure 57–5).
Duration: 5 s ± 10%.

pdu_timer
Timer used to ensure OAM sublayer adheres to maximum number of OAMPDUs per second and emits at least one OAMPDU per second.
Duration: 1 s ± 10%.

57.3.2 Control

The Control function provides the interfaces with the OAM client necessary to transmit and receive OAMPDUs and convey control and status parameters. The Control function also contains the Discovery process, which enables OAM to be established on a link, and the Transmit process, which governs the transmission of OAMPDUs to the Multiplexer block. Rules governing the reception of OAMPDUs are also contained within the Control function.

57.3.2.1 OAM Discovery

OAM provides a mechanism to detect the presence of an OAM sublayer at the remote DTE. This mechanism is called Discovery. OAM sublayer entities shall implement the OAM Discovery state diagram shown in Figure 57–5.

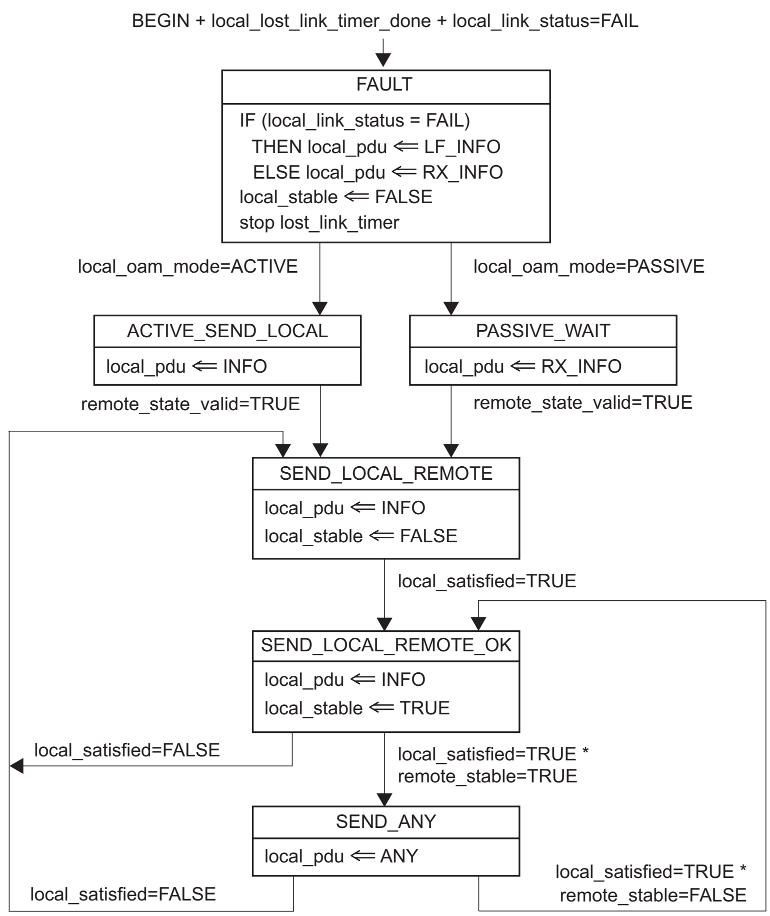


Figure 57–5—OAM Discovery state diagram

In each state, the OAM sublayer sends specified OAMPDUs in a periodic fashion, normally once a second. When local_pdu is set to LF_INFO, the OAM sublayer sends Information OAMPDUs with the Link Fault bit of the Flags field set and without any Information TLVs. When local_pdu is set to RX_INFO, the OAM sublayer does not send any OAMPDUs. When local_pdu is set to INFO, only Information OAMPDUs are sent. When local_pdu is set to ANY, all permissible OAMPDUs may be sent, subject to the restrictions found in Table 57–1.

57.3.2.1.1 FAULT state

Upon entering the FAULT state, local_pdu is set based on the value of local_link_status. If it is set to FAIL, local_pdu is set to LF_INFO, otherwise is it set to RX_INFO. Then, local_stable is set to FALSE and local_lost_link_timer is stopped. While local_link_status is set to FAIL, the DTE will remain in this state indicating to the remote DTE there is link fault. This is accomplished by sending Information OAMPDUs once per second with the Link Fault bit of the Flags field set and no Information TLVs in the Data field. The unidirectional transmission of Information OAMPDUs is supported by some physical coding sublayers (see 57.2.12).

If OAM is reset, disabled, the local_lost_link_timer expires or the local_link_status equals FAIL, the Discovery process returns to the FAULT state.

57.3.2.1.2 ACTIVE_SEND_LOCAL state

Once local_link_status is set to OK, the DTE evaluates local_oam_mode. A DTE configured in Active mode (see 57.2.9.1) sends Information OAMPDUs that only contain the Local Information TLV (see 57.5.2.1). This state is called ACTIVE_SEND_LOCAL. While in this state, the local DTE waits for Information OAMPDUs received from the remote DTE.

57.3.2.1.3 PASSIVE_WAIT state

A DTE configured in Passive mode (see 57.2.9.2) waits until receiving Information OAMPDUs with Local Information TLVs before sending any Information OAMPDUs with Local Information TLVs. This state is called PASSIVE_WAIT. By waiting until first receiving an Information OAMPDU with the Local Information TLV, a Passive DTE cannot complete the OAM Discovery process when connected to another Passive DTE.

57.3.2.1.4 SEND_LOCAL_REMOTE state

Once the local DTE has received an Information OAMPDU with the Local Information TLV from the remote DTE, the local DTE begins sending Information OAMPDUs that contain both the Local and Remote Information TLVs. This state is called SEND_LOCAL_REMOTE. If at any time the settings on either the local or remote DTE change resulting in the local OAM client becoming unsatisfied with the settings, the Discovery process returns to the SEND_LOCAL_REMOTE state.

57.3.2.1.5 SEND_LOCAL_REMOTE_OK state

If the local OAM client deems the settings on both the local and remote DTEs are acceptable, it enters the SEND_LOCAL_REMOTE_OK state. If at any time the settings on the local OAM client change resulting in the remote OAM client becoming unsatisfied with the settings, the OAM Discovery process returns to the SEND_LOCAL_REMOTE_OK state.

57.3.2.1.6 SEND_ANY state

Finally, once an OAMPDU has been received indicating the remote device is satisfied with the respective settings, the local device enters the SEND_ANY state. This is the expected normal operating state for OAM on fully operational links.

57.3.2.1.7 Sending Discovery status to peer

The Local Stable and Local Evaluating bits of the Flags field communicate the status of the local Discovery process to the peer. When the OAM Discovery process is started, the local DTE sets the Local Stable to 0 and Local Evaluating bits to 1 indicating OAM Discovery has not completed.

If, after learning of the remote OAM settings, the local OAM client determines it is unsatisfied it sets the Local Stable and Local Evaluating bits to 0 indicating Discovery cannot successfully complete. If the local OAM client is satisfied, the local DTE sets the Local Stable bit to 1 and Local Evaluating bit to 0 indicating the local OAM client is satisfied.

When Local Stable is set to 1 and Local Evaluating is set to 0 and Remote Stable is set to 1 and Remote Evaluating is set to 0 indicating that both OAM clients are satisfied, the OAM Discovery process has successfully completed and local_pdu is set to ANY. See Table 57–3 for more information.

57.3.2.2 Transmit

OAM sublayer entities shall implement the Transmit state diagram shown in Figure 57–6.

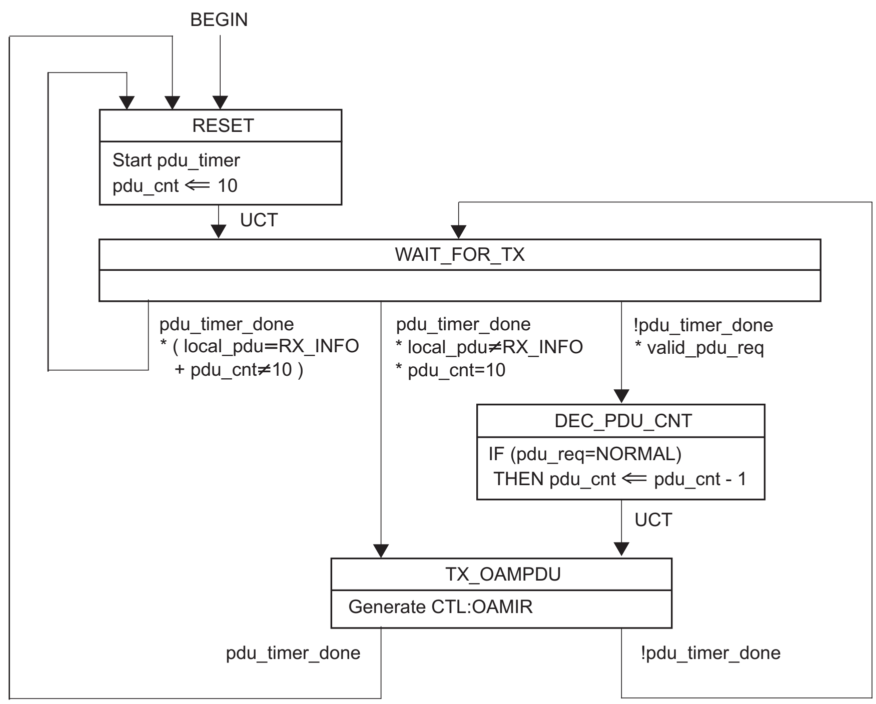


Figure 57–6—Transmit state diagram

57.3.2.2.1 RESET state

Upon initialization, the RESET state is entered. A one second timer is started called pdu_timer. The pdu_cnt variable is reset with a value of ten, the maximum number of OAMPDUs that may be sent in one second. Following RESET, the WAIT_FOR_TX state is entered.

57.3.2.2.2 WAIT_FOR_TX state

While in the WAIT_FOR_TX state, the Transmit process waits for the occurrence of one of three conditions. These three conditions are summarized below:

a) Expiration of pdu_timer:
   1) With one or more OAMPDUs sent within the last second
   2) Without any OAMPDUs being sent within the last second and without a valid pending request to send an OAMPDU
b) Valid request to send an OAMPDU present

57.3.2.2.3 Expiration of pdu_timer

While in the WAIT_FOR_TX state, if the pdu_timer expires and one or more OAMPDUs have been sent within the last second, the Transmit process transitions to the RESET state. If, however, the pdu_timer expires and no OAMPDUs have been sent within the last second and there is no valid request to send an OAMPDU present, the Transmit process transitions to the TX_OAMPDU state sending an Information OAMPDU. This prevents the Discovery process from restarting. If local_pdu is set to LF_INFO, the Transmit process ensures the Information OAMPDU has the Link Fault bit of the Flags field set and has no Information TLVs in the Data field.

If, however, the OAM sublayer entity is configured to not send any OAMPDUs, as indicated by the local_pdu variable set to RX_INFO, the Transmit function will simply restart the pdu_timer by returning to the RESET state.

57.3.2.2.4 Valid request to send an OAMPDU

While in the WAIT_FOR_TX state, if a valid request to send an OAMPDU is present, the Transmit process transmits the requested OAMPDU in the TX_OAMPDU state. If the Flags field of the OAMPDU to be sent does not contain any critical link events, the pdu_cnt variable is decremented in the DEC_PDU_CNT state. A valid request is either one of the following:

a) An OAMPDU.request service primitive from the OAM client with the local_pdu variable set to INFO or ANY and pdu_cnt not equal to zero.
b) An OAM_CTL.request service primitive from the OAM client with one or more critical event parameters set and the local_pdu variable set to ANY. When the local_pdu variable is set to ANY, the Discovery process has completed and is in the SEND_ANY state. The Discovery process needs to complete before critical events, other than Link Fault, may be sent to the peer OAM entity.

57.3.2.2.5 TX_OAMPDU state

The TX_OAMDPU state generates the CTL:OAMI.request service primitive, which requests the transmission of an OAMPDU to the Multiplexer process. After generating the request, the Transmit process returns to the RESET state if the pdu_timer is expired or the WAIT_FOR_TX state if the pdu_timer has not expired.

57.3.2.2.6 Transmit rules

The following rules govern the generation of the CTL:OAMIR service primitive:

a) While local_pdu is set to LF_INFO, only Information OAMPDUs with the Link Fault bit of the Flags field set and without any Information TLVs shall be generated.
b) While local_pdu is set to RX_INFO, CTL:OAMIR service primitives shall not be generated.
c) While local_pdu is set to INFO, only Information OAMPDUs shall be generated.
d) While local_pdu is set to ANY:
    1) An OAM_CTL.request service primitive with one or more of the critical link event parameters set shall generate a CTL:OAMIR service primitive, requesting the transmission of an Information OAMPDU with the appropriate bit(s) of the Flags field set.
    2) An OAMPDU.request service primitive shall generate a CTL:OAMIR service primitive, requesting the transmission of the particular OAMPDU.

57.3.2.3 Receive rules

CTL:OAMII service primitives indicate a received OAMPDU and in turn generate an OAMPDU.indication service primitive to the OAM client entity subject to the following rules:

a) When local_pdu is not set to ANY, Information OAMPDUs shall be passed to the OAM client and non-Information OAMPDUs are discarded.

b) When local_pdu is set to ANY, all OAMPDUs, including those with unknown Code fields shall be passed to the OAM client.[3] It is anticipated that the OAM client will ignore unknown or unsupported OAMPDUs.

57.3.3 Multiplexer

OAM sublayer entities shall implement the Multiplexer state diagram shown in Figure 57–7.

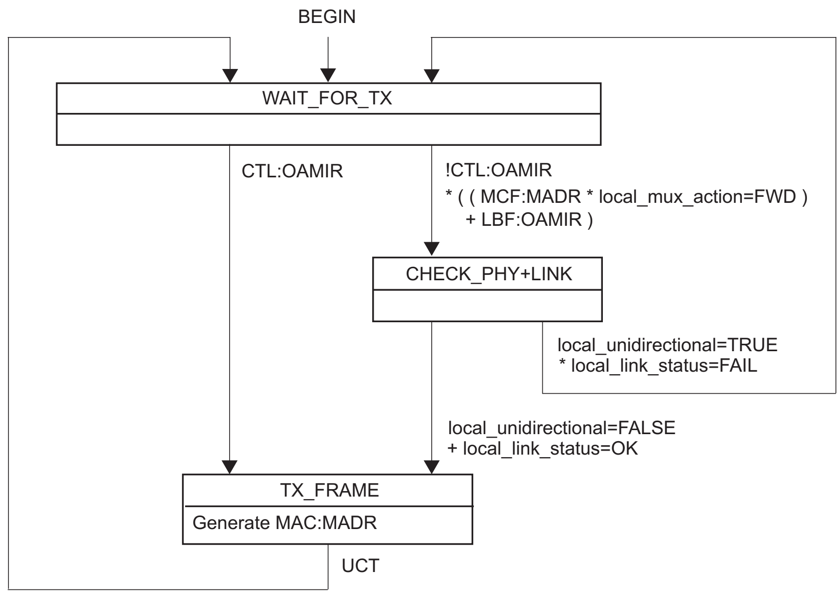


Figure 57–7—Multiplexer state diagram

57.3.3.1 WAIT_FOR_TX state

Upon initialization, the WAIT_FOR_TX state is entered. While in the WAIT_FOR_TX state, the Multiplexer waits for the occurrence of one of two conditions. These two conditions are summarized below:

a) Valid request to send an OAMPDU present
b) Valid request to forward a MAC client frame or loop back frame from Parser

57.3.3.1.1 Valid request to send an OAMPDU

While in the WAIT_FOR_TX state, if a request to send an OAMPDU is present, the Multiplexer function transmits the requested OAMPDU in the TX_FRAME state.

57.3.3.1.2 Valid request to forward or loop back frame

While in the WAIT_FOR_TX state, if a valid request to forward or loop back a frame is present and no request to send an OAMPDU is present, the Multiplexer will then check the status of the underlying physical layer and unidirectional configuration (in the CHECK_PHY+LINK state) and either transmit the frame in the TX_FRAME state or simply return to the WAIT_FOR_TX state.

[3]The behaviour of the OAM sublayer is different in this regard from the behaviour of the MAC Control sublayer (see Clauses 31 and 64).

A valid request to forward a frame from the superior sublayer is indicated by the variable MCF:MADR with the Multiplexer configured to forward frames as indicated by the local_mux_action variable set to FWD. A request to loop back a frame from the Parser function is indicated by the variable LBF:OAMIR. When either request occurs, the local_unidirectional variable needs to be FALSE or the local_link_status variable needs to be OK in order for the frame to be sent to the subordinate sublayer via the TX_FRAME state. Since only Information OAMPDUs with the Link Fault critical link event indication set and no Information TLVs are sent on a unidirectional link, the status of the link is evaluated to ensure the same behaviour as devices that do not support the optional Unidirectional OAM capability. When the local_link_status variable is OK, the MAC client frame will be transmitted regardless of the Unidirectional OAM capability or setting (see 57.2.12).

57.3.3.2 TX_FRAME state

Once the Multiplexer process reaches the TX_FRAME state, it shall provide transparent pass-through of frames submitted by the superior sublayer, the Transmit process and the Parser process. The transmission of an OAMPDU shall not affect the transmission of a frame that has been submitted to the subordinate sublayer (i.e., the MAC's TransmitFrame function is synchronous, and is never interrupted). After the frame has been sent to the subordinate sublayer, the Multiplexer process returns to the WAIT_FOR_TX state.

57.3.4 Parser

OAM sublayer entities shall implement the Parser state diagram shown in Figure 57–8.

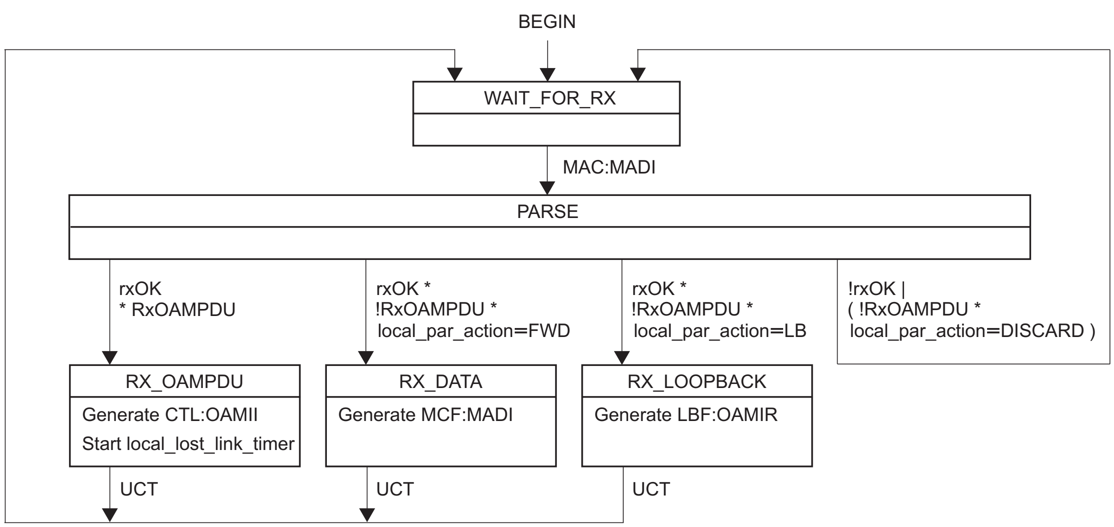


Figure 57–8—Parser state diagram

The Parser decodes frames received from the subordinate sublayer, passes OAMPDUs to the Control function, MAC client frames to the superior sublayer and loop back frames to the Multiplexer function. After reset, the Parser function enters the WAIT_FOR_RX state. The reception of a frame is detected when the MAC:MADI service primitive occurs. When a frame is received, the Parser function enters the PARSE state.

57.3.4.1 Reception of OAMPDU

The RX_OAMPDU state is entered when the receive frame is identified as an OAMPDU. Received OAMPDUs are sent to the OAM Control function via the CTL:OAMII service primitive. Following the receive rules in 57.3.2.3, the OAM Control function then passes the received OAMPDU to the OAM client. In addition, the local_lost_link_timer is reset. The Parser function then returns to the WAIT_FOR_RX state.

57.3.4.2 Reception of non-OAMPDUs

Received non-OAMPDUs are handled according to the setting of the local_par_action parameter. Refer to 57.2.11 for a complete description of OAM remote loopback operation and the local_par_action variable.

57.3.4.2.1 Reception of non-OAMPDU in FWD mode

The RX_DATA state is entered if the frame is determined to not be an OAMPDU and the local_par_action variable is set to FWD. The received frame is passed up to the superior sublayer via the MCF:MADI service primitive. The Parser then returns to the WAIT_FOR_RX state.

57.3.4.2.2 Reception of non-OAMPDU in LB mode

The RX_LOOPBACK state is entered if the frame is determined to not be an OAMPDU and the local_par_action parameter is set to LB. The received loopback frame is passed to the Multiplexer function via the LBF:OAMIR service primitive to be looped back to the remote DTE. After the frame is passed to the Multiplexer function, the Parser function returns to the WAIT_FOR_RX state.

57.3.4.2.3 Reception of non-OAMPDU in DISCARD mode

If the local_par_action parameter is set to DISCARD, the Parser function simply returns to the WAIT_FOR_RX state.

57.4 OAMPDUs

57.4.1 Ordering and representation of octets

All OAMPDUs comprise an integral number of octets. When the encoding of (an element of) an OAMPDU is depicted in a diagram:

a) Octets are transmitted from top to bottom.
b) Within an octet, bits are shown with bit 0 to the left and bit 7 to the right.
c) When consecutive octets are used to represent a binary number, the octet transmitted first has the more significant value.
d) When consecutive octets are used to represent a MAC address, the least significant bit of the first octet is assigned the value of the first bit of the MAC address, the next most significant bit the value of the second bit of the MAC address, and so on for all the octets of the MAC address.

When the encoding of an element of an OAMPDU is depicted in a table, the least significant bit is bit 0.

The bit/octet ordering of any Organizationally Unique Identifier (OUI) field within an OAMPDU is identical to the bit/octet ordering of the OUI portion of the DA/SA. Additional detail defining the format of OUIs can be found in IEEE Std 802-2001 Clause 9.

57.4.2 Structure

OAMPDUs are basic frames; they shall not be tagged (see Clause 3). The OAMPDU structure shall be as shown in Figure 57–9.

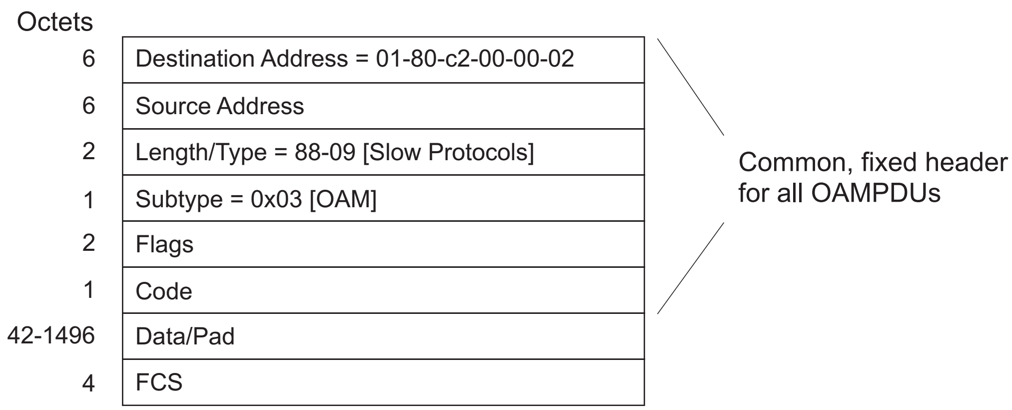


Figure 57–9—OAMPDU frame structure

OAMPDUs shall have the following fields:

a) ***Destination Address*** (DA). The DA in OAMPDUs is the Slow_Protocols_Multicast address. Its use and encoding are specified in Annex 43B.
b) ***Source Address*** (SA). The SA in OAMPDUs carries the individual MAC address associated with the port through which the OAMPDU is transmitted.
c) ***Length/Type***. OAMPDUs are always Type encoded, and carry the Slow_Protocols_Type field value. The use and encoding of this type is specified in Annex 43B.
d) ***Subtype***. The Subtype field identifies the specific Slow Protocol being encapsulated. OAMPDUs carry the Subtype value 0x03.
e) ***Flags***. The Flags field contains status bits as defined in 57.4.2.1.
f) ***Code***. The Code field identifies the specific OAMPDU. The use and encoding of this field is specified in Table 57–4.
g) ***Data/Pad***. This field contains the OAMPDU data and any necessary pad. Implementations shall support OAMPDUs at least minFrameSize in length.
h) ***FCS***. This field is the Frame Check Sequence, as defined in Clause 4.

57.4.2.1 Flags field

The Flags field is encoded as individual bits within two octets as shown in Table 57–3. Additional diagnostic information may be sent using the Event Notification OAMPDU.

Table 57–3—Flags field

Bit(s)	Name	Description
15:7	*Reserved*	Reserved bits shall be set to zero when sending an OAMPDU, and should be ignored on reception for compatibility with future use of reserved bits.
6	Remote Stable	When remote_state_valid is set to TRUE, the Remote Stable and Remote Evaluating values shall be a copy of the last valid received Local Stable and Local Evaluating values from the remote OAM peer. Otherwise, the Remote Stable and Remote Evaluating bits shall be set to 0.
5	Remote Evaluating	

Table 57–3—Flags field *(continued)*

Bit(s)	Name	Description
4	Local Stable	Local Stable and Local Evaluating form a two-bit encoding shown below: 4:3 0x0 = Local DTE Unsatisfied, Discovery can not complete 0x1 = Local DTE Discovery process has not completed 0x2 = Local DTE Discovery process has completed 0x3 = Reserved. This value shall not be sent. If the value 0x3 is received, it should be ignored and not change the last received value.
3	Local Evaluating	
2	Critical Event	1 = A critical event has occurred. 0 = A critical event has not occurred.
1	Dying Gasp	1 = An unrecoverable local failure condition has occurred. 0 = An unrecoverable local failure condition has not occurred.
0	Link Fault	The PHY has detected a fault has occurred in the receive direction of the local DTE (e.g., link, Physical layer). 1 = Local device's receive path has detected a fault. 0 = Local device's receive path has not detected a fault.

NOTE—The definition of the specific faults comprising the Critical Event, Dying Gasp, and Link Fault flags is implementation specific and beyond the scope of this standard.

57.4.2.2 Code field

The value of the Code field is set by the Transmit process in the Control function for Information OAMPDUs it generates. The OAM client sets the Code field for all OAMPDUs it generates. Table 57–4 contains the defined OAMPDU codes.

Table 57–4—OAMPDU codes

Code	OAMPDU	Comment	Source
00	Information	Communicates local and remote OAM information.	OAM client / OAM sublayer
01	Event Notification	Alerts remote DTE of link event(s).	OAM client
02	Variable Request	Requests one or more specific MIB variables.	OAM client
03	Variable Response	Returns one or more specific MIB variables.	OAM client
04	Loopback Control	Enables/disables OAM remote loopback.	OAM client
05-FD	*Reserved*	*Reserved*	OAM client
FE	Organization Specific	Reserved for Organization Specific Extensions, distinguished by Organizationally Unique Identifier	OAM client
FF	*Reserved*	*Reserved*	OAM client

57.4.3 OAMPDU descriptions

The local OAM sublayer communicates with the remote OAM sublayer via OAMPDUs. OAMPDUs are identified with a specific code. OAMPDUs are formatted as compliant IEEE 802.3 frames, where the IEEE 802.3 frame header format is described in Clause 3. OAMPDUs are further defined, as shown in Figure 57–9, to include a Subtype field, a Flags field, and a Code field following the IEEE 802.3 defined Length/Type field. The Data field begins in a fixed location within the OAMPDU. The Data field contents are unique to the particular OAMPDU. The following sections provide a detailed description of each

OAMPDU and its corresponding Data field. All received OAMPDUs, including those with reserved Code fields, are passed to the OAM client. OAMPDUs with reserved Code field values shall not be transmitted.

57.4.3.1 Information OAMPDU

The Information OAMPDU, identified by the Code field 0x00, is used to send OAM state information to the remote DTE. The Information OAMPDU frame structure shall be as depicted in Figure 57–10.

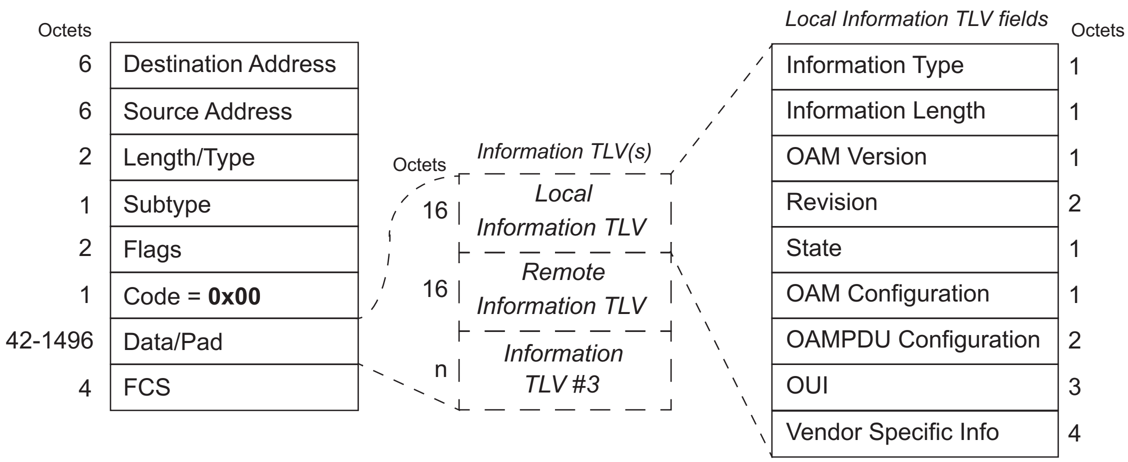


Figure 57–10—Information OAMPDU frame structure

When local_pdu is set to LF_INFO, the Information OAMPDU Data field shall not have any Information TLVs. When local_pdu is not set to LF_INFO, the Information OAMPDU Data field shall consist of the Local Information TLV (see 57.5.2.1) immediately following the Code field. In addition, if the Discovery state diagram variable remote_state_valid is TRUE, the Data field shall also contain the Remote Information TLV (see 57.5.2.2), immediately following the Local Information TLV and may also contain other Information TLVs found in Table 57–6.

57.4.3.2 Event Notification OAMPDU

The optional Event Notification OAMPDU, identified with the Code field set to 0x01, is used to alert the remote DTE of link events introduced in 57.2.10.2. The Event Notification OAMPDU frame structure shall be as depicted in Figure 57–11.

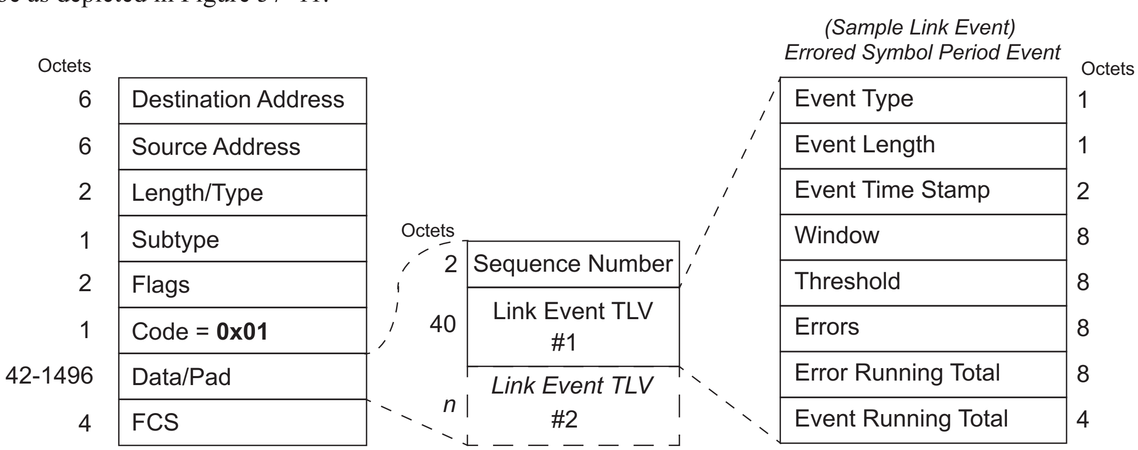


Figure 57–11—Event Notification OAMPDU frame structure

The first two octets of the Data field shall contain a Sequence Number, encoded as a 16-bit unsigned integer. As described in 57.2.3, the OAM client may send duplicate Event Notification OAMPDUs to increase the likelihood the remote DTE receives a particular event. The OAM client increments the Sequence Number for each unique Event Notification OAMPDU formed by the OAM client. A particular Event Notification OAMPDU may be sent multiple times with the same sequence number. It is recommended that any duplicate Event Notification OAMPDUs follow its original without a different, intervening Event Notification OAMPDU. A duplicate Event Notification OAMPDU should not be transmitted if a new Event Notification OAMPDU has already followed the original OAMPDU. Any particular event can be signaled in only one unique Event Notification OAMPDU (though that OAMPDU may be transmitted multiple times). Upon receiving an Event Notification OAMPDU, the OAM client compares the Sequence Number with the last received Sequence Number. If equal, the current event is a duplicate and is ignored by the OAM client.

Following the Sequence Number field, the Data field shall contain one or more optional Link Event TLVs which may provide useful information for troubleshooting events and faults. Link Event TLVs are defined in 57.5.3.

57.4.3.3 Variable Request OAMPDU

The optional Variable Request OAMPDU, identified with a Code field of 0x02, is used to request one or more MIB variables from the remote DTE. The Variable Request OAMPDU frame structure shall be as depicted in Figure 57–12.

The Variable Request OAMPDU Data field shall contain one or more Variable Descriptors. Variable Descriptors are defined in 57.6.1.

.

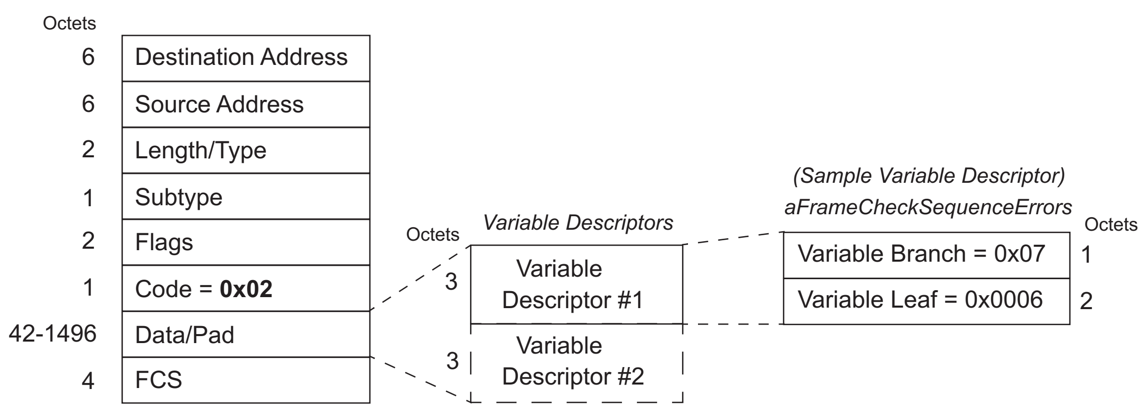


Figure 57–12—Variable Request OAMPDU frame structure

57.4.3.4 Variable Response OAMPDU

The optional Variable Response OAMPDU, identified with the Code field of 0x03, is used to return one or more MIB variables. The Variable Response OAMPDU frame structure shall be as depicted in Figure 57–13.

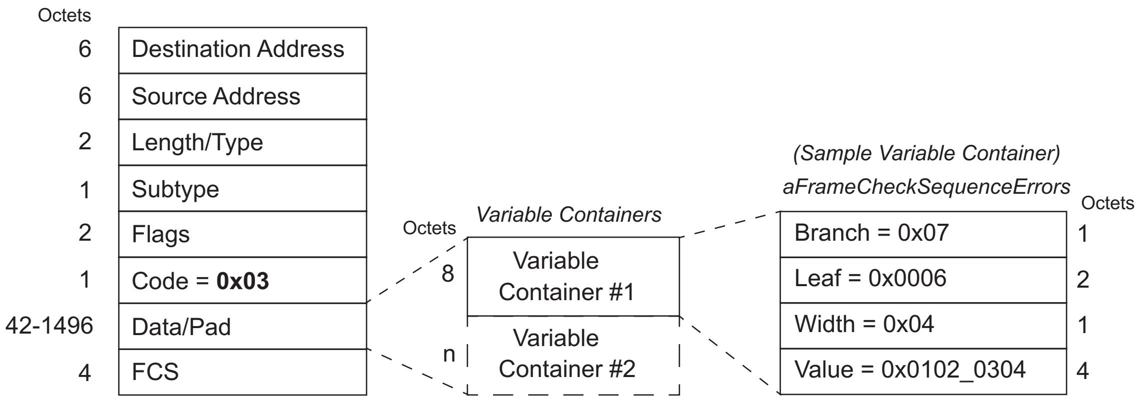


Figure 57–13—Variable Response OAMPDU frame structure

The Variable Response OAMPDU Data field shall contain one or more Variable Containers. Variable Containers are defined in 57.6.2. A Variable Response OAMPDU needs to be sent by the OAM client within one second of receipt of a Variable Request OAMPDU. If a DTE is unable to retrieve one or more variables, it needs to respond within one second and indicate the appropriate error(s) as found in Table 57–17. If a DTE is unable to retrieve one or more attributes within a package or object, it needs to either a) return the appropriate Variable Indication for the particular attribute(s) and return all other requested variables or b) return a Variable Indication for the entire package or object.

57.4.3.5 Loopback Control OAMPDU

The optional Loopback Control OAMPDU, identified with the Code field set to 0x04, is used to control the remote DTE's OAM remote loopback state. The Loopback Control OAMPDU frame structure shall be as depicted in Figure 57–14.

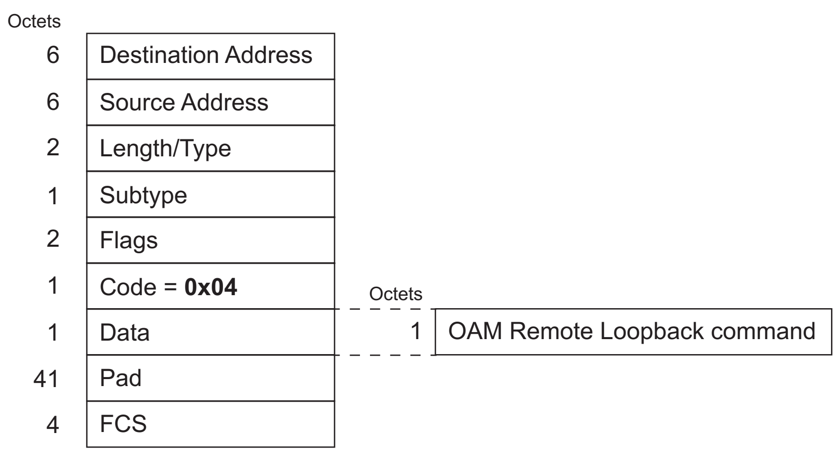


Figure 57–14—Loopback Control OAMPDU frame structure

The Loopback Control OAMPDU Data field shall consist of an OAM remote loopback command. Table 57–5 lists the defined OAM remote loopback commands.

Table 57–5—OAM remote loopback commands

Command	Description
0x00	*Reserved - shall not be transmitted, should be ignored on reception by OAM client*
0x01	Enable OAM Remote Loopback
0x02	Disable OAM Remote Loopback
0x03-0xFF	*Reserved - shall not be transmitted, should be ignored on reception by OAM client*

For a complete description of OAM remote loopback refer to 57.2.11.

57.4.3.6 Organization Specific OAMPDU

The optional Organization Specific OAMPDU, identified with the Code field set to 0xFE, is used for organization specific extensions. The Organization Specific OAMPDU frame structure shall be as depicted in Figure 57–15.

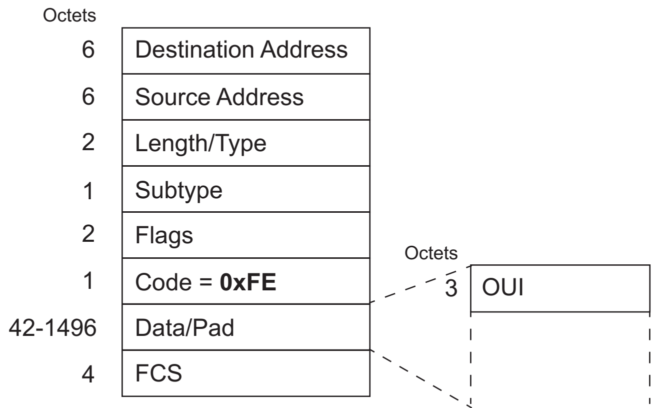


Figure 57–15—Organization Specific OAMPDU frame structure

The first three octets of the Organization Specific OAMPDU Data field shall contain the Organizationally Unique Identifier (OUI).[4] The format and function of the rest of the Organization Specific OAMPDU Data field is dependent on OUI value and is beyond the scope of this standard.

57.5 OAM TLVs

57.5.1 Parsing

The OAM client parses OAM TLVs. All OAM TLVs contain a single octet Type field and a single octet Length field. The Length field encompasses the entire TLV including the Type and Length fields. TLV processing should follow these recommendations:

a) Detection of a TLV type 0x00 should indicate there are no more TLVs to process (the length and value of the Type 0x00 TLV can be ignored).
b) TLVs with lengths 0x00 or 0x01 should be considered invalid, and the OAMPDU should be considered to have no more TLVs.
c) TLVs with unknown or unexpected types should be ignored.
d) If the length of a TLV is less than that defined for the Type, that TLV should be ignored and the rest of the frame may be ignored. If the length of a TLV is greater than that defined for the Type, the expected fields of the TLV should be processed, and the remainder of the frame after the TLV should also be processed.

[4]Interested applicants should contact the IEEE Standards Department, Institute of Electrical and Electronics Engineers, http://standards.ieee.org/regauth/index.html, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA.

e) If a TLV length indicates that the TLV extends beyond the frame (e.g., the length cannot fit into the frame given its length and starting point), then the TLV should be ignored.

57.5.2 Information TLVs

This subclause contains the definitions for Information TLVs. Information TLVs are found in Information OAMPDUs. Table 57–6 contains the defined Information TLVs.

Table 57–6—Information TLV types

Type	Description
0x00	*End of TLV marker*
0x01	Local Information
0x02	Remote Information
0x03-0xFD	*Reserved - shall not be transmitted, should be ignored on reception by OAM client*
0xFE	Organization Specific Information
0xFF	*Reserved - shall not be transmitted, should be ignored on reception by OAM client*

The following subclauses describe the defined Information TLVs.

57.5.2.1 Local Information TLV

The Local Information TLV shall have the following fields:

a) ***Information Type*** = *Local Information*. This one-octet field indicates the nature of the data carried in this TLV-tuple. The encoding of this field is found in Table 57–6.
b) ***Information Length***. The one-octet field indicates the length (in octets) of this TLV-tuple. Local Information TLV uses a length value of 16 (0x10).
c) ***OAM Version***. This one-octet field indicates the version supported by the DTE. This field shall contain the value 0x01 to claim compliance with Version 1 of this protocol.
d) ***Revision.*** This two-octet field indicates the current revision of the Information TLV. The value of this field shall start at zero and be incremented each time something in the Information TLV changes. Upon reception of an Information TLV from a peer, an OAM client may use this field to decide if it needs to be processed (an Information TLV that is identical to the previous Information TLV doesn't need to be parsed as nothing in it has changed).
e) ***State***. This one-octet field contains OAM state information and shall be as shown in Table 57–7.
f) ***OAM Configuration***. This one-octet field contains OAM configuration variables and shall be as shown in Table 57–8.
g) ***OAMPDU Configuration***. This two-octet field contains OAMPDU configuration variables and shall be as shown in Table 57–9 and encoded as specified in 57.4.1 (c).
h) ***OUI***. This three-octet field contains the 24-bit Organizationally Unique Identifier and shall be as shown in Table 57–10.
i) ***Vendor Specific Information***. This four-octet field contains the Vendor Specific Information field and shall be as shown in Table 57–11.

Table 57–7—State field

Bit(s)	Name	Description
7:3	*Reserved*	In Local Information TLVs, reserved bits shall be set to zero when sending an OAMPDU, and should be ignored on reception for compatibility with future use of reserved bits.
2	Multiplexer Action	0 = Device is forwarding non-OAMPDUs to the lower sublayer (local_mux_action = FWD). 1 = Device is discarding non-OAMPDUs (local_mux_action = DISCARD).
1:0	Parser Action	00 = Device is forwarding non-OAMPDUs to higher sublayer (local_par_action = FWD). 01 = Device is looping back non-OAMPDUs to the lower sublayer (local_par_action = LB). 10 = Device is discarding non-OAMPDUs (local_par_action = DISCARD). 11 = Reserved. In Local Information TLVs, this value shall not be sent. If the value 11 is received, it should be ignored and not change the last received value.

Table 57–8—OAM Configuration field

Bit(s)	Name	Description
7:5	*Reserved*	In Local Information TLVs, reserved bits shall be set to zero when sending an OAMPDU, and should be ignored on reception for compatibility with future use of reserved bits.
4	Variable Retrieval	1 = DTE supports sending Variable Response OAMPDUs. 0 = DTE does not support sending Variable Response OAMPDUs.
3	Link Events	1 = DTE supports interpreting Link Events. 0 = DTE does not support interpreting Link Events.
2	OAM Remote Loopback Support	1 = DTE is capable of OAM remote loopback mode. 0 = DTE is not capable of OAM remote loopback mode.
1	Unidirectional Support	1 = DTE is capable of sending OAMPDUs when the receive path is non-operational. 0 = DTE is not capable of sending OAMPDUs when the receive path is non-operational.
0	OAM Mode	1 = DTE configured in Active mode. 0 = DTE configured in Passive mode.

Table 57–9—OAMPDU Configuration field

Bit(s)	Name	Description
15:11	*Reserved*	In Local Information TLVs, reserved bits shall be set to zero when sending an OAMPDU, and should be ignored on reception for compatibility with future use of reserved bits.
10:0	Maximum OAMPDU Size	11-bit field which represents the largest OAMPDU, in octets, supported by the DTE. This value is compared to the remote's Maximum PDU Size and the smaller of the two is used. Prior to exchanging and agreeing upon a Maximum OAMPDU Size, a DTE sends minFrameSize OAMPDUs. The minimum value is minFrameSize / 8. The maximum value is equal to maxUntaggedFrameSize, which is defined in 4.4.2. The OAMPDUs transmitted by a DTE are limited by both the local DTE's Maximum OAMPDU size and the remote DTE's Maximum OAMPDU size as indicated in received Information OAMPDUs. A DTE is not required to change the value transmitted in this field after negotiation to an agreed size as each end will dynamically determine the correct maximum OAMPDU size to use.

Table 57–10—OUI field

Bit(s)	Name	Description
23:0	OUI [a]	24-bit Organizationally Unique Identifier of the vendor.

[a]Organizations that have previously received OUIs from the IEEE Registration Authority should use one of their allocated OUIs consistently as the company identifier.

Table 57–11—Vendor Specific Information field

Bit(s)	Name	Description
31:0	Vendor Specific Information	32-bit identifier that may be used to differentiate a vendor's product models/versions.

57.5.2.2 Remote Information TLV

The Remote Information TLV shall be a copy of the last received Local Information TLV from the remote OAM peer, with the exception of the Information Type field. The encoding of this field is found in Table 57–6.

57.5.2.3 Organization Specific Information TLV

The Organization Specific Information TLV shall have the following fields:

a) ***Information Type*** = *Organization Specific Information*. This one-octet field indicates the nature of the data carried in this TLV-tuple. The encoding of this field is found in Table 57–6.
b) ***Information Length***. This one-octet field indicates the length (in octets) of this TLV_tuple. The length of an Organization Specific Information TLV is unspecified.
c) ***Organizationally Unique Identifier.*** This three-octet field shall contain the 24-bit Organizationally Unique Identifier (OUI).
d) ***Organization Specific Value***. This field indicates the value of the Organization Specific Information TLV. This field's length and contents are unspecified.

57.5.3 Link Event TLVs

This subclause contains the definitions for Link Event TLVs. Link Event TLVs are found in Event Notification OAMPDUs. Table 57–12 contains the defined Link Event TLVs.

Table 57–12—Link Event TLV type value

Type	Description
0x00	*End of TLV marker*
0x01	Errored Symbol Period Event
0x02	Errored Frame Event
0x03	Errored Frame Period Event
0x04	Errored Frame Seconds Summary Event
0x05-0xFD	*Reserved - shall not be transmitted, should be ignored on reception by OAM client*
0xFE	Organization Specific Event
0xFF	*Reserved - shall not be transmitted, should be ignored on reception by OAM client*

The following subclauses describe the defined Link Event TLVs.

57.5.3.1 Errored Symbol Period Event TLV

The Errored Symbol Period Event TLV counts the number of symbol errors that occurred during the specified period. The period is specified by the number of symbols that can be received in a time interval on the underlying physical layer. This event is generated if the symbol error count is equal to or greater than the specified threshold for that period.

The Errored Symbol Period Event TLV shall have the following fields:

a) ***Event Type*** = *Errored Symbol Period Event*. This one-octet field indicates the nature of the information carried in this TLV tuple. The encoding of this field is found in Table 57–12.
b) ***Event Length***. This one-octet field indicates the length (in octets) of this TLV_tuple. Errored Symbol Period Event uses a length value of 40 (0x28).
c) ***Event Time Stamp.*** This two-octet field indicates the time reference when the event was generated, in terms of 100 ms intervals, encoded as a 16-bit unsigned integer. When this event is generated by the local DTE and if Clause 30 is present, this maps to 30.3.6.1.35. When received from the remote DTE and if Clause 30 is present, this maps to 30.3.6.1.42.
d) ***Errored Symbol Window***. This eight-octet field indicates the number of symbols in the period, encoded as a 64-bit unsigned integer. When this event is generated by the local DTE and if Clause 30 is present, this maps to 30.3.6.1.35. When this event is received from the remote DTE and if Clause 30 is present, this maps to 30.3.6.1.42.
    1) The default value is the number of symbols in one second for the underlying physical layer.
    2) The lower bound is the number of symbols in one second for the underlying physical layer.
    3) The upper bound is the number of symbols in one minute for the underlying physical layer.
e) ***Errored Symbol Threshold***. This eight-octet field indicates the number of errored symbols in the period is required to be equal to or greater than in order for the event to be generated, encoded as a 64-bit unsigned integer. When generated by the local DTE and if Clause 30 is present, this maps to 30.3.6.1.35. When received from the remote DTE and if Clause 30 is present, this maps to 30.3.6.1.42.
    1) The default value is one symbol error.
    2) The lower bound is zero symbol errors.
    3) The upper bound is unspecified.
f) ***Errored Symbols***. This eight-octet field indicates the number of symbol errors in the period, encoded as a 64-bit unsigned integer. When this event is generated by the local DTE and if Clause 30 is present, this maps to 30.3.6.1.35. When this event is received from the remote DTE and if Clause 30 is present, this maps to 30.3.6.1.42.
g) ***Error Running Total***. This eight-octet field indicates the sum of symbol errors since the OAM sublayer was reset. When this event is generated by the local DTE and if Clause 30 is present, this maps to 30.3.6.1.35. When this event is received from the remote DTE and if Clause 30 is present, this maps to 30.3.6.1.42.
h) ***Event Running Total***. This four-octet field indicates the number of Errored Symbol Period Event TLVs that have been generated since the OAM sublayer was reset, encoded as a 32-bit unsigned integer. When this event is generated by the local DTE and if Clause 30 is present, this maps to 30.3.6.1.35. When this event is received from the remote DTE and if Clause 30 is present, this maps to 30.3.6.1.42.

This event is generated at the end of the event window rather than when the threshold is crossed.

57.5.3.2 Errored Frame Event TLV

The Errored Frame Event TLV counts the number of errored frames detected during the specified period. The period is specified by a time interval. This event is generated if the errored frame count is equal to or greater than the specified threshold for that period. Errored frames are frames that had transmission errors as detected at the Media Access Control sublayer as communicated via the reception_status parameter of the MA_DATA.indication service primitive. Refer to 4.2.9 for the definition of detectable transmission errors during reception.

The Errored Frame Event TLV shall have the following fields:

a) ***Event Type*** = *Errored Frame Event*. This one-octet field indicates the nature of the information carried in this TLV tuple. The encoding of this field is found in Table 57–12.
b) ***Event Length***. This one-octet field indicates the length (in octets) of this TLV_tuple. Errored Frame Event uses a length value of 26 (0x1A).
c) ***Event Time Stamp.*** This two-octet field indicates the time reference when the event was generated, in terms of 100 ms intervals, encoded as a 16-bit unsigned integer. When this event is generated by the local DTE and if Clause 30 is present, this maps to 30.3.6.1.37. When received from the remote DTE and if Clause 30 is present, this maps to 30.3.6.1.43.
d) ***Errored Frame Window***. This two-octet field indicates the duration of the period in terms of 100 ms intervals, encoded as a 16-bit unsigned integer. When this event is generated by the local DTE and if Clause 30 is present, this maps to 30.3.6.1.37. When this event is received from the remote DTE and if Clause 30 is present, this maps to 30.3.6.1.43.
    1) The default value is one second.
    2) The lower bound is one second.
    3) The upper bound is one minute.
e) ***Errored Frame Threshold***. This four-octet field indicates the number of detected errored frames in the period is required to be equal to or greater than in order for the event to be generated, encoded as a 32-bit unsigned integer. When this event is generated by the local DTE and if Clause 30 is present, this maps to 30.3.6.1.37. When this event is received from the remote DTE and if Clause 30 is present, this maps to 30.3.6.1.43.
    1) The default value is one frame error.
    2) The lower bound is zero frame errors.
    3) The upper bound is unspecified.
f) ***Errored Frames***. This four-octet field indicates the number of detected errored frames in the period, encoded as a 32-bit unsigned integer. When this event is generated by the local DTE and if Clause 30 is present, this maps to 30.3.6.1.37. When this event is received from the remote DTE and if Clause 30 is present, this maps to 30.3.6.1.43.
g) ***Error Running Total***. This eight-octet field indicates the sum of errored frames that have been detected since the OAM sublayer was reset. When this event is generated by the local DTE and if Clause 30 is present, this maps to 30.3.6.1.37. When this event is received from the remote DTE and if Clause 30 is present, this maps to 30.3.6.1.43.
h) ***Event Running Total***. This four-octet field indicates the number of Errored Frame Event TLVs that have been generated since the OAM sublayer was reset, encoded as a 32-bit unsigned integer. When this event is generated by the local DTE and if Clause 30 is present, this maps to 30.3.6.1.37. When this event is received from the remote DTE and if Clause 30 is present, this maps to 30.3.6.1.43.

This event is generated at the end of the event window rather than when the threshold is crossed.

57.5.3.3 Errored Frame Period Event TLV

The Errored Frame Period Event TLV counts the number of errored frames detected during the specified period. The period is specified by a number of received frames. This event is generated if the errored frame count is greater than or equal to the specified threshold for that period (for example, if the errored frame count is greater than or equal to 10 for the last 1,000,000 frames received). Errored frames are frames that had transmission errors as detected at the Media Access Control sublayer as communicated via the reception_status parameter of the MA_DATA.indication service primitive. Refer to 4.2.9 for the definition of detectable transmission errors during reception.

The Errored Frame Period Event TLV shall have the following fields:

a) ***Event Type*** = *Errored Frame Period Event*. This one-octet field indicates the nature of the information carried in this TLV tuple. The encoding of this field is found in Table 57–12.
b) ***Event Length***. This one-octet field indicates the length (in octets) of this TLV_tuple. Errored Frame Period Event uses a length value of 28 (0 x 1C).
c) ***Event Time Stamp.*** This two-octet field indicates the time reference when the event was generated, in terms of 100 ms intervals, encoded as a 16-bit unsigned integer. When this event is generated by the local DTE and if Clause 30 is present, this maps to 30.3.6.1.39. When received from the remote DTE and if Clause 30 is present, this maps to 30.3.6.1.44.
d) ***Errored Frame Window***. This four-octet field indicates the duration of period in terms of frames, encoded as a 32-bit unsigned integer. When this event is generated by the local DTE and if Clause 30 is present, this maps to 30.3.6.1.39. When this event is received from the remote DTE and if Clause 30 is present, this maps to 30.3.6.1.44.
    1) The default value is the number of minFrameSize frames that can be received in one second on the underlying physical layer.
    2) The lower bound is the number of minFrameSize frames that can be received in 100 ms on the underlying physical layer.
    3) The upper bound is the number of minFrameSize frames that can be received in one minute on the underlying physical layer.
e) ***Errored Frame Threshold***. This four-octet field indicates the number of errored frames in the period is required to be equal to or greater than in order for the event to be generated, encoded as a 32-bit unsigned integer. When this event is generated by the local DTE and if Clause 30 is present, this maps to 30.3.6.1.39. When this event is received from the remote DTE and if Clause 30 is present, this maps to 30.3.6.1.44.
    1) The default value is one frame error.
    2) The lower bound is zero frame errors.
    3) The upper bound is unspecified.
f) ***Errored Frames***. This four-octet field indicates the number of frame errors in the period, encoded as a 32-bit unsigned integer. When this event is generated by the local DTE and if Clause 30 is present, this maps to 30.3.6.1.39. When this event is received from the remote DTE and if Clause 30 is present, this maps to 30.3.6.1.44.
g) ***Error Running Total***. This eight-octet field indicates the sum of frame errors that have been detected since the OAM sublayer was reset. When this event is generated by the local DTE and if Clause 30 is present, this maps to 330.3.6.1.39. When this event is received from the remote DTE and if Clause 30 is present, this maps to 30.3.6.1.44.
h) ***Event Running Total***. This four-octet field indicates the number of Errored Frame Period Event TLVs that have been generated since the OAM sublayer was reset, encoded as a 32-bit unsigned integer. When this event is generated by the local DTE and if Clause 30 is present, this maps to 30.3.6.1.39. When this event is received from the remote DTE and if Clause 30 is present, this maps to 30.3.6.1.44.

This event is generated at the end of the event window rather than when the threshold is crossed.

57.5.3.4 Errored Frame Seconds Summary Event TLV

The Errored Frame Seconds Summary Event TLV counts the number of errored frame seconds that occurred during the specified period. The period is specified by a time interval. This event is generated if the number of errored frame seconds is equal to or greater than the specified threshold for that period. An errored frame second is a one second interval wherein at least one frame error was detected. Errored frames are frames that had transmission errors as detected at the Media Access Control sublayer and communicated via the reception_status parameter of the MA_DATA.indication service primitive. Refer to 4.2.9 for the definition of detectable transmission errors during reception.

The Errored Frame Seconds Summary Event TLV shall have the following fields:

a) ***Event Type*** = *Errored Frame Seconds Summary Event*. This one-octet field indicates the nature of the information carried in this TLV tuple. The encoding of this field is found in Table 57–12.
b) ***Event Length***. This one-octet field indicates the length (in octets) of this TLV_tuple. Errored Frame Seconds Summary Event uses a length value of 18 (0x12).
c) ***Event Time Stamp.*** This two-octet field indicates the time reference when the event was generated, in terms of 100 ms intervals, encoded as a 16-bit unsigned integer. When this event is generated by the local DTE and if Clause 30 is present, this maps to 30.3.6.1.41. When received from the remote DTE and if Clause 30 is present, this maps to 30.3.6.1.45.
d) ***Errored Frame Seconds Summary Window***. This two-octet field indicates the duration of the period in terms of 100 ms intervals, encoded as a 16-bit unsigned integer. When this event is generated by the local DTE and if Clause 30 is present, this maps to 30.3.6.1.41. When this event is received from the remote DTE and if Clause 30 is present, this maps to 30.3.6.1.45.
    1) The default value is 60 seconds.
    2) The lower bound is 10 seconds.
    3) The upper bound is 900 seconds.
e) ***Errored Frame Seconds Summary Threshold***. This two-octet field indicates the number of errored frame seconds in the period is required to be equal to or greater than in order for the event to be generated, encoded as a 16-bit unsigned integer. When this event is generated by the local DTE and if Clause 30 is present, this maps to 30.3.6.1.41. When this event is received from the remote DTE and if Clause 30 is present, this maps to 30.3.6.1.45.
    1) The default value is one errored second.
    2) The lower bound is zero errored seconds.
    3) The upper bound is unspecified.
f) ***Errored Frame Seconds Summary***. This two-octet field indicates the number of errored frame seconds in the period, encoded as a 16-bit unsigned integer. When this event is generated by the local DTE and if Clause 30 is present, this maps to 30.3.6.1.41. When this event is received from the remote DTE and if Clause 30 is present, this maps to 30.3.6.1.45.
g) ***Error Running Total***. This four-octet field indicates the sum of errored frame seconds that have been detected since the OAM sublayer was reset. When this event is generated by the local DTE and if Clause 30 is present, this maps to 30.3.6.1.41. When this event is received from the remote DTE and if Clause 30 is present, this maps to 30.3.6.1.45.
h) ***Event Running Total***. This four-octet field indicates the number of Errored Frame Seconds Summary Event TLVs that have been generated since the OAM sublayer was reset, encoded as a 32-bit unsigned integer.When this event is generated by the local DTE and if Clause 30 is present, this maps to 30.3.6.1.41. When this event is received from the remote DTE and if Clause 30 is present, this maps to 30.3.6.1.45.

This event is generated at the end of the event window rather than when the threshold is crossed.

57.5.3.5 Organization Specific Event TLVs

The optional Organization Specific Event TLV may be used by organizations to define extensions to the Event mechanisms in this clause. Organization Specific Event TLVs shall have the following fields:

a) ***Event Type*** = *Organization Specific Event*. This one-octet field indicates the nature of the information carried in this TLV tuple. The encoding of this field is found in Table 57–12.
b) ***Event Length***. This one-octet field indicates the length (in octets) of this TLV_tuple. The length of the Organization Specific Event is unspecified.
c) ***Organizationally Unique Identifier.*** This three-octet field shall contain a 24-bit Organizationally Unique Identifier.
d) ***Organization Specific Value***. This field indicates the value of the Organization Specific Event. This field's length and contents are unspecified.

57.6 Variables

MIB variables are queried through the use of Variable Request OAMPDUs and returned through the use of Variable Response OAMPDUs. Variable Request OAMPDUs, defined in 57.4.3.3, use data structures called Variable Descriptors (see 57.6.1). An OAM client may request one or more variables in each Variable Request OAMPDU.

Variable Response OAMPDUs, defined in 57.4.3.4, use data structures called Variable Containers (see 57.6.2). Each returned Variable Container resides within a single Variable Response OAMPDU. If a Variable Container does not fit within a Variable Response OAMPDU, an error code is returned. In returning requested variables, an OAM client generates at least one and perhaps additional Variable Response OAMPDUs per received Variable Request OAMPDU. The following sections describe the format of Variable Descriptors and Variable Containers.

See 57.6.3 for a description of the parsing rules for Variable Descriptors and Variable Containers.

57.6.1 Variable Descriptors

A Variable Descriptor is used to request MIB attributes, objects and packages and uses the CMIP protocol encodings as found in Annex 30A. The Variable Descriptor structure shall be as shown in Table 57–13.

Table 57–13—Variable Descriptor format

Octet(s)	Name	Description
1	Variable Branch	Derived from the CMIP protocol encodings in Annex 30A, Variable Branches may reference attributes, objects or packages. If an object or package is referenced, only the attributes within the object or package shall be found within the Variable Container. Actions shall not be found within Variable Containers.
2	Variable Leaf	The Variable Leaf field is derived from the CMIP protocol encodings in Annex 30A.

57.6.2 Variable Containers

Variable Containers are used to return MIB attributes, objects and packages. One or more Variable Containers may exist in the Data field of a Variable Response OAMPDU (see 57.4.3.4).

57.6.2.1 Format of Variable Containers when returning attributes

The Variable Container structure for an attribute shall be as shown in Table 57–14.

Table 57–14—Variable Container format when returning an attribute

Octet(s)	Name	Description
1	Variable Branch	Derived from the CMIP protocol encodings in Annex 30A, Variable Branches may reference attributes, objects or packages. If an object or package is referenced, only the attributes within the object or package shall be found within the Variable Container. Actions shall not be found within Variable Containers.
2	Variable Leaf	The Variable Leaf field is derived from the CMIP protocol encodings in Annex 30A.
1	Variable Width	When bit 7 = 1, bits 6:0 represent a Variable Indication. Refer to Table 57–17 for the encoding of bits 6:0. There is no Variable Value field when bit 7 = 1. When bit 7 = 0, bits 6:0 represent the length of the Variable Value field in octets. An encoding of 0x00 equals 128 octets. All other encodings represent actual lengths.
varies	Variable Value	The Variable Value field may be 1 to 128 octets in length. Its width is determined by the Variable Width field.

The first field is the one-octet Variable Branch field. The second field is the two-octet Variable Leaf field. See Table 57–16 for examples of Variable Branch and Variable Leaves. The third field is the dual purpose one-octet Variable Width field. This field either contains the actual width of the attribute or a Variable Indication providing information as to the reason this particular attribute could not be returned. See Table 57–17 for the defined Variable Indications. If the Variable Width field contains a width value, the fourth field is the Variable Value field, which contains the attribute. This field may be up to 128 octets in length. Octets of the attribute are ordered most significant first, followed by each successive octet. If the Variable Width field contains a Variable Indication, the Variable Value field does not exist.

57.6.2.2 Format of Variable Containers when returning packages and objects

The Variable Container structure for packages and objects shall be as shown in Table 57–15.

Table 57–15—Variable Container format when returning packages and objects

Octet(s)	Name	Description
1	Variable Branch	Derived from the CMIP protocol encodings in Annex 30A, Variable Branches may reference attributes, objects or packages. If an object or package is referenced, only the attributes within the object or package shall be found within the Variable Container. Actions shall not be found within Variable Containers.
2	Variable Leaf	The Variable Leaf field is derived from the CMIP protocol encodings in Annex 30A.
1	Variable Width	When bit 7 = 1, bits 6:0 represent a Variable Indication. Refer to Table 57–17 for the encoding of bits 6:0. There is no Variable Value field when bit 7 = 1. When bit 7 = 0, bits 6:0 represent the length of the Variable Value field in octets. An encoding of 0x00 equals 128 octets. All other encodings represent actual lengths.
varies	Variable Value	The Variable Value field may be 1 to 128 octets in length. Its width is determined by the Variable Width field.

A package is defined as a set of MIB attributes and/or actions. An object is a set of packages, which in turn are made up of MIB attributes and/or actions. Variable Containers provide an efficient method for returning packages and objects. Attributes within packages and objects are returned in the order those attributes are listed in Annex 30A.

The Variable Container structure for packages and objects is similar to the structure for attributes. The first field is the one-octet Variable Branch field for the specific package or object being returned. The second field is the two-octet Variable Leaf field for the specific package or object being returned. See Table 57–16 for examples of Variable Branch and Variable Leaves. The third field is the dual purpose one-octet Variable Width field of the first attribute within the package or object being returned. This field either contains the actual width of the attribute or a Variable Indication providing information as to the reason this particular attribute could not be returned. See Table 57–17 for the defined Variable Indications. If the Variable Width field contains a width value, the fourth field is the Variable Value field, which contains the first attribute of the package or object being returned. This field may be up to 128 octets in length. Octets of the attribute are ordered most significant first, followed by each successive octet. If the Variable Width field contains a Variable Indication, the Variable Value field does not exist.

For each successive attribute within the package, the third field (Variable Width) and fourth field (Variable Value), if applicable, are repeated.

For each successive attribute within each successive package of the object, the third field (Variable Width) and fourth field (Variable Value), if applicable, are repeated.

57.6.3 Parsing

The OAM client parses Variable Descriptors and Variable Containers. All Variable Descriptors/Containers contain a one-octet Variable Branch field and a two-octet Variable Leaf field. Variable Descriptor/Container processing should follow these recommendations:

a) Detection of a Variable Branch field equal to 0x00 should indicate there are no more Variable Descriptors/Containers to process (subsequent fields can be ignored).
b) Variable Branch or Variable Leaf fields with unknown or unexpected values should be ignored.
c) If a Variable Width field indicates Variable Container extends beyond the frame (e.g., the length cannot fit into the frame given its length and starting point), then the Variable Container should be ignored.
d) Detection of a Variable Indication value equal to 0x40 should indicate there are no more attributes within the object to process.
e) Detection of a Variable Indication value equal to 0x60 should indicate there are no more objects within the package to process.

57.6.4 Variable Branch/Leaf examples

Table 57–16 contains a set of example branch and leaf values for attributes, packages and objects.

Table 57–16—Variable Branch/Leaf examples

Variable Type	Variable Name	Variable Branch	Variable Leaf
attribute	aFramesTransmittedOK	0x07	0x0002
attribute	aFramesReceivedOK	0x07	0x0005
package	pMandatory	0x04	0x0001
package	pRecommended	0x04	0x0002

Table 57–16—Variable Branch/Leaf examples *(continued)*

Variable Type	Variable Name	Variable Branch	Variable Leaf
object	oMACEntity	0x03	0x0001
object	oPHYEntity	0x03	0x0002

57.6.5 Variable Indications

If a DTE is unable to retrieve one or more variables, the Variable Container is used to return the appropriate Variable Indication for the particular variable(s). The Variable Indications are defined in Table 57–17.

Table 57–17—Variable indications

Coding	Indication
0x00	*Reserved - shall not be transmitted, should be ignored on reception by OAM client*
0x01	Length of requested Variable Container(s) exceeded OAMPDU data field.
0x02 to 0x1F	*Reserved—shall not be transmitted, should be ignored on reception by OAM client*
Attribute Indications	
0x20	Requested attribute was unable to be returned due to an undetermined error.
0x21	Requested attribute was unable to be returned because it is not supported by the local DTE.
0x22	Requested attribute may have been corrupted due to reset.
0x23	Requested attribute unable to be returned due to a hardware failure.
0x24	Requested attribute experienced an overflow error.
0x25 to 0x3F	*Reserved—shall not be transmitted, should be ignored on reception by OAM client*
Object Indications	
0x40	End of object indication.
0x41	Requested object was unable to be returned due to an undetermined error.
0x42	Requested object was unable to be returned because it is not supported by the local DTE.
0x43	Requested object may have been corrupted due to reset.
0x44	Requested object unable to be returned due to a hardware failure.
0x45 to 0x5F	*Reserved—shall not be transmitted, should be ignored on reception by OAM client*
Package Indications	
0x60	End of package indication.
0x61	Requested package was unable to be returned due to an undetermined error.
0x62	Requested package was unable to be returned because it is not supported by the local DTE.
0x63	Requested package may have been corrupted due to reset.
0x64	Requested package unable to be returned due to a hardware failure.
0x65 to 0x7F	*Reserved—shall not be transmitted, should be ignored on reception by OAM client*

57.7 Protocol implementation conformance statement (PICS) proforma for Clause 57, Operations, Administration, and Maintenance (OAM)[5]

57.7.1 Introduction

The supplier of a protocol implementation that is claimed to conform to Clause 57, Operations, Administration, and Maintenance (OAM), 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.

57.7.2 Identification

57.7.2.1 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).	

57.7.2.2 Protocol summary

Identification of protocol standard	IEEE Std 802.3-2005, Clause 57, Operations, Administration, and Maintenance (OAM)
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 802.3-2005.)	

Date of Statement	

57.7.2.3 Major capabilities/options

57.7.3 PICS proforma tables for Operation, Administration, and Maintenance (OAM)

57.7.3.1 Functional specifications

[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.

Item	Feature	Subclause/ Table	Value/Comment	Status	Support
OM	OAM object class	30.3.6		O	Yes [ ] No [ ]
CSI	OAM client service interfaces	57.2.5		M	Yes [ ]
ISI	Internal service interfaces	57.2.8		M	Yes [ ]
*ACTV	Active mode	57.2.9		O.1	Yes [ ] No [ ]
*PASS	Passive mode	57.2.9		O.1	Yes [ ] No [ ]
*LB	OAM remote loopback	57.2.11, Table 57–8		O	Yes [ ] No [ ]
UNI	Unidirectional operation	57.2.12, Table 57–8	Requires support for unidirectional operation as defined in Clause 66.	O	Yes [ ] No [ ]
*EVNT	Link Events	57.4.3.2, 57.5.3		O	Yes [ ] No [ ]
*VAR	Variable Retrieval	57.4.3.3, 57.4.3.4		O	Yes [ ] No [ ]
*OSP	Organization Specific OAMPDU	57.4.3.6		O	Yes [ ] No [ ]
*OSE	Organization Specific Events	57.5.3.5		O	Yes [ ] No [ ]
OSI	Organization Specific Information TLV	57.5.2.3		O	Yes [ ] No [ ]

Item	Feature	Subclause/ Table	Value/Comment	Status	Support
OFS1	Passive mode limited transmission	57.2.9.2	Cannot send Variable Request or Loopback Control OAMPDUs	PASS:M	Yes [ ] No [ ] N/A [ ]
OFS2	Discovery state diagram	57.3.2.1	Implemented as defined in Figure 57–5	M	Yes [ ]
OFS3	Transmit state diagram	57.3.2.2	Implemented as defined in Figure 57–6	M	Yes [ ]
OFS4	OAMPDU transmission when local_pdu is set to LF_INFO	57.3.2.2.6	Only Information OAMPDUs with Link Fault bit of Flags field and without Information TLVs can be transmitted	M	Yes [ ]
OFS5	OAMPDU transmission when local_pdu is set to RX_INFO	57.3.2.2.6	No OAMPDU transmission allowed	M	Yes [ ]
OFS6	OAMPDU transmission when local_pdu is set to INFO	57.3.2.2.6	Only Information OAMPDUs can be transmitted	M	Yes [ ]
	OAMPDU transmission when local_pdu is set to ANY:				
OFS7	OAM_CTL.request service primitive with one or more critical link event parameters	57.3.2.2.6	Requests transmission of Information OAMPDU with appropriate bits of Flags field set	M	Yes [ ]
OFS8	OAMPDU.request service primitive	57.3.2.2.6	Requests transmission of OAMPDU	M	Yes [ ]

Item	Feature	Subclause/ Table	Value/Comment	Status	Support
	OAMPDU Flags field reserved encodings				
OFS9	Remote Stable and Remote Evaluating bits	Table 57–3	Encoding of 0x3 is not transmitted	M	Yes [ ]
OFS10	Local Stable and Local Evaluating bits	Table 57–3	Encoding of 0x3 is not transmitted	M	Yes [ ]
OFS11	Reserved bits	Table 57–3	Reserved bits are zero on transmission	M	Yes [ ]
OFS12	OAMPDU Code field	57.4.2.2	Only defined Code field values are permitted in transmitted OAMPDUs	M	Yes [ ]
OFS13	OAMPDU reception when local_pdu is not set to ANY	57.3.2.3	Only Information OAMPDUs are sent to OAM client entity	M	Yes [ ]
OFS14	OAMPDU reception when local_pdu is set to ANY	57.3.2.3	All OAMPDUs are sent to OAM client entity	M	Yes [ ]
OFS15	Multiplexer state diagram	57.3.3	Implemented as defined in Figure 57–7	M	Yes [ ]
OFS16	Multiplexer transparent pass-through	57.3.3.2	Provide transparent pass-through of frames from superior sublayer to subordinate sublayer	M	Yes [ ]
OFS17	Effect of OAMPDU on a frame already submitted to subordinate sublayer	57.3.3.2	Has no effect	M	Yes [ ]
OFS18	Parser state diagram	57.3.4	Implemented as defined in Figure 57–8	M	Yes [ ]

57.7.3.2 Event Notification Generation and Reception

Item	Feature	Subclause/ Table	Value/Comment	Status	Support
EV1	Response to Critical Events	57.2.10.3	Set/clear Flag bits based on OAM_CTL.request service primitive	M	Yes [ ]
EV2	Critical Event reception	57.2.10.4	Indicated via Flags field of OAMPDU.indication service primitive	M	Yes [ ]
EV3	Link Event reception	57.2.10.4	Indicated via OAMPDU.indication service primitive with all received Event Notification OAMPDUs	EVNT:M	Yes [ ] N/A [ ]

57.7.3.3 OAMPDUs

Item	Feature	Subclause/ Table	Value/Comment	Status	Support
PDU1	Tagging	57.4.2	OAMPDUs cannot be tagged	M	Yes [ ]
PDU2	OAMPDU structure	57.4.2	As defined in Figure 57–9 and field definitions	M	Yes [ ]
PDU3	Minimum OAMPDU size	57.4.2	Support OAMPDUs minFrame-Size in length	M	Yes [ ]
PDU4	Information OAMPDU frame structure	57.4.3.1	Shown in Figure 57–10	M	Yes [ ]
PDU5	Information OAMPDU when local_pdu set to LF_INFO	57.4.3.1	Data field contains zero Information TLVs	M	Yes [ ]
	Information OAMPDU when local _pdu not set to LF_INFO				
PDU6	remote_state_valid=FALSE	57.4.3.1	Data field contains Local Information TLV	M	Yes [ ]
PDU7	remote_state_valid=TRUE	57.4.3.1	Data field contains Local and Remote Information TLVs	M	Yes [ ]
PDU8	Type values 0x03-0xFD	Table 57–6	Not to be sent	M	Yes [ ]
PDU9	Type value 0xFF	Table 57–6	Not to be sent	M	Yes [ ]
PDU10	Event Notification OAMPDU frame structure	57.4.3.2	Shown in Figure 57–11	EVNT:M	Yes [ ] N/A [ ]
PDU11	Event Notification OAMPDU Sequence Number	57.4.3.2	The first two bytes of the Data field contain a Sequence Number encoded as an unsigned 16-bit integer	EVNT:M	Yes [ ] N/A [ ]
PDU12	Event Notification OAMPDU Event(s)	57.4.3.2	Data field containing one or more Link Event TLVs following the Sequence Number	EVNT:M	Yes [ ] N/A [ ]
PDU13	Variable Request OAMPDU frame structure	57.4.3.3	Shown in Figure 57–12	VAR * ACTV:M	Yes [ ] No [ ] N/A [ ]
PDU14	Variable Request OAMPDU Data field	57.4.3.3	Data field contains one or more Variable Descriptors	VAR * ACTV:M	Yes [ ] N/A [ ]
PDU15	Variable Response OAMPDU frame structure	57.4.3.4	Shown in Figure 57–13	VAR:M	Yes [ ] N/A [ ]
PDU16	Variable Response OAMPDU Data field	57.4.3.4	Data field contains one or more Variable Containers	VAR:M	Yes [ ] N/A [ ]
PDU17	Loopback Control OAMPDU frame structure	57.4.3.5	Shown in Figure 57–14	!PASS * LB:M	Yes [ ] N/A [ ]
PDU18	Loopback Control OAMPDU Data field	57.4.3.5	Data field contains a single OAM Remote Loopback command from Table 57–5.	!PASS * LB:M	Yes [ ] N/A [ ]
PDU19	Command value 0x00	Table 57–5	Not to be sent	!PASS * LB:M	Yes [ ] N/A [ ]
PDU20	Command values 0x03-0xFF	Table 57–5	Not to be sent	!PASS * LB:M	Yes [ ] N/A [ ]
PDU21	Organization Specific OAMPDU frame structure	57.4.3.6	Shown in Figure 57–15	OSP:M	Yes [ ] N/A [ ]
PDU22	Organization Specific OAMPDU Organizationally Unique Identifier field	57.4.3.6	Contains 24-bit Organizationally Unique Identifier	OSP:M	Yes [ ] N/A [ ]

57.7.3.4 Local Information TLVs

Item	Feature	Subclause/ Table	Value/Comment	Status	Support
LIT1	Local Information TLV	57.5.2.1	Contains the following fields: Information Type, Information Length, OAM Version, Revision, State, OAM Configuration, OAMPDU Configuration, OUI, Vendor Specific Information	M	Yes [ ]
LIT2	Local Information TLV OAM Version field	57.5.2.1	Contains 0x01 to claim compliance to this specification	M	Yes [ ]
LIT3	Local Information TLV Revision Field	57.5.2.1	Starts at zero and incremented each time a Local Information TLV field changes.	M	Yes [ ]
LIT4	Local Information TLV State field	57.5.2.1	As defined in Table 57–7	M	Yes [ ]
LIT5	Local Information TLV State field Parser Action 0x3 value	57.5.2.1	Is not transmitted	M	Yes [ ]
LIT6	Reserved bits	Table 57–7	Reserved bits are zero on transmission	M	Yes [ ]
LIT7	Local Information TLV OAM Configuration field	57.5.2.1	As defined in Table 57–8	M	Yes [ ]
LIT8	Reserved bits	Table 57–8	Reserved bits are zero on transmission	M	Yes [ ]
LIT9	Local Information TLV OAMPDU Configuration field	57.5.2.1	As defined in Table 57–9	M	Yes [ ]
LIT10	Local Information TLV OUI field	57.5.2.1	As defined in Table 57–10	M	Yes [ ]
LIT11	Reserved bits	Table 57–9	Reserved bits are zero on transmission	M	Yes [ ]
LIT12	Local Information TLV Vendor Specific Information field	57.5.2.1	As defined in Table 57–11	M	Yes [ ]

57.7.3.5 Remote Information TLVs

Item	Feature	Subclause	Value/Comment	Status	Support
RIT1	Remote Information TLV	57.5.2.2	Contains the Information Type field specifying the Remote Information TLV Type value and all remaining fields are copied from the last received Local Information TLV from remote OAM peer	M	Yes [ ]

57.7.3.6 Organization Specific Information TLVs

Item	Feature	Subclause	Value/Comment	Status	Support
OIT1	Organization Specific Information TLV	57.5.2.3	Contains the following fields: Information Type, Information Length, OUI, Organization Specific Value	M	Yes [ ]
OIT2	Organization Specific Information TLV OUI field	57.5.2.3	Contains 24-bit OUI	M	Yes [ ]

57.7.4 Link Event TLVs

Item	Feature	Subclause/ Table	Value/Comment	Status	Support
ET1	Errored Symbol Period Event TLV structure	57.5.3.1	Contains the following fields: Event Type, Event Length, Event Time Stamp, Errored Symbol Window, Errored Symbol Threshold, Errored Symbols, Error Running Total, Event Running Total	EVNT:M	Yes [ ] N/A [ ]
ET2	Errored Frame Event TLV structure	57.5.3.2	Contains the following fields: Event Type, Event Length, Event Time Stamp, Errored Frame Window, Errored Frame Threshold, Errored Frames, Error Running Total, Event Running Total	EVNT:M	Yes [ ] N/A [ ]
ET3	Errored Frame Period Event TLV structure	57.5.3.3	Contains the following fields: Event Type, Event Length, Event Time Stamp, Errored Frame Window, Errored Frame Threshold, Errored Frames, Error Running Total, Event Running Total	EVNT:M	Yes [ ] N/A [ ]
ET4	Errored Frame Seconds Summary Event TLV structure	57.5.3.4	Contains the following fields: Event Type, Event Length, Event Time Stamp, Errored Frame Seconds Summary Window, Errored Frame Seconds Summary Threshold, Errored Frame Seconds Summary, Error Running Total, Event Running Total	EVNT:M	Yes [ ] N/A [ ]
ET5	Organization Specific Event TLV structure	57.5.3.5	Contains the following fields: Event Type, Event Length, Organizationally Unique Identifier, Organization Specific Value	EVNT * OSE:M	Yes [ ] N/A [ ]
ET6	Organization Specific Event Organizationally Unique Identifier field	57.5.3.5	Contains 24-bit Organizationally Unique Identifier	EVNT * OSE:M	Yes [ ] N/A [ ]
ET7	Type values 0x05 to 0xFD	Table 57–12	Not to be sent	EVNT:M	Yes [ ] N/A [ ]
ET8	Type value 0xFF	Table 57–12	Not to be sent	EVNT:M	Yes [ ] N/A [ ]

57.7.5 Variables Descriptors and Containers

Item	Feature	Subclause/ Table	Value/Comment	Status	Support
VAR1	Variable Descriptor structure	57.6.1	As defined in Table 57–13	VAR * ACTV:M	Yes [ ] N/A [ ]
	Variable Descriptor / Variable Branch				
VAR2	references attributes	57.6.1	If an object or package is referenced, only attributes can be found within Variable Container	VAR * ACTV:M	Yes [ ] N/A [ ]
VAR3	does not reference actions	57.6.1	Actions are not found in Variable Containers	VAR * ACTV:M	Yes [ ] N/A [ ]
VAR4	Variable Container structure for an attribute	57.6.2	As defined in Table 57–14	VAR:M	Yes [ ] N/A [ ]
	Variable Container / Variable Branch				
VAR5	references attributes	57.6.2	If an object or package is referenced, only attributes can be found within Variable Container	VAR:M	Yes [ ] N/A [ ]
VAR6	does not reference actions	57.6.2	Actions are not found in Variable Containers	VAR:M	Yes [ ] N/A [ ]
VAR7	Type value 0x00	Table 57–16	Not to be sent	VAR:M	Yes [ ] N/A [ ]
VAR8	Type values 0x02 to 0x1F	Table 57–16	Not to be sent	VAR:M	Yes [ ] N/A [ ]
VAR9	Type values 0x25 to 0x2F	Table 57–16	Not to be sent	VAR:M	Yes [ ] N/A [ ]
VAR10	Type values 0x45 to 0x5F	Table 57–16	Not to be sent	VAR:M	Yes [ ] N/A [ ]
VAR11	Type values 0x65 to 0x7F	Table 57–16	Not to be sent	VAR:M	Yes [ ] N/A [ ]

58. Physical Medium Dependent (PMD) sublayer and medium, type 100BASE-LX10 (Long Wavelength) and 100BASE-BX10 (BiDirectional Long Wavelength)

58.1 Overview

The 100BASE-LX10 and 100BASE-BX10 PMD sublayers provide point-to-point 100 Mb/s Ethernet links over a pair of single-mode fibers or an individual single-mode fiber, respectively, up to at least 10 km. They complement 100BASE-TX (twisted-pair cable, see Clause 25) and 100BASE-FX (multimode fiber, see Clause 26).

This clause specifies the 100BASE-LX10 PMD and the 100BASE-BX10 PMDs for operation over single-mode fiber. A PMD is connected to the 100BASE-X PMA of 66.1, and to the medium through the MDI. A PMD is optionally combined with the management functions that may be accessible through the management interface defined in Clause 22 or by other means.

Table 58–1 shows the primary attributes of each PMD type.

Table 58–1—Classification of 100BASE-LX10 and 100BASE-BX10

Description	100BASE-LX10	100BASE-BX10-D	100BASE-BX10-U	Unit
Fiber type	B1.1, B1.3 SMF[a]			
Number of fibers	2	1		
Typical transmit direction	Any	Downstream	Upstream	
Nominal transmit wavelength	1310	1550	1310	nm
Minimum range	0.5 m to 10 km			
Maximum channel insertion loss[b]	6.0	5.5	6.0	dB

[a]Specified in IEC 60793-2
[b]At the nominal wavelength

A 100BASE-LX10 link uses 100BASE-LX10 PMDs at each end while a 100BASE-BX10 link uses a 100BASE-BX10-D PMD at one end and a 100BASE-BX10-U PMD at the other. Typically, the 1550 nm band is used to transmit away from the center of the network (“downstream”) and the 1310 nm band towards the center (“upstream”), although this arrangement, or the notion of hierarchy, is not required. The suffixes “D” and “U” indicate the PMDs at each end of a link which transmit in these directions and receive in the opposite directions.

Two optional temperature ranges are defined; see 58.8.4 for further details. Implementations may be declared as compliant over one or both complete ranges, or not so declared (compliant over parts of these ranges or another temperature range).

58.1.1 Goals and objectives

The following are the objectives of 100BASE-LX10 and 100BASE-BX10:

a) Point-to-point on optical fiber
b) 100BASE-X up to at least 10 km over single-mode fiber (SMF)
c) BER better than or equal to 10^{-12} at the PHY service interface.

58.1.2 Positioning of this PMD set within the IEEE 802.3 architecture

Figure 58–1 depicts the relationships of the PMD (shown shaded) with other sublayers and the ISO/IEC Open System Interconnection (OSI) reference model.

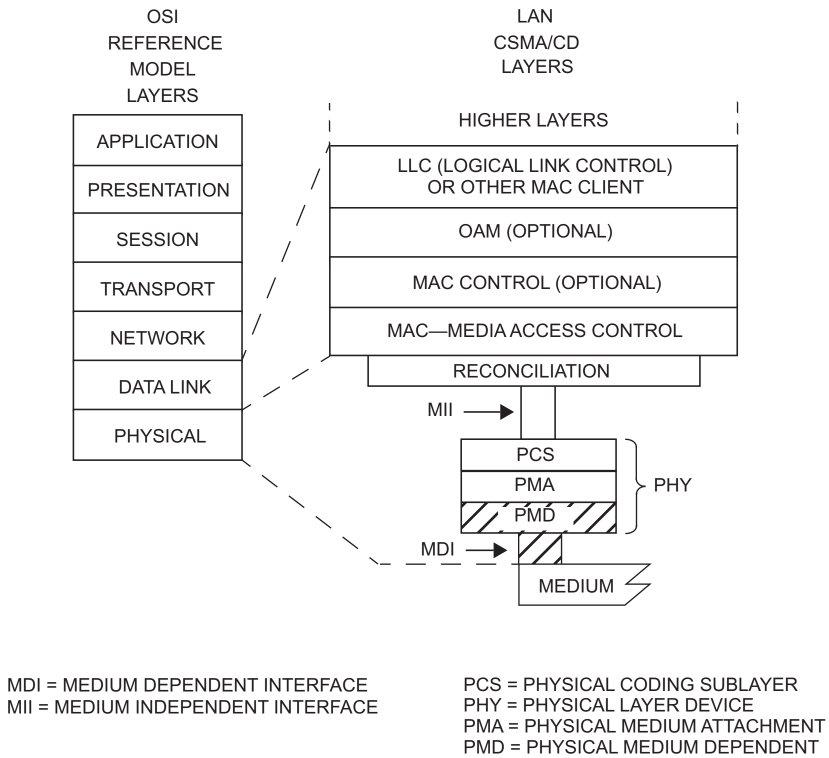


Figure 58–1—100BASE-LX10 and 100BASE-BX10 PMDs relationship to the ISO/IEC Open Systems Interconnection (OSI) reference model and the IEEE 802.3 CSMA/CD LAN model

58.1.3 Terminology and conventions

The following list contains references to terminology and conventions used in this clause:

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 shown referenced in the format [Bn], see Annex A.

Introduction to 100 Mb/s baseband networks, see Clause 21.

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

58.1.4 Physical Medium Dependent (PMD) sublayer service interface

The following specifies the services provided by the 100BASE-LX10 and 100BASE-BX10 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 NRZI encoded 4B/5B bit streams between the PMA and PMD entities. The PMD translates the serialized data of the PMA to and from signals suitable for the specified medium.

The following primitives are defined:

PMD_UNITDATA.request

PMD_UNITDATA.indication

PMD_SIGNAL.indication

58.1.4.1 Delay constraints

Delay requirements which affect the PMD layer are specified in 24.6. Of the budget, up to 12 ns is reserved for each of the transmit and receive functions of the PMD to account for those cases where the PMD includes a pigtail.

58.1.4.2 PMD_UNITDATA.request

This primitive defines the transfer of a serial data stream from the 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 where the tx_bit parameter can take one of two values: ONE or ZERO. The PMA continuously sends the appropriate stream of bits to the PMD for transmission on the medium, at a nominal 125 MBd signaling speed. Upon receipt of this primitive, the PMD converts the specified stream of bits into the appropriate signals at the MDI.

58.1.4.3 PMD_UNITDATA.indication

This primitive defines the transfer of data from the PMD to the 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 where the rx_bit parameter can take one of two values: ONE or ZERO. The PMD continuously sends a stream of bits to the PMA corresponding to the signals received from the MDI.

58.1.4.4 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.

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.

58.2 PMD functional specifications

The 100BASE-X PMDs perform the transmit and receive functions that convey data between the PMD service interface and the MDI.

58.2.1 PMD block diagram

The PMD sublayer is defined at the four reference points shown in Figure 58–2. Two points, TP2 and TP3, are compliance points. TP1 and TP4 are reference points for use by implementors. The optical transmit signal is defined at the output end of a patch cord (TP2), between 2 and 5 m in length, of single-mode fiber. Unless specified otherwise, all transmitter measurements and tests defined in 58.7 are made at TP2. The optical receive signal is defined at the output of the fiber optic cabling (TP3) connected to the receiver. Unless specified otherwise, all receiver measurements and tests defined in 58.7 are made at TP3.

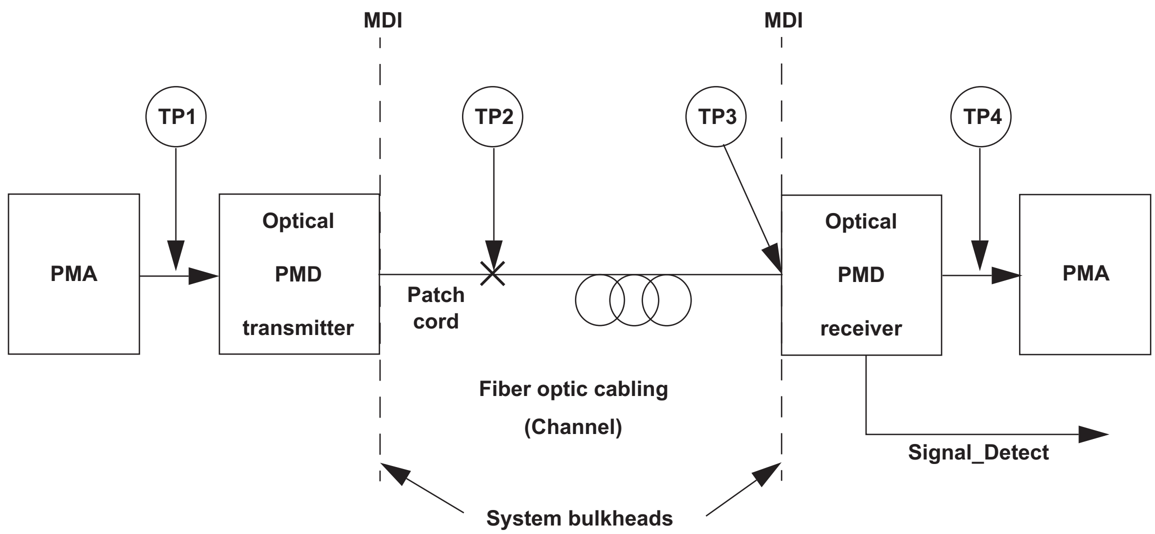


Figure 58–2—100BASE-X block diagram

The electrical specifications of the PMD service interface (TP1 and TP4) are not system compliance points (these are not readily testable in a system implementation). It is expected that in many implementations, TP1 and TP4 will be common between 100BASE-LX10, 100BASE-BX10-D, 100BASE-BX10-U, and 100BASE-FX (multimode fiber, see Clause 26).

58.2.2 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 this clause. The higher optical power level should correspond to tx_bit = ONE.

NOTE—Because the NRZI coding distinguishes between a transition and no transition on the line, as opposed to 0 and 1, an inverted signal is usable.

58.2.3 PMD receive function

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

NOTE—Because the NRZI coding distinguishes between a transition and no transition on the line, as opposed to 0 and 1, an inverted signal is usable.

58.2.4 100BASE-LX10 and 100BASE-BX10 signal detect function

The PMD signal detect function 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 optical signal presence.

The value of the SIGNAL_DETECT parameter for 100BASE-LX10 and 100BASE-BX10 shall be generated according to the conditions defined in Table 58–2. The PMD receiver is not required to verify whether a compliant 100BASE-LX10 signal or 100BASE-BX10 signal is being received. This standard imposes no response time requirements on the generation of the SIGNAL_DETECT parameter.

Table 58–2—100BASE-LX10 and 100BASE-BX10 SIGNAL_DETECT value definition

Receive conditions		SIGNAL_DETECT value
100BASE-LX10	**100BASE-BX10**	
Average input optical power ≤ Signal detect threshold (min) in Table 58–4	Average input optical power ≤ Signal detect threshold (min) in Table 58–6	FAIL
Average input optical power ≥ Receiver sensitivity (max) in Table 58–4 with a compliant 100BASE-LX10 signal input	Average input optical power ≥ Receiver sensitivity (max) in Table 58–6 with a compliant 100BASE-BX10 signal input at the specified receiver wavelength	OK
All other conditions		Unspecified

As an unavoidable consequence of the requirements for the setting of the SIGNAL_DETECT parameter, implementations must provide adequate margin between the input optical power level at which the SIGNAL_DETECT parameter is set to OK, and the inherent noise level of the PMD due to cross talk, power supply noise, etc.

Various implementations of the signal detect function are permitted by this standard, including implementations that generate the SIGNAL_DETECT parameter values in response to the amplitude of the modulation of the optical signal and implementations that respond to the average optical power of the modulated optical signal.

58.3 PMD to MDI optical specifications for 100BASE-LX10

The operating range for 100BASE-LX10 is defined in Table 58–1. A 100BASE-LX10 compliant transceiver operates over the media types listed in Table 58–1 according to the specifications described in 58.9. A transceiver which exceeds the operational range requirement while meeting all other optical specifications is considered compliant.

NOTE—In this subclause and 58.4, the specifications for OMA have been derived from extinction ratio and average launch power (minimum) or receiver sensitivity (maximum). The calculation is explained in 58.7.6.

58.3.1 Transmitter optical specifications

The 100BASE-LX10 transmitter's signaling speed, operating wavelength, spectral width, average launch power, extinction ratio, return loss tolerance, OMA, eye and TDP shall meet the specifications defined in Table 58–3 per measurement techniques described in 58.7. Its $RIN_{12}OMA$ should meet the value listed in Table 58–3 per measurement techniques described in 58.7.7.

Table 58–3—100BASE-LX10 transmit characteristics

Description	Type B1.1, B1.3 SMF	Unit
Transmitter type[a]	Longwave laser	
Signaling speed (range)	125 ± 50 ppm	MBd
Operating wavelength range[b]	1260 to 1360	nm
RMS spectral width (max)	7.7	nm
Average launch power (max)	–8	dBm
Average launch power (min)	–15	dBm
Average launch power of OFF transmitter (max)	–45	dBm
Extinction ratio (min)	5	dB
$RIN_{12}OMA$[c] (max)	–110	dB/Hz
Optical return loss tolerance (max)	12	dB
Launch OMA (min)	–14.8 (33.1)	dBm (μW)
Transmitter eye mask definition {X1, X2, X3, Y1, Y2, Y3, Y4}	{0.18, 0.29, 0.35, 0.35, 0.38, 0.4, 0.55}	UI
Transmitter and dispersion penalty (max)	4.5	dB
Decision timing offsets for transmitter and dispersion penalty (min)	±1.6	ns

[a]The nominal transmitter type is not intended to be a requirement on the source type, and any transmitter meeting the transmitter characteristics specified may be substituted for the nominal transmitter type.
[b]The great majority of the transmitted spectrum must fall within the operating wavelength range, see 58.7.2.
[c]The $RIN_{12}OMA$ recommendation is informative not mandatory.

58.3.2 Receiver optical specifications

The 100BASE-LX10 receiver's signaling speed, operating wavelength, damage, overload, sensitivity, reflectivity and signal detect shall meet the specifications defined in Table 58–4 per measurement techniques defined in 58.7. Its stressed receive characteristics should meet the values listed in Table 58–4 per measurement techniques described in 58.7.11. The receiver sensitivity includes the extinction ratio penalty.

A compliant receiver may be shown to deliver an error ratio lower than that in the table at the received power shown in the table, or shown to deliver an error ratio lower than 10^{-10} at a received power 1 dB lower than the value in the table. Sensitivity measurement is described in 58.7.10. Similarly, stressed receiver conformance may be shown for the error ratio and power shown in the table, or for 10^{-10} and 1 dB lower power. The 10^{-10} limits are more demanding but can be verified more accurately with reasonable test times.

Table 58–4—100BASE-LX10 receive characteristics

Description	Type B1.1, B1.3 SMF	Unit
Signaling speed (range)	125 ± 50 ppm	MBd
Operating wavelength range	1260 to 1360	nm
Bit error ratio (max)	10^{-12}	

Table 58–4—100BASE-LX10 receive characteristics *(continued)*

Description	Type B1.1, B1.3 SMF	Unit
Average received power[a] (max)	–8	dBm
Receiver sensitivity (max)	–25	dBm
Receiver sensitivity as OMA (max)	–24.8 (3.3)	dBm (μW)
Receiver reflectance[b] (max)	–12	dB
Stressed receiver sensitivity[c]	–20.1	dBm
Stressed receiver sensitivity as OMA (max)	–19.9 (10.2)	dBm (μW)
Vertical eye-closure penalty[d] (min)	3.7	dB
Stressed eye jitter (min)	0.25	UI pk-pk
Jitter corner frequency	20	kHz
Sinusoidal jitter limits for stressed receiver conformance test (min, max)	0.05, 0.15	UI
Signal detect threshold (min)	–45	dBm

[a]The receiver shall be able to tolerate, without damage, continuous exposure to an optical input signal having a power level equal to the average received power (max) plus at least 1 dB.
[b]See 1.4 for definition of reflectance.
[c]The stressed receiver sensitivity is optional.
[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.

58.4 PMD to MDI optical specifications for 100BASE-BX10

The operating range for 100BASE-BX10 is defined in Table 58–1. A 100BASE-BX10-D or 100BASE-BX10-U compliant transceiver operates over the media types listed in Table 58–1 according to the specifications described in 58.9. A transceiver which exceeds the operational range requirement while meeting all other optical specifications is considered compliant.

NOTE—In this subclause and 58.3, the specifications for OMA have been derived from extinction ratio and average launch power (minimum) or receiver sensitivity (maximum). The calculation is explained in 58.7.6.

58.4.1 Transmit optical specifications

The 100BASE-BX10 transmitters' signaling speed, operating wavelength, spectral width, average launch power, extinction ratio, return loss tolerance, OMA, eye and TDP shall meet the specifications defined in Table 58–5 per measurement techniques described in 58.7. Its $RIN_{12}OMA$ should meet the value listed in Table 58–5 per measurement techniques described in 58.7.7.

Table 58–5—100BASE-BX10 transmit characteristics

Description	100BASE-BX10-D	100BASE-BX10-U	Unit
Nominal transmitter type[a]	Longwave laser		
Signaling speed (range)	125 ± 50 ppm		MBd
Operating wavelength range[b]	1480 to 1580	1260 to 1360	nm
RMS spectral width (max)	4.6	7.7	nm

Table 58–5—100BASE-BX10 transmit characteristics *(continued)*

Description	100BASE-BX10-D	100BASE-BX10-U	Unit
Average launch power (max)	–8		dBm
Average launch power (min)	–14		dBm
Average launch power of OFF transmitter (max)	–45		dBm
Extinction ratio (min)	6.6		dB
$RIN_{12}OMA$[c] (max)	–110		dB/Hz
Optical return loss tolerance (max)	12		dB
Launch OMA (min)	–12.9 (51.0)		dBm (µW)
Transmitter eye mask definition {X1, X2, X3, Y1, Y2, Y3, Y4}	{0.18, 0.29, 0.35, 0.35, 0.38, 0.4, 0.55}		UI
Transmitter and dispersion penalty (max)	4.5		dB
Decision timing offsets for transmitter and dispersion penalty (min)	±1.6		ns

[a]The nominal transmitter type is not intended to be a requirement on the source type, and any transmitter meeting the transmitter characteristics specified may be substituted for the nominal transmitter type.
[b]The great majority of the transmitted spectrum must fall within the operating wavelength range, see 58.7.2.
[c]The $RIN_{12}OMA$ recommendation is informative not mandatory.

58.4.2 Receiver optical specifications

The 100BASE-BX10 receivers' signaling speed, operating wavelength, damage, overload, sensitivity, reflectivity and signal detect shall meet the specifications defined in Table 58–6 per measurement techniques defined in 58.7. Its stressed receive characteristics should meet the values listed in Table 58–6 per measurement techniques described in 58.7.11. The receiver sensitivity includes the extinction ratio penalty.

Table 58–6—100BASE-BX10 receive characteristics

Description	100BASE-BX10-D	100BASE-BX10-U	Unit
Signaling speed (range)	125 ± 50 ppm		MBd
Operating wavelength range[a]	1260 to 1360	1480 to 1600	nm
Bit error ratio (max)	10^{-12}		
Average received power[b] (max)	–8		dBm
Receiver sensitivity (max)	–28.2		dBm
Receiver sensitivity as OMA (max)	–27.1 (1.94)		dBm (µW)
Receiver reflectance[c] (max)	–12		dB
Stressed receiver sensitivity[d]	–23.3		dBm
Stressed receiver sensitivity as OMA (max)	–22.3 (6.0)		dBm (µW)
Vertical eye-closure penalty[e] (min)	3.8		dB

Table 58–6—100BASE-BX10 receive characteristics *(continued)*

Description	100BASE-BX10-D	100BASE-BX10-U	Unit
Stressed eye jitter (min)	0.25		UI pk-pk
Jitter corner frequency	20		kHz
Sinusoidal jitter limits for stressed receiver conformance test (min, max)	0.05, 0.15		UI
Signal detect threshold (min)	–45		dBm

[a]The receiver wavelength range of 100BASE-BX10-U is wider than the associated transmitter to allow interoperation with existing implementations of 100 Mb/s bidirectional transceivers.
[b]The receiver shall be able to tolerate, without damage, continuous exposure to an optical input signal having a power level equal to the average received power (max) plus at least 1 dB.
[c]See 1.4 for definition of reflectance.
[d]The stressed receiver sensitivity is optional.
[e]Vertical eye closure penalty and jitter specifications are test conditions for measuring stressed receiver sensitivity. They are not required characteristics of the receiver.

A compliant receiver may be shown to deliver an error ratio lower than that in the table at the received power shown in the table, or shown to deliver an error ratio lower than 10^{-10} at a received power 1 dB lower than the value in the table. Sensitivity measurement is described in 58.7.10. Similarly, stressed receiver conformance may be shown for the error ratio and power shown in the table, or for 10^{-10} and 1 dB lower power. The 10^{-10} limits are more demanding but can be verified more accurately with reasonable test times.

58.5 Illustrative 100BASE-LX10 and 100BASE-BX10 channels and penalties (informative)

Illustrative channels and penalties for 100BASE-LX10 and 100BASE-BX10 are shown in Table 58–7.

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

Table 58–7—Illustrative 100BASE-LX10 and 100BASE-BX10 channels and penalties

Description	100BASE-LX10	100BASE-BX10-D	100BASE-BX10-U	Unit
Fiber type	B1.1, B1.3 SMF			
Measurement wavelength for fiber	1310	1550	1310	nm
Nominal distance	10			km
Available power budget	10	14.2		dB
Maximum channel insertion loss[a]	6.0	5.5	6.0	dB
Allocation for penalties[b]	4.0	8.7	8.2	dB

[a]The maximum 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.
[b]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. For 100BASE-X, it is possible for the allocation for penalties to be less than the TDP limit, as some penalties measured by TDP may arise in the receiver and need not be counted twice.

58.6 Jitter at TP1 and TP4 for 100BASE-LX10 and 100BASE-BX10 (informative)

The entries in Table 58–8 represent high-frequency jitter (above 20 kHz) and do not include low frequency jitter or wander. The informative Table 58–8 shows jitter specifications which may be of interest to implementors. High probability jitter at TP2 is constrained by the eye mask. Total jitter at TP3 (and therefore at TP2 also) is constrained by the error detector timing offsets. High levels of high probability jitter at TP2, TP3 and TP4 are expected, caused by high probability baseline wander. The jitter difference between TP2 and TP3 is expected to be lower than for higher speed PMDs.

Table 58–8—100BASE-LX10 and 100BASE-BX10 jitter budget (informative)

[a]	Total jitter		High probability jitter (*W*)	
Reference point	**UI**	**ns**	**UI**	**ns**
TP1	0.09	0.72	0.05	0.40
TP2	0.40	3.2	0.305	2.44
TP3	0.43	3.54	0.305	2.44
TP4	0.51	4.04	0.305	2.44

[a]Informative jitter values are chosen to be compatible with the limits for eye mask and TDP (see 58.7.9). Because of the way the different components may interact, the differences in jitter between test points cannot be used to indicate a performance level of the intervening sections.

Total jitter in this table is defined at 10^{-12} BER. In a commonly used model,

$$TJ_{12} = 14.1\sigma + W \text{ at } 10^{12}. \tag{58–1}$$

The total jitter at 10^{-10} BER may be calculated assuming

$$TJ_{10} = 12.7\sigma + W \tag{58-2}$$

NOTE—As an example, TJ_{10} at TP1 is 0.085 UI (0.69 ns).

W is similar but not necessarily identical to deterministic jitter (DJ). A jitter measurement procedure is described in 58.7.12. Jitter at TP2 or TP3 is defined with a receiver of the same bandwidth as specified for the transmitted eye.

58.7 Optical measurement requirements

The following sections describe definitive patterns and test procedures for certain PMDs of this standard. Implementors using alternative verification methods must 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, shall be made through a short patch cable, between 2 and 5 m in length.

NOTE—58.7.5, 58.7.6, 58.7.7, 58.7.9, 58.7.10, 58.7.11, and 58.7.12 apply to Clause 58, Clause 59, and Clause 60. Clause 59 (1000BASE-LX10) uses multimode fiber, although Clause 58 (100BASE-LX10 and 100BASE-BX10) and Clause 60 (1000BASE-PX10 and 1000BASE-PX20) do not.

58.7.1 Test patterns

Compliance is to be achieved in normal operation. The definitive patterns for testing are shown in Table 58–9.

Table 58–9—List of test patterns and tests

Test pattern	Test	Related subclause
Valid 100BASE-X signal	Wavelength Spectral width	58.7.2
Valid balanced NRZI encoded 4B/5B bit stream	Optical power	58.7.3
Idle or far-end fault indication (see Clause 24)	Extinction ratio OMA RIN_xOMA	58.7.4 58.7.5 58.7.7
Optical frame based test pattern of 58.7.1.1	Eye mask TDP Receiver sensitivity Stressed receiver sensitivity Jitter measurements	58.7.8 58.7.9 58.7.10 58.7.11 58.7.12

58.7.1.1 100BASE-X optical frame based test pattern

Transmit eye mask, TDP and sensitivity are to be assured against the test pattern defined below. This represents an extremely untypical pattern. The BER in service can be expected to be lower than with the test pattern. In this clause, extinction ratio, OMA and RIN_xOMA are referred to the idle pattern (1010… for 4B/5B NRZI) or the nearly identical far-end fault indication.

The following test pattern is intended for frame based testing of the 100BASE-LX10 and 100BASE-BX10 PMDs. It contains compliant Ethernet frames with adequate user defined fields to allow them to be passed through a system to the point of the test. Further information on frame based testing is included in Annex 58A. The test suite and the recommended patterns are shown in Table 58–9.

NOTE—Users are advised to take care that the system under test is not connected to a network in service.

The test pattern shall be constructed as follows.

A test pattern for base line wander is composed of a sequence of three frames continuously repeated. Each frame has a 1500 octet length client data field and a zero length pad field. The contents of the destination address, source address, length/type fields and the first 32 octets of the client data field are at the discretion of the tester and may be implementation specific. The remaining 1468 octets of the client data field are filled with symbols with an even number of ones in the 4B/5B encoded data prior to NRZI transmission as shown in Table 58–10.

Frames are separated by a near minimum inter-packet gap (IPG) of 14 octets.

Within the limits of the three bit maximum run length of the 4B/5B code this sequence gives a near worst case ISI pattern and provides alternating periods of high and low transition density to test clock and data recovery (CDR) performance.

The first 32 octets of the client data field are configured such that, after the frame check sequence (FCS) is added, there are an even number of ones in the first two packets and an odd number of ones in the third packet. This results in a six frame sequence on the line (after NRZI) with three frames containing near 40% ones density and three frames with near 60% ones density. Table 58–11 shows a pattern, nearly identical to the pattern in Table 58–10, that ends in 0 rather than 1 and can be used to join a 40% section to a 60% section. The "flipping" content causes a different frame check sequence which in turn causes the following idle to be inverted.

When transmitted with a near minimum inter-packet gap the resulting data stream has baseline wander at 1.35 kHz. In the example shown, IEEE Std 802.2 logical link control headers are used to form TEST command PDUs with null DSAP and SSAP addresses.

Table 58–10—Example unbalanced pattern

Item	Number of octets	Code-group name or hexa-decimal value	TXD<3:0>[a] (binary)		4B/5B encoded (binary)		NRZI encoded (binary)			
			1st nibble	2nd nibble	1st code-group[b]	2nd code-group	40% mark ratio		60% mark ratio	
Idle	13	I	Idle	Idle	11111	11111	10101	01010	01010	10101
Start-of-stream delimiter (SSD)	1	/J/K/			11000	10001	10000	11110	01111	00001
Remainder of preamble	6	55	0101	0101	01011	01011	01101	10010	10010	01101
Start of frame delimiter	1	D5	0101	1101	01011	11011	01101	01101	10010	10010
Destination address[c]	6	FF	1111	1111	11101	11101	01001	01001	10110	10110
Source address	6	00	0000	0000	11110	11110	01011	01011	10100	10100
Length/type	2	05	0101	0000	01011	11110	10010	10100	01101	01011
		DC	1100	1101	11010	11011	10011	01101	01100	10010
DSAP	1	00	0000	0000	11110	11110	01011	01011	10100	10100
SSAP	1	00	0000	0000	11110	11110	01011	01011	10100	10100
Control	1	F3	0011	1111	10101	11101	11001	01001	00110	10110
Implementation specific (example)	1	06	0110	0000	01110	11110	10100	10100	01011	01011
	28	00	0000	0000	11110	11110	10100	10100	01011	01011
Low transition density[d]	968	42	0010	0100	10100	01010	11000	01100	00111	10011
		24	0100	0010	01010	10100	01100	11000	10011	00111
Mixed	8	00	0000	0000	11110	11110	10100	10100	01011	01011
		D2	0010	1101	10100	11011	11000	10010	00111	01101
High transition density	484	07	0111	0000	01111	11110	01010	10100	10101	01011
		70	0000	0111	11110	01111	10100	01010	01011	10101
Mixed	8	00	0000	0000	11110	11110	10100	10100	01011	01011
		D2	0010	1101	10100	11011	11000	10010	00111	01101
Frame check sequence 1[e]	1	FF	1111	1111	11101	11101	10110	10110	01001	01001
Frame check sequence 2	1	13	0011	0001	10101	01001	00110	01110	11001	10001
Frame check sequence 3	1	9E	1110	1001	11100	10011	10111	00010	01000	11101
Frame check sequence 4	1	59	1001	0101	10011	01011	11101	10010	00010	01101
End-of-stream delimiter (ESD)	1	/T/R/			01101	00111	01001	11010	10110	00101

[a]See Table 24–2.
[b]The five bit code-groups are transmitted left most bit first.
[c]Use of the example broadcast address may cause problems in a system test; any unicast address is preferable. Other source and destination addresses may be chosen.
[d]The first row precedes the second row and the sub-sequence is repeated 16 times. This pattern can be varied to cause the disparity to remain the same or flip.
[e]The frame check sequence for another pattern may be calculated following 3.2.8 and Clause 24.

Table 58–11— Example unbalanced pattern to flip polarity

Item	Number of octets	Code-group name or hexa-decimal value	TXD<3:0> (binary)		4B/5B encoded (binary)		NRZI encoded (binary)			
			1st nibble	2nd nibble	1st code-group	2nd code-group	40% mark ratio		60% mark ratio	
Idle, SSD, preamble, SFD, DA, SA, Length/ type, DSAP, SSAP, Control	38	As in Table 58–10								
Flipping	1	05	0101	0000	01011	11110	10010	10100	01101	01011
Implementation specific, and pattern	1496	As in Table 58–10								
Frame check sequence 1	1	0B	1011	0000	10111	11110	11010	10100	00101	01011
Frame check sequence 2	1	E2	0010	1110	10100	11100	11000	10111	00111	01000
Frame check sequence 3	1	08	1000	0000	10010	11110	00011	01011	11100	10100
Frame check sequence 4	1	3B	1011	0011	10111	10101	00101	11001	11010	00110
End-of-stream delimiter (ESD)	1	/T/R/			01101	00111	10110	00101	01001	11010

NOTE—While it is expected that these frames will be counted by a DTE under test, the likelihood of additional behaviour means that the DTE should not be connected to a network in service while being tested.

58.7.2 Wavelength and spectral width measurements

The wavelength and spectral width (RMS) shall meet specifications according to ANSI/EIA/TIA-455-127, under modulated conditions using a valid 100BASE-X signal.

NOTE—The great majority of the transmitted spectrum must fall within the operating wavelength range. The allowable range of central wavelengths is narrower than the operating wavelength range by the actual RMS spectral width at each extreme.

58.7.3 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 balanced NRZI encoded 4B/5B bit stream.

58.7.4 Extinction ratio measurements

Extinction ratio shall meet specifications according to ANSI/TIA/EIA-526-4A with the port transmitting the NRZI encoded 4B/5B idle pattern (1010…) or far-end fault indication, that may be interspersed with OAM packets per 43B.2 and with minimal back reflections into the transmitter, lower than –20 dB. The extinction ratio is expected to be similar for other valid balanced NRZI encoded 4B/5B bit streams. The test receiver has the frequency response as specified for the transmitter optical waveform measurement.

58.7.5 Optical modulation amplitude (OMA) measurements (informative)

The normative way of measuring transmitter characteristics is extinction ratio and mean power. The following clause is intended to inform on how the OMA measurement is performed.

In this clause, OMA is the difference in optical power for “1” and “0” levels of the optical signal in an idle (10101… for 100BASE-LX10 and 100BASE-BX10) sequence or far-end fault indication. It may be found using waveform averaging or histogram means. The measurement is recommended to be equivalent to that described below.

The recommended technique for measuring optical modulation amplitude is illustrated in Figure 58–3. A fourth-order Bessel-Thomson filter as specified for measuring the transmitter concerned is to be used with the O/E converter. The measurement system consisting of the O/E converter, the filter and the oscilloscope is calibrated at the appropriate wavelength for the transmitter under test.

With the device under test transmitting the idle pattern or far-end fault indication, use the following procedure to measure optical modulation amplitude:

a) Configure the test equipment as illustrated in Figure 58–3.
b) Measure the mean optical power P_1 of the logic “1” as defined over the center 20% of the time interval, here 1 UI long, where the signal is in the high state.
c) Measure the mean optical power P_0 of the logic “0” as defined over the center 20% of the time interval, here 1 UI long, where the signal is in the low state.
d) $OMA = P_1 - P_0$.

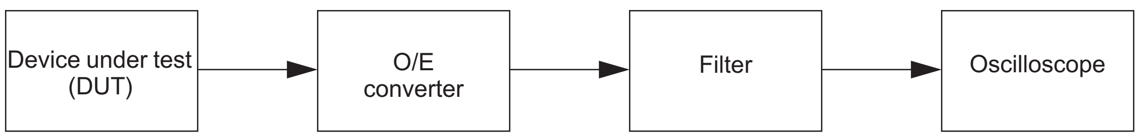


Figure 58–3—Recommended test equipment for measurement of optical modulation amplitude

A method of approximating OMA is shown in Figure 58–9.

Similarly, the optical power measure A_N is to be measured with a square wave pattern consisting of four to eleven consecutive ones followed by an equal run of zeros. Five ones followed by five zeros is convenient (the /H/ code-group in Clause 24, or K28.7 in 1000BASE-X which is the “Low-frequency test pattern” of 36A.2). The OMA of Clause 52 is A_N, and OMA here may differ.

NOTE—This OMA measurement procedure applies to Clause 58, Clause 59, and Clause 60.

58.7.6 OMA relationship to extinction ratio and power measurements (informative)

The normative way of measuring transmitter characteristics is extinction ratio and mean power. The following clause is intended to inform on how the three quantities OMA, extinction ratio, and mean power, are related to each other.

Optical modulation amplitude (OMA) is the difference between light levels for “1” and “0”. Extinction ratio is the ratio between light levels for “1” and “0”. If a signal contains equal density of “1” and “0” bits, and does not suffer from duty cycle distortion, the mean power is close to the mean of the light levels for “1” and “0”.

$$OMA = P_1 - P_0 \tag{58-3}$$

OMA may be expressed in Watts or dBm.

$$ER = \frac{P_1}{P_0} \quad (58\text{-}4)$$

Extinction ratio may be expressed in dB, as $10 \times \log_{10} (P_1 / P_0)$, or directly as a ratio. Sometimes extinction ratio is defined as P_0 / P_1.

$$P_{mean} \approx \frac{P_0 + P_1}{2} \quad (58\text{-}5)$$

Mean power may be expressed in Watts or dBm.

P_1 and P_0 are usually measured with a standardized instrument bandwidth to reduce the effects of overshoot. It should be noted that the values of P_1 and P_0 depend on the measurement technique and pattern to be used, which vary with PMD type. For some PMD types, e.g. 10GBASE, different patterns leading to different values of P_1 and P_0 are used for OMA on the one hand, and extinction ratio on the other.

Aside from these differences:

$$P_1 \approx 2 \times P_{mean} \times \frac{ER}{ER + 1} \quad (58\text{-}6)$$

$$P_0 \approx 2 \times \frac{P_{mean}}{ER + 1} \quad (58\text{-}7)$$

$$OMA \approx 2 \times P_{mean} \times \frac{ER - 1}{ER + 1} \quad (58\text{-}8)$$

Receiver sensitivity, which is an optical power, can be expressed in OMA or mean power terms according to the same relations.

NOTE—The OMA relationship to extinction ratio and power measurements applies to Clauses 52, 53, 58, 59, and 60.

58.7.7 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 is performed as described in 58.7.7.1, 58.7.7.2, and 58.7.7.3.

NOTE—This RIN_xOMA measurement procedure applies to Clause 58, Clause 59, and Clause 60.

58.7.7.1 General test description

The test arrangement is shown in Figure 58–4. The optical path between the Device Under Test (DUT) and the detector has a single discrete reflection with the specified optical return loss as seen by the DUT.

Both the OMA power and noise power are measured by AC coupling the O/E converter into the electrical power meter. If needed, an amplifier may be used to boost the signal to the power meter. A low pass filter is used between the photo detector and the power meter to limit the noise measured to the passband appropriate to the data rate of interest. In order to measure the noise, the modulation to the DUT is turned off.

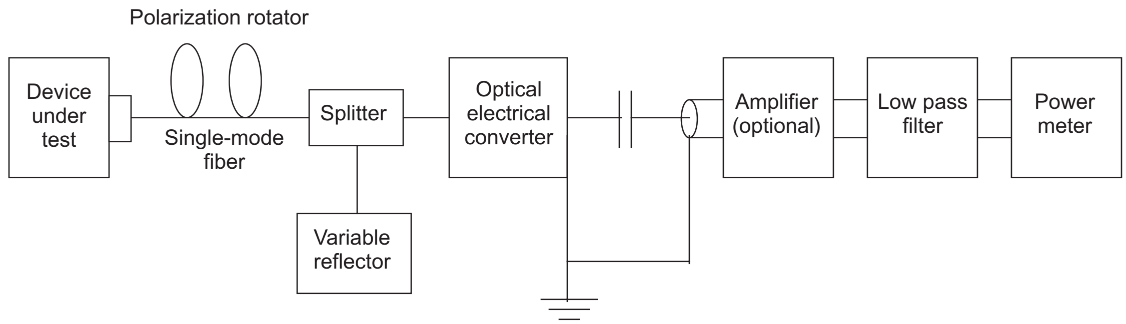


Figure 58–4—RIN$_x$OMA measurement setup

58.7.7.2 Component descriptions

The optical path and detector combination must be configured for a single dominant reflection with an optical return loss as specified in the appropriate transmitter table, e.g., Table 58–3 (The optical return loss may be determined by the method of FOTP-107). The length of the fiber is not critical but should be in excess of 2 m.

The polarization rotator is capable of transforming an arbitrary orientation elliptically polarized wave into a fixed orientation linearly polarized wave.

If necessary, the noise may be amplified to a level consistent with accurate measurement by the power meter.

The upper –3 dB limit of the measurement apparatus is as specified for the transmitter optical waveform test. The bandwidth used in the RIN calculation takes the low-frequency cutoff of the DC blocking capacitor into consideration. The low-frequency cutoff is recommended to be less than 1 MHz. The filter should be placed in the circuit as the last component before the power meter so that any high-frequency noise components generated by the detector/amplifier are eliminated. If the power meter used has a very wide bandwidth, care should be taken to ensure that the filter does not lose its rejection at extremely high frequencies.

The RMS electrical power meter should be capable of being zeroed in the absence of input optical power to remove any residual noise.

58.7.7.3 Test procedure

Use the following procedure to test relative intensity noise optical modulation amplitude:

a) With the DUT disconnected, zero the power meter;
b) Connect the DUT, turn on the laser, and ensure that the laser is not modulated;
c) Operate the polarization rotator while observing the power meter output to maximize the noise read by the power meter. Note the maximum power, P_N;
d) Turn on the modulation to the laser using the pattern specified for the PMD type (e.g., in 58.7.1 and 59.7.1) and note the power measurement, P_M. It may be necessary to change or remove the effective reflection to obtain an accurate reading;
e) Calculate RIN from the observed electrical signal power and noise power by use of the equation:

$$RIN_xOMA = 10 \times \log_{10}\frac{P_N}{BW \times P_M} \text{ [dB/Hz]} \qquad (58\text{-}9)$$

Where:

RIN_xOMA = Relative Intensity Noise referred to optical modulation amplitude measured with *x* dB reflection,

P_N = Electrical noise power in Watts with modulation off,

P_M = Electrical power in Watts with modulation on,

BW = Low pass bandwidth of apparatus - high pass bandwidth of apparatus due to DC blocking capacitor [noise bandwidth of the measuring system (Hz)].

For testing multimode components or systems, the polarization rotator is removed from the setup and the single-mode fiber replaced with a multimode fiber. Step c) of the test procedure is eliminated.

58.7.8 Transmitter 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 58–5 for 100BASE-LX10 and 100BASE-BX10. Compliance is to be assured during system operation. The transmitter optical waveform of a port transmitting the test pattern specified for the PMD type, e.g., in 58.7.1, shall meet specifications according to the methods specified below.

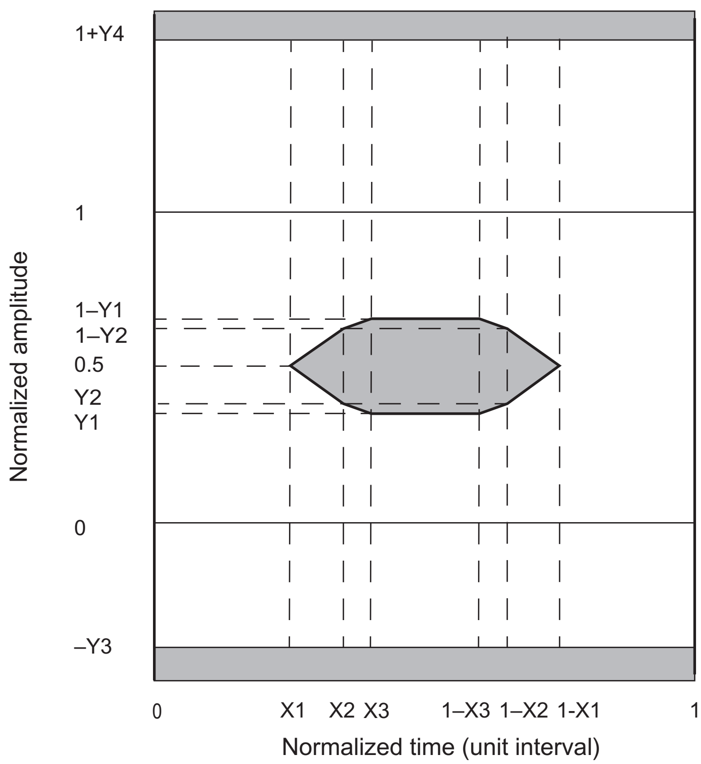


Figure 58–5—Transmitter eye mask definition

NOTE—This transmitter optical waveform measurement procedure applies to Clause 58, Clause 59, and Clause 60.

Normalized amplitudes of 0 and 1 represent the amplitudes of logic ZERO and ONE respectively. These are defined by the means of the lower and upper halves of the central 0.2 UI of the eye. 0 and 1 on the unit interval scale are to be determined by the eye crossing means. A clock recovery unit (CRU) may be used to trigger the scope for mask measurements as shown in Figure 58–6. It should have a high frequency corner bandwidth of less than or equal to the jitter corner frequency in the appropriate table for the transmitter's peer receiver, e.g., Table 58–4 or Table 58–6, and a slope of –20 dB/decade. The CRU tracks acceptable levels of low frequency jitter and wander. The frequency response of the measurement instrument (e.g., oscilloscope) extends substantially lower than the test pattern repetition frequency. A DC coupled instrument is convenient.

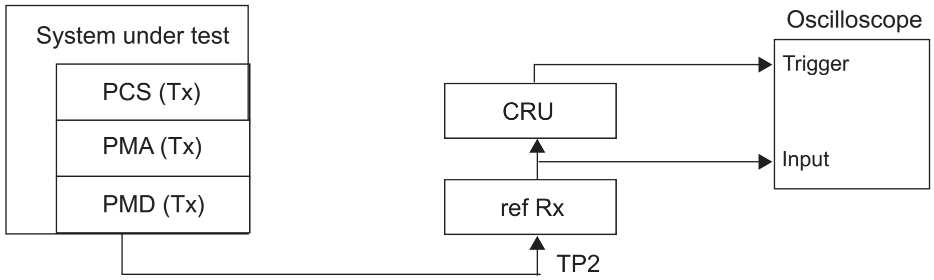


Figure 58–6—Transmitter optical waveform test block diagram

For 100BASE-LX10 and 100BASE-BX10, the eye is measured with respect to the mask of the eye using a receiver with a fourth-order Bessel-Thomson response with nominal *fr* of 116.64 MHz as specified for STM-1 in ITU-T G.957, with the tolerances there specified. Receiver responses for other PMD types are specified in the appropriate clause. The Bessel-Thomson receiver is not intended to represent the noise filter used within a compliant optical receiver, but is intended to provide uniform measurement conditions at the transmitter.

The transmitter shall achieve a hit ratio lower than 5×10^{-5} hits per sample, where “hits” are the number of samples within the grey areas of Figure 58–5, and the sample count is the total number of samples from 0 to 1 UI.

NOTE—As an example, if an oscilloscope records 1350 samples/screen, and the timebase is set to 0.2 UI/div with 10 divisions across the screen, and the measurement is continued for 200 waveforms, then a transmitter with an expectation of less than 6.75 hits is compliant:

$$5 \times 10^{-5} \times 200 \times \frac{1350}{(0.2 \times 10)} = 6.75 \qquad (58\text{-}10)$$

Likewise, if a measurement is continued for 1000 waveforms, then an expectation of less than 33.75 hits is compliant. An extended measurement is expected to give a more accurate result, and a single reading of 6 hits in 200 waveforms would not give a statistically significant pass or fail. Measurements to “zero hits”, which involve finding the position of the worst single sample in the measurement, have degraded reproducibility because random processes cause the position of such a single low-probability event to vary.

The hit ratio limit has been chosen to avoid misleading results due to transmitter and oscilloscope noise, and to give the best correlation to transmitter penalty; see 58.7.9.5.

Further information on optical eye pattern measurement procedures may be found in IEC 61280-2-2.

58.7.9 Transmitter and dispersion penalty (TDP) measurement

The TDP of a port transmitting the appropriate test pattern test shall meet specifications according to the methods specified below. The transmitter and dispersion penalty (TDP) measurement tests for transmitter impairments with chromatic effects for a transmitter to be used with single-mode fiber, and for transmitter impairments with modal (not chromatic) dispersion effects for a transmitter to be used with multimode fiber. Possible causes of impairment include intersymbol interference, jitter, RIN and mode partition noise. Meeting the separate requirements (e.g., eye mask, spectral characteristics) does not in itself guarantee the TDP. The procedure tests for pattern dependent effects; for 100BASE-LX10 and 100BASE-BX10, a standardized element of pattern dependent baseline wander is included in the reference channel.

Transmitter and dispersion penalty may be measured with apparatus shown in Figure 58–7, consisting of a reference transmitter, the transmitter under test, a controlled optical reflection, an optical attenuator, a test fiber, and a reference receiver system containing a reference receiver front end (optical to electrical converter), a transversal filter to emulate multimode fiber, if appropriate, and a bit error ratio tester. All BER and sensitivity measurements are made with the test patterns specified for the PMD type, e.g., in 58.7.1

NOTE 1—This TDP measurement procedure applies to Clause 58, Clause 59, and Clause 60.

NOTE 2—Multimode fiber is not used with 100BASE-LX10 or 100BASE-BX10.

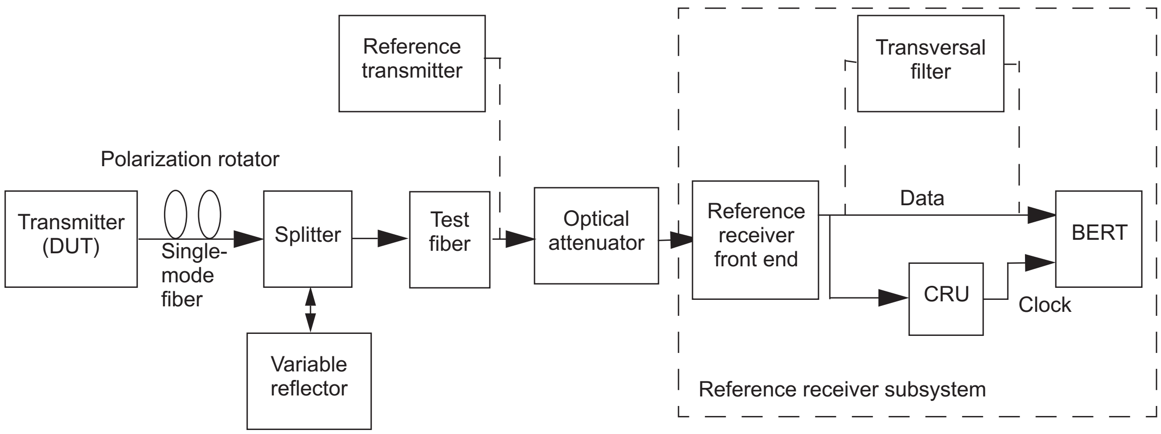


Figure 58–7—Test setup for measurement of transmitter and dispersion penalty

58.7.9.1 Reference transmitter requirements

The reference transmitter is a high-quality instrument-grade device, which can be implemented by a CW laser modulated by a high-performance modulator. It should meet the following basic requirements:

a) The rise/fall times should be less than 0.15 UI at 20% to 80%.
b) The output optical eye is symmetric and with good margin to the eye mask test for the transmitter (PMD) type under test.
c) In the center 20% region of the eye, the worst-case vertical eye closure penalty, as defined in 58.7.11.2, is less than 0.5 dB.
d) Jitter less than 0.20 UI peak-peak.
e) $RIN_{12}OMA$ should be minimized to less than –120 dB/Hz for 100BASE-X and –125 dB/Hz for 1000BASE-X.

58.7.9.2 Channel requirements

The transmitter is tested using an optical and electrical channel that meets the requirements specified for the PMD type listed in Table 58–12.

A transmitter is to be compliant with a total dispersion at least as negative as the “minimum dispersion” and at least as positive as the “maximum dispersion” columns specified for the wavelength of the device under test. This may be achieved with a channel or channels consisting of fibers with lengths chosen to meet the dispersion requirements.

To verify that the fiber has the correct amount of dispersion, the measurement method defined in ANSI/TIA/EIA-455-175A-92 may be used. The measurement is made in the linear power regime of the fiber.

Table 58–12—Transmitter compliance channel specifications

PMD transmitter wavelength, fiber type	Optical channel			Electrical channel
	Dispersion[a] (ps/nm)		Optical return loss[b] (max)	Differential delay (ps)
	Minimum	Maximum		
1310 nm band for SMF	$0.02325 \cdot L^{c} \cdot \lambda \cdot [1-(1324/\lambda)^4]$	$0.02325 \cdot L \cdot \lambda \cdot [1-(1300/\lambda)^4]$	See ORLT in Transmitter spec	N/A
1550 nm band for SMF	0	$0.02325 \cdot L \cdot \lambda \cdot [1-(1300/\lambda)^4]$		N/A

[a]The dispersion is specified for the actual wavelength of the device under test.
[b]The optical return loss is applied with respect to TP2.
[c]L is the upper operating range limit (reach) as defined e.g. in Table 58–1.

When emulating a multimode fiber link, the optical channel is a 2 m to 5 m patch cord meeting the appropriate specifications. In this case, the link bandwidth is emulated in the electrical domain.

The channel provides a maximum optical return loss specified as “Optical return loss tolerance (maximum)” in the specification of the transmitter under test. For a single-mode fiber channel, the state of polarization of the back reflection is adjusted to create the greatest RIN. The methods of 58.7.7.2 and 58.7.7.3 may be used.

The BERT’s receiver sensitivity must be adequate to meet the BER with the worst-case test signal and minimum attenuation.

58.7.9.3 Reference receiver requirements

The reference receiver system should have the bandwidth specified for the transmitter optical waveform measurement for the transmitter under test. The sensitivity of the reference receiver system should be limited by Gaussian noise. The receiver system should have minimal threshold offset, deadband, hysteresis, deterministic jitter or other distortions. Decision sampling should be instantaneous with minimal uncertainty and setup/hold properties. When testing 100BASE-X optical transmitters, the receiver should have a passband not extending below 10 kHz at the –3 dBe (electrical) point, so as to emulate the pattern-induced baseline wander expected in a compliant receiver.

For all transmitter and dispersion penalty measurements, determination of the center of the eye is required. The center of the eye is defined as the time halfway between the left and right sampling points within the eye where the measured BERs are equal to each other, and greater than or equal to 10^{-3} (the BER at the eye center is much lower). The decision threshold is to occur at the average signal level.

For a transmitter to be used with multimode fiber the reference receiver is followed by a transversal filter with two equal amplitude paths with a differential delay as specified for the transmitter. In this case, the receiver front end should be operating in its linear regime (not clipping). For a transmitter to be used with single-mode fiber, the transversal filter is not used.

The clock recovery unit (CRU) used in the TDP measurement has a corner frequency of less than or equal to the jitter tolerance frequency specified for the appropriate receiver (the peer PMD to the transmitter under test), and a slope of 20 dB/decade. When using a clock recovery unit as a clock for BER measurements, passing of low-frequency jitter from the data to the clock removes this low-frequency jitter from the measurement.

The nominal sensitivity of the reference receiver system, S, is measured in OMA using the apparatus described above but with a short patchcord in place of the test fiber and without any transversal filter. The sensitivity S must be corrected for any significant reference transmitter impairments including any vertical eye closure. It should be measured while sampling at the eye center or corrected for off-center sampling. It is calibrated at the wavelength of the transmitter under test. For 100BASE-LX10 and 100BASE-BX10, TDP includes a pattern dependent penalty. It may be inconvenient or impossible to obtain reference transmitters and receivers which are immune to this penalty. For these cases S may be measured with a benign pattern e.g., PRBS7.

58.7.9.4 Test procedure

To measure the transmitter and dispersion penalty (TDP) the following procedure is used. The sampling instant is displaced from the eye center by the amount specified for decision timing offsets in e.g., Table 58–3 or Table 58–5. The following procedure is repeated for early and late decision and the larger TDP value is used:

a) Configure the test equipment as described above and illustrated in Figure 58–7.
b) Adjust the attenuation of the optical attenuator to obtain a BER of 10^{-12}. Extrapolation techniques may be used with care.
c) Record the optical power in OMA at the input to the reference receiver, P_DUT, in dBm.
d) If P_DUT is larger than S, the transmitter and dispersion penalty (TDP) for the transmitter under test is the difference between P_DUT and S, TDP = P_DUT – S. Otherwise the transmitter and dispersion penalty is zero, TDP = 0.

It is to be ensured that the measurements are made in the linear power regime of the fiber.

58.7.9.5 Approximate measures of TDP (informative)

Transmitter and dispersion penalty may be considered as a transmitter penalty (TP) followed by a dispersion penalty, which is also attributable to the transmitter. Measurements at TP2 can reveal the transmitter penalty. TP can be related to eye mask margin (MM) as follows.

In the absence of any noise or significant jitter,

$$TP = 10 \times \log_{10}\left(\frac{1}{H}\right) \tag{58-11}$$

$$MM = \frac{H - M}{1 - M} \tag{58-12}$$

where H is height of inner eye and M is the height of the central polygon of the mask.

Transmitter noise or noise-like impairments degrade both apparent MM and actual TP. To obtain a useful correlation between the two, MM is defined to an appropriate percentile of measured samples, to give the right weight to this noise; see 58.7.8. Oscilloscope noise degrades apparent MM only. This would distort the correlation, but in many measurement circumstances the error is reduced at the appropriate percentile. The one-dimensional statistics of MM measurement and the hit ratio are related by the frequency of relevant bit patterns in a stream (typically 1/4 of bits are flanked by two opposite bits) and by a factor related to mask dimensions.

This approach could be applied to a situation with combinations of noise of jitter.

It may be feasible to correlate TDP to eye measurements at TP3. However, the signal at TP3 is weaker, so oscilloscope noise is more of a concern.

The following suggestions apply to 100 Mb/s optical PMDs.

In practice it may be necessary to do without the clock recovery unit at 100 Mb/s. Experimentally, timing stability at this rate may be acceptable, and the jitter due to the CRU could be accounted for by adjusting the eye mask length and the TDP decision timing offsets.

A significant component of TDP is baseline wander. A wander of ± OMA/10 will be created by many receivers if it is not already present in the transmitted signal. Higher levels of pattern dependent penalty can in some cases be estimated from the mask margin (if necessary, by ignoring the upper and lower mask regions). The mask margin may also be measured with an AC coupled measurement instrument with a high pass filter of 10 kHz. It is likely that compliant implementations will pass the transmitter mask with both DC and AC coupling. Certain implementations may be characterized by comparing the transmitted signal with the STM-1 mask, using a benign pattern such as PRBS7.

The accuracy of these approaches have not been established by the committee. Oscilloscope measurements at TP3 may be degraded by instrument noise.

58.7.10 Receiver sensitivity measurements

Receiver sensitivity is defined for an ideal input signal. The test signal should have negligible impairments such as intersymbol interference (ISI), jitter and RIN (but see the end of this subclause). The test pattern shall be as specified in 58.7.1, 59.7.1 or 60.7.1 as appropriate. Sensitivity is defined by the specified bit error ratio, which may be determined by counting bit or byte errors or errored frames. Extrapolation techniques may be used with care. Sensitivity is measured at a low but compliant extinction ratio, and correction made for any difference between the measurement extinction ratio and the specified minimum extinction ratio. This assurance should be met with asynchronous data flowing out of the optical transmitter of the system under test. The output data pattern from the transmitter of the system under test is the same pattern as defined for this measurement.

The sampling point is set by the system under test. While this standard applies to complete data terminal equipment (DTE), the test may be used as a diagnostic for testing components with appropriate margin, in which case the sampling point should be set at the average optical power level and at the specified timing offsets from the eye center, which may be found as the mid-point between the 10^{-3} BER points.

An implementor may use a combination of extrapolation and margin to assure compliance. This can entail a statistical analysis which could be implementation specific. As an example, with a small margin, it might not be advisable to extrapolate beyond a limited optical power difference; this represents an extrapolation in BER terms which varies according to circumstance.

In the case of 100BASE-X, systematic baseline wander of the input signal is to be expected. This may be generated with AC coupling above 10 kHz within the transmitter, and/or with the interfering signal technique as described in 58.7.11.2. A standardized baseline wander of ± OMA/10 is defined for these PMD types. This causes some jitter in the test signal, which is acceptable.

For 100BASE-LX10 and 100BASE-BX10 only, sensitivities are defined for 10^{-12} and 10^{-10} bit error rates. It is sufficient to show compliance to either of these. The 10^{-10} limit is the more demanding but can be verified more accurately with reasonable test times.

NOTE—This receiver sensitivity measurement applies to Clause 58, Clause 59, and Clause 60.

58.7.11 Stressed receiver conformance test

The stressed receiver conformance test is intended to screen against receivers with poor frequency response or timing characteristics which could cause errors when combined with a distorted but compliant signal at

TP3. Modal (MMF) or chromatic (SMF) dispersion can cause distortion. Stressed receiver tolerance testing may be performed in accordance with the requirements of 58.7.11.1, 58.7.11.2, and 58.7.11.3. If this test is applied the receiver shall be compliant to for example Table 58–4.

A receiver should receive a conditioned input signal that combines vertical eye closure and jitter according to this clause with BER specified in the receiver tables. This assurance should be met with asynchronous data flowing out of the optical transmitter of the system under test. The output data pattern from the transmitter of the system under test is to be the same pattern as defined for this measurement.

NOTE 1—The length of the test pattern, low signaling rate and narrow rate tolerance of 100BASE-X means that the input and output patterns beat very slowly. Long test times or a slight modification to the length of one pattern may be appropriate.

NOTE 2—This stressed receiver conformance test applies to Clause 58, Clause 59, and Clause 60.

58.7.11.1 Stressed receiver conformance test block diagram

A block diagram for the receiver conformance test is shown in Figure 58–8. A pattern generator continuously generates a signal or test pattern as specified for the receiver under test, e.g., in 58.7.1. The optical test signal is conditioned (stressed) using the methodology, as defined in 58.7.11.2, while applying sinusoidal jitter, as specified e.g., in 58.7.11.4. The receiver of the system under test is tested for conformance by counting bit or byte errors or errored frames. The optical power penalty for the stressed eye is intended to be similar to its vertical eye closure penalty. This is not necessarily the same as the highest TDP anticipated in service, but represents a standardized test condition for the receiver.

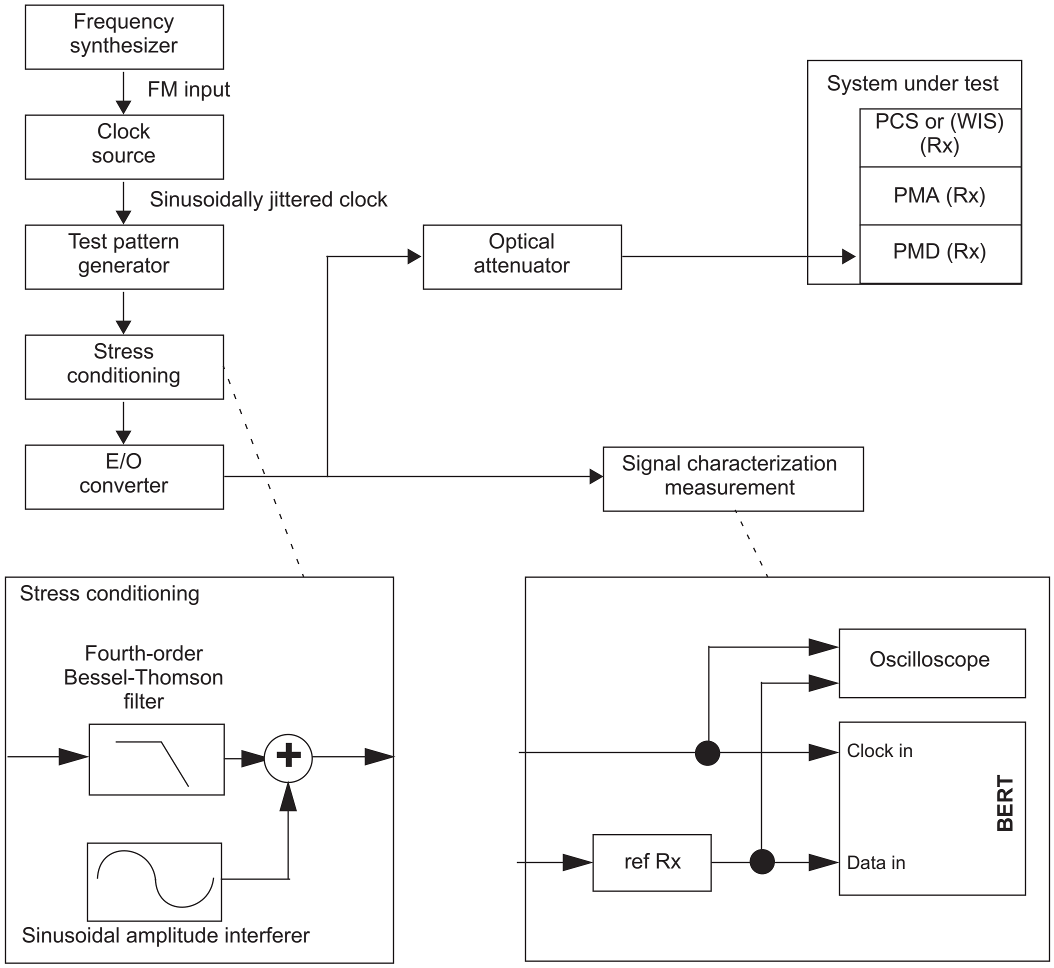


Figure 58–8—Stressed receiver conformance test block diagram

A suitable test set is needed to characterize and verify that the signal used to test the receiver has the appropriate characteristics. The test fiber called out for single-mode fiber based PMD layers and the transversal filter called out to emulate multimode fiber are not needed to characterize the receiver input signal; nor are they used during testing.

The fourth-order Bessel-Thomson filter is used to create ISI-induced vertical eye closure. The sinusoidal amplitude interferer causes additional eye closure, but in conjunction with the slowed edge rates from the filter, also causes jitter. The nature of the jitter is intended to emulate instantaneous bit shrinkage that can occur with DDJ. This type of jitter cannot be created by simple phase modulation. The sinusoidal phase modulation represents other forms of jitter and also verifies that the receiver under test can track low-frequency jitter.

For improved visibility for calibration, it is imperative that the Bessel-Thomson filter and all other elements in the signal path (cables, DC blocks, E/O converter, etc.) have wide and smooth frequency response and linear phase response throughout the spectrum of interest. Overshoot and undershoot should be minimized. If this is achieved, then data dependent effects should be minimal, and short data patterns can be used for calibration with the benefit of providing much improved trace visibility on sampling oscilloscopes. Actual patterns for testing the receiver are specified in the appropriate clause.

To further improve visibility for calibration, random noise effects, such as RIN and random clock jitter, should also be minimized. A small amount of residual noise and jitter from all sources is unavoidable, but should be less than 0.25 UI peak-peak of jitter.

The test pattern generator, filter and E/O converter should together have a frequency response to result in the appropriate level of initial ISI eye closure before the sinusoidal terms are added. The E/O converter should have a linear response if electrical summing is used, linearity of all elements including the E/O modulator is critical. Summing with an optical coupler after the modulator is an option that eases linearity requirements, but requires a second source for the interfering signal, will complicate settings of extinction ratio, and will add more RIN. In either case, a typical optical transmitter with built-in driver is not linear and not suitable.

The vertical and horizontal eye closures to be used for receiver conformance testing are verified using an optical reference receiver with the response specified for the appropriate transmitter (the peer PMD to the receiver under test) e.g. in 58.7.8. Use of standard tolerance filters may significantly degrade this calibration. Care should be taken to ensure that all the light from the fiber is collected by the fast photo detector and (if using multimode fiber) that there is negligible mode selective loss, especially in the optical attenuator and the optical coupler, if used. The reference receiver and oscilloscope should achieve adequately low noise and jitter.

The clock output from the clock source in Figure 58–8 will be modulated with the sinusoidal jitter. To use an oscilloscope to calibrate the final stressed eye jitter that includes the sinusoidal jitter component, a separate clock source (clean clock of Figure 58–8) is required that is synchronized to the source clock, but not modulated with the jitter source.

58.7.11.2 Stressed receiver conformance test signal characteristics and calibration

The conformance test signal is used to validate that the PMD receiver meets BER requirements with near worst case waveforms at TP3 including pulse width shrinkage, power, simulated channel penalties, and a swept frequency sinusoidal jitter contribution.

Signal characteristics are described below along with a suggested approach for calibration.

The test signal includes vertical eye closure and high-probability jitter components. Vertical eye closure is measured at the time center of the eye (halfway between 0 and 1 on the unit interval scale as determined by the eye crossing means) and is the vertical eye closure penalty (VECP) when calculated relative to the measured A_N value. J is measured at the average optical power, which can be obtained with AC coupling. The values of these components are defined as below by their histogram results. The vertical eye closure penalty is given in Equation (58-13):

$$\text{Vertical eye closure penalty [dB, optical]} = 10 \times \log_{10}\frac{A_N}{A_O} \tag{58-13}$$

where, A_O is the amplitude of the eye opening and A_N is the normal amplitude without ISI, as shown in Figure 58–9. A_N can be approximated with histograms as suggested in Figure 58–9. However, the definition for A_N is given in 58.7.5.

For this test, VECP is defined by the 99.95th percentile of the histogram of the lower half of the signal and the 0.05th percentile of the histogram of the upper half of the signal, and jitter is defined by the 0.5th and 99.5th percentiles of the jitter histogram. Histograms should include at least 10 000 hits, and should be about 1%-width in the direction not being measured. Residual low-probability noise and jitter should be minimized —that is, the outer slopes of the final histograms should be as steep as possible down to very low probabilities.

The following steps describe a suggested method for calibrating a stressed eye generator:

a) Set the signaling speed of the test-pattern generator as specified for the appropriate transmitter. Sinusoidal interference and jitter signals should be turned off at this point.
b) Turn on the calibration pattern. A repetitive pattern may be used for calibration if the conditions described in 58.7.11.1 are met, but this increases the risk that the longer test pattern used during testing will overstress the device under test.
c) Set the extinction ratio to approximately the extinction ratio (minimum) value as specified for the appropriate transmitter. If optical summing is used, the extinction ratio may need to be adjusted after the sinusoidal interference signal is added below.
d) Measure the settled signal amplitude A_N of the test signal (without attenuation). A_N may be measured according to 58.7.5 using a square wave pattern, although for the purposes of this clause, OMA is to be measured with a different pattern; A_N and OMA are not likely to be equal.
e) The requirements for vertical eye closure and jitter of the stressed eye test signal are given by the vertical eye closure penalty (VECP) and stressed eye jitter (J) values given in the appropriate receiver specification table.

   There are three components involved in calibration for vertical closure and J. These are a linear phase filter, sinusoidal interference, and sinusoidal jitter.

   In general, the majority of the vertical eye closure penalty value should be created by use of a linear phase, low jitter filter (such as Bessel-Thomson). In the case of 100BASE-X, the majority of the vertical eye closure penalty value should be created by baseline wander or sinusoidal interference. The filter should be tested with the prescribed test patterns to verify that residual jitter is small, less than 0.25 UI peak-peak. If not, the stress may be more than desired, leading to conservative results. However, compensation is not allowed. Once done, revert to the calibration pattern, if different than the specified test pattern.

   Any remaining vertical eye closure required must be created with sinusoidal interference or sinusoidal jitter.

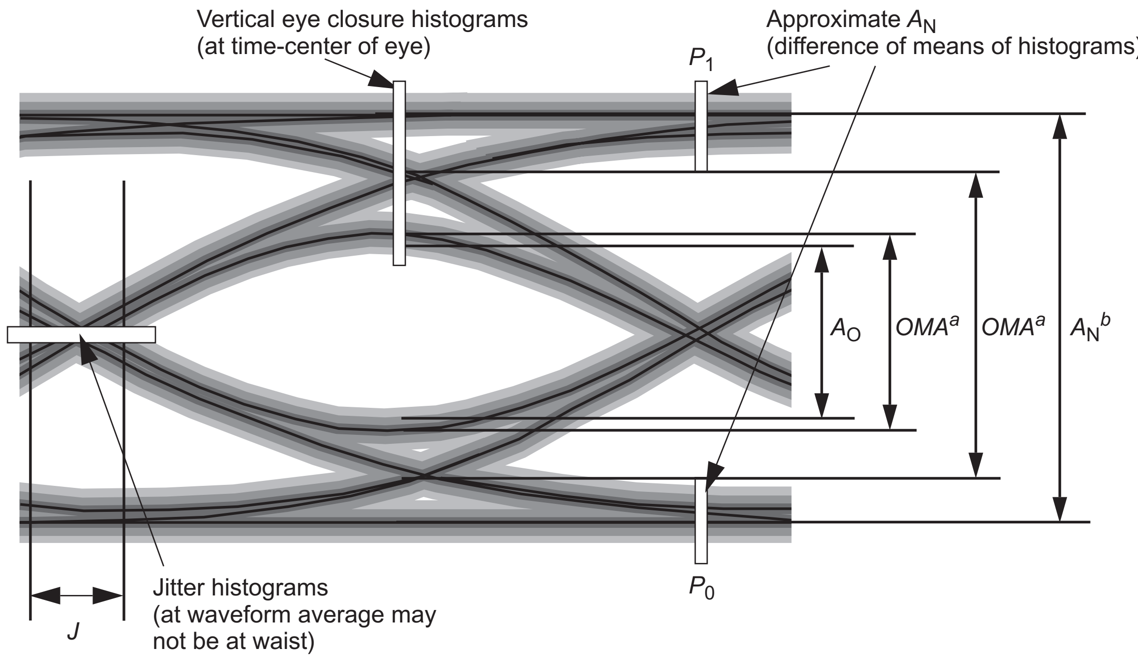
   To emulate the effects of DCD or data-dependent jitter, at least 0.05 but no more than 0.15 UI peak-peak of pulse shrinkage jitter should have been achieved. This imposes a limit of less than 1.2 dB of vertical closure from sinusoidal interference, applied after vertical closure created by filtering.

   The frequency of the sinusoidal interference may be set at any frequency between B / 100 and B / 5 where B is the signaling speed, although care should be taken to avoid a harmonic relationship between the sinusoidal interference, the sinusoidal jitter, the signaling speed and the pattern repetition rate.
   Sinusoidal jitter (phase modulation) must be added according to the appropriate jitter specification. For calibration purposes, sinusoidal jitter frequencies must be well within the flat portion of the template above the corner frequency.

   Iterate the filter bandwidth and the settings for sinusoidal interference and/or jitter until all constraints are met, including jitter (J), vertical eye closure penalty (VECP), and that sinusoidal jitter above the corner frequency is as specified.

   Verify that the optical power penalty for the stressed eye (relative to the reference transmitter per 58.7.9.1) is greater than or equal to VECP.
f) Decrease the amplitude with the optical attenuator until the OMA complies with the OMA values specified for the receiver under test.
g) For testing, turn on the actual required test pattern(s).

Care should be taken when characterizing the signal used to make receiver tolerance measurements. In the case of a transmit jitter measurement, excessive and/or uncalibrated noise/jitter in the test system makes it more difficult to meet the specification and may have a negative impact on yield but will not effect



[a]This measure of OMA on the eye of the conformance test signal differs between 100BASE-X, 1000BASE-X and 10GBASE-R/W.
[b]This is also OMA for 10GBASE-R/W.

Figure 58–9—Required characteristics of the conformance test signal at TP3

interoperability. Running the receiver tolerance test with a signal that is under-stressed may result in the deployment of non-compliant receivers. Care should be taken to minimize and/or correct for the noise/jitter introduced by the reference receiver, filters, oscilloscope, and BERT. While the details of measurement and test equipment are beyond the scope of this standard it is recommended that the implementors fully characterize their test equipment and apply appropriate guard bands to ensure that the receive input signal meets the specified requirements.

58.7.11.3 Stressed receiver conformance test procedure

The test apparatus is set up as described in 58.7.11.1 and 58.7.11.2. The sinusoidal jitter is then stepped across the specified frequency and amplitude range while monitoring errors at the receiver. The BER is to be compliant at all jitter frequencies in the specified frequency range. This method does not result in values for jitter contributed by the receiver. It does, however, ensure that a receiver meeting the requirements of this test will operate with the worst-case optical input.

58.7.11.4 Sinusoidal jitter for receiver conformance test

The sinusoidal jitter is used to test receiver jitter tolerance. Sinusoidal jitter may vary over a magnitude range as required to accurately calibrate a stressed eye per 58.7.11.2. The range is limited by the constraints of Table 58–13 as illustrated in Figure 58–10, where *f2*, *SJ1* and *SJ2* are specified in the appropriate receiver table: Table 58–4, Table 58–6, Table 59–6, Table 59–8, Table 60–5, Table 60–6 or Table 60–9. The frequency *f2* is specified as “Jitter corner frequency” in the receiver tables. *SJ1* and *SJ2* are defined as “sinusoidal jitter limits for stressed receiver conformance test (min, max)” in e.g., Table 58–4.

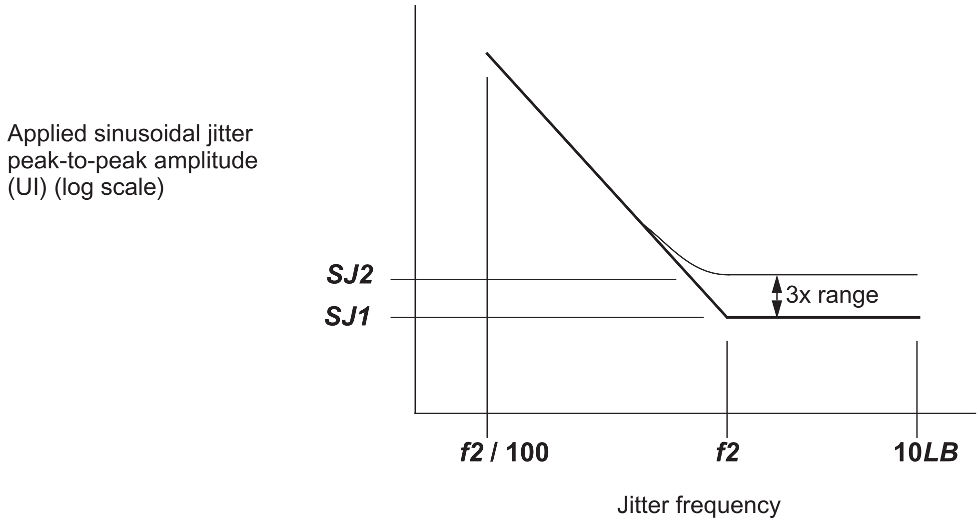


Figure 58–10—Mask of the sinusoidal component of jitter tolerance (informative)

Table 58–13—Applied sinusoidal jitter

Frequency range	Sinusoidal jitter (UI pk-pk)
$f < f2 / 100$	N/A
$f2 / 100 < f \leq f2$	$0.05 \times f2 / f + S - 0.05$[a]
$f2 < f < 10 \times LB$[b]	$SJ1 \leq S \leq SJ2$[a]

[a] *S* is the magnitude of sine jitter actually used in the calibration of the stressed eye per the methods of 58.7.11.2.
[b] *LB* = Loop Bandwidth; Upper frequency bound for added sine jitter should be at least 10 times the loop bandwidth of the receiver being tested.

58.7.12 Jitter measurements (informative)

A jitter measurement method for use at 100 or 1000 Mb/s is described in this subclause. The measurement is performed after any relevant fiber dispersion (at virtual TP3). The test pattern is specified in 58.7.1 or 59.7.1 as appropriate.

The transmit jitter is tested using a bit error ratio tester (BERT), where the tester scans the eye opening horizontally (varying the decision time) at the average optical power, at a virtual TP3 (hereafter referred to as simply TP3) and measures the bit error ratio at each point in time. The plot of BER as a function of sampling time is called the "bathtub curve." The channel and receiver are as specified in e.g., 58.7.9.2 and 58.7.9.3. The receiver includes a defined filter function. The test pattern is the same as for receiver sensitivity measurements.

NOTE—The parameter *W* may also be estimated from jitter histograms using an oscilloscope. Jitter of an optical signal is measured with a test optical receiver with the receiver bandwidth specified (e.g., for eye mask conformance) for the transmitter under test concerned.

The experimental curve is compared with a mask defined by the following equations and illustrated in Figure 58–11:

$$\log_{10}(BER) \le A - B\left(\frac{t - 0.5W}{\sigma}\right)^2 \qquad (58\text{-}14)$$

$$\log_{10}(BER) \le A - B\left(\frac{1 - t - 0.5W}{\sigma}\right)^2 \qquad (58\text{-}15)$$

where:

$$A = -1.75, B = \frac{\log_{10}(e)}{2} \approx 0.217$$

and t is the decision time specified in unit intervals (UI). $t = 0$ at the mean crossing time, which may be estimated as the mid-point between the 10^{-3} BER points.

The BER mask is defined for $10^{-12} < \text{BER} < 10^{-6}$. All points on the BER "bathtub curve" must fall within the white area or below. It can be seen that in the case of an asymmetric measured bathtub curve, the worse side determines W and σ.

W ("high probability jitter") and deterministic jitter (DJ) are not necessarily the same, but may be similar. The quantity σ can be similar to random jitter (RJ) although it is determined by low probability pattern dependent jitter also. "Total jitter" (TJ) is taken to be $W + 14\sigma$.

.

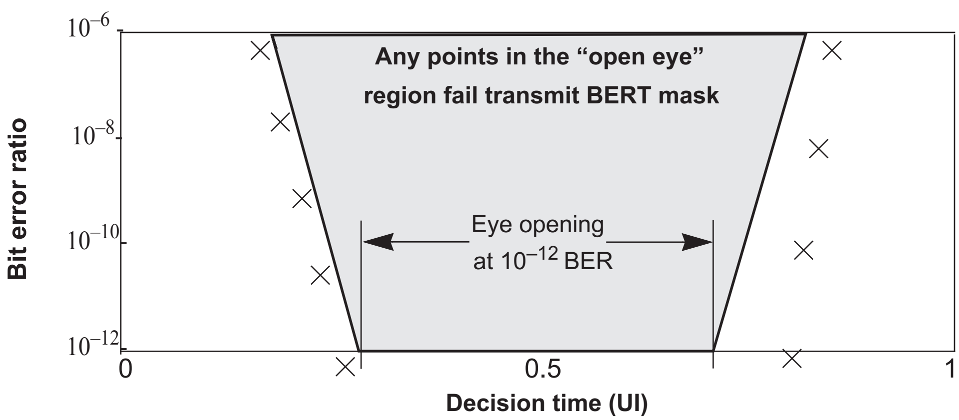


Figure 58–11—Example transmit BER mask at TP3

NOTE—This jitter measurement method applies to Clause 58, Clause 59, and Clause 60.

58.8 Environmental, safety, and labeling

58.8.1 General safety

All equipment meeting this standard shall conform to IEC 60950.

58.8.2 Laser safety

100BASE-LX10 and 100BASE-BX10 optical transceivers shall conform to Class 1 laser requirements as defined in IEC 60825-1, 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 geographical 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 shall explicitly define requirements and usage restrictions on the host system necessary to meet these safety certifications.

58.8.3 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.

58.8.4 Environment

Two optional temperature ranges are defined in Table 58–14. 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).

Table 58–14—Component case temperature classes

Class	Low temperature (˚C)	High temperature (˚C)
Warm extended	–5	+85
Cool extended	–40	+60
Universal extended	–40	+85

Reference Annex 67A for additional environmental information.

58.8.5 PMD labeling requirements

It is recommended that each PHY (and supporting documentation) be labeled in a manner visible to the user, with at least the applicable safety warnings and the applicable port type designation (e.g., 100BASE-BX10-U).

Labeling requirements for Class 1 lasers are given in the laser safety standards referenced in 58.8.2.

Compliant systems and field pluggable components shall be clearly labeled with the operating temperature range over which their compliance is ensured.

58.9 Characteristics of the fiber optic cabling

The 100BASE-LX10 and 100BASE-BX10 fiber optic cabling shall meet the dispersion specifications of IEC 60793-2 and ITU-T G.652, as shown in Table 58–15. The fiber cable attenuation is for information only; the end-to-end channel loss shall meet the requirements of Table 58–1. The fiber optic cabling consists of one or more sections of fiber optic cable and any intermediate connections required to connect sections together. The fiber optic cabling spans from one MDI to another MDI, as shown in Figure 58–12.

58.9.1 Fiber optic cabling model

The fiber optic cabling model is shown in Figure 58–12.

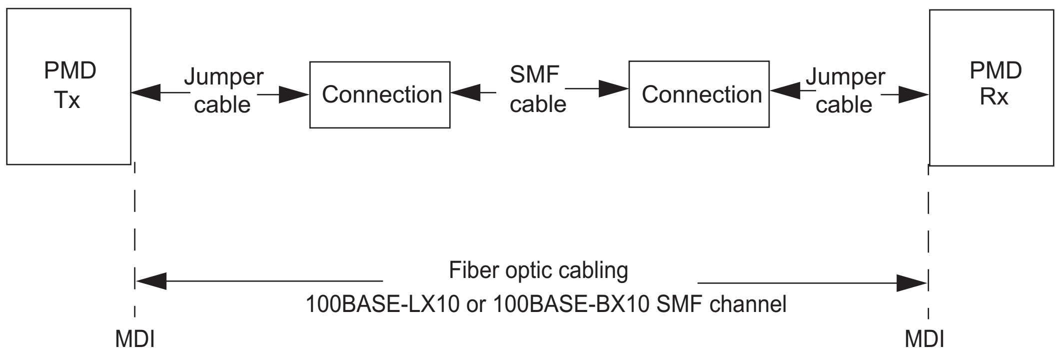


Figure 58–12—Fiber optic cabling model

The maximum channel insertion losses shall meet the requirements specified in Table 58–1. The minimum loss for 100BASE-LX10 and 100BASE-BX10 is zero. A channel may contain additional connectors or other optical elements as long as the optical characteristics of the channel, such as attenuation, dispersion and reflections, meet the specifications. Insertion loss measurements of installed fiber cables are made in accordance with ANSI/TIA/EIA-526-7 [B15], method A-1. 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.

NOTE—In extreme cases with minimum length links (less than 2 m), care may be taken to avoid excess optical power delivered through cladding modes to the receiver.

58.9.2 Optical fiber and cable

The fiber optic cable requirements are satisfied by the fibers specified in IEC 60793-2, Types B1.1 (dispersion un-shifted single-mode) and B1.3 (low water peak single-mode) and ITU-T G.652 as noted in Table 58–15.

Table 58–15—Optical fiber and cable characteristics

Description[a]	B1.1, B1.3 SMF		Unit
Nominal fiber specification wavelength[b]	1310	1550	nm
Fiber cable attenuation (max)[c]	0.4	0.35	dB/km
Zero dispersion wavelength (λ_0)[d]	$1300 \le \lambda_0 \le 1324$		nm
Dispersion slope (max) (S_0)	0.093		ps/nm^{2}km

[a]The fiber dispersion values are normative, all other values in the table are informative.
[b]Wavelength specified is the nominal fiber specification wavelength which is the typical measurement wavelength. Power penalties at other wavelengths are accounted for.
[c]Attenuation values are informative not normative. Attenuation for single-mode optical fiber cables is defined in ITU-T G.652.
[d]See IEC 60793 or G.652 for correct use of zero dispersion wavelength and dispersion slope.

58.9.3 Optical fiber connection

The maximum link distances for single-mode fiber are calculated based on an allocation of 2 dB total connection and splice loss. Connections with different loss characteristics may be used provided the requirements of Table 58–1 are met.

The maximum discrete reflectance of e.g., a connection or splice shall be less than –26 dB.

58.9.4 Medium Dependent Interface (MDI)

The 100BASE-LX10, 100BASE-BX10-D or 100BASE-BX10-U PMD is coupled to the fiber optic cabling at the MDI. The MDI is the interface between the PMD and the "fiber optic cabling" (as shown in Figure 58–12). Examples of an MDI include the following:

a) Connectorized fiber pigtail
b) PMD receptacle

The MDI carries the signal in both directions. For 100BASE-BX10 it couples a single fiber and for 100BASE-LX10 it couples dual fibers.

When the MDI is a remateable connection it shall meet the interface performance specifications of IEC 61753-1.

NOTE—Compliance testing is performed at TP2 and TP3 as defined in 58.2.1, not at the MDI.

58.10 Protocol implementation conformance statement (PICS) proforma for Clause 58, Physical Medium Dependent (PMD) sublayer and medium, type 100BASE-LX10 (Long Wavelength) and 100BASE-BX10 (BiDirectional Long Wavelength)[6]

58.10.1 Introduction

The supplier of a protocol implementation that is claimed to conform to Clause 58, Physical Medium Dependent (PMD) sublayer and medium, type 100BASE-LX10 and 100BASE-BX10, 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.

58.10.2 Identification

58.10.2.1 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]	
NOTES 1—Required for all implementations. 2—May be completed as appropriate in meeting the requirements for the identification. 3—The terms Name and Version should be interpreted appropriately to correspond with a supplier’s terminology (e.g., Type, Series, Model).	

58.10.2.2 Protocol summary

Identification of protocol standard	IEEE Std 802.3-2005, Clause 58, Physical Medium Dependent (PMD) sublayer and medium, type 100BASE-LX10 and 100BASE-BX10
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 802.3-2005.)	

Date of Statement	

[6]*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.

58.10.2.3 Major capabilities/options

Item	Feature	Subclause	Value/Comment	Status	Support
HT	High temperature operation	58.8.4	–5 to 85 ˚C	O	Yes [ ] No [ ]
LT	Low temperature operation	58.8.4	–40 to 60 ˚C	O	Yes [ ] No [ ]
*LX	100BASE-LX10 PMD	58.3	Device supports long wavelength (1310 nm) over dual single-mode fiber operation	O/1	Yes [ ] No [ ]
*BD	100BASE-BX10-D	58.4	Device operates with one single single-mode fiber and transmits at downstream wavelength (1550 nm)	O/1	Yes [ ] No [ ]
*BU	100BASE-BX10-U	58.4	Device operates with one single single-mode fiber and transmits at upstream wavelength (1310 nm)	O/1	Yes [ ] No [ ]
*INS	Installation / Cable	58.9	Items marked with INS include installation practices and cable specifications not applicable to a PHY manufacturer	O	Yes [ ] No [ ]

58.10.3 PICS proforma tables for Physical Medium Dependent (PMD) sublayer and medium, type 100BASE-LX10 and 100BASE-BX10

58.10.3.1 PMD functional specifications

Item	Feature	Subclause	Value/Comment	Status	Support
FN1	Transmit function	58.2.2	Conveys bits from PMD service interface to MDI	M	Yes [ ]
FN2	Transmitter optical signal	58.2.2	Higher optical power transmitted is a logic 1	O	Yes [ ] No [ ]
FN3	Receive function	58.2.3	Conveys bits from MDI to PMD service interface	M	Yes [ ]
FN4	Receiver optical signal	58.2.3	Higher optical power received is a logic 1	O	Yes [ ] No [ ]
FN5	Signal detect function	58.2.4	Mapping to PMD service interface	M	Yes [ ]
FN6	Signal detect behaviour	58.2.4	Generated according to Table 58–2	M	Yes [ ]

58.10.3.2 PMD to MDI optical specifications for 100BASE-LX10

Item	Feature	Subclause	Value/Comment	Status	Support
LX1	100BASE-LX10 transmitter	58.3.1	Meets specifications in Table 58–3	LX:M	Yes [ ] N/A [ ]
LX2	100BASE-LX10 receiver	58.3.2	Meets specifications in Table 58–4	LX:M	Yes [ ] N/A [ ]
LX3	100BASE-LX10 stressed receiver sensitivity	58.3.2	Meets specification in Table 58–4	LX:O	Yes [ ] No [ ] N/A [ ]

58.10.3.3 PMD to MDI optical specifications for 100BASE-BX10-D

Item	Feature	Subclause	Value/Comment	Status	Support
BD1	100BASE-BX10 transmitter	58.4.1	Meets specifications in Table 58–5	BD:M	Yes [ ] N/A [ ]
BD2	100BASE-BX10 receiver	58.4.2	Meets specifications in Table 58–6	BD:M	Yes [ ] N/A [ ]
BD3	100BASE-BX10 stressed receiver sensitivity	58.4.2	Meets specification in Table 58–6	BD:O	Yes [ ] No [ ] N/A [ ]

58.10.3.4 PMD to MDI optical specifications for 100BASE-BX10-U

Item	Feature	Subclause	Value/Comment	Status	Support
BU1	100BASE-BX10 transmitter	58.4.1	Meets specifications in Table 58–5	BU:M	Yes [ ] N/A [ ]
BU2	100BASE-BX10 receiver	58.4.2	Meets specifications in Table 58–6	BU:M	Yes [ ] N/A [ ]
BU3	100BASE-BX10 stressed receiver sensitivity	58.4.2	Meets specification in Table 58–6	BU:O	Yes [ ] No [ ] N/A [ ]

58.10.3.5 Optical measurement requirements

Item	Feature	Subclause	Value/Comment	Status	Support
OM1	Measurement cable	58.7	2 m to 5 m in length	M	Yes [ ]
OM2	Test pattern	58.7.1, 58.7.8, 58.7.10	For eye, sensitivity, TDP, stressed sensitivity, jitter	M	Yes [ ]
OM3	Wavelength and spectral width	58.7.2	Per TIA/EIA-455-127 under modulated conditions	M	Yes [ ]
OM4	Average optical power	58.7.3	Per TIA/EIA-455-95	M	Yes [ ]
OM5	Extinction ratio	58.7.4	Per ANSI/TIA/EIA-526-4A	M	Yes [ ]
OM6	Transmit eye	58.7.8	Per ANSI/TIA/EIA-526-4A with test pattern and fourth-order Bessel-Thomson receiver	M	Yes [ ]
OM7	Receiver sensitivity	58.7.10	With specified pattern	M	Yes [ ]
OM8	Transmitter and dispersion penalty	58.7.9	With dispersion, reflection and decision timing offsets	M	Yes [ ]
OM9	Stressed receiver conformance test	58.7.11	According to 58.7.11.1, 58.7.11.2, and 58.7.11.3	O	Yes [ ] No [ ]

58.10.3.6 Environmental specifications

Item	Feature	Subclause	Value/Comment	Status	Support
ES1	General safety	58.8.1	Conforms to IEC-60950	M	Yes [ ]
ES2	Laser safety —IEC Class 1	58.8.2	Conform to Class 1 laser requirements defined in IEC 60825-1	M	Yes [ ]
ES3	Documentation	58.8.2	Explicitly defines requirements and usage restrictions to meet safety certifications	M	Yes [ ]
ES4	Operating temperature range labeling	58.8.5	If required	M	Yes [ ] N/A [ ]

58.10.3.7 Characteristics of the fiber optic cabling and MDI

Item	Feature	Subclause	Value/Comment	Status	Support
FO1	Fiber optic cabling	58.9	Dispersion specifications of Table 58–15	INS:M	Yes [ ] N/A [ ]
FO2	End-to-end channel loss	58.1, 58.9	Meet the requirements of Table 58–1	INS:M	Yes [ ] N/A [ ]
FO3	Maximum discrete reflectance	58.9.3	Less than –26 dB	INS:M	Yes [ ] N/A [ ]
FO4	MDI requirements	58.9.4	IEC 61753-1 if remateable	INS:O	Yes [ ] No [ ] N/A [ ]

59. Physical Medium Dependent (PMD) sublayer and medium, type 1000BASE-LX10 (Long Wavelength) and 1000BASE-BX10 (BiDirectional Long Wavelength)

59.1 Overview

The 1000BASE-LX10 and 1000BASE-BX10 PMD sublayers provide point-to-point (P2P) 1000BASE-X links over a pair of fibers or a single fiber, respectively, up to 10 km.

This clause specifies the 1000BASE-LX10 PMD for both single-mode and multimode fiber, and the 1000BASE-BX10 PMD for single-mode fiber. A PMD is connected to the 1000BASE-X PMA of 66.2, and to the medium through the MDI. A PMD is optionally combined with the management functions that may be accessible through the management interface defined in Clause 22 or by other means.

Table 59–1 shows the primary attributes of each PMD type.

Table 59–1—Classification of 1000BASE-LX10 and 1000BASE-BX10 PMDs

Description	1000BASE-LX10		1000BASE-BX10-D	1000BASE-BX10-U	Unit
Fiber type[a]	B1.1, B1.3 SMF	50, 62.5 µm MMF	B1.1, B1.3 SMF		
Number of fibers	2	2	1		
Typical transmit direction	N/A		Downstream	Upstream	
Nominal transmit wavelength	1310	1310	1490	1310	nm
Minimum range	0.5 m to 10 km	0.5 m to 550 m[b]	0.5 m to 10 km		
Maximum channel insertion loss[c]	6.0	2.4	5.5	6.0	dB

[a]per IEC 60793-2
[b]see Table 59–16 for fiber and cable characteristics
[c]at the nominal operating wavelength

A 1000BASE-LX10 link uses 1000BASE-LX10 PMDs at each end while a 1000BASE-BX10 link uses a 1000BASE-BX10-D PMD at one end and a 1000BASE-BX10-U PMD at the other. Typically the 1490 nm band is used to transmit away from the center of the network (“downstream”) and the 1310 nm band towards the center (“upstream”), although this arrangement, or the notion of hierarchy, is not required. The suffixes “D” and “U” indicate the PMDs at each end of a link which transmit in these directions and receive in the opposite directions.

1000BASE-LX10 is interoperable with 1000BASE-LX (see Clause 38). If used on single-mode fiber, operation is not ensured by this standard beyond the reach given in Table 38-6.

Two optional temperature ranges are defined; see 59.8.4 for further details. Implementations may be declared as compliant over one or both complete ranges, or not so declared (compliant over parts of these ranges or another temperature range).

59.1.1 Goals and objectives

The following are the objectives of 1000BASE-LX10 and 1000BASE-BX10:

a) Point to point on optical fiber

b) 1000BASE-LX extended temperature range optics

c) 1000BASE-X up to 10km over SM fiber

d) BER better than or equal to 10^{-12} at the PHY service interface

59.1.2 Positioning of 1000BASE-LX10 and 1000BASE-BX10 PMDs within the IEEE 802.3 architecture

Figure 59–1 depicts the relationships of the PMD (shown shaded) with other sublayers and the ISO/IEC Open System Interconnection (OSI) reference model.

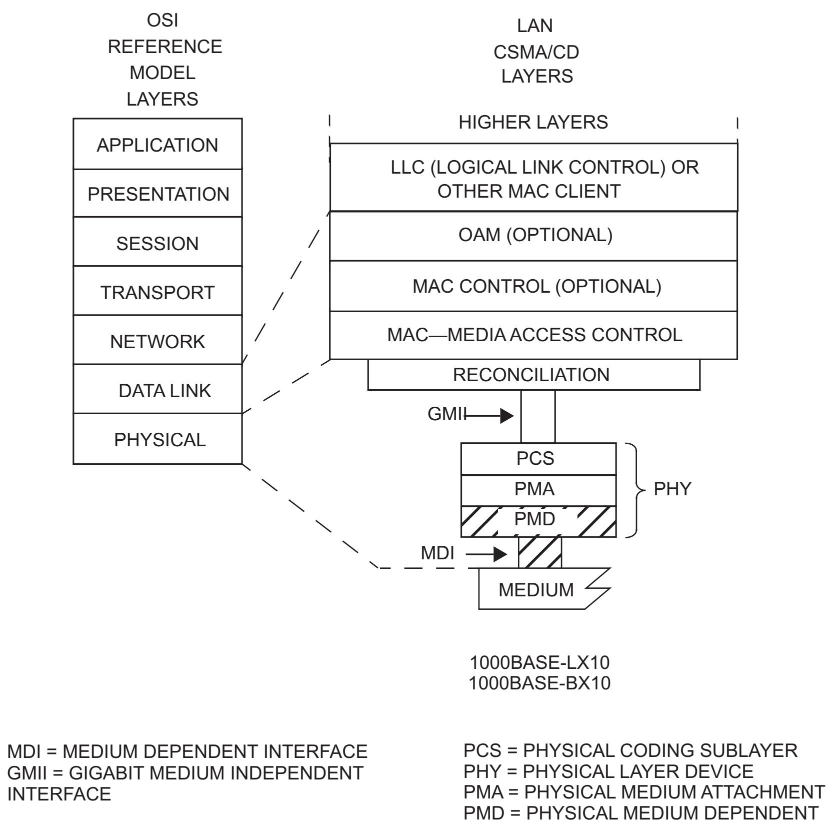


Figure 59–1—1000BASE-LX10 and 1000BASE-BX10 PMDs relationship to the ISO/IEC Open Systems Interconnection (OSI) reference model and the IEEE 802.3 CSMA/CD LAN model

59.1.3 Terminology and conventions

The following list contains references to terminology and conventions used in this clause:

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 Ethernet for subscriber access networks, see Clause 56.

59.1.4 Physical Medium Dependent (PMD) sublayer service interface

The following specifies the services provided by the 1000BASE-LX10 and 1000BASE-BX10 PMDs. These PMD sublayers are described in an abstract manner and do not imply any particular implementation. The PMD service interface supports the exchange of encoded 8B/10B code-groups between the PMA and PMD entities. The PMD translates the serialized data of the PMA to and from signals suitable for the specified medium.

The following primitives are defined

PMD_UNITDATA.request

PMD_UNITDATA.indication

PMD_SIGNAL.indication

59.1.5 Delay constraints

Delay requirements from the MDI to the GMII which include the PMD layer are specified in clause 36. Of the budget, up to 20 ns is reserved for each of the transmit and receive functions of the PMD to account for those cases where the PMD includes a pigtail.

59.1.5.1 PMD_UNITDATA.request

This primitive defines the transfer of a serial data stream from the 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 where the tx_bit parameter can take one of two values: ONE or ZERO. The PMA continuously sends the appropriate stream of bits to the PMD for transmission on the medium, at a nominal 1.25 GBd signaling speed. Upon receipt of this primitive, the PMD converts the specified stream of bits into the appropriate signals at the MDI.

59.1.5.2 PMD_UNITDATA.indication

This primitive defines the transfer of data from the PMD to the 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 where the rx_bit parameter can take one of two values: ONE or ZERO. The PMD continuously sends a stream of bits to the PMA corresponding to the signals received from the MDI.

59.1.5.3 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.

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.

59.2 PMD functional specifications

The 1000BASE-X PMDs perform the transmit and receive functions that convey data between the PMD service interface and the MDI.

59.2.1 PMD block diagram

The PMD sublayer is defined at the four reference points shown in Figure 59–2. Two points, TP2 and TP3, are compliance points. TP1 and TP4 are reference points for use by implementors. The optical transmit signal is defined at the output end of a patch cord (TP2), between 2 and 5 m in length, of a fiber type consistent with the link type connected to the transmitter. If a single-mode fiber offset-launch mode-conditioning patch cord is used, the optical transmit signal is defined at the end of this single-mode fiber offset-launch mode-conditioning patch cord at TP2. Unless specified otherwise, all transmitter measurements and tests defined in 59.7 are made at TP2. The optical receive signal is defined at the output of the fiber optic cabling (TP3) connected to the receiver. Unless specified otherwise, all receiver measurements and tests defined in 59.7 are made at TP3.

The electrical specifications of the PMD service interface (TP1 and TP4) are not system compliance points (these are not readily testable in a system implementation). It is expected that in many implementations, TP1 and TP4 will be common between 1000BASE-X PMD types.

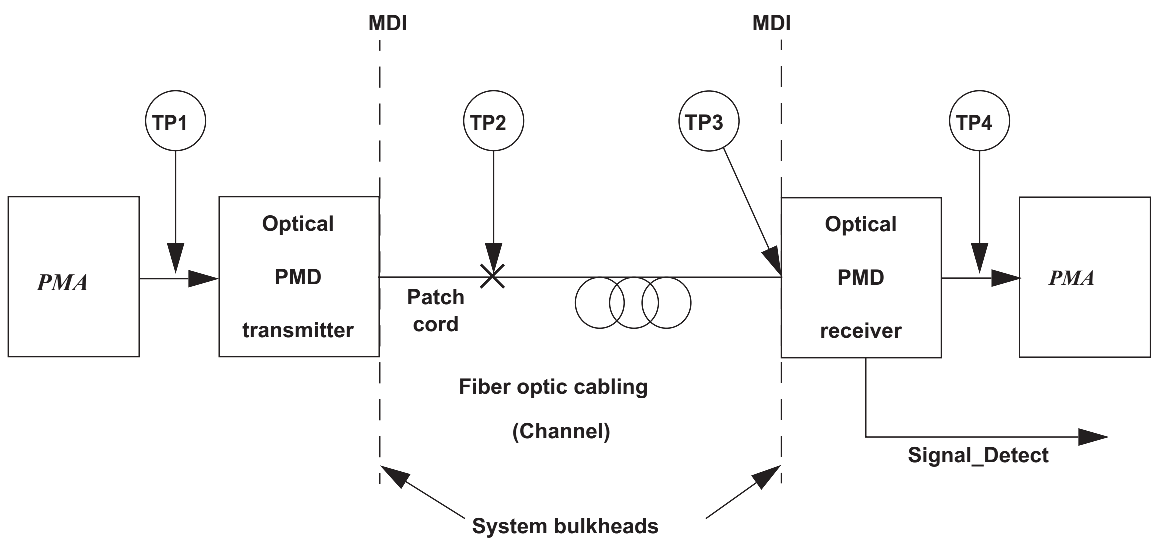


Figure 59–2—1000BASE-X block diagram

59.2.2 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 this clause. The higher optical power level shall correspond to tx_bit =ONE.

59.2.3 PMD receive function

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

59.2.4 PMD signal detect function

The PMD signal detect function 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 optical signal presence.

The value of the SIGNAL_DETECT parameter shall be generated according to the conditions defined in Table 59–2. The PMD receiver is not required to verify whether a compliant 1000BASE-X signal is being received. This standard imposes no response time requirements on the generation of the SIGNAL_DETECT parameter.

As an unavoidable consequence of the requirements for the setting of the SIGNAL_DETECT parameter, implementations must provide adequate margin between the input optical power level at which the SIGNAL_DETECT parameter is set to OK, and the inherent noise level of the PMD due to cross talk, power supply noise, etc.

Various implementations of the Signal Detect function are permitted by this standard, including implementations which generate the SIGNAL_DETECT parameter values in response to the amplitude of the 8B/10B modulation of the optical signal and implementations which respond to the average optical power of the 8B/10B modulated optical signal.

Table 59–2—1000BASE-LX10 and 1000BASE-BX10 SIGNAL_DETECT value definition

Receive conditions		Signal_detect value
1000BASE-LX10	**1000BASE-BX10**	
Average input optical power ≤ signal detect threshold (min) in Table 59–5	Average input optical power ≤ signal detect threshold (min) in Table 59–7	FAIL
Average input optical power ≥ receiver sensitivity (max) in Table 59–5 with a compliant 1000BASE-LX or 1000BASE-LX10 signal input	Average input optical power ≥ receiver sensitivity (max) in Table 59–7 with a compliant 1000BASE-BX10 signal input at the specified receiver wavelength	OK
All other conditions		Unspecified

59.3 PMD to MDI optical specifications for 1000BASE-LX10

The operating range for 1000BASE-LX10 is defined in Table 59–1. A 1000BASE-LX10 compliant transceiver operates over the media types listed in Table 59–1 according to the specifications described in 59.9. A transceiver which exceeds the operational range requirement while meeting all other optical specifications is considered compliant

NOTE—In this subclause and Table 59–5, the specifications for OMA have been derived from extinction ratio and average launch power (minimum) or receiver sensitivity (maximum). The calculation is explained in 58.7.6.

59.3.1 Transmitter optical specifications

The 1000BASE-LX10 transmitter's signaling speed, operating wavelength, spectral width, average launch power, extinction ratio, return loss tolerance, OMA, eye and TDP shall meet the specifications defined in Table 59–3 per measurement techniques described in 59.7. Its RIN_{12}OMA should meet the value listed in Table 59–3 per measurement techniques described in 58.7.7. To ensure that the specifications of Table 59–3 are met with MMF links, the 1000BASE-LX10 transmitter output shall be coupled through a single-mode fiber offset-launch mode-conditioning patch cord, as defined in 59.9.5.The maximum RMS spectral width vs. center wavelength for 1000BASE-LX10 is shown in Table 59–4 and Figure 59–3. The equation used to generate these values is included in 59.7.2. The values in bold are normative, the others informative.

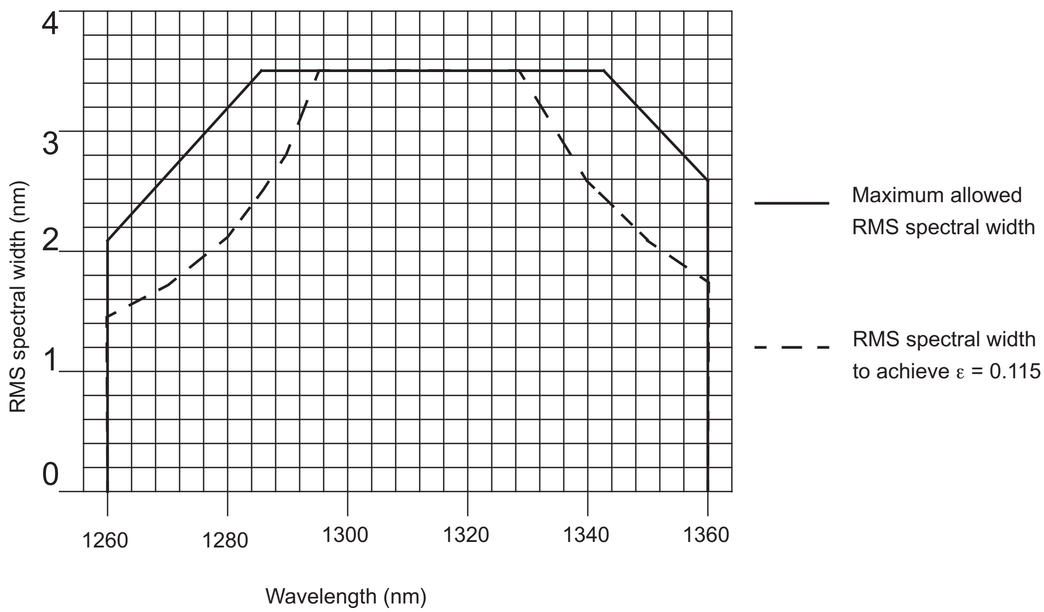


Figure 59–3—1000BASE-LX-10 Transmitter spectral limits

Table 59–3—1000BASE-LX10 transmit characteristics

Description	SMF	50 µm MMF	62.5 µm MMF	Unit
Nominal transmitter type[a]	Longwave Laser			
Signaling speed (range)	1.25 ± 100 ppm			GBd
Operating wavelength range[b]	1260 to 1360			nm
T rise /T fall (max, 20–80% response time)	0.30			ns
RMS spectral width (max)	See Table 59–4			nm
Average launch power (max)	–3			dBm
Average launch power (min)	–9	–11.0	–11.0	dBm
Average launch power of OFF transmitter (max)	–45			dBm
Extinction ratio (min)	6			dB
$RIN_{12}OMA$ (max)	–113			dB/Hz
Optical return loss tolerance (max)	12			dB
Launch OMA (min)	–8.7 (130)	–10.2 (100)	–10.2 (100)	dBm (µW)
Transmitter eye mask definition {X1, X2, Y1, Y2, Y3}	0.22, 0.375, 0.20, 0.20, 0.30			UI
Decision timing offsets for transmitter and dispersion penalty (min)	±80			ps
Transmitter reflectance (max)	–6			dB
Transmitter and dispersion penalty, TDP (max)	3.3	3.5		dB
Differential delay, reference receiver for TDP (min)[c]	NA	367		ps

[a]The nominal device type is not intended to be a requirement on the source type, and any device meeting the transmitter characteristics specified may be substituted for the nominal device type.
[b]The great majority of the transmitted spectrum must fall within the operating wavelength range. The allowable range of central wavelengths is narrower than the operating wavelength range by the actual RMS spectral width at each extreme.
[c]Delay is calculated as Td = L/(3.BWf) where BWf is defined to –3 dB (optical). 1000BASE-LX is rated for 550 m of 500 MHz.km fiber while 1000BASE-LX also covered 550 m of 400 MHz.km fiber, but this is now seen as a historical bandwidth requirement.

Table 59–4—1000BASE-LX10 and 1000BASE-BX10 transmitter spectral limits

Center wavelength	RMS spectral width (max)[a]	RMS spectral width to achieve ε ≤0.115 (informative)
nm	nm	nm
1260	2.09	1.43
1270	2.52	1.72
1280	3.13	2.14
1286	3.50	2.49
1290		2.80
1297		3.50
1329		
1340		2.59
1343		2.41
1350	3.06	2.09
1360	2.58	1.76
1480 to 1500	0.88	0.60

[a]These limits for the 1000BASE-LX10 transmitter are illustrated in Figure 59–3. Limits at intermediate wavelengths may be found by interpolation.

59.3.2 Receiver optical specifications

The 1000BASE-LX10 receiver's signaling speed, operating wavelength, damage, overload, sensitivity, stressed receive characteristics, reflectivity and signal detect shall meet the specifications defined in Table 59–5 per measurement techniques defined in 59.7.

Table 59–5—1000BASE-LX10 receive characteristics

Description	Value	Unit
Signaling speed (range)	1.25 ± 100 ppm	GBd
Wavelength (range)	1260 to 1360	nm
Average receive power (max)	–3	dBm
Receive sensitivity (max)	–19.5	dBm
Receiver sensitivity as OMA (max)	–18.7 (13.4)	dBm (μW)
Bit error ratio (max)	10^{-12}	
Receiver reflectance (max)[a]	–12	dB
Stressed receive sensitivity (max)	–15.4	dBm
Stressed receiver sensitivity as OMA (max)	–14.6 (35)	dBm (μW)
Vertical eye-closure penalty (min)	3.6	dB

Table 59–5—1000BASE-LX10 receive characteristics *(continued)*

Description	Value	Unit
Receive electrical 3 dB upper cutoff frequency (max)	1500	MHz
Signal detect threshold (min)	–45	dBm
Stressed eye jitter (min)[b]	0.3	UI pk-pk
Jitter corner frequency	637	kHz
Sinusoidal jitter limits for stressed receiver conformance test (min, max)	0.05, 0.15	UI

[a]See 1.4 for definition of reflectance.
[b]Vertical eye closure penalty and jitter specifications are test conditions for measuring stressed receiver sensitivity. They are not required characteristics of the receiver.

59.4 PMD to MDI optical specifications for 1000BASE-BX10-D and 1000BASE-BX10-U

The operating range for 1000BASE-BX10-D and 1000BASE-BX10-U is defined in Table 59–1. A 1000BASE-BX10 compliant transceiver operates over all single-mode fibers listed in Table 59–1. A transceiver which exceeds the operational range requirement while meeting all other optical specifications is considered compliant.

NOTE—In this subclause and 59.3, the specifications for OMA have been derived from extinction ratio and average launch power (minimum) or receiver sensitivity (maximum). The calculation is explained in 58.7.6.

59.4.1 Transmit optical specifications

The 1000BASE-BX10-D and 1000BASE-BX10-U transmitter's signaling speed, operating wavelength, spectral width, average launch power, extinction ratio, return loss tolerance, OMA, eye and TDP shall meet the specifications defined in Table 59–6 per measurement techniques described in 59.7. Its $RIN_{12}OMA$ should meet the value listed in Table 59–6 per measurement techniques described in 59.7.7.

Table 59–6—1000BASE-BX10-D and 1000BASE-BX10-U transmit characteristics

Description	1000BASE-BX10-D	1000BASE-BX10-U	Unit
Nominal transmitter type[a]	Longwave Laser		
Signaling speed (range)	1.25 ± 100 ppm		GBd
Operating wavelength range[b]	1480 to 1500	1260 to 1360	nm
RMS spectral width (max)	See Table 59–4		nm
Average launch power (max)	-3		dBm
Average launch power (min)	–9		dBm
Average launch power of OFF transmitter (max)	–45		dBm
Extinction ratio (min)	6		dB
$RIN_{12}OMA$ (max)	–113		dB/Hz

Table 59–6—1000BASE-BX10-D and 1000BASE-BX10-U transmit characteristics *(continued)*

Description	1000BASE-BX10-D	1000BASE-BX10-U	Unit
Optical return loss tolerance (max)	12		dB
Launch OMA	–8.2 (151)		dBm (μW)
Transmitter eye mask definition {X1, X2, Y1, Y2, Y3}	0.22, 0.375, 0.20, 0.20, 0.30		UI
Transmitter reflectance (max)	–10	–6	dB
Transmitter and dispersion penalty, TDP (max)	3.3		dB
Decision timing offsets for transmitter and dispersion penalty (min)	± 80		ps

[a]The nominal device type is not intended to be a requirement on the source type, and any device meeting the transmitter characteristics specified may be substituted for the nominal device type.

[b]The great majority of the transmitted spectrum must fall within the operating wavelength range. The allowable range of central wavelengths is narrower than the operating wavelength range by the actual RMS spectral width at each extreme.

59.4.2 Receiver optical specifications

The 1000BASE-BX10-D and 1000BASE-BX10-U receiver’s signaling speed, operating wavelength, damage, overload, sensitivity, reflectivity and signal detect shall meet the specifications defined in Table 59–7 per measurement techniques defined in 59.7. Its stressed receive characteristics should meet the values listed in Table 59–7 per measurement techniques described in 59.7.11.

Table 59–7—1000BASE-BX10-D and 1000BASE-BX10-U receive characteristics

Description	1000BASE-BX10-D	1000BASE-BX10-U	Unit
Signaling speed (range)	1.25 ± 100 ppm		GBd
Wavelength (range)	1260 to 1360	1480 to 1500	nm
Bit error ratio (max)	10^{-12}		
Average receive power (max)	–3		dBm
Receive sensitivity (max)	–19.5		dBm
Receiver sensitivity as OMA (max)	–18.7 (13.4)		dBm (μW)
Receiver reflectance (max)	–12		dB
Stressed receive sensitivity (max)[a]	–15.4		dBm
Stressed receiver sensitivity as OMA (max)	–14.6 (35)		dBm (μW)
Vertical eye-closure penalty (min)[b]	2.6		dB
Receive electrical 3 dB upper cutoff frequency (max)	1500		MHz
Signal detect threshold (min)	–45		dBm

Table 59–7—1000BASE-BX10-D and 1000BASE-BX10-U receive characteristics *(continued)*

Description	1000BASE-BX10-D	1000BASE-BX10-U	Unit
Stressed eye jitter (min)	0.3		UI pk-pk
Jitter corner frequency	637		kHz
Sinusoidal jitter limits for stressed receiver conformance test (min, max)	0.05, 0.15		UI

[a]The stressed receiver sensitivity is optional
[b]Vertical eye closure penalty and jitter specifications are test conditions for measuring stressed receiver sensitivity. They are not required characteristics of the receiver.

59.5 Illustrative 1000BASE-LX10 and 1000BASE-BX10 channels and penalties (informative)

The illustrative channel and penalties for 1000BASE-LX10 and 1000BASE-BX10 PMDs are shown in Table 59–8.

Table 59–8—Illustrative 1000BASE-LX10 and 1000BASE-BX10 channel and penalties

PMD type	1000BASE-LX10		1000BASE-BX10-D	1000BASE-BX10-U	Unit
Fiber type	B1.1, B1.3 SMF	50µm, 62.5µm MMF	B1.1, B1.3 SMF		
Measurement wavelength for fiber	1310	1300	1550	1310	nm
Nominal distance	10	0.55	10		km
Available power budget	10.5	8.5	10.5		dB
Maximum channel insertion loss[a]	6.0	2.4	5.5	6.0	dB
Allocation for penalties[b]	4.5	6.1	5.0	4.5	dB

[a]The maximum 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.
[b]The allocation for penalties is the difference between the available power budget and the channel insertion loss; insertion loss difference between nominal and worse case operating wavelength is considered a penalty.

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

59.6 Jitter specifications

The entries for the 1000BASE-LX10 jitter budget on MMF in Table 59–9 and the 1000BASE-LX10 and 1000BASE-BX10 jitter budget on SMF in Table 59–10 represent high-frequency jitter (above 637 kHz) and do not include low frequency jitter or wander. All values are informative.

W is similar but not necessarily identical to deterministic jitter (DJ). A jitter measurement procedure is described in 58.7.12. Other jitter measurements are described in 59.7.12 and 59.7.13. Jitter at TP2 or TP3 is defined with a receiver of the same bandwidth as specified for the transmitted eye.

Table 59–9—1000BASE-LX10 jitter budget on MMF (informative)

	Total jitter		*W*	
Reference point	UI	ps	UI	ps
TP1	0.240	192	0.100	80
TP1 to TP2	0.284	227	0.100	80
TP2	0.431	345	0.200	160
TP2 to TP3	0.170	136	0.050	40
TP3	0.510	408	0.250	200
TP3 to TP4	0.332	266	0.212	170
TP4	0.749	599	0.462	370

Table 59–10—1000BASE-LX10 and 1000BASE-BX10 jitter budget on SMF (informative)

	Total jitter		*W*	
Reference point	UI	ps	UI	ps
TP1	0.240	192	0.100	80
TP1 to TP2	0.334	267	0.150	120
TP2	0.481	385	0.250	200
TP2 to TP3	0.119	95	0	0
TP3	0.510	408	0.250	200
TP3 to TP4	0.332	266	0.212	170
TP4	0.749	599	0.462	370

NOTE—Informative jitter values are chosen to be compatible with the limits for eye mask and TDP (see 58.7.9). A margin between the total jitter at TP4 and the eye opening imposed by the decision point offsets for TDP is intended to allow for the performance of test equipment used for TDP measurement, to avoid very involved jitter calibrations.

Total jitter in this table is defined at 10^{-12} BER. In a commonly used model,

$$TJ = 14.1\sigma + DJ \text{ at } 10^{12} \quad (59\text{-}1)$$

59.7 Optical measurement requirements

All optical measurements, except TDP and RIN, shall be made through a short patch cable, between 2 m and 5 m in length.

The following sections describe definitive patterns and test procedures for certain PMDs of this standard. Implementors using alternative verification methods must ensure adequate correlation and allow adequate margin such that specifications are met by reference to the definitive methods.

59.7.1 Test patterns

The frame based test patterns defined here are suitable for testing all Clause 59 and Clause 60 PMDs. Further information on frame based testing in included in Annex 58A. The test suite and the patterns are shown in Table 59–11.

The following test patterns are intended for frame based testing of the 1000BASE-X PMDs of Clause 59 and Clause 60. They are compliant Ethernet packets with adequate user defined fields to allow them to be routed through a system to the point of the test. The common portions of the frames are given in Table 59–12.

Table 59–11—List of test patterns and tests

Test pattern	Tests	Related subclauses
Any valid 8B/10B encoded signal	Eye mask Optical power Central wavelength Spectral width	59.7.8 59.7.3 59.7.2 59.7.2
Idles	Extinction ratio $RIN_{12}OMA$ OMA	59.7.4 59.7.7
Random pattern test frame	Receiver sensitivity Stressed receiver sensitivity Receiver 3dB upper cutoff frequency TDP	59.7.11 59.7.14 59.7.15 59.7.10
Jitter pattern test frame	All jitter tests	59.7.12

Table 59–12—Common portion of frame based test pattern

Field	Number of octets	Hexadecimal	8B10B encoded binary[a]	
			Starting disparity +	Starting disparity–
SPD (/S/)	1	N/A[b]	N/A[c]	110110 1000
Remainder of preamble	6	55	N/A[c]	101010 0101
SFD	1	D5	N/A[c]	101010 0110
Destination address	6	User defined	User defined	User defined
Source address	6	User defined	User defined	User defined
Length / type	2	User defined	User defined	User defined
First portion of MAC client data	32	User defined	User defined	User defined
Second portion of MAC client data	456	See Table 59–13 or Table 59–14	See Table 59–13 or Table 59–14	See Table 59–13 or Table 59–14
Frame check sequence[d]	4	As required by frame	As required by frame	As required by frame
EPD (/T/R/)[e]	2	N/A[b]	010001 0111 000101 0111	101110 1000 111010 1000
Idle (/I1/ or /I2/)[e]	2	N/A[b]	110000 0101 101001 0110	001111 1010 100100 0101
Idle (/I2/)[e]	10	N/A[b]	N/A[f]	001111 1010 100100 0101

[a]The binary bits are transmitted left most bit first.
[b]The SPD, EPD, and Idle code-groups are generated by the PCS and their hexadecimal octet values have no meaning without relation to the signals transmitted across the GMII.
[c]Except when operating in a half-duplex mode, it is not possible to transmit an SPD with a positive starting disparity. The first code-group that could begin with a positive running disparity would be the second octet of the destination address.
[d]The frame check sequence may be calculated using the method described in 3.2.8.
[e]The first row precedes the second row.
[f]The first idle code-group following the frame will be an /I1/ if the running disparity is positive and an /I2/ if the running disparity is negative. All subsequent idle code-groups will be /I2/.

NOTE—Users are advised to take care that the system under test is not connected to a network in service.

Two payloads are defined. The first, which emulates a random pattern with broad spectral content and minimal peaking, is shown in Table 59–13.

Table 59–13—Payload for random pattern test frame

Number of octets	Hexadecimal	8B10B encoded binary	
		Starting disparity +	Starting disparity –
Repeat 19 times for 228 bytes	BE	100001 1010	011110 1010
	D7	111010 0110	000101 0110
	23	110001 1001	110001 1001
	47	000111 0101	111000 0101
	6B	110100 0011	110100 1100
	8F	101000 1101	010111 0010
	B3	110010 1010	110010 1010
	14	001011 0100	001011 1011
	5E	011110 0101	100001 0101
	FB	001001 1110	110110 0001
	35	101010 1001	101010 1001
	59	100110 0101	100110 0101
Transmit once for 12 bytes	BC	001110 1010	001110 1010
	D7	000101 0110	111010 0110
	23	110001 1001	110001 1001
	47	111000 0101	000111 0101
	6B	110100 1100	110100 0011
	8F	010111 0010	101000 1101
	B3	110010 1010	110010 1010
	14	001011 1011	001011 0100
	5E	100001 0101	011110 0101
	FB	110110 0001	001001 1110
	35	101010 1001	101010 1001
	59	100110 0101	100110 0101
Repeat 18 times for 216 bytes	BE	011110 1010	100001 1010
	D7	000101 0110	111010 0110
	23	110001 1001	110001 1001
	47	111000 0101	000111 0101
	6B	110100 1100	110100 0011
	8F	010111 0010	101000 1101
	B3	110010 1010	110010 1010
	14	001011 1011	001011 0100
	5E	100001 0101	011110 0101
	FB	110110 0001	001001 1110
	35	101010 1001	101010 1001
	59	100110 0101	100110 0101

The payload for the second pattern is shown in Table 59–14.

Table 59–14—Payload for jitter test frame

Field	Hexadecimal	8B10B encoded binary	
		Starting disparity +	Starting disparity –
Low Transition Density, Repeat 96 times for 192 bytes	7E	100001 1100	011110 0011
	7E	011110 0011	100001 1100
Phase Jump, Repeat one time for 8 bytes	F4	001011 0001	001011 0111
	EB	110100 1110	110100 1000
	F4	001011 0001	001011 0111
	EB	110100 1110	110100 1000
	F4	001011 0001	001011 0111
	EB	110100 1110	110100 1000
	F4	001011 0001	001011 0111
	AB	110100 1010	110100 1010
High Transition Density, Repeat 20 times for 20 bytes	B5	101010 1010	101010 1010
Phase Jump, Repeat 4 times for 8 bytes	EB	110100 1110	110100 1000
	F4	001011 0001	001011 0111
Low Transition Density, Repeat 96 times for 192 bytes	7E	011110 0011	100001 1100
	7E	100001 1100	011110 0011
Phase Jump, Repeat one time for 9 bytes	F4	001011 0111	001011 0001
	EB	110100 1000	110100 1110
	F4	001011 0111	001011 0001
	EB	110100 1000	110100 1110
	F4	001011 0111	001011 0001
	EB	110100 1000	110100 1110
	F4	001011 0111	001011 0001
	AB	110100 1010	110100 1010
High Transition Density, Repeat 20 times for 20 bytes	B5	101010 1010	101010 1010
Phase Jump, Repeat 4 times for 8 bytes.	EB	110100 1000	110100 1110
	F4	001011 0111	001011 0001

This pattern has areas of high and low transition density to aggravate jitter susceptibility.

Frames are separated by a near minimum inter-packet gap (IPG) of 14 octets.

59.7.2 Wavelength and spectral width measurements

The wavelength and spectral width (RMS) shall meet the specifications according to ANSI/EIA/TIA-455-127, under modulated conditions using a valid 1000BASE-X signal.

NOTE 1—The great majority of the transmitted spectrum must fall within the operating range. The allowable range of central wavelengths is narrower than the operating wavelength range by the actual RMS spectral width at each extreme.

NOTE 2—The 20 dB width for SLM lasers is taken as 6.07 times the RMS width.

The interaction between the transmitter and the chromatic dispersion of the fiber is accounted for by a parameter ε (epsilon), which is defined as the product of 10^{-3} times the signaling speed (in GBd) times the path dispersion (in ps/nm) times the RMS spectral width (in nm).

$$\varepsilon = \text{dispersion} \times \text{length} \times \text{RMS spectral width} \times \text{signaling speed} \times 10^{-3} \quad (59\text{-}2)$$

A maximum ε close to 0.168 is imposed by column 2 of Table 59–5. If the spectral width is kept below the limits of column 3, ε will not exceed 0.115, and the chromatic dispersion penalty is expected to be below 2 dB. The chromatic dispersion penalty is a component of transmitter and dispersion penalty (TDP) which is specified in Table 59–3, Table 59–6 and described in 58.7.9.

59.7.3 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 data stream.

59.7.4 Extinction ratio measurements

Extinction ratio shall meet specifications according to ANSI/TIA/EIA-526-4A with the port transmitting a repeating idle pattern /I2/ ordered_set (see 36.2.4.12) that may be interspersed with OAM packets per 43B.2, and with minimal back reflections into the transmitter, lower than –20 dB. The /I2/ ordered_set is defined in Clause 36, and is coded as /K28.5/D16.2/ which is binary 001111 1010 100100 0101 within idles. The extinction ratio is expected to be similar for other valid 8B/10B bit streams. The test receiver has the frequency response as specified for the transmitter optical waveform measurement.

59.7.5 OMA measurements (informative)

58.7.5 provides a reference technique for performing OMA measurements.

59.7.6 OMA relationship to extinction ratio and power measurements (informative)

The normative way of measuring transmitter characteristics is extinction ratio and mean power. Clause 58 provides information on how OMA, extinction ratio, and mean power, are related to each other (see 58.7.6).

59.7.7 Relative intensity noise optical modulation amplitude ($RIN_{12}OMA$)

$RIN_{12}OMA$ is the ratio of noise to modulated optical signal in the presence of a back reflection. The measurement procedure is described in 58.7.7.

59.7.8 Transmitter 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 59–4.

The measurement procedure is described in 58.7.8 and references therein.

The eye shall comply to the mask of the eye using a fourth-order Bessel-Thomson receiver response with fr = 0.9375 GHz, and where the relative response vs. relative frequency is defined in ITU-T G.957, Table B.2 (STM-16 values), along with the allowed tolerances for its physical implementation.

NOTE 1—This Bessel-Thomson filter is not intended to represent the noise filter used within an optical receiver, but is intended to provide uniform measurement conditions on the transmitter.

NOTE 2—The fourth order Bessel-Thomson filter is reactive. In order to suppress reflections, a 6 dB attenuator may be required at the filter input and/or output.

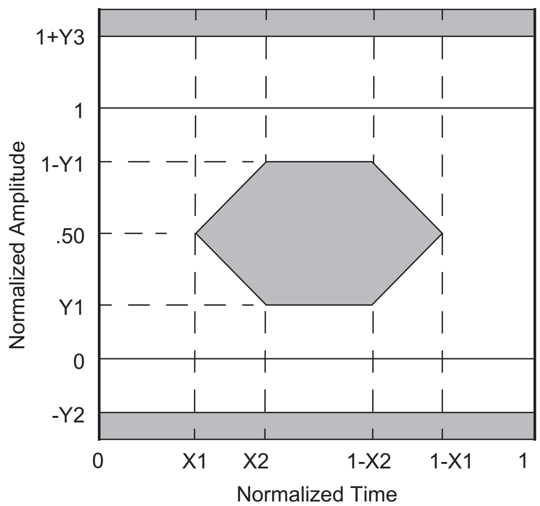


Figure 59–4—Transmitter eye mask definition

59.7.9 Transmit rise/fall characteristics

Optical response time specifications are based on unfiltered waveforms. Some lasers have overshoot and ringing on the optical waveforms, which, if unfiltered, reduce the accuracy of the 20–80% response times. For the purpose of standardizing the measurement method, measured waveforms shall conform to the mask defined in 59.7.8. If a filter is needed to conform to the mask, the filter response should be removed using the equation:

$$T_{\text{rise, fall}} = \sqrt{(T_{\text{rise, fall, measured}})^2 - (T_{\text{rise, fall, filter}})^2} \quad (59\text{-}3)$$

where the filter may be different for rise and fall. Any filter should have an impulse response equivalent to a fourth order Bessel-Thomson filter. The fourth order Bessel-Thomson filter describe in 59.7.8 may be a convenient filter for this measurement, however its low bandwidth adversely impacts the accuracy of the rise and fall time measurements.

59.7.10 Transmitter and dispersion penalty (TDP)

This measurement tests for transmitter impairments with modal (not chromatic) dispersion effects for a transmitter to be used with multimode fiber, and for transmitter impairments with chromatic effects for a transmitter to be used with single-mode fiber. Possible causes of impairment include intersymbol interference, jitter, RIN and mode partition noise. Meeting the separate requirements (e.g. eye mask, spectral characteristics) does not in itself guarantee the transmitter and dispersion penalty (TDP). The TDP limit shall be met. See 59.7.9 for details of the measurement.

59.7.11 Receive sensitivity measurements

Receiver sensitivity is defined for the random pattern test frame (see 59.7.1) and an ideal input signal quality with the specified extinction ratio. The measurement procedure is described in 58.7.10. The sensitivity shall be met for the bit error ratio defined in Table 59–5 or Table 59–7 as appropriate. Stressed sensitivity is described in 59.7.14 and 58.7.11.

59.7.12 Total jitter measurements (informative)

Total jitter measurements may be made according to the method in ANSI X3.230 [B20](FC-PH), Annex A, A.4.2, or according to 58.7.12. Total jitter at TP2 should be measured utilizing a BERT (Bit Error Ratio Tester). References to use of the Bessel-Thomson filter should substitute use of the Bessel-Thomson filter defined in this clause (see 59.7.8). The test should utilize the mixed frequency test pattern specified in 59.7.1.

Total jitter at TP4 should be measured using the conformance test signal at TP3, as specified in 59.7.14. The optical power should be at the stressed receive sensitivity level in Table for 1000BASE-LX10 and in Table 59–7 for 1000BASE-BX10. This power level should be corrected if the extinction ratio differs from the specified extinction ratio (minimum). Measurements at TP4 should be taken directly without additional Bessel-Thomson filters.

Jitter measurement may use a clock recovery unit (commonly referred to in the industry as a "golden PLL") to remove low-frequency jitter from the measurement as shown in Figure 59–5. The clock recovery unit has a low pass filter with 20 dB/decade rolloff with –3 dB point of 637 kHz. For this measurement, the recovered clock will run at the signaling speed. The golden PLL is used to approximate the PLL in the deserializer function of the PMA. The PMA deserializer is able to track a large amount of low-frequency jitter (such as drift or wander) below its bandwidth. This low-frequency jitter would create a large measurement penalty, but does not affect operation of the link.

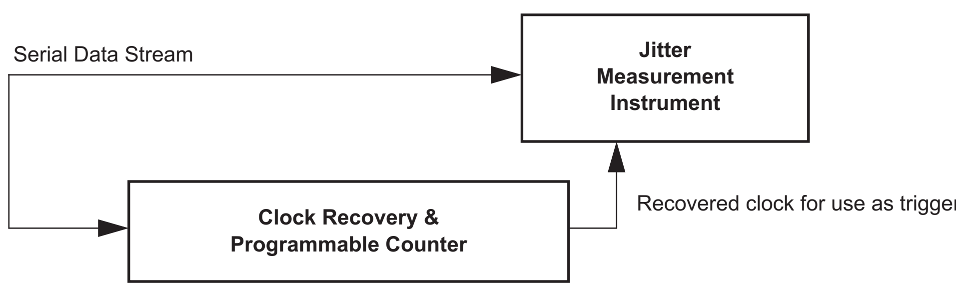


Figure 59–5—Utilization of clock recovery unit during measurement

59.7.13 Deterministic or high probability jitter measurement (informative)

Deterministic jitter may be measured according to ANSI X3.230-1994 [B20] (FC-PH), Annex A, A.4.3, DJ Measurement or high probability jitter may be measured according to 58.7.12. The test utilizes the mixed frequency test pattern specified in 36A.3. This method utilizes a digital sampling scope to measure actual vs. predicted arrival of bit transitions of the 36A.3 data pattern (alternating K28.5 code-groups).

It is convenient to use the clock recovery unit described in 59.7.12 for purposes of generating a trigger for the test equipment. This recovered clock should have a frequency equivalent to 1/20th of the signaling speed.

Measurements at TP2 and TP3 use the filter specified in 59.7.8, measurements at TP1 and TP4 do not use this filter.

59.7.14 Stressed receiver conformance test

The stressed receiver conformance test is intended to screen against receivers with poor frequency response or timing characteristics which could cause errors when combined with a distorted but compliant signal at TP3. Modal (MMF) or chromatic (SMF) dispersion can cause distortion. The conformance test signal uses the random pattern test frame and is conditioned by applying deterministic jitter and intersymbol interference. If the option for stressed receiver compliance is chosen, the receiver shall meet the specified bit error ratio at the power level and signal quality defined in Table 59–5 and Table 59–7 as appropriate, according to the measurement procedures of 58.7.11.

59.7.15 Measurement of the receiver 3 dB electrical upper cutoff frequency

The receiver 3 dB electrical upper cutoff frequency shall meet specifications according to the methods specified below. The test setup is shown in Figure 59–6. The test is performed with a laser that is suitable for analog signal transmission. The laser is modulated by a digital data signal. In addition to the digital modulation, the laser is modulated with an analog signal. The analog and digital signals should be asynchronous. The data pattern to be used for this test is the random pattern test frame defined in 59.7.1. The frequency response of the laser must be sufficient to allow it to respond to both the digital modulation and the analog modulation. The laser should be biased so that it remains linear when driven by the combined signals. Alternatively the two signals may be combined in the optical domain.

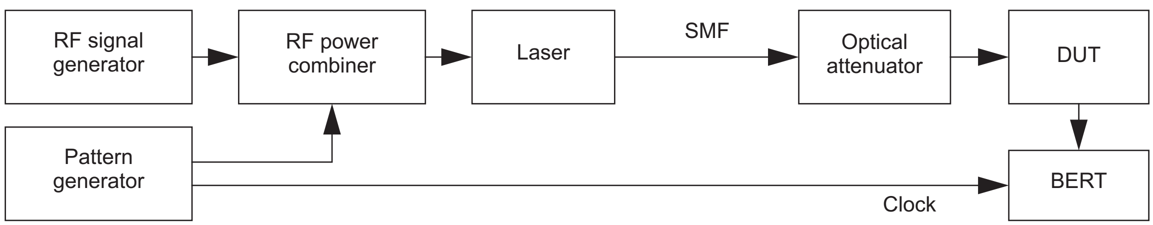


Figure 59–6—Test setup for receiver bandwidth measurement

The 3 dB upper cutoff frequency is measured using the following steps a) through e):

a) Calibrate the frequency response characteristics of the test equipment including the analog radio frequency (RF) signal generator, RF power combiner, and laser source. Measure the laser's extinction ratio according to 59.7.4. With the exception of extinction ratio, the optical source shall meet the requirements of Clause 59.
b) Configure the test equipment as shown in Figure 59–6. Take care to minimize changes to the signal path that could affect the system frequency response after the calibration in step a. Connect the laser output with no RF modulation applied to the receiver under test through an optical attenuator and taking into account the extinction ratio of the source, set the optical power to a level that approximates the stressed receive sensitivity level in Table for 1000BASE-LX10 and in Table 59–7 for 1000BASE-BX10.
c) Locate the center of the eye with the BERT. Turn on the RF modulation while maintaining the same average optical power established in step (b).
d) Measure the necessary RF modulation amplitude (in dBm) required to achieve a constant BER (e.g., 10^{-8}) for a number of frequencies.
e) The receiver 3 dB electrical upper cutoff frequency is that frequency where the corrected RF modulation amplitude (the measured amplitude in step (d) corrected with the calibration data in step (a) increases by 3 dB (electrical). If necessary, interpolate between the measured response values.

59.8 Environmental, safety and labeling specifications

59.8.1 General Safety

All equipment meeting this standard shall conform to IEC 60950.

59.8.2 Laser safety

1000BASE-BX10 and 1000BASE-LX10 optical transceivers shall conform to Class 1 laser requirements as defined in IEC 60825-1, 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 geographical 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 shall explicitly define requirements and usage restrictions on the host system necessary to meet these safety certifications.

59.8.3 Installation

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

59.8.4 Environment

Reference Annex 67A for additional environmental information.

Two optional temperature ranges are defined in Table 59–15. 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).

Table 59–15—Component case temperature classes

Class	Low temperature (˚C)	High temperature (˚C)
Warm extended	–5	+85
Cool extended	–40	+60
Universal extended	–40	+85

59.8.5 PMD labeling requirements

It is recommended that each PHY (and supporting documentation) be labeled in a manner visible to the user, with at least the applicable safety warnings and the applicable port type designation (e.g., 1000BASE-BX10-U).

Labeling requirements for Class 1 lasers are given in the laser safety standards referenced in 59.8.2.

Compliant systems and field pluggable components shall be clearly labeled with the operating temperature range over which their compliance is ensured.

59.9 Characteristics of the fiber optic cabling

The 1000BASE-BX10 and 1000BASE-LX10 fiber optic cabling shall meet the dispersion and modal bandwidth specifications defined in IEC 60793-2 and ITU-T G.652, as shown in Table 59–16. The fiber cable attenuation is shown for information only; the end-to-end channel loss shall meet the requirements of Table 59–1. The fiber optic cabling consists of one or more sections of fiber optic cable and any intermediate connections required to connect sections together. The fiber optic cabling spans from one MDI to another MDI, as shown in Figure 59–7.

59.9.1 Fiber optic cabling model

The fiber optic cabling model is shown in Figure 59–7.

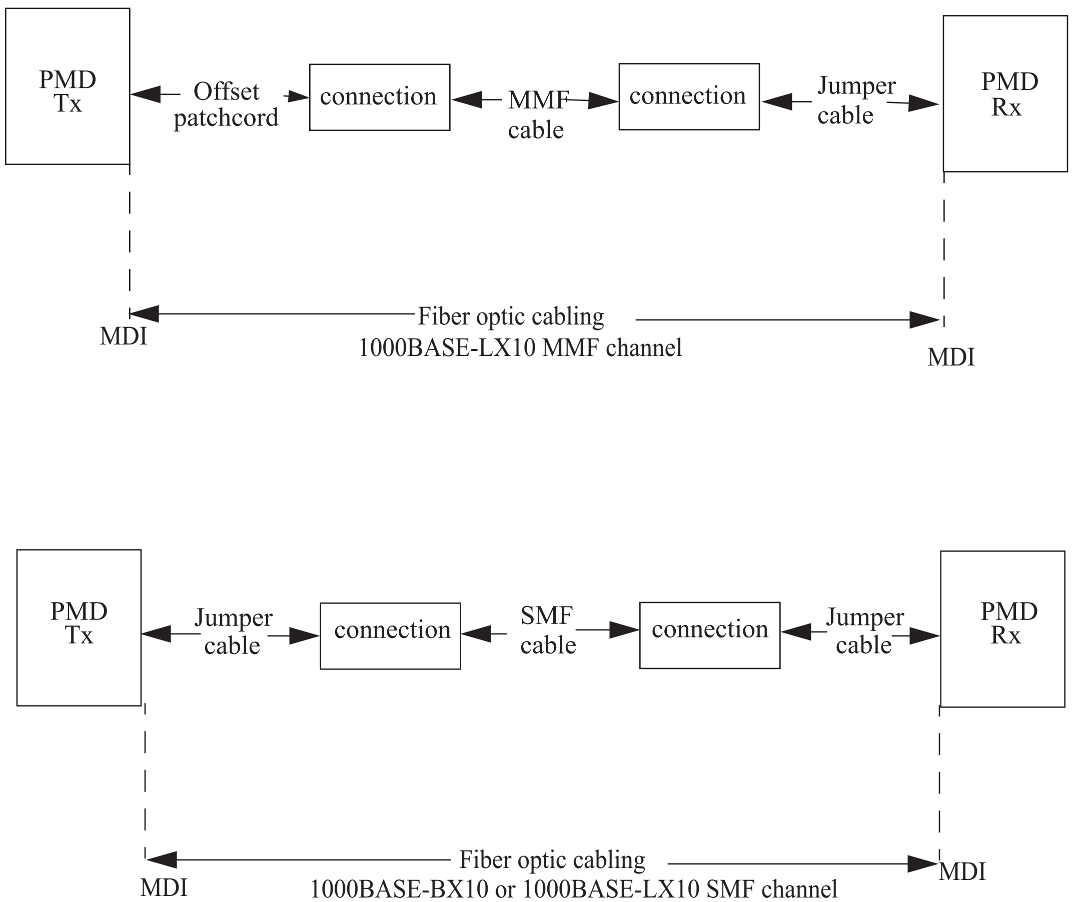


Figure 59–7—Fiber optic cable model

The maximum channel insertion loss shall meet the requirements specified in Table 59–1. The minimum loss for 1000BASE-BX10 and 100BASE-LX10 is zero. A channel may contain additional connectors or other optical elements as long as the optical characteristics of the channel, such as attenuation, dispersion and reflections, meet the specifications. Insertion loss measurements of installed fiber cables are made in accordance with ANSI/TIA/EIA-526-14A [B14], method B for multimode cabling and ANSI/TIA/EIA-526-7 [B15], method A-1 for single-mode cabling. 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.

59.9.2 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 single-mode fiber) and Type B1.3 (low water peak single-mode fiber) and ITU-T G.652 as noted in Table 59–16.

Table 59–16—Optical fiber and cable characteristics

Description[a]	B1.1, B1.3 SMF		50 µm MMF	62.5 µm MMF	Unit
Nominal fiber specification wavelength[b]	1310	1550	1300		nm
Fiber cable attenuation (max)[c]	0.4	0.35	1.5		dB/km
Modal Bandwidth (min; overfilled launch)	N/A		500[d]		MHz· km
Zero dispersion wavelength[e]	$1300 \le \lambda_0 \le 1324$		$1295 \le \lambda_0 \le 1320$	$1320 \le \lambda_0 \le 1365$	nm
Dispersion slope (max)	0.093		0.11 for $1300 \le \lambda_0 \le 1320$ and $0.001(\lambda_0\text{-}1190)$ for $1295 \le \lambda_0 \le 1300$	0.11 for $1320 \le \lambda_0 \le 1348$ and $0.001(1458\text{-}\lambda_0)$ for $1348 \le \lambda_0 \le 1365$	ps /nm^2 · km

[a]The fiber dispersion values are normative, all other values in the table are informative.
[b]The wavelength specified is the nominal fiber specification wavelength which is the typical measurement wavelength. Power penalties at other wavelengths are accounted for.
[c]Attenuation values are informative. Attenuation for single-mode optical fiber cables is defined in ITU-T G.652 and for multimode fiber cables is defined in ISO/IEC 11801.
[d]1000BASE-LX10 is rated for 550 m of 500 MHz·km fiber, while 1000BASE-LX also covered 550 m of 400 MHz·km, but this now seen as a historical bandwidth requirement.
[e]See IEC 60793 or G.652 for correct use of zero dispersion wavelength and dispersion slope.

59.9.3 Optical fiber connection

The maximum link distances for multimode fiber are calculated based on the allocation of 1.5 dB total connection and splice loss. Connections with different loss characteristics may be used provided the requirements of Table 59–1 are met.

The maximum link distances for single-mode fiber are calculated based on the allocation of 2 dB total connection and splice loss for 1000BASE-LX10 and 1000BASE-BX10. Connections with different loss characteristics may be used provided the requirements of Table 59–1 are met.

The maximum discrete reflectance for multimode connections shall be less than –20 dB.

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

59.9.4 Medium Dependent Interface (MDI)

The 1000BASE-LX10 or 1000BASE-BX10 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 59–7. Examples of an MDI include:

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 1000BASE-BX10 it couples a single fiber and for 1000BASE-LX10 it couples dual fibers.

NOTE—Compliance testing is performed at TP2 and TP3 as defined in 59.2.1, not at the MDI.

59.9.5 Single-mode fiber offset-launch mode-conditioning patch cord for MMF operation of 1000BASE-LX10

This subclause specifies an example embodiment of a mode conditioner for 1000BASE-LX10 operation with MMF cabling. The mode conditioner consists of a single-mode fiber permanently coupled off-center to a graded index fiber. This example embodiment of a patch cord is not intended to exclude other physical implementations of offset-launch mode conditioners. However, any implementation of an offset-launch mode conditioner used for 1000BASE-LX10 shall meet the specifications of Table 59–17. The offset launch shall be contained within the patch cord assembly and is not adjustable by the user.

NOTE—The single-mode fiber offset-launch mode-conditioning patch cord described in Clause 38 may be used, although its labeling and coloring requirements are not mandatory here. See 38.11.4.

Table 59–17—Single-mode fiber offset-launch mode conditioner specifications

Description	62.5 µm MMF	50 µm MMF	Unit
Maximum insertion loss	0.5	0.5	dB
Coupled power ratio (CPR)	28 < CPR < 40	12 < CPR < 20	dB
Optical center offset between SMF and MMF	17 < Offset < 23	10 < Offset < 16	µm
Maximum angular offset	1	1	degree

Patch cord connectors and ferrules for the single-mode-to-multimode offset launch shall have single-mode tolerances, float, and other mechanical requirements according to IEC 61754-1.

The single-mode fiber used in the construction of the single-mode fiber offset-launch mode conditioner shall meet the requirements of 59.9.2. The multimode fiber used in the construction of the single-mode fiber offset-launch mode conditioner shall be of the same type as the cabling over which the 1000BASE-LX10 link is to be operated. If the cabling is 62.5 µm MMF then the MMF used in the construction of the mode conditioner is of type 62.5 µm MMF. If the cabling is 50 µm MMF, then the MMF used in the construction of the mode conditioner is of type 50 µm MMF.

Figure 59–8 shows an example of an embodiment of the single-mode fiber offset-launch mode-conditioning patch cord. This patch cord consists of duplex fibers including a single-mode-to-multimode offset launch fiber connected to the transmitter MDI and a second conventional graded index MMF connected to the receiver MDI. The preferred configuration is a plug-to-plug patch cord since it maximizes the power budget margin of the 1000BASE-LX10 link. The single-mode end of the patch cord is labeled “To Equipment”. The multimode end of the patch cord is labeled “To Cable”. The recommended color identifier of the single-mode fiber connector is blue. The recommended color identifier of all multimode fiber connector plugs is beige. The patch cord assembly is labeled “Offset-launch mode-conditioning patch cord assembly”. Labeling identifies which size multimode fiber is used in the construction of the patch cord. The keying of this duplex optical plug ensures that the single-mode fiber end is automatically aligned to the transmitter MDI.

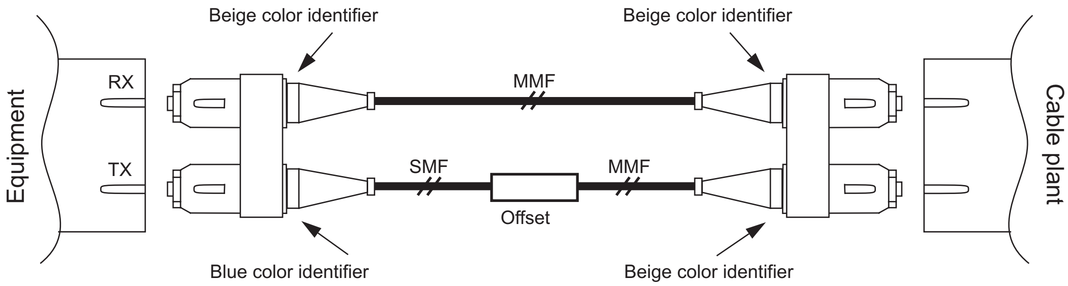


Figure 59–8—1000BASE-LX10 single-mode fiber offset-launch mode-conditioning patch cord assembly

59.10 Protocol implementation conformance statement (PICS) proforma for Clause 59, Physical Medium Dependent (PMD) sublayer and medium, type 1000BASE-LX10 (Long Wavelength) and 1000BASE-BX10 (BiDirectional Long Wavelength)[7]

59.10.1 Introduction

The supplier of a protocol implementation that is claimed to conform to Clause 59, Physical Medium Dependent (PMD) sublayer and medium, type 1000BASE-LX10 and type 1000BASE-LX10, 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.

59.10.2 Identification

59.10.2.1 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]	
NOTES 1—Required for all implementations. 2—May be completed as appropriate in meeting the requirements for the identification. 3—The terms Name and Version should be interpreted appropriately to correspond with a supplier's terminology (e.g., Type, Series, Model).	

59.10.2.2 Protocol summary

Identification of protocol standard	IEEE Std 802.3-2005, Clause 59, Physical Medium Dependent (PMD) sublayer and medium, type 1000BASE-LX10 and 1000BASE-BX10
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 802.3-2005.)	

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.

59.10.3 Major capabilities/options

Item	Feature	Subclause	Value/Comment	Status	Support
HT	High temperature operation	59.8.4	–5 to 85˚C	O	Yes [ ] No [ ]
LT	Low temperature operation	59.8.4	–40 to 60˚C	O	Yes [ ] No [ ]
*LX	1000BASE-LX10 PMD	59.3	Device supports long wavelength (1310 nm) over dual multimode and single-mode fibers.	O/1	Yes [ ] No [ ]
*BXD	1000BASE-BX10-D PMD	Table 59–6	Device operates with one single single-mode fiber and transmits at downstream wavelength (1490 nm).	O/1	Yes [ ] No [ ]
*BXU	1000BASE-BX10-U PMD	Table 59–6	Device operates with one single single-mode fiber and transmits upstream wavelength (1310 nm).	O/1	Yes [ ] No [ ]
*INS	Installation / cable	59.9	Items marked with INS include installation practices and cable specifications not applicable to a PHY manufacturer.	O	Yes [ ] No [ ]
*OFP	Single-mode offset-launch mode-conditioning patch cord	59.9.5	Items marked with OFP include installation practices and cable specifications not applicable to a PHY manufacturer.	O	Yes [ ] No [ ]

59.10.3.1 PMD functional specifications

Item	Feature	Subclause	Value/Comment	Status	Support
FN1	Transmit function	59.2.2	Convey bits requested by PMD_UNITDATA.request() to the MDI.	M	Yes [ ]
FN2	Transmitter optical signal	59.2.2	Higher optical power is a logical 1.	M	Yes [ ]
FN3	Receive function	59.2.3	Convey bits received from the MDI to PMD_UNITDATA.indication().	M	Yes [ ]
FN4	Receiver optical signal	59.2.3	Higher optical power is a logical 1.	M	Yes [ ]
FN5	Signal detect function	59.2.4	Mapping to PMD interface.	M	Yes [ ]
FN6	Signal detect behaviour	59.2.4	Generated according to Table 59–2.	M	Yes [ ]

59.10.3.2 PMD to MDI optical specifications for 1000BASE-LX10

Item	Feature	Subclause	Value/Comment	Status	Support
LX1	1000BASE-LX10 transmitter	59.3.1	Transmitter meets specifications in Table 59–3.	LX:M	Yes [ ] N/A [ ]
LX2	Offset-launch mode-conditioning patch cord	59.3.1	Required for LX10 multi-mode operation.	OFP:M	Yes [ ] N/A [ ]
LX3	1000BASE-LX10 receiver	59.3.2	Receiver meets mandatory specifications in Table 59–5.	LX:M	Yes [ ] N/A [ ]
LX4	1000BASE-LX10 stressed receiver sensitivity	59.3.2	Receiver meets mandatory specifications in Table 59–5	LX:M	Yes [ ] N/A [ ]

59.10.3.3 PMD to MDI optical specifications for 1000BASE-BX10-D

Item	Feature	Subclause	Value/Comment	Status	Support
BXD1	1000BASE-BX10-D transmitter	59.4.1	Transmitter meets specifications in Table 59–6.	BXD:M	Yes [ ] N/A [ ]
BXD2	1000BASE-BX10-D receiver	59.4.2	Receiver meets mandatory specifications in Table 59–7.	BXD:M	Yes [ ] N/A [ ]
BXD3	1000BASE-BX10-D stressed receiver sensitivity	59.4.2	Receiver meets specifications in Table 59–7.	BXD:O	Yes [ ] No [ ] N/A [ ]

59.10.3.4 PMD to MDI optical specifications for 1000BASE-BX10-U

Item	Feature	Subclause	Value/Comment	Status	Support
BXU1	1000BASE-BX10-U transmitter	59.4.1	Transmitter meets specifications in Table 59–6.	BXU:M	Yes [ ] N/A [ ]
BXU2	1000BASE-BX10-U receiver	59.4.2	Receiver meets mandatory specifications in Table 59–7.	BXU:M	Yes [ ] N/A [ ]
BXU3	1000BASE-BX10-U stressed receiver sensitivity	59.4.2	Receiver meets specifications in Table 59–7.	BXU:O	Yes [ ] No [ ] N/A [ ]

59.10.3.5 Optical Measurement Requirements

Item	Feature	Subclause	Value/Comment	Status	Support
OM1	Measurement cable		2 m to 5 m in length	M	Yes [ ]
OM2	Test patterns	59.7.1	See Table 59–11	M	Yes [ ]
OM3	Wavelength and spectral width	59.7.2	Per TIA/EIA-455-127 under modulated conditions.	M	Yes [ ]
OM4	Average optical power	59.7.3	Per TIA/EIA-455-95	M	Yes [ ]
OM5	Extinction ratio	59.7.4	Per ANSI/TIA/EIA-526-4A with minimal back reflections and fourth-order Bessel-Thomson receiver.	M	Yes [ ]
OM6	$RIN_{12}OMA$	58.7.7	As described in 58.7.7	M	Yes [ ]
OM7	Transmit optical waveform (transmit eye)	59.7.8	Per ANSI/TIA/EIA-526-4A with test pattern and fourth-order Bessel-Thomson receiver.	M	Yes [ ]
OM8	Transmit rise/fall characteristics	59.7.9	Waveforms conform to mask in Figure 59–4, measure from 20% to 80%, using patch cable per 59.7.	LX:M	Yes [ ]
OM9	Transmitter and dispersion penalty	59.7.10	As described in 58.7.9	M	Yes [ ]
OM10	Receive sensitivity	59.7.11	With specified pattern	M	Yes [ ]
*OM11	Stressed receiver conformance	59.7.14	As described in 59.7.14	O	Yes [ ] N/A[ ]
OM12	Receiver 3dB electrical upper cutoff frequency	59.7.15	As described in 59.7.15	M	Yes [ ]

59.10.3.6 Environmental, safety and labeling specifications

Item	Feature	Subclause	Value/Comment	Status	Support
ES1	General safety	59.8.1	Conforms to IEC 60950.	M	Yes [ ]
ES2	Laser safety - IEC Class 1	59.8.2	Conforms to Class 1 laser requirements defined in IEC 60825-1.	M	Yes [ ]
ES3	Documentation	59.8.2	Explicitly define requirements and usage restrictions to meet safety certifications.	M	Yes [ ]
ES4	Operating temperature range labeling	59.8.5	If required, label range over which compliance is ensured.	M	Yes [ ] N/A[ ]

59.10.3.7 Characteristics of the fiber optic cabling

Item	Feature	Subclause	Value/Comment	Status	Support
FO1	Fiber optic cabling	59.9	Meets specifications in Table 59–16.	INS:M	Yes [ ] N/A [ ]
FO2	End-to-end channel loss	59.9.1	Meet the requirements specified in Table 59–1.	INS:M	Yes [ ] N/A [ ]
FO3	Maximum discrete reflectance for multimode connections	59.9.3	Less than –20 dB	INS:M	Yes [ ] N/A [ ]
FO4	Maximum discrete reflectance for single-mode connections	59.9.3	Less than –26 dB	INS:M	Yes [ ] N/A [ ]
FO5	MDI Requirements	59.9.4	Meet the interface performance specifications of IEC 61753-1, if remateable.	INS:O	Yes [ ] No[ ] N/A [ ]

59.10.3.8 Offset-launch mode-conditioning patch cord

Item	Feature	Subclause	Value/Comment	Status	Support
LPC1	Offset-launch mode-conditioning patch cord	59.9.5	Meet conditions of 59.9.5	OFP:M	Yes [ ] N/A [ ]
LPC2	Single-mode mechanics in offset-launch mode-conditioning patch cords	59.9.5	IEC 61754-1: 1997 [B28] grade 1 ferrule	OFP:M	Yes [ ] N/A [ ]
LPC3	Single-mode fiber in offset-launch mode-conditioning patch cords	59.9.5	Per 59.9.5	OFP:M	Yes [ ] N/A [ ]
LPC4	Multimode fiber in offset-launch mode-conditioning patch cords	59.9.5	Same type as used in cable plant	OFP:M	Yes [ ] N/A [ ]

60. Physical Medium Dependent (PMD) sublayer and medium, type 1000BASE-PX10 and 1000BASE-PX20 (long wavelength passive optical networks)

60.1 Overview

The 1000BASE-PX10 and 1000BASE-PX20 PMD sublayers provide point-to-multipoint (P2MP) 1000BASE-X connections over passive optical networks (PONs) up to at least 10 km and 20 km, respectively and with a typical split ratio of 1:16. In an Ethernet PON, a single downstream (D) PMD broadcasts to multiple upstream (U) PMDs and receives bursts from each "U" PMD over a single branched topology, single-mode fiber network. The same fibers are used simultaneously in both directions. This clause specifies the 1000BASE-PX10-D PMD, 1000BASE-PX10-U PMD, 1000BASE-PX20-D PMD and the 1000BASE-PX20-U PMD (including MDI) and the medium, single-mode fiber. A 1000BASE-PX-U PMD or a 1000BASE-PX-D PMD is connected to the appropriate 1000BASE-X PMA of Clause 65, and to the medium through the MDI. A PMD is optionally combined with the management functions that may be accessible through the management interface defined in Clause 22 or by other means.

A 1000BASE-PX10 link uses a 1000BASE-PX10-U PMD at one end and a 1000BASE-PX10-D PMD at the other. A 1000BASE-PX20 link uses a 1000BASE-PX20-U PMD at one end and a 1000BASE-PX20-D PMD at the other. A 1000BASE-PX20-D PMD is interoperable with a 1000BASE-PX10-U PMD. This allows certain upgrade possibilities from 10 km to 20 km PONs. Typically, the 1490 nm band is used to transmit away from the center of the network D and the 1310 nm band towards the center U. The suffixes D and U indicate the PMDs at each end of a link which transmit in these directions and receive in the opposite directions. The splitting ratio or reach length may be increased in an FEC enabled link. FEC refers to forward error correction for P2MP optical links and is described in 65.2. The maximum reach length is not limited by the protocol, see 64.3.3.

Two optional temperature ranges are defined; see 60.8.4 for further details. Implementations may be declared as compliant over one or both complete ranges, or not so declared (compliant over parts of these ranges or another temperature range).

Table 60–1 shows the primary attributes of each PMD type.

Table 60–1—PMD types specified in this Clause

Description	1000BASE-PX10-U	1000BASE-PX10-D	1000BASE-PX20-U	1000BASE-PX20-D	Unit
Fiber type	B1.1, B1.3 SMF				
Number of fibers	1				
Nominal transmit wavelength	1310	1490	1310	1490	nm
Transmit direction	Upstream	Downstream	Upstream	Downstream	
Minimum range[a]	0.5 m to 10 km		0.5 m to 20 km		
Maximum channel insertion loss[b]	20	19.5	24	23.5	dB
Minimum channel insertion loss[c]	5		10		dB

[a]In an FEC enabled link, the minimum range may be increased, or, links with a higher channel insertion loss may be used.
[b]At nominal transmit wavelength.
[c]The differential insertion loss for a link is the difference between the maximum and minimum channel insertion loss.

60.1.1 Goals and objectives

The following are the objectives of 1000BASE-PX10 and 1000BASE-PX20:

a) Point-to-multipoint on optical fiber.
b) 1000 Mbps up to 10 km on one single-mode fiber supporting a fiber split ratio of 1:16.
c) 1000 Mbps up to 20 km on one single-mode fiber supporting a fiber split ratio of 1:16.
d) BER better than or equal to 10^{-12} at the PHY service interface.

60.1.2 Positioning of this PMD set within the IEEE 802.3 architecture

Figure 60–1 depicts the relationships of the PMD (shown shaded) with other sublayers and the ISO/IEC Open System Interconnection (OSI) reference model.

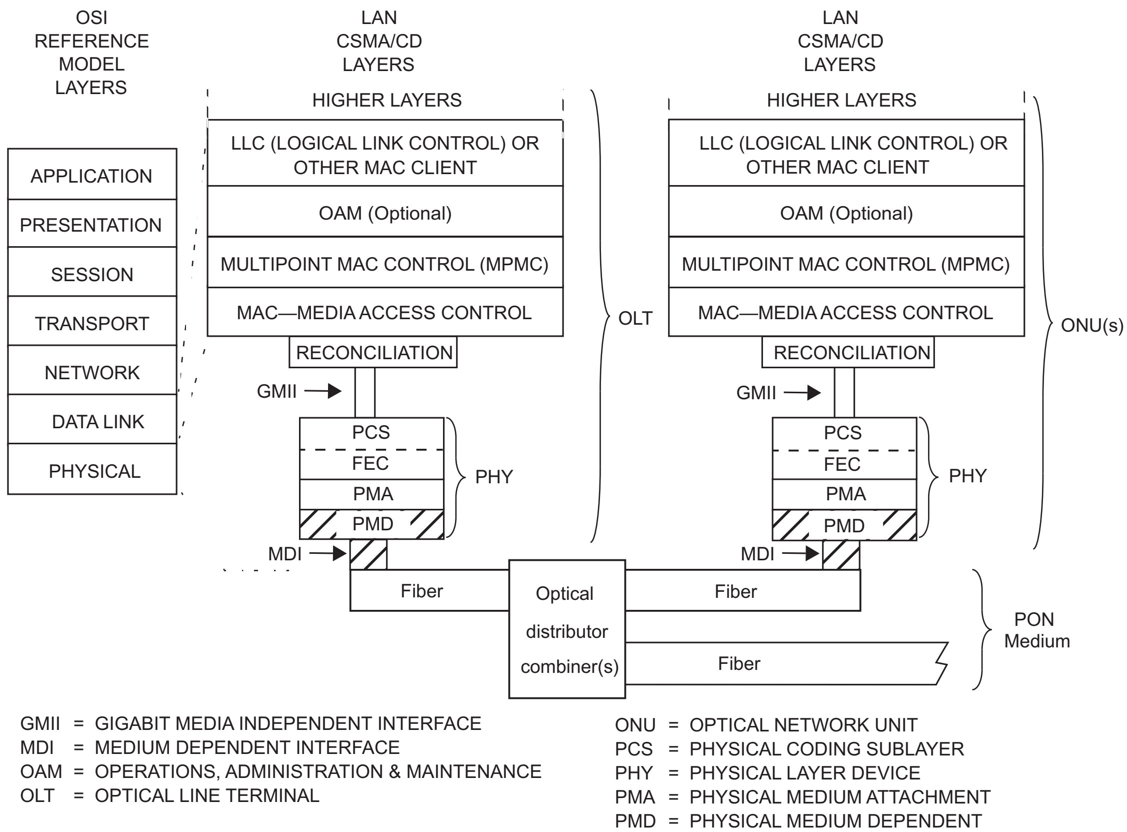


Figure 60–1—P2MP PMDs relationship to the ISO/IEC Open Systems Interconnection (OSI) reference model and the IEEE 802.3 CSMA/CD LAN model

60.1.3 Terminology and conventions

The following list contains references to terminology and conventions used in this clause:

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 Ethernet for subscriber access networks, see Clause 56.

60.1.4 Physical Medium Dependent (PMD) sublayer service interface

The following specifies the services provided by the 1000BASE-PX10 and 1000BASE-PX20 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 8B/10B code-groups between the PMA and PMD entities. The PMD translates the serialized data of the 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

60.1.5 Delay constraints

Delay requirements from the MDI to the GMII which include the PMD layer are specified in Clause 36. Of the budget, up to 20 ns is reserved for each of the transmit and receive functions of the PMD to account for those cases where the PMD includes a pigtail.

60.1.5.1 PMD_UNITDATA.request

This primitive defines the transfer of a serial data stream from the 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 PMA continuously sends the appropriate stream of bits to the PMD for transmission on the medium, at a nominal 1.25 GBd signaling speed. Upon receipt of this primitive, the PMD converts the specified stream of bits into the appropriate signals at the MDI.

60.1.5.2 PMD_UNITDATA.indication

This primitive defines the transfer of data from the PMD to the 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 PMA corresponding to the signals received from the MDI.

60.1.5.3 PMD_SIGNAL.request

In the upstream direction, this primitive is generated by the PCS to turn on and off the transmitter according to the granted time. A signal for laser control is generated in 65.3.1.1.

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 PCS generates this primitive to indicate a change in the value of tx_enable. Upon receipt of this primitive, the PMD turns the transmitter on or off as appropriate.

60.1.5.4 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 60.2.4.

60.2 PMD functional specifications

The 1000BASE-PX PMDs perform the transmit and receive functions that convey data between the PMD service interface and the MDI.

60.2.1 PMD block diagram

The PMD sublayer is defined at the four reference points shown in Figure 60–2 where the first digit represents the downstream direction and the second the upstream. Two points, TP2 and TP3, are compliance points. TP1 and TP4 are reference points for use by implementors. The optical transmit signal is defined at the output end of a patch cord (TP2), 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 60.7 are made at TP2. The optical receive signal is defined at the output of the fiber optic cabling (TP3) connected to the receiver. Unless specified otherwise, all receiver measurements and tests defined in 60.7 are made at TP3.

The electrical specifications of the PMD service interface (TP1 and TP4) are not system compliance points (these are not readily testable in a system implementation). It is expected that in many implementations, TP1 and TP4 will be common between 1000BASE-PX PMDs.

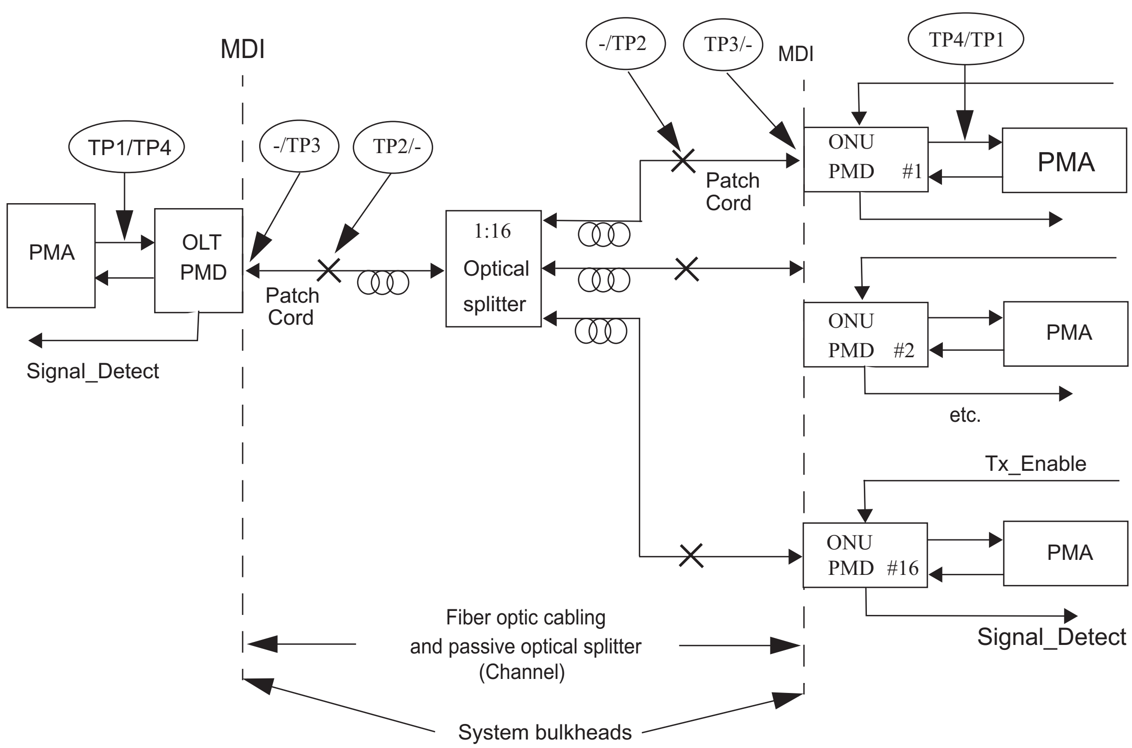


Figure 60–2—1000BASE-PX block diagram

60.2.2 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 this clause. The higher optical power level shall correspond to tx_bit = ONE.

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.

60.2.3 PMD receive function

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

60.2.4 PMD signal detect function

60.2.4.1 ONU PMD signal detect (downstream)

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 optical signal presence.

The value of the SIGNAL_DETECT parameter shall be generated according to the conditions defined in Table 60–2 for 1000BASE-PX. The PMD receiver is not required to verify whether a compliant 1000BASE-PX signal is being received.

60.2.4.2 OLT PMD signal detect (upstream)

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 PMA layer.

The value of the SIGNAL_DETECT parameter shall be generated according to the conditions defined in Table 60–2 for 1000BASE-PX. The PMD receiver is not required to verify whether a compliant 1000BASE-PX signal is being received.

60.2.4.3 1000BASE-PX Signal detect functions

The Signal Detect value definitions for the 1000BASE-PX PMDs are shown in Table 60–2.

Table 60–2—1000BASE-PX SIGNAL_DETECT value definition

Receive conditions		Signal_detect value
1000BASE-PX10	**1000BASE-PX20**	
Average input optical power ≤ Signal Detect Threshold (min) in Table 60–5 at the specified receiver wavelength	Average input optical power ≤ Signal Detect Threshold (min) in Table 60–8 at the specified receiver wavelength	FAIL
Average input optical power ≥ Receive sensitivity (max) in Table 60–5 with a compliant 1000BASE-X signal input at the specified receiver wavelength	Average input optical power ≥ Receive sensitivity (max) in Table 60–8 with a compliant 1000BASE-X signal input at the specified receiver wavelength	OK
All other conditions	All other conditions	Unspecified

60.2.5 PMD transmit enable function for ONU

PMD_SIGNAL.request(tx_enable) is defined for the two ONU PMDs. PMD_SIGNAL.request(tx_enable) is asserted prior to data transmission by the ONU PMDs.

60.3 PMD to MDI optical specifications for 1000BASE-PX10-D and 1000BASE-PX10-U

The operating range for 1000BASE-PX10 is defined in Table 60–1. A 1000BASE-PX10 compliant transceiver supports all media types listed in Table 60–14 according to the specifications described in 60.9. A transceiver which exceeds the operational range requirement while meeting all other optical specifications is considered compliant (e.g., a single-mode solution operating at 10.5 km meets the minimum range requirement of 0.5 m to 10 km for 1000BASE-PX10).

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.

60.3.1 Transmitter optical specifications

The 1000BASE-PX10-D and 1000BASE-PX10-U transmitter's signaling speed, operating wavelength, spectral width, average launch power, extinction ratio, return loss tolerance, OMA, eye and TDP shall meet the specifications defined in Table 60–3 per measurement techniques described in 60.7. Its RIN_{15}OMA should meet the value listed in Table 60–3 per measurement techniques described in 60.7.7.

Table 60–3—1000BASE-PX10-D and 1000BASE-PX10-U transmit characteristics

Description	1000BASE-PX10-D	1000BASE-PX10-U	Unit
Nominal transmitter type[a]	Longwave Laser	Longwave Laser	
Signaling speed (range)	1.25 ± 100 ppm	1.25 ± 100 ppm	GBd
Wavelength[b] (range)	1480 to 1500	1260 to 1360	nm
RMS spectral width (max)	see Table 60–4		nm
Average launch power (max)	+2	+4	dBm
Average launch power (min)	–3	–1	dBm
Average launch power of OFF transmitter (max)	–39	–45	dBm
Extinction ratio (min)	6	6	dB
RIN_{15}OMA (max)	–118	–113	dB/Hz
Launch OMA (min)	–2.2 (0.6)	–0.22 (0.95)	dBm (mW)
Transmitter eye mask definition {X1, X2, Y1, Y2, Y3}	{0.22, 0.375, 0.20, 0.20, 0.30}	{0.22, 0.375, 0.20, 0.20, 0.30}	UI
Ton (max)	N/A	512	ns
Toff (max)	N/A	512	ns
Optical return loss tolerance (max)	15	15	dB
Optical return loss of ODN (min)	20	20	dB
Transmitter reflectance (max)	–10	–6	dB
Transmitter and dispersion penalty (max)	1.3	2.8	dB
Decision timing offset for transmitter and dispersion penalty (min)	± 0.1	± 0.125	UI

[a]The nominal device type is not intended to be a requirement on the source type, and any device meeting the transmitter characteristics specified may be substituted for the nominal device type.
[b]This represents the range of centre wavelength ±1σ of the rms spectral width.

The maximum The maximum RMS spectral width vs. wavelength for 1000BASE-PX10 is shown in Table 60–4 and for 1000BASE-PX10-U in Figure 60–3. The equation used to generate these values is included in 60.7.2. The central column values are normative, the right hand column is informative.

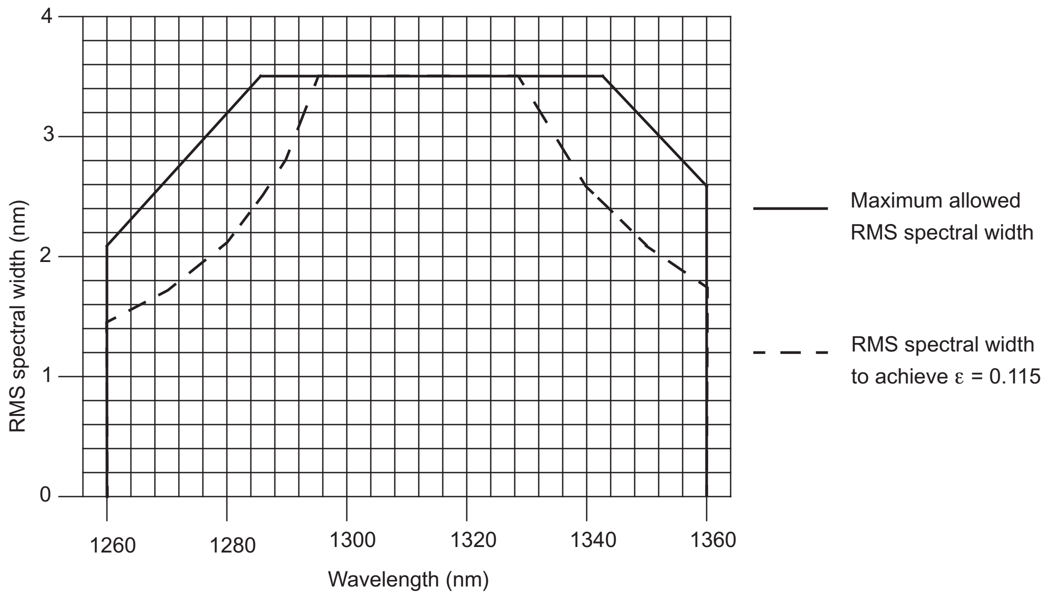


Figure 60–3—1000BASE-PX10-U transmitter spectral limits

Table 60–4—1000BASE-PX10-D and 1000BASE-PX10-U transmitter spectral limits

<table>
<tr><th>Center Wavelength</th><th>RMS spectral width (max)[a]</th><th>RMS spectral width to achieve epsilon ε <=0.115 (informative)</th></tr>
<tr><th>nm</th><th>nm</th><th>nm</th></tr>
<tr><td>1260</td><td>2.09</td><td>1.43</td></tr>
<tr><td>1270</td><td>2.52</td><td>1.72</td></tr>
<tr><td>1280</td><td>3.13</td><td>2.14</td></tr>
<tr><td>1286</td><td rowspan="6">3.50</td><td>2.49</td></tr>
<tr><td>1290</td><td>2.80</td></tr>
<tr><td>1297</td><td rowspan="2">3.50</td></tr>
<tr><td>1329</td></tr>
<tr><td>1340</td><td>2.59</td></tr>
<tr><td>1343</td><td>2.41</td></tr>
<tr><td>1350</td><td>3.06</td><td>2.09</td></tr>
<tr><td>1360</td><td>2.58</td><td>1.76</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td>1480 to 1500</td><td>0.88</td><td>0.60</td></tr>
</table>

[a]These limits for the 1000BASE-PX10-U transmitter are illustrated in Figure 60–3. The equation used to calculate these values is detailed in 60.7.2. Limits at intermediate wavelengths may be found by interpolation.

60.3.2 Receiver optical specifications

The 1000BASE-PX10-D and 1000BASE-PX10-U receiver's signaling speed, operating wavelength, overload, sensitivity, reflectivity and signal detect shall meet the specifications defined in Table 60–5 per measurement techniques defined in 60.7.10. Its stressed receive characteristics should meet the values listed in Table 60–5 per measurement techniques described in 60.7.11 Either the damage threshold included in Table 60–5 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.

Table 60–5—1000BASE-PX10-D and 1000BASE-PX10-U receive characteristics

Description	1000BASE-PX10-D	1000BASE-PX10-U	Unit
Signaling speed (range)	1.25 ± 100 ppm	1.25 ± 100 ppm	GBd
Wavelength (range)	1260 to 1360	1480 to 1500	nm
Bit error ratio (max)	10^{-12}		
Average receive power (max)	–1	–3	dBm
Damage threshold (max)	+4	+2	dBm
Receiver sensitivity (max)	–24	–24	dBm
Receiver sensitivity OMA (max)	–23.2 (5.0)	–23.2 (5.0)	dBm (μW)
Signal detect threshold (min)	–45	– 44	dBm
Receiver reflectance (max)	–12	–12	dB
Stressed receive sensitivity (max)[a]	–22.3	–21.4	dBm
Stressed receive sensitivity OMA (max)	–21.5 (7.0)	–20.7 (8.6)	dBm (μW)
Vertical eye-closure penalty (min)[b]	1.2	2.2	dB
Treceiver_settling[c] (max)	400	N/A	ns
Stressed eye jitter (min)	0.25	0.25	UI pk to pk
Jitter corner frequency	637	637	kHz
Sinusoidal jitter limits for stressed receiver conformance test (min, max)	0.05, 0.15	0.05, 0.15	UI

[a]The stressed receiver sensitivity is optional.
[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]Treceiver_settling is informative. The combined Treceiver_settling and CDR lock time is normative. See 65.3 for CDR lock times.

60.4 PMD to MDI optical specifications for 1000BASE-PX20-D and 1000BASE-PX20-U

The operating range for 1000BASE-PX20 is defined in Table 60–1. A 1000BASE-PX20 compliant transceiver supports all media types listed in Table 60–14 according to the specifications described in 60.9.2. A transceiver that exceeds the operational range requirement while meeting all other optical specifications is considered compliant (e.g., a single-mode solution operating at 20.5 km meets the minimum range requirement of 0.5 m to 20 km for 1000BASE-PX20).

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

60.4.1 Transmit optical specifications

The 1000BASE-PX20-D and 1000BASE-PX20-U transmitter's signaling speed, operating wavelength, spectral width, average launch power, extinction ratio, return loss tolerance, OMA, eye and TDP shall meet the specifications defined in Table 60–6 per measurement techniques described in 60.7. Its $RIN_{15}OMA$ should meet the value listed in Table 60–6 per measurement techniques described in 60.7.7.

Table 60–6—1000BASE-PX20-D and 1000BASE-PX20-U transmit characteristics

Description	1000BASE-PX20-D	1000BASE-PX20-U	Unit
Nominal transmitter type[a]	Longwave Laser	Longwave Laser	
Signaling speed (range)	1.25 ± 100 ppm	1.25 ± 100 ppm	GBd
Wavelength[b] (range)	1480 to 1500	1260 to 1360	nm
RMS spectral width (max)	see Table 60–7		nm
Average launch power (max)	+7	+4	dBm
Average launch power (min)	+2	–1	dBm
Average launch power of OFF transmitter (max)	–39	–45	dBm
Extinction ratio (min)	6	6	dB
$RIN_{15}OMA$ (max)	–115	–115	dB/Hz
Launch OMA (min)	2.8 (1.9)	–0.22 (0.95)	dBm (mW)
Transmitter eye mask definition {X1, X2, Y1, Y2, Y3}	{0.22, 0.375, 0.20, 0.20, 0.30}	{0.22, 0.375, 0.20, 0.20, 0.30}	UI
Ton (max)	N.A.	512	ns
Toff (max)	N.A.	512	ns
Optical return loss tolerance (max)	15	15	dB
Optical return loss of ODN (min)	20	20	dB
Transmitter reflectance (max)	–10	–10	dB
Transmitter and dispersion penalty (max)	2.3	1.8	dB
Decision timing offset for transmitter and dispersion penalty (min)	± 0.1	± 0.125	UI

[a]The nominal device type is not intended to be a requirement on the source type, and any device meeting the transmitter characteristics specified may be substituted for the nominal device type.
[b]This represents the range of centre wavelength ±1σ of the rms spectral width.

The maximum RMS spectral width vs. wavelength for 1000BASE-PX20 is shown in Table 60–7 and for 1000BASE-PX20-U in Figure 60–4. The equation used to generate these values is included in 60.7.2. The central column values are normative, the right hand column is informative.

Table 60–7—1000BASE-PX20-D and 1000BASE-PX20-U transmitter spectral limits

Center Wavelength	RMS spectral width (max) [a]	RMS spectral width to achieve epsilon ε <=0.10 (informative)
nm	nm	nm
1260	**0.72**	0.62
1270	**0.86**	0.75
1280	**1.07**	0.93
1290	**1.40**	1.22
1300	**2.00**	1.74
1304	**2.5**	2.42
1305	**2.55**	2.5
1308	**3.00**	
1317		
1320	**2.53**	2.2
1321	**2.41**	
1330	**1.71**	1.48
1340	**1.29**	1.12
1350	**1.05**	0.91
1360	**0.88**	0.77
1480 to 1500	**0.44**	0.30

[a]These limits for the 1000BASE-PX20-U are illustrated in Figure 60–4. The equation used to calculate these values is detailed in 60.7.2. Limits at intermediate wavelengths may be found by interpolation.

60.4.2 Receiver optical specifications

The 1000BASE-PX20-D and 1000BASE-PX20-U receiver's signaling speed, operating wavelength, overload, sensitivity, reflectivity and signal detect shall meet the specifications defined in Table 60–8 per measurement techniques defined in 60.7.10. Its stressed receive characteristics should meet the values listed in Table 60–8 per measurement techniques described in 60.7.11. Either the damage threshold included in Table 60–8 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.

60.5 Illustrative 1000BASE-PX10 and 1000BASE-PX20 channels and penalties (informative)

Illustrative power budget for 1000BASE-PX10 and 1000BASE-PX20 channels are shown in Table 60–9.

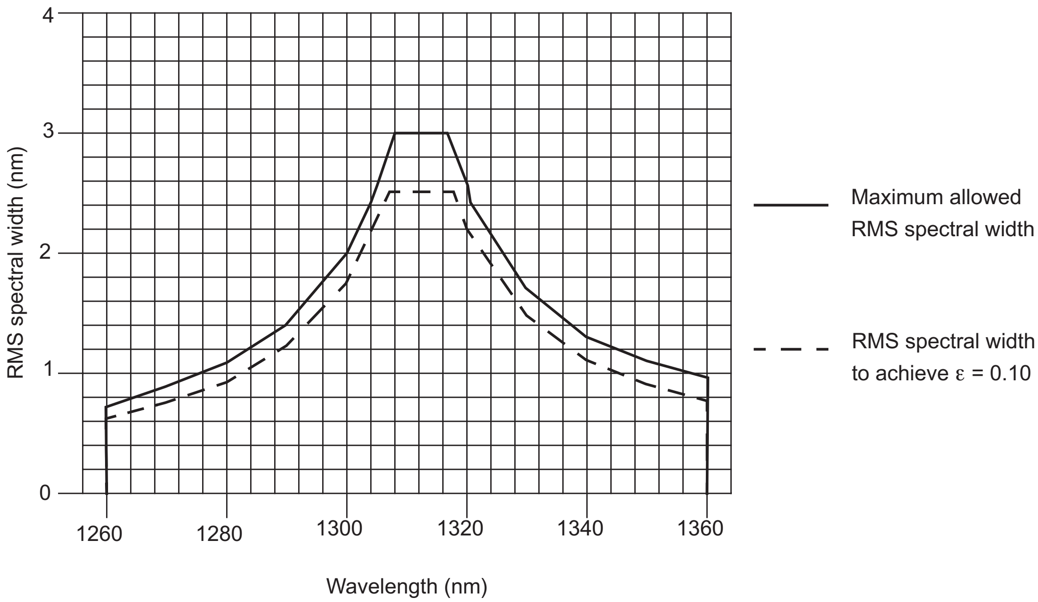


Figure 60–4—1000BASE-PX20-U transmitter spectral limits

Table 60–8—1000BASE-PX20-D and 1000BASE-PX20-U receive characteristics

Description	1000BASE-PX20-D	1000BASE-PX20-U	Unit
Signaling speed (range)	1.25 ± 100 ppm	1.25 ± 100 ppm	GBd
Wavelength (range)	1260 to 1360	1480 to 1500	nm
Bit error ratio (max)	10^{-12}		
Average receive power (max)	–6	–3	dBm
Damage threshold (max)	+4	+7	dBm
Receive sensitivity (max)	–27	–24	dBm
Receiver sensitivity OMA (max)	–26.2 (2.4)	–23.2 (5)	dBm (μW)
Signal detect threshold (min)	– 45	– 44	dBm
Receiver reflectance (max)	–12	–12	dB
Stressed receive sensitivity (max)[a]	–24.4	–22.1	dBm
Stressed receive sensitivity OMA (max)	–23.6 (4.3)	–21.3 (7.4)	dBm (μW)
Vertical eye-closure penalty (min)[b]	2.2	1.5	dB
Treceiver_settling[c] (max)	400	N.A.	ns
Stressed eye jitter (min)	0.28	0.25	UI pk to pk
Jitter corner frequency	637	637	kHz
Sinusoidal jitter limits for stressed receiver conformance test (min, max)	0.05, 0.15	0.05, 0.15	UI

[a]The stressed receiver sensitivity recommendation is optional.
[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]Treceiver_settling is informative. The combined Treceiver_settling and CDR lock time is normative. See 65.3 for CDR lock times.

Table 60–9—Illustrative 1000BASE-PX10 and 1000BASE-PX20 channel insertion loss and penalties

Description	1000BASE-PX10		1000BASE-PX20		Unit
	Upstream	Downstream	Upstream	Downstream	
Fiber Type	B1.1, B1.3 SMF				
Measurement wavelength for fiber	1310	1550[a]	1310	1550[a]	nm
Nominal distance	10		20		km
Available power budget[b]	23.0	21.0	26.0	26.0	dB
Channel insertion loss (max)[c]	20	19.5	24	23.5	dB
Channel insertion loss (min)[d]	5		10		dB
Allocation for penalties[e]	3	1.5	2	2.5	dB
Optical return loss of ODN (min)	20				dB

[a]The nominal transmit wavelength is 1490 nm.
[b]In an FEC enabled link, when not operating at the dispersion limit, the available power budget is increased by 2.5 dB.
[c]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.
[d]The power budgets for PX10 and PX20 links are such that a minimum insertion loss is assumed between transmitter and receiver. This minimum attenuation is required for PMD testing.
[e]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 60.7.2.

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

60.6 Jitter at TP1-4 for 1000BASE-PX10 and 1000BASE-PX20 (informative)

The entries in Table 60–10 and Table 60–11 represent high-frequency jitter (above 637 kHz) and do not include low frequency jitter or wander. They are two sided (peak-to-peak) measures. Table 60–10 applies to the downstream direction (D to U) while Table 60–11 applies to the upstream direction (U to D). All values are informative. For the 1000BASE-PX upstream jitter budget, the jitter transfer function is defined by Equation (60-2) where the value is given in Figure 60–5 when input sinusoidal jitter according to the mask defined in 58.7.11.4 and values in Table 60–5 and Table 60–8 are applied to the receiver input of the ONU. Two sets of upstream jitter values are defined in Table 60–11, one set corresponds to testing the upstream link with no jitter on the downstream (jitter generation) and the other set with maximum jitter on the downstream (generated and transferred jitter).

NOTE—Informative jitter values are chosen to be compatible with the limits for eye mask and TDP (see 58.7.9).

Total jitter in this table is defined at 10^{-12} BER. In a commonly used model,

$$TJ = 14.1\sigma + DJ \text{ at } 10^{12} \quad (60\text{-}1)$$

W is similar but not necessarily identical to deterministic jitter (DJ). A jitter measurement procedure is described in 58.7.12. Other jitter measurements are described in 59.7.12 and 59.7.13. Jitter at TP2 or TP3 is defined with a receiver of the same bandwidth as specified for the transmitted eye.

Table 60–10—1000BASE-PX10 and 1000BASE-PX20 downstream jitter budget (informative)

	Total jitter		Deterministic jitter	
Reference point	**UI**	**ps**	**UI**	**ps**
TP1	0.24	192	0.10	80
TP1 to TP2	0.191	153	0.15	120
TP2	0.431	345	0.25	200
TP2 to TP3	0.009	7	0	0
TP3	0.44	352	0.25	200
TP3 to TP4	0.309	247	0.212	170
TP4	0.749	599	0.462	370

Table 60–11—1000BASE-PX10 and 1000BASE-PX20 upstream jitter budget (informative)

	No Jitter input to ONU				Jitter input to ONU			
	Total jitter		***W***		**Total jitter**		***W***	
Reference point	**UI**	**ps**	**UI**	**ps**	**UI**	**ps**	**UI**	**ps**
TP1	0.19	152	0.06	48	0.24	192	0.11	88
TP1 to TP2	0.16	128	0.14	112	0.16	128	0.14	112
TP2	0.35	280	0.20	160	0.40	320	0.25	200
TP2 to TP3	0.09	72	0.05	40	0.09	72	0.05	40
TP3	0.44	352	0.25	200	0.49	392	0.30	24
TP3 to TP4	0.18	144	0.15	120	0.18	144	0.15	120
TP4	0.62	496	0.40	320	0.67	536	0.45	360

$$\text{Jitter Transfer} = 20\log_{10}\left[\frac{\text{Jitter on upstream signal (UI)}}{\text{Jitter on downstream signal (UI)}}\right] \quad (60\text{-}2)$$

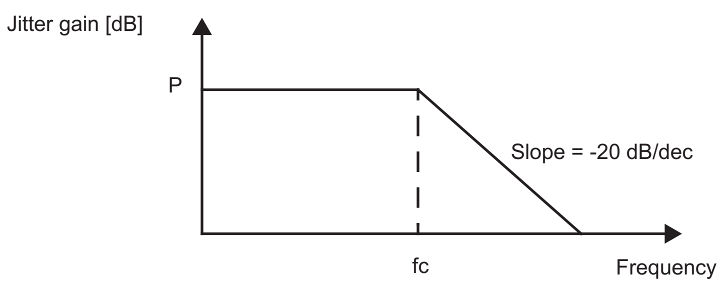


Figure 60–5—Jitter gain curve values for 1000BASE-PX10-U and 1000BASE-PX20-U

Table 60–12—Jitter gain curve values for 1000BASE-PX10-U and 1000BASE-PX20-U

	Value	Unit
P	0.3	dB
fc	1274	kHz

60.7 Optical measurement requirements

The following sections describe definitive patterns and test procedures for certain PMDs of this standard. Implementors using alternative verification methods must 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 and 5 m in length.

60.7.1 Frame based test patterns

59.7.1 provides suitable patterns for frame based testing.

NOTE—Users are advised to take care that the system under test is not connected to a network in service.

60.7.2 Wavelength and spectral width measurements

The wavelength and spectral width (RMS) shall meet specifications according to ANSI/EIA/TIA-455-127, under modulated conditions using a valid 1000BASE-X signal.

NOTE 1—The allowable range of central wavelengths is narrower than the operating wavelength range by the actual RMS spectral width at each extreme.

NOTE 2—The 20 dB width for SLM lasers is taken as 6.07 times the RMS width.

The interaction between the transmitter and the chromatic dispersion of the fiber is accounted for by a parameter ε (epsilon), which is defined as the product of 10^{-3} times the signaling speed (in GBd) times the path dispersion (in ps/nm) times the RMS spectral width (in nm).

$$\varepsilon = \text{dispersion} \times \text{length} \times \text{RMS spectral width} \times 10^{-3} \quad (60\text{-}3)$$

For the 1000BASE-PX10-D and 1000BASE-PX10-U links, a maximum ε close to 0.168 is imposed by the middle column of Table 60–4. If the spectral width is kept below the limits of the right hand column, ε will not exceed 0.115, and the chromatic dispersion penalty is expected to be below 2 dB when all link parameters are simultaneously at worst case values. For the 1000BASE-PX20-D and 1000BASE-PX20-U links, a maximum ε close to 0.115 is imposed by the middle column of Table 60–7. If the spectral width is kept below the limits of the right hand column, ε will not exceed 0.10, and the chromatic dispersion penalty is expected to be below 1.5 dB when all link parameters are simultaneously at worst case values.

The chromatic dispersion penalty is a component of transmitter and dispersion penalty (TDP) which is specified in Table 60–3, Table 60–6 and described in 58.7.9.

60.7.3 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 data stream.

60.7.4 Extinction ratio measurements

Extinction ratio shall meet specifications according to ANSI/TIA/EIA-526-4A with the port transmitting a repeating idle pattern /I2/ ordered_set (see 36.2.4.12) that may be interspersed with OAM packets per 43B.2, and with minimal back reflections into the transmitter, lower than –20 dB. The /I2/ ordered_set is defined in Clause 36, and is coded as /K28.5/D16.2/ which is binary 001111 1010 100100 0101 within idles. The extinction ratio is expected to be similar for other valid 8B/10B bit streams. The test receiver has the frequency response as specified for the transmitter optical waveform measurement.

60.7.5 OMA measurements (informative)

58.7.5 provides a reference technique for performing OMA measurements.

60.7.6 OMA relationship to extinction ratio and power measurements (informative)

The normative way of measuring transmitter characteristics is extinction ratio and mean power. Clause 58 provides information on how OMA, extinction ratio and mean power are related to each other (see 58.7.6).

60.7.7 Relative intensity noise optical modulation amplitude ($RIN_{15}OMA$)

$RIN_{15}OMA$ is the ratio of noise to modulated optical signal in the presence of a back reflection. The measurement procedure is described in 58.7.7.

60.7.8 Transmitter 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 60–6.

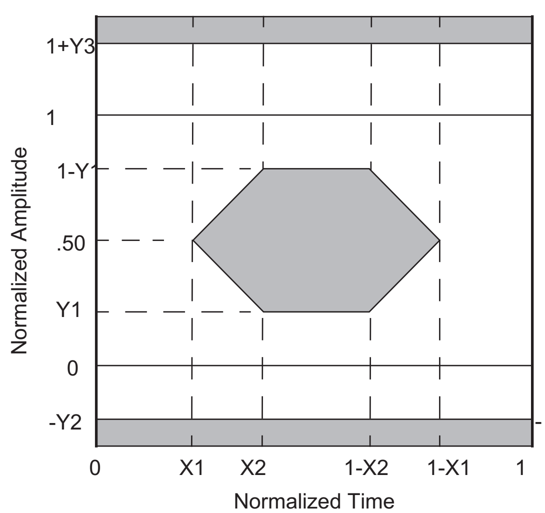


Figure 60–6—Transmitter eye mask definition

The measurement procedure is described in 58.7.8 and references therein.

The eye shall comply to the mask of the eye using a fourth-order Bessel-Thomson receiver response with *fr* = 0.9375 GHz, and where the relative response vs. relative frequency is defined in ITU-T G.957, Table B.2 (STM-16 values), along with the allowed tolerances for its physical implementation.

NOTE 1—This Bessel-Thomson filter is not intended to represent the noise filter used within an optical receiver, but is intended to provide uniform measurement conditions on the transmitter.

NOTE 2—The fourth order Bessel-Thomson filter is reactive. In order to suppress reflections, a 6 dB attenuator may be required at the filter input and/or output.

60.7.9 Transmitter and dispersion penalty (TDP)

TDP measurement tests for transmitter impairments with chromatic effects for a transmitter to be used with single-mode fiber. Possible causes of impairment include intersymbol interference, jitter, RIN and mode partition noise. Meeting the separate requirements (e.g. eye mask, spectral characteristics) does not in itself guarantee the transmitter and dispersion penalty (TDP). The TDP limit shall be met. See 58.7.9 for details of the measurement.

60.7.10 Receive sensitivity measurement

Receiver sensitivity is defined for the random pattern test frame and an ideal input signal quality with the specified extinction ratio. The measurement procedure is described in 58.7.10. The sensitivity shall be met for the bit error ratio defined in Table 60–5 or Table 60–8 as appropriate.

60.7.11 Stressed receive conformance test

The stressed receiver conformance test is intended to screen against receivers with poor frequency response or timing characteristics which could cause errors when combined with a distorted but compliant signal at TP3. Modal (MMF) or chromatic (SMF) dispersion can cause distortion. The conformance test signal uses the random pattern test frame and is conditioned by applying deterministic jitter and intersymbol interference. If the option for stressed receiver compliance is chosen, the receiver shall meet the specified bit error ratio at the power level and signal quality defined in Table 60–5 and Table 60–8 as appropriate, according to the measurement procedures of 58.7.11.

60.7.12 Jitter measurements (informative)

Jitter measurements for 1000 Mb/s are described in 58.7.12.

60.7.13 Other measurements

60.7.13.1 Laser On/Off timing measurement

Ton is defined in 60.7.13.1.1, value is less than 512 ns (defined in Table 60–3 and Table 60–6).

Treceiver_settling is defined in 60.7.13.2.1 (informative), value is less than 400 ns (defined in Table 60–5 and Table 60–8).

Tcdr is defined in 65.3.2.1 value is less than 400 ns (defined in 60.2.2).

Tcode_group_align is defined in 36.3.2.4 value is less than 4 octets.

Toff is defined in 60.7.13.1.1, value is less than 512 ns (defined in Table 60–3 and Table 60–6).

60.7.13.1.1 Definitions

Denote Ton as the time beginning from the falling edge of the Tx_Enable line to the ONU PMD and ending at the time that the optical signal at TP2 of the ONU PMD is within 15% of its steady state parameters (average launched power, wavelength, RMS spectral width, transmitter and dispersion penalty, optical return loss tolerance, jitter, $RIN_{15}OMA$, extinction ratio and eye mask opening) as defined in Table 60–3 for 1000BASE-PX10-U and Table 60–6 for 1000BASE-PX20-U. Ton is presented in Figure 60–7. The data transmitted may be any valid 8B/10B symbols.

Denote Toff as the time beginning from the rising edge of the Tx_Enable line to the ONU PMD and ending at the time that the optical signal at TP2 of the ONU PMD reaches the specified average launch power of off transmitter as defined in Table 60–3 for 1000BASE-PX10-U and Table 60–6 for 1000BASE-PX20-U. Toff is presented in Figure 60–7. The data transmitted may be any valid 8B/10B symbols.

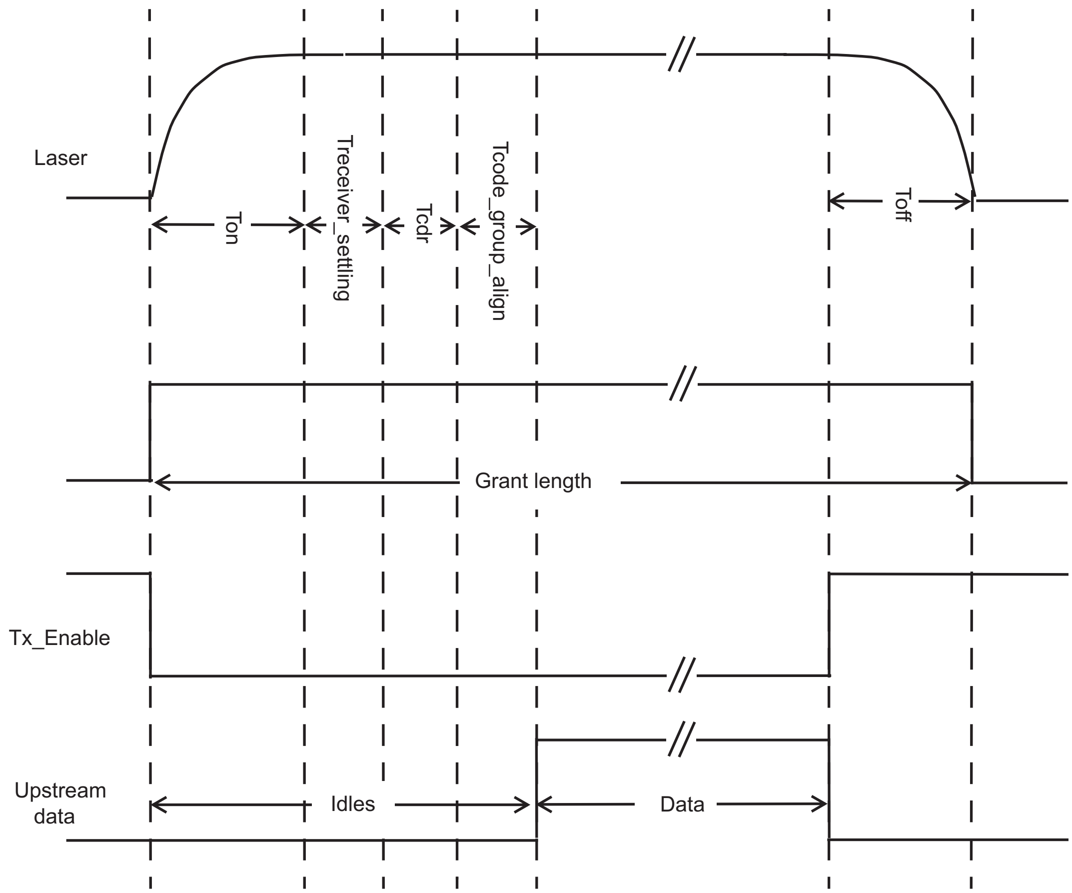


Figure 60–7—P2MP timing parameter definition

60.7.13.1.2 Test specification

The test setup for measuring Ton and Toff is described in Figure 60–8. An O/E converter is used to convert the optical signal at TP3 to an electrical signal at TP4 where it is assumed that the response time of the converter is considerably shorter that the Ton value under measurement. A scope, with a variable delay, can measure the time from the Tx_Enable trigger to the time the optical signal reaches all its specified conditions. The delay to the scope trigger is adjusted until the point that the received signal meets all its specified conditions. This is the Ton in question.

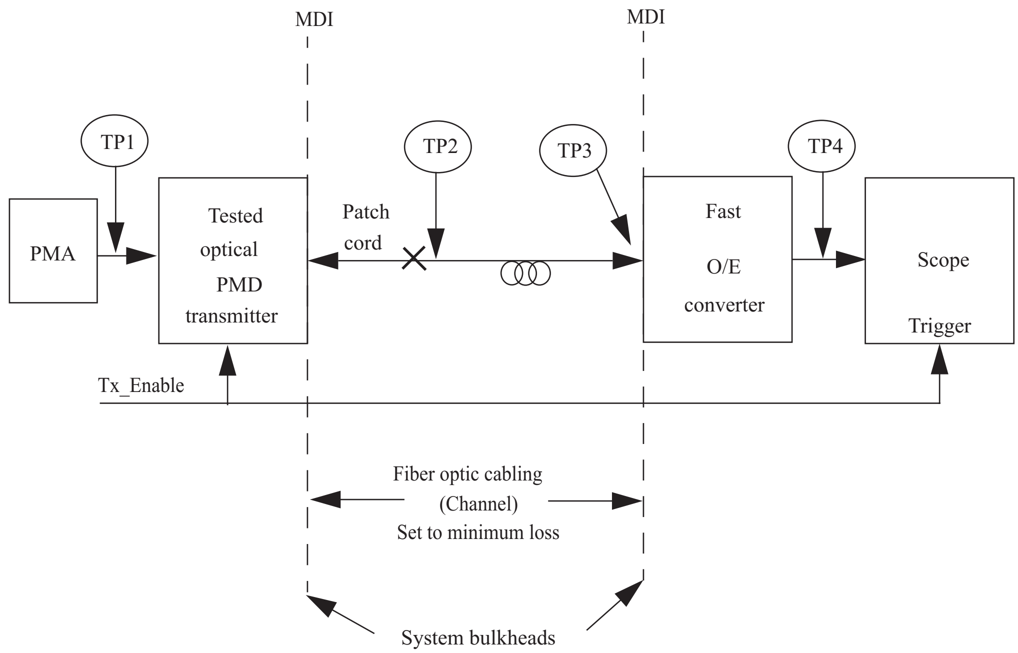


Figure 60–8—ONU PMD Laser on/off time measurement setup

A non-rigorous way to describe this test setup would be: for a PMD with a declared Ton and Toff, measure all PMD optical parameter after Ton and Toff from the Tx_Enable trigger, reassuring conformance 15% of the steady state values. Notice that only the steady state optical OFF power must be conformed when measuring Toff time, since that is the only relevant parameter.

60.7.13.2 Receiver settling timing measurement (informative)

60.7.13.2.1 Definitions

Denote Treceiver_settling as the time beginning from the time that the optical power in the receiver at TP3 reaches the conditions specified in 38.6.11, 58.7.11.2 and ending at the time that the electrical signal after the PMD at TP4, reaches within 15% of its steady state parameter, (average power, jitter), see Table 60–5 and Table 60–8. Treceiver_settling is presented in Figure 60–7. The data transmitted may be any valid 8B/10B symbols (or a specific power synchronization sequence). The optical signal at TP3, at the beginning of the locking, may have any valid 8B/10B pattern, optical power level, jitter, or frequency shift matching the standard specifications.

60.7.13.2.2 Test specification

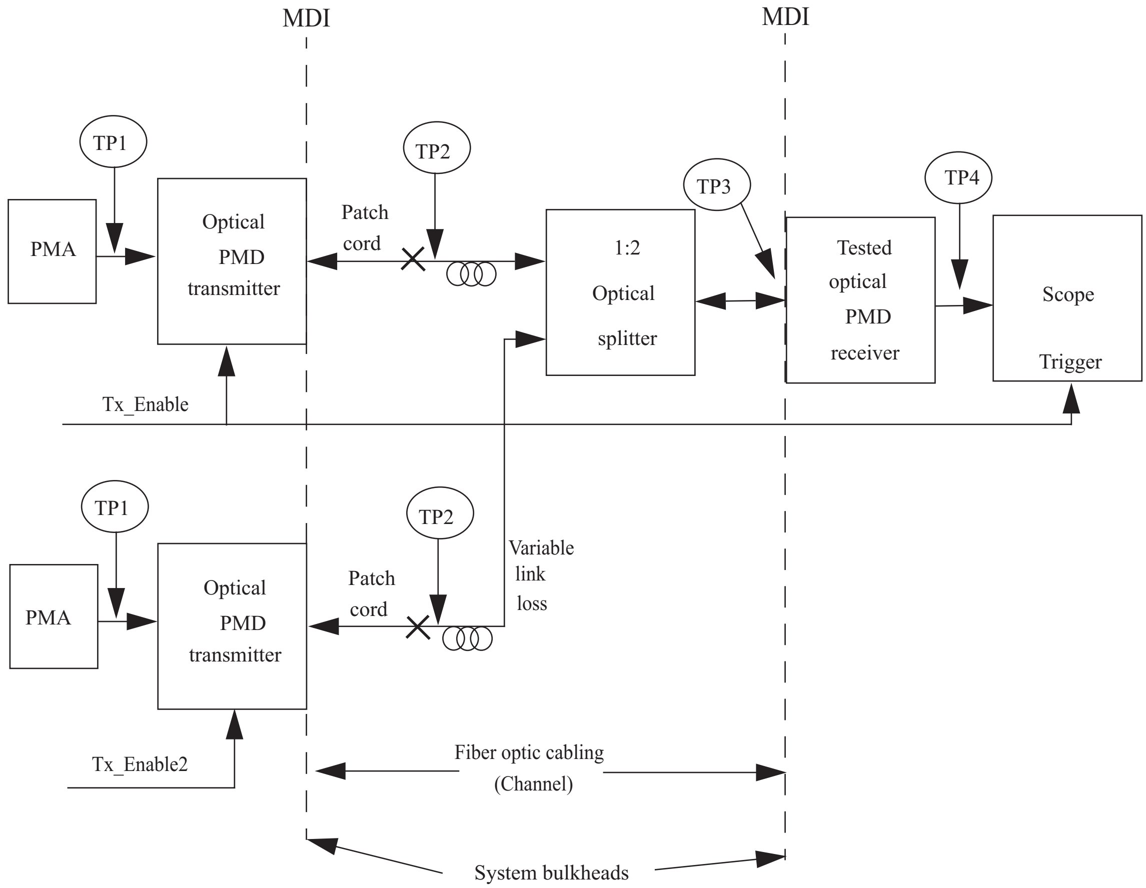


Figure 60–9—Receiver settling time measurement setup

Figure 60–9 illustrates the test setup for the OLT PMD receiver (upstream) Treceiver_settling time. The optical PMD transmitter has well-known parameters, with a fixed known Ton time. After Ton time the parameters of the reference transmitter, at TP2 and therefore at TP3, reach within 15% of its steady state values as specified in Table 60–3 for 1000BASE-PX10-U and Table 60–6 for 1000BASE-PX20-U.

Define Treceiver_settling time as the time from the Tx_Enable assertion, minus the known Ton time, to the time the electrical signal at TP4 reaches within 15% of its steady state conditions.

Conformance should be assured for an optical signal at TP3 with any level of its specified parameters before the Tx_Enable assertion. Especially the Treceiver_settling time must be met in the following scenarios:

- Switching from a ‘weak’ (minimal received power at TP3) ONU to a ‘strong’ (maximal received power at TP3) 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 Ton).

For a tested PMD receiver with a declared Treceiver_settling time, measure all PMD receiver electrical parameters at TP4 after Treceiver_settling from the TX_ENABLE trigger minus the reference transmitter Ton, reassuring conformance to within 15% of its specified steady state values.

60.8 Environmental, safety, and labeling

60.8.1 General safety

All equipment meeting this standard shall conform to IEC 60950.

60.8.2 Laser safety

1000BASE-PX10 and 1000BASE-PX20 optical transceivers shall conform to Class 1 laser requirements as defined in IEC 60825-1, 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 shall explicitly define requirements and usage restrictions on the host system necessary to meet these safety certifications.

60.8.3 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.

60.8.4 Environment

Reference 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).

Table 60–13—Component case temperature classes

Class	Low temperature (˚C)	High temperature (˚C)
Warm extended	–5	+85
Cool extended	–40	+60
Universal extended	–40	+85

60.8.5 PMD labeling requirements

It is recommended that each PHY (and supporting documentation) be labeled in a manner visible to the user, with at least the applicable safety warnings and the applicable port type designation (e.g., 1000BASE-PX10-U).

Labeling requirements for Class 1 lasers are given in the laser safety standards referenced in 60.8.2.

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

60.9 Characteristics of the fiber optic cabling

The 1000BASE-PX fiber optic cabling shall meet the dispersion specifications defined in IEC 60793-2 and ITU-T G.652, as shown in Table 60–14. 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 60–10.

60.9.1 Fiber optic cabling model

The fiber optic cabling model is shown in Figure 60–10.

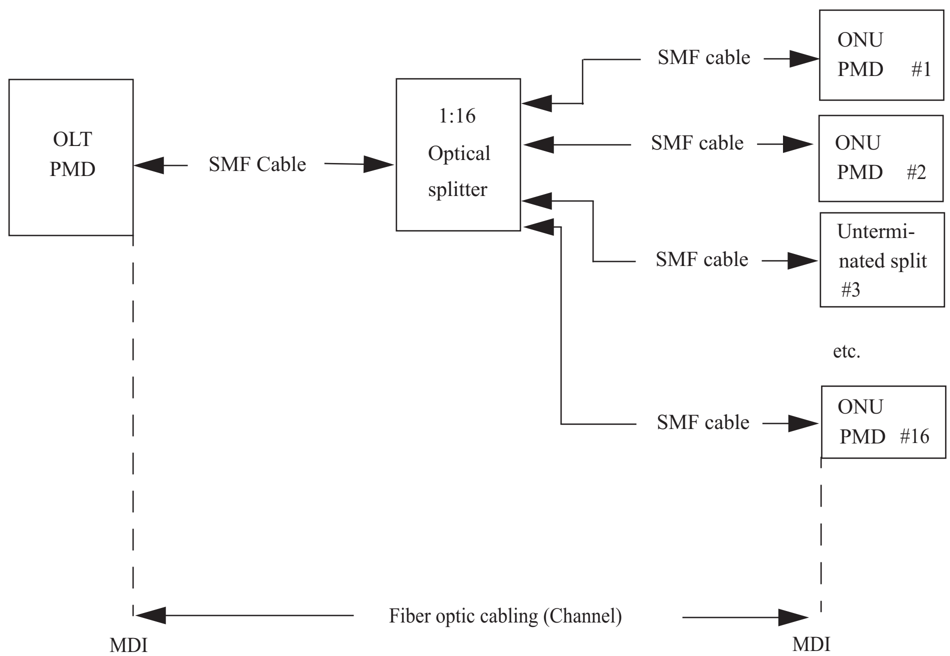


Figure 60–10—Fiber optic cable model

NOTE—The 1:16 optical splitter 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 60–9.

The maximum channel insertion losses shall meet the requirements specified in Table 60–1. Insertion loss measurements of installed fiber cables are made in accordance with ANSI/TIA/EIA-526-7 [B15], method A-1. 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.

60.9.2 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 single-mode fiber) and Type B1.3 (low water peak single-mode fiber) and ITU G.652 as noted in Table 60–14.

60.9.3 Optical fiber connection

Table 60–14—Optical fiber and cable characteristics

Description[a]	Type B1.1, B1.3 SMF		Unit
Nominal wavelength[b]	1310	1550	nm
Cable attenuation (max)[c]	0.4	0.35	dB/km
Zero dispersion wavelength[d]	$1300 \le \lambda_0 \le 1324$		nm
Dispersion slope (max)	0.093		ps / nm^2 · km

[a]The fiber dispersion values are normative, all other values in the table are informative.
[b]Wavelength specified is the nominal wavelength and typical measurement wavelength. Power penalties at other wavelengths are accounted for.
[c]Attenuation for single-mode optical fiber cables is defined in ITU-T G.652.
[d]See IEC 60793 or ITU-T G.652.

An optical fiber connection as shown in Figure 60–10 consists of a mated pair of optical connectors. The 1000BASE-PX is coupled to the fiber optic cabling through an optical connection and any optical splitters into the MDI optical receiver, as shown in Figure 60–10. The channel insertion loss includes the loss for connectors, splices and other passive components such as splitters, see Table 60–9.

The link attenuations have been calculated on the assumption of 14.5 dB for a 16:1 splitter; 3.5, 4, 7.5, or 8 dB (at the appropriate measurement wavelength where these attenuations are a combination of the minimum range given in Table 60–1 and the values in Table 60–14) for fiber cable attenuation and 1.5 dB for connectors and splices. For example, this allocation supports three connections with an average insertion loss equal to 0.5 dB (or less) per connection, or two connections with a maximum insertion loss of 0.75 dB. Other arrangements, such as a shorter link length and a higher split ratio in the case of 1000BASE-PX20, may be used provided the requirements of Table 60–1 are met.

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

60.9.4 Medium Dependent Interface (MDI)

The 1000BASE-PX10 or 1000BASE-PX20 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 60–10. Examples of an MDI include:

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 1000BASE-PX10 and 1000BASE-PX20 and couples to a single fiber.

NOTE—Compliance testing is performed at TP2 and TP3 as defined in 60.2.1, not at the MDI.

60.10 Protocol implementation conformance statement (PICS) proforma for Clause 60, Physical Medium Dependent (PMD) sublayer and medium, type 1000BASE-PX10 and 1000BASE-PX20 (long wavelength passive optical networks)[8]

60.10.1 Introduction

The supplier of a protocol implementation that is claimed to conform to Clause 60, Physical Medium Dependent (PMD) sublayer and medium, type 1000BASE-PX10 and 1000BASE-PX20 (long wavelength passive optical networks), 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.

60.10.2 Identification

60.10.2.1 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]	
NOTES 1—Required for all implementations. 2—May be completed as appropriate in meeting the requirements for the identification. 3—The terms Name and Version should be interpreted appropriately to correspond with a supplier's terminology (e.g., Type, Series, Model).	

60.10.2.2 Protocol Summary

Identification of protocol standard	IEEE Std 802.3-2005, Clause 60, Physical Medium Dependent (PMD) sublayer and medium, type 1000BASE-PX
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 802.3-2005.)	

Date of Statement	

[8]*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.

60.10.3 Major capabilities/options

Item	Feature	Subclause	Value/Comment	Status	Support
HT	High temperature operation	60.8.4	–5 to 85 °C	O	Yes [ ] No [ ]
LT	Low temperature operation	60.8.4	–40 to 60 °C	O	Yes [ ] No [ ]
*PX10U	1000BASE-PX10-D or 1000BASE-PX10-U PMD	60.2	Device supports 10 km	O/1	Yes [ ] No [ ]
*PX10D	1000BASE-PX10-D or 1000BASE-PX10-U PMD	60.2	Device supports 10 km	O/1	Yes [ ] No [ ]
*PX20U	1000BASE-PX20-D or 1000BASE-PX20-U PMD	60.3	Device supports 20 km	O/1	Yes [ ] No [ ]
*PX20D	1000BASE-PX20-D or 1000BASE-PX20-U PMD	60.3	Device supports 20 km	O/1	Yes [ ] No [ ]
*INS	Installation / Cable	60.3.1	Items marked with INS include installation practices and cable specifications not applicable to a PHY manufacturer.	O	Yes [ ] No [ ]

60.10.4 PICS proforma tables for Physical Medium Dependent (PMD) sublayer and medium, type 1000BASE-PX10 and 1000BASE-PX20 (long wavelength passive optical networks)

60.10.4.1 PMD functional specifications

Item	Feature	Subclause	Value/Comment	Status	Support
FN1	Transmit function	60.2.2	Conveys bits from PMD service interface to MDI	M	Yes [ ]
FN2	Transmitter optical signal	60.2.2	Higher optical power transmitted is a logic 1	M	Yes [ ]
FN3	Receive function	60.2.3	Conveys bits from MDI to PMD service interface	M	Yes [ ]
FN4	Receiver optical signal	60.2.3	Higher optical power received is a logic 1	M	Yes [ ]
FN5	Signal detect function (down-stream)	60.2.4.1	Mapping to PMD service interface	M	Yes [ ]
FN6	Signal detect parameter (down-stream)	60.2.4.1	Generated according to Table 60–2	M	Yes [ ]
FN7	Signal detect function (upstream)	60.2.4.2	Mapping to PMD service interface	O/2	Yes [ ]
FN7	Signal detect function (upstream)	60.2.4.2	Provided by higher layer	O/2	Yes [ ]
FN8	Signal detect parameter (upstream)	60.2.4.1	Generated according to Table 60–2	O	Yes [ ]

60.10.4.2 PMD to MDI optical specifications for 1000BASE-PX10-D

Item	Feature	Subclause	Value/Comment	Status	Support
PX10D1	1000BASE-PX10-D transmitter	60.3.1	Meets specifications in Table 60–3	PX10D:M	Yes [ ] N/A [ ]
PX10D2	1000BASE-PX10-D receiver	60.3.2	Meets specifications in Table 60–5	PX10D:M	Yes [ ] N/A [ ]
PX10D3	1000BASE-PX10-D stressed receiver sensitivity	60.3.2	Meets specifications in Table 60–5	PX10D:O	Yes [ ] No [ ] N/A[ ]
PX10D4	1000BASE-PX10-D receiver damage threshold	60.3.2	If the receiver does not meet the damage requirements in Table 60–5 then label accordingly	PX10D:M	Yes [ ] N/A [ ]

60.10.4.3 PMD to MDI optical specifications for 1000BASE-PX10-U

Item	Feature	Subclause	Value/Comment	Status	Support
PX10U1	1000BASE-PX10-U transmitter	60.3.1	Meets specifications in Table 60–3	PX10U:M	Yes [ ] N/A [ ]
PX10U2	1000BASE-PX10-U receiver	60.3.2	Meets specifications in Table 60–5	PX10U:M	Yes [ ] N/A [ ]
PX10U3	1000BASE-PX10-U stressed receiver sensitivity	60.3.2	Meets specifications in Table 60–5	PX10U:O	Yes [ ] No [ ] N/A[ ]
PX10U4	1000BASE-PX10-U receiver damage threshold	60.3.2	If the receiver does not meet the damage requirements in Table 60–5 then label accordingly	PX10U:M	Yes [ ] N/A [ ]

60.10.4.4 PMD to MDI optical specifications for 1000BASE-PX20-D

Item	Feature	Subclause	Value/Comment	Status	Support
PX20D1	1000BASE-PX20-D transmitter	60.4.1	Meets specifications in Table 60–6	PX20D:M	Yes [ ] N/A [ ]
PX20D2	1000BASE-PX20-D receiver	60.4.2	Meets specifications in Table 60–8	PX20D:M	Yes [ ] N/A [ ]
PX20D3	1000BASE-PX20-D stressed receiver sensitivity	60.4.2	Meets specifications in Table 60–8	PX20D:O	Yes[ ] No [ ] N/A[ ]
PX20D4	1000BASE-PX20-D receiver damage threshold	60.4.2	If the receiver does not meet the damage requirements in Table 60–8 then label accordingly	PX20D:M	Yes [ ] N/A [ ]

60.10.4.5 PMD to MDI optical specifications for 1000BASE-PX20-U

Item	Feature	Subclause	Value/Comment	Status	Support
PX20U1	1000BASE-PX20-U transmitter	60.4.1	Meets specifications in Table 60–6	PX20U:M	Yes [ ] N/A [ ]
PX20U2	1000BASE-PX20-D receiver	60.4.2	Meets specifications in Table 60–8	PX20U:M	Yes [ ] N/A [ ]
PX20U3	1000BASE-PX20-U stressed receiver sensitivity	60.4.2	Meets specifications in Table 60–8	PX20U:O	Yes[ ] No [ ] N/A[ ]
PX20U4	1000BASE-PX20-U receiver damage threshold	60.4.2	If the receiver does not meet the damage requirements in Table 60–8 then label accordingly	PX20U:M	Yes [ ] N/A [ ]

60.10.4.6 Optical measurement requirements

Item	Feature	Subclause	Value/Comment	Status	Support
OM1	Measurement cable	60.7	2 m to 5 meters in length	M	Yes [ ]
OM2	Wavelength and spectral width measurement	60.7.2	Per TIA/EIA-455-127 under modulated conditions	M	Yes [ ]
OM3	Average optical power	60.7.3	Per TIA/EIA-455-95	M	Yes [ ]
OM4	Extinction ratio	60.7.4	Per ANSI/TIA/EIA-526-4A with minimal back reflections and fourth-order Bessel-Thomson receiver	M	Yes [ ]
OM5	$RIN_{15}OMA$	60.7.7	As described in 58.8.7	M	Yes [ ]
OM6	Transmit optical waveform (transmit eye)	60.7.8	Per ANSI/TIA/EIA-526-4A with test pattern and fourth-order Bessel-Thomson receiver	M	Yes [ ]
OM7	Transmitter and dispersion penalty measurements	60.7.9	As described in 58.7.9	M	Yes [ ]
OM8	Receive sensitivity	60.7.10	With specified pattern	M	Yes [ ]
*OM9	Stressed receiver conformance test	60.7.11	As described in 60.7.11	O	Yes[ ] N/A[ ]

60.10.4.7 Characteristics of the fiber optic cabling and MDI

Item	Feature	Subclause	Value/Comment	Status	Support
FO1	Fiber optic cabling	60.9	Specified in Table 60–14	INS:M	Yes [ ] N/A[ ]
F02	End -to-end channel loss	60.9	Meeting the requirements of Table 60–1	INS:M	Yes [ ] N/A[ ]
FO3	Maximum discrete reflectance - single-mode fiber	60.9.2	Less than –26 dB	INS:M	Yes [ ] N/A [ ]
FO4	MDI requirements	60.9.4	Meet the interface performance specifications of IEC 61753-1, if remateable	INS:O	Yes [ ] No [ ] N/A [ ]

60.10.4.8 Environmental specifications

Item	Feature	Subclause	Value/Comment	Status	Support
ES1	General safety	60.8.1	Conforms to IEC-60950	M	Yes [ ]
ES2	Laser safety —IEC Class 1	60.8.2	Conform to Class 1 laser requirements defined in IEC 60825-1	M	Yes [ ]
ES3	Documentation	60.8.2	Explicitly defines requirements and usage restrictions to meet safety certifications	M	Yes [ ]
ES4	Operating temperature range labeling	60.8.5	If required	M	Yes [ ] N/A[ ]

61. Physical Coding Sublayer (PCS), Transmission Convergence (TC) sublayer, and common specifications, type 10PASS-TS and type 2BASE-TL

61.1 Overview

This clause specifies the Physical Coding Sublayer (PCS), Transmission Convergence sublayer (TC), and handshaking mechanisms that are common to a family of Physical Layer implementations for Ethernet over voice-grade copper known as 10PASS-TS and 2BASE-TL. These PHYs deliver a minimum of 10 Mb/s over distances of up to 750 m, and a minimum of 2 Mb/s over distances of up to 2700 m, using a single copper pair. Optionally, transmission over multiple copper pairs is supported.

The copper category of EFM PHYs is based on Digital Subscriber Line (DSL) PMDs defined for use in the access network according to ATIS T1, ETSI, and ITU-T standards. These systems are intended to be used in public as well as private networks; therefore they shall be capable of compliance with appropriate regulatory, governmental and regional requirements.

Unlike the specified copper categories for 10BASE-T, 100BASE-T and 1000BASE-T, existing common carrier voice-grade copper has channel characteristics that are very diverse. Therefore it is conventional to discuss the channel behaviour only in terms of averages, standard deviations and percentage worst case.

The 10PASS-TS and 2BASE-TL EFM Copper PHYs, in conjunction with the MAC specified in Clause 4 and Annex 4A, are used for point-to-point communications on a subscriber access network, typically between centralized distribution equipment, such as a Central Office (CO), and equipment located at the subscriber premises [Customer Premises Equipment, (CPE)].

For the 10PASS-TS and 2BASE-TL EFM Copper PHYs, two subtypes are defined: 10PASS-TS-O and 10PASS-TS-R are the subtypes of 10PASS-TS; 2BASE-TL-O and 2BASE-TL-R are the subtypes of 2BASE-TL. A connection can only be established 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, or between a 2BASE-TL-O PHY on one end and a 2BASE-TL-R PHY on the other end. In public networks, a 10PASS-TS-O or 2BASE-TL-O PHY is used at a CO, a cabinet or other centralized distribution point; a 10PASS-TS-R or 2BASE-TL-R PHY is used as CPE. In private networks, the network administrator will designate one end of each link as the network end. In this clause, 10PASS-TS-O and 2BASE-TL-O are collectively referred to as “CO-subtypes”; 10PASS-TS-R and 2BASE-TL-R are collectively referred to as “CPE-subtypes”. The CO and CPE subtypes of a 10PASS-TS or 2BASE-TL PHY may be implemented in a single physical device.

10PASS-TS and 2BASE-TL PHYs do not provide support for unidirectional links as described in 57.2.12. If a particular anomaly or failure occurs in either downstream or upstream, sublayer-specific signaling will alert the remote end of this condition. In the case of a sustained anomaly or failure, the link will reinitialize.

61.1.1 Scope

This clause defines the Physical Coding Sublayer (PCS) and Transmission Convergence sublayer (TC) for 2BASE-TL and 10PASS-TS. The PCS has similarities to other IEEE 802.3 PCS types, but also differs since new sublayers are added within the PCS sublayer to accommodate the operation of Ethernet over access network copper channels. The TC contains additional functions specific to the EFM Copper PHYs. This clause also defines the common startup and handshaking mechanism used by both PHYs. Parts of register 3.0, parts of register 3.4, and registers 3.60 through 3.73 specified in Clause 45 may be used to control the PCS specified in this clause. The remaining PCS registers defined in Clause 45 do not have any effect on the PCS specified in this clause. Parts of register 6.0 and registers 6.16 through 6.23 specified in Clause 45 may be used to control the TC sublayer specified in this clause.

61.1.2 Objectives

The following are the objectives for 2BASE-TL and 10PASS-TS:

a) To provide 100 Mb/s burst data rate at the MII using Rate Matching.
b) To provide support for simultaneous transmission and reception without interference.
c) To provide for operating over unshielded voice grade twisted pair cable.
d) To provide a communication channel with a mean BER at the PMA service interface of less than 10^{-7} with a noise margin of 6 dB (10PASS-TS) or 5 dB (2BASE-TL).
e) To provide optional support for operation on multiple pairs.
f) To provide functional layering in the PCS which ensures compatibility with the layering and frame interfaces for xDSL systems, including a γ-interface based on that used for the PTM-TC sublayer as defined in ITU-T Recommendation G.993.1.

61.1.3 Relation of 2BASE-TL and 10PASS-TS to other standards

The relation of 2BASE-TL and 10PASS-TS to other standards is shown schematically in Figure 61–1.

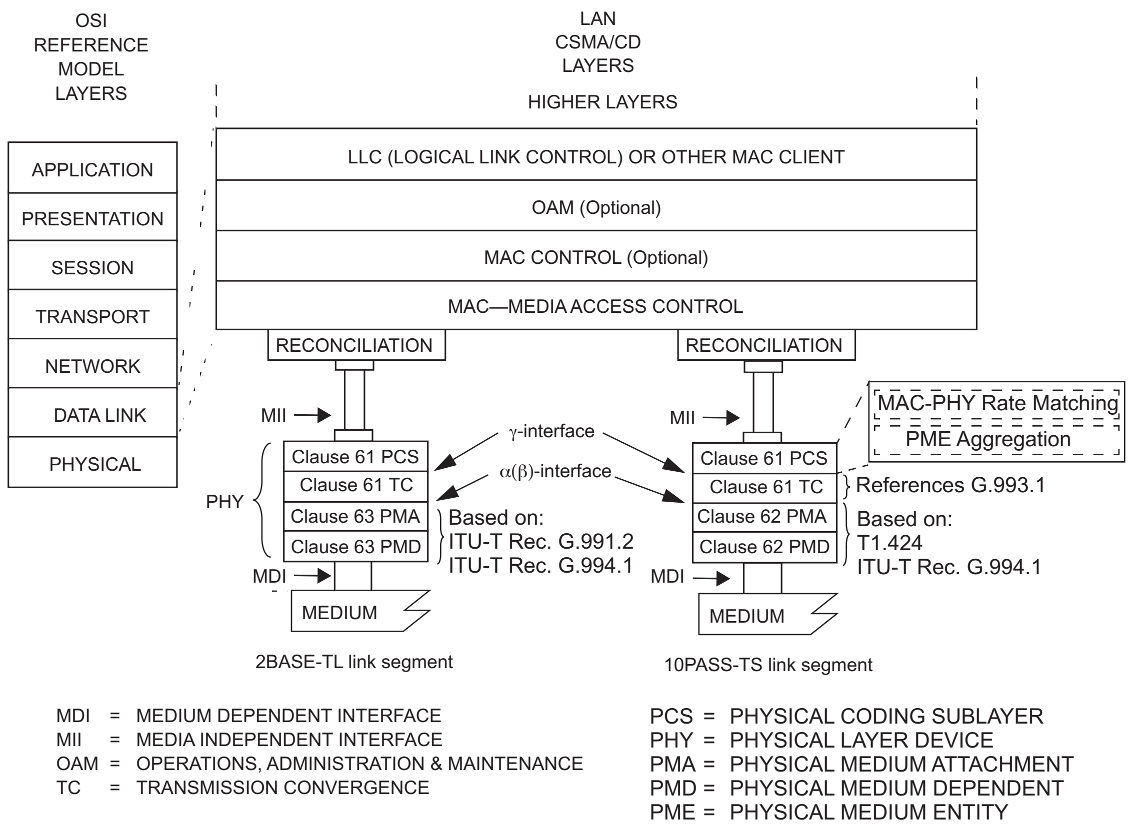


Figure 61–1—Relation of this clause to other standards

NOTE—The PCS shown in the 2BASE-TL PHY and the PCS shown in the 10PASS-TS PHY are two instances of one unique PCS, specified in this clause. The TC shown in the 2BASE-TL PHY and the TC shown in the 10PASS-TS PHY are two instances of one unique TC, specified in this clause.

61.1.4 Summary

61.1.4.1 Summary of Physical Coding Sublayer (PCS) specification

The Physical Coding Sublayer (PCS) for 2BASE-TL and 10PASS-TS contains two functions: MAC-PHY rate matching and PME aggregation. The functional position of the PCS is shown in Figure 61–2.

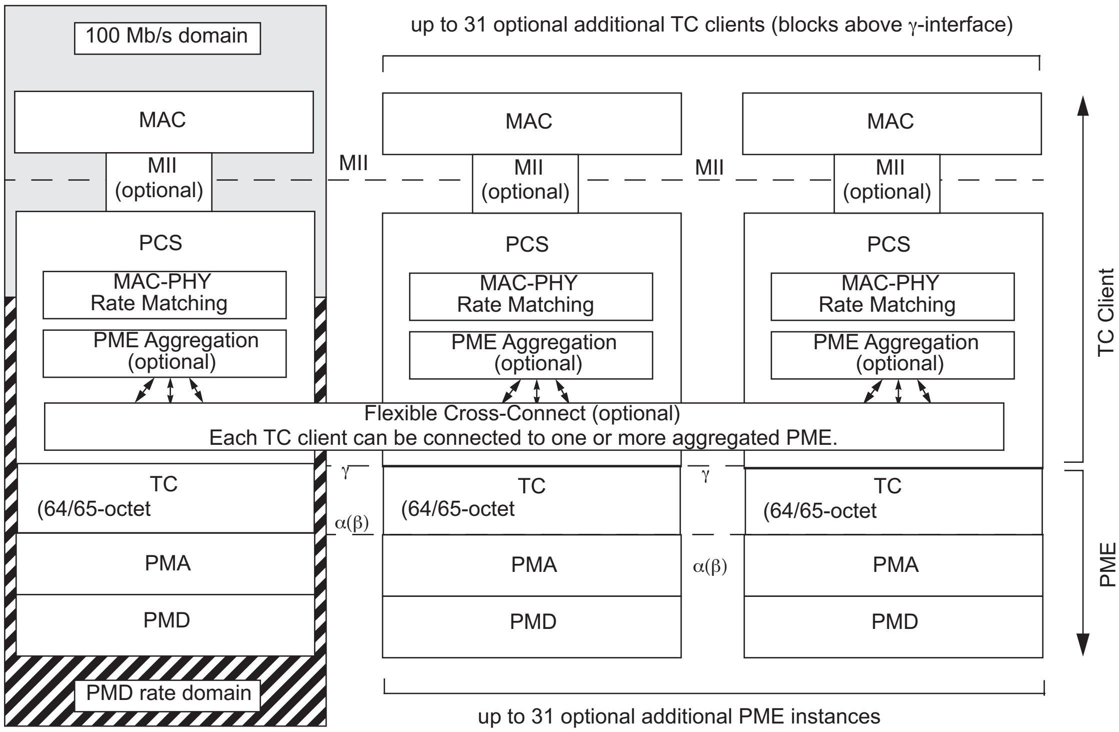


Figure 61–2—Overview of PCS functions

The γ-interface and α(β)-interface are specified in 61.3.1 and 61.3.2, respectively. They are generic interfaces used in various xDSL specifications, such as the ones referenced in Clause 62 and Clause 63. The α(β)-interface is a simple octet-synchronous data interface; the γ-interface adds protocol-awareness (in the case of the TC sublayer defined in this Clause, the γ-interface can signal packet boundaries).

The bit rates in the shaded area labeled "PMD rate domain" are derived from the DSL bit rates. Data is transferred across the γ-interface at the rate imposed by the lower layers. The bit rates in the shaded area labeled "100 Mb/s domain" are synchronous to the MII rate. Data is transferred across the MII at the rate of one nibble per MII clock cycle. The MAC-PHY rate matching function adjusts the inter packet gap so that the net data rate across these interface matches the sum of rates across the γ-interfaces.[9]

In the transmit direction, frames are transferred from the MAC to the PCS across the MII when the MAC-PHY rate matching function allows this. In the PCS, preamble and SFD octets are removed. If the optional PME aggregation function (PAF) is present, the data frame is fragmented by the PAF, and fragments are forwarded, optionally through a flexible cross-connect, towards each of the aggregated Physical Medium Entity (PME) instances via their γ-interfaces. If the PAF is not present, the data frame is forwarded to the TC sublayer via the γ-interface. The TC sublayer accepts data from the MAC-PHY rate matching function or the PAF, at the rate at which it can be processed by the TC sublayer, by asserting Tx_Enbl on the γ-interface.

[9]Bit rate domains and physical clock domains do not necessarily coincide. The TC sublayer receives a clock signal from the PMA via the α(β)-interface, and a clock signal from the optional PAF or the MAC-PHY Rate Matching function via the γ-interface. The TC provides matching between these two clock domains.

In the receive direction the TC sublayer pushes data to the PAF (if present) or the MAC-PHY rate matching function by asserting Rx_Enbl on the γ-interface. If multiple links are aggregated, the PAF reassembles the received fragments into data frames. Preamble and SFD octets are generated and prepended to the data frame prior to passing it up to the MAC across the MII. The MAC-PHY Rate Matching function may delay the transfer of the frame to avoid simultaneous transfer of Transmit and Receive frames if required.

61.1.4.1.1 Implementation of Media Independent Interface

10PASS-TS and 2BASE-TL specify the optional use of the MII electrical interface as defined in Clause 22 (see also 61.1.5.2). 10PASS-TS and 2BASE-TL do not utilize the MII management interface as described in 22.2.4. The use of the MDIO interface specified in Clause 45 or an equivalent management interface is recommended.

Notwithstanding the specifications in 22.2.2.9, CRS may be asserted by a full-duplex EFM Copper PHY to reduce the effective MAC rate to that of the PHY.

61.1.4.1.2 Summary of MAC-PHY Rate Matching specification

The 10PASS-TS and 2BASE-TL PCS is specified to work with a MAC operating at 100 Mb/s using the MII as defined in Clause 22. The PCS matches the MAC's rate of data transmission to the transmission data rate of the medium, if slower. This is achieved using deference as defined in Annex 4A.

The MAC transmits data at a rate of 100 Mb/s, which is buffered by the PCS before being transmitted onto the medium. Prior to transmission, the MAC checks the carrierSense variable (mapped from the MII signal CRS), and will not transmit another frame as long as carrierSense is asserted. In order to prevent the PCS's transmit buffer from overflowing, the PCS keeps CRS asserted until it has space to receive a maximum length frame. The PCS forces COL to logic zero to prevent the MAC from dropping the frame and performing a re-transmission.

The transmitter MAC-PHY Rate Matching function strips the Preamble and SFD fields from the MAC frame, and forwards the resulting data frame to the PME Aggregation Function or to the TC sublayer.

For reception the PHY buffers a complete frame, prepends the Preamble and SFD fields, and sends it to the MAC at 100 Mb/s.

It is recognized that some MAC implementations have to be configured for half duplex operation to support deference (according to 4.2.3.2.1), and that these may not allow the simultaneous transmission and reception of data while operating in half duplex mode. To permit operation with these MACs the PHY has an operating mode where MAC data transmission is deferred using CRS when received data is sent from the PHY to the MAC. This mode of operation is defined in Figure 61–8 which describes the MAC-PHY rate matching receive state machine. This state machine gives receive frames priority over transmitted frames to ensure the receive buffer does not overflow.

The definition of MAC-PHY rate matching is presented in 61.2.1.

61.1.4.1.3 Summary of PME Aggregation specification

An optional PME Aggregation Function (PAF) allows one or more PMEs to be combined together to form a single logical Ethernet link. The PAF is located in the PCS, between the MAC-PHY Rate Matching function and the TC sublayer. It interfaces with the PMEs across the γ-interface, and to the MAC-PHY Rate Matching function using an abstract interface. The definition of the PAF is presented in 61.2.2.

61.1.4.1.4 Overview of management

Ethernet OAM (Clause 57) runs over a MAC service which uses a PHY consisting of either a single physical link, or more than one physical 2BASE-TL or 10PASS-TS links, aggregated as described in 61.2.2. The Ethernet OAM operates as long as there is at least one PME in the PHY that is operational. The physical xDSL PMEs in Clause 62 and Clause 63 each have their own management channel that operates per loop (eoc, VOC and IB for 10PASS-TS; EOC and IB for 2BASE-TL).

61.1.4.2 Summary of Transmission Convergence (TC) specification

The Transmission Convergence sublayer (TC) resides between the γ-interface of the PCS and α(β)-interface of the PMA. It is intended to convert the data frame to be sent into the format suitable to be mapped into PMA, and to recognize the received frame at the other end of the link. Since PMA and MII clocks may be unequal, the TC also provides clock rate matching. The definition of the TC sublayer is presented in 61.3.

61.1.4.3 Summary of handshaking and PHY control specification

Both 2BASE-TL and 10PASS-TS use handshake procedures defined in ITU-T G.994.1 at startup. Devices implementing both 2BASE-TL and 10PASS-TS port types may use G.994.1 to determine a common mode of operation.

61.1.5 Application of 2BASE-TL, 10PASS-TS

61.1.5.1 Compatibility considerations

The PCS, TC, PMA, and the MDI are defined to provide compatibility among devices designed by different manufacturers. Designers are free to implement circuitry within the PCS, TC, and PMA in an application-dependent manner provided the MDI and MII specifications are met.

61.1.5.2 Incorporating the 2BASE-TL, 10PASS-TS PHY into a DTE

When the PHY is incorporated within the physical bounds of a DTE, conformance to the MII is optional, provided that the observable behaviour of the resulting system is identical to that of a system with a full MII implementation. For example, an integrated PHY may incorporate an interface between PCS and MAC that is logically equivalent to the MII, but does not have the full output current drive capability called for in the MII specification.

61.1.5.3 Application and examples of PME Aggregation

The PME Aggregation Function defined in 61.2.2 allows multiple PME instances to be aggregated together to form one logical link underneath one MII (or MAC). Additionally, the control mechanism allows multi-MAC devices to be built with flexible connections between the MACs and the PMEs. Clause 45 defines a mechanism for addressing and controlling this flexible connectivity. The relationship between the flexible connectivity and the other functions within the PCS is shown in Figure 61–2.

The connection relationship between the PCS instances (including MIIs) and the PME instances is defined in two registers: PME_Available_register (see 45.2.3.19) and PME_Aggregate_register (see 45.2.3.20). The PME_Available_register controls which PMEs may be aggregated into a particular PCS (and MII). This register value is limited by the physical connectivity in the device, may be further constrained by management, and is additionally constrained as PMEs are aggregated into other PCSs (which causes their bit to be cleared to zero in the PCS instances that they are not aggregated into). The register represents the potential for connectivity into this PCS at the particular point in time. The PME_Aggregate_register indicates the actual connectivity, i.e., which PMEs are being aggregated into the particular PCS.

NOTE—The addressing of PCS instances is independent of the addressing of PME instances in order to support the flexible connectivity. Each PCS consumes one of the 32 available port addresses.

Bits corresponding to the same PME may appear in multiple PME_Available_registers but the PME_Aggregate_register for each MII shall be set such that each PME is only actively connected to at most one MII. A particular bit set in one PME_Aggregate_register shall exclude the same corresponding bit in all other PME_Aggregate_registers for the same MDIO connected system.

61.1.5.3.1 Addressing PCS and PME instances

The addressing of the MDIO management interface is defined in 45.1. It is assumed that the reader is familiar with the definition of this interface. The examples here assume that only three MMDs are used: PCS (MMD = 3), TC (MMD = 6), and PMA/PMD (MMD = 1). The combination of TC, PMA and PMD is shown as PME in Figure 61–3. The difference between these examples and the example shown in 45.1 is that the PCS instances are addressed independently of the PME instances. Up to 32 PCS instances and up to 32 PME instances may be addressed by one MDIO bus. These instances may make up one or more aggregateable subdomains. The connection of the MDIO bus to the MMDs is shown in Figure 61–3.

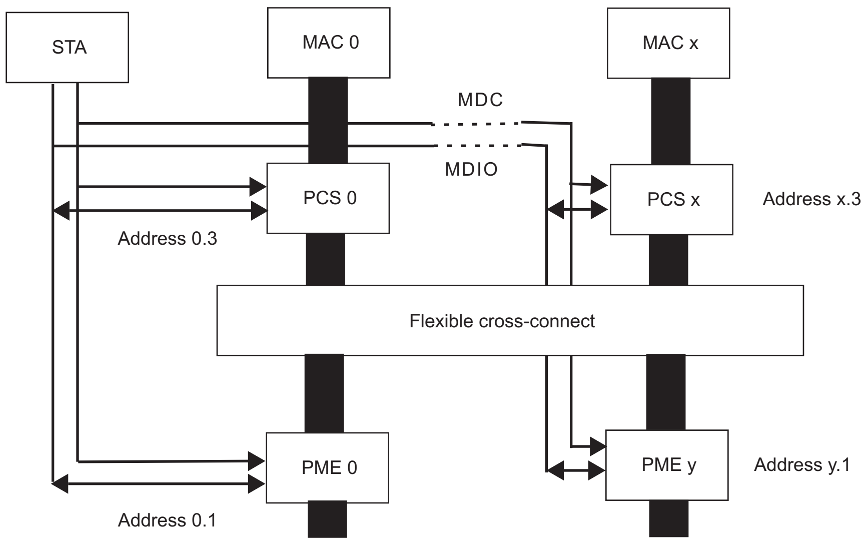


Figure 61–3—Connection of MDIO bus to MMD instances

In the example shown in Figure 61–3 there is no necessary connection between the PCS address and the PME address. The number of PCS instances may be different from the number of PME instances.

61.1.5.3.2 Indicating PME aggregation capability

The PME aggregation capability is indicated by the state of the PME_Available_register (see 45.2.3.19). An instance of this register is readable for each PAF instance *x* at register addresses *x*.3.62 and *x*.3.63. (Device address 3 of every port *x* is assigned to the PCS. The PAF specific registers reside under the *x*.3 register tree, because the PAF is part of the PCS as shown in Figure 61–2.) A bit is set in this register corresponding to the PME address for each PME which can be aggregated through the PAF in that PCS. Some examples are given which show register contents and connectivity for some popular configurations:

a) Simple two PME per MII connections, 32 PMEs are available for aggregation into 16 MIIs (PCS instances). PME_Available_register contents are shown in Table 61–1. A diagram of the connectivity is shown in Figure 61–4.
b) Pairs of 4-to-1 connections, 32 PMEs are available for aggregation into 16 MIIs (PCS instances) in a manner that allows each PME to connect to one of 2 MIIs and each MII to aggregate up to 4 PMEs. PME_Available_register contents are shown in Table 61–2. A diagram of the connectivity is shown in Figure 61–5.
c) 24-to-12 fully flexible connections, 24 PMEs are available for aggregation into 12 MIIs (PCS instances) in a manner that allows any PME to connect to any MII. PME_Available_register contents are shown in Table 61–3. No connectivity diagram is shown as any connection is possible between PMEs and MIIs.

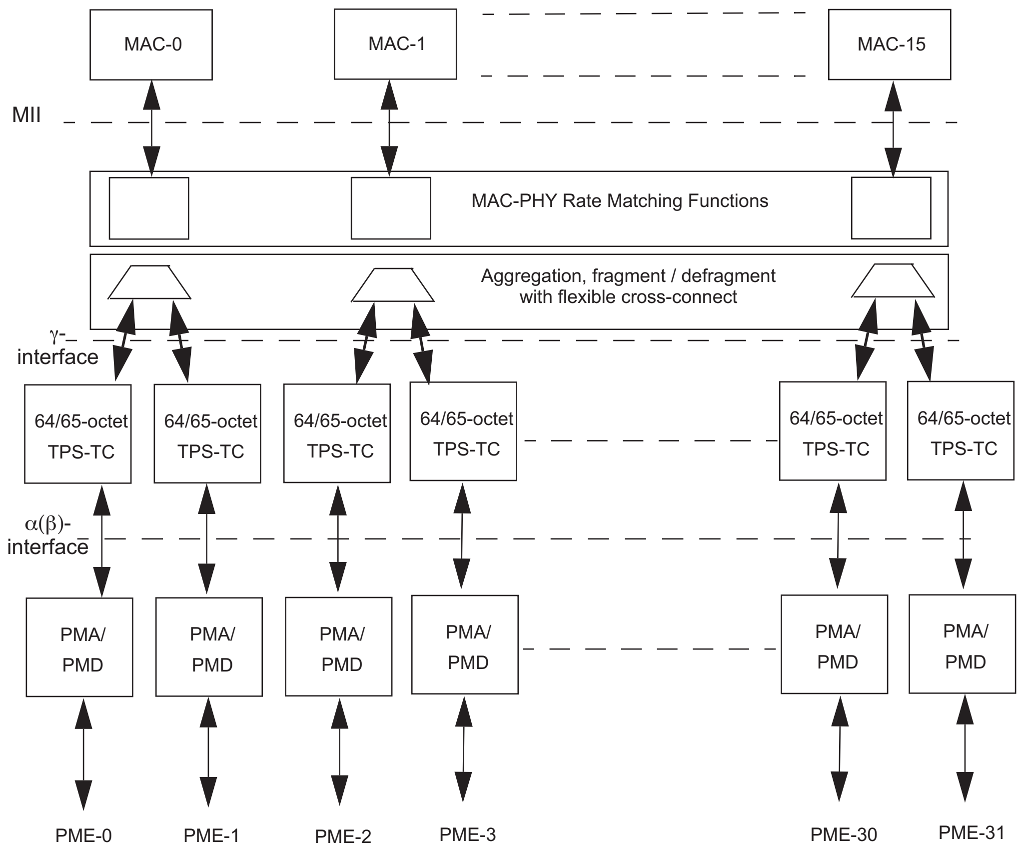


Figure 61–4—2 PME for each MII connectivity

Table 61–1—PME_Available_register contents (example a)

PME_Available_register	Contents
0.3.62 / 63	b11000000_00000000_00000000_00000000
1.3.62 / 63	b00110000_00000000_00000000_00000000
etc.	etc.
15.3.62 / 63	b00000000_00000000_00000000_00000011

Table 61–2—PME_Available_register contents (example b)[a]

PME_Available_register	Contents
0.3.62 / 63	b11110000_00000000_00000000_00000000
1.3.62 / 63	b11110000_00000000_00000000_00000000
etc.	etc.
15.3.62 / 63	b00000000_00000000_00000000_00001111

[a]NOTE—A mapping in which the same PME is available for connection to several PCS instances (as shown) is only allowed at the CO-side.

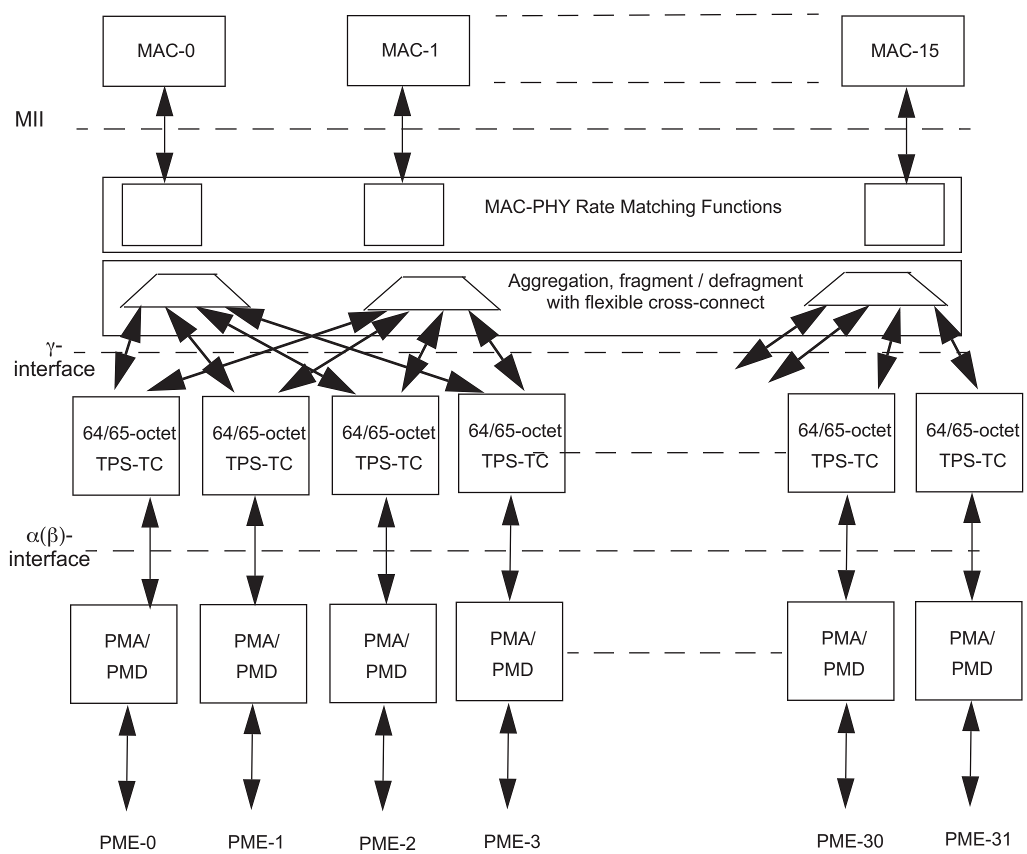


Figure 61–5—4 PME for each 2 MII connectivity

Table 61–3—PME_Available_register contents (example c)[a]

PME_Available_register	Contents
0.3.62 / 63	b11111111_11111111_11111111_00000000
1.3.62 / 63	b11111111_11111111_11111111_00000000
etc.	etc.
11.3.62/ 63	b11111111_11111111_11111111_00000000

[a]NOTE—A mapping in which the same PME is available for connection to several PCS instances (as shown) is only allowed at the CO-side.

61.1.5.3.3 Setting PME aggregation connection

The PME aggregation connection is set using the PME_Aggregate_register (see 45.2.3.20). This register is writeable for each PCS instance (*x*) at register addresses *x*.3.64 and *x*.3.65. A bit is set in this register corresponding to the PME address for each PME that is to be aggregated through that PCS. Some examples are given that show register contents and connectivity for some popular configurations:

a) Simple two PME per MII connections (as shown in example a above), the first MII aggregates 2 PMEs, the second MII only connects through 1 PME, as does the sixteenth. PME_Aggregate_register contents are shown in Table 61–4.

b) Pairs of 4-to-1 connections (as shown in example b above), the first MII aggregates 3 PMEs, the second MII only connects through 1 PME, the sixteenth MII aggregates 2 PMEs. PME_Aggregate_register contents are shown in Table 61–5.

c) 24-to-12 fully flexible connections (as shown in example c above), the first MII aggregates 5 PMEs, the second MII only connects through the 24th PME, the eleventh MII is not used, twelfth MII aggregates 2 PMEs. PME_Aggregate_register contents are shown in Table 61–6.

Table 61–4—PME_Aggregate_register contents (example a)

PME_Aggregate_register	Contents
0.3.64 / 65	b11000000_00000000_00000000_00000000
1.3.64 / 65[a]	b00010000_00000000_00000000_00000000
etc.	etc.
15.3.64 / 65	b00000000_00000000_00000000_00000010

[a]NOTE—The PME Aggregation functions have to be performed when PAF_enable is set, even if only 1 bit is set in the PME_Aggregate_register.

Table 61–5—PME_Aggregate_register contents (example b)

PME_Aggregate_register	Contents
0.3.64 / 65	b11100000_00000000_00000000_00000000
1.3.64 / 65[a]	b00010000_00000000_00000000_00000000
etc.	etc.
15.3.64 / 65	b00000000_00000000_00000000_00000110

[a]NOTE—The PME Aggregation functions have to be performed when PAF_enable is set, even if only 1 bit is set in the PME_Aggregate_register.

Table 61–6—PME_Aggregate_register contents (example c)

PME_Aggregate_register	Contents
0.3.64 / 65	b11111000_00000000_00000000_00000000
1.3.64 / 65[a]	b00000000_00000000_00000001_00000000
etc.	etc.
10.3.64 / 65	b00000000_00000000_00000000_00000000
11.3.64 / 65	b00000000_00000000_00000110_00000000

[a]NOTE—The PME Aggregation functions have to be performed when PAF_enable is set, even if only 1 bit is set in the PME_Aggregate_register.

61.1.5.4 Support for handshaking

It is the goal of the ITU-T that all specifications for digital transceivers for use on public telephone network copper subscriber lines use G.994.1 for startup. G.994.1 procedures allow for a common startup mechanism for identification of available features, exchange of capabilities and configuration information, and selection of operating mode. As the two loop endpoints are usually separated by a large distance (e.g., in separate buildings) and often owned and installed by different entities, G.994.1 also aids in diagnosing interoperability problems. G.994.1 codespaces have been assigned by ITU-T to ATIS T1, ETSI, and IEEE 802.3 in support of this goal.

The description of how G.994.1 procedures are used for Ethernet in the First Mile handshaking and PHY control are contained in 61.4.

61.2 PCS functional specifications

61.2.1 MAC-PHY Rate Matching functional specifications

61.2.1.1 MAC-PHY Rate Matching functions

The PHY shall use CRS to match the MAC's faster rate of data transmission to the PHY's slower rate.

Upon receipt of a MAC frame on the MII, the PHY shall discard the Preamble and SFD fields, and transmit the resulting data frame across the physical link.

The PHY shall prepend the Preamble and the SFD fields to a received frame before sending it to the MAC.

The PHY shall support a mode of operation where it does not send data to the MAC while the MAC is transmitting (see MII receive during transmit register, defined in 45.2.3.18).

If the PAF is disabled or not present, transmit frames shall not be forwarded to the TC sublayer unless TC_link_state is true for the whole frame. If the PAF is enabled, transmit fragments shall not be forwarded from the PAF to a TC sublayer unless the TC_link_state value of that TC sublayer instance is true for the whole fragment.

NOTE—This implies that in the absence of an active PAF, frames being transmitted over the MII when TC_link_state becomes true are never forwarded to the TC sublayer. A frame being transmitted over the MII when TC_link_state becomes false is aborted.

61.2.1.2 MAC-PHY Rate Matching functional interfaces

61.2.1.2.1 MAC-PHY Rate Matching – MII signals

MII signals are defined in 22.2.2 and listed in Table 23–1 in 23.2.2.1.

COL shall be forced to logic zero by the PCS.

CRS behaves as defined in 61.2.1.3.2.

61.2.1.2.2 MAC-PHY Rate Matching–Management entity signals

See 61.2.3.

61.2.1.3 MAC-PHY Rate Matching state diagrams

61.2.1.3.1 MAC-PHY Rate Matching state diagram constants

No constants are defined for the MAC-PHY rate matching state diagrams.

61.2.1.3.2 MAC-PHY Rate Matching state diagram variables

CRS
: CRS signal of the MII as specified in Clause 22. It is asserted when either of crs_tx or crs_rx are true: CRS ⇐ crs_tx + crs_rx

crs_and_tx_en_infer_col
: True if a reduced-pin MAC-PHY interface is present that infers a collision when TX_EN and CRS are both true simultaneously.

crs_rx
: Asserted by the MAC-PHY rate matching receive state machine to control CRS

crs_tx
: Asserted by the MAC-PHY rate matching transmit state machine to control CRS

power_on
: 'power_on' is true while the device is powering up. It becomes false once the device has

reached full power. Values:
FALSE; The device is completely powered (default).
TRUE; The device has not been completely powered.

Reset
True when the PCS is reset via control register bit 3.0.15.

RX_DV
RX_DV signal of the MII as specified in Clause 22

rx_frame_available
Set when the PHY's receive FIFO contains one or more complete frames

transferFrameCompleted
Variable of type boolean
TRUE if the transmission of the received frame over the MII has been completed,
FALSE otherwise.
The variable returns to the default state (FALSE) upon entry into any state.

tx_buffer_available
Set when the PHY's transmit FIFO has space to receive a maximum length packet from the MAC

TX_EN
TX_EN signal of the MII as specified in Clause 22

tx_rx_simultaneously
False if the MAC is configured in half duplex mode to support deference and it is not capable of transmitting and receiving simultaneously in this mode.

61.2.1.3.3 MAC-PHY Rate Matching state diagram timers

ipg_timer
Timer used to generate a gap between receive packets across the MII.
Duration: 960 ns, tolerance ±100 ppm.

rate_matching_timer
Timer used in rate matching state machine
Duration: 1120 ns, tolerance ±100 ppm.

The rate_matching_timer operates in a manner consistent with 14.2.3.2. The timer is restarted on entry to the WAIT_FOR_TIMER_DONE state with the action: 'Start rate_matching_timer'. It is then tested in the exit condition with the expression "rate_matching_timer_done".

The duration is set to 1120 ns to allow 960 ns for the inter frame gap plus 160 ns for the MAC to recognize CRS. 160 ns is equivalent to 16 bit times and is consistent with the assumptions about MAC performance listed in Table 21-2 in 21.8.

61.2.1.3.4 MAC-PHY Rate Matching state diagram functions

transferFrame()
This function transmits a packet to the MAC across the MII, according to the MII protocol as described in 22.2. This function generates RX_DV to delimit the frame in accordance with 22.2.2.6. Upon completion of frame transfer to the MAC, this function sets the variable transferFrameCompleted to TRUE.

61.2.1.3.5 MAC-PHY Rate Matching state diagrams

The state diagrams for the MAC-PHY Rate Matching functions are shown in Figure 61–6, Figure 61–7, and Figure 61–8.

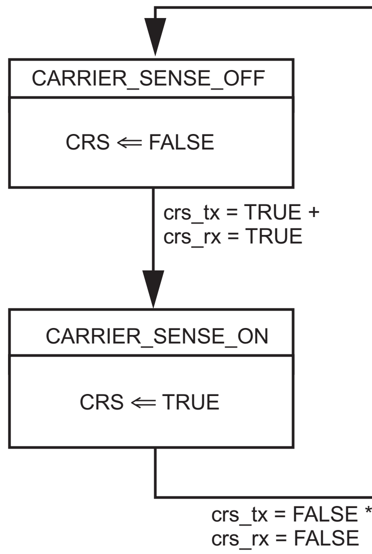


Figure 61–6—Carrier Sense state diagram

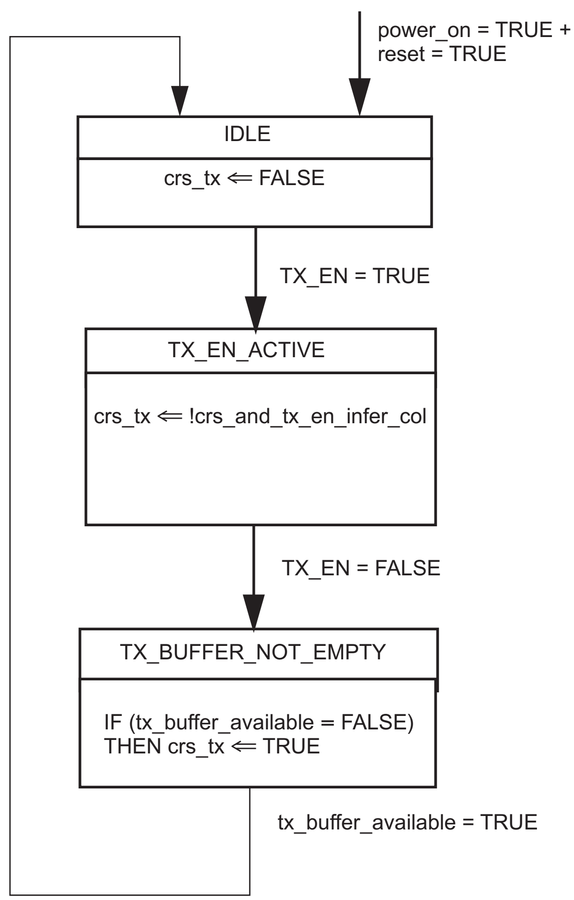


Figure 61–7—MAC-PHY rate matching transmit state machine

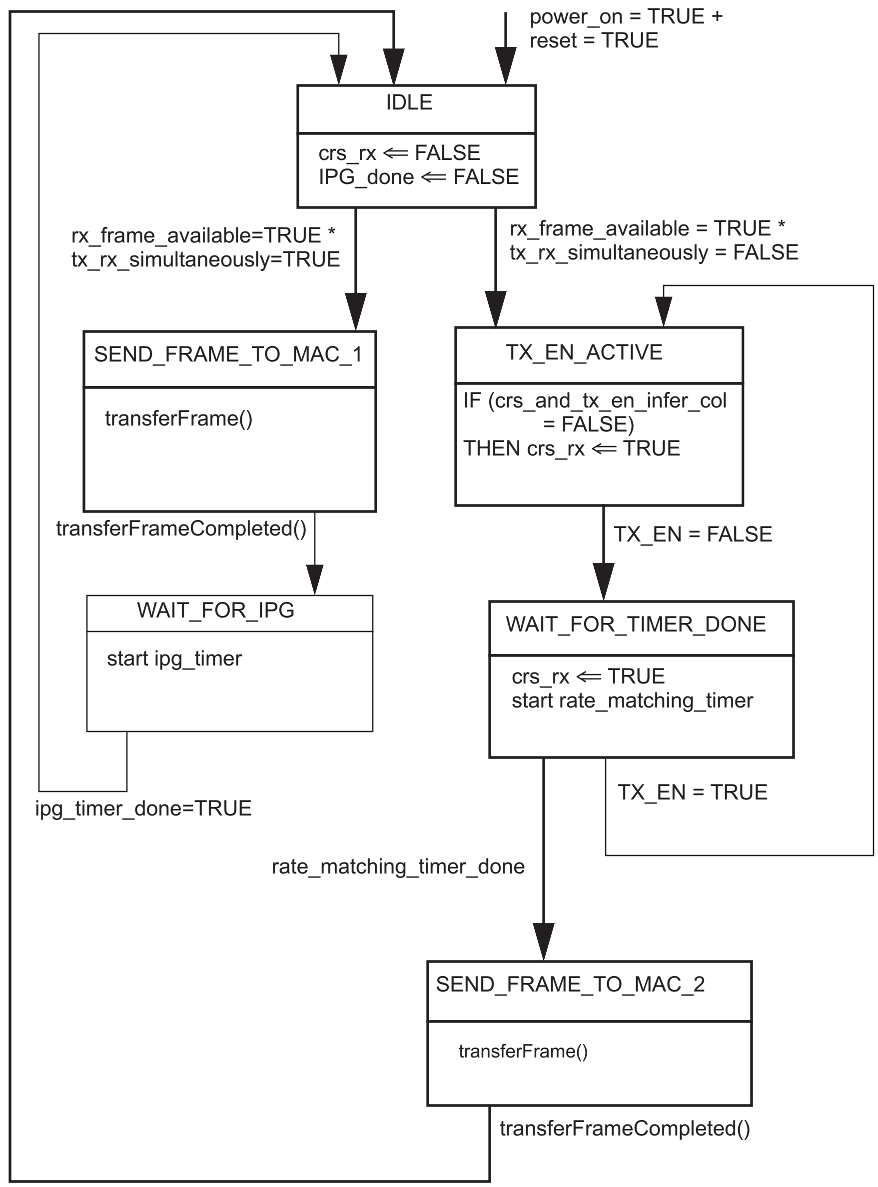


Figure 61–8—MAC-PHY rate matching receive state machine

61.2.2 PME Aggregation functional specifications

This subclause defines an optional PME Aggregation Function (PAF) for use with CSMA/CD MACs in EFM copper PHYs. PME Aggregation allows one or more PMA/PMDs to be combined together to form a single logical Ethernet link.

The PAF is located between the MAC-PHY Rate Matching function and the TC sublayer as shown in Figure 61–2. The PAF interfaces with the TC sublayer instances across the γ-interface. The PAF interfaces to the MAC-PHY Rate Matching function using an abstract interface whose physical realization is left to the implementor, provided the requirements of this standard are met.

The PME Aggregation function has the following characteristics:

a) Supports aggregation of up to 32 PMA/PMDs
b) Supports individual PMA/PMDs having different data rates
c) Ensures low packet latency and preserves packet sequence
d) Scalable and resilient to PME failure
e) Independent of type of EFM copper PHY
f) Allows vendor discretionary algorithms for fragmentation

61.2.2.1 PAF Enable and Bypass

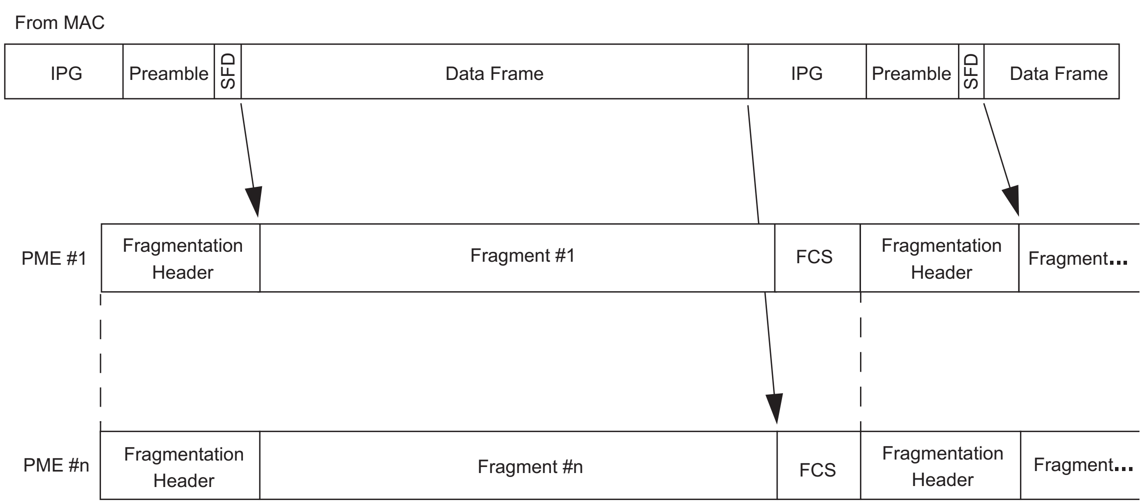
For systems that do not have the ability to aggregate loops PAF_available will not be asserted. Additionally, a system may have PAF_available asserted but PAF_enable will be deasserted to indicate that aggregation is not activated.

In both of these cases, the entire data frame is passed across the γ-interface to the TC sublayer without any fragmentation and without fragmentation header. On the receive end, entire data frames are transferred from the γ-interface to the MAC-PHY rate matching function without any reference to the PAF error detecting rules (see 61.2.2.7). If an error has been detected by the FCS in the TC then the MAC-PHY rate matching function shall assert RX_ER during at least one octet of the frame across the MII.

Systems that have the ability to aggregate but are not enabled for aggregation will have the connectivity between the PCS and one PME set either by default, by local management (for CO-subtype devices) or by remote management (for CPE-subtype devices). This will define which γ-interface is used for the transfer of non-fragmented frames. Refer to 61.2.2.8.3 for the function of PAF_available and PAF_enable and Clause 45 for access to these registers.

61.2.2.2 PME Aggregation functions

The PME Aggregation functions provide a fragmentation procedure at the transmitter and a reassembly procedure at the receiver. The fragmentation and reassembly procedures take a data frame and partition it into one or more fragments as shown in Figure 61–9. Each fragment is given a fragmentation header and transmitted over a specific TC sublayer instance. A Frame Check Sequence, known as the TC-CRC, is added to each fragment by the TC sublayer. The fragmentation header has the format shown in Figure 61–10. Short data frames can be transported over a single fragment, and consequently both StartOfPacket and EndOfPacket can be set to ‘1’ simultaneously.



NOTE—This is one example of how a frame may be fragmented across multiple PMEs.

Figure 61–9—Data frame fragmentation

SequenceNumber (14 bits)	StartOfPacket (1 bit)	EndOfPacket (1 bit)	Fragment Data

Figure 61–10—Fragment format

61.2.2.3 PME Aggregation Transmit function

The PME Aggregation transmit functions uses the following algorithm:

a) Select an active PME (i.e., one with TC_link_state asserted, see 61.3.1) for the next transmission.
b) Select the number of octets to transmit on that PME (shall not be less than minFragmentSize nor greater than maxFragmentSize, see 61.2.2.6).
c) Increment by one (modulo 2^{14}) and set fragment sequence number in the Fragmentation Header. There is a single sequence number stream for each aggregation, not one per PME. It is this sequence number stream that the receiver uses for fragment reassembly.
d) Set the start-of-packet and end-of-packet bits in the Fragmentation Header as appropriate.
e) Transmit fragment to the TC sublayer.

It is important to note that the selection of the next PME to use in transmission [step a)] and the number of octets to transmit [step b)] is implementation dependent. However, implementations shall follow the restrictions as outlined in 61.2.2.6.

61.2.2.4 PME Aggregation Receive function

The PME aggregation receive function requires per-PME queues as well as a per-MAC fragment buffer for fragment reassembly. The algorithm assumes only "good" fragments are placed on the per-PME receive queues ("bad" fragments are discarded according to the rules in 61.2.2.7).

The sequence number rolls over after it reaches the maximum value, thus all sequence number comparisons shall use "split horizon" calculations. Split horizon calculations are defined for comparisons that are valid for numbers that roll over after reaching the maximum value. Generically, "x is less than y" is defined as $x < y \leq x$ + (maxSequenceNumber+1)/2.

61.2.2.4.1 Expected sequence number

During initial start-up and in the event of certain errors, the receive algorithm has to determine which sequence number is expected next (expectedFragmentSequenceNumber). When the link state is changed to UP, the expected sequence number is unknown and no errors in fragment sequencing (see 61.2.2.7.2) shall be recorded.

61.2.2.4.2 PME Aggregation Receive function state diagram variables

The following variables are used in the PME Aggregation Receive function state diagram.

allQueuesNonEmpty
: variable of type boolean that indicates whether any active queue is currently empty.
TRUE if none of the active queues is currently empty
FALSE if at least one active queue is currently empty

expectedFragmentSequenceNumber
: the sequence number expected in the receive process that would not result in a fragment error, initialized to the smallest sequence number of fragments at the head of per-PME queues when either all active queues are non-empty or at least one queue has been non-empty for maxDifferentialDelay bit times at the bit rate of the PMD associated with that queue

frameLengthOverflow
: variable of type boolean, indicating that the reassembly buffer is overflowing due to a received frame that is too long, as described in 61.2.2.7.3.

TRUE if the overflow condition exists
FALSE during normal operation

missingStartOfPacket
: variable of type boolean, indicating that a fragment was received with the StartOfPacket bit deasserted while the packet assembly function was between frames (i.e., waiting for a Start of Packet).

nextFragmentSequenceNumber
: smallest sequence number of fragments at the head of per-PME queues

noFragmentProcessed_Timer
: variable of type boolean that indicates whether at least one active queue has been non-empty for maxDifferentialDelay bit times at the bit rate of the PMD associated with that queue. Each fragment processed on any queue restarts all per-queue timers.
TRUE if a timeout of maxDifferentialDelay bit times has expired
FALSE if the timeout of maxDifferentialDelay bit times has not yet expired

oneQueueNonEmpty_Timer
: variable of type boolean that indicates whether at least one active queue has been non-empty for at least maxDifferentialDelay bit times.
TRUE if at least one active queue has been non-empty for at least maxDifferentialDelay bit times
FALSE otherwise

smallestFragmentSequenceNumber
: smallest sequence number of fragments at the head of per-PME queues

unexpectedEndOfPacket
: variable of type boolean, indicating that a fragment was received with the EndOfPacket bit asserted and the StartofPacket bit deasserted while the packet assembly function was between frames (i.e. waiting for a Start of Packet)

unexpectedStartOfPacket
: variable of type boolean, indicating that a fragment is received with the StartOfPacket bit asserted while the packet assembly function was mid-frame (i.e., waiting for an End of Packet)

The following functions are used in the PME Aggregation Receive function state diagram.

errorDetection()
: function comprising the process described in 61.2.2.7.2

fragmentError()
: function comprising the process described in 61.2.2.7.3

61.2.2.4.3 PME Aggregation Receive function state diagram

The receive function executes the algorithm as shown in Figure 61–11. The initial state of the state machine is INITIALIZING. This state is entered when at least one TC_link_state is asserted for the first time after system power-on, and each time when at least one TC_link_state is asserted after all having been deasserted for any reason.

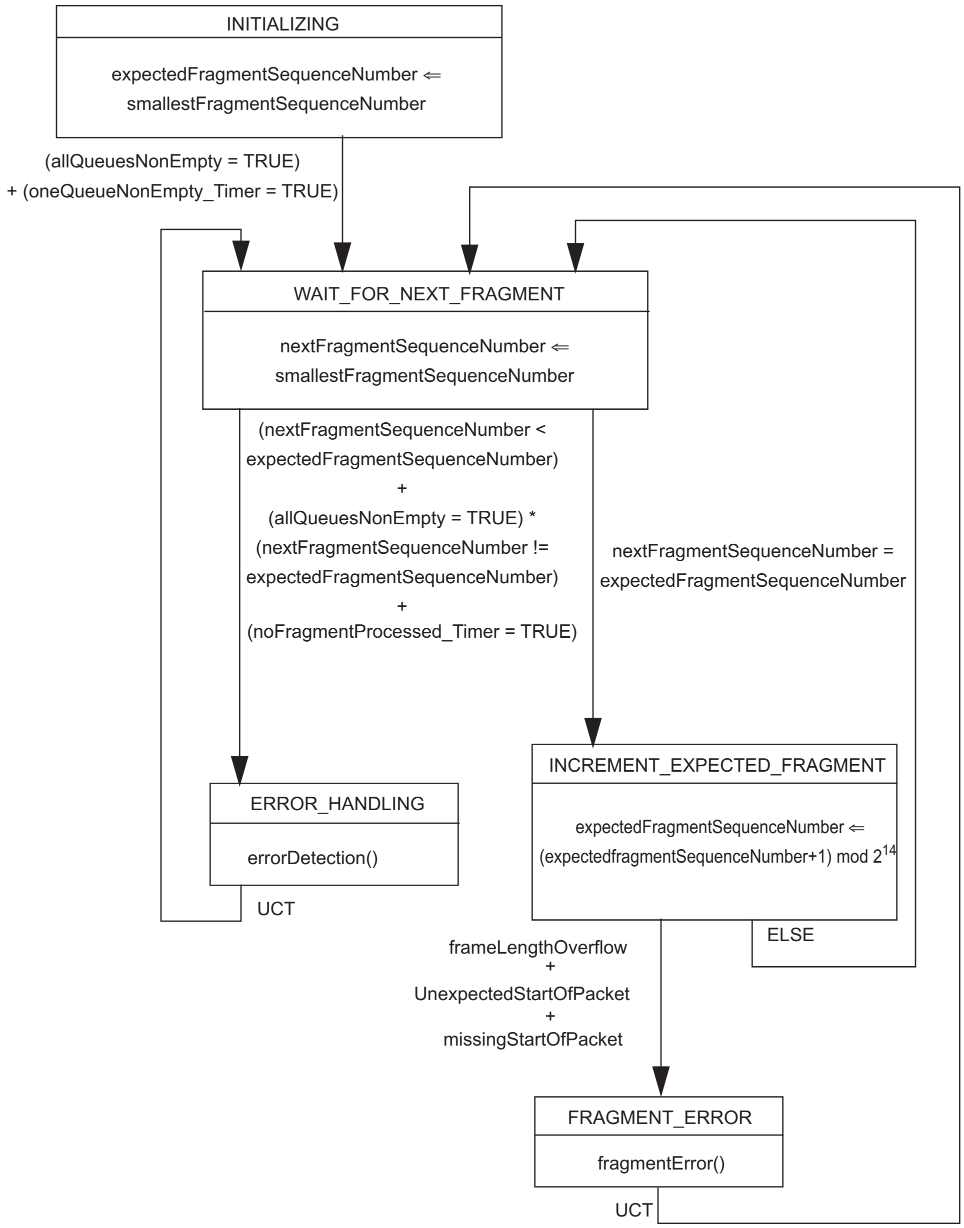


Figure 61–11—Aggregation receive function

61.2.2.4.4 PME Aggregation Receive function state diagram description

Aggregation receive algorithm:

a) Determine the nextFragmentSequenceNumber via the algorithm in 61.2.2.4.1.
b) If the nextFragmentSequenceNumber is equal to the expectedFragmentSequenceNumber, process that fragment and continue to step c). If (nextFragmentSequenceNumber is less than expectedFragmentSequenceNumber) or (all the active PME queues are non-empty and nextFragmentSequenceNumber ≠ expectedFragmentSequenceNumber) or (any PME queue has been non-empty for maxDifferentialDelay bit times without any fragment being processed) follow the fragment sequence error handling rules described in 61.2.2.7.2 before returning to normal fragment processing.
c) Accept the fragment into the fragment buffer. If (accepting the fragment into the fragment buffer causes a frame length overflow) or (the fragment is an unexpected start of packet) or (the fragment is an unexpected end of packet) or (the fragment has the StartOfPacket bit deasserted when the start of a new packet is expected) then follow the error handling procedures described in 61.2.2.7.3. Else if that fragment is an end-of-packet, pass the packet to the MAC-PHY Rate Matching layer.
d) Increment (modulo 2^{14}) the expectedFragmentSequenceNumber.
e) Repeat processing.

61.2.2.5 PME Aggregation restrictions

In order to guarantee correct receiver operation, a transmitter must ensure that pairs in an aggregate group obey certain restrictions.

NOTE—These restrictions ensure that buffer sizes for receivers of 2^{14} bits per PME are sufficient.

One factor is the differential latency between multiple PMEs in an aggregated group. Differential latency measures the variation in the time required to transmit across different PMEs. To normalize the latency measurement for high and low speed links it is measured in bit times. A differential latency between two PMEs is defined as the number of bits, N, that can be sent across the fast link, in the time that it takes one maxFragmentSize fragment to be sent across the slow link. Large differential latencies generate greater variance in bit delivery times across aggregated PMEs, which in turn require large sequence number ranges. The PMD control of aggregated links controls the maximum latency difference between any two aggregated links. This is achieved by configuring the bit rate, error correction and interleaving functions in the PMA/PMD of each link. The burst noise protection offered by the error correction and interleaving[10] functions is directly proportional to the latency, therefore it is logical that multiple aggregated links in the same environment should be optimized to have similar latencies. Differences in electrical length will not contribute significantly to the differential latency; no additional per-PME buffer size is required for this variation.

NOTE—The value for differential latency for two identical links will be 4096 bit times because the definition includes the length of a maximum size fragment.

The speed ratio of the links also restricts what PMEs can be aggregated together. The speed ratio is defined as the ratio of the bit rate of the faster link divided by the bit rate of the slower link.

The restrictions that govern which PMEs can be aggregated are:

a) The differential latency between any two PMEs in an aggregated group shall be no more than maxDifferentialDelay.
b) The highest ratio of speeds between any two aggregated links shall be maxSpeedRatio. A speed ratio of 4 may only be used if the latency is controlled to meet the restriction.

[10] Interleaving is the relevant issue here, since it affects latency. While 2BASE-TL does not have block error correction, it does use trellis coding, which is sometimes considered forward error correction.

Table 61–7 specifies the values for constants maxDifferentialDelay and maxSpeedRatio.

Table 61–7—PME Aggregation constants

Constant name	Value
maxDifferentialDelay	15 000 bit times
maxSpeedRatio	4

61.2.2.6 PME Aggregation transmit function restrictions

There are factors that limit the freedom of the transmission algorithm specified in 61.2.2.3.

A first factor is the size of the fragments being transmitted across the PMEs. Very small fragments require larger sequence number ranges as there can be more fragments within the same number of bit times.

Another restriction on the size of the fragments, is that fragments shall be a multiple of 4 octets in size when possible.

The restrictions for the transmission algorithm in 61.2.2.3 are:

a) Fragments shall not be less than minFragmentSize not including PAF header.
b) Fragments shall not be more than maxFragmentSize not including PAF header.
c) The fragment size, not including PAF header, shall be a multiple of 4 octets except for the last fragment of a data frame.

NOTE—A fragment size of maxFragmentSize may only be used if the latency is controlled to meet the restriction a) in 61.2.2.5.

These restrictions allow the use of a 14-bit sequence number space. As a consequence, the maximum sequence number is 2^{14}–1 (maxSequenceNumber).

Table 61–8 specifies the values for constants maxFragmentSize and minFragmentSize.

Table 61–8—Fragment size constants

Constant name	Value
maxFragmentSize	512 octets
minFragmentSize	64 octets

61.2.2.7 Error-detecting rules

There are three classes of error detected by the PAF: Errors during fragment reception; Errors in fragment sequencing; and Errors during packet reassembly. In the case of an error detected by the PAF, it sends the frame or part of frame to the MAC with RX_ER asserted. When the PAF is unable to reconstruct or partially reconstruct a frame due to such errors, it sends a garbage frame up to the MAC, in order to allow higher-layer event counters to register the error. The garbage frame shall consist of 64 octets of 00 (including CRC). Preamble and SFD are prepended before the frame is sent to the MII according to 61.2.1.1.

The rules described in this subclause are applied by the functions errorDetection() and fragmentError() referenced in Figure 61–11.

61.2.2.7.1 Errors during fragment reception

The receive TC function passes all decapsulated fragments to the PAF across the γ-interface. If the TC detects an error in the encapsulation, it asserts Rx_Err on the γ-interface. If the TC detects an error in the TC-CRC, it asserts Rx_Err on the γ-interface. Asserting Rx_Err during fragment reception invalidates the entire fragment.

For each PMA (α(β)-interface), the per-PMA buffering mechanism shall discard the fragment if any of the following conditions occur:

a) Rx_Err is asserted during the reception of the fragment across the γ-interface.
b) The fragment is too small - less than minFragmentSize as defined in 61.2.2.6.
c) The fragment is too large - more than maxFragmentSize as defined in 61.2.2.6.
d) The fragment would cause the per-PMA received buffer to overflow.

The PAF shall then assert one of the per-PMA error flags as appropriate:

a) TC_PAF_RxErrorReceived
b) TC_PAF_FragmentTooSmall
c) TC_PAF_FragmentTooLarge
d) TC_PAF_Overflow

61.2.2.7.2 Errors in fragment sequencing

If nextFragmentSequenceNumber is outside the range (expectedFragmentSequenceNumber through expectedFragmentSequenceNumber + (maxSequenceNumber+1)/2) then assert PAF_BadFragmentReceived. Discard the fragment, do not increment ExpectedFragmentSequenceNumber.

If all active PMA buffers are non empty and nextFragmentSequenceNumber is greater than expectedFragmentSequenceNumber then assert PAF_LostFragment, set expectedFragmentSequenceNumber equal to nextFragmentSequenceNumber.

If any PMA buffer is non empty for maxDifferentialDelay bit times (for that PMA/PMD) and no fragment is transferred then assert PAF_LostFragment, set expectedFragmentSequenceNumber equal to nextFragment-SequenceNumber.

Having detected one of the above fragment sequencing errors, the packet assembly function shall act as follows:

— If the packet assembly function was mid-frame (i.e. waiting for an End of Packet), the first part of the frame shall be transferred across the MII, then assert RX_ER signal on the MII, abort frame transfer and flush PMA buffers until the next Start of Packet is received.
— If the packet assembly function was between frames (i.e. waiting for a Start of Packet), assert RX_ER signal on the MII and send a garbage frame as defined in 61.2.2.7 to the MAC.

61.2.2.7.3 Errors in packet reassembly

If a fragment is received with the StartofPacket bit deasserted while the packet assembly function was between frames (i.e., waiting for a Start of Packet), discard the offending fragment, assert RX_ER signal on the MII and send a garbage frame as defined in 61.2.2.7 to the MAC. Assert PAF_LostStart.

If a fragment is received with the StartOfPacket bit asserted while the packet assembly function was mid-frame (i.e., waiting for an End of Packet), the first part of the frame shall be transferred across the MII, then assert RX_ER signal on the MII, abort frame transfer and flush the PMA buffers, starting the next frame with the Start of Packet fragment just received. Assert PAF_LostEnd.

If a fragment is received while the packet assembly function was mid-frame (i.e., waiting for an End of Packet) and would cause the frame size to exceed the maximum allowable frame size [i.e., maxUntagged-FrameSize + qTagPrefixSize, currently 1522 octets (see 3.5, 4.2.7.1 and 4.4)] then the first part of the frame, excluding the error causing fragment, shall be transferred across the MII, then assert RX_ER signal on the MII, abort frame transfer and flush PMA buffers until the next Start of Packet is received. Assert PAF_LostEnd.

61.2.2.8 PME aggregation functional interfaces

The PAF interfaces with the TC sublayer instances across the γ-interface. The PAF interfaces to the MAC-PHY Rate Matching function using an abstract interface whose physical realization is left to the implementor, provided the requirements of this standard are met.

61.2.2.8.1 PME aggregation–γ-interface signals

The PAF interfaces with the PMA/PMDs across the γ-interface. The γ-interface specification is defined in 61.3.1. This subclause specifies the data, synchronization and control signals that are transmitted between the TC sublayer and the PAF.

61.2.2.8.2 PME aggregation–management entity signals

The management entity signals pertaining to PME aggregation are specified in 61.2.3.

61.2.2.8.3 PME aggregation register functions

If an MDIO interface is provided (see Clause 22 and Clause 45), PME aggregation registers are accessed via that interface. If not, it is recommended that an equivalent access be provided.

Clause 45 defines one bit each in the EFM 10P/2B capability register and the 10P/2B PCS control register to control the PAF function (see 45.2.3.17 and 45.2.3.18 respectively). PAF_available is used to indicate that the system has the capability to aggregate PMEs, PAF_enable is used to control whether this ability is enabled or not. In all cases, the PAF_available bit is read-only; the PAF_enable bit is read-only when the PAF_available bit is not asserted.

For CO-subtype devices, both the PAF_available and the PAF_enable bits are only accessible locally, the PAF_enable bit is writeable.

For CPE-subtype devices, both the PAF_available and the PAF_enable bits are locally read only and remotely readable. Additionally, the PAF_enable bit is remotely writeable.

Clause 45 defines access to two registers which relate to the PME aggregation function: the PME_Available_register (see 45.2.3.19) and the PME_Aggregate_register (see 45.2.3.20). Additionally the remote_discovery_register and Aggregation_link_state_register shall be implemented.

NOTE—The remote_discovery_register is a variable which is defined for CPE-subtypes only. It is used during the PME aggregation discovery process. The Aggregation_link_state_register is a variable with significance for the PCS only. These variables have no associated management interface registers.

The PME_Available_register is read-only for CO-subtype and may be writeable for CPE-subtype (in order to restrict CPE-subtype connection capability according to 45.2.3.19). It indicates whether an aggregateable link is possible between this PCS and multiple PMDs. For a device that does not support aggregation of multiple PMEs, a single bit of this register shall be set and all other bits clear. The position of bits indicating aggregateable PME links correspond to the PMA/PMD sub-address defined in Clause 45.

For CPE-subtype devices, the PME_Available_register may optionally be writeable by the local management entity. The reset state of the register reflects the capabilities of the device. The management entity (through Clause 45 access) may clear bits which are set, in order to limit the mapping between MII and PME for PME aggregation. For CPE-subtype devices, PMD links shall not be enabled (such that it shall not respond to or initiate any G.994.1 handshaking sessions, on any of its PMEs) until the PME_Available register has been set to limit the connectivity such that each PME maps to at most one MII (see 45.2.3.19). This condition is necessary so that remote commands from the network-end which affect PCS registers have a defined target. PMDs that are not associated to any PCS shall not respond to or initiate any G.994.1 handshaking signals. Multiple PMEs per MII are allowed.

The PME_Aggregate_register is defined in Clause 45. For CO-subtype devices, access to this register is through Clause 45 register read and write mechanisms. For CPE-subtype devices the register may be read locally through Clause 45, and reads and writes shall be allowed from remote devices via the remote access signals passed across the γ-interface from the PMA (see 61.3.1). The operation of the PME_Aggregate_register for CPE-subtype devices is defined as follows:

a) If the remote_discovery_register is clear then the PME_Aggregate_register shall be cleared.
b) If write_remote_Aggregation_reg is asserted, the contents of remote_write_data bit zero is written to PME_Aggregate_register in the bit location corresponding to the PMA/PMD from which the request was received. Acknowledge_read_write is asserted for one octet clock cycle.
c) If read_remote_Aggregation_reg is asserted, the contents of PME_Aggregate_register are placed onto remote_read_data_bus, bits 31 through 0. Unsupported bits are written as zero if the full width of PME_Aggregate_register is not supported. Acknowledge_read_write is asserted for one octet clock cycle.

61.2.2.8.4 PME aggregation discovery register functions

The remote_discovery_register shall be implemented for CPE-subtype devices. The remote_discovery_register shall support atomic write operations and reads from remote devices via the remote access signals passed across the γ-interface from the PMA (see 61.3.1). The operation of the remote_discovery_register for CPE-subtype devices is defined as follows:

a) If read_remote_discovery_reg is asserted, which corresponds to a "Get" command as described in 61.4.7.1, the contents of remote_discovery_register are placed onto remote_read_data_bus. Acknowledge_read_write is asserted for one octet clock cycle[11].
b) If write_remote_discovery_reg is asserted, which corresponds to a "Set if Clear" command as described in 61.4.7.1, the action depends on the contents of remote_discovery_register. If the remote_discovery_register is currently clear (no bits asserted), the contents of the remote_write_data bus are placed into the remote_discovery_register. The new contents of remote_discovery_register are placed on the remote_read_data_bus. Acknowledge_read_write is asserted for one octet clock cycle. Else if the remote_discovery_register is not currently clear (any bit asserted), no data is written. The old contents of remote_discovery_register are placed on the remote_read_data_bus. NAcknowledge_read_write is asserted for one octet clock cycle. If multiple write_remote_discovery_reg signals are asserted (from multiple γ-interfaces) they shall be acted upon serially.
c) If clear_remote_discovery_reg is asserted, which corresponds to a "Clear if Same" command as described in 61.4.7.1, the action depends on the contents of remote_discovery_register. If the contents of the remote_write_data bus match that of the remote_discovery_register, the remote_discovery_register is cleared, the PME_Aggregate_register is cleared, the new contents of remote_discovery_register are placed on the remote_read_data_bus, and Acknowledge_read_write is asserted for one octet clock cycle. If the contents of the remote_write_data bus do not match that of the remote_discovery_register, the remote_discovery_register is unchanged; its contents are placed on the remote_read_data_bus; and NAcknowledge_read_write is asserted for one octet clock cycle.

[11]If the CPE device fails to respond, NAcknowledge_read_write is asserted with remote_read_data_bus set to 000000000000_{16}.

d) If the logical AND of the Aggregation_link_state_register and the PME_Aggregate_register is clear then a timeout counter shall be started. If this condition continues for 30 seconds (the timeout period) then the remote_discovery_register shall be cleared.

A single device may be implemented which has multiple MIIs and (therefore) multiple PCS instances. There shall be one remote_discovery_register per PCS instance. The PME_Available_register shall be set prior to the enabling of links so that each PMA/PMD is linked to only one PCS. Access to the remote_discovery_register (read or write) shall be restricted to PMA/PMD instances for which the corresponding PME_Available_register bit is asserted.

The Aggregation_link_state_register is a pseudo-register corresponding to the TC_link_state bits from each γ-interface in the appropriate bit positions according to the PMA/PMD from which the signal is received. Bits corresponding to unsupported aggregation connections are zero.

The remote access mechanisms for the PME aggregation registers are defined in 61.4.7.

61.2.3 PCS sublayer: Management entity signals

The management interface has pervasive connections to all functions. Operation of the management control lines MDC and MDIO is specified in Clause 22 and Clause 45, and requirements for managed objects inside the PCS and PMA are specified in Clause 30.

The following MAC-PHY Rate Matching function signals are mapped to Clause 45 registers:

tx_rx_simultaneously
: this signal is asserted by the management entity to indicate that the MAC which is connected to the PHY is capable of receiving and transmitting simultaneously while in half-duplex mode. The corresponding register (“MII receive during transmit”) is defined in 45.2.3.18.

crs_and_tx_en_infer_col
: this signal is asserted by the management entity to indicate that the MAC uses simultaneous detection of TX_EN and CRS to infer a collision. This signal is used in the rate matching state diagrams (Figure 61–7 and Figure 61–8). The corresponding register (“TX_EN and CRS infer a collision”) is defined in 45.2.3.18.

The following PAF signals are mapped to Clause 45 registers or cause Clause 45 counters to increment:

PAF_available
: this signal indicates to the management whether the PAF function is available for use. The corresponding register is defined in 45.2.3.17.1.

PAF_enable
: this signal is asserted by the management entity to indicate that the PAF function is enabled. The corresponding register is defined in 45.2.3.18.3.

TC_PAF_RxErrorReceived
: (for each PMA, γ-interface) this signal is asserted to indicate that a fragment has been received across the γ-interface with Rx_Err asserted. The errored fragment has been discarded. The corresponding register is defined in 45.2.3.21.

TC_PAF_FragmentTooSmall
: (for each PMA, γ-interface) this signal is asserted to indicate that a fragment has been received across the γ-interface that was smaller than the minFragmentSize defined. The errored fragment has been discarded. The corresponding register is defined in 45.2.3.22.

TC_PAF_FragmentTooLarge
: (for each PMA, γ-interface) this signal is asserted to indicate that a fragment has been received across the γ-interface that was larger than the maxFragmentSize defined. The errored fragment has been discarded. The corresponding register is defined in 45.2.3.23.

TC_PAF_Overflow
: (for each PMA, γ-interface) this signal is asserted to indicate that a fragment has been received across the γ-interface that would have caused the receive buffer to overflow. The errored fragment has been discarded. The corresponding register is defined in 45.2.3.24.

PAF_BadFragmentReceived
: this signal is asserted to indicate that a fragment has been received that does not fit into the sequence expected by the frame assembly function. The errored fragment has been discarded and the frame buffer flushed to the next valid frame start. The corresponding register is defined in 45.2.3.25.

PAF_LostFragment
: this signal is asserted to indicate that a fragment (or fragments) expected according to sequence has not been received by the frame assembly function. The missing fragment (or fragments) has been skipped and the frame buffer flushed to the next valid frame start. The corresponding register is defined in 45.2.3.26.

PAF_LostStart
: this signal is asserted to indicate that the packet reassembly function did not receive a StartOf Packet indicator in the appropriate sequence. The corresponding register is defined in 45.2.3.27.

PAF_LostEnd
: this signal is asserted to indicate that the packet reassembly function did not receive an EndOfPacket indicator in the appropriate sequence. The corresponding register is defined in 45.2.3.28.

PCS_link_state
: this signal is asserted to indicate that at least one TC_link_state in the assigned aggregation group is up.

Additionally, the following PAF register is mapped to a Clause 45 register:

remote_discovery_register
: this register is implemented in CPE-subtype devices. It is written or read by the PME via the γ-interface. The PME relays this information to and from the associated CO-subtype device via the handshake messages described in 61.4.7. The CO-subtype device interprets the contents of the remote_discovery_register to determine which remote PMEs connect to the same PCS and may be aggregated. The corresponding Clause 45 register is defined in 45.2.6.6.1.

61.3 TC sublayer functional specifications

The functional model of the TC sublayer is presented in Figure 61–12. The term "TPS-TC" (Transport Protocol Specific - Transmission Convergence) is used in ITU-T Recommendation G.993.1. In this context the term "TC" (Transmission Convergence) is sufficient as no other types of TC are defined in this subclause (e.g., PMS-TC).

Because the PAF function is optional, either entire data frames or data frame fragments may be passed across the γ-interface. In this section, the term "fragment" will be used to describe either fragments or data frames depending on the existence of the PAF.

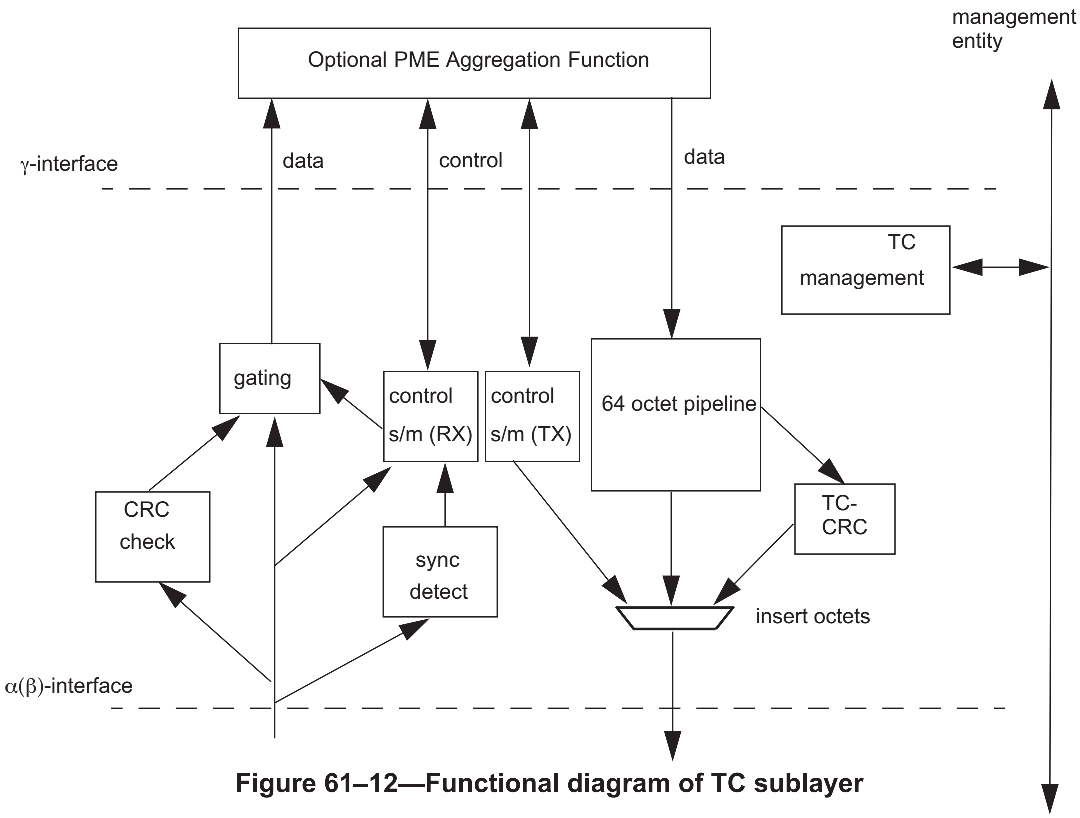


Figure 61–12—Functional diagram of TC sublayer

61.3.1 The γ-interface

The γ-interface is specified by incorporating section H.3.1 and all subsections of ITU-T Recommendation G.993.1 (Annex H) by reference, with the following exceptions and additions:

The PCS shall assert Tx_Avbl when an entire data fragment is available for transmission, and de-assert Tx_Avbl when there are no data fragments to transmit. Tx_Avbl shall never be de-asserted during the transmission of a data fragment.

OAM Information flow across the γ-interface supports access to registers referenced in Clause 45. Refer to Clause 45 for a complete description of access to TC, PMA and PMD registers from the MDIO interface.

Additional signals, which would be represented in the referenced document section H.3.1.4, are described in Table 61–9. Some of these signals may be unused when Clause 45 is not implemented.

Table 61–9—Additional γ-interface signals for OAM[a]

Signal	Size	Description	Direction
TC_link_state	1 bit	Control signal asserted when link is active and framing has synchronized according to the definition in 61.3.3 (TC_synchronized = TRUE) and remote_TC_out_of_sync (see 61.3.3.7) is not asserted.	TC → PCS
write_remote_aggregation_reg[b]	1 bit	Control signal to write PME_Aggregate_register. Active (min) 1 octet clock cycle	to PCS

Table 61–9—Additional γ-interface signals for OAM[a] *(continued)*

Signal	Size	Description	Direction
write_remote_discovery_reg[b]	1 bit	Control signal to write remote_discovery_register. Active (min) 1 octet clock cycle	to PCS
clear_remote_discovery_reg[b]	1 bit	Control signal to clear remote_discovery_register. Active (min) 1 octet clock cycle	to PCS
read_remote_aggregation_reg[b]	1 bit	Control signal to read PME_Aggregate_register. Active (min) 1 octet clock cycle	to PCS
read_remote_discovery_reg[b]	1 bit	Control signal to read remote_discovery_register. Active (min) 1 octet clock cycle	to PCS
remote_write_data_bus[b]	48 bit	Data bus for writing to PME aggregation registers. Valid during octet clock cycle when write control is asserted	to PCS
remote_read_data_bus[b]	48 bit	Data bus for the results of a read or atomic write function. Valid during octet clock cycle when Acknowledge_read_write or NAcknowledge read_write is asserted	from PCS
Acknowledge_read_write[b]	1 bit	Control signal responding (positively) to read or write. Active 1 octet clock cycle	from PCS
NAcknowledge read_write[b]	1 bit	Control signal responding (negatively) to read or write. Active 1 octet clock cycle	from PCS

[a]The term “OAM” as used here refers to the OAM facilities as defined in the referenced G.993.1 document.
[b]These signals are defined only if PAF is implemented, and then only in CPE subtypes. They are used only during G.994.1 handshake. For CO subtypes, pervasive access by management may be used to obtain the corresponding information. In case of read/write collision the PAF has to process the read/write-requests sequentially.

61.3.2 The α(β)-interface

The α(β)-interface is specified by incorporating section 7.1 and all subsections of ITU-T Recommendation G.993.1 by reference.

NOTE—An identical α(β)-interface is defined in ITU-T G.991.2.

The α and β reference points define interfaces between the PCS and PMA in the 2BASE-TL-O/10PASS-TS-O and the 2BASE-TL-R/10PASS-TS-R, respectively. Both interfaces are functional, application independent and identical. Both interfaces are defined by the following signal flow:

a) Data flow
b) Synchronization flow
c) OAM flow[12]

61.3.2.1 α(β) data flow: reference G.993.1 section 7.1.1

Referenced as is, with the additions shown in Table 61–10.

61.3.2.2 α(β) synchronization flow

The synchronization flow comprises the following synchronization signals:

a) Transmission data flow octet synchronization (Osync_t)

[12]The term “OAM” as used here refers to the OAM facilities as defined in the referenced G.993.1 document.

Table 61–10— Additional α(β)-Interface signals

Signal(s)	Size	Description	Direction
PMA_receive_synchronized	1 bit	Receive PMA state machine synchronized	PMA → TC
PMA_PMD_type	8 bit[a]	Signal indicating PMA/PMD mode of operation. Defined values: 00_{16} — 10PASS-TS CO subtype 01_{16} — 2BASE-TL CO subtype 02_{16}–$7B_{16}$ — reserved for allocation by IEEE 802.3 $7C_{16}$–$7F_{16}$ — reserved for allocation by ATIS T1E1.4 80_{16} – 10PASS-TS CPE subtype 81_{16} – 2BASE-TL CPE subtype 82_{16}–FB_{16} — reserved for allocation by IEEE 802.3 FC_{16}–FF_{16} — reserved for allocation by ATIS T1E1.4	PMA → TC

[a]NOTE—The MSB of this octet-wide signal is used to differentiate between CO-subtype and CPE-subtype.

b) Reception data flow octet synchronization (Osync_r)
c) Transmit and receive data flow bit-synchronization (Clk_t, Clk_r), optional
d) Transmit and receive data flow frame-synchronization (Fsync_t, Fsync_r), optional.
e) Receive PMA state machine synchronized (PMA_receive_synchronized)

The synchronization signals are asserted by the PMA and directed towards the PCS. The synchronization flow signals are described in Table 61–10.

61.3.2.3 α(β) OAM flow[13]

The OAM Flow across the α(β)-interface exchanges OAM information between the PHY-OAM entity, the PMA and the PMD. The OAM flow is bidirectional and transports line related primitives, parameters, configuration setup and maintenance signals or commands.

Refer to Clause 62 and Clause 63 for definitions of the G.994.1 messaging, Operation Channel (OC) and Indicator Bits (IB) mechanisms for accessing remote parameters.

Refer to Annex 61A for an example of aggregation discovery.

61.3.3 TC functions

The TC shall provide full transparent transfer of data fragments between γ_O-interface and γ_R-interface (except non-correctable errors caused by the transmission medium). It shall also provide fragment integrity and fragment error monitoring capability.

In the transmit direction, the TC receives fragments from the PCS via the γ-interface. An additional 16- or 32-bit CRC is calculated on the data and appended. The TC then performs 64/65-octet encapsulation, and sends the resulting codewords to the PMA via the α(β)-interface. In the receive direction, the TC receives codewords from the PMA via α(β)-interface, recovers the transported TC fragment, checks the CRC, and submits the extracted fragment to the PCS via the γ-interface.

An implementation is shown in Figure 61–13 and some example timing diagrams are shown in Figure 61–14.

[13]The term “OAM” as used here refers to the OAM facilities as defined in the referenced G.993.1 document.

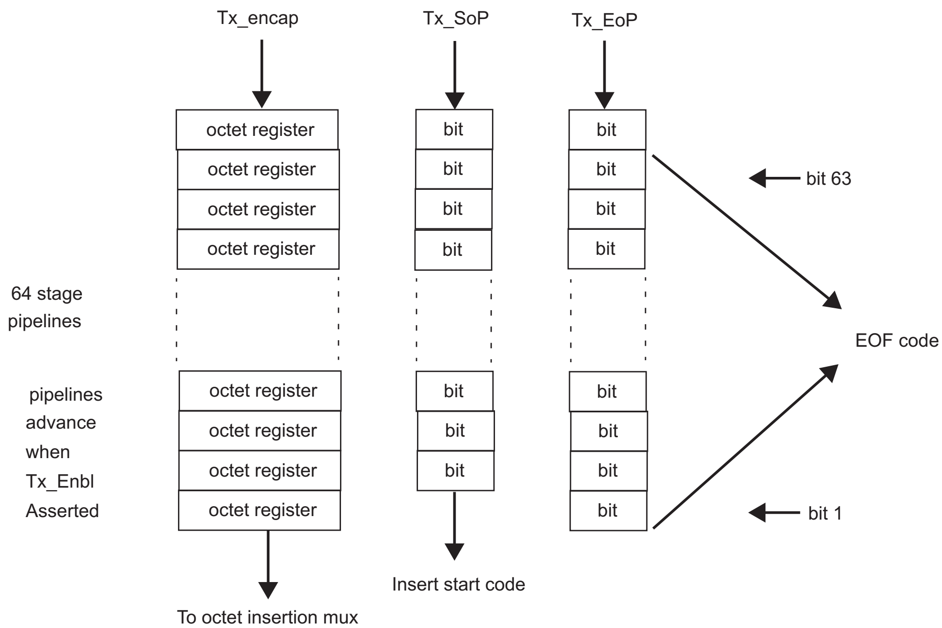


Figure 61–13—Example transmit pipeline

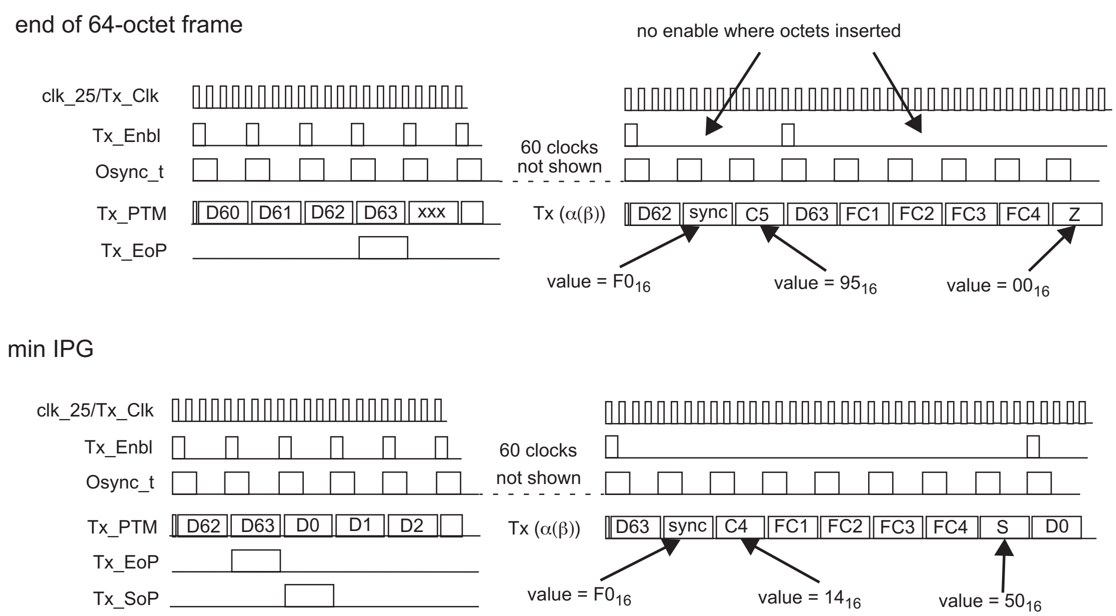


Figure 61–14—Example transmit timing

61.3.3.1 TC encapsulation and coding

A TC fragment consists of a fragment, followed by a 16- or 32-bit CRC (referred to as the TC-CRC) as defined in 61.3.3.3.

The TC coding function generates codewords with a fixed length of 65 octets (64/65-octet coding). A codeword consists of a Sync Octet and one of the following combinations:

a) all data: all of the octets in the codeword belong to the same TC fragment.

b) end of frame (go to idle): up to 63 octets in the codeword belong to the same TC fragment, the rest of the codeword consists of Idle octets.
c) end of frame (start new frame): up to 62 octets in the codeword belong to the same TC fragment, a number of Idle octets and a single Start of Frame octet precede the first data octets of the next TC fragment.
d) idle: all of the octets in the codeword are Idle octets.
e) idle (start new frame): a number of Idle octets and a single Start of Frame octet precede up to 63 data octets of the next TC fragment.
f) out-of-sync idle: all of the octets in the codeword are idle octets and the 64/65-octet receive state machine is out-of-sync (TC_synchronized = FALSE).

Both transmit and receive data may be transferred across both the $\alpha(\beta)$ and the γ-interfaces at rates that are different from the rate across the MII; the frame buffering is managed in the sublayer above the γ-interface. The TC layer uses the γ-interface flow control signal, Tx_Enbl, to slow transmit data to the rate required for the encapsulated data across the $\alpha(\beta)$-interface. The TC layer uses the γ-interface flow control signal, Rx_Enbl, to allow idle cycles in the flow of receive data across the γ-interface.

When a fragment arrives from the γ-interface while an End of Frame codeword is being transmitted, a Start of Frame octet shall be inserted prior to the transmission of data octets belonging to the next fragment. The Start of Frame octet *S* is distinct from the Idle octet *Z*. Valid locations for *S* are any valid location for *Z*, and the presence of an *S* rather than a *Z* octet indicates that what follows is the commencement of data for a new fragment.

No new fragment shall be transmitted when TC_link_state = FALSE (TC_link_state is defined in 61.3.3.7). If a fragment is being transmitted when TC_link_state becomes false, the End of Frame codeword completing the fragment shall not contain an *S* symbol after the end of the fragment. If an Idle codeword is being transmitted when TC_link_state becomes false, it shall be completed with *Z* symbols only. After the completed End of Frame or Idle codeword, only All Idle or All Idle Out-of-Sync codewords shall be transmitted until TC_link_state becomes TRUE again. After TC_link_state becomes true again, transmission of data can restart when a new fragment is available for transmission over the gamma-interface.

The data and sync format of the encapsulated data is shown in Table 61–11.

Table 61–11—Codeword formats

Type	Frame Data	Sync Octet	Octet fields 1–64									
all data	*DDDD—DDDD*	$0F_{16}$	D_0	D_1	D_2	D_3	D_4	D_5	...	D_{61}	D_{62}	D_{63}
end of frame	contains *k* *D*'s, where *k* = 0 to 63	$F0_{16}$	C_k	D_0	D_1	D_2	D_3	...	D_{k-1}	*Z*	...	*Z*
start of frame while transmit-ting	contains last *k* *D*'s of 1st frame, where *k*=0 to 62; & first *j* *D*'s of 2nd frame, where *j*=0 to 62-*k*	$F0_{16}$	C_k	D_0	...	D_{k-1}	*Z*	...	*S*	D_0	...	D_{j-1}
all idle	ZZZZ—ZZZZ	$F0_{16}$	*Z*	*Z*	*Z*	*Z*	*Z*	*Z*	...	*Z*	*Z*	*Z*
start of frame while idle	contains *k* *D*'s, where *k*=0 to 63, and contains *j* Z's, where *j*=63-*k*	$F0_{16}$	*Z*	*Z*	*S*	D_0	D_1	...	...	D_{k-3}	D_{k-2}	D_{k-1}
all idle out-of-sync	YZZZ—ZZZZ	$F0_{16}$	*Y*	*Z*	*Z*	*Z*	*Z*	*Z*	...	*Z*	*Z*	*Z*

The end of a TC fragment is always marked with an "end of frame" or "start of frame while transmitting" codeword; e.g., the received sequence [All Data codeword][All Idle codeword] is considered a sequencing error. When any of the following events occur, signal TC_coding_error shall be asserted:

a) An incorrect octet is received when a Sync Octet is expected.
b) Outside a fragment, the received octet following a valid $F0_{16}$ sync is not a *Z*, *Y*, *S*;
c) Inside a fragment, the received octet following a valid $F0_{16}$ sync is not a valid value of C_k;
d) *Z* or *S* is expected, and a value different from *Z* and *S* is received.

Signal remote_TC_out_of_sync shall be asserted when *Y* is received after an expected $F0_{16}$ sync symbol, and remain asserted until the beginning of a codeword other than All Idle Out-of-Sync is detected.

NOTE—When the local TC is not synchronized (TC_synchronized = FALSE), it may fail to detect incoming "All Idle Out-of-Sync" codewords. However, this does not affect the behaviour of the local TC, which is sending "All Idle Out-of-Sync" codewords itself. Higher sublayers only use the combined signal TC_link_state, defined in 61.3.1.

Figure 61–15 illustrates two interesting examples. In the first example, the last 60 octets of a data frame, plus the 4 encapsulation CRC octets, are transmitted in an All Data codeword. In other words, the end of the (TC-CRC-augmented) frame coincides with the end of the codeword. In this case, the next codeword begins with Sync Octet equal to $F0_{16}$, C_k equal to C_0 (90_{16}). The second codeword indicates an End Of Frame, but with no additional data; in other words, the data in the previous codeword were the last of the frame. In the second example, the first octet of a frame is aligned with the first octet of an All Data codeword.

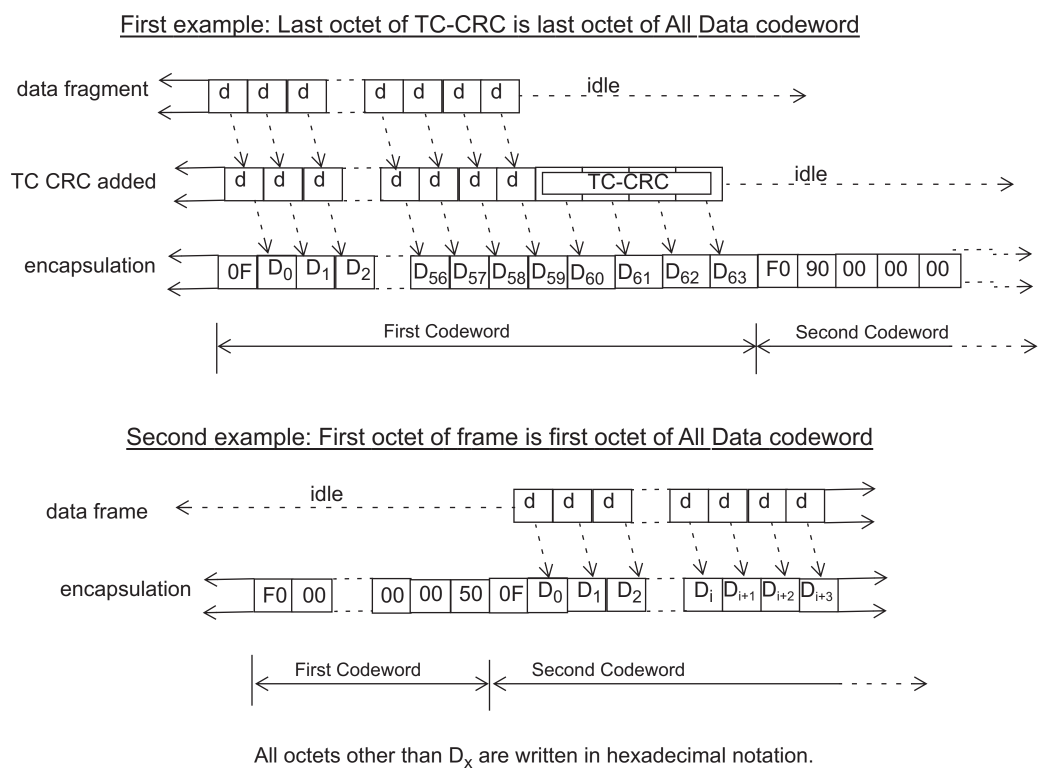


Figure 61–15—TC Encapsulation examples

The values of the TC control characters are shown in Table 61–12.

Table 61–12—TC control character values

Character	Value
Z	00_{16}
C_k, k=0–63	$C_k = k+10_{16}$, with MSB set so that resulting value has even parity; $C_0=90_{16}$, $C_1=11_{16}$, $C_2=12_{16}$, $C_3=93_{16}$, ... $C_{62}=4E_{16}$, $C_{63}=CF_{16}$
Y	$D1_{16}$
S	50_{16}
R	All other values[a]

[a]See the state diagram for the 64/65-octet receive function (Figure 61–19) for required action when receiving reserved codewords.

61.3.3.2 Sync insertion and transmit control

The transmit data path needs a 64 stage pipeline in order to generate the appropriate sync octet along with an end-of-frame indicator when required. The flow control signal, Tx_Enbl, is used to slow the flow of data across the γ-interface to cater for the difference in clock speed between the α(β)-interface and the γ-interface and also to allow for the insertion of sync octets and CRC codes into the data stream.

A simple implementation may use a 64 bit pipeline for the Tx_EOP control signal. In that case, an end of frame sync code ($F0_{16}$, then C_k) would be inserted whenever a bit is set in stages 63 to 1 of the pipeline (stage 64 is the first stage). The value of C_k inserted would be such that k is equal to the stage number of the bit that is set.

Some implementations may optimize the insertions of idles between fragments. In particular an implementation may remove idle characters between fragments to increase the effective bandwidth of the channel.

If PMA/PMD link status is not Up (i.e. either Down or Initializing), the TC sublayer shall transmit only Out-of-Sync Idle codewords. The PMA/PMD link status is defined in 45.2.1.13.4.

61.3.3.3 TC-CRC functions

The TC-CRC is generated for the entire payload fragment including any attached header (from PAF), including the Ethernet CRC; i.e., the TC-CRC is computed over octets from the first octet of the PAF header (if present), or the first octet of the DestinationAddress (in the case where the PAF header not present), to the last octet of the Ethernet CRC (for a frame) or the last octet of the fragment (if PAF fragmentation is operating), inclusive. The TC-CRC is added to the data stream after the end of the fragment in the transmit direction. The TC-CRC is checked against the last 2 or 4 octets of the fragment in the receive direction. If the receive TC-CRC is incorrect then Rx_Err is asserted to signal that the fragment is errored.

The encoding for 2BASE-TL is defined by the following generating polynomial.

$$x^{32}+x^{28}+x^{27}+x^{26}+x^{25}+x^{23}+x^{22}+x^{20}+x^{19}+ \\ x^{18}+x^{14}+x^{13}+x^{11}+x^{10}+x^{9}+x^{8}+x^{6}+1 = \\ (x+1)(x^{31}+x^{30}+x^{29}+x^{28}+x^{26}+x^{24}+x^{23}+x^{21}+x^{20}+x^{18}+x^{13}+x^{10}+x^{8}+x^{5}+x^{4}+x^{3}+x^{2}+x+1) \quad (61–1)$$

The encoding for 10PASS-TS is defined by the following generating polynomial.[14]

$$x^{16}+x^{12}+x^{5}+1 \quad (61–2)$$

Mathematically, the TC-CRC value corresponding to a given payload fragment (including any attached header) is defined by the following procedure:

a) The first 32 bits (in the case of 2BASE-TL) or the first 16 bits (in the case of 10PASS-TS) of the payload are complemented.
b) The n bits of the payload are then considered to be the coefficients of a polynomial M(x) of degree n–1. (e.g., the first bit of the fragment corresponds to the x^{n-1} term and the last bit of the fragment corresponds to the x^0 term.)
c) $M(x)$ is multiplied by x^{32} (in the case of 2BASE-TL), or by x^{16} (in the case of 10PASS-TS), and divided by $G(x)$, the TC-CRC polynomial, producing a remainder $R(x)$ of degree 31 (in the case of 2BASE-TL), or degree 15 (in the case of 10PASS-TS).
d) The coefficients of $R(x)$ are considered to be a 32-bit sequence (in the case of 2BASE-TL), or a 16-bit sequence (in the case of 10PASS-TS).
e) The bit sequence is complemented and the result is the TC-CRC.

In the case of 2BASE-TL, the 32 bits of the TC-CRC value are placed so that the x^{31} term is the bit in position b_8 on the α(β)-interface (as shown in Figure 61–16) of the first octet, and the x^0 term is the bit in position b_1 on the α(β)-interface (as shown in Figure 61–16) of the last octet. (The bits of the CRC are thus transmitted in the order x^{31}, x^{30},.., x^1, x^0). At the receiver, a payload received without error will result in the remainder $1C2D19ED_{16}$ when divided by $G(x)$.

In the case of 10PASS-TS, the 16 bits of the TC-CRC value are placed so that the x^{15} term is the bit in position b_8 on the α(β)-interface (as shown in Figure 61–16) of the first octet, and the x^0 term is the bit in position b_1 on the α(β)-interface (as shown in Figure 61–16) of the last octet. (The bits of the CRC are thus transmitted in the order x^{15}, x^{14},.., x^1, x^0). At the receiver, a payload received without error will result in the remainder $1D0F_{16}$ when divided by $G(x)$.

If, in the transmitter, the TX_Err signal is asserted during the transmission of the fragment across the γ-interface, the last octet of the TC-CRC shall be ones-complemented (i.e., intentionally corrupted by inverting all the bits of the last octet).

61.3.3.4 Bit ordering

In the transmitter, after encapsulation into 64/65-octet codewords, bits within each octet are labeled from b_1 to b_8, with the MSB labeled as b_1, the LSB labeled as b_8, and intervening bits labeled accordingly. In keeping with the labeling convention for the α(β)-interface in ITU-T Recommendations, bit b_8 is regarded as the MSB at the α(β)-interface, and is transmitted first if the α(β)-interface is serial by implementation.

Observe that the TC functionality defines a correspondence between the LSB at the γ-interface and b_8, between the next-order bit and b_7, etc., in order to conform to the Ethernet bit order convention of transmitting LSB first. See also H.4.1.1 in Annex H of ITU-T Recommendation G.993.1. In transmitting and calculating the TC-CRC, the octets at the γ-interface are processed LSB first.

[14]For 10PASS-TS, a 16-bit TC-CRC is sufficient for detecting payload errors, as the error-detecting capabilities of its Reed-Solomon decoder is also employed (see 61.2.3.3.8). In 2BASE-TL PHYs, a Reed-Solomon decoder is not present, hence a stronger TC-CRC is required.

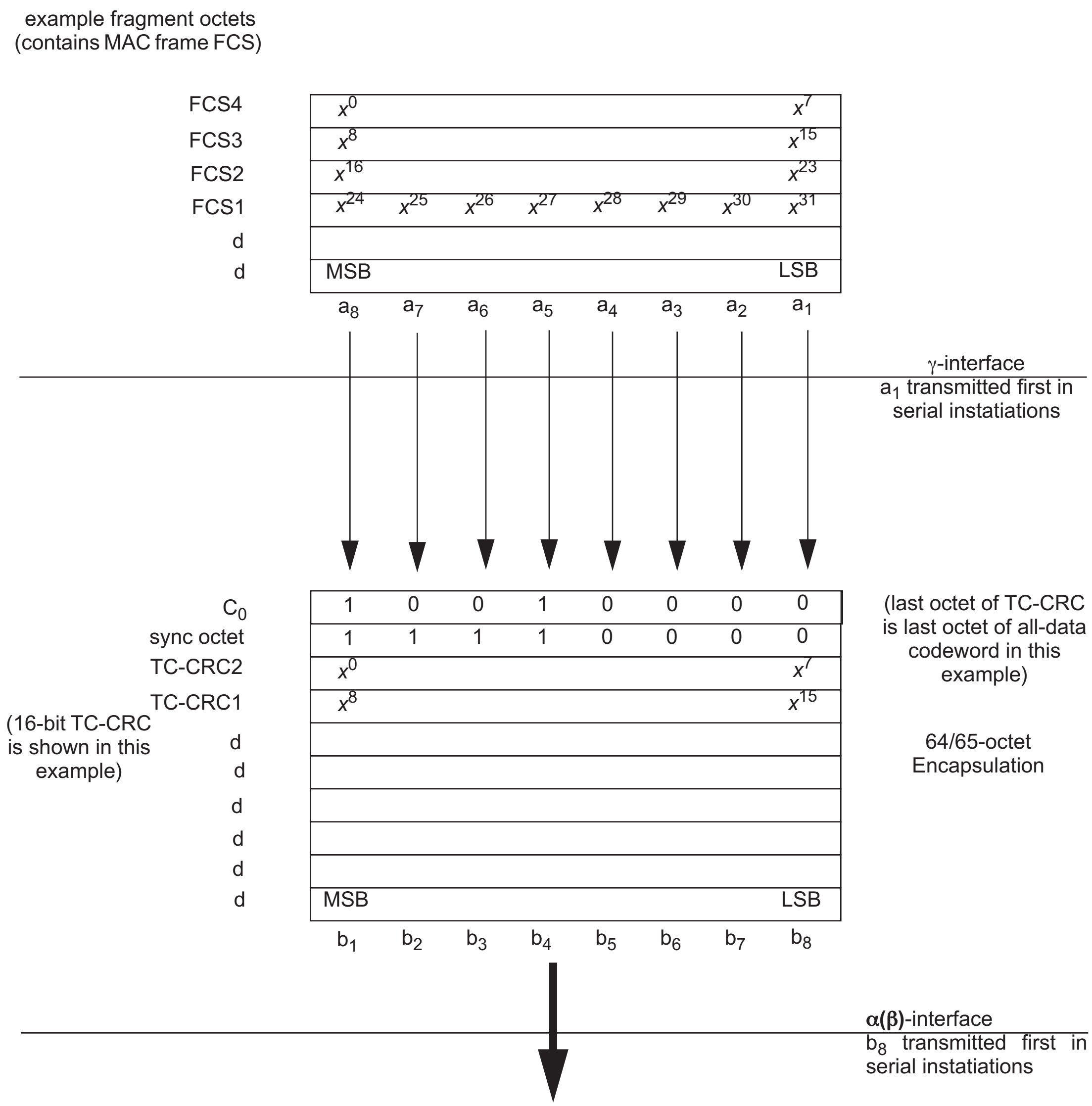


Figure 61–16—γ-interface to α(β)-interface bit ordering

61.3.3.5 Sync detection

The sync detection function serves two purposes. Firstly, the synchronization is acquired from the incoming data stream, the sync detection function controls the initial acquisition and maintenance of the synchronization. Secondly, the sync detection is needed so that the receive control state machine can extract framing information from the receive data stream and remove the sync characters and CRC codes. The sync detection state machine is shown in Figure 61–17.

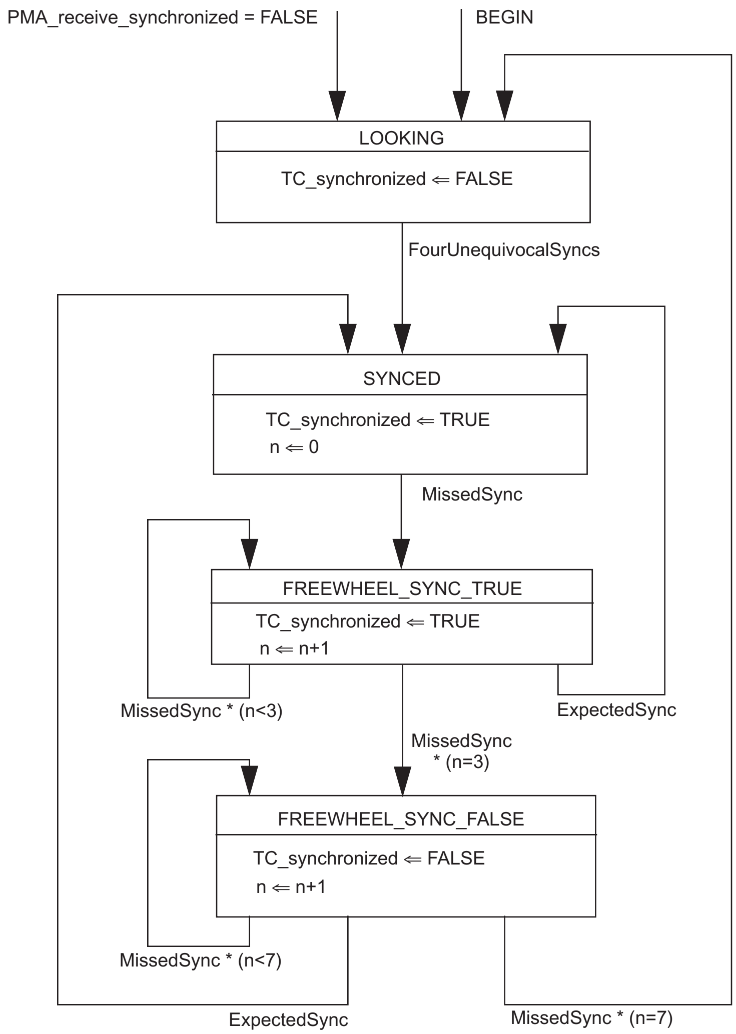


Figure 61–17—Sync detect state machine

61.3.3.5.1 State diagram variables

BEGIN
: A variable that resets the functions within the sync detection function (see 45.2.1.1.1.)
TRUE when the TC sublayer is reset.
FALSE when (re-)initialization has completed.

ExpectedSync
: variable of type boolean, TRUE indicating the occurrence of a sync character in the correct position in the octet stream. The default value of this variable is FALSE; the value of the variable resets to FALSE on every state transition.

FourUnequivocalSyncs
: variable of type boolean, TRUE indicating the occurrence of a 196-octet sequence with the following two characteristics:

a) the sequence is of the form <sync><data><sync><data><sync><data><sync>, where each <sync> is $0F_{16}$ or $F0_{16}$ and each <data> is 64 octets of any value;
b) the pattern <sync><data><sync><data><sync> occurs nowhere in the sequence, where <sync> and <data> are as defined in (a, unless the <sync> values are coincident with those in (a;

The default value of this variable is FALSE; the value of the variable resets to FALSE on every state transition.

MissedSync
: variable of type boolean, TRUE indicating the occurrence of a non-sync character in the octet stream position where a sync character is expected. The default value of this variable is FALSE; the value of the variable resets to FALSE on every state transition.

n
: variable of type integer, counting the occurrences of MissedSync = TRUE, used to determine when to leave state FREEWHEEL_SYNC_TRUE or FREEWHEEL_SYNC_FALSE.

PMA_receive_synchronized
: signal of the α(β)-interface, see 61.3.2.

TC_synchronized
: variable of type boolean, TRUE indicating that the state machine is in state SYNCED or FREEWHEEL_SYNC_TRUE. This variable is used to calculate the value of signal TC_link_state on the γ-interface (see 61.3.1), and to generate “All Idle Out Of Sync” codewords in the 64/65-octet transmit function (see Figure 61–18).

61.3.3.5.2 State diagram

The receiver shall implement the sync detect state machine shown in Figure 61–17.

61.3.3.6 Receive control

The receive control function removes the sync characters and encapsulation CRC octets from the data stream and passes it upward across the γ-interface. If TC_synchronized = false then signal RX_Enbl shall be de-asserted. If a CRC error is detected the receive controller shall assert signal TC_CRC_error. The receive controller shall assert signal RX_Err at the γ-interface during at least one octet of a fragment as it is passed up across the γ-interface, if TC_CRC_error is asserted, or if the fragment contains data from a block of data in which the PMA detected errors, but did not correct them (the means by which the PHY passes this information from the PMA to the TC is unspecified).

61.3.3.7 State diagrams for 64/65-octet encapsulation

This subclause contains the state diagrams for the 64/65-octet encapsulation function. Only the signals that affect the operation of the state machines are explicitly mentioned in the state diagrams. Other signals are to be set and read in accordance with the specifications of the γ-interface (see 61.3.1) and the α(β)-interface (see 61.3.2).

61.3.3.7.1 Transmit state diagram

The following variables are used in the state diagram.

BEGIN
: A variable that resets the functions within the sync detection function.
TRUE when the TC-sublayer is reset.
FALSE when (re-)initialization has completed.

k
: variable of type integer, used to keep track of the number of octets used in the current code-word, not including the sync symbols

loop
: variable of type boolean, keeping track of the fact that an Out-of-Sync Idle codeword is being transmitted, thus preventing a Start-of-Frame to occur within this codeword (initial value is TRUE).

TC_link_state
: variable of type boolean, indicating the current state of the TC_link_state signal on the γ-interface

TC_link_stateCHANGE
: This function monitors the TC_link_state variable for a state change. The function is set to TRUE on state change detection.
Values:
TRUE; A TC_link_state variable state change has been detected.
FALSE; A TC_link_state variable state change has not been detected (default).

NOTE—TC_link_stateCHANGE is set by this function definition; it is not set explicitly in the state diagrams. TC_link_stateCHANGE evaluates to its default value upon state entry.

TC_synchronized
: variable of type boolean, indicating whether synchronization has been acquired (as used in Figure 61–17)

Tx_Avbl
: variable of type boolean, indicating the current state of the Tx_Avbl (transmit data available) signal on γ-interface

Tx_EoP
: variable of type boolean, indicating the current state of the Tx_EoP (end of packet) signal on γ-interface

The following functions are used in the state diagram.

flushBuffer()
: function that removes any octets that have been pulled from the PCS by the function pullOctet() from the transmit fifo.

pullOctet()
: function that receives a single octet of data from the γ-interface. This function takes one cycle of the Tx_Enbl (transmit enable) signal (see 61.3.1) to complete. At the end of a fragment, this function returns the octets of the TC-CRC in the order specified in 61.3.3.3.

transmitAllDataSync()
: function that transmits the all-data sync symbol ($0F_{16}$) to the α(β)-interface. This function takes one cycle of the Osync_t signal (see 61.3.2.2) to complete.

transmitC(int k)
: function that transmits the C_k symbol as specified in Table 61-10 to the α(β)-interface. This function takes one cycle of the Osync_t signal (see 61.3.2.2) to complete.

transmitData()
: function that transmits all data currently in the transmit fifo to the α(β)-interface. This function takes one cycle of the Osync_t signal (see 61.3.2.2) per octet of data transmitted to complete.

transmitS()
: function that transmits the *S* symbol as specified in Table 61–12 to the α(β)-interface. This function takes one cycle of the Osync_t signal (see 61.3.2.2) to complete.

transmitSync()
: function that transmits the regular sync symbol ($F0_{16}$) to the α(β)-interface. This function takes one cycle of the Osync_t signal (see 61.3.2.2) to complete.

transmitZ(int k, boolean loop)
: function that transmits the *Y* symbol ($D1_{16}$) to the α(β)-interface if (k=1) and (loop=TRUE), and transmits the *Z* symbol (00_{16}) to the α(β)-interface otherwise. This function takes one cycle of the Osync_t signal (see 61.3.2.2) to complete.

Figure 61–18 specifies the 64/65-octet encapsulation (transmit) function.

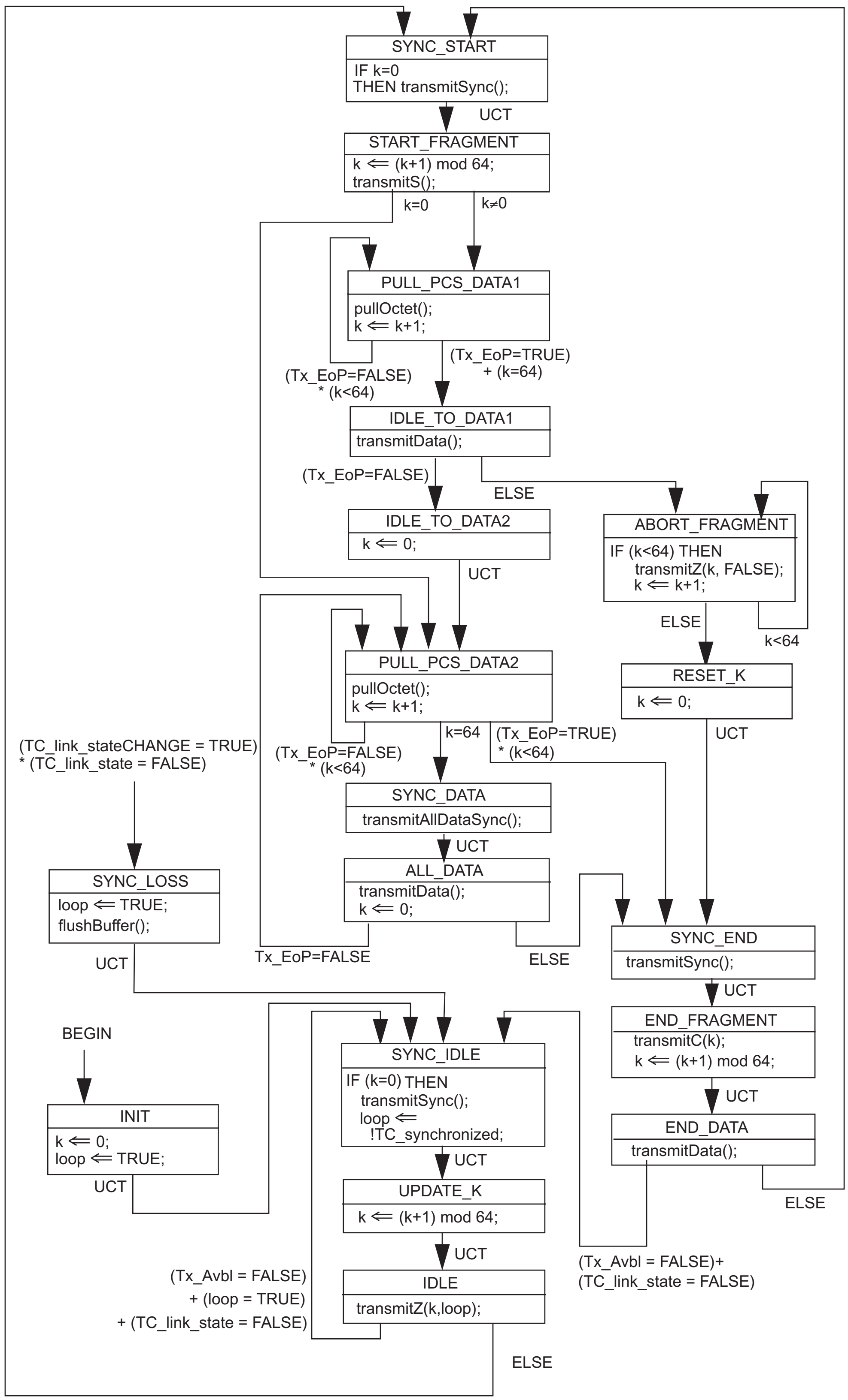


Figure 61–18—State diagram for 64/65-octet transmit function

61.3.3.7.2 Receive state diagram

The following variables are used in the state diagram.

B
: variable of type octet, used to store a single received octet

C
: variable of type octet, used to store a received C_k symbol

codingViolation
: variable of type boolean, used to mark detection of a coding violation when a sync octet was expected

expectedSync
: variable of type boolean, used to mark successful sync octet detections, which are counted towards achieving synchronization as specified in Figure 61–17. The default value of this variable is FALSE; it returns to FALSE on every state transition.

k
: variable of type integer, used to keep track of the number of octets received in the current code-word, not including the sync symbols

kmax
: variable of type integer, used to store the decoded value of a C_k symbol

missedSync
: variable of type boolean, used to mark unsuccessful sync octet detections, which are counted towards losing synchronization as specified in Figure 61–17. The default value of this variable is FALSE; it returns to FALSE on every state transition.

remote_TC_out_of_sync
: variable of type boolean, representing the state of the remote TC synchronization state machine (see 45.2.6.13).
TRUE if the remote TC has lost synchronization according to 61.3.3.5
FALSE if the remote TC has acquired synchronization according to 61.3.3.5

Rx_Err
: variable of type boolean, representing the corresponding signal (receive error) on the γ-interface

TC_coding_error
: when this signal is asserted, the TPS-TC coding violations counter register is incremented (see 45.2.6.12). The default value of this variable is FALSE; it returns to FALSE on every state transition. If TC_coding_error becomes true during the reception of a fragment, Rx_Err is asserted on the γ-interface to signal this condition to the PCS, thus invalidating the entire fragment.

TC_synchronized
: variable of type boolean, identical to the variable TC_synchronized defined in 61.3.3.7.1.

TC_synchronizedCHANGE
: This function monitors the TC_synchronized variable for a state change. The function is set to TRUE on state change detection.
Values:
TRUE; A TC_synchronized variable state change has been detected.
FALSE; A TC_synchronized variable state change has not been detected (default).

NOTE—TC_synchronizedCHANGE is set by this function definition; it is not set explicitly in the state diagrams. TC_synchronizedCHANGE evaluates to its default value upon state entry.

The following functions are used in the state diagram.

decode(octet B)
: function that decodes the C_k symbol as specified in Table 61–12. A return value between 0 and 63 indicates a valid C_k symbol was read.

receiveOctet()
: function that receives a single octet of data over the α(β)-interface. This function takes one cycle of the Osync_r signal (see 61.3.2.2) to complete.

sendOctetToPCS()
: function that sends a single octet of data over an internal γ-interface to an intermediate fifo. The size of the intermediate fifo is more than 2 octets for 10PASS-TS and more than 4 octets for 2BASE-TL. Data is transmitted at the same rate from the intermediate fifo to the PCS (if present) over the γ-interface. This function takes one cycle of the Rx_clk (receive clock) signal (see 61.3.1) to complete. At the end of a fragment, the fifo contains the TC_CRC octets. The TC_CRC octets are never forwarded over the γ-interface. After verification of the TC_CRC octets, the result of the TC_CRC verification is signalled to the PCS (if present) over the γ-interface.

Figure 61–19 specifies the 64/65-octet decapsulation (receive) function.

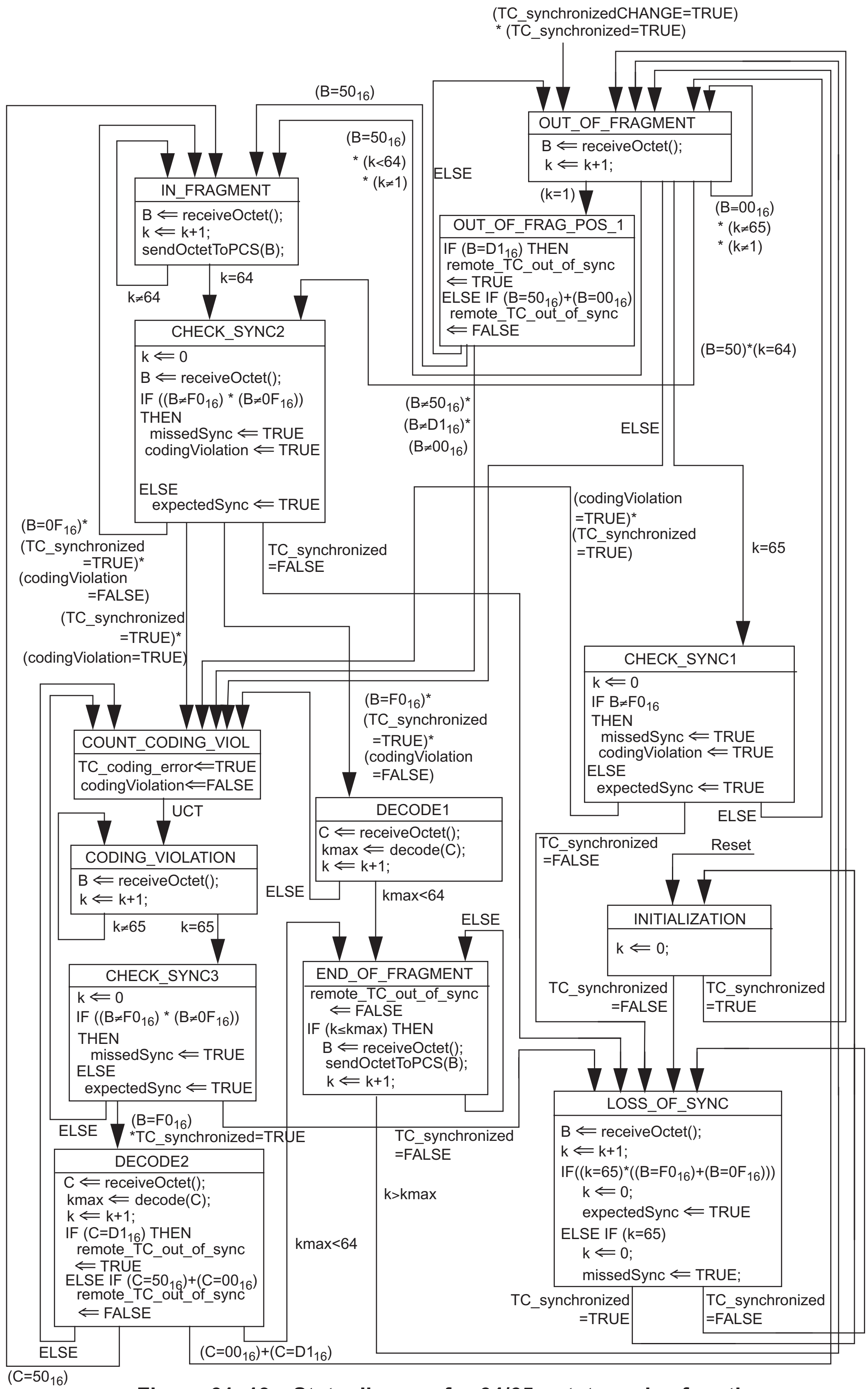


Figure 61–19—State diagram for 64/65-octet receive function

61.3.3.8 TC sublayer management entity signals

The following TC sublayer signals are mapped to Clause 45 registers or cause Clause 45 counters to increment:

remote_TC_out_of_sync
: (for each PMA, γ-interface) this signal is asserted to indicate that the remote TC has signaled loss-of-sync. See Figure 61–19 and 45.2.6.13.

TC_synchronized
: (for each PMA, γ-interface) this signal is asserted to indicate that the state machine has achieved codeword synchronization. See Figure 61–17 and 45.2.6.10.

TC_CRC_error
: (for each PMA, γ-interface) this signal is asserted to indicate that the synchronization state machine has detected a false CRC code for a received frame (see 45.2.6.11).

TC_coding_error
: (for each PMA, γ-interface) this signal is asserted to indicate that a coding violation has been detected in the received octet stream (see 45.2.6.12).

61.4 Handshaking and PHY control specification for type 2BASE-TL and 10PASS-TS

61.4.1 Overview

This subclause defines the startup and handshaking procedures by incorporating ITU-T Recommendation G.994.1 by reference, with the exceptions listed below. Where there is conflict between specifications in G.994.1 and those in this standard, those of this standard will prevail. The G.994.1 parameter values and options to be used by 2BASE-TL and 10PASS-TS are specified here.

At the time of publication, G.994.1 Revision 3 (2004) is in force. Earlier Revisions of this Recommendation shall not be implemented in 2BASE-TL or 10PASS-TS.

61.4.2 Replacement of 1, “Scope”

61.4.2.1 Scope

This subclause defines signals, messages, and procedures for exchanging these between 2BASE-TL and 10PASS-TS port types, when the modes of operation of the equipment need to be automatically established and selected, but before signals are exchanged which are specific to a particular port type.

The startup procedures defined here are compatible with those used by other equipment on the public access network, such as DSL transceivers compliant with ITU-T Recommendations. For interrelationships of this subclause with ITU-T G.99x-series Recommendations, see Recommendation G.995.1 (informative).

The principal characteristics of this subclause are as follows:

a) Use over metallic local loops
b) Provisions to exchange capabilities information between DSL equipment and EFM PHYs to identify common modes of operation
c) Provisions for equipment at either end of the loop to select a common mode of operation or to request the other end to select the mode
d) Provisions for exchanging non-standard information between equipment
e) Provisions to exchange and request service and application related information
f) Support for both duplex and half-duplex transmission modes
g) Support for multi-pair operation
h) Provisions for equipment at the remote end of the loop (xTU-R) to propose a common mode of operation

61.4.2.2 Purpose

It is the goal of the ITU-T that all specifications for digital transceivers for use on public telephone network copper subscriber lines use G.994.1 for startup. G.994.1 procedures allow for a common mechanism for identification of available features, exchange of capabilities and configuration information, and selection of operating mode. As the two loop endpoints are usually separated by a large distance (e.g., in separate buildings) and often owned and installed by different entities, G.994.1 also aids in diagnosing interoperability problems. G.994.1 codespaces have been assigned by ITU-T to ATIS, ETSI, and IEEE 802.3 in support of this goal.

In private networks, the management entity may additionally use G.994.1 tones or messages to autoconfigure the subtype (CO or CPE) in devices which implement both (see 61.1).

61.4.3 Changes to 6.1, "Description of signals"

NOTE 4 and NOTE 5 are not applicable.

Replace paragraph 3 of 6.1.1, "4.3125 kHz signaling family" with the following.

The carrier sets in this family are mandatory for the port types listed in Table 61–13. One or more carriers listed in Reference Table 1 or Reference Table 3 may be transmitted in addition to the mandatory carrier set listed in Table 61–13. Carriers not listed in Reference Table 1 or Reference Table 3 shall not be transmitted.

Table 61–13—Mandatory carrier sets

Port Types	Carrier set designation
10PASS-TS	V43

Replace paragraph 3 of section 6.1.2, "4 kHz signaling family" with the following.

The carrier sets in this family are mandatory for the port types listed in Table 61–14. One or more carriers listed in Reference Table 1 or Reference Table 3 may be transmitted in addition to the mandatory carrier set listed in Table 61–14. Carriers not listed in Reference Table 1 or Reference Table 3 shall not be transmitted.

Table 61–14—Mandatory carrier sets

Port Types	Carrier set designation
2BASE-TL	A4

61.4.4 Changes to 9.4, "Standard information field (S)"

Paragraphs 1–5: referenced as is.

Table 11.1 to Table 11.52 and Table 11-57 and beyond are not applicable.

The Standard information field (S) codepoints specified in Annex 61B shall be used in the transactions specified in this subclause.

61.4.5 Changes to 9.5, "Non-standard information field (NS)"

Add this paragraph: The contents of the NS information field are outside the scope of this standard.

61.4.6 Applicability of Annex A–B and Appendix I–VI

Annex A / G.994.1—Support for legacy non-G.994.1 devices—Not applicable

Annex B / G.994.1—Operation over multiple wire pairs—Not applicable to the multipair operation for EFM

Appendix I / G.994.1—Not applicable

Appendix II / G.994.1—Provider Code contact Information —Referenced as is

Appendix III / G.994.1—Support for legacy DMT-based devices —Not applicable

Appendix IV / G.994.1—Procedure for the assignment of additional G.994.1 parameters—Not applicable

Appendix V / G.994.1—Rules for code point table numbering—Not applicable

Appendix VI / G.994.1—Bibliography

61.4.7 PME Aggregation – remote access of PME Aggregation registers

As the CO-subtype accesses PME Aggregation registers (i.e., remote_discovery_register and PME_Aggregate_register) in the CPE-subtype prior to training and establishment of the PMD-to-PMD link, it is performed using G.994.1 handshake messages.

The G.994.1 handshake messages described in this subclause shall assert the "Ethernet bonding" NPar(2) codepoint if and only if PAF_available is asserted. The "TDIM Bonding" NPar(2) bit shall be deasserted. In addition, the "Ethernet bonding" NPar(2) codepoint shall be asserted by the -O device in an MS message if and only if PAF_enable is asserted.

NOTE 1—A G.994.1 session including configuration of the PME Aggregation Function may violate the maximum activation time specified for SHDSL transceivers by ITU-T Recommendation G.991.2.

NOTE 2—In the transactions specified in this subclause, each CLR message may be preceded by MR/REQ-CLR messages. Each CL message is followed by an ACK(1). These messages are not shown in the diagrams.

61.4.7.1 Remote_discovery_register

2BASE-TL-R and 10PASS-TS-R PHYs shall assert the PME Aggregation Discovery SPar(2) bit in all G.994.1 CLR messages, if and only if its local PAF_available bit is set. CPE-subtypes shall place the contents of the remote_discovery_register in the corresponding NPar(3) bits in the outgoing CLR message, with the "Clear if Same" NPar(3) set to zero.

In response to a "Get" command, the CO-subtype shall perform a G.994.1 capabilities exchange with the CPE-subtype. The contents of the NPar(3) remote_discovery_register bits in the CLR message received from the CPE-subtype shall be reported as the result. The CL message sent by the CO-subtype in response to the CLR shall have the PME Aggregation Discovery SPar(2) bit set to zero.

In response to a "Set if Clear" command, the CO-subtype shall perform two back-to-back G.994.1 capabilities exchanges with the CPE-subtype. The contents of the NPar(3) remote_discovery_register bits in the first CLR message received from the CPE-subtype shall be ignored. The CL message sent by the CO-subtype in response to this first CLR shall have the PME Aggregation Discovery SPar(2) bit set to one, the Clear if Same NPar(3) bit set to zero, and the NPar(3) remote_discovery_register bits set to the CO-subtype

PME Aggregation Discovery Code register. The CPE-subtype shall set the remote_discovery register to this value if it is currently clear. The contents of the NPar(3) remote_discovery_register bits in the CLR message received from the CPE-subtype during the second capabilities exchange shall be reported as the result. The CL message sent by the CO-subtype in response to this second CLR shall have the PME Aggregation Discovery SPar(2) bit set to zero.

In response to a "Clear if Same" command, the CO-subtype shall perform two back-to-back G.994.1 capabilities exchanges with the CPE-subtype. The contents of the NPar(3) remote_discovery_register bits in the first CLR message received from the CPE-subtype shall be ignored. The CL message sent by the CO-subtype in response to this first CLR shall have the PME Aggregation Discovery SPar(2) bit set to one, the Clear if Same NPar(3) bit set to one, and the NPar(3) remote_discovery_register bits set to the CO-subtype PME Aggregation Discovery Code register. The CPE-subtype shall clear the remote_discovery register if it is currently equal to this value. The contents of the NPar(3) remote_discovery_register bits in the CLR message received from the CPE-subtype during the second capabilities exchange shall be reported as the result. The CL message sent by the CO-subtype in response to this second CLR shall have the PME Aggregation Discovery SPar(2) bit set to zero.

Figure 61–20 illustrates the relevant sequences of G.994.1 transactions.

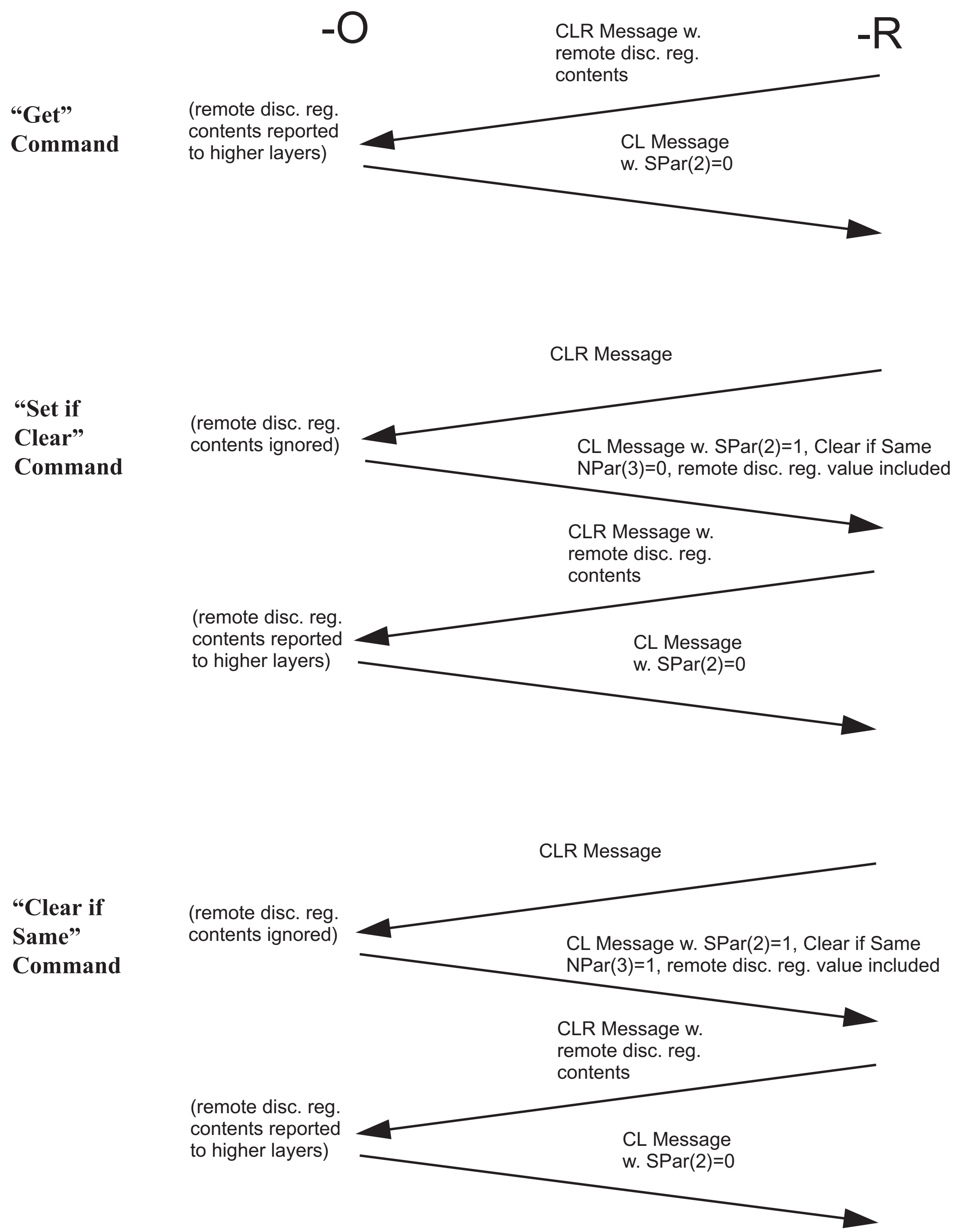


Figure 61–20—G.994.1 transactions for remote_discovery_register access

61.4.7.2 PME_Aggregate_register

2BASE-TL-R and 10PASS-TS-R PHYs shall assert the PME Aggregation SPar(2) bit in all G.994.1 CLR messages, if and only if its local PAF_available bit is set. CPE-subtypes shall place the contents of the PME_Aggregate_register in the corresponding NPar(3) bits in the outgoing CLR message.

In response to a "get" command, the CO-subtype shall perform a G.994.1 capabilities exchange with the CPE-subtype. The contents of the NPar(3) PME_Aggregate_register bits in the CLR message received from the CPE-subtype shall be reported as the result. The CL message sent by the CO-subtype in response to the CLR shall have the PME Aggregation SPar(2) bit set to zero.

In response to a “set” command, the CO-subtype shall perform two back-to-back G.994.1 capabilities exchanges with the CPE-subtype. The contents of the NPar(3) PME_Aggregate_register bits in the first CLR message received from the CPE-subtype shall be ignored. The CL message sent by the CO-subtype in response to this first CLR shall have the PME Aggregation SPar(2) bit set to one and the NPar(3) PME_Aggregate_register bit zero. The -R device sets the bit position in the PME_Aggregate_register corresponding to the PME upon which the G.994.1 exchange takes place. The contents of the NPar(3) PME_Aggregate_register bits in the CLR message received from the CPE-subtype during the second capabilities exchange shall be reported as the result. The CL message sent by the CO-subtype in response to this second CLR shall have the PME Aggregation SPar(2) bit set to zero.

61.4.7.3 Timing and preferred transactions

This subclause is applicable to devices in which 10PASS-TS and/or 2BASE-TL are the only G.994.1-initiated PHYs implemented and enabled. Start-up procedures for devices which include additional G.994.1-initiated modes of operation are outside the scope of this standard.

NOTE 1—Handshake operations specified in this subclause occur autonomously in the PHY, without intervention of the STA. They may however be triggered by an STA using the management interface.

If the PMA/PMD link control bit is set to 1 in the -O device (Table 45–12), or discovery register operations are initiated (Table 45–108), or link partner aggregation register operations are initiated (Table 45–111), the -O device initiates G.994.1 startup procedures by transmitting C-TONES.

If the PMA/PMD link control bit is set to 1 in the -R device (Table 45–12), the -R device initiates G.994.1 startup procedures by transmitting R-TONES-REQ.

At the conclusion of G.994.1 startup, the -R device shall begin G.994.1 transactions by transmitting an MR message. The -O device responds by sending C-TONES if the Ignore incoming handshake register bit (see 45.2.1.11) is set to 0_b.

If the G.994.1 session was initiated by the PMA/PMD link control bit (signifying that the link is to be brought up) in either the -O or -R device, then the -O device shall respond with an MS message specifying the configured mode of operation. However, if the PMA/PMD type selection bits in the -O device are set to the value 0011 or 0100, and a capabilities exchange has not previously taken place, the -O device shall instead respond with an REQ-CLR so that a capabilities exchange is performed. Following the final message of the capabilities exchange (i.e., an ACK(1)), the -R device once again sends an MR message. The -O device shall respond with an MS message specifying the configured mode of operation.

If the G.994.1 session was initiated in response to discovery register operations (Table 45–108), or link partner aggregation register operations (Table 45–111), then the -O device shall respond with an REQ-CLR message (MR received before) or with a CL message (CLR received before). This is then followed by one or two capability exchanges as described in the previous two subclauses. Following the final message of the final capabilities exchange (i.e., an ACK(1)), the CPE device once again sends an MR message. If neither the PMA/PMD control bit nor the discovery or link partner aggregation register operations are activated within the next 0.5 seconds, the -O shall transmit an MS message with the SPar(1) silent bit set.

NOTE 2—It is understood that the entire activation sequence consisting of PAF Discovery, PAF and line activation is time-consuming, therefore 2BASE-TL and 10PASS-TS devices are encouraged to exchange only relevant information in G.994.1 sessions during various stages of initialization.

61.5 Link segment characteristics

As stated in 61.1, the channel characteristics of voice grade copper are very diverse. Some typical channels are defined as part of the Performance Guidelines contained in Annex 62B (for 10PASS-TS) and Annex 63B (for 2BASE-TL). These annexes also define the reference performance levels for each PHY in these conditions. Behaviour in other voicegrade installations may be interpolated or extrapolated from that set of references.

61.6 MDI specification

The MDI interface for 10PASS-TS and the Service Splitter and Electrical Characteristics for 10PASS-TS are defined in 62.3.5.

The Electrical Characteristics of the MDI interface for 2BASE-TL are defined in 63.3.2.

The local regulations may dictate interface characteristics in addition to or in place of some or all of these requirements.

61.7 System considerations

Both EFM Copper port types are defined for full duplex operation only, although certain MACs may still require to be configured for half duplex operation in order to respond to the carrier Sense signal, as required by the specification of MAC-PHY Rate Matching. The requirements of 31B.1 restrict the transmission of PAUSE frames to DTEs configured to the full duplex mode of operation. If PAUSE frames are used on an EFM Copper link, consideration should be given to the link latency, and the fact that the MAC-PHY Rate Matching mechanism can interfere with the expected operation of the PAUSE frame mechanism.

NOTE—It is recognized that an EFM Copper system may have to comply with additional requirements and/or restrictions outside the scope of this standard (see 61.6 and 61.8 for examples) in order to be allowed to be connected to a public infrastructure in a certain geographic area or regulatory environment. These additional requirements and/or restrictions may prohibit operation under certain profiles, or degrade the performance of the system when working under certain profiles.This may limit the system's compliance with this standard, as compliant systems support all profiles (see Annex 62A for 10PASS-TS and Annex 63A for 2BASE-TL) and meet all performance guidelines (see Annex 62B for 10PASS-TS and Annex 63B for 2BASE-TL).

A compliant CPE-side system cannot distinguish a CO-side system designed to operate under a limited set of profiles from a fully compliant CO-side system, as the selection of profiles is under control of the CO-side. A CPE-side system designed to operate under a limited set of profiles cannot be guaranteed to correctly interoperate with compliant CO-side systems.

It is recommended that vendors of systems that support a limited set of profiles provide PICS forms to indicate which profiles are supported, in order to allow users to assess the impact on interoperability.

61.8 Environmental specifications

The requirements of 14.7 should be considered as baseline Environmental Specifications for types 10PASS-TS and type 2BASE-TL. Since equipment specified in this Clause will typically be deployed into public network environments, the specific requirements of the network operator or the local authority having jurisdiction shall prevail in all cases, and shall be considered in the development of such equipment. Such requirements may be statutory and may include product safety, electromagnetic compatibility and protection of the public network against harms from attached equipment.

61.9 PHY labeling

It is recommended that PHY equipment (and supporting documentation) be labeled in a manner visible to the user with at least the following parameters.

a) PMA/PMD (sub-)type. A type (e.g., 10PASS-TS) can be specified if both -O and -R subtypes are supported. A subtype should be specified (e.g. 10PASS-TS-R) if only a single subtype is supported.
b) PAF capability if supported. The following information should be provided: number of MII/PCS ports provided; maximum number of PMEs per MII/PCS; total number of PMEs. For example:
    1) x8 or 1x8:8 for a single MII port with 8 PMEs
    2) 2x2:4 for a device with 2 MII ports and 4 PMEs, which can be aggregated up to 2 PMEs per port
    3) 4x4:4 for a device with 4 MII ports and 4 PMEs, which can be aggregated up to 4 PMEs per port
c) Homologation information
d) Applicable safety warnings

61.10 Protocol implementation conformance statement (PICS) proforma for Clause 61, Physical Coding Sublayer (PCS), Transmission Convergence (TC) sublayer, and common specifications type 10PASS-TS, 2BASE-TL[15]

61.10.1 Introduction

The supplier of a protocol implementation that is claimed to conform to Clause 61, Physical Coding Sublayer (PCS), Transmission Convergence (TC) sublayer, and common specifications type 10PASS-TS, 2BASE-TL, 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.

61.10.2 Identification

61.10.2.1 Implementation identification

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

61.10.2.2 Protocol summary

Identification of protocol standard	IEEE Std 802.3-2005, Physical Coding Sublayer (PCS) and common specifications, type 10PASS-TS and 2BASE-TL.
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 802.3-2005.)	
Date of Statement	

[15]*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.

61.10.3 Major capabilities/options

Item	Feature	Subclause	Value/Comment	Status	Support
RM	MAC-PHY Rate Matching	61.2.1	CRS deference mechanism supported.	M	Yes [ ]
TC	64/65-octet Encapsulation	61.3	The Ethernet-specific TPS-TC, between α(β)-interface and γ-interface is implemented.	M	Yes [ ]
*PAF	PME Aggregation	61.2.2	Up to 32 PMA/PMD instances can be aggregated into a single MAC.	O	Yes [ ] No [ ]
HS	Support for G.994.1 handshake	61.4	PHY uses G.994.1 handshake to identify remote transceiver and exchange capabilities.	M	Yes [ ]
*2BO	2BASE-TL-O subtype	61, 63	The 2BASE-TL CO subtype is implemented.	O.1	Yes [ ] No [ ]
*2BR	2BASE-TL-R subtype	61, 63	The 2BASE-TL CPE subtype is implemented.	O.1	Yes [ ] No [ ]
*10PO	10PASS-TS-O subtype	61, 62	The 10PASS-TS CO subtype is implemented.	O.1	Yes [ ] No [ ]
*10PR	10PASS-TS-R subtype	61, 62	The 10PASS-TS CPE subtype is implemented.	O.1	Yes [ ] No [ ]

61.10.4 PICS proforma tables for the Physical Coding Sublayer (PCS), Transmission Convergence (TC) sublayer, and common specifications type 10PASS-TS, 2BASE-TL

61.10.4.1 MAC-PHY Rate Matching

Item	Feature	Subclause	Value/Comment	Status	Support
RM-1	MAC-PHY Rate Matching functions	61.2.1.1	The PHY uses CRS to match the MAC’s faster rate of data transmission to the PHY’s slower rate.	M	Yes [ ]
RM-2	MAC-PHY Rate Matching functions	61.2.1.1	Upon receipt of a MAC frame from the MII, the PHY discards the Preamble and SFD fields, and transmits the resulting data frame across the physical link.	M	Yes [ ]
RM-3	MAC-PHY Rate Matching functions	61.2.1.1	The PHY prepends the Preamble and the SFD fields to a received frame before sending it to the MAC.	M	Yes [ ]
RM-4	MAC-PHY Rate Matching functions	61.2.1.1	The PHY supports a mode of operation where it does not send data to the MAC while the MAC is transmitting.	M	Yes [ ]

61.10.4.2 64/65-octet Encapsulation

Item	Feature	Subclause	Value/Comment	Status	Support
TC-1	The γ-interface	61.3.1	The PAF asserts Tx_Avbl when it has a whole data fragment available for transmission, and de-assert Tx_Avbl when there are no data fragments to transmit.	M	Yes [ ]
TC-2	TC functions	61.3.3	The TC provides full transparent transfer of data frames between γ_O-interface and γ_R-interface.	M	Yes [ ]
TC-3	TC functions	61.3.3	The TC provides fragment integrity and fragment error monitoring capability.	M	Yes [ ]
TC-4	TC functions	61.3.3	The bit rate of data transport in the upstream and downstream directions are set independently of each other to any eligible value up to the maximum rate determined by the PMD.	M	Yes [ ]
TC-5	TC Encapsulation and Coding	61.3.3.1	When a frame arrives from the γ-interface while an End of Frame codeword is being transmitted, a Start of Frame octet is inserted prior to the transmission of data octets belonging to the next frame.	M	Yes [ ]
TC-6	Sync detection	61.3.3.5	The synchronization is acquired from the incoming data stream.	M	Yes [ ]
TC-7	Sync detection	61.3.3.5.2	The receiver implements the sync detect state machine shown in Figure 61–17.	M	Yes [ ]
TC-8	Receive control	61.3.3.6	If TC_synchronized = false then signal RX_Enbl is de-asserted.	M	Yes [ ]
TC-9	Receive control	61.3.3.6	If a TC-CRC error is detected, the receive controller asserts signal RX_Err during at least one octet of the fragment as it is passed up across the γ-interface.	M	Yes [ ]
TC-10	Receive control	61.3.3.6	If the fragment contains data from a block in which the PMA detected errors but did not correct them, the receive controller asserts signal RX_Err during at least one octet of a fragment as it is passed up across the γ-interface.	M	Yes [ ]

61.10.4.3 PME Aggregation[16]

Item	Feature	Subclause	Value/Comment	Status	Support
PAF-1	PME Aggregation Receive function	61.2.2.4	When the link state is changed to UP, the expected sequence number is unknown and no frame sequence errors are recorded.	*PAF:M	Yes [ ]
PAF-2	PME Aggregation Transmit Function Restrictions	61.2.2.6	The differential latency between any two PMEs in an aggregated group is no more than 15 000 bit times.	*PAF:M	Yes [ ]
PAF-3	PME Aggregation Transmit Function Restrictions	61.2.2.6	Fragments are not less than 64 octets.	*PAF:M	Yes [ ]
PAF-4	PME Aggregation Transmit Function Restrictions	61.2.2.6	Fragments are not more than 512 octets.	*PAF:M	Yes [ ]
PAF-5	PME Aggregation Transmit Function Restrictions	61.2.2.6	The highest ratio of speeds between any two aggregated links is 4.	*PAF:M	Yes [ ]
PAF-6	PME Aggregation Transmit Function Restrictions	61.2.2.6	The fragment size is a multiple of 4 octets except for the last fragment of a data frame.	*PAF:M	Yes [ ]
PAF-7	Error-detecting Rules	61.2.2.7	For each PMA, the per-PMA buffering mechanism discards the fragment if any of the listed conditions occur, and asserts the PAF error flags as appropriate. If the packet assembly function was mid-frame, the first part of the frame is transferred across the MII, then the RX_ER signal is asserted on the MII, the frame transfer is aborted and PMA buffers are flushed until the next Start of Packet is received.	*PAF:M	Yes [ ]
PAF-8	Error-detecting Rules	61.2.2.7	If a fragment is received with the StartOfPacket bit asserted while the packet assembly function was mid-frame, the first part of the frame is transferred across the MII, then the RX_ER signal is asserted on the MII, the frame transfer is aborted and PMA buffers are flushed until the next Start of Packet is received.	*PAF:M	Yes [ ]
PAF-9	PME aggregation register functions	61.2.2.8.3	The remote_discovery_register and Aggregation_link_state_register are implemented.	*PAF:M	Yes [ ]
PAF-10	PME aggregation register functions	61.2.2.8.3	The PME_Available_register is read-only.	*PAF: *2BO:M *10PO:M	Yes [ ]

PAF-11	PME aggregation register functions	61.2.2.8.3	The PME_Available_register is writeable.	*PAF: *2BR:O *10PR:O	Yes [ ] No [ ]
PAF-12	PME aggregation register functions	61.2.2.8.3	For a device that does not support aggregation of multiple PMEs, a single bit of the PME_Available_register is set and all other bits clear.	*PAF:M	Yes [ ]
PAF-13	PME aggregation register functions	61.2.2.8.3	The PME_Available_register is read-only.	*PAF: *2BO:M *10PO:M	Yes [ ]
PAF-14	PME aggregation register functions	61.2.2.8.3	The PME_Available_register is writeable.	*PAF: *2BR:O *10PR:O	Yes [ ] No [ ]
PAF-15	PME aggregation register functions	61.2.2.8.3	For CPE-subtype devices, PMD links are not enabled until the PME_Available_register has been set to limit the connectivity such that each PME maps to one, and only one MII.	*PAF:M	Yes [ ]
PAF-16	PME aggregation register functions	61.2.2.8.3	If the remote_discovery_register is clear then the PME_Aggregate_register is cleared.	*PAF:M	Yes [ ]
PAF-17	PME aggregation register functions	61.2.2.8.3	The remote_discovery_register is implemented for CPE-sub-type devices.	*PAF: *2BR:M *10PR:M	Yes [ ]
PAF-18	PME aggregation register functions	61.2.2.8.3	The remote_discovery_register supports atomic write operations and reads from remote devices via the remote access signals passed across the γ-interface from the PMA.	*PAF:M	Yes [ ]
PAF-19	PME aggregation register functions	61.2.2.8.3	If multiple write_remote_discovery_reg signals are asserted they are acted upon serially.	*PAF:M	Yes [ ]
PAF-20	PME aggregation register functions	61.2.2.8.3	If the logical AND of the Aggregation_link_state_register and the PME_Aggregate_register is clear then a time-out counter is started. If this condition continues for 30 seconds then the remote_discovery_register is cleared.	*PAF:M	Yes [ ]
PAF-21	Remote access of PME Aggregation registers	61.4.7	The “TDIM Bonding” SPar(1) bit is deasserted.	*PAF:M	Yes [ ]

[16]All items listed in this section are only applicable if the optional PME Aggregation Function is supported.

PAF-22	Remote_discovery_register	61.4.7.1	2BASE-TL-R and 10PASS-TS-R PHYs assert the PME Aggregation Discovery SPar bit in all G.994.1 CLR messages, if and only if its local PAF_available bit is set.	*PAF:M	Yes [ ]
PAF-23	Remote_discovery_register	61.4.7.1	CPE-subtypes place the contents of the remote_discovery_register in the corresponding NPar bits in the outgoing CLR message, with the "Clear if Same" NPar set to zero.	*PAF:M	Yes [ ]
PAF-24	Remote_discovery_register	61.4.7.1	In response to a "Get" command, the CO-subtype performs a G.994.1 capabilities exchange with the CPE-subtype. The contents of the NPar remote_discovery_register bits in the CLR message received from the CPE-subtype are reported as the result.	*PAF:M	Yes [ ]
PAF-25	Remote_discovery_register	61.4.7.1	The CL message sent by the CO-subtype in response to the CLR has the PME Aggregation Discovery SPar bit set to zero.	*PAF:M	Yes [ ]
PAF-26	Remote_discovery_register	61.4.7.1	In response to a "Set if Clear" command, the CO-subtype performs two back-to-back G.994.1 capabilities exchanges with the CPE-subtype. The contents of the NPar remote_discovery_register bits in the first CLR message received from the CPE-subtype are ignored.	*PAF:M	Yes [ ]
PAF-27	Remote_discovery_register	61.4.7.1	The CL message sent by the CO-subtype in response to the first CLR has the PME Aggregation Discovery SPar bit set to one, the Clear if Same NPar bit set to zero, and the NPar remote_discovery_register bits set to the CO-subtype PME Aggregation Discovery Code register.	*PAF:M	Yes [ ]
PAF-28	Remote_discovery_register	61.4.7.1	In a set-if-clear exchange, the CPE-subtype sets the remote_discovery register to the value of the Remote Discovery register NPar(3) if it is currently clear.	*PAF:M	Yes [ ]
PAF-29	Remote_discovery_register	61.4.7.1	The contents of the NPar remote_discovery_register bits in the CLR message received from the CPE-subtype during the second capabilities exchange are reported as the result.	*PAF:M	Yes [ ]

PAF-30	Remote_discovery_register	61.4.7.1	The CL message sent by the CO-subtype in response to the second CLR has the PME Aggregation Discovery SPar bit set to zero.	*PAF:M	Yes [ ]
PAF-31	Remote_discovery_register	61.4.7.1	In response to a “Clear if Same” command, the CO-subtype performs two back-to-back G.994.1 capabilities exchanges with the CPE-subtype. The contents of the NPar remote_discovery_register bits in the first CLR message received from the CPE-subtype are ignored.	*PAF:M	Yes [ ]
PAF-32	Remote_discovery_register	61.4.7.1	The CL message sent by the CO-subtype in response to the first CLR has the PME Aggregation Discovery SPar bit set to one, the Clear if Same NPar bit set to one, and the NPar remote_discovery_register bits set to the CO-subtype PME Aggregation Discovery Code register.	*PAF:M	Yes [ ]
PAF-33	Remote_discovery_register	61.4.7.1	In a clear-if-same exchange, the CPE-subtype clears the remote_discovery register if it is currently equal to the value of the Remote Discovery register NPar(3).	*PAF:M	Yes [ ]
PAF-34	Remote_discovery_register	61.4.7.1	The contents of the NPar remote_discovery_register bits in the CLR message received from the CPE-subtype during the second capabilities exchange are reported as the result.	*PAF:M	Yes [ ]
PAF-35	Remote_discovery_register	61.4.7.1	The CL message sent by the CO-subtype in response to the second CLR has the PME Aggregation Discovery SPar bit set to zero.	*PAF:M	Yes [ ]
PAF-36	PME_Aggregate_register	61.4.7.2	2BASE-TL-R and 10PASS-TS-R PHYs assert the PME Aggregation SPar bit in all G.994.1 CLR messages, if and only if their local PAF_available bit is set.	*PAF:M	Yes [ ]
PAF-37	PME_Aggregate_register	61.4.7.2	CPE-subtypes place the contents of the PME_Aggregate_register in the corresponding NPar bits in the outgoing CLR message.	*PAF:M	Yes [ ]

PAF-38	PME_Aggregate_register	61.4.7.2	In response to a "get" command, the CO-subtype performs a G.994.1 capabilities exchange with the CPE-subtype. The contents of the NPar PME_Aggregate_register bits in the CLR message received from the CPE-subtype are reported as the result.	*PAF:M	Yes [ ]
PAF-39	PME_Aggregate_register	61.4.7.2	The CL message sent by the CO-subtype in response to the CLR has the PME Aggregation SPar bit set to zero.	*PAF:M	Yes [ ]
PAF-40	PME_Aggregate_register	61.4.7.2	In response to a "set" command, the CO-subtype performs two back-to-back G.994.1 capabilities exchanges with the CPE-subtype. The contents of the NPar PME_Aggregate_register bits in the first CLR message received from the CPE-subtype are ignored.	*PAF:M	Yes [ ]
PAF-41	PME_Aggregate_register	61.4.7.2	The CL message sent by the CO-subtype in response to the first CLR has the PME Aggregation SPar bit set to one and the NPar PME_Aggregate_register bit zero.	*PAF:M	Yes [ ]
PAF-42	PME_Aggregate_register	61.4.7.2	The contents of the NPar PME_Aggregate_register bits in the CLR message received from the CPE-subtype during the second capabilities exchange are reported as the result.	*PAF:M	Yes [ ]
PAF-43	PME_Aggregate_register	61.4.7.2	The CL message sent by the CO-subtype in response to the second CLR has the PME Aggregation SPar bit set to zero.	*PAF:M	Yes [ ]
PAF-44	Timing and preferred transactions	61.4.7.3	At the conclusion of G.994.1 startup, the -R device begins G.994.1 transactions by transmitting an MR message.	*PAF:M	Yes [ ]
PAF-45	Timing and preferred transactions	61.4.7.3	If the G.994.1 session was initiated by the PMA/PMD link control bit in either the -O or -R device, then the -O device responds with an MS message specifying the configured mode of operation.	*PAF:M	Yes [ ]
PAF-46	Timing and preferred transactions	61.4.7.3	If the PMA/PMD type selection bits in the -O device are set to the value 0011 or 0100, and a capabilities exchange has not previously taken place, the -O device instead responds with an REQ-CLR so that a capabilities is performed.	*PAF:M	Yes [ ]

PAF-47	Timing and preferred transactions	61.4.7.3	The -O device responds with an MS message specifying the configured mode of operation.	*PAF:M	Yes [ ]
PAF-48	Timing and preferred transactions	61.4.7.3	If the G.994.1 session was initiated in response to discovery register operations, or link partner aggregation register operations, then the -O device responds with an REQ-CLR message or with a CL message.	*PAF:M	Yes [ ]
PAF-49	Timing and preferred transactions	61.4.7.3	If neither the PMA/PMD control bit nor the discovery or link partner aggregation register operations are activated within 0.5 seconds after an MR message, the -O transmits an MS message with the SPar silent bit set.	*PAF:M	Yes [ ]

61.10.4.4 Handshaking

Item	Feature	Subclause	Value/Comment	Status	Support
HS-1	Revision number: reference G.994.1 section 9.3.2	61.4.1	G.994.1 Revision Number 3 or higher is implemented.	M	Yes [ ]
HS-2	Summary of handshaking and PHY control specification	61.1.4.3	Devices implementing both 2BASE-TL and 10PASS-TS port types use G.994.1 to determine a common mode of operation.	O	Yes [ ] No [ ]
HS-3	4.3125 kHz signaling family: reference G.994.1 section 6.1.1	61.4.3	The mandatory carrier set listed in Table 61–13 is transmitted.	10PR:M 10PO:M	Yes [ ]
HS-4	4 kHz signaling family: reference G.994.1 section 6.1.2	61.4.3	The mandatory carrier set listed in Table 61–14 is transmitted.	2BR:M 2BO:M	Yes [ ]
HS-5	Prohibited carrier sets	61.4.3	Carriers not listed in Reference Table 1 or Reference Table 3 are not transmitted.	M	Yes [ ]
HS-6	Optional carrier sets	61.4.3	One or more carriers listed in Reference Table 1 or Reference Table 3 are transmitted in addition to a mandatory carrier set listed in Table 61–13 or Table 61–14.	O	Yes [ ] No [ ]
HS-7	Standard information field coding	61.4.4	The Standard information field (S) codepoints specified in Annex 61B are used in the transactions specified in 61.4.4.	M	Yes [ ]

62. Physical Medium Attachment (PMA) and Physical Medium Dependent (PMD), type 10PASS-TS

62.1 Overview

62.1.1 Scope

This clause specifies the 10PASS-TS Physical Medium Attachment (PMA) and Physical Medium Dependent (PMD) for voice grade twisted-pair wiring. In order to form a complete 10PASS-TS PHY, the 10PASS-TS PMA and PMD are integrated with the TC and PCS of Clause 61. Parts of register 3.0, parts of register 3.4, and registers 3.60 through 3.73 specified in Clause 45 may be used to control the PCS of Clause 61. Parts of register 6.0 and registers 6.16 through 6.23 specified in Clause 45 may be used to control the TC sublayer of Clause 61. Registers 1.16 through 1.71 may be used to control the 10PASS-TS PMA and PMD.

62.1.2 Objectives

The following are the objectives for the 10PASS-TS PMA and PMD:

a) To provide 10Mb/s encapsulated packet data rate at the α(β)-interface.
b) To provide full duplex operation.
c) To provide for operating over non-loaded voice grade twisted pair cable at distances up to 750 m.
d) To provide a communication channel with a mean bit error ratio, at the α(β)-interface, of less than one part in 10^7 with 6 dB noise margin.

62.1.3 Relation of 10PASS-TS to other standards

The specifications of 10PASS-TS PMA and PMD are based on the VDSL transceiver specified in ANSI T1.424.

62.1.4 Summary of Physical Medium Attachment (PMA) specification

This layer is defined by the α(β)-interface and the I-interface.

62.1.4.1 α(β)-interface

A complete definition of the α(β)-interface is contained in 61.3.2.

62.1.4.2 The I-interface

The I_O and I_R reference points define interfaces between the PMA and PMD in the 10PASS-TS-O and 10PASS-TS-R, respectively. Both interfaces are functional, application independent and identical. Both interfaces are defined by the following signal flows:

a) Data flow
b) Synchronization flow

62.1.4.2.1 The I Data Flow

The data flow consists of two octet-oriented streams, both with the PMA frame format, with the bit rates defined by the PMD transmission profile:

a) Transmitted data (Tx)
b) Received data (Rx)

If data streams are implemented serially, the MSB of each octet is sent first.

Each stream bit rate value is set during PMD configuration.

62.1.4.2.2 The I Synchronization Flow

The synchronization flow consists of the transmitted and received octet synchronization signals (Clko_t, Clko_r). Optional transmit and receive bit-synchronization signals (Clkp_t, Clkp_r) are defined too.

Synchronization signals are asserted by the PMD and directed towards the PMA.

The synchronization flow signals are described in Table 62–1.

Table 62–1—I-interface signals

Signal(s)	Description	Direction	Notes
Data signals			
Tx	Transmitted data stream	PMA → PMD	Transmission frame format.
Rx	Received data stream	PMA ← PMD	
Synchronization signals			
Clko_t	Transmitted octet timing	PMA ← PMD	
Clko_r	Received octet timing	PMA ← PMD	
Clkp_t	Transmitted bit timing	PMA ← PMD	Optional
Clkp_r	Received bit timing	PMA ← PMD	Optional

62.2 PMA functional specifications

For the purpose of transmission over a serial implementation of the α(β)-interface or the I-interface, bit b_8 as defined in Figure 61–16 is considered MSB and shall therefore be transmitted first. However, for the purpose of all serial processing (e.g.: scrambling, CRC calculation) bit b_8 is considered LSB and shall therefore be the first bit processed. Thus, the outside world MSB is considered as the 10PASS-TS LSB.

62.2.1 PMA functional diagram

Figure 62–1 shows a diagram of the PMA sublayer.

62.2.2 PMA functional specifications

The 10PASS-TS PMA is specified by incorporating the VDSL standard, American National Standard T1.424, by reference, with the modifications noted below. This standard provides support for voice-grade twisted pair. For improved legibility in this clause, American National Standard T1.424, will henceforth be referred to as MCM-VDSL.

62.2.3 General exceptions

The 10PASS-TS PMA is precisely the PMS-TC specified in MCM-VDSL, with the following general modifications:

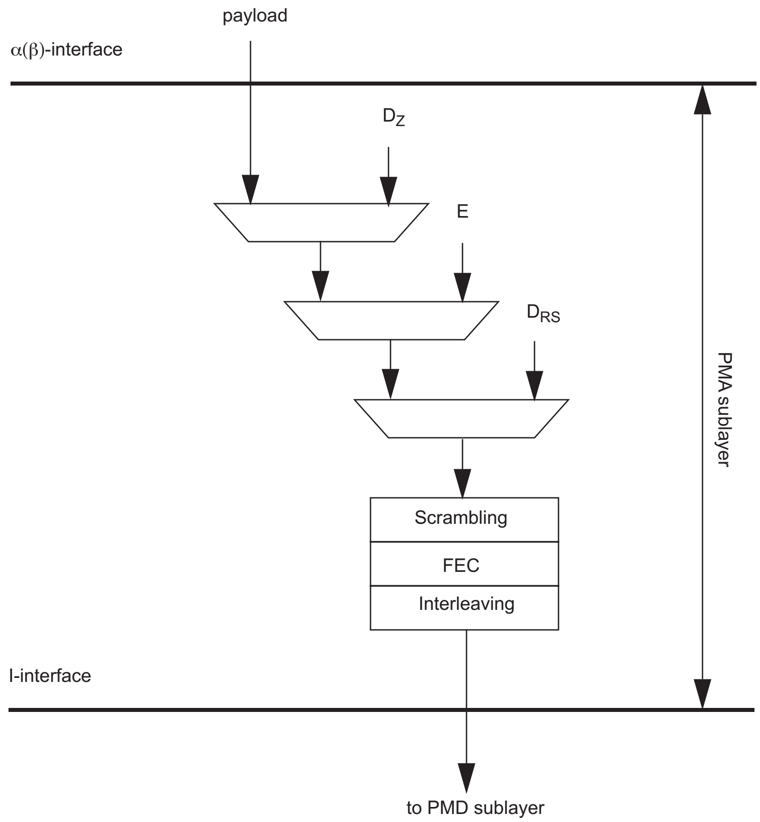


Figure 62–1—Diagram of PMA sublayer

a) There are minor terminology differences between this standard and MCM-VDSL that do not cause ambiguity. The terminology used in 10PASS-TS was chosen to be consistent with other IEEE 802 standards, rather than with MCM-VDSL. Terminology is both defined and consistent within each standard. Special note should be made of the interpretations shown in Table 62–2.
b) The 10PASS-TS PMA does not support the “fast path”.

Table 62–2—Interpretation of general MCM-VDSL terms and concepts

MCM-VDSL term or concept	Interpretation for 10PASS-TS
PMS-TC	PMA
VTU-O, LT	10PASS-TS-O
VTU-R, NT	10PASS-TS-R
Transmission medium dependent interface	MDI
U1-interface (splitter present)	
U2-interface (splitter absent)	

62.2.4 Specific requirements and exceptions

The 10PASS-TS PMA shall comply to the requirements of MCM-VDSL Section 9.3 with the exceptions listed below. Where there is conflict between specifications in MCM-VDSL and those in this standard, those of this standard shall prevail.

62.2.4.1 Replacement of 9.3.1, "PMS-TC functional diagram"

Replace 9.3.1 of MCM-VDSL by the PMA functional diagram in 62.2.1.

62.2.4.2 Changes to 9.3.3, "Forward error correction"

Referenced as is, with the exception of required Reed-Solomon encoder and interleaver settings.

The mandatory settings in MCM-VDSL (144,128) and (240,224) shall be supported. Other values are out of scope.

The following interleaver parameters shall be supported:

a) For (N,K)=(144,128) the following values for M and I shall be supported: I=36 and M between 2 and 52
b) For (N,K)=(240,224) the following values for M and I shall be supported: I=30 and M between 2 and 62

Other settings for M and I are out of scope.

62.2.4.3 Changes to 9.3.5, "Framing"

Referenced as is, with following exceptions:

a) The "fast" buffer is not supported
b) There shall be 1 VOC byte per packet; other values of V as defined in 9.3.5.5 are outside the scope of this standard
c) 9.3.5.5.4 (NTR) is not applicable
d) In Table 9-4 (9.3.5.5.3), following changes apply
    1) bits B2, B3 of Byte #2 are reserved
    2) bits B1, B2, B3, B4 of Byte #3 shall be set to 0

Additional text: the signal PMA_receive_synchronized, defined in 61.3.2.2, shall be asserted when 10PASS-TS is in the state "STEADY_STATE_TRANSMISSION" (see Figure 62–4), and deasserted when 10PASS-TS is in any other state.

62.3 PMD functional specifications

62.3.1 PMD Overview

The 10PASS-TS PMD functional model is presented in Figure 62–2. In the transmit direction, the PMD layer receives frames from the PMA layer. It sends a DMT modulated signal towards the physical medium over the MDI.

The bytes within the frame are encoded to a set of QAM constellation points that are used to modulate the carriers of the DMT symbol. The time-domain symbol is cyclically extended and then windowed to reduce sidelobe energy.

In the receive direction, a modulated signal is received from the transmission medium over the MDI. The PMD layer outputs a data frame to the PMA layer. The receiver is responsible for equalization and demodulation of the signal.

62.3.2 PMD functional specifications

The 10PASS-TS PMD (and MDI) is specified by incorporating the MCM-VDSL standard, ANSI T1.424, by reference, with the modifications noted below. This standard provides support for voice-grade twisted pair.

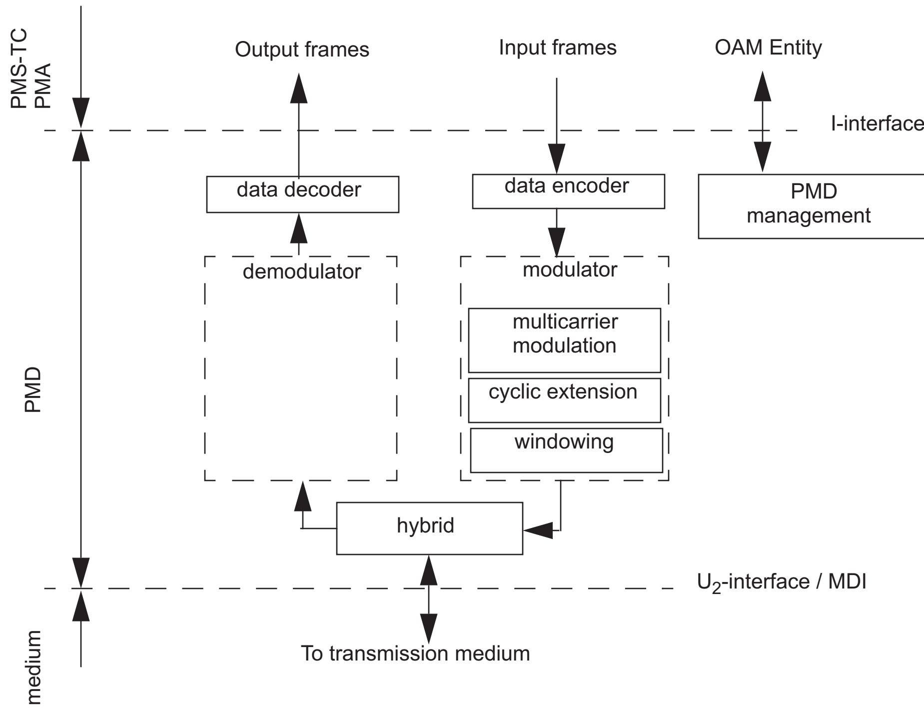


Figure 62–2—Functional diagram of PMD sublayer

62.3.3 General exceptions

The 10PASS-TS PMD is precisely the PMD specified as MCM-VDSL, with the following general modifications:

There are minor terminology differences between this standard and MCM-VDSL that do not cause ambiguity. The terminology used in 10PASS-TS was chosen to be consistent with other IEEE 802 standards, rather than with MCM-VDSL. Terminology is both defined and consistent within each standard. Special note should be made of the interpretations shown in Table 62–3.

Table 62–3—Interpretation of general MCM-VDSL terms and concepts

MCM-VDSL term or concept	Interpretation for 10PASS-TS
PMS-TC	PMA
VTU-O, LT	10PASS-TS-O
VTU-R, NT	10PASS-TS-R
Transmission medium dependent interface	MDI
U1-interface (splitter present)	
U2-interface (splitter absent)	

62.3.4 Specific requirements and exceptions

The 10PASS-TS PMD (including MDI) shall comply to the requirements of MCM-VDSL Section 8 (Physical medium dependent (PMD) sublayer), Section 10 (Operations and maintenance), Section 11 (Link activation and deactivation) and Section 18 (Normative Annex 4 - Handshake procedure for VDSL) with the exceptions listed below. Section 12 (Test procedures and requirements), Section 13 (Physical conditions), Section 14 (Environmental conditions), Section 15 (Normative Annex 1: International amateur bands), Section 16 (Informative Annex 2: VDSL PSD templates figures), Section 17 (Informative Annex 3: Utopia implementation of the ATM-TC interface), Section 19 (Informative Annex 5: FMT implementation), Section 20 (Informative Annex 6: 8.625kHz tone spacing), Section 21 (Normative Annex 7: Electrical characteristics of service splitter at remote subscriber end), Section 22 (Informative Annex 8: Electrical characteristics of service splitter at network end), and Section 23 (Informative Annex 9: Alien crosstalk descriptions), are outside the scope of this standard. Where there is conflict between specifications in MCM-VDSL and those in this standard, those of this standard shall prevail. Optional specifications in MCM-VDSL are out of scope unless explicitly referenced in this document as mandatory. If out-of-scope optional features are implemented, the mode of operation of the PHY cannot be labeled “10PASS-TS” when these features are activated.

NOTE—If optional features are implemented, their use is negotiated during initialization.

62.3.4.1 Replacement of 8.2.1, “Multi-carrier Modulation”

10PASS-TS transceivers shall use Frequency Division Duplexing (FDD) to separate upstream and downstream transmission. 10PASS-TS transceivers shall support modulation of N_{SC} = 4096 subcarriers (n = 4). Disjoint subsets of the N_{SC} subcarriers shall be defined for use in the downstream and upstream directions. These subsets are determined by the choice of frequency plan. The exact subsets of subcarriers used to modulate data in each direction shall be determined during initialization and shall be based on management system settings and the signal-to-noise ratios (SNRs) of the subchannels. In many cases the number of subcarriers used in a direction will be less than the maximum number allowed by the partitioning.

Frequency plans are defined in Annex 62A. In standard frequency plans, frequency bands are allocated as shown in Figure 62–3. The values of the splitting frequencies are given in Annex 62A. Adherence to a particular frequency plan may be mandatory under local regulations when 10PASS-TS is deployed in public networks. Other frequency plans, for use in private networks, can be supported by means of Clause 45 register settings (see Annex 62C for examples).

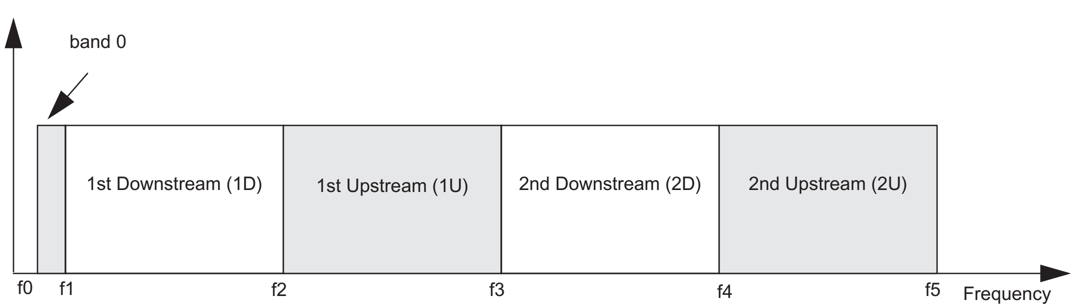


Figure 62–3—10PASS-TS band allocation

8.2.1.1 (Tone Spacing) is referenced as is.

8.2.1.2 (Data Sub Carriers) is referenced as is.

8.2.1.3 (IDFT modulation) is referenced as is.

62.3.4.2 Changes to 8.2.2, "Cyclic extension"

8.2.2 of MCM-VDSL is further restricted by the following normative text:

The cyclic extension length is specified by the value of parameter *m*. In 10PASS-TS, support for the values $m = 10$, $m = 20$, and $m = 40$ is mandatory. The value m=20 is the default setting. Support for other values is out of scope.

62.3.4.3 Changes to 8.2.3, "Synchronization"

8.2.3.1 of MCM-VDSL is further clarified by the following text:

Support for pilot tones is mandatory. 10PASS-TS-O PHYs shall support the transmission of a pilot tone on any downstream tone.

8.2.3.2 (Loop Timing) is referenced as is.

8.2.3.3 (Timing Advance) is referenced as is.

8.2.3.4 of MCM-VDSL is replaced with the following:

The use of synchronous mode as defined in MCM-VDSL 8.2.3.4 may improve operation in certain binder environments and is a system implementation item which is outside the scope of this standard.

62.3.4.4 Replacement of 8.2.4, "Power back-off in the upstream direction"

To mitigate the effects of FEXT from short lines into long lines in distributed cable topologies, upstream power back-off shall be applied. Transceivers shall be capable of performing frequency-dependent power back-off.

It shall be possible to temporarily disable UPBO for performance testing purposes (as required by Annex 62B). In normal operation, only one UPBO mode shall be supported as described below:

a) It shall be possible for the network management system to set the limiting transmit PSD template PSD_0 for the 10PASS-TS-R to one of the standard transmit PSD templates as defined in the applicable section of 62A.3.3.
b) The 10PASS-TS-R shall perform UPBO autonomously, i.e., without sending any significant information to the 10PASS-TS-O until the UPBO is applied.
c) After UPBO has been applied as described in b), the 10PASS-TS-O shall be capable of adjusting the transmit PSD selected by the 10PASS-TS-R; the adjusted transmit PSD shall be subject to the limitations given in the applicable section of 62A.3.3.

To enable the 10PASS-TS-R to initiate a connection with the 10PASS-TS-O, which will occur before UPBO has been applied, the 10PASS-TS-R shall be allowed to cause more degradation to other loops than expected when using the mode described below.

NOTE—Initiation refers to a request from the 10PASS-TS-R to start the initialization of the link. The particular method is in MCM-VDSL 11.2.

The 10PASS-TS-R shall explicitly estimate the electrical length of its line, kl_0, and use this value to calculate the transmit PSD template $TxPSD(kl_0,f)$. The 10PASS-TS-R shall then adapt its transmit signal PSD to conform to the template $TxPSD(kl_0,f)$ and the corresponding PSD mask which is defined in the applicable section of 62A.3.3.

The transmit PSD template shall be calculated as:

$$TxPSD(kl_0,f) = \min(PSD\_REF(f) + LOSS(kl_0,f), PSD_0), \text{ in dBm/Hz} \quad (62–1)$$

where PSD_0 as defined in a) above, and:

$$LOSS = kl_0 \text{ sqrt}(f), \text{ in dB} \quad (62–2)$$

where the *LOSS* function is an approximation of the loop attenuation (insertion loss).

NOTE—The estimation of the electrical length should be sufficiently accurate to avoid spectrum management problems and additional performance loss.

PSD_REF will depend on the limiting transmit PSD template PSD_0 and on the noise model that is relevant for a given deployment scenario. The values of *PSD_REF* depend on the selected UPBO Reference PSD profile, as shown in Table 62A-3. The same bandwidth as for all regular transmit PSD masks defined in the applicable section of 62A.3.3 shall be used to check the conformance of *TxPSD* with power back-off. The general methodology for testing PSD conformance is defined in 6.1 of T1.417. Conformance with the PSD template shall be verified using a 100 kHz sliding window in the in-band frequency range below 1 MHz and a 1 MHz sliding window in the in-band frequency range above 1 MHz.

PSD_REF shall be input via the management interface (by means of the UPBO Reference PSD field in the 10P tone control parameter register, see 45.2.1.36) and shall be transmitted from the 10PASS-TS-O to the 10PASS-TS-R.

The 10PASS-TS-R shall estimate the insertion losses of the upstream bands based on the received downstream signals. From this, the shape of the *LOSS* function (or, equivalently, the electrical length) as defined above shall be derived. The 10PASS-TS-R shall then compute the transmit PSD by dividing the reference PSD in the upstream bands by the estimated *LOSS* function. Next, the 10PASS-TS-R shall take a tone-by-tone minimum of this computed PSD and the maximum allowed transmit PSD in the upstream direction. The result shall be used as the initial upstream transmit PSD. The PSD received by the 10PASS-TS-O should approximate the reference PSD. Upon receiving signals from the 10PASS-TS-R, the 10PASS-TS-O shall compare the actual received PSD to the reference PSD. If necessary, it shall instruct the 10PASS-TS-R to fine-tune its PSD.

The 10PASS-TS-O shall also have the capability to directly impose a maximum allowed transmit PSD at the 10PASS-TS-R. This maximum transmit PSD shall also be input via the management interface and shall be transmitted from 10PASS-TS-O to 10PASS-TS-R in the early stages of the initialization. The 10PASS-TS-O shall allow the operator to select one of these two methods. If the PBO is defined as a maximum transmit PSD at the 10PASS-TS-R, the 10PASS-TS-R shall adjust its transmit PSD such that it does not exceed the maximum allowed transmit PSD. The restrictions specified in the previous paragraph shall also apply in this case (i.e. the 10PASS-TS-O shall not impose a transmit PSD mask that violates the mask specified there).

62.3.4.5 Changes to 8.2.5, “Constellation encoder”

In 8.2.5 of MCM-VDSL, the constraints on B_{max_d} and B_{max_u} are replaced by the following constraints:

$$B_{max\_d} = 12 \quad (62–3)$$

$$B_{max\_u} = 12 \quad (62–4)$$

62.3.4.6 Changes to 8.2.8, “U-interface characteristics”

8.2.8 is replaced with the requirements specified in 62A.3.5.

All other subclauses in MCM-VDSL Clause 8 are referenced as is.

62.3.4.7 Changes to section 10, "Operations and maintenance"

Referenced as is, with the addition of the mapping between VTU-R data registers and Clause 45 register access shown in Table 62–4.

Table 62–4—Mapping of VTU-R data registers to Clause 45

VTU-R data register (eoc)		Clause 45 register access 10PASS-TS-O		Clause 45 register access 10PASS-TS-R	
Register number	**Description[a]**	**register**	**Subclause**	**Clause 45 register**	**Subclause**
0_{16}	VTU-R vendor ID	not applicable			
1_{16}	VTU-R revision number	not applicable			
2_{16}	VTU-R serial number	not applicable			
3_{16}	Self-test results	PMA/PMD link status[b]	45.2.1.13.4	PMA/PMD link status[c]	45.2.1.13.4
4_{16}	Performance[d]	bytes 00_{16}–03_{16}: attainable DS rate bytes 04_{16}–05_{16}: FEC correctable errors bytes 08_{16}–09_{16}: FEC uncorrectable errors	45.2.1.42 45.2.1.25 45.2.1.26	bytes 00_{16}–03_{16}: attainable DS rate bytes 04_{16}–05_{16}: FEC correctable errors bytes 08_{16}–09_{16}: FEC uncorrectable errors	45.2.1.42 45.2.1.23 45.2.1.24
5_{16}	Vendor-discretionary	not applicable			
6_{16}	Loop attenuation	10P/2B line attenuation	45.2.1.20	10P/2B line attenuation	45.2.1.19
7_{16}	SNR margin	10P/2B RX SNR margin	45.2.1.18	10P/2B RX SNR margin	45.2.1.17
8_{16}	VTU-R configuration	not applicable			
9-F_{16}	For future use	not applicable			

[a]This is the description of the VTU-R data registers as given in MCM-VDSL.
[b]A non-zero value of the Self-test results register shall cause PMA/PMD link status to be cleared to 0.
[c]A non-zero value of the Self-test results register shall cause PMA/PMD link status to be cleared to 0.
[d]This field contains 16 bytes in total. The bytes that are not mapped to a Clause 45 register in this table, are reserved.

62.3.4.8 Changes to 11.1, "VDSL Link State and Timing Diagram"

See Figure 62–4.

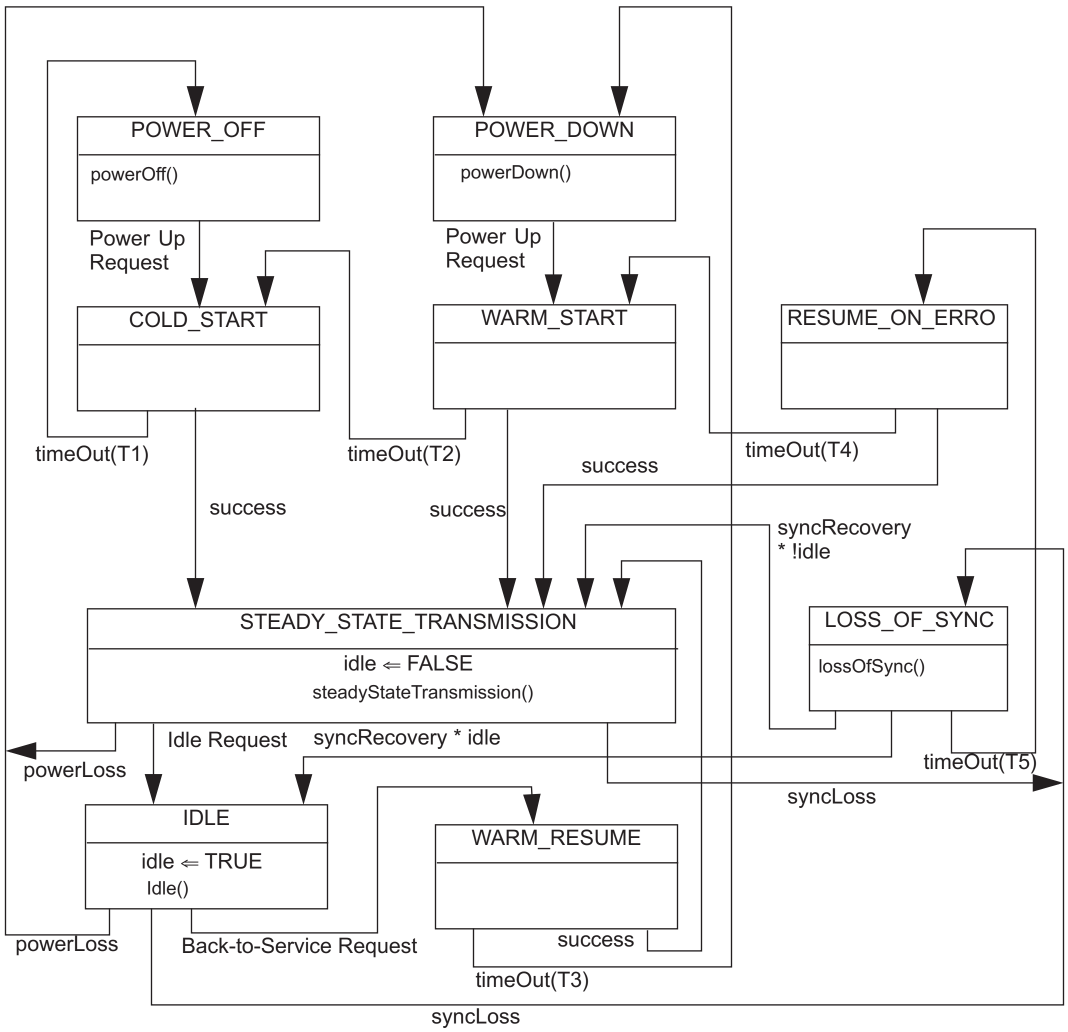


Figure 62–4—Link state and timing diagram

The function timeOut (time) returns FALSE upon entry of the associated state, and returns TRUE as soon as the interval specified by the argument "time" has expired. In addition, the state diagram uses following variables and constants.

T1
: Constant indicating the maximum cold-start activation time, equal to 10000 ms

T2
: Constant indicating the maximum warm-start activation time, equal to 5000 ms

T3
: Constant indicating the maximum warm-resume activation time, equal to 100 ms

T4
: Constant indicating the maximum resume-on-error activation time, equal to 300 ms

T5
: Constant indicating the maximum sync-loss recovery time, equal to 200 ms

idle Variable which indicates if the PMD has transitioned from STEADY_STATE_TRANSMISSION to IDLE. The idle variable becomes TRUE when the PMD enters the IDLE state, and becomes FALSE when the PMD enters the STEADY_STATE_TRANSMISSION mode.

success
Variable which is TRUE if and only if the procedures in the associated state were completed without error.

The following procedures are introduced to represent the actions associated with various states, as defined in MCM-VDSL.

powerOff()
See description of *Power-off* in MCM-VDSL section 11.1.1.1

steadyStateTransmission()
See description of *Steady-State Transmission* in MCM-VDSL section 11.1.1.1

lossOfSync()
See description of *Loss of Sync (Loss of Signal)* in MCM-VDSL section 11.1.1.1

powerDown()
See description of *Power Down* in MCM-VDSL section 11.1.1.1

idle()
See description of *Idle* in MCM-VDSL section 11.1.1.1

The remaining actions and transitions are documented in MCM-VDSL section 11.1, referenced as is.

62.3.4.9 Changes to section 18 (Annex 4), "Handshake procedure for VDSL"

62.3.4.9.1 Replacement of 18.1, "Introduction"

The 10PASS-TS handshake procedure is based on ITU-T Recommendation G.994.1 (G.hs). The carrier set used is specified in 61.3. During the handshake procedure, the following parameters shall be transmitted:

a) The size of IDFT/DFT;
b) the initial length of the cyclic extension;
c) flags indicating the use of the optional band, 25 – 138 kHz.

The parameters above shall be encoded using the information fields specified in 61.4.

62.3.4.9.2 Replacement of 18.2, "Description of signals"

The carrier set and signals used are specified in 61.4.

62.3.4.9.3 Replacement of 18.3, "Message coding format"

The message coding format and field definition tables are specified in 61.4.

62.3.4.9.4 Replacement of 18.4.1, "Handshake - 10PASS-TS-O"

The detailed procedures for handshake at the 10PASS-TS-O are defined in Recommendation G.994.1. A 10PASS-TS-O, after power-up, loss of signal, recovery from errors during the initialization procedure, shall enter the initial G.994.1 state C-SILENT1. The 10PASS-TS-O may transition to the Initialization Reset Procedure under instruction from the network. From either state, operation shall proceed according to the procedures defined in G.994.1.

If Recommendation G.994.1 procedures select 10PASS-TS as the mode of operation, the10PASS-TS-O shall transition to state O-QUIET at the conclusion of G.994.1 operation.

A 10PASS-TS-O wishing to indicate 10PASS-TS capabilities during in a G.994.1 CL message shall do so by setting to 1_b the Level 1 SPar(1)10PASS-TS bit as defined in G.994.1. The NPar(2) and SPar(2) fields corresponding to the "10PASS-TS" Level 1 bit are defined in 61.4. For each Level 2 SPar(2) bit set to 1_b, a corresponding NPar(3) field shall also be present. These NPar(3) fields are defined in 61.4. The Level 2 bits in a CL message are defined in Table 62–5 and Table 62–6.

Table 62–5—10PASS-TS-O CL message NPar(2) bit definitions

NPar(2) bit	Definition
Upstream use of 25 kHz–138kHz band	If set to 1_b, signifies that the 10PASS-TS-O is capable of using the band between 25 kHz and 138 kHz and that the band can be used for the upstream transmission.
Downstream use of 25 kHz 138kHz band	If set to 1_b, signifies that the 10PASS-TS-O is capable of using the band between 25 kHz and 138 kHz and that the band can be used for the downstream transmission.
EOC-Clear	If set to 1_b, signifies that the 10PASS-TS-O supports transmission and reception of G.997.1 OAM frames.

Table 62–6—10PASS-TS-O CL message SPar(2) bit definitions

NPar(2) bit	Definition
Used bands in upstream	The use of this bit is optional. If set to 1_b, indicates the used upstream bands. The optional band between 25 kHz and 138 kHz shall not be included.
Used bands in downstream	The use of this bit is optional. If set to 1_b, indicates the used down-stream bands. The optional band between 25 kHz and 138 kHz shall not be included.
IDFT/DFT size	Always set to 1_b in a CL message. Indicates the maximum IDFT/DFT size that 10PASS-TS-O can support. The value shall be present in the corresponding NPar(3) field.
Initial length of *CE*	If set to 0_b, it signifies that the 10PASS-TS-O can support only the mandatory cyclic extension length of $40*2^n$ for a number of tones equal to $256*2^n$. If set to 1_b in a CL message, it indicates the initial sample length of the cyclic extension that 10PASS-TS-O can support. It also signifies that the 10PASS-TS-O can support CE lengths other than the mandatory length. The value shall be present in the corresponding NPar(3) field. If one of the modems supports only the mandatory value, then this value shall be used.
RFI bands	The use of this bit is optional. If set to 1_b, indicates the RFI bands.

A PHY selecting 10PASS-TS mode of operation in a G.994.1 MS message shall do so by setting to 1_b the Level 1 SPar(1) 10PASS-TS-O bit as defined in G.994.1. The NPar(2) and SPar(2) fields corresponding to this bit are defined in 61.3. For each Level 2 SPar(2) bit set to 1b, a corresponding NPar(3) field shall also be present, as defined in 61.3. The Level 2 bits in an MS message from the 10PASS-TS-O are defined in Table 62–7 and Table 62–8.

If both bits Upstream use of optional band and Downstream use of optional band are enabled in the CL and CLR message, one and only one of the bits shall be set to 1_b in an MS message sent from the 10PASS-TS-O, and the use of the band between 25 kHz and 138 kHz is at the 10PASS-TS-O's discretion. If the 10PASS-TS-O and 10PASS-TS-R have no common usage of the optional band, both bits shall be set to 0_b in an MS message sent from the 10PASS-TS-O.

Table 62–7—10PASS-TS-O MS message NPar(2) bit definitions

NPar(2) bit	Definition
Upstream use of 25 kHz-138 kHz band	Set to 1_b if and only if this bit was set to 1_b in both the last previous CL message and the last previous CLR message. It signifies that the band between 25kHz and 138kHz shall be used for the upstream transmission.
Downstream use of 25 kHz-138kHz band	Set to 1_b if and only if this bit was set to 1_b in both the last previous CL message and the last previous CLR message. It signifies that the band between 25kHz and 138kHz shall be used for the downstream transmission.
EOC-Clear	Set to 1_b if and only if this bit was set to 1_b in both the last previous CL message and the last previous CLR message. Signifies that both 10PASS-TS-O and 10PASS-TS-R may transmit and receive G.997.1 OAM frames.

Table 62–8—10PASS-TS-O MS message SPar(2) bit definitions

NPar(2) bit	Definition
Used bands in upstream	Always set to 0_b in an MS message.
Used bands in downstream	Always set to 0_b in an MS message.
IDFT/DFT size	Always set to 1_b in an MS message. Indicates the maximum IDFT/DFT size that both 10PASS-TS-O and 10PASS-TS-R can support. The value shall be present in the corresponding NPar(3) field.
Initial length of *CE*	Set to 0_b if and only if this bit was set to 0_b in the last previous CL message or the last previous CLR message, or both. It signifies that both 10PASS-TS-O and 10PASS-TS-R shall use only the mandatory cyclic extension length. Set to 1_b if and only if this bit was set to 1_b in both the last previous CL message and the last previous CLR message. It indicates the initial sample length of the cyclic extension. It also signifies that both 10PASS-TS-O and 10PASS-TS-R can support CE lengths other than the mandatory length. The value shall be given in the corresponding NPar(3) field.
RFI bands	Always set to 0_b in an MS message.

62.3.4.9.5 Replacement of 18.4.2, "Handshake - 10PASS-TS-R"

The detailed procedures for handshake at the 10PASS-TS-R are defined in Recommendation G.994.1. An 10PASS-TS-R, after power-up, loss of signal, recovery from errors during the initialization procedure, shall enter the initial G.994.1 state R-SILENT0. Upon command from the host controller, the 10PASS-TS-R shall initiate handshaking by invoking the Initialization Reset Procedure. Operation shall then proceed according to the procedures defined in G.994.1.

If Recommendation G.994.1 procedures select 10PASS-TS as the mode of operation, the 10PASS-TS-R shall transition to state R-QUIET at the conclusion of G.994.1 operation.

A 10PASS-TS-R wishing to indicate 10PASS-TS capabilities during in a G.994.1 CLR message shall do so by setting to 1_b the Level 1 SPar(1) 10PASS-TS bit as defined in G.994.1. The NPar(2) and SPar(2) fields corresponding to the "10PASS-TS" Level 1 bit are defined in 61.4. For each Level 2 SPar(2) bit set to 1_b, a corresponding NPar(3) field shall also be present. These NPar(3) fields are defined in 61.4. The Level 2 bits in a CLR message are defined in Table 62–9 and Table 62–10.

Table 62–9—10PASS-TS-R CLR message NPar(2) bit definitions

NPar(2) bit	Definition
Upstream use of 25 kHz-138 kHz band	If set to 1_b, signifies that the 10PASS-TS-R is capable of using the band between 25 kHz and 138 kHz and that the band can be used for the upstream transmission.
Downstream use of 25 kHz-138kHz band	If set to 1_b, signifies that the 10PASS-TS-R is capable of using the band between 25 kHz and 138 kHz and that the band can be used for the downstream transmission.
EOC-Clear	If set to 1_b, signifies that the 10PASS-TS-R supports transmission and reception of G.997.1 OAM frames.

Table 62–10—10PASS-TS-R CLR message SPar(2) bit definitions

NPar(2) bit	Definition
Used bands in upstream	Always set to 0_b in a CLR message.
Used bands in downstream	Always set to 0_b in a CLR message.
IDFT/DFT size	Always set to 1_b in a CLR message. Indicates the maximum IDFT/DFT size that 10PASS-TS-R can support. The value shall be present in the corresponding NPar(3) field.
Initial length of *CE*	If set to 0_b, it signifies that the 10PASS-TS-R can support only the mandatory cyclic extension length of $40*2^n$ for a number of tones equal to $256*2^n$. If set to 1_b in a CLR message, it indicates the initial sample length of the cyclic extension that 10PASS-TS-R can support. It also signifies that the 10PASS-TS-R can support CE lengths other than the mandatory length. The value shall be present in the corresponding NPar(3) field. If one of the modems supports only the mandatory value, then this value shall be used.
RFI bands	Always set to 0_b in a CLR message.

A 10PASS-TS-R selecting 10PASS-TS mode of operation in a G.994.1 MS message shall do so by setting to 1_b the Level 1 SPar(1) 10PASS-TS bit as defined in G.994.1. The NPar(2) and SPar(2) fields corresponding to this bit are defined in 61.4. For each Level 2 SPar(2) bit set to 1_b, a corresponding NPar(3) field shall also be present, as defined in 61.4. The Level 2 bits in an MS message from the 10PASS-TS-R are defined in Table 62–11 and Table 62–12.

If both bits Upstream use of optional band and Downstream use of optional band are enabled in the CL and CLR message, one and only one of the bits shall be set to 1_b in an MS message sent from the 10PASS-TS-R, and the use of the band between 25 kHz and 138 kHz shall be at the 10PASS-TS-R's discretion. If the 10PASS-TS-O and 10PASS-TS-R have no common usage of the optional band, both bits shall be set to 0_b in an MS message sent from the 10PASS-TS-R.

Table 62–11—10PASS-TS-R MS message NPar(2) bit definitions

NPar(2) bit	Definition
Upstream use of 25kHz-138kHz band	Set to 1_b if and only if this bit was set to 1_b in both the last previous CL message and the last previous CLR message. It signifies that the band between 25kHz and 138kHz shall be used for the upstream transmission.
Downstream use of 25kHz-138kHz band	Set to 1_b if and only if this bit was set to 1_b in both the last previous CL message and the last previous CLR message. It signifies that the band between 25kHz and 138kHz shall be used for the downstream transmission.
EOC-Clear	Set to 1_b if and only if this bit was set to 1_b in both the last previous CL message and the last previous CLR message. Signifies that both 10PASS-TS-O and 10PASS-TS-R may transmit and receive G.997.1 OAM frames.

Table 62–12—10PASS-TS-R MS message SPar(2) bit definitions

NPar(2) bit	Definition
Used bands in upstream	Always set to 0_b in an MS message.
Used bands in downstream	Always set to 0_b in an MS message.
IDFT/DFT size	Always set to 1_b in an MS message. Indicates the maximum IDFT/DFT size that both 10PASS-TS-O and 10PASS-TS-R can support. The value shall be present in the corresponding NPar(3) field.
Initial length of *CE*	Set to 0_b if and only if this bit was set to 0_b in the last previous CL message or the last previous CLR message, or both. It signifies that both 10PASS-TS-O and 10PASS-TS-R shall use only the mandatory cyclic extension length. Set to 1_b if and only if this bit was set to 1_b in both the last previous CL message and the last previous CLR message. It indicates the initial sample length of the cyclic extension. It also signifies that both 10PASS-TS-O and 10PASS-TS-R can support CE lengths other than the mandatory length. The value shall be given in the corresponding NPar(3) field.
RFI bands	Always set to 0_b in an MS message.

62.3.5 Transmission medium interface characteristics

This subclause specifies the interface between the transceiver and the transmission medium (U2 reference point). The interface at U1 reference point (see MCM-VDSL Section 5.1 for VDSL reference model) is specified by the corresponding characteristics of the service splitter. The definition of the service splitter is outside the scope of this standard. Relevant specifications may be found in MCM-VDSL Clause 21 and Clause 22.

62.3.5.1 Transmit signal characteristics

62.3.5.1.1 Wide-band power

The average wide-band power of the transmitted 10PASS-TS signal measured over the frequency range between 25 kHz to 12 MHz shall be no greater than the values listed in Table 62–13 when terminated with resistive impedance of R_V = 100 Ohm.

Table 62–13—10PASS-TS maximum transmit power

Central office deployment scenario		Cabinet deployment scenario	
Downstream [dBm]	**Upstream [dBm]**	**Downstream [dBm]**	**Upstream [dBm]**
14.5	14.5	11.5	14.5

NOTE 1—For compliance with this requirement, the 10PASS-TS transceiver is terminated with the impedance R_V and configured to transmit pseudo-random data with any repetitive framing patterns enabled.

NOTE 2—Power is measured across the termination resistance of R_V. No energy is inserted into the POTS/ISDN port of the splitter (if applied) during this test.

62.3.5.1.2 Power spectral density (PSD)

Transmit PSD is characterized by the PSD template and PSD mask. PSD templates and masks are defined in Annex 62A.

62.3.5.1.3 Egress control

To avoid potential harm to amateur radio service due to radiated emission from 10PASS-TS, it shall be possible to reduce the PSD of the transmit signal within the amateur radio bands. Specifications for egress power control are described in Annex 62A.

62.3.5.2 Termination impedance

A termination impedance of R_v = 100 Ohm (purely resistive, either source or load) shall be used over the entire 10PASS-TS frequency band for both the 10PASS-TS-O and 10PASS-TS-R when matching to the metallic wire-pair.

This termination impedance approximates (and is based upon) the insertion-point impedance of the 10PASS-TS test loop. It enables a compromise high-frequency impedance match to the various types of unshielded cable in metallic access networks.

62.3.5.3 Return loss

The return loss requirement is defined to limit signal power uncertainties due to the tolerance of the line interface impedance. The return loss RL specifies the amount of reflected differential signal upon a reference impedance R_V

$$RL = 20 \times \log\left|\frac{Z + R_V}{Z - R_V}\right| \tag{62–5}$$

where Z is the internal impedance of the VTU. Note that in Equation (62–5), the log is taken to base 10, such that RL is expressed in dB.

The in-band return loss value of the 10PASS-TS transceiver shall be greater than or equal to 12 dB. The out-of-band return loss value shall be greater than or equal or 3 dB. In-band and out-of-band frequencies are defined by the frequency plan as shown in Figure 62–3 and by the transmit direction.

The value of 12 dB assumes a flat transmit PSD is applied over the entire in-band region. Requirements may be relaxed in the frequency ranges of reduced PSD values. The exact value requirements are outside the scope of this standard.

The return loss shall be measured on a resistive test load of R_V = 100 Ohm while the tested implementation of the 10PASS-TS transceiver is powered.

NOTE—If a splitter is used, the return-loss requirements should be met for the full range of possible values of the POTS/ISDN port termination.

62.3.5.4 Output signal balance

Output signal balance (*OSB*) is a measure of unwanted longitudinal signals at the output of the transceiver, as defined by Equation (62–6). The longitudinal output voltage (V_{cm}) to the differential output voltage (V_{diff}) ratio shall be measured while the 10PASS-TS transmitter is active in accordance with ITU-T Recommendation G.117 and ITU-T Recommendation O.9.

$$OSB = 20\log\left|\frac{V_{diff}}{V_{cm}}\right| \tag{62–6}$$

The *OSB* of the 10PASS-TS transceiver shall be equal to or greater than 35 dB in the entire 10PASS-TS band.

NOTE—The equipment balance should be better than the anticipated cable balance in order to minimize the unwanted emissions and susceptibility to external RFI. The typical worst case balance for an aerial drop-wire has been observed to be in the range 30 dB – 35 dB, therefore the balance of the 10PASS-TS equipment should be equal or better.

62.4 Protocol implementation conformance statement (PICS) proforma for Clause 62, Physical Medium Attachment (PMA) and Physical Medium Dependent (PMD), type 10PASS-TS[17]

62.4.1 Introduction

The supplier of a protocol implementation that claimed to conform to Clause 62, Physical Medium Attachment (PMA) and Physical Medium Dependent (PMD), type 10PASS-TS, 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.

62.4.2 Identification

62.4.2.1 Implementation identification

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

62.4.2.2 Protocol summary

Identification of protocol standard	IEEE Std 802.3-2005, Physical Medium Attachment (PMA) and Physical Medium Dependent (PMD), type 10PASS-TS.
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 802.3-2005.)	
Date of Statement	

[17]*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.

62.4.3 Major capabilities/options

Item	Feature	Subclause	Value/Comment	Status	Support
10PPMA	MCM-VDSL based PMA	62.2	The PMA based on the PMS-TC specified in American National Standard T1.424 is implemented.	M	Yes [ ]
10PPMD	MCM-VDSL based PMD	62.3	The PMD based on the PMD specified in American National Standard T1.424 is implemented.	M	Yes [ ]

62.4.4 PICS proforma tables for the Physical Medium Attachment (PMA) and Physical Medium Dependent (PMD), type 10PASS-TS

62.4.4.1 MCM-VDSL based PMA

Item	Feature	Subclause	Value/Comment	Status	Support
10PPMA-1	DMT PMA functional specifications	62.2	All data bytes are transmitted MSB first.	M	Yes [ ]
10PPMA-2	DMT PMA functional specifications	62.2	All serial processing is performed LSB first, with the outside world MSB considered as the VDSL LSB.	M	Yes [ ]
10PPMA-3	Specific requirements and exceptions	62.2.4	The 10PASS-TS PMA complies to the requirements of MCM-VDSL Section 9.3, with the exception of support for the fast path, support for V>1, NTR, and TPS-TC specific bits as listed.	M	Yes [ ]
10PPMA-4	Specific requirements and exceptions: Reed-Solomon	62.2.4.2	The 10PASS-TS PMA supports Reed-Solomon settings (144,128) and (240, 224).	M	Yes [ ]
10PPMA-5	Specific requirements and exceptions: Interleaver	62.2.4.2	For (N,K) = (144,128) the following values for M and I are supported: I=36 and M between 2 and 52. For (N,K)=(240,224) the following values for M and I are supported: I=30 and M between 2 and 62.	M	Yes [ ]

62.4.4.2 MCM-VDSL based PMD

Item	Feature	Subclause	Value/Comment	Status	Support
10PPMD-1	Specific requirements and exceptions	62.3.4	The PMD complies to the requirements of MCM-VDSL Section 8, Section 10, Section 11, and Section 12, with the exceptions listed.	M	Yes [ ]
10PPMD-2	Duplexing and Modulation	62.3.4.1	The PMD uses Frequency Division Duplexing to separate upstream and downstream transmission.	M	Yes [ ]
10PPMD-3	Duplexing and Modulation	62.3.4.1	The PMD supports modulation of N_{SC} = 4,096 subcarriers.	M	Yes [ ]
10PPMD-4	Duplexing and Modulation	62.3.4.1	The PMD supports modulation of B_{max_d} = 12 bits per downstream subcarrier and B_{max_u} = 12 bits per upstream subcarrier.	M	Yes [ ]
10PPMD-5	Duplexing and Modulation	62.3.4.1	Disjoint subsets of the N_{SC} subcarriers are defined for use in the downstream and upstream directions.	M	Yes [ ]
10PPMD-6	Duplexing and Modulation	62.3.4.1	The exact subsets of subcarriers used to modulate data in each direction are determined during initialization, based on management system settings and the signal-to-noise ratios of the subchannels.	M	Yes [ ]
10PPMD-7	Duplexing and Modulation	62.3.4.1	The use of the band between 25 kHz and 138 kHz is negotiated during the initialization to indicate if the capability exists and select one of the following options: use for upstream transmission, use for downstream transmission, not used.	M	Yes [ ]
10PPMD-8	Duplexing and Modulation	62.3.4.1	10PASS-TS-O PMD supports the transmission of a pilot tone on any downstream tone.	M	Yes [ ]
10PPMD-9	Upstream Power Back-Off	62.3.4.1	Upstream power back-off is applied to mitigate the effects of FEXT from short lines into long lines in distributed cable topologies.	M	Yes [ ]
10PPMD-10	Upstream Power Back-Off	62.3.4.1	The PMD is capable of performing frequency-dependent power back-off.	M	Yes [ ]
10PPMD-11	Upstream Power Back-Off	62.3.4.1	It is possible for the network management system to set the limiting transmit PSD template PSD_0 for the 10PASS-TS-R to one of the standard transmit PSD templates as defined in the applicable section of 62A.3.4.	M	Yes [ ]
10PPMD-12	Upstream Power Back-Off	62.3.4.1	The 10PASS-TS-R PMD performs UPBO autonomously, i.e., without sending any significant information to the 10PASS-TS-O until the UPBO is applied.	M	Yes [ ]
10PPMD-13	Upstream Power Back-Off	62.3.4.1	The 10PASS-TS-O is capable of adjusting the transmit PSD selected by the 10PASS-TS-R, after UPBO has been applied. The adjusted transmit PSD is subject to the limitations given in the applicable section of 62A.3.3.	M	Yes [ ]

10PPMD-14	Upstream Power Back-Off	62.3.4.1	The 10PASS-TS-R estimates the insertion losses of the upstream bands based on the received downstream signals. The 10PASS-TS-R explicitly estimates the electrical length of its line, kl_0, and uses this value to calculate the transmit PSD template TxPSD per Equation (62–1) and Equation (62–2).	M	Yes [ ]
10PPMD-15	Upstream Power Back-Off	62.3.4.1	The 10PASS-TS-R adapts its transmit signal PSD to conform to the template TxPSD and the corresponding PSD mask which is defined in the applicable section of 62A.3.3. The same bandwidth as for all regular transmit PSD masks defined in the applicable section of 62A.3.3 are used to check the conformance of TxPSD with power back-off. Conformance with the PSD template is verified using a 100 kHz sliding window in the in-band frequency range below 1 MHz and a 1 MHz sliding window in the in-band frequency range above 1 MHz.	M	Yes [ ]
10PPMD-16	Upstream Power Back-Off	62.3.4.1	PSD_REF is input via the management interface.	M	Yes [ ]
10PPMD-17	Upstream Power Back-Off	62.3.4.1	PSD_REF is transmitted from the 10PASS-TS-O to the 10PASS-TS-R.	M	Yes [ ]
10PPMD-18	Upstream Power Back-Off	62.3.4.1	The 10PASS-TS-R takes a tone-by-tone minimum of this computed PSD and the maximum allowed transmit PSD in the upstream direction. The result is used as the initial upstream transmit PSD.	M	Yes [ ]
10PPMD-19	Upstream Power Back-Off	62.3.4.1	Upon receiving signals from the 10PASS-TS-R, the 10PASS-TS-O compares the actual received PSD to the reference PSD. If necessary, it instructs the 10PASS-TS-R to fine-tune its PSD.	M	Yes [ ]
10PPMD-20	Upstream Power Back-Off	62.3.4.1	The 10PASS-TS-O has the capability to directly impose a maximum allowed transmit PSD at the 10PASS-TS-R.	M	Yes [ ]
10PPMD-21	Upstream Power Back-Off	62.3.4.1	The maximum transmit PSD is input via the management interface.	M	Yes [ ]
10PPMD-22	Upstream Power Back-Off	62.3.4.1	The maximum transmit PSD is transmitted from 10PASS-TS-O to 10PASS-TS-R during initialization.	M	Yes [ ]
10PPMD-23	Upstream Power Back-Off	62.3.4.1	The 10PASS-TS-O allows the operator to select between the UPBO method based on Reference PSD and the UPBO method based on maximum transmit PSD.	M	Yes [ ]
10PPMD-24	Handshake	62.3.4.9	The handshake uses the 4.3125kHz signaling family and the duplex transmission mode.	M	Yes [ ]

10PPMD-25	Handshake	62.3.4.9	The handshake proceeds as specified in 61.4.	M	Yes [ ]
10PPMD-26	Wide-band power	62.3.5.1.1	The average wide-band power of the transmitted 10PASS-TS signal measured over the frequency range between 25 kHz to 12 MHz is no greater than the values listed in Table 62–13 when terminated with resistive impedance of RV = 100 Ohm.	M	Yes [ ]
10PPMD-27	Egress control	62.3.5.1.3	To avoid potential harm to amateur radio service due to radiated emission from 10PASS-TS, it is possible to reduce the PSD of the transmit signal within the amateur radio bands.	M	Yes [ ]
10PPMD-28	Termination impedance	62.3.5.2	A termination impedance of Rv = 100 Ohm is used over the entire 10PASS-TS frequency band for both the 10PASS-TS-O and 10PASS-TS-R when matching to the metallic wire-pair.	M	Yes [ ]
10PPMD-29	Return loss	62.3.5.3	The in-band return loss value of the 10PASS-TS transceiver are greater than or equal to 12 dB.	M	Yes [ ]
10PPMD-30	Return loss	62.3.5.3	The out-of-band return loss value are greater than or equal or 3 dB.	M	Yes [ ]
10PPMD-31	Return loss	62.3.5.3	Requirements are relaxed in the frequency ranges of reduced PSD values.	O	Yes [ ] No [ ]
10PPMD-32	Return loss	62.3.5.3	The return loss are measured on a resistive test load of R_V = 100 Ohm while the tested implementation of the 10PASS-TS transceiver is powered.	M	Yes [ ]
10PPMD-33	Output signal balance	62.3.5.4	The longitudinal output voltage to the differential output voltage ratio is measured while the VTU transmitter is active in accordance with ITU-T Recommendation G.117 and ITU-T Recommendation O.9.	M	Yes [ ]
10PPMD-34	Output signal balance	62.3.5.4	The OSB of the 10PASS-TS transceiver is equal to or greater than 35 dB in the entire 10PASS-TS band.	M	Yes [ ]

63. Physical Medium Attachment (PMA) and Physical Medium Dependent (PMD), type 2BASE-TL

63.1 2BASE-TL Overview

63.1.1 Scope

This clause specifies the 2BASE-TL Physical Medium Attachment (PMA) and Physical Medium Dependent (PMD) sublayer for voice grade twisted-pair wiring. In order to form a complete 2BASE-TL PHY, the 2BASE-TL PMA and PMD are integrated with the TC and PCS of Clause 61. Parts of register 3.0, parts of register 3.4 and registers 3.60 through 3.73 specified in Clause 45 may be used to control the PCS of Clause 61. Parts of register 6.0 and registers 6.16 through 6.23 specified in Clause 45 may be used to control the TC sublayer of Clause 61. Registers 1.16 through 1.42 and 1.80 through 1.109 specified in Clause 45 may be used to control the 2BASE-TL PMA and PMD.

63.1.2 Objectives

The following are the objectives for the 2BASE-TL PMA and PMD:

a) To provide 2 Mb/s encapsulated packet data rate at the α(β)-interface.

b) To provide full duplex operation.

c) To provide for operating over non-loaded voice grade twisted pair cable at distances up to 2700 m.

d) To provide a communication channel with a mean bit error ratio, at the α(β)-interface, of less than one part in 10^7 with 5 dB noise margin.

63.1.3 Relation of 2BASE-TL to other standards

The specifications of the 2BASE-TL PMA and PMD are based on the SHDSL transceiver (PMD and PMS-TC) specified in ITU-T Recommendation G.991.2 “Single-Pair High-Speed Digital Subscriber Line (SHDSL) transceivers”.

63.1.4 Summary of Physical Medium Attachment (PMA) specification

This layer is defined by the α(β)-interface and the I-interface. Figure 63–1 shows a functional diagram of the 2BASE-TL PMA layer functionality. The payload is formed into a 2BASE-TL PMA frame with overhead added (for example, the PME aggregation Header). The framed data is then scrambled and sent to the PMD sublayer. One distinguishes between the data mode PMA specification which is used during normal data operation and the activation PMA specification which is used when the PMD is training.

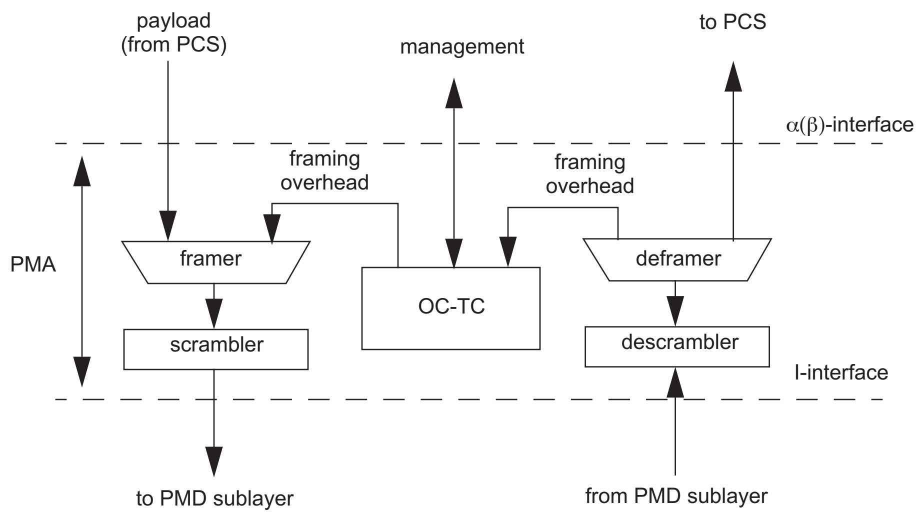


Figure 63–1—Diagram of PMA sublayer

63.1.4.1 α(β)-interface

A complete definition of the α(β)-interface is contained in 61.3.2. The signal PMA_receive_synchronized, defined in 61.3.2.2, shall be asserted when the LOSW bit is set to 0 (see 63.2.2.2), and deasserted when the LOSW is set to 1.

63.1.4.2 The I-interface

The I_O and I_R reference points define interfaces between the PMA and PMD in the 2BASE-TL-O and 2BASE-TL-R, respectively. Both interfaces are functional, application independent and identical. Both interfaces are defined by the following signal flows:

a) Data flow
b) Synchronization flow

The specification of the I-interface is implicit in ITU-T Recommendation G.991.2.

63.1.4.2.1 The I Data Flow

The data flow consists of two octet-oriented streams, both with the PMA frame format, with the bit rates defined by the PMD transmission profile:

a) Transmit data (Tx)
b) Receive data (Rx)

If data streams are implemented serially, the LSB of each octet (i.e., b_8 of Figure 61–16) shall be sent first. In section 7.1.1 of G.991.2, with i = 0, the payload blocks are made of a stream of octets. Each octet consists of 8 bits. The first bit of each octet (i.e., lowest frame bit number in an octet) maps to b_8 in Figure 61–16 and the last bit of each octet maps to b_1 of Figure 61–16.

Each stream bit rate value is set during PMD configuration.

63.1.4.2.2 The I Synchronization Flow

The synchronization flow consists of the transmitted and received octet synchronization signals (Clko_t, Clko_r). Optional transmit and receive bit-synchronization signals (Clkp_t, Clkp_r) are defined too.

Synchronization signals are asserted by the PMD and directed towards the PMA.

The synchronization signals are described in Table 63–1.

Table 63–1—I-interface signals

Signal(s)	Description	Direction	Notes
Data Signals			
Tx	Transmit data stream	PMA → PMD	Transmission frame format.
Rx	Receive data stream	PMA ← PMD	
Synchronization Signals			
Clko_t	Transmitted octet timing	PMA ← PMD	
Clko_r	Received octet timing	PMA ← PMD	
Clkp_t	Transmitted bit timing	PMA ← PMD	Optional
Clkp_r	Received bit timing	PMA ← PMD	Optional

63.1.4.3 Operation Channel (OC)

The OC-TC function of the PMA shall receive the EOC and overhead indicators over the OC-TC interface. For each 2BASE-TL PMA frame, the OC shall deliver a fixed number of embedded operations channel (EOC) and overhead indicators bits to the framer. These bits shall be included in the overhead sections of the 2BASE-TL PMA frames.

63.1.5 Summary of Physical Medium Dependent (PMD) specification

The PMD specification is based on Pulse Amplitude Modulation (PAM) and is divided into three consecutive phases, summarized as:

a) Preactivation: during this phase, the PMDs determine each other capabilities and the bit rate they will operate at in data mode. Reference section 6.3.1 (included in this standard per 63.3.2.2) describes the preactivation reference model. The preactivation uses G.994.1 as a handshake mechanism to exchange parameters in accordance with the specifications in 61.4. It also offers an optional line probing capability. The line probe uses 2-level PAM signals to determine a suitable bit rate to run at on the copper link.
b) Activation: during this phase, the PMDs train and exchange information necessary to adapt and operate the various filters and processes necessary during data mode operation. Reference section 6.2.1 describes the Activation reference model. The activation uses 2-level PAM to train the various filters.
c) Data Mode: once pre-activation and activation are complete, the PMD can start transmitting payload data. Reference section 6.1.1 describes the Data Mode reference model.

NOTE—Line activation takes place after entire discovery and PME aggregation operation.

63.2 2BASE-TL PMA functional specifications

The 2BASE-TL PMA is specified by incorporating the SHDSL standard, ITU-T Recommendation G.991.2 (02/2001) with the changes specified in G.991.2 Amendment 1 (11/2001), by reference, with the modifications noted below. This standard provides support for voice-grade twisted pair. For improved legibility in this clause, ITU-T Recommendation G.991.2 and G.991.2 Amendment 1, will henceforth be referred to as G.991.2.

63.2.1 General exceptions

The 2BASE-TL PMA is precisely the PMS-TC specified in G.991.2, with the following general modifications:

a) There are minor terminology differences between this standard and G.991.2 that do not cause ambiguity. The terminology used in 2BASE-TL was chosen to be consistent with other IEEE 802 standards, rather than with G.991.2. Terminology is both defined and consistent within each standard. Special note should be made of the interpretations shown in Table 63–2.

Table 63–2—Interpretation of general G.991.2 terms and concepts

G.991.2 term or concept	Interpretation for 2BASE-TL
PMS-TC	PMA
STU-C, LT	2BASE-TL-O
STU-R, NT	2BASE-TL-R
Transmission medium dependent interface, U-interface	MDI
byte	octet

b) The 2BASE-TL PMA supports only one channel of user data with an associated γ-interface.
c) The 2BASE-TL PMA does not support the optional “four-wire mode”. Operation over multiple pairs is optional; if implemented, multi-pair operation shall comply to the specifications in 61.2.2.
d) The 2BASE-TL PMA does not support “plesiochronous mode”.
e) The 2BASE-TL PMA shall be octet oriented; hence, the bit oriented parameter i defined for Equation (63–1) shall be equal to 0 in all cases.
f) The 2BASE-TL PMA does not support the notion of “sub-blocks” in the Payload Block. Each payload block consists of a contiguous sequence of $12n$ octets, with parameter n as defined for Equation (63–1).

63.2.2 Specific requirements and exceptions

The 2BASE-TL PMA shall comply to the requirements of G.991.2 Section 7 and Section 9 with the exceptions listed below. Where there is conflict between specifications in G.991.2 and those in this standard, those of this standard shall prevail.

Implementation of optional specifications in G.991.2 is not required for compliance with this standard. Reference Section 8 (TPS-TC Layer Functional Characteristics), Reference Annex D (Signal Regenerator Operation), Reference Annex E (Application-specific TPS-TC Framing) and Reference Appendices I, II and III are out of scope for 2BASE-TL PMA. Deployment of compatible versions of G.991.2 Annex D is an implementation specific option for the purposes of 2BASE-TL.

63.2.2.1 Changes to 7.1, "Data Mode Operation"

Reference 7.1.1 (Frame Structure) is replaced with the following:

Table 7-1 of the Reference summarizes the SHDSL frame structure. Complete bit definitions may be found in Reference 7.1.2. The size of each payload block is defined as k bits, where $k = 96n$. The payload rate r (in kb/s) is given by Equation (63–1) and Equation (63–3), with $i = 0$. The value of n is limited by Equation (63–2) and Equation (63–4).

Reference 7.1.2.6 (Stuff Indicator bits) is replaced with the following:

2BASE-TL operates in synchronous mode, therefore *sbid1* and *sbid2* are spare bits.

Reference 7.1.2.7 (Stuffing Bits) is replaced with the following:

2BASE-TL operates in synchronous mode, therefore *stb1* and *stb2* shall be present in every frame, and *stb3* and *stb4* shall not be present.

Reference 7.1.4 (Frame synchronization) is replaced with the following:

The precise manner in which frame synchronization is acquired or maintained is the choice of the receiver designer. Since different frame synchronization algorithms may require different values for the bits of the FSW, a provision has been made to allow the receiver to inform the far end transmitter of the particular values that are to be used for this field in the transmitted PMS-TC frame.

All other subsections of Reference 7.1 are referenced as is.

63.2.2.2 Changes to Section 9, "Management"

Referenced as is, with the exception of 9.5.5.6 where Message IDs 17 "ATM Cell Status Request", 20 "ISDN Request", 145 "ATM Cell Status Information" and 148 "ISDN Response" are out of scope.

63.2.2.3 Relation between the 2BASE-TL registers and the SHDSL management functions

The parameters of the various 2BASE-TL registers of the -R device, defined in Clause 45, are gathered via the SHDSL management. SNR margin, code violations, ES, SES, LOSW, UAS, SNR margin defect, Loop attenuation defect and loss of sync word failure shall be obtained in the following way:

The 2BASE-TL-O shall send a Status Request (Msg ID 11) EOC message. If there has been any change in performance status other than SNR margin since the last time a unit was polled, the peer 2BASE-TL-R shall respond with an SHDSL Network Side Performance Status (Msg ID 140) EOC message.

The following octets and bits are then mapped to the Clause 45 registers (see Table 63–3):

Otherwise, the peer 2BASE-TL-R shall respond with a Status/SNR (Msg ID 139) EOC message, in which the SNR margin is communicated in octet 2.

Loop attenuation and SNR margin threshold for both 2BASE-TL-O and 2BASE-TL-R devices shall be set in the Clause 45 register of the 2BASE-TL-O device; the 2BASE-TL-R thresholds will be passed to the 2BASE-TL-R using message ID 3.

The segment defect is defined in section 9.2.4 and uses a dedicated framing bit rather than the EOC messaging.

The retrieval of the remote vendor ID is defined in G.997.1. The use of this mechanism is outside the scope of this standard.

Table 63–3—Mapping of registers to “Network Side Performance Status” EOC message octets

register	octets / bits
LOSW failure	octet 2 / bit 1
Loop attenuation defect	octet 2 / bit 2
SNR margin defect	octet 2 / bit 3
SNR margin	octet 3
Loop attenuation	octet 4
ES	octet 5
SES	octet 6
Code violations	octet 7 and 8
LOSW	octet 9
UAS	octet 10
See footnote[a].	octet 11

[a]NOTE—Bit 6 and 7 of octet 11 indicate that either an overflow or reset condition has occurred on any of the code violations / ES/ SES / LOSW / UAS registers.

NOTE—The code violation, ES, SES, LOSW and UAS in SHDSL are modulo counters. The absolute value of the counter is meaningless, however the difference in between two consecutive readings provides the change in code violation/ES/SES/LOSW/UAS. If there are no changes in the performance registers, message ID 139 rather than 140 will be sent by the 2BASE-TL-R. It only contains the SNR value and none of the other parameters.

63.3 2BASE-TL PMD functional specifications

The 2BASE-TL PMD (and MDI) is specified by incorporating the SHDSL standard, ITU-T Recommendation G.991.2 (02/2001) with the changes specified in G.991.2 Amendment 1 (11/2001), by reference, with the modifications noted below. This standard provides support for voice-grade twisted pair. For improved legibility in this clause, ITU-T Recommendation G.991.2 and G.991.2 Amendment 1, will henceforth be referred to as G.991.2.

63.3.1 General exceptions

The 2BASE-TL PMD is precisely the PMD specified in G.991.2, with the following general modifications:

a) There are minor terminology differences between this standard and G.991.2 that do not cause ambiguity. The terminology used in 2BASE-TL was chosen to be consistent with other IEEE 802 standards, rather than with G.991.2. Terminology is both defined and consistent within each standard. Special note should be made of the interpretations shown in Table 63–4.
b) The 2BASE-TL PMD does not support the optional “four-wire mode”. Operation over multiple pairs is optional; if implemented, multi-pair operation shall comply to the specifications in 61.2.2.
c) The 2BASE-TL PMD does not support “plesiochronous mode”.
d) The 2BASE-TL PMD shall be octet oriented; hence, the bit oriented parameter i defined for Equation (63–1) shall be equal to 0 in all cases.
e) The 2BASE-TL PMD shall support the use of the 32-TCPAM constellation for specific rates (see 63.3.2.1).
f) The 2BASE-TL PMD shall support the use of the enhanced SHDSL[18] extended bandwidths.

[18]“Enhanced SHDSL” refers to 32TC-PAM modulation and higher values of n as defined in Equation (63–2) and Equation (63–4), which are not part of ITU-T Recommendation G.991.2.

Table 63–4—Interpretation of general G.991.2 terms and concepts

G.991.2 term or concept	Interpretation for 2BASE-TL
PMS-TC	PMA
STU-C, LT	2BASE-TL-O
STU-R, NT	2BASE-TL-R
Transmission medium dependent interface, U-interface	MDI

63.3.2 Specific requirements and exceptions

The 2BASE-TL PMD (including MDI) shall comply to the requirements of G.991.2 Section 5 (Transport Capacity), Section 6 (PMD Layer Functional Characteristics), Section 10 (Clock Architecture), Section 11 (Electrical Characteristics), Section 12 (Conformance Testing) with the exceptions listed below. The 2BASE-TL PMD supports the requirements of G.991.2 Annex A (Regional Requirements - Region 1) and Annex B (Regional Requirements - Region 2) with the exception of performance requirements, which are replaced by Annex 63B. Where there is conflict between specifications in G.991.2 and those in this standard, those of this standard shall prevail.

Implementation of optional specifications in G.991.2 is not required for compliance with this standard. Reference Section 8 (TPS-TC Layer Functional Characteristics), Reference Annex D (Signal Regenerator Operation), Reference Annex E (Application-specific TPS-TC Framing) and Reference Appendices I, II and III are out of scope for the 2BASE-TL PMD.

63.3.2.1 Replacement of section 5, “Transport Capacity”

This recommendation specifies a two-wire operational mode for 2BASE-TL transceivers that is capable of supporting user (payload) data rates from 192 kb/s to 3.840 Mb/s, using the 16-TCPAM constellation, and 768 kb/s to 5.696 Mb/s, using the 32-TCPAM constellation. The allowed rates r (in kb/s), using the 16-TCPAM constellation, are given by:

$$r = n \times 64 + i \times 8 \tag{63–1}$$

where

$$3 \le n \le 60 . \tag{63–2}$$

The allowed rates r (in kb/s), using the 32-TCPAM constellation, are given by:

$$r = n \times 64 + i \times 8 \tag{63–3}$$

where

$$12 \le n \le 89 . \tag{63–4}$$

In all cases, i is restricted to the value of 0. See 63.3.2.4, 63.3.2.5 and 63.3.2.6 for details of specific regional requirements.

63.3.2.2 Changes to section 6, "PMD Layer Functional Characteristics"

Referenced as is, with the exception of subsection 6.4 (G.994.1 Preactivation Sequence), which is supplanted by 61.4.

Section 6.1.2.3 is superseded by the following text:

Mapper:

The K+1 bits $Y_K(m)$, ..., $Y_1(m)$, and $Y_0(m)$ shall be mapped to a level $x(m)$. In section 6.1.2.3 of G.991.2, the mapper function is specified for 16-TCPAM. This text extends that mapping to include both 16- and 32-TCPAM encodings. Table 63–5 shows the bit to level mapping for 16 and 32 level mapping.

Table 63–5—Mapping of bits to PAM levels

Y_4(m)	Y_3(m)	Y_2(m)	Y_1(m)	Y_0(m)	32-PAM (5 Bits)	16-PAM (4 Bits)
0	0	0	0	0	–31/32	–15/16
0	0	0	0	1	–29/32	–13/16
0	0	0	1	0	–27/32	–11/16
0	0	0	1	1	–25/32	–9/16
0	0	1	0	0	–23/32	–7/16
0	0	1	0	1	–21/32	–5/16
0	0	1	1	0	–19/32	–3/16
0	0	1	1	1	–17/32	–1/16
0	1	1	0	0	–15/32	1/16
0	1	1	0	1	–13/32	3/16
0	1	1	1	0	–11/32	5/16
0	1	1	1	1	–9/32	7/16
0	1	0	0	0	–7/32	9/16
0	1	0	0	1	–5/32	11/16
0	1	0	1	0	–3/32	13/16
0	1	0	1	1	–1/32	15/16
1	1	0	0	0	1/32	—
1	1	0	0	1	3/32	—
1	1	0	1	0	5/32	—
1	1	0	1	1	7/32	—
1	1	1	0	0	9/32	—
1	1	1	0	1	11/32	—

Table 63–5—Mapping of bits to PAM levels *(continued)*

$Y_4(m)$	$Y_3(m)$	$Y_2(m)$	$Y_1(m)$	$Y_0(m)$	32-PAM (5 Bits)	16-PAM (4 Bits)
1	1	1	1	0	13/32	—
1	1	1	1	1	15/32	—
1	0	1	0	0	17/32	—
1	0	1	0	1	19/32	—
1	0	1	1	0	21/32	—
1	0	1	1	1	23/32	—
1	0	0	0	0	25/32	—
1	0	0	0	1	27/32	—
1	0	0	1	0	29/32	—
1	0	0	1	1	31/32	—

63.3.2.3 Changes to section 10, "Clock Architecture"

Referenced as is, with the exception of Reference Table 10-1, which is replaced by Table 63–6.

Table 63–6—Clock Synchronization Configurations

Mode Number	2BASE-TL-O Symbol Clock Reference	2BASE-TL-R Symbol Clock Reference	Example Application	Mode
3a	Transmit data clock	Received symbol clock	Main application is synchronous transport in both directions.	Synchronous

63.3.2.4 Changes to Annex A, "Regional Requirements – Region 1"

63.3.2.4.1 General Changes

Referenced as is, with the exception of optional support for asymmetric PSD masks. Asymmetric PSD masks are not supported by 2BASE-TL.

Section A.5.3 "Span Powering" is out of scope.

63.3.2.4.2 Additional requirement: wetting current

The 2BASE-TL-R shall be capable of sustaining 20 mA of wetting (sealing) current. The maximum rate of change of the wetting current shall be no more than 20 mA per second.

NOTE—The -R device cannot be guaranteed to operate correctly if more than 20 mA (tip to ring) is sourced.

63.3.2.5 Changes to Annex B, “Regional Requirements – Region 2”

63.3.2.5.1 General Changes

Referenced as is, with the exception of optional support for asymmetric PSD masks. Asymmetric PSD masks are not supported by 2BASE-TL.

Section B.5.3. “Span Powering” is out of scope.

The RL_{min} value of section B.5.2 is modified from 14 to 12 dB for the purpose of 2BASE-TL.

63.3.2.5.2 Additional requirement: wetting current

The 2BASE-TL-R shall be capable of sustaining 20 mA of wetting (sealing) current. The maximum rate of change of the wetting current shall be no more than 20 mA per second.

NOTE—The -R device cannot be guaranteed to operate correctly if more than 20 mA (tip to ring) is sourced.

63.3.2.6 Changes to Annex C, “Regional Requirements – Region 3”

Referenced as is, with the exception of optional support for asymmetric PSD masks. Asymmetric PSD masks are not supported by 2BASE-TL.

63.4 Protocol implementation conformance statement (PICS) proforma for Clause 63, Physical Medium Attachment (PMA) and Physical Medium Dependent (PMD), type 2BASE-TL[19]

63.4.1 Introduction

The supplier of a protocol implementation that is claimed to conform to Clause 63, Physical Medium Attachment (PMA) and Physical Medium Dependent (PMD), type 2BASE-TL, 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.

63.4.2 Identification

63.4.2.1 Implementation identification

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

63.4.2.2 Protocol summary

Identification of protocol standard	IEEE Std 802.3-2005, Physical Medium Attachment (PMA) and Physical Medium Dependent (PMD), type 2BASE-TL.
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 802.3-2005.)	
Date of Statement	

[19]*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.

63.4.3 Major capabilities/options

Item	Feature	Subclause	Value/Comment	Status	Support
2BPMA	SHDSL based PMA	63.2	The PMA based on the PMS-TC specified in ITU-T Recommendation G.991.2 is implemented.	M	Yes [ ]
2BPMD	SHDSL based PMD	63.3	The PMD based on the PMD specified in ITU-T Recommendation G.991.2 is implemented.	M	Yes [ ]

63.4.4 PICS proforma tables for the Physical Medium Attachment (PMA) and Physical Medium Dependent (PMD) sublayers, type 2BASE-TL

63.4.4.1 SHDSL based PMA

Item	Feature	Subclause	Value/Comment	Status	Support
2BPMA-1	α(β)-interface	63.1.4.1	The PMA_receive_synchronized is asserted when LOSW is "0" and deasserted when LOSW is "1"	M	Yes [ ]
2BPMA-2	The I-data flow	63.1.4.2.1	If data streams are implemented serially, the LSB of each octet (i.e. b_8 of Figure 61–16) is sent first.	M	Yes [ ]
2BPMA-3	Operation Channel	63.1.4.3	The OC-TC function of the PMA receives the EOC and overhead indicators over the OC-TC interface.	M	Yes [ ]
2BPMA-4	Operation Channel	63.1.4.3	The EOC and overhead indicators are included in the overhead sections of the 2BASE-TL PMA frames.	M	Yes [ ]
2BPMA-5	General exceptions	63.2.1	The 2BASE-TL PMA is octet oriented.	M	Yes [ ]
2BPMA-6	General exceptions	63.2.1	The bit oriented parameter i defined for Equation (63–1) and Equation (63–3) is equal to 0 in all cases.	M	Yes [ ]
2BPMA-7	Specific requirements and exceptions	63.2.2	The 2BASE-TL PMA complies to the requirements of G.991.2 Section 7.	M	Yes [ ]
2BPMA-8	Specific requirements and exceptions	63.2.2	The 2BASE-TL PMA complies to the requirements of G.991.2 Section 9.	M	Yes [ ]
2BPMA-9	Reference 7.1	63.2.2.1	2BASE-TL operates in synchronous mode. Bits stb1 and stb2 are present in every frame, and stb3 and stb4 are not present.	M	Yes [ ]
2BPMA-10	Reference 7.1	63.2.2.1	Since different frame synchronization algorithms require different values for the bits of the FSW, a provision has been made to allow the receiver to inform the far end transmitter of the particular values that are to be used for this field according to 61.4.	M	Yes [ ]

63.4.4.2 SHDSL based PMD

Item	Feature	Subclause	Value/Comment	Status	Support
2BPMD-1	General exceptions	63.3.1	The 2BASE-TL PMD is octet oriented.	M	Yes [ ]
2BPMD-2	General exceptions	63.3.1	The 2BASE-TL PMD supports the use of the 32-TCPAM constellation for specific rates.	M	Yes [ ]
2BPMD-4	General exceptions	63.3.1	The 2BASE-TL PMD supports the use of the enhanced SHDSL extended bandwidths.	M	Yes [ ]
2BPMD-5	General exceptions	63.3.1	The bit oriented parameter *i* defined for Equation (63–1) and Equation (63–3) is equal to 0 in all cases.	M	Yes [ ]
2BPMD-6	Specific requirements and exceptions	63.3.2	The 2BASE-TL PMD complies to the requirements of G.991.2 Section 5, Section 6, Section 10, Section 11, Section 12.	M	Yes [ ]
2BPMD-7	Specific requirements and exceptions	63.3.2	The 2BASE-TL PMD complies to at least one of the three regional annexes: Annex A, Annex B, or Annex C with the exception of performance, which is defined in Annex 63B.	M	Yes [ ]
2BPMD-8	Reference section 6	63.3.2.2	The 16 & 32 TC-PAM mappings are per Table 63–5.	M	Yes [ ]
2BPMD-9	Changes to Annex A/B	63.3.2.4.2 63.3.2.5.2	The DC resistance of the 2BASE-TL-R is 1000 ohms plus or minus 10%.	M	Yes [ ]
2BPMD-10	Changes to Annex A/B	63.3.2.4.2 63.3.2.5.2	The 2BASE-TL-R is capable of sustaining 20 mA of wetting (sealing) current.	M	Yes [ ]

64. Multipoint MAC Control

64.1 Overview

This clause deals with the mechanism and control protocols required in order to reconcile the 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 paths 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 asymmetrical 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, 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 64–1. Clause 67 provides additional examples of P2MP topologies.

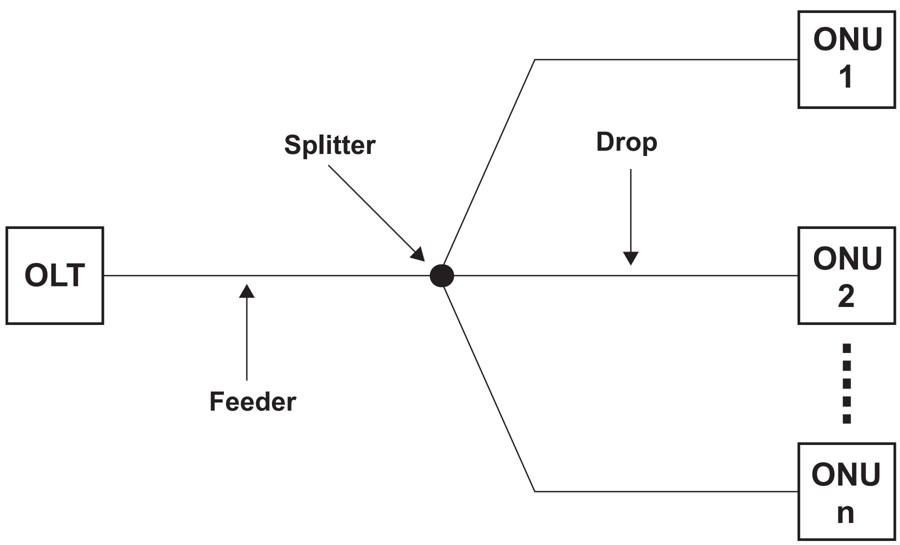


Figure 64–1—PON topology example

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 65.1.3.3.2), and dynamic binding to a MAC connected to the OLT.

The Multipoint MAC Control functionality shall be implemented for subscriber access devices containing point-to-multipoint physical layer devices defined in Clause 60.

64.1.1 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:

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

64.1.2 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 64–2 depicts 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.

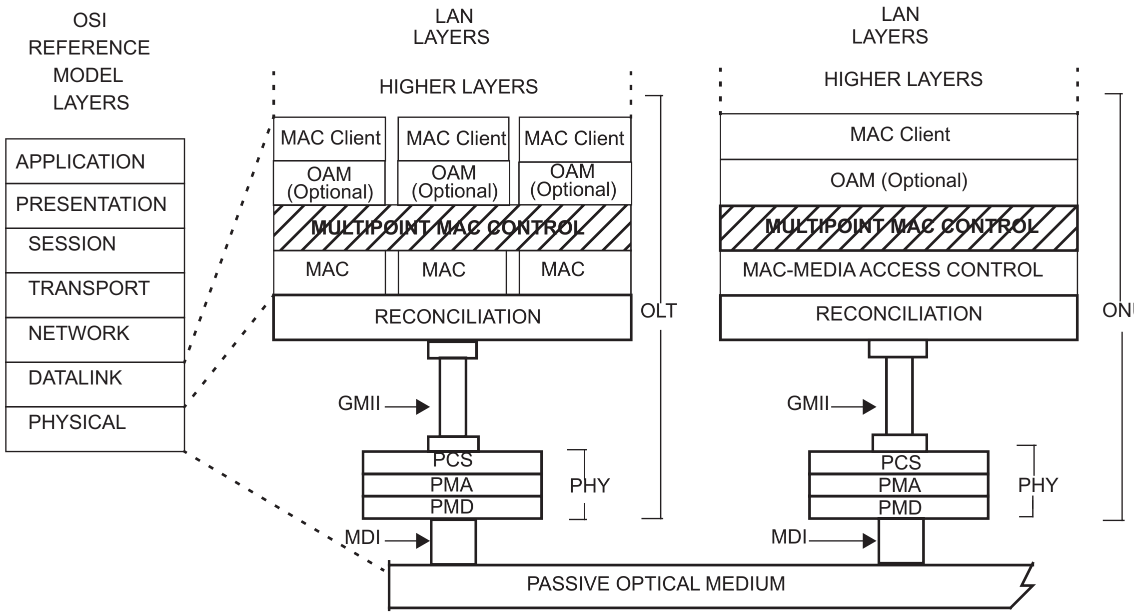
Multipoint MAC Control is defined using the mechanisms and precedents of the MAC Control sublayer. The MAC Control sublayer has extensive functionality designed to manage the real-time control and manipulation of MAC sublayer operation. This clause specifies the extension of the MAC Control mechanism 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 64–2, 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 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 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 65.1.3.3).

Although Figure 64–2 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 LLID which is dynamically assigned by the registration process.



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 64–2—Relationship of Multipoint MAC Control and the OSI protocol stack

64.1.3 Functional block diagram

Figure 64–3 provides a functional block diagram of the Multipoint MAC Control architecture.

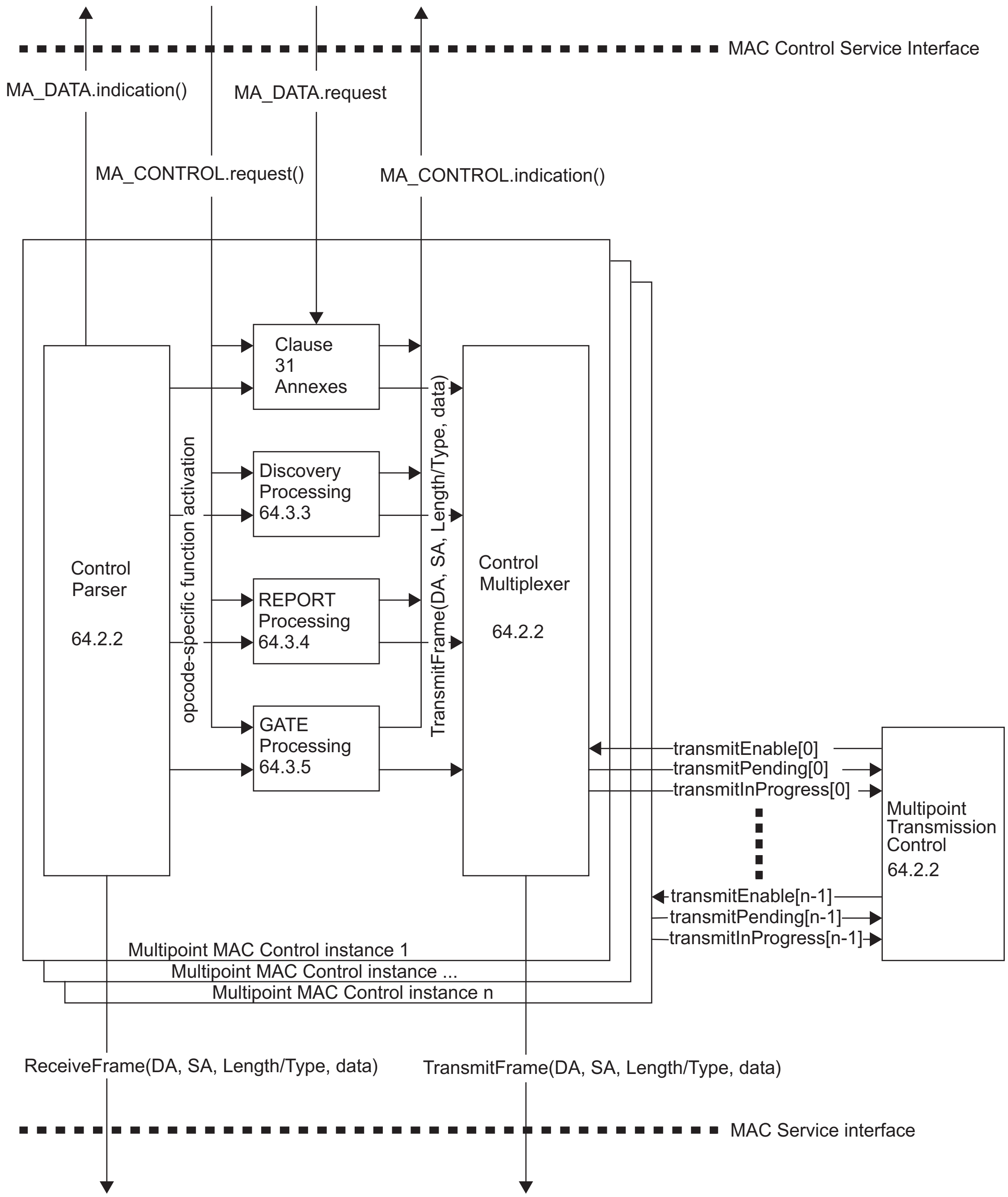


Figure 64–3—Multipoint MAC Control Functional Block Diagram

64.1.4 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 4A.3.2. Similarly, Multipoint MAC Control communicates internally using primitives and interfaces consistent with definitions in Clause 31.

64.1.5 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 !($a > b$)

64.2 Multipoint MAC Control operation

As depicted in Figure 64–3, 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.

64.2.1 Principles of Multipoint MAC Control

As depicted in Figure 64–3, 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 65.1.

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 ReceiveFrame interface in MAC *j* enables the indication interface of Client *j*. Conversely, the assertion of the request service interface in Client *i* enables the TransmitFrame interface 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 ReceiveFrame function calls 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 ReceiveFrame 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 ReceiveFrame function call.

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 MA_DATA primitive, and for this purpose 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 enables the ReceiveFrame interface of the MAC. Only one receive MAC interface will be 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 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 are forwarded to the MAC Client by asserting MA_DATA.indication primitives

Transmit operation at each instance:

e) The MAC Client signals a frame transmission by asserting 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.

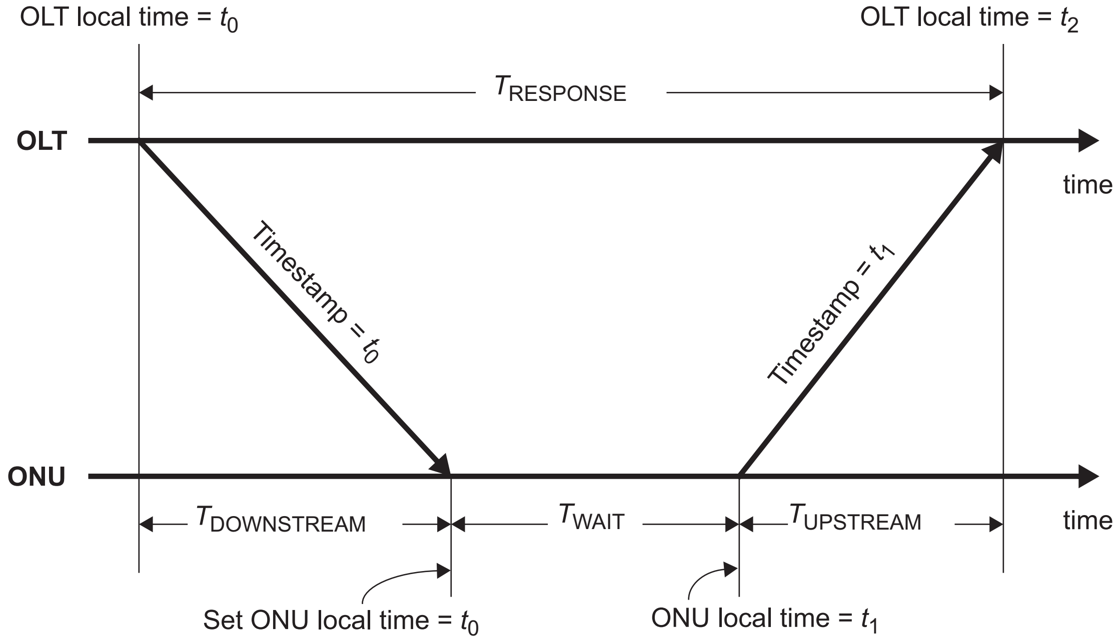
64.2.1.1 Ranging and Timing Process

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 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 64.2.2.1), as shown in Figure 64–10. 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 64.2.2.1), as is shown in Figure 64–11.



$T_{DOWNSTREAM}$ = 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 64–4—Round trip time calculation

64.2.2 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.

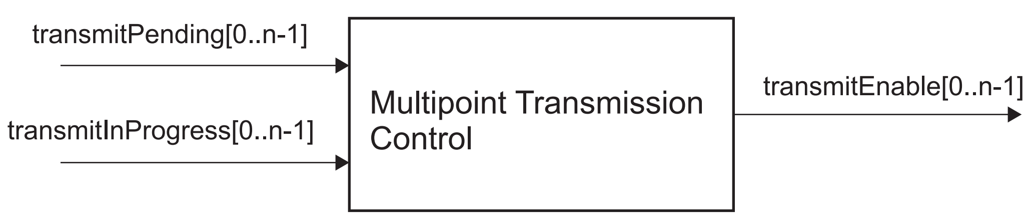


Figure 64–5—Multipoint Transmission Control Service Interfaces

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 64–3).

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 MA_DATA.request primitives from the MAC Client, and MA_CONTROL.request primitives from the MAC Control Clients, a single TransmitFrame 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.

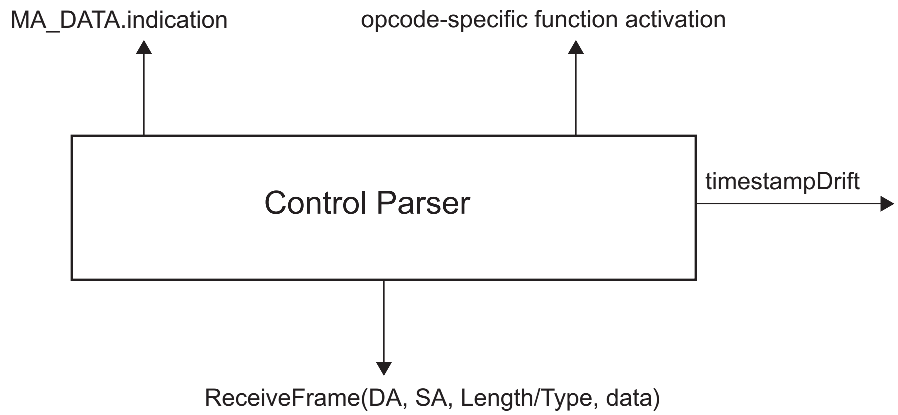
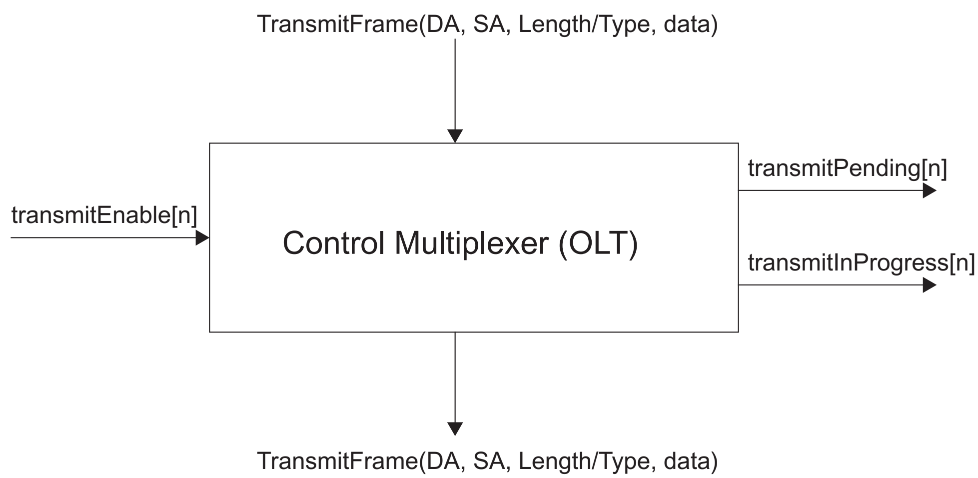
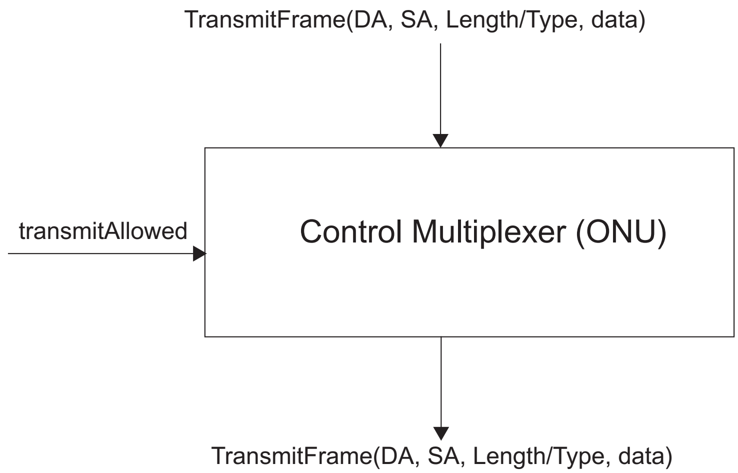


Figure 64–6—Control Parser Service Interfaces



NOTE—TransmitFrame primitive may be issued from multiple MAC Control processing blocks.

Figure 64–7—OLT Control Multiplexer Service Interfaces



NOTE—TransmitFrame primitive may be issued from multiple MAC Control processing blocks.

Figure 64–8—ONU Control Multiplexer Service Interfaces

64.2.2.1 Constants

defaultOverhead
: This constant holds the size of packet transmission overhead. This overhead is measured in units of time quanta.
TYPE: integer
VALUE: 6

guardThresholdOLT
: This constant holds the maximal amount of drift allowed for a timestamp received at the OLT. This value is measured in units of time_quantum (16 bit times).
TYPE: integer
VALUE: 12

guardThresholdONU
: This constant holds the maximal amount of drift allowed for a timestamp received at the ONU. This value is measured in units of time_quantum (16 bit times)
TYPE: integer
VALUE: 8

MAC_Control_type
: The value of the Length/Type field as defined in Clause 31.4.1.3.
TYPE: integer
VALUE: 0x8808

tailGuard
: 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 the End of Packet Delimiter (EPD). The sizes of the above listed MAC overhead items are described in Clause 3.1.1. The size of the EPD is described in Clause 36.2.4.14.
TYPE: integer
VALUE: 29

time_quantum

The unit of time_quantum is used by all mechanisms synchronized to the advancement of the localTime variable. All variables that represent counters and time intervals are defined using time_quantum. Each time_quantum is 16 ns.

TYPE: integer

VALUE: 16

tqSize

This constant represents time_quantum in octet transmission times.

TYPE: integer

VALUE: 2

64.2.2.2 Counters

localTime

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 65.3.1.2. It is reloaded with the received timestamp value (from the OLT) by the Control Parser (see Figure 64–11). Changing the value of this variable while running using Layer Management is highly undesirable and is unspecified.

TYPE: 32 bit unsigned

64.2.2.3 Variables

BEGIN

This variable is used when initiating operation of the functional block state machine. It is set to true following initialization and every reset.

TYPE: boolean

data_rx

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.

TYPE: bit array

data_tx

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.

TYPE: bit array

fecEnabled

This variable represents whether the FEC function is enabled. If FEC function is enabled, this variable equals true, otherwise it equals false.

TYPE: boolean

newRTT

This variable temporary holds a newly-measured Round Trip Time to the ONU. The new RTT value is represented in units of time_quanta.

TYPE: 16 bit unsigned

nextTxTime

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 nextTxTime includes packet transmission time, tailGuard defined in 64.2.2.1, and FEC parity data overhead, if FEC is enabled. This variable is measured in units of time quanta.

TYPE: 16 bit unsigned

opcode_rx
This variable holds an opcode of the last received MPCPDU.
TYPE: 16 bit unsigned

opcode_tx
This variable holds an opcode of an outgoing MPCPDU.
TYPE: 16 bit unsigned

packet_initiate_delay
This variable is used to set the time-out interval for packet_initiate_timer defined in 64.2.2.5. The packet_initiate_delay value is represented in units of time_quanta.
TYPE: 16 bit unsigned

RTT
This variable holds the measured Round Trip Time to the ONU. The RTT value is represented in units of time_quanta.
TYPE: 16 bit unsigned

stopTime
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 64.3.5.
TYPE: 32 bit unsigned

timestamp
This variable holds the value of timestamp of the last received MPCPDU frame.
TYPE: 32 bit unsigned

timestampDrift
This variable is used to indicate whether an error is signaled as a result of uncorrectable timestamp drift.
TYPE: boolean

transmitAllowed
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.
TYPE: boolean

transmitEnable[j]
These variables are used to control the transmit path in a Multipoint MAC Control instance at the OLT. Setting them to on indicates that the selected instance is permitted to transmit a frame. Setting it to off inhibits the transmission of frames in the selected instance. Only one of transmitEnable[j] should be set to on at a time.
TYPE: boolean

transmitInProgress[j]
This variable indicates that the Multipoint MAC Control instance *j* is in a process of transmitting a frame.
TYPE: boolean

transmitPending[j]
This variable indicates that the Multipoint MAC Control instance *j* is ready to transmit a frame.
TYPE: boolean

64.2.2.4 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.

FEC_Overhead(length)

This function calculates the size of additional overhead to be added by the FEC encoder while encoding a frame of size length. Parameter length represents the size of an entire frame including preamble, SFD, DA, SA, Length/Type, and FCS. As specified in 65.2.3, FEC encoder adds 16 parity octets for each block of 239 data octets. Additionally, 26 code-groups are required to accommodate IPG and longer start-of-frame and end-of-frame sequences, which are used to allow reliable packet boundary detection in presence of high bit error ratio. The function returns the value of FEC overhead in units of time quanta. The following formula is used to calculate the overhead:

$$FEC\_Overhead = 13 + \left\lceil \frac{length}{239} \right\rceil \times 8$$

NOTE–The notation $\lceil x \rceil$ represents a *ceiling* function, which returns the value of its argument x rounded up to the nearest integer.

ReceiveFrame(DA, SA, Length/Type, data)

The MAC Sublayer function that is called to receive a frame with the specified parameters.

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 will be 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.

TransmitFrame(DA, SA, Length/Type, data)

The MAC Sublayer function that is called to transmit a frame with the specified parameters.

64.2.2.5 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, when FEC is enabled, this timer increases interframe spacing just enough to accommodate the extra parity data to be added by the FEC encoder.

64.2.2.6 Messages

MA_DATA.indication(DA, SA, m_sdu, receiveStatus)
The service primitive is defined in 2.3.2.

64.2.2.7 State Diagrams

The Multipoint transmission control function in the OLT shall implement state diagram shown in Figure 64–9. Control parser function in the OLT shall implement state diagram shown in Figure 64–10. Control parser function in the ONU shall implement state diagram shown in Figure 64–11. Control multiplexer function in the OLT shall implement state diagram shown in Figure 64–12. Control multiplexer function in the ONU shall implement state diagram shown in Figure 64–13.

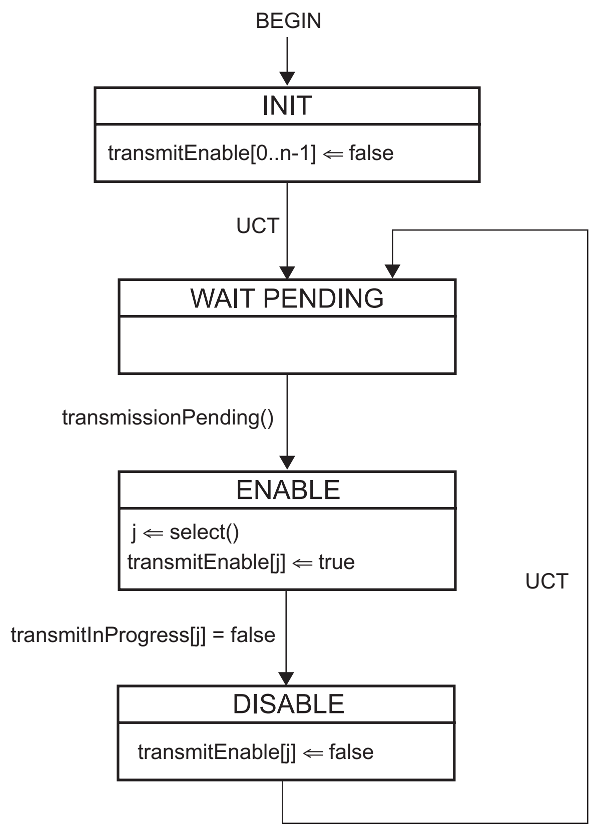
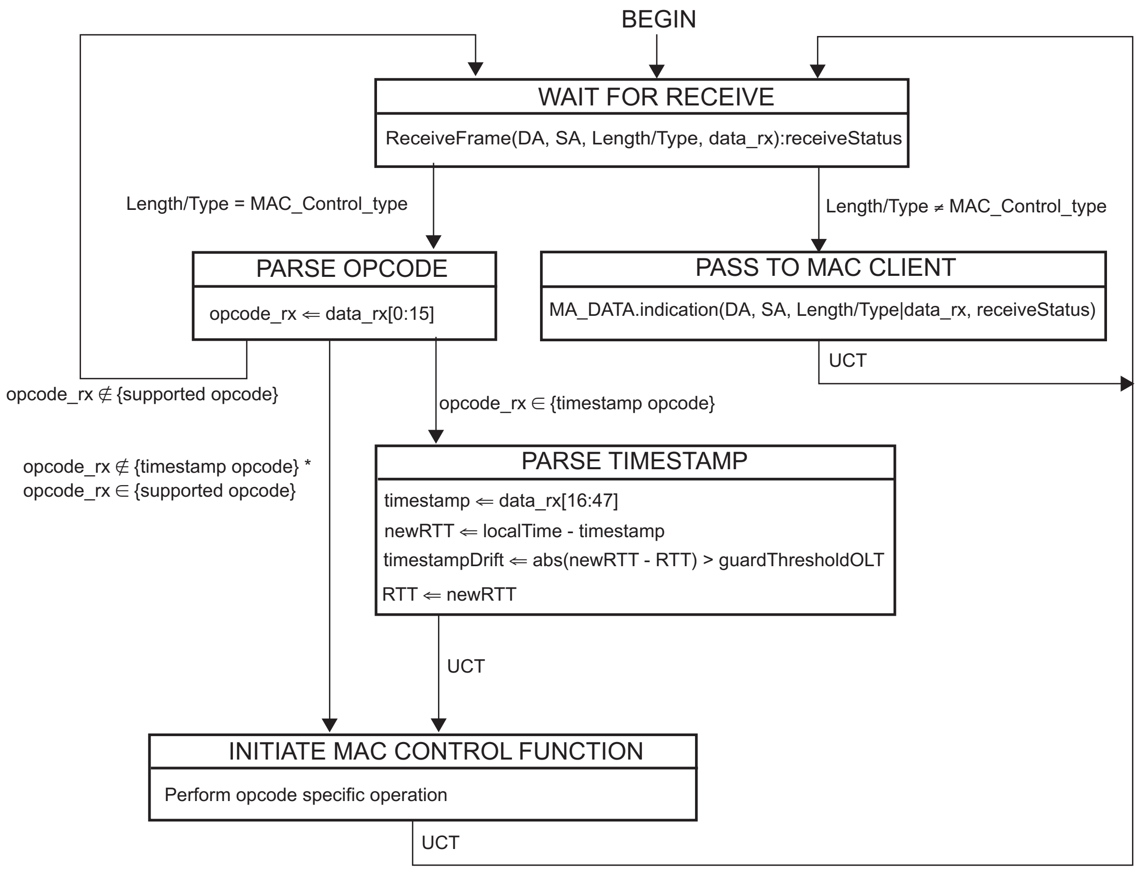


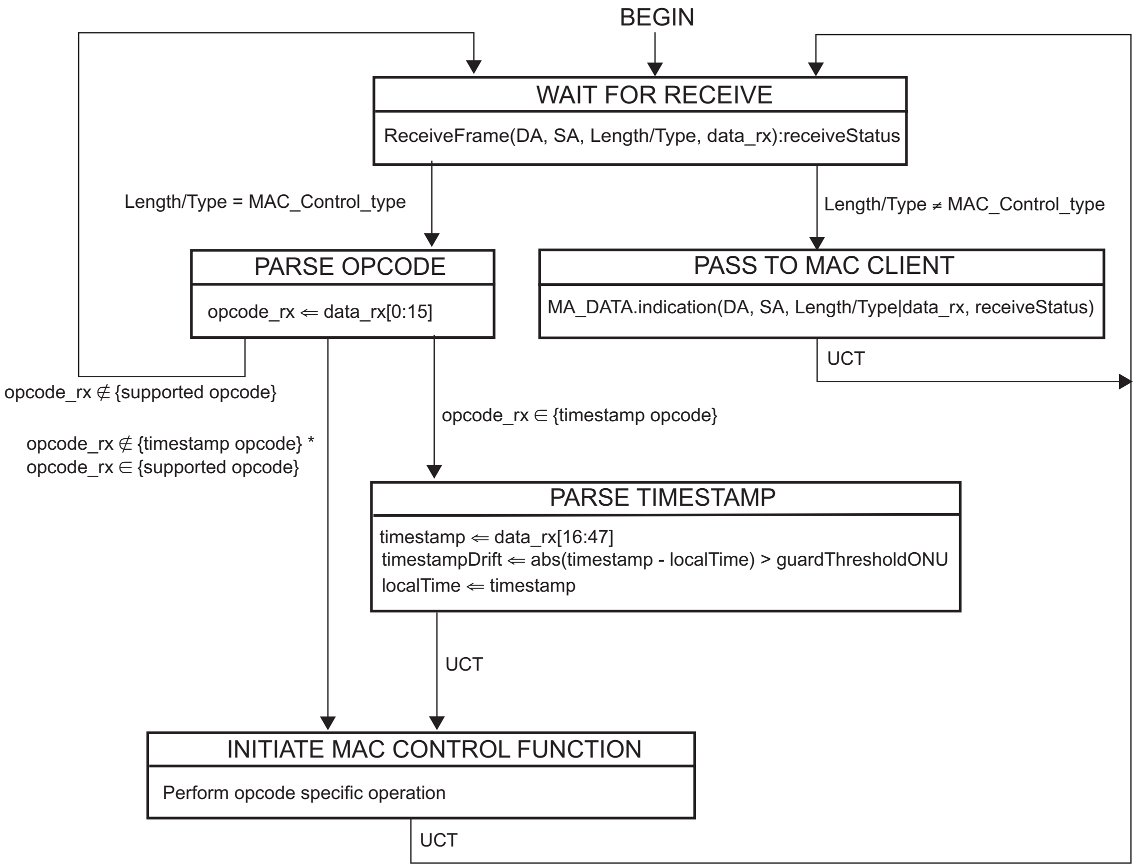
Figure 64–9—OLT Multipoint Transmission Control state diagram



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 machine (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 64–10—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 machine (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 64–11—ONU Control Parser state diagram

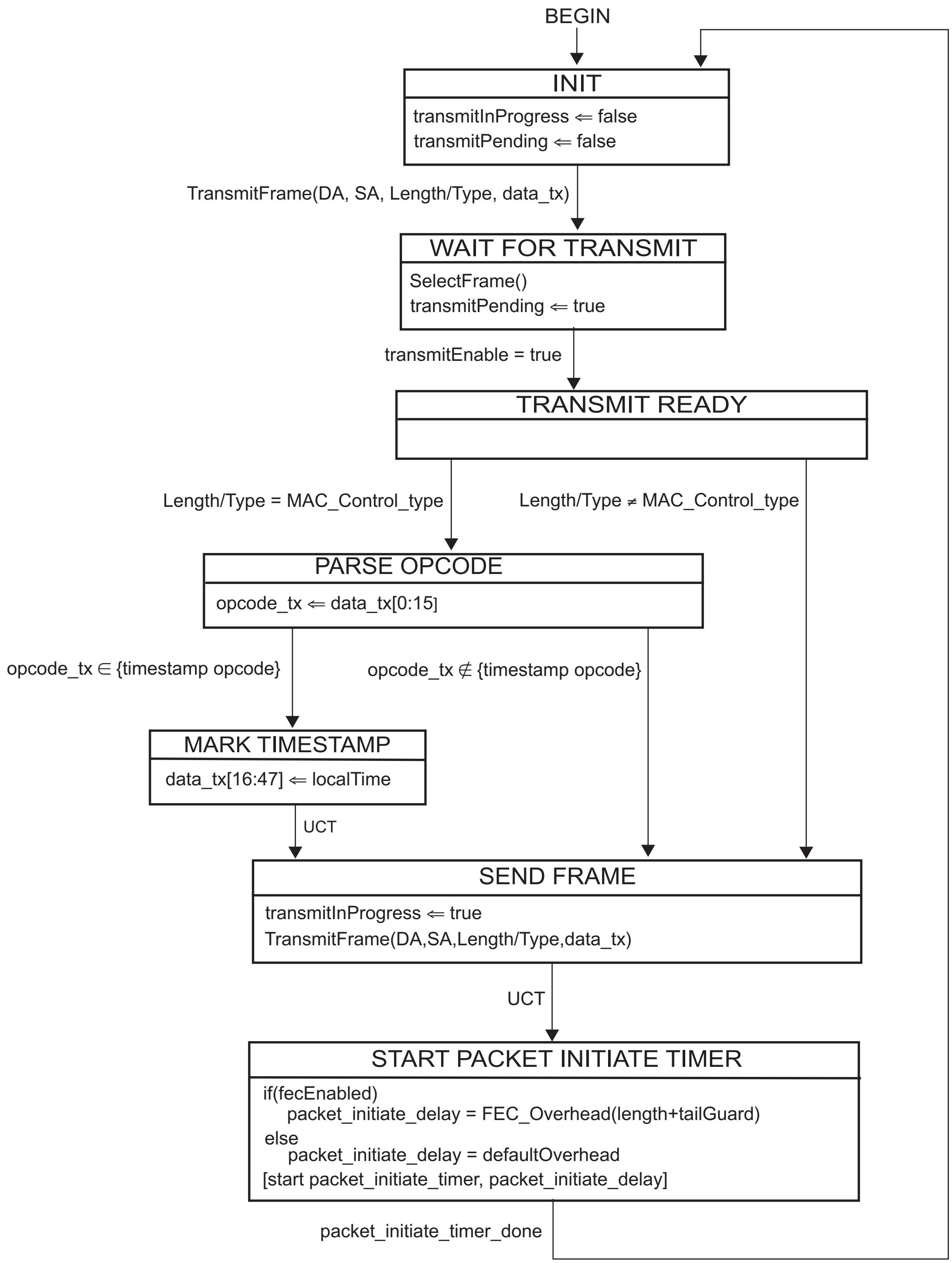


Figure 64–12—OLT Control Multiplexer state diagram

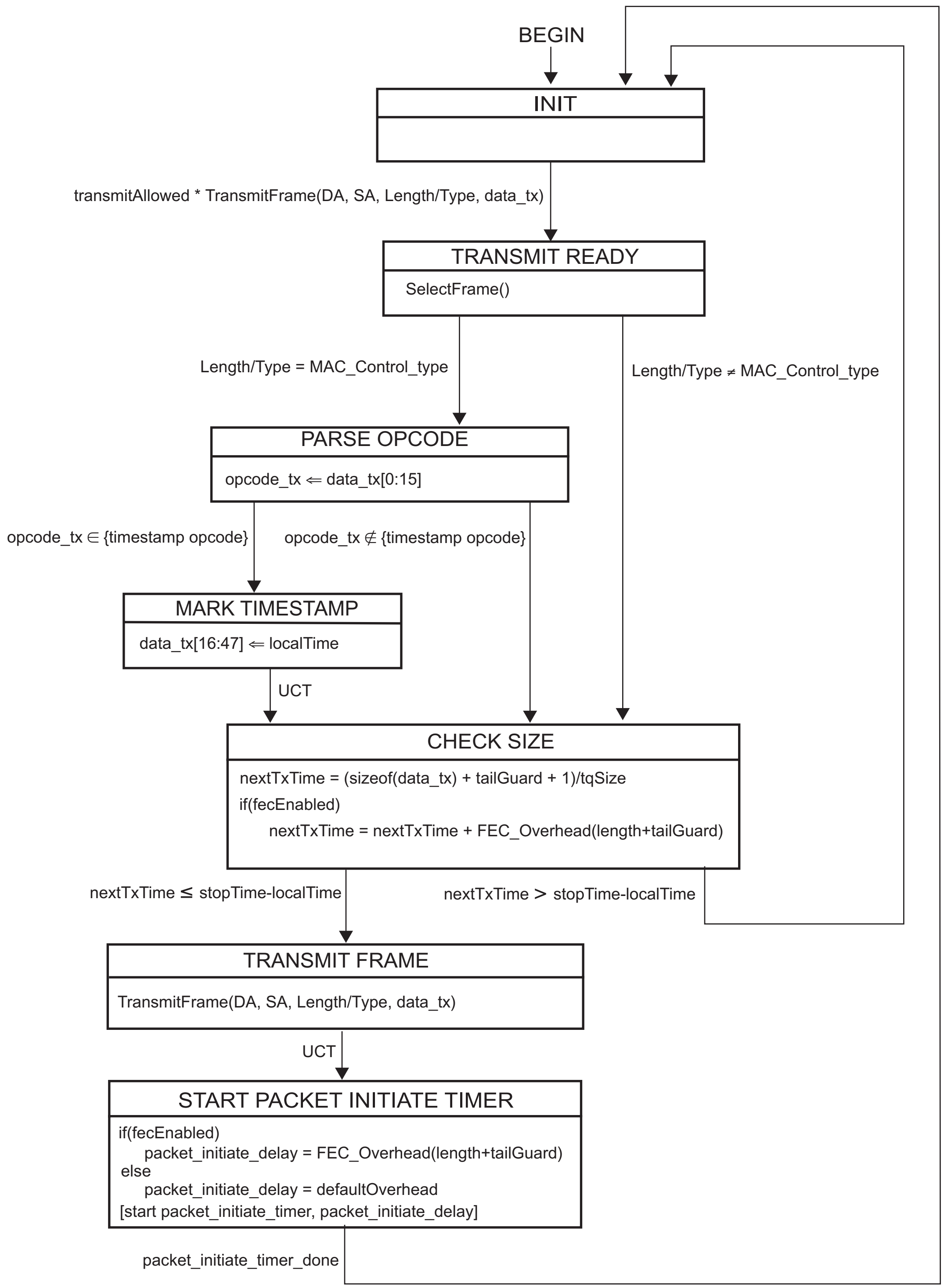


Figure 64–13—ONU Control Multiplexer state diagram

64.3 Multipoint Control Protocol (MPCP)

As depicted in Figure 64–3, 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 64–3, 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.

64.3.1 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 asymmetrical, with the OLT assuming the role of master, and the ONU assuming the role of slave.

64.3.2 Compatibility considerations

64.3.2.1 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 64.3.2.4.

NOTE—MAC at an ONU can receive frames from unicast channel and single-copy-broadcast (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.

64.3.2.2 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 65.1.3.3.2.

64.3.2.3 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 multiple duplication for each ONU, the single-copy broadcast (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 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 802.1D bridge port.

SCB channel configuration as well as filtering and marking of frames for support of SCB is defined in 65.1.3.3.2.

64.3.2.4 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 16 bit times through the implemented MAC stack.

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 as 16 ns.

64.3.3 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 Time 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 message, which includes the starting time and length of the discovery window. Off-line ONUs, upon receiving this message, wait for the period to begin and then transmit a REGISTER_REQ message to the OLT. Discovery windows are unique in that they are the only times where 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 shall wait a random amount of time before transmitting the REGISTER_REQ message that is shorter than the length of the discovery time window. It should be noted that multiple valid REGISTER_REQ messages can be received by the OLT during a single discovery time period. Included in the REGISTER_REQ message is the ONU's MAC address and number of maximum pending grants. Upon receipt of a valid REGISTER_REQ message, the OLT registers the ONU, allocating and assigning new port identities (LLIDs), and bonding corresponding MACs to the LLIDs.

The next step in the process is for the OLT to transmit a Register message to the newly discovered ONU, which contains the ONU's LLID, and the OLT's required synchronization time. Also, the OLT echoes the maximum number of pending grants. 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 64–14.

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 will force 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.

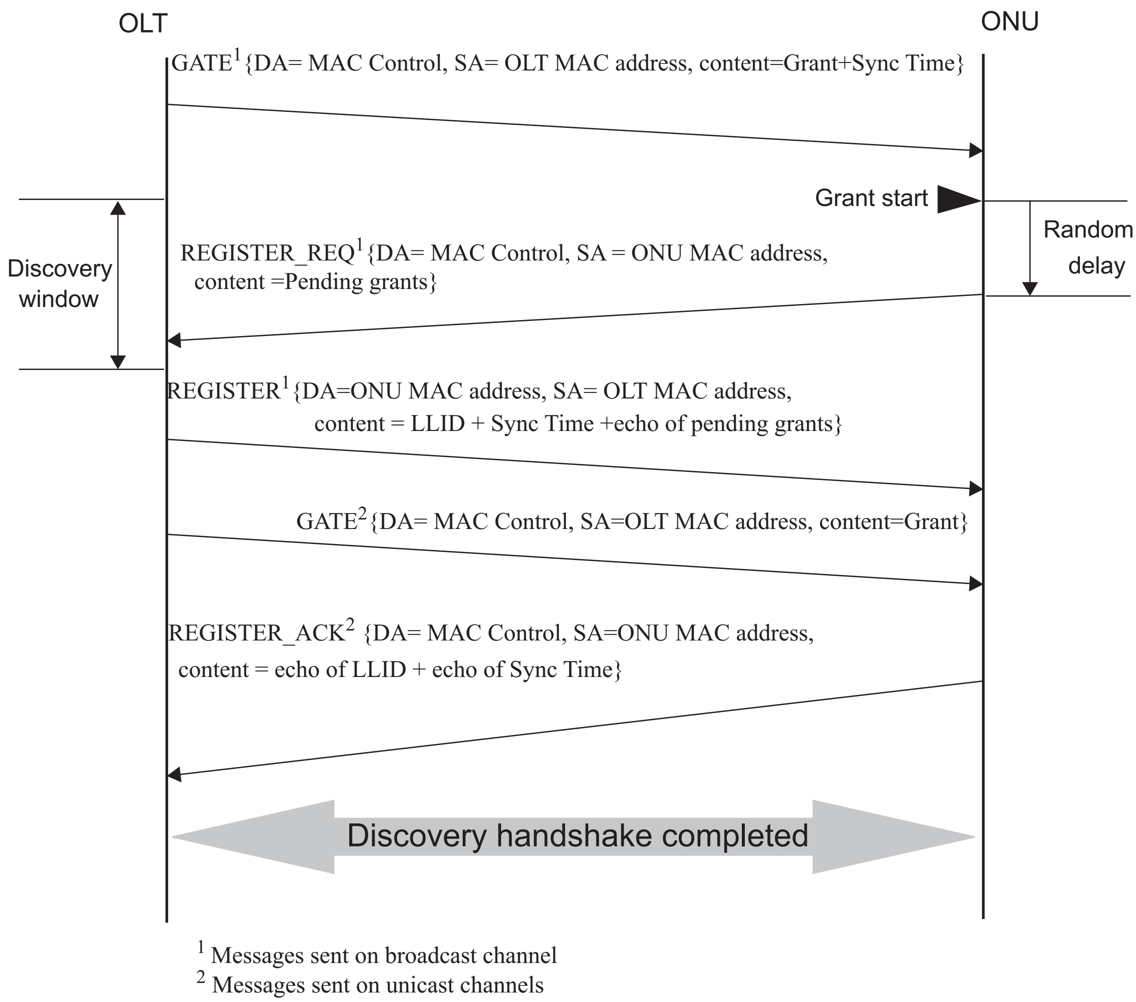


Figure 64–14—Discovery Handshake Message Exchange

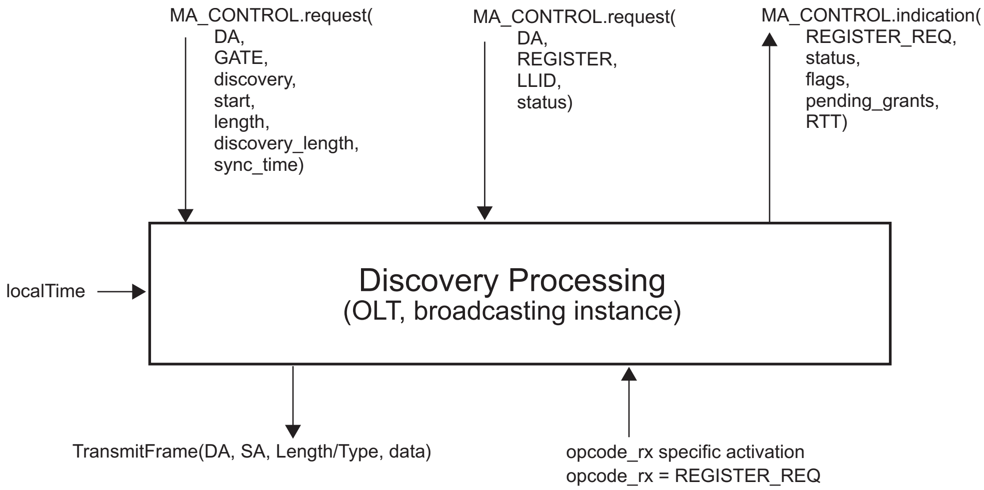


Figure 64–15—Discovery Processing Service Interfaces (OLT, broadcasting instance)

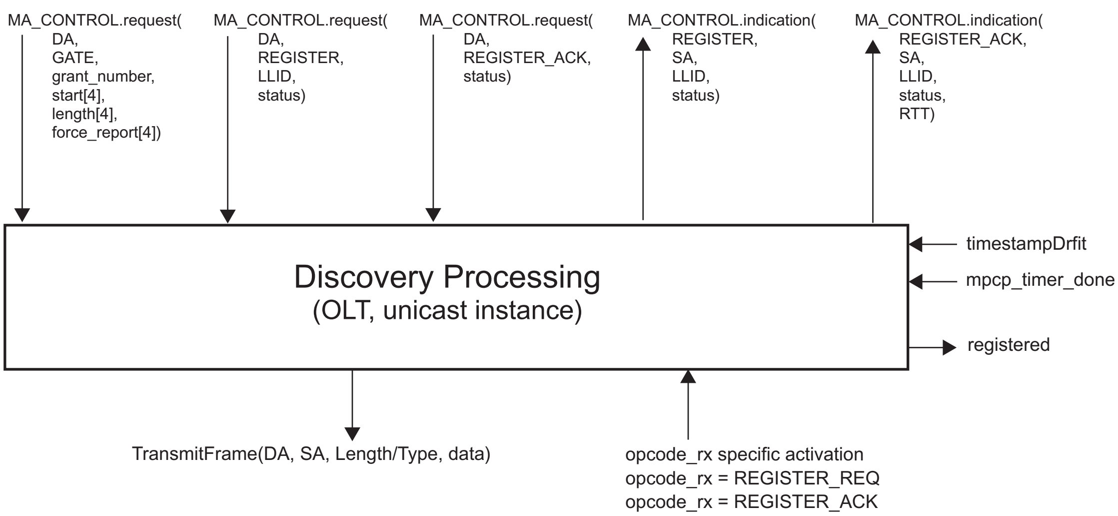


Figure 64–16—Discovery Processing Service Interfaces (OLT, unicasting instance)

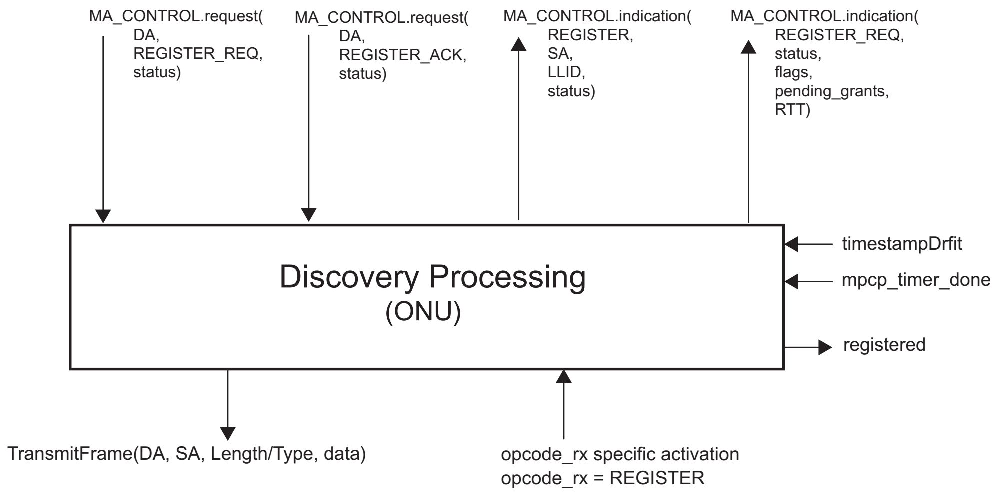


Figure 64–17—Discovery Processing Service Interfaces (ONU)

64.3.3.1 Constants

No constants defined.

64.3.3.2 Variables

BEGIN
: This variable is defined in 64.2.2.3.

data_rx
: This variable is defined in 64.2.2.3.

data_tx
: This variable is defined in 64.2.2.3.

grantEndTime
: 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.
: TYPE: 32-bit unsigned

insideDiscoveryWindow
: 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.
: TYPE: boolean

localTime
: This variable is defined in 64.2.2.2.

opcode_rx
: This variable is defined in 64.2.2.3.

opcode_tx
: This variable is defined in 64.2.2.3.

pendingGrants

This variable holds the maximum number of pending grants that an ONU is able to queue.

TYPE: 16 bit unsigned

registered

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.

TYPE: boolean

syncTime

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 60.7.13.2. The OLT conveys the value of syncTime to ONUs in Discovery GATE and REGISTER messages. During the synchronization time only IDLE patterns can be transmitted by an ONU.

TYPE: 16 bit unsigned

timestampDrift

This variable is defined in 64.2.2.3.

64.3.3.3 Functions

ReceiveFrame(DA, SA, Length/Type, data)

This function is defined in 64.2.2.4.

TransmitFrame(DA, SA, Length/Type, data)

This function is defined in 64.2.2.4.

64.3.3.4 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.

64.3.3.5 Messages

MA_CONTROL.request(DA, GATE, discovery, start, length, discovery_length, sync_time)

The service primitive 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.

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)

The service primitive 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 64–3.

MA_CONTROL.indication(REGISTER_REQ, status, flags, pending_grants, RTT)

The service primitive 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 will 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 is in the OLT.
pending_grants:	This parameters 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.

MA_CONTROL.request(DA, REGISTER, LLID, status, pending_grants)

The service primitive 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 64–4.
pending_grants: This parameters echoes back the pending_grants field that was previously received in the REGISTER_REQ message.

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 is 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 64–5.

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 is 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.

64.3.3.6 State Diagram

Discovery process in the OLT shall implement the discovery window setup state diagram shown in Figure 64–18, request processing state diagram as shown in Figure 64–19, register processing state diagram as shown in Figure 64–20, and final registration state diagram as shown in Figure 64–21. The discovery process in the ONU shall implement registration state diagram as shown in Figure 64–22.

Instantiation of state machines as described in Figure 64–18, Figure 64–19, and Figure 64–20 is performed only at the Multipoint MAC Control instance attached to the broadcast LLID. Instantiation of state machines as described in Figure 64–21 and Figure 64–22 is performed for every Multipoint MAC Control instance, except the instance attached to the broadcast channel.

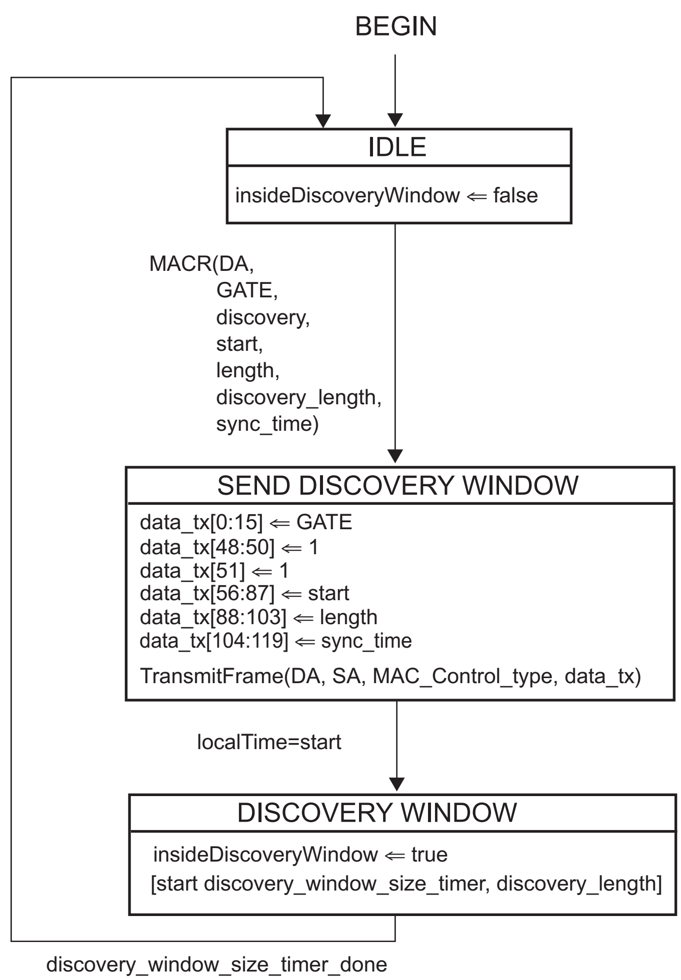


Figure 64–18—Discovery Processing OLT Window Setup State Diagram

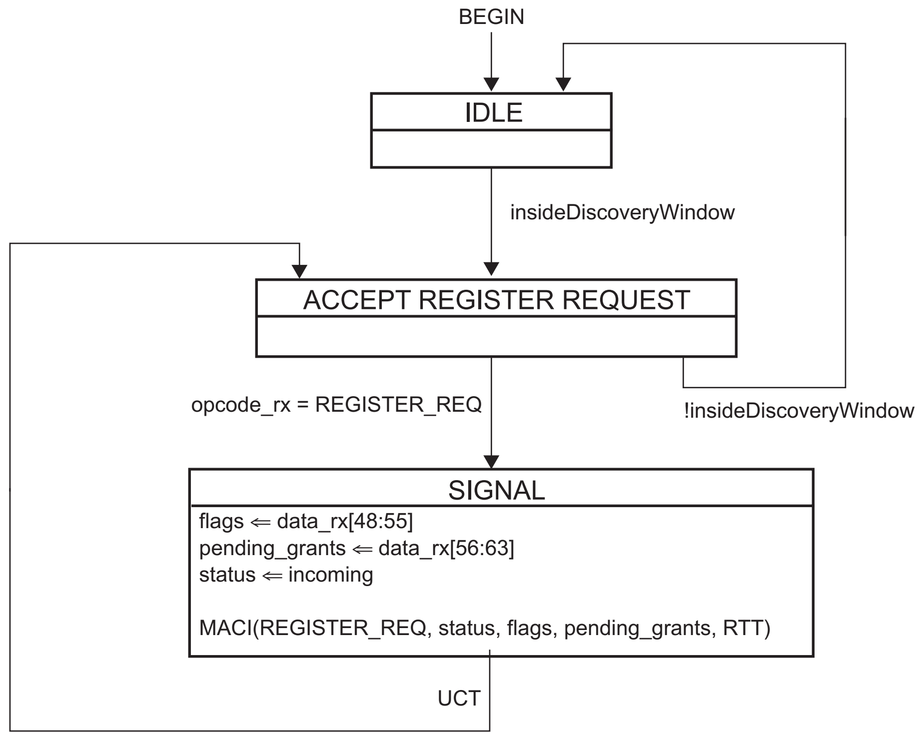


Figure 64–19—Discovery Processing OLT Process Requests State Diagram

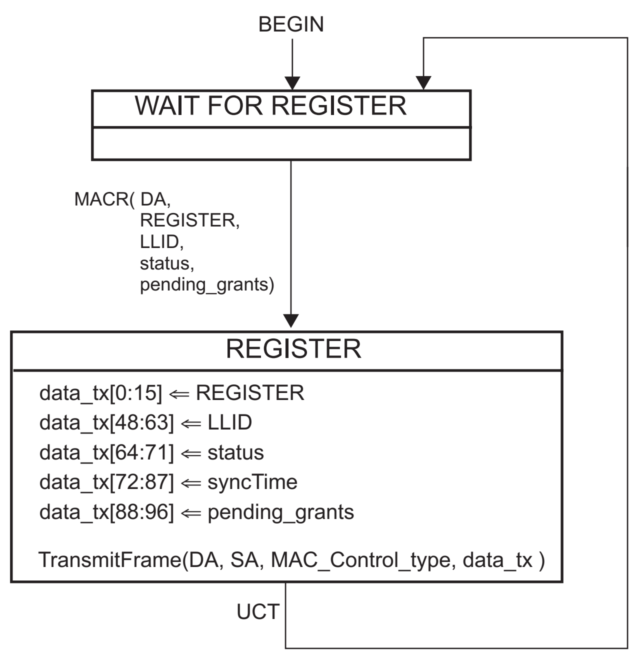
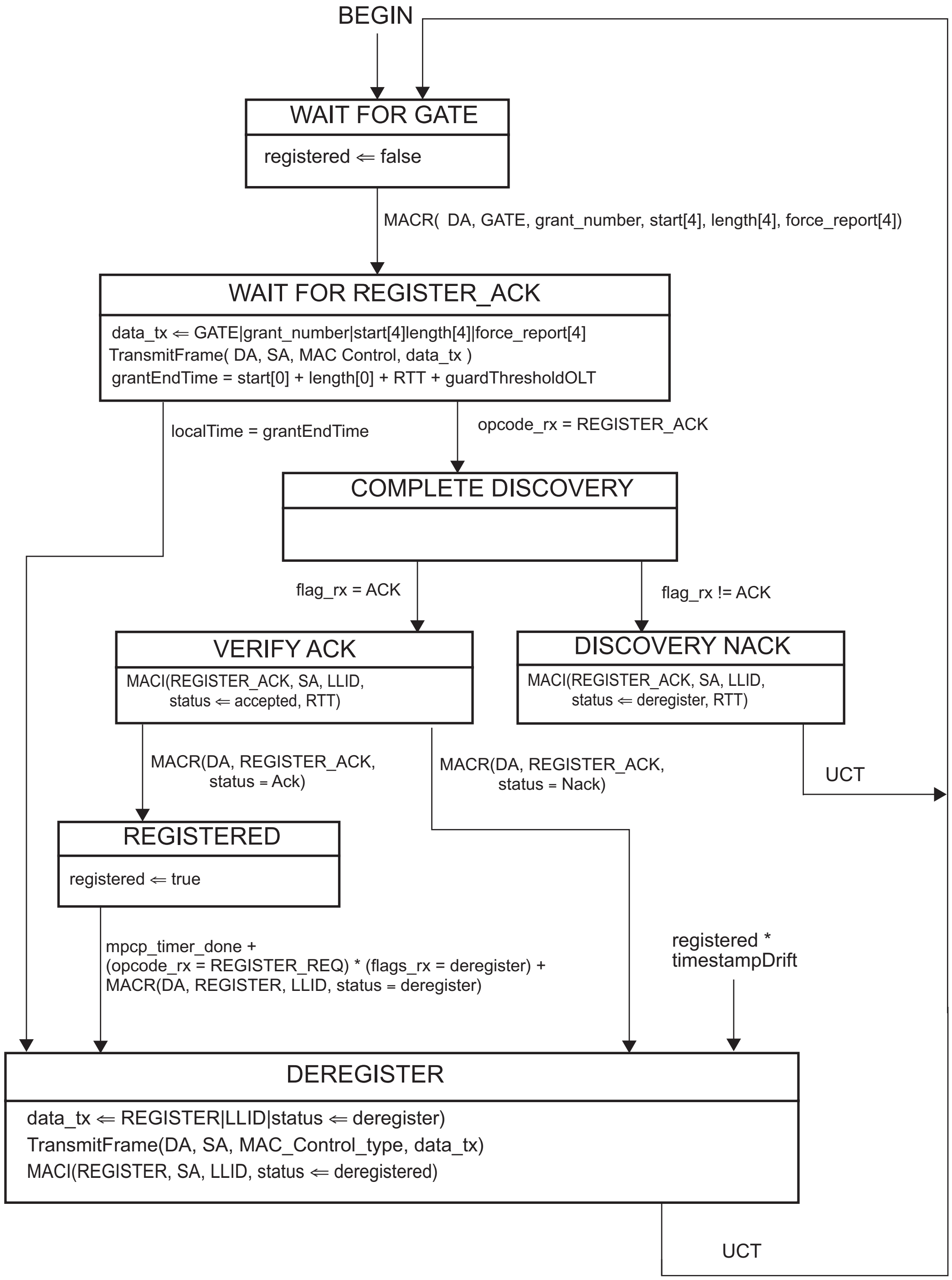


Figure 64–20—Discovery Processing OLT Register State Diagram



NOTE— The MAC Control Client issues the grant following the REGISTER message, taking the ONU processing delay of REGISTER message into consideration.

Figure 64–21—Discovery Processing OLT Final Registration State Diagram

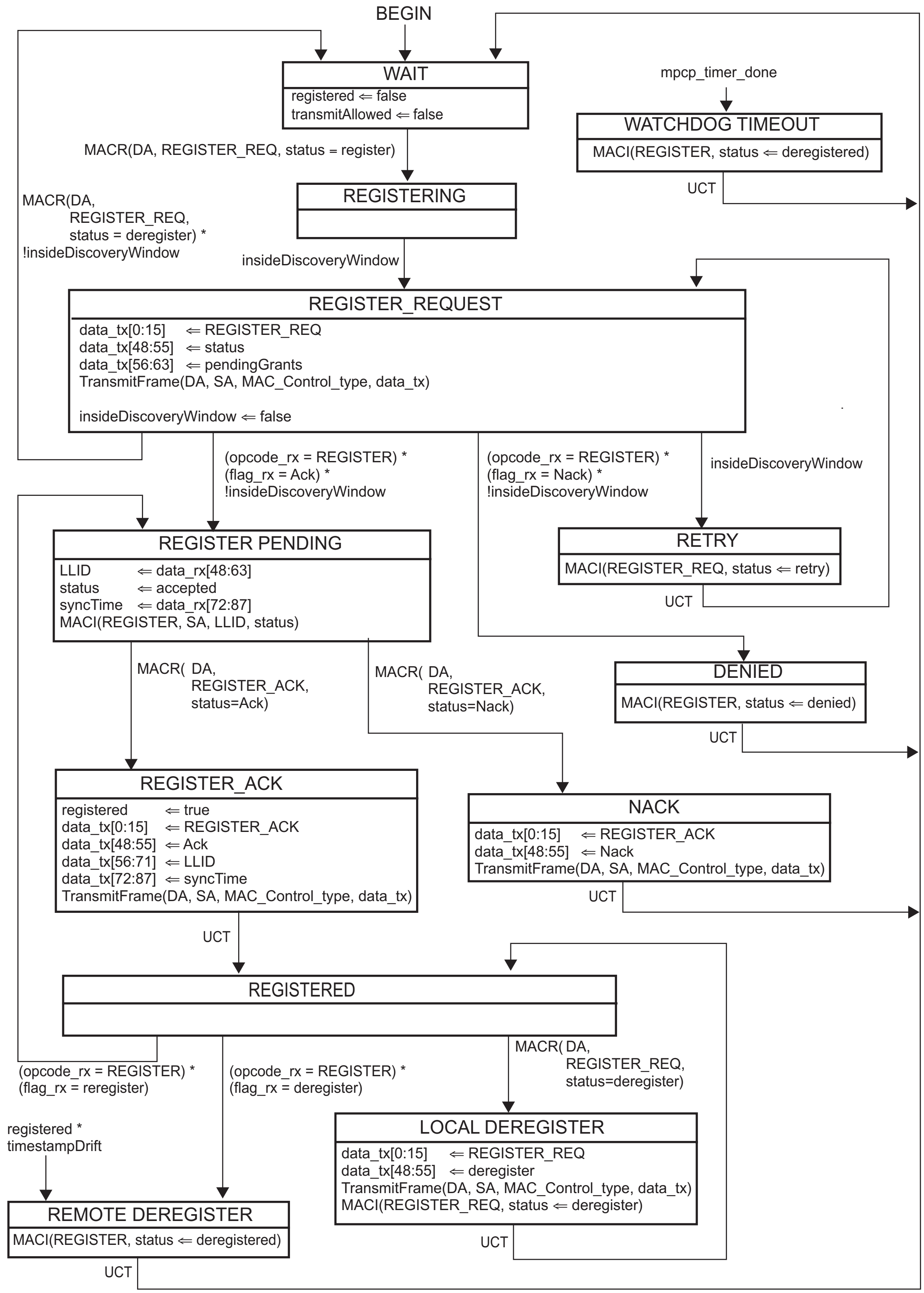


Figure 64–22—Discovery Processing ONU Registration State Diagram

64.3.4 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 802.1P capable bridge.

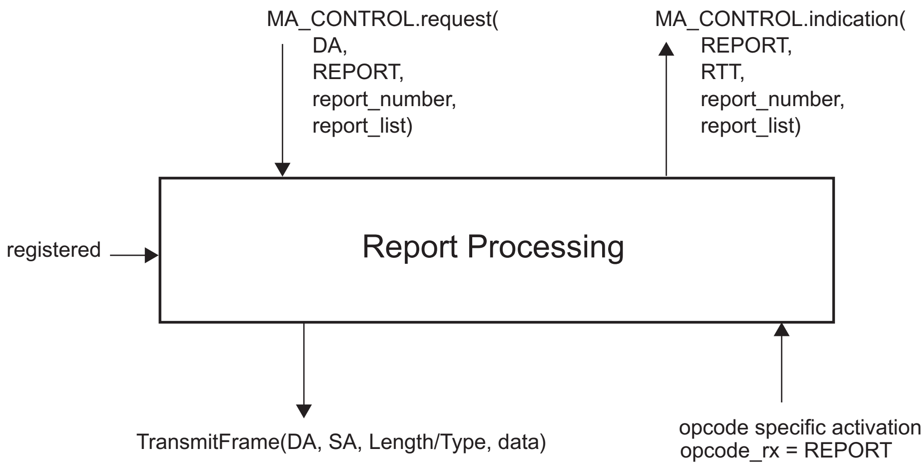


Figure 64–23—Report Processing Service Interfaces

64.3.4.1 Constants

mpcp_timeout
: 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.
TYPE 32-bit unsigned
VALUE 03-B9-AC-A0 (1 second)

report_timeout
: This constant represents the maximum allowed interval of time between two REPORT messages generated by the ONU.
TYPE 32-bit unsigned
VALUE 00-2F-AF-08 (50 milliseconds)

64.3.4.2 Variables

BEGIN
: This variable is used when initiating operation of the functional block state machine. It is set to true following initialization and every reset.
TYPE: boolean

data_rx
: This variable is defined in 64.2.2.3.

data_tx
 This variable is defined in 64.2.2.3.

opcode_rx
 This variable is defined in 64.2.2.3.

opcode_tx
 This variable is defined in 64.2.2.3.

registered
 This variable is defined in 64.3.3.2.

64.3.4.3 Functions

TransmitFrame(DA, SA, Length/Type, data)
 This function is defined in 64.2.2.4.

64.3.4.4 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 64.3.3.4.

64.3.4.5 Messages

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 with length of 8, ‘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 index of the array is meant to reflect the same numbered priority queue in the 802.1P nomenclature. The parameter status is an array of 16-bit unsigned integer values. This array consists only of entries whose corresponding bit in filed valid is set to true.

MA_CONTROL.indication(REPORT, RTT, report_number, report_list)

The service primitive 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 which 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 with length of 8, ‘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 index of the array is meant to reflect the same numbered priority queue in the 802.1P nomenclature. The parameter status is an array of 16-bit unsigned integer values. This array consists only of entries whose corresponding bit in filed 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.

64.3.4.6 State Diagram

The report process in the OLT shall implement the report processing state diagram as shown in Figure 64–23. The report process in the ONU shall implement the report processing state diagram as shown in Figure 64–24. Instantiation of state machines as described is performed for Multipoint MAC Control instances attached to unicast LLIDs only.

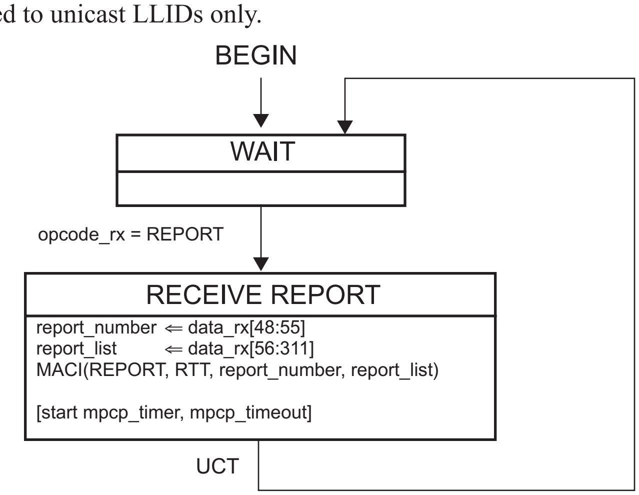


Figure 64–24—Report Processing State Diagram at OLT

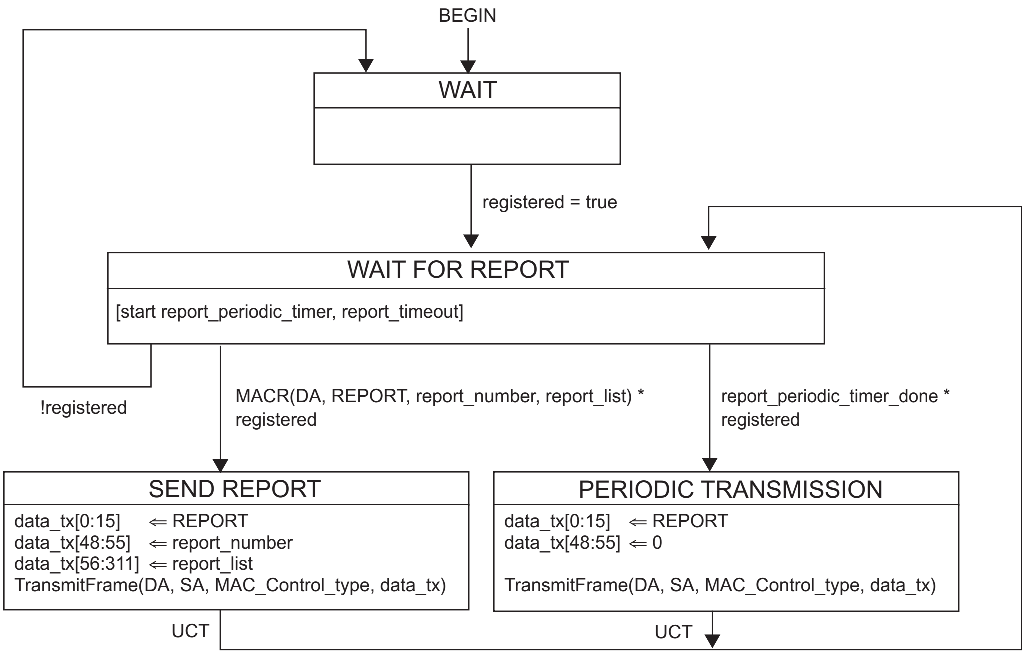


Figure 64–25—Report Processing State Diagram at ONU

64.3.5 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 GATE message where start time and length are specified. An ONU will begin transmission when its localTime counter matches start_time value indicated in the GATE message. An ONU will conclude 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 maximal supported maximal outstanding grants as advertised by the ONU during registration (see pending grants in 64.3.6.3).

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.

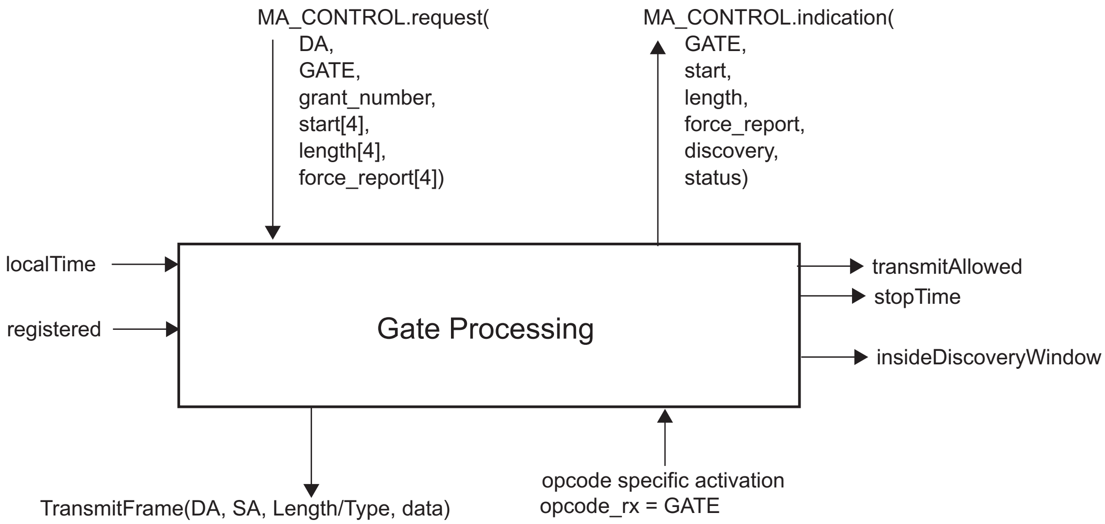


Figure 64–26—Gate Processing Service Interface

64.3.5.1 Constants

discoveryGrantLength
: This constant represents the duration of ONU's transmission during discovery attempt. The value of discoveryGrantLength includes MPCPDU transmission time and tailGuard as defined in 64.2.2.1. discoveryGrantLength is represented in units of time_quanta.
TYPE: 32 bit unsigned
VALUE: 00-00-00-26 (608 ns)

gate_timeout
: This constant represents the maximum allowed interval of time between two GATE messages generated by the OLT to the same ONU.
TYPE 32-bit unsigned
VALUE 00-2F-AF-08 (50 milliseconds)

laserOffTime
: This constant 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 in 60.7.13.1.
TYPE: 32 bit unsigned
VALUE: 00-00-00-20 (512 ns)

laserOnTime
: This constant 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 in 60.7.13.1.
TYPE: 32 bit unsigned
VALUE: 00-00-00-20 (512 ns)

max_future_grant_time
: This constant holds the time limiting the future time horizon for a valid incoming grant.
TYPE: 32 bit unsigned
VALUE: 03-B9-AC-A0 (1 second)

min_processing_time
: This constant is the time required for the ONU processing time.
TYPE: 32 bit unsigned
VALUE: 00-00-04-00 (16.384 us)

tqSize
: This constant is defined in 64.2.2.1.

64.3.5.2 Variables

BEGIN
This variable is used when initiating operation of the functional block state machine. It is set to true following initialization and every reset.
TYPE: boolean

counter
This variable is used as a loop iterator counting the number of incoming grants in a GATE message.
TYPE: integer

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 state is a structure field composed of multiple subfields.
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}

data_rx
This variable is defined in 64.2.2.3.

data_tx
This variable is defined in 64.2.2.3.

effectiveLength
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.
TYPE: 32 bit unsigned

fecEnabled
This variable is defined in 64.2.2.3.

grantList
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.
TYPE: list of elements having the structure define in currentGrant

insideDiscoveryWindow
This variable is defined in 64.3.3.2.

maxDelay
This variable holds the maximum delay that can be applied by an ONU before sending the REGISTER MPCPDU. This delay is calculated such that the ONU would have sufficient time to transmit the REGISTER message and its associated overhead (FEC parity date, end-of-frame sequence, etc.) and terminate the laser before the end of the discovery grant.
TYPE 16 bit unsigned

nextGrant
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.
TYPE: element having same structure as defined in currentGrant

nextStopTime
This variable holds the value of the localTime counter corresponding to the end of the next grant.
TYPE: 32 bit unsigned

registered
This variable is defined in 64.3.3.2.

stopTime
This variable is defined in 64.2.2.3.

syncTime
This variable is defined in 64.3.3.2.

transmitAllowed
This variable is defined in 64.2.2.3.

64.3.5.3 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.

InsertInOrder(sorted_list, inserted_element)
This function is used to queue an element inside a sorted list. The queueing 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 maximal 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.

TransmitFrame(DA, SA, Length/Type, data)
This function is defined in 64.2.2.4.

64.3.5.4 Timers

gntStTmr
This timer is used to wait for the event signaling the start of a grant window.
VALUE: The timer value is dynamically set according to the signaled grant start time.

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 64.3.3.4.

rndDlyTmr

This timer is used to measure a random delay inside the discovery window. The purpose of the delay is to apriori 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.

64.3.5.5 Messages

MA_CONTROL.request(DA, GATE, grant_number, start[4], length[4], force_report[4])

This service primitive is defined in 64.3.3.5.

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 status value is deactive.
length:	length of the grant. This parameter is not present when the status value is deactive.
force_report:	flags indicating whether a REPORT message should be transmitted in this grant. This parameter is not present when the status value is 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 status value is 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.

64.3.5.6 State Diagrams

The gating process in the OLT shall implement the gate processing state diagram as shown in Figure 64–26. The gating process in the ONU shall implement the gate processing state diagram as shown in Figure 64–27. Instantiation of state machines as described is performed for all Multipoint MAC Control instances.

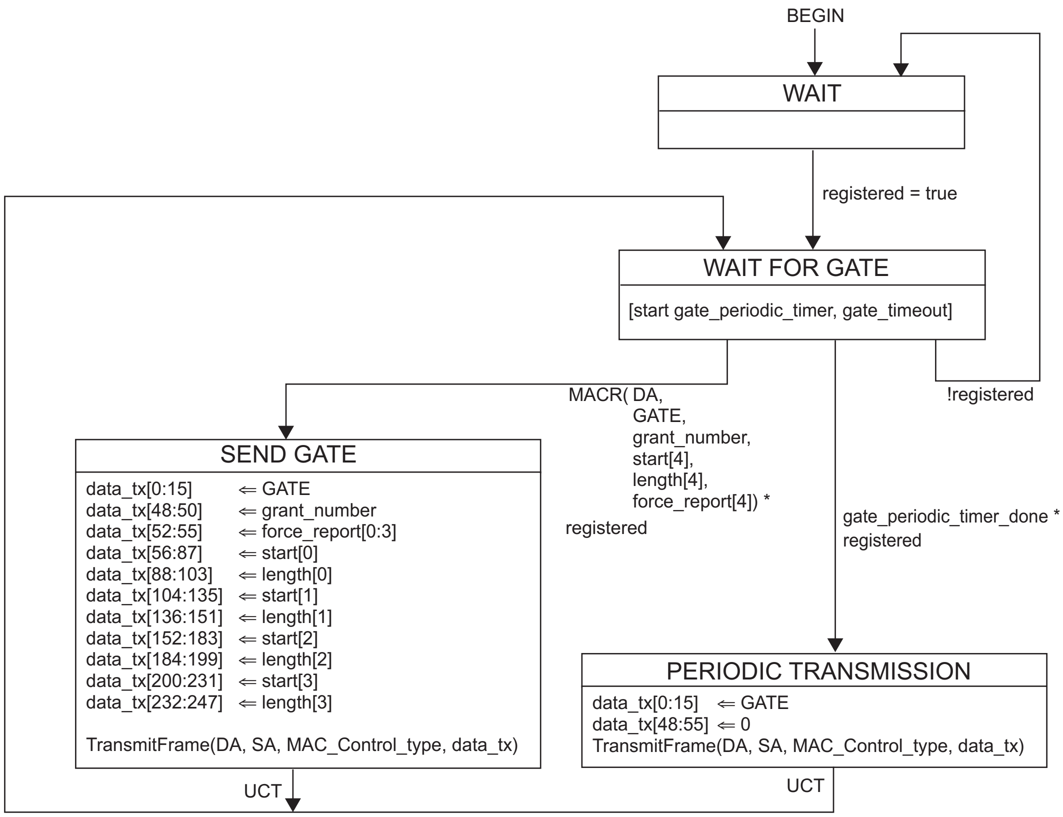


Figure 64–27—Gate Processing State Diagram at OLT

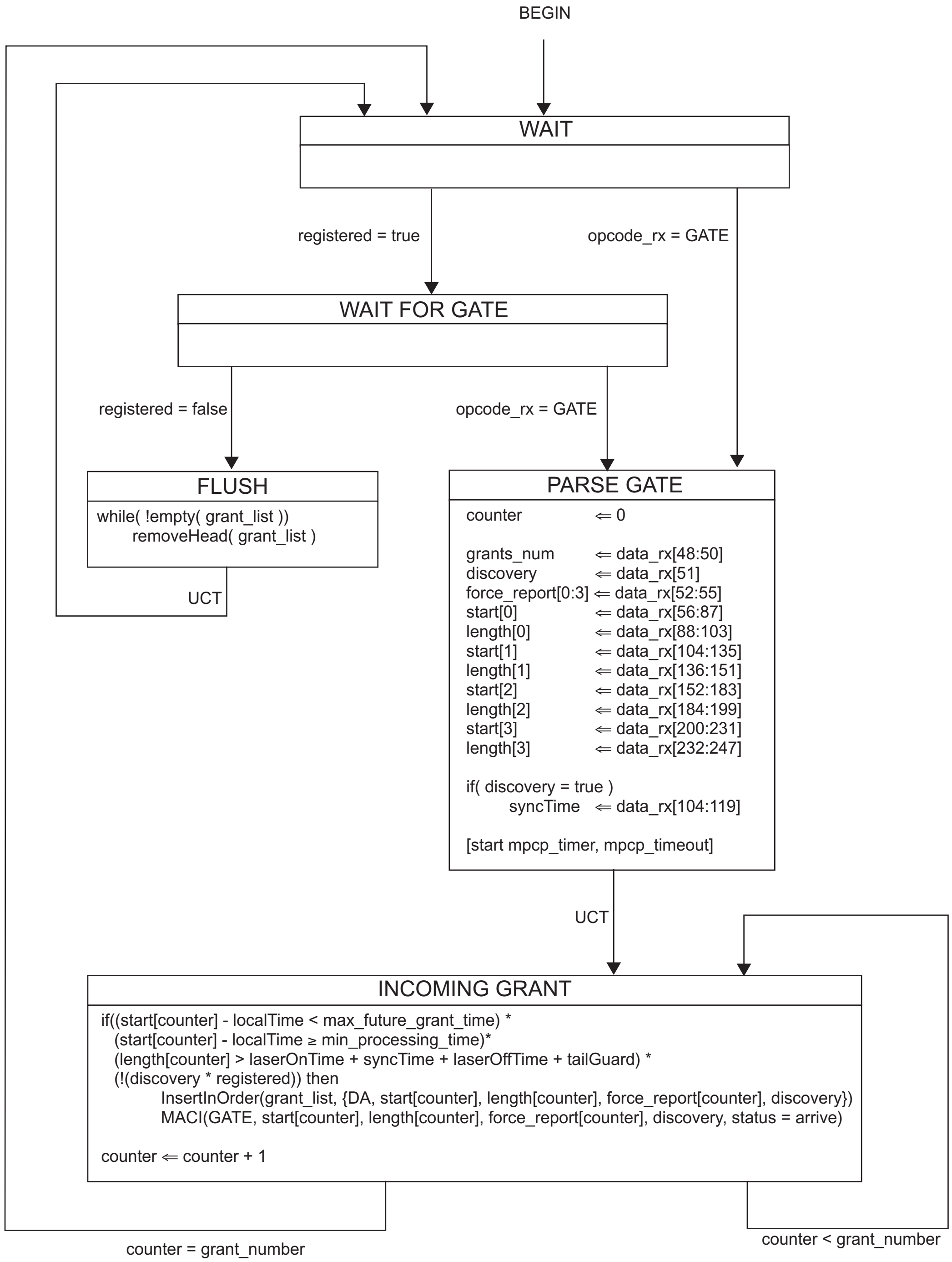


Figure 64–28—Gate Processing ONU Programing State Diagram

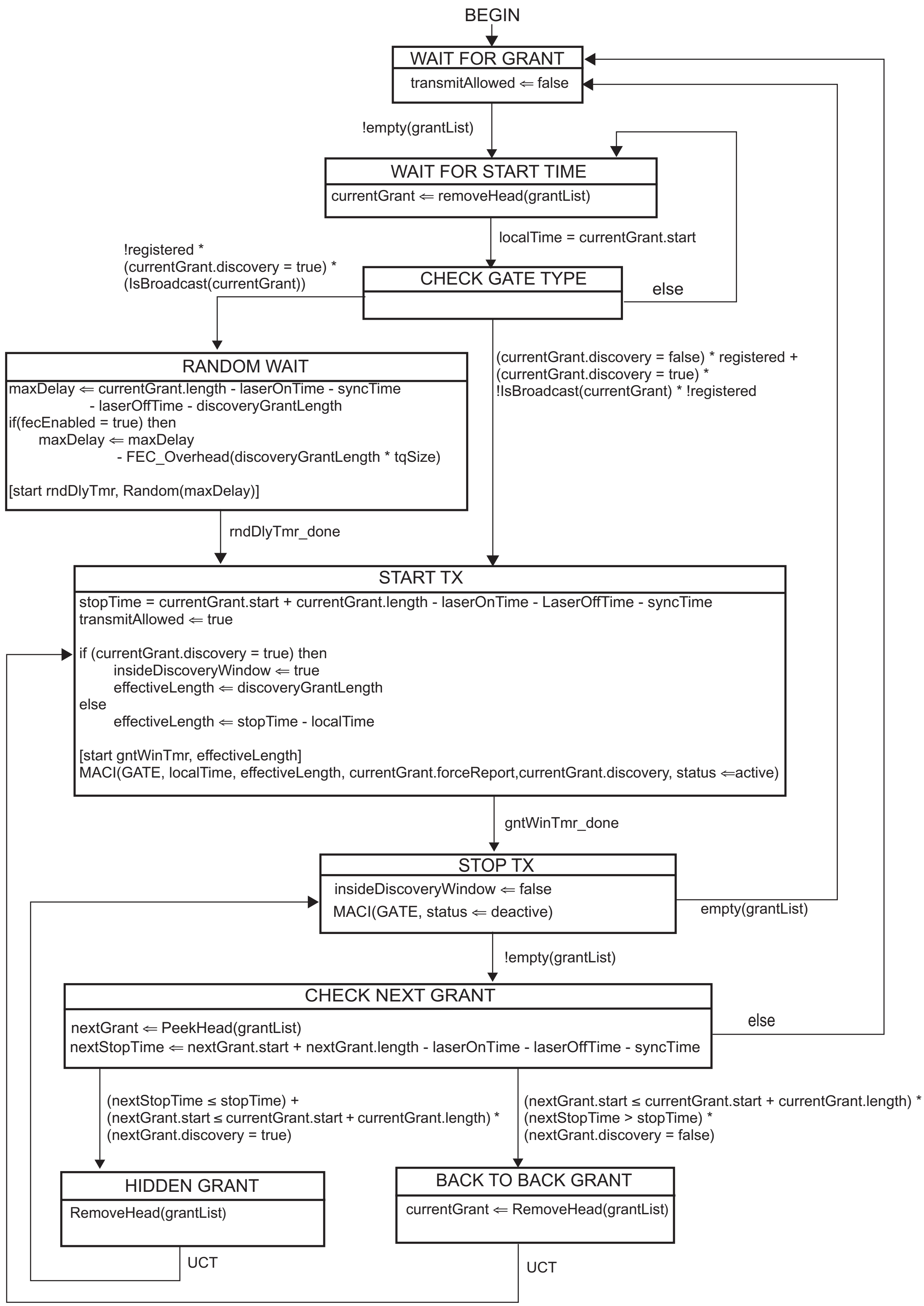


Figure 64–29—Gate Processing ONU Activation State Diagram

64.3.6 MPCPDU structure and encoding

MPCP PDU (MPCPDU) are basic IEEE 802.3 frames; they shall not be tagged (see Clause 3). The MPCPDU structure is shown in Figure 64–30, 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 64.1.2.
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 16 bit transmissions. The timestamp counts time in 16 bit time granularity.
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.

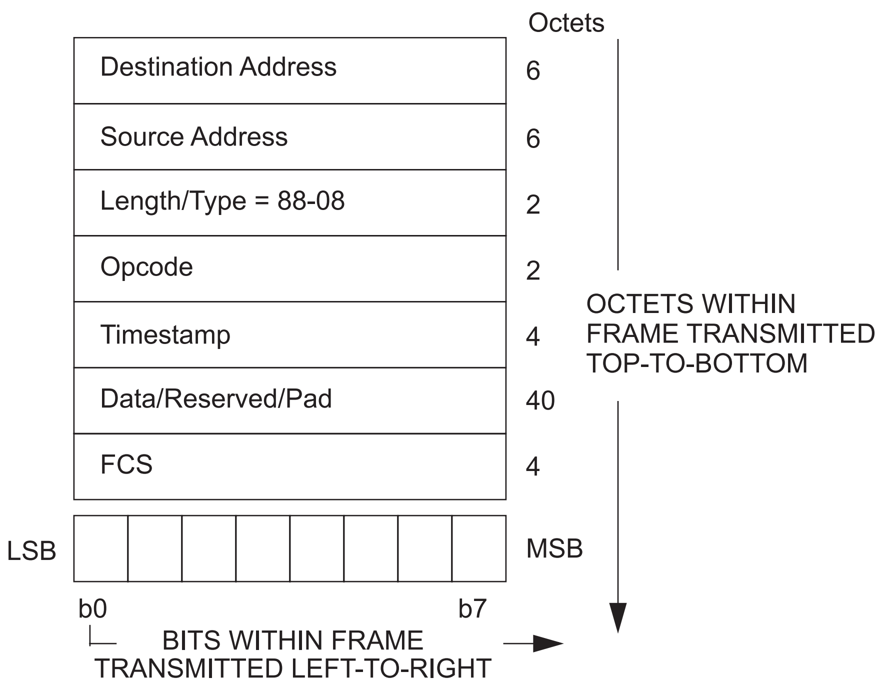


Figure 64–30—Generic MPCPDU

64.3.6.1 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.

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 00-02.
b) Flags. This is an 8 bit flag register that holds the following flags: 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.
c) Grant #n Length. Length of the signaled grant, this is an 16 bit unsigned field. The length is counted in 16 bit time increments. There are 4 Grants that are possibly packed into the GATE MPCPDU. The laserOnTime, syncTime, and laserOffTime are included in and thus consume part of Grant #n Length.
d) Grant #n Start Time. Start time of the grant, this is an 32 bit unsigned field. 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.
e) Sync Time. This is an unsigned 16 bit value signifying the required synchronization time of the OLT receiver. During the synchronization time the ONU shall send IDLE code-pairs. The value is counted in 16 bit time 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.

Pad/Reserved. This is an empty field that is transmitted as zeros, and ignored on reception when constructing a complying MPCP protocol implementation. The size of this field depends on the used Grant #n Length/Start Time entry-pairs, and varies in length from 13 – 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 discovery flag is set where the MAC Control instance is mapped to all ONUs and such frame is marked by the broadcast LLID.

Table 64–1—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

.

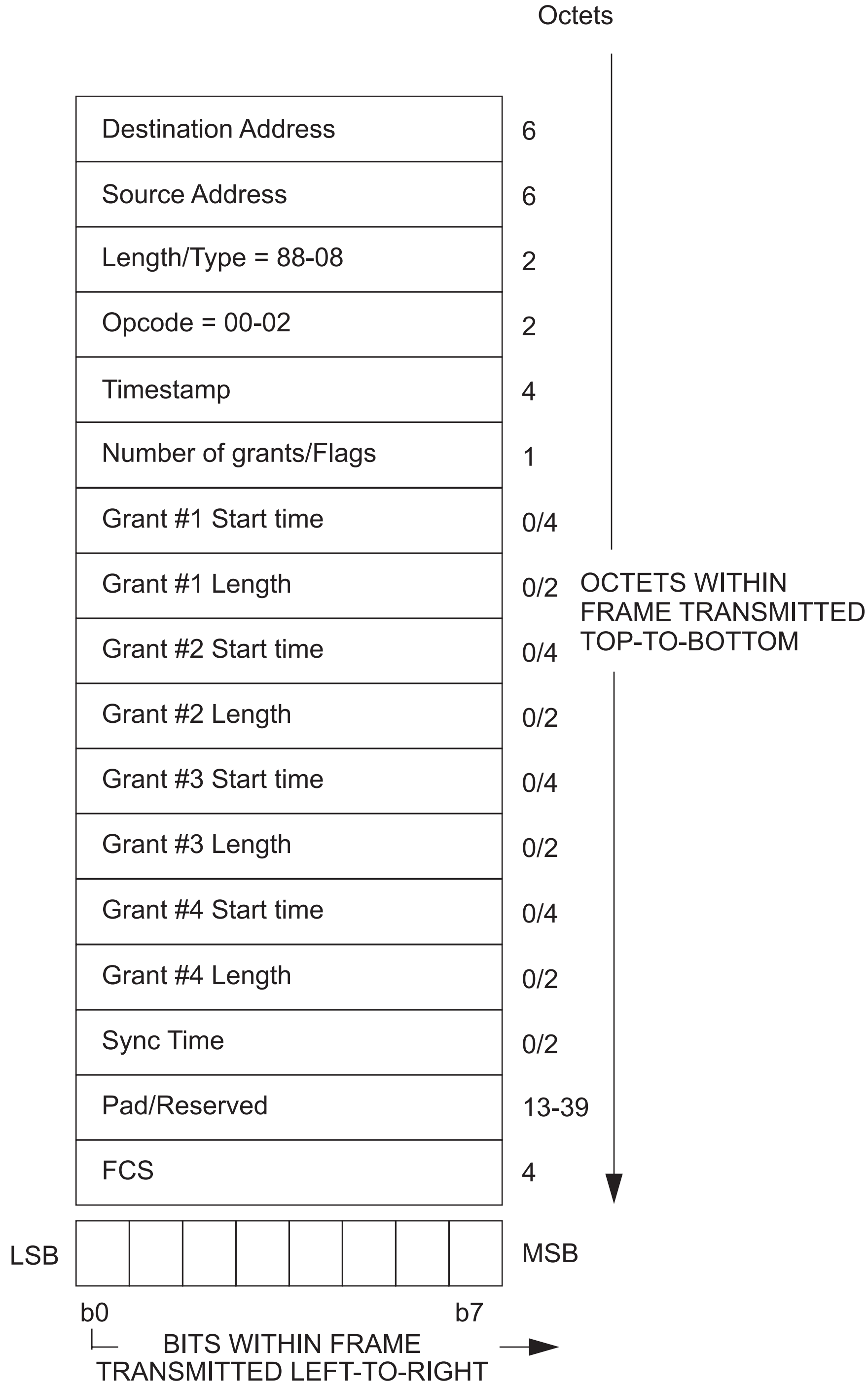


Figure 64–31—GATE MPCPDU

64.3.6.2 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 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 64.3.4. 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 00-03.
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.

Table 64–2—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
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 to account for the necessary inter-frame spacing and FEC parity data overhead, if FEC is enabled. The Queue #n Report field is an unsigned 16 bit integer representing 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 when constructing a complying MPCP protocol implementation. 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.

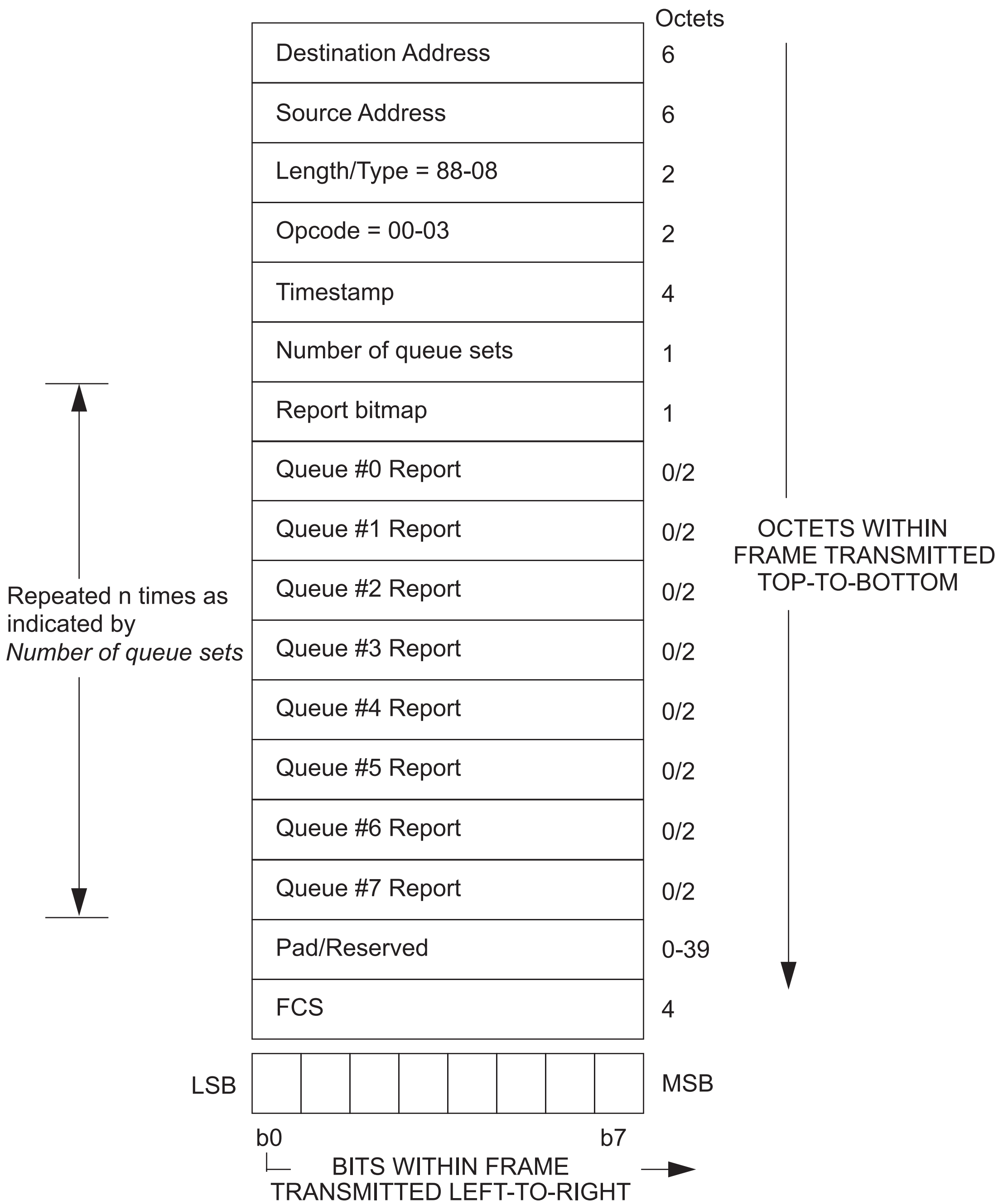


Figure 64–32—REPORT MPCPDU

64.3.6.3 .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 00-04.
b) Flags. This is an 8 bit flag register that indicates special requirements for the registration.

.

Table 64–3—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) Pad/Reserved. This is an empty field that is transmitted as zeros, and ignored on reception when constructing a complying MPCP protocol implementation.

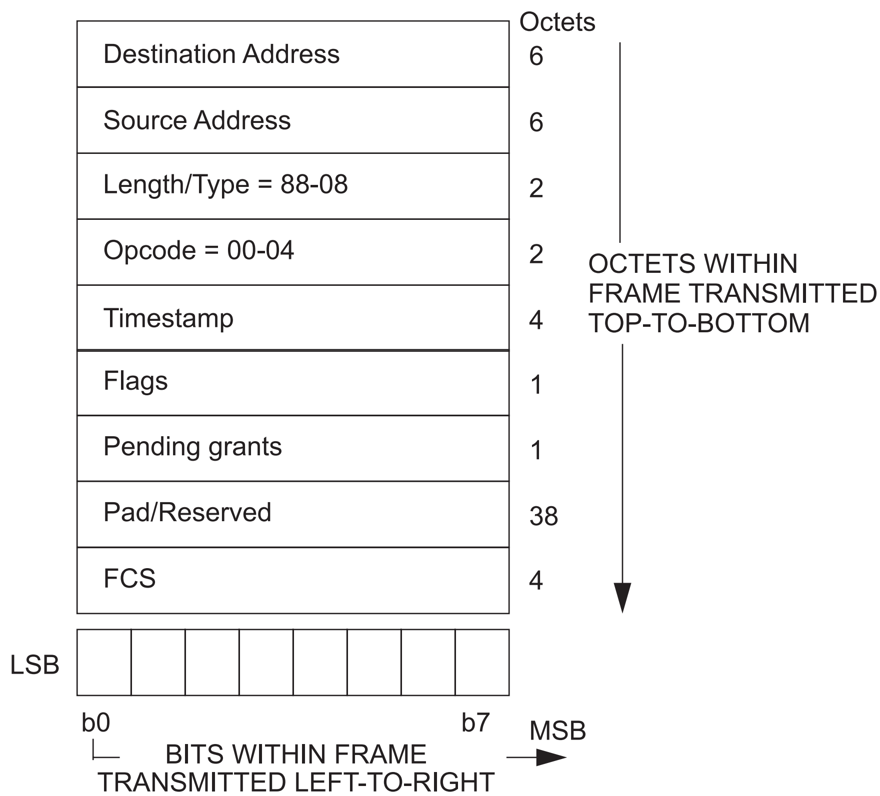


Figure 64–33—REGISTER_REQ MPCPDU

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.

64.3.6.4 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 00-05.
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.

Table 64–4—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 higher-layer-entity.
5–255	Reserved	Ignored on reception.

e) Sync Time. This is an unsigned 16 bit value signifying the required synchronization time of the OLT receiver. During the synchronization time the ONU transmits only IDLE code-pairs. The value is counted in 16 bit time increments. The advertised value includes synchronization requirement on all receiver elements including PMD, PMA and PCS.
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) Pad/Reserved. This is an empty field that is transmitted as zeros, and ignored on reception when constructing a complying MPCP protocol implementation.

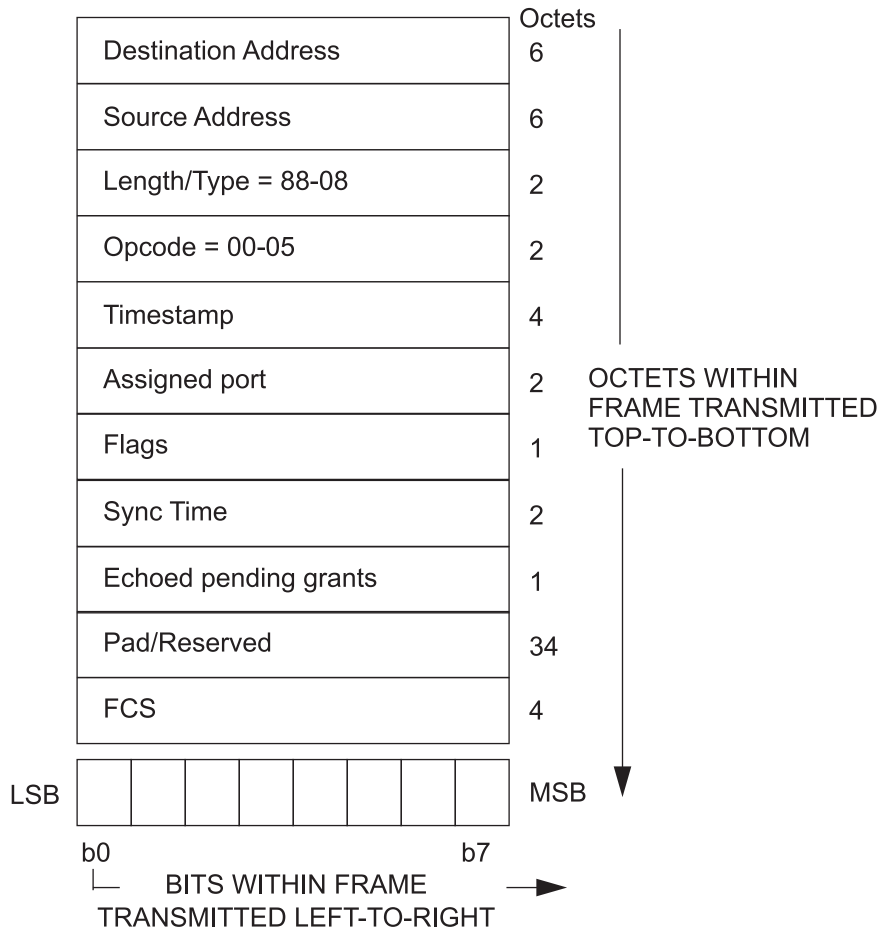


Figure 64–34—REGISTER MPCPDU

The REGISTER MPCPDU shall be generated by a MAC Control instance mapped to all ONUs and such frame is marked by the broadcast LLID.

64.3.6.5 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 00-06.
b) Flags. this is an 8 bit flag register that indicates special requirements for the registration.Echoed assigned port. This field holds a 16 bit unsigned value reflecting the LLID of the port assigned following registration.
c) Echoed Sync Time. This is an unsigned 16 bit value echoing the required synchronization time of the OLT receiver as previously advertised (see 64.3.6.4).
d) Pad/Reserved. This is an empty field that is transmitted as zeros, and ignored at reception when constructing a complying MPCP protocol implementation.

.

Table 64–5—REGISTER_ACK MPCPDU Flags fields

Value	Indication	Comment
0	Nack	The requested registration attempt is denied by the higher-layer-entity.
1	Ack	The registration process is successfully acknowledged.
2–255	Reserved	Ignored on reception.

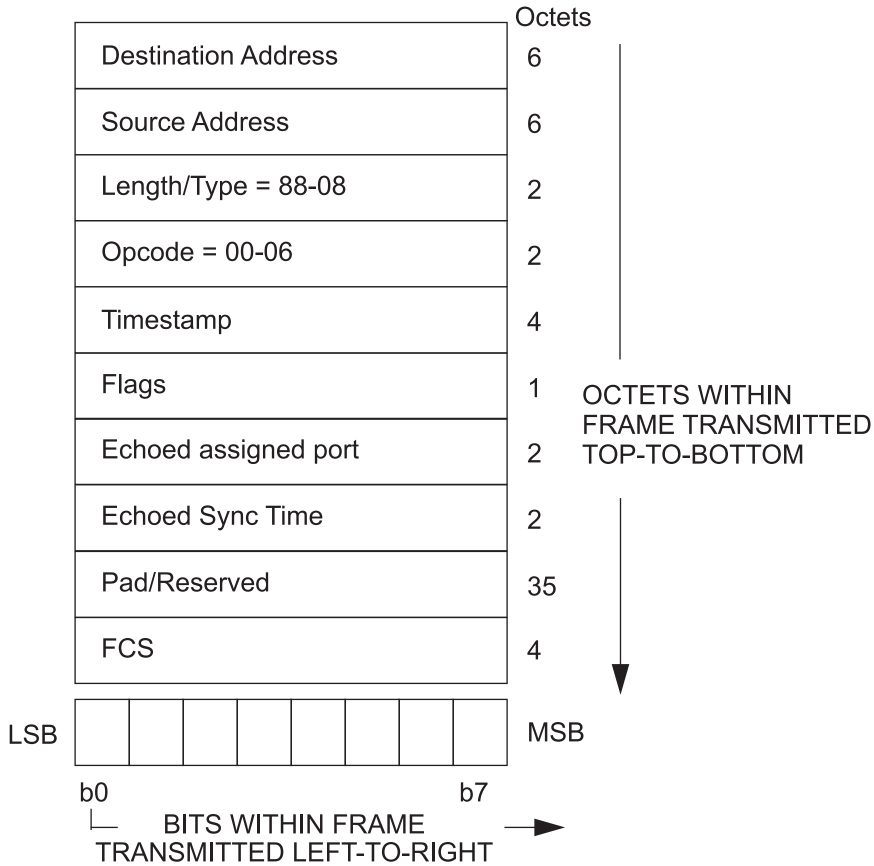


Figure 64–35—REGISTER_ACK MPCPDU

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.

64.4 Protocol implementation conformance statement (PICS) proforma for Clause 64, Multipoint MAC Control[20]

64.4.1 Introduction

The supplier of a protocol implementation that is claimed to conform to Clause 64 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.

64.4.2 Identification

64.4.2.1 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).	

64.4.2.2 Protocol summary

Identification of protocol standard	IEEE Std 802.3-2005, Clause 64, 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 802.3-2005.)	
Date of Statement	

[20]*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.

64.4.3 Major capabilities/options

Item	Feature	Subclause	Value/Comment	Status	Support
*OLT	OLT functionality	64.1	Device supports functionality required for OLT	O/1	Yes [ ] No [ ]
*ONU	ONU functionality	64.1	Device supports functionality required for ONU	O/1	Yes [ ] No [ ]

64.4.4 PICS proforma tables for Multipoint MAC Control

64.4.4.1 Compatibility Considerations

Item	Feature	Subclause	Value/Comment	Status	Support
CC1	Delay through MAC and PHY	64.3.2.4	Maximum delay variation of 16 ns (1 time_quantum)	M	Yes [ ]
CC2	OLT grant time delays	64.3.2.4	Not grant nearer than 1024 time_quanta into the future	OLT:M	Yes [ ]
CC3	ONU processing delays	64.3.2.4	Must process all messages in less than 1024 time_quanta	ONU:M	Yes [ ]
CC4	OLT grant issuance	64.3.2.4	Not grant more than one message every 1024 time_quanta	OLT:M	Yes [ ]

64.4.4.2 Multipoint MAC Control

Item	Feature	Subclause	Value/Comment	Status	Support
OM1	OLT localTime	64.2.2.2	Track transmit clock	OLT:M	Yes [ ]
OM2	ONU localTime	64.2.2.2	Track receive clock	ONU:M	Yes [ ]
OM3	Random wait for transmitting REGISTER_REQ messages	64.3.3	Shorter than length of discovery time window	ONU:M	Yes [ ]
OM4	Periodic report generation	64.3.4	Reports are generated periodically	ONU:M	Yes [ ]
OM5	Periodic granting	64.3.4	Grants are issued periodically	OLT:M	Yes [ ]
OM6	Issuing of grants	64.3.5	Not issue more than maximal supported grants	OLT:M	Yes [ ]

64.4.4.3 State Machines

Item	Feature	Subclause	Value/Comment	Status	Support
SM1	Multipoint Transmission Control	64.2.2.7	Meets the requirements of Figure 64–9	M	Yes [ ]
SM2	OLT Control Parser	64.2.2.7	Meets the requirements of Figure 64–10	M	Yes [ ]
SM3	ONU Control Parser	64.2.2.7	Meets the requirements of Figure 64–11	M	Yes [ ]
SM4	OLT Control Multiplexer	64.2.2.7	Meets the requirements of Figure 64–12	OLT:M	Yes [ ]
SM5	ONU Control Multiplexer	64.2.2.7	Meets the requirements of Figure 64–13	OLT:M	Yes [ ]
SM6	Discovery Processing OLT Window Setup	64.3.3.6	Meets the requirements of Figure 64–18	OLT:M	Yes [ ]
SM7	Discovery Processing OLT Process Requests	64.3.3.6	Meets the requirements of Figure 64–19	OLT:M	Yes [ ]
SM8	Discovery Processing OLT Register	64.3.3.6	Meets the requirements of Figure 64–20	ONU:M	Yes [ ]
SM9	Discovery Processing OLT Final Registration	64.3.3.6	Meets the requirements of Figure 64–21	OLT:M	Yes [ ]
SM10	Discovery Processing ONU Registration	64.3.3.6	Meets the requirements of Figure 64–22	ONU:M	Yes [ ]
SM11	Report Processing at OLT	64.3.4.6	Meets the requirements of Figure 64–24	OLT:M	Yes [ ]
SM12	Report Processing at ONU	64.3.4.6	Meets the requirements of Figure 64–25	ONU:M	Yes [ ]
SM13	Gate Processing at OLT	64.3.5.6	Meets the requirements of Figure 64–27	OLT:M	Yes [ ]
SM14	Gate Processing at ONU	64.3.5.6	Meets the requirements of Figure 64–28	ONU:M	Yes [ ]
SM15	Gate Processing ONU Activation	64.3.5.6	Meets the requirements of Figure 64–29	ONU:M	Yes [ ]

64.4.4.4 MPCP

Item	Feature	Subclause	Value/Comment	Status	Support
MP1	VLAN Tags	64.3.6	MPCPDU are not tagged	M	Yes [ ]
MP2	LLID for MPCPDU	64.3.6	RS generates LLID for MPCPDU	M	Yes [ ]
MP3	Grants during discovery	64.3.6.1	Single grant in GATE message during discovery	OLT:M	Yes [ ]
MP4	Grant start time	64.3.6.1	Grants within one GATE MPCPDU are sorted by their Start time values	OLT:M	Yes [ ]
MP5	TX during synchronization	64.3.6.1	Transmit IDLE code groups	ONU:M	Yes [ ]
MP6	GATE generation	64.3.6.1	GATE generated for active ONU except during discovery	OLT:M	Yes [ ]
MP7	GATE LLID	64.3.6.1	Unicast LLID except for discovery	OLT:M	Yes [ ]
MP8	REPORT issuing	64.3.6.2	Issues REPORT periodically	ONU:M	Yes [ ]
MP9	REPORT generation	64.3.6.2	Generated by active ONU	ONU:M	Yes [ ]
MP10	REPORT LLID	64.3.6.2	REPORT has unicast LLID	ONU:M	Yes [ ]
MP11	REGISTER_REQ generation	64.3.6.3	Generated by undiscovered ONU	ONU:M	Yes [ ]
MP12	REGISTER_REQ LLID	64.3.6.3	Use broadcast LLID	ONU:M	Yes [ ]
MP13	REGISTER DA address	64.3.6.4	Use individual MAC address	OLT:M	Yes [ ]
MP14	REGISTER generation	64.3.6.4	Generated for all ONUs	OLT:M	Yes [ ]
MP15	REGISTER_ACK generation	64.3.6.5	Generated by active ONU	ONU:M	Yes [ ]
MP16	REGISTER_ACK LLID	64.3.6.5	Use unicast LLID	ONU:M	Yes [ ]

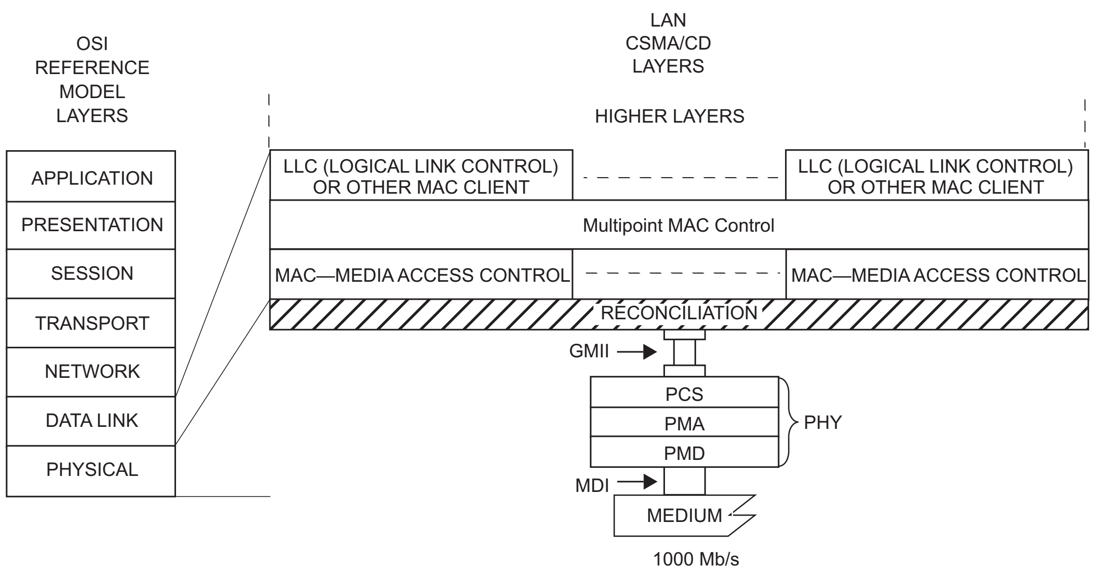
65. Extensions of the Reconciliation Sublayer (RS) and Physical Coding Sublayer (PCS) / Physical Media Attachment (PMA) for 1000BASE-X for multipoint links and forward error correction

This clause describes functions for use in a 1000BASE-PX point-to-multipoint (P2MP) networks. This is an optical multipoint network that connects multiple DTEs using a single shared fiber. The architecture is asymmetrical, 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 64.

65.1 Extensions of the Reconciliation Sublayer (RS) for point-to-point emulation

65.1.1 Overview

This subclause extends Clause 35 to enable multiple data link layers to interface with a single physical layer. 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 65–1 shows the relationship of this RS to the ISO/IEC OSI reference model. The mapping of GMII signals to PLS service primitives is described in 35.2.1.



GMII = GIGABIT MEDIA INDEPENDENT INTERFACE
MDI = MEDIUM DEPENDENT INTERFACE
PHY = PHYSICAL LAYER DEVICE
PCS = PHYSICAL CODING SUBLAYER
PMA = PHYSICAL MEDIUM ATTACHMENT
PMD = PHYSICAL MEDIUM DEPENDENT

Figure 65–1—RS location in the OSI protocol stack

65.1.2 Principle of operation

A successful registration process, described in 64.3.3, 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 Optical Line Terminal (OLT) or a single MAC in an Optical Network Unit (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 PCS of OLT shall operate in unidirectional mode as defined in 66.2.2.

As described in 64.1.2, multiple MACs within an OLT are bound to a single GMII, while at the ONU a single MAC is bound to the GMII. The multipoint control protocol (MPCP) ensures that only one MAC is transmitting at any one time. Correspondingly, only one PLS_DATA.request primitive is active at any time. The active PLS_DATA.request is mapped to the GMII signals, TXD<7:0>, TX_EN, TX_ER, and GTX_CLK. The RS replaces octets of preamble with the values of the transmitting MAC's MODE and LLID variables.

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

65.1.3 Functional specifications

The variables below provide a mapping between MODE and LLID variables and multiple MACs. While the usage of this mapping is less interesting in the ONU, it is critical in the OLT. This mapping is used to replace transmitted preambles with MODE and LLID fields as well as to steer received packets to the appropriate MAC.

65.1.3.1 Variables

enable
Value: Boolean
This variable shall be TRUE for an ONU MAC. For an OLT MAC, this variable is defined as below:
TRUE when management has assigned a value to mode and logical_link_id. Indicates the MAC is enabled to receive frames.
FALSE when the MAC is not in use.

mode
Value: 1 bit
This variable shall be 0 for an ONU MAC and may be 0 or 1 for an OLT MAC.
When the LLID is used to emulate a single copy broadcast or multicast channel, this variable will be set to 1. When emulating a unicast channel, this variable will be set to 0.

logical_link_id
Value: 15 bits
This variable shall be set to the broadcast value of 0x7FFF for the unregistered ONU MAC. Enabled OLT MACs may use any value for this variable. Registered ONU MACs may use any value other than 0x7FFF for this variable.

65.1.3.2 Transmit

The transmit function of this extended RS replaces some of the octets of the preamble as transmitted by the MAC with several fields: SLD (start of LLID delimiter), LLID and CRC8. The SLD field is used by the receiver function to locate the LLID and CRC8 fields. The LLID field identifies the source or destination MAC. The CRC8 field provides a level of integrity on the LLID field. Table 65–1 shows the replacement mapping.

Table 65–1—Preamble/SFD replacement mapping

Offset	Field	Preamble/SFD	Modified preamble/SFD
1	-	0x55	same
2	-	0x55	same
3	SLD	0x55	0xd5
4	-	0x55	same
5	-	0x55	same
6	LLID[15:8]	0x55	<mode,logical_link_id[14:8]>[a]
7	LLID[7:0]	0x55	<logical_link_id[7:0]>[b]
8	CRC8	0xd5	The 8 bit CRC calculated over offsets 3 through 7

[a]mode maps to TXD[7], logical_link_id[14] maps to TXD[6], logical_link_id[8] maps to TXD[0]
[b]logical_link_id[7] maps to TXD[7], logical_link_id[0] maps to TXD[0]

65.1.3.2.1 SLD

The SLD field is one octet in length and replaces the third octet of the preamble.

NOTE—The 1000BASE-X PCS transmit function replaces the first octet of preamble with the /S/ code-group or it discards the first octet and replaces the second octet of preamble with the /S/ code-group. This decision is based upon the even or odd alignment of the PCS's transmit state diagram (see Figure 36–5). The 1000BASE-X PCS receive function replaces the /S/ code-group with an octet of preamble. The third octet of preamble is the first octet passed through the 1000BASE-X PHY without modification.

65.1.3.2.2 LLID

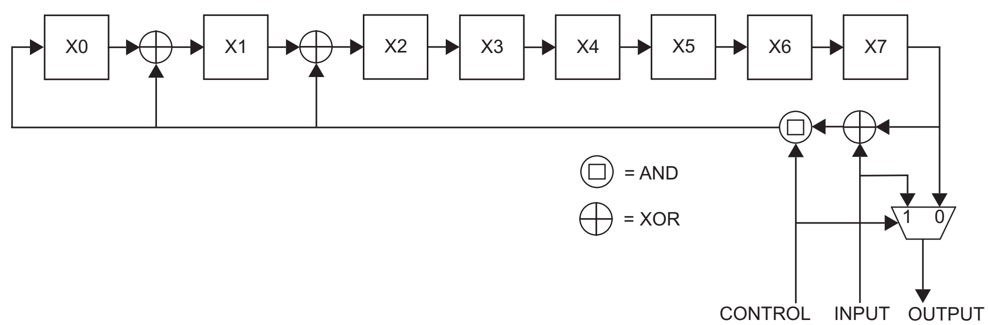
The LLID field is two octets in length and replaces the last two octets of preamble. The LLID field is a concatenation of the mode and logical_link_id variables for the associated MAC.

65.1.3.2.3 CRC-8

The CRC8 field contains an 8-bit cyclic redundancy check value. This value is computed as a function of the contents of the modified preamble beginning with the SLD field (offset 3) through the LLID field (offset 7). The encoding is defined by the following generating polynomial:

$$G(x) = x^8 + x^2 + x + 1 \qquad (65\text{-}1)$$

This CRC calculation shall produce the same result as the serial implementation shown in Figure 65–2. Before calculation begins, the shift register shall be initialized to the value 0x00. The content of the shift register is transmitted without inversion.



CONTROL = 1 when shifting the modified preamble and calculating the CRC
CONTROL = 0 when transmitting the CRC8 field

Figure 65–2—CRC8 field generation

65.1.3.3 Receive function

The receive function of this extended RS is responsible for the following functions:

a) Locate the SLD field.
b) Use the location of the SLD field to locate the CRC8 field and verify that the received value matches the CRC calculated using the received data.
c) Use the location of the SLD field to locate the LLID field and parse it to determine the destination MAC.
d) If the packet is not discarded due to incorrect CRC or unknown LLID, then replace the SLD and LLID fields with normal preamble and the CRC8 field with the SFD and transfer the packet to the appropriate MAC.
e) Otherwise, discard the entire packet, replacing it with normal inter-frame.

Table 65–2 shows the mapping of the modified preamble/SFD to RXD.

Table 65–2—Preamble/SFD replacement mapping

Signal	Bit values of octets received through GMII[a]									
RXD0	X	1[b]	1	1[c]	1	1	logical_link_id[8][d]	logical_link_id[0][e]	X7[f]	D0[g]
RXD1	X	0	0	0	0	0	logical_link_id[9]	logical_link_id[1]	X6	D1
RXD2	X	1	1	1	1	1	logical_link_id[10]	logical_link_id[2]	X5	D2
RXD3	X	0	0	0	0	0	logical_link_id[11]	logical_link_id[3]	X4	D3
RXD4	X	1	1	1	1	1	logical_link_id[12]	logical_link_id[4]	X3	D4
RXD5	X	0	0	0	0	0	logical_link_id[13]	logical_link_id[5]	X2	D5
RXD6	X	1	1	1	1	1	logical_link_id[14]	logical_link_id[6]	X1	D6
RXD7	X	0	0	1	0	0	mode	logical_link_id[7]	X0	D7
RX_DV	0	1	1	1	1	1	1	1	1	1

[a]Leftmost octet is the first received
[b]This octet may be missing per 1000BASE-X PCS transmit state diagram (see Figure 36-5)
[c]SLD field
[d]First octet of LLID field
[e]Second octet of LLID field
[f]CRC8 field
[g]D0 through D7 is the first octet of the PDU (first octet of the Destination Address)

65.1.3.3.1 SLD

Recall that the 1000BASE-X transmit function must maintain an even alignment for its Start_of_Packet delimiters. It may replace the first octet of preamble with the /S/ code-group and pass the second octet unchanged or it may discard the first octet of preamble and replace the second octet of preamble with the /S/ code-group. The SLD is transmitted in the third octet. These are the only two possibilities 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 one or two octets preceding the SLD and the two octets following the SLD are passed without modification.

65.1.3.3.2 LLID

The third and fourth octets following the SLD contain the mode and logical_link_id values. These values are acted upon differently for OLTs and ONUs.

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 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 value is any value other than 0x7FFF and an enabled MAC exists with a mode variable with a value of 0 and a logical_link_id variable with a value 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:

a) If the received mode bit is 0 and the received logical_link_id value matches the logical_link_id variable then the comparison is considered a match.
b) If the received mode bit is 1 and the received logical_link_id value does not match the logical_link_id variable, or the received logical_link_id matches 0x7FFF, 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.

65.1.3.3.3 CRC-8

The octet following the LLID field contains the CRC8 field. The value of this field is compared against the calculated CRC of the received octets, beginning with the SLD field and ending with the last octet of the LLID field. If the received and calculated CRC values do not match, then the packet shall be discarded. If the values match then the packet is transferred. If the packet is transferred, then the CRC8 field shall be replaced with the SFD.

65.2 Extensions of the physical coding sublayer for data detection and forward error correction

65.2.1 Overview

This subclause extends the physical coding sublayer Clause 36 to support burst mode operation of the point-to-multipoint physical medium. This subclause also specifies an optional forward error correction (FEC) mechanism to increase the optical link budget or the fiber distance. Figure 65–3 shows the relationship between the extended PCS sublayer and the ISO/IEC OSI reference model. Auto-Negotiation, as defined in Clause 37, establishes a point-to-point handshaking mechanism for allowing 1000BASE-X devices to achieve a highest common denominator link. The P2MP aspect of a 1000BASE-PX network prohibits the use of the auto-negotiation protocol.

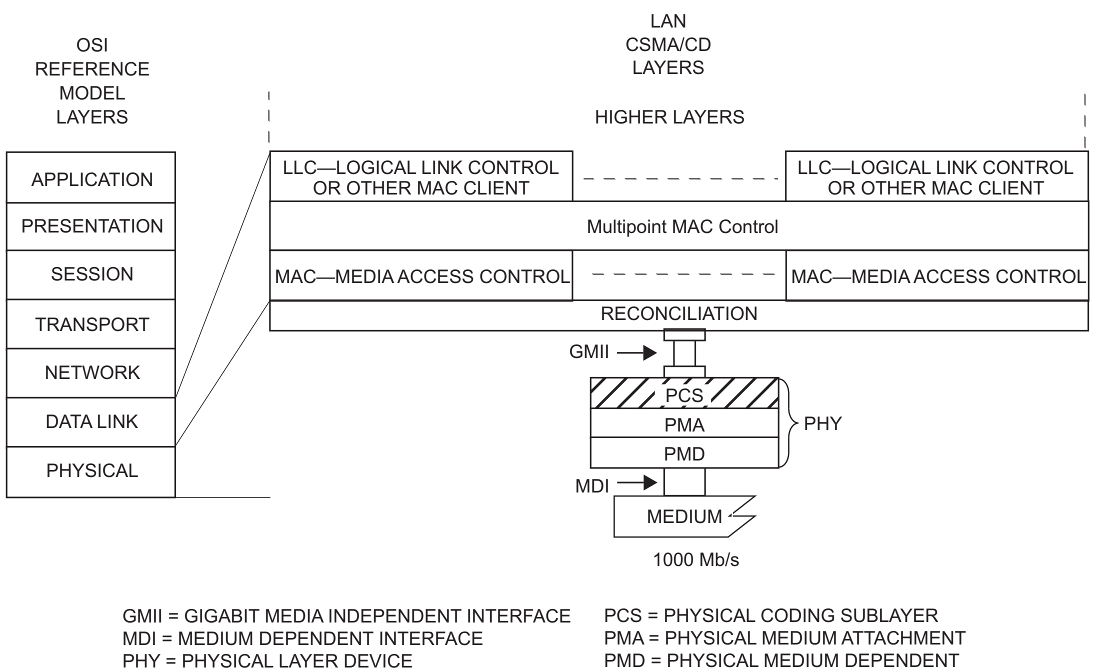


Figure 65–3—PCS location in the OSI protocol stack

65.2.2 Burst-mode operation

To avoid spontaneous emission noise from near ONUs obscuring signal from a distant ONU, the ONUs' lasers should be turned off between their transmissions. To control the laser, the PCS is extended to detect the presence of transmitted data and generate the PMD_SIGNAL.request(tx_enable) primitive to turn the laser on and off at the correct times. This function is performed by the Data Detector shown in the functional block diagram in Figure 65–4.

65.2.2.1 Principle of operation

The Data Detector contains a delay line (FIFO buffer) storing code-groups to be transmitted. The length of the FIFO buffer 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 predefined number of idle characters to be transmitted. This number of idle characters is needed by the receiver to adjust its gain ($T_{receiver\_settling}$), synchronize its receiving clock (T_{cdr}), and complete the synchronization process (T_{sync}).

Upon initialization, the FIFO buffer is filled with /I/ ordered_sets and the laser is turned off. When the first code-group that is not /I/ arrives at the buffer, the Data Detector sets the PMD_SIGNAL.request(tx_enable) primitive to the value ON, instructing the PMD sublayer to start the process of turning the laser on (see Figure 65–4).

When the buffer empties of data (i.e., contains only /I/ ordered_sets), the Data Detector sets the PMD_SIGNAL.request(tx_enable) primitive to the value OFF, instructing the PMD sublayer to start the process of turning the laser off. Between packets, /I/ or /R/ ordered_sets will arrive at the buffer. If the number of these /I/ or /R/ ordered_sets is insufficient to fill the buffer then the laser is not turned off.

Figure 65–5 shows the relationship of filling the buffer and the generation of laser_control. In the OLT, the laser always remains turned on. Correspondingly, therefore the OLT's Data Detector does not need a delay line or buffer in the data path for this purpose.

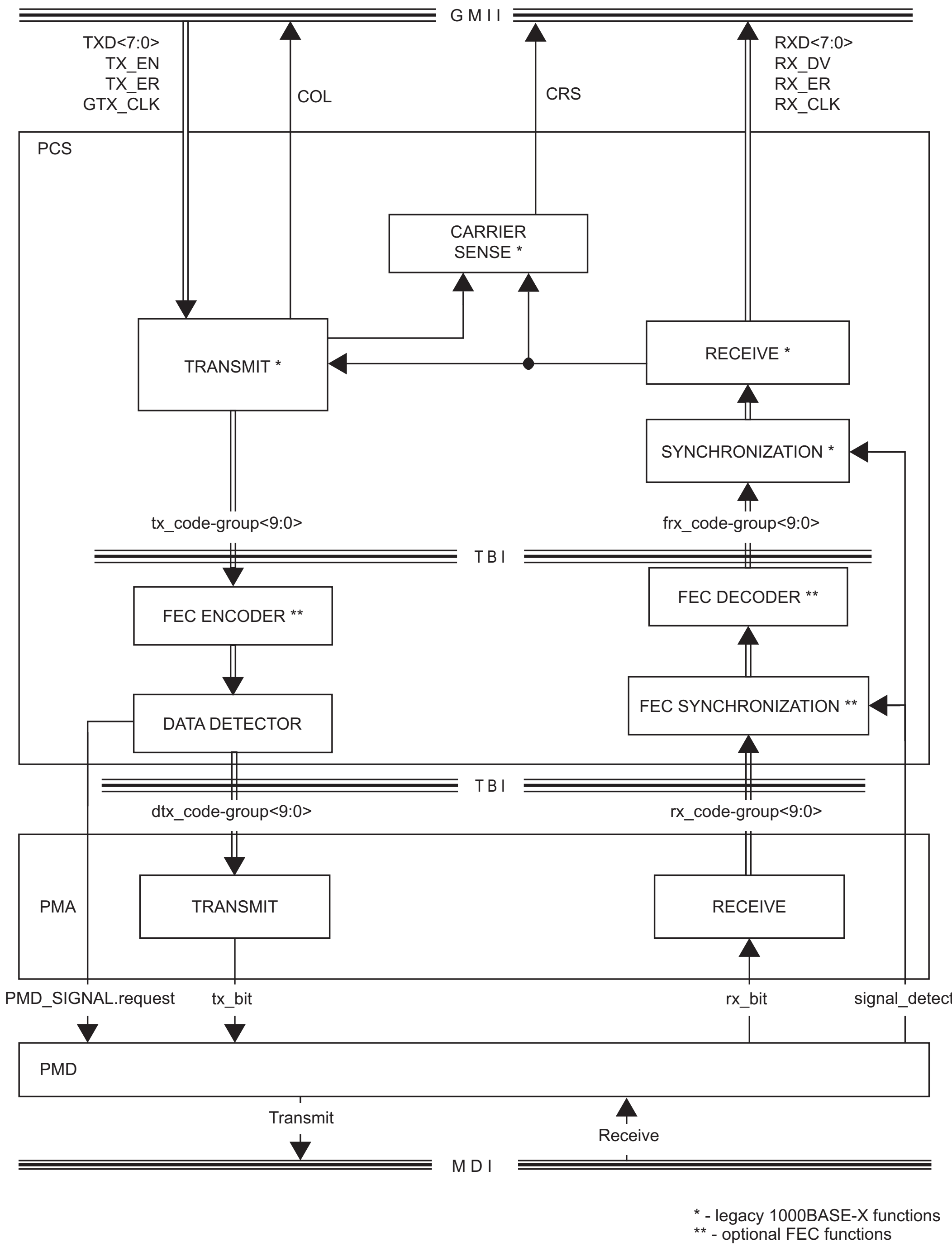


Figure 65–4—PCS Extension functional block diagram

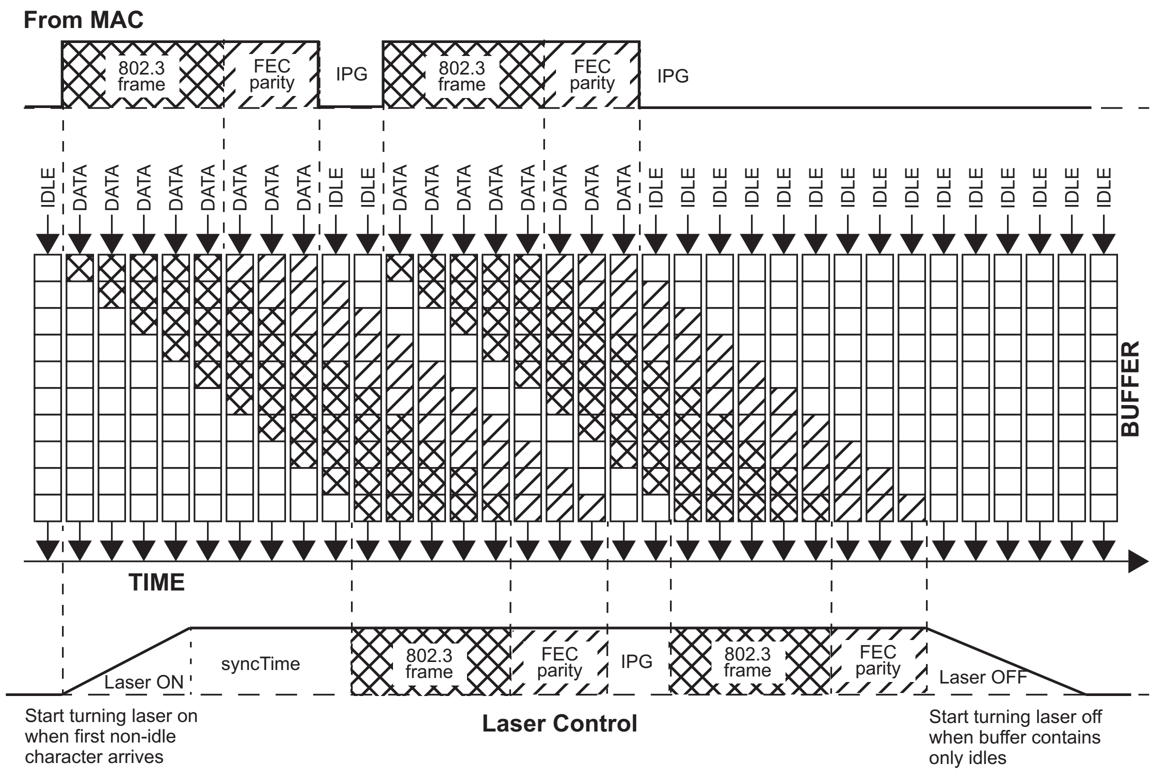


Figure 65–5—Laser control as a function of buffer fill

65.2.2.2 Detailed functions and state diagrams

The body of this clause 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 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. Variables in a state diagram with default values evaluate to the variable default in each state where the variable value is not explicitly set.

65.2.2.2.1 Variables

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

DelayBound
TYPE: 16-bit unsigned
DEFAULT VALUE: 00-6A (106 code-groups = 848 ns)
This represents the delay sufficient to initiate the laser and to stabilize the receiver at the OLT. The default value of DelayBound is based on default values of laserOnTime (64.3.5.1) and SyncTime (64.3.3.2). This variable is only used by the ONU.

dtx_code-group
A 10-bit vector representing one code-group, as specified in Tables 36–1a through 36–2, which has been prepared for transmission by the Data Detector process. This vector is conveyed to

the PMA as the parameter of a PMA_UNITDATA.request(dtx_code-group) service primitive. The element dtx_code-group<0> is the first bit transmitted and dtx_code-group<9> is the last bit transmitted.

laser_control
: This variable represents the status of the laser. The value on corresponds to the laser being turned on, and the value off corresponds to laser being off.
TYPE: boolean.

tx_code-group
: A 10-bit vector of bits representing one code-group, as specified in Table 36-1a or Table 36-2, which has been prepared for transmission by the PCS Transmit process. The element tx_code-group<0> is the first tx_bit transmitted; tx_code-group<9> is the last tx_bit transmitted.

65.2.2.2.2 Functions

IsIdle(tx_code-group)
: This function is used to determine whether tx_code-group is a code-group in /I/, the IDLE ordered_set, or /C/, the Configuration ordered_set. This function returns true if tx_code-group is /K28.5/ or any code-group that follows a /K28.5/ or any two consecutive /D/ code-groups that follow /K28.5/D21.5/ or /K28.5/D2.2/. Otherwise, the IsIdle function returns false.

FIFO.RemoveHead()
: This function removes the first code-group from the FIFO buffer and advances all remaining code-groups one position ahead. This function returns the 10-bit vector representing the removed code-group.

FIFO.Append(tx_code-group)
: This function appends a new 10-bit vector to the end of the FIFO buffer.

65.2.2.2.3 Messages

PMD_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 65–6).

PUDR
: Alias for PMA_UNITDATA.request(tx_code-group<9:0>).

65.2.2.2.4 Counters

IdleLength
: This counter represents the length of the consecutive interval of idles ending with the most recent tx_code-group. If the most recent tx_code-group represents a non-idle character, the IdleLength is reset to 0.
TYPE: 32-bit unsigned

65.2.2.3 State Diagrams

The Data Detector shall be implemented for an ONU as depicted in Figure 65–6, including compliance with the associated state variables as specified in 65.2.2.2.

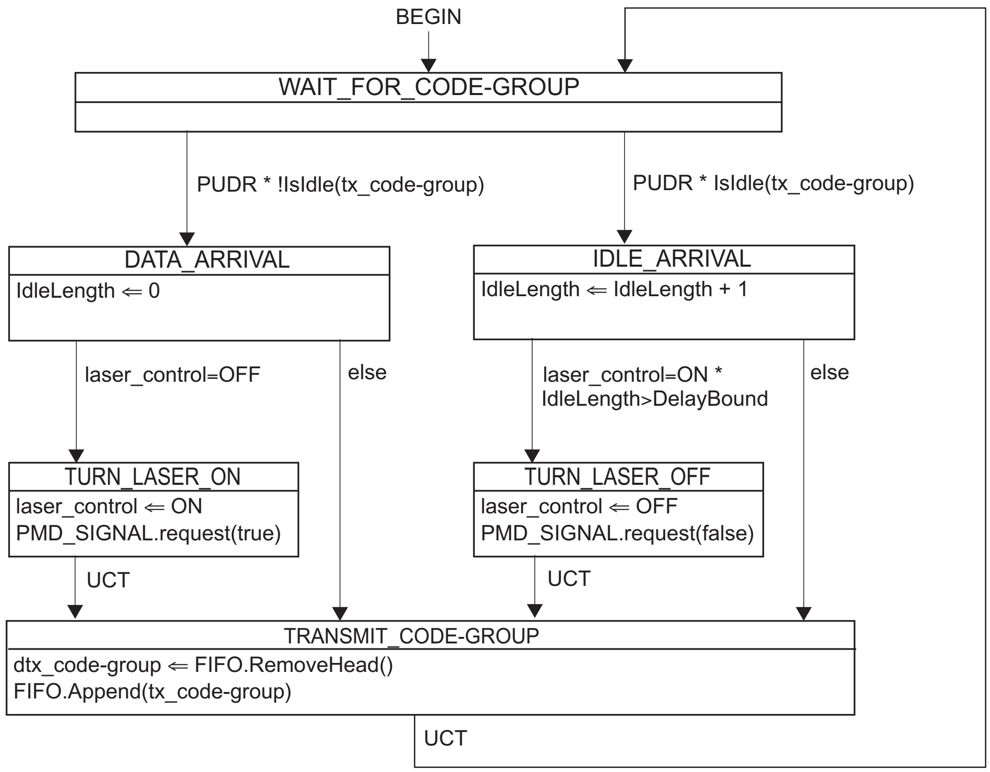


Figure 65–6—ONU data decoder state diagram

65.2.3 Forward error correction

This subclause specifies an optional forward error correction (FEC) mechanism to increase the optical link budget or the fiber distance. The FEC appends to the Ethernet frame additional data that is a result of a set of non-binary arithmetic functions (known as Galois arithmetic) performed on the data of the Ethernet frame. This additional data (known as the FEC parity octets) is used to correct errors at the receiving end of the link that may occur when the data is transferred through the link.

The FEC function comprises three functional blocks: FEC Encoder, FEC Decoder, and FEC Synchronization, as shown in Figure 65–4. These blocks have ten-bit interfaces (TBIs) to both sides and can be omitted for implementations not requiring FEC. Though the FEC functionality is optional, if implemented for operation over a multipoint optical link, it shall behave as specified in 65.2.3.

The following are the objectives of FEC:

a) Keep frame format compliant to 1000BASE-X PCS.
b) Support optional functionality.
c) Allow backwards compatibility with legacy 1000BASE-X devices.
d) Support BER objective of 10^{-12} at PCS.
e) Support BER objective of 10^{-4} at FEC sublayer.

65.2.3.1 FEC code

The FEC code specification, properties and performance analysis are specified in ITU-T G.975.

The FEC code used is a linear cyclic block code - the Reed-Solomon code (255, 239, 8) over the Galois Field of $GF(2^8)$ - a non-binary code operating on 8-bit symbols. The code encodes 239 information symbols and adds 16 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 the systematic form of the RS code based on the generating polynomial $G(x) = \prod_{i=0}^{15}(x - \alpha^i)$

where α is equal to 0x02 and is a root of the binary primitive polynomial $x^8+x^4+x^3+x^2+1$.

A codeword of the systematic code is presented by $D(x) + P(x) = G(x) * \mathrm{L}(x)$ where:

$D(x)$ is the data vector – $D(\mathrm{x})=\mathrm{D}_{238}X^{254} + ... + \mathrm{D}_0X^{16}$. D_{238} is the first data octet and D_0 is the last.

$P(x)$ is the parity vector – $P(x)=\mathrm{P}_{15}X^{15} + ... + \mathrm{P}_0$. P_{15} is the first parity octet and P_0 is the last.

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

NOTE—For the (255,239,8) Reed-Solomon code, the symbol size equals one octet. d_0 is identified as the LSB and d_7 is identified as the MSB bit in accordance with the conventions of 3.1.1.

The FEC decoder shall replace all octets in an uncorrectable block with /V/ to clearly propagate the error condition to the PCS.

65.2.3.2 FEC frame format

The frame format of an FEC coded Ethernet frame is herein described.

65.2.3.2.1 Placing parity octets

Ethernet packets are received from the PCS. The data is partitioned into 239-symbol frames (blocks), with the first block beginning with the first symbol after the /S/ code-group and the last block ending with the last symbol before the /T/ code-group. Each block is encoded using the (255, 239, 8) Reed-Solomon encoder, which results in an additional 16 parity symbols for each block. The block plus the associated 16 parity symbols form the 255 symbol Reed-Solomon codeword. The additional 16 parity symbols, which are generated from this encoding process for each block, are gathered and added at the end of the packet.

65.2.3.2.2 Shortened last block

When dividing the data into blocks there might be a case where the last block is shorter than 239 symbols. This block is noted as a shortened block. A shortened block of length r octets results in the data vector assignment of D_{238} to D_r as zeros and D_{r-1} to D_0 as valid data, where D_{r-1} is the first octet of the shortened block and D_0 is the last. This full size block is then encoded and the 16 parity symbols are generated. The data is then sent without the zero symbols. At the receiver, the decoder completes the block again into the full block (by adding back the zeros) for decoding.

65.2.3.2.3 Special frame markers

The Ethernet frame consists of a number of blocks plus special frame start and stop markers. In order to decode the FEC code, the receiver must first synchronize on the Ethernet frame. The Ethernet frame markers are not protected by the FEC code and are exposed to higher BER. Therefore, special start and stop marker symbols are added at the beginning and the end of the FEC coded frame that are capable of being correctly detected in a high noise environment. The special symbol noise immunity is made possible by the implementation of a simple correlator. The marker framing sequences used are at least 5 octets long, long enough to be detected with very high probability. The start FEC framing sequence is denoted by /S_FEC/ and the end FEC framing sequence is denoted by /T_FEC/.

In order to determine that an FEC coded frame has started, the input symbol stream is scanned for a match with the /S_FEC/ ordered_set with fewer than d/2 errors. In order to determine that an FEC coded frame has ended, the input symbol stream is scanned for a match with the /T_FEC_O/ or /T_FEC_E/ ordered_sets with fewer than d/2 errors.

The value chosen for d is 10, the number of bits that are different between these ordered_sets and any other regularly occurring 5 consecutive code-groups when considered in the 10-bit domain.

The sequence can flow through non-FEC PCS transparently (in a False_Carrier_Sense mode).

The start and end symbols are constructed from 8B/10B code-groups:

- /S_FEC/ - start of FEC coded packet - /K28.5/D6.4/K28.5/D6.4/S/
- /T_FEC_E/ - end of FEC coded packet with even alignment. If the starting running disparity is positive, the /T_FEC_E/ has the following pattern: /T/R/K28.5/D10.1/T/R/. If the starting running disparity is negative, the T_FEC_E has the following pattern: /T/R/K28.5/D29.5/T/R/.
- /T_FEC_O/ - end of FEC coded packet with odd alignment - /T/R/R/I/T/R/

/S/, /T/, /R/ and /I/ are described in Table 36-3. The /I/ in both the /T_FEC_E/ and the /T_FEC_O/ ordered_sets can be either an /I1/ (a disparity correcting IDLE) or an /I2/ (a disparity preserving IDLE).

Figure 65–7 describes the FEC coded Ethernet frame. Between the FCS and PARITY fields, the T_FEC can be either the /T_FEC_E/ or the /T_FEC_O/ ordered_set. After the PARITY field, the T_FEC can only be a /T_FEC_E/ ordered_set.

S_FEC	PREAMBLE/SLD	FRAME	FCS	T_FEC	PARITY	T_FEC

Figure 65–7—FEC coded Ethernet frame

65.2.3.3 FEC sublayer operation

This section describes the functionality and operation of the FEC sublayer.

65.2.3.3.1 Principles of operation

At transmission, the FEC sublayer receives the packets from the PCS, performs the FEC coding, appends the parity octets in place of the stretched IPG and sends the data to the PMA. At reception, the FEC sublayer receives the data from the PMA, performs the octet alignment, detects the Start FEC Framing Sequence, decodes the FEC code, correcting data where necessary and possible, replaces the parity octets with IDLE and sends the data to the PCS.

NOTE—To ensure correct MPCP operation, FEC function must maintain constant and equal delay for all code-groups and all signals transmitted from PMA to PCS. Timing effects of adding FEC function should be indistinguishable from an increased propagation delay.

65.2.3.3.2 Functional block diagram

As depicted in Figure 65–4, the FEC sublayer comprises a transmit side and a receive side. The following sections define the functionality of each block in the sublayer. See 36.3.3 for a complete description of the TBI.

65.2.3.3.3 Transmission

Figure 65–8 describes a block diagram of the FEC sublayer transmit data path. The packet delimiters of the packets from the PCS are detected. The /I/I/S/ is replaced with the /S_FEC/ ordered_set. The data in the frame is then 8B/10B decoded so that the FEC coding can take place and the parity octets buffered. The /T/R/I/I/ or /T/R/R/I/I/ is detected and replaced with the /T_FEC_E/ or /T_FEC_O/, respectively. Then the parity octets and another /T_FEC_E/ is appended, replacing the stretched interframe spacing.

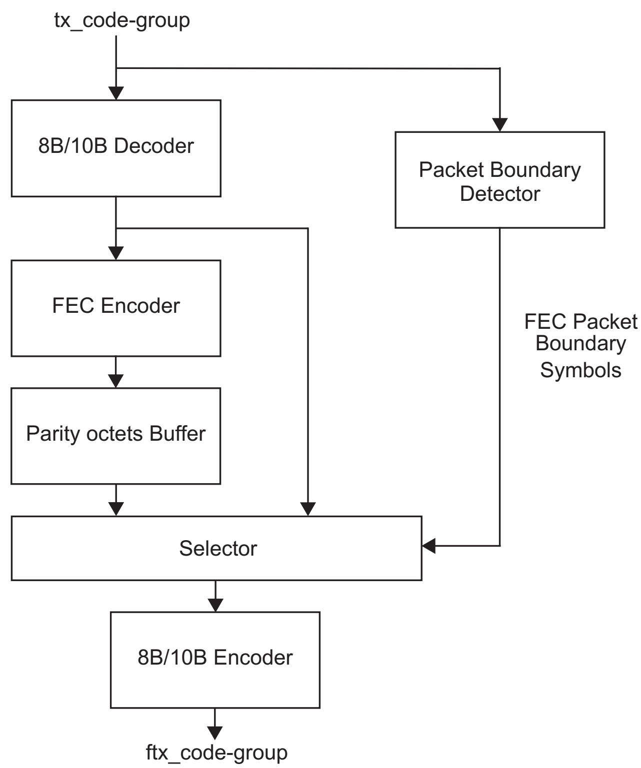


Figure 65–8—Transmit block diagram

The FEC Transmit process continually generates code-groups based upon information provided in the PMA_UNITDATA.request primitive with the tx_code-group<9:0> parameter, sending them immediately to the PMA Service Interface via the same primitive with the ftx_code-group<9:0> parameter.

65.2.3.3.4 Reception

Figure 65–9 describes the receive synchronization block diagram of the FEC sublayer receive data path. The FEC Synchronization process continually accepts code-groups via the PMA_UNITDATA.indication service primitive and conveys received code-groups to the FEC Receive process via the SYNC_UNITDATA.indicate service primitive. The FEC Synchronization process sets the sync_status flag to indicate whether the PMA is functioning dependably (as well as can be determined without exhaustive error-rate analysis).

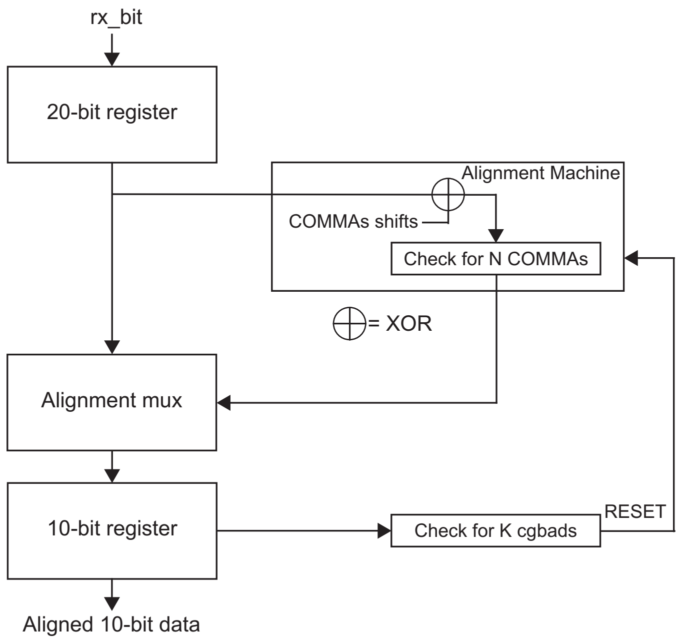


Figure 65–9—Receive synchronization block diagram

Figure 65–10 describes a block diagram of the FEC sublayer receive data path. The FEC Receive process continuously accepts code-groups via the SYNC_UNITDATA.indicate service primitive. It fills a buffer with these code-groups, converting an /S_FEC/ with fewer than d/2 errors to /I/I/S/ and converting all /T_FEC/ with fewer than d/2 errors to a clean /T_FEC/. This buffer exists in order to store all necessary data until the parity octets are available for performing data correction. Data correction is performed within the buffer. While emptying the buffer, the parity octets, along with the latter /T/R/ of the first /T_FEC/ and the entire second /T_FEC/ are converted to /I/.

NOTE—Under specific conditions, the PCS may generate a large number of FALSE_CARRIER events. FEC encryption only protects Ethernet frames. The IDLEs are not FEC-protected. During idle periods, excessive bit errors may results in FALSE_CARRIER events. Additionally, when FEC and non-FEC devices are combined in the same EPON, a non-FEC device will treat FEC parity data as FALSE_CARRIER events.

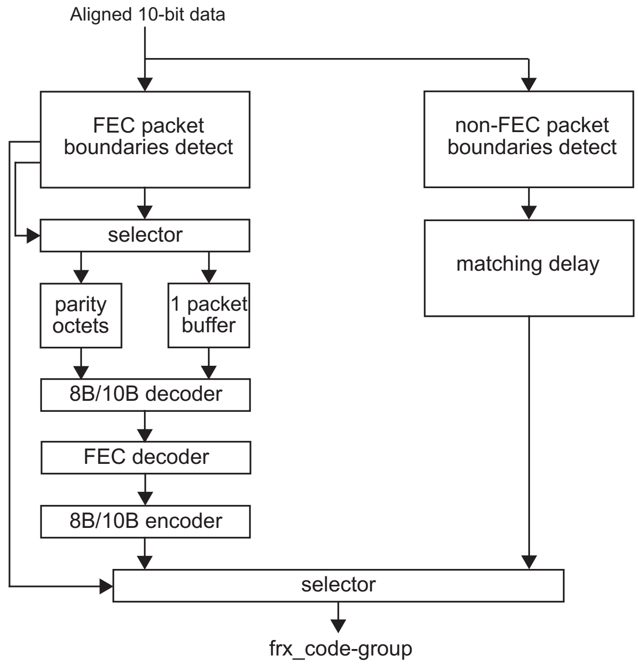


Figure 65–10—Receive data block diagram

65.2.3.4 Detailed functions and state diagrams

The body of this clause 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 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. Variables in a state diagram with default values evaluate to the variable default in each state where the variable value is not explicitly set.

65.2.3.4.1 State variables

65.2.3.4.2 Notation Conventions

/x/
: Denotes the constant code-group specified in 36.2.5.1.2 (valid code-groups must follow the rules of running disparity as per 36.2.4.5 and 36.2.4.6).

[/x/]
: Denotes the latched received value of the constant code-group (/x/) specified in 36.2.5.1.2 and conveyed by the SYNC_UNITDATA.indicate message described in 36.2.5.1.6.

65.2.3.4.3 Constants

/COMMA/
: The set of special code-groups that include a comma as specified in 36.2.4.9 and listed in Table 36–2.

/D/
: The set of 256 code-groups corresponding to valid data, as specified in 36.2.4.11.

/Dx.y/
One of the set of 256 code-groups corresponding to valid data, as specified in 36.2.4.11.

/I/
The IDLE ordered_set group, comprising either the /I1/ or /I2/ ordered_sets, as specified in 36.2.4.12.

/INVALID/
The set of invalid data or special code-groups, as specified in 36.2.4.6.

/Kx.y/
One of the set of 12 code-groups corresponding to valid special code-groups, as specified in Table 36–2.

/R/
The code-group used as either: End_of_Packet delimiter part 2; End_of_Packet delimiter part 3; Carrier_Extend; and /I/ alignment.

/S/
The code-group corresponding to the Start_of_Packet delimiter (SPD) as specified in 36.2.4.13.

/T/
The code-group used for the End_of_Packet delimiter part 1.

/V/
The Error_Propagation code-group, as specified in 36.2.4.16.

65.2.3.4.4 Variables

buffer
The Receive process buffer of undefined length containing code-groups.

buffer_head
The code-group at the head of the Receive process buffer.

cgbad
Alias for the following terms: ((rx_code-group∈/INVALID/) + (rx_code-group=/COMMA/ *rx_even=TRUE)) * PMA_UNITDATA.indication

cggood
Alias for the following terms: !((rx_code-group∈/INVALID/) + (rx_code-group=/COMMA/ *rx_even=TRUE)) * PMA_UNITDATA.indication

fec_encode
A boolean set by the FEC Transmit process to indicate the status of the RS_Encode(Data) function.

Values: TRUE; data is acted upon by the RS_Encode(Data) function.
FALSE; data is not being acted upon by the RS_Encode(Data) function.

ftx_bit
A binary parameter used to convey data from the PMA to the PMD via the PMD_UNITDATA.request service primitive as specified in 60.1.5.1.

Values: ZERO; Data bit is a logical zero.
ONE; Data bit is a logical one.

ftx_code-group<9:0>
A vector of bits representing one code-group, as specified in Table 36–1a through Table 36–2, which has been prepared for transmission by the FEC Transmit process. This vector is conveyed to the PMA as the parameter of a PMA_UNITDATA.request(ftx_code-group) service primitive. The element ftx_code-group<0> is the first ftx_bit transmitted; ftx_code-group<9> is the last ftx_bit transmitted.

parity<D7:D0>
An 8-bit array that contains the current parity bits to be encoded in the FEC Transmit Process. The elements within the array are updated with the next 8-bits to be encoded upon each entry into the XMIT_PARITY state.

Values for each element in the array: ZERO; Data bit is a logical zero.
ONE; Data bit is a logical one.

parity_buffer_empty
A boolean set by the FEC Transmit process to indicate if more parity octets need to be encoded.

Values: TRUE; No more parity octets need to be encoded.
FALSE; More parity octets need to be encoded.

rx_disparity
A boolean set by the FEC Receive process to indicate the running disparity at the end of code-group reception as a binary value. Running disparity is described in 36.2.4.3.

Values: POSITIVE
NEGATIVE

rx_even
A boolean set by the FEC Synchronization process to designate received code-groups as either even- or odd-numbered code-groups as specified in 36.2.4.2.

Values: TRUE; Even-numbered code-group being received.
FALSE; Odd-numbered code-group being received.

rx_code-group<9:0>
A 10-bit vector represented by the most recently received code-group from the PMA. The element rx_code-group<0> is the least recently received (oldest) rx_bit; rx_code-group<9> is the most recently received rx_bit (newest). When code-group alignment has been achieved, this vector contains precisely one code-group.

signal_detect
A boolean set by the PMD continuously via the PMD_SIGNAL.indication(signal_detect) message to indicate the status of the incoming link signal.

Values: FAIL; A signal is not present on the link.
OK; A signal is present on the link.

sync_status
A parameter set by the FEC Synchronization process to reflect the status of the link as viewed by the receiver.

Values: FAIL; The receiver is not synchronized to code-group boundaries.
OK; The receiver is synchronized to code-group boundaries.

tx_bit

A binary parameter used to convey data from the PMA to the PMD via the PMD_UNITDATA.request service primitive as specified in 60.1.5.1.

Values: ZERO; Data bit is a logical zero.
ONE; Data bit is a logical one.

tx_code-group<9:0>

A vector of bits representing one code-group, as specified in Table 36–1a or Table 36–2, which has been prepared for transmission by the PCS Transmit process. This vector is conveyed to the PMA as the parameter of a PMD_UNITDATA.request(tx_bit) service primitive. The element tx_code-group<0> is the first tx_bit transmitted; tx_code-group<9> is the last tx_bit transmitted.

tx_disparity

A boolean set by the FEC Transmit process to indicate the running disparity at the end of code-group transmission as a binary value. Running disparity is described in 36.2.4.3.

Values: POSITIVE
NEGATIVE

65.2.3.4.5 Functions

check_ahead_tx

Prescient function used by the FEC Transmit process to find the Start_of_Packet in order to replace the Start_of_Packet and its two preceding IDLE ordered_sets with /S_FEC/.

check_ahead_rx

Prescient function used by the FEC Receive process to find the /S_FEC/ and /T_FEC/, with fewer than d/2 errors.

DECODE ([/x/])

In the PCS Receive process, this function takes as its argument the latched value of rx_code-group<9:0> ([/x/]) and the current running disparity, and returns the corresponding GMII RXD<7:0>, rx_Config_Reg<D7:D0>, or rx_Config_Reg<D15:D8> octet, per Table 36–1a–e. DECODE also updates the current running disparity per the running disparity rules outlined in 36.2.4.4.

ENCODE(x)

In the PCS Transmit process, this function takes as its argument (x), where x is a GMII TXD<7:0>, tx_Config_Reg<D7:D0>, or tx_Config_Reg<D15:D8> octet, and the current running disparity, and returns the corresponding ten-bit code-group per Table 36–1a. ENCODE also updates the current running disparity per Table 36–1a–e.

POP_BUFFER

Removes the octet at the head of the Receive process buffer, making the next octet available.

RS_Encode(Data)

This function is used to encode the Reed-Solomon (255, 239, 8) code. The encoder encodes the 239 octets data frame and generates 16 parity octets for each data frame. Before being passed to the Reed-Solomon encoder, this function passes the data through DECODE([/x/]).

RS_Decode(Data)

This function is used to decode the Reed-Solomon (255, 239, 8) code. The decoder decodes the 255 symbols data frame and generates 239 corrected data octets for each frame and an error signal.

signal_detectCHANGE
In the PCS Synchronization process, this function monitors the signal_detect variable for a state change. The function is set upon state change detection.

Values: TRUE; A signal_detect variable state change has been detected.
FALSE; A signal_detect variable state change has not been detected (default).

65.2.3.4.6 Counters

good_cgs
Count of consecutive valid code-groups received.

loop_count
A 3-bit counter used to keep track of the number of loops in the receive synchronization process.

65.2.3.4.7 Messages

FEC_UNITDATA.indicate(frx_code-group<9:0>)
A signal sent by the FEC Receive process conveying the next code-group received over the medium.

FUDI
Alias for FEC_UNITDATA.indicate(frx_code-group<9:0>).

PMA_UNITDATA.indication(rx_code-group<9:0>)
A signal sent by the PMA Receive process conveying the next code-group received over the medium (see 36.3.1.2).

PMA_UNITDATA.request(tx_code-group<9:0>)
A signal sent to the PMA or FEC Transmit process conveying the next code-group ready for transmission over the medium (see 36.3.1.1).

PUDI
Alias for PMA_UNITDATA.indication(rx_code-group<9:0>).

PUDR
Alias for PMA_UNITDATA.request(tx_code-group<9:0>).

SUDI
Alias for SYNC_UNITDATA.indicate(parameters).

SYNC_UNITDATA.indicate(parameters)
A signal sent by the FEC Synchronization process to the FEC Receive process conveying the following parameters:

Parameters: [/x/]; the latched value of the indicated code-group (/x/);
EVEN/ODD; The latched state of the rx_even variable;

Value: EVEN; Passed when the latched state of rx_even=TRUE.
ODD; Passed when the latched state of rx_even=FALSE.

65.2.3.5 State diagrams

65.2.3.5.1 Transmit state diagram

The FEC shall implement its transmit process as depicted in Figure 65–11, including compliance with the associated state variables as specified in 65.2.3.4.1.

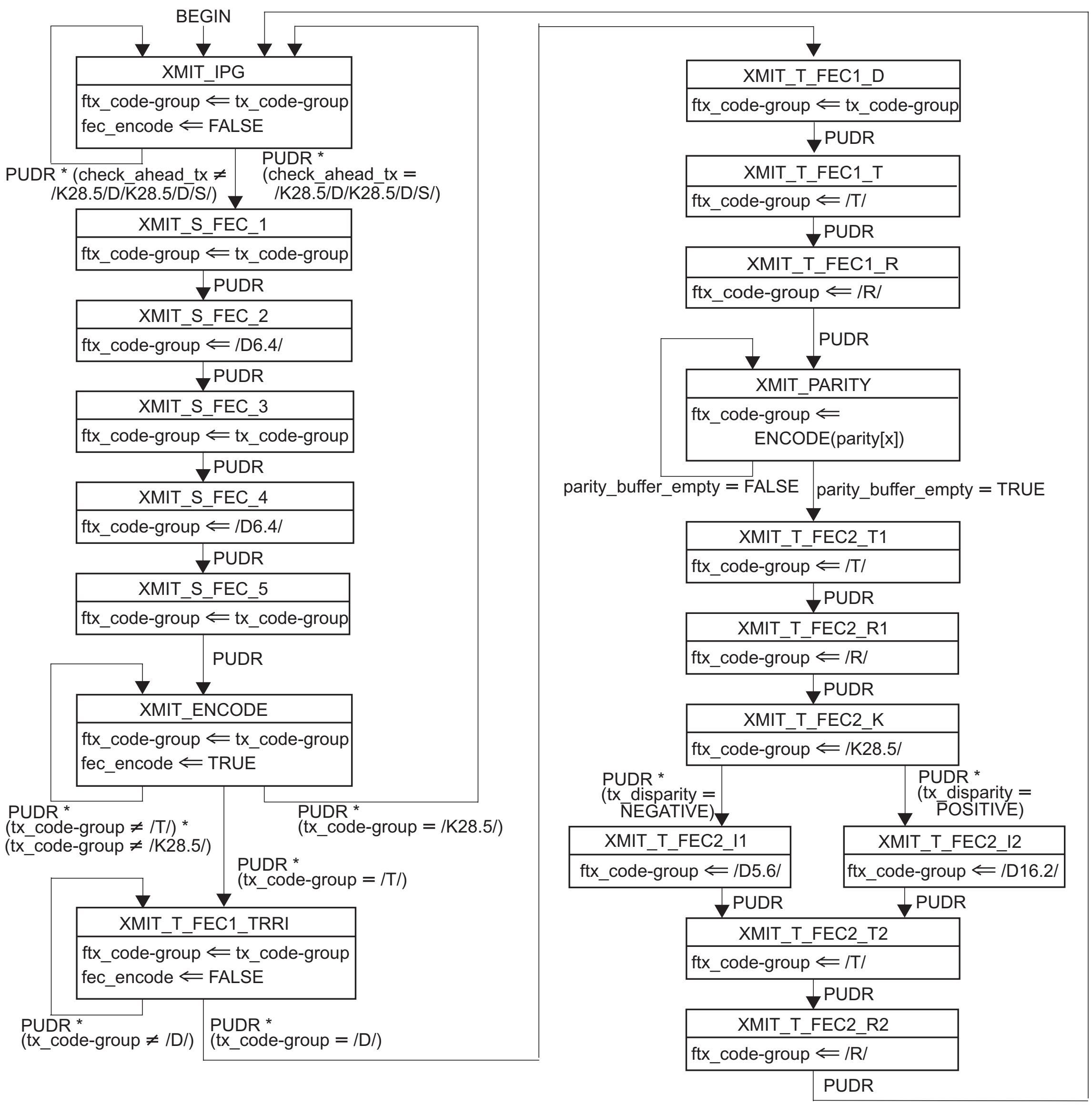


Figure 65–11—Transmit state diagram

65.2.3.5.2 Receive synchronization state diagram

The FEC shall implement its synchronization process as depicted in Figure 65–12, including compliance with the associated state variables in 65.2.3.4.1.

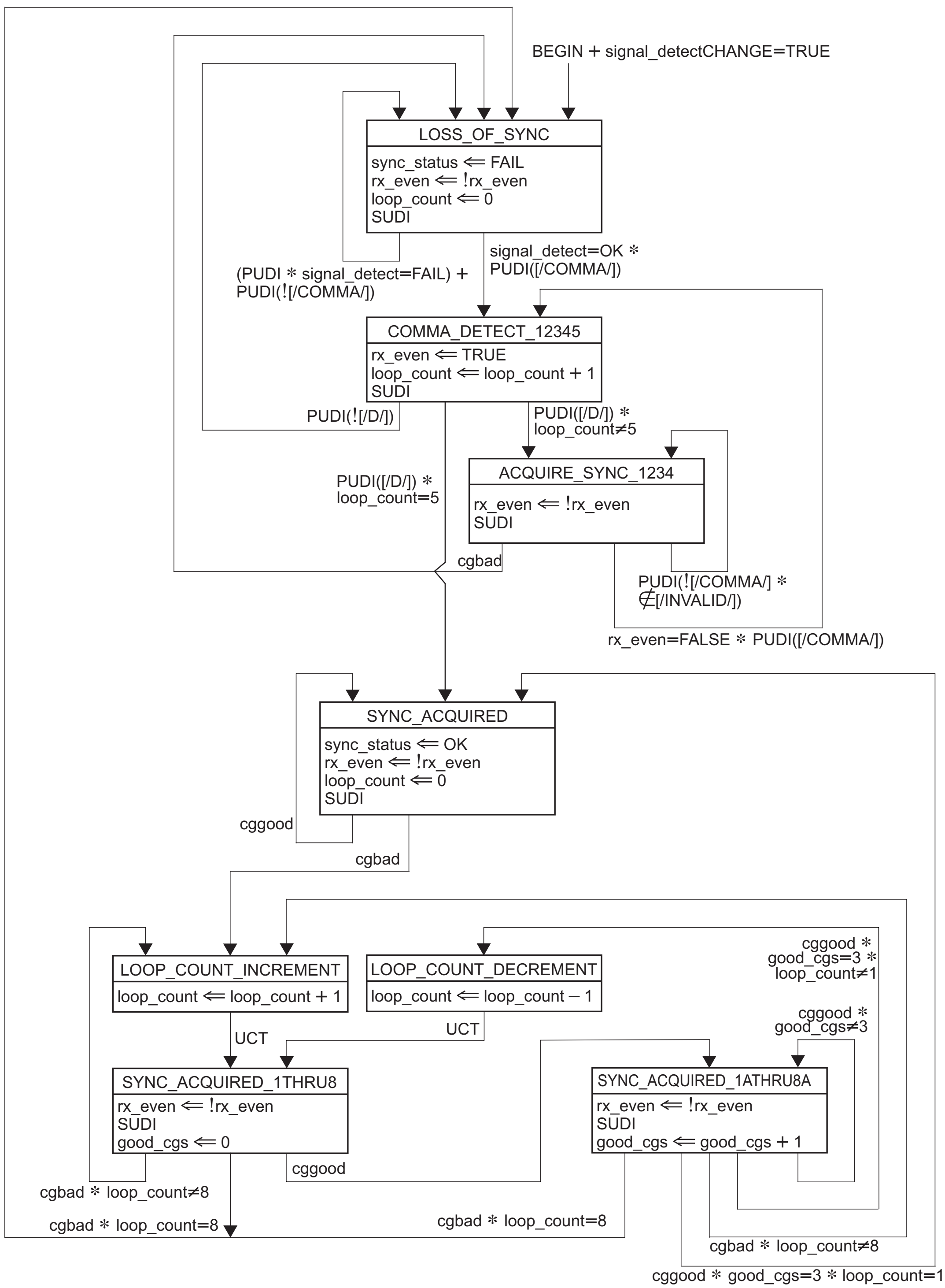


Figure 65–12—Receive synchronization state diagram

65.2.3.5.3 Receive state diagram

The FEC shall implement its receive process as depicted in Figure 65–13 and Figure 65–14, including compliance with the associated state variables in 65.2.3.4.1.

It is expected that the FEC decoding is performed while the data is in the buffer.

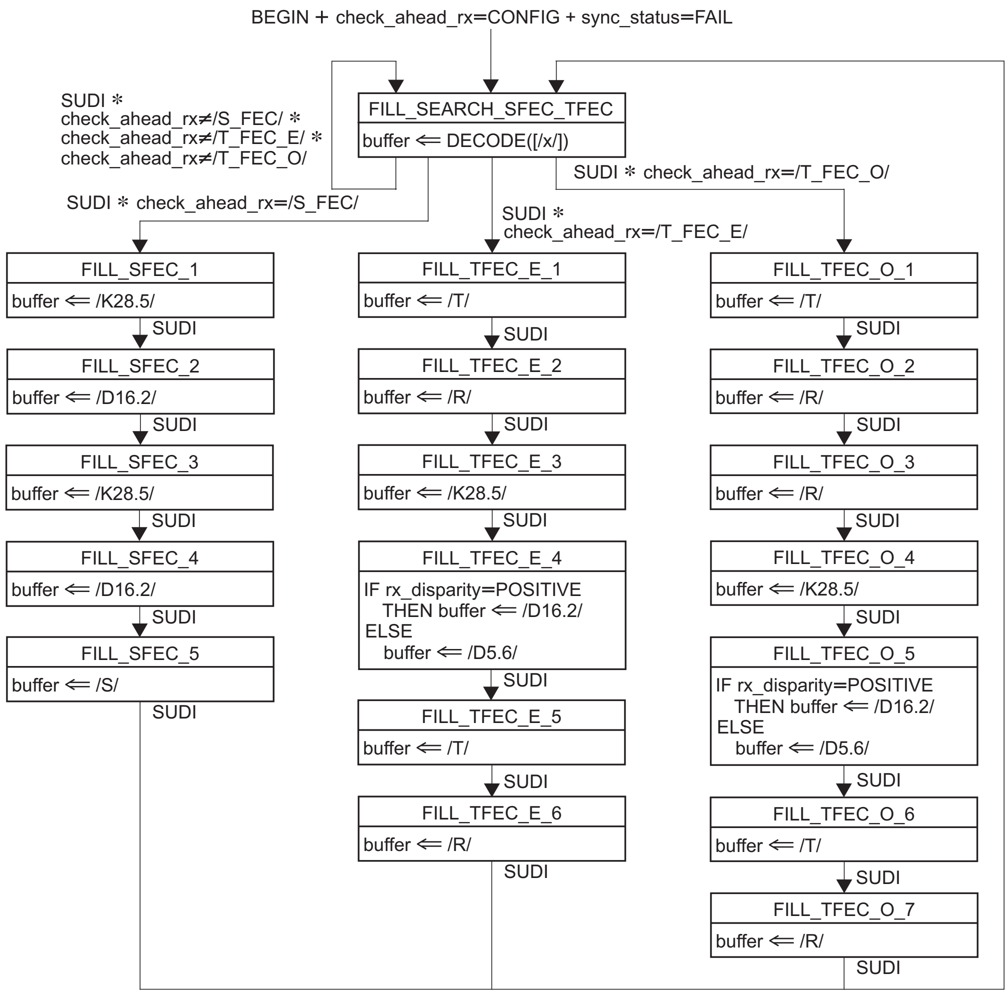


Figure 65–13—Receive buffer-fill state diagram

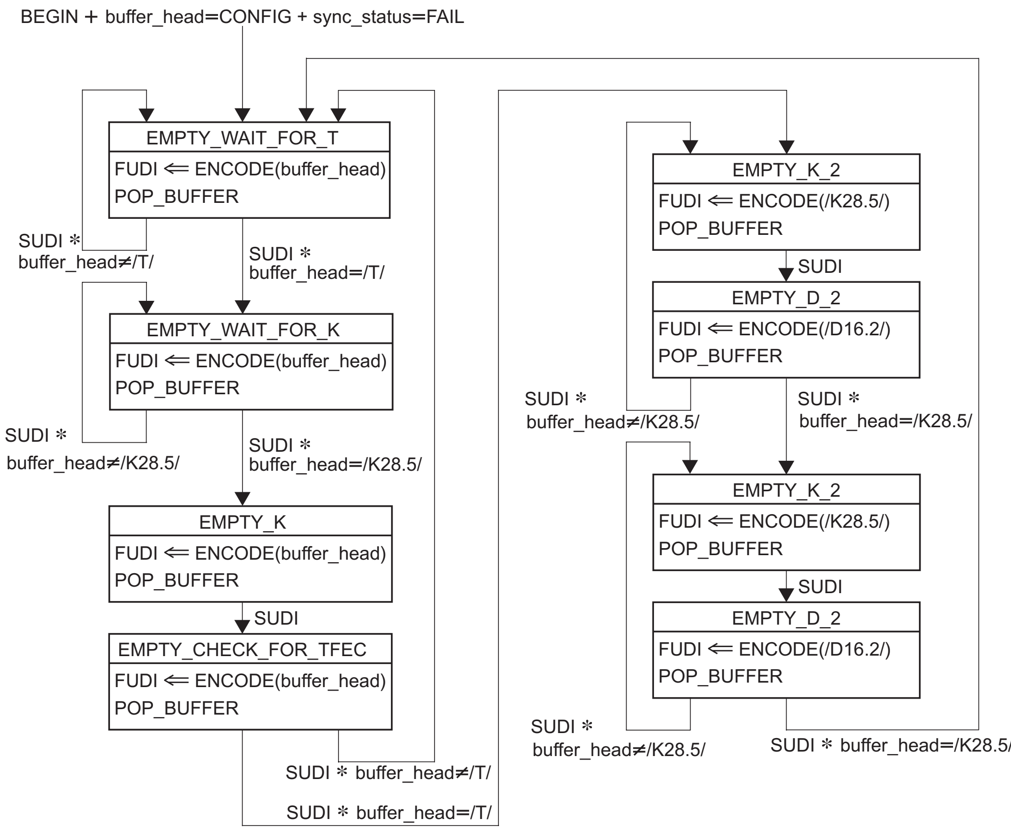


Figure 65–14—Receive buffer-empty state diagram

65.2.3.6 Error monitoring capability

The following counters apply to FEC sublayer management and error monitoring. If an MDIO interface is provided (see Clause 22), it is accessed via that interface. If not, it is recommended that an equivalent access be provided. These counters are reset to zero upon read or upon reset of the FEC sublayer. When a counter reaches all ones, it stops counting. The counters' purpose is to help monitor the quality of the link.

65.2.3.6.1 buffer_head_coding_violation_counter

32-bit counter. buffer_head_coding_violation_counter counts once for each invalid code-group received directly from the link. This variable is provided by a management interface that may be mapped to the 45.2.7.4 register (29.9.15:0).

65.2.3.6.2 FEC_corrected_blocks_counter

32-bit counter. FEC_corrected_blocks_counter counts once for each corrected FEC blocks in the decoding. This variables is provided by a management interface that may be mapped to the 45.2.7.5 register (29.10.15:0).

65.2.3.6.3 FEC_uncorrected_Blocks_counter

32-bit counter. FEC_uncorrected_blocks_counter counts once for each uncorrected FEC blocks in the decoding. This variables is provided by a management interface that may be mapped to the 45.2.7.6 register (29.11.15:0).

65.3 Extensions to PMA for 1000BASE-PX

In addition to the requirements defined in Clause 36, P2MP operation imposes the following requirement on the PMA sublayer of the OLT and ONU.

65.3.1 Extensions for 1000BASE-PX-U

65.3.1.1 Physical Medium Attachment (PMA) sublayer interfaces

In addition to the primitives of Clause 36, the following primitive is defined:

PMD_SIGNAL.request(tx_enable)

This primitive controls PMD emission of light. It is generated by the PCS's data detector (see 65.2.2.2.3) and the effect of its receipt is defined in 60.1.5.3. This primitive is received from the PCS and passed in timely fashion and without modification to the PMD. It takes the following parameter:

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

65.3.1.2 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. Jitter transfer masks are defined in 60.6.

65.3.2 Extensions for 1000BASE-PX-D

65.3.2.1 CDR lock timing measurement

A PMA instantiated in an OLT becomes synchronized at the bit level within 400 ns (T_{cdr}) and code-group level within an additional 32 ns ($T_{code\_group\_alignment}$) of the appearance of a valid 1000BASE-X IDLE pattern at TP4 when the PMA_TX_CLK frequency is equal to twice the PMA_RX_CLK frequency.

65.3.2.1.1 Definitions

CDR Lock Time (denoted T_{CDR}) is defined as a time interval required by the receiver to acquire phase and frequency lock on the incoming data stream. T_{CDR} is measured as the time elapsed from the moment when electrical signal after the PMD at TP4 reaches the conditions specified in 60.7.13.2.1 for receiver settling time to the moment when the phase and frequency are recovered and jitter is maintained for a network with BER of no more than $10^{–12}$ for non-FEC systems, or no more than $10^{–4}$ for FEC enabled systems.

The combined value of measured T_{CDR} and $T_{code\_group\_alignment}$ shall not exceed 432 ns.

65.3.2.1.2 Test specification

Figure 60–2 illustrates the tests setup for the OLT PMA receiver (upstream) T_{CDR} time. The test assumes that there is an optical PMD transmitter at the ONU with well known parameters, having a fixed known T_{On} time as defined in 60.7.13.1, and an optical PMD receiver at the OLT with well-known parameters, having a fixed known $T_{Receiver\_settling}$ time as defined in 60.7.13.2. After T_{On} + $T_{Receiver\_settling}$ time the parameters at TP4 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 PMA reaches up to phase difference from the input signal of the transmitting PMA, assuring BER of $10^{–12}$ for non-FEC systems, or BER of $10^{–4}$ for FEC enabled systems, and maintaining its jitter specifications. The signal throughout this test, is the 1000BASE-X IDLE pattern.

A non-rigorous way to describe this test setup would be (using a transmitter PMD at the ONU, with a known T_{On} time and a receiver PMD at the OLT, with a known $T_{Receiver\_settling}$ time):

For a tested PMA receiver with a declared T_{CDR} time, measure the phase and jitter of the recovered PMA receiver signal after T_{CDR} time from the TX_ENABLE trigger minus the reference T_{On} + $T_{Receiver\_settling}$ time, reassuring synchronization to the ONU PMA input signal and conformance to the specified steady state phase, frequency, and jitter values for BER of $10^{–12}$ for non-FEC systems, or BER of $10^{–4}$ for FEC enabled systems.

65.3.3 Delay variation requirements

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 16 bit times so as to comply with this mechanism.

65.4 Protocol implementation conformance statement (PICS) proforma for Clause 65, Extensions of the Reconciliation Sublayer (RS) and Physical Coding Sublayer (PCS) / Physical Media Attachment (PMA) for 1000BASE-X for multipoint links and forward error correction[21]

65.4.1 Introduction

The supplier of a protocol implementation that is claimed to conform to Clause 65, Extensions of the Reconciliation Sublayer (RS) and Physical Coding Sublayer (PCS) / Physical Media Attachment (PMA) for 1000BASE-X for multipoint links and forward error correction, 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.

65.4.2 Identification

65.4.2.1 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)	
Only the first three items are required for all implementations; other information may be completed as appropriate in meeting the requirements for the identification. The terms Name and Version should be interpreted appropriately to correspond with a supplier's terminology (e.g., Type, Series, Model).	

65.4.2.2 Protocol summary

Identification of protocol standard	IEEE Std 802.3-2005, Extensions of the Reconciliation Sublayer (RS) and Physical Coding Sublayer (PCS) / Physical Media Attachment (PMA) for 1000BASE-X for multipoint links and forward error correction
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 802.3-2005)	
Date of Statement	

[21]*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.

65.4.3 Major capabilities/options

Item	Feature	Subclause	Value/Comment	Status	Support
*OLT	OLT functionality	65.1.1	Device supports functionality required for OLT	O.1	Yes [ ] No [ ]
*ONU	ONU functionality	65.1.1	Device supports functionailty required for ONU	O.1	Yes [ ] No [ ]
*FEC	Forward error correction for multipoint optical links	65.2.3	Device supports FEC for multipoint optical links	O	Yes [ ] No [ ]

65.4.4 PICS proforma tables for Extensions of Reconciliation Sublayer (RS) and Physical Coding Sublayer (PCS) / Physical Media Attachment (PMA) for 1000BASE-X for multipoint links and forward error correction

65.4.4.1 Operating modes of OLT MACs

Item	Feature	Subclause	Value/Comment	Status	Support
OM1	Unidirectional mode	65.1.2	Device operates in unidirectional transmission mode	OLT:M	Yes [ ]

65.4.4.2 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	65.1.3.1	Set to 0x7FFF until ONU MAC is registered Set to any value for enabled OLT MAC. Set to any value other then 0x7FFF for registered ONU MAC	M	Yes [ ]

65.4.4.3 Preamble mapping and replacement

Item	Feature	Subclause	Value/Comment	Status	Support
PM1	CRC-8 generation	65.1.3.2.3	CRC calculation produces same result as serial implementation	M	Yes [ ] No [ ]
PM2	CRC-8 initial value	65.1.3.2.3	CRC shift register initialized to 0x00 before each new calculations	M	Yes [ ] No [ ]
PM3	SLD parsing	65.1.3.3.1	If SLD is not found then discard packet	M	Yes [ ] No[ ]
PM4	SLD replacement	65.1.3.3.1	Replace SLD with preamble	M	Yes [ ] No [ ]
PM5	LLID matching	65.1.3.3.2	If LLID does not match then discard packet	M	Yes [ ] No [ ]
PM6	LLID Replacement	65.1.3.3.2	Replace LLID with preamble	M	Yes [ ] No [ ]
PM7	CRC-8 checking	65.1.3.3.3	If CRC does not match then discard packet	M	Yes [ ] No [ ]
PM8	CRC-8 replacement	65.1.3.3.3	Replace CRC with preamble	M	Yes [ ] No [ ]

65.4.4.4 Data detection

Item	Feature	Subclause	Value/Comment	Status	Support
DD1	Buffer depth	65.2.2.1	Depth sufficient to turn on laser and settle receiver	ONU:M	Yes [ ] No [ ]
DD2	OLT laser control	65.2.2.2.3	Always takes the value ON	OLT:M	Yes [ ] No [ ]
DD3	State diagrams	65.2.2.3	Meets the requirements of Figure 65–6	ONU:M	Yes [ ] No[ ]

65.4.4.5 FEC requirements

Item	Feature	Subclause	Value/Comment	Status	Support
FE1	FEC Coding Choice	65.2.3	If FEC is used, it is this one	FEC:M	Yes [ ] No [ ]
FE2	Uncorrectable block replacement	65.2.3.1	Replace all code-groups in an uncorrectable block with /V/	FEC:M	Yes [ ] No [ ]

65.4.4.6 FEC state machines

Item	Feature	Subclause	Value/Comment	Status	Support
SM1	Transmit	65.2.3.5.1	Meets the requirements of Figure 65–11	FEC:M	Yes [ ]
SM2	Receive synchronization	65.2.3.5.2	Meets the requirements of Figure 65–12	FEC:M	Yes [ ]
SM3	Receive	65.2.3.5.3	Meets the requirements of Figure 65–13 for buffer fill and Figure 65–14 for buffer empty	FEC:M	Yes [ ]

65.4.4.7 PMA

Item	Feature	Subclause	Value/Comment	Status	Support
BMC1	Loop Timing	65.3.1.2	ONU RX clock tracks OLT TX clock	ONU:M	Yes [ ] No [ ]

65.4.4.8 Delay variation

Item	Feature	Subclause	Value/Comment	Status	Support
DV1	Delay variation	65.3.3	Combined delay variation through RS, PCS, and PMA sublayers is limited to 16 bit times	M	Yes [ ] No [ ]

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

In the absence of unidirectional operation, the sublayers in this clause are precisely the same as their equivalents in Clause 24, Clause 36, and Clause 46. Otherwise, this clause describes additions and modifications to the 100BASE-X, 1000BASE-X, 10GBASE-R, 10GBASE-W, and 10GBASE-X physical layers, making them capable of unidirectional operation, which is required to initialize a 1000BASE-PX network, and allows the transmission of Operations, Administration and Management (OAM) frames regardless of whether the PHY has determined that a valid link has been established.

However, unidirectional operation may only be enabled under very limited circumstances. Before enabling this mode, the MAC shall be operating in full-duplex mode and Auto-Negotiation, if applicable, shall be disabled. In addition, the OAM sublayer above the MAC (see Clause 57) shall be present and enabled or (for 1000BASE-X), the PCS shall be part of a 1000BASE-PX-D PHY (see Clause 60 and Clause 64). Unidirectional operation shall not be invoked for a PCS that is part of a 1000BASE-PX-U PHY (except for out-of-service test purposes or where the PON contains just one ONU). Failure to follow these restrictions results in an incompatibility with the assumptions of IEEE 802.1 protocols, a PON that cannot initialize, or collisions, which are unacceptable in the P2MP protocol.

66.1 Modifications to the physical coding sublayer (PCS) and physical medium attachment (PMA) sublayer, type 100BASE-X

66.1.1 Overview

This subclause specifies the 100BASE-X PCS and PMA for support of subscriber access networks.

66.1.2 Functional specifications

The 100BASE-X PCS and PMA for subscriber access networks shall conform to the requirements of the 100BASE-X PCS specified in 24.2 and the 100BASE-X PMA specified in 24.3 with the following exception: The 100BASE-X PCS for 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 24 in order to support this additional ability.

66.1.2.1 Variables

Insert a new variable among those already described in 24.2.3.2:

mr_unidirectional_enable

A control variable that enables the unidirectional mode of operation. This variables is provided by a management interface that may be mapped to the Clause 22 Control register Unidirectional enable bit (0.5).

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

66.1.2.2 Transmit state diagram

The description of the transmit state diagram is changed to include the contribution of the new mr_unidirectional_enable variable. The third paragraph of 24.2.4.2 is changed to read (~~strikethroughs~~ show deleted text and underscores show inserted text):

> The indication of link_status ≠ OK by the ~~PMA at any time~~ PMA, when mr_unidirectional_enable = FALSE, causes an immediate transition to the IDLE state and supersedes any other Transmit process operations. When mr_unidirectional_enable = TRUE, the Transmit process ignores the value of link_status. This enables the ability to transmit data from the MII when link_status ≠ OK.

Additionally, the functionality of Figure 24–12 shall be changed as represented by Figure 66–1.

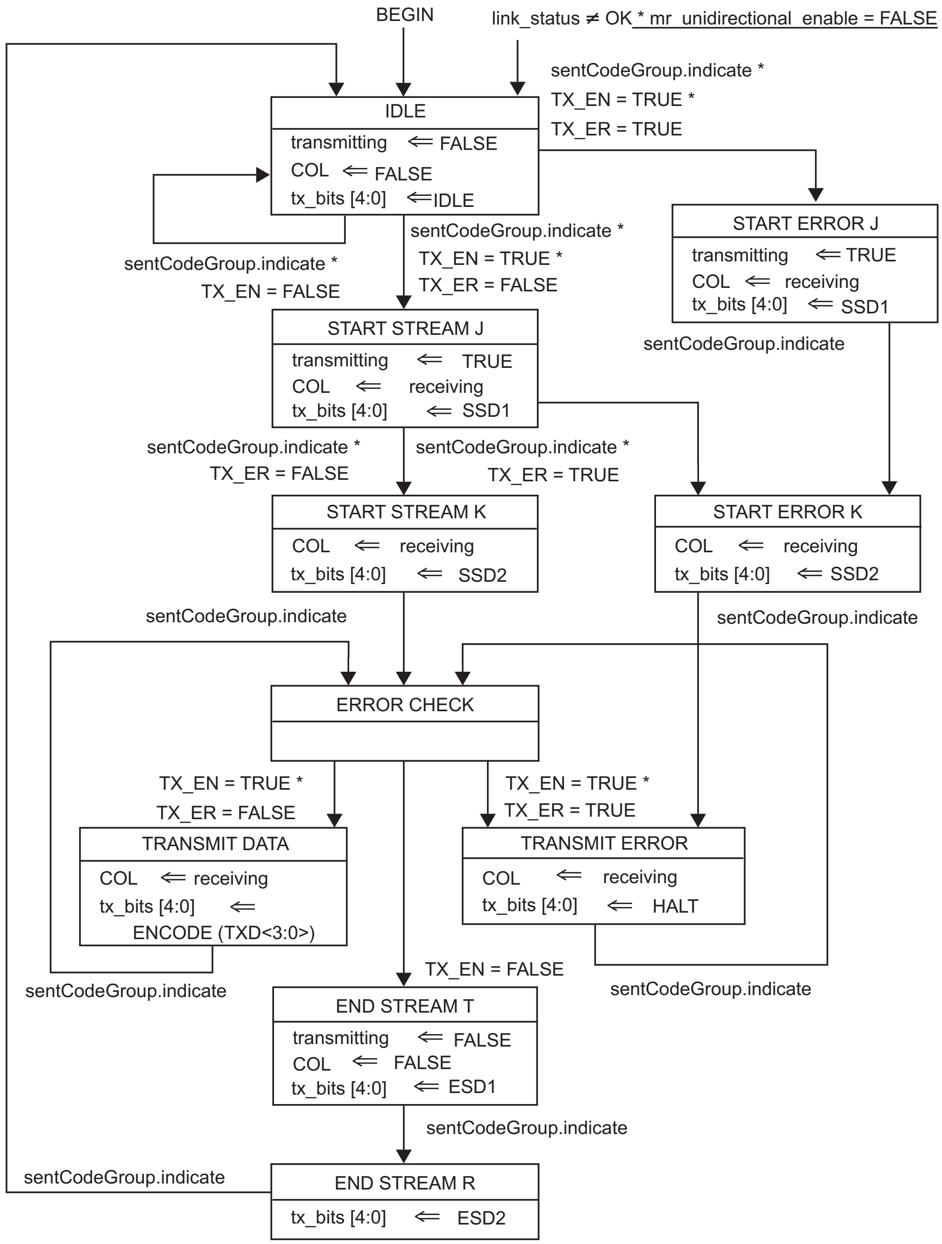


Figure 66–1—Transmit state diagram

66.1.2.3 Far-end fault generate

The description of the far-end fault generate state diagram is also changed to include the contribution of the new mr_unidirectional_enable variable. The first paragraph of 24.3.4.5 is changed to read (~~strikethroughs~~ show deleted text and underscores show inserted text):

> Far-End Fault Generate simply passes tx_code-bits to the TX process when signal_status=ON or when mr_unidirectional_enable=TRUE. When signal_status=OFF and mr_unidirectional_enable=FALSE, it repetitively generates each cycle of the Far-End Fault Indication until signal_status is reasserted or mr_unidirectional_enable is set to TRUE.

Additionally, the functionality of Figure 24–16 shall be changed as represented by Figure 66–2.

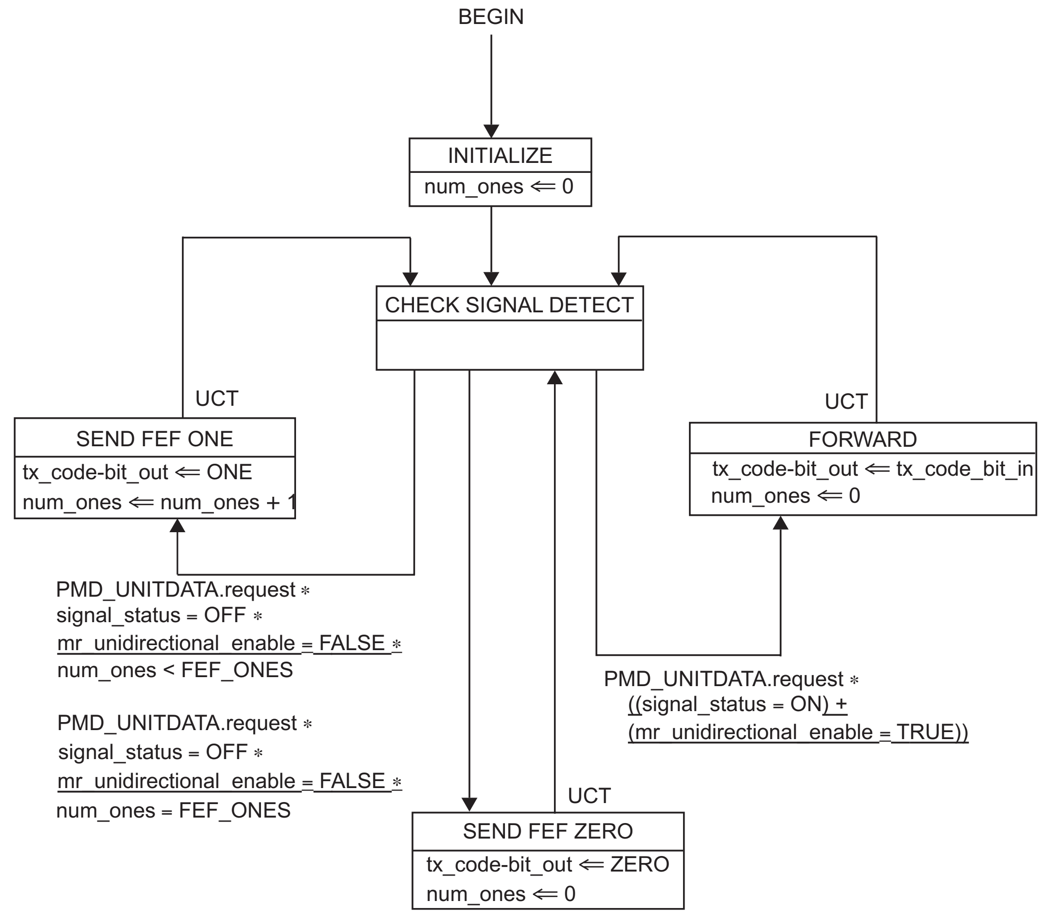


Figure 66–2—Far-End Fault Generate state diagram

66.2 Modifications to the physical coding sublayer (PCS) and physical medium attachment (PMA) sublayer, type 1000BASE-X

66.2.1 Overview

This subclause specifies the 1000BASE-X PCS and PMA for support of subscriber access networks.

66.2.2 Functional specifications

The 1000BASE-X PCS for subscriber access networks shall conform to the requirements of the 1000BASE-X PCS specified in 36.2 with the following exception: The 1000BASE-X PCS for 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 1000BASE-X PMA for subscriber access networks shall conform to the requirements of the 1000BASE-X PMA specified in 36.3 with no changes. The following are the detailed changes to Clause 36 in order to support this additional ability.

66.2.2.1 Variables

Insert a new variable among those already described in 36.2.5.1.3:

mr_unidirectional_enable
: A control variable that enables the unidirectional mode of operation. This variable is provided by a management interface that may be mapped to the Clause 22 Control register Unidirectional enable bit (0.5).

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

Additionally, modify the existing xmit variable from 36.2.5.1.3 as follows (~~strikethroughs~~ show deleted text and underscores show inserted text):

xmit
: When mr_unidirectional_enable=FALSE, xmit is d~~D~~efined in 37.3.1.1. When mr_unidirectional_enable=TRUE, xmit always takes the value DATA.

66.2.2.2 Transmit

The description of the transmit state diagram is changed to include the contribution of the new mr_unidirectional_enable variable. The second paragraph of 36.2.5.2.1 is changed to read (~~strikethroughs~~ show deleted text and underscores show inserted text):

> The Transmit ordered_set process continuously sources ordered_sets to the Transmit code-group process. When mr_unidirectional_enable = TRUE, the Auto-Negotiation process xmit flag always takes the value DATA and the Auto-Negotiation process is never invoked. Otherwise, when initially invoked, and when the Auto-Negotiation process xmit flag indicates CONFIGURATION, the Auto-Negotiation process is invoked. When the Auto-Negotiation process xmit flag indicates IDLE, and between packets (as delimited by the GMII), /I/ is sourced. Upon the assertion of TX_EN by the GMII when the Auto-Negotiation process xmit flag indicates DATA, the SPD ordered_set is sourced. Following the SPD, /D/ code-groups are sourced until TX_EN is deasserted. Following the de-assertion of TX_EN, EPD ordered_sets are sourced. If TX_ER is asserted when TX_EN is deasserted and carrier extend error is not indicated by TXD, /R/ ordered_sets are sourced for as many GTX_CLK periods as TX_ER is asserted with a delay of two GTX_CLK periods to first source the /T/ and /R/ ordered sets. If carrier extend error is indicated by TXD during carrier extend, /V/ ordered_sets are sourced. If TX_EN and TX_ER are both de-asserted, the /R/ ordered_set may be sourced, after which the sourcing of /I/ is resumed. If, while TX_EN is asserted, the TX_ER signal is asserted, the /V/ ordered_set is sourced except when the SPD ordered set is selected for sourcing.

66.2.2.3 Transmit state diagram

The 1000BASE-X PCS for subscriber access networks shall implement the transmit process as depicted in Figure 36–5 and Figure 36–6, including compliance with the associated state variables as specified in 36.2.5.1 and as modified in 66.2.2.1.

66.3 Modifications to the reconciliation sublayer (RS) for 10 Gb/s operation

66.3.1 Overview

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

66.3.2 Functional specifications

The 10 Gb/s RS for 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 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.

66.3.2.1 Link fault signaling

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

> Sublayers within the PHY are capable of detecting faults that render a link unreliable for communication. 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 tests the unidirectional_enable variable. If this variable is FALSE, the RS stops sending MAC data, and continuously generates a Remote Fault status on the transmit data path (possibly truncating a MAC frame being transmitted). If this variable is TRUE, the RS continues to allow the transmission of MAC data but replaces IPG with a Remote Fault status. When Remote Fault status is received by an RS, the RS tests the unidirectional_enable variable. If this variable is FALSE, the RS stops sending MAC data, and continuously generates Idle control characters. If this variable is TRUE, the RS continues to allow the transmission of MAC data. When the RS no longer receives fault status messages, it returns to normal operation, sending MAC data.

66.3.2.2 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

66.3.2.3 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 mr_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 Remote Fault Sequence ordered_sets.
If unidirectional_enable=TRUE, the RS shall send MAC frames as requested through the PLS service interface. After a MAC frame and before transition to generation of Remote Fault Sequence the RS shall ensure a column of idles has been sent. In the absence of MAC frames, the RS shall generate Remote Fault Sequence ordered_sets.

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.

66.4 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[22]

66.4.1 Introduction

The supplier of a protocol implementation that is claimed to conform to Clause 66, Extensions of the 10 Gb/s Reconciliation Sublayer (RS), 100BASE-X PHY, and 1000BASE-X PHY for unidirectional transport, 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.

66.4.2 Identification

66.4.2.1 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)	
Only the first three items are required for all implementations; other information may be completed as appropriate in meeting the requirements for the identification. The terms Name and Version should be interpreted appropriately to correspond with a supplier’s terminology (e.g., Type, Series, Model).	

66.4.2.2 Protocol summary

Identification of protocol standard	IEEE Std 802.3-2005, Extensions of the 10 Gb/s Reconciliation Sublayer (RS), 100BASE-X PHY, and 1000BASE-X PHY for unidirectional transport
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 802.3-2005.)	
Date of Statement	

[22]*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.

66.4.3 Major capabilities/options

Item	Feature	Subclause	Value/Comment	Status	Support
*PUNI	Unidirectional operation	66	Device supports unidirectional operation	O	Yes [ ] No [ ]
*HUN	100BASE-X functionality	66.1	Device supports functionality required for 100BASE-X PHY for subscriber access networks	O	Yes [ ] No [ ]
*GIG	1000BASE-X functionality	66.2	Device supports functionality required for 1000BASE-X PCS for subscriber access networks	O	Yes [ ] No [ ]
*XG	10 Gb/s functionality	66.3	Device supports functionality required for 10 Gb/s RS for subscriber access networks	O	Yes [ ] No [ ]

66.4.4 PICS proforma tables for Extensions of the 10 Gb/s Reconciliation Sublayer (RS), 100BASE-X PHY, and 1000BASE-X PHY for unidirectional transport

66.4.4.1 Maintaining compatibility with IEEE 802.1 protocols

Item	Feature	Subclause	Value/Comment	Status	Support
MC1	Unidirectional mode enabled	66	Full duplex and disable AutoNeg and ((OAM present and enabled) or 1000BASE-PX-D) and not 1000BASE-PX-U	M	Yes [ ] No [ ]

66.4.4.2 Extensions of the 100BASE-X PHY

Item	Feature	Subclause	Value/Comment	Status	Support
H1	Integrates 100BASE-X PCS and PMA	66.1.2	See Clause 24	HUN:M	Yes [ ]
H2	Transmit state machine	66.1.2.2	Replaces Figure 24–8	PUNI* HUN:M	Yes [ ]
H3	Far-End Fault Generate state machine	66.1.2.3	Replaces Figure 24–16	PUNI* HUN:M	Yes [ ]

66.4.4.3 Extensions of the 1000BASE-X PHY

Item	Feature	Subclause	Value/Comment	Status	Support
G1	Integrates 1000BASE-X PCS and PMA	66.2.2	See Clause 36	GIG:M	Yes [ ]
G2	Transmit state machine	66.2.2.3	As modified by the new variables	PUNI* GIG:M	Yes [ ]

66.4.4.4 Extensions of the 10 Gb/s RS

Item	Feature	Subclause	Value/Comment	Status	Support
LF1	Integrates 10 Gb/s RS	66.3.2	See Clause 46	XG:M	Yes [ ]
LF2	link_fault = OK and MAC frames	66.3.2.3	RS services MAC frame transmission requests	PUNI* XG:M	Yes [ ] No [ ]
LF3	link_fault = OK and no MAC frames	66.3.2.3	In absence of MAC frames, RS transmits Idle control characters	PUNI* XG:M	Yes [ ] No [ ]
LF4	link_fault = Local Fault and unidirectional_enable = FALSE	66.3.2.3	RS transmits continuous Remote Fault Sequence ordered_sets	PUNI* XG:M	Yes [ ] No[ ]
LF5	link_fault = Local Fault and unidirectional_enable = TRUE and MAC frames	66.3.2.3	RS services MAC frame transmission requests	PUNI* XG:M	Yes [ ] No[ ]
LF6	link_fault = Local Fault and unidirectional_enable = TRUE and MAC frame ends	66.3.2.3	RS transmits one full column of IDLE after frame	PUNI* XG:M	Yes [ ] No[ ]
LF7	link_fault = Local Fault and unidirectional_enable = TRUE and no MAC frames	66.3.2.3	RS transmits continuous Remote Fault Sequence ordered_sets	PUNI* XG:M	Yes [ ] No[ ]
LF8	link_fault = Remote Fault and unidirectional_enable = FALSE	66.3.2.3	RS transmits continuous Idle control characters	PUNI* XG:M	Yes [ ] No [ ]
LF9	link_fault = Remote Fault and unidirectional_enable = TRUE and MAC frames	66.3.2.3	RS services MAC frame transmission requests	PUNI* XG:M	Yes [ ] No [ ]
LF10	link_fault = Remote Fault and unidirectional_enable = TRUE and no MAC frames	66.3.2.3	RS transmits continuous Idle control characters	PUNI* XG:M	Yes [ ] No[ ]

67. System considerations for Ethernet subscriber access networks

67.1 Overview

This clause provides information on building Ethernet subscriber access networks, also referred to as "Ethernet in the First Mile" or EFM networks.

EFM encompasses a family of technologies that vary in media type and signaling speed. EFM is designed to be deployed in networks of one or multiple EFM media type(s) as well as interact with mixed 10/100/1000/10000 Mb/s Ethernet networks. Any network topology defined in IEEE Std 802.3 can be used within the subscriber premises and then connected to an Ethernet subscriber access network via an IEEE Std 802.1D compliant bridge, or a router.

Further, within a given EFM domain, the specific EFM technologies allow for a variety of topologies affording the subscriber access network maximum flexibility. For example, a 1000BASE-PX10 P2MP system with 16 ONUs can be built with a 1:16 splitter or as a tree-and-branch network utilizing more than one splitter.

The design of multiple-domain networks is governed by the rules defining each of the transmission systems incorporated into the design. The physical size of a network is limited by the characteristics of individual network components. These characteristics include the media lengths and type.

Table 67–1 summarizes the various EFM media characteristics.

Table 67–1—Characteristics of the various EFM network media segments

Media type	Rate (Mb/s)	Number of PHYs per segment	Nominal reach (km)
Optical 100 Mb/s fiber segment (100BASE-LX10, 100BASE-BX10)	100	2	10
Optical 1000 Mb/s fiber segment (1000BASE-LX10, 1000BASE-BX10)	1000	2	10
Optical 1000 Mb/s P2MP segment (1000BASE-PX10)	1000	17[a b]	10
Optical 1000 Mb/s P2MP segment (1000BASE-PX20)	1000	17[a b]	20
Copper high-speed segment (10PASS-TS)	10[c]	2	0.75
Copper long reach segment (2BASE-TL)	2[c]	2	2.7

[a]P2MP segments may be implemented with a trade off between link span and split ratio listed. Refer to 67.2.1.
[b]The number of PHYs in the P2MP segment includes the OLT PHY.
[c]Nominal rate stated at the nominal reach in this table. Rate and reach can vary depending on the plant. For 2BASE-TL please refer to Annex 63B for more information. For 10PASS-TS, please refer to Annex 62A for more information.

67.2 Discussion and examples of EFM P2MP topologies

This section discusses EFM P2MP topologies. It details flexibility of trading off split ratio for link span. This section also shows some examples of different P2MP topologies.

67.2.1 Trade off between link span and split ratio

While the P2MP PMDs are nominally described in terms of a link span of either 10 km or 20 km with a 1:16 split ratio, other link spans and split ratios can be implemented provided that the requirements of Table 60–1 are met.

67.2.2 Single splitter topology

A P2MP topology implemented with a single optical splitter is shown in Figure 67–1.

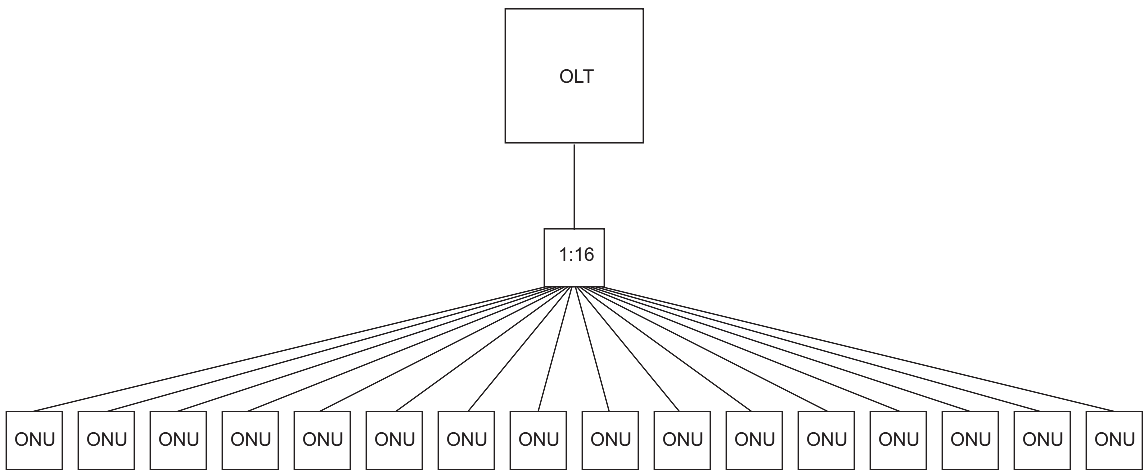


Figure 67–1—Single splitter topology

67.2.3 Tree-and-branch topology

A P2MP topology implemented with a tree-and-branches of optical splitters is shown in Figure 67–2.

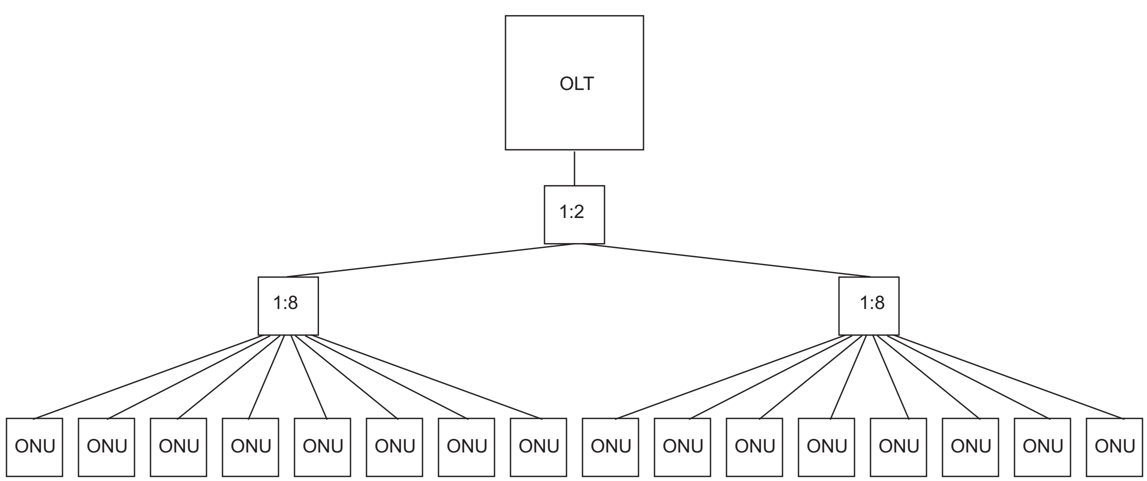


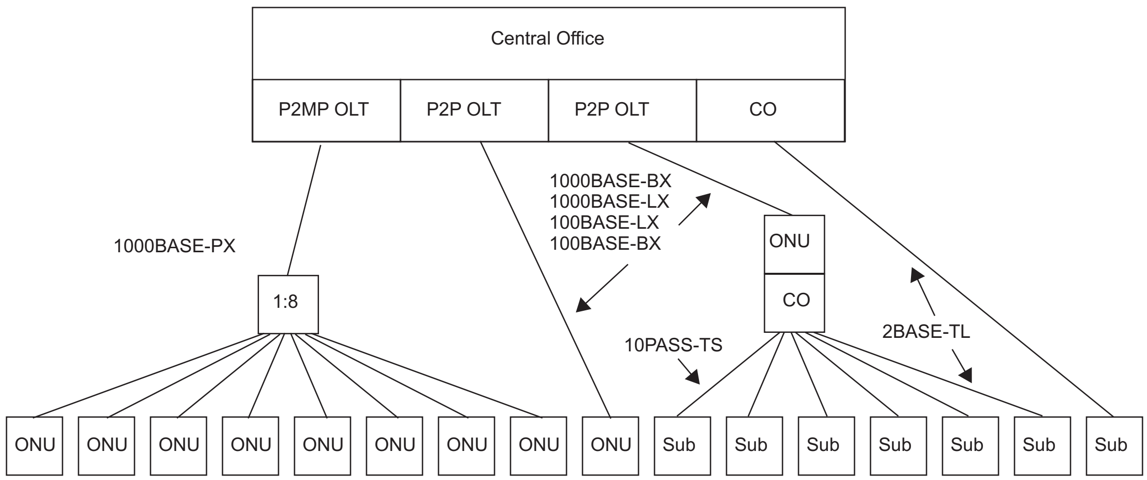
Figure 67–2—Tree-and-branch topology

67.2.4 Interoperability between certain 1000BASE-PX10 and 1000BASE-PX20

1000BASE-PX20-D PMD is interoperable with a 1000BASE-PX10-U PMD, this allows certain upgrade possibilities from 10 km to 20 km P2MP networks.

67.3 Hybrid media topologies

Hybrid media topologies, such as those shown in Figure 67–3, can be implemented using a combination of P2P or P2MP optical links and copper links.



CO = central office
ONU = optical network unit
Sub = subscriber premise equipment
OLT = optical line terminal

Figure 67–3—Hybrid Media Topologies

67.4 Topology limitations

The physical size of EFM networks is not limited by the round-trip collision propagation delay. Instead, the maximum link length between DTEs is limited by the signal transmission characteristics of the specific link.

67.5 Deployment restrictions for subscriber access copper

10PASS-TS and 2BASE-TL PHYs have been specified to allow deployment on public access networks. Non-loaded cable is a requirement of the signaling methods employed. The 10PASS-TS do not preclude coexistence with POTS. However, it is important that systems are designed and configured to comply with all appropriate regulatory, governmental and regional requirements. Refer to Annex 62A (10PASS-TS) and Annex 63A (2PASS-TL) for further information regarding configuration profiles.

67.6 Operations, Administration, and Maintenance

All P2P and emulated P2P links, including all of the EFM network media segments, support the optional OAM sublayer as defined in Clause 57. 2BASE-TL and 10PASS-TS PHYs do not support unidirectional links as defined in 57.2.6 (see 61.1).

67.6.1 Unidirectional links

Some physical layer devices have the optional ability to encode and transmit data while one direction of the link is non-operational.

This ability should be used only when the OAM sublayer is present and enabled or for a 1000BASE-PX-D PHY. Otherwise, MAC Client frames will be sent across a unidirectional link potentially causing havoc with bridge and other higher layer protocols. The feature should not be enabled for 1000BASE-PX-U PHYs in service, to avoid simultaneous transmission by more than one ONU.

67.6.2 Active and Passive modes

A device may be configured to be in either Active or Passive OAM mode. At least one end of a given link is required to be in Active mode.

In an access network, customer premises devices will commonly be configured as Passive devices. All other devices in an access network will commonly be configured as Active devices. For a detailed description of Active and Passive mode, refer to 57.2.6.

67.6.3 Link status signaling in P2MP networks

In P2MP networks the local_link_status parameter should reflect the status of a logical link associated with the underlying instance of Multipoint MAC Control. This is achieved by mapping the local_link_status parameter to variable 'registered' defined in 64.3.3.2 as follows:

local_link_status = OK if registered = true

local_link_status = FAIL if registered = false

Annex 58A

(informative)

Frame based testing

The use of the frame based test patterns described in Clause 58, Clause 59, and Clause 60 provides for the most general testing of the external interfaces. They combine patterns appropriate for testing the desired parameters with a flexible frame structure that allows the test pattern to be passed through a compliant system. However, the frame based nature of the patterns may cause difficulties with some bit oriented test systems if care is not taken.

The concern is that streams of data that are passed through a system under test may have their inter-frame gap altered by rate control mechanisms. This changes the bit sequence, even in the presence of no errors, and causes difficulties with bit sequence oriented test systems. There are several methods of addressing this issue. The solutions fall roughly into three categories:

a) Error detection internal to the equipment under test
b) Use of frame based test equipment
c) Synchronized systems

An example of the first type of test where the internal error detection would be used is a receiver sensitivity test. The input pattern may be generated by any method, including a bit oriented serial pattern generator or a frame based pattern generator. Errored frames would be rejected internal to the system under test based on FCS errors. This type of test has the advantage of testing all of the components of an input interface. The error count may be made by accessing the error counters internal to the system under test.

The number of bit errors may be assumed to be the same as the number of frame errors to a 90% confidence level as long as frame error ratio is less than 0.2. The bit error ratio may be determined by dividing the frame error ratio by the number of bits in the test frame that are used in the computation of the FCS.

If the internal error counters are not accessible, the test frames may be passed to an output port and the number of received frames may the counted. Any missing frames may be assumed to have had errors. The frame count may be made by conventional frame based test equipment. The missing frames render the use of bit stream oriented test equipment inappropriate.

When testing transmitter outputs, frames may be passed to the port under test from another port in the system under test. In this case, loss of frames within the system is not expected and testing may be done using a bit oriented test system by making the system synchronous. This may be done by recovering the clock from the output under test and using this as a clock source for the input. If there are no variable delays in the system under test, such as variable queuing delays, the input data stream will be reproduced in the output and conventional Bit Error Ratio Testing (BERT) systems may be used. In the case of 100BASE-X, the output bit stream may be inverted.

Two frame based alternatives avoid the need for synchronization. The first is to use a frame based tester for both the pattern generation and the error detection. The optical signal will need to be received by an optical receiver with the proper characteristics for the specific test. The processed data stream would then be sent to the frame based receiver to determine possible frame errors.

Another method would be to use a bit oriented test system suitable for burst mode operation. This type of tester will examine only the frame contents for errors. Two methods are used for determining the frame contents. An external gating signal may be used. This must be triggered by the data source and include any latency associated with the system under test. Alternately, the test set may recognize the frame boundaries in the incoming data stream.

As the behaviour above the MAC is not specified by this standard, the system under test might not be able to forward, return or respond to incoming frames at line rate. Diluting the frame rate is thought to be acceptable for 1000BASE-X but for 100BASE-X testing, groups of 12 frames should be kept together. A system might emit additional frames from a port and may need to be configured so that it does not.

NOTE—Users are advised to take care that the system under test is not connected to a network in service.

Annex 61A

(informative)

EFM Copper examples

61A.1 Purpose and scope

The purpose of this informative annex is to provide practical examples of the use of

a) Aggregation Discovery, for aggregated operation of 10PASS-TS PHYs (Clause 62) or 2BASE-TL PHYs (Clause 63); see 61A.2.
b) 64/65-octet encapsulation, as specified in 61.3.3; see 61A.3.

61A.2 Aggregation Discovery example

An example procedure for PME aggregation discovery is described for system components as shown in Figure 61A–1, connected as in Figure 61A–2. Additional information on example discovery transactions are shown in Figure 61A–3. An example procedure for discovering this connectivity follows:

a) -O system writes remote_discovery_register to value *alpha* (*alpha* may be any 48-bit value, but would benefit from being locally unique e.g. MAC address) using PME-1.
b) -O system reads remote_discovery_register for all other PMEs.
c) -O system discovers that PME-2, PME-6 and PME-7 are associated with the same remote MAC device as PME-1.
d) -O system writes remote_discovery_register to value *alpha* using PME-3— the next non-associated PME.
e) -O system reads remote_discovery_register for all other PMEs.
f) -O system expects that PME-1, PME-2, PME-3, PME-6 and PME-7 will already be written to value *alpha*.
g) -O system discovers that no other PME is associated with the same remote MAC device as PME-3.
h) -O system writes remote_discovery_register to value *alpha* using PME-4—the next non-associated PME.
i) -O system reads remote_discovery_register for all other PMEs.
j) -O system expects that PME-1, PME-2, PME-3, PME-4, PME-6 and PME-7 will already be written to value *alpha*.
k) -O system discovers that PME-5, PME-9 and PME-11 are associated with the same remote MAC device as PME-4.
l) This procedure repeats for all of the PMEs connected to -O system.

An alternate example procedure for discovering this connectivity uses two different 48-bit values:

m) -O system writes remote_discovery_register to value *alpha* (*alpha* may be any 48-bit value, but would benefit from being locally unique e.g. MAC address) using PME-1.
n) -O system reads remote_discovery_register for all other PMEs.
o) -O system discovers that PME-2, PME-6 and PME-7 are associated with the same remote MAC device as PME-1.
p) -O system rewrites remote_discovery_register to value *beta* (*beta* may be any 48-bit value, different to *alpha*) using PME-1.
q) -O system writes remote_discovery_register to value *alpha* using PME-3— the next non-associated PME.

r) -O system reads remote_discovery_register for all other PMEs.
s) -O system discovers that no other PME is associated with the same remote MAC device as PME-3.
t) -O system rewrites remote_discovery_register to value *beta* using PME-3.
u) -O system writes remote_discovery_register to value *alpha* using PME-4—the next non-associated PME.
v) -O system reads remote_discovery_register for all other PMEs.
w) -O system discovers that PME-5, PME-9 and PME-11 are associated with the same remote MAC device as PME-4.
x) -O system rewrites remote_discovery_register to value *beta* using PME-4.
y) This procedure repeats for all of the PMEs connected to -O system.

NOTE— This procedure can be expanded at the -O end to provide up to 32 unique alpha values. The -O end would then write a different alpha value on each port and then read all remote_discovery_register. Since the write operation is an atomic write, only one alpha value for each remote PCS will be written. All other subsequent write operations on that PCS will fail.

Observe also that a large and complex -O system may perform multiple discovery operations in parallel by using multiple unique 48-bit values for writing the remote_discovery_register.

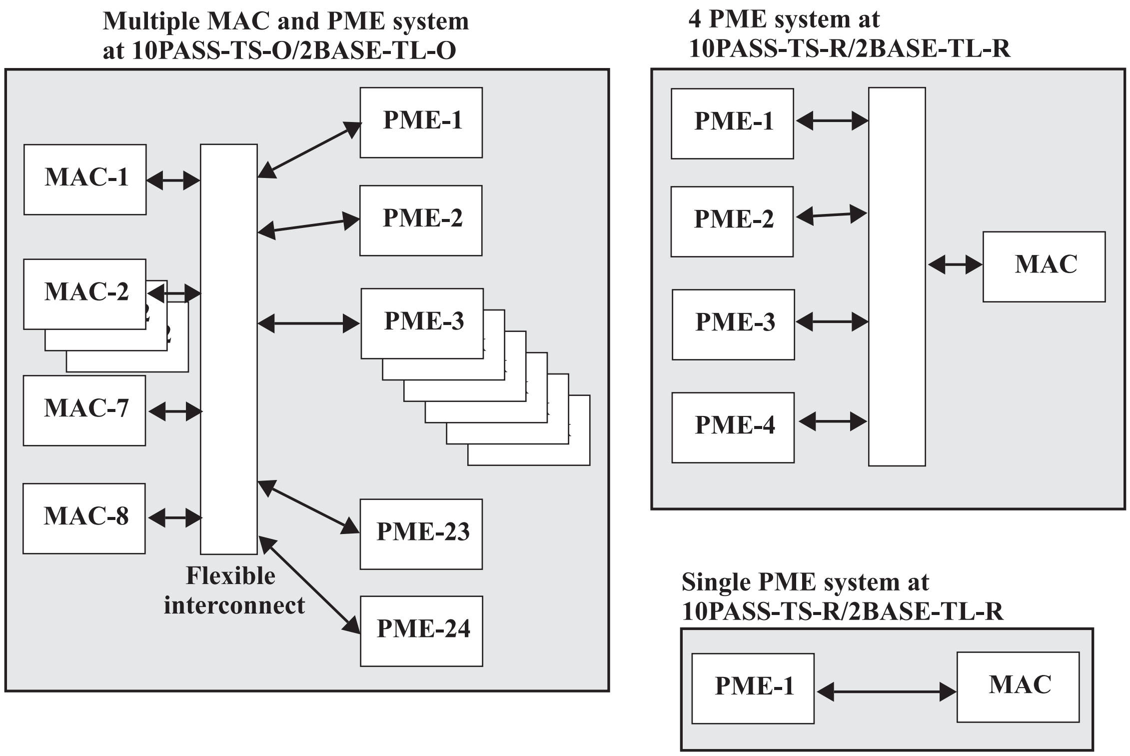


Figure 61A–1—Example systems for discovery

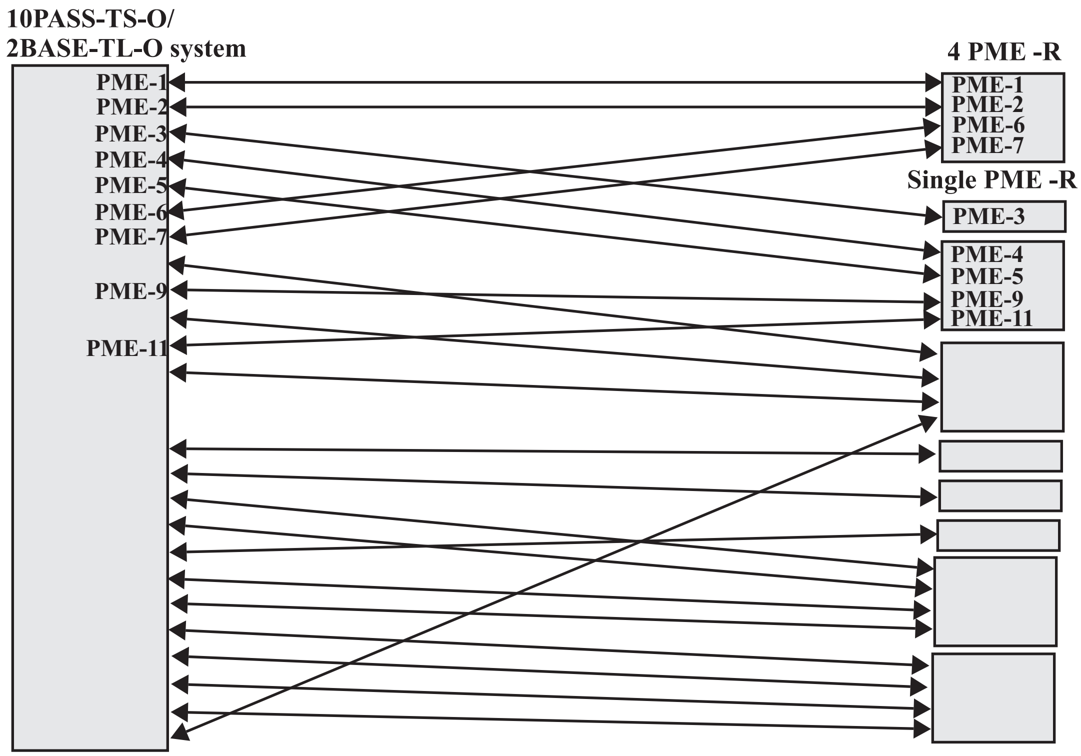


Figure 61A–2—System connectivity for discovery example

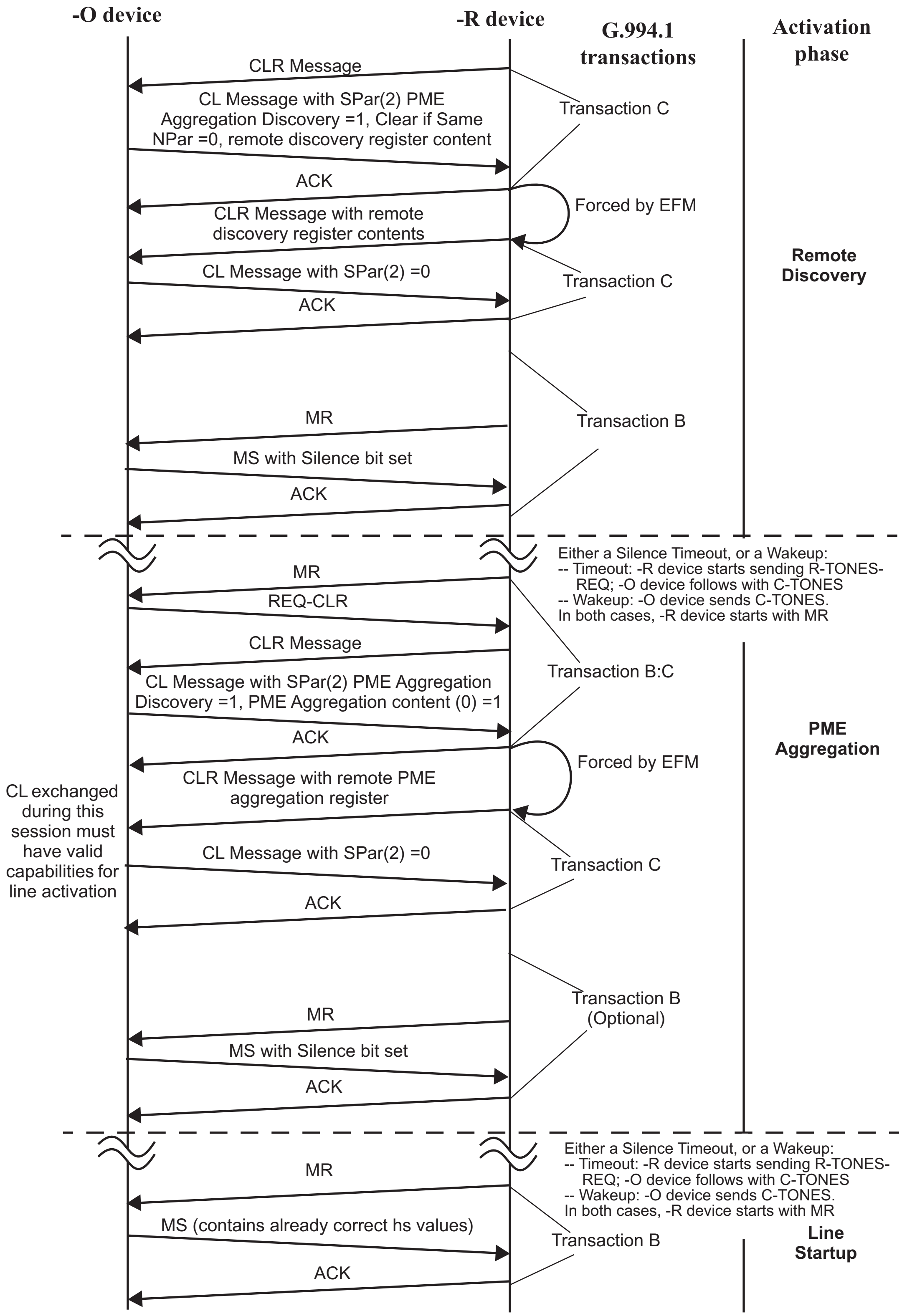


Figure 61A–3—Example activation sequence example

61A.3 Example of 64/65-octet encapsulation

The code below [Equation (61A–1)] consists of an example “C” implementation of the 64/65-octet encapsulation specified in 61.3.3.

NOTE—The example implementation operates under the assumption that the receiver is synchronized at all times.

```
/*
*   802.3ah (EFM) 2BASE-TL (SHDSL) TC Transmitter simulator from 61.2.3
*/

#include <stdio.h>

/* test frame data */
char p0[] = {0x00, 0x01, 0x02, 0x03, 0x04, 0x05, 0x06, 0x07,
 0x08, 0x09, 0x0a, 0x0b, 0x0c, 0x0d, 0x0e, 0x0f,
 0x10, 0x11, 0x12, 0x13, 0x14, 0x15, 0x16, 0x17,
 0x18, 0x19, 0x1a, 0x1b, 0x1c, 0x1d, 0x1e, 0x1f,
 0x20, 0x21, 0x22, 0x23, 0x24, 0x25, 0x26, 0x27,
 0x28, 0x29, 0x2a, 0x2b, 0x2c, 0x2d, 0x2e, 0x2f,
 0x30, 0x31, 0x32, 0x33, 0x34, 0x35, 0x36, 0x37,
 0x38, 0x39, 0x3a, 0x3b, 0x3c, 0x3d, 0x3e, 0x3f};

char p1[] = {0x40, 0x41, 0x42, 0x43, 0x44, 0x45, 0x46, 0x47,
 0x48, 0x49, 0x4a, 0x4b, 0x4c, 0x4d, 0x4e, 0x4f,
 0x50, 0x51, 0x52, 0x53, 0x54, 0x55, 0x56, 0x57,
 0x58, 0x59, 0x5a, 0x5b, 0x5c, 0x5d, 0x5e, 0x5f,
 0x60, 0x61, 0x62, 0x63, 0x64, 0x65, 0x66, 0x67,
 0x68, 0x69, 0x6a, 0x6b, 0x6c, 0x6d, 0x6e, 0x6f,
 0x70, 0x71, 0x72, 0x73, 0x74, 0x75, 0x76, 0x77,
 0x78, 0x79, 0x7a, 0x7b, 0x7c, 0x7d, 0x7e, 0x7f,
 0x80, 0x81, 0x82, 0x83, 0x84, 0x85, 0x86, 0x87,
 0x88, 0x89, 0x8a, 0x8b, 0x8c, 0x8d, 0x8e, 0x8f};

char p2[] = {0x65, 0x43, 0x21};

#define NUM_CODEWORDS 14    /* number of 65 byte EFM codewords to transmit */

/*
* Define a list of user frames to transmit
*  NOTE: This list defines the set of test cases to transmit.
*/

struct frame {
 int  startingByteNum;    /* byte position at which frame is available to send */
 int  length;             /* number of bytes in ethernet frame */
 char *theBytes;          /* pointer to ethernet frame bytes */
} FrameList[] = {       /* To test: */
 {200, 64, p0},   /* vanilla frame, scrambler, C(k), crc */
 {389, 64, p0},   /* all data sync byte, sync splitting S/data/crc */
 {465, 50, p1},   /* end frame & start new frame in same codeword, C(0) */
 {530,  3, p2},   /* align small frame to span sync byte */
 {650, 64, p0},   /* S following sync byte */
 {700, 55, p1},   /* back-to-back frames, sync byte within crc */
 {0,0,0}          /* end test */
};

/* constants as per TC spec */

#define CODEWORD_BYTE_COUNT     65
#define SYNC_ALL_DATA           0x0f     /* all data sync byte */
#define SYNC_NOT_ALL_DATA       0xf0     /* not all data sync byte */
#define START_OF_FRAME_BYTE     0x50     /* start data byte */
#define IDLE_BYTE               0x00     /* idle data byte */
#define EFM_CRC_POLY 0x82f63b78  /* X**28 + X**27 + X**26 + X**25 + X**23 +
 X**22 + X**20 + X**19 + X**18 + X**14 +
 X**13 + X**11 + X**10 + X**09 + X**08 +
 X**06 + X**00  (lsb is x**31) */

/* the EFM TC crc accumulator */
unsigned long CrcAccum;

void EfmCrcReset(void) {
 CrcAccum = 0xffffffff;
}

void EfmCrc(unsigned char TheByte) {
```

```
   int i;
   /* for all the bits in TheByte, lsb first */
   for( i=0; i<8; i++) {
      /* xor the lsb of TheByte with the x**31 of CrcAccum */
      int FeedBack = 0x01 & (CrcAccum ^ TheByte);
      TheByte  = TheByte  >> 1;
      CrcAccum = CrcAccum >> 1;
      if(FeedBack) {
         CrcAccum = CrcAccum ^ EFM_CRC_POLY;
      }
   }
}

/* run with an argument to get test tags in output, else just the numbers */
main(int argc, char * argv[])
{
  int   ByteNum;
  int   UserFrameIndex   = 0;
  int   HaveUserFrame    = 0;
  int   FrameBytesToGo   = 0;
  char *FrameBytePointer = 0;
  int   NeedCZero        = 0;
  int   b;
  char  Foo[50];

  for(ByteNum=0; ByteNum < (CODEWORD_BYTE_COUNT * NUM_CODEWORDS) ; ByteNum++) {
      unsigned char ByteToSend;
      int BytesLeftInCodeword = CODEWORD_BYTE_COUNT - (ByteNum % CODEWORD_BYTE_COUNT);
      char *FrameTag = 0;
      /* decide what I'm doing */
      switch(ByteNum % CODEWORD_BYTE_COUNT) {
         case 0: /* output start of a codeword */
            if(FrameBytesToGo >= (CODEWORD_BYTE_COUNT-1)) {
               /* 64 or more bytes to go, send an all data codeword */
               ByteToSend = SYNC_ALL_DATA;
               FrameTag = "CODEWORD START (all data)";
            } else {
               ByteToSend = SYNC_NOT_ALL_DATA;
               FrameTag = "CODEWORD START (not all data)";
               if( ByteNum == 0) FrameTag = "EFM bitstream reading right to left.";
            }
            break;
         case 1: /* if a C(k) byte is needed */
            if((FrameBytesToGo && (FrameBytesToGo < (CODEWORD_BYTE_COUNT-1))) ||
NeedCZero) {
               int kVal = FrameBytesToGo;
               /* output a C(k) */
               ByteToSend = 0x10 + kVal;
               /* calculate even parity */
               for(b=0x40; b; b=b>>1) {
               if(ByteToSend & b) {
                  ByteToSend ^= 0x80;
               }
            }
            NeedCZero = 0;
            /* display C(k) with decimal k */
            sprintf(Foo,"    C(%d)",kVal);
            FrameTag = Foo;
            break;
         }
         /* else fall into default case */
         default:
            /* if I'm
            *   not sending a frame and
            *   there are more to send, and
            *   it's time to start (next frame is available), and
            *   the frame is not too short to start now (including S and crc bytes)
            */
            if(   (FrameBytesToGo == 0)
            && (FrameList[UserFrameIndex].length != 0)
            && (ByteNum >= FrameList[UserFrameIndex].startingByteNum)
            && ((FrameList[UserFrameIndex].length+5) >= BytesLeftInCodeword) )
            {
               /* then start a new frame */
               FrameTag = "  Start Frame";
               ByteToSend = START_OF_FRAME_BYTE;
               FrameBytesToGo = FrameList[UserFrameIndex].length + 4;
               FrameBytePointer = FrameList[UserFrameIndex].theBytes;
               UserFrameIndex++;
               EfmCrcReset();
            } else if(FrameBytesToGo) {
```



```
                /* else if inside a frame then handle outputting
                 * a data byte (or the crc to go with it) */
                switch(FrameBytesToGo) {
                case 4: /* send first crc byte */
                    FrameTag = "    First Crc Byte";
                    ByteToSend = 0xff & ~CrcAccum;
                    break;
                case 3:
                    ByteToSend = 0xff & ~(CrcAccum >> 8);
                    break;
                case 2:
                    ByteToSend = 0xff & ~(CrcAccum >> 16);
                    break;
                case 1: /* send last crc byte */
                    FrameTag = "    Last Crc Byte";
                    ByteToSend = 0xff & ~(CrcAccum >> 24);
                    /* if crc ends just before sync byte,
                     * prepare to send C(0) byte */
                    if (ByteNum % CODEWORD_BYTE_COUNT == 64) {
                    NeedCZero = 1;
                    }
                    break;
                default: /* just send next data byte and update crc */
                    ByteToSend = (unsigned char)*FrameBytePointer++;
                    /* calculate CRC on data (61.2.3.3) */
                    EfmCrc(ByteToSend);
                    break;
                }
            FrameBytesToGo--;
        } else {
            /* else just output an idle byte */
            ByteToSend = IDLE_BYTE;
        }
    }
    /* output the byte (msb on left) (transmission order is right to left)*/
    printf("%05.5d: %02.2X ", ByteNum, ByteToSend);
    for(b=0x80; b; b = b >> 1) {
        if(ByteToSend & b) {
            printf("1");
        } else {
            printf("0");
        }
    }
    if((argc > 1) && FrameTag) {
        printf("    ;%s", FrameTag);
    }
    printf("\n");
  }
  return(0);
}                                                                    (61A–1)
```

The following data represents a valid data stream generated by the 64/65-octet encapsulation function (read left-to-right, then top-to-bottom).

```
F0 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 F0 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 F0 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 F0 00 00 00 00 50 00 01 02 03 04 05 06 07 08 09 0A 0B 0C 0D 0E 0F 10 11 12 13 14 15 16
17 18 19 1A 1B 1C 1D 1E 1F 20 21 22 23 24 25 26 27 28 29 2A 2B 2C 2D 2E 2F 30 31 32 33 34 35 36
37 38 39 3A F0 99 3B 3C 3D 3E 3F EB 36 6D FB 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 F0 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 50 0F 00 01 02 03 04 05 06 07 08 09 0A 0B 0C 0D 0E 0F 10 11 12 13 14 15 16 17 18
19 1A 1B 1C 1D 1E 1F 20 21 22 23 24 25 26 27 28 29 2A 2B 2C 2D 2E 2F 30 31 32 33 34 35 36 37 38
39 3A 3B 3C 3D 3E 3F F0 14 EB 36 6D FB 00 00 00 00 50 40 41 42 43 44 45 46 47 48 49 4A 4B 4C 4D
4E 4F 50 51 52 53 54 55 56 57 58 59 5A 5B 5C 5D 5E 5F 60 61 62 63 64 65 66 67 68 69 6A 6B 6C 6D
6E 6F 70 71 55 A6 27 CE F0 90 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 50 65 43 21 93 8D FC 64 F0 90 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 F0 50 00 01 02 03 04 05 06 07 08 09 0A 0B 0C 0D 0E 0F 10 11 12 13
14 15 16 17 18 19 1A 1B 1C 1D 1E 1F 20 21 22 23 24 25 26 27 28 29 2A 2B 2C 2D 2E 2F 30 31 32 33
34 35 36 37 38 39 3A 3B 3C 3D 3E F0 95 3F EB 36 6D FB 50 40 41 42 43 44 45 46 47 48 49 4A 4B 4C
4D 4E 4F 50 51 52 53 54 55 56 57 58 59 5A 5B 5C 5D 5E 5F 60 61 62 63 64 65 66 67 68 69 6A 6B 6C
6D 6E 6F 70 71 72 73 74 75 76 16 7C F0 12 07 58 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
```

```
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 F0 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00
```


Annex 61B

(normative)

Handshake codepoints for 2BASE-TL and 10PASS-TS

61B.1 Purpose and scope

This Annex contains the G.994.1 “standard information field” codepoints to be used by 2BASE-TL and 10PASS-TS in the procedures described in 61.4.

61B.2 Level-1 S field codepoints for 2BASE-TL and 10PASS-TS

The Npar(1) codepoints common to 2BASE-TL and 10PASS-TS are specified in Table 10 of G.994.1.

The SPar(1) codepoints to be used by 2BASE-TL and 10PASS-TS transceivers are specified in ITU-T Recommendation G.994.1. The EFM-specific codepoints are shown in Table 61B–1 for information only.

Table 61B–1—Standard information field — SPar(1) coding – Octet 4

Bits								SPar(1)s – Octet 4
8	7	6	5	4	3	2	1	
x	x	1	x	x	x	x	x	2BASE-TL
x	1	x	x	x	x	x	x	10PASS-TS
x	0	0	0	0	0	0	0	No parameters in this octet

61B.3 Codepoints for 2BASE-TL

61B.3.1 Level-2 S field codepoints for 2BASE-TL

Table 61B–2 through Table 61B–5 contain the level-2 codepoints specific to 2BASE-TL.

To support a wide range of data rates and multiple encodings, this section introduces a new way to encode data rates in G.994.1 code points. This method of encoding rates is used for both the PMMS rates and the training rates. Data rates are encoded as a set of ranges, where each range is expressed as a 3-tuple (minimum, maximum, step). The 3-tuple represents all rates of the form (m+ks)(64 kb/s) where m is the minimum value, s is the step value, and k is the set of all integers greater than or equal to zero such that m+ks is less than or equal to the maximum value. Thus, for example, the 3-tuple (40, 70, 10) represents the rates (40)(64 kb/s), (50)(64 kb/s), (60)(64 kb/s), and (70)(64 kb/s).

Each data rate parameter can be expressed as a set of between 1 to 8 ranges, where the supported rates are the union of those supported by the individual ranges. Thus, for example, the 3-tuples (20,30,4), (40,70,10) represent the rates (20)(64 kb/s), (24)(64 kb/s), (28)(64 kb/s), (40)(64 kb/s), (50)(64 kb/s), (60)(64 kb/s), and (70)(64 kb/s). If all bits of the extended base data rate minimum and maximum are set to zero, then those rates are not supported for line probe. If only one range of rates is required, then only the octets associated with (min1,max1,step1) shall be sent.

Also, in many cases, the values in the data range 3-tuple can be less than or equal to 89 (representing the maximum data rate of 5696 kb/s supported by 2BASE-TL). When using G.994.1 code point representation, only 6 bits are available for the value of an NPar(3). To support numbers greater than 63, the value must be split across multiple octets. When encoding a data range using G.994.1, 4 octets are used, where the first octet contains the highest order bit from each of the values in the 3-tuple.

The following definition is added to the G.994.1 code point definitions in §6.4.1 of G.991.2 for the support of the extended data rates specified in this subclause.

Extended Base Data Rate These octets are used to specify payload rates, as follows:

- The PMMS octets indicate rates for line probing segments. Note that while PMMS uses 2-PAM modulation, the PMMS symbol rates are specified assuming 32 TC-PAM encoding, so the PMMS symbol rate (in kbaud) would be equal to the (payload data rate (kb/s) + 8 kb/s)/4. Valid values for minimum and maximum shall be between 4 and 89, inclusive, and valid values for step shall be between 1 and 89, inclusive. The variables j_5 and j_6 associated with the PMMS rates shall be independent, and shall range from 2 to 8, inclusive. If only one range of rates is required, then only the octets associated with (min1,max1,step1) shall be sent. If more than one range of rates is required, then j_5*4 and j_6*4 correspond to the number of octets sent.
- The training parameter octets indicate extended payload data rates supported.
- In CLR, upstream training parameters indicate which data mode rates the 2BASE-TL-R is capable of transmitting and downstream training parameters indicate which data mode rates the 2BASE-TL-R is capable of receiving. If the optional line probe is used, the receiver training parameters will be further limited by the probe results. Valid values for minimum and maximum shall be between 3 and 60, inclusive, for 16-TCPAM and between 12 and 89, inclusive, for 32-TCPAM. Valid values for step shall be between 1 and 89, inclusive. The variables j_1, j_2, j_3 and j_4 associated with the training rates shall be independent, and shall range from 2 to 8, inclusive. If only one range of rates is required, then only the octets associated with (min1,max1,step1) shall be sent. If more than one range of rates is required, then j_1*4, j_2*4, j_3*4 and j_4*4 correspond to the number of octets sent.
- In CL, downstream training parameters indicate which data mode rates the 2BASE-TL-O is capable of transmitting and upstream training parameters indicate which data mode rates the 2BASE-TL-O is capable of receiving. Valid values for minimum and maximum shall be between 3 and 60, inclusive, for 16-TCPAM and between 12 and 89, inclusive, for 32-TCPAM. Valid values for step shall be between 1 and 89, inclusive. The variables j_1, j_2, j_3 and j_4 associated with the training rates shall be independent, and shall range from 2 to 8, inclusive. If only one range of rates is required, then only the octets associated with (min1,max1,step1) shall be sent. If more than one range of rates is required, then j_1*4, j_2*4, j_3*4 and j_4*4 correspond to the number of octets sent. If optional line probe is used, the receiver training parameters will be further limited by the probe results.
- Data rate selections shall be specified in MP and MS messages by setting the maximum and minimum rates to the same value.

Table 61B–2—Standard information field – 2BASE-TL - NPar(2) coding – Octet 1

Bits								
8	7	6	5	4	3	2	1	**2BASE-TL NPar(2)s - Octet 1**
x	x	x	x	x	x	x	1	2BASE-TL Training mode[a]
x	x	x	x	x	x	1	x	2BASE-TL PMMS mode[a]
x	x	x	x	x	1	x	x	2BASE-TL G.991.2 Annex A Operation
x	x	x	x	1	x	x	x	2BASE-TL G.991.2 Annex B Operation
x	x	x	1	x	x	x	x	Reserved for allocation by IEEE 802.3
x	x	1	x	x	x	x	x	Reserved for allocation by IEEE 802.3
x	x	0	0	0	0	0	0	No parameters in this octet

[a]Only one of these bits shall be set at any given time.

Table 61B–3—Standard information field – 2BASE-TL - NPar(2) coding – Octet 2

Bits								
8	7	6	5	4	3	2	1	2BASE-TL NPar(2)s - Octet 2
x	x	x	x	x	x	x	1	Regenerator silent period[a,b]
x	x	x	x	x	x	1	x	SRU[b]
x	x	x	x	x	1	x	x	Diagnostic Mode[b]
x	x	x	x	1	x	x	x	Reserved for allocation by IEEE 802.3
x	x	x	1	x	x	x	x	Reserved for allocation by IEEE 802.3
x	x	1	x	x	x	x	x	Reserved for allocation by IEEE 802.3
x	x	0	0	0	0	0	0	No parameters in this octet

[a]This bit shall be set to 0_b if the 2BASE-TL PMMS mode NPar(2) bit is set to 1_b or the 2BASE-TL Training mode NPar(2) bit is set to 1_b.
[b]The specification and use of regenerators is outside the scope of this standard.

Table 61B–4—Standard information field – 2BASE-TL - SPar(2) coding – Octet 1

Bits								
8	7	6	5	4	3	2	1	2BASE-TL SPar(2)s – Octet 1
x	x	x	x	x	x	x	1	2BASE-TL Downstream training parameters
x	x	x	x	x	x	1	x	2BASE-TL Downstream training rates - 16-TCPAM
x	x	x	x	x	1	x	x	2BASE-TL Downstream training rates - 32-TCPAM
x	x	x	x	1	x	x	x	2BASE-TL Upstream training parameters
x	x	x	1	x	x	x	x	2BASE-TL Upstream training rates - 16-TCPAM
x	x	1	x	x	x	x	x	2BASE-TL Upstream training rates - 32-TCPAM
x	x	0	0	0	0	0	0	No parameters in this octet

61B.3.2 Level-3 S field codepoints for 2BASE-TL

61B.3.2.1 Training parameter codepoints

Tables 61B–6 through 61B–39 contain the level-3 codepoints specific to 2BASE-TL training parameters.

Table 61B–5—Standard information field – 2BASE-TL SPar(2) coding – Octet 2

Bits								
8	7	6	5	4	3	2	1	2BASE-TL SPar(2)s – Octet 2
x	x	x	x	x	x	x	1	2BASE-TL Downstream PMMS parameters
x	x	x	x	x	x	1	x	2BASE-TL Downstream PMMS rates
x	x	x	x	x	1	x	x	2BASE-TL Upstream PMMS parameters
x	x	x	x	1	x	x	x	2BASE-TL Upstream PMMS rates
x	x	x	1	x	x	x	x	2BASE-TL Downstream framing parameters
x	x	1	x	x	x	x	x	2BASE-TL Upstream framing parameters
x	x	0	0	0	0	0	0	No parameters in this octet

Table 61B–6—Standard information field – 2BASE-TL - Downstream training parameters - NPar(3) coding – Octet 1

Bits								
8	7	6	5	4	3	2	1	2BASE-TL downstream training NPar(3)s – Octet 1
x	x	0	x	x	x	x	x	Downstream PBO (dB) (bits 5-1 x 1.0 dB)
x	x	1	x	x	x	x	x	Reserved for allocation by IEEE 802.3

Table 61B–7—Standard information field – 2BASE-TL - Downstream training rate - 16-TCPAM- NPar(3) coding – Octet 1

Bits								
8	7	6	5	4	3	2	1	2BASE-TL downstream training rate - 16-TCPAM NPar(3)s – Octet 1
x	x						x	Downstream base data rate -16-TCPAM Minimum 1 (bit 7)
x	x					x		Downstream base data rate -16-TCPAM Maximum 1 (bit 7)
x	x				x			Downstream base data rate -16-TCPAM Step 1 (bit 7)
x	x	x	x	x				Reserved for allocation by IEEE 802.3

Table 61B–8—Standard information field – 2BASE-TL - Downstream training rate - 16-TCPAM- NPar(3) coding – Octet 2

Bits 8	7	6	5	4	3	2	1	2BASE-TL downstream training rate - 16-TCPAM NPar(3)s – Octet 2
x	x	x	x	x	x	x	x	Downstream base data rate -16-TCPAM Minimum 1 (bit 1-6)[a]

[a]Note that the rates are determined by combining (bit 7) and the 6-bits in this octet to create a 7-bit number.

Table 61B–9—Standard information field – 2BASE-TL - Downstream training rate - 16-TCPAM - NPar(3) coding – Octet 3

Bits 8	7	6	5	4	3	2	1	2BASE-TL downstream training rate - 16-TCPAM NPar(3)s – Octet 3
x	x	x	x	x	x	x	x	Downstream base data rate -16-TCPAM Maximum 1 (bit 1-6)[a]

[a]Note that the rates are determined by combining (bit 7) and the 6-bits in this octet to create a 7-bit number.

Table 61B–10—Standard information field – 2BASE-TL - Downstream training rate - 16-TCPAM - NPar(3) coding – Octet 4

Bits 8	7	6	5	4	3	2	1	2BASE-TL downstream training rate - 16-TCPAM NPar(3)s Octet 4
x	x	x	x	x	x	x	x	Downstream base data rate -16-TCPAM Step 1 (bit 1-6)[a]

[a]Note that the rates are determined by combining (bit 7) and the 6-bits in this octet to create a 7-bit number.

Table 61B–11—Standard information field – 2BASE-TL - Downstream training rate - 16-TCPAM- NPar(3) coding – Octet j_1*4-3

Bits 8	7	6	5	4	3	2	1	2BASE-TL downstream training rate - 16-TCPAM NPar(3)s – Octet j_1*4-3
x	x						x	Extended Downstream base data rate -16-TCPAM Minimum j_1 (bit 7)
x	x					x		Extended Downstream base data rate -16-TCPAM Maximum j_1 (bit 7)
x	x				x			Extended Downstream base data rate -16-TCPAM Step j_1 (bit 7)
x	x	x	x	x				Reserved for allocation by IEEE 802.3

Table 61B–12—Standard information field – 2BASE-TL - Downstream training rate - 16-TCPAM- NPar(3) coding – Octet j_1*4-2

Bits 8	7	6	5	4	3	2	1	2BASE-TL downstream training rate - 16-TCPAM NPar(3)s – Octet j_1*4-2
x	x	x	x	x	x	x	x	Extended Downstream base data rate -16-TCPAM Minimum j_1 (bit 1-6)[a]

[a]Note that the rates are determined by combining (bit 7) and the 6-bits in this octet to create a 7-bit number.

Table 61B–13—Standard information field – 2BASE-TL - Downstream training rate - 16-TCPAM - NPar(3) coding – Octet j_1*4-1

Bits 8	7	6	5	4	3	2	1	2BASE-TL downstream training rate - 16-TCPAM NPar(3)s – Octet j_1*4-1
x	x	x	x	x	x	x	x	Extended Downstream base data rate -16-TCPAM Maximum j_1 (bit 1-6)[a]

[a]Note that the rates are determined by combining (bit 7) and the 6-bits in this octet to create a 7-bit number.

Table 61B–14—Standard information field – 2BASE-TL - Downstream training rate - 16-TCPAM - NPar(3) coding – Octet j_1*4

Bits 8	7	6	5	4	3	2	1	2BASE-TL downstream training rate - 16-TCPAM NPar(3)s Octet j_1*4
x	x	x	x	x	x	x	x	Extended Downstream base data rate -16-TCPAM Step j_1 (bit 1-6)[a]

[a]Note that the rates are determined by combining (bit 7) and the 6-bits in this octet to create a 7-bit number.

Table 61B–15—Standard information field – 2BASE-TL - Downstream training rate - 32-TCPAM- NPar(3) coding – Octet 1

Bits 8	7	6	5	4	3	2	1	2BASE-TL downstream training rate - 32-TCPAM NPar(3)s – Octet 1
x	x						x	Downstream base data rate -32-TCPAM Minimum 1 (bit 7)
x	x					x		Downstream base data rate -32-TCPAM Maximum 1 (bit 7)
x	x				x			Downstream base data rate -32-TCPAM Step 1 (bit 7)
x	x	x	x	x				Reserved for allocation by IEEE 802.3

Table 61B–16—Standard information field – 2BASE-TL - Downstream training rate - 32-TCPAM- NPar(3) coding – Octet 2

Bits 8	7	6	5	4	3	2	1	2BASE-TL downstream training rate - 32-TCPAM NPar(3)s – Octet 2
x	x	x	x	x	x	x	x	Downstream base data rate -32-TCPAM Minimum 1 (bit 1-6)[a]

[a]Note that the rates are determined by combining (bit 7) and the 6-bits in this octet to create a 7-bit number.

Table 61B–17—Standard information field – 2BASE-TL - Downstream training rate - 32-TCPAM - NPar(3) coding – Octet 3

Bits 8	7	6	5	4	3	2	1	2BASE-TL downstream training rate - 32-TCPAM NPar(3)s – Octet 3
x	x	x	x	x	x	x	x	Downstream base data rate -32-TCPAM Maximum 1 (bit 1-6)[a]

[a]Note that the rates are determined by combining (bit 7) and the 6-bits in this octet to create a 7-bit number.

Table 61B–18—Standard information field – 2BASE-TL - Downstream training rate - 32-TCPAM - NPar(3) coding – Octet 4

Bits 8	7	6	5	4	3	2	1	2BASE-TL downstream training rate - 32-TCPAM NPar(3)s Octet 4
x	x	x	x	x	x	x	x	Downstream base data rate -32-TCPAM Step 1 (bit 1-6)[a]

[a]Note that the rates are determined by combining (bit 7) and the 6-bits in this octet to create a 7-bit number.

Table 61B–19—Standard information field – 2BASE-TL - Downstream training rate - 32-TCPAM- NPar(3) coding – Octet j_2*4-3

Bits 8	7	6	5	4	3	2	1	2BASE-TL downstream training rate - 32-TCPAM NPar(3)s – Octet j_2*4-3
x	x						x	Extended Downstream base data rate - 32-TCPAM Minimum j_2 (bit 7)
x	x					x		Extended Downstream base data rate - 32-TCPAM Maximum j_2 (bit 7)
x	x				x			Extended Downstream base data rate - 32-TCPAM Step j_2 (bit 7)
x	x	x	x	x				Reserved for allocation by IEEE 802.3

Table 61B–20—Standard information field – 2BASE-TL - Downstream training rate - 32-TCPAM- NPar(3) coding – Octet j_2*4-2

Bits 8	7	6	5	4	3	2	1	2BASE-TL downstream training rate - 32-TCPAM NPar(3)s – Octet j_2*4-2
x	x	x	x	x	x	x	x	Extended Downstream base data rate - 32-TCPAM Minimum j_2 (bit 1-6)[a]

[a]Note that the rates are determined by combining (bit 7) and the 6-bits in this octet to create a 7-bit number.

Table 61B–21—Standard information field – 2BASE-TL - Downstream training rate - 32-TCPAM - NPar(3) coding – Octet j_2*4-1

Bits 8	7	6	5	4	3	2	1	2BASE-TL downstream training rate - 32-TCPAM NPar(3)s – Octet j_2*4-1
x	x	x	x	x	x	x	x	Extended Downstream base data rate - 32-TCPAM Maximum j_2 (bit 1-6)[a]

[a]Note that the rates are determined by combining (bit 7) and the 6-bits in this octet to create a 7-bit number.

Table 61B–22—Standard information field – 2BASE-TL - Downstream training rate - 32-TCPAM - NPar(3) coding – Octet j_2*4

Bits 8	7	6	5	4	3	2	1	2BASE-TL downstream training rate - 32-TCPAM NPar(3)s Octet j_2*4
x	x	x	x	x	x	x	x	Extended Downstream base data rate - 32-TCPAM Step j_2 (bit 1-6)[a]

[a]Note that the rates are determined by combining (bit 7) and the 6-bits in this octet to create a 7-bit number.

Table 61B–23—Standard information field – 2BASE-TL - Upstream training parameters - NPar(3) coding – Octet 1

Bits 8	7	6	5	4	3	2	1	2BASE-TL upstream training NPar(3)s – Octet 1
x	x	0	x	x	x	x	x	Upstream PBO (dB) (bits 5-1 x 1.0 dB)
x	x	1	x	x	x	x	x	Reserved for allocation by IEEE 802.3

Table 61B–24—Standard information field – 2BASE-TL - upstream training rate - 16-TCPAM-NPar(3) coding – Octet 1

Bits 8	7	6	5	4	3	2	1	2BASE-TL upstream training rate - 16-TCPAM NPar(3)s – Octet 1
x	x						x	Upstream base data rate -16-TCPAM Minimum 1 (bit 7)
x	x					x		Upstream base data rate -16-TCPAM Maximum 1 (bit 7)
x	x				x			Upstream base data rate -16-TCPAM Step 1 (bit 7)
x	x	x	x	x				Reserved for allocation by IEEE 802.3

Table 61B–25—Standard information field – 2BASE-TL - upstream training rate - 16-TCPAM-NPar(3) coding – Octet 2

Bits 8	7	6	5	4	3	2	1	2BASE-TL upstream training rate - 16-TCPAM NPar(3)s – Octet 2
x	x	x	x	x	x	x	x	Upstream base data rate -16-TCPAM Minimum 1 (bit 1-6)[a]

[a]Note that the rates are determined by combining (bit 7) and the 6-bits in this octet to create a 7-bit number.

Table 61B–26—Standard information field – 2BASE-TL - upstream training rate - 16-TCPAM - NPar(3) coding – Octet 3

Bits 8	7	6	5	4	3	2	1	2BASE-TL upstream training rate - 16-TCPAM NPar(3)s – Octet 3
x	x	x	x	x	x	x	x	Upstream base data rate -16-TCPAM Maximum 1 (bit 1-6)[a]

[a]Note that the rates are determined by combining (bit 7) and the 6-bits in this octet to create a 7-bit number.

Table 61B–27—Standard information field – 2BASE-TL - Upstream training rate - 16-TCPAM - NPar(3) coding – Octet 4

Bits 8	7	6	5	4	3	2	1	2BASE-TL upstream training rate - 16-TCPAM NPar(3)s Octet 4
x	x	x	x	x	x	x	x	Upstream base data rate -16-TCPAM Step 1 (bit 1-6)[a]

[a]Note that the rates are determined by combining (bit 7) and the 6-bits in this octet to create a 7-bit number.

Table 61B–28—Standard information field – 2BASE-TL - Upstream training rate - 16-TCPAM-NPar(3) coding – Octet j_3*4-3

Bits 8	7	6	5	4	3	2	1	2BASE-TL upstream training rate - 16-TCPAM NPar(3)s – Octet j_3*4-3
x	x						x	Extended Upstream base data rate - 16-TCPAM Minimum j_3 (bit 7)
x	x					x		Extended Upstream base data rate -16-TCPAM Maximum j_3 (bit 7)
x	x				x			Extended Upstream base data rate -16-TCPAM Step j_3 (bit 7)
x	x	x	x	x				Reserved for allocation by IEEE 802.3

Table 61B–29—Standard information field – 2BASE-TL - Upstream training rate - 16-TCPAM-NPar(3) coding – Octet j_3*4-2

Bits 8	7	6	5	4	3	2	1	2BASE-TL upstream training rate - 16-TCPAM NPar(3)s – Octet j_3*4-2
x	x	x	x	x	x	x	x	Extended Upstream base data rate -16-TCPAM Minimum j_3 (bit 1-6)[a]

[a]Note that the rates are determined by combining (bit 7) and the 6-bits in this octet to create a 7-bit number.

Table 61B–30—Standard information field – 2BASE-TL - Upstream training rate - 16-TCPAM - NPar(3) coding – Octet j_3*4-1

Bits 8	7	6	5	4	3	2	1	2BASE-TL upstream training rate - 16-TCPAM NPar(3)s – Octet j_3*4-1
x	x	x	x	x	x	x	x	Extended Upstream base data rate -16-TCPAM Maximum j_3 (bit 1-6)[a]

[a]Note that the rates are determined by combining (bit 7) and the 6-bits in this octet to create a 7-bit number.

Table 61B–31—Standard information field – 2BASE-TL - Upstream training rate - 16-TCPAM - NPar(3) coding – Octet j_3*4

Bits 8	7	6	5	4	3	2	1	2BASE-TL upstream training rate - 16-TCPAM NPar(3)s Octet j_3*4
x	x	x	x	x	x	x	x	Extended Upstream base data rate -16-TCPAM Step j_3 (bit 1-6)[a]

[a]Note that the rates are determined by combining (bit 7) and the 6-bits in this octet to create a 7-bit number.

Table 61B–32—Standard information field – 2BASE-TL - Upstream training rate - 32-TCPAM-NPar(3) coding – Octet 1

Bits 8	7	6	5	4	3	2	1	2BASE-TL upstream training rate - 32-TCPAM NPar(3)s – Octet 1
x	x						x	Upstream base data rate -32-TCPAM Minimum 1 (bit 7)
x	x					x		Upstream base data rate -32-TCPAM Maximum 1 (bit 7)
x	x				x			Upstream base data rate -32-TCPAM Step 1 (bit 7)
x	x	x	x	x				Reserved for allocation by IEEE 802.3

Table 61B–33—Standard information field – 2BASE-TL - Upstream training rate - 32-TCPAM-NPar(3) coding – Octet 2

Bits 8	7	6	5	4	3	2	1	2BASE-TL upstream training rate - 32-TCPAM NPar(3)s – Octet 2
x	x	x	x	x	x	x	x	Upstream base data rate -32-TCPAM Minimum 1 (bit 1-6)[a]

[a]Note that the rates are determined by combining (bit 7) and the 6-bits in this octet to create a 7-bit number.

Table 61B–34—Standard information field – 2BASE-TL - Upstream training rate - 32-TCPAM - NPar(3) coding – Octet 3

Bits 8	7	6	5	4	3	2	1	2BASE-TL upstream training rate - 32-TCPAM NPar(3)s – Octet 3
x	x	x	x	x	x	x	x	Upstream base data rate -32-TCPAM Maximum 1 (bit 1-6)[a]

[a]Note that the rates are determined by combining (bit 7) and the 6-bits in this octet to create a 7-bit number.

Table 61B–35—Standard information field – 2BASE-TL - Upstream training rate - 32-TCPAM - NPar(3) coding – Octet 4

Bits 8	7	6	5	4	3	2	1	2BASE-TL upstream training rate - 32-TCPAM NPar(3)s Octet 4
x	x	x	x	x	x	x	x	Upstream base data rate -32-TCPAM Step 1 (bit 1-6)[a]

[a]Note that the rates are determined by combining (bit 7) and the 6-bits in this octet to create a 7-bit number.

Table 61B–36—Standard information field – 2BASE-TL - Upstream training rate - 32-TCPAM-NPar(3) coding – Octet j_4*4-3

Bits 8	7	6	5	4	3	2	1	2BASE-TL upstream training rate - 32-TCPAM NPar(3)s – Octet j_4*4-3
x	x						x	Extended Upstream base data rate - 32-TCPAM Minimum j_4 (bit 7)
x	x					x		Extended Upstream base data rate - 32-TCPAM Maximum j_4 (bit 7)
x	x				x			Extended Upstream base data rate - 32-TCPAM Step j_4 (bit 7)
x	x	x	x	x				Reserved for allocation by IEEE 802.3

Table 61B–37—Standard information field – 2BASE-TL - Upstream training rate - 32-TCPAM-NPar(3) coding – Octet j_4*4-2

Bits 8	7	6	5	4	3	2	1	2BASE-TL upstream training rate - 32-TCPAM NPar(3)s – Octet j_4*4-2
x	x	x	x	x	x	x	x	Extended Upstream base data rate - 32-TCPAM Minimum j_4 (bit 1-6)[a]

[a]Note that the rates are determined by combining (bit 7) and the 6-bits in this octet to create a 7-bit number.

Table 61B–38—Standard information field – 2BASE-TL - Upstream training rate - 32-TCPAM - NPar(3) coding – Octet j_4*4-1

Bits 8	7	6	5	4	3	2	1	2BASE-TL upstream training rate - 32-TCPAM NPar(3)s – Octet j_4*4-1
x	x	x	x	x	x	x	x	Extended Upstream base data rate -32-TCPAM Maximum j_4 (bit 1-6)[a]

[a]Note that the rates are determined by combining (bit 7) and the 6-bits in this octet to create a 7-bit number.

Table 61B–39—Standard information field – 2BASE-TL - Upstream training rate - 32-TCPAM - NPar(3) coding – Octet j_4*4

Bits 8	7	6	5	4	3	2	1	2BASE-TL upstream training rate - 32-TCPAM NPar(3)s Octet j_4*4
x	x	x	x	x	x	x	x	Extended Upstream base data rate -32-TCPAM Step j_4 (bit 1-6)[a]

[a]Note that the rates are determined by combining (bit 7) and the 6-bits in this octet to create a 7-bit number.

61B.3.2.2 PMMS parameter codepoints

Tables 61B–40 through 61B–67 contain the level-3 codepoints specific to 2BASE-TL PMMS parameters.

Table 61B–40—Standard information field – 2BASE-TL - Downstream PMMS parameters - NPar(3) coding – Octet 1

Bits 8	7	6	5	4	3	2	1	2BASE-TL downstream PMMS NPar(3)s – Octet 1
x	x	0	x	x	x	x	x	Downstream PBO (dB) (bits 5-1 x 1.0 dB)
x	x	1	x	x	x	x	x	Reserved for allocation by IEEE 802.3

Table 61B–41—Standard information field – 2BASE-TL - Downstream PMMS parameters - NPar(3) coding – Octet 2

Bits 8	7	6	5	4	3	2	1	2BASE-TL downstream PMMS NPar(3)s – Octet 2
x	x	0	0	0	0	0	0	Downstream PMMS duration unspecified by terminal
x	x	x	x	x	x	x	x	Downstream PMMS duration (bits 6-1 x 50 ms)
x	x	1	1	1	1	1	1	Reserved for allocation by IEEE 802.3

Table 61B–42—Standard information field – 2BASE-TL - Downstream PMMS parameters - NPar(3) coding – Octet 3

Bits 8	7	6	5	4	3	2	1	2BASE-TL downstream PMMS NPar(3)s – Octet 3
x	x	0	0	0	x	x	x	Downstream PMMS scrambler polynomial Index (i2, i1, i0)

Table 61B–43—Standard information field – 2BASE-TL - Downstream PMMS parameters - NPar(3) coding – Octet 4

Bits 8	7	6	5	4	3	2	1	2BASE-TL downstream PMMS NPar(3)s – Octet 4
x	x	1	x	x	x	x	x	Worst-case PMMS target margin (dB) (bits 5-1 x 1.0 dB - 10 dB)
x	x	0	0	0	0	0	0	Worst-case PMMS target margin unspecified by terminal (values of bits 6-1 from 1 to 31 reserved for allocation by IEEE 802.3)

Table 61B–44—Standard information field – 2BASE-TL - Downstream PMMS parameters - NPar(3) coding – Octet 5

Bits 8	7	6	5	4	3	2	1	2BASE-TL downstream PMMS NPar(3)s – Octet 5
x	x	1	x	x	x	x	x	Current-condition PMMS target margin (dB) (bits 5-1 x 1.0 dB - 10 dB)
x	x	0	0	0	0	0	0	Current-condition PMMS target margin unspecified by terminal (values of bits 6-1 from 1 to 31 reserved for allocation by IEEE 802.3)

Table 61B–45—Standard information field – 2BASE-TL - Downstream PMMS parameters - NPar(3) coding – Octet 6

Bits 8	7	6	5	4	3	2	1	2BASE-TL downstream PMMS NPar(3)s – Octet 6
x	x	x	x	x	x	x	1	Reserved for allocation by IEEE 802.3
x	x	x	x	x	x	1	x	Transmit Silence
x	x	x	x	x	1	x	x	Reserved for allocation by IEEE 802.3
x	x	x	x	1	x	x	x	Reserved for allocation by IEEE 802.3
x	x	x	1	x	x	x	x	Reserved for allocation by IEEE 802.3
x	x	1	x	x	x	x	x	Reserved for allocation by IEEE 802.3
x	x	0	0	0	0	0	0	No parameters in this octet

Table 61B–46—Standard information field – 2BASE-TL - Downstream PMMS rates - NPar(3) coding – Octet 1

Bits 8	7	6	5	4	3	2	1	2BASE-TL downstream PMMS NPar(3)s – Octet 1
x	x						x	Downstream base data rate- 32-TCPAM Minimum 1 (bit 7)
						x		Downstream base data rate- 32-TCPAM Maximum 1 (bit 7)
x	x				x			Downstream base data rate- 32-TCPAM Step 1 (bit 7)
x	x	x	x	x				Reserved for allocation by IEEE 802.3

Table 61B–47—Standard information field – 2BASE-TL - Downstream PMMS rates - NPar(3) coding – Octet 2

Bits 8	7	6	5	4	3	2	1	2BASE-TL downstream PMMS rates NPar(3)s – Octet 2
x	x	x	x	x	x	x	x	Downstream base data rate- 32-TCPAM Minimum 1 (bit 1-6)[a]

[a]Note that the rates are determined by combining (bit 7) and the 6-bits in this octet to create a 7-bit number.

Table 61B–48—Standard information field – 2BASE-TL - Downstream PMMS rates - NPar(3) coding – Octet 3

Bits 8	7	6	5	4	3	2	1	2BASE-TL downstream PMMS rates NPar(3)s – Octet 3
x	x	x	x	x	x	x	x	Downstream base data rate- 32-TCPAM Maximum 1 (bit 1-6)[a]

[a]Note that the rates are determined by combining (bit 7) and the 6-bits in this octet to create a 7-bit number.

Table 61B–49—Standard information field – 2BASE-TL - Downstream PMMS rates - NPar(3) coding – Octet 4

Bits 8	7	6	5	4	3	2	1	2BASE-TL downstream PMMS NPar(3)s Octet 6
x	x	x	x	x	x	x	x	Downstream base data rate- 32-TCPAM Step 1 (bit 1-6)[a]

[a]Note that the rates are determined by combining (bit 7) and the 6-bits in this octet to create a 7-bit number.

Table 61B–50—Standard information field – 2BASE-TL - Downstream PMMS rates - NPar(3) coding – Octet j_5*4-3

Bits 8	7	6	5	4	3	2	1	2BASE-TL downstream PMMS NPar(3)s – Octet j_5*4-3
x	x						x	Downstream base data rate- 32-TCPAM Minimum j_5 (bit 7)
x	x					x		Downstream base data rate- 32-TCPAM Maximum j_5 (bit 7)
x	x				x			Downstream base data rate- 32-TCPAM Step j_5 (bit 7)
x	x	x	x	x				Reserved for allocation by IEEE 802.3

Table 61B–51—Standard information field – 2BASE-TL - Downstream PMMS rates - NPar(3) coding – Octet j_5*4-2

Bits 8	7	6	5	4	3	2	1	2BASE-TL downstream PMMS rates NPar(3)s – Octet j_5*4-2
x	x	x	x	x	x	x	x	Downstream base data rate- 32-TCPAM Minimum j_5 (bit 1-6)[a]

[a]Note that the rates are determined by combining (bit 7) and the 6-bits in this octet to create a 7-bit number.

Table 61B–52—Standard information field – 2BASE-TL - Downstream PMMS rates - NPar(3) coding – Octet j_5*4-1

Bits 8	7	6	5	4	3	2	1	2BASE-TL downstream PMMS rates NPar(3)s – Octet j_5*4-1
x	x	x	x	x	x	x	x	Downstream base data rate- 32-TCPAM Maximum j_5 (bit 1-6)[a]

[a]Note that the rates are determined by combining (bit 7) and the 6-bits in this octet to create a 7-bit number.

Table 61B–53—Standard information field – 2BASE-TL - Downstream PMMS rates - NPar(3) coding – Octet j_5*4

Bits 8	7	6	5	4	3	2	1	2BASE-TL downstream PMMS NPar(3)s Octet j_5*4
x	x	x	x	x	x	x	x	Downstream base data rate- 32-TCPAM Step j_5 (bit 1-6)[a]

[a]Note that the rates are determined by combining (bit 7) and the 6-bits in this octet to create a 7-bit number.

Table 61B–54—Standard information field – 2BASE-TL - Upstream PMMS parameters - NPar(3) coding – Octet 1

Bits 8	7	6	5	4	3	2	1	2BASE-TL upstream PMMS NPar(3)s – Octet 1
x	x	0	x	x	x	x	x	Upstream PBO (dB) (bits 5-1 x 1.0 dB)
x	x	1	x	x	x	x	x	Reserved for allocation by IEEE 802.3

Table 61B–55—Standard information field – 2BASE-TL - Upstream PMMS parameters - NPar(3) coding – Octet 2

Bits 8	7	6	5	4	3	2	1	2BASE-TL upstream PMMS NPar(3)s – Octet 2
x	x	0	0	0	0	0	0	Upstream PMMS duration unspecified by terminal
x	x	x	x	x	x	x	x	Upstream PMMS duration (bits 6-1 x 50 ms)
x	x	1	1	1	1	1	1	Reserved for allocation by IEEE 802.3

Table 61B–56—Standard information field – 2BASE-TL - Upstream PMMS parameters - NPar(3) coding – Octet 3

Bits 8	7	6	5	4	3	2	1	2BASE-TL upstream PMMS NPar(3)s – Octet 3
x	x	0	0	0	x	x	x	Upstream PMMS scrambler polynomial Index (i2, i1, i0)

Table 61B–57—Standard information field – 2BASE-TL - Upstream PMMS parameters - NPar(3) coding – Octet 4

Bits 8	7	6	5	4	3	2	1	2BASE-TL upstream PMMS NPar(3)s – Octet 4
x	x	1	x	x	x	x	x	Worst-case PMMS target margin (dB) (bits 5-1 x 1.0 dB - 10 dB)
x	x	0	0	0	0	0	0	Worst-case PMMS target margin unspecified by terminal (values of bits 6-1 from 1 to 31 reserved for allocation by IEEE 802.3)

Table 61B–58—Standard information field – 2BASE-TL - Upstream PMMS parameters - NPar(3) coding – Octet 5

Bits 8	7	6	5	4	3	2	1	2BASE-TL upstream PMMS NPar(3)s – Octet 5
x	x	1	x	x	x	x	x	Current-condition PMMS target margin (dB) (bits 5-1 x 1.0 dB – 10 dB)
x	x	0	0	0	0	0	0	Current-condition PMMS target margin unspecified by terminal (values of bits 6-1 from 1 to 31 reserved for allocation by IEEE 802.3)

Table 61B–59—Standard information field – 2BASE-TL - Upstream PMMS parameters - NPar(3) coding – Octet 6

Bits 8	7	6	5	4	3	2	1	2BASE-TL upstream PMMS NPar(3)s – Octet 6
x	x	x	x	x	x	x	1	Reserved for allocation by IEEE 802.3
x	x	x	x	x	x	1	x	Transmit Silence
x	x	x	x	x	1	x	x	Reserved for allocation by IEEE 802.3
x	x	x	x	1	x	x	x	Reserved for allocation by IEEE 802.3
x	x	x	1	x	x	x	x	Reserved for allocation by IEEE 802.3
x	x	1	x	x	x	x	x	Reserved for allocation by IEEE 802.3
x	x	0	0	0	0	0	0	No parameters in this octet

Table 61B–60—Standard information field – 2BASE-TL - Upstream PMMS rates - NPar(3) coding – Octet 1

Bits 8	7	6	5	4	3	2	1	2BASE-TL upstream PMMS NPar(3)s – Octet 1
x	x						x	Upstream base data rate- 32-TCPAM Minimum 1 (bit 7)
x	x					x		Upstream base data rate- 32-TCPAM Maximum 1 (bit 7)
x	x				x			Upstream base data rate- 32-TCPAM Step 1 (bit 7)
x	x	x	x	x				Reserved for allocation by IEEE 802.3

Table 61B–61—Standard information field – 2BASE-TL - Upstream PMMS rates - NPar(3) coding – Octet 2

Bits 8	7	6	5	4	3	2	1	2BASE-TL upstream PMMS rates NPar(3)s – Octet 2
x	x	x	x	x	x	x	x	Upstream base data rate- 32-TCPAM Minimum 1 (bit 1-6)[a]

[a]Note that the rates are determined by combining (bit 7) and the 6-bits in this octet to create a 7-bit number.

Table 61B–62—Standard information field – 2BASE-TL - Upstream PMMS rates - NPar(3) coding – Octet 3

Bits 8	7	6	5	4	3	2	1	2BASE-TL upstream PMMS rates NPar(3)s – Octet 3
x	x	x	x	x	x	x	x	Upstream base data rate- 32-TCPAM Maximum 1 (bit 1-6)[a]

[a]Note that the rates are determined by combining (bit 7) and the 6-bits in this octet to create a 7-bit number.

Table 61B–63—Standard information field – 2BASE-TL - Upstream PMMS rates - NPar(3) coding – Octet 4

Bits 8	7	6	5	4	3	2	1	2BASE-TL upstream PMMS NPar(3)s Octet 6
x	x	x	x	x	x	x	x	Upstream base data rate- 32-TCPAM Step 1 (bit 1-6)[a]

[a]Note that the rates are determined by combining (bit 7) and the 6-bits in this octet to create a 7-bit number.

Table 61B–64—Standard information field – 2BASE-TL - Upstream PMMS rates - NPar(3) coding – Octet j_6*4-3

Bits 8	7	6	5	4	3	2	1	2BASE-TL upstream PMMS NPar(3)s – Octet j_6*4-3
x	x						x	Upstream base data rate- 32-TCPAM Minimum j_6 (bit 7)
x	x					x		Upstream base data rate- 32-TCPAM Maximum j_6 (bit 7)
x	x				x			Upstream base data rate- 32-TCPAM Step j_6 (bit 7)
x	x	x	x	x				Reserved for allocation by IEEE 802.3

Table 61B–65—Standard information field – 2BASE-TL - Upstream PMMS rates - NPar(3) coding – Octet j_6*4-2

Bits 8	7	6	5	4	3	2	1	2BASE-TL upstream PMMS rates NPar(3)s – Octet j_6*4-2
x	x	x	x	x	x	x	x	Upstream base data rate- 32-TCPAM Minimum j_6 (bit 1-6)[a]

[a]Note that the rates are determined by combining (bit 7) and the 6-bits in this octet to create a 7-bit number.

Table 61B–66—Standard information field – 2BASE-TL - Upstream PMMS rates - NPar(3) coding – Octet j_6*4-1

Bits 8	7	6	5	4	3	2	1	2BASE-TL upstream PMMS rates NPar(3)s – Octet j_6*4-1
x	x	x	x	x	x	x	x	Upstream base data rate- 32-TCPAM Maximum j_6 (bit 1-6)[a]

[a]Note that the rates are determined by combining (bit 7) and the 6-bits in this octet to create a 7-bit number.

Table 61B–67—Standard information field – 2BASE-TL - Upstream PMMS rates - NPar(3) coding – Octet j_6*4

Bits 8	7	6	5	4	3	2	1	2BASE-TL upstream PMMS NPar(3)s Octet j_6*4
x	x	x	x	x	x	x	x	Upstream base data rate- 32-TCPAM Step j_6 (bit 1-6)[a]

[a]Note that the rates are determined by combining (bit 7) and the 6-bits in this octet to create a 7-bit number.

61B.3.2.3 Framing parameter codepoints

Tables 61B–68 through 61B–73 contain the level-3 codepoints specific to 2BASE-TL framing parameters.

Table 61B–68—Standard information field – 2BASE-TL - Downstream framing parameters - NPar(3) coding – Octet 1

Bits 8	7	6	5	4	3	2	1	2BASE-TL Downstream framing NPar(3)s – Octet 1
x	x					x	x	Sync Word (bits 14 and 13)
x	x			x	x			Stuff Bits (bits 1 to 2)
		x	x					Reserved for allocation by IEEE 802.3

Table 61B–69—Standard information field – 2BASE-TL - Downstream framing parameters - NPar(3) coding – Octet 2

Bits 8	7	6	5	4	3	2	1	2BASE-TL Downstream framing NPar(3)s – Octet 2
x	x	x	x	x	x	x	x	Sync Word (bits 12 to 7)

Table 61B–70—Standard information field – 2BASE-TL - Downstream framing parameters - NPar(3) coding – Octet 3

Bits 8	7	6	5	4	3	2	1	2BASE-TL Downstream framing NPar(3)s – Octet 3
x	x	x	x	x	x	x	x	Sync Word (bits 6 to 1)

Table 61B–71—Standard information field – 2BASE-TL - Upstream framing parameters - NPar(3) coding – Octet 1

Bits 8	7	6	5	4	3	2	1	2BASE-TL Upstream framing NPar(3)s – Octet 1
x	x					x	x	Sync Word (bits 14 and 13)
x	x			x	x			Stuff Bits (bits 1 to 2)
		x	x					Reserved for allocation by IEEE 802.3

Table 61B–72—Standard information field – 2BASE-TL - Upstream framing parameters - NPar(3) coding – Octet 2

Bits 8	7	6	5	4	3	2	1	2BASE-TL Upstream framing NPar(3)s – Octet 2
x	x	x	x	x	x	x	x	Sync Word (bits 12 to 7)

Table 61B–73—Standard information field – 2BASE-TL - Upstream framing parameters - NPar(3) coding – Octet 3

Bits 8	7	6	5	4	3	2	1	2BASE-TL Upstream framing NPar(3)s – Octet 3
x	x	x	x	x	x	x	x	Sync Word (bits 6 to 1)

61B.4 Codepoints for 10PASS-TS

61B.4.1 Level-2 S field codepoints for 10PASS-TS

Table 61B–74 and Table 61B–75 contain the level-2 codepoints specific to 10PASS-TS.

Table 61B–74—Standard information field – 10PASS-TS NPar(2) coding – Octet 1

Bits 8	7	6	5	4	3	2	1	10PASS-TS NPar(2)s
x	x	x	x	x	x	x	1	Upstream use of 25-138 KHz band
x	x	x	x	x	x	1	x	Downstream use of 25-138 KHz band
x	x	x	x	x	1	x	x	Reserved for allocation by IEEE 802.3
x	x	x	x	1	x	x	x	Reserved for allocation by IEEE 802.3
x	x	x	1	x	x	x	x	Reserved for allocation by IEEE 802.3
x	x	1	x	x	x	x	x	G.997.1 - Clear EOC OAM
x	x	0	0	0	0	0	0	No parameters in this octet

Table 61B–75—Standard information field – 10PASS-TS SPar(2) coding – Octet 1

Bits 8	7	6	5	4	3	2	1	10PASS-TS SPar(2)s
x	x	x	x	x	x	x	1	Reserved for allocation by IEEE 802.3
x	x	x	x	x	x	1	x	Used bands in upstream[a]
x	x	x	x	x	1	x	x	Used bands in downstream[a]
x	x	x	x	1	x	x	x	IDFT/DFT size
x	x	x	1	x	x	x	x	Initial length of CE
x	x	1	x	x	x	x	x	MCM RFI bands[a]
x	x	0	0	0	0	0	0	No parameters in this octet

[a]The length of the corresponding NPar(3) field is variable and is a multiple of 4 octets. The length depends on the total number of bands to be specified.

61B.4.2 Level-3 S field codepoints for 10PASS-TS

61B.4.2.1 Used bands in upstream codepoints

Tables 61B–76 through 61B–79 contain the level-3 codepoints specific to 10PASS-TS Used bands in upstream.

Table 61B–76—Standard information field – Used bands in upstream NPar(3) coding – Octet 4n-3 (n = 1, 2, 3, 4, 5)

Bits 8	7	6	5	4	3	2	1	10PASS-TS Used bands in upstream NPar(3)s Octet 4n-3 (n = 1, 2, 3, 4, 5)
x	x	x	x	x	x	x	x	End tone index of band n (bits 7 to 12)[a]

[a]n is the band index, starting from 1.

Table 61B–77—Standard information field – Used bands in upstream NPar(3) coding – Octet 4n-2 (n = 1, 2, 3, 4, 5)

Bits 8	7	6	5	4	3	2	1	10PASS-TS Used bands in upstream NPar(3)s Octet 4n-2 (n = 1, 2, 3, 4, 5)
x	x	x	x	x	x	x	x	End tone index of band n (bits 1 to 6)[a]

[a]n is the band index, starting from 1.

Table 61B–78—Standard information field – Used bands in upstream NPar(3) coding – Octet 4n-1 (n = 1, 2, 3, 4, 5)

Bits 8	7	6	5	4	3	2	1	10PASS-TS Used bands in upstream NPar(3)s Octet 4n-1 (n = 1, 2, 3, 4, 5)
x	x	x	x	x	x	x	x	Start tone index of band n (bits 7 to 12)[a]

[a]n is the band index, starting from 1.

Table 61B–79—Standard information field – Used bands in upstream NPar(3) coding – Octet 4n (n = 1, 2, 3, 4, 5)

Bits 8	7	6	5	4	3	2	1	10PASS-TS Used bands in upstream NPar(3)s Octet 4n (n = 1, 2, 3, 4, 5)
x	x	x	x	x	x	x	x	Start tone index of band n (bits 1 to 6)[a]

[a]n is the band index, starting from 1.

61B.4.2.2 Used bands in downstream codepoints

Table 61B–80 through Table 61B–83 contain the level-3 codepoints specific to 10PASS-TS Used bands in downstream.

Table 61B–80—Standard information field – Used bands in downstream NPar(3) coding – Octet 4n-3 (n = 1, 2, 3, 4, 5)

Bits 8	7	6	5	4	3	2	1	10PASS-TS Used bands in downstream NPar(3)s Octet 4n-3 (n = 1, 2, 3, 4, 5)
x	x	x	x	x	x	x	x	End tone index of band n (bits 7 to 12)[a]

[a]n is the band index, starting from 1.

Table 61B–81—Standard information field – Used bands in downstream NPar(3) coding – Octet 4n-2 (n = 1, 2, 3, 4, 5)

Bits 8	7	6	5	4	3	2	1	10PASS-TS Used bands in downstream NPar(3)s Octet 4n-2 (n = 1, 2, 3, 4, 5)
x	x	x	x	x	x	x	x	End tone index of band n (bits 1 to 6)[a]

[a]n is the band index, starting from 1.

Table 61B–82—Standard information field – Used bands in downstream NPar(3) coding – Octet 4n-1 (n = 1, 2, 3, 4, 5)

Bits 8	7	6	5	4	3	2	1	10PASS-TS Used bands in downstream NPar(3)s Octet 4n-1 (n = 1, 2, 3, 4, 5)
x	x	x	x	x	x	x	x	Start tone index of band n (bits 7 to 12)[a]

[a]n is the band index, starting from 1.

Table 61B–83—Standard information field – Used bands in downstream NPar(3) coding – Octet 4n (n = 1, 2, 3, 4, 5)

Bits 8	7	6	5	4	3	2	1	10PASS-TS Used bands in downstream NPar(3)s Octet 4n (n = 1, 2, 3, 4, 5)
x	x	x	x	x	x	x	x	Start tone index of band n (bits 1 to 6)[a]

[a]n is the band index, starting from 1.

61B.4.2.3 IDFT/DFT size codepoints

Table 61B–84 contains the level-3 codepoints specific to 10PASS-TS IDFT/DFT size.

Table 61B–84—Standard information field – IDFT/DFT size NPar(3) coding – Octet 1

Bits 8	7	6	5	4	3	2	1	10PASS-TS IDFT/DFT size NPar(3)s Octet 1
x	x	x	x	x	x	x	x	IDFT/DFT size (bits 6-1 x 256 points)

61B.4.2.4 Initial length of CE codepoints

Table 61B–85 through Table 61B–86 contain the level-3 codepoints specific to 10PASS-TS Initial length of CE.

Table 61B–85—Standard information field – Initial length of CE NPar(3) coding – Octet 1

Bits 8	7	6	5	4	3	2	1	10PASS-TS Initial length of CE NPar(3)s Octet 1
x	x	0	0	x	x	x	x	Initial sample length of cyclic extension (bits 7 to 10)

Table 61B–86—Standard information field – Initial length of CE NPar(3) coding – Octet 2

Bits 8	7	6	5	4	3	2	1	10PASS-TS Initial length of CE NPar(3)s Octet 2
x	x	x	x	x	x	x	x	Initial sample length of cyclic extension (bits 6-1)

61B.4.2.5 MCM RFI band codepoints

Table 61B–87 through Table 61B–90 contain the level-3 codepoints specific to 10PASS-TS MCM RFI bands.

Table 61B–87—Standard information field – MCM RFI bands NPar(3) coding – Octet 4n-3 (n = 1, 2, 3, 4, 5)

Bits 8	7	6	5	4	3	2	1	10PASS-TS MCM RFI bands NPar(3)s Octet 4n-3 (n = 1, 2, 3, 4, 5)
x	x	x	x	x	x	x	x	End tone index of band n (bits 7 to 12)[a]

[a]n is the band index, starting from 1.

Table 61B–88—Standard information field – MCM RFI bands NPar(3) coding – Octet 4n-2 (n = 1, 2, 3, 4, 5)

Bits 8	7	6	5	4	3	2	1	10PASS-TS MCM RFI bands NPar(3)s Octet 4n-2 (n = 1, 2, 3, 4, 5)
x	x	x	x	x	x	x	x	End tone index of band n (bits 1 to 6)[a]

[a]n is the band index, starting from 1.

Table 61B–89—Standard information field – MCM RFI bands NPar(3) coding – Octet 4n-1 (n = 1, 2, 3, 4, 5)

Bits 8	7	6	5	4	3	2	1	10PASS-TS MCM RFI bands NPar(3)s Octet 4n-1 (n = 1, 2, 3, 4, 5)
x	x	x	x	x	x	x	x	Start tone index of band n (bits 7 to 12)[a]

[a]n is the band index, starting from 1.

Table 61B–90—Standard information field – MCM RFI bands NPar(3) coding – Octet 4n (n = 1, 2, 3, 4, 5)

Bits								10PASS-TS MCM RFI bands NPar(3)s Octet 4n (n = 1, 2, 3, 4, 5)
8	7	6	5	4	3	2	1	
x	x	x	x	x	x	x	x	Start tone index of band n (bits 1 to 6)[a]

[a]n is the band index, starting from 1.

61B.5 Protocol implementation conformance statement (PICS) proforma for Annex 61B, Handshake codepoints for 2BASE-TL and 10PASS-TS[23]

61B.5.1 Introduction

The supplier of a protocol implementation that is claimed to conform to Annex 61B, Handshake codepoints for 2BASE-TL and 10PASS-TS, 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.

61B.5.2 Identification

61B.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., names and versions for machines and/or operating systems; System Name(s)	
Only the first three items are required for all implementations; other information may be completed as appropriate in meeting the requirements for the identification. The terms Name and Version should be interpreted appropriately to correspond with a supplier’s terminology (e.g., Type, Series, Model).	

61B.5.2.2 Protocol summary

Identification of protocol standard	IEEE Std 802.3-2005, Handshake codepoints for 2BASE-TL and 10PASS-TS.
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 802.3-2005.)	
Date of Statement	

61B.5.3 Major capabilities/options

Item	Feature	Subclause	Value/Comment	Status	Support
HSCP	Handshake Codepoints	61B	The coding rules for 2BASE-TL handshake messages are implemented.	M	Yes [ ]

[23]*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.

61B.5.4 2BASE-TL handshake coding rules

Item	Feature	Subclause	Value/Comment	Status	Support
HSCP-1	PMMS coding	61B.3.1	Values for min and max are between 4 and 89, inclusive.	M	Yes [ ]
HSCP-2	PMMS coding	61B.3.1	Valid values for step are between 1 and 89, inclusive.	M	Yes [ ]
HSCP-3	PMMS coding	61B.3.1	The variables j_5 and j_6 associated with the PMMS rates are independent, and range from 2 to 8, inclusive.	M	Yes [ ]
HSCP-4	PMMS coding	61B.3.1	If only one range of rates is required, then only the octets associated with (min1,max1,step1) are sent.	M	Yes [ ]
HSCP-5	CLR coding	61B.3.1	Valid values for minimum and maximum are between 3 and 60, inclusive, for 16-TCPAM and between 12 and 89, inclusive, for 32-TCPAM.	M	Yes [ ]
HSCP-6	CLR coding	61B.3.1	Valid values for step are between 1 and 89, inclusive.	M	Yes [ ]
HSCP-7	CLR coding	61B.3.1	The variables j_1, j_2, j_3 and j_4 associated with the training rates are independent, and range from 2 to 8, inclusive.	M	Yes [ ]
HSCP-8	CLR coding	61B.3.1	If only one range of rates is required, then only the octets associated with (min1,max1,step1) is sent. If more than one range of rates is required, then j_1*4, j_2*4, j_3*4 and j_4*4 correspond to the number of octets sent.	M	Yes [ ]
HSCP-9	CL coding	61B.3.1	Valid values for minimum and maximum are between 3 and 60, inclusive, for 16-TCPAM and between 12 and 89, inclusive, for 32-TCPAM.	M	Yes [ ]
HSCP-10	CL coding	61B.3.1	Valid values for step are between 1 and 89, inclusive.	M	Yes [ ]
HSCP-11	CL coding	61B.3.1	The variables j_1, j_2, j_3 and j_4 associated with the training rates are independent, and range from 2 to 8, inclusive.	M	Yes [ ]
HSCP-12	CL coding	61B.3.1	If only one range of rates is required, then only the octets associated with (min1,max1,step1) is sent. If more than one range of rates is required, then j_1*4, j_2*4, j_3*4 and j_4*4 correspond to the number of octets sent.	M	Yes [ ]
HSCP-13	SPar(2) coding	61B.3.1	Only one of the bits 2BASE-TL training mode and 2BASE-TL PMMS mode is set at any given time.	M	Yes [ ]
HSCP-14	SPar(2) coding	61B.3.1	The Regenerator silent period bit is set to 0_b if the 2BASE-TL PMMS mode NPar(2) bit is set to 1_b or the 2BASE-TL Training mode NPar(2) bit is set to 1_b.	M	Yes [ ]

Annex 62A

(normative)

PMD profiles for 10PASS-TS

62A.1 Introduction and rationale

Annex 62A defines the PMD profiles for 10PASS-TS. These profiles define the transmission characteristics of the PHY on the media. 10PASS-TS PHYs are required to operate across varying media quality, regulatory and noise environments.

The profiles defined in this clause have two purposes. The first is to describe a bounded set of operating modes that a party might choose from when implementing, integrating and installing 10PASS-TS equipment. 10PASS-TS PHYs are inherently flexible in their transmission capabilities. The possible combination of transmission parameters are nearly infinite. The defined profiles collect a small subset of these parameters into modes that work well in most deployments. For deployments that require an operating mode not defined in this Annex, profiles can be overridden by setting PHY PMD registers directly, via Clause 45 for example. Informative Annex 62C contains examples of such user-defined modes of operation.

The second purpose of profiles is to define a set of operating modes against which PHY performance compliance may be tested. The topic of performance compliance is addressed for 10PASS-TS in Annex 62B.

62A.2 Relationship to other clauses

Clause 30 describes how the selection of Annex 62A profiles is exported to a management entity.

Clause 45 registers describe an optional mechanism for configuring a 10PASS-TS PHY to use a particular profile. The register settings for each profile are contained in 62A.4.

62A.3 Profile definitions

The following sections define the mandatory profiles for 10PASS-TS operation, in terms of bandplan, PSD mask, UPBO Reference PSD, notching parameters and payload rate.

62A.3.1 Bandplan and PSD mask profiles

The spectral characteristics of 10PASS-TS communication on the copper medium are defined by a choice of bandplans and PSD Masks.

Each of 5 standard frequency bands (Band 0, D1, U1, D2, U2) used for 10PASS-TS communication are defined in a bandplan. 10PASS-TS PHYs operating in the same cable bundle should use the same bandplan to ensure spectral compatibility. Furthermore, the selection of bandplan may be governed by regional regulations that pertain to the deployment. While all 10PASS-TS PHYs may operate in any of the below bandplans, installers should be aware of any regulations that might restrict their choice of modes. Bandplan profiles specify the use of 2, 3, 4, or 5 standard frequency bands.

PSD Masks further define the spectral environment by specifying the maximum transmit power spectral density at a given frequency. Like bandplans, the PSD mask should be selected to be compatible with applicable regulations and to match other PHYs operating in the same cable bundle.

Profiles are defined here for various regulatory environments as well as for private installation. Additionally, operation with a bandplan or PSD mask not defined in this clause is supported by configuration through Clause 45 registers. All 10PASS-TS PHYs shall be capable of operating in all profiles listed in this clause. Profile definitions are listed in Table 62A-1.
.

Table 62A-1—Bandplan and PSD Mask Profiles

Profile Number	PSD Mask	Band Assignment[a]	Bandplan
1	T1.424 FTTCab.M1	x/D/U/D/U	G.993.1 Bandplan A
2	T1.424 FTTEx.M1		
3	T1.424 FTTCab.M2		
4	T1.424 FTTEx.M2		
5	T1.424 FTTCab.M1	D/D/U/D/U	
6	T1.424 FTTEx.M1		
7	T1.424 FTTCab.M2		
8	T1.424 FTTEx.M2		
9	T1.424 FTTCab.M1	U/D/U/D/x	
10	T1.424 FTTEx.M1		
11	T1.424 FTTCab.M2		
12	T1.424 FTTEx.M2		
13	TS1 101 270-1 Pcab.M1.A	x/D/U/D/U	G.993.1 Bandplan B
14	TS1 101 270-1 Pcab.M1.B		
15	TS1 101 270-1 Pex.P1.M1		
16	TS1 101 270-1 Pex.P2.M1		
17	TS1 101 270-1 Pcab.M2		
18	TS1 101 270-1 Pex.P1.M2		
19	TS1 101 270-1 Pex.P2.M2		
20	TS1 101 270-1 Pcab.M1.A	U/D/U/D/x	
21	TS1 101 270-1 Pcab.M1.B		
22	TS1 101 270-1 Pex.P1.M1		
23	TS1 101 270-1 Pex.P2.M1		
24	TS1 101 270-1 Pcab.M2		
25	TS1 101 270-1 Pex.P1.M2		
26	TS1 101 270-1 Pex.P2.M2		
27	G.993.1 F.1.2.1 (VDSL over POTS)	x/D/U/D/U	G.993.1 Annex F
28	G.993.1 F.1.2.2 (VDSL over TCM-ISDN)		
29	G.993.1 F.1.2.3 (PSD reduction)		
30	T1.424 FTTCab.M1 (extended)	x/D/U/D/U/D	G.993.1 Annex A[b]

[a]For each band in the bandplan, the Band Assignment indicates the use or direction of communication for that band. U=upstream, D=downstream, x=band is unused. Bands are listed in this order: 0/1/2/3/4.

[b]This profile uses a 5th band (12 MHz—16.5 MHz) for downstream transmission at –60 dBm/Hz.

62A.3.2 Bandplan definitions

The management entity should load the appropriate Clause 45 registers according to the bandplan specified by the selected profile. 62A.4 contains examples of the use of Clause 45 registers for the purpose of setting profiles.

The VDSL bandplans defined in ITU-T Recommendation G.993.1 shall be supported by all 10PASS-TS PMDs. These bandplans are represented for information in Table 62A-2.

Table 62A-2—Bandplans defined by ITU-T Recommendation G.993.1

Plan	Band 0 (optional) US/DS	Band D1	Band U1	Band D2	Band U2
Bandplan A (formerly Plan 998)	25 kHz – 138 kHz	138 kHz – 3.75 MHz	3.75 Mhz – 5.2 MHz	5.2 MHz – 8.5 MHz	8.5 MHz – 12 MHz
Bandplan B (formerly Plan 997)	25 kHz – 138 kHz	138 kHz – 3.0 MHz	3.0 MHz – 5.1 MHz	5.2 MHz – 7.05 MHz	7.05 MHz – 12 MHz
Bandplan C[a]	25 kHz – 138 kHz	138 kHz – 2.5MHz	2.5 MHz – 3.75 MHz	3.75 MHz – *Fx*	*Fx* – 12MHz
Annex F[b,c]	25 kHz – 138 kHz	138 kHz – 3.75 MHz	3.75 Mhz – 5.2 MHz	5.2 MHz – 8.5 MHz	8.5 MHz – 12 MHz

[a]Bandplan C is characterized by a variable split frequency between band D2 and band U2, represented as "*Fx*". 10PASS-TS shall support operation in Bandplan C for $Fx = 3750\text{kHz} + n \times 250\text{kHz}$, where $0 \le n \le 33$.
[b]Subsets composed of at least one downstream band and one upstream band among D1, U1, D2 and U2 may be implemented.
[c]Band 1D starts at 640kHz when operating in the frequency region above TCM-ISDN DSL band. Band 1D starts at 1.104MHz when operating with PSD reduction function in the frequency region below 1.104Mhz.

62A.3.3 PSD mask definitions

The management entity should load the appropriate Clause 45 registers according to the PSD Mask specified by the selected profile. 62A.4 contains examples of the use of Clause 45 registers for the purpose of setting profiles.

The VDSL PSD Masks defined in ITU-T Recommendation G.993.1, T1.424 and ETSI TS 101 270-1 shall be supported by all 10PASS-TS PMDs.

NOTE—The reference documents in which the PSD Masks are specified also specify the relationship between PSD Mask and PSD template, and the appropriate method to assess compliance with a PSD Mask or a PSD template.

62A.3.4 UPBO Reference PSD Profiles

Upstream Power Back-Off (UPBO) is defined in 62.3.4.1. Its operation requires the specification of a Reference PSD, by means of which the 10PASS-TS-R calculates the maximum upstream transmit PSD. Different UPBO Reference PSDs have been standardized in T1.424 and ETSI TS 101 270-1, as shown in Table 62A-3. 10PASS-TS implementations shall support all UPBO Reference PSDs listed in Table 62A-3. The 10PASS-TS PHY shall additionally allow a profile value of "0" to be selected, which indicates that UPBO is to be disabled.

62A.3.5 Band Notch Profiles

In certain deployments, 10PASS-TS operation may interfere with nearby amateur radio equipment. The Band Notch profiles specify notches that 10PASS-TS PHYs shall add to their transmit PSDs when selected.

Table 62A-3—UPBO Reference PSD Profiles
(*f* is in MHz, the PSD level is in dBm/Hz)

#	Reference PSD			1U	2U
1	T1.424	Noise A	M1	$-60-22.00\sqrt{f}$	$-60-17.18\sqrt{f}$
2			M2	$-53-24.47\sqrt{f}$	$-54-18.93\sqrt{f}$
3		Noise F	M1	$-60-18.54\sqrt{f}$	$-60-16.865\sqrt{f}$
4			M2	$-53-21.19\sqrt{f}$	$-54-18.69\sqrt{f}$
5	ETSI TS 101 270-1	Noise A&B		$-47.3-28.01\sqrt{f}$	$-54-19.22\sqrt{f}$
6		Noise C		$-47.3-21.14\sqrt{f}$	$-54-16.29\sqrt{f}$
7		Noise D		$-47.3-26.21\sqrt{f}$	$-54-17.36\sqrt{f}$
8		Noise E		$-47.3-27.27\sqrt{f}$	$-54-18.1\sqrt{f}$
9		Noise F		$-47.3-19.77\sqrt{f}$	$-54-15.77\sqrt{f}$

When a notch is activated, the transmitter shall reduce its PSD to less than –80 dBm/Hz in the frequencies of the notch. More than one notch may be activated at one time.

All Band Notches specified in the following standards shall be supported:

a) ITU-T Recommendation G.993.1 Annex F, Table F-5
b) T1.424, Clause 15
c) ETSI TS1 101 270 subclause 9.3.3.6.1

The Band Notch Profiles are listed for information in Table 62A-4. This table includes notches that are above 12MHz, that are therefore outside the scope of this standard.

Table 62A-4—Band Notch Profile definitions

Band Notch Profile	Specification			Start Frequency (MHz)	End Frequency (MHz)
	ITU-T Rec. G.993.1	T1.424	TS 101 270-1		
1	Table F-5 #01	—	—	1.810	1.825
2	Table 6-2	Table 15-1	Table 17	1.810	2.000
3	Table F-5 #02	—	—	1.9075	1.9125
4	Table F-5 #03	—	—	3.500	3.575
5	Table 6-2	—	Table 17	3.500	3.800
6	—	Table 15-1	—	3.500	4.000
7	Table F-5 #04	—	—	3.747	3.754
8	Table F-5 #05	—	—	3.791	3.805
9	Table 6-2	—	Table 17	7.000	7.100
10	Table F-5 #06	Table 15-1	—	7.000	7.300
11	Table 6-2	Table 15-1	Table 17	10.100	10.150
—	Table 6-2 Table F-5 #08	Table 15-1	Table 17	14.000	14.350
—	Table 6-2 Table F-5 #09	Table 15-1	Table 17	18.068	18.168
—	Table 6-2 Table F-5 #10	Table 15-1	Table 17	21.000	21.450
—	Table 6-2 Table F-5 #11	Table 15-1	Table 17	24.890	24.990
—	Table 6-2	—	Table 17	28.000	29.100
—	Table F-5 #12	Table 15-1	—	28.000	29.700

62A.3.6 Payload rate profiles

The Payload Rate Profile describes the payload bitrate as seen at the MII interface.

The Payload Rate Profile consists of a payload rate for each of the downstream and upstream directions. The profile is specified in the format Drate/Urate as the payload bitrate that the PHY link shall provide, where *Drate* and *Urate* are expressed in Mb/s. For example a Payload Rate Profile of 10/2.5 corresponds to a downstream payload rate of 10 Mb/s and an upstream payload rate of 2.5 Mb/s. *Drate* values of 2.5, 5, 7.5, 10, 12.5, 15, 25, 35, 50, 70, and 100 shall be supported where the loop environment, bandplan and PSD mask allow this. *Urate* values of 2.5, 5, 7.5, 10, 12.5, 15, 25, 35, and 50 shall be supported where the loop environment, bandplan and PSD mask allow this. This leads to a total of 9 symmetric and 90 asymmetric Payload Rate Profiles.

The selected Payload Rate Profile sets a target for the PHY's operation. If the payload rates of the selected profile cannot be achieved based on the loop environment, bandplan and PSD mask, the PHY shall drop the link.

62A.3.7 Complete profiles

The complete PMD operation of the 10PASS-TS PHY can be selected by choosing one Bandplan and PSD Mask profile, one UPBO Reference PSD profile, one Payload Rate profile, and any number of Band Notch profiles.

62A.3.8 Default profile

A 10PASS-TS device that is not managed (i.e., no management functions are provided, or enabled) shall operate in the default profile and the default mode specified in this subclause and summarized in Table 62A-5.

Table 62A-5—Default profile and default mode settings

Profile / Setting	Value
Payload bitrate profile	10/10
Bandplan and PSD mask profile	#1
Band notch profiles	#2, #6, #10, and #11
UPBO reference PSD profile	#3
Reed-Solomon setting	(240, 224)
Interleaver setting	I=30, M=62

The default profile shall consist of the 10/10 payload bitrate profile, bandplan and PSD mask profile #1, band notch profiles #2, #6, #10, and #11 enabled, and UPBO reference PSD profile #3.

In addition, the default mode of 10PASS-TS implementations shall use Reed-Solomon setting (240, 224)[24], and interleaver setting I=30, M=62.

NOTE—The default profile may not be spectrally compatible to any particular regional requirement, nor may it be the optimal profile for a particular cable segement.

[24]See 62.2.4.2.

62A.4 Register settings

Tables 62A-6 through 62A-8 contain the register settings required to implement the profiles described in this Annex. The referenced registers are defined in 45.2.

Table 62A-6 contains the MCM tone group definitions to be used in order to support the band plan profiles described in 62A.3.2. For each of the listed tone groups, the Tone Active and/or Tone Direction bits in the 10P MCM tone control parameter register shall be set according to the use indicated in the first column of the table.

Table 62A-6—MCM register settings implementing bandplan profiles

Band Allocation	Band Plan A 10P MCM Tone Group Register		Band Plan B 10P MCM Tone Group Register		Band Plan C 10P MCM Tone Group Register		Band Plan Ann. F 10P MCM Tone Group Register	
	lower	upper	lower	upper	lower	upper	lower	upper
0 (upstream, downstream or not used)	0007_{16}	$001F_{16}$	0007_{16}	$001F_{16}$	0007_{16}	$001F_{16}$	0007_{16}	$001F_{16}$
1D (downstream)	0021_{16}	0365_{16}	0021_{16}	$02B7_{16}$	0021_{16}	0243_{16}	0021_{16}	0365_{16}
1U (upstream)	0367_{16}	$04B5_{16}$	$02B9_{16}$	$049E_{16}$	0245_{16}	0365_{16}	0367_{16}	$04B5_{16}$
2D (downstream)	$04B7_{16}$	$07B2_{16}$	$04A0_{16}$	0662_{16}	0367_{16}	fx1[a]	$04B7_{16}$	$07B2_{16}$
2U (upstream)	$07B4_{16}$	$0ADE_{16}$	0664_{16}	$0ADE_{16}$	fx2[b]	$0ADE_{16}$	$07B4_{16}$	$0ADE_{16}$
3D (downstream)[c]	$0ADF_{16}$	$0EF2_{16}$	—	—	—	—	—	—

[a]Values for fx1 shall be in the range 0369_{16} to $0ADA_{16}$
[b]Values for fx2 shall be in the range (fx1 + 2) to $0ADE_{16}$
[c]Band 3D is only used in Band Plan and PSD Mask profile #30.

Unlike the other parameters governed by the profiles specified in the Annex, PSDs are typically defined by means of a functional expression, rather than a set of values. Transmit PSDs and Reference PSDs typically vary for each individual tone. A pseudo-C procedure for setting a PSD profile and a Reference PSD profile is shown in Equation (62A–1) below. It assumes the existence of the functions getPSDLevel(float frequencyInKHz) and getReferencePSD(float frequencyInKHz) specifying the transmit PSD and Reference PSD respectively, both expressed as a floating-point value in dBm/Hz. Registers are addressed by means of pointers ToneGroupRegister, ToneControlParameterRegister and ToneControlActionRegister.

```
for (int tone=0;tone<4096;tone++) {
 ToneGroupRegister[0] = tone;              // set lower bound of tone group
 ToneGroupRegister[1] = tone;              // set upper bound of tone group
                                           // to the same value
 short TxPSD = floor(4*(getPSDLevel(tone*4.3125)+100)) & 0x01FF;
                                           // convert to 9-bit value
 ToneControlParameterRegister[1] &= 0xFFFC; // clear first two bits of PSD level
 ToneControlParameterRegister[2] &= 0x01FF; // clear remaining 7 bits of PSD level
 ToneControlParameterRegister[1] |= TxPSD >> 7;// store first two bits of PSD level
 ToneControlParameterRegister[2] |= (TxPSD << 9) & 0xFE00;
                                           // store remaining 7 bits of PSD level
 short RefPSD = floor(4*(getReferencePSD(tone*4.3125)+100)) & 0x01FF;
                                           // convert to 9-bit value
 ToneControlParameterRegister[2] &= 0xFFE0; // clear Reference PSD level
 ToneControlParameterRegister[2] |= RefPSD; // store Reference PSD level
 *ToneControlActionRegister |= 0x0020;     // refresh contents of the selected
                                           // tones entries in table
}
*ToneControlActionRegister |= 0x0002;      // activates PSD level setting as in
                                           // ToneControlParameterRegister
*ToneControlActionRegister |= 0x0001;      // activates UPBO Ref. PSD level
                                           // setting as in
                                           // ToneControlParameterReg
```

(62A–1)

Functions specifying standard transmit PSDs can be found in the documents referenced in 62A.3.3. Functions specifying UPBO Reference PSDs can be found in Table 62A-3.

Table 62A-7 contains the MCM tone group definitions to be used in order to support the band notch profiles desribed in 62A.3.5. For each of the listed tone groups, the Tone Active bit in the 10P MCM tone control parameter register shall be cleared to activate the corresponding band notch.

Table 62A-7—MCM register settings implementing band notch profiles

Band Notch Profile	10P MCM Tone Group Register	
	lower	upper
1	$01A3_{16}$	$01A7_{16}$
2	$01A3_{16}$	$01D0_{16}$
3	$01B9_{16}$	$01BB_{16}$
4	$032B_{16}$	$033D_{16}$
5	$032B_{16}$	0371_{16}
6	$032B_{16}$	$03A0_{16}$
7	0364_{16}	0366_{16}
8	$036E_{16}$	0372_{16}
9	0656_{16}	$066E_{16}$
10	0656_{16}	$069D_{16}$
11	0925_{16}	0932_{16}

Table 62A-8 contains the MCM register settings for the payload rate profiles listed in 62A.3.6. When operating under a payload rate profile, the minimum and maximum data rates in the 10P MCM upstream/downstream data rate configuration registers shall be set to the same value.

Table 62A-8—MCM register settings implementing payload rate profiles

Profile (payload rate in Mb/s)	Downstream Data Rate Configuration Register setting (bits 15:0)	Upstream Data Rate Configuration Register setting (bits 15:0)
2.5	0027_{16}	0027_{16}
5	$004E_{16}$	$004E_{16}$
7.5	0075_{16}	0075_{16}
10	$009C_{16}$	$009C_{16}$
12.5	$00C3_{16}$	$00C3_{16}$
15	$00EA_{16}$	$00EA_{16}$
25	0186_{16}	0186_{16}
35	0222_{16}	0222_{16}
50	$030D_{16}$	$030D_{16}$
70	0445_{16}	no profile defined
100	$061A_{16}$	no profile defined

62A.5 Protocol implementation conformance statement (PICS) proforma for Annex 62A, PMD profiles for 10PASS-TS[25]

62A.5.1 Introduction

The supplier of a protocol implementation that is claimed to conform to Annex 62A, PMD profiles for 10PASS-TS, 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.

62A.5.2 Identification

62A.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., names and versions for machines and/or operating systems; System Name(s)	
Only the first three items are required for all implementations; other information may be completed as appropriate in meeting the requirements for the identification. The terms Name and Version should be interpreted appropriately to correspond with a supplier's terminology (e.g., Type, Series, Model).	

62A.5.2.2 Protocol summary

Identification of protocol standard	IEEE Std 802.3-2005, PMD profiles for 10PASS-TS.
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 802.3-2005.)	
Date of Statement	

62A.5.3 Major capabilities/options

Item	Feature	Subclause	Value/Comment	Status	Support
10PProf	PMD profiles for 10PASS-TS	Annex 62A	The PMD profiles listed in Annex 62A are supported.	10PASS-TS: M	Yes [ ]

[25]*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.

62A.5.4 PICS proforma tables for PMD profiles for 10PASS-TS

Item	Feature	Subclause	Value/Comment	Status	Support
10PProf-1	Bandplan and PSD mask profiles	62A.3.1	The 10PASS-TS PHYs is capable of operating in all profiles listed in this Clause.	M	Yes [ ]
10PProf-2	Bandplan and PSD mask profiles	62A.3.1	The VDSL bandplans defined in ITU-T Recommendation G.993.1 are supported.	M	Yes [ ]
10PProf-3	Bandplan and PSD mask profiles	62A.3.1	The VDSL PSD Masks defined in ITU-T Recommendation G.993.1, T1.424 and ETSI TS 101 270-1 are supported by all 10PASS-TS PMDs.	M	Yes [ ]
10PProf-4	Bandplan and PSD mask profiles	62A.3.1	The 10PASS-TS PHY is capable of operating in profile #1 as specified in Table 62A-1.	M	Yes [ ]
10PProf-5	Bandplan and PSD mask profiles	62A.3.1	The 10PASS-TS PHY is capable of operating in profile #2 as specified in Table 62A-1.	M	Yes [ ]
10PProf-6	Bandplan and PSD mask profiles	62A.3.1	The 10PASS-TS PHY is capable of operating in profile #3 as specified in Table 62A-1.	M	Yes [ ]
10PProf-7	Bandplan and PSD mask profiles	62A.3.1	The 10PASS-TS PHY is capable of operating in profile #4 as specified in Table 62A-1.	M	Yes [ ]
10PProf-8	Bandplan and PSD mask profiles	62A.3.1	The 10PASS-TS PHY is capable of operating in profile #5 as specified in Table 62A-1.	M	Yes [ ]
10PProf-9	Bandplan and PSD mask profiles	62A.3.1	The 10PASS-TS PHY is capable of operating in profile #6 as specified in Table 62A-1.	M	Yes [ ]
10PProf-10	Bandplan and PSD mask profiles	62A.3.1	The 10PASS-TS PHY is capable of operating in profile #7 as specified in Table 62A-1.	M	Yes [ ]
10PProf-11	Bandplan and PSD mask profiles	62A.3.1	The 10PASS-TS PHY is capable of operating in profile #8 as specified in Table 62A-1.	M	Yes [ ]
10PProf-12	Bandplan and PSD mask profiles	62A.3.1	The 10PASS-TS PHY is capable of operating in profile #9 as specified in Table 62A-1.	M	Yes [ ]
10PProf-13	Bandplan and PSD mask profiles	62A.3.1	The 10PASS-TS PHY is capable of operating in profile #10 as specified in Table 62A-1.	M	Yes [ ]
10PProf-14	Bandplan and PSD mask profiles	62A.3.1	The 10PASS-TS PHY is capable of operating in profile #11 as specified in Table 62A-1.	M	Yes [ ]
10PProf-15	Bandplan and PSD mask profiles	62A.3.1	The 10PASS-TS PHY is capable of operating in profile #12 as specified in Table 62A-1.	M	Yes [ ]

10PProf-16	Bandplan and PSD mask profiles	62A.3.1	The 10PASS-TS PHY is capable of operating in profile #13 as specified in Table 62A-1.	M	Yes [ ]
10PProf-17	Bandplan and PSD mask profiles	62A.3.1	The 10PASS-TS PHY is capable of operating in profile #14 as specified in Table 62A-1.	M	Yes [ ]
10PProf-18	Bandplan and PSD mask profiles	62A.3.1	The 10PASS-TS PHY is capable of operating in profile #15 as specified in Table 62A-1.	M	Yes [ ]
10PProf-19	Bandplan and PSD mask profiles	62A.3.1	The 10PASS-TS PHY is capable of operating in profile #16 as specified in Table 62A-1.	M	Yes [ ]
10PProf-20	Bandplan and PSD mask profiles	62A.3.1	The 10PASS-TS PHY is capable of operating in profile #17 as specified in Table 62A-1.	M	Yes [ ]
10PProf-21	Bandplan and PSD mask profiles	62A.3.1	The 10PASS-TS PHY is capable of operating in profile #18 as specified in Table 62A-1.	M	Yes [ ]
10PProf-22	Bandplan and PSD mask profiles	62A.3.1	The 10PASS-TS PHY is capable of operating in profile #19 as specified in Table 62A-1.	M	Yes [ ]
10PProf-23	Bandplan and PSD mask profiles	62A.3.1	The 10PASS-TS PHY is capable of operating in profile #20 as specified in Table 62A-1.	M	Yes [ ]
10PProf-24	Bandplan and PSD mask profiles	62A.3.1	The 10PASS-TS PHY is capable of operating in profile #21 as specified in Table 62A-1.	M	Yes [ ]
10PProf-25	Bandplan and PSD mask profiles	62A.3.1	The 10PASS-TS PHY is capable of operating in profile #22 as specified in Table 62A-1.	M	Yes [ ]
10PProf-26	Bandplan and PSD mask profiles	62A.3.1	The 10PASS-TS PHY is capable of operating in profile #23 as specified in Table 62A-1.	M	Yes [ ]
10PProf-27	Bandplan and PSD mask profiles	62A.3.1	The 10PASS-TS PHY is capable of operating in profile #24 as specified in Table 62A-1.	M	Yes [ ]
10PProf-28	Bandplan and PSD mask profiles	62A.3.1	The 10PASS-TS PHY is capable of operating in profile #25 as specified in Table 62A-1.	M	Yes [ ]
10PProf-29	Bandplan and PSD mask profiles	62A.3.1	The 10PASS-TS PHY is capable of operating in profile #26 as specified in Table 62A-1.	M	Yes [ ]
10PProf-30	Bandplan and PSD mask profiles	62A.3.1	The 10PASS-TS PHY is capable of operating in profile #27 as specified in Table 62A-1.	M	Yes [ ]
10PProf-31	Bandplan and PSD mask profiles	62A.3.1	The 10PASS-TS PHY is capable of operating in profile #28 as specified in Table 62A-1.	M	Yes [ ]
10PProf-32	Bandplan and PSD mask profiles	62A.3.1	The 10PASS-TS PHY is capable of operating in profile #29 as specified in Table 62A-1.	M	Yes [ ]

10PProf-33	Bandplan and PSD mask profiles	62A.3.1	The 10PASS-TS PHY is capable of operating in profile #30 as specified in Table 62A-1.	M	Yes [ ]
10PProf-34	UPBO Reference PSD Profiles	62A.3.4	The implementation supports all UPBO Reference PSDs listed in Table 62A-3.	M	Yes [ ]
10PProf-35	Band Notch Profiles	62A.3.5	The 10PASS-TS PHY adds the notches specified by the band notch profile to their transmit PSDs when selected.	M	Yes [ ]
10PProf-36	Band Notch Profiles	62A.3.5	When a notch is activated, the transmitter reduces its PSD to less than -80 dBm/Hz in the frequencies of the notch.	M	Yes [ ]
10PProf-37	Band Notch Profiles	62A.3.5	All Band Notches specified in the following standards are supported: -ITU-T Recommendation G.993.1 Annex F, Table F-5 -T1.424, Clause 15 -ETSI TS1 101 270 subclause 9.3.3.6.1	M	Yes [ ]
10PProf-38	Payload rate profiles	62A.3.6	Drate values of 2.5, 5, 7.5, 10, 12.5, 15, 25, 35, 50, 70, and 100 are supported where the loop environment, bandplan and PSD mask allow this.	M	Yes [ ]
10PProf-39	Payload rate profiles	62A.3.6	Urate values of 2.5, 5, 7.5, 10, 12.5, 15, 25, 35, and 50 are supported where the loop environment, bandplan and PSD mask allow this.	M	Yes [ ]
10PProf-40	Payload rate profiles	62A.3.6	If the payload rates of the selected profile cannot be achieved based on the loop environment, bandplan and PSD mask, the PHY drops the link.	M	Yes [ ]
10PProf-41	Default profile	62A.3.8	A 10PASS-TS device that is not managed operates in the default profile and the default mode specified in 62A.3.8 and summarized in Table 62A-5.	M	Yes [ ]
10PProf-42	Register settings	62A.4	For each of the listed tone groups, the Tone Active and/or Tone Direction bits in the 10P MCM tone control parameter register are set according to the use indicated in the first column of Table 62A-6.	M	Yes [ ]
10PProf-43	Register settings	62A.4	For each of the listed tone groups, the Tone Active bit in the 10P MCM tone control parameter register are cleared to activate the corresponding band notch.	M	Yes [ ]
10PProf-44	Register settings	62A.4	When operating under a payload rate profile, the minimum and maximum data rates in the 10P MCM upstream/ downstream data rate configuration registers are set to the same value.	M	Yes [ ]

Annex 62B

(normative)

Performance guidelines for 10PASS-TS PMD profiles

62B.1 Introduction and rationale

Annex 62B defines performance guidelines for 10PASS-TS PMD profiles. The definition of these guidelines is challenging due to the varying nature of the access network. The access network has large variations in cable characteristics from region to region. In addition, the make-up of a cable can encompass multiple cable gauges and/or different configuration of bridged taps. Finally, services may vary from region to region creating different noise scenarios. Typically, deployment guidelines are a function of the telecommunications operator, which is operating a loop and the regional spectrum management policies, which govern deployment on that loop.

Given that one cannot test every possible combination of loop make-up and noise conditions, the performance guidelines are covered from two perspectives. Firstly, 62B.3 lists a suite of artificial tests crafted to test the 10PASS-TS PHYs under representative worst-case noise and loop conditions. Secondly, 62B.4 defines a deployment guideline rule which allows a service provider to determine whether a given loop will support a given profile.

62B.2 Relationship to other clauses

Annex 62A lists a set of PMD profiles for 10PASS-TS. Clause 30 describes how the selection of Annex 62A profiles is exported to a management entity. Clause 45 registers describe an optional mechanism for configuring a 10PASS-TS PHY to use a particular profile. The register settings for each profile are contained in 62A.4.

62B.3 Performance test cases

The performance test cases are derived from the standard definition of test loops in T1.424/Trial-Use, part 1, section 13.2, the noise models are defined in T1.424/Trial-Use, part 1, section 13.3 and the profiles are defined in 62A.3.1. In all cases the PHYs shall attain link in the specified profile in the presence of noise and impairments and maintain link with a Bit Error Ratio less than 10^{-7} with the noise raised by 6dB.

During the test the PHY shall meet the requirements of the bandplan, PSD and Upstream Power Back Off (where appropriate) specified. The control of the profile shall be through the Clause 30 MIB if supported. If the PHY under test includes any implementation options defined in the reference document (but out of scope for this standard) these options shall be disabled in such a manner as to render the behaviour identical to implementations without such options.

If a PHY is capable of operating as both CO-subtype and CPE-subtype then both modes of operation shall be tested. If the PHY is capable of supporting PME aggregation then each PME shall be capable of passing the performance tests independently.

Table 62B-1 lists the performance test cases. The test loops are described in T1.424/Trial-Use, part 1, section 13.2. For tests using test loop "VDSL1" the table specifies which of the two cable types (TP1 or TP2) is used. The length value refers to the dimension "x", "y", "z", "u" or "v" depending on the test loop. If "notch" is specified to be "on" then the RF notches specified in T1.424/Trial-Use, part 1, Annex 1 are applied as described in section 13.3.3. If "UPBO" is specified to be "on" then the Power Back Off specified in 62.3.4.1 is applied. The noise model applied will be noise model "A" or "F" as described in T1.424/Trial-Use, part 1, section 13.3.1.1 (also 13.3.1.4.2). The definition of self crosstalk is in section 13.3.1.4.1.

Table 62B-1—Test cases for 10PASS-TS

Test	Test Loop	L (m)	Profile	Payload Data Rate down/up (Mb/s)	Notch	UPBO	Noise Model[a]
1	TP1	750	13	10/10	—	5	AWGN
2	TP2	750	13	10/10	—	5	ETSI A
3	TP2	300	1	10/10	—	1	T1.424 A
4	TP2	200	16	50/50	—	—	AWGN
5	TP2	100	16	35/25	—	—	self
6	TP1	650	6	25/5	—	—	self
7	TP2	700	17	15/15	—	—	self
8	TP1	1000	8	15/2.5	—	—	self
9	TP2	400	4	12.5/12.5	—	—	self
10	TP2	750	4	7.5/7.5	—	—	self
11	TP2	1000	23	5/5	—	—	self
12	TP2	1200	23	2.5/2.5	—	—	self
13	TP2	150	16	50/50	2, 5, 9, 11	—	AWGN
14	TP2	100	16	35/25	2, 5, 9, 11	—	self
15	TP1	650	6	25/5	2, 6, 10, 11	—	self
16	TP2	600	17	15/15	2, 5, 9, 11	—	self
17	TP1	1000	8	15/2.5	2, 6, 10, 11	—	self
18	TP2	400	4	12.5/12.5	2, 6, 10, 11	—	self
19	TP2	750	4	7.5/7.5	2, 6, 10, 11	—	self
20	TP2	900	23	5/5	2, 5, 9, 11	—	self
21	TP2	1200	23	2.5/2.5	2, 5, 9, 11	—	self
22	TP2	150	30	100/25	—	—	AWGN

[a]"AWGN" means that only white gaussian noise at -140dBm/Hz is present. "Self" means that the equivalent crosstalk generated by 20 10PASS-TS transceivers operating in the same mode (assuming the same loop length and the same UPBO configuration) as the device under test is present in addition to white gaussian noise at -140dBm/Hz. "T1.424 A" means that alien crosstalk according to T1.424 Noise Model A is present in addition to white gaussian noise at –140dBm/Hz. "ETSI A" means that alien crosstalk according to ETSI TS 101 270-1 Noise Model A is present in addition to white gaussian noise. Self crosstalk and alien crosstalk are not to be applied simultaneously.

62B.3.1 Additional tests

Additional testing to prove the requirements for link establishment, UPBO, burst noise immunity, link state and error reporting, etc. may be performed using any test scenarios from Table 62B-1.

62B.4 Deployment guidelines

The relationship between specific cable parameters and performance is complex and cannot be guaranteed. The performance tests described in section 62B.3 are designed to ensure that compliant PHYs will achieve a similar level of performance when applied in similar environments. The tests are designed to represent realistic worst case conditions but real world installations may sometimes experience worse performance for apparently similar conditions.

Annex A of ETSI TS1 101 270-1 (1999) contains some additional information regarding performance expectations related to cable parameters.

62B.5 Protocol implementation conformance statement (PICS) proforma for Annex 62B, Performance guidelines for 10PASS-TS PMD profiles[26]

62B.5.1 Introduction

The supplier of a protocol implementation that is claimed to conform to Annex 62B, Performance guidelines for 10PASS-TS PMD profiles, 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.

62B.5.2 Identification

62B.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., names and versions for machines and/or operating systems; System Name(s)	
Only the first three items are required for all implementations; other information may be completed as appropriate in meeting the requirements for the identification. The terms Name and Version should be interpreted appropriately to correspond with a supplier's terminology (e.g., Type, Series, Model).	

62B.5.2.2 Protocol summary

Identification of protocol standard	IEEE Std 802.3-2005, Performance guidelines for 10PASS-TS PMD profiles.
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 802.3-2005.)	
Date of Statement	

[26]*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.

62B.5.3 Major capabilities/options

Item	Feature	Subclause	Value/Comment	Status	Support
10PPerf	Performance guidelines for 10PASS-TS PMD profiles	Annex 62B	The performance guidelines listed in Annex 62B are supported.	10PASS-TS: M	Yes [ ]

62B.5.4 PICS proforma tables for Performance guidelines for 10PASS-TS PMD profiles

Item	Feature	Subclause	Value/Comment	Status	Support
10PPerf-1	Performance test cases	62B.3	In all cases the PHY attains link in the specified profile in the presence of noise and impairments and maintains link with a Bit Error Ratio less than 10^{-7} with the noise raised by 6dB.	M	Yes [ ]
10PPerf-2	Performance test cases	62B.3	During the test the PHY meets the requirements of the bandplan, PSD and Upstream Power Back Off specified.	M	Yes [ ]
10PPerf-3	Performance test cases	62B.3	The control of the profile is through the Clause 30 MIB if supported.	MDIO: M	Yes [ ] No [ ]
10PPerf-4	Performance test cases	62B.3	If the PHY under test includes any implementation options defined in the reference document these options are disabled in such a manner as to render the behaviour identical to implementations without such options.	M	Yes [ ]
10PPerf-5	Performance test cases	62B.3	If a PHY is capable of operating as both CO-subtype and CPE-subtype then both modes of operation are tested.	M	Yes [ ]
10PPerf-6	Performance test cases	62B.3	If the PHY is capable of supporting PME aggregation then each PME is capable of passing the performance tests independently.	M	Yes [ ]

Annex 62C

(informative)

10PASS-TS Examples

62C.1 Introduction

Annex 62A contains profiles for deployment of 10PASS-TS in typical environments, as well as for testing purposes. Certain situations may require the full use of the 10PASS-TS PHY's flexibility, going beyond what is offered by the predefined profiles, in order to obtain optimal performance. Examples of such circumstances:

a) the 10PASS-TS system shares a cable bundle with a legacy system; the PSD mask can be configured to minimize crosstalk between 10PASS-TS and the legacy system
b) for a specific application, a particular symmetry ratio is required, which is not easily obtained with the standard band plans
c) the desired payload bit rates are beyond the ones that can be set by means of the standard payload rate profiles
d) other unanticipated situations

To use this flexibility, the 10PASS-TS equipment is configured by means of the appropriate Clause 45 registers. This Annex provides examples of such configurations.

62C.2 Bandplan configuration

Example situation: a user wishes to implement a custom bandplan for a 10PASS-TS deployment in a private network, in order to minimize near-end crosstalk to and from a certain legacy system.

Band plans can be configured by selecting any group of tones in the Tone Group register (45.2.1.35), and allocating them to either upstream or downstream by setting the tone direction bit to the appropriate value (0 = downstream, 1 = upstream) in the Tone Control Parameter register (45.2.1.36). This procedure is repeated until the desired number of frequency bands has been allocated. The new configuration is applied by writing binary 1 to the Change Tone Direction bit in the Tone Control Action register (45.2.1.37).

An example of a custom bandplan and PSD is shown in Figure 62C–1 (the solid line represents the upstream PSD, the dashed line represents the downstream PSD). The overall transmission power is assumed to be 14.5 dBm in either direction which is similar to the T1.424/Trial-Use M2 mask and SHDSL transmit power. The example defined here is such that it should meet VDSL compatibility requirements for up to 1524 m (5000 ft).

The example PSD was tested for spectral compatibility with existing VDSL systems using ITU-T Bandplan A (formerly known as plan 998). The spectral compatibility guideline was obtained by assuring that the new service will not disturb the guaranteed data rates for VDSL basis system as shown in Table 62C–1.

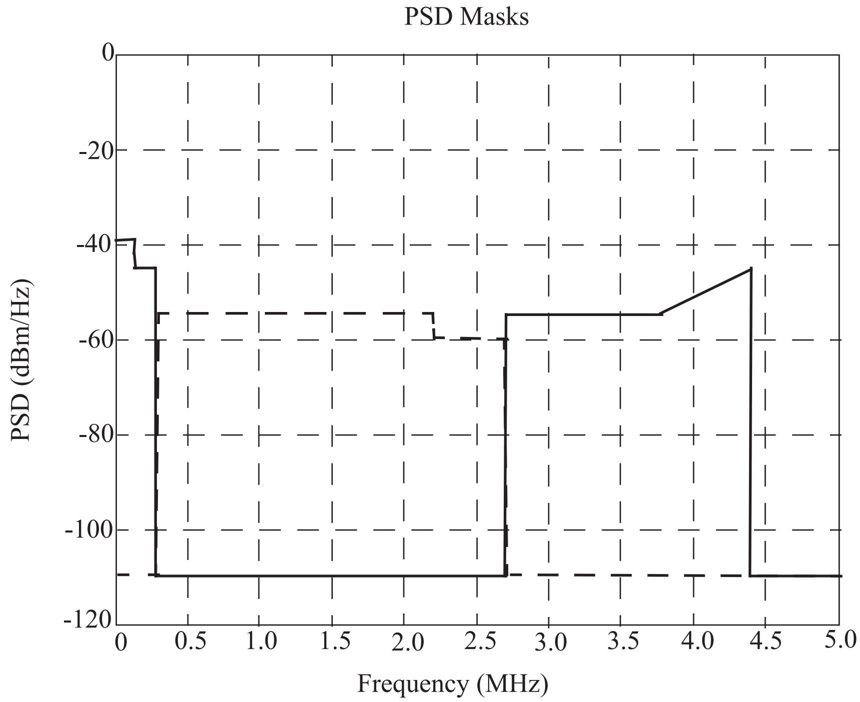


Figure 62C–1—Example PSD Masks for MCM 10PASS-TS

Table 62C–1—Required VDSL performance for spectral compatibility

Performance Level	Loop length (m)[a]	Upstream (Mb/s)	Downstream (Mb/s)
A	152.4	15.66	42.29
B	304.8	14.01	42.29
C	457.2	12.86	38.85
D	609.6	11.97	36.29
E	762.0	9.08	32.5
F	914.4	5.47	26.3
G	1066.8	3.66	22.12
H	1219.2	1.65	18.70
I	1371.6	0.42	15.40
J	1524.0	0.074	11.67

[a]NOTE—The performance requirements are taken from American National Standard T1.417, which specifies loop lengths in 500 ft (152.4 m) increments.

The results of the spectral compatibility analysis are shown in Figures 62C–1 through 62C–4.

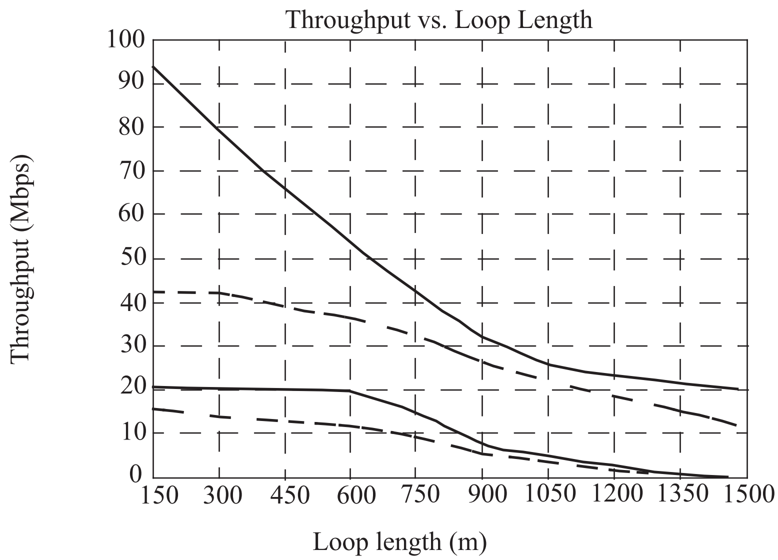


Figure 62C–2—Simulated performance of a VDSL system (using ITU-T Bandplan A) in the presence of 24 disturbers using the example PSD of this subclause.

NOTE—Dashed line = minimum VDSL performance required for spectral compatibility; solid line = simulated VDSL performance in presence of new disturbers.

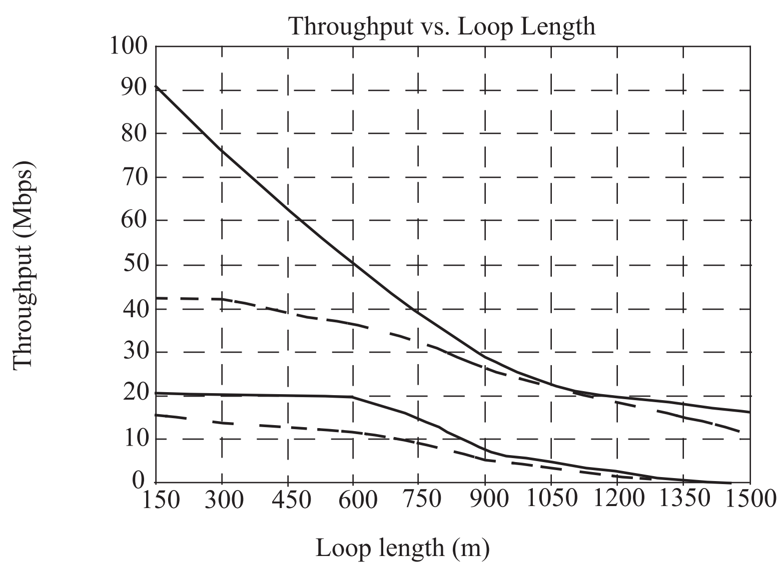


Figure 62C–3—Simulated performance of a VDSL system (using ITU-T Bandplan A) in the presence of 12 disturbers using the example PSD of this subclause and 12 disturbers using T1.417 mask SM9.

NOTE—Dashed line = minimum VDSL performance required for spectral compatibility; solid line = simulated VDSL performance in presence of new disturbers.

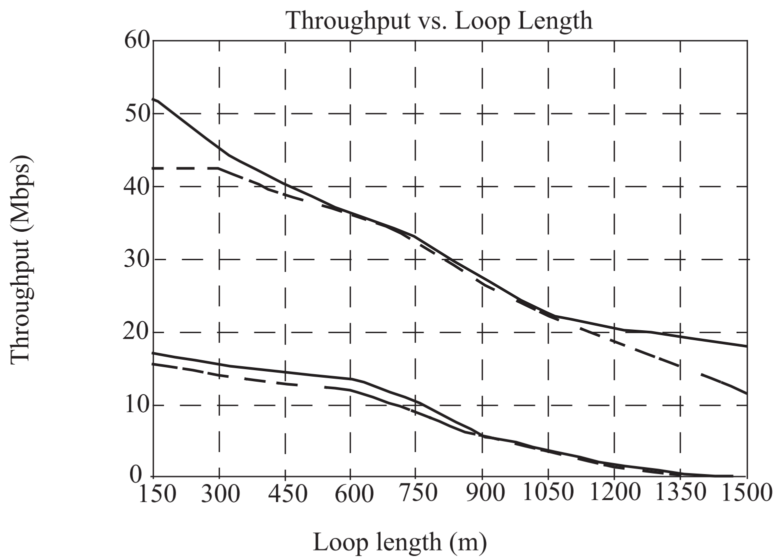


Figure 62C–4—Simulated performance of a VDSL system (using ITU-T Bandplan A) in the presence of 12 disturbers using the example PSD of this subclause and 12 disturbers using T1.417 mask SM6.

NOTE—Dashed line = minimum VDSL performance required for spectral compatibility; solid line = simulated VDSL performance in presence of new disturbers.

62C.2.1 Plan A with variable LF region

As an additional example, this subclause describes a modified version of ITU-T Bandplan A (formerly known as 998) with variable low-frequency region. Its target is to improve the reach of symmetric bitrates using 10PASS-TS or VDSL.

Plan A with variable LF region is shown in Figure 62C–5. The transition frequency between band 0 (used in upstream) and band 1D can be varied between 25 kHz and 490 kHz to boost the upstream channel bitrate. This principle is similar to the variable bandwidth capability of 2BASE-TL and SHDSL. A supporting PSD which observes spectral compatibility requirements is described in 62C.3.2.

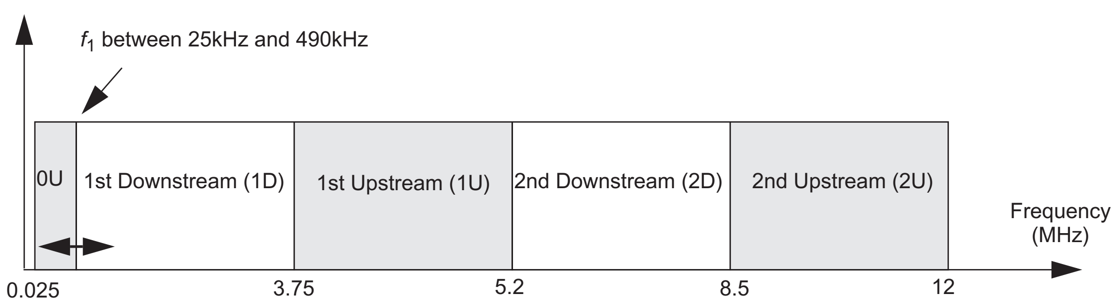


Figure 62C–5—Plan A with variable LF region

This family of bandplans can be implemented by assigning the appropriate tones to upstream and downstream, as shown in Table 62C–2.

Table 62C–2—Implementation of Plan A with variable LF region

Band	Tone Group
0 (upstream)	$6 \rightarrow \lfloor f_1/(4.3125\text{kHz}) \rfloor$
1D (downstream)	$\lceil f_1/(4.3125\text{kHz}) \rceil \rightarrow 869$
1U (upstream)	$870 \rightarrow 1205$
2D (downstream)	$1206 \rightarrow 1970$
2U (upstream)	$1972 \rightarrow 2782$

62C.3 PSD mask configuration

62C.3.1 General procedure

Example situation: a mixed (transitional) deployment where certain subscribers are served with a 10PASS-TS line from a central office (longer lines), while others are served with a 10PASS-TS line from a cabinet (shorter lines). In order to guarantee high link quality for all subscribers, the transmit PSDs from the cabinet are reduced to mimic a longer line (downstream power back-off).

The properties of the different tones are configured by means of the Tone Group register (1.x.15:0; 1.x+1.15:0, defined in 45.2.1.35). The 8-bit PSD Level field in the Tone Control Parameter register (45.2.1.36) is used to set the TX PSD level for the selected group of tones. Given the tone spacing of 4.3125 kHz, a very fine-grained PSD control is possible. To implement a gradual frequency-dependent power back-off, a narrow sliding window is defined in the Tone Group register; each time the window is moved towards higher frequencies, the allowed TX PSD for that frequency range is set. The new configuration is applied by writing binary 1 to the Change PSD Level bit in the Tone Control Action register (45.2.1.37). This approach is illustrated by the algorithm in Equation (62C–1).[27]

```
for (tone=0;tone<4096;tone+=16) {
 ToneGroupRegister[0] = tone;
 ToneGroupRegister[1] = tone+16;
 ToneControlParameterRegister[1] &= 0xFFFC; // clear first 2 bits
 ToneControlParameterRegister[2] &= 0x01FF; // clear last 7 bits
 ToneControlParameterRegister[1] |= TxPSD[tone] >> 7;
 ToneControlParameterRegister[2] |= (TxPSD[tone] << 9) & 0xFE00;
}
*ToneControlActionRegister |= 0x0002; // activate PSD level setting
```

(62C–1)

62C.3.2 PSD Masks for Plan A with variable LF region

As an additional example, this subclause describes PSD masks for Plan A with variable LF region, as introduced in 62C.2.1.

In band 0 (up to f_1 between 25 kHz and 490 kHz), the PSD is limited to –50 dBm/Hz, as is the case for 2.32 Mb/s SHDSL.

The PSD in bands 1D, 1U, 2D and 2U is limited to comply with mask M2 as defined in T1.424.

[27]Variables and pointers are used as described in 62A.4.

Annex 63A

(normative)

PMD Profiles for 2BASE-TL

63A.1 Introduction and rationale

Annex 63A defines the PMD profiles for 2BASE-TL. These profiles define the transmission characteristics of the PHY on the media. 2BASE-TL PHYs are required to operate across varying media quality, regulatory and noise environments. The profiles defined in this clause have two purposes.

The first is to describe a bounded set of operating modes that a party might choose from when implementing, integrating and installing 2BASE-TL equipment. 2BASE-TL PHYs are inherently flexible in their transmission capabilities. The defined profiles collect a subset of these parameters into modes that work well in most deployments. For deployments that require an operating mode not defined in this Annex, profiles can be overridden by setting PHY PMD registers directly, via Clause 45 for example.

The second purpose of the profiles is to define a set of operating modes against which PHY performance compliance may be tested. The topic of performance compliance is addressed for 2BASE-TL in Annex 63B.

63A.2 Relationship to other clauses

Clause 30 describes how the selection of Annex 63A profiles is exported to a management entity.

Clause 45 registers describe an optional mechanism for configuring a 2BASE-TL PHY to use a particular profile. The register settings for each profile are contained in 63A.4.

63A.3 Profile definitions

A 2BASE-TL profile is characterized by 4 parameters: data rate, power, constellation size and region. Different regions have different constraints on the PHY. ITU-T Recommendation G.991.2 distinguishes 3 regions and lists regional requirements in three annexes labeled A, B, C. Reference Annex A generally describes those specifications that are unique to SHDSL systems operating under conditions such as those typically encountered within the North American network; Reference Annex B, within European networks; and Reference Annex C, within networks with existing TCM-ISDN service.

The profiles of Table 63A–1 will generate a net data rate greater than 2 Mb/s at the MII interface on 1 to 4 pairs. Note that the profiles are defined on a single pair basis. The aggregation mechanism is specified in Clause 61. The data rate is the closest multiple of 64 kb/s greater than a net data rate of 2 Mb/s plus the corresponding 64/65-octet encapsulation overhead divided by the number of pairs. The line rate has an additional 8 kb/s of SHDSL overhead.

The default profile shall be profile #7 (Annex B).

Table 63A–1—2BASE-TL profiles

Profile #	Data rate per pair (kb/s)	Line rate per pair (kb/s)	Power (dBm)	Region	Constellation
1	5696	5704	13.5	Annex A sec. A.4.1	32-TCPAM
2	3072	3080	13.5	Annex A sec. A.4.1	32-TCPAM
3	2048	2056	13.5	Annex A sec. A.4.1	16-TCPAM
4	1024	1032	13.5	Annex A sec. A.4.1	16-TCPAM
5	704	712	13.5	Annex A sec. A.4.1	16-TCPAM
6	512	520	13.5	Annex A sec. A.4.1	16-TCPAM
7	5696	5704	14.5	Annex B sec. B.4.1	32-TCPAM
8	3072	3080	14.5	Annex B sec. B.4.1	32-TCPAM
9	2048	2056	14.5	Annex B sec. B.4.1	16-TCPAM
10	1024	1032	13.5	Annex B sec. B.4.1	16-TCPAM
11	704	712	13.5	Annex B sec. B.4.1	16-TCPAM
12	512	520	13.5	Annex B sec. B.4.1	16-TCPAM

63A.4 Register settings

This subclause contains Clause 45 register settings required to comply with the profiles defined in 63A.3. The 2B general parameter register (see 45.2.1.43) selects a region. The 2B PMD parameters register (see 45.2.1.44) selects values for data rate, power and constellation size. The 2B extended PMD parameters registers (see 45.2.1.58) define four additional data range sets to be used in conjunction with the 2B PMD parameters registers when additional PMD configuration detail is desired. Detailed register settings are shown in Table 63A–2.

Table 63A–2—2BASE-TL register settings

Profile #	2B general parameter register	2B PMD parameters register	
		1.81.15:0	1.82.15:0
1	0000_{16}	5959_{16}	0045_{16}
2	0000_{16}	3030_{16}	0045_{16}
3	0000_{16}	2020_{16}	0046_{16}
4	0000_{16}	1010_{16}	0046_{16}
5	0000_{16}	$0B0B_{16}$	0046_{16}
6	0000_{16}	0808_{16}	0046_{16}
7	0001_{16}	5959_{16}	$004D_{16}$
8	0001_{16}	3030_{16}	$004D_{16}$
9	0001_{16}	2020_{16}	$004E_{16}$
10	0001_{16}	1010_{16}	0046_{16}
11	0001_{16}	$0B0B_{16}$	0046_{16}
12	0001_{16}	0808_{16}	0046_{16}

63A.5 Protocol implementation conformance statement (PICS) proforma Annex 63A, PMD Profiles for 2BASE-TL[28]

63A.5.1 Introduction

The supplier of a protocol implementation that is claimed to conform to Annex 63A, PMD Profiles for 2BASE-TL, 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.

63A.5.2 Identification

63A.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., names and versions for machines and/or operating systems; System Name(s)	
Only the first three items are required for all implementations; other information may be completed as appropriate in meeting the requirements for the identification. The terms Name and Version should be interpreted appropriately to correspond with a supplier's terminology (e.g., Type, Series, Model).	

63A.5.2.2 Protocol summary

Identification of protocol standard	IEEE Std 802.3-2005, 2BASE-TL PMD profiles.
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 802.3-2005.)	
Date of Statement	

[28]*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.

63A.5.3 Major capabilities/options

Item	Feature	Subclause	Value/Comment	Status	Support
2BProf	2BASE-TL PMD profiles	Annex 63A	The PMD profiles listed in Annex 63A are supported.	2BASE-TL: M	Yes [ ]

63A.5.4 PICS proforma tables for Performance guidelines for 2BASE-TL PMD profiles

Item	Feature	Subclause	Value/Comment	Status	Support
2BProf-1	Default Profile	63A.3	The default profile shall be profile #7.	M	Yes [ ]
2BProf-2	Register settings	63A.4	The register settings comply with Table 63A–2.	M	Yes [ ]
2BProf-3	Profiles	63A.3	A 2BASE-TL PHY supports all profiles listed in Table 63A–1.	M	Yes [ ]

Annex 63B

(normative)

Performance guidelines for 2BASE-TL PMD profiles

63B.1 Introduction and rationale

Annex 63B defines performance guidelines for 2BASE-TL PMD profiles. The definition of those guidelines is challenging due to the varying nature of the access network. The access network has large variations in cable characteristics from region to region. In addition, the make-up of a cable can encompass multiple cable gauges and/or different configuration of bridged taps. Finally, services may vary from region to region creating different noise scenarios. Typically, deployment guidelines are a function of the telecommunications operator, which is operating a loop and the regional spectrum management policies, which govern deployment on that loop.

Given that one cannot test every possible combination of loop make-up and noise conditions, the performance guidelines are covered from two perspectives. Firstly, 63B.3 lists a suite of artificial tests crafted to test the 2BASE-TL PHYs under representative worst-case noise and loop conditions. Secondly, 63B.4 defines a deployment guideline rule which allows a service provider to determine whether a given loop will support a given profile.

63B.2 Relationship to other clauses

Annex 63A lists a set of PMD profiles for 2BASE-TL.

Clause 30 describes how the selection of Annex 63A profiles is exported to a management entity.

Clause 45 registers describe an optional mechanism for configuring a 2BASE-TL PHY to use a particular profile. The register settings for each profile are contained in 63A.4.

63B.3 Performance test cases.

The profiles associated with the 5696, 3072, 1024, 704 and 512 kb/s (profiles 1, 2, 4, 5 and 6) shall satisfy the tests described in Table 63B-1. The same test methodology defined in G.991.2 Annex A shall be applied. The test cases are numbered 57 to 78 to differentiate them from the existing tests 1 to 56 in Table A-1 of G.991.2. Profile 3 shall successfully pass the corresponding tests described in Table A-1 of G.991.2.

Table 63B-1—Additional tests for the Annex A data rate

Test	Test loop	L (km)	Test unit	Payload data rate (kb/s)	PSD	Interferer Combination	Required Margin (dB)
57	S	2.80	2BASE-TL-O	1024	symmetric	49-HDSL	5 + Δ*
58	BT1-C	2.47	2BASE-TL-O	1024	symmetric	49-SHDSL_768_sym	5 + Δ*
59	BT1-C	2.47	2BASE-TL-O	1024	symmetric	49-HDSL	5 + Δ*
60	S	2.83	2BASE-TL-R	1024	symmetric	49-HDSL	5 + Δ*
61	BT1-R	2.47	2BASE-TL-R	1024	symmetric	49-SHDSL_768_sym	5 + Δ*
62	BT1-R	2.47	2BASE-TL-R	1024	symmetric	49-HDSL	5 + Δ*

Table 63B-1—Additional tests for the Annex A data rate *(continued)*

Test	Test loop	L (km)	Test unit	Payload data rate (kb/s)	PSD	Interferer Combination	Required Margin (dB)
63	S	3.44	2BASE-TL-O	704	symmetric	49-HDSL	5 + Δ*
64	BT1-C	3.17	2BASE-TL-O	704	symmetric	49-SHDSL_768_sym	5 + Δ*
65	BT1-C	3.17	2BASE-TL-O	704	symmetric	49-HDSL	5 + Δ*
66	S	3.44	2BASE-TL-R	704	symmetric	49-HDSL	5 + Δ*
67	BT1-R	3.17	2BASE-TL-R	704	symmetric	49-SHDSL_768_sym	5 + Δ*
68	BT1-R	3.17	2BASE-TL-R	704	symmetric	49-HDSL	5 + Δ*
69	S	4.08	2BASE-TL-O	512	symmetric	49-HDSL	5 + Δ*
70	BT1-C	3.75	2BASE-TL-O	512	symmetric	49-SHDSL_768_sym	5 + Δ*
71	BT1-C	3.75	2BASE-TL-O	512	symmetric	49-HDSL	5 + Δ*
72	S	4.08	2BASE-TL-R	512	symmetric	49-HDSL	5 + Δ*
73	BT1-R	3.75	2BASE-TL-R	512	symmetric	49-SHDSL_768_sym	5 + Δ*
74	BT1-R	3.75	2BASE-TL-R	512	symmetric	49-HDSL	5 + Δ*
75	S	1.37	2BASE-TL-O	3072	symmetric	49-SHDSL_2304 (case 11)	5 + Δ*
76	S	1.37	2BASE-TL-R	3072	symmetric	49-SHDSL_2304 (case 11)	5 + Δ*
77	S	0.85	2BASE-TL-O	5696	symmetric	24-HDSL2+24-T1 (case 4)	5 + Δ*
78	S	0.85	2BASE-TL-R	5696	symmetric	24-HDSL2+24-T1 (case 14)	5 + Δ*

Profiles 7 and 8 shall be tested using tests B-1 to B-4 defined in Table 63B-2. The same test methodology defined in G.991.2 Annex B shall be applied. Profile 9, 10 and 12 shall be tested using the tests defined in Annex B of ITU-T Recommendation G.991.2. The loops defined in Annex B do not scale as well as the loops of Annex A because they are defined in terms of insertion loss at a given frequency (with a granularity of 0.5 dB), rather than a length in meters. The 704 kb/s data rate (profile 11) is expected to successfully pass the test associated with the 768 kb/s data rate. Therefore, for Annex B testing, the 704 kb/s data rate shall be tested using the 768 kb/s test.

Table 63B-2—Additional tests for the Annex B data rate

Test	Test loop	L (km)	Test unit	Payload data rate (kb/s)	PSD	Interferer Combination[a]	Required Margin (dB)
B-1	Loop 2	1.37	2BASE-TL-O	3072	symmetric	C2048sD2	5 + Δ*
B-2	Loop 2	1.37	2BASE-TL-R	3072	symmetric	R1536sB2	5 + Δ*
B-3	Loop 2	0.85	2BASE-TL-O	5696	symmetric	C2304sD2	5 + Δ*
B-4	Loop 2	0.85	2BASE-TL-R	5696	symmetric	R2048sA2	5 + Δ*

[a]The following nomenclature is used to describe Annex B noise shapes: ABBBCDE; where A is the Side (either C or R), BBB, the rate, C the PSD type (either ‘s’ for symmetric or ‘a’ for asymmetric), D the Noise type (A,B,C or D) and E, the loop number (from 1 to 7).

63B.4 Deployment Guidelines

The ITU-T G.991.2 defines an equivalent loop attenuation which can be used to determine whether a cable insertion loss function 1/H(f), can support a given profile associated with a nominal transmit signal power spectral density S(f). The loop attenuation should not be confused with another popular metric called the loop insertion loss at a given frequency. The latter specifies the insertion loss of the loop at a single frequency while the former weights the transmitted signal PSD and insertion loss of the loop over a frequency range corresponding to the transmitted signal bandwidth. The loop attenuation provides a more precise estimate of the loop capability to support a given data rate.

The SHDSL Loop Attenuation shall be defined as follows (section 9.5.5.7.5 of G.991.2):

$$LoopAtten_{SHDSL}(H) = \frac{2}{f_{Baud}} \left(\int_0^{\frac{f_{Baud}}{2}} 10\log\left[\sum_{n=0}^{1} S(f - nf_{Baud})\right] df - \int_0^{\frac{f_{Baud}}{2}} 10\log\left[\sum_{n=0}^{1} S(f - nf_{Baud}) \left|H(f - nf_{Baud})\right|^2\right] df \right) \quad (63B\text{–}1)$$

where f_{Baud} is the symbol rate, $1/H(f)$ is the insertion loss of the loop, and $S(f)$ is the nominal transmit PSD.

Table 63B-3 lists the maximum loop attenuation for a margin of 5 dB assuming the presence of 49 and 12 self-interferers for the profiles defined in Annex 63A. The 49 self-interferer case corresponds to a very conservative deployment reach.

Assuming a data rate of 2048 kb/s, the deployment reach for AWG24 gauge cable corresponds to 2.8 km for the 49-self number and 3.2 km for the 12-self number.

Table 63B-3—Loop attenuation guideline

Profile	Data rate (kb/s)	Maximum SHDSL Loop Attenuation for 49-self-interferers	Maximum SHDSL Loop Attenuation for 12-self-interferers
2 and 7	2048	24.0	27.7
3 and 8	1024	28.6	32.1
4 and 9	704	31.0	34.7
5 and 10	512	33.1	36.7

63B.5 Protocol implementation conformance statement (PICS) proforma for Annex 63B, Performance guidelines for 2BASE-TL PMD profiles[29]

63B.5.1 Introduction

The supplier of a protocol implementation that is claimed to conform to Annex 63B, Performance guidelines for 2BASE-TL PMD profiles, 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.

63B.5.2 Identification

63B.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., names and versions for machines and/or operating systems; System Name(s)	
Only the first three items are required for all implementations; other information may be completed as appropriate in meeting the requirements for the identification. The terms Name and Version should be interpreted appropriately to correspond with a supplier's terminology (e.g., Type, Series, Model).	

63B.5.2.2 Protocol summary

Identification of protocol standard	IEEE Std 802.3-2005, Performance guidelines for 2BASE-TL PMD profiles.
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 802.3-2005.)	
Date of Statement	

[29]*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.

63B.5.3 Major capabilities/options

Item	Feature	Subclause	Value/Comment	Status	Support
2BPerf	Performance guidelines for 2BASE-TL PMD profiles	Annex 63B	The performance guidelines listed in Annex 63B are supported.	2BASE-TL: M	Yes [ ]

63B.5.4 PICS proforma tables for Performance guidelines for 2BASE-TL PMD profiles

Item	Feature	Subclause	Value/Comment	Status	Support
2BPerf-1	Performance	63B.3	A 2BASE-TL PHY successfully passes the performance tests described in 63B.3.	M	Yes [ ]

Annex 67A

(informative)

Environmental characteristics for Ethernet subscriber access networks

67A.1 Introduction

The purpose of EFM and its distinction from traditional Ethernet networks, is that it specifies functionality required for the subscriber access network, i.e., public network access. Network design considerations for "public" access that may differ from traditional Ethernet LANs include the operations, administration and management (OAM) function, and the regulatory requirements, as well as the environmental factors which are addressed in this annex. This annex applies to Clause 56 through Clause 67 with particular relevance for Clause 58, Clause 59, and Clause 60.

The optical link is expected to operate over a reasonable range of environmental conditions related to temperature, humidity, and physical handling (such as shock and vibration). Implementors are expected to indicate in their literature the operating environmental conditions to facilitate selection, installation, and maintenance, and may also give summary information on a product label. The normative specifications of this standard are understood to apply over the range of conditions defined by the implementor.

This informative annex provides information, to both the design engineer and the eventual user of specific product implementations, on the environmental factors to be considered when designing EFM network topologies. It is intended to record the assumptions used in developing the specifications contained in the normative specifications. The following sections give an example of likely deployment of the different physical layer types, followed by a discussion of temperature issues. Informative references may be found in Annex A.

It is believed that the most critical environmental factor on an Ethernet terminal will be temperature and that the most temperature sensitive element in a link is the semiconductor laser. The temperature sensitivity of these components may impact potential deployment scenarios if not considered. The remaining environmental factors (humidity, vibration, etc.) are not considered to be of such major importance and may be handled by conventional design practice. Therefore, the remainder of this annex addresses temperature.

67A.1.1 Terminal deployment scenarios

The terminal equipment of a link may or may not be in a weather-protected environment. 100BASE-LX10 and 1000BASE-LX10 links may be widely deployed with conventional building cabling for general purpose IT applications, as well as in Ethernet subscriber access applications. The other link types in Table 67A–1 are intended for Ethernet subscriber access applications. The table gives an example deployment scenario. Other scenarios are also supported by this standard, and may be deployed in significant numbers.

This example scenario places the customer premises equipment in a non-weather-protected position, e.g. the outside wall of a house, to allow ease of access for installation and maintenance. Where the premises is a large building such as a hotel, apartment block or office, a weather-protected space such as a basement within the building may be accessible enough.

It is expected that the physical format of the equipment at each end of the link will be different; however, this is outside the scope of the standard. The physical layer type (e.g., 2BASE-TL) and the PMD type (e.g., 1000BASE-PX20-U) are classifications of the signal on the line, and do not imply a temperature range or physical format.

Table 67A–1—Informative deployment examples

Head end (nearer the center of the network)	Customer premises (nearer the periphery of the network)
Weather-protected	**Not weather-protected or weather-protected**
100BASE-LX10	100BASE-LX10
100BASE-BX10-D	100BASE-BX10-U
1000BASE-LX10	1000BASE-LX10
1000BASE-BX10-D	1000BASE-BX10-U
1000BASE-PX10-D	1000BASE-PX10-U
1000BASE-PX20-D	1000BASE-PX20-U
10PASS-TS-O	10PASS-TS-R
2BASE-TL-O	2BASE-TL-R

67A.2 Temperature

Large portions of Ethernet subscriber access optical and copper links are expected to operate in environmental conditions consistent with the outside plant. However, it is recognized that the exact requirements for a particular deployment will vary greatly depending on the geographic location, system structure, and governing regulations. It is also recognized that portions of the network may be deployed in more benign and protected environments and that in some geographic location the outside environment may also be considered benign.

There are many factors. The temperatures in coastal regions are not usually extreme. Tropical regions are usually hot or hot and wet. The widest temperature swings are found in dry regions in the interior of large continents, e.g. central North America or central Asia. High altitude may reduce the efficacy of air cooling systems. To an extent, this is offset by the typically cooler air temperature at high altitude. Direct sunshine can add up to 1120 W/m^2 heating - see Table 1 of ETSI EN 300 019-1-3 [B23].

As a reference, Table 67A–2 shows the annual extreme air temperature values for the nine classes of climates from IEC 60721-2-1 [B26].

The climate is the basic determining factor in the component temperature. However, the temperature of the equipment using the component is significantly modified by a number of factors related to the location of the equipment. Some of these are:

- Is the equipment location weather-protected or non-weather-protected
- Is the building temperature controlled
- Are locations without temperature control subject to solar heating

Equipment temperatures for a number of locations from ETSI and Telcordia documents are shown in Table 67A–3.

An additional factor is the internal thermal design of the equipment using the optical component. The component temperature will be higher than the equipment ambient and the increase will be implementation dependant. For equipment with the complexity of EFM systems an internal temperature rise of 15 ºC to 20 ºC may be anticipated.

Table 67A–2—Informative listing of climate types

Type of climate	Low temperature (˚C)	High temperature (˚C)
Extremely cold (except the Central Antarctic)	–65	+32
Cold	–50	+32
Cold temperate	–33	+34
Warm temperate	–20	+35
Warm dry	–20	+40
Mild warm dry	–5	+40
Extremely warm dry	+3	+55
Warm damp	+5	+40
Warm damp, equable	+13	+35

Table 67A–3—Informative listing of equipment temperature ranges

Climate or location	Specified ambient temperature	Reference
Weather-protected		
Telecom control rooms	15 – 30˚C	ETSI Class 3.6
Temperature controlled	5 – 40˚C (–5 – 45˚C with cooling failure)	ETSI Class 3.1
Controlled - long term	5 – 40˚C (–5 – 50˚C short term)	Telcordia GR-63 [B37]
Partly temperature-controlled	–5 – 45˚C	ETSI Class 3.2
Not temperature-controlled	–25 – 55˚C	ETSI Class 3.3
Sheltered locations	–40 – 40˚C	ETSI Class 3.5
Extended/uncontrolled	–40 – 46˚C (-40 to 65˚C inside enclosure)	Telcordia GR-487 [B36], GR-468 [B35]
Sites with heat trap	–40 – 70˚C	ETSI Class 3.4
Non-weather-protected		
Temperate	–33 – 40˚C	ETSI Class 4.1
Extended	–45 – 45˚C	ETSI Class 4.1E
Extremely cold	–65 – 35˚C	ETSI Class 4.2L
Extremely warm dry	–20 – 55˚C	ETSI Class 4.2H

67A.3 Temperature impact on optical components

Components are often commercially available in two grades, 0 to 70˚C and –40 to 85˚C, although optoelectronic components are also available in –20 or –10 to 85˚C grade, depending on format. The GBIC MSA requires an operating temperature range of 0 to 50˚C in moving air. Because of the varied physical format of equipment and components, the reader is advised to refer to specific product literature or multi source agreements for precise information.

The most temperature sensitive sub-component in an Ethernet terminal is expected to be the semiconductor laser, if for a fiber optic link. There are two categories of laser presently commonplace in the physical layers addressed here; Fabry-Perot (FP), a type of multi longitudinal mode (MLM) laser, and distributed feedback (DFB), a type of single longitudinal mode (SLM) laser.

Fabry-Perot lasers may have a temperature coefficient of wavelength around 0.45 nm/K, so the operating wavelength of a particular FP may vary by 55 nm over the range –40 to 85˚C. The operating wavelength windows within this standard are generally 100 nm wide where FPs are anticipated, allowing adequate margin for manufacturing tolerances. To allow for the widest variety of implementation the spectral width is specified as a function of wavelength where appropriate. However, the requirement for low error rates over substantial distances of fiber, as specified by transmitter and dispersion penalty (TDP), forces the implementor of 1000 Mb/s FP laser based implementations to pay careful attention to both wavelength and spectral width to avoid excessive mode partition noise. In practice, the full range of wavelengths in the standard is not actually available for use because at the temperature extremes the required spectral width would be too narrow. It can be seen that the wider the temperature range required, the more precisely the wavelength and spectral width must be contained to achieve a particular reach. This may have an impact on cost. This consideration would be expected to apply to 1000BASE-LX10, 1000BASE-BX10-U and 1000BASE-PX10-U.

Where the dispersion of the link or the wavelength limits are more demanding than can be met cost-effectively with FPs, DFBs may be used. They may have a temperature coefficient of wavelength under 0.1 nm/K and much narrower spectral widths than FPs. Because only a single longitudinal mode is present, a DFB does not suffer from mode partition noise. DFBs are generally more expensive than FPs. A DFB’s lasing wavelength varies at 0.1 nm/K while its gain peak varies at around 0.45 nm/K. At extremes of temperature these two wavelengths are far apart and the laser may perform poorly. For this reason, DFBs for extended temperature range may be more expensive again. This consideration would be expected to apply to 1000BASE-BX10-D, 1000BASE-PX10-D and 1000BASE-PX20.

67A.3.1 Component case temperature recommendations

67A.2 discussed the temperature progression from climate to equipment to component. 67A.3 discussed the impact of temperature, and particularly temperature range, on the design and cost of laser based optical components. In order to balance these two effects, contain costs, and yet cover the widest range of climates to allow access to the greatest markets the following recommendations are made.

Two component case temperature ranges, and by inference a third, are developed. These are defined as follows:

- Warm Extended: Intended for outdoor application in warmer climate locations.
- Cool Extended: Intended for outdoor applications in cooler climate locations.
- Universal Extended: (This is not a separate class, but is defined by simultaneously complying with the Warm and Cool Extended temperature ranges) This is a combination of the requirements for the Warm Extended and Cool Extended Classes and is intended for general outdoor applications in areas with wide seasonal variations or those designs intended for deployment in multiple geographic locations.

The recommended component case temperature ranges for these two classes are shown in Table 67A–4.

Table 67A–4—Component case temperature class recommendations

Class	Low temperature (˚C)	High temperature (˚C)
Warm extended	–5	+85
Cool extended	–40	+60
Universal extended	–40	+85

It will be noted that the recommendations of Table 67A–4 do not address the extremely cold climates of Table 67A–2 or the cold non-weather-protected equipment requirements of Table 67A–3. In these geographic locations it is common practice to avoid non-weather-protected locations for systems of EFM complexity and place the equipment indoors.

These temperature ranges are optional and conformance with these ranges is not required. This allows lower cost components to be had for those applications that require less extreme temperature ranges. This may be done by taking advantage of the reduced wavelength change to ease the central wavelength tolerance and spectral width requirements from the trade-off curves and more particularly, the TDP limit. This allows equipment and component suppliers, at their discretion, to develop systems and components that tolerate less severe environmental conditions that they view as suitable for their market as long as the PMD is consistent with the PICS proforma of the relevant clause. This limitation assures interoperability while allowing the equipment to be developed for specific markets. It is to be noted that the PMD specifications included in the optics Clause 58, Clause 59, and Clause 60 are based on a temperature range of –40 to 85˚C in terms of the wavelength ranges and spectral widths defined.