802.3cg 10SPE TF AdHoc
IEEE 802.3 OAM Overview

Peter Jones, Cisco
June 19 2018

Agenda

- OAM in 802 Architecture
- 802.1AB LLDP
- OAM in 802.3
  - Clause 57
  - Specific OAM
    - EFM
    - EPON
    - 1000BASE-T1
  - General approach
- Summary

OAM IN 802 ARCHITECTURE

OAM in 802 Architecture

- From IEEE 802-2014

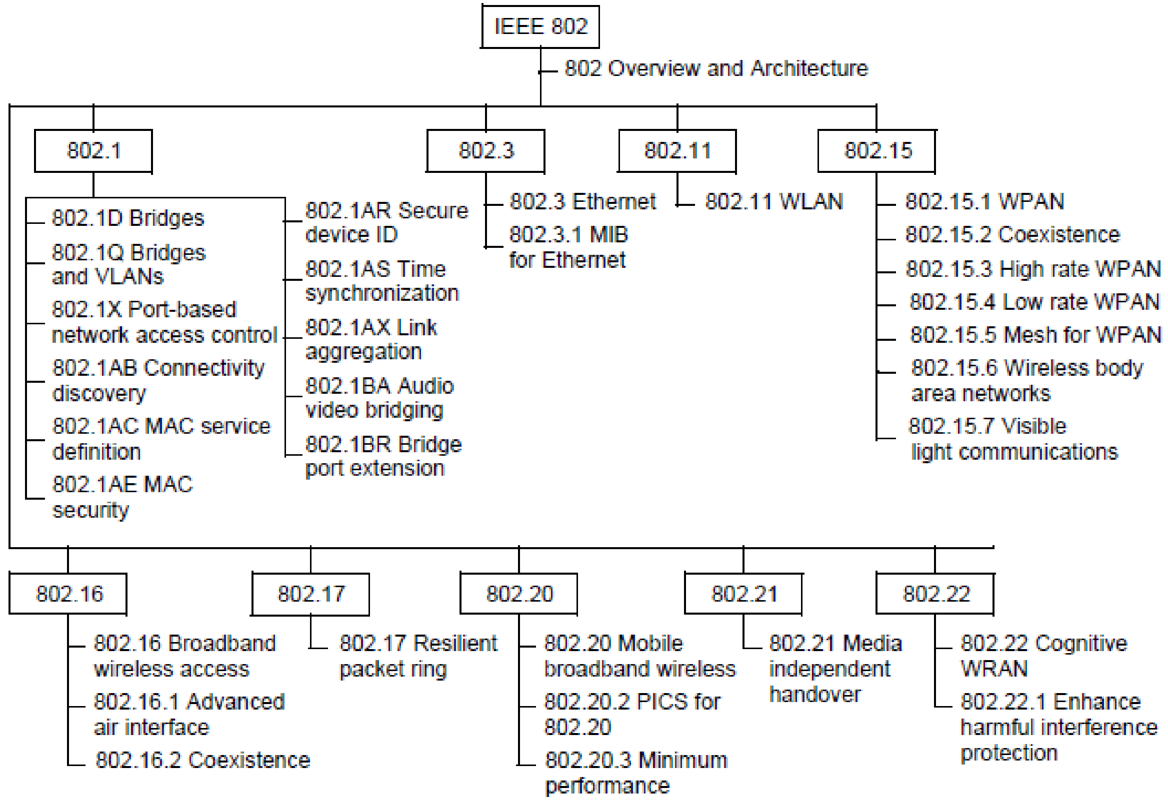


Figure 1—Current family of IEEE 802 standards and recommended practices

OAM in 802 Architecture (cont.)

- From IEEE 802-2014 (cont.)

7.3 Special-purpose IEEE 802 network management standards

Special-purpose protocols relating to the management functionality of IEEE 802 stations can be developed when the use of a general-purpose management protocol is inappropriate. Examples of special-purpose management protocols that can be found in the family of IEEE 802 standards include the Connectivity Fault Management Protocol specified in IEEE Std 802.1Q; the Operations, Administration, and Maintenance (OAM) Protocol specified in IEEE Std 802.3; and the Link Layer Discovery Protocol (LLDP) in IEEE Std 802.1AB™.

Annex B

(informative)

RMs for IEEE 802 standards

B.1 IEEE 802.3 RMs

IEEE Std 802.3 offers multiple options, each of which has a different RM.

The basic RM for IEEE 802.3 stations without optional sublayers is illustrated in Figure B.1.

RS reconciliation sublayer
LSAP link service access point
MSAP MAC service access point
PSAP PHY service access point

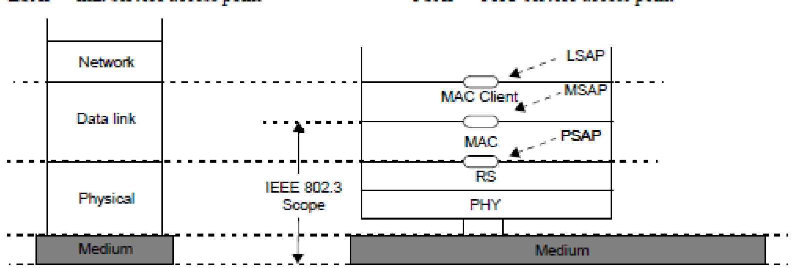


Figure B.1—Basic RM for IEEE 802.3 stations

The RM for IEEE Std 802.3 is illustrated in Figure B.2.

OAM operations, administration and maintenance sublayer
RS reconciliation sublayer
LSAP link service access point
MSAP MAC service access point
OSAP OAM service access point
MCSAP MAC control service access point
PSAP PHY service access point

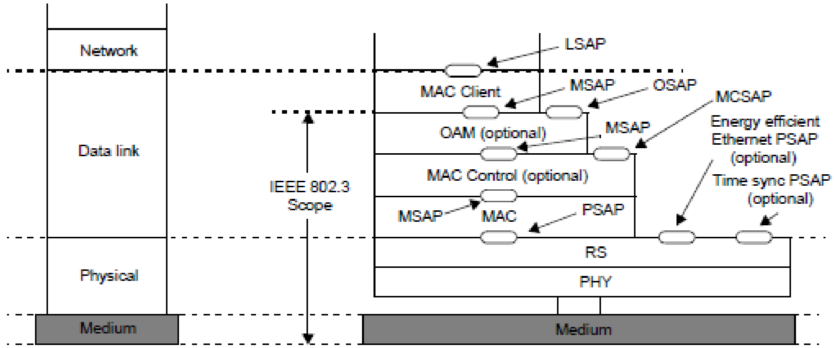


Figure B.2—The RM for IEEE 802.3 point-to-point stations

OAM in 802 Architecture (cont.)

- From IEEE 802-2014 (cont.)

The RM for IEEE 802.3 Ethernet passive optical networks (EPON) optical line terminal (OLT) is illustrated in Figure B.3.

OAM	operations, administration and maintenance sublayer	MSAP	MAC service access point
RS	reconciliation sublayer	OSAP	OAM service access point
LSAP	link service access point	MCSAP	MAC control service access point
		PSAP	PHY service access point

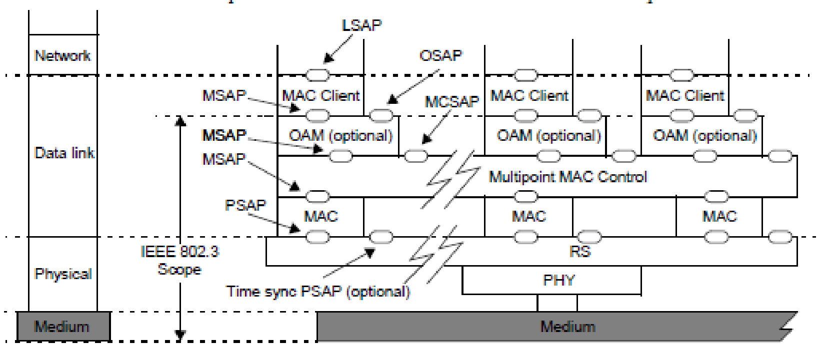


Figure B.3—IEEE 802.3 RM for point-to-multipoint OLT

The RM for IEEE 802.3 EPON optical network unit (ONU) is illustrated in Figure B.4.

OAM	operations, administration and maintenance sublayer	MSAP	MAC service access point
RS	reconciliation sublayer	OSAP	OAM service access point
LSAP	link service access point	MCSAP	MAC control service access point
		PSAP	PHY service access point

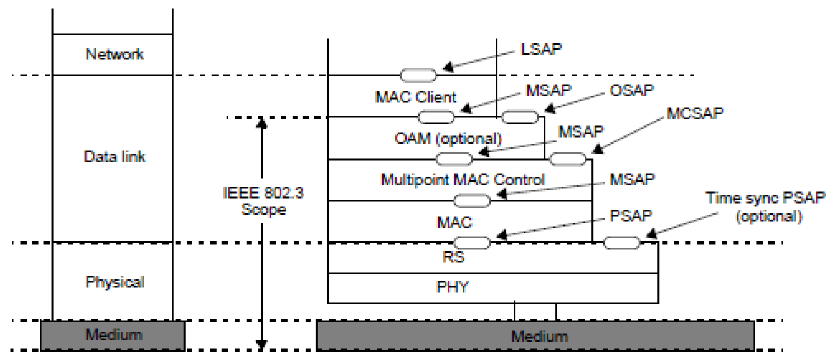


Figure B.4—The RM for IEEE 802.3 point-to-multipoint ONU

IEEE Std 802.3 was amended in 2004 to introduce the concept of subscriber access network.[24] The purpose of Ethernet in the first mile (EFM), as well as 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 OAM function and the regulatory requirements.

802.1AB LLDP

802.1 OAM: 802.1AB LLDP

IEEE Standard for
Local and metropolitan area networks—

Station and Media Access Control Connectivity Discovery

1. Overview

The Link Layer Discovery Protocol (LLDP) specified in this standard allows stations attached to an IEEE 802® LAN to advertise, to other stations attached to the same IEEE 802 LAN, the major capabilities provided by the system incorporating that station, the management address or addresses of the entity or entities that provide management of those capabilities, and the identification of the station's point of attachment to the IEEE 802 LAN required by those management entity or entities.

The information distributed via this protocol is stored by its recipients in a standard Management Information Base (MIB), making it possible for the information to be accessed by a Network Management System (NMS) using a management protocol such as the Simple Network Management Protocol (SNMP).

802.1AB LLDP – 802.1 OAM support (cont.)

1.1 Scope

The scope of this standard is to define a protocol and management elements, suitable for advertising information to stations attached to the same IEEE 802 LAN, for the purpose of populating physical topology and device discovery management information databases. The protocol facilitates the identification of stations connected by IEEE 802 LANs/MANs, their points of interconnection, and access points for management protocols.

This standard defines a protocol that

a) Advertises connectivity and management information about the local station to adjacent stations on the same IEEE 802 LAN.
b) Receives network management information from adjacent stations on the same IEEE 802 LAN.
c) Operates with all IEEE 802 access protocols and network media.
d) Establishes a network management information schema and object definitions that are suitable for storing connection information about adjacent stations.
e) Provides compatibility with the IETF PTOPO MIB (IETF RFC 2922 [B9]).[1]

1.2 Purpose

An IETF MIB (IETF RFC 2922 [B9]) and a number of vendor specific MIBs have been created to describe a network's physical topology and associated systems within that topology.

This standard specifies the necessary protocol and management elements to

a) Facilitate multi-vendor inter-operability and the use of standard management tools to discover and make available physical topology information for network management.
b) Make it possible for network management to discover certain configuration inconsistencies or malfunctions that can result in impaired communication at higher layers.
c) Provide information to assist network management in making resource changes and/or re-configurations that correct configuration inconsistencies or malfunctions identified in b) above.

802.1AB LLDP – 802.1 OAM support (cont.)

6. Principles of operation

LLDP is a link layer protocol that allows an IEEE 802 LAN station to advertise the capabilities and current status of the system associated with an MSAP. The MSAP provides the MAC service to an LLC Entity, and that LLC Entity provides an LSAP to an LLDP agent that transmits and receives information to and from the LLDP agents of other stations attached to the same LAN. The information distributed and received in each LLDPDU is stored in one or more Management Information Bases (MIBs). Figure 6-1 illustrates the LLDP agent and its relationship to its LLC Entity and MSAP, and to additional MIBs designed by the IETF, IEEE 802, and others.

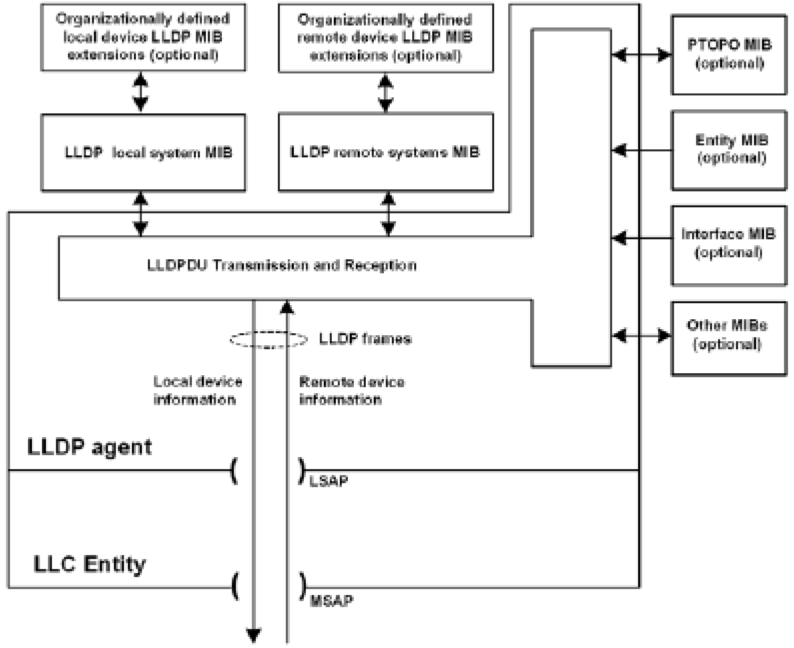


Figure 6-1—LLDP agent and its relationship to its LLC entity

802.1AB LLDP – 802.1 OAM support (cont.)

7. LLDPDU transmission, reception, and addressing

This standard is intended to be compatible with all IEEE 802 MACs.

LLDP uses the service provided by the LLDP/LSAP and LLC to transmit and receive LLDPDUs. Each LLDPDU is transmitted as a single MAC service request by an LLC entity that uses a single instance of the MAC Service provided at an MSAP. Each incoming LLDP frame is received at the MSAP by the LLC entity as a MAC service indication.

NOTE—For the purposes of this standard, the terms “LLC” and “LLC entity” include the service provided by the operation of entities that support protocol discrimination using an EtherType, i.e., Ethertype Protocol Discrimination (EPD) as specified in IEEE Std 802.

The parameters of each service request and service indication comprise

a) Destination address
b) Source address
c) EtherType
d) LLDPDU

The LLDP EtherType, used to identify the LLDP protocol, is prepended to the LLDPDU as shown in Figure 7-1 to form the MSDU of the corresponding MAC service request.

Figure 7-1—MSDU format

The values of the parameters used by LLDP, and their encoding by the LLC entity that supports the LLDP LSAP, are specified in the following subclauses.

802.1AB LLDP – 802.1 OAM support (cont.)

8. LLDPDU and TLV formats

8.1 LLDPDU bit and octet ordering conventions

All LLDPDUs shall contain an integral number of octets. The octets in an LLDPDU are numbered starting from 1 and increasing in the order they are put into the LLDPDU. The bits in an octet are numbered from 1 to 8, where bit 1 is the low-order bit.

8.2 LLDPDU format

The LLDPDU shall contain the following ordered sequence of three mandatory TLVs followed by zero or more optional TLVs as shown in Figure 8-1. An End of LLDPDU TLV may be present as the last TLV in the LLDPDU.

a) Three mandatory TLVs shall be included at the beginning of each LLDPDU and shall be in the order shown.
   1) Chassis ID TLV
   2) Port ID TLV
   3) Time To Live TLV

b) Optional TLVs as selected by network management (may be inserted in any order).

NOTE 1—"Optional" in the sense that they are not required for LLDP operation; however, their presence could be required by other system elements that use LLDP.

c) If the End Of LLDPDU TLV is present, it shall be the last TLV in the LLDPDU.

Octets: 1 … N

Chassis ID TLV	Port ID TLV	Time To Live TLV	Optional TLV	...	Optional TLV	End Of LLDPDU TLV
M	M	M				

M - mandatory TLV - required for all LLDPDUs

Figure 8-1—LLDPDU format

802.3 CLAUSE 57

OAM in 802.3: Clause 57

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.

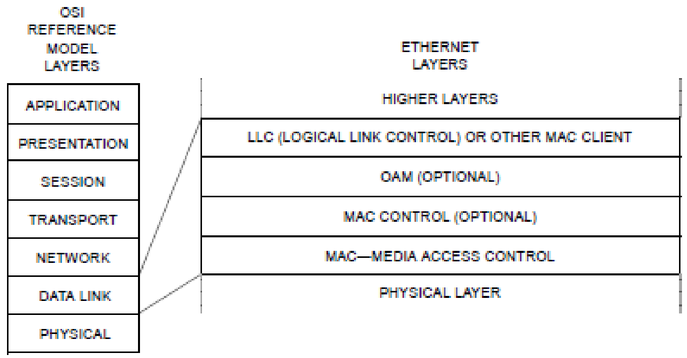


Figure 57–1—OAM sublayer relationship to the ISO/IEC Open Systems Interconnection (OSI) reference model and the IEEE 802.3 Ethernet model

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.

OAM in 802.3: Clause 57

IEEE Std 802.3-2015
IEEE Standard for Ethernet
SECTION FIVE

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 57A) 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 [B51].

OAM in 802.3: Annex 57A

Annex 57A

(normative)

Requirements for support of Slow Protocols

57A.1 Introduction and rationale

There are two distinct classes of protocols used to control various aspects of the operation of IEEE 802.3 devices. They are as follows:

a) Protocols such as the MAC Control PAUSE operation (Annex 31B) that need to process and respond to PDUs rapidly in order to avoid performance degradation. These are likely to be implemented as embedded hardware functions, making it relatively unlikely that existing equipment could be easily upgraded to support additional such protocols.

NOTE—This consideration was one of the contributing factors in the decision to use a separate group MAC address to support LACP and the Marker protocol, rather than re-using the group MAC address currently used for PAUSE frames.

b) Protocols such as LACP, with less stringent frequency and latency requirements. These may be implemented in software, with a reasonable expectation that existing equipment be upgradeable to support additional such protocols, depending upon the approach taken in the original implementation.

In order to place some realistic bounds upon the demands that might be placed upon such a protocol implementation, this annex defines the characteristics of this class of protocols and identifies some of the behaviors that an extensible implementation needs to exhibit.

57A.2 Slow Protocol transmission characteristics

Protocols that make use of the addressing and protocol identification mechanisms identified in this annex are subject to the following constraints:

a) The number of frames transmitted in any one-second period per Slow Protocol subtype shall not exceed aSlowProtocolFrameLimit (see 30.3.1.1.38).
b) The maximum number of Slow Protocols subtypes is 10.
c) The MAC Client data generated by any of these protocols shall be no larger than maxBasicDataSize (see 4.2.7.1). It is recommended that the maximum length for a Slow Protocol frame be limited to 128 octets.

The effect of these restrictions is to restrict the bandwidth consumed and performance demanded by this set of protocols; by default the maximum traffic loading that would result is 100 maximum length frames per second per point-to-point link and 100 maximum length frames per ONU for point-to-multipoint topologies.

OAM in 802.3: Annex 57A

57A.4 Protocol identification

All Slow Protocols use type interpretation of the Length/Type field, and use the Slow_Protocols_Type value as the primary means of protocol identification; its value is shown in Table 57A–2.

Table 57A–2—Slow_Protocols_Type value

Name	Value
Slow_Protocols_Type	88-09

The first octet of the MAC Client data following the Length/Type field is a protocol subtype identifier that distinguishes between different Slow Protocols. Table 57A–3 identifies the semantics of this subtype.

Table 57A–3—Slow Protocols subtypes

Protocol Subtype value	Protocol name
0	Unused—Illegal value
1	Link Aggregation Control Protocol (LACP)
2	Link Aggregation—Marker Protocol
3	Operations, Administration, and Maintenance (OAM)
4	Reserved for future use
5	Reserved for future use
6	Reserved for future use
7	Reserved for future use
8	Reserved for future use
9	Reserved for future use
10	Organization Specific Slow Protcol (OSSP)
11–255	Unused—Illegal values

802.3 CLAUSE SPECIFIC OAM

OAM in 802.3: CLAUSE Specific OAM

- A number of 802.3 projects have included dedicated OAM features. These include:
  - EFM - 10PASS-TS & 2BASE-TL
  - EPON - Various
  - 1000BASE-T1

802.3 10PASS-TS & 2BASE-TL

OAM in 802.3: 10PASS-TS & 2BASE-TL

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.

61.1.4.1.4 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).

OAM in 802.3: 10PASS-TS & 2BASE-TL (cont.)

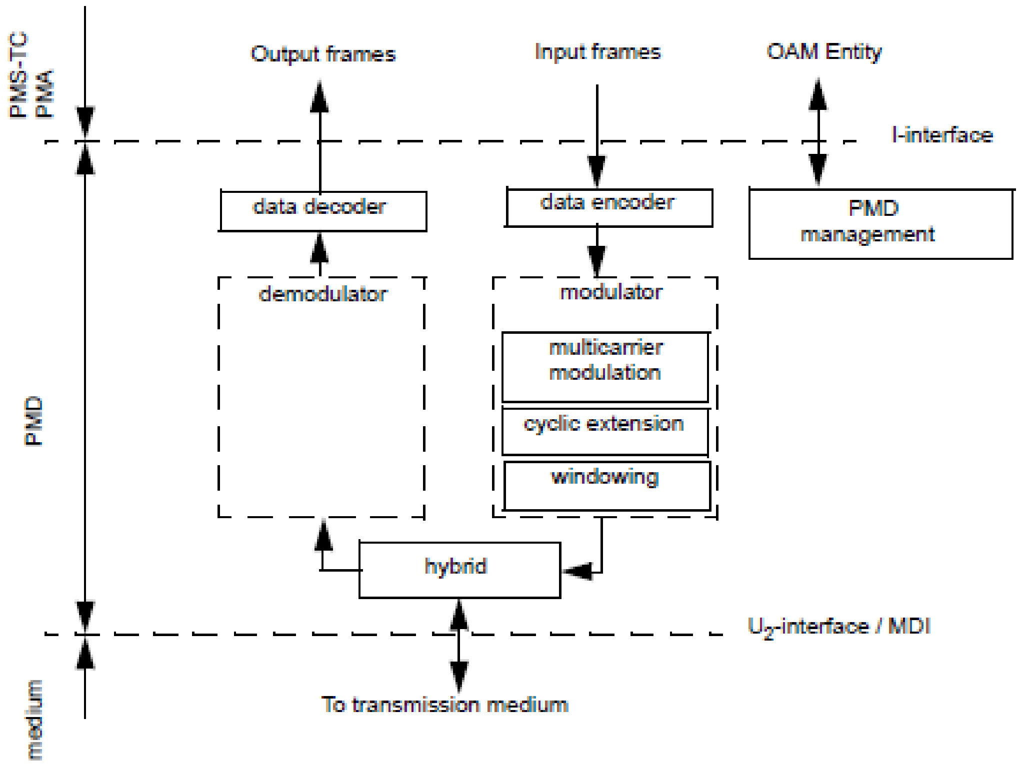


Figure 62–2—Functional diagram of PMD sublayer

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.

OAM in 802.3: 10PASS-TS & 2BASE-TL (cont.)

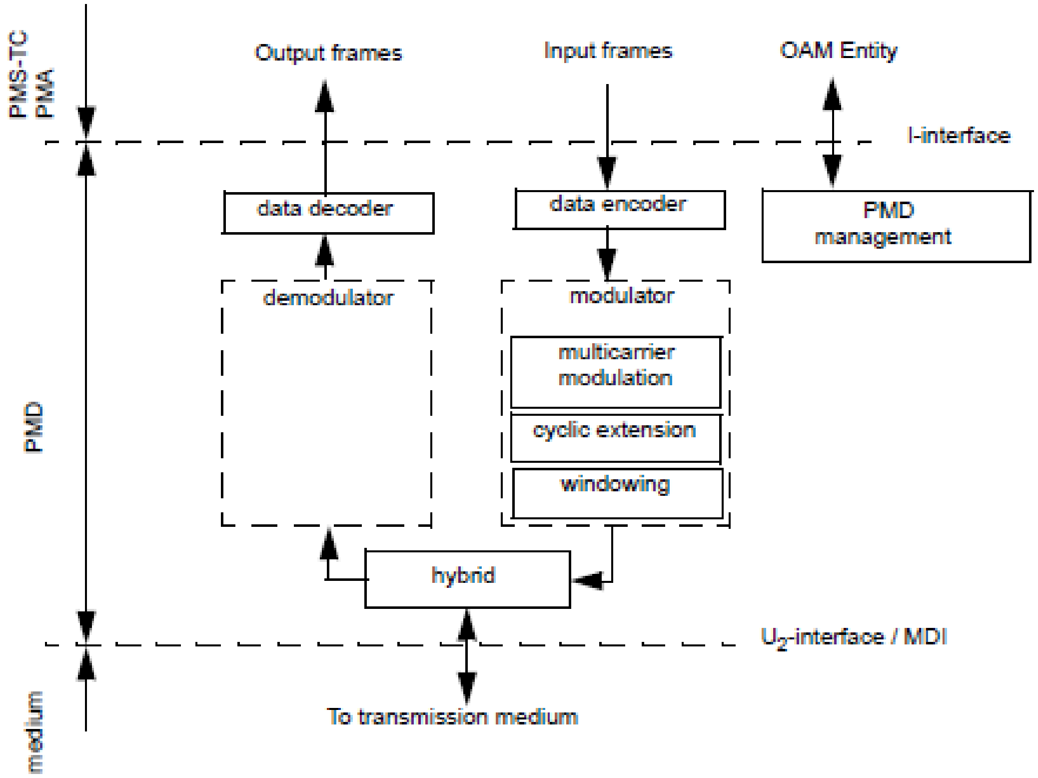


Figure 62–2—Functional diagram of PMD sublayer

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.

OAM in 802.3: 10PASS-TS & 2BASE-TL (cont.)

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.

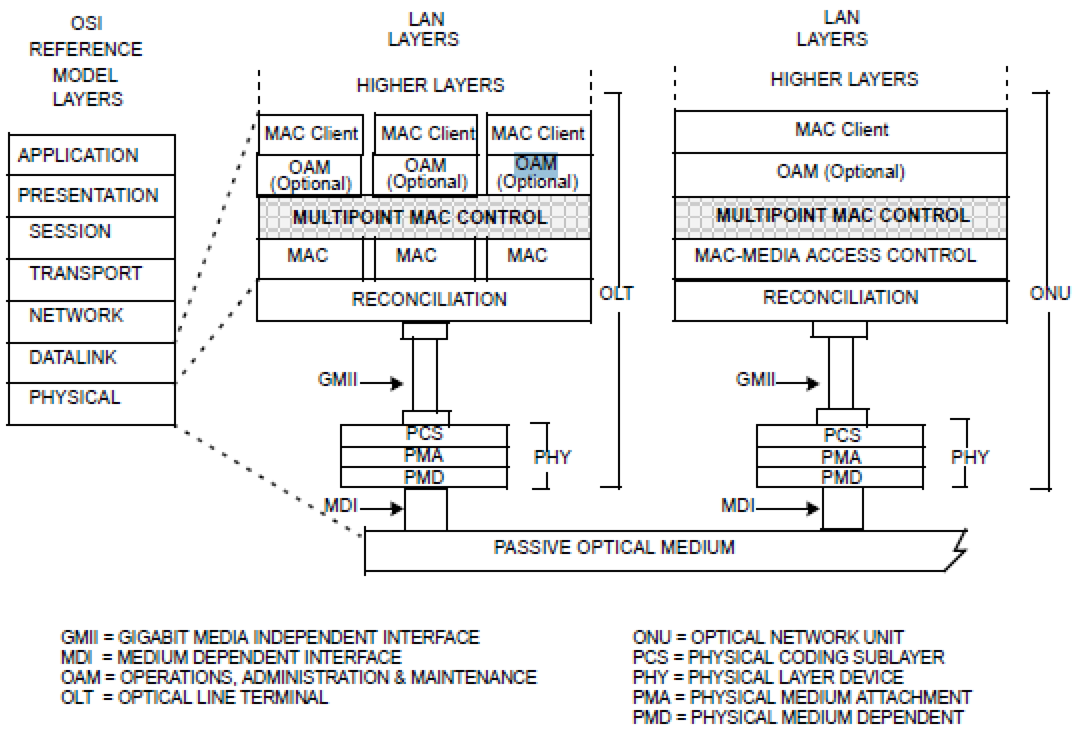


Figure 64–2—Relationship of Multipoint MAC Control and the OSI protocol stack

802.3 UNIDIRECTIONAL & SUBSCRIBER ACCESS

OAM in 802.3: Unidirectional

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.

OAM in 802.3: Subscriber Access

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.

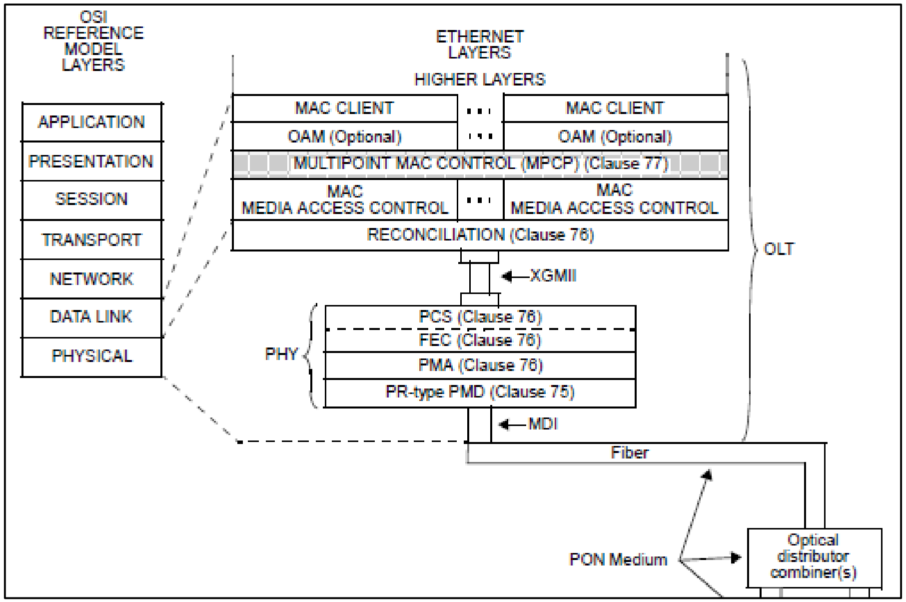
The design of multiple-domain networks is governed by the rules defining each of the transmission systems incorporated into the design. The physical size of a network is limited by the characteristics of individual network components. These characteristics include the media lengths and type.

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).

802.1 EPON

OAM in 802.3: EPON



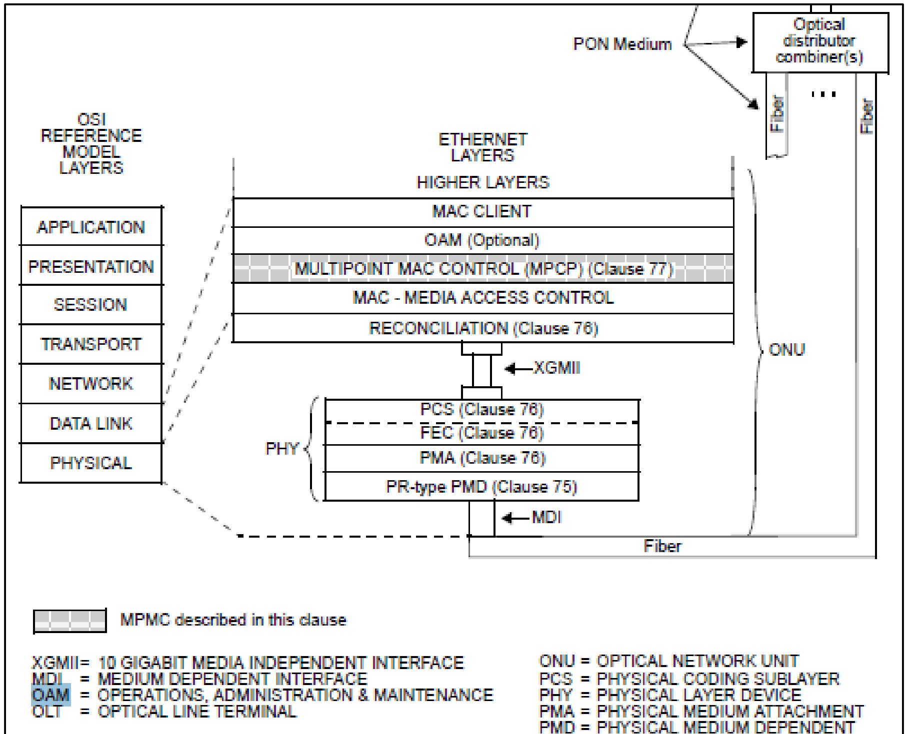


Figure 77–2—Relationship of Multipoint MAC Control and the OSI protocol stack for 10/10G–EPON (10 Gb/s downstream and 10 Gb/s upstream)

802.3 1000BASE-T1

OAM in 802.3:1000BASE-T1

97. Physical Coding Sublayer (PCS), Physical Medium Attachment (PMA) sublayer, and baseband medium, type 1000BASE-T1

97.1 Overview

This clause defines the type 1000BASE-T1 Physical Coding Sublayer (PCS) and type 1000BASE-T1 Physical Medium Attachment (PMA) sublayer. Together, the PCS and PMA sublayers comprise a 1000BASE-T1 Physical Layer (PHY). Provided in this clause are fully functional and electrical specifications for the type 1000BASE-T1 PCS and PMA.

The 1000BASE-T1 PHY is one of the Gigabit Ethernet family of high-speed full-duplex PHY specifications, capable of operating at 1000 Mb/s. The 1000BASE-T1 PHY is intended to be operated over a single twisted-pair copper cable, referred to as an *automotive link segment* (Type A) or *optional link segment* (Type B), defined in 97.6. The automotive link segment specifications defined in 97.6 may also be used for other applications that have similar link segment requirements. The cabling supporting the operation of the 1000BASE-T1 PHY is defined in terms of performance requirements between the attachment points [Medium Dependent Interface (MDI)], allowing implementers to provide their own cabling to operate the 1000BASE-T1 PHY as long as the normative requirements included in this clause are met.

This clause also specifies an optional Energy-Efficient Ethernet (EEE) capability. A 1000BASE-T1 that supports this capability may enter a Low Power Idle (LPI) mode of operation during periods of low link utilization as described in Clause 78.

The 1000BASE-T1 PHY may optionally support the 1000BASE-T1 PCS-based Operations, Administration, and Maintenance (OAM). The 1000BASE-T1 OAM is useful for monitoring link operation by exchanging PHY link health status and messages. The 1000BASE-T1 OAM information is exchanged between two 1000BASE-T1 PHYs out-of-band. The 1000BASE-T1 OAM is specified in 97.3.8, and the 1000BASE-T1 PHY advertises its 1000BASE-T1 OAM capability as described in 97.4.2.4.5.

OAM in 802.3:1000BASE-T1

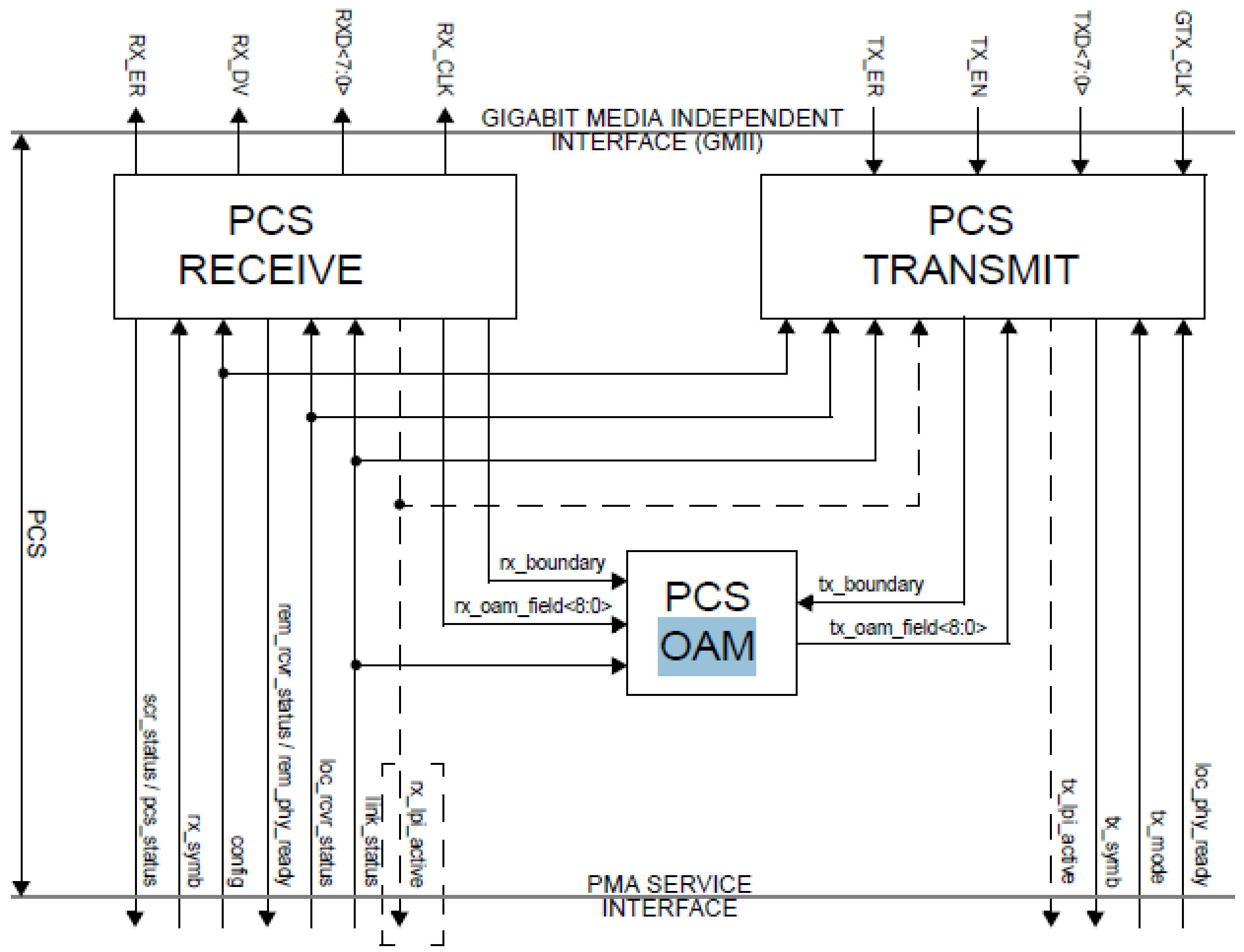


Figure 97–4—PCS reference diagram

OAM in 802.3:1000BASE-T1

97.3.8 1000BASE-T1 Operations, Administration, and Maintenance (OAM)

The 1000BASE-T1 PCS level Operations, Administration, and Maintenance (OAM) provides an optional mechanism useful for monitoring link operation such as exchanging PHY link health status and message exchange. The 1000BASE-T1 OAM information is exchanged in-band between two PHYs using excess bandwidth available on the link. The 1000BASE-T1 OAM is strictly between two 1000BASE-T1 PHYs on the physical layer and their associated management entities if present. Passing 1000BASE-T1 OAM information to other layers is outside the scope of this standard.

1000BASE-T1 OAM is operational as long as both PHYs implement this mechanism and link is up. It continues to be operational during low power idle albeit the information is transferred at a slower rate during the refresh cycle.

The 1000BASE-T1 OAM frame data is carried in the OAM9 field described in 97.3.2.2.4 for the normal power data mode and 97.3.5.3 for low power mode. This 9-bit field is used to exchange 1000BASE-T1 OAM frames. The implementation of 1000BASE-T1 OAM frame exchange function is optional. However, if 1000BASE-T1 EEE is implemented, then the 1000BASE-T1 OAM frame exchange function is implemented to exchange, at a minimum, the link partner health status.

For the remainder of this subclause, the term 1000BASE-T1 OAM is specific to the 1000BASE-T1 PCS level OAM.

WRAP-UP

General approach?

Use 802/802.1 facilities!

Summary

- **In general, 802.3 uses 802.1AB**
- **802.3 defines OAM for a subset of PHYs**

Does 802.3cg fit within this subset?

Thank You!

IEEE STANDARDS ASSOCIATION

Consensus

WE BUILD IT.

Connect with us on:

Facebook: https://www.facebook.com/ieeesa

Twitter: @ieeesa

LinkedIn: http://www.linkedin.com/groups/IEEESA-Official-IEEE-Standards-Association-1791118

IEEE-SA Standards Insight blog: http://standardsinsight.com

YouTube: IEEE-SA Channel

IEEE
standards.ieee.org
Phone: +1 732 981 0060 Fax: +1 732 562 1571