91. Physical Medium Dependent (PMD) sublayer and medium, type 10GBASE-PR (symmetric 10 Gbps long wavelength passive optical networks) and 10/1GBASE-PRX (asymmetric 10 Gbps downstream, 1 Gbps upstream long wavelength passive optical networks)

91.1 Overview

This clause describes Physical Medium dependent (PMD) sublayer for Ethernet Passive Optical Networks operating at 10.3125 Gbps line rate in either only one or both directions.

91.1.1. 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 10 Gb/s baseband network, see Clause 44.
- Introduction to Ethernet for subscriber access networks, see Clause 56.

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

91.1.2. Goals and objectives

The following are the PMD objectives fulfilled by this clause:

a) Support subscriber access networks using point to multipoint topologies on optical fiber.
b) Provide physical layer specifications:
    1) PHY for PON, 10 Gbps downstream/1 Gbps upstream, single single-mode fiber
    2) PHY for PON, 10 Gbps downstream/10 Gbps upstream, single single-mode fiber
c) PHY(s) to have a BER better than or equal to 10^{-12} at the PHY service interface.
d) Define up to 3 optical power budgets that support split ratios of 1:16 and 1:32, and distances of at least 10 and at least 20 km.

91.1.3. Power Budget Classes

To support the above-stated objectives, this clause defines three power budget classes:

- *Low power budget class* supports P2MP media with split ratio of 1:16 and distance of at least 10 km (channel insertion loss ≤ 20 dB);
- *Medium power budget class* supports P2MP media with split ratio of 1:16 and distance of at least 20 km or split ratio of 1:32 and distance of at least 20 km (channel insertion loss ≤ 24 dB);
- *High power budget class* supports P2MP media with split ratio of 1:32 and distance of at least 20 km (channel insertion loss ≤ 29 dB)

Each power budget class is represented by PRX-type power budget and PR-type power budget.

- PRX-type power budget describes PHY for PON operating at 10 Gbps downstream and 1 Gbps upstream over single single-mode fiber (see objective b.1 above). PRX-type power budgets are also called *asymmetric*.
- PR-type power budget describes PHY for PON operating at 10 Gbps downstream and 10 Gbps upstream over single single-mode fiber (see objective b.2 above). PR-type power budgets are also called *symmetric*.

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

- PRX10 – asymmetric low power budget, compatible with PX10 power budget defined in Clause 60;
- PRX20 – asymmetric, medium power budget, compatible with PX20 power budget defined in Clause 60;
- PRX30 – asymmetric, high power budget;
- PR10 – symmetric low power budget, compatible with PX10 power budget defined in Clause 60;
- PR20 – symmetric, medium power budget, compatible with PX10 power budget defined in Clause 60;
- PR30 – symmetric, high power budget;

Table 91-1 shows primary attributes of all power budget types defined in this clause.

Table 91-1: Power budget classes defined in this clause (Layout option 1)

Description	Low Power Budget		Medium Power Budget		High Power Budget		Units
	PRX10	**PR10**	**PRX20**	**PR20**	**PRX30**	**PR30**	
Fiber Type	B1.1, B1.3 SMF						
Number of Fibers	1						
Nominal downstream line rate	10.3125						Gbps
Nominal upstream line rate	1.25	10.3125	1.25	10.3125	1.25	10.3125	Gbps
Nominal downstream wavelength	1590				1577		nm
Nominal upstream wavelength							nm
Minimum range	10		20		20		km
Maximum channel insertion loss	20		24		29		dB
Minimum channel insertion loss	5		10		15		dB

91.1.4. Positioning of PMD sublayer within the IEEE 802.3 architecture

Figure 91-1 depicts the relationships of the PMD sublayer (shown hashed) with other sublayers and the ISO/IEC Open System Interconnection (OSI) reference model.

<modified Figure 91-1 here>

91.2 PMD Types

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

The asymmetry of the P2MP topology results in the EPON PMDs being inherently asymmetric. For example, the OLT PMD operates in continuous mode in the transmit direction (downstream), but uses burst mode in the receive direction (upstream). The ONU PMD, on the contrary, receives data in a continuous mode, but transmits in burst mode. To differentiate OLT PMDs from ONU PMDs, the OLT PMD name has a suffix "D" appended to it, where D stands for *d*ownstream-facing PMD, e.g., 10G-BASE-PR-D1. ONU PMDs receive suffix "U" for *u*pstream-facing PMD, e.g., 10GBASE-PR-U1.

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

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

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

1) 10/1GBASE-PRX-D1– transmits at 10.3125 Gbps continuous mode, receives at 1.25 Gbps burst mode
2) 10/1GBASE-PRX-D2 – transmits at 10.3125 Gbps continuous mode, receives at 1.25 Gbps burst mode
3) 10/1GBASE-PRX-D3 – transmits at 10.3125 Gbps continuous mode, receives at 1.25 Gbps burst mode
4) 10GBASE-PR-D1 – transmits at 10.3125 Gbps continuous mode, receives at 10.3125 Gbps burst mode
5) 10GBASE-PR-D2 – transmits at 10.3125 Gbps continuous mode, receives at 10.3125 Gbps burst mode
6) 10GBASE-PR-D3 – transmits at 10.3125 Gbps continuous mode, receives at 10.3125 Gbps burst mode

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

7) 10/1GBASE-PRX-U1 – transmits at 1.25 Gbps burst mode, receives at 10.3125 Gbps continuous mode
8) 10/1GBASE-PRX-U2 – transmits at 1.25 Gbps burst mode, receives at 10.3125 Gbps continuous mode
9) 10/1GBASE-PRX-U3 – transmits at 1.25 Gbps burst mode, receives at 10.3125 Gbps continuous mode
10) 10GBASE-PR-U1 – transmits at 10.3125 Gbps burst mode, receives at 10.3125 Gbps continuous mode
11) 10GBASE-PR-U3 – transmits at 10.3125 Gbps burst mode, receives at 10.3125 Gbps continuous mode

A specific power budget is achieved by combining an OLT PMD (D-type) with an ONU PMD (U-type) as shown in Section 91.2.1.1 below. Detailed PMD receive and transmit characteristics for D-type PMDs are given in Section 91.4 and characteristics for U-type PMDs are presented in section 91.5. Every PMD has non-overlapping transmit and receive wavelength bands and operates over a single, single-mode fiber.

91.2.1. Mapping of PMDs to Power Budgets

The end-to-end power budget is determined by the PMDs located at each end of the physical media. This section describes how PMDs may be combined to achieve the power budgets listed in Table 91-1.

91.2.1.1 Asymmetric, 10 Gbps downstream and 1 Gbps upstream power budgets (PRX type)

The asymmetric power budgets are created by combining asymmetric ONU PMDs (10/1GBASE–PRX–U1, 10/1GBASE–PRX–U2, or 10/1GBASE–PRX–U3) with asymmetric OLT PMDs (10/1GBASE–PRX–D1, 10/1GBASE–PRX–D2, or 10/1GBASE–PRX–D3) as presented in Table 91-3.

Table 91–3— PMD – power budget mapping for asymmetric PRX-type devices

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

91.2.1.2 Symmetric, 10 Gbps power budgets (PR type)

The symmetric power budgets are created by combining symmetric ONU PMDs (10GBASE–PR–U1 or 10GBASE–PR–U3) with symmetric OLT PMDs(10GBASE–PR–D1, 10GBASE–PR–D2, or 10GBASE–PR–D3) as presented in Table 91-2.

Table 91–2— PMD – power budget mapping for symmetric PR-type devices

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

91.3 PMD functional specifications

91.3.1. PMD service interface

91.3.1.1 Delay constraints

91.3.1.2 PMD_UNITDATA.request

91.3.1.3 PMD_UNITDATA.indication

91.3.1.4 PMD_SIGNAL.request

91.3.1.5 PMD_SIGNAL.indication

91.3.2. PMD block diagram

91.3.3. PMD transmit function

91.3.4. PMD receive function

91.3.5. PMD signal detect function

91.3.5.1 ONU PMD signal detect (downstream)

91.3.5.2 OLT PMD signal detect (upstream)

91.3.5.3 10GBASE–R and 1000BASE–X Signal detect functions

91.3.6. PMD transmit enable function for ONU

91.4 PMD to MDI optical specifications for 10GBASE–PR–D1, 10GBASE–PR–D2, 10GBASE–PR–D3, 10/1GBASE–PRX–D1, 10/1GBASE–PRX–D2 and 10/1GBASE–PRX–D3 (OLT PMDs).

91.5 PMD to MDI optical specifications for 10GBASE–PR–U1, 10GBASE–PR–U3, 10/1GBASE–PRX–U1, 10/1GBASE–PRX–U2 and 10/1GBASE–PRX–U3 (ONU PMDs).

91.6 Illustrative channels and penalties (informative) for PR10, PR20, PR30, PRX10, PRX20 and PRX30 PBCs.

91.7 Jitter at TP1–4 for PR10, PR20, PR30, PRX10, PRX20, PRX30 (informative)

91.8 Environmental, safety, and labeling

91.9 Characteristics of the fiber optic cabling

91.10 Protocol implementation conformance statement (PICS) proforma for Clause 91, Physical Medium Dependent (PMD) sublayer and medium, type 10GBASE-PR (symmetric 10 Gbps long wavelength passive optical networks) and 10/1GBASE-PRX (asymmetric 10 Gbps downstream, 1 Gbps upstream long wavelength passive optical networks)[1]

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91. PHYSICAL MEDIUM DEPENDENT (PMD) SUBLAYER AND MEDIUM, TYPE 10GBASE-PR (SYMMETRIC 10 GBPS LONG WAVELENGTH PASSIVE OPTICAL NETWORKS) AND 10/1GBASE-PRX (ASYMMETRIC 10 GBPS DOWNSTREAM, 1 GBPS UPSTREAM LONG WAVELENGTH PASSIVE OPTICAL NETWORKS)

91.1 Overview

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91.4 PMD to MDI optical specifications for 10GBASE–PR–D1, 10GBASE–PR–D2, 10GBASE–PR–D3, 10/1GBASE–PRX–D1, 10/1GBASE–PRX–D2 and 10/1GBASE–PRX–D3 (OLT PMDs).

91.5 PMD to MDI optical specifications for 10GBASE–PR–U1, 10GBASE–PR–U3, 10/1GBASE–PRX–U1, 10/1GBASE–PRX–U2 and 10/1GBASE–PRX–U3 (ONU PMDs).

91.6 Illustrative channels and penalties (informative) for PR10, PR20, PR30, PRX10, PRX20 and PRX30 PBCs.

91.7 Jitter at TP1–4 for PR10, PR20, PR30, PRX10, PRX20, PRX30 (informative)

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