75. Physical Medium Dependent (PMD) sublayer and medium, type 10GBASE–PR (symmetric 10 Gb/s long wavelength passive optical networks) and 10/1GBASE–PRX (asymmetric 10 Gb/s downstream, 1 Gb/s upstream long wavelength passive optical networks)

Editors' Note #1 (to be removed prior to release): This amendment is based on the current edition of IEEE P802.3ay (D2.2). The editing instructions define how to merge the material contained in this amendment into the base document set to form the new comprehensive standard as created by the addition of IEEE P802.3av.

This amendment is new material to be added to IEEE P802.3ay (D2.2). The material contained in this amendment forms the new comprehensive standard as created by the addition of IEEE P802.3av.
External cross references are marked with double "@" signs (for example Clause @@1.1.1@@) and will be converted to hyperlinks in the later release of the draft.

Editors' Note #2 (to be removed prior to release): Draft revision history for Clause 75

Draft	***Date***	***Comment***
Draft 0.8	*Jul 2007*	*Preliminary draft outline for IEEE P802.3av Task Force*
Draft 0.9	*Sep 2007*	*Preliminary draft for IEEE P802.3av Task Force*
Draft 0.91	*Oct 2007*	*Initial draft for IEEE P802.3av Task Force (pre–release)*
Draft 1.0	*Nov 2007*	*Initial draft for IEEE P802.3av Task Force*
Draft 1.1	*Feb 2008*	*Draft for Task Force review with comment resolution from January 2008 meeting*
Draft 1.2	*Apr 2008*	*Draft for Task Force review with comment resolution from March 2008 meeting*
Draft 1.3	*Apr 2008*	*Draft for Task Force review with comment resolution from April 2008 meeting*
Draft 1.8023	*Jun 2008*	*Draft for Task Force review with comment resolution from May 2008 meeting*
Draft 2.0	*Jul 2008*	*Draft for Work Group review with comment resolution from July 2008 meeting*

75.1 Overview

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

75.1.1 Terminology and conventions

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

Basic terminology and conventions, see @@Subclause 1.1@@ and @@Subclause 1.2@@.

Normative references, see @@Subclause 1.3@@.

Definitions, see @@Subclause 1.4@@.

Abbreviations, see @@Subclause 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.

75.1.2 Goals and objectives

The following are the PMD objectives fulfilled by Clause 75:

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

75.1.3 Power Budget Classes

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

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

75.1.4 Power Budgets

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

- PRX–type power budget describes PHY for PON operating at 10 Gb/s downstream and 1 Gb/s upstream over a single SMF (see objective b.1 above). PRX–type power budgets are also called *asymmetric*.
- PR–type power budget describes PHY for PON operating at 10 Gb/s downstream and 10 Gb/s upstream over a single SMF (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 Clause 75:

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

Table 75–1—Power budgets defined in Clause 75

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						GBd
Nominal upstream line rate	1.25	10.3125	1.25	10.3125	1.25	10.3125	GBd
Nominal downstream wavelength	1590				1577		nm
Downstream wave-length band width	20				6		nm
Nominal upstream wavelength	1310	1270	1310	1270	1310	1270	nm
Upstream wavelength band width	100	20	100	20	100	20	nm
Maximum reach	≥10		≥20		≥20		km
Minimum reach	≤0.5						m
Maximum channel insertion loss	20		24		29		dB
Minimum channel insertion loss	5		10		15		dB

75.1.5 Positioning of PMD sublayer within the IEEE 802.3 architecture

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

75.2 PMD Types

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

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

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

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

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

75.3.1.3 PMD_UNITDATA.indication

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

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

75.3.1.4 PMD_SIGNAL.request

In the upstream direction, this primitive is generated by the @@Clause 76@@ PCS to turn on and off the transmitter according to the granted time. A signal for laser control is generated as described in @@Subclause 76.3.1.1@@ for @@Clause 76@@ PCS.

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

75.3.1.5 PMD_SIGNAL.indication

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

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

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

75.3.2 PMD block diagram

The PMD sublayer is defined at the eight reference points shown in Figure 75–3 for 10GBASE–PR PMDs and in Figure 75–4 for 10/1GBASE–PRX PMDs. In Figure 75–3 and Figure 75–4, test points in ovals represent the downstream channel, while the test points in rectangles represent the upstream channel.

For 10GBASE–PR PMDs, test points TP1 – TP4 refer to the downstream channel, while test points TP5 – TP8 refer to the upstream channel. In the downstream channel, TP2 and TP3 are compliance points, while in the upstream channel TP6 and TP7 are compliance points. TP1 and TP4 and TP5 and TP8 are reference points for use by implementers. The optical transmit signal is defined at the output end of a patch cord (TP2 for the downstream channel and TP6 ~~in~~ the upstream channel), between 2 m and 5 m in length, of a fiber type consistent with the link type connected to the transmitter. Unless specified otherwise, all transmitter measurements and tests defined in Subclause 75.9 are made at TP2 and TP6. The optical receive signal is defined at the output of the fiber optic cabling (TP3 for the downstream channel and TP7 for the upstream channel) connected to the receiver. Unless specified otherwise, all receiver measurements and tests defined in Subclause 75.9 are made at TP3 and TP7.

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

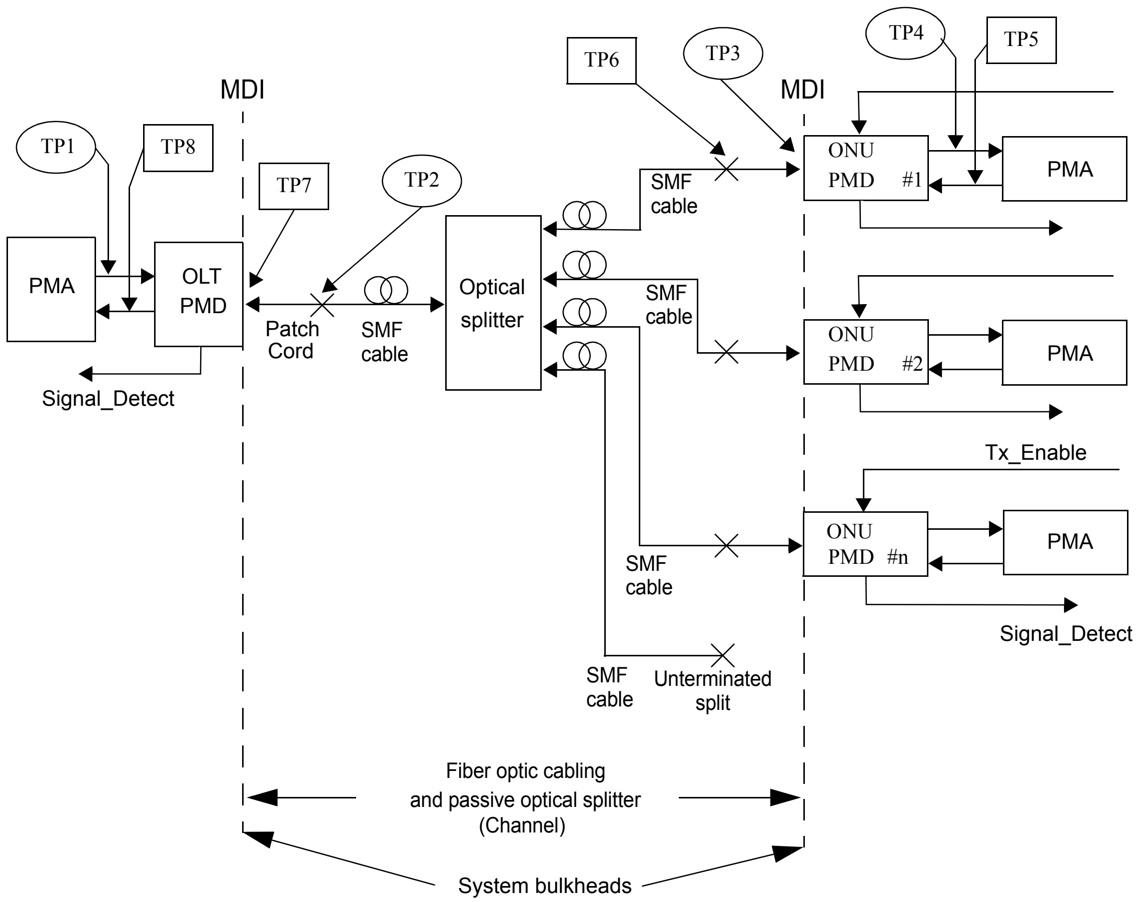

Figure 75–3—10GBASE–PR block diagram

For 10/1GBASE–PRX PMDs, test points TP1 – TP4 refer to the downstream channel (ovals), while test points TP1 – TP4 (rectangles) refer to the upstream channel. Two points, TP2 and TP3, are compliance points. TP1 and TP4 are reference points for use by Implementers. 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 @@Subclause 60.7@@ are made at TP2. The optical receive signal is defined at the output of the fiber

75.4 PMD to MDI optical specifications for symmetric and asymmetric OLT PMDs.

This section details the PMD to MDI optical specifications for symmetric and asymmetric OLT PMDs, as specified in Subclause 75.2. Specifically, Subclause 75.4.1 defines the OLT transmit parameters, while Subclause 75.4.2 defines the OLT receive parameters.

The operating ranges for PR and PRX power budget classes are defined in Table 75–1. A PR and PRX compliant transceiver operates over the media types listed in Table 75–20 according to the specifications described in Subclause 75.11. 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 PR10).

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 @@Subclause 58.7.6@@.

75.4.1 Transmitter optical specifications

The signaling speed, operating wavelength, side mode suppression ratio, average launch power, extinction ratio, return loss tolerance, OMA, eye and Transmitter and Dispersion Penalty (TDP) for transmitters making part of the symmetric and asymmetric OLT PMDs (as specified in Subclause 75.2) shall meet the specifications defined in Table 75–5 per measurement techniques described in Subclause 75.9. Its $RIN_{15}OMA$ should meet the value listed in Table 75–5 per measurement techniques described in Subclause 75.9.8. Note that 10GBASE–PR–D1 and 10/1GBASE–PRX–D1, 10GBASE–PR–D2 and 10/1GBASE–PRX–D2 and ~~finally,~~ 10GBASE–PR–D3 and 10/1GBASE–PRX–D3 share the same transmit parameters.

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

Description	10GBASE–PR–D1 and 10/1GBASE–PRX–D1	10GBASE–PR–D2 and 10/1GBASE–PRX–D2	10GBASE–PR–D3 and 10/1GBASE–PRX–D3	Unit
Signaling speed (range)	10.3125 ± 100 ppm	10.3125 ± 100 ppm	10.3125 ± 100 ppm	GBd
Wavelength (range)	1580 to 1600	1580 to 1600	1574 to 1580	nm
Side Mode Suppression Ratio (min)[a]	30	30	30	dB
Average launch power (max)	4	9	5	dBm
Average launch power (min)[b]	1	5	2	dBm
Average launch power of OFF transmitter (max)	–39	–39	–39	dBm
Extinction ratio (min)	6	6	6	dB
$RIN_{15}OMA$ (max)	–128	–128	–128	dB/Hz
Launch OMA (min)[b]	2.91 (1.95)	6.91 (4.91)	3.91 (2.46)	dBm (mW)
Transmitter eye mask definition {X1, X2, X3, Y1, Y2, Y3}	{0.25, 0.40, 0.45, 0.25, 0.28, 0.40}	{0.25, 0.40, 0.45, 0.25, 0.28, 0.40}	{0.25, 0.40, 0.45, 0.25, 0.28, 0.40}	UI
Optical return loss tolerance (max)	15	15	15	dB
Transmitter reflectance (max)	–10	–10	–10	dB
Transmitter and dispersion penalty (max)	1.5	1.5	1.5	dB
Decision timing offset for transmitter and dispersion penalty	±0.05	±0.05	±0.05	UI

[a]Transmitter is a single longitudinal mode device. Chirp is allowed such that the total optical path penalty does not exceed that found in Table 75–13.
[b]Minimum average launch power and minimum launch OMA are valid for ER = 9 dB (see Figure 75–5 for details)

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

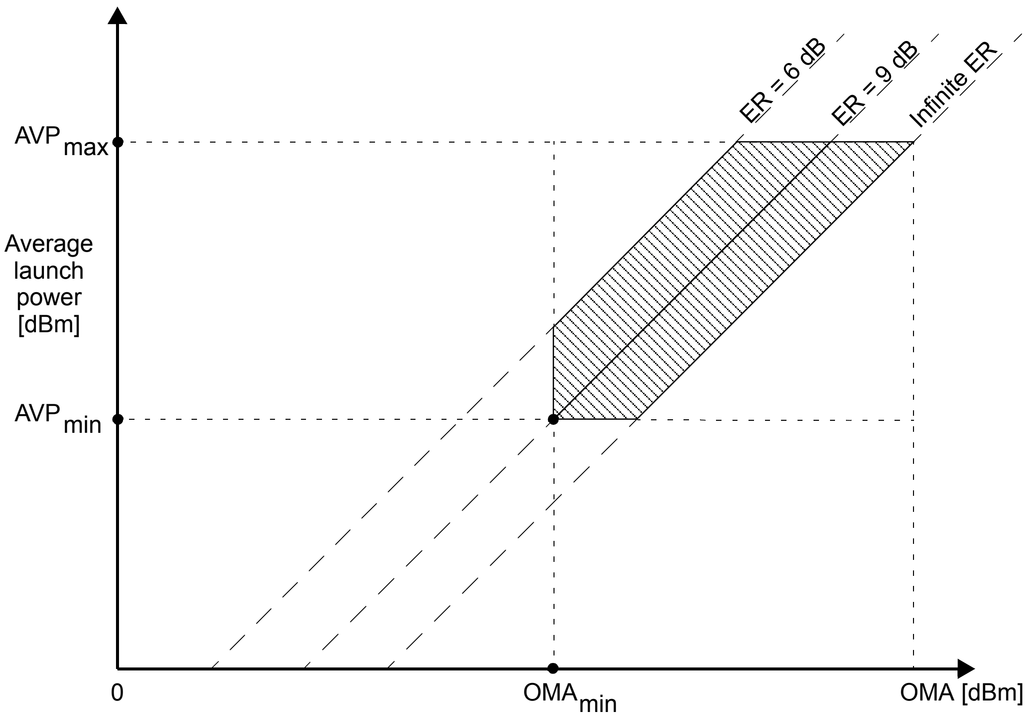

Figure 75–5—Relaxed PR–D type PMD specifications.

75.4.2 Receiver optical specifications

The signaling speed, operating wavelength, overload, stressed sensitivity, reflectivity and signal detect for receivers ~~making~~ part of the symmetric and asymmetric OLT PMDs (as specified in Clause 75.2) shall meet the specifications defined in Table 75–6 for symmetric OLT PMDs and in Table 75–7 for asymmetric OLT PMDs, per measurement techniques defined in Subclause 75.9. Its (unstressed) receive characteristics should meet the values listed in Table 75–6 and Table 75–7 per measurement techniques described in Subclause 75.9.11. Either the damage threshold included in Table 75–6 and Table 75–7 shall be met, or, the receiver shall be labeled to indicate the maximum optical input power level to which it can be continuously exposed without damage.

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

Table 75–6—PR type OLT PMD receive characteristics

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

[a]The BER of 10^{-12} is achieved by the utilization of FEC as described in @@Subclause 76.2@@.
[b]Direct ONU–OLT connection may result in damage of the receiver.
[c]The stressed receiver sensitivity is mandatory.
[d]Vertical eye closure penalty and the jitter specifications are test conditions for measuring stressed receiver sensitivity. They are not required characteristics of the receiver.
[e]$T_{receiver\_settling}$ represents an upper bound. Optics with better performance may be used in compliant implementations, since the OLT notifies the ONUs ~~on~~ its requirements in terms of the $T_{receiver\_settling}$ time via the SYNCTIME parameter (see @@Subclause 77.3.3.2@@).

Table 75–7—PRX type OLT PMD receive characteristics

Description	10/1GBASE –PRX–D1	10/1GBASE –PRX–D2	10/1GBASE –PRX–D3	Unit
Signaling speed (range)	same as 1000BASE–PX10–D receive parameters (see Table 60–5)	same as 1000BASE–PX20–D receive parameters (see Table 60–8)	1.25 ± 100 ppm	GBd
Wavelength (range)			1260 to 1360	nm
Bit error ratio (max)			10^{-12}	
Average receive power (max)			–9.38	dBm
Damage threshold (max)			–8.38	dBm
Receiver sensitivity (max)			–29.78	dBm
Receiver sensitivity OMA (max)			–29.00 (1.26)	dBm (μW)
Signal detect threshold (min)			–45	dBm
Receiver reflectance (max)			–12	dB
Stressed receive sensitivity (max)[a]			–28.38	dBm
Stressed receive sensitivity OMA (max)			–27.60 (1.74)	dBm (μW)
Vertical eye–closure penalty[b]			1.4	dB
$T_{receiver\_settling}$ (max)[c]			400	ns
Stressed eye jitter			0.28	UI pk to pk
Jitter corner frequency for a sinusoidal jitter			637	kHz
Sinusoidal jitter limits for stressed receiver conformance test (min, max)			(0.05, 0.15)	UI

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

75.5 PMD to MDI optical specifications for symmetric and asymmetric ONU PMDs.

This section details the PMD to MDI optical specifications for symmetric and asymmetric ONU PMDs, as specified in Subclause 75.2. Specifically, Subclause 75.5.1 defines the ONU transmit parameters, while Subclause 75.5.2 defines the ONU receive parameters.

The operating ranges for PR10, PR20, PR30 power budget classes are defined in Table 75–1. The operating ranges for PRX10, PRX20, PRX30 power budget classes are defined in Table 75–1. A PR10, PR20, PR30, PRX10, PRX20 or PRX30 compliant transceiver operates over the media types listed in Table 75–20 according to the specifications described in Subclause 75.11. 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 PR10).

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 @@Subclause 58.7.6@@.

75.5.1 Transmitter optical specifications

The signaling speed, operating wavelength, spectral width (for asymmetric ONU PMDs) or side mode suppression ratio (for symmetric ONU PMDs), average launch power, extinction ratio, return loss tolerance, OMA, eye and TDP for transmitters making part of the symmetric and asymmetric ONU PMDs (as specified in Subclause 75.2) shall meet the specifications defined in Table 75–8 for symmetric ONU PMDs and in Table 75–9 for asymmetric ONU PMDs, per measurement techniques described in Subclause 75.9. Its $RIN_{15}OMA$ should meet the value listed in Table 75–8 and Table 75–9 per measurement techniques described in Subclause 75.9.8.

Table 75–8—PR type ONU PMD transmit characteristics

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

[a]Transmitter is a single longitudinal mode device. Chirp is allowed such that the total optical path penalty does not exceed that found in Table 75–13.
[b]Minimum average launch power and minimum launch OMA are valid for ER = 6 dB (see Figure 75–6 for details).
[c]If a laser source has a lower TDP, the minimum transmitter launch OMA (OMA_{min}) and average minimum launch power (AVP_{min}) may be relaxed by the same amount as the TDP.

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

Table 75–9—PRX type ONU PMD transmit characteristics

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

[a]This represents the range of center wavelength ±1σ of the rms spectral width.
[b]In case FP–LD is used, RMS spectral width shall comply with Table 75–10. In case DFB laser is used, transmitter's side mode suppression ratio (min) shall be 30 dB.
[c]Minimum average launch power and minimum launch OMA are valid for ER = 6 dB.

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

75.5.2 Receiver optical specifications

The signaling speed, operating wavelength, overload, stressed sensitivity, reflectivity and signal detect for receivers ~~making~~ part of the symmetric ONU and asymmetric ONU PMDs (as specified in Subclause 75.2) shall meet the specifications defined in Table 75–11 for Clause 75 ONU PMDs, per measurement techniques defined in Subclause 75.9. The (unstressed) receive characteristics should meet the values listed in Table 75–11 per measurement techniques described in Subclause 75.9.11. Either the damage threshold included in Table 75–11 shall be met, or the receiver shall be labeled to indicate the maximum optical input power level to which it can be continuously exposed without damage.

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

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

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

[a]These limits for the 10/1GBASE–PRX–U3 transmitter are illustrated in Figure 75–7. The equation used to calculate these values is detailed in Subclause 60.7.2. Limits at intermediate wavelengths may be found by interpolation.

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

Description	10GBASE–PR–U1 10/1GBASE–PRX–U1 10/1GBASE–PRX–U2	10GBASE–PR–U3 10/1GBASE–PRX–U3	Unit
Signaling speed (range)	10.3125 ± 100 ppm	10.3125 ± 100 ppm	GBd
Wavelength (range)	1580 to 1600	1574 to 1580	nm
Bit error ratio (max)[a]	10^{-3}	10^{-3}	–
Average receive power (max)	–1	–10	dBm
Damage threshold (max)[b]	0	–9	dBm
Receiver sensitivity (max)	–20.50	–28.50	dBm
Receiver sensitivity OMA (max)	–18.59 (13.84)	–26.59 (2.19)	dBm (μW)
Signal detect threshold (min)	–44	–44	dBm
Receiver reflectance (max)	–12	–12	dB
Stressed receive sensitivity (max)[c]	–19	–27	dBm

75.6 Illustrative channels and penalties (informative) for PR10, PR20, PR30, PRX10, PRX20 and PRX30 power budget classes.

Illustrative power budget for PR10, PR20 and PR30 power budget classes are shown in Table 75–12. Illustrative power budget for PRX10, PRX20 and PRX30 power budget classes are shown in Table 75–13.

Table 75–12—Illustrative PR10, PR20 and PR30 channel insertion loss and penalties (symmetric, 10 Gb/s power budget classes)

Description	PR10		PR20		PR30		Unit
	US[a]	DS[a]	US[a]	DS[a]	US[a]	DS[a]	
Fiber Type	B1.1, B1.3 SMF						
Measurement wavelength for fiber	1270	1590[b]	1270	1590[b]	1270	1577[c]	nm
Nominal distance[d]	10		20		20		km
Available power budget[e]	23	21.5	27	25.5	32	30.5	dB
Channel insertion loss (max)[f]	20		24		29		dB
Channel insertion loss (min)[g]	5		10		15		dB
Allocation for penalties[h]	3	1.5	3	1.5	3	1.5	dB
Optical return loss of ODN (min)	20						dB

[a] US stands for Upstream, DS stands for Downstream

[b] The nominal transmit wavelength is 1590 nm.

[c] The nominal transmit wavelength is 1577 nm.

[d] Nominal distance refers to the expected maximum distance a PMD will be capable of achieving in a typical ODN, numerous ODN implementation practices may result is longer or shorter distances being actually achievable in a ~~users'~~ network.

[e] The available power budget assumes input BER from the PMD service interface of 10^{-3}. The required BER of 10^{-12} at the PCS service interface is achieved by the FEC function of the PCS.

[f] The channel insertion loss is based on the cable attenuation at the target distance and nominal measurement wavelength. The channel insertion loss also includes the loss for connectors, splices and other passive components such as splitters.

[g] The power budgets for PR10, PR20 and PR30 power budget classes are such that a minimum insertion loss is assumed between transmitter and receiver. This minimum attenuation is required for PMD testing.

[h] The allocation for penalties is the difference between the available power budget and the channel insertion loss; insertion loss difference between nominal and worst case operating wavelength is considered a penalty. This allocation may be used to compensate for transmission related penalties. Further details are given in Subclause 75.9.2.

Table 75–13—Illustrative PRX10, PRX20 and PRX30 channel insertion loss and penalties (asymmetric, 10 Gb/s downstream, 1 Gb/s upstream power budget classes)

Description	PRX10		PRX20		PRX30		Unit
	US[a]	DS[a]	US[a]	DS[a]	US[a]	DS[a]	
Fiber Type	B1.1, B1.3 SMF						
Measurement wavelength for fiber	1310	1590[b]	1310	1590[b]	1310	1577[c]	nm
Nominal distance[d]	10		20		20		km
Available power budget	23.0	21.5[e]	26.0	25.5[e]	30.4	30.5[e]	dB
Channel insertion loss (max)[f]	20		24		29		dB
Channel insertion loss (min)[g]	5	5	10	10	15	15	dB
Allocation for penalties[h]	3	1.5	2	1.5	1.4	1.5	dB
Optical return loss of ODN (min)	20						dB

[a]US stands for Upstream, DS stands for Downstream
[b]The nominal transmit wavelength is 1590 nm.
[c]The nominal transmit wavelength is 1577 nm.
[d]Nominal distance refers to the expected maximum distance a PMD will be capable of achieving in a typical ODN, numerous ODN implementation practices may result is longer or shorter distances being actually achievable in a ~~users'~~ network.
[e]The available power budget assumes input BER from the PMD service interface of 10^{-3}. The required BER of 10^{-12} at the PCS service interface is achieved by the FEC function of the PCS.
[f]The channel insertion loss is based on the cable attenuation at the target distance and nominal measurement wavelength. The channel insertion loss also includes the loss for connectors, splices and other passive components such as splitters.
[g]The power budgets for PRX10, PRX20 and PRX30 power budget classes are such that a minimum insertion loss is assumed between transmitter and receiver. This minimum attenuation is required for PMD testing.
[h]The allocation for penalties is the difference between the available power budget and the channel insertion loss; insertion loss difference between nominal and worst case operating wavelength is considered a penalty. This allocation may be used to compensate for transmission related penalties. Further details are given in Subclause 75.9.2.

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

75.6.1 Wavelength allocation

Figure 75–7 depicts the wavelength allocation plan for EPON and 10G–EPON systems, as discussed below.

75.6.1.1 Downstream wavelength allocation

The 1 Gb/s downstream transmission uses the 1480 – 1500 nm wavelength band, as specified in @@Clause 60@@. The 10 Gb/s downstream transmission uses the 1574 – 1600 nm wavelength band, as specified in Clause 75. Therefore, there are two distinct downstream channel ranges, as depicted in Figure 75–7.

NOTE—different power budget classes use different sub–sets of the 1574 – 1600 nm band, i.e. PR10, PR20, PRX10 and PRX20 power budgets use 1580 – 1600 nm range while PR30 and PRX30 power budgets use 1574 – 1580 nm range.

An OLT supporting both downstream channels may multiplex the output of the two transmitters using a WDM coupler, while an ONU selects the relevant downstream channel using an optical filter.

Figure 75–8—Wavelength allocation plan for (a) EPON and (b) 10G–EPON.

75.6.1.2 Upstream wavelength allocation

The 1 Gb/s upstream transmission uses the 1260 – 1360 nm wavelength band, as specified in @@Clause 60@@. The 10 Gb/s upstream transmission uses the 1260 – 1280 nm wavelength band, as specified in @@Clause 76@@. The two wavelength bands overlap, thus WDM channel multiplexing cannot be used to separate the two data channels.

An OLT supporting both upstream channels must use TDMA techniques to avoid collisions between transmissions originating from different ONUs, resulting in a dual–rate, burst mode transmission as discussed in Subclause 75.7.

75.7 Dual–rate operation (informative)

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

From a topological point of view, the PMD has a single optical input, sensitive to 1260 – 1360 nm signal, and two corresponding derived electrical outputs: 1.25 GBd and 10.3125 GBd. Thus, at a certain point in the stack it is necessary to introduce a signal split, where the location of such a signal split is an implementation choice. The incoming signal can be split in the optical domain and fed into two, independent photodetectors as shown in Figure 75–9(a). Alternatively, the signal can be detected using a single photodetector as shown in Figure 75–9(b) and then split in the electrical domain after the TIA block.

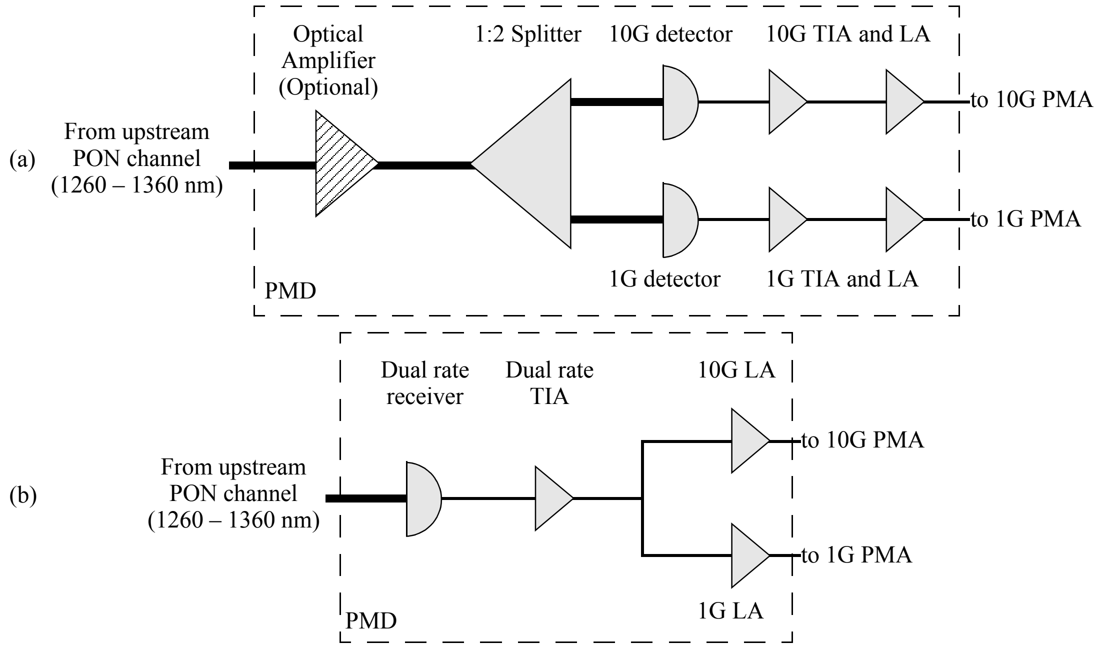

Figure 75–9—Dual–rate PMD topologies with the split in the (a) optical domain, (b) electrical domain.

When the incoming signal is split in the optical domain, it is possible to design each PMD channel specifically to match the signaling speed, offering optimum sensitivity for both 1 Gb/s and 10 Gb/s signals. However, the additional 1:2 optical splitter presented in Figure 75–9(a) will degrade the sensitivity of the PMD by introducing additional loss and lowering the power of the optical signal. Such a sensitivity reduction may be tolerable in the PX10/PR10/PRX10 type PMDs, but the more stringent power budgets including PX20, PR20, PRX20, PR30 and PRX30 may be very challenging or even impossible to implement with such an additional loss on the OLT receiver side. This particular problem may be resolved via an additional, low–gain optical amplifier introduced in–line with the 1:2 optical splitter, as presented in Figure 75–9(a), used to boost the power level of the incoming signal sufficiently to overcome the loss introduced by the 1:2 optical splitter.

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

a) This design fixes the detector parameters at some predefined value, resulting in the reduction of the OLT receiver sensitivity by approximately 2 dB. However, it should be noted that this penalty can be divided in such a way that both 1 Gb/s and 10 Gb/s sensitivities are 1 dB lower than their ideal values.
b) This design fixes the APD bias, but switches the TIA transimpedance depending on the target signaling speed for the given incoming burst, resulting in the reduction of the receiver sensitivity by approximately 1 dB. The said sensitivity penalty could be subdivided to both data rate channels by setting the APD bias to a compromise value.

c) This design switches both the APD bias and the TIA transimpedance depending on the signaling speed of the incoming burst. This results in ideal performance at both 1 Gb/s and 10 Gb/s data rates. However, it is the most complex design in terms of the number of elements and the control complexity, and it is unclear if the benefits outweigh the costs.

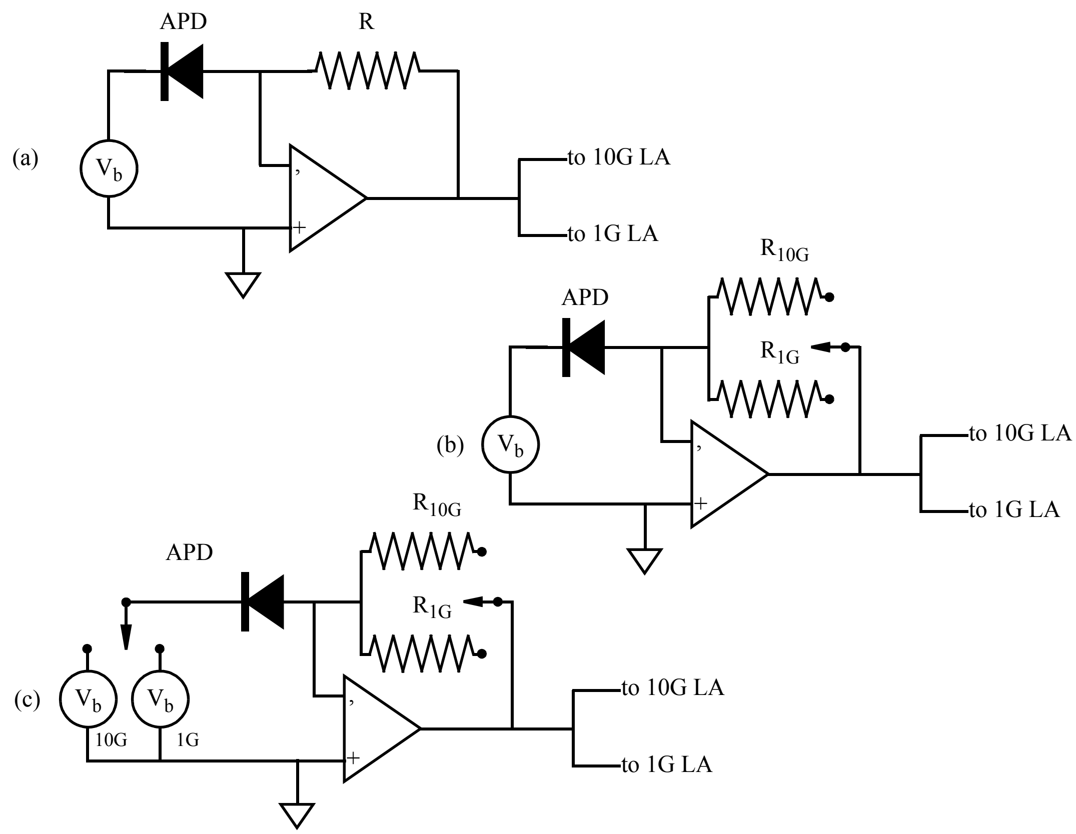

Figure 75–10—Dual rate APD–TIA architectures: (a) static, (b) half–dynamic, (c) fully–dynamic

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

In general, the PMD layer does not have the a–priori knowledge of which data rate will be used in the given burst – such information is available only at the MAC Client level and its delivery to the PMD layer would violate the stack layering restrictions. Therefore, some sort of data rate detector circuit must be utilized. One of the simple methods is based on measuring the spectral energy content of the received signal at frequencies well above 1.25 GHz (e.g., in the range of 2 – 10 GHz). The 1 Gb/s signal has very little energy ~~at said~~ frequency range, while the 10 Gb/s signal has ample energy there. Thus, the presence of 5 GHz energy indicates that a 10 Gb/s signal is incident. Other implementation specific methods to control the APD–TIA speed are also possible, though are not discussed in this document.

In the dual–rate PMD topologies with the split in the electrical domain, 10 Gb/s detector and TIA are ~~being~~ implemented for receiving both 1 Gb/s and 10 Gb/s signals. Therefore, damage threshold (max) of the 1/10 Gb/s dual–rate receiver shall comply with the 10 Gb/s receiver specification in Table 75–6, even when receiving 1 Gb/s signal. Those values for 1000BASE–PX10–D and 1000BASE–PX20–D in @@Table 60–5@@ and @@Table 60–8@@, and also those of 10/1GBASE–PRX–D1 and 10/1GBASE–PRX–D2 in Table 75–7 cannot be applied for dual–rate OLT receiver.

Table 75–18—Jitter gain curve values for PRX10, PRX20 and PRX30

	Value	Unit
P	0.3	dB
fc	1274	kHz

In measuring TP1 and TP5 it is recommended that jitter contributions at frequencies below receiver corner frequencies viz. 4 MHz for 10.3125 GBd receiver and 637 kHz for 1.25 GBd receiver are filtered at the measurement unit. The following sections describe definitive patterns and test procedures for certain PMDs of this standard. Implementers 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.

75.9.1 Insertion loss

Insertion loss for SMF fiber optic cabling (channel) is defined at 1270, 1310, 1577 or 1590 nm, depending on the particular PMD. A suitable test method is described in ITU–T G.650.1.

75.9.2 Allocation for penalties in 10G EPON PMDs

The Clause 75 receivers are required to tolerate a path penalty not exceeding 1 dB to account for total degradations due to reflections, intersymbol interference, mode partition noise, laser chirp and detuning of the central wavelength, including chromatic dispersion penalty. All the transmitter types specified in Clause 75 introduce less than 1 dB of optical path penalty over the PON plant. An increase in the optical path penalty is acceptable, provided that any increase in optical path penalty over 1 dB is compensated by an increase of the minimum transmitter OMA. The path penalty is a component of transmitter and dispersion penalty (TDP) which is specified in Table 75–5, Table 75–8, Table 75–9 and described in @@Subclause 58.7.9@@.

75.9.3 Test patterns

Compliance is to be achieved in normal operation. Two types of test patterns are used, square wave (@@Subclause 52.9.1.2@@) and other (@@Subclause 52.9.1.1@@) for testing of 10 Gb/s optical PMDs. These 10 Gb/s test patterns for 10GBASE–PR and 10/1GBASE–PRX are in Table 75–19. Two types of test frames ~~are used~~, random and jitter (@@Subclause 59.7.1@@) for 1 Gb/s tests relevant to the 10/1GBASE–PRX PHY. All test patterns are listed in Table 75–19.

75.9.4 Wavelength and spectral width measurement

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

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.

75.9.5 Optical power measurements

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

Table 75–19—Test patterns

Test	10 Gb/s Pattern[a]	1 Gb/s Pattern	Related Subclause
Average optical power	1 or 3	Valid 8B/10B	75.9.5
OMA (modulated optical power)	Square	Idles	75.9.7
Extinction ratio	1 or 3	Idles	75.9.6
Transmit eye	1 or 3	Valid 8B/10B	75.9.7
Receive upper cutoff frequency	1 or 3	Random frame	75.9.14
$RIN_{15}OMA$	Square	Idles	75.9.8
Wavelength, spectral width	1 or 3	Valid 8B/10B	75.9.4
Side mode suppression ratio	1 or 3	Valid 8B/10B	–
VECP calibration	2 or 3	Jitter frame	75.9.12
Receiver sensitivity	1 or 3	Random frame	75.9.11
Receiver overload	1 or 3	Valid 8B/10B	–
Stressed receive sensitivity	2 or 3	Random frame	75.9.12
Transmitter and dispersion penalty	2 or 3	Random frame	75.9.10
Jitter	2 or 3	Jitter frame	75.9.13
Laser On/Off	1 or 3	Valid 8B/10B	75.9.15
Receiver settling	1 or 3	Valid 8B/10B	75.9.16

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

75.9.6 Extinction ratio measurements

Extinction ratio shall meet specifications according to IEC 61820–2–2 with the port transmitting a repeating idle pattern /I2/ ordered_set (see @@Subclause 36.2.4.12@@) or valid 10GBASE–PR signal that may be interspersed with OAM packets per @@Subclause 43.B.2@@, and with minimal back reflections into the transmitter, lower than –20dB. The test receiver has the frequency response as specified for the transmitter optical waveform measurement.

75.9.7 Optical modulation amplitude (OMA) test procedure

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

75.9.8 Relative intensity noise optical modulation amplitude (RINxOMA) measuring procedure

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

75.9.14 Measurement of the receiver 3 dB electrical upper cutoff frequency

The receiver 3 dB electrical upper cutoff frequency may be measured as described in @@Subclause 52.9.11@@.

75.9.15 Laser On/Off timing measurement

Laser On/Off timing measurement procedure is described in @@Subclause 60.7.13.1@@ with the following changes:

a) T_{on} is defined in @@Subclause 60.7.13.1.1@@, value is less than 512 ns (defined in Table 75–8 and Table 75–9).
b) $T_{receiver\_settling}$ is defined in @@Subclause 60.8.13.2.1@@ (informative) value is defined in Table 75–6 and Table 75–7.
c) T_{cdr} is defined in @@Subclause 76.3.2.1@@, value less than 400 ns.
d) $T_{code\_group\_align}$ is defined in @@Subclause 36.6.2.4@@ value is less than 4 ten–bit code–groups for 1 Gb/s PHYs, and is defined as 0 for 10 Gb/s PHYs.
e) T_{off} is defined in @@Subclause 60.7.13.11.1@@, value is less than 512 ns (defined in Table 75–8 and Table 75–9).

75.9.16 Receiver settling timing measurement (informative)

The receiver settling time measurement is described in @@Subclause 60.7.13.2@@.

75.10 Environmental, safety, and labeling

75.10.1 Safety

The 10GBASE–PR and 10/1GBASE–PRX environmental specifications are as defined in @@Subclause 52.10.1@@ for general safety, and as defined in @@Subclause 52.10.2@@ for laser safety.

75.10.2 Installation

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

75.10.3 Environment

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

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).

75.10.4 PMD labeling

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

75.11.3 Optical fiber connection

Table 75–20—Optical fiber and cable characteristics

Description[a]	**Type B1.1, B1.3 SMF**					**Unit**
Nominal wavelength[b]	1270	1310	1550	1577	1590	nm
Cable attenuation (max)[c]	0.44	0.4	0.35	0.35	0.36	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 for 1310 nm and 1550 nm is defined in ITU–T G.652. The attenuation in the 1270 nm, 1577 nm and 1590 nm windows ~~was~~ calculated using spectral attenuation modelling method (5.4.4) included in G.650.1 (06/2004) and the matrix coefficients included in Appendix III herein. 1310 nm (0.4 dB/km), 1380 nm (0.5 dB/km) and 1550 nm (0.35 dB/km) attenuation values were used as the input for the predictor model.
[d]See IEC 60793 or ITU–T G.652.

An optical fiber connection as shown in Figure 75–3 and Figure 75–4 consists of a mated pair of optical connectors. The 10GBASE–PR or 10/1GBASE–PRX PMD is coupled to the fiber optic cabling through an optical connection and any optical splitters into the MDI optical receiver, as shown in Figure 75–3. The channel insertion loss includes the loss for connectors, splices and other passive components such as splitters, see Table 75–12 and Table 75–13.

The channel insertion loss was calculated under the assumption of 14.5 dB loss for a 1:16 splitter / 18.1 dB loss for a 1:32 splitter (G.671 am 1). Unitary fiber attenuation for particular transmission wavelength is provided in Table 75–20. The number of splices / connectors is not predefined – the number of individual fiber sections between the OLT MDI and the ONU MDI is not defined. The only requirement is that the resulting channel insertion loss is within the limits specified in Table 75–1. Other fiber arrangements (i.e. increasing the split ratio while decreasing the fiber length or vice versa) are supported as long as the limits for the channel insertion loss specified in Table 75–1 are observed.

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

75.11.4 Medium Dependent Interface (MDI)

The 10GBASE–PR or 10/1GBASE–PRX PMD is coupled to the fiber cabling at the MDI. The MDI is the interface between the PMD and the "fiber optic cabling" as shown in Figure 75–3 and Figure 75–4. 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 10GBASE–PR or 10/1GBASE–PRX PMD and couples to a single fiber.

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

76. Reconciliation Sublayer (RS), Physical Coding Sublayer (PCS), and Physical Media Attachment (PMA) for point-to-multipoint media, types 10GBASE-PR and 10/1GBASE-PRX

Editors' Note 76-1 (to be removed prior to release): This amendment is based on the current edition of IEEE P802.3ay (D2.2). The editing instructions define how to merge the material contained in this amendment into the base document set to form the new comprehensive standard as created by the addition of IEEE P802.3av.

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Editors' Note 76-2 (to be removed prior to release): Draft revision history for Clause 76

Version	*Date*	*Comments*
Draft 0.8	*Jul 2007*	*Preliminary draft outline for IEEE P802.3av Task Force review.*
Draft 0.9	*Sep 2007*	*Preliminary draft for IEEE P802.3av Task Force review.*
Draft 1.0	*Nov 2007*	*Initial draft for IEEE P802.3av Task Force comments.*
Draft 1.1	*Jan 2008*	*Draft for Task Force review with comment resolution from January 2008 meeting.*
Draft 1.2	*Apr 2008*	*Draft for Task Force review with comment resolution from March 2008 meeting.*
Draft 1.3	*May 2008*	*Draft for Task Force review with comment resolution from April 2008 meeting.*
Draft 1.8023	*Jun 2008*	*Draft for Task Force review with comment resolution from May 2008 meeting.*
Draft 2.0	*Jul 2008*	*Draft for Work Group review with comment resolution from July 2008 meeting*

External cross references are marked with double "@" signs (for example @@1.1.1@@). These will be converted to hyper links in a later draft.

This Clause describes the Reconciliation Sublayer (RS) and Physical Coding Sublayer (PCS) / Physical Media Attachment (PMA) used with 10GBASE-PR and 10/1GBASE-PRX point-to-multipoint (P2MP) networks. These are passive optical multipoint networks (PONs) that connect multiple DTEs using a single shared fiber. The architecture is 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 77.

76.1 Reconciliation Sublayer (RS)

76.1.1 Overview

This Subclause extends Clause 46 to enable multiple data link layers to interface with a single physical layer and Clause 65 to enable asymmetrical data links, transmitting at one data rate (e.g. 10 Gb/s) and receive in another data rate (e.g. 1 Gb/s). The number of MACs supported is limited only by the implementation. It is acceptable for only one MAC to be connected to this Reconciliation Sublayer. Figure 76–1 and Figure 76–2 show the relationship between this RS ~~to~~ the ISO/IEC OSI reference model. The mapping of GMII/XGMII signals to PLS service primitives is described in Subclause @@35.2.1@@ for GMII and @@46.1.7@@ for XGMII with exceptions noted herein.

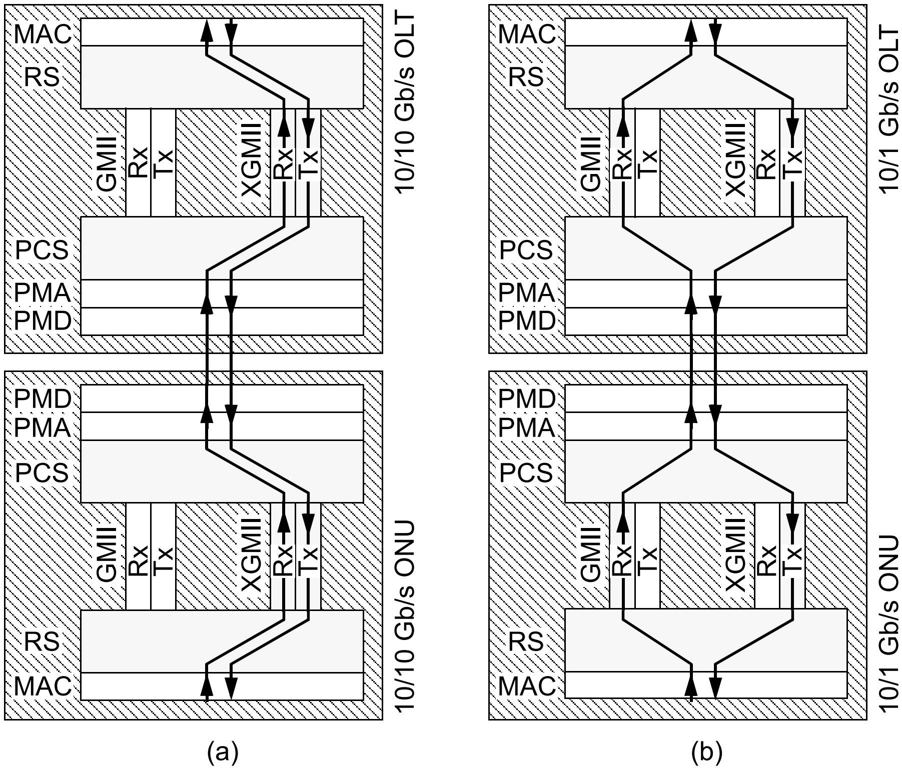


Figure 76–3—Symmetric (a) and asymmetric (b) operation of OLT and ONU.

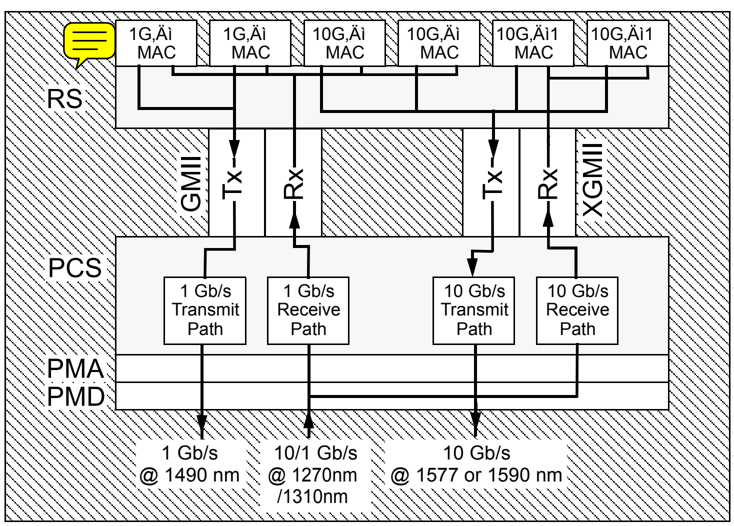


Figure 76–4—PCS and Reconciliation sublayer for dual rate mode at OLT.

76.1.2.4 Binding of XGMII and GMII primitives

Subclause 76.1.6 describes the mapping of XGMII/GMII signals to the PLS.DATA.request and PLS_DATA.indication primitives. Additional details are provided below in Table 76–1 which shows the mapping of PLS_DATA.request primitives to transmit interface signals for different types of OLTs and

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

76.2.1.1 10/1GBASE-PRX PCS

Conceptually, 10/1GBASE-PRX PCS represents a combination of transmit and receive functions defined in 10GBASE-PR PCS (specified in this clause) and 1000BASE-PX PCS (specified in Clause 65). At the OLT, the 10/1GBASE-PRX consists of 10GBASE-PR transmit function and 1000BASE-PX receive function (see Figure 76–6). Reciprocally, at the ONU, the 10/1GBASE-PRX PCS consists of 10GBASE-PR receive function and 1000BASE-PX transmit function (see Figure 76–7).

In this clause, no explicit specification is provided for 10/1GBASE-PRX PCS. It is expected that deriving such specification from 10GBASE-PR and 1000BASE-PX PCS specifications as described above will be a straightforward process.

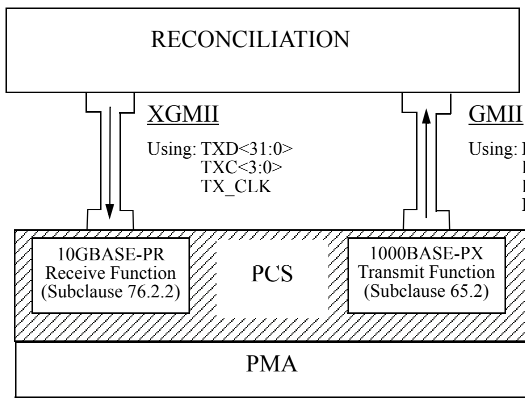


Figure 76–6—Conceptual Diagram of 10/1GBASE-PRX PCS, OLT Side

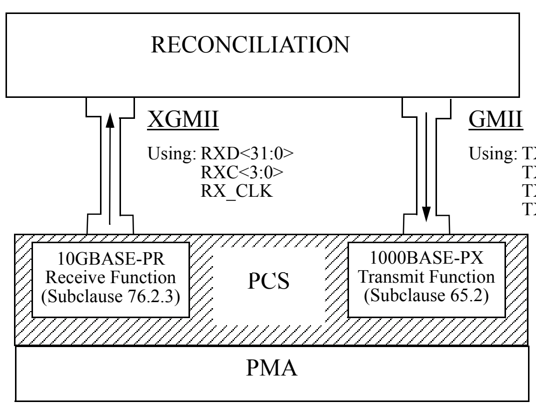


Figure 76–7—Conceptual Diagram of 10/1GBASE-PRX PCS, ONU Side

76.2.1.2 10GBASE-PR PCS

The 10GBASE-PR PCS extends the physical coding sublayer described in Clause 49 to support burst mode operation of the point-to-multipoint physical medium. Figure 76–8 illustrates functional block diagram of the downstream path and Figure 76–9 represents functional block diagram of the upstream path.

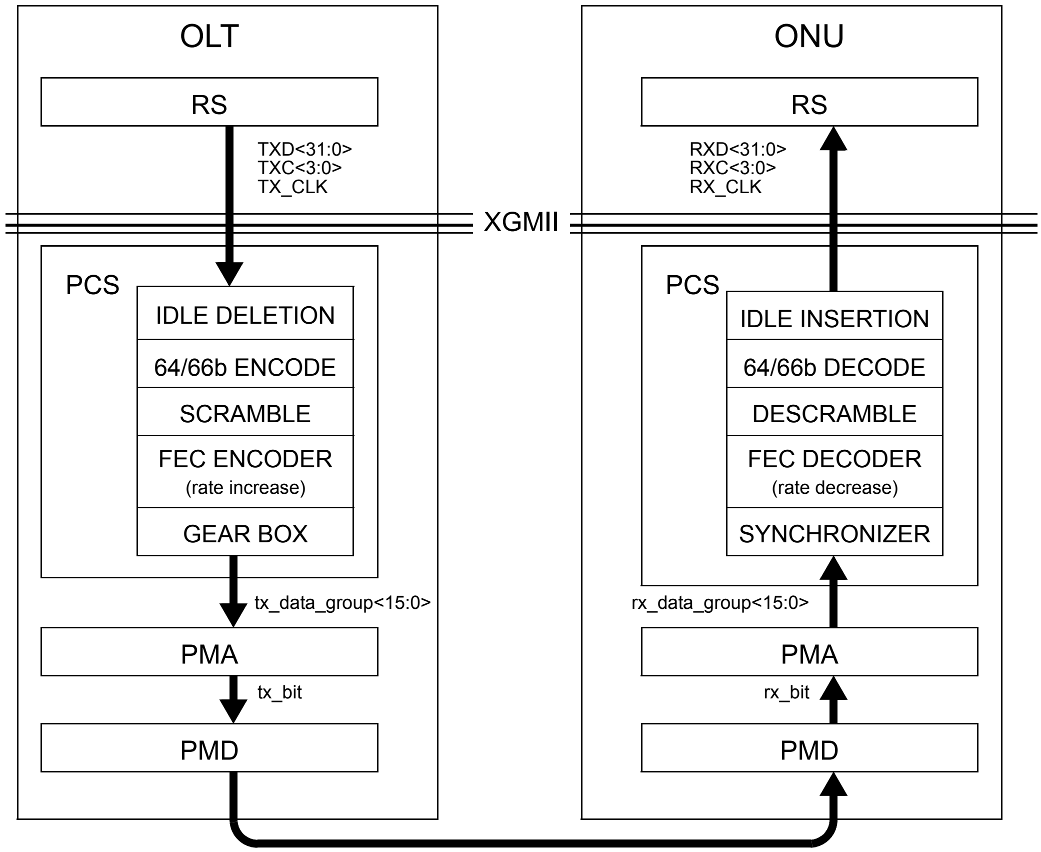


Figure 76–8—PCS Extension functional block diagram, downstream path

76.2.2 PCS Transmit function

This subclause defines the transmit direction of physical coding sublayers for 10GBASE-PR and 10/1GBASE-PRX. In the OLT, the PCS operates at a 10 Gb/s rate in a continuous mode. In the ONU, the PCS may operate at a 10 Gb/s rate, as specified herein (10GBASE-PR), or at a 1 Gb/s rate, compliant with Clause 65 (10/1GBASE-PRX). For both 10GBASE-PR and 10/1GBASE-PRX, the ONU PCS always operates in a burst mode. When operating at the 10 Gb/s rate, the PCS includes a mandatory FEC encoder. The transmit direction of OLT PCS is illustrated in Figure 76–8 and in Figure 76–9 for the transmit direction of the ONU PCS.

76.2.2.4.3 FEC Transmission Block Formating

As shown in Figure 76–13, after the Reed-Solomon codeword has been computed, the FEC encoder constructs the transmittable FEC frame with the original sequence of 27 66-bit blocks (including the redundant sync bit, but not including the 29 "0" padding bits). The FEC encoder prepends a 2 bit sync header to each group of 64 parity bits to construct a properly formed 66-bit codeword, according to the predefined sync header pattern for the four 64-bit parity blocks: 00 11 11 00. Finally the four 66-bit parity blocks are appended following the 27 66-bit data blocks and transmitted to the PMA.

76.2.2.5 Data Detector and Burst Mode Considerations (ONU only)

To avoid spontaneous emission noise from near ONUs obscuring the signal from a distant ONU, the lasers in ONUs must be turned off between transmissions. To control the laser, the ONU 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 76–9.

The DATA DETECTOR contains a delay line (FIFO buffer) storing code-groups to be transmitted. Figure 76–14 shows the relationship of filling the buffer and the generation of laser control. 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 laser synchronization pattern, Burst Delimiter pattern and a predefined number of IDLE control character to be transmitted. The laser synchronization pattern allows the receiving optical detector to adjust its gain ($T_{receiver\_settling}$) and synchronize its receive clock (T_{cdr}). The Burst Delimiter allows the receiver to easily identify the beginning of FEC protected portion of the ONU transmission. The IDLE control characters are used to synchronize the scrambler and start of packet delineation.

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.

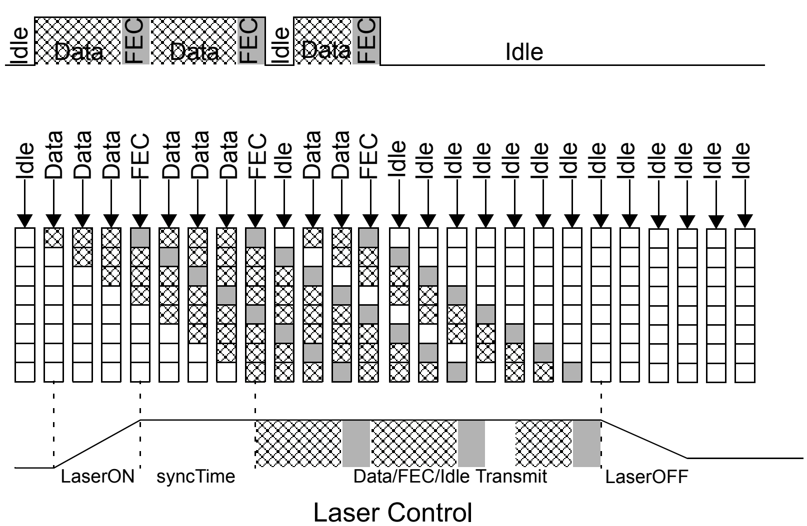


Figure 76–14—Laser control as a function of buffer fill

Upon initialization, the FIFO buffer is filled with IDLE control characters and the laser is turned off. When the first, non-IDLE code group 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.

When the buffer empties of data (i.e., contains only IDLE control characters), 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, IDLE control characters will arrive at the buffer. If the number of these IDLE control characters is insufficient to fill the buffer then the laser is not turned off.

Figure 76–15 illustrates the details of the ONU burst transmitition. In particular, this figure shows the details of the synchronization time and the FEC protected portions of the burst transmision.

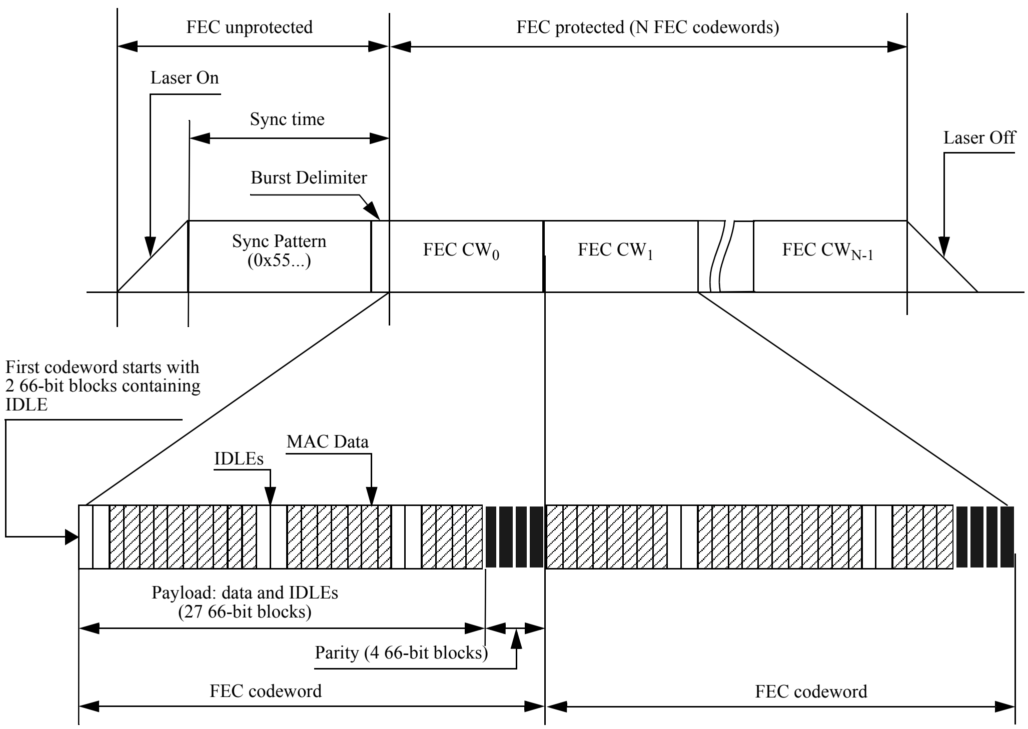


Figure 76–15—Details of burst composition

The ONU burst transmission begins with a synchronization pattern 0x55 (transmission bit sequence 1010 ...), which facilitates receiver clock recovery and gain control at the OLT. To facilitate FEC codeword synchronization, the ONU transmits a 66-bit BURST_DELIMITER (see Figure 76–15). When received at the OLT, the BURST_DELIMITER allows for FEC codeword alignment on the incoming data stream, even in the presence of bit errors. The BURST_DELIMITER is followed by two 66-bit blocks containing IDLE codes. The first 66-bit block is used to synchronize the descrambler and a second 66-bit block is needed to provide IPG at the OLT. These two 66-bit IDLE blocks are part of the first FEC codeword.

76.2.3 PCS Receive Function

This subclause defines the receive direction of physical coding sublayers for 10GBASE-PR and 10/1GBASE-PRX. In the ONU, the PCS operates at a 10 Gb/s rate in a continuous mode. In the OLT, the PCS may operate at a 10 Gb/s rate, as specified herein (10GBASE-PR), or at a 1 Gb/s rate, compliant with Clause 65 (10/1GBASE-PRX). For both 10GBASE-PR and 10/1GBASE-PRX, the OLT PCS always operates in burst mode. When operating at the 10 Gb/s rate, the PCS includes a mandatory FEC decoder. The receive direction of ONU PCS is illustrated in Figure 76–8 and receive direction for the OLT PCS is illustrated in Figure 76–9.

76.2.3.1 OLT Synchronizer

The OLT codeword synchronization function receives data via 16-bit PMA_UNITDATA.request primitive.

The OLT synchronizer shall form a bit stream from the primitives by concatenating requests with the bits of each primitive in order from rx_data-group<0> to rx_data-group<15> (see Figure 76–19). It obtains lock to the 31*66-bit blocks in the bit stream by looking for the burst delimiter. Lock is obtained as specified in the codeword lock state diagram shown in Figure 76–19. When in codeword lock, the state diagram accumulates the appropriate contents of the 31 blocks that constitute a codeword in an input buffer. When the codeword is complete, the FEC decoder is triggered, and the input buffer is freed for the next codeword. When in codeword lock, the state diagram looks for the end of the burst. When this is observed, then the state diagram deasserts codeword lock. The state diagram then goes back to searching for the burst delimiter.

76.2.3.1.1 Variables

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

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

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

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

EOB_valid
TYPE: boolean
Indication that is set true if:

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

It is set to false otherwise.

inbuffer[]
TYPE: array
An array of 2040 bits.

76.2.3.1.4 State diagram

The OLT Synchronizer shall implement the state diagram as depicted in Figure 76–19. Should there be a discrepancy between a state diagram and descriptive text, the state diagram prevails.

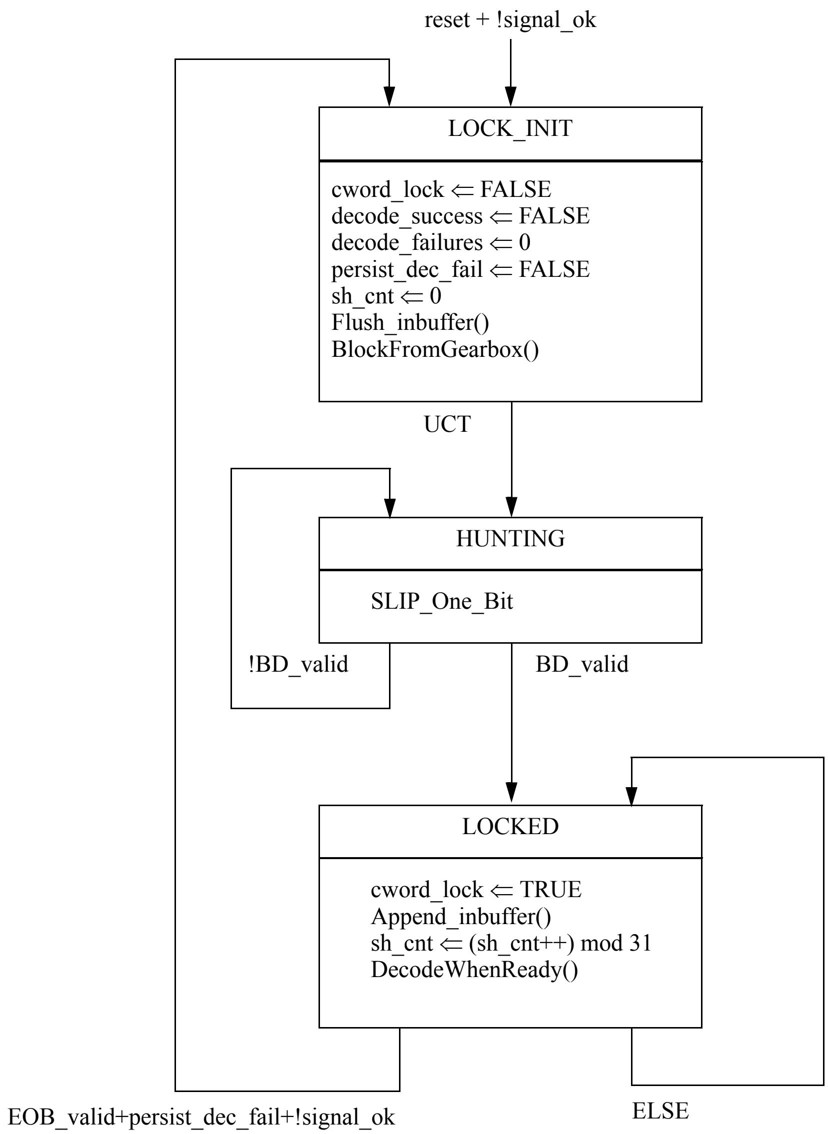


Figure 76–19—OLT Synchronizer state diagram

76.2.3.2 ONU Synchronizer

The codeword synchronization function receives data via 16-bit PMA_UNITDATA.request primitive.

The synchronizer shall form a bit stream from the primitives by concatenating requests with the bits of each primitive in order from rx_data-group<0> to rx_data-group<15> (see Figure 76–20). It obtains lock to the 31*66-bit blocks in the bit stream using the sync headers and outputs 2040-bit codewords to the FEC decoder function. Lock is obtained as specified in the codeword lock state diagram shown in Figure 76–21.

When in codeword lock, the state diagram accumulates the appropriate contents of the 31 blocks that constitute a codeword in an input buffer. When the codeword is complete, the FEC decoder is triggered, and the input buffer is freed for the next codeword.

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

76.2.3.2.1 Constants

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

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

76.2.3.2.2 Variables

cword_lock
See Subclause 76.2.3.1.1.

decode_success
See Subclause 76.2.3.1.1.

persist_dec_fail
See Subclause 76.2.3.1.1.

reset
This variable is inherited from @@Subclause 49.2.13.2.2@@.

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

signal_ok
This variable is inherited from @@Subclause 49.2.13.2.2@@.

slip_done
This variable is inherited from @@Subclause 49.2.13.2.2@@.

test_sh
This variable is inherited from @@Subclause 49.2.13.2.2@@.

76.2.3.2.3 Counters

decode_failures
See Subclause 76.2.3.1.1.

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

sh_cnt
See Subclause 76.2.3.1.2.

sh_valid_cnt
This counter is inherited from @@Subclause 49.2.13.2.4@@.

76.2.3.2.4 Functions

Append_inbuffer()
See Subclause 76.2.3.1.3.

DecodeWhenReady()
See Subclause 76.2.3.1.3.

SLIP
This function is inherited from @@Subclause 49.2.13.2.3@@.

76.2.3.2.5 State diagram

The ONU Synchronizer shall implement the state diagram as depicted in Figure 76–21. Should there be a discrepancy between a state diagram and descriptive text, the state diagram prevails.

76.2.3.3 FEC Decoder

The FEC decoder corrects or confirms the correctness of the 27 66-bit blocks contained in the frame based on the four 66-bit blocks of parity information. The decoder then forwards the 66-bit data blocks to the descrambler and discards the parity blocks. The FEC decoder is also responsible for setting bit <0> of sync header to the inverse of bit <1> of sync header. The handling of data leaving the FEC decoder and going to the descrambler is specified in the FEC-decoder state diagram shown in Figure 76–22.

The synchronizer state diagram accumulates a full codeword in a buffer. If the synchronizer is locked, then the FEC decoding process is triggered. The FEC algorithm then processes the buffer. The algorithm produces two outputs: the decode_success signal and (if successful) the corrected buffer. The data portion of the buffer is then read out to the descrambler logic in 66-bit blocks, as normal. Note that the rate of 66-bit transfers is lower then normal here. This is corrected in the idle insertion step (see Figure 76–26).

If ~~the~~ decode_success is false, then a counter is incremented. If there are three decoding failures in a row, then the Persist_dec_fail signal is asserted. This signal will then reset the synchronizer.

The FEC decoder provides a user option to indicate an uncorrectable FEC block (due to an excess of symbols containing errors) to the PCS layer. If this option is set to be true, the FEC decoder will check for the value of decode_failures. If the variable decode_failures is set to be 1, then all sync headers for the received

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

SLIP
This function is inherited from @@Subclause 49.2.13.2.3@@.

76.2.3.3.4 State diagrams

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

The FEC Decoding function shall be implemented in the PCS as depicted in Figure 76–22. Should there be a discrepancy between a state diagram and descriptive text, the state diagram prevails.

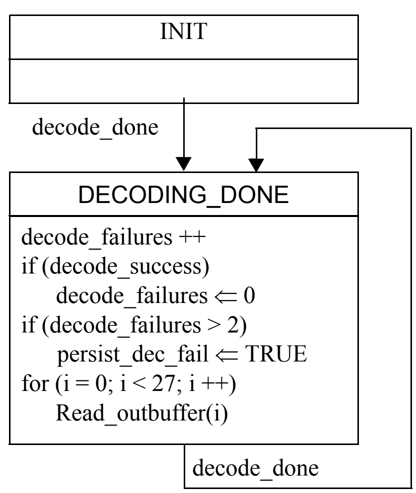


Figure 76–22—FEC Decoder state diagram

76.2.3.4 BER Monitor control

The following objects apply to 10G-EPON PCS management. If an MDIO Interface is provided (see Clause 45), they are accessed via that interface. If not, it is recommended that an equivalent access be provided.

The BER monitor is described in Figure 76–25.

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

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

76.3.2.1 CDR lock timing measurement for the upstream direction

CDR lock time (denoted T_{CDR}) is defined as a time interval required by the receiver to acquire phase 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, as illustrated in @@Figure 75-3@@ and @@Figure 75-4@@, reaches the conditions specified in @@Subclause 75.9.16@@ 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^{-3}.

A PMA instantiated in an OLT becomes synchronized at the bit level within 400 ns (T_{CDR}) after the appearance of a valid synchronization pattern (0x55…) at TP4.

76.3.2.1.1 Test specification

@@Figure 75-3@@ and @@Figure 75-4@@ illustrate 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 @@Subclause 75.9.15@@, and an optical PMD receiver at the OLT with well-known parameters, having a fixed known $T_{receiver\_settling}$ time as defined in @@Subclause 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 the phase difference from the input signal of the transmitting PMA assuring BER of 10^{-3}, and maintaining its jitter specifications. The signal throughout this test is the synchronization pattern, as illustrated in Figure 76–15.

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^{-3}.

Annex 76A

(informative)

FEC Frame Encoding example

Editors' Note 76-1 (to be removed prior to release): This amendment is based on the current edition of IEEE P802.3ay (D2.2). The editing instructions define how to merge the material contained in this amendment into the base document set to form the new comprehensive standard as created by the addition of IEEE P802.3av.

Editing instructions are shown in 8 point arial Bold red italic font. Four editing instructions are used: ***change***, ***delete***, ***insert***, *and* ***replace***.
Change *is used to make small corrections in existing text or tables. The editing instruction specifies the location of the change and describes what is being changed either by using strikethrough (to remove old material) or underscore (to add new material).*
Delete *removes existing material.*
Insert *adds new material without disturbing the existing material. Insertions may require renumbering. If so, renumbering instructions are given in the editing instruction.*
Replace *is used to make large changes in existing text, subclauses, tables, or figures by removing existing material and replacing it with new material. Editorial notes will not be carried over into future editions*
To simplify the addition of new tables, tables in this amendment clause are numbered based on their relationship to tables in the base document (IEEE P802.3ay D2.2). For example, Table 45-BB in this amendment would be renumbered Table-CC when the amendment is merged with IEEE P802.3ay D2.2. Continuing the example, a Table-AAb would then be renumbered Table-DD. All original table numbers in the base document can then be incremented after the merge.
External cross references are marked with double "@" signs (for example Clause @@1.1.1@@) and will be converted to hyperlinks in the later release of the draft.:

Editors' Note 76-2 (to be removed prior to release): Draft revision history for Clause (informative)

Draft	***Date***	***Comment***
Draft 1.3	*May 2008*	*Draft for Task Force review with comment resolution from April 2008 meeting*
Draft 1.8023	*Jun 2008*	*Draft for Task Force review with comment resolution from May 2008 meeting*
Draft 2.0	*Jul 2008*	*Draft for Work Group review with comment resolution from July 2008 meeting*

76A.2 Introduction and rationale

This Annex provides an example of FEC frame encoding with RS (255,223) code. See @@Subclause 76.2.2.4.3@@ for the format of the FEC frame.

76A.3 64B/66B Block Input

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

The 66-bit blocks in the Table 76A-1 are transmitted from left to right within each row and from top to bottom between rows. The 64 bit payload portion of the 66-bit block is described as a series of hexadecimal octets - the leftmost octet of each payload portion is transmitted first. Bits within each octet of the payload are transmitted in least-significant-bit-first order (ie. the rightmost bit of each octet is transmitted first).

77. Multipoint MAC Control for 10G–EPON

Editors' Note #1 (to be removed prior to release): This amendment is based on the current edition of IEEE P802.3ay (D2.2). The editing instructions define how to merge the material contained in this amendment into the base document set to form the new comprehensive standard as created by the addition of IEEE P802.3av.

This amendment is new material to be added to IEEE P802.3ay (D2.2). The material contained in this amendment forms the new comprehensive standard as created by the addition of IEEE P802.3av.
External cross references are marked with double "@" signs (for example Clause @@1.1.1@@) and will be converted to hyperlinks in the later release of the draft.

Editors' Note #2 (to be removed prior to release): Draft revision history for Clause 77

Draft	Date	Comment
Draft 1.1	Feb 2008	Draft for Task Force review with comment resolution from January 2008 meeting First version of Clause 77 draft available
Draft 1.2	Apr 2008	Draft for Task Force review with comment resolution from March 2008 meeting
Draft 1.3	May 2008	Draft for Task Force review with comment resolution from April 2008 meeting
Draft 1.8023	Jun 2008	Draft for Task Force review with comment resolution from May 2008 meeting
Draft 2.0	Jul 2008	Draft for Work Group review with comment resolution from July 2008 meeting

77.1 Overview

This clause deals with the mechanism and control protocols required in order to reconcile the 10 Gb/s P2MP topology into the Ethernet framework. The P2MP medium is a passive optical network (PON), an optical network with no active elements in the signal's 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 77–1. Clause 67 provides additional examples of P2MP topologies.

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

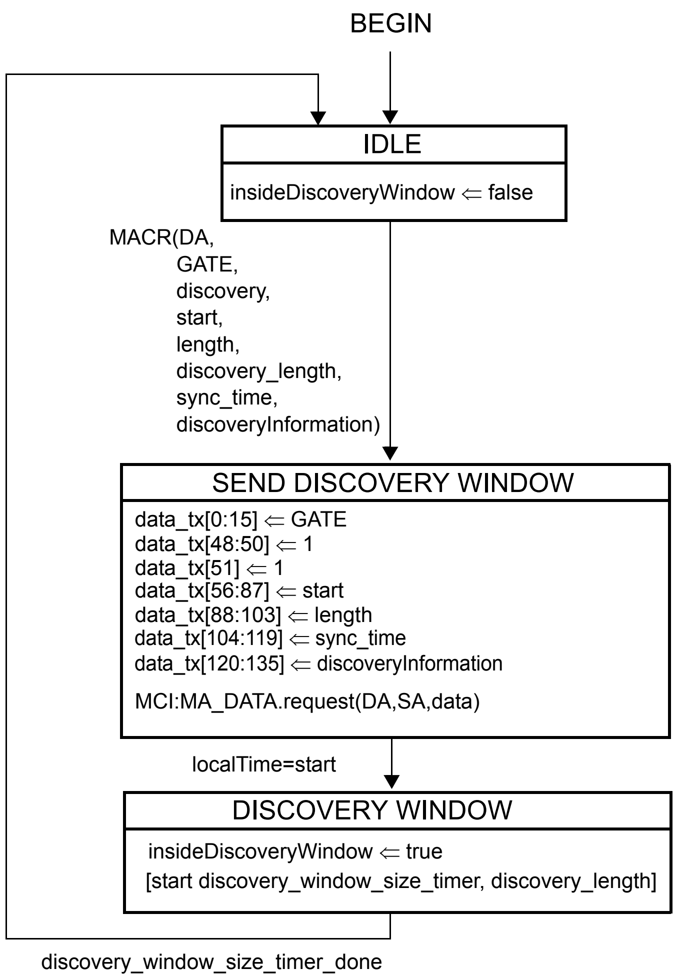
This clause does not deal with topics including bandwidth allocation strategies, authentication of end–devices, quality–of–service definition, provisioning, or management.

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

77.3.3.6 State Diagram

~~D~~iscovery Process in the OLT shall implement the discovery window setup state diagram shown in Figure 77–18, request processing state diagram as shown in Figure 77–19, register processing state diagram as shown in Figure 77–20, and final registration state diagram as shown in Figure 77–21. The discovery process in the ONU shall implement registration state diagram as shown in Figure 77–22.

Instantiation of state diagrams as described in Figure 77–18, Figure 77–19, and Figure 77–20 is performed only at the Multipoint MAC Control instances attached to the appropriate broadcast LLID(s) (0x7FFF and/or 0x7FFE for EPON and 10G–EPON, respectively). Instantiation of state diagrams as described in Figure 77–21 and Figure 77–22 is performed for every Multipoint MAC Control instance, except the instance attached to the broadcast channel.



Instances of MAC data service interface:
MCI=interface to MAC Control multiplexer

Figure 77–18—Discovery Processing OLT Window Setup state diagram

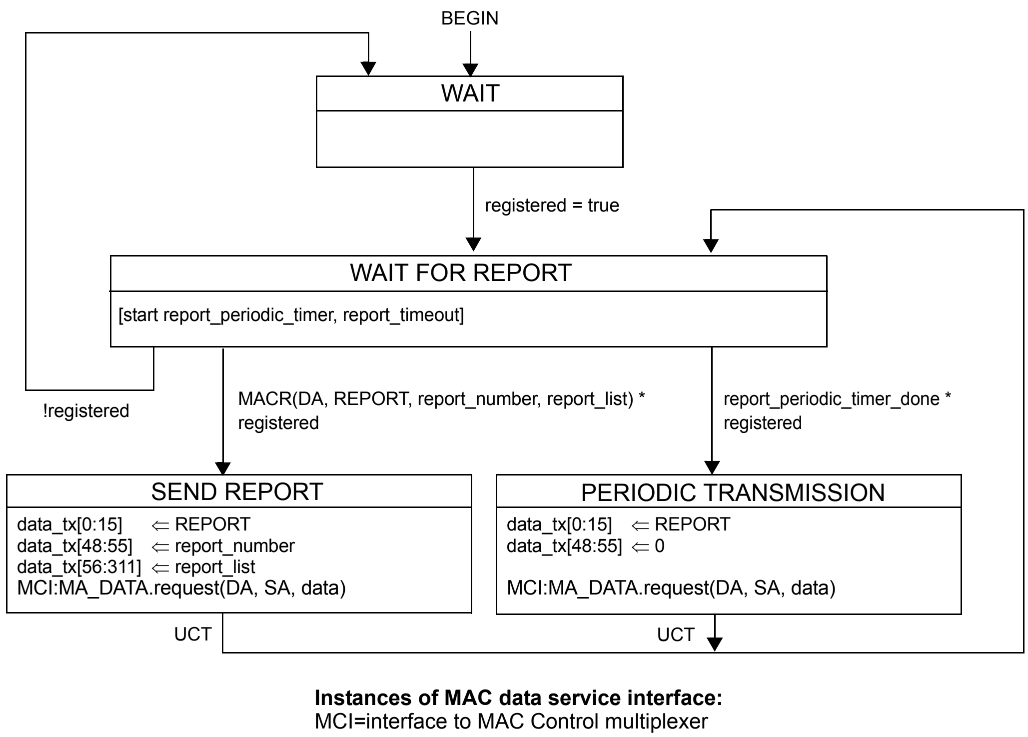


Figure 77–25—Report Processing state diagram at ONU

77.3.5 Gate Processing

A key concept pervasive in Multipoint MAC Control is the ability to arbitrate a single transmitter out of a plurality of ONUs. The OLT controls an ONU's transmission by the assigning of grants.

The transmitting window of an ONU is indicated in 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 maximum supported maximum outstanding grants as advertised by the ONU during registration (see pending grants in Subclause 77.3.6.3).

In order to maintain the watchdog timer at the ONU, grants are periodically generated. For this purpose empty GATE messages may be issued periodically.

When registered, the ONU ignores all gate messages where the discovery flag is set.

A dual speed ONU capable of asymetric 10/1 Gb/s operation or symmetric 10/10 Gb/s operation is also only capable of receiving discovery GATE MPCPDU transmitted by the OLT on the 10 Gb/s broadcast channel. These messages need to be parsed, and the ONU makes the registration decision based on the available information. The ONU should attempt to register ~~based~~ during the discovery window announced as supporting the highest speed common to both the OLT and ONU. Table 77–11 shows the action the ONU should take based on the ONU transmit capabilities and the received discovery information.

Table 77–11—ONU action during discovery window

OLT Discovery Information				ONU Tx capability		ONU Action
Upstream Capable		Discovery Window				
1G	10G	1G	10G	1G	10G	
1	0	1	0	1	X	Attempt 1G registration
0	1	0	1	X	1	Attempt 10G registration
1	1	0	1	0	1	Attempt 10G registration
1	1	0	1	1	0	Wait for 1G discovery window
1	1	0	1	1	1	Attempt 10G registration
1	1	1	0	0	1	Wait for 10G discovery window
1	1	1	0	1	0	Attempt 1G registration
1	1	1	0	1	1	Wait for 10G discovery window
1	1	1	1	0	1	Attempt 10G registration
1	1	1	1	1	0	Attempt 1G registration
1	1	1	1	1	1	Attempt 10G registration