60 Physical Medium Dependent (PMD) sublayer and medium, type 1000BASE-PX10, ~~and~~ 1000BASE-PX20, 1000BASE-PX30, and 1000BASE-PX40 (long wavelength passive optical networks)

Change the title of Clause 60 as shown above:

Change the text of 60.1 as shown below:

60.1 Overview

~~The 1000BASE-PX10 and 1000BASE-PX20 PMD sublayers provide point-to-multipoint (P2MP) 1000BASE-X connections over passive optical networks (PONs) up to at least 10 km and 20 km, respectively and with a typical split ratio of 1:16.~~ The 1000BASE-PX10, 1000BASE-PX20, 1000BASE-PX30, and 1000BASE-PX40 PMD sublayers provide point-to-multipoint (P2MP) 1000BASE-X connections over passive optical networks (PONs). The 1000BASE-PX10 PMD sublayers provide the reach of at least 10 km whereas the 1000BASE-PX20, 1000BASE-PX30, and 1000BASE-PX40 PMD sublayers provide the reach of at least 20 km. The 1000BASE-PX10 and 1000BASE-PX20 PMD sublayers provide a typical split ratio of 1:16. The 1000BASE-PX30 PMD sublayers provide a typical split ratio of 1:32. The 1000BASE-PX40 PMD sublayers provide a typical split ratio of 1:64. In an Ethernet PON, a single downstream (D) PMD broadcasts to multiple upstream (U) PMDs and receives bursts from each "U" PMD over a single branched topology, single-mode fiber network. The same fibers are used simultaneously in both directions. ~~This clause specifies the 1000BASE-PX10-D PMD, 1000BASE-PX10-U PMD, 1000BASE-PX20-D PMD and the 1000BASE-PX20-U PMD (including MDI) and the medium, single-mode fiber.~~ This clause specifies the single-mode fiber medium and the following PMDs (including MDI): 1000BASE-PX10-D, 1000BASE-PX10-U, 1000BASE-PX20-D, 1000BASE-PX20-U, 1000BASE-PX30-D, 1000BASE-PX30-U, 1000BASE-PX40-D, and 1000BASE-PX40-U. A 1000BASE-PX-U PMD or a 1000BASE-PX-D PMD is connected to the appropriate 1000BASE-X PMA of Clause 65, and to the medium through the MDI. A PMD is optionally combined with the management functions that may be accessible through the management interface defined in Clause 22 or by other means.

A 1000BASE-PX10 link uses a 1000BASE-PX10-U PMD at one end and a 1000BASE-PX10-D PMD at the other. A 1000BASE-PX20 link uses a 1000BASE-PX20-U PMD at one end and a 1000BASE-PX20-D PMD at the other. A 1000BASE-PX30 link uses a 1000BASE-PX30-U PMD at one end and a 1000BASE-PX30-D PMD at the other. A 1000BASE-PX40 link uses a 1000BASE-PX40-U PMD at one end and a 1000BASE-PX40-D PMD at the other. ~~A 1000BASE-PX20-D PMD is interoperable with a 1000BASE-PX10-U PMD.~~ A 1000BASE-PX40-D PMD is interoperable with a 1000BASE-PX40-U PMD.

Typically, the 1490 nm band is used to transmit away from the center of the network D and the 1310 nm band towards the center U. The suffixes D and U indicate the PMDs at each end of a link which transmit in these directions and receive in the opposite directions. The splitting ratio or reach length may be increased in an FEC enabled link. FEC refers to forward error correction for P2MP optical links and is described in 65.2. The maximum reach length is not limited by the protocol, see 64.3.3.

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

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

Change Table 60–1 for 1000BASE-PX30-U, 1000BASE-PX30-D, 1000BASE-PX40-U, and 1000BASE-PX40-D PMDs, as shown below:

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

60.4b.1 Transmitter optical specifications

The 1000BASE-PX40-D and 1000BASE-PX40-U transmitter's signaling speed, operating wavelength, Side Mode Suppression Ratio (min), average launch power, extinction ratio, return loss tolerance, OMA, eye and TDP shall meet the specifications defined in Table 60–8d per measurement techniques described in 60.7. Its RIN_{15}OMA should meet the value listed in Table 60–8d per measurement techniques described in 60.7.7.

Table 60–8d—1000BASE-PX40-D and 1000BASE-PX40-U transmit characteristics

Description	1000BASE-PX40-D	1000BASE-PX40-U	Unit
Nominal transmitter type[a]	Longwave Laser	Longwave Laser	
Signaling speed (range)	1.25 ± 100 ppm	1.25 ± 100 ppm	GBd
Wavelength (range)	1480 to 1500	~~1290 to 1330~~1260 to 1360	nm
Side Mode Suppression Ratio (min)[b]	30	-	dB
RMS spectral width (max)	-	see Table 60–8b	nm
Average launch power (max)	10	~~7~~5.62	dBm
Average launch power (min)	~~4~~7	~~2~~0.62	dBm
Average launch power of OFF transmitter (max)	–39	–45	dBm
Extinction ratio (min)	6	6	dB
RIN_{15}OMA (max)	–115	–115	dB/Hz
Launch OMA (min)	~~4~~7.78 (~~3.01~~6.00)	~~2.78~~1.40 ~~(1.90)~~(1.38)	dBm (mW)
Transmitter eye mask definition {X1, X2, Y1, Y2, Y3}	{0.22, 0.375, 0.20, 0.20, 0.30}	{0.22, 0.375, 0.20, 0.20, 0.30}	UI
Ton (max)	N.A.	512	ns
Toff (max)	N.A.	512	ns
Optical return loss tolerance (max)	15	15	dB
Optical return loss of ODN (min)	20	20	dB
Transmitter reflectance (max)	–10	–10	dB
Transmitter and dispersion penalty (max)	1.0	1.4~~0~~	dB
Decision timing offset for transmitter and dispersion penalty (min)	±0.1	±0.125	UI

[a]The nominal device type is not intended to be a requirement on the source type, and any device meeting the transmitter characteristics specified may be substituted for the nominal device type.
[b]Transmitter is a single longitudinal mode device. Chirp is allowed such that the total penalty does not exceed that found in Table 60–9.

60.4b.2 Receiver optical specifications

The 1000BASE-PX40-D and 1000BASE-PX40-U receiver's signaling speed, operating wavelength, overload, sensitivity, reflectance and signal detect shall meet the specifications defined in Table 60–8e per measurement techniques defined in 60.7.10. Its stressed receive characteristics should meet the values listed in Table 60–8e per measurement techniques described in 60.7.11 Either the damage threshold included in Table 60–8e 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.

The damage threshold included in Table 60–8e 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 the damage threshold.

Table 60–8e—1000BASE-PX40-D and 1000BASE-PX40-U receive characteristics

Description	1000BASE-PX40-D	1000BASE-PX40-U	Unit
Signaling speed (range)	1.25 ± 100 ppm	1.25 ± 100 ppm	GBd
Wavelength (range)	1260 to 1360	1480 to 1500	nm
Bit error ratio (max)	10^{-12}		
Average receive power (max)	–8	–8	dBm
Damage threshold (max)[a]	–3	~~–3~~+4	dBm
Receiver sensitivity (max)	–33.78~~2~~	~~–30~~ –27	dBm
Receiver sensitivity OMA (max)	~~–31.22~~33.00 (~~0.76~~0.50)	~~–29.22~~–26.22 ~~(1.20)~~(2.39)	dBm (µW)
Signal detect threshold (min)	–45	–44	dBm
Receiver reflectance (max)	–12	–12	dB
Stressed receive sensitivity (max)[b]	–3~~1~~2.38	~~–29~~ –26	dBm
Stressed receive sensitivity OMA (max)	~~–30.22~~31.60 (~~0.95~~0.69)	~~–28.22~~–25.22 ~~(1.51)~~(3.01)	dBm (µW)
Vertical eye-closure penalty (min)[c]	2.2	1.5	dB
$T_{receiver\_settling}$ (max)[d]	400	N.A.	ns
Stressed eye jitter (min)	0.28	0.25	UI pk to pk
Jitter corner frequency	637	637	kHz
Sinusoidal jitter limits for stressed receiver conformance test (min, max)	(0.05,0.15)	(0.05,0.15)	UI

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

Change the title and text of 60.5 as shown below:

60.5 Illustrative 1000BASE-PX10~~ and~~, 1000BASE-PX20, 1000BASE-PX30, and 1000BASE-PX40 channels and penalties (informative)

Illustrative power budget for 1000BASE-PX10~~ and~~, 1000BASE-PX20, 1000BASE-PX30, and 1000BASE-PX40 channels are shown in Table 60–9.

Table 60–9—Illustrative ~~1000BASE-PX10 and 1000BASE-PX20~~1000BASE-PX10, 1000BASE-PX20, 1000BASE-PX30, and 1000BASE-PX40 channel insertion loss and penalties

Description	1000BASE -PX10		1000BASE -PX20		1000BASE -PX30		1000BASE -PX40		Unit
	US[a]	DS[a]	US[a]	DS[a]	US[a]	DS[a]	US[a]	DS[a]	
Fiber Type	B1.1, B1.3 SMF				B1.1, B1.3 SMF ITU-T G.652, G.657 SMF				
Measurement wavelength for fiber	1310	1550[b]	1310	1550[b]	1310	1550[b]	1310	1550[b]	nm
Nominal distance	10		20						km
Available power budget[c]	23.0	21.0	26.0	26.0	30.4	30.0	34.~~0~~4	34.0	dB
Channel insertion loss (max)[d]	20	19.5	24	23.5	29		33		dB
Channel insertion loss (min)[e]	5		10		15		18		dB
Allocation for penalties[f]	3	1.5	2	2.5	1.4	1	1.4	1	dB
Optical return loss of ODN (min)	20								dB

[a]US stands for Upstream, DS stands for Downstream.
[b]The nominal transmit wavelength is 1490 nm.
[c]In an FEC enabled link, when not operating at the dispersion limit, the available power budget is increased by 2.5 dB.
[d]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.
[e]The power budgets for PX10, PX20, PX30, and PX40 links are such that a minimum insertion loss is assumed between transmitter and receiver. This minimum attenuation is required for PMD testing.
[f]The allocation for penalties is the difference between the available power budget and the channel insertion loss; insertion loss difference between nominal and worst case operating wavelength is considered a penalty. This allocation may be used to compensate for transmission related penalties. Further details are given in 60.7.2.

Change the title and text of 60.6 as shown below:

60.6 Jitter at TP1-4 for ~~1000BASE-PX10 and 1000BASE-PX20~~1000BASE-PX10, 1000BASE-PX20, 1000BASE-PX30, and 1000BASE-PX40 (informative)

The entries in Table 60–10 and Table 60–11 represent high-frequency jitter (above 637 kHz) and do not include low frequency jitter or wander. They are two sided (peak-to-peak) measures. Table 60–10 applies to the downstream direction (D to U) while Table 60–11 applies to the upstream direction (U to D). All values are informative.

For the 1000BASE-PX upstream jitter budget, the jitter transfer function is defined by Equation (60-2) where the value is given in Figure 60–5 when input sinusoidal jitter according to the mask defined in 58.7.11.4 and values in Table 60–5 ~~and,~~ Table 60–8, Table 60–8c, and Table 60–8e are applied to the receiver input of the ONU. Two sets of upstream jitter values are defined in Table 60–11, one set corresponds to testing the upstream link with no jitter on the downstream (jitter generation) and the other set with maximum jitter on the downstream (generated and transferred jitter).

Editorial note (to be removed prior to publication): What used to be a single paragraph is divided into two paragraphs as shown above for clarity and simpler addition of PX30 PMD in this document.

For the 1000BASE-PX30-D ~~and~~ , 1000BASE-PX30-U ~~links~~, and 1000BASE-PX40-U links, a maximum ε close to 0.095 is imposed by the middle column of Table 60–8b. If the spectral width is kept below the limits of the right hand column, ε will not exceed 0.08, and the chromatic dispersion penalty is expected to be below TBD dB when all link parameters are simultaneously at worst case values.

The chromatic dispersion penalty is a component of transmitter and dispersion penalty (TDP), which is specified in Table 60–3 ~~and~~, Table 60–6, Table 60–8a, and Table 60–8d, and described in 58.7.9.

Change the text in 60.7.10 as follows:

60.7.10 Receive sensitivity measurement

Receiver sensitivity is defined for the random pattern test frame and an ideal input signal quality with the specified extinction ratio. The measurement procedure is described in 58.7.10. The sensitivity shall be met for the bit error ratio defined in Table 60–5, Table 60–8, Table 60–8c, or Table 60–8e as appropriate.

Change the text in 60.7.11 as follows:

60.7.11 Stressed receive conformance test

If the option for stressed receiver compliance is chosen, the receiver shall meet the specified bit error ratio at the power level and signal quality defined in Table 60–5 ~~and~~, Table 60–8, Table 60–8c, and Table 60–8e as appropriate, according to the measurement procedures of 58.7.11.

Change text in 60.7.13.1 as follows:

60.7.13.1 Laser On/Off timing measurement

Ton is defined in 60.7.13.1.1, value is less than 512 ns (defined in Table 60–3~~and~~, Table 60–6, Table 60–8a, and Table 60–8d).

Treceiver_settling is defined in 60.7.13.2.1 (informative), value is less than 400 ns (defined in Table 60–5~~and~~, Table 60–8, Table 60–8c, and Table 60–8e).

Tcdr is defined in 65.3.2.1 value is less than 400 ns (defined in 60.2.2).

Tcode_group_align is defined in 36.3.2.4 value is less than 4 ten-bit code-groups.

Toff is defined in 60.7.13.1.1, value is less than 512 ns (defined in Table 60–3~~and~~, Table 60–6, Table 60–8a, and Table 60–8d).

Change text in 60.7.13.1.1 as follows:

60.7.13.1.1 Definitions

Denote Ton as the time beginning from the falling edge of the Tx_Enable line to the ONU PMD and ending at the time that the optical signal at TP2 of the ONU PMD is within 15% of its steady state parameters (average launched power, wavelength, RMS spectral width, transmitter and dispersion penalty, optical return loss tolerance, jitter, $RIN_{15}OMA$, extinction ratio and eye mask opening) as defined in Table 60–3 for 1000BASE-PX10-U ~~and~~, Table 60–6 for 1000BASE-PX20-U, Table 60–8a for 1000BASE-PX30-U, and Table 60–8d for 1000BASE-PX40-U. Ton is presented in Figure 60–7. The data transmitted may be any