IEEE 802.3av™-2009 10G-EPON and Support for Loss Budgets beyond 29dB

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Abstract: The recently approved 10G-EPON support the maximum loss budget of 29dB. Through straightforward reconfiguration of existing PMD components, 32dB loss budget can be supported (providing 1:512 split at approx. 6.4km), exceeding G.987.2 XG-PON Nominal2 class

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1. Introduction

In this paper, we discuss a potential extension to the existing 10G-EPON PMDs, defined in the IEEE 802.3av™-2009 standard, approved by IEEE SA board on the 11th of September 2009. Using the official 10G-EPON link model available on the project website, we compare the target reach versus spit ratio for existing 10/1G-EPON PMDs and the proposed PRX30+. We find that the standard 10G-EPON PMDs can support high split ratios at the commercially viable distance: 1:128 split at ~16km and 1:256 split at ~6km. The proposed PRX30+ PMD increases supported split ratio to 1:512 at ~6.4km, with further increase in the target reach for 1:256 split (~16km) and 1:128 split (~26km), making 10G-EPON inherently suited for densely populated areas and MDU type deployment.

2. Power classes in 10G-EPON

IEEE 802.3av™-2009 10G-EPON standard defines three power budget classes, i.e.: (i) **low power budget class** with Point To MultiPoint (P2MP) media Channel Insertion Loss (ChIL) of ≤ 20 dB e.g. a PON with the split ratio of at least 1:16 and the distance of at least 10 km; (ii) **medium power budget class** with P2MP media ChIL 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; and (iii) **high power budget class** with P2MP media ChIL of ≤ 29 dB e.g. a PON with the split ratio of at least 1:32 and the distance of at least 20 km.

Table 1: Target implementation of 10G-EPON OLT PMDs.

PMD type	Tx technology 10.3125 Gbit/s	Rx technology 1.25 Gbit/s
PRX30	EML, launch power +2 to +5 dBm mandatory FEC RS(255,223)	PIN + FEC / APD[1], -29.78 dBm for BER ≤ 10^{-12} optional FEC RS(255,239)
PRX20	EML + OA[2], launch power +5 to +9 dBm mandatory FEC RS(255,223)	PIN + FEC / APD[3], -27 dBm for BER ≤ 10^{-12} no FEC requirements
PRX10	EML, launch power +2 to +5 dBm mandatory FEC RS(255,223)	PIN, -24 dBm for BER ≤ 10^{-12} no FEC requirements

Table 2: Target implementation of 10G-EPON ONU PMDs.

PMD type	Tx technology 1.25 Gbit/s	Rx technology 10.3125 Gbit/s
PRX30	DML, launch power +0.6 to +5.6 dBm optional FEC RS(255,239)	APD, -28.5 dBm for BER ≤ 10^{-3} mandatory FEC RS(255,223)
PRX20	DML, launch power -1 to +4 dBm no FEC requirements	PIN, -20.5 dBm for BER ≤ 10^{-3} mandatory FEC RS(255,223)
PRX10	DML, launch power -1 to +4 dBm no FEC requirements	PIN, -20.5 dBm for BER ≤ 10^{-3} mandatory FEC RS(255,223)

[1] An APD is typically used to avoid the use of FEC in the upstream channel.
[2] Currently, such transmitters are under development and their commercial viability is yet to be proven.
[3] The APD is typically used to avoid the use of FEC in the upstream channel.

Each power budget class is represented by PRX–type power budget and PR–type power budget. A **PRX–type power budget** describes asymmetric–rate PHY for PON operating at 10 Gbit/s downstream and 1 Gbit/s upstream over a single strand of standard compliant Single Mode Fibre (SMF); and a **PR–type power budget** describes symmetric–rate PHY for PON operating at 10 Gbit/s downstream and 10 Gbit/s upstream over a single strand of SMF. Each power budget defined in IEEE 802.3av™-2009 10G-EPON standard is further identified with a numeric representation of its class, where value of 10 represents low power budget, 20 - medium power budget, and 30 - high power budget. The particular power budget classes are described in more detail in Table 1 and Table 2.

3. Support for loss budgets beyond 29dB in 10G-EPON (PRX30+)

Taking into account the availability of PMD subcomponents for 3 different power budget classes, with varied launch powers on the Tx side and sensitivity on the Rx side as well as continued evolution of low-cost, uncooled transmitters, individual components of 10G-EPON PMDs can be combined in new ways, providing support for loss budgets beyond 29dB specified for PRX30 class budgets in the IEEE 802.3av™-2009 10G-EPON standard.

3.1. Downstream link for PR(X)30+

In the downstream link, it is possible to combine PRX-D2 transmitter (Average Launch Power – ALP: +5 ÷ +9 dBm with a very modest Extinction Ratio (ER) of only 6 dB) with PRX-U3 receiver (Receiver Sensitivity (RS): -28.5dBm at BER $\leq 10^{-3}$), providing a total link budget of 33.5dB. Table 3 summarizes major optical parameters for such an extended, PRX30+ downstream link. Given a 1.5dB Transmitter Dispersion Penalty (TDP), the available link budget of 33.5dB is converted into loss budget (ChIL) of 32dB, which exceeds even the stringent requirements for Nominal2 class (ITU-T G.987.2 XG-PON1), as consented during September 2009 ITU-T plenary meeting.

Table 3: Major optical parameters for the PRX30+ power budget class, downstream link.

General		OLT				ONU		
Link budget [dB]	Loss budget [dB]	ALP (min) [dBm]	ALP (max) [dBm]	ER (min) [dB]	TDP (max) [dB]	RS(max) [dBm]	BER	Wavelength range [nm]
33.5	32	+5	+9	6	1.5	-28.5	10^{-3}	1575 – 1580

3.2. Upstream link for PRX30+

The upstream link for PRX30+ class is composed of an extended ONU PRX-U3 class transmitter (with increased launch power – ALP ranging +4 to +9 dBm) and standard 10G-EPON OLT PRX-D3 receiver (RS equal to –29.78dBm). The link is intended to operate at the data rate of 1.25Gbit/s (effective 1Gbit/s) compliant with the IEEE 802.3av™-2009 10G-EPON standard. The extended ONU transmitter, despite relatively high launch power (+4 dBm minimum) does not represent technical challenges given the low data rate as well as relaxed ER requirements, and was confirmed to be available from at least two suppliers at this time.

Table 4: Major optical parameters for the PRX30+ power budget class, upstream link.

General		OLT				ONU		
Link budget [dB]	Loss budget [dB]	ALP (min) [dBm]	ALP (max) [dBm]	ER (min) [dB]	TDP (max) [dB]	RS(max) [dBm]	BER	Wavelength range [nm]
33.78	32.78	+4	+9	6	1.0	–29.78	10^{-4}	1260 – 1360

It is proposed to decrease TDP to 1.0dB, which in this case accommodates all the transmitter induced penalties, while the dispersion related penalty is considered to be negligible given the central transmission wavelength of 1310nm, which coincides with dispersion zero for a G.652 compliant SMF. Note that despite the standard prescribed transmission window of 100 nm (1260 – 1360 nm) in practice most PRX-type ONU PMDs operate in a much more narrow transmission window (typically 1290 – 1330 nm, compliant with Reduced band for ITU-T G.984.5 recommendation), further assuring negligible impact of the dispersion induced penalty on the upstream link. Limited data rate (1.25Gbit/s) further restricts the impact of dispersion on the designed link. Given the available 33.78dB power budget and a TDP of 1.0dB, the resulting supported ChIL is equal to 32.78dB, guaranteeing additional compensation for the increased fibre loss in the target transmission window.

3.2. Target reach / split for PRX30+ and other IEEE 802.3av™-2009 10G-EPON power budget classes

Using the official EPON link model as provided in the Tools section on the official 10G-EPON website (http://www.ieee802.org/3/av/public/tools/index.html), the worst case and typical case target reach versus split ratio supported by IEEE 802.3av™-2009 10G-EPON PMDs as well as the proposed PRX30+ PMD were examined, with the results shown in Figure 1 for downstream (left) and upstream (right) channels.

The worst-case conditions correspond to the IEEE link design assumptions, where the highest fibre loss (in the given transmission direction), largest splitter loss as well as any other loss contributions were assumed. The typical conditions provide a look at respective loss contributors considering basic fibre and splitter selection process commonly performed by operators – in this case, SMF is assumed to have loss of 0.25dB/km at 1570nm and 0.33dB/km at 1310nm, with splitter loss of 22.6dB (1:128), 25.8dB (1:256) and 28.9dB (1:512). In the worst-case scenario, SMF is assumed to have loss of 0.35dB/km at 1570nm and 0.36dB/km at 1310nm, with splitter loss of 28dB (1:128), 31.2dB (1:256) and 33.6dB (1:512). Note that both 1:256 and 1:512 splitters are assumed to be multi-stage given the lack of such devices in a single-stage design. It can be observed, that the worst-case conditions confirm target split ratio / distance defined as goals for 10G-EPON PMDs (e.g. at least 20km at split ratio of at least 1:16 for PRX20 power class), while typical conditions provide substantial increase in the target reach for the same split ratio (e.g. 27.5km versus 22km for PRX20 at 1:16 split).

downstream		PRX10	PRX20	PRX30	PRX30+
	split	worst-case (distance in km)			
	1x16	11.7	23.1	37.4	46.0
	1x32	1.7	13.1	27.4	36.0
	1x64	☒	3.1	17.4	26.0
	1x128	☒	☒	☒	8.6
	1x256	☒	☒	☒	☒
	1x512	☒	☒	☒	☒
	split	typical case (distance in km)			
	1x16	24.4	40.4	60.4	72.4
	1x32	11.6	27.6	47.6	59.6
	1x64	☒	14.4	34.4	46.4
	1x128	☒	1.6	21.6	33.6
	1x256	☒	☒	8.8	20.8
	1x512	☒	☒	☒	8.4

upstream		PRX10	PRX20	PRX30	PRX30+
	split	worst-case (distance in km)			
	1x16	11.4	22.5	36.4	44.7
	1x32	1.7	12.8	26.7	35.0
	1x64	☒	3.1	16.9	25.3
	1x128	☒	☒	☒	8.3
	1x256	☒	☒	☒	☒
	1x512	☒	☒	☒	☒
	split	typical case (distance in km)			
	1x16	18.5	30.6	45.8	54.8
	1x32	8.8	20.9	36.1	45.2
	1x64	☒	10.9	26.1	35.2
	1x128	☒	1.2	16.4	25.5
	1x256	☒	☒	6.7	15.8
	1x512	☒	☒	☒	6.4

Figure 1: Worst-case and typical scenario reach vs. split ratio supported by 10G-EPON PMDs and PRX30+.

Moreover, it can be also observed that 10G-EPON PMDs support inherently high and very high split ratios, with 1:128 split factor supported by PRX30 at ~16km (typical scenario). In case of a typical deployment scenario, PRX30 supports even 1:256 split at ~7km, which still represents a viable deployment scenario for densely populated areas. The proposed PRX30+ PMD increases the potential 10G-EPON network reach, supporting 1:256 split ratio at the distance of ~16km or even 1:512 split at the distance of ~6.4km, both under typical deployment conditions.

4. Conclusions

Considering the observed increase in bandwidth demand from end-users, next generation access networks (and 10G-EPON in particular, as a precursor of the new, 10 Gbit/s enabled PON infrastructure) must support not only higher data rates but also higher split ratios or alternatively providing services at a larger distance from the Central Office of the local Service Provider. 10G-EPON PMDS standardized in IEEE 802.3av™-2009 provide support for 1:128 split at ~16km and 1:256 split at ~7km (for PRX30), though in countries with very dense population and predominant deployment of FTTB architecture, even higher split ratios are required, especially when using MDU type ONUs. The proposed PRX30+ PMD is capable of supporting either very high split ratios (1:512 at a commercially viable distance of around 6.4km) or increase the target reach at decent split ratios (e.g. ~35km at 1:64 split), meeting the requirements of primary operators with existing deployments of EPON networks and targeting migration towards 10G-EPON. Given the extra 3dB of loss budget provided by PRX30+ class PMD, an operator can also attempt to aggregate two existing 29dB loss 1G-EPON networks into a single 10G-EPON network, assuming that high quality splitters are used. In this way, it is envisioned that the proposed PRX30+ class PMD can be used both in green-field as well as brown-field scenarios. The extra cost of a new ONU transmitter is found to be negligible given that commercially available 1.25 Gbit/s components can be used off the shelf.