Triple Coexistence of G-PON, XGS-PON and 50G-PON Systems with Extended Reach

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Abstract *A real-time 50G-PON prototype is evaluated in coexistence simultaneously with G-PON and XGS-PON systems, without increasing losses in the current ODN. We also demonstrate extension of the reach of the 50G-PON by 5 km + 3dB losses, with a bidirectional in-line SOA.*

Introduction

Fibre To The Home relies in most cases on Gigabit Passive Optical Networks (G-PON) or XGS-PON technologies [1]. 50G-PON was recently published [2] to deliver 50 Gbit/s Downstream (DS) line rate and 12.5 Gbit/s, 25 Gbit/s and 50 Gbit/s options in upstream (US). Operators are facing different strategic choices regarding the future deployment of 50G-PON and reusing the Optical Distribution Network (ODN) is a necessity. Operators can choose to have coexistence of 50G-PON over the same ODN according to the US wavelength range option selected for their system. 50G-PON coexistence [3] is considered respectively with either G-PON only (if 50G-PON US band is 1260-1280 nm), or XGS-PON only (if 50G-PON US band is 1290-1310 nm) or both with the most recent option included in the standard (if 50G-PON US band is 1284-1288 nm). For the latter, a triple CoExistence (CEx) element is described in ITU-T as a passive mux/demux device inserted at the Optical Line Terminal (OLT) ports to combine each PON technology. However, this solution requires extra optical budget to support its insertion losses (~1dB) and new infrastructure in the Central Office (CO) to host the CEx devices.

As was done for G-PON / XGS-PON coexistence, Multiple PON Modules (MPM) are being developed to support triple coexistence with the integration of G-PON, XGS-PON and 50G-PON optics in a single transceiver at the OLT. Yet, operators are facing huge challenges to reduce their carbon footprint and current trends in some operators are to reduce the number of OLTs to be deployed and extend the reach and/or splitting ratio of current PONs. Deployments with higher budget classes that allow more users per PON are being considered with ODN losses reaching up to 35 dB (class D). However, for 50G-PON, it is more challenging to reach the high optical budget required to support coexistence with the currently deployed ODNs with such high losses. Nevertheless, lab demonstrations have already shown E2/D class (35dB) budgets are technically feasible for 50G-PON [4].

In this paper, we assess the performances of a 50G-PON prototype system with 2 ONUs and we demonstrate its coexistence with currently deployed PON technologies i.e., G-PON and XGS-PON. Without adding losses to the current ODN, we also evaluate extending the reach of the 50G-PON system to reduce the number of OLTs and COs equipped with 50G-PON line cards.

Experimental setup of 50G-PON system coexisting with G-PON and XGS-PON

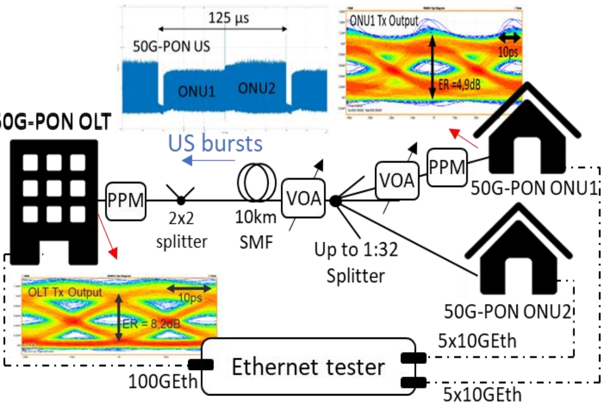

Fig. 1: Experimental setup of 50G-PON prototype

Figure 1 depicts the 50G-PON system which consists of a dedicated line card inserted in a commercial OLT shelf which supports a 100GEth uplink card to avoid traffic congestion to the fixed backhaul networks. In this PON line card, a QSFP28 50G-PON port is connected to the ODN via a 2x2 splitter followed by the 10 km ODN fibre and up to two 1:32 splitters to connect up to 64 Optical Network Units (ONUs) at the user premises. With this prototype, two 50G-PON ONUs were connected and we assessed the receivers sensitivities and optical budget with

Variable Optical Attenuators (VOAs) and PON Power Meters (PPM) added inline before the US and DS receivers. The DS wavelength is measured as 1340.9 nm with a line rate of 49.766 Gbit/s and the US wavelengths of each of the ONUs are at 1292.4 nm with a line rate of 24.883 Gbit/s, as specified in the standard (US option 1290-1310 nm). To assess the quality of the transmission, we used an Ethernet traffic tester sending 1450 bytes long Ethernet frames at both ends of the system: connecting a 100 GEth port from the tester to the 100 GEth uplink port at the OLT and connecting five 10 GEth ports to the User Network Interfaces (UNIs) at the two ONUs. The maximum total traffic load was limited mainly by the FEC and burst overhead respectively to 42.2 Gbit/s in DS and 15.9 Gbit/s in US. Figure 2 shows the US and DS optical budget measurements of the 50G-PON system, according to the Packet Error Rate (PER). With 1450 bytes long frames, we assume an error free limit when the PER $< 1.2.10^{-5}$ corresponding to a BER $< 1.10^{-9}$ [5].

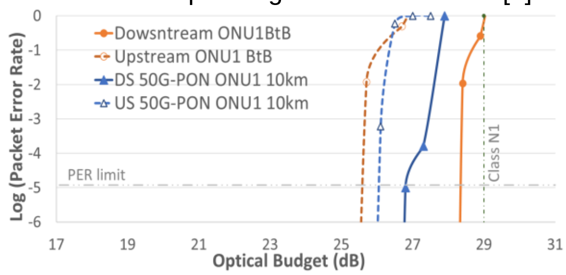

Fig. 2: 50G-PON optical budget vs PER for DS and US transmissions in BtB and after 10 km of SMF

We measured the optical budgets of this 50G-PON system as 25.5 dB and 25.6 dB in US from ONU 2 and ONU 1 respectively, and 28.4 dB in DS to ONU1 in back-to-back (BtB). After 10 km of SMF, we measured a path penalty of 1.6 dB on the DS due to chromatic dispersion at 1340.9 nm. For the US, we obtain a slightly better optical budget limit after 10 km of fibre due to negative dispersion at 1292.4 nm in conjunction with a DFB with positive chirp at the ONU. Higher optical budget should be reached with future generation of prototypes, with enhanced TDEC [6] (here estimated at 6.89 dB with our post-processing computing, corresponding Eye diagram as an inset in Figure 1) at the OLT transmitter and new generation of receivers [7].

Then, to assess the triple coexistence of PON technologies, we introduced the 50G-PON over an ODN with G-PON and XGS-PON, as depicted in Figure 3. At the OLT, G-PON and XGS-PON are transmitting from a single class C+ MPM which is connected to the 2x2 splitter at the CO. After going through the ODN with 10 km of fibre and a 1:8 splitter, the link connects to a VOA

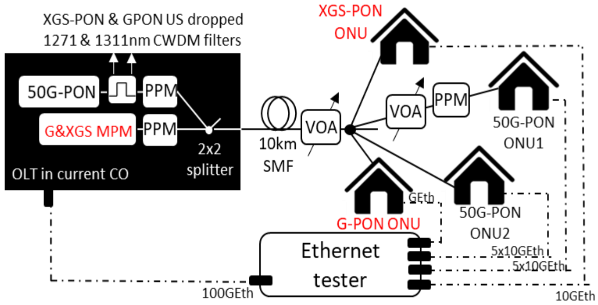

Fig. 3: Experimental setup of 50G-PON prototype assessment with G-PON and XGS-PON coexistence

before a G-PON ONU and XGS-PON ONU with respectively symmetrical 500 Mbit/s and 5 Gbit/s of Ethernet traffic.

This coexistence is possible without adding a coexistence element to the G-PON and XGS-PON link since the MPM module includes diplexers to direct G-PON and XGS-PON wavelengths to their associated receivers. As shown in [8], this diplexer is blocking the US wavelengths in a range from 1285 nm to 1300 nm, where the 50G-PON US is located. In this way, the 50G-PON is neither disturbing the US receivers of G-PON nor XGS-PON. However, to prevent the US signals from G-PON and XGS-PON disturbing the 50G-PON OLT receiver, we added CWDM drop filters (one centred at 1271 nm, followed by another centred at 1311 nm) at the optical interface of the 50G-PON OLT. At the ONUs side, internal filters block the DS wavelengths of the coexisting PONs technologies: GPON DS filter is around 1490 nm, XGS-PON one around 1577 nm and 50G-PON around 1342 nm.

Figure 4 shows the optical budget measurements according to the PER, for G-PON, XGS-PON and 50G-PON, after 10 km of transmission in SMF. We observed no penalty due to coexistence, showing no crosstalk due to wavelength overlays and proper filtering in the MPM and 50G-PON US. Optical budgets of 34.5 dB in US and 35.1 dB in DS are achieved with XGS-PON. G-PON transmissions are limited to 32.5 dB in US and 36 dB in DS. 50G-PON demonstrates the same performances seen in Fig. 2, in the case of no coexistence.

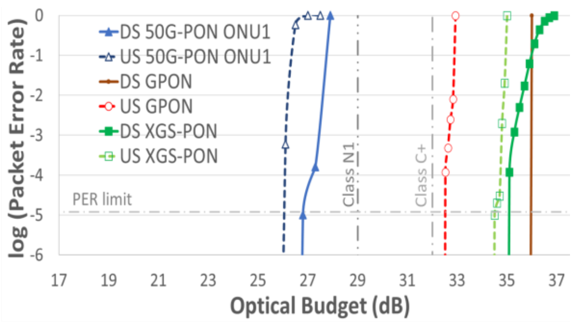

Fig. 4: Optical Budget of coexisting 50G-PON, XGS-PON and G-PON vs PER, for DS and US, after 10km of SMF

Extended reach 50G-PON with a bidirectional SOA at the CO and triple coexistence

Finally, as depicted in Figure 5, we assessed the possibility to extend the reach and optical budget of the 50G-PON by adding a single bidirectionnal SOA on the remaining branch of the 2x2 splitter at the CO side. Still with 10 km of SMF in the ODN, we measure the optical budget achieved in US and DS, from the SOA to the ONUs, with/ without coexistence of 50G-PON with G-PON and XGS-PON. In the case of triple coexistence, US and DS signals from 50G-PON are amplified to obtain enhanced link budget and US signals from G-PON and XGS-PON are also going through the SOA before being droped by the CWDM filters at the remote CO. To evaluate the possibility to place the 50G-PON OLT in a remote CO, the 50G-PON OLT is connected to the coexistence CWDM filters (2 dB total insertion losses) followed by 5 km of SMF before reaching the SOA. A longer reach extension, beyond 15km, was not possible due to a gap in the available system configuration profiles in the 50G-PON prototype at the time of testing.

The SOA, biased at 400 mA, at 25 °C has 18 dB of small signal gain at 1310 nm. It provides an output power of 10.2 dBm after amplifying the 50G-PON DS signal (1340.9 nm), with only the US signal also being transmitted in the SOA. In the case of triple coexistence, this 50G-PON DS SOA output power was reduced to 9.9 dBm due to shared amplification of four co-and-contra-propagating signals in the SOA.

Figure 6 shows the measurements results of the PER vs the 50G-PON optical budget measured on the ODN with 10 km of SMF, with/ without coexistence, and with 5 km. The DS input power at the SOA was optimized to avoid saturation of the amplifier by adding 3 dB attenuation on the extended path. For example, these 3dB could be considered as the losses from more fibre (e.g. 5 km including connectors and splices) or an extra 1x2 splitter to increase the splitting ratio of 50G-PON.

With the bidirectional amplification of the SOA, in the access path (from the SOA output to the ONU1), we can reach up to 29.3 dB of optical budget in DS, which is 1.5 dB more than without the SOA. For the US (from ONU1 to the SOA), the optical budget remains the same with / without SOA, measured at 26.3 dB but the US performance here was limited by DS losses of frames that degrades the US, due to regular PON system behavior. Similar performance is found with / without coexistence of 50G-PON with G&XGS-PON, showing good behavior of the SOA amplifying two or four wavelengths at the same time. The possible reach/budget extension is here limited by the output saturation power of the SOA. This could be improved with newer SOA designs.

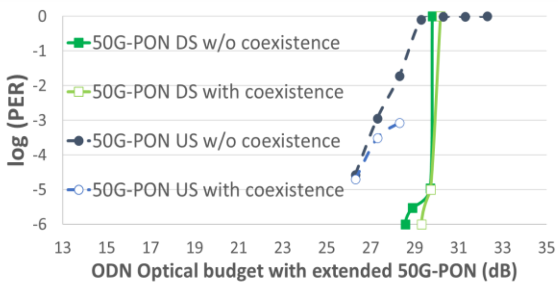

Fig. 6: Optical Budget (SOA output to ONU) of coexisting 50G-PON with 5 km reach extension, for DS and US, after 10 km of SMF. w/ and w/o coexistence with G&XGS-PON

Conclusions

We demonstrate for the first time, to our knowledge, a 50G-PON system prototype with two ONUs in triple coexistence with G-PON and XGS-PON without introducing extra losses on the current ODN. We also demonstrate for the first time with a real-time 50G-PON prototype that a single SOA can be used at the current CO location to extend the reach and the splitting ratio of 50G-PON and so place its OLT at a remote CO at least 5 km away, plus 3 dB extra loss for more extended reach or splitting ratio. In this way, operators can optimise their deployments when upgrading to the latest generation of PON.

Acknowledgments

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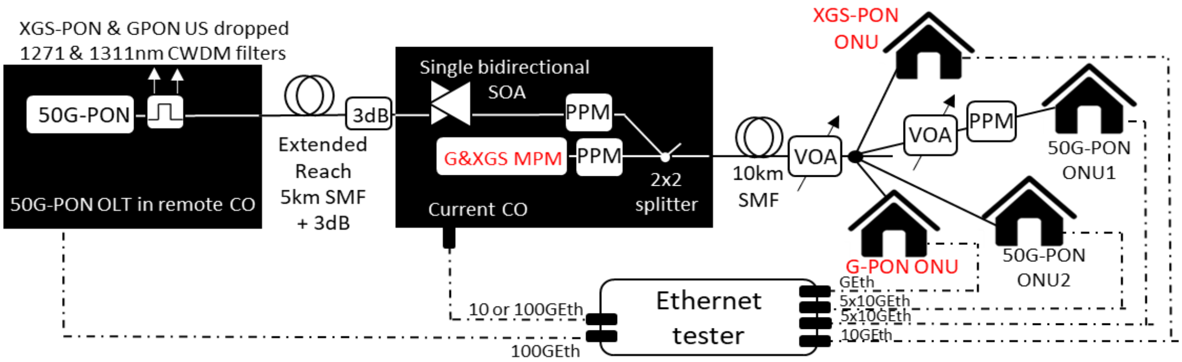

Fig. 5: Experimental setup of 50G-PON prototype coexistence with GPON and XGS-PON, where the 50G-PON OLT is located at remote CO with SOA bidirectional amplification at current CO.

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