Triple Coexistence of PON Technologies: Experimentation of G-PON, XGS-PON and 50G(S)-PON over a Class C+ ODN

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Abstract *With measurements from the field and commercial MPM modules, we demonstrate experimentally how 50G-PON upstream wavelength plan can be adopted to coexist with both G-PON and XGS-PONs. DSP free 50Gbit/s burst mode upstream is then demonstrated in overlay with 10km of fibre and -27dBm sensitivity. ©2022 The Authors*

Introduction

As it is becoming too expensive to keep running two separate networks for copper and fibre access, operators started to announce their plans to switch-off their copper networks in favor of a one and only fibre access network. In December 2021, more than 752 million users subscribed to Fibre to the Home or Building, with more than 94% with Passive Optical Networks (PON) [1]. To avoid huge re-investments for Fibre To The Home (FTTH), next generation of Passive Optical Networks (PON) technologies must be deployed over the current deployed fibre plant: XGS-PON (10G Symmetrical PON) is now being deployed in wavelength overlay with G-PON (Gigabit capable PON) thanks to an allowing wavelength plan and Class C+ (17-32 dB Optical Budget (OB)) Wavelength Division Multiplexing - Multiple PON Modules (WDM-MPM). The latter consist of integrating G-PON and XG/XGS-PON emitters and receivers, plus a wavelength multiplexer coexistence element in a single transceiver at the Optical Line Terminal (OLT) side [2]. Recently, the ITU-T has edited the physical layer of the 50G-PON recommendation of the Higher Speed PON standard [3]. It will deliver 50 Gbit/s line rate for the downstream and 12,5 Gbit/s or 25 Gbit/s for the upstream. Current discussions are still going on for specifying a bidirectional 50 Gbit/s PON that we called here after 50GS-PON, "S" for symmetrical. The wavelength plan of 50G-PON specifies a downstream carrier at 1342+/-2 nm and 3 options remain for the upstream (US): US1: 1270+/- 10 nm; US2 wideband: 1300+/-10 nm or US2 narrowband: 1300+/-2 nm defined for 25 Gbit/s only. However, US coexistence with XGS-PON will not be possible if US1 option is chosen (exact same wavelength range) and coexistence with G-PON is also at risk with 10nm or 2nm overlap of the US2 option over the G-PON's narrow band (1310+/-10 nm). If 50G-PON would adopt the same wavelength range as G-PON, coexistence of G-PON and 50G-PON with a multirate receiver (Time Division Multiplexing MPM) is also proposed [4] but would lead to very un-efficient throughput time allocation for the users. This is for the same reason why it has not been adopted already for coexistence of G-PON and XG/XGS-PON. In the end, the worst for the operators who have already deployed G-PON and XG/XGS-PON would be to be obliged to disconnect all G-PON terminations to be able to deploy and fully benefit of the 50G-PON generation over the same Optical Distribution Network (ODN).

To avoid that, in this paper, we investigate on the possibilities to realize the triple co-existence of G-PON, XGS-PON and 50G-PON. First, we exploit field data from commercially deployed G-PON Optical Network Units (ONUs) wavelength excursion and then we measure the filters included in the MPM OLT modules of 2 different vendors. Finally, we demonstrate experimentally a 50Gbit/s burst mode upstream coexisting with G-& XGS-PON in overlay over the same ODN.

Finding triple co-existence filters options

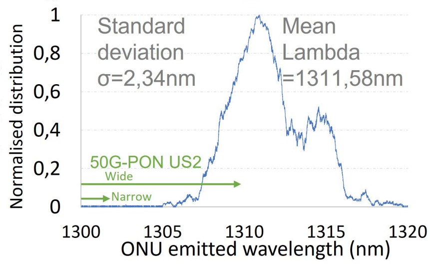

Fig. 1: Distribution of emitted wavelengths of 4180 G-PON ONUs measured on the field from 96 PON in rural area

To investigate on the best wavelength options for the 50G-PON not to disturb G-PON and XGS-PON performances, we first measured with an Optical Spectrum Analyser (20pm resolution) on the field the emitted wavelength of 4180 G-PON ONUs deployed in a medium density area connected to 3 OLTs shelves with 96 OLT active ports. Seven different vendor types of ONUs including simple ONUs and fibre gateways are referenced on these 96 ODNs. All ONUs are deployed indoor, in homes or in attached garages. Fig. 1 represents the normalized spectral distribution of the sum of the emitted US wavelengths of all the G-PON ONUs. We observe that their emitted wavelength remains between 1305 nm and 1320 nm so any 50G channel outside this window would not interfere with G-PON. For XGS-PON, no field measurement is yet possible so we can exclude by default its full emitted wavelength window (1260-1280 nm) as a possible candidate for the 50G-PON. With these measurements, we confirm that current standard 50G-PON US wavelength wideband options (1260-1280 nm or 1290-1310 nm) cannot provide triple co-existence of PON technologies. Only the narrowband US2 1298-1302 nm would be. However, if the US2 filter embedded in the transceiver is not sharp enough at its edges, there is a risk of crosstalk with G-PON ONUs emitting at least as low as 1305 nm according to our field measurements. Moreover, with such a narrow passband width allowed, high constraints will be on the emitted wavelength excursion allowed at the 50Gbit/s ONUs, thus increasing the costs at the user side with high precision temperature controllers. Other options of filters are possible to satisfy cost issues of PON access systems while permitting triple co-existence of PONs, in reusing filters designed for other applications:

- Standard Coarse WDM (CWDM) filter centered at 1291 nm and with a passband width of 13 nm: low-cost filter but with risk of crosstalk if borders of the filter are not sharp enough (its minimum at 1284.5 nm is close to the XGS US filter borders if not sharp enough as well).
- Medium WDM (MWDM) filter centered at 1294.5 nm with a passband width <7 nm. It is a low-cost filter that can reuse the production process and industrial chain of CWDM filter and provides lower the risk of crosstalk with XGS-PON US.
- Standard Local Area Network (LAN- or L-WDM) filter centered at 1295.56 nm with passband width <2.3 nm: maybe too narrow for low-cost solutions.

Thus, we believe that MWDM filters at 1294.5 nm +/-3.5 nm are good candidates to ensure triple co-existence of G-PON, XGS-PON and 50G-PON technologies over the same ODN. Figure 2 depicts a proposed scheme for a new definition of a MPM considering this US option for 50G-PON. Also, since all G-PON ONUs are emitting between 1305 nm and 1320 nm, the G-PON filter width can be reduced to 1300 to 1320 nm, corresponding to the G-PON narrow standard option (so far, reduced band (1290-1330nm) is specified in MPM by the ITU-T).

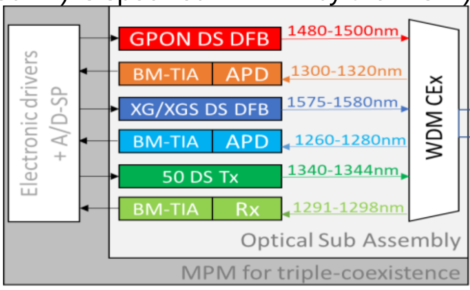

Fig. 2: Proposed scheme of MPM for triple co-existence

Experimentation of co-existence of G-PON, XGS-PON and 50G-PON

Figure 3 represents the experimental setup of a 50Gbit/s US signal of a 50G-PON coexisting with a G-PON and an XGS-PON commercial systems with an MPM at the OLT side. Since no coexistence issues related to crosstalk are expected in downstream, we focused our measurement only on the US signals.

At the OLT side, a WDM-MPM module is used to connect a G-PON ONU and a XGS-PON ONU over the same ODN. The receivers' sensitivities are exceeding Class C+ standard specifications: measured with FEC activated at -33.9 dBm for G-PON and -30.0 dBm for XGS-PON, with Ethernet traffic tests configured respectively with at 900 Mbit/s and 8 Gbit/s throughput with 1516 bytes frames.

We first measured the filters ranges of this commercially deployed MPM, testing two different modules provided by two vendors. A continuous external optical source called "alien wavelength" is injected in the ODN and is received within the filter's wavelength range of G-PON or XGS-PON receiver, to cause traffic errors if the optical filter fails to reject the alien optical signal. Fig. 4, shows the packet loss ratio measured on the US of G-&XGS-PON according to an alien source injected on the same ODN. The alien wavelength is varied from 1250 to 1350 nm. To get noticeable impact of the alien

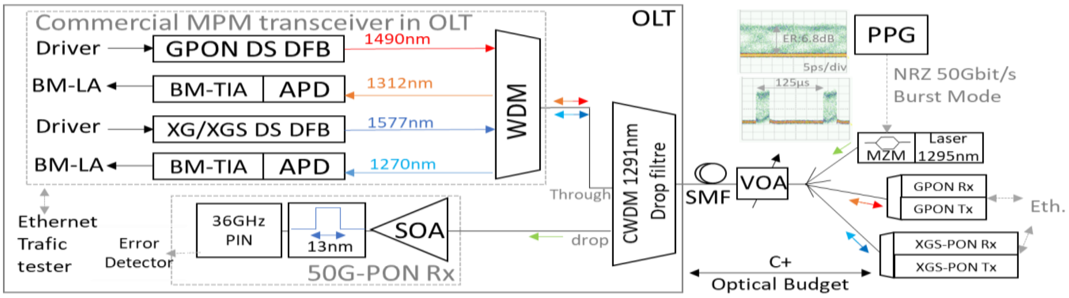

Fig. 3: Experimental setup of triple co-existence of G-PON, XGS-PON and 50G-PON upstream at 50 Gbit/s (burst mode)

source, its injected power had to be 11 dB and 16 dB higher than respectively G-PON and XGS-PON ONUs'.

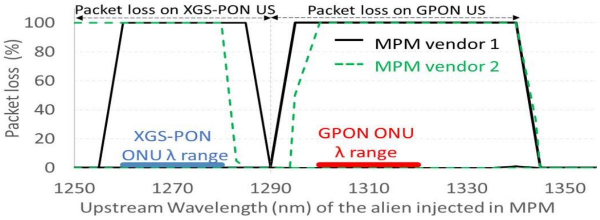

Fig. 4: G-PON and XGS-PON MPM OLT RX packet losses depending on the alien wavelength

Results show that MPM filters are wider than the permitted wavelength excursion of the ONU lasers for both technologies. Also, MPM from vendor 1 gives no wide enough open window for the 50G-US signal to coexist with this MPM without disturbing either the G-PON or XGS-PON OLT receivers. Thus, before the MPMs, we added a CWDM drop filter centered at 1291 nm, that drops the 50G-PON signal before entering the MPM and thus open a non-disturbing window between 1285.5 nm and 1297.5 nm. Then, the 50G-PON ONU can emit within this window. An Externally Modulated Laser with Distributed Feed Back-Electro Absorption Modulator would be the recommended source at the ONU for US burst mode transmission at 50Gbit/s and this have been demonstrated previously in [5]. However, lacking an EML emitting in this wavelength window, we used a 50G-PON ONU Tx consisting of a laser emitting at 1295 nm followed by a 40 GHz Mach-Zehnder Modulator (MZM). The MZM was driven by a 4 Vpp NRZ signal with a 2^{31}-1 bits long Pseudo Random Binary Sequence of data at 50 Gbit/s in burst mode. Bursts of 25 µs duration with a cycle of 125 µs were transmitted with a measured optical Extinction Ratio (ER) of 6.8 dB. At the OLT side, the 50GS-PON receiver consists of a preamplifier Semi-Conductor Optical Amplifier (SOA) [6]; It is followed by a 13 nm wide optical filter centred at 1291 nm (CWDM) to reduce the ASE noise before reception by a 36 GHz PIN photodiode. After the PIN, the 50 Gbit/s burst mode signal is sent to an error detector to measure in real time the Bit Error Rate (BER). No digital signal processing or electronic equalizer were used in this experiment.

To estimate the capabilities of such transmission in terms of receiver sensitivity, a Variable Optical Attenuator and up to 10 km fibre were inserted in the ODN. Figure 5 presents the BER results according to the optical received power at the 50G-PON receiver when G-&XGS-PON ONUs were set to 1 dB before their OLT sensitivity limits to maximize crosstalk chances. With the 50 Gbit/s burst mode transmission, in back-to-back (BTB), we measured a sensitivity of -25 dBm at the FEC threshold (BER ≤ 1.10^{-2}). With 10km of fibre reach (not displayed here), a sensitivity of -20 dBm was measured at FEC threshold. For higher measurement repeatability to precisely estimate a possible crosstalk in the transmissions, we then modulated continuously (CW) the 50G-PON US. Thus, a -27 dBm sensitivity was measured at FEC limit for 50G-PON signal alone (grey dotted line) and when coexisting with G-PON and XGS-PON ONUs (black line with square markers). According to these BER curves, no penalty is observed due the triple coexistence. Also, no impairment occurred on the G-PON and XGS-PON ethernet traffics when the 50G-PON US signal was injected in the ODN splitter. This concludes that the spectral choices for the emitter and filters ranges provided enough isolation between channels to avoid any crosstalk.

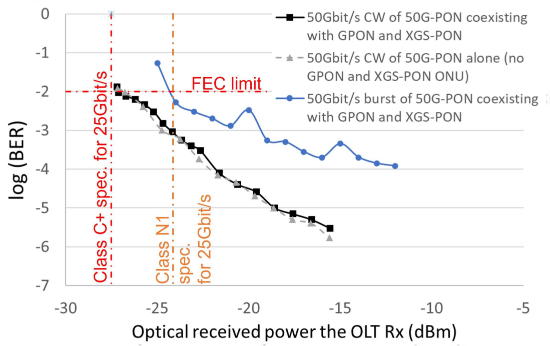

Fig.5: BER measured on the 50Gbit/s CW and burst mode upstream transmissions of 50G-PON coexisting with commercial G-PON and XGS-PON

No specification on the 50 Gbit/s US OLT sensitivity is yet edited in the standard. We expect that the receiver sensitivity will be increased by a few dBs compared to 25 Gbit/s US ones (-24.5 dBm and -27.5 dBm respectively for class N1 [14-29 dB] and class C+ [17-32 dB]). Thus, we believe that performances measured with this experimental setup with 50 Gbit/s CW and burst mode US signal, demonstrate the feasibility to reach class N1 and class C+ with the proposed receiver scheme.

Conclusions

This paper demonstrates experimentally and for the first time the possibility to have a triple coexistence of legacy PON technologies with 50GS-PON over deployed ODN with class N1 and C+ optical budgets. A new MPM scheme with an appropriate wavelength plan is proposed for the 50G-PON upstream option (1291-1298 nm) to allow this triple coexistence with existing low-cost filters technologies based on CWDM or MWDM standards.

Acknowledgements

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