Cascaded Passive Optical Networks for Access and Every Room in the Office and Impact of Alien Point to Point

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Abstract *This paper presents latency and jitter results of cascaded regular Passive Optical Network to serve consecutively access and several rooms in the office. We also consider the impact of the wavelength and optical power of an alien Point to Point source on PON transmission. ©2023 The Author(s)*

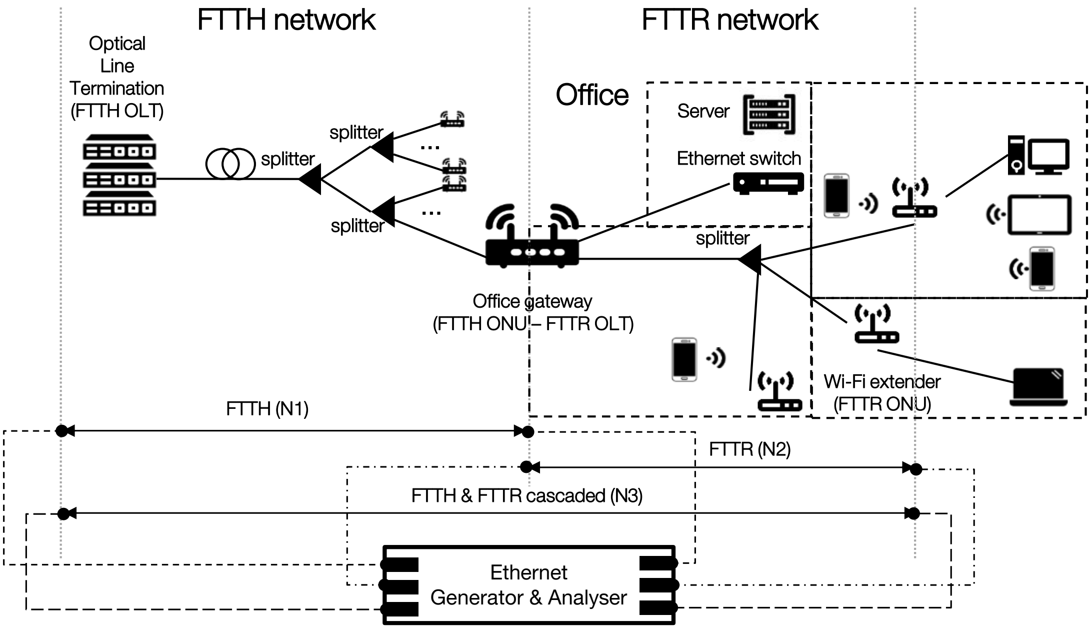

Fig. 1: Architecture of the experimental setup of two cascaded PONs for FTTH and FTTR.

Introduction

Passive Optical Network (PON) is now a mature technology to serve Fiber To The Home (FTTH). This technical and market maturity for G-PON (Gigabit-capable PON) and in progress for XGS-PON (10-Gigabit-capable symmetric PON) allow to address other network segments. The campus offices are one of this “new” [1-7] networks for which it makes sense to use PON. The topology of office network is based on “N” terminations with several Wi-Fi (Wireless Fidelity) access points or other radio or fixed local network interfaces, all connected to a single enclosure which host the single FTTH termination, with the ONU (Optical Network Unit) close (or even inside) the enterprise gateway. This “1 to N” topology, the feasibility to address Gigabit/s or higher throughputs and the need to have dynamic bandwidth allocation at the end points in function of enterprise usages, are the main drivers for FTTR (Fiber To The Room) [8-10]. It can be based on PON technology working with TDM (Time Division Multiplexing) and TDMA (Time Division Multiple Access) for downstream and upstream respectively.

In this context, there are two cascaded PONs to serve consecutively access and the local networks to serve the office rooms. In the first section, we present experimental results of latency and jitter based on the cascaded G-PON set up. Latency and jitter traffic performances are keys to support the newer generation Tactile Internet. This Tactile Internet will allow to control and steer real and/or virtual objects through the broadband with ultra-low round-trip latency and jitter [11]. In the second section, we consider the business office context that could support Point to Point (PtP) and PON interfaces. The wrong connection of a PtP transceiver to the PON network provides an unexpected optical signal in upstream. We consider wavelength and optical power of this troublesome signal.

Latency and Jitter for cascaded G-PON

As Fig.1 shows, the experiment setup is based on two cascaded PONs. This architecture

Tab. 1: Downstream latency and jitter experimental measurements of Ethernet traffic

Downstream	Latency (µs)			Jitter (µs)		
	Average	Minimum	Maximum	Average	Minimum	Maximum
FTTH only (N1)	24.17	23.57	28.45	0.09	0	3.87
FTTR only (N2)	23.64	22.01	24.23	0.21	0	1.84
FTTH & FTTR cascaded (N3)	40.19	38.24	51.34	0.24	0	3.81

Tab. 2: Upstream latency and jitter experimental measurements of Ethernet traffic

Upstream	Latency (µs)			Jitter (µs)		
	Average	Minimum	Maximum	Average	Minimum	Maximum
FTTH only (N1)	82.01	26.65	391.86	36.78	0	348.28
FTTR only (N2)	106.7	19.03	455.66	35.75	0	230.52
FTTH & FTTR cascaded (N3)	170.05	39.38	590.34	36.96	0	348.36

corresponds to the location of a FTTH OLT (Optical Line Terminal) at the central office and a FTTH ONU inside the office gateway which also includes the FTTR OLT. The office gateway has two optical ports and the full stacks to support the PMD (Physical Media Dependent) and TC (Transmission Convergence) layers for ONU and OLT functions. The FTTR ONU and Wi-Fi extender is a single equipment 12, 13] localised at the extremity of the local network. In this setup, the fiber reach are < 1 km (capable to support 20 km) for FTTH network with 64 splitting ratio and 100 m for FTTR network with 1:4 splitting ratio. Table 1 and 2 present the experimental one-way latency and packet jitter measurements for downstream and upstream for the three networks segments: FTTH only (between FTTH OLT and ONU gateway, named N1), FTTR only (between FTTR OLT gateway and ONU Wi-Fi extender, named N2), the cascaded FTTH & FTTR (between FTTH OLT and FTTR ONU Wi-Fi extender, named N3). For all these measurements, we use an Ethernet generator and analyzer connected at the wired interfaces of the PON equipment. For FTTH and FTTR upstream PONs, we use a configuration with a DT (Delay Tolerance) of 1 (125 µs long cycle) and 100 Mbit/s T-CONT (Transmission-CONTainer) type 1 ("fixed"). The main conclusion of this experimental section is that the end-to-end latency and jitter of the cascaded PON correspond to the sum of both FTTH and FTTR PONs.

Now, we propose to compare these latency and jitter values with WiFi performance. The new Wi-Fi generations improve the latency with OFDMA preamble puncturing features (Wi-Fi6) and Multi-Link operation (Wi-Fi7). The typical latency and jitter average values with several (about 10's) connected Wi-Fi devices, is about 10 to 50 ms and <20 ms, respectively. The combination in cascaded mode of FTTH and FTTR is the ideal companion of Wi-Fi with a negligeable jitter and latency contributions.

Impact of alien optical Point to Point (PtP)

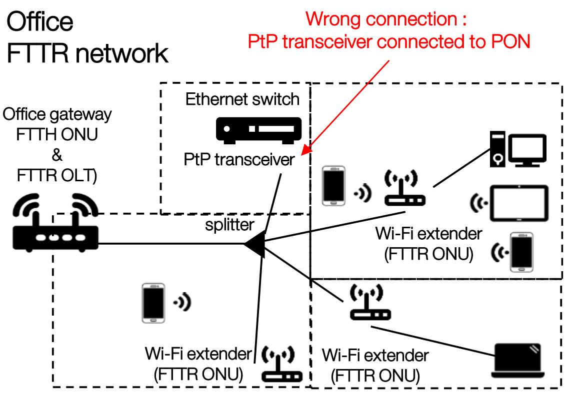

Fig. 2: Alien PtP transceiver on FTTR infrastructure.

ONUs

Business offices could support different optical interfaces in their local networks. A wrong connection of a PtP optical transceiver to the FTTR infrastructure could impact, in function of the wavelength and optical power, the OLT receiver. To investigate this alien behaviour, we consider the PtP bidirectional single fiber parameters for several line rate (cf. Table 3) [15]. We use PtP transceivers working at 1270, 1290, 1310 and 1330 nm. These transceivers transmit an Ethernet signal (Idle frame). Figure 3 shows the shape of the optical filter at the OLT receiver. This shape confirms the sensibility of these PtP wavelengths. We assess the impact of this alien

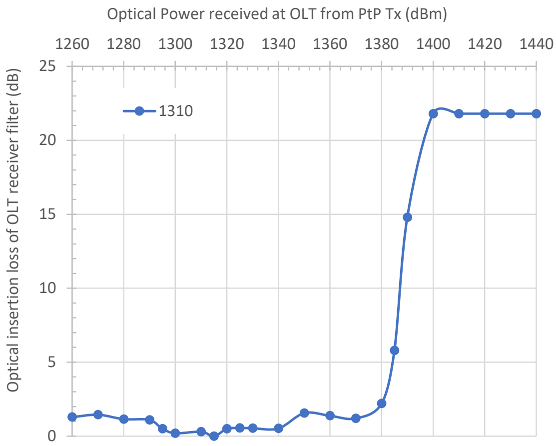

Fig. 3: Wavelength filter shape at the OLT receiver

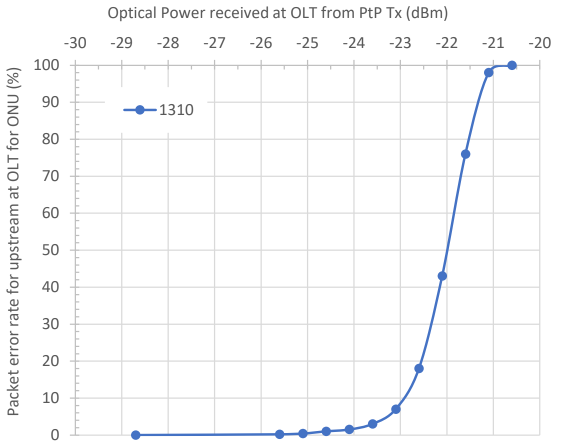

Fig. 4: Upstream Packet Error Rate of an PON ONU working at -30dBm at OLT in function of the optical power received at OLT by a 1310 nm PtP alien

PtP signal measuring the Packet Error Rate (PER) for the upstream link between PON ONU and OLT. Figure 4 shows the degradation of the PER in function of the optical power received at OLT by the PtP transceiver at 1310 nm.

It is considered that a range of 4dB causes a degradation of the PER which is finalized by the disconnection of the ONU. We are not considering, in this paper, the impact of alien PtP signal during the quiet window for ranging new FTTR ONU.

The Figure 5 shows, for each PtP wavelength, the maximum optical power supported from several alien PtP signal wavelengths measured at the OLT receiver in function of the optical power received at OLT from the regular ONU. If we consider a 1Gbit/s PtP transceiver working at 1310 nm with an optical output power of 0 dBm connected to the OLT through 15 dB optical attenuation, we notice no upstream traffic degradation on the FTTR ONU, which upstream optical signal detected at OLT reached a level higher than -21 dBm. The minimal mean launched power of a G-PON ONU is +0.5 dBm.

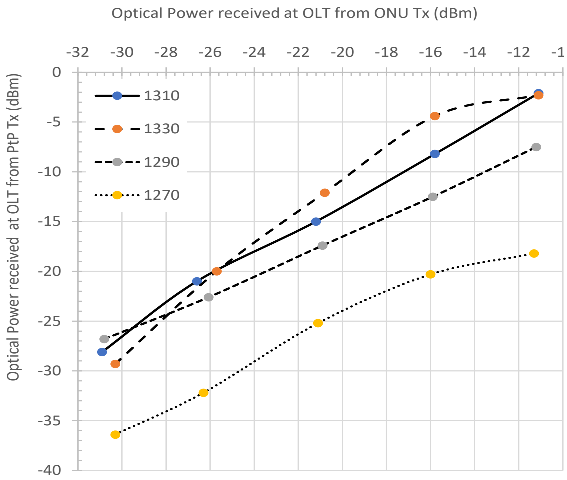

Fig. 5: Optical power threshold **of O**NU before a PER degradation by an alien PtP wavelength in function of optical power received at OLT from the ONU Tx and the PtP Tx**.**

So, the supported optical budget for an FTTR ONU is about 21.5 dB. In conclusion, if the fiber PON infrastructure is based on an equal splitter loss (we could consider an equal optical budget for PtP alien and regular FTTR ONU), we have no critical behaviour for connected FTTR ONUs from a ONU PtP. Now, if the fiber infrastructure is based on chained asymmetrical optical splitters, we could have critical behaviour.

Tab. 3: PtP wavelength and maximum output power in function of the line rate for bidirectional single fiber transmission following ITU-T recommendations

Line rate (Gb/s)	**Wavelength** (nm)	**Max. Output power** (dBm)	
		Class S	**Class B**
1	1310 / 1490	0	+4
10	1330 / 1270	-5.6	+4
25	1314 / 1289	0	+8
50	1314 / 1289	+3.6	+11.6

Conclusions

We showed that the upstream and downstream performances of a system composed of two cascaded PONs, in terms of latency (40 and 170 µs) and jitter (<1 and 37µs), corresponds to the accumulation of both FTTH and FTTR PONs which are compliant with ultra-low round-trip latency bellow 1 ms and jitter bellow 0.5ms, suitable for tactile internet requirements.

The impact of an alien optical PtP is also considered on the FTTR operation. We conclude that it is preferred to have a fiber infrastructure with symmetric splitter losses to avoid potential PtP alien perturbation.

Acknowledgements

This work was carried out in 5G-COMPLETE H2020-ICT-2019 and MARSAL H2020-ICT-52 projects.

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