Performance study of a coexistence system in a PON network taking into account the stimulated scattering of Raman

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Abstract. Some problems introduced by the need for coexistence between a Passive Optical Network PON technologies (GPON, XGS-PON, and NG-PON2 in particular) especially the Stimulated Raman Scattering SRS which appears when different PON technologies transfer undesirable powers between them. And in order to reduce the investment cost of the PON network including optical fibers, multiplexers, distributors, cabinets, ...etc, and to meet the needs in terms of speed and new services such as: video on demand, high-definition television. The coexistence system is the privileged. In this paper, we will evaluate the performance of the following systems: GPON, XGS-PON, RF-video and NG-PON2 PtP with comparison and optimization in terms of bit error rate BER and Q factor taking into account the effect of Raman SRS. By varying the laser power from -10 dBm up to 10 dBm as well as the fiber lengths from 5 km up to 40 km while maintaining the best performance.

Keywords: GPON; SRS; WDM; CEx; Q factor; XGS-PON; NG-PON2; PtP; performances; BER.

1 Introduction

The growing demand for integrated voice, data and video services has paved the way for the development of new transmission techniques with the ultimate goal of realizing a broadband access network. Passive optical networks PON are one of the alternatives offered to telecommunications operators, they allow the delivery of high-speed interactive services to the home. These networks were considered to be the most economical solution with the introduction of optical fiber in the access networks. NG-PON2 PtP WDM technology has been designed to meet the increasing demand for throughput, it enables symmetrical downstream and upstream bit rate of 40 Gbps [1], while GPON and XGS-PON operate on a time division multiplexing TDM and only offer 10 Gbps in both directions [2]. In order to avoid the switch from one technology to another, these should be able to coexist on the same fiber optic network as well as the RF-video cable television (see Fig.1) [3]. In the coexistence model, the NG-PON2 ONT of new clients need only be connected to the ODN and can coexist with the existing ONT. In order to tune to individual wavelengths (up to 8 of them) the NG-PON2 ONT use tunable transceivers, while a tuning mechanism on the OLT configures the lengths of the wavelengths ONT [4]. The coexistence of the GPON system, XGS-PON and the NG-PON2 PtP-WDM is done by a Coexistence Element (CEx). The CEx allows the convergence of several services on a common access network, allowing flexibility while reducing costs (see Fig.2) [5].

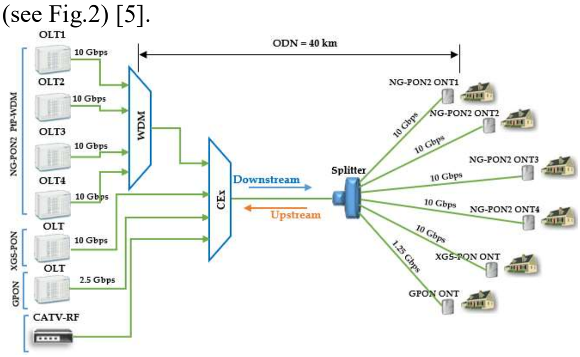

Fig. 1. Coexistence model of the GPON, XGS-PON, NG-PON2 PtP-WDM and RF-video system.

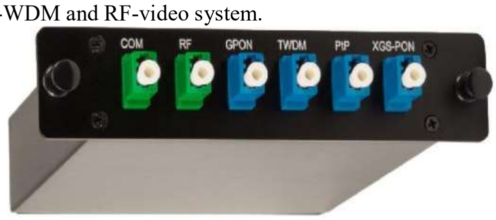

Fig. 2. Coexistence Element (CEx).

This paper is structured as follows: first, we review the characteristics of each technology, then we contribute to the design of a coexistence model for the PON network

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over a distance of 40 km, then we will interpret the results found, we end with a conclusion.

2 Types of PON Services

The PON is a network that transports data in the optical domain between the OLT and the ONU where the optical signal transport path is passive. Several services are available on the same optical medium, namely : video on demand, voice, data and high-definition television. Figure 3 shows the different standards of the PON network used
in our paper.

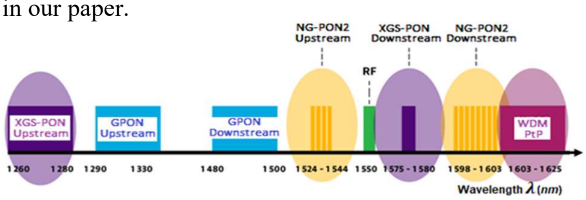

Fig. 3. PON networks standards.

2.1 GPON

GPON is an approach of the PON network, it belongs to the ITU-T G.984.x standard. It uses a downstream wavelength of 1490 nm and an upstream wavelength of 1310 nm to transmit data and voice. For television distribution (only in the downstream direction) a wavelength of 1550 nm is used. This system uses a downstream bit rate of 2.5 Gbps and 1.25 Gbps upstream. GPON system packets handle ATM packets that use the encapsulation method to carry other protocols (Ethernet, IP, TCP, UDP, T1 / E1, video, VoIP). GPON encryption is AES (Advanced Encryption Standard) for securing data downstream from the OLT to the ONU. GPON generally practices wavelength division multiplexing (WDM), it consists of an OLT, an ONU and a splitter of at most 1:128 ie. it can reach a maximum of 128 ONU. It uses TDMA (Time Division Multiple Access) in the upstream direction from the ONU to the OLT in order to avoid what are called (collisions between transmissions) [6]. The attenuation between the ONU and the OLT is specified in the ITU-T G.982 standard in three classes [7]: Class A (20 dB), Class B (25 dB), Class C (30 dB).

2.2 XGS-PON

XGS-PON is a similar approach to XG-PON, it was developed in 2016 under ITUT G.9807.1 standard, it is a symmetrical version of higher bandwidth GPON. Its first large-scale deployment was in 2018, with symmetrical downstream and upstream bit rate of 10 Gbps. Its downstream wavelength is 1577 nm (1575 nm-1580 nm) and upstream is 1270 nm (1260 nm-1280 nm) to transmit data and voice. It takes advantage of TDM in the downstream direction from the OLT to the ONU and TDMA in the upstream direction from the ONU to the OLT. It can reach a maximum of 256 ONU with a distance from the ODN of 100 km. The XGS-PON operates on ODN at a nominal loss of 28/29 dB [8].

2.3 NG-PON2 PtP

The NG-PON2 was developed in 2015 by the FSAN group (Full-Service Access Network) under the ITU-T G.989 standard [9]. It uses WDM wavelength multiplexing in the case of PtP (Point-to-Point) topology. This standard has a symmetrical downstream and upstream bit rate of 40 Gbps, and it uses between 4-8 wavelengths in both directions. Table 1, shows the downstream and upstream wavelengths for data and voice transmission [9].

Table 1. Downstream and upstream wavelengths.

NG-PON2 PtP-WDM	
Wavelength (Down)	1603 nm -1625 nm (shared)
Wavelength (Up)	1524 nm -1625 nm (full)

The attenuation between the ONU and the OLT is given for four categories according to the ITU-T G.989.2 (08/2019) standard [10] : Class N1 (14/29 dB), Class N2 (16/31 dB), Class E1 (18/33 dB), Class E2 (20/35 dB). The NG-PON2, can reach 64 ONU with a maximum distance of 40 km from ODN (Optical Distribution Network).

2.4 RF-Video

RF television signals (analog or digital) can be broadcast over a PON network by being modulated to a single optical wavelength, typically 1550 nm [11].

3 Simulations and Results

In this part, we will evaluate the performance of the overall system with the coexistence of four systems namely the NG-PON2 PtP-WDM, the XGS-PON, the GPON and the RF-Video for different bit rates in the downstream and upstream, at different SMF fiber lengths ranging from 5 km up to 40 km, at laser powers ranging from -10 dBm up to 10 dBm, taking into account the non-linear phenomenon known as stimulated Raman scattering (SRS) [12]. The Raman effect appears when different PON technologies transfer unwanted powers between them [13]. NG-PON2 PtP transmitters require high optical power to meet optical budget recommendations. On the other hand, the four-wave mixing (FWM) does not affect the system because the spacing wavelength between the GPON and the NG-PON2 is of the order of 100 nm [14]. The parameters of the overall system are shown in Table 2.

Table 2. Simulation parameters.

Parameters	Coexistence system		
	NG-PON2 PtP WDM	XGS-PON	GPON
Bite rate (down/up)	40/40 Gbps	10/10 Gbps	2.5/1.25 Gbps
Power	-10, -5, 0, 5, 10 dBm	-10, -5, 0, 5, 10 dBm	-10, -5, 0, 5, 10 dBm

Pulse generators	NRZ	NRZ	NRZ
SMF Length	5, 10, 15, 20, 25, 30, 35, 40 km	5, 10, 15, 20, 25, 30, 35, 40 km	5, 10, 15, 20, 25, 30, 35, 40 km
Number of users	4	1	1
Chromatic dispersion	17 ps/nm/km	17 ps/nm/km	17 ps/nm/km
PMD dispersion	0.5 ps/km$^{1/2}$	0.5 ps/km$^{1/2}$	0.5 ps/km$^{1/2}$
Attenuation	0.25 dB/km	0.25 dB/km	0.25 dB/km
EDFA gain	17 dB.	17 dB.	17 dB.
Wavelength down	1603 nm - 1625 nm (shared)	1577 nm.	1490 nm.
Wavelength up	1524 nm - 1625 nm (full)	1270 nm.	1310 nm.
Video (broadcast)	1550 nm.		

3.1 Impact of link length

From Figures 4 and 5 for a transmission power of 0 dBm, we see that the coexistence system has been successfully evaluated over a distance of 5 up to 40 km in both directions of transmission. This system has better consistency in terms of performance. However, the performance of the system begins to deteriorate beyond a distance of 40 km with an average value of the quality factor equal to 8.78.

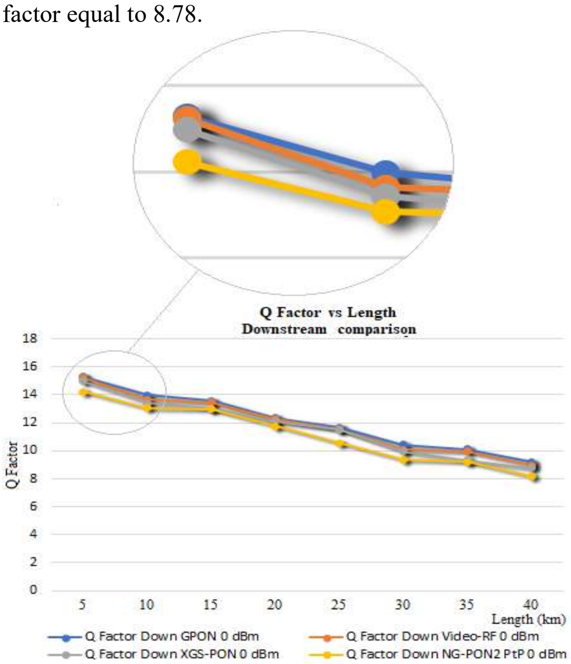

Fig. 4. Q factor vs length (downstream comparison) at 0 dBm power laser.

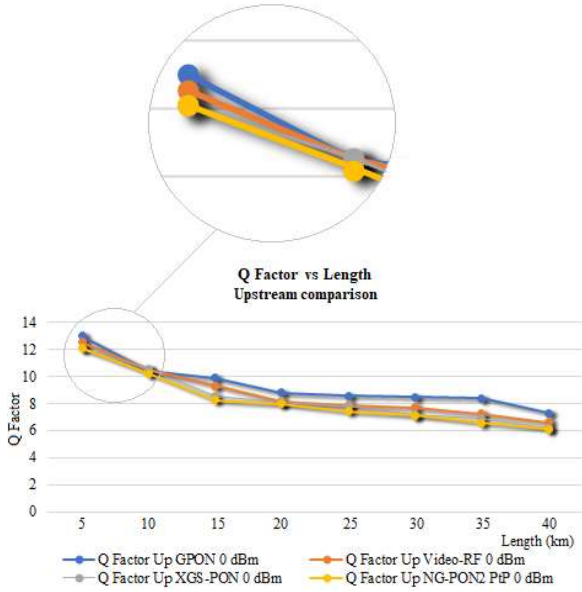

Fig. 5. Q factor vs length (upstream comparison) at 0 dBm power laser.

For Figures 6 and 7, the results in terms of BER are consistent and conclusive during all the different lengths of the optical fiber with a fixed power equal to 0 dBm.

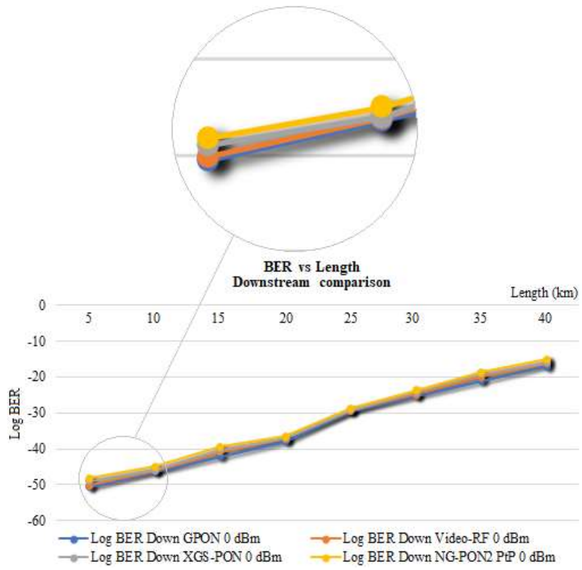

Fig. 6. BER vs length (downstream comparison) at 0 dBm power laser.

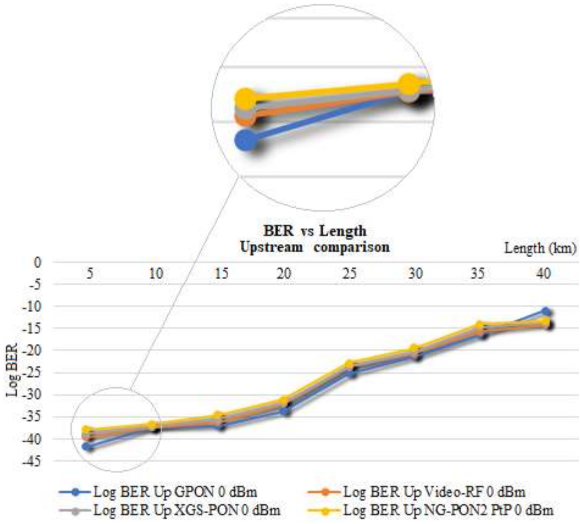

Fig. 7. BER vs length (upstream comparison) at 0 dBm power laser.

3.2 Impact of laser power

Figures 8 and 9 show that an increase in the emission power of the laser results in an increase in the quality factor Q. However this increase does not seem as good in the absence of the coexistence or the power is not the same for all technologies. This is due to the Raman effect because the SRS decreases the emission power of the laser while the NG-PON2 PtP system is very power hungry. It should also be noted that the minimum value of the overall system power is fixed at -5 dBm with an average value of the quality factor equal to 6.

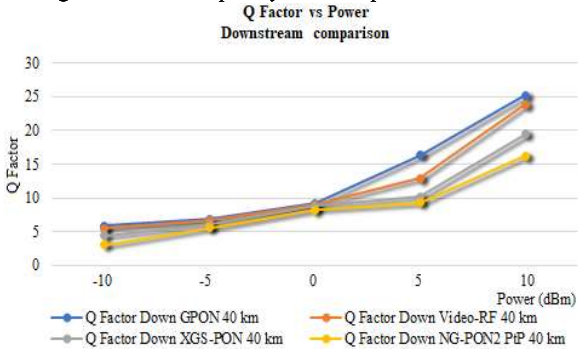

Fig. 8. Q Factor vs power (downstream comparison) at 40 km.

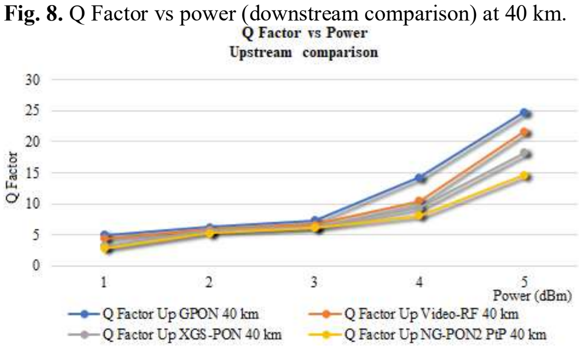

Fig. 9. Q Factor vs power (upstream comparison) at 40 km.

4 Conclusion

In this work, we first studied the global coexistence system namely GPON, XGS-PON, RF-video and NG-PON2 PtP-WDM taking into account the Stimulated Raman Scattering SRS, the link length as well as the emission power of the laser, we found following a performance comparison of each technology that the GPON seems better compared to other techniques over a maximum length equal to 40 km with consistency and convergence in terms of performance towards the others techniques. We have also observed on the whole system by assigning the same power value for all the technologies that the minimum value of the overall power of the system is fixed at -5 dBm with an average value of the Q factor equal to 6. All the technologies admit a point-to-point connection and do not require access controllers in the upstream direction unlike the TDM-PON network.

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