Evaluating Characteristics of 2.5 Gbps GPON using Various Distance and Wavelength

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Abstract. In this paper, a discussion has been made to analysis the performance of a Gigabyte Passive Optical Network (GPON) receiver for various distances and wavelengths with a constant power equal to 5 dB in a system having four users on the transmitter side and four in the destination. We will measure the Q-factor for four wavelengths downlink Optical-receiver to decide which wavelength has the best performance and cover the longest distance. Among the two data format, we used Return to Zero (RZ) and Non-Return to Zero (NRZ). Then prove how RZ gives higher effectiveness in the contrast to NRZ and longer distance to cover specialty the wavelength (1310) followed with (1270) that it could reach 60 km with Q-factor (7.48) and (6.77) respectively.

1. Introduction
A Passive Optical Network (PON) technology was presented in the middle 90s [1]. This led to making here an important role in revolutionizing communication world technologies as one of the most powerful access technology [2]. Therefore, it is considered a network design that brings fiber to the house using a point to multipoint, so one fiber can serve multiple premises [3].

PON has no active parts between the main office and client, as shown in Figure. 1 [4]. Passive instrumentation installed between the Optical Line Terminal (OLT) and Optical Network Unit (ONU) and does not required any power. It guides the traffic signals inside specific optical wavelengths. Voice, video and knowledge traffic [5].
There are many other techniques in passive optical networks that give the signal to the house. One of them is GPON that provides higher resource usage with lower cost, lower maintenance requirements and more bandwidth delivered more efficiently [7].

GPON has a capability of 2.488 Gbps for downstream and a capability of 1.244 Gbps for upstream distribution among users. One of the major topologies that makes the GPON special is star topology because it gave him a significant performance for access the fiber network [8,9].

PON design has three main parts: OLT, located in the Central Office (CO). The second part is the Optical Distribute Network (ODN), representing the fiber distribution network. It conjointly features a most split quantitative relation of about 1:128. And finally, the third part ONU, which located in the user premises or near to it. A typical deployed split issue is 1:32, a result of a trade-off between the distance from the house and, therefore, the splitter, and then the range of homes passed. GPON has a protocol that allows the road terminal to overlap every packet’s idle time interval [10]. Transmissions with the virtual polling cycle to extend the effective information measure. It uses time-division multiplexing to send knowledge packets onto the network, and therefore, the total bandwidth is shared victimization Dynamic Bandwidth Allocation (DBA) protocol [11].

Below a related work shows the problems that happening to the GPON system among the last 12 years and how our design solves these problems

- In 2008 Sang Hyun Parka Mikko Karppinenb Quan Lec Bin YoungYoon : Proposed a new GPON ONU that successfully shows the 2.5-Gb/s GPON has fast timing characteristics equal to 2.17 nsec for Transmitter enable stage and 1.17 ns for Transmitter disable stage that known as the first burst-mode transmitter.
- In 2012 Kwang-OkKimab Jie-HyunLeea Sang-Soo Leea Youn-Seon Jangb: propose a hybrid PON system to support a 128-way split with 2.5 Gb/s per single wavelength channel over a 50 km transmission distance. This system can please the downstream and upstream transmission Packet Loss Ratio (PLR) of 10 e−10, including forwarding error correction (FEC).
- In 2014 Anu Merciana Michael P.Mc Garryb1Martin Reisslein: propose s a new PONs system that improve the use of DBA and reduces channel idle time and thus gives substantial reductions at high loads in this mean packet delay.
- In 2016 Yubao Wangab Zhaohui ZhucLu Wangab Jian Bai: Proposed a new GPON-oriented system that can work in some harsh environments to sense data digitalization. the system can achieve remote optical communication networks monitoring utilizing fiber grating sensing
- In 2016 I-Ju Chena Chang-Chia Chia Chen-Wen Tarn: support multiple optical wavelengths like 1650 nm, 1610 nm, 1550 nm, 1490 nm and 1310 nm by utilizing diffractive grating elements to gather with Gradient-Index (GRIN) lens to produce a special design that has the advantages of high efficiency and low cost.
- In 2017 Yuchao Zhang Chaoqin Gan Kaiyu Gou Jian Hua: proposed Virtual Private Optical Network (VPONs) with two various standards, that is appropriate with the multi-standard

**Figure 1. Basic PON Configuration [6].**
management structure. To transmit GPON frames in the same wavelength, this design makes
the GPON allocate bandwidth sub-networks fairly.

The first part of the paper was the introduction that we present a simple background of the PON in
general and the GPON in particular, and then was moved in the second part to talk about the properties
of the GPON in details, after that in the third part we briefly explain the tools and materials that we
need to design and build an integrated pocket system. Then, in the fourth part, the results that appeared
in the design of the system were demonstrated under the influence of variables distance and
wavelength, and finally in the fifth part show our analysis conclusions from these variables.

2. GPON Characteristics

2.1. GPON in General

GPON recognized by International Telecommunication Union (ITU) as recommendation series
G.984.1 to G.984.4, which appears common characteristics. It also has the ability to grow with a co-
existing system unlike ATM PON (APON) and Broadband PON (BPON). Using GPON encapsulating
method (GEM) allows us to transmit Ethernet and TDM and ATM. The major feature of the GPON
standard are [12]:

- GPON protocol backing three-player service in addition to many data rate choices that deploy
  in the identical protocol.
- A very good abilities in Operation, Administration, Maintenance and Provision (OAM&P),
  especially with end-to-end services
- Duo to PON multicast, quality, a high-Security transmission is available in the downstream
  protocol standard. The working wavelength range in GPON for upstream is 1260-1360 nm,
  and the downstream signal is 1480-1500 nm signal
- Covered area at minimum 20 km, with backing for reasonable distances up to 60 km, With
  best circumstance GPON can present 1.2 Gbps in the upstream direction and 2.4 Gbps in
  downstream. Figure 2 illustrates GPON Architecture [13].

![Figure 2. GPON Architecture](image-url)
To disassemble upstream / downstream signals of several connectors through a single fiber, GPON embraces two multiplexing techniques used:

- OLT broadcasts Downstream traffic signals to all ONUs. Each one of these operate the traffic, which is allocated to it over an address included in the beginning of the Protocol Data Unit (PDU), the OLT multiplexes GEM frames onto the transmission medium by using the GEM Port ID as an electronic key to distinguish the GEM frames that own by various downstream logical links. Each ONU insulates the downstream GEM frames depending on their GEM Port IDs and work only with the GEM frames that belong to that ONU [15].

- Upstream traffic utilizes Time Division Multiple Access (TDMA) techniques. the time slots allocated by OLT, which has the management used for every ONU to synchronize the data transfer. The bandwidth allocated to each ONU may be static or dynamically [16].

2.2. Protection in GPON

By boosting the accuracy of the entered, GPON , design protection will increase. despite that and due to achievement, building on the understanding of economic system protection is treated as an optional technique. Protection switching is divided into two types:

- Automatic switching is launched by discovering the fault in the signal such as the disappearance of the signal, absence of the pack frame signal and many other regions.

- Forced switching: This is happening with managerial proceedings, such as fiber redirecting and fiber change.

2.3. Error Rates

Through to distortion, noise or interference. The BER represents the numeral of bit errors to the numeral of incoming bits in any telecommunication system. In the transmission of any system, analyzing the output is done Depending on an essential parameter that makes a comparison between the bits that have errors to the whole number of bits without error received in a transmission side we called it the Bit Error Rate (BER). So the BER indicates how should data transmit over any system and facing all kinds of Causes of error effect because BER can be used to describe the effectiveness of telecommunication system, for a standard distance from 10^-9 to 10^-12 depending on the sensitivity of the receiver and the wavelength used [17,18].

2.4. Eye Diagram

All common superposition bits in the signal explain the overlapping of The Eye diagram that is displayed in the BER analyzer. The Eye-opening represents the various of the logic 0 from the logic 1 in the shape of the received signal. As much as the Eye is mostly wide open, the bigger the various is so we can recognize the 1 from 0 easily on the receiver side; due to this it is best signal to noise ratio. There are other legible things from this diagram Inter-Symbol Interference (ISI) can be read. Figure. 3 illustrates the interpretation of the eye diagram [19].

Figure 3. Eye Diagram Interpretation [19].
2.5. Q-Factor
The Q factor, also known as the quality factor represents the absence in the signal’s energy. The maximum Q factor has less loss of energy. Q-factor is a convenient measure of overall system quality provided when two SNRs may be mutual into a single size. There is two signal standards in binary DCS and each of these signal standards probably has a diverse medium noise linked with it. This led to two discrete signal-to-noise ratios one of them is electrical SNR and the second one is optical SNR; in order to Figure out all the eventualities of bit error, we should calculate both the signal-to-noise ratios. Figure. 4 illustrates the relationship between Q factor and bit error rate [20,21].

![Figure 4. BER versus the Q Parameter [21].](image)

3. Material and Method

3.1. OLT
The transmitter side mainly consists of Pseudo-Random Bit Sequence Generator (PRBS) which is designed to generate random data that is in our design equal to 2.5 Gbps, then the data coded via NRZ, RZ As shown in Figure. 5.

![Figure 5. GPON block diagram.](image)
The optical modulation consists of Continuous Wavelength (CW) and Mesh Zener Modulator (MZM), works generate operating wavelength equal to (1490,1557,1270,1310), and then the MZM work to convert the electrical signal to optical signal for transporting among the directional fiber. CW power was set to constant values to 5 dB to test the performance of the network and the line width was set to 10 MHz, which it is the main job in the total emission area is to characterize the width of the frequency interval; finally the downstream window is only 10 nm wide.

MZM has three inputs work as gates, with suppression ratio was set to 30 dB. The first gate represents the output of the optical signal the second one for electrical modulation kind, and the third one is the CW laser input.

Moreover, the NRZ was used, then replaced it with the RZ modulation format to generate two types of data with the same block diagram, as we will see in the next part.

3.2. ODN

Fiber optic represent The passband of the project The directional optical fiber with reference wavelength equal to 1310 nm, located in the middle of 1300 nm and 1320 nm, with nonlinear refractive index \((n_2) = 26 \times 10^{-21} \text{m}^2/\text{W}\) with fractional Raman contribution = 0.18 with a dispersion = 0, having attenuation equal to 0.2 dB / km. The effective core area (Aeff) of fiber = 80 um2

3.3. ONU

As shown in Figure. 5, the receiver consists of a cutoff frequency of the low pass Bessel filter set to 0.75×bitrate, Avalanche Photodiode (APD) with responsivity set to 1 A/W and Dark current was set to 10. After receiving and filtering the signal, 3R regenerator is established with three outputs work as gates. The first gate is the reference signal, the second one is a bit sequence and the third one is the output signal. Finally, to analyze the performance, these three output signals should link directly to the BER Analyzer. The Performance of GPON simulation in access technology is done using OptiSystem where all four user GPON system had met during the implementation specified by its bit error rate and Quality factor.

4. Result and Discussion

This scenario took into account different values of the operating wavelength used for downstream direction (1490nm - 1557- 1270- 1310) nm at a constant power of CW laser of OLT (5 dBm) and (10-20-30-40-50-60-70-80-90-100) km of the fiber length for all wavelengths. It was used to test the performance and decide which wavelength has the optimum performance and can cover the long distance as shown in Figure6 for NRZ and Figure 7 for RZ, explaining the Q-factor versus distance.
As shown in Figure 6 and 7, the privilege among RZ and NRZ in various distances goes with the RZ data format to cover the large distance with a good Q-factor in all four different wavelengths compared to NRZ in the same circumstances. This Q-factor is decreased every time the distance increase. Except in certain distance (50 to 60) km in both two data format types (RZ, NRZ). It starts raising a little bite (especially 1557 nm), then it continues to fail until it reaches 0 Q-factor. At the time
the powers raised, different wavelengths go to overlap each other, driving the system to a more controlling in nonlinearities.

![Figure 8](image)

**Figure 8.** The output signal of 1270 nm RZ reaching distance 60 km

Therefore, the Q-factor bigger than 3dBm is decreasing as shown in Figure 6. Figure that explain the RZ data format produces higher efficiency in the countries to NRZ seen from Figure 7. The long distance to cover specialty the wavelength (1310) followed with (1270) it can reach 60 km with Q-factor (7.48) and (6.77) respectively as shown in Figure 8 and 9.

![Figure 9](image)

**Figure 9.** The output signal of 1310 nm RZ reaching distance 60 km
5. CONCLUSION
From all the results above, it was concluded that RZ gives higher effectiveness in the contras to NRZ and longer distance to cover specialty the wavelength (1310) followed with (1270) that it could reach 60 km with Q-factor (7.48) and (6.77) respectively. Even with some expected behavior in the range between 50-60 km, the Q-factor increases as the range increases.

6. References

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