International Journal of Applied Engineering Research ISSN 0973-4562 Volume 13, Number 5 (2018) pp. 2452-2457

Ethernet Passive Optical Network (EPONs): Physical Layer Analysis and Survivability

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Abstract

The Ethernet passive optical networks(EPON) is an effective network which provide higher bandwidth, lower costs and broader service capabilities. In this study we have aimed to design and planning of a passive optical network.The main emphasis is to build a imaginary environment, for this, firstly we choose the main elements of these networks like elements used in OLT, distribution of optical fiber and elements used in the design of ONUs. The architecture works in two modes upstream and downstream, for this TDMA approach is used to deliver data from ONU to OLT in upstream. A simulation model is designed by choosing a simulation software that meets the design requirements and results will justify that the network is capable of working successfully and can be implemented in a real case will be obtained.

Keywords: Optical fiber, Passive Optical Network(PON), Time division multiple access(TDMA), Simulation, Optical network unit(ONU),Optical line terminal(OLT)

INTRODUCTION

From the last decade, there is a huge turning point in telecommunication field from a copper world to a fiber world. In telecommunication, Fiber is todays globally adopted well established network for communication as it provides larger bandwidth at longer ranges for data transfer without any active devices. For upcoming several years, Implementation of Passive Optical Network between service providers and customer premises contribute to cost efficient, reliable access network and required bandwidth among different customers [8]. A PON based access network has some important features as it has lower capital and operational expenditures because it requires no electronic components in the field. PON is less prone to failure and offers high reliability due to no use of electronic components outside the plant[9]. Finally PON access network is transparent for its frame format and signaling rate[1]. For all of the reasons above, passive optical network are the most promising technology, as it is cost effective, high performance and high capacity solution to the end users over the past

decades[2].Classification of Passive Optical Network on the basis of Link layer protocol as APON(Asynchronous Transfer Mode based PON), an EPON(Ethernet PON) and a GPON(Gigabit PON).Standards given by ITU-T for passive Optical Networks are G.983 is BPON(Broadband PON)[5], G.984 is GPON(Gigabit PON) whose full service access network(FSAN) consortium is specified in 2001 and upgraded by ITU-T till February 2004[2].IEEE 802.34ah Ethernet in the first mile) is given by ITU-T for Ethernet PON. Fact behind the declaration of standard is maximum of data traffic routes with the use of Ethernet frames, using an EPON, routing of data from LAN to access network will be easier. The article below reviews and categorizes the existing research on EPONS. The main focus is on upstream and downstream transmission for broadcast network of EPON. The EPON research area has been very active over the last few years, resulting in a dramatically expanded and more intricate body of EPON research. Therefore, a fundamentally new classification and survey of this area is required and provided in this article. We review the standard PON architecture. We classify this work in a meaningful way that provides insight to researchers currently working on EPONs and those considering working on EPONs. We discuss the parameters and scenarios of simulation. The main goal is to show how optical fiber links behaves when the signal passes through optical fiber, splitter, multiplexer so as to find a good quality of signal in all receivers. Finally, we conclude the article with an evaluation of BER and eye diagram as the performance of whole system.

PON ARCHITECTURE

A Ethernet passive optical network mainly has three entities OLT,ONU and CO(Central office) as shown in fig.1.Optical line terminal (OLT) is residing at the central office(CO) of service providers and connects to many optical network units (ONU's) in the field by using a tree topology. OLT has a multi-tasking capability including network assembling and access functions in EPON. OLT also handles bandwidth assignment, network security and management configurations according to the demand of customers different QoS requirements.

Optical fiber cables configures point to point and point to multipoint links between the central node and the end user. Point to point configuration requires active electronic component at the end of each fiber and outside the plant. Each subscriber has a dedicated electronic components. Passive optical network (PON) is based on point to multipoint configuration.

In this bandwidth is not dedicated but multiplexed in a single fiber in the network access point.

In PON network the OLT and ONU are connected with a feeder fiber cable and 1:N optical Splitter is used to enable the ONU's to share the optical fiber. In upstream direction the signal propagate from ONU to OLT but not reflected back to each ONU, hence its multipoint-to-point [3].Due to this type of transmission in which ONUs cannot detect each others transmission as the upstream signal is not received by the ONUs, multipoint to point transmission is used in upstream.

A. Downstream principle in EPON

1: N Passive splitters are used for transmission of data in downstream direction from OLT to ONU by using point to multipoint link to reach each ONU as shown in fig.1. Splitting ratios are typically between 4 and 64.EPON architecture perfectly suits due to the broadcasting nature of Ethernet in downstream direction (from Network to user), as packets are broadcasted by the OLT and received by their destination ONU based on their media access control

(MAC) address. OLT broadcast ethernet frames to ONUs in downstream direction.All the ethernet frames of different ONUs are transmitted in one downstream timeslot. Packet broadcasts to all the ONUs and each ONU only extracts its own data and transmit them to the users, discarding other frames.

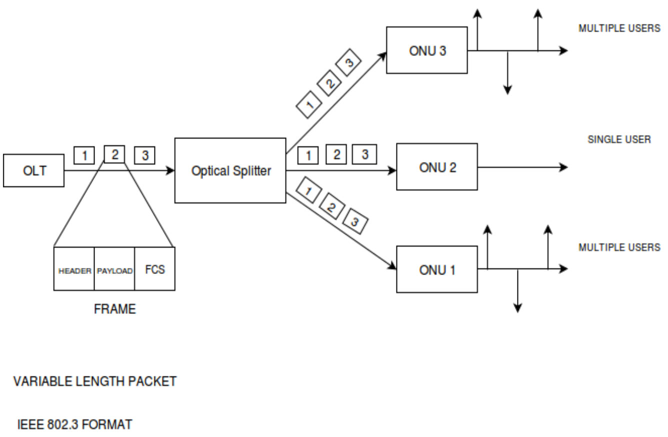

Figure 1. Downstream principle in EPON

B. Upstream principle in EPON

In the upstream direction from ONUs to OLT, a PON is a multipoint to point network in which data frames from any ONU will only reach the OLT,not other ONUs as shown in fig.2.In the upstream direction to avoid collissions, time division multiplexing(TDM) or wavelength division multiplexing (WDM) can be used[3].WDM gives a large amount of bandwidth to each user but it is challenging for service providers to stock many different ONU types which requires each ONU to use a different wavelength. Using a TDM as a multiple access technique reduces a number of transceivers at the OLT and allows a single ONU type, as TDM allows all ONUs to share a single wavelength.

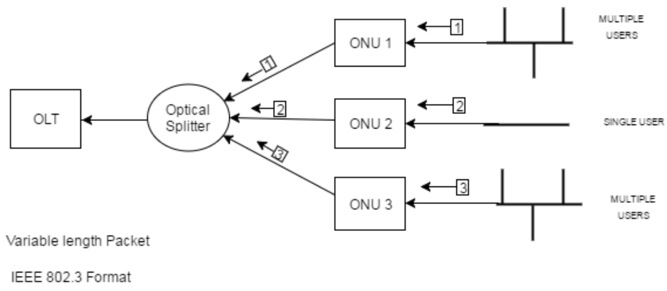

Figure 2. Upstream principle in EPON

PERFORMANCE EVALUATION

The integrated system performance is designed for experimental simulation using the OptiSystem 14.0 software design tool. Physical layer simulation is designed virtually of an Etherent Passive Optical network. Now, the most important part of the work will be discussed. The parameter and scenario of simulation work is shown. The main emphasis is how optical fiber behaves when the signal pass through all the elements of the design such as optical fiber, splitter, multiplexers so as to get a good quality signal at the receiver. At last finally the simulation indicates the performance of the whole system by evaluating Q-factor, Min BER, Threshold at min BER and Eye diagrams.

Basically BER (Bit error rate) at the receiver is used to access the performance of the link. Simulations are done to achieve a minimum BER. Eye diagram shows the quality of the received signal. In the presence of ISI i.e the signal will not satisfy nyquist criteria, the diagram will tend to close vertically that means in the absence of noise the eye is vertically open. Higher vertical opening of the eye means greater immunity to noise.

The complete design of Ethernet-PON is shown in fig.3. The design reflects each of the elements with their important parameters. For the understanding of design , it will describe the design from OLT to the different ONU's for downstream and from the ONU's for downstream and from the ONU's of the different areas to the OLT for upstream.

SIMULATION SETUP

Design defines the OLT which will transmit information to different users in the left side of architecture. All this information will be transmitted multiplexed at different wavelengths through a single optical fiber, demultiplexed and multiplexed from different areas respectively in downstream and upstream transmissions.

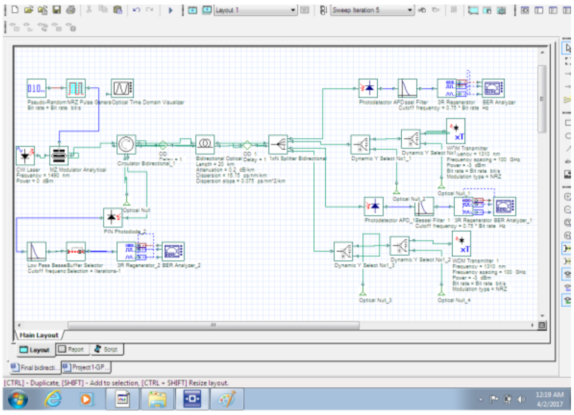

Figure 3. Complete Design of EPON

Table 1 lists the Global parameters of the layout which are used throughout the simulation. The bit rate which is used globally throughout the design is 2.5 Gbps. All other components in the design work for lower than this bit rate. Other parameters are also important as the bit rate.

Table I: Parameters for Epon Simulation

S. No.	DESCRIPTION	VALUES
1	Bit rate	2.5 Gbps
2	Sequence length	128 bits
3	Samples per bit	64
4	Guard bits	0
5	Symbol rate	1 Gbps
6	Number of samples	8192
7	Number of iterations	5

SIMULATION RESULTS

I. Performance of EPON network in downstream data transmission

Downstream, the transmission of data from OLT-ONU in EPON, is an attractive choice for access networks as it is a cost efficient and flexible infrastructure that will provide the required bandwidth to customers. The design architecture is shown in fig 3,which is simulated in 20 sec. We consider a Model with 2 ONUs. In fig.3, four elements namely Pseudorandom bit generator, NRZ pulse generator, CW Laser and MZ modulator combinedly called as Optical line terminal (OLT). The laser will generate a signal of 1490nm wavelength. This laser signal and the signal from NRZ pulse generator i.e (101010) is multiplexed in MZ modulator and produced a signal which is transmitted to a bidirectional circulator. Since the OLT has to handle both the downstream and upstream traffic, inserted an optical circulator with insertion loss of 3 dB and return loss of 65dB. Further the optical signal is transmitted with the help of bidirectional optical fiber having length as 20Km, and with some other important parameters like attenuation of 0.2 dB/Km, dispersion of 16.75 ps/nm2/km and dispersion slope as 0.075 ps/nm2/km. Now next is splitter which will contain a multiplexer and Demultiplexer which will be used for one direction of traffic. The spliiter demux into two different wavelengths. The first branch of splitter is given to ONU1 and the second branch to ONU2.The figure 4, below shows the spectrum of the signal that has been inserted into the optical fiber.

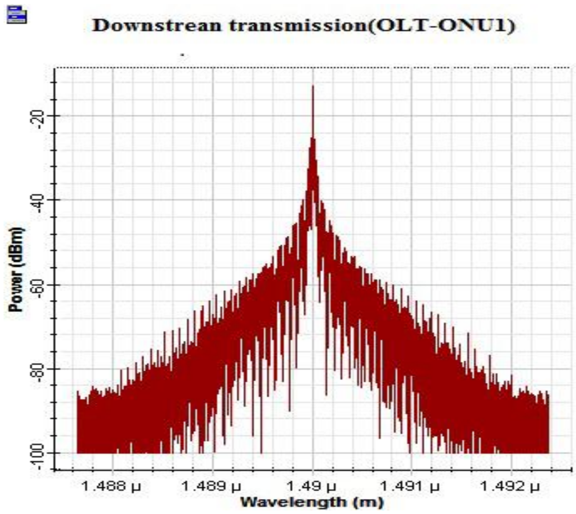

Figure 4. Downstream spectrum into the first optical fiber

The ONU part consist of a photodetector, Bessels low pass filter, 3R regenerator and BER analyzer. After whole design explaination, it is required to get the results that will decide if the design works or not and hence check whether it will be survivable to implement in a practical case. The results that are going to expose are the eye diagram, the quality factor, the probability of error (BER) and the decision threshold as a function of the width of the bit. First downstream results and later upstream results are shown below.The outputs of ONU1 has been obtained the following results

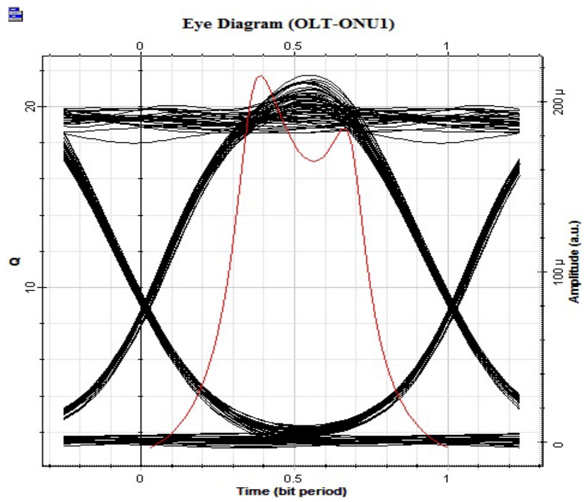

Figure 5. EyeDiagram(OLT-ONU1)

International Journal of Applied Engineering Research ISSN 0973-4562 Volume 13, Number 5 (2018) pp. 2452-2457

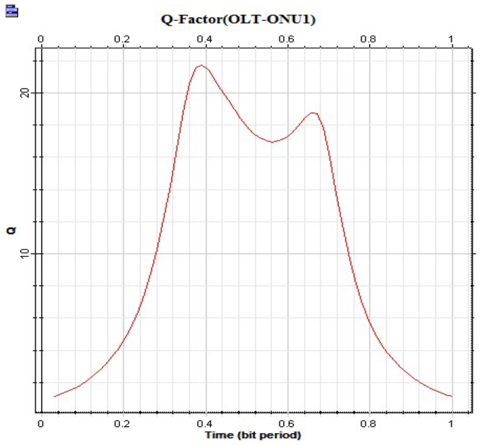

Figure 6. Q- Factor (OLT-ONU1)

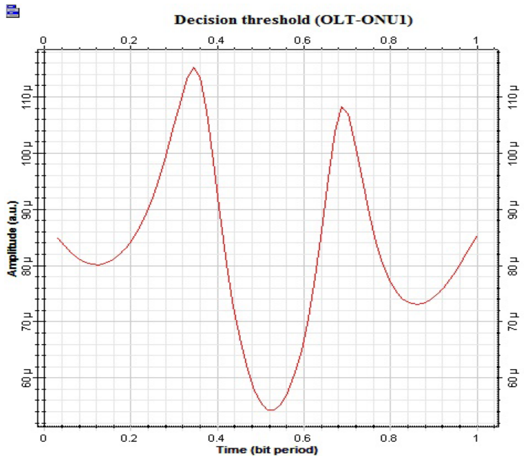

Figure 7. Decision Threshold (OLT-ONU1)

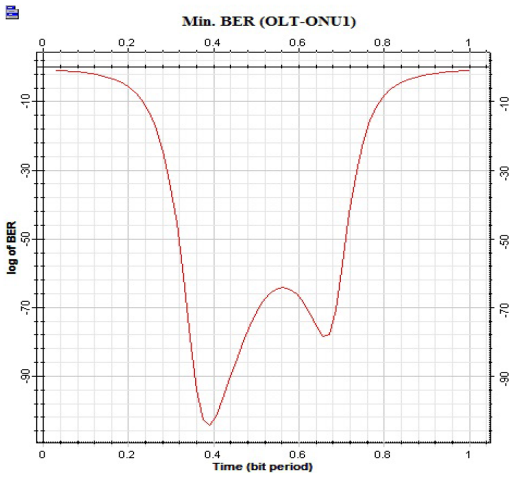

Figure 8. Min. BER(OLT-ONU1)

II. Performance of EPON network in upstream data transmission

The upstream layout using TDMA is shown below in fig.9.Basically in upstream direction, the optical signal will travel from each of the end user(ONU's) to the OLT. The signal in upstream will pass through the same elements and have the same characteristics and parameters. Every ONU is assigned a different time slot and implemented a TDMA for each user to transmit.

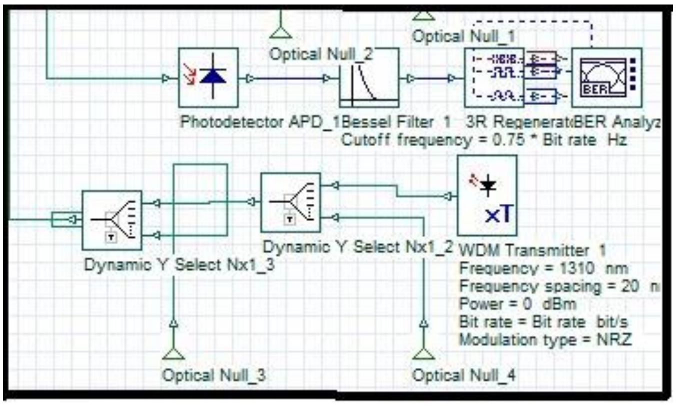

Figure 9. Upstream layout of TDMA

Each ONU user consist of 1310 nm of a signal with a power of 0 dBm, NRZ modulation TDMA, use a Dynamic select Y which will allow to pass the signal only at a determined time instant rest all are zero. For only two ONU's, the formula to define the time interval of each one is

Timeslot * (1/Bit rate) * sequence length / 2 + Time window/2

Where time slot 0 is for the first ONU and 1 is for the second ONU.

The output of OLT which combine the inputs of ONU1 and ONU2 are shown below

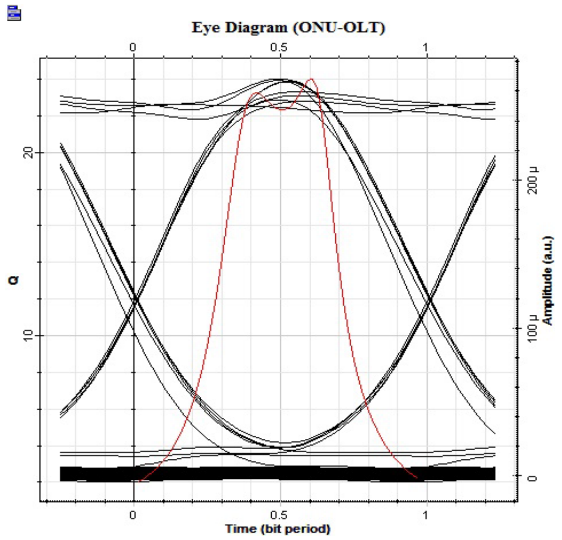

Figure 10. Eye Diagram (ONU-OLT)

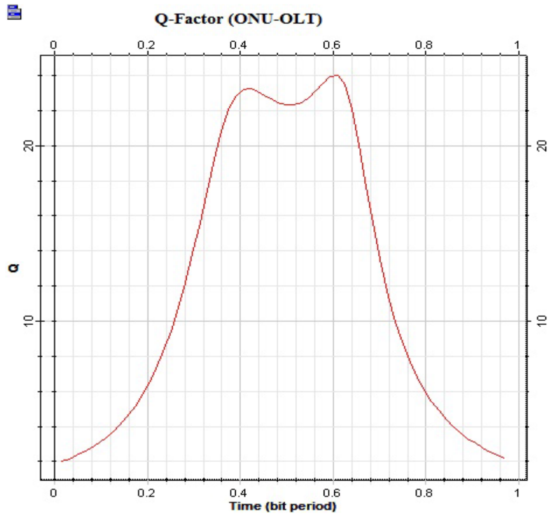

Figure 11. Q-Factor(ONU-OLT)

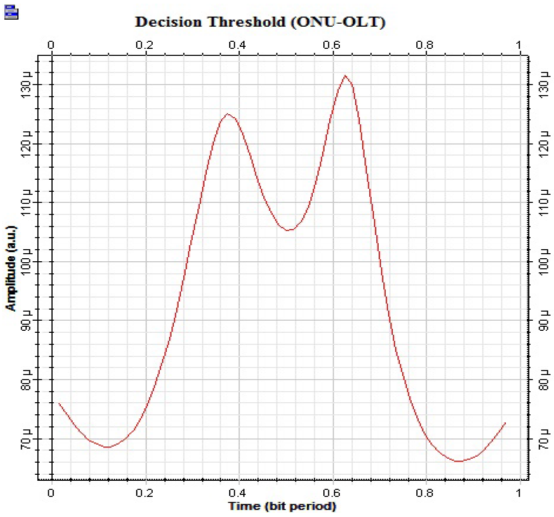

Figure 12. Decision Threshold (ONU-OLT)

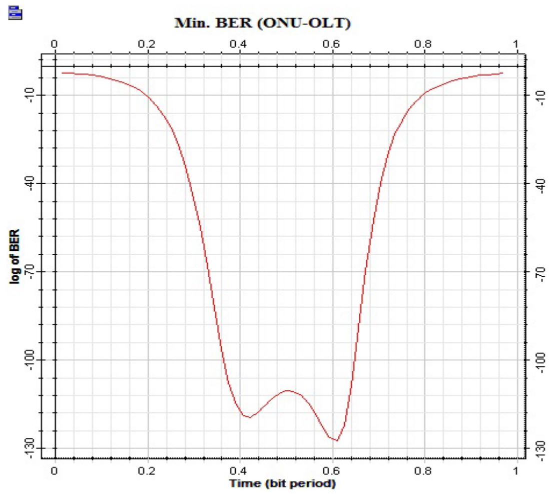

Figure 13. Min. BER (ONU-OLT)

CONCLUSION

In this study we discussed and designed EPON access network. These design issues were led us to describe the operating principles of a network taking into account of all the elements of passive optical network. On comparing with Active optical network(AON), PON design are more exploit for its bandwidth and lower implementation cost. On comparing with all other optical networks(APON,10GPON), WDM-PON is the best option as it has greater speed and supports more number of users. For the understanding of the design, the explaination is supported into two parts, downstream and upstream. Finally all the results including eye diagram, quality factor, the BER and the decision threshold for the minimum BER are attached. With the help of results and final design of the network, it has taken into account all the important elements and parameters which provide feasibility to the design and make it worked.

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