Performance analysis of bi-directional broadband passive optical network using travelling wave semiconductor optical amplifier

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Abstract

In this paper performance analysis of a bi-directional broadband passive optical network (BPON) for both downstream and upstream traffic by using travelling wave semiconductor optical amplifier (TSOA) is carried out in terms of bit error rate (BER). The system has been analyzed on the basis of drive current of TSOA, data rate, fiber length, coding technique, number of users. From the simulation it has been observed that as we increases the no. of users, fiber length, data rate bit error rate is increasing due to optical pulse brodening and dispersion. It is found that value of bit error rate 3.65089x10^{-035} is more acceptable for drive current 0.27A at 20 km. From the investigations it has been found that system performance is better for NRZ modulation format than RZ format because NRZ coding is more tolerable to optical dispersion than RZ coding.

Key words: Passive optical network (PON), Broadband passive optical network (BPON), Bit error rate (BER), Travelling wave semiconductor optical amplifier (TSOA).

I. INTRODUCTION

Optical fiber communication is an approach to transport information from one point to another using light as a carrier .Initially optical fiber is not popular, because the fiber exhibits very high attenuation than the coaxial cables in the early 1970's. But now these days, attenuation is reduced to very low attenuation of 0.2dB/km. The advantages of fiber- optics are mainly due to its high communication capacity, low transmission loss, immunity to electromagnetic interference and many more.

The access network, also known as the "first-mile network," connects the service provider central offices (COs) to businesses and residential subscribers. The bandwidth demand in the access network has been increasing rapidly over the past several years. The explosive growth in the demand for higher bandwidth has triggered the introduction of fiber-to-the-home (FTTH) based broadband access networks. The bandwidth demand in the access network has been increasing rapidly over the past several years [1].

Since optical fiber is being extended to the access network, it is economically to share fibers between different users without adding active components in the network. Among various FTTH implementations, passive optical network (PON) is one which can provide very high bandwidths to the customers, appears to be an attractive solution to the access network [1]. Other than offering high bandwidth, a PON system offers a large coverage area, reduced fiber deployment as the result of its point-to-multipoint (P2MP) architecture, and reduced cost of maintenance due to the use of passive components in the network. PON is an optical fiber based network architecture, which can provide much higher bandwidth in the access network compared to traditional copper-based networks.

PONs has a tree topology in order to maximize their coverage with minimum network splits, thus reducing optical power loss [2]. Since a passive network has no amplifiers or regenerators. A PON basically consists of an optical line terminal (OLT) at the central office which transmits traffic received from the access network to the Internet and vice versa, an remote node (RN) which contains passive splitters/couplers for de-multiplexing the downstream traffic received from the OLT and multiplexing the upstream traffic to the OLT, and multiple optical network unit (ONU) close to user's premises which receive the downstream traffic from the RN and generate the upstream traffic to the RN [2].

There are five main schemes of multiplexing in which PON can be used and they are TDM, WDM, CDM, SCM, and OFDM. The only difference in the outside plant (OSP) between these five approaches is at the RN location. Among these five schemes wavelength division multiplexing (WDM) is one of the most important approach used because of its almost-unlimited bandwidth. In WDM-PONs, each ONU uses a different wavelength channel to send its packets to the OLT [3]. The same wavelength channel can be used for both upstream and downstream communication. The network management is much simpler than a TDM PON, and all future services can be delivered over a single network platform. Major challenge in PON is transmission distance. It is challenge to increase the transmission distance from 20km because after this there is power penalty.

There are mainly three standards of PON: Ethernet PON (E-PON), Gigabit PON (G-PON) and Broadband PON (B-PON). Ethernet PON (EPON) is a PON-based network that carries data traffic encapsulated in ethernet frames (defined in the IEEE 802.3 standard). Ethernet is an inexpensive technology [4]. Gigabit Passive Optical Network (GPON) is defined by ITU-T recommendation series G.984.1 through G.984.4. A big advantage of the GPON over other schemes is that interfaces to all main services are provided. The first TDM-PON system developed by FSAN was called Broadband Passive Optical Network (BPON) [5]. It is based on Asynchronous Transfer Mode (ATM) and is sometimes referred to as Asynchronous Transfer Mode Passive Optical Network (APON). The first BPON standard was published in 1998 in the ITU-T G.983 series recommendations [ITU09]. The architecture of the BPON is very flexible and adapts well to different scenarios. The primary differences between GPON and B-PON are the data rates and client data encapsulation methods [5].

A typical BPON architecture consists of OLT and ONU and has symmetric PON or asymmetric PON. B-PON provides reliable communication. Because a splitter used in BPON is a passive device, maintenance free operation between user sites and the central office is feasible. Moreover, the total cost of a B-PON system is lower than other conventional approaches. In many ways, BPON has proved to be currently the most trusted technology for access networks.

For optical access networks, wavelength-division-multiplexing passive optical networks (WDM-PON) are considered as one of the best solution for the next-generation of FTTH because of its unlimited bandwidth. Bidirectional single fiber PON can reduce the use of fiber links, as well as the number of network equipments, and hence reduce the cost and energy consumption [6]. An access network architecture utilizing a centralized light source at central office (CO) with wavelength 1550 nm and 1300nm wavelength received at the optical network unit (ONU) is an
attractive solution for low-cost implementation of the architecture. Both the wavelengths are selected because of its low attenuation window. To increase the performance of passive optical network an amplifier can be inserted between transmitter and splitter. Several schemes have been proposed based on SOAs, because it can reuse the downstream signal received at the ONU for upstream transmission [7]. TSOA is capable to describe the amplification of CW and optical pulse signals. In downlink, a TSOA is placed in between the transmitter and optical fiber.

II. Simulation set up

The simulation setup for analyzing downstream traffic and upstream traffic has been shown in Figure 1. The transmitter, single mode fiber, an optical splitter, the Optical Network Units (ONUs) and BER analyzer have been connected systematically. Table1.list all the parametric values set in the simulation environment according to standard network values.

All the ONUs contain a separate transmitter to modulate user data onto laser beam and send to the optical splitter, which acts as signal combiner in the upstream case. The combined signal is then travelled on the optical fiber and at the OLT side a receiver detects the optical signal and produces a BER value corresponding to the signal quality received.

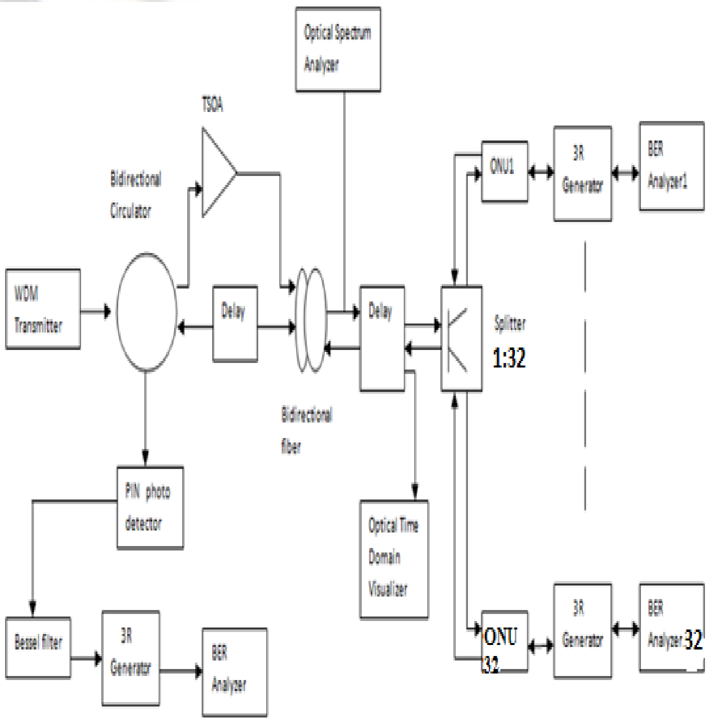

Fig.1. Simulation set up of bi-directional BPON

Table 1: BPON Simulation parameters

Component	Parameter type	Value
PRBS generator	Downstream Bit rate (Mbps) Upstream Bit rate (Mbps)	622.08 622.08
Light source	Downstream wavelength (nm) Upstream wavelength (nm)	1550 1300
Modulator	Modulation format	RZ,NRZ
Optical fiber	Fiber length (km) Attenuation constant (dB/km) Dispersion (ps/nm/km) Dispersion slope (ps/nm^2/km) Effective area (um^2)	20-100 0.2 16.75 0.75 80

Travelling wave SOA	Injection current (A) Optical confinement factor Length (m)	0.15 0.3 .0005
Splitter bi-directional	Insertion loss (dB)	1.5
Circulator bi-directional	Insertion loss (dB)	3
Photodetector	Responsivity (A/W) Dark current (nA)	1 10

The architecture of bidirectional PON for 32 ONUs using single fiber is based on circulator. Circulator is used to isolate optical signals of uplink and downlink, and hence to realize bidirectional transmission in single fiber. Uplinks are allocated to upload burst data from clients and downlinks are used to download multimedia data to clients, such as audio, video and data services.
The circulator used in this set up is bidirectional with wavelength dependent isolation, insertion and return losses. In downlink, we place a TSOA in between the transmitter and optical fiber to improve the performance of passive optical network. Delay element which is used in transmission is used to generate optical signal delay. The delay is added by sending NULL signal to the output port. Photoelectric detectors (PIN) are used to convert optical signals into electrical signals, which pass through low-pass Bessel filters and 3R regenerators. By using 3R generator, it is possible to recover the original bit sequence and electrical signal. These three signals can be directly connected to BER analyzer, avoiding additional connections between the transmitter and receiver stage.

III. Results and Discussion

As we know that we use optical splitter as a passive device, so on the basis of these factors some experimental results have been obtained. Results obtained are on the basis of bi-directional broadband passive optical network (B-PON) for 32 users. Downlink data is transmitted at the wavelength of 1550 nm and the uplink data is transmitted at the wavelength of 1300 nm. These both wavelengths are selected because these wavelengths has low attenuation window. In downlink, to improve the performance of bi-directional B-PON we placed a TSOA in between the transmitter and optical fiber. Results are obtained by changing drive current of travelling wave semiconductor optical amplifier (TSOA) , number of users , coding techniques, value of dispersion, data rate and fiber length. S.F. Shaukat [7] had investigated the bi-directional broadband passive optical network (B-PON) system for fiber length up to 20 km only but in this paper we have extended the system using TSOA for fiber length 20 to 100 km in terms of bit error rate (BER).

The effect of changing the drive current of TSOA is shown in the fig.1.It has been observed that as we increase the drive current of TSOA the bit error rate of system decrease, but as we increase the fiber length bit error rate increases. Bit error rate is more accepted at short fiber length because dispersion increases as we increase the length of optical fiber. The effect of changing the length of bi-directional optical fiber is also shown in the fig.2 (a). It is analyzed that as we increases the length of bi-directional optical fiber the bit error rate of system increases due to pulse spreading and dispersion phenomena and also bit error rate increases as we increase the value of dispersion of bi-directional optical fiber.

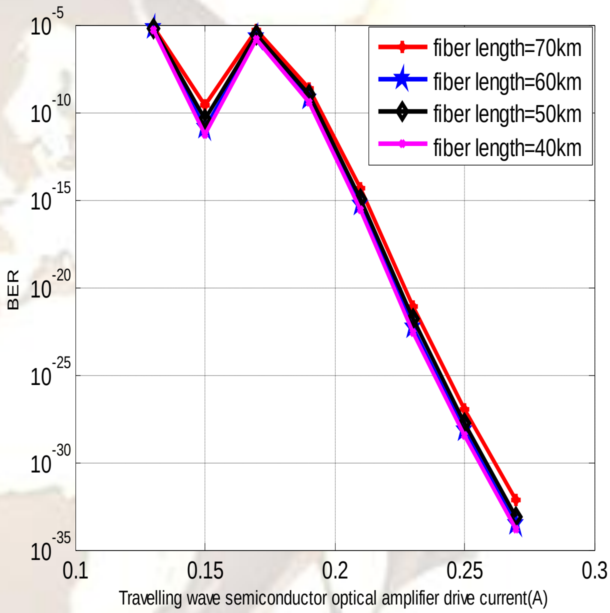

Fig.1 BER vs Driving current with the variation of fiber length

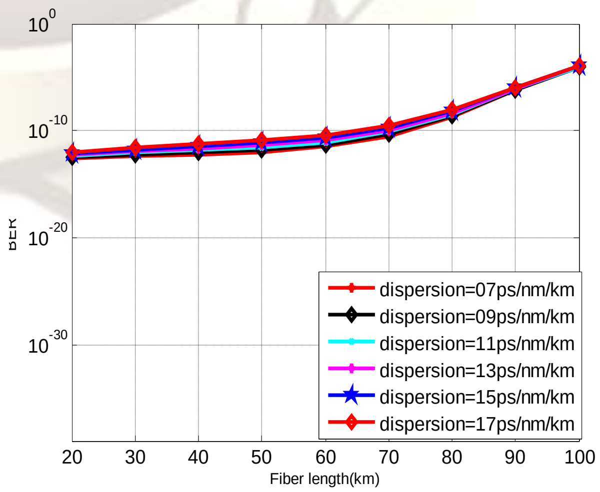

Fig. 2(a).BER vs Fiber length with the variation of dispersion

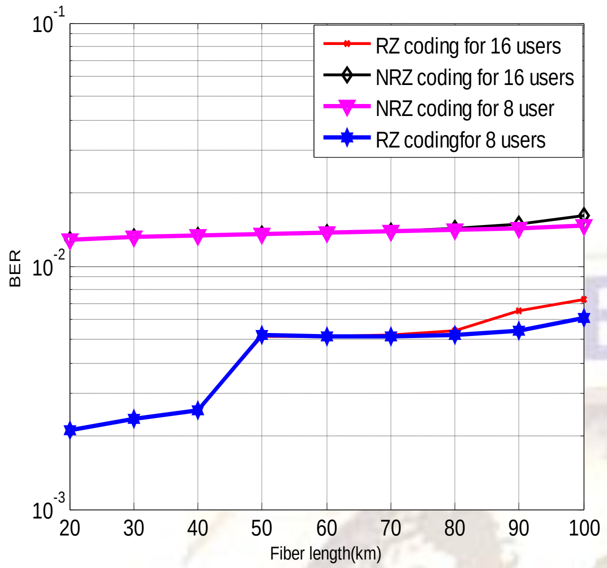

Fig. 2(b) 1 BER vs Driving current with the changing of modulation format

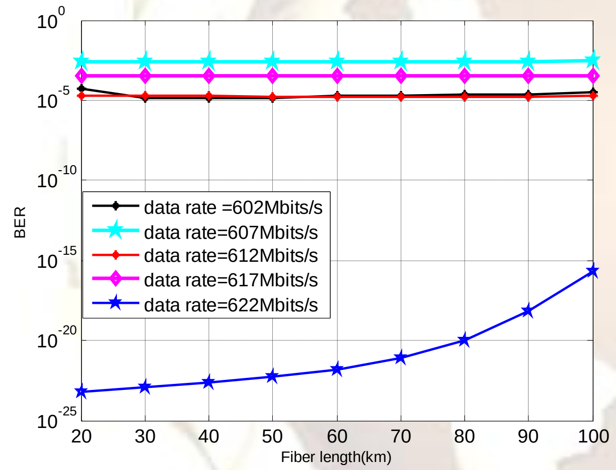

Fig.2(c) BER vs fiber length with the variation of data rate

Modulation formats are indispensable elements to judge system performance in terms of channel capacity. Two types of modulation formats can be used in B-PON system are RZ and NRZ coding. The effect of coding for 8 and 16 users in terms of bit error rate over different fiber lengths is shown in fig.2 (b). RZ coding suffer more non-linearity and dispersion due to short pulse width. It has been observed that RZ performs poorer than NRZ format.NRZ format is used because it requires less bandwidth than RZ format. The effect of data rate over different fiber lengths is also shown in the fig2(c). It has observed that as we increase data rate, bit error rate increases sharply or it accommodates less fiber length and if we decrease the data rate, bit error rate decreases as well as more fiber length get accommodated. So there lies a trade-off between bit error rate (BER), fiber length and data rate.

Basically we extend or increase the number of users using a passive device named as optical splitter. The effect of number of users on bit error rate is shown in fig3. In fig.3.bit error rate is observed for 8, 16 and 32 users. It is analyzed that as we increases the no. of users and fiber length bit error rate also increases. BER is more acceptable at short fiber length and for less number of users.

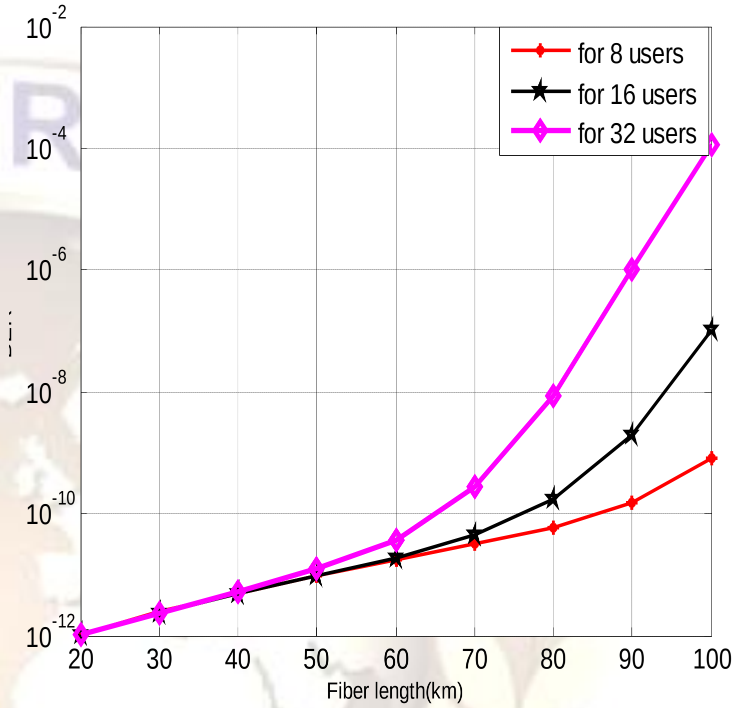

Fig.3. BER vs Fiber length with the variation of number of users

IV. Conclusion

Bi-directional BPON access network has been successfully analyzed in this paper. The performance of system is analyzed on the bases of parameters driving current of TSOA, fiber length, dispersion, no. of users, coding techniques and data rate in terms of bit error rate (BER). S.F. Shaukat [7] had investigated the bi-directional broadband passive optical network (B-PON) system for fiber length up to 20km only but in this paper we have extending the work using TSOA for current range from 0.13 A to 0.27 A and fiber length 20 to 100 km in terms of bit error rate(BER).

From the simulation it has been observed that due to dispersion bit error rate is increased as we increases the no. of users, fiber length, data rate but as we increases the drive current of TSOA bit error rate decreases . It is found that value of bit error rate 3.65089×10^{-035} is more acceptable for drive current 0.27 A at 20 km. From the simulation it has been observed that system performance is better for NRZ modulation format than RZ format because NRZ coding requires less bandwidth requirement and is more tolerable to optical dispersion than RZ coding. It is found that bit error rate is more acceptable at short fiber length and for less number of users.

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