International Journal of Theoretical & Applied Sciences, 9(2): 222-226(2017)

ISSN No. (Print): 0975-1718
ISSN No. (Online): 2249-3247

Performance Evaluation of Optical Access Network

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(Received 14 October, 2017 accepted 3 November, 2017)
(Published by Research Trend, Website: www.researchtrend.net)

ABSTRACT: In this paper, performance of a hybrid WDM-TDM-PON 2x16 network is optimized for longer reach. In this system, information is effectively conveyed through a separation of up to 160 km. In addition, we investigated and compared information signal with different input power. Analysis has shown that 10db input power signal gives better results. Signal with acceptable quality was received at longer distance without the help of amplifiers making the system economically viable.

Index Terms: PON, WDM-PON, TDM-PON, Hybrid PON, Q- factor.

I. INTRODUCTION

Recently, a great emphasis has been going on in enhancing capacity of backbone networks. Backbone networks operate in excess of 40Gbps. Although, communication systems comprises of backbone network, metro network and access network [1-2]. Because of economic reasons backbone systems have developed quickly, but the cost of access network remains restrictively high for the subscriber [3]. In the previous decade, there is little development in the access technology which is still based on copper wire. Access network has been outpaced by development of the Internet activity and the unparalleled levels of system limit offered by backbone systems. Service providers are tested with installing access arrangements that are adaptable, quick and economical to guarantee their aggressive positions. Passive Optical Network (PON) innovation can address these needs using fiber cables instead of the customary copper wire [4].

II. PASSIVE OPTICAL NETWORK

PON has a point to multipoint optical system, in which Optical Line Terminal (OLT) situated at the Central Office (CO) is associated with numerous Optical Network Units (ONUs) situated at the client's site using different 1: N optical splitters. Passive system is used between OLT and ONU which does not require power supply [5-6]. PON decreases the system cost by dispensing with the power supply reducing the operational cost along the fiber from CO to end clients, and by sharing the noteworthy part of the system cost among numerous clients [7]. The PON conveys the service by various multiplexing Schemes like TDM, WDM and Hybrid TDM/WDM [8-9].

Initially, PONs is based on time division multiplexing scheme (TDM-PON). TDM-PON utilizes a solitary wavelength for downstream (CO to clients) and upstream (clients to CO). Both downstream and upstream are multiplexed in single optical fiber. There are two primary standards for TDM-PON: Ethernet PON (EPON) and Gigabit PON (GPON) [10], [11]. Though, TDM-PON can't adapt to future necessities of access networks in regards to reach, bandwidth and power budget [11]. To adapt to this issues, it has been broadly acknowledged that the following stride of advancement for PON designs is the use of wavelength division multiplexing in PON (WDM-PON) [11-13]. In WDM-PON every ONU is allocated a separate wavelength. This scheme provides more bandwidth for every ONU, long reach and higher data rates [11], [13].

Hybrid plans of TDM and WDM are a hotly debated issue, for the improvement of next generation PON systems. A blend of TDM and WDM over PON transforms out into a composite optical system known as Hybrid TDM-WDM-PON. Hybrid TDM–WDM–PON enhances the system asset's productivity utilization [14]. Giga Ethernet hybrid PON with 1:8 splitter for 10Gbps has been researched at various lengths [15].

The simulation of two 1.25-Gbps wavelength channels with a distance of 26km using a single-mode fiber conveying information to and from the client was done. The analysis on hybrid WDM/TDM PON using optical add-drop multiplexer (OADM) and a reflective semiconductor optical amplifier (RSOA) were done 16]. WDM/TDM-PON system was designed by utilizing Free Spectral Range (FSR) periodicity. In this a common tunable laser, photodiode and remote modulation were utilized for transmission and reception. Analysis on transmitter indicated operation at 2.5Gbps up to 30km. With the use of optical transmission evaluation authors exhibited that this design was practical and offered great execution with low losses when contrasted with other PON models. Error free communication with 8-channels for more than 20km using WDM-PON based on Fabry-Perot laser at 2.5Gbps was demonstrated [17-18].

Long-reach passive optical network (LR-PON) was proposed as a more savvy answer for the broadband optical access system. LR-PON expands the scope of PONs from the conventional 20 km range to 100 km by using Optical Amplifier and WDM advances [7]. The performance of hybrid WDM/TDM PON network with 128 ONUs was reported for a distance of up to 28 km. schemes like NRZ, RZ and Manchester encoding for different distances were evaluated at a data rate of 1.25Gbps in terms of BER and q factor. Optical fiber cable is used as a communication medium. It was noted that q factor of 9.77 was measured at 19 km and at 31 km Q value of 5.60 was observed. It is concluded that NRZ performs better [19-21].

In this paper, we have broadened the work of literature, hybrid WDM-TDM 2x16 PON systems performance is analyzed for a distance up to 160km. Here, in segment 3, the proposed system architecture is presented. In segment 4, the results of proposed system have been discussed. At last in segment 5, conclusions are made.

III. PROPOSED SIMULATION MODEL

In this segment, we have introduced the simulated model of hybrid WDM-TDM 2 × 16 network. Architecture of the proposed simulation network is shown in the figure 1. In the proposed model, transmitter section comprises of OLT equipments. ONUs are placed at the client premises. In the transmitter segment, two OLTs are placed which generate and transmit information to ONUs. OLTs consists of data generator whose output is fed to electrical signal generator. Electrical signal generator converts the communicative data into electrical signals. Electrical signals so produced are optically modulated with the help of light source. The light sources transmit signals at various frequencies. In this model CW Laser has been employed which is generating signals at a frequency of 193.1 and 193.2 THz.

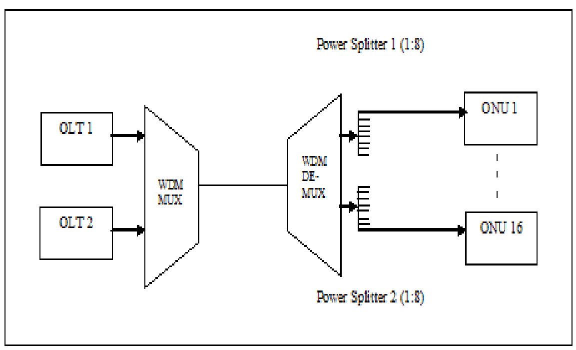


Fig. 1. Proposed Simulated Model.

Information data is transmitted at variable data rates. In this model, network is evaluated with a information rate of 2.5 Gbps to 10 Gbps. The network is configured in a tree and branch configuration. Information signals generated from OLTs are multiplexed using WDM technique. The signals so generated are communicated using optical fiber cable. The separation between the transmitter section and the client place is kept from few kilometers to hundreds of kilometers. In this model maximum distance of 160 Km is used for analysis. The multiplexed signal is separated using WDM demultiplexer. At the receiver side 16 ONUs receive the signal from two power splitters. Power splitter is having a split ratio of 1x8. Each ONU comprise of a photodiode used to convert incoming optical signal to electrical signal. Avalanche photo diode is employed for the simulation of this model.The electrical signal so generated is fed to low pass filter and 3R regenerator. Electrical signals are subjected to comprehensive analysis using BER analyzer. A no. of parametrers are used for evaluation like Q factor, eye diagram, Noise figure and BER.

IV. RESULT AND DISCUSSSION

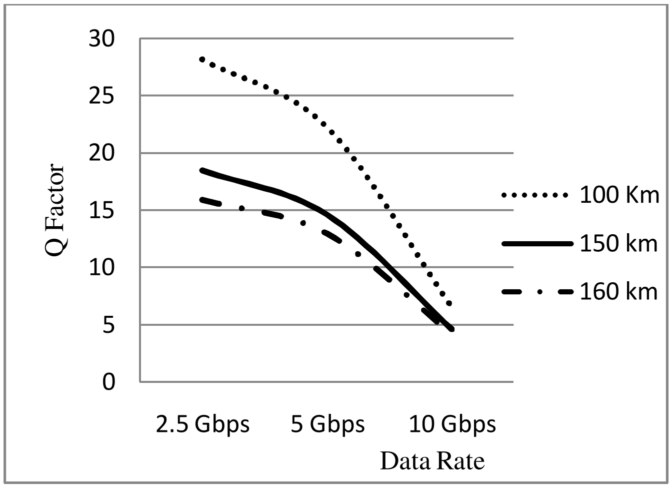


Fig. 2. Q Factor vs. Data rate at 10 db input power.

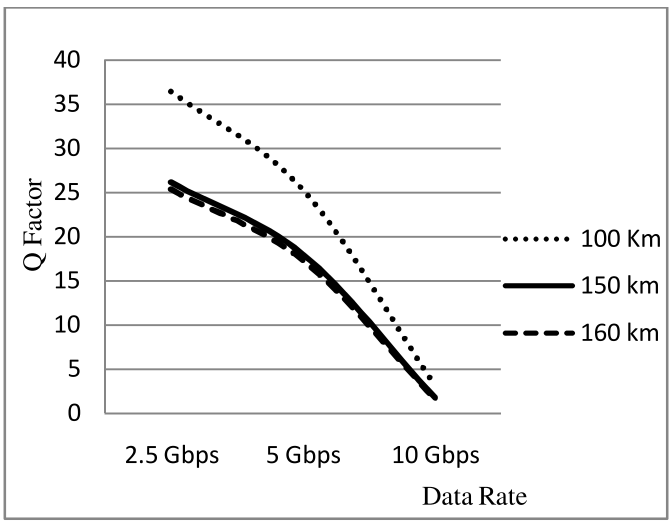


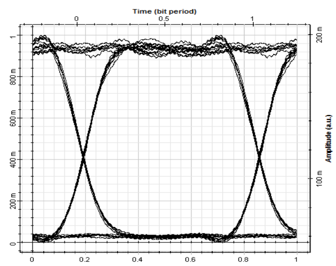
Fig. 3. Q Factor vs. Data rate at 0.2 db input power.

In this segment, results of the simulated model are deliberated. In this system data is communicated at different data rates spanning from 2.5Gbps to 10Gbps. For electrical modulation NRZ scheme is used. The electrical signal is optically modulated by the use of a laser. The signal is optically modulated with the help of laser. The graphical portrayal appeared in figure 2 and 3 demonstrate the variety of Q-element with fiber length for various input powers. The input powers utilized are 0.2 and 10 dB for various lengths ranging from 100 to 160 km. As we can deduce from the above figures Q factor is decreasing with the increase in information rate and separation of the ONU from OLT. Figure 2 show that quality factor is nearly same at a distance of 150km and 160 km. It is witnessed that the Q-factor increments with an increase in input power.

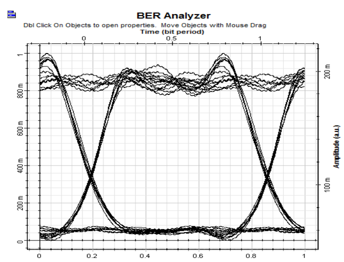
Table 1: Values of Noise Figure with 5Gbps data rate at 10db input signal.

Frequency (Hz)	Noise Figure (db) at 100 Km	Noise Figure (db) at 150 Km
193.1	9.09708	9.1489
193.2	1.20144	1.21163

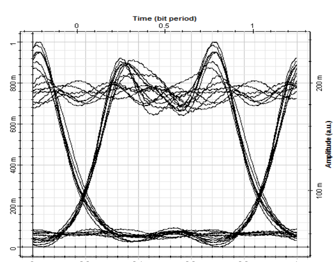
We can observe from the figure 2 and 3 that the system performs better if the power level of the input signal is increased. Noise figure measures the signal to noise ratio (SNR) caused by components of the system. It is a number, with low values depicting good performance of the system. Table 1, shows the values of noise figure with a data rate of 5Gbps and 10db input power. It is observed from the table, noise figure is 9.09708db at 100 km which increases to 9.1489db when measured at 150 km. We can deduce, that the performance of the system is decreasing as the transmission distance is increasing, which is consistent with the earlier results.



(a)



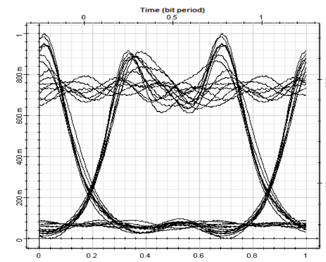
(b)



(c)

The figure 3 (a)-(d) demonstrates the maximum widths and height of the eye which means the signal distortion. The sensitivity of the network is dictated by the rate of closing of the eye. As the distance are increase it is unmistakably noticeable from figure that the eye width and additionally eye height diminishes which demonstrates loss of signal deformation with a similar power levels as OLT.

(c)



(d)

Fig. 3 (a)-(d) Eye Diagram at a data rates of 2.5 Gbps & 10 db input power with a distance of (a) 50, (b) 100, (c)150, (d)160 Km.

The outcomes demonstrate that a superior execution is accomplished at 50 Km in light of the fact that the eye is totally open at 50 Km as opposed to at 160 Km.

Table 2: Observed values of BER for 10 db input signal.

Distance (Km)	2.5Gbps	5Gbps	10Gbps
100	1.33 x 10^{-174}	8.54x10^{-110}	4.18 x 10^{-11}
150	1.79 x 10^{-76}	1.10x 10^{-48}	1.88 x 10^{-06}
160	2.81 x 10^{-57}	1.11x10^{-38}	1.67 x 10^{-05}

Table 2 demonstrates the observed values of Bit Error Rate (BER) for10 db input signal. BER is a key parameter that is utilized as a part of estimation of communicated information starting with one area then onto the next. BER gauges the full end to end execution of a network including the transmitter, recipient and the communication channel between the two. It gives the no. of bits having errors in a specified time interval which indicates how frequently information units must be retransmitted due to error. It is noticed from the table that for information signal with a data rate of 2.5Gbps has a BER of 1.33 x10^{-174} with a separation of 100km. BER increases to a value of 2.81x10^{-57} when measured over a reach upto 160km. It is caused by random noise, bursty and impulsive interference. It shows that signal is degraded as the communication separation is growing. Further, it is perceived from the table that the BER is increasing with data rate. It is concluded, slower information rate would really enhance transmission time for a given measure of transmitted information since the BER is lessened, bringing down the quantity of packets that must be resent.

V. CONCLUSION

In this paper, the performance of hybrid WDM/TDM 2x16 PON system is investigated for longer reach to make it economically viable. Information is communicated at a data rate of 2.5Gbps, 5Gbps and 10Gbps. Investigation is done over a span of 160 km. The receiver is able to accept data through a single optic fiber. The frequency used for simulation is 193.1THz and 193.2 THz. It is found that better signal is received, when the data is communicated at 2.5 Gbps. It is noted that the system gives a better response when the power level of information signal is more. It is also observed that the lower information rate signal gives better results by bringing BER to a lower value. Hybrid networks help in improving the split ratio of the system. It is concluded that acceptable data signal is received without the help of amplifiers. This makes the simulated system economically more viable. The performance of the system is optimized by increasing the reach of the network.

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