Analysis of TDM and WDM PON using Different Coding Schemes for Extended Reach

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ABSTRACT

Telecommunication's future technology is increasing day by day with need for more data rate with high speed of reliable data transmission. Optical networks play a vital role in meetings these demands. Network needs to be promising improved for high data rates and long reach capabilities by implementing optical fibre using passive optical networks. This paper analysis and estimates the performance achieved by TDM PON and WDM PON using Different Coding Schemes by the use of 16 users in Optical Network Unit (ONU) receiver side. Simulation work estimates the gain performance achieved up to 10Gbps in terms of data capacity per ONU and distance at 100 km in terms of system reach at the downstream direction in the receiver side.

Keywords:
Passive Optical Networks (PON); Time Division Multiplexing (TDM); Wavelength Division Multiplexing (WDM; Bit Error Rate (BER); Optical Networks Unit (ONU).

1.Introduction

Optical Fibre communication has been playing a vital role in communication for its huge bandwidth capacity. This has led to a many applications such as FTTH. It offers the benefit in a cost effective manner. It is capable of technologies for next generation accesses networks, Passive optical networks are (PON) are considered to be a promising method for implementation of FTTH. FTTH provides many services such as video file swapping, peer-to peer transmission, a Video on Demand (VoD) and Internet Protocol TV (IPTV), etc. "Last mile access networks " have insufficient bandwidth problem called as "Last Mile" bottleneck, is in research nowadays[1-3].

To fulfil all these future demands the requirements are done by passive optical networks using high bandwidth, increased reach, increasing more subscriber flexibility, required security, and greater density . The demands those being offered additionally gives symmetric bandwidths, in both downstream (the exchange to the user end) & upstream (user end to the exchange). PON provides multiservice up to 1Gbps to end users.[4] The PON delivers the service by means of different multiplexing Schemes, such as TDM,WDM and Hybrid TDM/WDM[5-6].

In WDM-PON an intensive research is been done for different applications by using of different types of modulation formats at the Optical Network Unit (OLT).

Different WDM PON architectures are recently being deployed which increases the feasibility of using modulation techniques because of tremendous improvements in system reach the data carrying capability. This research work carried and examined the feasibility of using efficient photo receivers in the Central Office, in a WDM-PON network during the downstream direction. This paper is structured as follows. A brief outline of coding techniques in section II. Section III describes about the recent challenges and current PON technologies existing in the TDM and WDM PON. The simulation techniques and the values of the parameters are outlined under the heading performance evaluation in section IV. This is followed by Section V which describes the results and discussions and finally section VI conclusions.

2. Coding Techniques Overview

2.1 NRZ Coding

Line coding defines the arrangement of symbols in a particular pattern for transmission that represent binary data. NRZ coding is a line code in which binary value '1' is represented by positive voltage and '0' is represented by negative voltage. The pulses have more energy than others. It requires only half the bandwidth than other coding. This is for Bipolar NRZ coding. There is also another type called unipolar NRZ coding, represented by 1' is represented by positive voltage and '0' is represented by DC line.

2.2 RZ Coding:

In RZ encoding, a binary 1 is represented by first half of the bit duration, during the second half the level returns to zero. Absence of a pulse represents a binary 0, during the entire bit duration. Twice the bandwidth is required for RZ coding, because for data transmission it takes only half a bit duration.

2.3 Manchester

Manchester code is another type of line coding technique used for data transmission, also called as Phase Encoding. In this type of encoding, each bit has minimum one transition

and occupies the same time. Since the DC component carries no data, it is not present in this coding. Manchester code is widely used for all practical applications, since it consumes less bandwidth in order to achieve the original transmitted data rate. It ensures frequent line voltages, directly proportional to the clock rate. The below fig.1 shows various coding techniques.
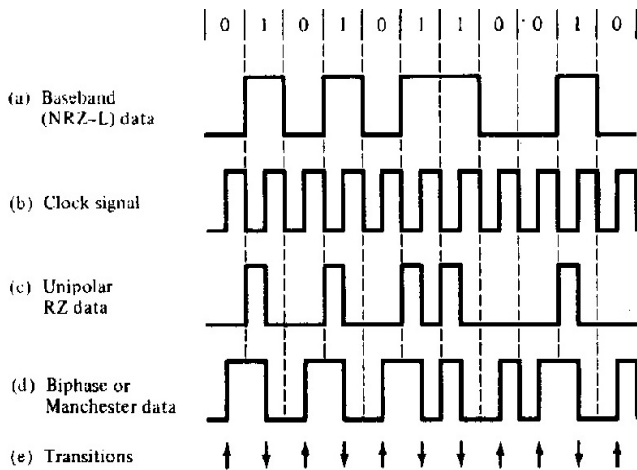

Fig 1. Various coding techniques

3. Optocal Fiber Access Nwtworks

During the year 1980's only Passive optical networks (PONs) were developed. PON are receiving interest since it is a cheapest way to implement. It is used as a cost effective method for sharing fiber infrastructure to business premises, curb, and home etc. The PON architectures use the passive components, which potentially reduces the cost and maintenance since it is point to multi point transport network.

Using optoelectronics PONs are characterized to have low power consumption, except laser amplifiers and photo receivers. PON has several advantages such as fiber data rates up to 10 Gbits, and passive power splitters which can be installed anywhere. Using upstream and downstream the PONs is served bi-directionally [7]. Research is going on for carrying multiple applications and data rates through long/extended reach [9]. PONs provides cost effective solutions [10]. GPON has found to improve bandwidth factor by four through maintenance and security issues [11]. There are several architectures of PON using different modulation schemes like TDM, WDM and hybrid using both TDM/WDM.

3.1 TDM PON

Fig.2 shows the he physical tree topology of TDM PON network. At the Central Office (CO) the Optical Line Termination (OLT) transmits the data in the downstream traffic. A optical fibre connects the OLT to the ONU users which is connected through a optical Combiner/ optical Splitter which is a passive component which combines or divides the signal from OLT to ONU. At the user end the ONU used is the optoelectronic component.
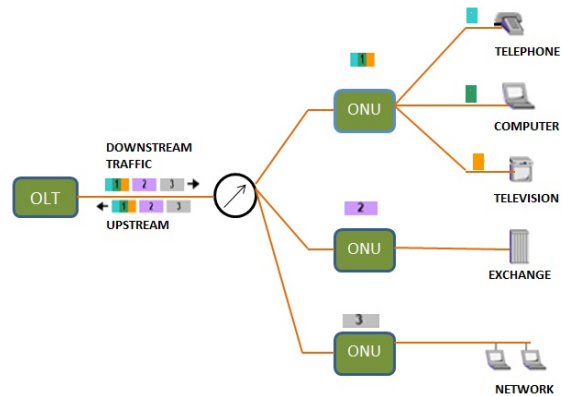

Fig 2. TDM PON Model

The TDM PON is a point to multipoint architecture. In the downstream direction the packets were broadcasted by the OLT. It is passed through a 1: N optical splitter and it is extracted by the designated ONU. The data is sent in the form of packets and each user transmits after a definite time delay. The same time delay is utilized at the destination ONU to distinguish the packets meant for it.

3.2 WDM PON

WDM PONs has been widely researched as a potential technology. This PON uses multiple wavelengths in a single fiber to multiply the capacity without increasing the data rate. But a single wavelength. is assigned for TDM PON. A TDM PON provides moderate bandwidth but more channels. As a result of it both methods have merits and demerits, therefore both the methods needs to be evaluated. For the past 10 years PON is being researched and many new architectures have been developed, through which WDM PON increases the broadband access capacity.[12-13]. The PON architecture consist of a Single Mode fiber which connects a Central Office to the network distribution unit which consist of passive optical splitters or/and Multiplexers and Demultiplexer. PON can be operates beyond the distance of 20 km. PON also provides data rates in Gbits/sec due to its tree network topology. PON has maximum passive component and minimum active components. Therefore it provides cost advantage, because maintenance and power

are the two major cost affecting factors in the optical network unit.

Fig. 3 represents WDM PON architecture. The OLT housed in CO has a set of tunable laser source or fixed wavelength laser sources used to transmit the downstream traffic to ONU. Each user has been assigned a fixed frequency at which the laser operates. The frequency allotment can be permanent or it can be based on the requirement of bandwidth demanded. The data is then given to a multiplexer which combines all the data together and sends it through the optical fiber of lengths varying from 20km to 100km.
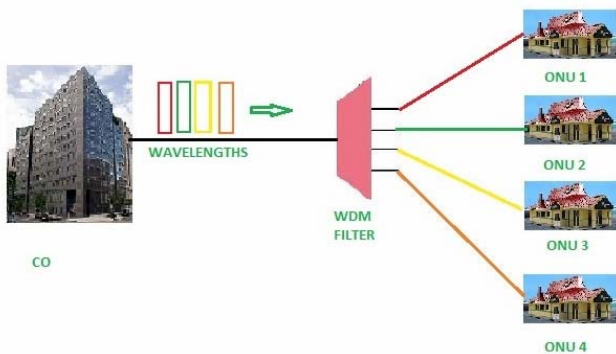

Fig 3. WDM PON MODEL

The Optical fiber that comes from the central office is connected to a passive WDM Demultiplexer. The function of it is to split the light depending on the wavelength and to transmits the same to the corresponding ONU. The ONU us again an optoelectronic component and converts the light signal to electrical signal and the data is retrieved

4. Performance Evaluation

The performance is evaluated using the simulation done in the OptiSystem.7 simulation tool of OptiWave Corporation [14]. To compare the performance of the network we have analyzed BER performance, fiber length and different data rates. The PON network simulated support 16 users with the objective to determine the Q factor and min BER achievable at different data rates and different fiber lengths. Then comparing the min BER with the different SMF lengths

4.1 TDM PON Simulation

The architecture consists of 16 transmitters, a CW laser with a frequency of 193.1 THz, a time delay circuit provides with the specific time delay for each transmitter at OLT. Since the data is sent in the form of packets with each user transmitting at a specific time interval. Figure 4, shows the TDM architecture. The transmitter consists of a PRBS generator set at 1 Gbit/sec. the bit sequence is modulated using a RZ MachZehnder modulator. The optical signal from each user is then combined using a power Combiner and is sent

through the SMF of length varying from 20-100km. At the receivers end a Power Splitter is used, which directs the optical data signals to each one of the ONU and it is synchronized with the specific time delay as given at OLT. The ONU signals are multiplexed in time sharing basis during the upstream traffic, therefore each ONU transmitter has a fixed time slot with different delay times, by which the ONU are allowed to transmits the data. The time slot assigned in the networks limits the throughput per user. Table 1. List majorly used network components and the values assigned for simulation of TDM PON parameters.
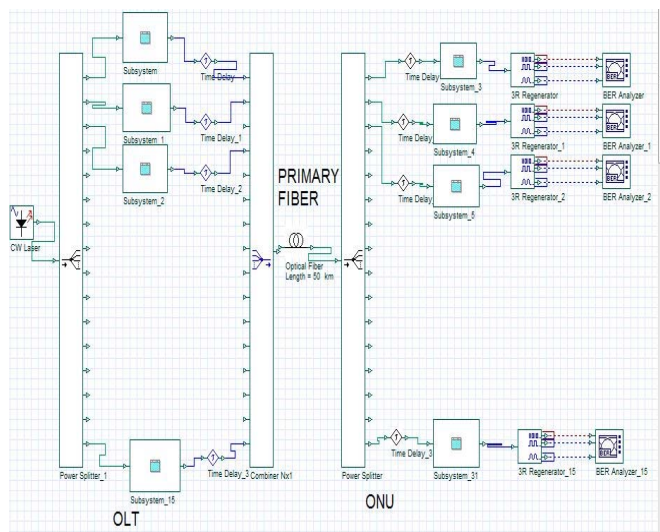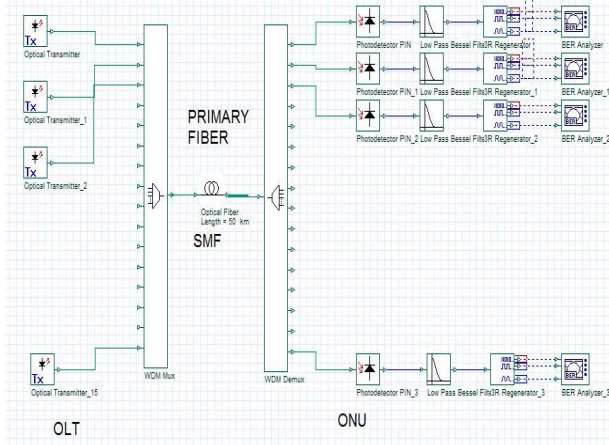

Fig. 4 TDM PON Simulation set up

Table 1. The parameters and their values for TDM PON Network

Components	Parameters	
	Type	Value
Light Source	Frequency	193.1THz
	Power	5dBm
PRBS generator	Bit rate	2-5 GBPS
Photo detector	Responsivity	1 A/W
	Dark Current	10nA
Modulator	Modulation format	RZ
Time Delay	OlT-1	0 sec
	OLT-2	1/(Bit Rate)*1/4 sec
	OLT-3	1/(Bit Rate)*2/4 sec
	OLT-4	1/(Bit Rate)*3/4 sec
Optical Fiber	Fiber length	20-100

4.2 WDM PON Simulation

Figure 5, shows the architecture of WDM PON, it consists of 16 users. At the transmitting end it consists of a PRBS generator at 1Gbit/sec, RZ/NRZ pulse generator, a CW Laser operating at frequency varying from 193.1 to 194.6 THz. The output from all the modulators is then multiplexed

and connected to a SMF of length varying from 20km to 100km and terminating into a WDM Demultiplexer. The optical signal received at the demultiplexer is then separated to their respective wavelength and then they were combined at the OLT. The ONU consists of a PIN photo detector which detects the optical signal and converts it into electrical signals. BER analyzer is then connected to each of the ONU to compute BER values of each of ONU received signal. Table 1, lists the major components utilized and the

parameters assigned to them. Table 2. List majorly used network components for simulation of TDM PON along with the values assigned to the parameter.

Fig 5. WDM PON Simulation Set Up

Table 2 The parameters and their values for WDM PON Network

Components	Parameters	
	Type	Value
Light source	Wavelength	1552-1527 nm
PRBS generator	Bit Rate	1-5 GBPS
Optical fiber	Fiber length	20-100km
Modulator	Modulation format	NRZ
		RZ
		MANCHESTER
WDM MUX	Insertion loss	0dB
	Filter type	Bessel
	Filter order	2
Photo detector	Responsivity	1A/W
	Dark current	10nA
Layout parameters	Sequence length	128 Ts

5. Results and Discussions

The BER values computed as measured in the simulation environment all corresponds to the mean values. The data rates used are 1, 2.5 and 4Gbps. Single mode fibers used show us that there is no intermodal attenuation in it as compared to multimode fibers which signify longer length of

transmission due to less attenuation and signal remains stronger for a considerable length.

Table 3 compares the values of TDM PON and WDM PON network for Manchester coding. It shows that WDM PON have better BER and Q factor. WDM PON has many advantages than TDM PON, so we proceeded the research for WDM PON. Table 4 compares the values of different coding techniques using the WDM PON simulation setup and with the necessary parameters. It shows that Manchester coding techniques has better min BER and Q factor when compared with RZ, NRZ.

Table 3 Analysis of Manchester coding with different

Comparison of Access Techniques		
Analysis	TDM	WDM
Max Q Factor	8.16056	19.431
Min.BER	1.6617e-016	2.06995e-084
Eye Height	7.62008e-005	2.12685e-005
Threshold	7.46073e-005	1.1314e-005

Table 4 The parameters for WDM PON Network

Comparison of Coding Techniques			
Analysis	Manchester	RZ	NRZ
Min BER	1.891 e-126	3.39019e-090	2.0934e-081
Max Q factor	23.591	20.1041	19.0735
Eye height	0.790052	2.3279e-005	2.11968e-005
Threshold	0.435916	1.38412e-005	1.2590e-005

Table 5 is been evaluated for WDM PON using different data rate only with Manchester coding for 100kms. At 2.5Gbps min BER is achieved, similarly for NRZ coding Min BER is obtained using 100kms for 1Gbps as shown in table no 6, and finally we evaluated for RZ coding for 100kms long reach WDM PON networks using different data rates, it finds that

Table 5 Analysis of Manchester coding at different bit rate

Analysis	1 GBPS	2.5 GBPS	4 GBPS	10 GBPS
Max Q factor	42.8501	23.891	7.9998	2.19703
Min BER	3.256e-216	1.891e-126	6.01501e-16	0.01038
Eye height	0.876858	0.790052	0.47418	0.1771
Threshold	0.4276691	0.435916	0.34992	0.562996

Table 6 Analysis of NRZ coding at different Bit rates

Analysis	1 GBPS	2.5 GBPS	4 GBPS	10 GBPS
Max Q factor	29.9408	19.4313	15.2277	3.28311
Min BER	2.8801e-197	2.0699e-084	1.1432e-52	0.000416
Eye height	2.255e-05	2.1268e-05	1.9889e-05	1.5119e-05
Threshold	1.1763e-05	1.1314e-05	1.1389e-05	5.6716e-05

Table 7 Analysis of RZ coding at different bit rates

Analysis	1 GBPS	2.5 GBPS	4 GBPS	10 GBPS
Max Q factor	37.7415	20.163	13.2549	6.03914

Min BER	5.1531e-312	1.77282e-90	1.6694e-05	0.000275
Eye height	2.92e-05	2.3291e-05	1.6694e-05	0.000275
Threshold	1.692e-05	1.38694e-05	1.024e-05	0.000140

Figure 6, here shows the SMF lengths for acceptable BER values. This shows that as the length of SMF is increased the acceptable BER value is not achieved. The maximum length for which BER value is below acceptable value is 28km for Manchester coding, 42 km for NRZ coding and 40km for RZ coding at 4Gbps. Figure shows the graph between SMF lengths and BER for data rates of 7Gbps and 10Gbps. The graph clearly indicates that as the data rates are increased the BER values go down as well as the length of SMF in decreased to achieve acceptable data rates. In case of 7Gbps the maximum length for which BER value is acceptable is 43km and it is 22km for 10Gbps. This clearly indicates that as the data rates go up the power level needs to be increased at OLT. The Eye Pattern technique is used for assessing the data handling capabilities and evaluating the performance of an optical system. The width of the eye opening defines the time interval over which the received signal can be sampled

without error from intersymbol interference. The figure shows the BER patterns as well as Min Q Factor for systems with different data rates. The figure 6.1 (a) shows the maximum widths as well as the eye height which signifies the least signal distortion as compared to other coding techniques. As the data rates are increased it is clearly visible from figure 6.1 (b) and 6.1 (c) that the eye width as well as eye height decreases which shows considerable signal distortion keeping the same power levels as OLT. The sensitivity of the system is determined by the rate of closing of the eye. If the sampling time is varied, the eye closing is also varied. The probability of the timing error increases as the sampling time is varied as in the case with higher data rates of figure 6.1 (c). This implies that as the data rates go higher the possibility of error in the signal increases. Fig 6.2 and Fig 6.3 is been evaluated using NRZ and RZ coding which shows inferior results when compared with Manchester coding. When comparing the graphs of fig 6.4, fig 6.5, and fig 6.6, it shows considerable lower BER at 10 Gbps than other used data rates such as 4 Gbps, 7 Gbps.
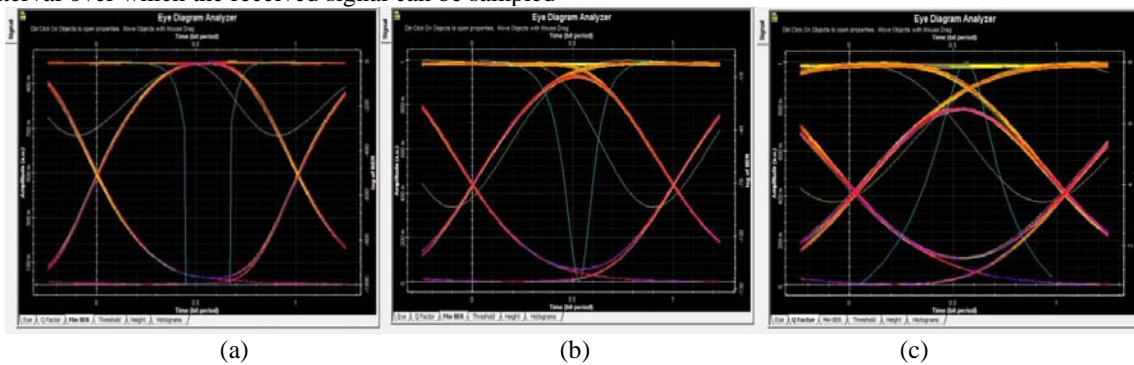

(a)   (b)   (c)

Fig. 6.1 Eye diagrams form left to right::for manchester coding at (a) 1 Gbps (b) 2. 5 Gbps and (c) 4 Gbps

(a)   (b)   (c)

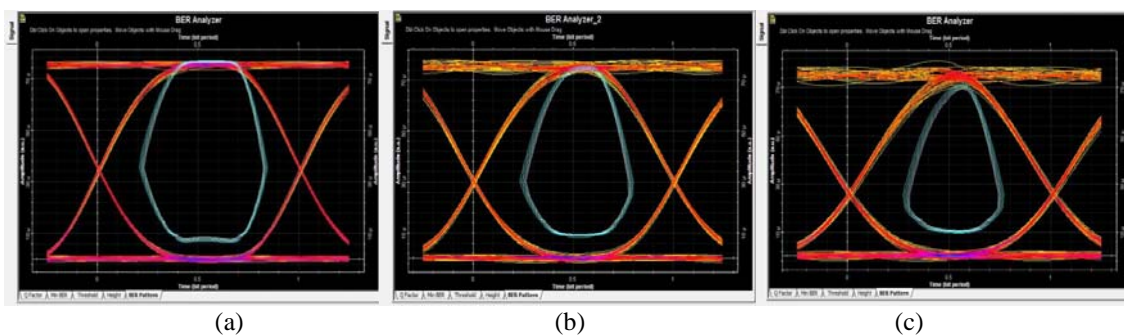Fig. 6.2 Eye diagrams form left to right :for NRZ coding at (a) 1 Gbps (b) 2. 5 Gbps and (c) 4 Gbps

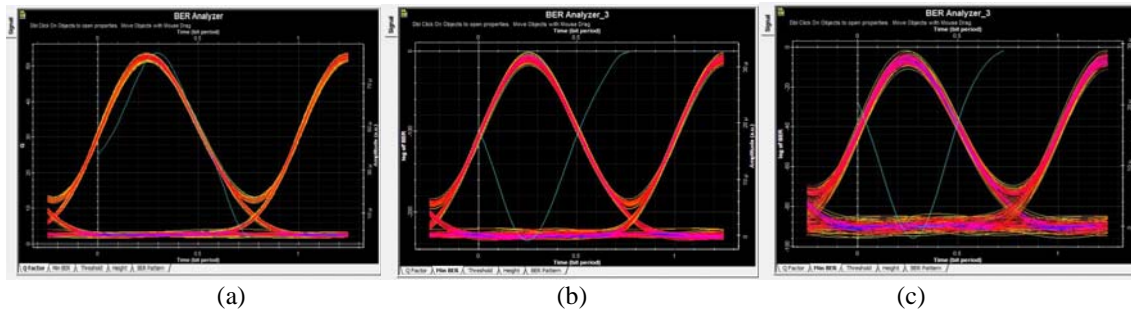(a)   (b)   (c)

Fig. 6.3 Eye diagrams form left to right : for RZ coding at (a) 1 Gbps (b) 2. 5 Gbps and (c) 4 Gbps
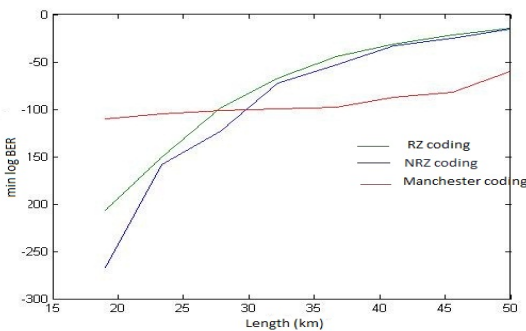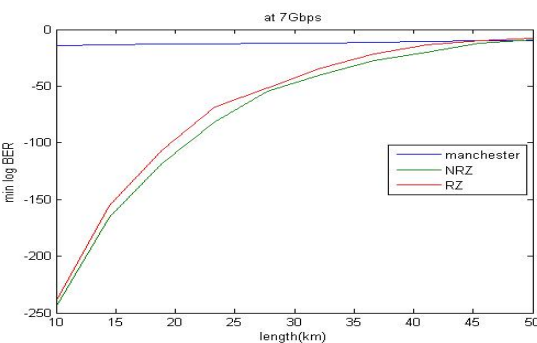

Fig 6.4 Fiber length Vs min BER at 4 Gbps

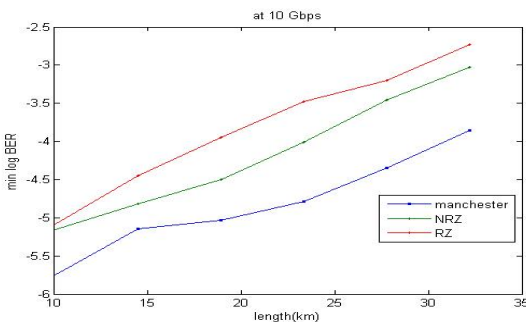Fig 6.5 Fiber length Vs min log BER at 7 Gbps

Fig 6.6 Fiber length Vs min log BER at 10Gbps

6. Conclusions

TDM and WDM-PON access network architecture was designed using 16 users has been successfully evaluated in this research work. Results simulated using optisystem have confirmed that WDM PON network performance is better than TDM PON networks. This has been evaluated for different coding techniques for both TDM PON and WDM PON. Through simulation it is revealed that Manchester coding shows better performance through Min BER, Max Q factor, and Eye Diagram when compared with RZ and NRZ coding techniques. In the long reach enhanced system the data rates are compared using 1Gbps, 2.5Gbps, 4Gpbs and 10Gbps. It is also estimated from graphs, that if power consumption is increased at the central office, it can transmit high data rates with minimum BER, and it also shows that if power consumption is lowered in the central office, it works for lower data rates with optimum BER. The research work can be extended for DWDM PON and CWDM PON and OCDMA PON architectures using various coding techniques.

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