Performance Analysis of Receivers in WDM for Extended Reach Passive Optical Networks

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Abstract

In this paper we have investigated and analyzed the performance of receivers for different classes of WDM PON system for next generation Passive Optical Networks. The performance is analyzed using Manchester coding for different receivers using various data rates and various fibre distances at the optical network unit in a 32 user WDM PON and DWDM PON. The experimental results are analyzed using the parameters BER, Qfactor and Eye Pattern. The simulation results revealed that the performance gain of around 2.5 Gbps in terms of data carrying capacity per user over a distance of could be achieved if APD receivers are used in the receiver side downstream direction.

Keywords: *Wavelength Division Multiplexing(WDM), Dense Wavelength Division Multiplexing(DWDM), Passive Optical Networks (PON), Optical Line Terminal (OLT), Optical Networks Unit (ONU), Bit Error Rate(BER), PIN and Avalanche Photo detectors(APD).*

1. Introduction

FTTH is a innovative technology which is upcoming for next generation fibre access networks. Passive Optical Networks are presently now enormously developing to implement FTTH. The recent PON candidates are ATM, Ethernet and WDM. WDM PON requires only passive components, active components are not required, therefore heat and power issues are not considered. Network requires less components, therefore maintenance cost is also less. Now a days WDM PON plays a critical role for multiservice and multicasting because of increased bandwidth facility. To support multiservice WDM and DWDM are implemented through a single mode fibre. They provide services to deliver data, voice and video.

To fulfil all these future demands the requirements are done by passive optical networks using high bandwidth, increased reach, increasing subscriber density, greater flexibility, and security. Additionally, those demands which is being offered provides symmetric bandwidths, in both upstream (user end to the exchange) & downstream (exchange to user end).

Paper[1-2] reveals that APD when used in downstream gives better performance using NRZ coding for WDM PON. WDM PON is being deployed by the Korean telecom to provides commercial multiple services to end users.[3]. PON provides cost benefits in delivering the network access solutions. The PON delivers the service by means of different multiplexing Schemes, such as TDM,WDM and Hybrid TDM/WDM[4-5].
WDM PON have been analysed using the threshold level adjustments to improve the performance of the receivers[6].
TDMPON and WDM PON for ultra low loss transmission were discussed for PIN photo receivers[7]. Several key enabling technologies for converged WDM-PON systems are demonstrated, including the techniques for longer reach, higher data rate, and higher spectral efficiency. The cost-efficient architectures are designed for single-source systems and resilient protection for traffic restoration[8]. The capacity of the WDM is increased by the algorithm achievable rate region[9].

An intensive research has been undergoing in WDM-PONs for different applications by using of different receivers the Optical Network Unit(OLT). More recently the deployment of several WDM PON architectures have raised feasibility of using Manchester coding techniques due to potential improvements in the data carrying capability and system reach. This research work carried and examined the feasibility of using efficient photo receivers in the Central Office, in downstream direction in a WDM-PON. The rest of the paper is organized as follows. A brief overview of Photoreceivers in section II. The current PON technologies and research challenges along with WDM PON and DWDM PON operation is given in section III. The simulation methodologies and parameters assigned are outlined in section IV. This is followed by Section V which explains results and discussion and finally section VI concludes the paper.

2. Photo receivers Overview

Receivers basically converts optical signal into a electrical signal. Photo receivers convert the electrical signal proportional to a optical signal. Electrical signal is linearly proportional to a optical signal. Semiconductor materials are used for construction of receivers. The material used are Indium gallium arsenide phosphide, and Indium gallium arsenide. The photodetectors operate in the wavelength of 1.3 µm and 1.55 µm. Photdetectors operate for a wide bandwidth. They are characterised by the reponsivity. Two types of receivers are available, they are pin receivers and APD receivers.

2.1 PIN Receivers:

The simple semiconductor photo detector is the pin photdiode. The device structure consist of p and n region separated by a very lightly doped intrinsic material. It works in reverse bias. The detector is designed to operate in the wavelength region of 1100nm -1600 nm. The material used is III and V group elements such as InGaAs. It has the quantum efficiency ranging from 30 to 95%. The responsivity for silicon PIN at 900 nm is 0.65A/W and 0.45 A/W for germanium at 1.3 µm. For InGaAs it is 0.9 A/W at 1.3 µm and 1.0 A/W at 1.55 1.3 µm.

2.2. APD Receiver:

APD has very high sensitivity and responsivity when compared with PIN because of the phenomenon called avalanche effect in its intrinsic region to create an electrical gain. InGaAs will be used for detecting the wavelength of upto 1.55 µm. The commonly used structure is reach-through construction known as RAPD.

3. Optical Access Networks

Passive optical networks (PONs) were developed during the year 1980's. 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 uses 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, and it does not have any problem with heat and temperature, except lasers, amplifiers and photoreceivers. 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 are served bi-directionally[7]. Research is going on for carrying multiple applications such as subcarrier multiplexing, OFDM, carrier reuse, wavelength reuse and data rates thro long/extended reach[9]. PONs provide 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 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. Typically a TDM PON uses a single wavelength whereas a WDM PON uses many wavelengths. A TDM PON provides more channels but moderate bandwidth. As a consequence both solutions have merit and thus both methods need evaluation. PON has been researched for over 10 years and many architectures have been proposed, through which WDM PON increases the broadband access capacity.[12-13] In a generic PON architecture a SMF fiber connects a Central Office to a distribution center which contains passive splitters or/and Multiplexers and Demultiplexer. PON operate at distances beyond 20 km and provide data rates in the order of Gbits/sec due to its end to end fiber infrastructure. Minimizing the active components in PONs provides cost advantage since power and maintenance are one of the major cost factors for the local exchange carrier.

Fig.1 represents a WDM PON architecture. the OLT housed in CO has a set of fixed or tunable laser source to send 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 according to the bandwidth demand. 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. the

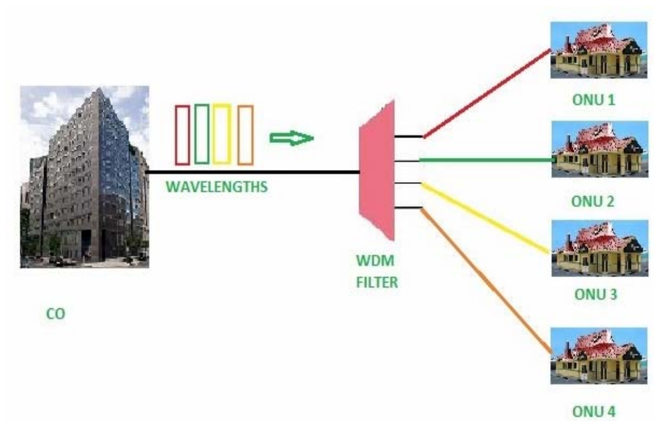


Fig 1. WDM PON Model

optical fiber terminates on a passive WDM Demultiplexer that separates light according to the wavelength and the transmits it to the corresponding ONU. The ONU us again an optoelectronic component and converts the light signal to electrical signal and the data is retrieved.

3.2 DWDM PON

DWDM stands for Dense wavelength division multiplexing. It increases the channel capacity as well as Bit rate. Signals multiplexed in the wavelength range of 1550 nm using EDFA. EDFAs operate between c band 1525 -1565 nm and L band 1570-1610 nm. In DWDM wavelength are positioned between 100 GHz(0.8 nm). Now a day's DWDM systems uses 160 channels for operation using lesser channel spacing of 50 GHz or even 25 GHz. The DWDM

PON architecture remains the same as that of WDM PON except the channel spacing.

4. Simulation Methodology

The simulation is done in Optisystem version 7 of OptiWave Corporation. To compare the performance of the network we have analyzed BER performance, fiber length and different data rates. The PON network simulated supports 2 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 WDM PON Simulation

Fig 2, shows the architecture of WDM PON, it consists of 2 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. Manchester coding is been used here, since it providesThe optical signal received at the demultiplexer is then separated according to the way they were combined at 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 at the ONU to compute BER values of each 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 WDM PON along with the values assigned to the parameter.

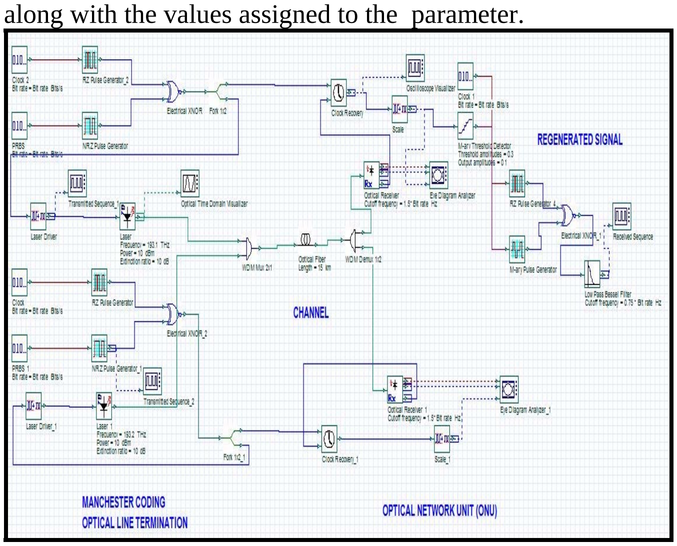


Fig. 2 WDM PON Simulation set up

Table 1: The parameters for WDM PON Network

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

4.2 DWDM PON Simulation

Fig 3, shows the architecture of DWDM PON, it consists of a CW Laser operating at wavelength varying from 1553.59 to 1553.27. The spacing between the channels are 100GHz. The architecture uses the same components as in WDM networks. Table 2. List majorly used network components for simulation of DWDM PON along with the values assigned to the parameter.

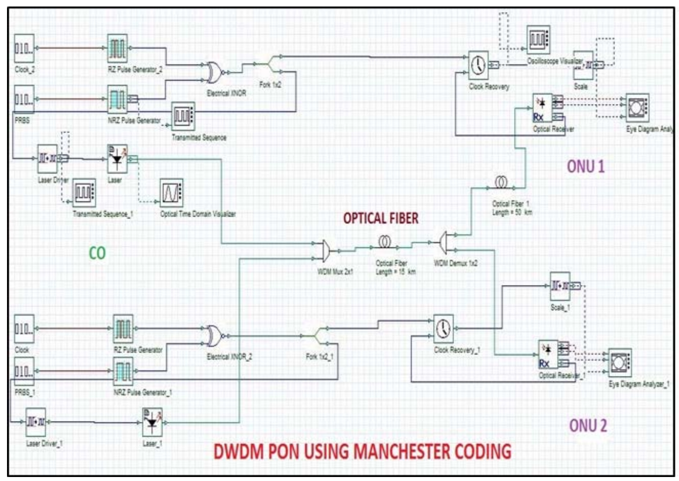


Fig 3. DWDM PON Simulation Set Up

Table 2 :The parameters for DWDM PON Network

Components	Parameters	
	Type	Value
PRBS generator	Bit Rate	2.5 GBPS
Light source	Wavelength	1553.59 1553.27 nm
Modulator	Modulation format	MANCHESTER
WDM MUX	Insertion loss	0dB
	Filter type	Bessel
	Filter order	2
Optical fiber	Fiber length	20-100km
Photodetector	Responsivity	1A/W
	Dark current	10 nA
Layout parameters	Sequence length	128 bits

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 4 Gbps. 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 PIN and APD for WDM PON network using Manchester coding. It shows that APD receivers have better BER and Q factor.

Table 4 compares the values of PIN and APD for DWDM PON network using Manchester coding. It shows that APD receivers have better BER and Q factor. It has been proved that Manchester coding provides better results.

TABLE 1: Analysis of WDM PON Network

Comparison of Receivers		
Analysis	PIN	APD
Max Q Factor	7.99988	23.89
Min.BER	6.0158e-16	1.891e-26
Eye Height	0.34992	0.790052
Threshold	0.56418	0.435916

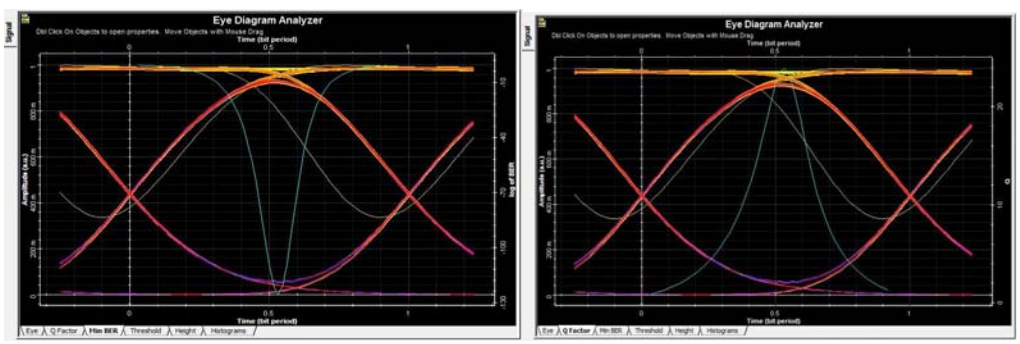
This analysis is done for the comparison of performance between PIN and APD photodiodes for both the WDM and DWDM networks and the results are provided in the form of tabular column and listing the improvements provided by APDs in simulated network in terms of system reach and data carrying capabilities.

TABLE 3:ANALYSIS OF DWDM PON NETWORK

Comparison of Receivers		
Analysis	PIN	APD
Max Q Factor	11.8159	14.6687
Min.BER	1.61442e-032	5.00423e-049
Eye Height	0.558667	0.626376
Threshold	0.435062	0.379033

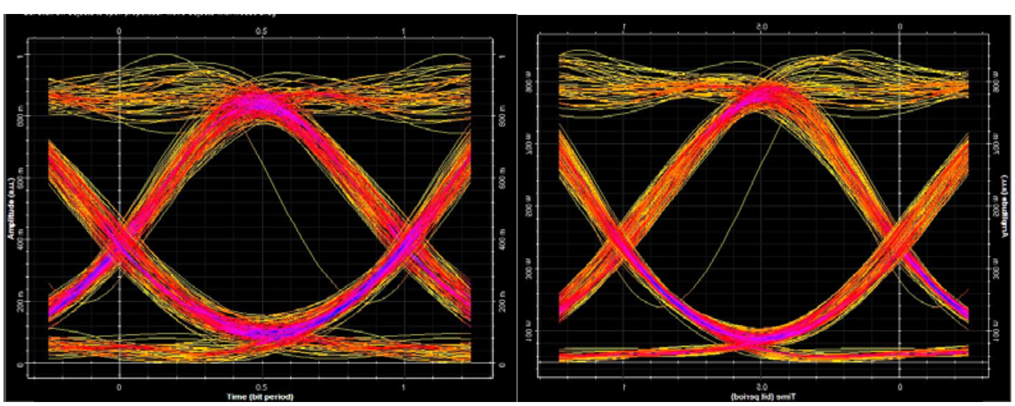
6. Evaluation of Performance Through Eye Diagrams

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 Max Q Factor for systems with different data rates. The height of the eye opening is reduced due to the amplitude distortion in the data signal. The rate at which the eye closes at the sampling time determines the sensitivity of the system to timing errors.



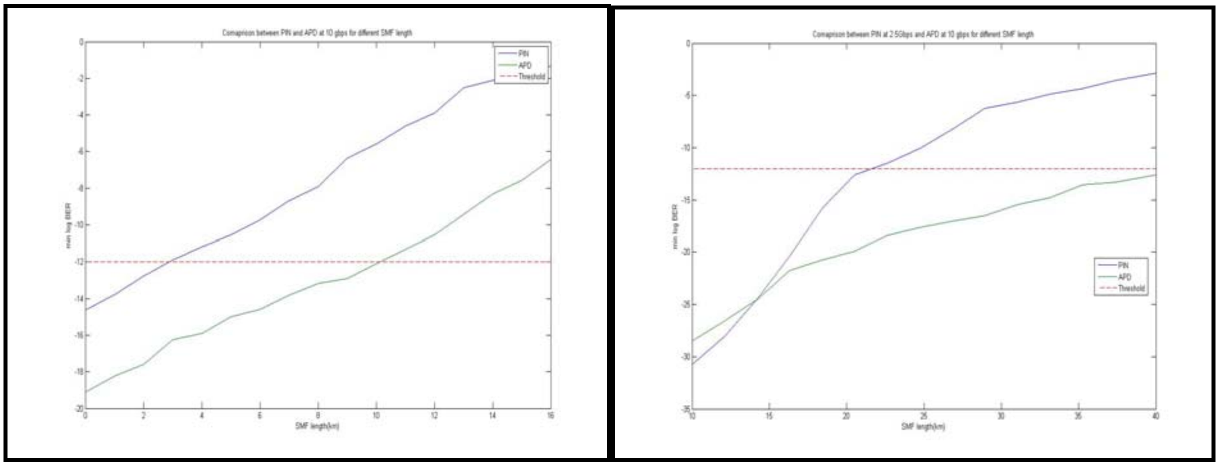
(a) (b) (c)

Figure 6.1 Eye diagrams for downstream: using PIN receiver at 2. 5 Gbps



(a) (b) (c)

Figure 6.2 Eye diagrams for downstream:for APD receivers at 2. 5 Gbps



(a) (b) (c)

Figure 6.3 Comparision between PIN and APD for WDM: downstream (a) 10Gbps (b) 2.5Gbps

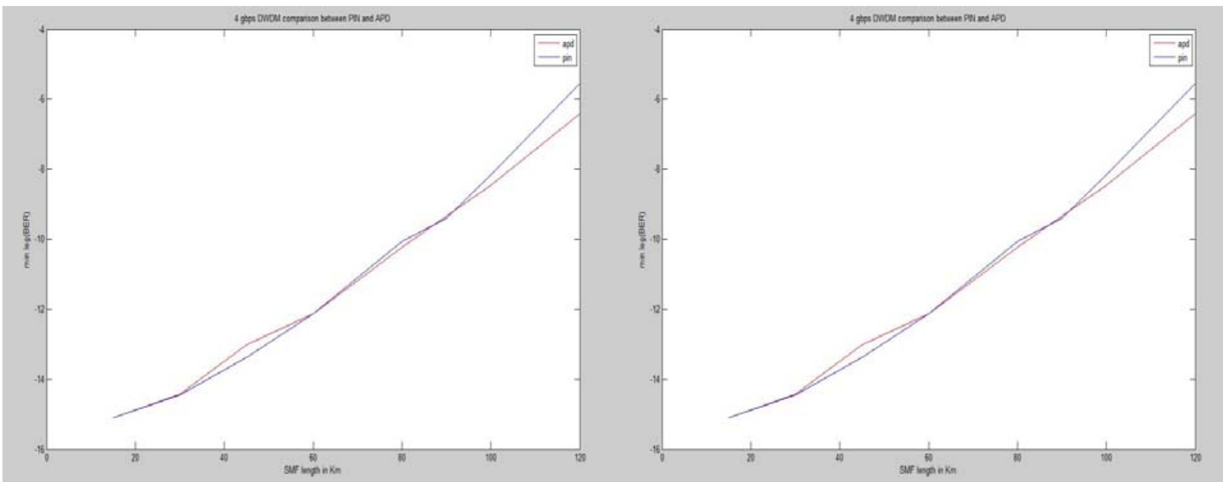


Figure 6.3 Comparision between PIN and APD for DWDM: downstream (a) 10Gbps (b) 2.5Gbps

7. Conclusions

Here we can see that at higher distance the BER value is significantly very less in PIN receiver as compared to that of APD receiver. As we increase the distance further we observe at 150 Km the BER value for PIN is even less than the min. required BER value. But at distances less than 60 Km range there is not much difference between PIN and APD BER values. Hence we can conclude that for 2.5Gbps data rate and for long distance data transmission APD receiver is much reliable and gives better performance than that of PIN photo receiver.

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