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Passive Optical Network Performance Analysis Using Dijkstra's Algorithm

تحليل أداء الشبكات الضوئية الغير فعالة باستخدام خوارزمية الدايجسترا

Thesis Submitted in Partial Fulfilment to the Requirements for the award of the Degree of M.SC. In Electronics Engineering (Communications)

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الآيـــة

بسم الله الرحمن الرحيم

قال تعالى:

﴿قَالُوا سُبْحَانَكَ لَا عِلْمَ لَنَا إِلَّا مَا عَلَّمْتَنَا إِنَّكَ أَنْتَ الْعَلِيمُ الْحَكِيمُ﴾

صدق الله العظيم

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I extend my thanks to all who stood

Withme to achieves this research which

It com because of grace of God

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For his great help and support.

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Finally yet importantly I dedicate this project for everyone that helped me to be at the place that I am today.

Dedication

Dedication to my mother. . .

Whit warmth and faith...

Dedication to my father. . .

Whit love and respect . . .

Dedication to my friends..

Whom we cherish their friendship

Dedication to my special people

Who mean so much to me. . .

Dedication to all my teachers . . .

In whom I believe so much . . .

Abstract

A fiber optic communication system has been employed using 2.5G (downstream) next generation passive optical network architecture. The problem is the shorter range possible commonly no more than 20 km, that reason of study and analysis the optimal requirements, configurations and parameters that can used to design and implement an XG-PON downstream Network. The simulation was done using Matlab. The results have been compared for non-return to zero and return to zero formats for downstream data in terms of quality factor value. It has been observed that return to zero modulation format is superior compared to conventional on-return to zero modulation and the distance has been increased to 80km.

المستخلص

تم استخدام نظام اتصالات الألياف البصرية باستخدام معمارية الشبكات الضوئية الغير فعالة من الجيل التالي 2.5 قيقا (المصب). والمشكلة هي المدى الأقصر الممكن و الذي لا يزيد عادة عن 20 كم، وهذا سبب دراسة وتحليل المتطلبات المثلى، والتكوينات والمعاملات التي يمكن استخدامها لتصميم وتنفيذ شبكة الضوئية الغير فعالة من الجيل التالي (المصب).تم إجراء المحاكاة باستخدام ماتلاب. وتمت مقارنة النتائج بالنسبة إلى صيغ عدم العودة للصفر والعودة للصفرللبيانات النهائية من حيث قيمة معامل الجودة. و لوحظ أن صيغة العودة للصفر افضل من عدم العودة للصفر التقليدية وتمت زيادة المسافة إلى 80كم.

Abbreviations

AWGN	Additive White Gaussian Noise
AON	Active Optical Network
BER	Bit Error Rate
CPU	Central Processing Unit
CO	Central Office (telephone switching center)
CWDM	Coarse Wavelength Division Multiplexing
dB	Decibel
DWDM	Dense Wavelength Division Multiplexing
DBA	Dynamic Bandwidth Assignment
DS	Down Stream
3DTV	Three Diminutions Television
Erfc	Complementary Error Function
EPON	Ethernet Passive Optical Network
FSAN	Full Service Access Network
FTTx	Fiber To The X
FAX	Far Away Xerox(xerographic printer)
FTTB	Fiber To The Building
FTTC	Fiber To The Curb
FTTCab	Fiber To The Cabinet
FTTH	Fiber To The Home
FTTCell	Fiber to the Cell
G-PON	Gigabit Passive Optical Network
Gbps	Gigabit per Second
HDTV	High Definition Television
ITU-T	International Telecommunication Union–Telecom sector

IEEE	Institute of Electrical and Electronics Engineers
IP	Internet Protocol
IPTV	Internet Protocol Television
InGaAs	Indium Gallium Arsenide
LR-PON	Long-Reach PON
LTE	Long Term Evolution
MTU	Multi-Tenant Unit
MDU	Multi Dwelling Unit
NG-PONs	Next Generation Passive Optical Networks
NRZ	Non Return To Zero
NS-3	Network Simulator 3
nA	Nano Ampere
OMNET	Objective Modular Network Tested
OLT	Optical Line Terminal
ONUs	Optical Network Units
ODN	Optical Distribution Network
ODSM	Opportunistic and Dynamic Spectrum Management
OFDMA	Orthogonal Frequency Division Multiple Access
OCDMA	Optical Code Division Multiple Access
OMCI	Optical Network Termination Management and Control Interface
ONT	Optical Network Terminal
OOK	On-Off Keying
PSTN	public Switching Telephone Network
PBX	Private Branch Exchange
P2MP	Point-To-Multipoint

PONs	Passive Optical Networks
P2P	Point To Point
Q-factor	Quality Factor
ROI	Return On Investment
RMS	Root Mean Square
RZ	Return To Zero
SBU	Single Business Unit
SFU	Single Family Unit
SNR	Signal-To-Noise Ratio
TDMA	Time Division Multiple Access
US	Upstream
VoIP	Voice Over Internet Protocol
WDM	Wavelength Division Multiplexing
WDMA	Wavelength Division Multiple Access
WIFI	Wireless Fidelity
WIMAX	Worldwide Interoperability For Microwave Access
XG-PON1	Next Generation Passive Optical Network

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CHAPTER ONE

INTRODUCTION

1.1 Preface

In telecommunications, the term asymmetric (also asymmetrical or non-symmetrical) refers to any system in which the data speed or quantity differs in one direction as compared with the other direction, averaged over time. Asymmetrical data flow can, in some instances, make more efficient use of the available infrastructure than symmetrical data flow, in which the speed or quantity of data is the same in both directions, averaged over time[1].

Increasing demand of bandwidth due to rapid growth of P2P, HDTV, 3DTV and Cloud Computing creates new challenges to bandwidth deployment and operation. Passive optical networks (PONs) are the most important class of fiber access network in the world today. A PON is a point-to-multipoint optical network, where an Optical Line Terminal (OLT) at the Central Office (CO) is connected to many Optical Network Units (ONUs) at remote nodes through one or multiple optical splitters. The network between the OLT and the ONU is passive i.e., it does not require any power supply [1][2]. The direction of PON evolution is a key issue for the telecom industry. As the users' demands for bandwidth are ever increasing, next generation passive optical networks (NG-PONs) are being standardized by ITU-T and IEEE standards. Furthermore, the future access network requires increased bit rates up to 10 GB/s to satisfy the increasing traffic demands. Two stages of NG-PON evolution have been planned by Full Service Access Network (FSAN) group: NG-PON1 and NG-PON2. NG-PON1 extended from the existing G-PON standards and compatible with the current optical distribution network (ODN). NG-PON2 is a long-term solution with an entirely new optical network type. In contrast, NG-PON1 is a mid-term upgrade from the G-PON system with backward compatibility to the existing fiber deployments. NG-PON1 is also called XG-PON1. XG-PON1 features asymmetric transmission of 10 GB/s downstream and 2.5 GB/s upstream [3]. 10Gb/s is selected for downstream transmission, as a cost effective way to transmit large amounts of data. In the upstream direction, 10 Gb/s burst mode time division multiple access (TDMA) is a challenging issue for its high data rate. The difficulty of designing and manufacturing such components prohibits using 10 Gb/s in the upstream direction. Thus 2.5Gb/s is selected as an economical and practical upgrade solution [4].

XG-PON2 is a symmetric system with the bidirectional rate of 10 GB/s. To ensure the smooth upgrade from GPON to XG-PON coexistence of both systems is mandatory and it can be done with wavelength division multiplexing [5]. A coexisting XG-PON and GPON can be very cost effective as the system shares common infrastructure and reduces the number of central offices (CO). As early as the year 2009, PONs began appearing in corporate networks. Users were adopting these networks because they were cheaper, faster, lower in power consumption, easier to provision for voice, data and video, and easier to manage, since they were originally designed to connect millions of homes for telephone, Internet and TV services[6].

Passive Optical Networks (PON) provide high-speed, high-bandwidth and secure voice, video and data service delivery over a combined fiber network. Inthe United States, Europe, and several Asiancountries, because residential customers requirehigh-bit-rate connections for broadband services.

This demand for bandwidth has exceeded recentpredictions, driven mostly by a number of factors,including the huge success of Internet video streaming services such as YouTube, the unanticipatedsuccess of high-definition television (HDTV), and the growing popularity of online social media sites where people meet, collaborate, and, more important, exchange photographs,video, and audio content with eachother[7]. The number of users demanding highbandwidth continues to increase at a rapid pace.Consequently, many service providers are planningnetworks capable of offering 50 Mb/s, 100Mb/s, or higher bandwidth per customer. In contrastto many existing broadband technologies,such as digital subscriber line (DSL) and wirelessaccess, fiber access can easily fulfill suchbandwidth requirements, on a per customerbasis, while still being capable of offering highercapability in the future. Several fiber access networkarchitectures have been developed, such aspoint-to-point (P2P)[8].Active optical network(AON) and passive optical network (PON)Furthermore, there are three main types ofPONs utilizing different resource sharing technologies:time-division multiplexing (TDM)PON, wavelength-division multiplexing (WDM)PON, and hybrid WDM/TDM PON.It has been examined that the feasibility of RZ format in XG-PON system is not available as such in the literature and thus is explored here to investigate the performance of 10G/2.5G asymmetric XG-PON system for NRZ and RZ data formats [9].

1.2 Problem Definition

The primary problemof passive optical network is the shorter range possible, commonly no more than 20 km.

1.3 Objectives

The aim of this research is to Design and analysis a downstream XG-Passive optical Network (PON). Moreover increase the distance of fiber optical.

1.4 Methodology

Study and analysis the fiber optic communication system based on 10G(down- stream) XGPON architecture. Evaluate the performance of the system for non-return-to-zero (NRZ) and return-to-zero (RZ) data formats by varying the length of the fiber for XG-PON system.

1.5 Thesis Outline

This thesis is divided into five chapters ,in chapter two represents the literature review and related works, in the third chapter the project methodology along with the scenarios and parameters used in the simulation was represented while Chapter Four includes the results and discussions in chapter five: Conclusion and Recommendations,in last of the thesis References.

CHAPTER TWO

BACKGROUND AND LITERATURE REVIEW

2.1 Introduction

In this chapter an introduction to the passive optical network was included with a brief notes on their structures and characteristics, and the coverage area along with the components of the network, moreover a summary of related works was included.

2.1.1 Passive Optical Network

A passive optical network (PON) features a point-to-multi-point (P2MP) architecture to provide broadband access. The P2MP architecture has become the most popular solution for Fiber To The X (FTTx) deployment among operators. PON-based FTTx has been widely deployed ever since 2004 when ITU-T Study Group 15 Q2 completed recommendations that defined GPON system (ITU-T series G.984)[10]. As full services are provisioned by the massive deployment of PON networks worldwide, operators expect more from PONs. These include improved bandwidths and service support capabilities as well as enhanced performance of access nodes and supportive equipment over their existing PON networks. The direction of PON evolution is a key issue for the telecom industry[11]. Full Service Access Network (FSAN) and ITU-T are the PON interest group and standard organization, respectively. In their view, the next-generation PONs are divided into two phases: NG-PON1 and NG-PON2. Mid-term upgrades in PON networks are defined as NG-PON1, while NG-PON2 is a long-term solution in PON evolution. Major requirements of NG-PON1 are the coexistence with the deployed GPON systems and the reuse of outside plant. The aforementioned requirements were tested in the recent Verizon field trials. Optical distribution networks (ODNs) account for 70% of the total investments in deploying PONs[12].

Therefore, it is crucial for the NGPON evolution to be compatible with the deployed networks. With the specification of system coexistence and ODN reuse, the only hold-up of the migration from GPON to NG-PON1 is the maturity of the industry chain. Unlike NG-PON1 that has clear goals and emerging developments, there are many candidate technologies for NG-PON2. The selection of NG-PON2 is under discussion. However, one thing is clear, NG-PON2 technology must outperform NG-PON1 technologies in terms of ODN compatibility, bandwidth, capacity, and cost-efficiency. This paper describes the design principles and prospective technologies for NG-PONs. It introduces Huawei's views of NG-PON evolution, focusing on the discussion and evaluation of various technologies. All of the discussion follows the FSAN and ITU-T framework of NG-PON recommendations[13].

2.1.2 Active Optical Network

An Active Optical Network (AON) utilizes electricity powered switching equipment like routers or a switch aggregator , repeaters, or shaping circuits to manage signal distribution and direction to the correct end users. These switches open and close to ensure that the outgoing and incoming messages are going in the right direction. Subscribers have a dedicated fiber optic strand.AON networks can cover a range to about 100 km, a PON is typically limited to fiber cable runs of up to 20 km it is also higher building cost as active networks requires more fiber[13].

2.2 PON Evolution

The evolution of passive optical network start from G-PON until NG-PON. In the view of Full Service Access Network (FSAN) and ITU-T, the nextgeneration PONs are divided into two phases: NG-PON1 and NG-PON2. Mid-term upgrades in PON networks are defined as NG-PON1, while NG-PON2 is a long-term solution in PON evolution [10].

2.2.1 Basic Principles

Ultra broadband and co-existence with existing technologies are the general requirements from network operations to direct PON evolution. Operators worldwide are seeking to increase revenue by developing bandwidth-consuming services. An exemplified service is HDTV, which requires about 20 Mbit/s per channel. In the near future, new business models, such as home video editing, online gaming, interactive E-learning, remote medical services, and next-generation 3D TV will dramatically increase bandwidth demand. The deployment of PON generally implies considerably initial investments and slow return on investment (ROI). ODN deployment accounts for 76% of the total investments in green field FTTH networks, while optical network units (ONUs) account for 21% Protecting investments by leveraging existing ODNs is essential to operators[13] .

2.2.2 Evolution Path

After GPON Recommendations were done, FSAN and ITU-T continued the study of NG-PONs and defined the first phase of NG-PONs as systems that offer low costs, large capacity, wide coverage, full service, and interoperability with existing technology. FSAN and ITU-T members also agree that long term PON evolution will be driven by new scenarios if coexistence with legacy systems is not required. In addition to time-division multiplexing (TDM) PONs, other technologies for NG-PON could also be taken into account. Based on the current application demands and technological maturity,. As indicated in Figure (2.1), FSAN divide NG-PON evolution into NG-PON1 and NG-PON2. NG-PON1 is a mid-term upgrade, which is compatible with legacy GPON ODNs. NG-PON2 is a long-term solution in PON evolution that can be deployed over new ODNs, independent of GPON standards. The selection of NG-PON1in FSAN is a trade-off between technology and cost. Operators require that NG-PON1 systems have a higher capacity, longer reach, larger bandwidth, and more users. Operators also require that NG-PON1 should leverage the use of existing GPON ODN to control cost. Moreover, driven by services, the downstream bandwidth demands will outpace upstream bandwidth demands for a long period[13].

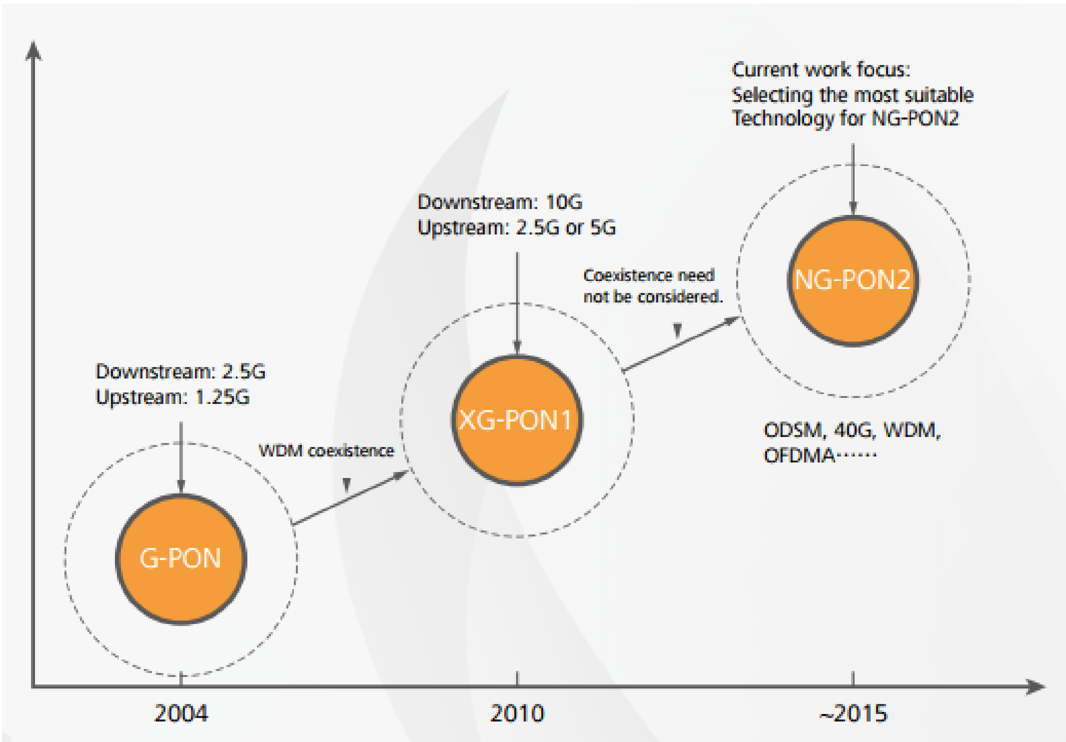


Figure (2.1) NG-PON roadmap by FSAN

Therefore, FSAN decided to define NG-PON1 as an asymmetric 10G system with rates of 10G downstream and 2.5G upstream. The selected NG-PON1 system is essentially an enhanced TDM PON from GPON. Unlike NG-PON1, there are several types of prospective technologies that can be adopted for NG-PON2. Among the prospective technologies, a suggested baseline is to improve the rate to 40G from 10G by following the TDM technology. The second method is the employment of wavelength division multiplexing (WDM) PON to achieve 40G access. The possible multiplexing schemes can be coarse wavelength division multiplexing (CWDM) or dense wavelength division multiplexing (DWDM). The ODSM PON topology based on TDMA+WDMA is also suggested, which dynamically manages user spectrum without modifying the ODN and ONUs. The third prospect is OCDMA-PON. OCDMA-PON uses code division multiple access (CDMA) to encode ONU signals, thereby avoiding the timeslot assignment for data transmission required by a time division multiple access (TDMA) systems. The O-OFDMA PON topology is an option that uses orthogonal frequency division multiple access (OFDMA) technology to differentiate ONUs, thus effectively improving bandwidth usage. However, most of these technologies are still in the research phase. More study and test are highly desired to promote them as industry standard[13].

2.2.3Smooth Evolution Based on Coexistence: NG-PON1

A general requirement of NG-PON1 is to provide higher data transmission rates than GPON. In addition, operators expect NG-PON1 to leverage existing optical deployments. Hence, FSAN and ITU-T specified the NG-PON1 backward compatibility with legacy GPON deployments to protect the initial GPON investments of operators. The specified NG-PON1 system is called XG-PON1. In an XG-PON1 system, the upstream rate is 2.5G and the downstream rate is 10G. Therefore, the downstream bandwidth of XG-PON1 is four times of that of GPON, while the upstream bandwidth of XG-PON1 is twice as that of GPON. Particularly, the ODN in XG-PON1 entirely inherits that of GPON, implying that optical fibers and splitters in legacy GPON systems can be reused in XG-PON1. After a 10G interface board is added to the OLT, smooth evolution from GPON to XGPON1 can be achieved, which completely leverages the value of GPON ODN[13].

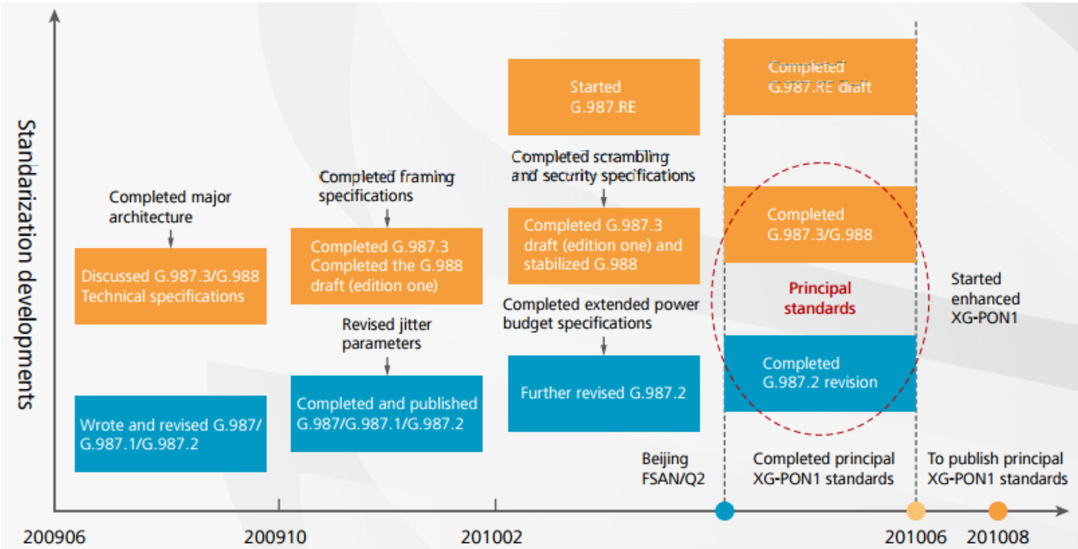


Figure (2.2)XG-PON1 standardization developments

As an enhancement to GPON, XG-PON1 inherits the framing and management from GPON. XG-PON1 provides full-service operations via higher rate and larger split to support a flattened PON network structure. The baseline XG-PON1 standards have been completed. In October 2009, ITU-T consented general requirements and physical layer specifications of XG-PON1 and published them in March 2010, announcing the NG-PON era. In June 2010, the transmission convergence (TC) layer and optical network termination management and control interface (OMCI) standards for

XGPON1 were consented in the general meeting of ITU-T SG15, and these standards will be published soon[13].

2.3 Network Architecture, Coexistence and Evolution

XG-PON1 is an enhancement to GPON. It inherits the point-to-multipoint (P2MP) architecture of GPON and is able to support diverse access scenarios, such as fiber to the home (FTTH), fiber to the cell (FTTCell), fiber to the building (FTTB), fiber to the curb (FTTCurb), and fiber to the cabinet (FTTCabinet). The application scenarios of XG-PON1 are shown in Figure (2.3)[13].

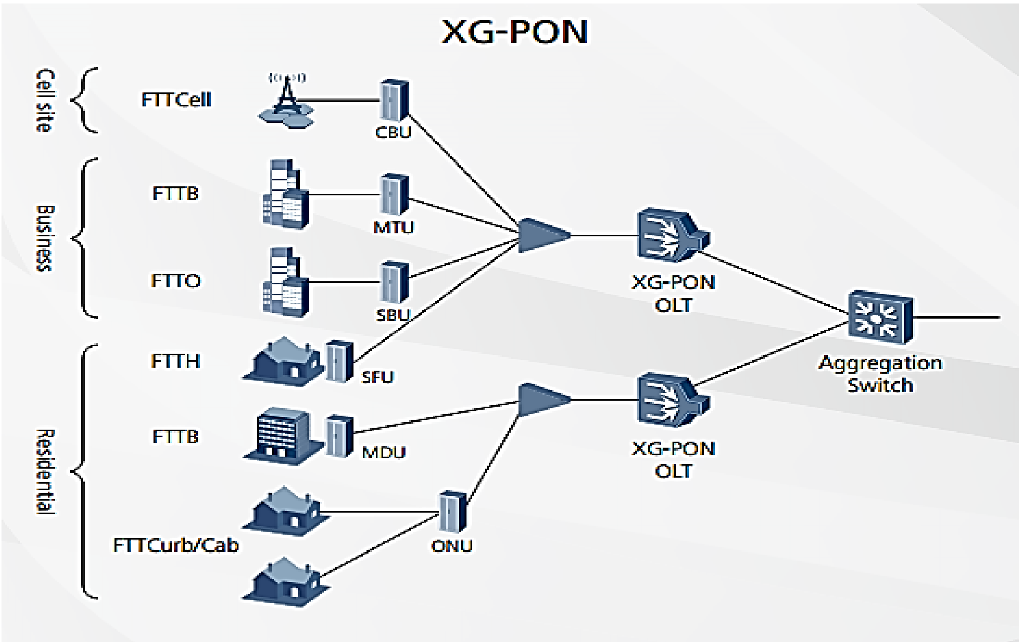


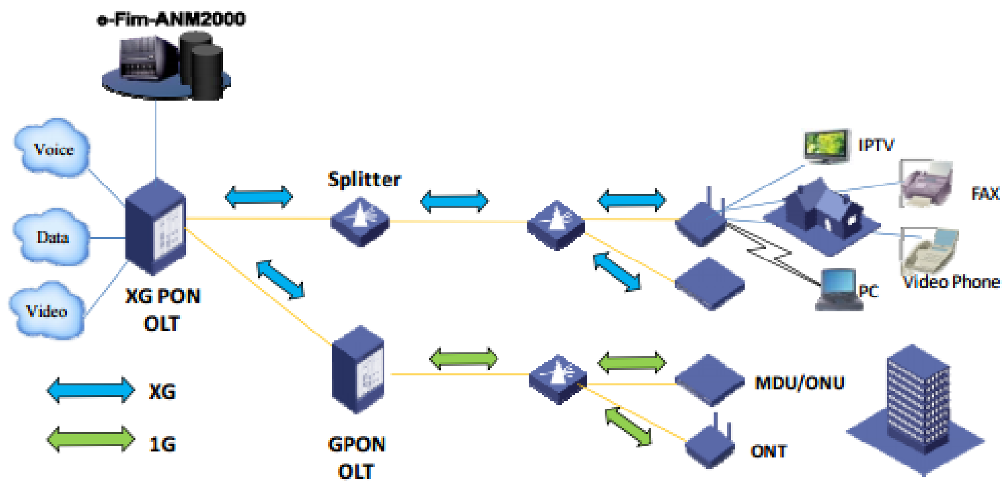
Figure (2.3) XG-PON Network Architecture

2.4 XGPON Application Scenarios

There are many applications of passive network such as fiber to the home(FTTH) fiber to the building (FTTB), fiber to the cell (FTTCell) and fiber to the cabinet .

2.4.1 The application of digital FTTH family

XGPON Application Scenarios The application of digital FTTH family Due to the service development, bandwidth requirements are raised. GPON will be replaced by XGPON technology which provides 10G/2.5G bandwidth. Through the smooth upgrade from GPON to the XGPON, the old network structure can be reserved, which means the ODN network needn't be changed and the user's bandwidth can be raised 4 times than in GPON access network. Via the big split ratio such as 1:128 and long distance coverage supporting 60km transmission and other advantage features, XGPON not only provides high bandwidth, but also covers more subscribers and regions. OLT cover scale and transmission distance can be expanded further by means of 1G OLT cascading 10G OLT[14].



Figure(2.4) XGPON FTTH typical network topology

2.4.2 The Application of FTTO Enterprise

Enterprise users are faced with online video conference, video telephone and other senior business needs. More and more cities have already hewed out special high-tech industrial parks, which characteristic is the distribution of many office buildings and factories, and distribution within the building companies. In order to realize the fiber to the office (FTTO), the PBX switches hung bellows the ONU and other equipment's, and provide the leased line access, it should firstly choose the appropriate point along the main road. For example, the optical splitter can placed in the engine room, and then set the secondary branching unit and ONU according to the branch distribution again, and the ONU are set in the company in a general way. In this simulation multistage splitter structure can be used to save cable laying at the most[15].

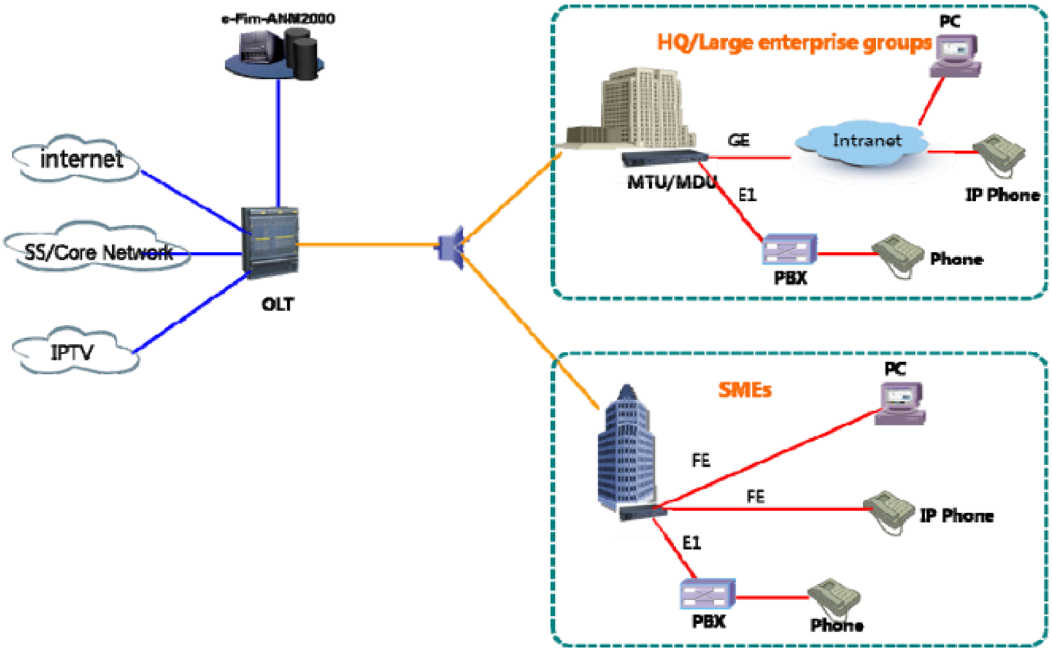


Figure (2.5) 10 G GPON FTTO Network model

2.4.3 The application of FTTC

FTTC solution is very similar as traditional MSAN technology. MDU with DSL and POTS service card will be placed in outdoor cabinet around 1km away from subscribers. In the FTTC structure, operators only need to lay optical distribution network (ODN) to each curb, and the rest from curb to the end-user is running on the existing copper. So FTTC Solution can be used in the scene where it is difficult to lay the fiber to the users such as in some old buildings. Also Telkom can reduce the cost with using the existing cable to connect MDU/ONU to the users[15].

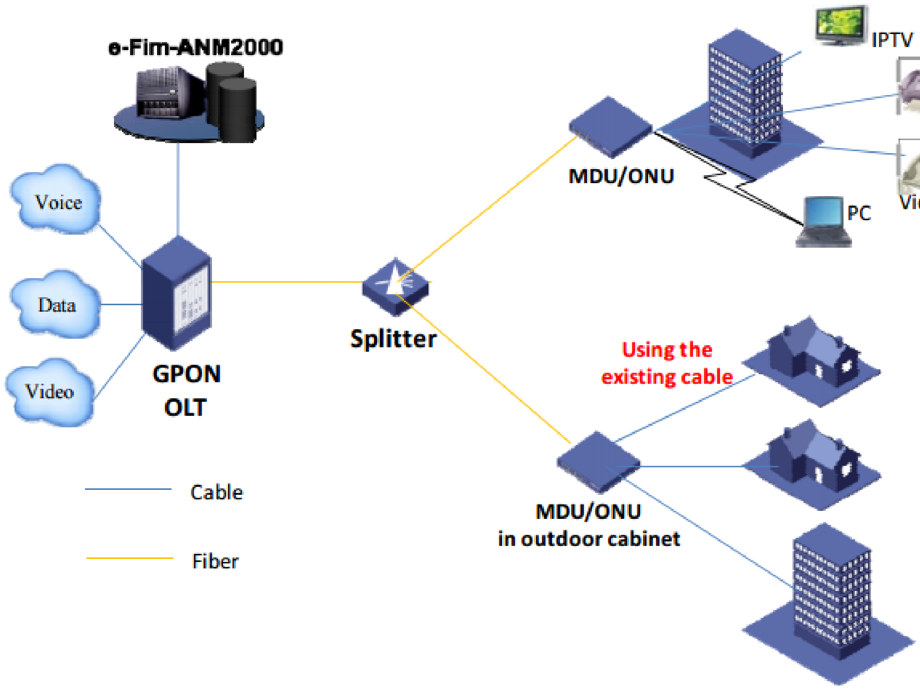


Figure (2.6)XGPON FTTC typical network topology

GPON Smooth Upgrade Compared with GPON, XGPON specifications is improved. XGPON optical module's optical power exceeding 30 dBm, means that it can support further transmit distance and the split ratio of 1:128 further exceeding GPON 1:64. That is why XGPON has access to more subscribers. Also Bandwidth of XGPON is largely increased to the 10G/2.5G.In the FTTH scenario; each subscriber can obtain 4 times bandwidth than GPON. In the FTTB/O scenario, MDU can provide the GE interfaces to meet the enterprise high bandwidth requirements. As known, FTTH solution by using GPON technology can provide more than 100M bandwidth to the users which can meet long term demand. But in FTTC solution, there are still some bandwidth troubles. However if the GPON platform can be smoothly upgraded to XGPON, the troubles will be solved[15].

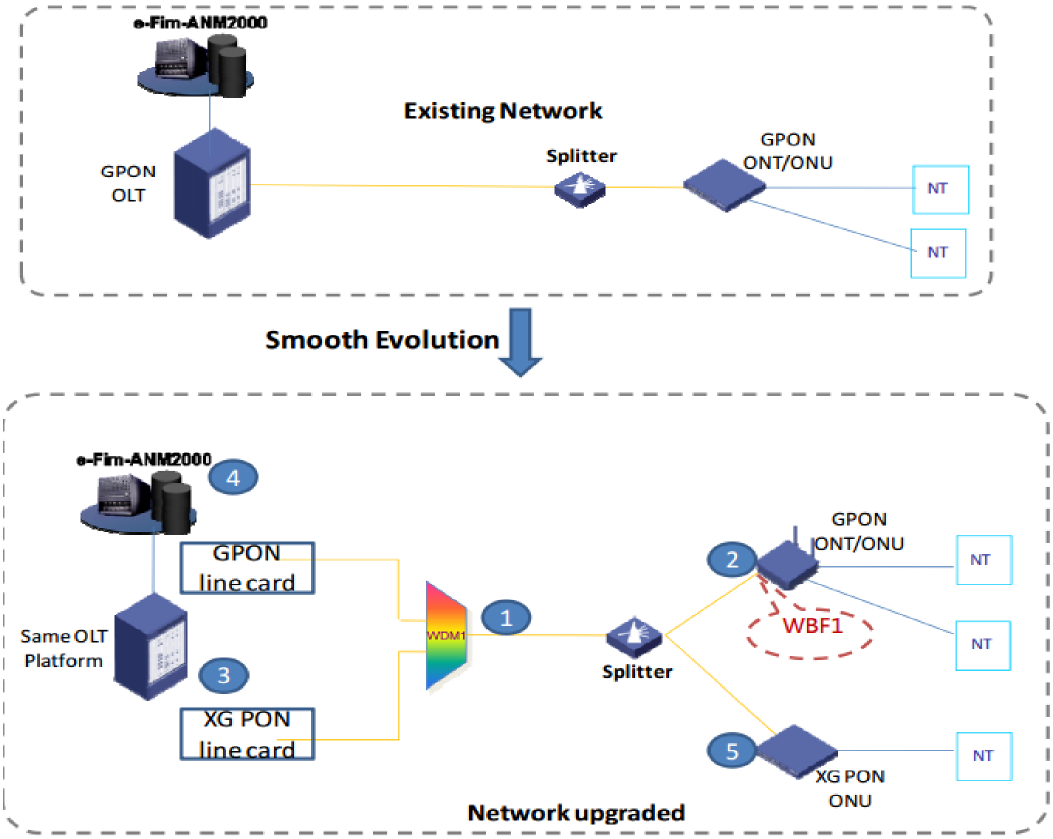


Figure (2.7) Smooth Evolution from GPON to XGPON

As seen in figure (2.7), there are five steps to complete the smooth evolution: Cut off the main optical fiber, and add WDM1 components ONU must use narrow spectrum transceiver, if not, WBF1 components are needed. Upgrade GPON platform to XGPON platform by adding XGPON OLT line cards Reconfiguring network management and resource system data Add New XGPON ONUs XGPON coexists with GPON over the same ODN to protect the investments of operators on GPON. As indicated in XGPON physical layer specifications, the upstream/downstream wavelength of

XGPON is different from that of GPON. Compatibility between XGPON and GPON is achieved by implementing WDM in the downstream and WDMA in the upstream. That is, a WDM1r is deployed at the central office (CO) and a WBF is deployed at the user side (could be located inside an ONU, between aONU and an optical splitter, or in an optical splitter) to multiplex or demultiplexer wavelengths on multiple signals in downstream and upstream directions. As above topology shown in an XG-PON&GPON coexisted system, the ODN in XG-PON entirely inherits that of GPON, implying that optical fibers and splitters in legacy GPON systems can be reused in XG-PON. After a 10G interface board is added to the unified OLT platform, smooth evolution from GPON to XGPON can be achieved, which completely leverages the value of GPON ODN and the CO device[15].

2.5 Related Works

Although simulation has been used to study PON, the existing work cannot be used directly or extended easily to study the performance issues arising with the deployment of XG-PON. In [16], the authors developed their own simulator to study dynamic bandwidth assignment (DBA) algorithms when the physical reach is much longer than the current PON networks. This simulator has limited functions and there is no Internet protocol stack, which is needed to study many research topics. EPON and GPON had also been studiedwith OPNET and several models have been implemented by different authors However, these EPON/GPON models are not available to the public. Furthermore, OPNET simulates too many details (CPU of a router, etc.) and the simulation speed is slow even when the simulated network bandwidth is lower than 1 GB/s. Since OPNET is not an open-source simulator, its core cannot be changed to simulate a 10 Gb/s XG-PON network with a reasonable simulation speed.

In [17,18], one simple EPON module has been developed for OMNeT++ and the code is available to the public. Since there are a lot of between EPON and XG-PON, the code of this EPON module may not be very helpful to implement one XG-PON module for OMNeT++. Considering the good points of NS-3 discussed above, it should be better to develop one XG-PON module from the scratch for the NS-3 network simulator.

In[19] XG-PON module is designed and implemented for NS-3. With such an XG-PON module, a simulation can be done to XG-PON and study its own performanceWith the more realistic Internet protocol stack of NS-3, a study of the performance experienced by users/applications in XG-PON networks can be done. With the existing NS-3 modules for various wireless networks (WiFi, WiMAX, LTE, etc.), also a study of the integration between XG-PON and wireless networks, which is the trend of the future Internet access networks. In summary, with this XG-PON module, NS-3 will become a good platform for studying the next generation Internet access networks composed by XG-PON and wireless networks. Not only XG-PON, the XG-PON module can be extended to study Long-Reach PON (LR-PON), an evolution of XG-PON with a larger number of users, symmetric data rate (10 Gb/s in both upstream and downstream), and longer reach (100 km) [20,21].

In [22,23]the aim of LR-PON research group is to initially build LR-PON from the XG-PON standard, while identifying the required modifications and improvements .

In [24] the authors explained how to design and planning of a passive optical network (PON) .and consists of deploying a WDM GPON from a central telecommunications to different areas where end users will enjoy the services that only optical fiber network can provide. It Supply all materials and components necessary to deploy a passive optical infrastructure of an FTTx network, which includes from OLT to the optical jack (ONT) in the house.In [25] the authors explained how to design of WDM-PON network, the simulation and analysis of transmission parameters in the OptiSystem 7.0 environment for bidirectional traffic. In this study two transmitters at the OLT with bit rate 2.5 GB/s, the two transmitters are transmitted with two different wavelengths, Each transmitter section consists of continuous wave. And used Q-factor to measure the signal quality fordetermining the BER.

In [26] the authors investigated and compared the performance of different modulation formats like Non Return to Zero (NRZ), Return to Zero (RZ) and On-Off Keying (OOK) for bi-directional passive optical networks (PON). The PON architecture is implemented by using a wavelength re-modulated scheme which in downstream optical signal is re-modulated as a carrier for upstream transmission. This modulation scheme issued to make the system cost effective by removing the laser source from Optical Network Unit (ONU). For NRZ, 10 Gbps data is successfully transmitted to 32 ONUs with acceptable Q-factor of 7.11 for downlink and2.5 Gbps data is received with Q-factor of 6.83 for uplink. Data successfully transmitted with Q-factor of 6.83 with NRZ, 6.11 with RZ and 5.25 with OOK at 150 km at OLT side and Q-factor of 7.01 with NRZ, 6.71 with RZ and 5.99 with OOK at ONU side at same distance. It has been observed that the most suitable data format for PON network is NRZ.

In [27], a fiber optic communication system has been employed using 10G/2.5G asymmetric XGPON architecture. In this system bidirectional optical fiber has been employed for upstream and downstream data transmission. The system performance has been investigated for non-return-to-zero (NRZ) and return-to-zero (RZ) data formats by varying the length of the fiber for co-existed GPON and XG-PON system .The results have been compared for NRZ and RZ formats for upstream and downstream data in terms of Q value and eye opening. It has been observed that RZ modulation format is superior compared to conventional NRZ modulation The potential of NRZ and RZ signal transmission for Coexisted GPON and XG-PON system has been analyzed over a transmission distance of 80km.It is found that the faithful transmission distance covered by XG-PON is greater than 80km for both upstream and downstream transmission in RZ format. It is concluded that for this co-existed system the RZ modulation format is superior to the conventional NRZ modulation scheme as it offers better immunity to fiber non-linearity's. Further, it is found that the performance of XG-PON deteriorates due to greater non- linear effects at higher Bit rate.

In [28], 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. 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.

CHAPTER THREE

METHODOLOGY

3.1 Introduction

In this chapter the project methodology is represented including the mathematical model, and the simulation scenario used to obtain the results.

3.2 Mathematical Model

In order to obtain results from the simulation the following parameter should be adjusted.

Table 3.1 simulation parameters set up

Parameters	Value
BER	10^{-9}
Bit Rate	10Gb/s
RZ Bandwidth	10GHz
Fiber Attenuation	0.2 dB/km

3.2.1 Bandwidth Required For Bit Rate

The conversion of bit rate to bandwidth in hertz depends on the digital coding format used. When NRZ format (non-return-to-zero) is employed, the binary 1level is held for the whole bit period τ.In this case there are two bit periods in one wavelength Hence the maximum bandwidth B is one-half the maximum data rate B=0.5 times bit rateHowever, when a return-to-zero code is considered, , the binary 1 level is held for only part (usually half) of the bit period this is why

B=bit rate =10×10^9 =10GHz [29].

3.2.2Q Factor, S/N Ratio, and BER

$$\text{BER} = \frac{1}{2}\,\text{erfc}\left(\frac{Q}{\sqrt{2}}\right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.1)$$

Since BER $= 10^{-9}$ then from erfc the Q factor is equal to 6 dB (3.9810) linear valueWhereerfc is the complementary error function[30].

$$\text{erfc}(x) = \frac{2}{\sqrt{\pi}} \int_{x}^{\infty} \exp(-y^2)\,dy \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.2)$$

$$Q = \frac{1}{2}\sqrt{\frac{\text{signal}}{\text{noise}}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.3)$$

S/N(dB)=$(Q \times 2)^2 = (6 \times 2)^2 = 12^2$ =144= 2.5118×10^{14}(linear value)

For BER of 10^{-9}, Q=6 then S/N=144

3.2.3 Fiber Attenuation

The transmission loss of optical fibers has proved to be one of the mostimportant factors in bringing about their wide acceptance in telecommunications. Aschannel attenuation largely determined the maximum transmission distance prior to signalrestoration,since The attenuation in single mode fiber is 0.2 dB/km and the link is 80 km long, then the total loss in the fiber will be 16.0 dB[31].

$$\text{Fiber Loss} = \alpha_{dB} \times L \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.4)$$

$$\text{Fiber Loss} = 0.2 \times 80 = 16.0\ \text{dB}$$

3.2.4 Fiber Dispersion

Dispersion of the transmitted optical signal causes distortion for both digital and analog transmission along optical fibers. When considering the major implementation of optical fiber transmission which involves some form of digital modulation, then dispersion mechanisms[32]within the fiber cause broadening of the transmitted light pulses as they travel along the channel and then it is cause ISI

$$\Delta_T = L \times \text{Dispersion/Km} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.5)$$

$$B = \frac{0.35}{\Delta_T} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.6)$$

where B is bandwidth ,Δ_T total dispersion and L fiber length.

For B=10$\times 10^9$ and L=80km

From equ(3.6) $\Delta_T = \frac{0.35}{B} = \frac{0.35}{10\times10^9} = 0.035 \times 10^{-9} = 0.035\ ns$

Then $Dispersion/km = \frac{\Delta_T}{L} = \frac{0.035\times10^{-9}}{80} = 4.375 \times 10^{-13} =$

$0.4375\text{ps}\ km^{-1}$

So the single mode fiber should haveDispersion of0.4375p/km

3.2.5 Signal-to-noise ratio and capacity

Signal-to-noise ratio (abbreviated SNR or S/N) is a measure used in science and engineering that compares the level of a desired signal to the level of background noise. It is defined as the ratio of signal power to the noise power, often expressed in decibels [33].A ratio higher than 1:1 (greater than 0 dB) indicates more signal than noise. While SNR is commonly quoted for electrical signals, it can be applied to any form of signal. The signal-to-noise ratio, the bandwidth, and the channel capacity of a communication channel are connected by the Shannon–Hartley theorem [34].

$$C = B\log_2\left(1 + \frac{S}{N}\right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.7)$$

Where C ischannel capacity

$B$is Channel bandwidth which equal 10GHz

$\frac{S}{N}$is signal to noise ratio which is equal 2.5118×10^{14}(linear value)

$C = 10 \times 10^9 \log_2(1 + 2.5118 \times 10^{14})$=10 $\times$

10^9 ×48.319204=483.19Gbps

Signal-to-noise ratio is sometimes used metaphorically to refer to the ratio of useful information to false or irrelevant data in a conversation or exchange. For example, in online discussion forums and other online communities, off-topic posts and spam are regarded as "noise" that interferes with the "signal" of appropriate discussion.

Signal-to-noise ratio is defined as the ratio of the power of a signal (meaningful information) and the power of background noise (unwanted signal.

$$\mathrm{SNR} = \frac{p_{\mathrm{signal}}}{p_{\mathrm{noise}}} \quad \ldots\ldots\ldots\ldots (3.8)$$

Where P is average power. Both signal and noise power must be measured at the same and equivalent points in a system, and within the same system bandwidth. If the variance α of the signal and noise are known, and the signal is zero-mean.

$$\mathrm{SNR} = \frac{\alpha^2{}_{\mathrm{signal}}}{\alpha^2{}_{\mathrm{noise}}} \quad \ldots\ldots\ldots\ldots (3.9)$$

If the signal and the noise are measured across the same impedance, then the SNR can be obtained by calculating the square of the amplitude ratio:

$$\mathrm{SNR} = \frac{p_{\mathrm{signal}}}{p_{\mathrm{noise}}} = \left(\frac{A_{\mathrm{signal}}}{A_{\mathrm{noise}}}\right)^2 \quad \ldots\ldots\ldots\ldots (3.10)$$

Where A is root mean square (RMS) amplitude (for example, RMS voltage).

3.2.6 Dijkstra's algorithm

is an algorithm for finding the shortest paths between nodes in a graph, which may represent, for example, road networks. It was conceived by computer scientistEdsger W. Dijkstra in 1956 and published three years later [35].The algorithm exists in many variants; Dijkstra's original variant found the shortest path between two nodes, but a more common variant fixes a single node as the "source" node and finds shortest paths from the source to all other nodes in the graph. Let the node at which we are starting be called the initial node. Let the distance of node Y be the distance from the initial node to Y. Dijkstra's algorithm will assign some initial distance values and will try to improve them step by step as follow:

- Assign to every node a tentative distance value: set it to zero for our initial node and to infinity for all other nodes.
- Set the initial node as current. Mark all other nodes unvisited. Create a set of all the unvisited nodes called the unvisited set.
- For the current node, consider all of its neighbors and calculate their distances. Compare the newly calculated distance to the current assigned value and assign the smaller one. For example, if the current node A is marked with a distance of 6, and the edge connecting it with a neighbor B has length 2, then the distance to B (through A) will be 6 + 2 = 8. If B was previously marked with a distance greater than 8 then change it to 8. Otherwise, keep the current value.
- When we are done considering all of the neighbors of the current node, mark the current node as visited and remove it from the unvisited set. A visited node will never be checked again.
- If the destination node has been marked visited (when planning a route between two specific nodes) or if the smallest tentative distance among the nodes in the unvisited set is infinity (when planning a complete traversal; occurs when there is no connection between the initial node and remaining unvisited nodes), then stop. The algorithm has finished.
- Otherwise, select the unvisited node that is marked with the smallest distance, set it as the new "current node", and go back to step 3.

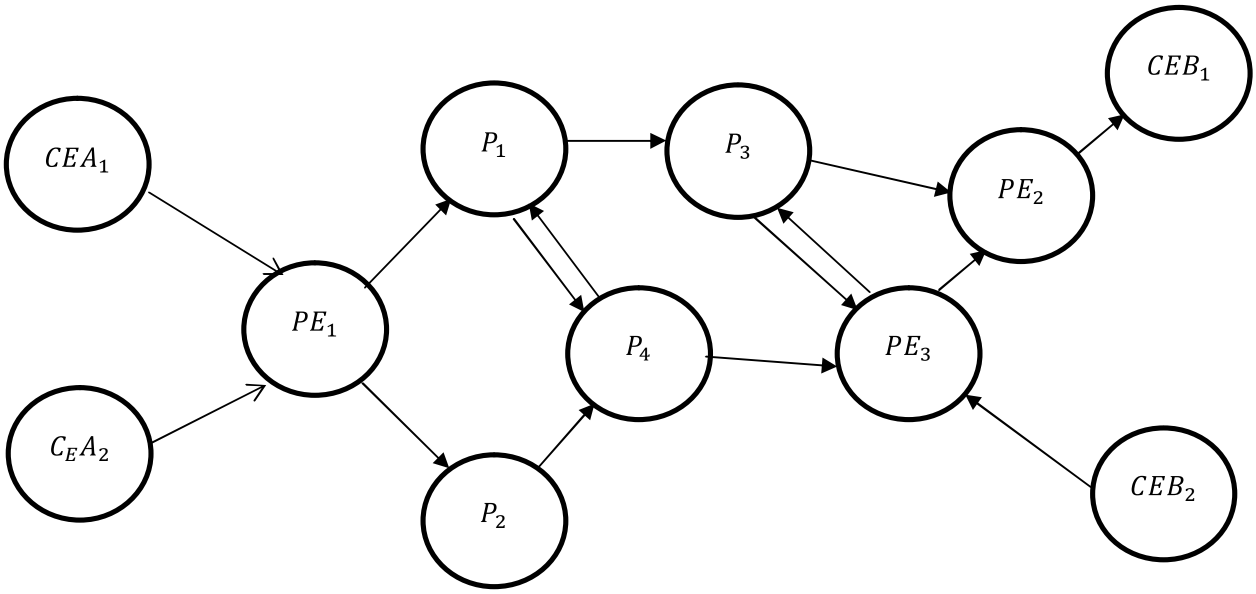


Fig (3.1) XG-PON Network Configuration

3.3 Block diagram

The following block diagram represents a full construction of multiservice provided into next generation passive optical network.

1-Multiservice can be served using XGPON, such as VoIP, PSTN.

2-Each services has a routing header.

3-Multiplexing of different services is done through different wavelength.

4-Add Additive white Gaussian Noisethat may occurs during the transmission and receiving process into channel.

5-D-multiplexing is then used to split the services into different channels to serve users.

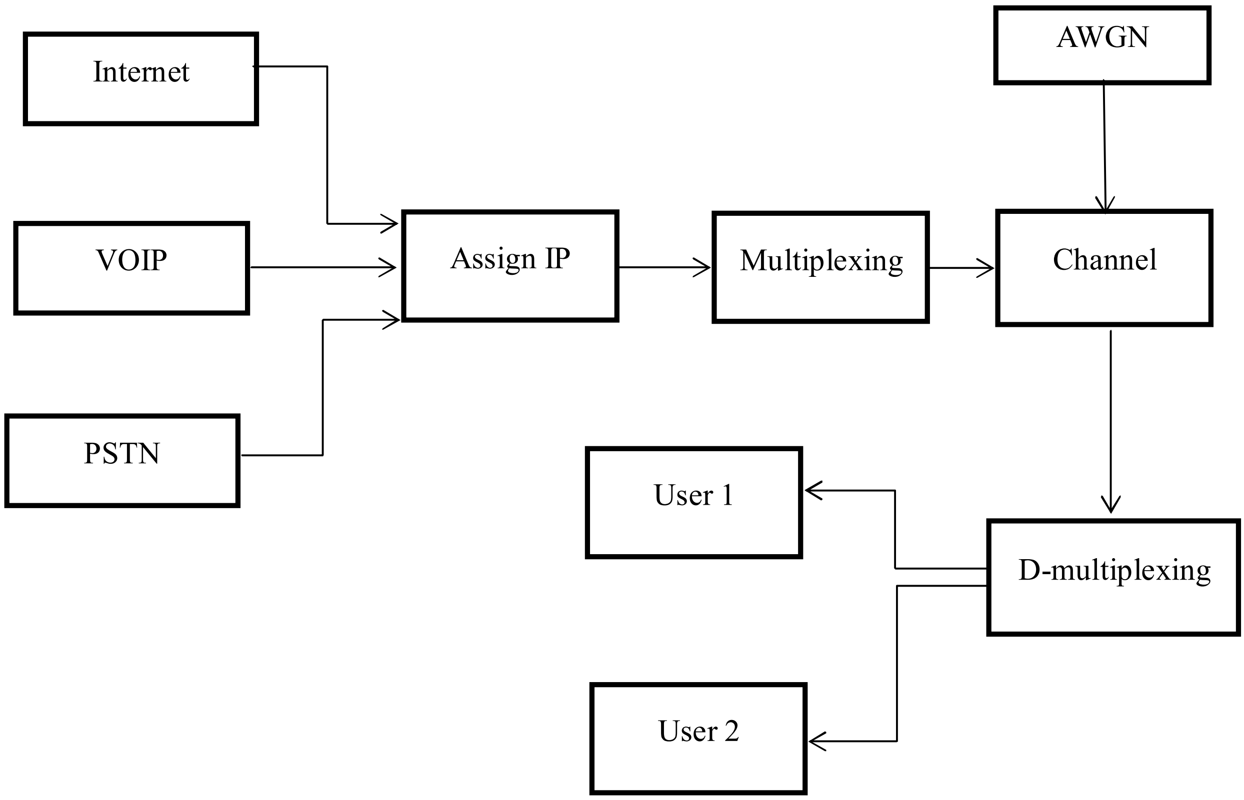


Figure (3.2) block diagram represent a full construction of multiservice provided into XGPON

3.3.1 OLT Transmitter

The following flowchart represents the OLT transmitter process from the combination of multiple services to the streaming.

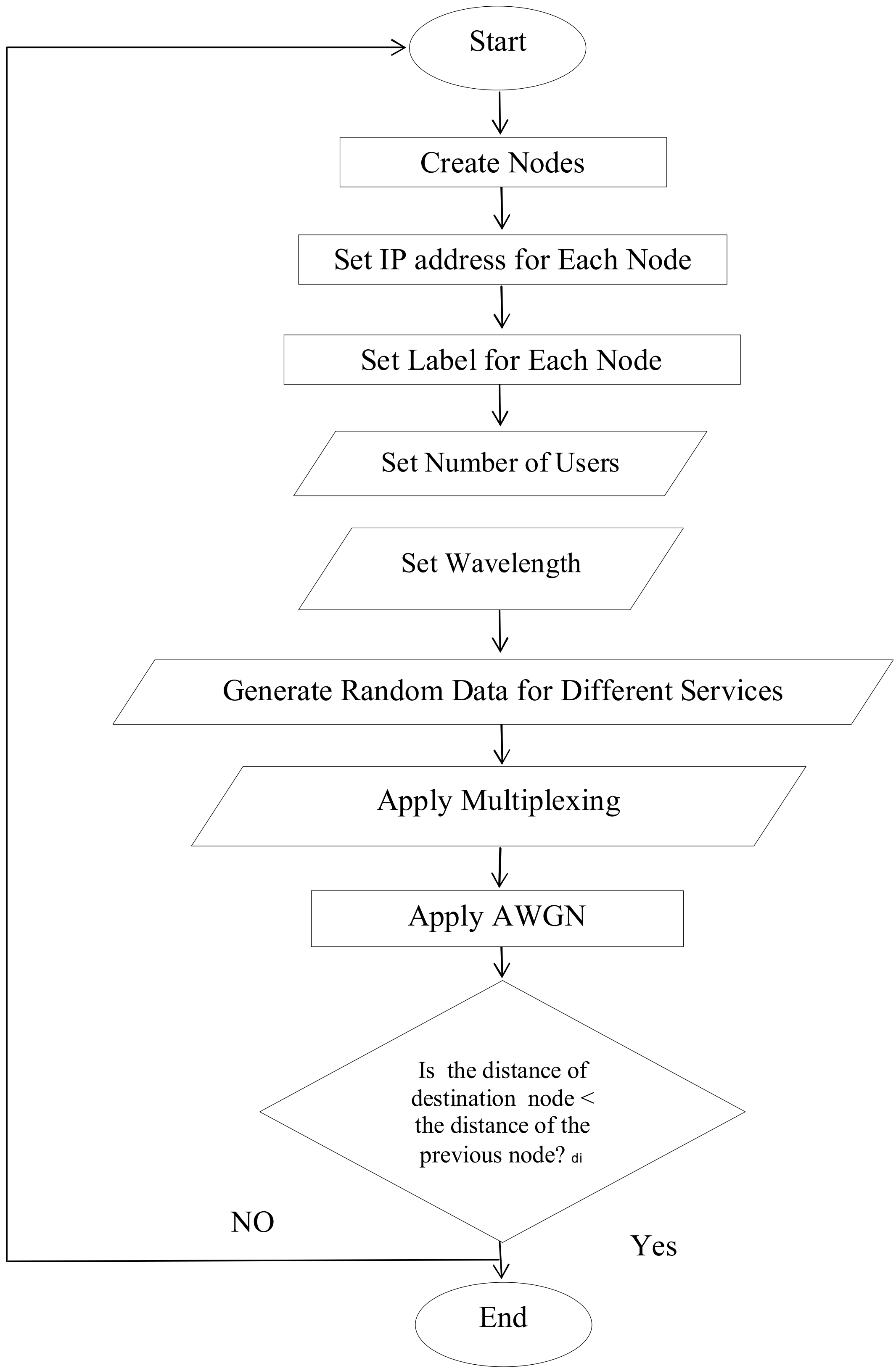


Figure (3.3) OLT Transmitter

3.3.2 ONU Receiver

The following flowchart represents the ONU Receiver process from the combination of multiple services to the streaming .

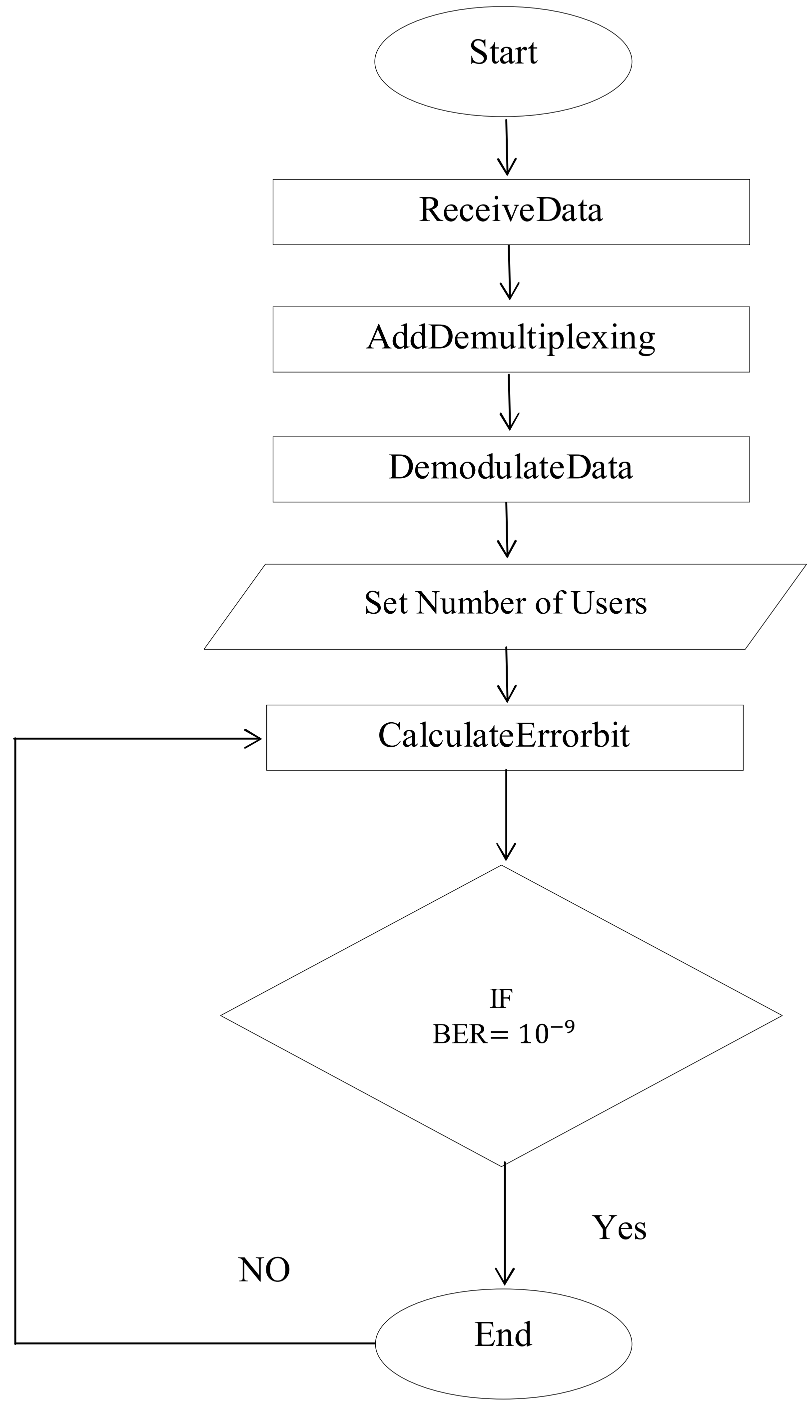


Figure (3.4) ONU Receiver

CHAPTER FOUR
RESULTS AND DISCUSSION

4.1 Introduction

The following chapter represents the results and discussion of the simulated work, a simulation was made using MATLAB programming and some parameters which are bit error rate, fiber attenuation,, bandwidth and data rate.

4.2Bit Error Rate and Quality Factor

It is clear from Fig (4.1),that BER decrease as Q-Factor increase .

For bit error rate equal to $0.986 \times 10^{-9} \approx 10^{-9}$the Q-Factor is 6 dB

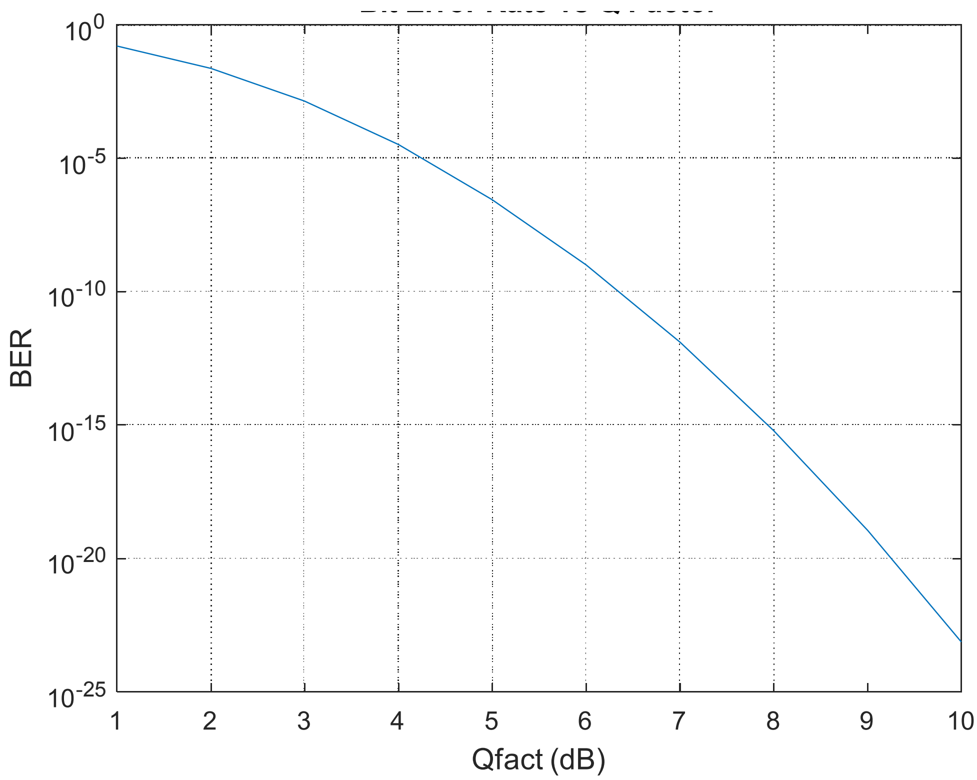


Fig (4.1) bit error rate vs. quality factor in dB

4.3 Signal to Noise Ratio and Quality Factor

The Q-factor suggests the minimum signal-to-noise ratio (SNR) required to obtain BER =10^{-9}.In Fig (4.2) as Signal to noise ratio increase the Q-Factor increase for Q-Factor equal to 6dB the minimumsignal to noise ratio equal to 144dB

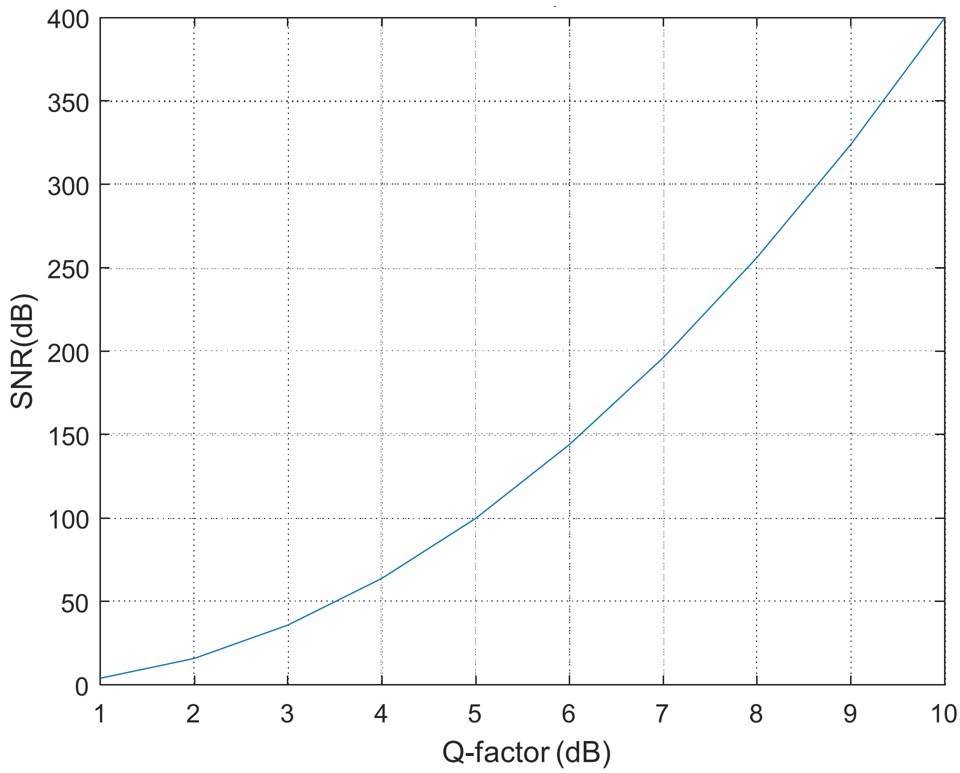


Fig (4.2) Signal to Noise Ratio vs. Quality Factor in dB

4.4FiberCapacity and Signal to Noise Ratio

According to Shannon Hartley theorem as signal to noise increase the capacity of channel increase .In Fig(4.3) the maximum amount of error-free digital data that can be transmitted over a fiber is 4.783×10^{11} =478.3Gbpswhen the signal to noise is 144 dB and BER $=10^{-9}$

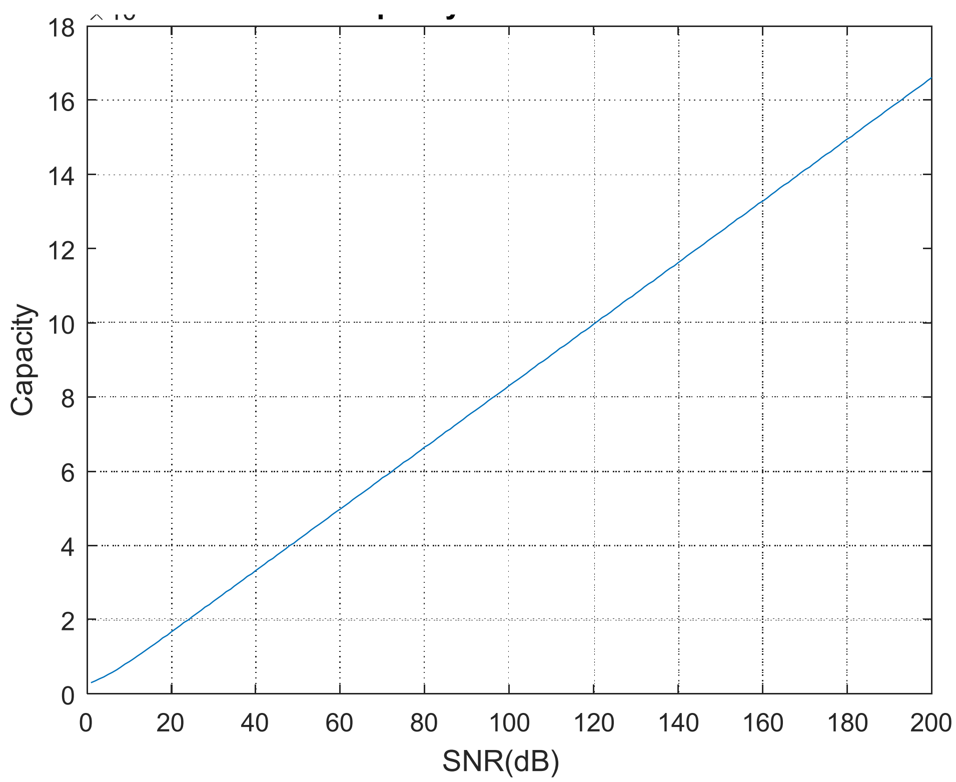


Fig (4.3) capacity of fiber vs. signal to noise in dB

4.5 Fiber Loss and Length of Fiber

It is clear from Fig (4.4) that fiber loss in dB is increased as distance increase the maximum length for fiber is 80 km for Q Factor 6dBso the dB 16fiber loss is .

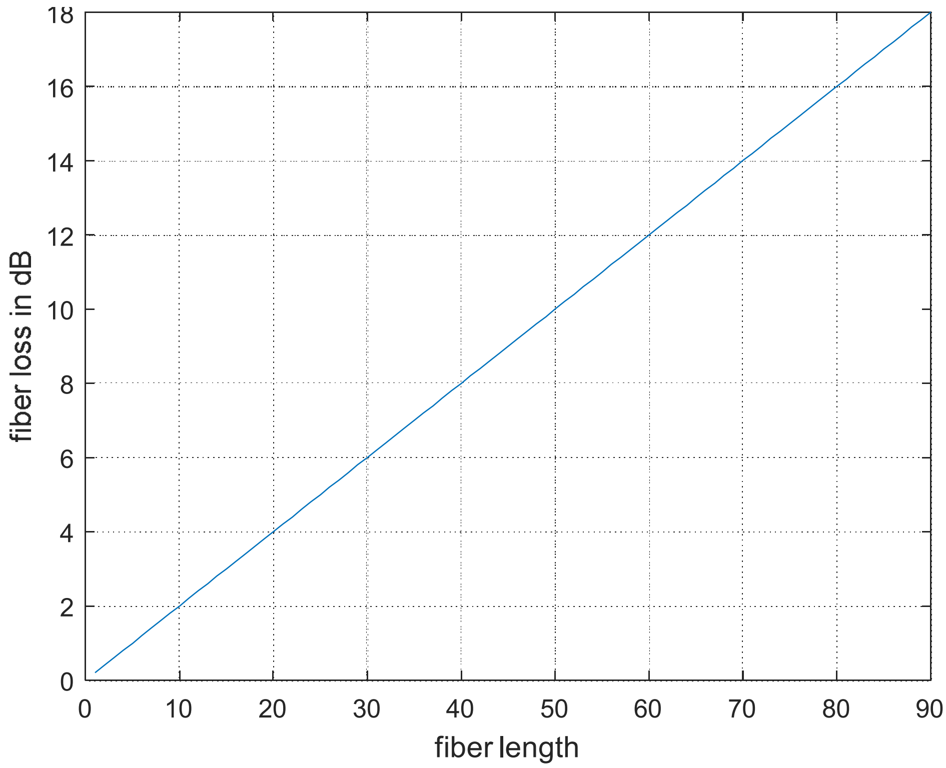


Fig (4.4) Fiber loss vs. length of fiber

4.6 XG-PON Q-Factor down stream

In Fig(4.4),RZ isbetter than NRZ format for XGPON system. The Q-factor obtained is 10dB and 9dB at a distance of 50km and 70km respectively for XGPON in downstream transmission for RZ (0.6) format. It is clear from figure that Q-value decreases with increase in length of fiber.

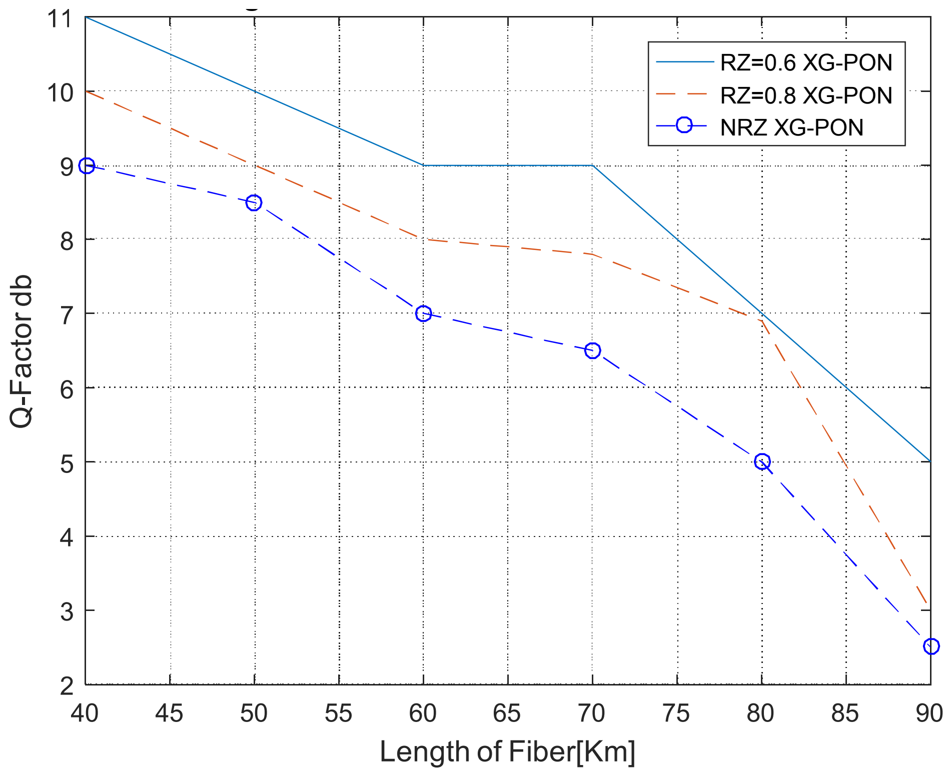


Figure (4.5) Lengthvs. Q-Factor of XGPON for NRZ and RZ formats for downstream transmission

4.7 Summary

RZ modulation has become a popular solution for 10 GB/s systems because it has average peak power, a higher signal-to-noise ratio, lower bit error rate and RZ modulation is found to be less susceptible to inter-symbol interference (ISI) than NRZ encoding. It also offers better immunity to fiber nonlinear effects. The minimum required Q-value for faithful transmission is 6.dB at BER= 10^{-9}.

and typically achieves better performance compared to NRZ Fig (4.5)shows the graphical representation of Q value as a function of Length for NRZ and RZ (with duty cycle = 0.6 and 0.8) data formats for XG-PON downstream data.The Q-factor obtained is 10dB and 9dB at a distance of 50km and 70km respectively in downstream transmission for RZ (0.6) formathe faithful transmission distance is up to 85km in RZ (0.6) format.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The potential of NRZ and RZ signal transmission for XG-PON downstream system has been analyzed over a transmission distance of 80km.It is found that the faithful transmission distance covered by XG-PON is greater than 80km for downstream transmission in RZ format. It is concluded that for this system the RZ modulation format is superior to the conventional NRZ modulation scheme as it offers better immunity to fiber non-linearity**.**

5.2 Recommendations

Comparison of different line coding schemes in XGPON, Apply bidirectional fiber in XGPON and analysis the performance of coexistence GPON-XGPON for both upstream and downstream transmission.

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Appendix A

```
% XGPON downstream  Simulation Program
%
% Four Routers Inside XGPON Network      PE1,PE2,P1,P2
% Four Routers Linked TO XGPON Network   CEA1,CEA2,CEB1,CEB2
% configured IP Address for the Network
%            PE1 : 0.0.0.0
%            PE2 : 0.0.0.0
%            PE3 : 0.0.0.0
%            CEA1: 0.0.0.0
%            CEA2: 0.0.0.0
%            CEB1: 0.0.0.0
%            CEB2: 0.0.0.0
clear all;
close all;
clc;
%%Configuring Network Link %%
% PE1--> P1
% PE1--> P2
% P1--> P3
% P1--> P4
% P2--> P4
% P3--> PE2
% P3--> PE3
% P4--> PE3
% PE3--> PE2
% CEA1--> PE1
% CEA2--> PE1
% CEB1--> PE2
% CEB2--> PE3
%Assign IP Addresses%%
P1_ip='192.168.0.2';

P2_ip='192.168.0.4';

P3_ip='192.168.0.5';

P4_ip='192.168.0.6';

PE1_ip ='192.168.0.1';

PE2_ip ='192.168.0.3';

PE3_ip ='192.168.0.7';

CEA1_ip = '10.0.0.10';

CEA2_ip ='10.0.1.20';

CEB1_ip ='20.0.0.10';

CEB2_ip = '20.0.1.20';
```

```
%%%%%%%%%%%%%%%%%%%%%%%Assign Labels for Each Router%%%%%%%%%%%%
PE1_label ='20';

P1_label ='40';

P2_label ='10';

P3_label ='30';

P4_label ='50';

PE2_label ='60';

CEA1_label = '70';

CEA2_label ='90';

CEB1_label ='80';

CEB2_label = '100';

PE3_label = '110';

%%%%%%%%%%%%%%%%%%%%%%%%Viewing Labels%%%%%%%%%%%%%%%%%%%%%%%%%

x=['Router PE1','  ',P1_ip,'  ','Label','  ',PE1_label];
disp(x);
 x=['Router PE2','  ',P2_ip,'  ','Label','  ',PE2_label];
disp(x);
 x=['Router P1','  ',P3_ip,'  ','Label','  ',P1_label];
disp(x);
 x=['Router P2','  ',P4_ip,'  ','Label','  ',P2_label];
disp(x);
 x=['Router P3','  ',PE1_ip,'  ','Label','  ',P3_label];
disp(x);
 x=['Router P4','  ',PE2_ip,'  ','Label','  ',P4_label];
disp(x);
x=['Router PE3','  ',PE3_ip,'  ','Label','  ',PE3_label];
disp(x);
x=['Router CEA1','  ',CEA1_ip,'  ','Label','  ',CEA1_label];
disp(x);
x=['Router CEA2','  ',CEA2_ip,'  ','Label','  ',CEA2_label];
disp(x);
x=['Router CEB1','  ',CEB1_ip,'  ','Label','  ',CEB1_label];
disp(x);
x=['Router CEB2','  ',CEB2_ip,'  ','Label','  ',CEB2_label];
disp(x);

%%%%%%%%%%%%%%%%%%%%%%%%Bandwidth Settings%%%%%%%%%%%%%%%%%%%%%%%%%%%%
band1=512;
band2=1024;
band3=256;
band4=2048;
band5=3000;
```

```
band6=2800;
band7=1800;
band8=1000;
band9=2100;

%%%%%%%%%%%%%%%%%%%%%%%%%Link Cost Claculations%%%%%%%%%%%%%%%
PE1_P1_cost =100000/band1;
PE1_P2_cost =100000/band2;
P1_P3_cost =100000/band3;
P2_P4_cost =100000/band4;
P1_P4_cost =100000/band5;
P4_PE3_cost  =100000/band6;
P3_PE2_cost =100000/band7;
P3_PE3_cost =100000/band8;
PE3_PE2_cost =100000/band9;
%%%%%%%%%%%%%%%%%%%%%%%%% Routing Cost Calculations%%%%%%%%%%%%%%
path1=PE1_P1_cost+P1_P3_cost+P3_PE2_cost;
path2=PE1_P1_cost+P1_P4_cost+P4_PE3_cost+PE3_PE2_cost;
path3=PE1_P1_cost+P1_P4_cost+P4_PE3_cost+P3_PE3_cost+P3_PE2_cost;
path4=PE1_P2_cost+P2_P4_cost+P4_PE3_cost+PE3_PE2_cost;
path5=PE1_P2_cost+P2_P4_cost+P1_P4_cost+P1_P3_cost+P3_PE2_cost;
path6=PE1_P2_cost+P2_P4_cost+P4_PE3_cost+P3_PE3_cost+P3_PE2_cost;
path7=PE1_P2_cost+P2_P4_cost+P1_P4_cost+P1_P3_cost+P3_PE3_cost;
path8=PE1_P1_cost+P1_P3_cost+P3_PE3_cost;
path9=PE1_P1_cost+P1_P4_cost+P4_PE3_cost;
path10=PE1_P2_cost+P2_P4_cost+P4_PE3_cost;
%%%%%%%%%%%%%%%%%%%%%%%Transmitting Scenrio%%%%%%%%%%%%%%%%%%
data_size =500;
% Wave Division Multiplexing
samples=1000;
% number of input Signals or Nodes
nos=8;
% modulating signal IN THZ
mfreq=[192.5 192.6 192.7 192.8 192.9 193.0  193.1 193.2];
% carrier wave allocated to the different users in THZ
cfreq=[300 600 900 12000 1500 1800 2100 2400];
% choose wave deviation
freqdev=10;
% generate modulating signal
t=linspace(0,1000,samples);
parfor i=1:nos
    m(i,:)=sin(2*pi*mfreq(1,i)*t)+2*sin(pi*8*t);
end
% Generate the modulated signal OLT
parfor i=1:nos
    y(i,:)=fmmod(m(i,:),cfreq(1,i),10*cfreq(1,i),freqdev);
end
% pass the modulated signal through the channel
ch_op=awgn(sum(y),0,'measured'); % Add Adaptive White Gausain Noise
%%
if (path1<path2 && path1<path3 && path1<path4 && path1<path5 &&
path1<path6)
disp('Link Thorugh path1 is selected\n');
disp(path1);
costs=path1;
end
```

```
if (path2<path1 && path2<path3 && path2<path4 && path2<path5 &&
path2<path6)
disp('Link Thorugh path2 is selected\n');
disp(path2);
costs=path2;
end


if (path3<path1 && path3<path2 && path3<path4 && path3<path5 &&
path3<path6)
disp('Link Thorugh path3 is selected\n');
disp(path3);
costs=path3;
end

if (path4<path1 && path4<path2 && path4<path3 && path4<path5 &&
path4<path6)
disp('Link Thorugh path4 is selected\n');
disp(path4);
costs=path4;
end

if (path5<path1 && path5<path2 && path5<path3 && path5<path4 &&
path5<path6)
disp('Link Thorugh path5 is selected\n');
disp(path5);
costs=path5;
end

if (path6<path1 && path6<path2 && path6<path3 && path6<path4 &&
path6<path5)
disp('Link Thorugh path6 is selected\n');
disp(path6);
costs=path6;
end
                    %%%%%%%%%%%%%%%%%%%%%%%
if (path7<path8 && path7<path9 && path7<path10)
disp('Link Thorugh path7 is selected\n');
disp(path7);
costs=path7;
end

if (path8<path7 && path8<path9 && path8<path10)
disp('Link Thorugh path8 is selected\n');
disp(path8);
costs=path8;
end

if (path9<path7 && path9<path8 && path9<path10)
disp('Link Thorugh path9 is selected\n');
disp(path9);
costs=path9;
end

if (path10<path7 && path10<path8 && path10<path9)
```

```
disp('Link Thorugh path10 is selected\n');
disp(path10);
costs=path10;
end
%%%%%%%%%%%%%%Using Dijkstra Algorithm%%%%%%%%%%%%%%
results=[];
for(i=1:3)
for(n=2:10)
randomMatrix = magic(n);
tic;
dijkstra(randomMatrix,1,2);
DijkstraTime = toc;
tic;
bellmanford(randomMatrix,1,2);
BellmanTime = toc;
results(n,3*i-2) = n;
results(n,3*i-1) = DijkstraTime;
results(n,3*i) = BellmanTime;
end
end
results

% %%%%%%%%%%%%%%%%%%%%%%%calculating %%%%%%%%%%%%%%%%%%%%%%%%%%%%
%  h = waitbar(0,'Please wait...');
% steps = 1000;
% for step = 1:steps
%         waitbar(step / steps)
% end
% close(h)
% %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
   b=10000000000; % Set the bandwidth
SNR_dB=1:200  % Set the range of SNR betweern 1 to 200 db
   SNR=10.^(SNR_dB/10);
   z=log2(1+SNR);
   c =b*z;  % calculate the fiber capacity
figure (1)
plot(c);
grid on
title ('Capacity of fiber vs SNR');
xlabel('SNR(dB)  ');
ylabel('Capacity');

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%  BERvs Q-Factor
Qfact_dB=1:10;
Qfact=10.^(Qfact_dB/10); % calculate Q-Factor
  BER=0.5*erfc(Qfact_dB/1.4142); % Calculagte BER based on Q-Factor
figure (2)
semilogy(Qfact_dB,BER)
grid on
title ('Bit Error Rate vs Q Factor');
xlabel('Qfact (dB)');
ylabel('BER');
   %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
Qfactsnr_dB=1:10;
SNRq=(2*Qfactsnr_dB).^2;
figure(3)
```

```
plot (SNRq);
grid on
title ('SNR VS Qfact  ');
xlabel(' Q-factor (dB)');
ylabel('SNR(dB)');

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
  % FIBER LOSS CALCULATION
A_dB=0.2;
    L=1:90;
floss_dB=0.2*L;
figure (4)
plot(floss_dB);
grid on
title ('fiberlossvs fiber length');
xlabel('fiber length');
ylabel('fiber loss in dB');
%  DISPERSION OF FIBER PER KM
DT=0.35/b;
   L=80;
dispersion =DT/L;


%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%
% Signal generation
x=0:.5:4*pi;                                % siganal taken upto 4pi
sig1=8*sin(x);                              % generate 1st sinusoidal
signal
l=length(sig1);
sig2=8*triang(l);                           % Generate 2nd traingularSigal
figure(5)
% Display of Both Signal
subplot(2,2,1);
plot(sig1);
title('Sinusoidal Signal');
ylabel('Amplitude--->');
xlabel('Time--->');
subplot(2,2,2);
plot(sig2);
title('Triangular Signal');
ylabel('Amplitude--->');
xlabel('Time--->');
% Display of Both Sampled Signal
subplot(2,2,3);
stem(sig1);
title('Sampled Sinusoidal Signal');
ylabel('Amplitude--->');
xlabel('Time--->');
subplot(2,2,4);
stem(sig2);
title('Sampled Triangular Signal');
ylabel('Amplitude--->');
xlabel('Time--->');
l1=length(sig1);
l2=length(sig2);
```

```
for i=1:l1
sig(1,i)=sig1(i);                          % Making Both row vector to a
matrix
sig(2,i)=sig2(i);
end

%  both quantize signal
tdmsig=reshape(sig,1,2*l1);
% Display of TDM Signal
figure(6)
stem(tdmsig);
title('  Signals');
ylabel('Amplitude--->');
xlabel('Time--->');

% Demultiplexing of Signal
demux=reshape(tdmsig,2,l1);
for i=1:l1
sig3(i)=demux(1,i);                      % Converting The matrix into row
vectors
sig4(i)=demux(2,i);
end
 % display of demultiplexed signal
figure(7)
subplot(2,1,1)
plot(sig3);
title('Recovered Sinusoidal Signal');
ylabel('Amplitude--->');
xlabel('Time--->');
subplot(2,1,2)
plot(sig4);
title('Recovered Triangular Signal');
ylabel('Amplitude--->');
xlabel('Time--->');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

figure(8)
x=[40 50 60 70 80 90];
y1=[11 10 9 9 7 5 ];
y2=[10 9 8 7.8 6.9  3];
y3=[9 8.5 7 6.5 5 2.5];
p=plot(x,y1,x,y2,'--',x,y3,'b--o');
gridon
holdon
title('Length Vs Q-Factor of XG-GPON downstream');
xlabel('Length of Fiber[Km]');
ylabel('Q-Factor db');
legend('RZ=0.6 XG-PON','RZ=0.8 XG-PON','NRZ XG-PON');

figure(8)
x=[40 50 60 70 80 90];
y1=[11 10 9 9 7 5 ];
plot(x,y1,'color','r','marker','.','Linewidth',0.5);
grid on
hold on
y2=[10 9 8 7.8 6.9  3];
```

```
plot(x,y2,'color','g','marker','.','Linewidth',0.5)
grid on
hold on
y3=[9 8.5 7 6.5 5 2.5];
plot(x,y3,'color','b','marker','.','Linewidth',0.5)
title('Length Vs Q-Factor of XG-GPON downstream');
xlabel('Length of Fiber[Km]');
ylabel('Q-Factor db');
legend('RZ=0.6 XG-PON','RZ=0.8 XG-PON','NRZ XG-PON');
```