Performance Analysis of 1.25 Gbps Downstream transmission of GPON-FTTX

Debasmita Hazra Vallabhaneni Manasa Prateek Singla

Abstract: In this paper, 1.25 Gb/s GPON downstream link is presented. The transmission capability and performance of the proposed downstream physical media (PM) GPON model is implemented, using Optisystem. Design constraints involved in an optical network design such as fiber span analysis, power budget and margin calculations are taken into consideration with worst case. The quality or performance of a digital communication system is specified by its Q value or bit error rate(BER) among other parameters such as receiver sensitivity. The simulated model can support 2, 8 and 15 number of users for classes A, B, and C respectively.

Index Terms: Bit error rate, GPON, FTTX, Power Budget, Power Margin, Passive optical network, OLT, ONU

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1 INTRODUCTION

A passive optical network (PON) is a fiber-optic access network architecture that brings fiber cabling and signals to the home using a point- to-multipoint scheme that enables a single optical fiber to serve multiple premises typically 16-128 by means of unpowered optical splitters. The architecture uses passive (unpowered) optical splitters, reducing the cost of equipment compared to point-to-point architectures. A PON consists of an optical line terminal (OLT) at the service provider's central office and a number of optical network units (ONUs) near end users. A PON reduces the amount of fiber and central office equipment required compared with point to point architectures. A PON is a shared network, in that the OLT sends a single stream of downstream traffic that is seen by all ONUs. Each ONU only reads the content of those packets that are addressed to it. Downstream signals are broadcasted to all premises sharing multiple users. Encryption can prevent eavesdropping. Upstream signals are combined using a multiple access protocol, usually time division multiple access (TDMA). The OLTs "range" the ONUs in order to provide time slot assignments for upstream communication.

The GPON (gigabit passive optical network) standard differs from other PON standards in that it achieves higher bandwidth and higher efficiency using larger, variable-length packets [5]. GPON offers efficient packaging of user traffic, with frame segmentation allowing higher quality of service (QoS) for delay-sensitive voice and video communications traffic.

Fiber to the *x* (FTT*x*) is a generic term for any broadband network architecture using optical fiber to replace all or part of the usual metal local loop used for last mile telecommunications. The generic term was initially a generalization for several configurations of fiber deployment (FTTN, FTTC, FTTB, FTTH...),all starting by FTT but differentiated by the last letter, which is substituted by an *x* in the generalization.

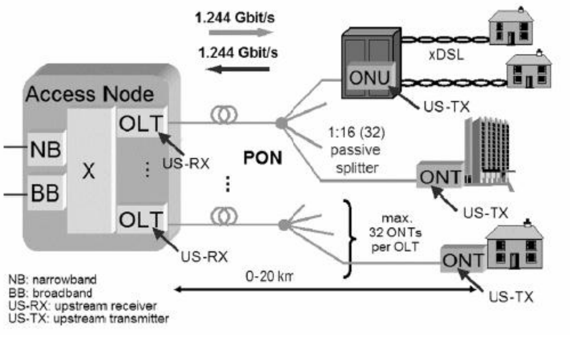

Fig:1:GPON network architecture for FTTx scenario

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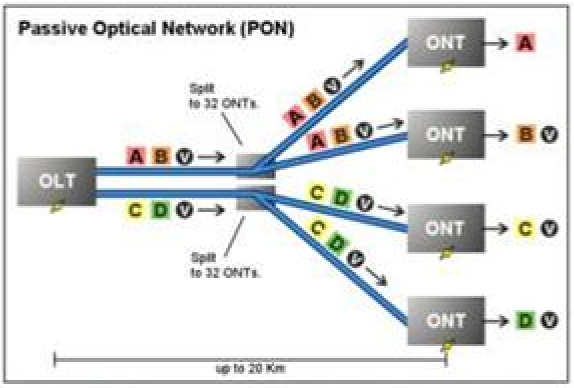
2 NEED FOR GPON

Commonly simplified as DSL, Asymmetric Digital Subscriber Line (ADSL),used for high-speed Internet access,uses existing copper telephone lines to send and receive data . The fastest dial- up modems are rated at 56 kilobits per second (Kbps), and usually operate at about 53 Kbps under good conditions and allows download speeds from 1.5 to 8 megabits per second (Mbps), depending on the grade of DSL service purchased.Cable Internet is capable of supporting up to 30 Mbps. By contrast, DSL is typically not as fast as cable Internet access. Thus, optical access is expected to become the default broadband access system in the future.

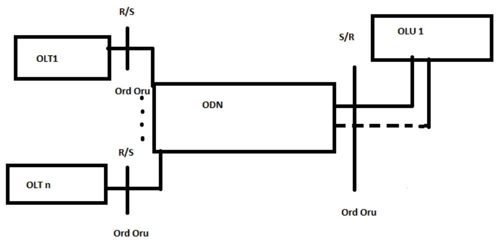
3 GENERATIONS OF PON

The International Telecommunications Union (ITU) standardized on two generations of PON. ITU-T G.983 being referred to more often as broadband PON, or BPON. A typical APON/BPON provides 622 megabits per second (Mbit/s) (OC-12) of downstream bandwidth and 155 Mbit/s (OC-3) of upstream traffic, although the standard accommodates higher rates [7].

The ITU-T G.984 (GPON) standard represents a boost, compared to BPON, in both the total bandwidth and bandwidth efficiency through the use of larger, variable-length packets. Again, the standards permit several choices of bit rate, but the industry has converged on 2.488 gigabits per second (Gbit/s) of downstream bandwidth, and 1.244 Gbit/s of upstream bandwidth. GPON Encapsulation Method (GEM) allows very efficient packaging of user traffic with frame segmentation.Hence, it is suitable as the next-generation optical access system.



Key A:Data and Voice B:Video Relay
Fig:2:PON Architecture



Key: R &S-Reference Points
Ord Oru-Optical Interfaces
_____ -One or more Fibres
-------- -Protection fibres

Fig:3:GPON generic physical configuration of the optical distribution network

4 GENERAL PON ARCHITECTURE:

PON takes advantage of wavelength division multiplexing (WDM), using one wavelength for downstream traffic and another for upstream traffic on a single Non-zero dispersion-shifted fiber (ITU-T G.652) [2]. BPON, EPON, GEPON, and GPON have the same basic wavelength plan and use the 1,490 nanometer (nm) wavelength for downstream traffic and 1310 nm wavelength for upstream traffic. 1550 nm is reserved for optional overlay services, typically RF (analog) video.

A PON consists of a central office node, called an optical line terminal (OLT), one or more user nodes, called optical network units (ONUs) or optical network terminals (ONTs), and the fibers and splitters between them, called the optical distribution network (ODN).[3]It is a passive tree network in which one OLT serves up to 128 customers .ONT is an ITU-T term to describe a special, single-user case of an ONU. In Multiple Tenant Units, the ONU may be bridged to a customer premises device within the individual dwelling unit using technologies such as Ethernet over twisted pair. An ONU is a device that terminates the PON and presents customer service interfaces to the user. Some ONUs implement a separate subscriber unit to provide services such as telephony, Ethernet data, or video.

The OLT provides the interface between the PON and the service providers network services. These typically include:

- Internet Protocol (IP) traffic over gigabit/s, 10 Gbit/s, or 100 Mbit/s Ethernet
- standard time division multiplexed (TDM) interfaces

such as SONET or Synchronous Digital Hierarchy (SDH)

- Asynchronous Transfer Mode (ATM) User–network interface (UNI) at 155–622 Mbit/s

The ONT or ONU terminates the PON and presents the native service interfaces to the user. These services can include voice, video, and/or telemetry. Often, the ONU functions are separated into two parts:

- the ONU, which terminates the PON and presents a converged interface – such as xDSL, coax, or multiservice Ethernet – toward the user, and
- network termination equipment (NTE), which provides the separate, native service interfaces directly to the user

Through dynamic bandwidth allocation (DBA), a PON can be oversubscribed for upstream traffic, according to the traffic engineering concepts of statistical multiplexing. Downstream traffic can also be oversubscribed, in the same way that any LAN can be oversubscribed. The only special feature in the PON architecture for downstream oversubscription is the fact that the ONU must be able to accept completely arbitrary downstream time slots, both in time and in size.

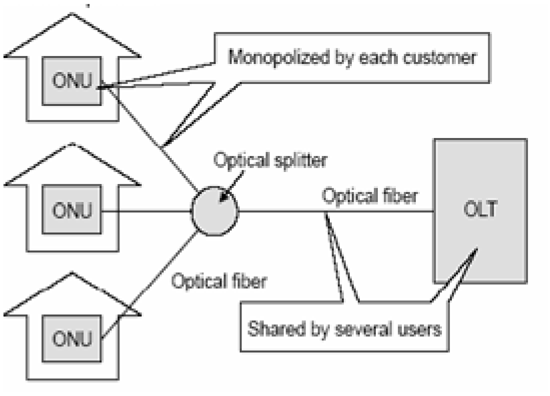


Fig :4:Basic PON Configuration

The two directions for optical transmission in the ODN (Optical Distribution Network) are identified for the symmetric GPON as follows: (1) Downstream direction for signals traveling from the
OLT to the ONU(s):

- Wavelength: 1480-1500 nm (basic band)
- Physical link rate: 1.24416 Gbit/s, TDM

(2) Upstream direction for signals traveling from the ONU(s) to the OLT:

- Wavelength: 1260-1360 nm bands
- Physical link rate: 1.24416 Gbit/s, TDMA

5 PHYSICAL MEDIA BUILDING BLOCKS

Figure 4 show the purely optical layer includes the optical fiber, splitters, WDM multiplexers/ demultiplexers, connectors, attenuators, optical filters and optical amplifiers (not used in this simulation).

Just above the purely optical layer there is a layer for electrical-to-optical and optical-to- electrical conversion; the electrical-to-optical conversion function is performed by a semiconductor laser diode, turning an electrical current signal into an optical power signal. At the other side of the link, the optical-to- electrical conversion is performed by an optical receiver comprising a semiconductor photodiode and an electrical (pre) amplifier. A further layer is then added above the analogue electrical layer for the conversion from/to the electrical digital layer.

Digital-to-analogue conversion is performed by the laser driver (including an electrical filter) in one direction and by the decision stage in the opposite direction. The digital layer is very useful for the link performance evaluation since it allows the BER evaluation.This model can be used for every fiber optics digital transmission system.

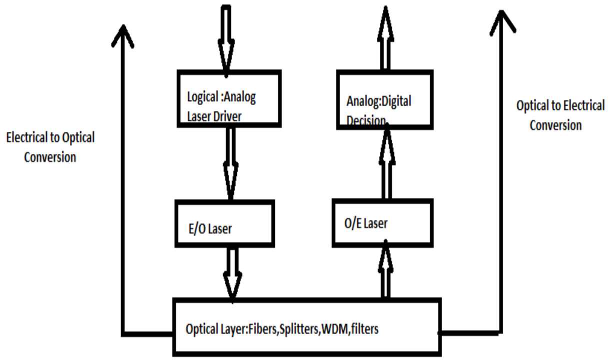


Fig:5:Physical media building blocks

6 OPERATION OF PON

[1]Passive optical networks do not use electrically powered components to split the signal. Instead, the signal is distributed using beam splitters. Each splitter typically splits the signal from a single fiber into 16, 32, or 64 fibers, depending on the manufacturer, and several splitters can be aggregated in a single cabinet. A beam splitter cannot provide any switching or buffering capabilities and doesn't use any power supply; the resulting connection is

called a point-to-multipointlink. For such a connection, the optical network terminals on the customer's end must perform some special functions which would not otherwise be required. For example, due to the absence of switching, each signal leaving the central office must be broadcast to all users served by that splitter (including to those for whom the signal is not intended). It is therefore up to the optical network terminal to filter out any signals intended for other customers. In addition, since splitters have no buffering, each individual optical network terminal must be coordinated in a multiplexing scheme to prevent signals sent by customers from colliding with each other. Two types of multiplexing are possible for achieving this: wavelength-division multiplexing and time-division multiplexing. With wavelength-division multiplexing,each customer transmits their signal using a unique wavelength. With time-division multiplexing (TDM), the customers "take turns" transmitting information. TDM equipment has been on the market longest; WDM-PON equipment became available in 2005.

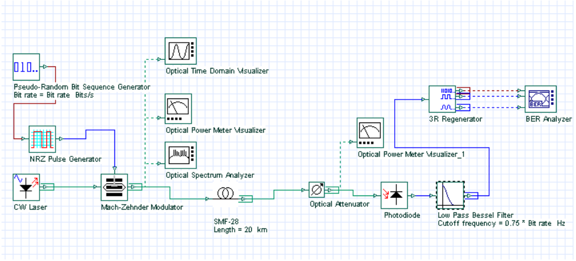
GPON uses GEM (GPON encapsulation Method) as a method which encapsulates data over GPON [7].

Downstream GPON Frame format Downstream traffic is broadcasted from the OLT to all ONUs in TDM manner [8].Every ONU must take into account only frames intended for it what is assured by encryption. The downstream frame consists of the physical control block downstream (PCBd), the ATM partition and the GEM partition. The downstream frame provides the common time reference for the PON and provides the common control signaling for the upstream.

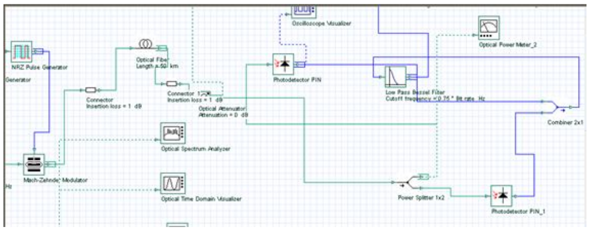
7 NETWORK DESGN AND MODELLING

7.1 Gpon Downstream Simulation Model

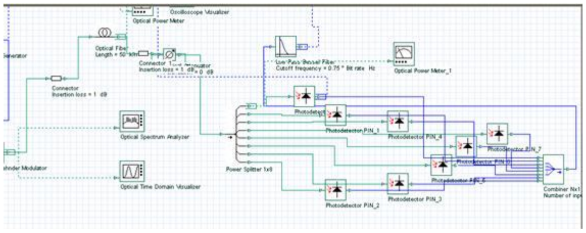
Figure 6 shows the proposed GPON Downstream Simulation schematic in Optisystem software. In the left side, where the OLT transmitter part is located, an external modulated transmitter is used. It consists of continuous wave laser source, Mach-Zehender modulator, NRZ pulse generator and pseudo random sequence generator. The right hand side an ONT receiver should have a photodiode, low pass filter and clock and data recovery. The link, sometimes called channel, is consists of 20 km of single mode fiber SMF28 and optical attenuator so as to add the loss for all the ODN classes.



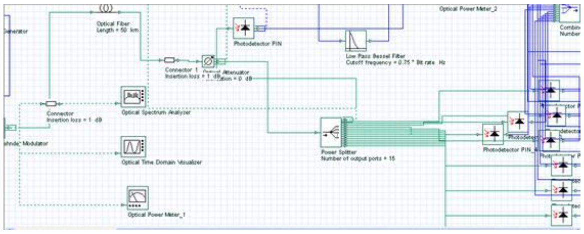
(i)General case



(ii)CASE A-2USERS



(iii)CASE B-8 USERS



(iii) CASE C-15 USERS

Fig6. GPON downstream simulation schematic in Optisystem

7.2 Components Used:

SL.NO	Component	Specification	Units
1	Sequence generator	Pseudo Random Bit	1
2.	Pulse generator	NRZ type	1
3.	CW laser	Frequency=193.1T Hz ,Power=0dBm	1
4.	Optical Fiber	Length=20 km Attenuation=0.2dB /km	1
5.	Optical Power Meter		2
6.	Optical Time Meter Visualizer		1
7.	Optical spectral Analyser		1
8.	Photodiode	PIN type	1
9.	Optical Attenuator	Attenuation=0dB	1
10.	Modulator	Mach-Zender type	1
11.	Filter	Low pass Bessel type, Cut off frequency= .75*	1
12.	Regenarator	3R	1
13.	BER Analyser		1
14.	Connector	Loss= 1dB	2
15.	Optical Spilter	Loss= 1 dB	1

7.3 Design Parameters

A network planner needs to optimize the various electrical and optical parameters to ensure smooth operations of an optical network. Whether the network topology is that of a point-to-point link, a ring, or a mesh, system design inherently can be considered to be of two separate parts:optical system design and electrical or higher-layer system design.

To ensure that the fiber system has sufficient power for correct operation, network designer needs to calculate the span's power budget, which is the maximum amount of power it can transmit.From a design perspective, worst-case analysis calls for assuming minimum transmitter power and minimum receiver sensitivity. This provides for a margin that compensates for variations of transmitter power and receiver sensitivity levels

***Power budget (Pb) = Minimum transmitter power PT – Minimum receiver sensitivity (PR)-* (1)**

The span losses can be calculated by adding the various linear and nonlinear losses. Factors that can cause span or link loss include fiber attenuation, splice attenuation, connector attenuation, chromatic dispersion, and other linear and nonlinear losses

Span loss (Ps)=(Fiber attenuatio n* Km)+(Splice attenuatio n*number of Splices)+(In line device losses)+(Nonlinear losses)+(Safety m in arg in) +(Connector attenuatio n*number of connectors)

The next calculation involves the power margin (*Pm*), which represents the amount of power available after subtracting linear and nonlinear span losses (*Ps*) from the power budget (*Pb*). A *Pm* greater than zero indicates that the power budget is sufficient to operate the receiver.The mathematical way for power margin (*Pm*) is as follows:

***Power m* arg *in* (*Pm*) = *Power budget* (*Pb*) – *Span loss* (*Ps*) -(3)**

To prevent receiver saturation, the input power received by the receiver, after the signal has undergone span loss, must not exceed the maximum receiver sensitivity specification *PR*max). This signal level is denoted as (*PIin*). The maximum transmitter power (*PR*max) must be considered as the launch power for this calculation. The span loss (*Ps*) remains constant.

***Input power* (*Pin*) = *Maximum transmitte r power* (*PT* max) – *Span loss* (4)**

The design equation:

Input power (*PIin*) <= Maximum receiver sensitivity (*PR*max)

must be satisfied to prevent receiver saturation and ensure system viability. If the input power (*PIin*) is greater than the maximum receiver sensitivity (*PR*max), passive attenuation must be considered to reduce signal level and bring it within the dynamic range of the receiver.

Bit Error Rate(BER)

The quality or performance of a digital communication system is specified by its BER or Q value. The BER is specified as the average probability of incorrect bit identification. In general, the higher the received Q-value, the lower the BER probability will be. Due to intensity modulation, this system is completely insensitive to laser phase noise. The dominant sources of noise are thermal noise and not shot noise.

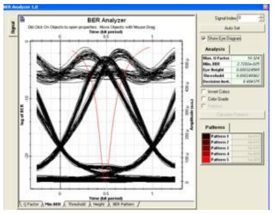
Minimum Bit Error Rate And Receiver Sensitivity

An optical link is designed by taking into account a figure of merit, which is generally the bit error rate (BER) of the system. The signal entering the decision circuit fluctuates due to the various noise mechanisms. It is the probability of incorrect bit identification by the decision circuit. For most practical optical networks, this requirement of BER is (~10 ^ -9 to 10^ -12), which means that a maximum one out of every 1012 bits can be corrupted during transmission.

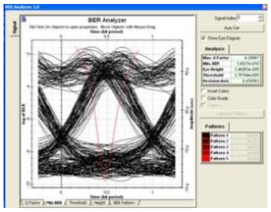
Typical requirements for optical receivers used in this simulation are optimized to be BER < 10 ^-10 . The receiver sensitivity is the minimum averaged received optical power required to achieve BER =10–10 and is equal to -32.8dBm. From this explanation, it becomes evident why optical system design considers power budget and power margins (safety margins for good design) so important.

8 SIMULATION AND RESULTS:

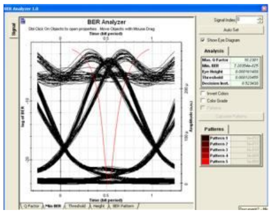
A.Simulation



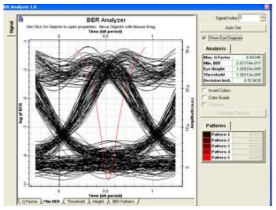
Power supplied=10dBm
Class A=2 users



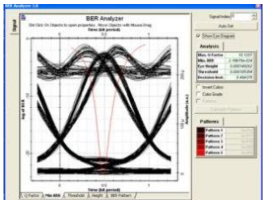
Power supplied=0.2dBm
Class A=2 users



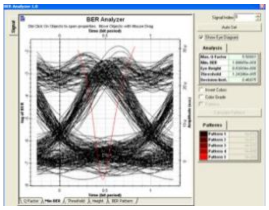
Power supplied=10dBm
Class B=8 users



Power supplied=0.2dBm
Class B=8 users



Power supplied=10dBm
Class C=15 users



Power supplied=0.2dBm
Class C=15 users

B.Results:

Span loss=13dB=43dBm
I/p power=Maximum receiver sensitivity=-32.8dBm
Minimum receiver sensitivity=-1dBm
Class A=2 users
Class B=8 users
Class C=15 users

TABLE

TABLE 1:
For power supplied=10dBm
Power transmitted=2.852dBm

TABLE 2:
For power supplied=0.2dBm
Power transmitted=-6.948dBm

Parameter	Class A	Class B	Class C
Maximum Received power(dBm)	-0.158	-8.179	-10.978
Power budget(dBm)	3.852	3.852	3.852
Power margin(dBm)	-39.148	-39.148	-39.148
Maximum power transmitted(dBm)	10.2	10.2	10.2

Parameter	Class A	Class B	Class C
Maximum received Power(dBm)	-9.958	-17.979	-20.779
Power	-5.948	-5.948	-5.948

Thus,we conclude that a change in no of stations by a large no in GPON doesn't increase the power budget, by an appreciable amount. This shows that GPON is the most suitable network when we consider large no of stations and leaves us room for expanding our network at very little cost.

9 ADVANTAGES

- Encryption can prevent eavesdropping.
- Achieves higher bandwidth.
- The higher variable length packet ensures higher efficiency.
- Fragmentation allows higher quality of service for delay sensitive communication.
- Better traffic packaging
- Application in Video TV Services.

10 CONCLUSION

This paper presented the downstream transmission performance of 1.25 Gb/s GPON bit rate.. A BER ≈ 10 ^ (-10) convenient to sustain a good communication. Multiple customers who are connected to the PON share the OLT costs.

Due to its unprecedented offered bandwidth, GPON is the Ideal technology for large-scale FTTH applications where multiple end-users are requiring an ever-growing bandwidth. Moreover, in areas populated by both business and residential customers, GPON is the most cost-effective solution.

In this simulation,the parameters are observed for number of users (ONTs) of 2, 8 and 15 are obtained for classes A, B and C respectively.

GPON standard allows the OLT PON card to support up to 128 ONTs,thereby making the GPON solution 4 to 8 times more cost effective.

ACKNOWLEDGEMENT

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