Using Ethernet/Gigabit Passive Optical Network (EPON/GPON) over traditional broadband networks in Bangladesh, its challenges and solutions

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Declaration

I, hereby, declare that the work presented in this thesis is the outcome of the investigation performed by me under the supervision of Dr. Anisur Rahman, Professor, Department of Computer Science and engineering, East West University. I also declare that no part of this thesis/project has been or is being submitted elsewhere for the awardof any degree or diploma.

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Abstract

Accessing Internet is going to be a fundamental right like other basic human rights. No matter how often a user uses Internet, waiting for a web page to load is really an annoyance. To overcome this situation, Internet speed has increased significantly in the past decade to keep pace with the demand of users, new services and bandwidth-hungry applications. These demands include as multimedia content based e-commerce, video on demand, high definition TV, IPTV, online gaming, social media, etc. Lots of different technologies like gigabit Ethernet, mobile Internet, etc. that have been trying to cater and satisfy the user demand. FTTH(Fiber to the home) is one of the high-speed access technology which offers triple play service (i. e., data, voice and video) EPON/GPON is easier, faster and low cost. EPON/ GPON can transport Ethernet, ATM and TDM (PSTN, ISDN, E1 and E3) traffic. It has been widely accepted by Internet service providers and operators in terms of bandwidth upgrade, service bearer as well as passive network maintenance. High bandwidth capacity, high quality and multi-play services through a single channel presents a strong business opportunity for telecom operators as it provides support which includes voice, Ethernet, ATM, leased lines and others. FTTH offers simple operation, administration, maintenance and provisioning capabilities as well as end-to-end service management. It not only provides substantially higher efficiency as a transport network, but also delivers simplicity and superb scalability for future expansion in supporting additional services.

According to the contents above, we can see that there are own advantages and disadvantages of EPON and GPON. In performance comparison, GPON is better than EPON, while EPON has many advantages on time and cost. And now, EPON is still the mainstream of PON, and meanwhile, GPON is catching up with it. Going forward to the broadband access market, maybe it is not substitution between EPON and GPON. It is more likely that they are co-exist to complement each other. For the users who have demands of multi-service, high QoS and security, as well as ATM backbone network, GPON seems to be an ideal.

Acknowledgments

As it is true for everyone, I/We have also arrived at this point of achieving a goalin my/our life through various interactions with and help from other people. However, written words are often elusive and harbor diverse interpretations even in one's mother language. Therefore, I/We would not like to make efforts to find best words to express my thankfulness other than simply listing those people who have contributed to this thesis itself in an essential way. This work was carried out in the Department of Computer Science and Engineering at East West University, Bangladesh.

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Chapter 01

1. Introduction

Bangladesh officially the People's Republic of Bangladesh, is a country in South Asia. It is surrounded by India on all sides except for a small border with Myanmar to the far southeast and the Bay of Bengal to the south. Together with the Indian state of West Bengal, it makes up the ethno-linguistic region of Bengal. The name Bangladesh means "Country of Bengal" in the official Bengali language. The borders of Bangladesh were set by the Partition of India in 1947, when it became the eastern wing of Pakistan (East Pakistan), separated from the western wing by 1,600 kilometers (1,000 miles). Despite their common religion of Islam, the ethnic and linguistic gulf between the two wings, compounded by an apathetic government based in West Pakistan, resulted in the independence of Bangladesh under the leadership of Sheikh Mujibur Rahman in 1971 after the bloody Bangladesh Liberation War, in which it was supported by India. The years following independence have been marked by political turmoil, with thirteen different heads of government, and at least four military coups. The population of Bangladesh ranks seventh in the world, but its land area is ranked ninety-fourth, making it one of the most densely populated countries in the world.1 The pioneering and bold computer magazine of Bangladesh, The Monthly Computer Jagat, expressed its deep concerns regarding Internet access in the country in its July 1996 issue. In an editorial it stated, Revolutions have been created round the world to use Internet for extension of knowledge, scientific activities and education. But, in Bangladesh we have no such initiative to provide Internet access to the educational institutions. Even most prestigious higher institutions like University of Dhaka and Bangladesh University of Engineering & Technology are beyond its reach. Online Internet was legalized in the country on 4 June 1996 and the same day one Internet service provider (ISP), the Information Services Network (ISN), started work. Within one and a half months, Grameen Cyber Net started service on 15 July 1996. At about the same time, two other off-line providers went online by taking leased lines from the major providers. Very recently two big nongovernmental organizations (NGOs) started online Internet service. But despite the presence of so many ISPs, Internet access is largely underutilized. All the ISPs are capital city based with no immediate plans to extend services outside Dhaka. Moreover, subscribers mainly use the e-mail facilities of Internet, with little Web browsing or newsgroup reading. This regrettable situation has led the authors to conduct a situation analysis study.

1.1 Background

The Internet is the global system of interconnected computer networks that use the Internet protocol suite (TCP/IP) to link billions of devices worldwide.2 September 2, 1969: First time two computers communicated with each other. October 29, 1969: Message sent from computer to computer in different locations. January 1, 1983: Arpanet adopted the standard TCP/IP protocol. March 1989: Tim Berners-Lee invented the World Wide Web.3 A world-wide computer network that can be accessed via a computer, mobile telephone, PDA, games machine, digital TV, etc. The Internet access service can be provided through a fixed (wired) or mobile network: analogue dial-up modem via standard telephone line, ISDN (Integrated Services Digital Network), DSL (Digital Subscriber Line) or ADSL, Cable modem, High speed leased lines, Fiber, Power line, Satellite broadband network, WiMAX, Fixed CDMA, Mobile broadband network (3G, e.g. UMTS) via a handset or card, Integrated SIM card in a computer, or USB modem. The internet is made up of millions of computers from all around the world, linked to each other by a network of telephone lines, cables and satellite connections.

1.2 Internet History of Bangladesh

The web or the World Wide Web is the information and the services we can use, thanks to these networked computers. Starting in the early 1990s, Bangladesh had dialup access to e-mail using the Bulletin Board Systems (BBSs) of a few local providers, but the number of users did not total more than 500. Users were charged by the kilobyte and email was transferred from the BBS service providers to the rest of the world by international dialup using UUCP. In June 1996 the first VSAT base data circuit in the country was commissioned and the Bangladesh Telegraph and Telephone Board (BTTB) granted licenses to two Internet Service Providers (ISPs). In subsequent years more liberal government policies led to a rapid expansion of the industry, resulting in over 180 registered ISP's by 2005. ISPs are currently regulated by the Bangladesh Telecommunication Regulatory Commission (BTRC) through the Bangladesh Telecommunications Act. In May 2006 Bangladesh inaugurated new submarine optic fiber connectivity as part of the 16 country consortium SEA-ME-WE 4 project. The landing station is in Cox's Bazar, the southern city near the Bay of Bengal. In July 2008 the Submarine Cable Project was transformed into the company Bangladesh Submarine Cable Company Limited (BSCCL), which is now responsible for all services related to the submarine cable. Between June and August 2012 international Internet service in Bangladesh was slowed following a cable cut on the eastern leg of the SEA-ME-WE 4 optical fiber cable and the fact that Bangladesh does not have an alternative submarine cable or other high-speed international connections. In 2014 the new SEA-ME-WE 5 cable is expected to provide an alternative operating at 100 Gbit/s, roughly 10 times faster than the current connection.

E-mail service was started in Bangladesh4 through a small private initiative sometime in late 1993. Another private organization came with a bulletin board service (BBS) with Internet e-mails and newsgroups in late 1994 that attracted many subscribers because of its good price package. There was demand from all quarters for BTTB to start VSAT or X.25 lines for Internet and data entry services. But BTTB was not willing. Bangladesh was fortunate that it got three dynamic leaders in the cabinet of the three months' neutral caretaker government formed to conduct the National Assembly election from April to June 1996. The leaders, Dr. M. Yunus (renowned for his micro credit bank for the poor), Dr. ManzoorElahi, and science educator Dr. Jamilur Reza Chowdhury, took initiative to remove all regulatory bars for setup and use of VSAT in the private sector. As a result online Internet service began in the country on 4 June 1996. Currently, six providers are giving online Internet access; four of them are using their own 64 kilobytes per second (kbps) VSAT and the other two are using leased lines from two major providers. [1]

Year	Internet Users	Penetration (% of Pop.)	Total Population[7]	Non Users (Internet Less)
2016	21,439,070	13.2%	162,910,864	141,471,794
2015	19,420,674	12.1%	160,995,642	141,574,968
2014	15,271,441	9.6%	159,077,513	143,806,072
2013	10,419,535	6.6%	157,157,394	146,737,859
2012	7,762,869	5.0%	155,257,387	147,494,518
2011	6,903,253	4.5%	153,405,612	146,502,359
2010	5,609,821	3.7%	151,616,777	146,006,956
2009	4,647,081	3.1%	149,905,836	145,258,755
2008	3,706,312	2.5%	148,252,473	144,546,161
2007	2,638,668	1.8%	146,592,687	143,954,019
2006	1,448,392	1.0%	144,839,238	143,390,846
2005	345,372	0.2%	142,929,979	142,584,607
2004	280,330	0.2%	140,843,786	140,563,456
2003	227,135	0.2%	138,600,174	138,373,039
2002	190,611	0.1%	136,228,456	136,037,845
2001	173,652	0.1%	133,776,064	133,602,412
2000	93,261	0.1%	131,280,739	131,187,478

Figure 1.1: Statement of Interment User in Bangladesh

The history of internet is not that old even in developed countries. The people of Bangladesh had to remain in dark about it for a long time because of the non-availability of the service in this part of the globe. The main obstacle to start the service was to have data circuits to a suitable overseas location. However in this condition a few young talents started dialup e-mail service and made it commercially available for public use. In late 1995 the government of Bangladesh invited applications to subscribe the VSAT (Very Small Aperture Terminal) data circuits. 2nd Submarine6 Cable 2013 a) BSCCL signed for SMW-5 submarine cable System b) Probable activation on 2016 c) Will reduce dependency to terrestrial cables in India.

1.3 Agenda:

- At first I want to represent the condition of Bangladesh how much bandwidth we need for every person.
- Then, I discuss about our traditional network. itry to elaborate about why now another technology is more importance for us.
- Depends on our demand, FTTX is now more needy for us. What is FTTX, why we need this, What's the advantages of FTTX , What is EPON technologies, What is GPON technology, What's the difference of EPON & GPON, What is PON technology, what's the equipment we need and what's the benefit of it and its advantages. What is OLT, ONU and splitter those term are also more important for us.

- Then I try to focus the application of FTTX project. What kind of application we developed.

- Then I elaborate about the benefit of the EPON and GPON. Difference between EPON & GPON and which is better between among EPON and GPON .Which is preferable foe which type of client and why EPON and GPON is Cost Effective.

- Then I ty to focused about the Technical issue. How we can minimize our cost and planning about the EPON and GPON And so on.

- The real life scenario in Bangladesh. And what type of problem in FTTX in Bangladesh. What type of limitation in PONtechnologies? What type of problem they face at most? Cost Analysis about the traditional network vs PON technologies.

Chapter 2

2. Traditional Network

2.1 Switch Network:

A scalable switch network design is a low-cost and easy-to-install solution for a small campus network. This design does not require knowledge of network address structure, is easy to manage, and enables all users to communicate with one another.

However, you do need to remember that a scalable switch network makes up a single broadcast domain, which can lead to network congestion if the amount of broadcasts increases, such as with additional users being added to the network. If a scaled switched network needs to grow beyond the broadcast domain, then VLANs should be used to create multiple smaller broadcast domains.

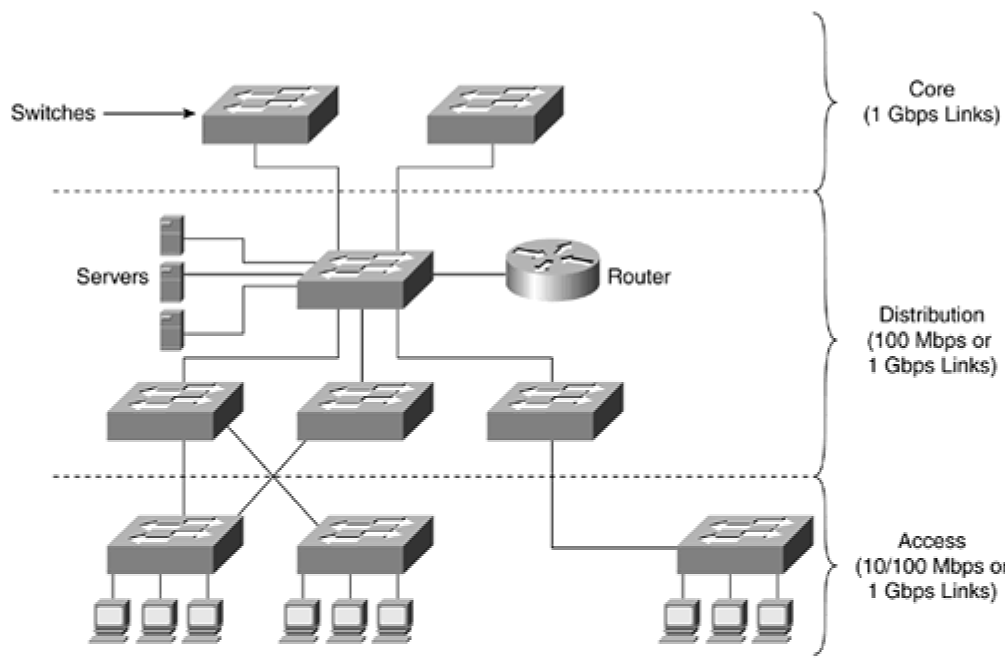


Figure 2.1: Switch Network

In the case of LAN switching in the distribution layer, the following issues need to be considered when designing your network:

Support for VLAN trunking technology in each enterprise-class LAN switch you use in the network. (Remember, some low-end switches do not support VLAN trunking.)

The switches in the distribution layer must run the Spanning Tree Protocol (STP) to prevent network loops. Running STP means that some connections will be blocked and load sharing will not be available for you to use in your network. However, you can load balance by having some VLANs block on one port and other VLANs block on the other port when using trunking.

If you want to scale the large switched with minimal routing network design, you must use a logical hierarchy. The logical hierarchy is made up of VLANs and routers enabling communication between the VLANs. In this topology, routing is used only in the distribution layer, and the access layer depends on bandwidth through the distribution layer to gain access to high-speed switching functionality in the core layer. The large switched/minimal routing design scales well when VLANs are used such that the majority of resources are available in the VLAN. If this topology can be designed so that 80 percent of traffic is inside the VLAN and 20 percent of traffic is external to the VLAN, the bandwidth needed for communication between VLANs is not a concern. If there is more than 20 percent communication required between VLANs, however, access to routing or Layer 3 switching in the core becomes a scalability issue, at which point you should take another look at how your VLANs are designed, possibly segmenting the VLANs even further or regrouping your users and servers.

2.2 Advantages of Fiber Optic Internet vs. Cable

1. Bandwidth

Investing in fiber optic Internet can significantly increase your bandwidth potential. Copper wire infrastructure and TDM technology are limited in nature. Because it was originally designed for transmitting voice calls only, the demand for bandwidth wasn't high. For instance, T-1 can only carry 1.5 Mbps of throughput. And because of how electrical signaling works, many types of connections over cable are limited by distance.

Ethernet over Copper service (EoC) is typically not available if the circuit is longer than 15,000 feet. For organizations considering shifting their voice communications to Voice-over-IP (VoIP), having your bandwidth delivered over fiber can be an indispensable asset.

2. Upload/Download Speed

Is the speed increase of fiber optic Internet noticeable compared to cable? Absolutely. Many Atlantics Online customers using fiber to connect to our network can transmit data at 1 gigabit per second. That's many times faster than the federal government's definition of broadband service, which is 25 Mbps uploads and 3 Mbps for downloads as of January 2019.Tech blog Northwest writes that downloads that take 22 minutes over most copper wire Internet connections can take as little as 8 seconds over fiber.

3. Distance

The signal for copper Internet networks degrades as the signal is carried from the central office (CO). Fiber was originally used for long haul networks. Cell phone towers in remote locations use fiber optic cable to connect towers to the network.

According to Black box Technology, certain types of fiber connections can be transmitted for almost 25 miles. While most business build outs won't require similarly robust types of fiber connections, your signal isn't in danger of degrading within metro fiber rings that would serve your business.

4. Security

In an era of increased attention towards cybersecurity, fiber optic is touted as a cost-effective way of instantly increasing your Internet security. Intercepting copper cable can be performed by connecting taps to a line to pick up the electronic signals. Putting a tap on a fiber optic Internet cable to intercept data transmissions, however, is incredibly difficult.

It's also easy to quickly identify compromised cables, which visibly emit light from transmissions. With distributed-denial-of-service (DDoS) attacks on the rise, it's more important than ever to have added security for your network.

5. Reliability

There are many factors that can cause outages when an organization is reliant on copper cable-based Internet. Temperature fluctuations, severe weather conditions, and moisture can all cause a loss of connectivity. Old or worn copper cable can even present a fire hazard, due to the fact it carries an electric current.

Additional reliability concerns associated with cable include risks of interference from electronic or radio signals. Additionally, copper wires are accessed in the building by telephone company personnel and sometimes they can make mistakes and fiddle with the wrong wires. Also, copper wires all go back to the telephone company Central Office where disconnections can happen. Fiber is typically independent of the phone company, their equipment, and their termination points.

6. Cable Size

The speed of Internet transmitted via copper cable is directly correlated with the weight of cable used. For a business to achieve higher speeds, more cable must be used, which requires more space in a company's telecommunications room.

Fiber's speed is not connected to its size, and it's far lighter weight than copper. This renders it easier to use and less demanding on the limited space of small rooms.

7. Cost

Investing in fiber Internet is more expensive than copper in the short term, though costs are drastically decreasing as this option becomes more commonplace. Ultimately, the total cost of ownership (TCO) over the lifetime of fiber is lower. It's more durable, cheaper to maintain, and requires less hardware.

The advantages of fiber optic Internet make it a more cost-effective investment for organizations of all sizes.

2.3 Optical fiber Network:

If you have a network that uses the older type of copper cables and another network that utilizes faster and more reliable fiber optic cables, it is possible to connect them together by using a special product named fiber media converter. A fiber media converter changes signals on a copper cable to signals that run on fiber, make one cable “look” like another cable without changing the nature of the network. Due to this function, network executives who need to upgrade their systems from copper to fiber but don’t have the budget, manpower or time, just turn to media converters.

2.4 What Is a Fiber Media Converter?

Fiber media converter is a small device with two media-dependent interfaces and a power supply, simply receive data signals from one media, convert and transmit them to another media. It can be installed almost anywhere in a network. The style of connector depends on the selection of media to be converted by the unit. The most common being UTP to multimode or single mode fiber. On the copper side, most media converters have an RJ-45 connector for 10BASE-T, 100BASE-T, and 1000BASE-T and 10GBASE-T connectivity. The fiber side usually has a pair of SC/ST connectors or SFP port. Media converters may support network speeds from 10 Mbps to 10 Gbps, thus there are Fast Ethernet media converters, Gigabit Ethernet media converters, and 10-Gigabit Ethernet media converters. Here is a 10/100/1000Base-T RJ45 to 1x 1000Base-X SFP Gigabit Ethernet media converter in the picture below

Figure 2.2: Optical media Converter

How Does a Fiber Media Converter Work?

Fiber media converters change the format of an Ethernet-based signal on Cat5 into a format compatible with fiber optic cables. At the other end of the fiber cable run, a second media converter is used to change the data back to its original format. One important difference to note between Cat5 and fiber is that Cat5 cables and RJ45 jacks are bidirectional while fiber is not. Thus, every fiber run in a system must include two fiber cables, one carrying data in each direction. These are typically labeled transmit (or Tx) and receive (or Rx).

Figure 2.3: Uses of Optical Media Converter

Types of Fiber Media Converters

Media converters may be simple devices, but they come in a dizzying array of types. Newer media converters are often really a switch, which confuses the issue even more.

Layer 1 vs Layer 2 Fiber Media Converter

Traditional media converters are purely Layer 1 devices that only convert electrical signals and physical media and do not do anything to the data coming through the link so they are totally transparent to data. Some media converters are more advanced Layer 2 Ethernet devices. Like traditional media converters, they provide Layer 1 electrical and physical conversion. But unlike traditional media converters, these converters also provide Layer 2 services. This kind of media converter often has more than two ports, enabling the user to extend two or more copper links across a single-fiber link. These media converters usually feature auto-sensing ports on the copper side, making them useful for linking segments operating at different speeds.

Unmanaged vs Managed Fiber Media Converter

A unmanaged media converter allows for simple communication with one another but does not provide monitoring, fault detection and setting up network configurations. The unmanaged option is a great choice for newbies and if you want a plug and play fiber network cable installation. Managed media converters are more costly but do offer additional network monitoring, fault detection, remote configuration and more. Besides, usually a managed media converters have the function of SNMP (Simple Network Management Protocol) management. There is no mention of SNMP for unmanaged fiber optic media converters.

Non-PoE vs PoE Fiber Media Converter

Standard media converters come with an AC power supply that plugs into a standard wall outlet. It may be 120V AC for domestic U.S. power only or may be an auto-sensing 120 to 240V AC power supply that can be used domestically or easily converted to European power with a simple plug adapter. When media converters are used in areas that do not have convenient power outlets, they may be powered by Power over Ethernet (PoE), which provides power to network devices over the same Category 5 or higher UTP cable used for data. PoE media converters may also provide power through PoE to a PoE-powered device such as a security camera or wireless access point. A use case of PoE media converters is shown in the picture below.

2.5 What Is Network Switch?

A network switch is a computer networking device that connects devices together on a computer network by using packet switching to receive, process, and forward data to the destination device. Usually, a switch serves as a controller, enabling networked devices to talk to each other efficiently. Through information sharing and resource allocation, switches save businesses money and increase employee productivity. And the network switch operates at the data link layer (Layer 2) of the Open Systems Interconnection (OSI) model called layer 2 switch, which operates at the network layer (layer 3) of the OSI model called layer 3 switch.

Figure 2.4: Network Switch

Media Converter vs Network Switch: What Is the Difference?

In fact, both a media converter and a network switch today can act and perform the same functions. And both of them operate within the OSI model which is hierarchical and structured in the form of layers such as layer 1, layer 2, and layer 3 and so on. A clear understanding of what OSI layers do, and what the differences between devices operating at different layers are, will help you learn about the difference between media converter and network switch.

2.6 Pros and Cons of Fiber Optics:

Pros of Fiber Optics

1) **Connection Quality:**

   Fiber optics are resistant to electromagnetic interference and have a low rate of bit error. Electromagnetic interference (EMI) is a disturbance caused by electromagnetic radiation from an external source. This disturbance can interrupt or degrade the performance of a conventional metallic cable connection. Any object that carries electrical currents can create interference, such as power lines or even the sun. Fiber optics are also resistant to corrosion.

2) **Scalability:**

   Fiber optics are more scalable, as it's simple to install new equipment can over original fiber. Wavelengths can be turned on or off on demand, which allows for the easy provisioning of services and quick scaling for a growing business. Optical fibers are also much smaller and lighter than copper wiring. These fibers can typically be placed in preparation for growth needs up to 15 to 20 years in the future. Alternatively, additional cables can be installed later to make way for network expansion.

3) **Security:**

   Security is a major concern for today's businesses. Fiber optics do not radiate signals, so there is no way to listen in on the transmissions passing through. Breaches are also easy to identify as soon as they occur, as any physical break in the system will cause a total system failure. Instead of hardware in several locations, fiber optic networks allow you to keep hardware in one location. This makes regulation and maintenance much simpler.

4) **Long-Term Cost-Effectiveness**:

   Long term, fiber optic networks do not require the same overhead as copper networks. Fiber optic networks are more expensive upfront. However, the capacity for scalability long-term outweighs the initial investment. As the popularity of fiber optics grows, we are likely to see a decrease in cost over time.

Cons of Fiber Optics

Although fiber optic networks present many advantages, there are also some disadvantages to take into consideration. These include physical damage, cost considerations, structure, and the possibility of a "fiber fuse".

1) **Physical Damage:**

   Fiber is thinner and lighter than metallic wiring, so it makes for a more delicate system. Because fiber optic cables are small, they can be easily cut by accident during building renovations or rewiring. As fiber optic cables can transmit much more data than metallic networks, fewer cables service a greater number of people. This means that cutting just one cable could disrupt service for a large number of businesses and individuals. Fibers are also sensitive to bending, making laying fibers around corners a tricky business. Fiber optic networks are also susceptible to radiation damage or chemical exposure.

2) **Short-Term Cost Effectiveness:**

   Although costs are lower over the long term, fiber installation costs can still cost a pretty penny to implement. Special test equipment is often required along with installers that have skilled knowledge about laying a fiber optic network. Fiber endpoints and connection nexuses also require special equipment and setup. In addition, it may take specialized equipment to diagnose an issue with a fiber optics network, making for higher-cost fixes should the cables sustain damage.

3) **Fiber Fuse:**

   At high power, fiber optic networks are also susceptible to something known in the industry as "fiber fuse". This occurs when too much light meets with an imperfection in the fiber. This occurrence can destroy long lengths of cable in a short amount of time.

4) **Unidirectional Light Propagation:**

   Fiber cables are also limited in the sense that they can only propagate light in one direction. If bidirectional communication is a necessary part of information transmission within a network, two concurrent cables must be laid in order to achieve bidirectional propagation of information.

   Although there are some disadvantages to having a fiber optic network, the technology is quickly taking the market by storm, and prices continue to drop significantly. Industry experts anticipate the compound annual growth rate of the fiber optics industry will be 9.8% by 2021.

Chapter 03

3. FTTX (Fiber to the home):

3.1 Passive Optical Networks

Starting in 1995, formed by major telecommunications service providers and system vendors. The International Telecommunications Union (ITU) did further work, and standardized on two generations of PON. The older ITU-T G.983 standard was based on Asynchronous Transfer Mode (ATM), and has therefore been referred to as APON (ATM PON). Further improvements to the original APON standard – as well as the gradual falling out of favor of ATM as a protocol – led to the full, final version of 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.

Passive Optical Networks (PON) are point-to-multipoint optical networks with no active elements in the signals' path from source to destination. The only interior elements used in such networks are passive combiners, couplers, and splitters. It starts from the optical line terminal (OLT) in the central office and ends at the optical network (ONU) at the customer's home.

A passive optical network consists of an optical line terminal (OLT) at the service provider's central office (hub) and a number of optical network units (ONUs) or optical network terminals (ONTs), near end users. A PON reduces the amount of fiber and central office equipment required compared with point-to-point architectures. A passive optical network is a form of fiber-optic access network. In most cases, downstream signals are broadcast to all premises sharing multiple fibers. Encryption can prevent eavesdropping. Upstream signals are combined using a multiple access protocol, usually time division multiple access (TDMA).

Previously, the most used access network technologies are ADSL and ADSL2+ over copper wire. With the arrival of new multimedia applications like voice IP (VoIP), video on demand (VoD) or IP television (IPTV), more capacity and QoS are needed. New Fiber to the Home (FTTH) technologies replace link copper by optical fiber. FTTx 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. Fiber to the x (FTTx) is a collective term for various optical fiber delivery topologies that are categorized according to where the fiber terminates. Fiber access is one of the most important technologies in the next generation network. It increases the access layer bandwidth and builds a sustainable-development access layer network. Optical Access Network (OAN) adopts technologies: active point-to-point (P-P)

Ethernet and passive optical network (PON). There are many common subsets of FTTxlike fiber to the node or fiber to the neighborhood (FTTN), fiber to the curb or fiber to the cabinet (FTTC), fiber to the premises (FTTP), fiber to the building or fiber to the basement (FTTB), fiber to the home (FTTH) etc.

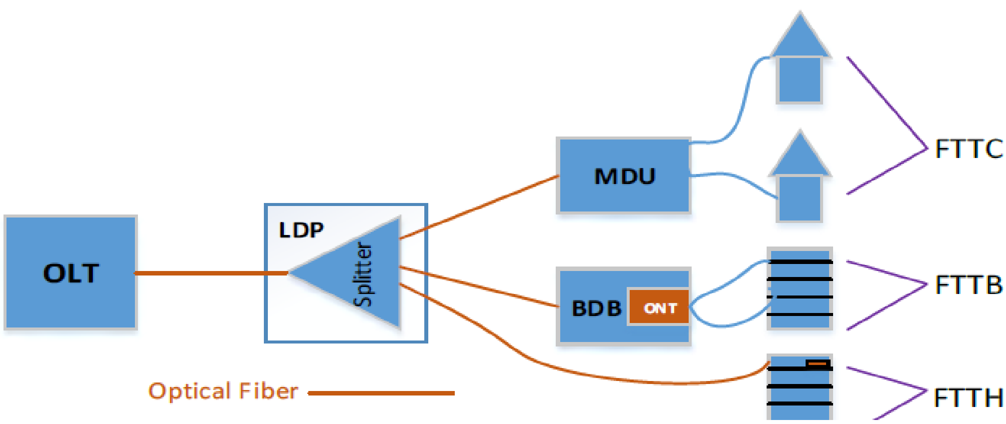


Figure 3.1: FTTH Sculpture

FTTH (fiber to the home): Optical fiber terminates inside an individual home or business. FTTP (fiber to the premises) may be used to describe optical cabling terminated at these places.

FTTB (fiber to the building): Similar to FTTH, FTTB optic cabling stops at a building’s electrical room.

FTTC (fiber to the curb): Cabling terminates within 300 yards of a subscriber's premises.

FTTN (fiber to the neighborhood): Optical cabling ends a few miles from a users' premises

3.2 Optical Communication System

Communication means the exchange of information which may be voice, video, or data. So, a communication system transmits information from one place to another place.

Communication systems exchange signals between two or more entities in a form suitable to process and manipulate most economically. The basic principle of a communication system is to bridge two entities at different locations. Twenty first century is the era of information technology (IT). There is no doubt that IT has achieved an exponential growth through the modern telecommunication systems. Particularly, optical fiber communication plays a vital role in the development of high quality and high-speed telecommunication systems. Today, optical fibers are not only used in telecommunication links but also used in the Internet and local area networks (LAN) to achieve high signaling rates.

3.3 Evaluation of Optical Communication

Even though an optical communication system had been conceived in the late 18th century by a French Engineer Claude Chappe who constructed an optical telegraph, electrical communication systems remained the dominant means of communication. In 1966, Kao and Hockham proposed the use of optical fiber as a guiding medium for the optical signal [8]. Four years later, a major breakthrough occurred when the fiber loss was reduced to about 20 dB/km from previous values of more than 1000 dB/km by applying improved fiber manufacturing and design techniques. Since that time, optical communication technology has developed rapidly to achieve larger transmission capacity and longer transmission distance. The capacity of transmission has been increasing about 100 fold in every 10 years.

There were several major technological breakthroughs during the past two decades to achieve such a rapid development. In 1980, the bit rate used was 45 Mb/s with repeater spacing of 10 km. The multimode fiber was used as the transmission medium and GaAs LED as the source of the system. In 1987, the bit rate was increased to 1.7 Gbps with repeater spacing of 50 km. By 1990, the bit rate was increased to 2.5 Gbps with repeater spacing further increased to 60- 70 km. Dispersion shifted fibers are used to minimize the bit error rate and to increase the repeater spacing and the bit rate

In 1996, the bit rate of the optical transmission system was increased to 5 Gbps. The development of optical amplifiers brought another important breakthrough in optical communication system. Optical amplifiers reduced the associated delay and power requirement of the electronic amplifiers. Wavelength Division Multiplexing (WDM) was also introduced at this time to increase the available bandwidth capacity in terms of the channels. By 2002, the bit rate of the optical system was increased to 10 Gbps with repeater spacing of 70-80 km. The introduction of the dense-wavelength division multiplexing (DWDM) system increased the channel capacity and the bit rate increased to 40 Gbps.

3.4 Classification of PON technologies:

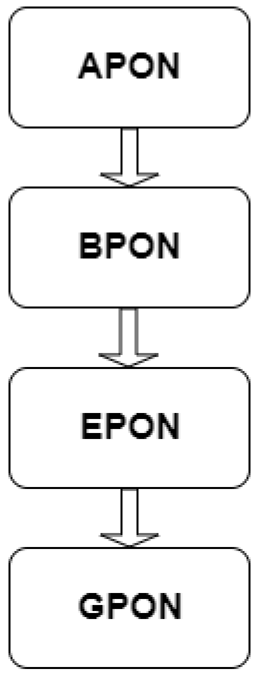


Figure 3.2: Series PON technologies

APON: Also known as Asynchronous Transfer Mode passive optical network (APON), or simply ATM PON (as it contains an electrical layer built on ATM), APON is the original PON system that was used for commercial deployment.

ATM Passive Optical Network APON was initiated in 1995 by ITU/FSAN and standardized as ITU-T G.983. In 1999, ITU adopted FSAN's APON standard. APON was the first PON based technology developed for FTTH deployment as most of the legacy network infrastructure was ATM based. There are different PON Technologies available today. Since the services offered by this architecture are not only the ATM based services but also video distribution, leased line services and Ethernet access and to express the broadband capability of PON systems APON was renamed as Broadband Passive Optical Network BPON. BPON was standardized by ITU recommendations G.983.1, .2, .3, and .4. BPON has two key advantages, first it provided a 3rd wavelength for video services, and second it is a stable standard that re-uses ATM infrastructures. ITU-T recommendation G.983.1 defines three classes of performance namely Class A, Class B and Class C.

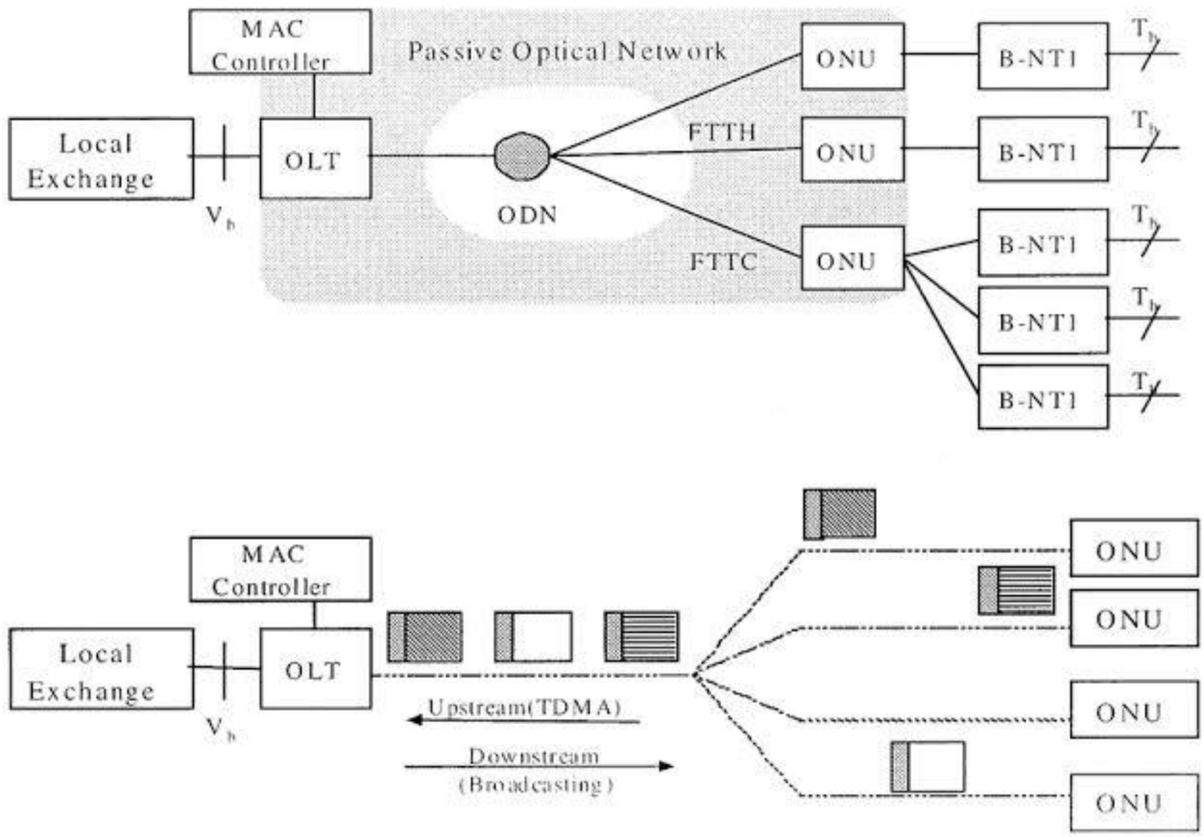


Figure 3.3: APON Diagram

BPON: Broadband PON (BPON) is the improved successor of APON and maintains the ATM structure. BPON has a transmission rate of up to 622 Mb/s, with downstream capabilities of 155 Mb/s to 622 Mb/s. BPON can be converted to EPON or GPON over time, as ATM bandwidth is not ideal for video.

BPON is a standard based on APON. It adds support for WDM (Wavelength Division Multiplexing), dynamic and higher upstream bandwidth allocation, and survivability. It also created a standard management interface, called OMCI, between the OLT and ONU/ONT, enabling mixed-vendor networks.

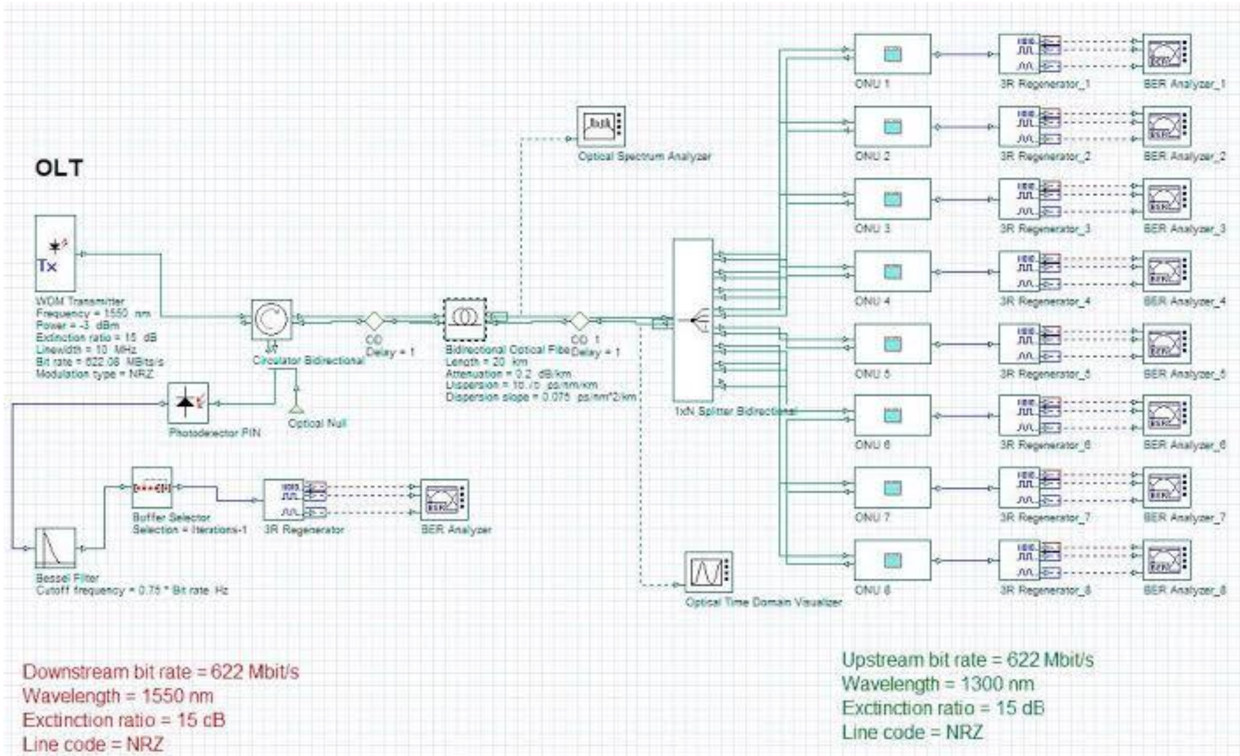


Figure 3.4: BPON Diagram

EPON: Ethernet PON (EPON) uses Ethernet packets rather than the ATM cells used in APON and BPON. EPON is popular for its 1 Gb/s bandwidth for modern networks.

Ethernet equipment vendors formed the Ethernet in the First Mile Alliance EFMA to work on an architecture for FTTH as Ethernet is a dominant protocol in Local Area Networks. EPON based FTTH was adopted by IEEE standard IEEE802.3ah in September 2004. Adopting Ethernet technology in the access network would result in a uniform protocol at the customer end simplifying network management. A single protocol for the Local Area Network, Access Network and Backbone network enables easy rollout of FTTH. EPON standards networking community renamed the term 'last mile’ to 'first mile' to symbolize the importance and significance of the access part of the network. EFM introduced the concept of Ethernet Passive Optical Networks EPONs, in which a point to multipoint P2MP network topology is implemented with passive optical splitters. EPON, is largely a vendor-driven standard and it is fundamentally similar to ATM-PON but transports Ethernet frames/packets instead of ATM cells. It specified minimum standardization and product differentiation, also it has decided not to standardize the Bandwidth allocation algorithm DBA, TDM and ATM support, Security, Authentication, WDM Overlay Plan, support for Analog Video Protection, Diagnostics, Monitoring, Compliance with existing OSS leaving these to the vendors to choose the best

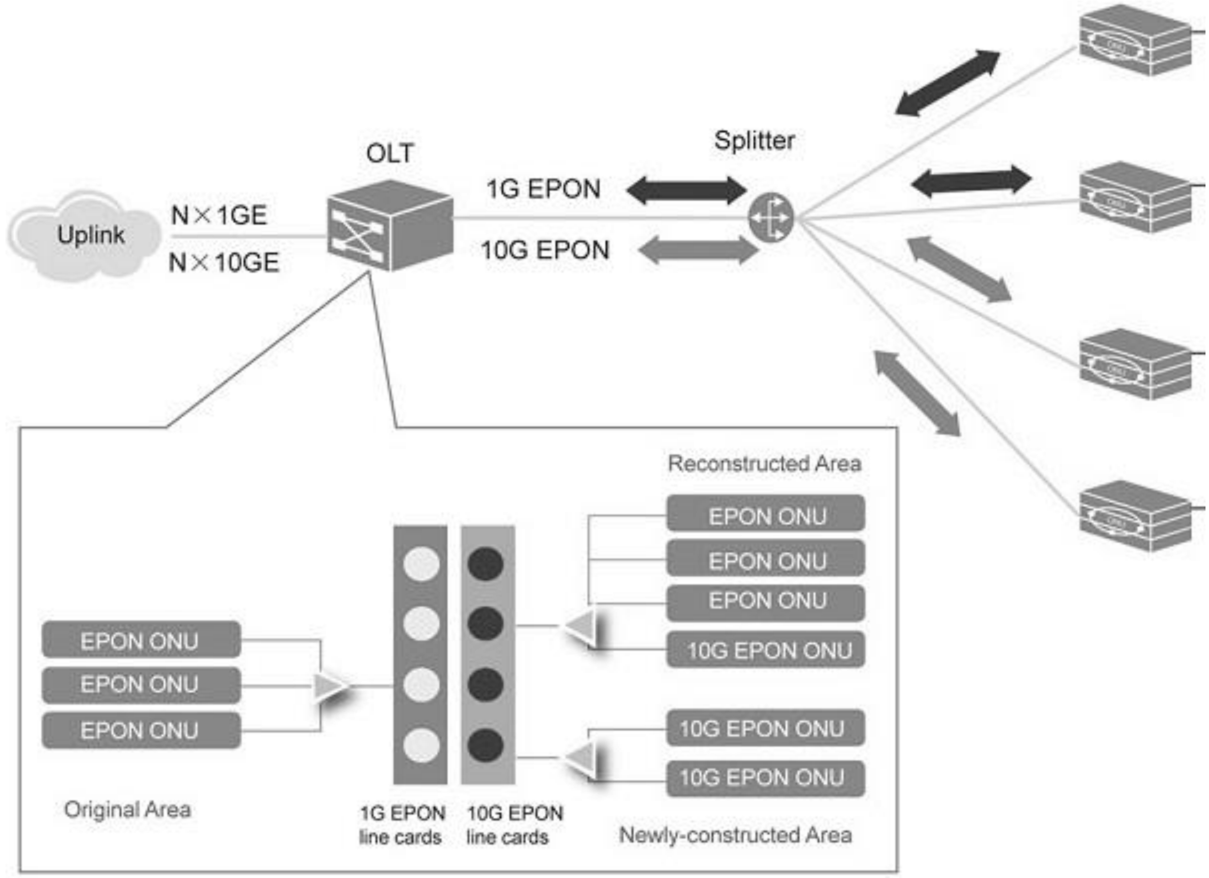


Figure 3.5: EPON Diagram

GPON: Gigabit PON (GPON) provides a very high bandwidth of 2.5 Gb/s. GPON uses IP and ATM or GPON encapsulation method (GEM) for encoding.

The progress in the technology, the need for larger bandwidths and the complexity of ATM forced the FSAN group to look for a better technology. Gigabit Passive Optical Network GPON standardization work was initiated by FSAN in the year 2001 for designing networks over 1Gbps. GPON architecture offers converged data and voice services at up to 2.5 Gbps. GPON enables transport of multiple services in their native formats, specifically TDM and data. In order to enable easy transition from BPON to GPON, many functions of BPON are reused for GPON. In January 2003, the GPON standards were ratified by ITU-T and are known as ITU-T Recommendations G.984.1, G.984.2 and G.984.3. GPON uses the Generic Framing Procedure GFP protocol to provide support for both voice and data oriented services. A big advantage of GPON over other schemes is that interfaces to all the main services are provided and in GFP enabled networks packets belonging to different protocols can be transmitted in their native formats.

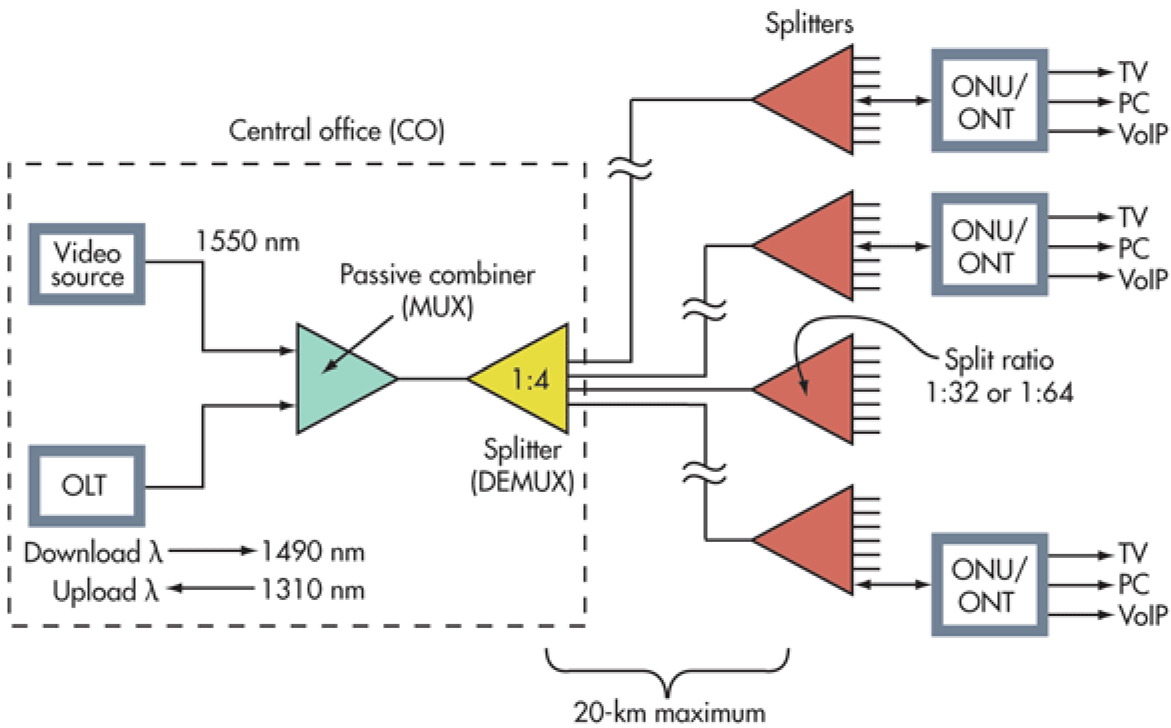


Figure 3.6: GPONDiagram

3.5 What Is OLT?

An OLT (optical line terminal), also known as optical line termination, acts as the endpoint hardware device in a passive optical network. The OLT contains a central processing unit (CPU), passive optical network cards, a gateway router (GWR) and a voice gateway (VGW) uplink cards. It can transmit a data signal to users at 1490 nanometers (nm). That signal can serve up to 128 ONTs at a range of up to 12.5 miles by using optical splitters.

Figure 3.7: OLT

Data/voice transmitter consist of 1.25 Gbps PRBS generator, NRZ driver, CW externally modulated laser at 1490 nm wavelength, and Mach-Zehnder external modulator. Video transmitter consists of PRBS generator and 64-QAM encoder for the digital part, two sine tone generators for the analog part, electrical combiner, CW externally modulated laser at 1550nm wavelength, and Mach-Zehnder external modulator. A 20dB EDFA booster is used at the output.

The Features of OLT

The OLT sends Ethernet data to the ONU, initiates and controls the ranging process, and records the ranging information. It provides numerous prominent features listed as follows.

- A downstream frame processing means for receiving and churning an asynchronous transfer mode cell to generate a downstream frame, and converting a parallel data of the downstream frame into a serial data thereof.
- A wavelength division multiplexing means for performing an electro/optical conversion of the serial data of the downstream frame and performing a wavelength division multiplexing thereof.
- An upstream frame processing means for extracting data from the wavelength division multiplexing means, searching an overhead field, delineating a slot boundary, and processing a physical layer operations administration and maintenance (PLOAM) cell and a divided slot separately.
- A control signal generation means for performing a media access control (MAC) protocol and generating variables and timing signals used for the downstream frame processing means and the upstream frame processing means.
- A control means for controlling the downstream frame processing means and the upstream frame processing means by using the variables and the timing signals from the control signal generation means
-

The Functions of OLT

OLT is generally employed for terminal connected to the fiber backbone. An OLT has two primary functions:

- Converting the standard signals use by a FiOS service provider to the frequency and framing used by the PON system;
- Coordinating the multiplexing between the conversion devices on the optical network terminals (OLTs) located on the customers' premises.

3.6What is ONU/ONT?

Optical Network Unit, the IEEE term for what is called an Optical Network Terminal in ITU-T terminology. The ONU is divided into an active optical network unit and a passive optical network unit. Generally, the devices equipped with optical receivers, uplink optical transmitters, and multiple bridge amplifier network monitoring equipment, are called optical nodes. The PON connects to the OLT, using a single optical fiber and the OLT connects to the ONU. ONU realizes "triple-play" applications by providing services such as data, IPTV (interactive network television) and voice (using IAD and Integrated Access Device).

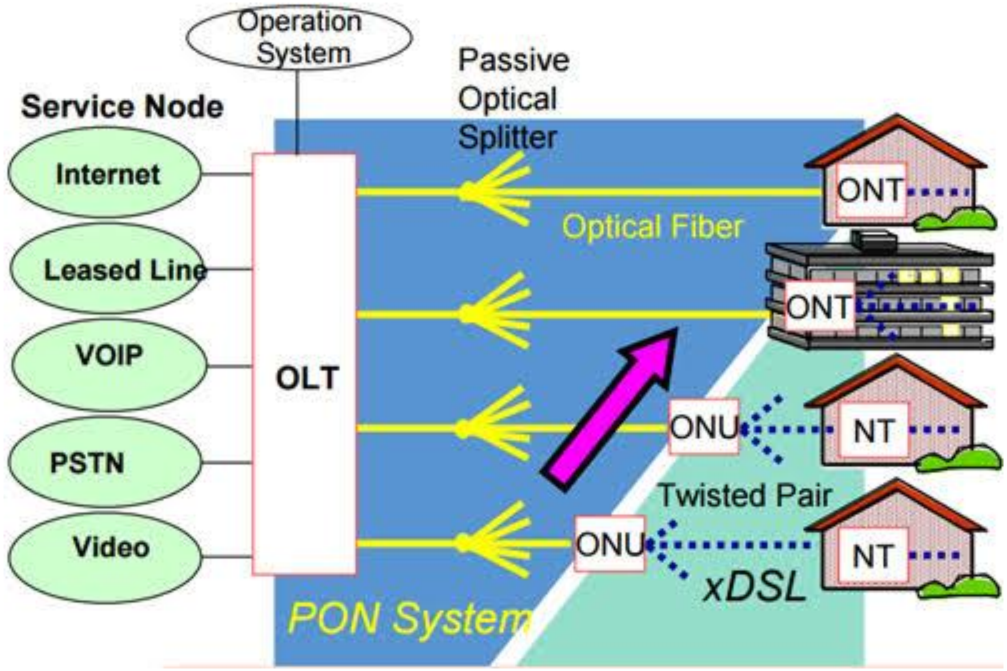


Figure 3.8: How ONU Works

Features of ONU

The Optical Network Unit can: Choose to receive broadcast data sent by the OLT;

- Respond to the ranging and power control commands sent by the OLT; and make corresponding adjustments;
- Cache the user's Ethernet data, send it in the uplink direction through the transmission window allocated by the OLT;
- Fully compliant with IEEE 802.3 / 802.3ah;
- Deliver up to -27.5dBm Receive sensitivity;
- Provide up to -1 to + 4dBm Transmit power;
- Realize "triple-play" applications by providing services such as data, IPTV (that is, interactive network television), voice (using IAD, Integrated Access Device Integrated Access Device);
- Deliver the highest rate PON: symmetrical 10Gb / s data uplink and downlink, VoIP voice and IP video services;
- Provide Plug and Play" based on auto discovery and configuration;
- Offer the Advanced Quality of Service (QoS) functions based on service level agreement (SLA) billing;
- Deliver the Rich remote management capabilities supported by OAM functions;
- Provide High sensitivity light reception and low input optical power consumption;

- Support Dying Gasp function.

Types of ONU

The ONU is divided into an active optical network unit and a passive optical network unit.

Active ONU

The Active optical network unit is mainly used in triple play, which integrates the full range of CATV RF output. It provides high-quality VOIP audio, three routing mode, wireless access and other functions. It’s easy to access to triple play terminal equipment.

Passive ONU

The Passive Optical Network Unit is a user-side device of the GEPON (Gigabit Passive Optical Network) system and is used to terminate the traffic transmitted from the OLT (Optical Line Terminal) through EPON (Passive Optical Network).

In conjunction with the OLT, ONUs provide various broadband services for the connected users, such as Internet surfing, VoIP, HDTV, Video Conference and other business. The ONU, as a user-side device for FTTX applications, is a high-bandwidth, cost-effective terminal device necessary for the transition from "Copper Age" to "Fiber Age." As the ultimate solution for wired access to users, GEPON ONU plays an important role in the overall network construction of NGN (Next Generation Network) in the future.

3.7What is Splitter?

PON is the basic structure for FTTH network, PON is short for Passive Optical Network. It consists of OLT, ODN (Splitter) and ONT. From the structure, splitter placement in ODN is very crucial. There are generally two types of splitter placement in ODN network, centralized splitting and cascading splitting. The centralized splitter uses single-stage splitter located in a central office in a star topology. The cascading splitter approach uses multi-layer splitters in a point to multi point topology.

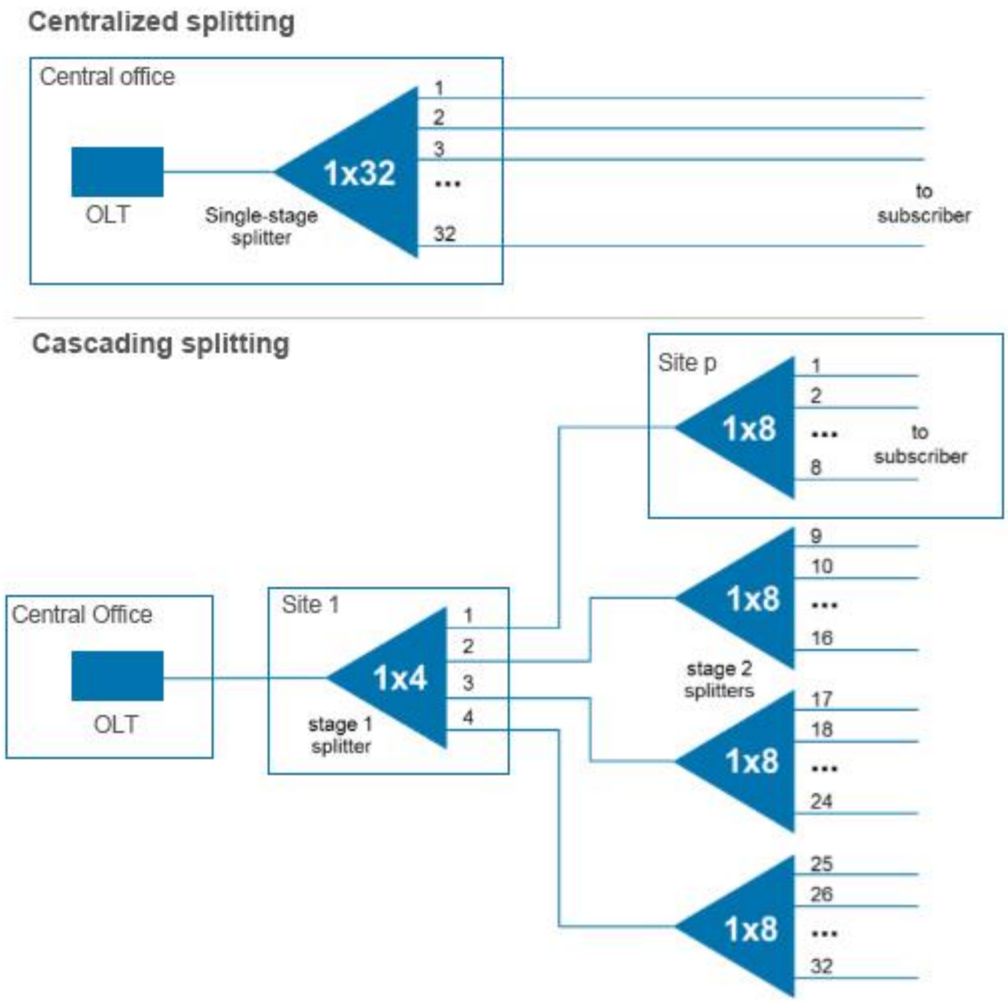


Figure 3.9: Splitting

The centralized splitting structure generally uses a 1×32 splitters in the central office. . The central office CO may be located anywhere in the network. The splitter input port is directly connected via a single fiber to a GPON/GEPON optical line terminal (OLT) in the central office. On the other side of the splitter, 32 fibers are routed through distribution panels, splice ports and/or access point connectors to 32 customers' homes, where it is connected to an optical network terminal (ONT). Thus, the PON network connects one OLT port to 32 ONTs.

A cascading splitting structure approach may use a 1×4/1×8 splitter residing in an outside plant enclosure/terminal box. This is directly connected to an OLT port in the central office. Each of the four fibers leaving this stage 1 splitter is routed to an access terminal that houses a 1×8/1×4, stage 2 splitter. In this scenario, there would be a total of 32 fibers (4×8) reaching 32 homes. It is possible to have more than two splitting stages in a cascaded system, and the overall split ratio may vary (1×16 = 4 x 4, 1×32 = 4 x 8, 1×64 = 4 x 16, 1×64 = 8 x 8).

A centralized architecture typically offers greater flexibility, lower operational costs and easier access for technicians. A cascaded approach may yield a faster return-on-investment with lower first-in and fiber costs. When deciding on the best approach, it’s important to understand these architectures in detail and weigh the trade-offs. The cascading type of splitting is the most commonly used in the FTTH ODN structures.The most common optical splitters deployed in a PON system is a uniform power splitter with a 1:N or 2:N splitting ratio (N=2~64), where N is the number of output ports. The optical input power is distributed uniformly across all output ports. Different ratio splitters may perform differently in your network. Then, how to design your splitting ratio? According to the passage mentioned above, if you choose the centralized splitting solution, you may need to use 1x32 or 1x64 splitter. However, if you choose the cascaded splitting solution, 1x4 and 1x8 splitter may be used more often. Besides, based on our EPON/GPON project experience, when the splitting ratio is 1:32, your current network can receive qualified fiber optic signal in 20 km. If your distance between OLT and ONU is small, like in 5 km, you can also consider about 1:64.

Figure 3:10: Splitter with Patch Panel

When to design your FTTH network splitting level, in fact, centralized splitting and cascaded splitting both has its advantages and disadvantages. We had to weight these factors and select an appropriate splitting level for our network. As for splitting ratio design, to ensure a reliable signal transmission, the longer the transmission distance, the lower splitting ratio should be used. FS.COM provides full series 1xN or 2xN PLC and FBT optical splitters which can divide a single/dual optical input(s) into multiple optical outputs uniformly, and offer superior optical performance, high stability and high reliability to meet various application requirements. For more information, you can visit our site to know more details about our PON splitters.

Test Optical Splitters Loss with Optical Power Meter & Light Source

Optical splitters are usually used in passive optical networks (PONs) to distribute fiber to individual homes or businesses. There is something different between testing an optical splitter and a patch cable although both of them use optical power meter and light source to test. In this tutorial, we are going to talk about optical splitter loss testing with optical power meter and light source.

Figure 3:11: Testing Equipment

Optical splitters, including FBT (Fused Biconical Taper) couplers and PLC (Planar Light wave Circuit) splitters, are common passive optical devices that split the fiber optic light into several parts by a certain ratio. For example, a splitter with 1x2 certain ratio configuration means that it has one input and two outputs. Likewise, there are 1x4 splitter, 1x8 splitter, 1x16 splitter, 1x32 splitter, and so on. When the splitter has two inputs and four outputs, it is called 2x4 splitter. Optical splitters play an important role in FTTH (Fiber to the Home) networks by allowing a single PON network interface to be shared among many customers. The following picture shows an optical splitter used in a PON system.

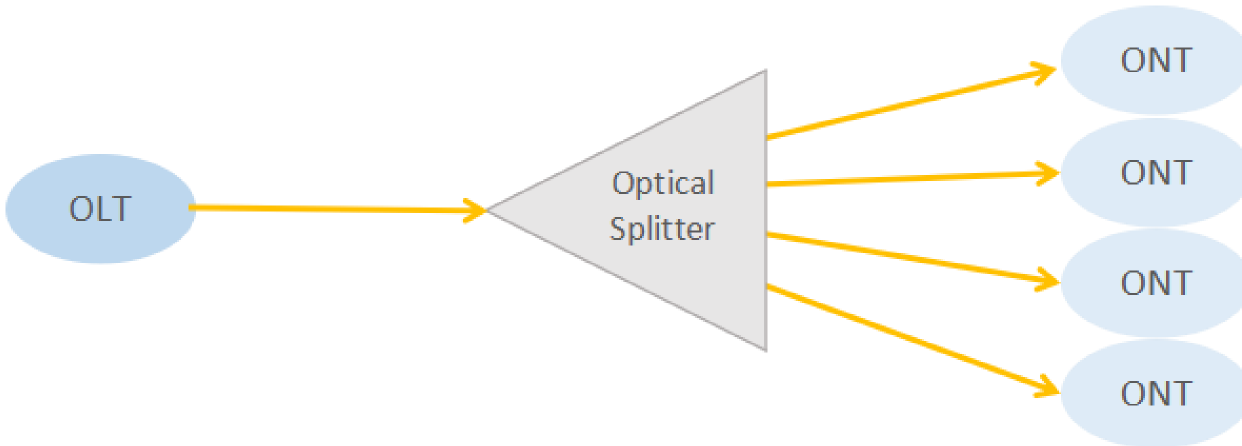


Figure 3.12: Optical splitter used in a PON system

3.8 Loss Specifications of Optical Splitters:

Insertion loss testing of optical splitter is very important to ensure compliance to the optical parameters of the manufactured splitter in accordance to the GR-1209 CORE specification. Here is a table of typical losses for splitters. Signal loss within a system is expressed using the decibel (dB) which is a measure of signal power attenuation.

Splitter Ratio	Ideal Loss / Port (dB)	Excess Loss (dB, max)	Typical Loss (dB)
1:2	3	1	4
1:4	6	1	7
1:8	9	2	11
1:16	12	3	15
1:32	15	4	19

Table3.1: Optical Splitter loss ratio

My observation,

1. Excess loss is the ratio of the optical power launched at the input port of the splitter to the total optical power measured from all output ports. It assures that the total output is never as high as the input.

2. Insertion loss is the ratio of the optical power launched at the given input port of the splitter to the optical power from any single output port. The insertion loss includes the splitting loss and excess loss.

How to Test Optical Splitter Loss with Optical Power Meter & Light Source

Before discussing the details of splitter loss testing, here is a fact that we should know about it. Attenuation of signal through an optical splitter is symmetrical which means it is identical in both directions. Whether an optical splitter is combining signal in the upstream direction or dividing signals in the downstream direction, it still introduces the same attenuation to an optical input signal. Thus, the principle of optical splitter loss testing is to follow the same directions for a double-ended loss test.

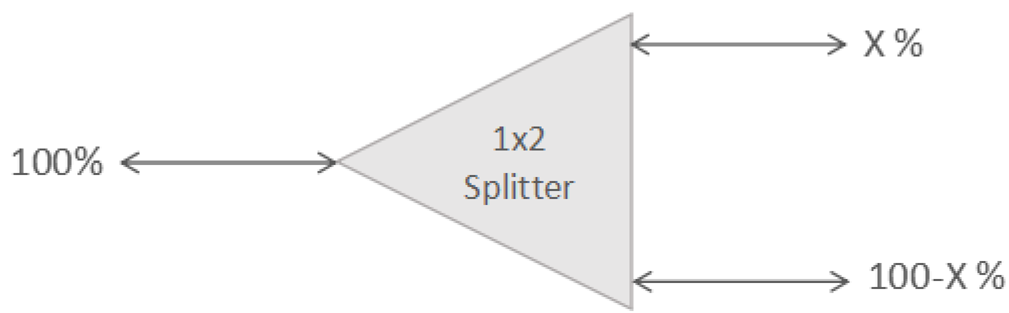


Figure 3.13: 1:2 Splitter/ 50:50 ratio splitter

Now, we test the simplest 1x2 optical splitter as the picture shown below. First, attach a launch reference cable to the optical light source of the proper wavelength (some splitters are wavelength dependent), and then calibrate the output of the launch reference cable with the optical power meter to set the 0dB reference. Attach to the light source launch to the splitter and attach a receive launch reference cable to the output and the optical power meter, and then measure the loss. Similarly, to test the loss to the second port—move the receive launch cable to the other port and read the loss from the meter. For the other direction from all the output ports, we should reverse the direction of the test.

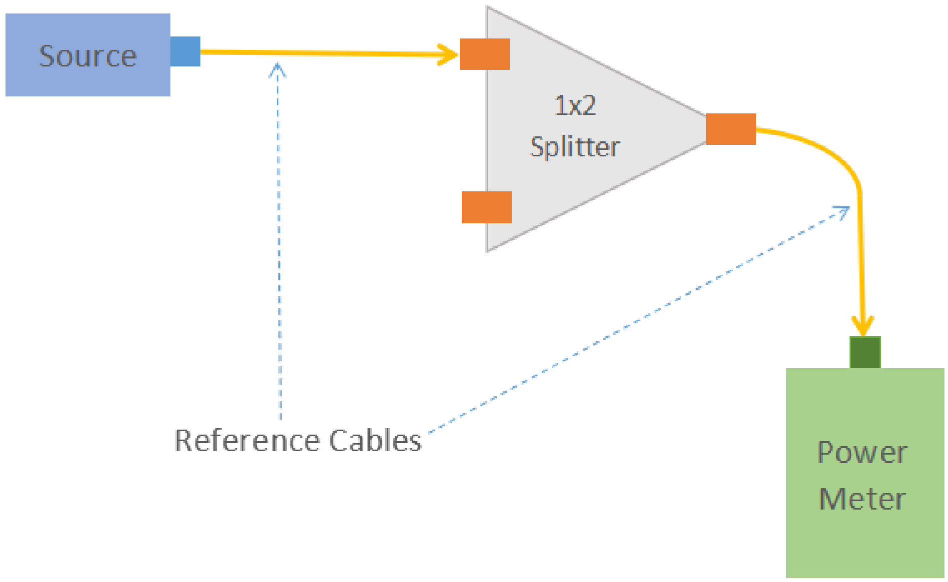


Figure 3:14: How measure the Power with Optical power meter

For other 1xN optical splitters, e.g. 1x32 splitter, this test method can also be used. Just set the light source up on the input and use the power meter and reference cable to test each output port in turn. But for upstream, we have to move the light source 32 times and record the results on the meter.

So, how about the 2X2 splitter? In this case, a lot of data are involved sometimes but it needs to be tested. We would need to test from one input port to the two outputs, then from the other input port to each of the two outputs. In the same way, we can test other 2xN splitters.

Warm Tips: What you are measuring is the loss of the splitter due to the split ratio, excess loss from the manufacturing process used to make the splitter and the input and output connectors. So the loss you measure is the loss you can expect when you plug the splitter into a cable plant. Once installed, the splitter simply becomes one source of loss in the cable plant and is tested as part of that cable plant loss for insertion loss testing.

3.9 Power Budgets and Loss Budgets

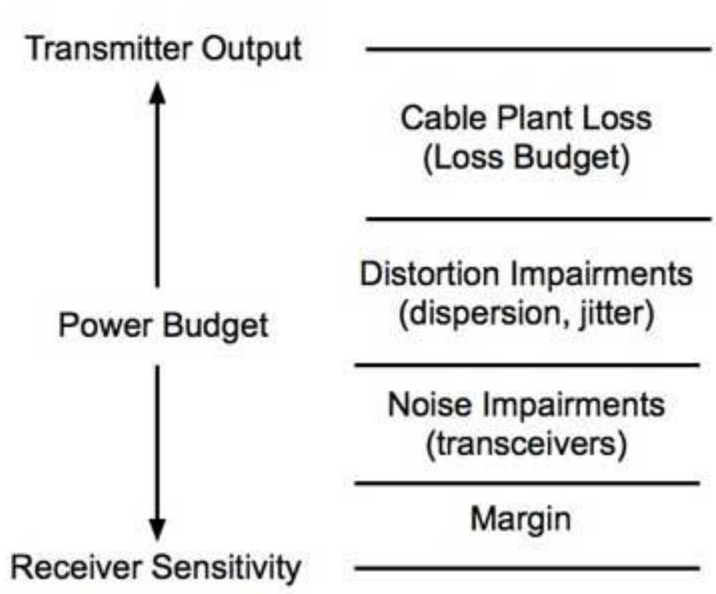
The terms "power budget" and "loss budget" are often confused. The power budget refers to the amount of loss that a datalink (transmitter to receiver) can tolerate in order to operate properly. Sometimes the power budget has both a minimum and maximum value, which means it needs at least a minimum value of loss so that it does not overload the receiver and a maximum value of loss to ensure the receiver has sufficient signal to operate properly.

The loss budget is the amount of loss that a cable plant should have. It is calculated by adding the estimated average losses of all the components used in the cable plant to get the estimated total end-to-end loss. The loss budget has two uses, 1) during the design stage it is used to ensure the cabling being designed will work with the links intended to be used over it and 2) after installation, the loss budget for the cabling is compared to the calculated loss to test results to ensure the cable plant is installed properly. Some standards refer to the loss budget as the "attenuation allowance" but there seems to be very limited use of that term. Obviously, the power budget and loss budget are related. A data link will only operate if the cable plant loss is within the power budget of the link.

Power Budget

All datalinks are limited by the power budget of the link. The power budget is the difference between the output power of the transmitter and the input power requirements of the receiver, both of which are defined as power coupled into and out of optical fiber of a type specified by the link. The power budget is not just a straightforward determinant of the maximum loss in the cable plant that the link can tolerate. As shown below, cable plant loss is only a part of the power budget. Distortion impairments, for example from dispersion (modal and chromatic dispersion in MM fiber, chromatic and polarization mode dispersion in SM fiber), reduce the power budget. Inmultimode gigabit Ethernet networks, for example, transceivers have a dynamic range (transmitter output to receiver sensitivity) of about 5-6 dB before dispersion is factored in, leaving a power budget of about 2 db.

Noise in transceivers, mainly in the receiver, affect the power budget also. The receiver has an operating range determined by the signal-to-noise ratio (S/N) in the receiver. The S/N ratio is generally quoted for analog links while the bit-error-rate (BER) is used for digital links. BER is practically an inverse function of S/N. Transceivers may also be affected by the distortion of the transmitted signal as it goes down the fiber, a big problem with multimode links at high speeds or very long OSP single mode links.



When testing a fiber in a cable plant to determine if the cable plant will allow a specific link to operate over it, the test should be made from transceiver to transceiver, e.g. the cable plant with patch cords installed on either end that would be used to connect the transceivers to the cable plant. When doing a link loss budget (below) for the cabling to be used with a given link to determine if the link will operate over that link, the loss of the patch cords may also be included.

Testing the Power Budget for A Link

How is the power budget determined? You test the link under operating conditions and insert loss while watching the data transmission quality. The test setup is like this:

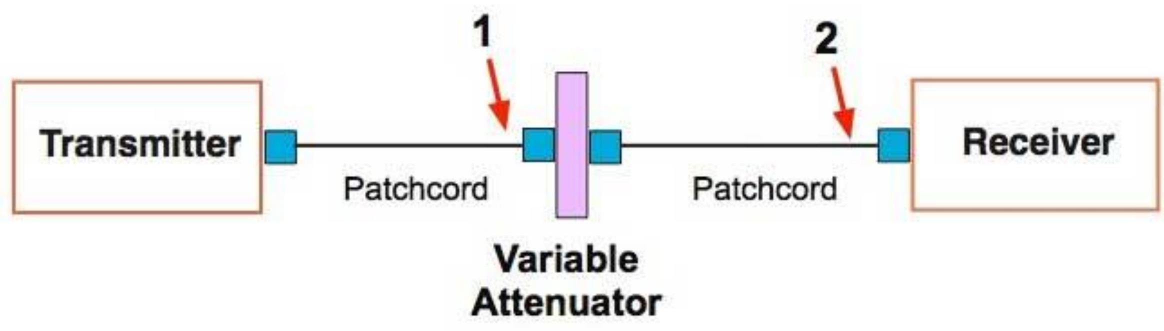


Figure 3:15: patch cord Variable Attenuator

Connect the transmitter and receiver with patch cords to a variable attenuator. Increase attenuation until you see the link has a high bit-error rate (BER for digital links) or poor signal-to-noise ratio (SNR for analog links). By measuring the output of the transmitter patch cord (point#1) and the output of the receiver patch cord (point #2), you can determine the maximum loss of the link and the maximum power the receiver can tolerate.

Receiver must have enough power to have a low BER (or high SNR, the inverse of BER) but not so much it overloads and signal distortion affects transmission. We show it as a function of receiver power here but knowing transmitter output, this curve can be translated to loss - you need low enough loss in the cable plant to have good transmission but with low loss the receiver may overload, so you add an attenuator at the receiver to get the loss up to an acceptable level.

You must realize that not all transmitters have the same power output nor do receivers have the same sensitivity, so you test several (often many) to get an idea of the variability of the devices. Depending on the point of view of the manufacturer, you generally error on the conservative side so that your likelihood of providing a customer with a pair of devices that do not work is low. It's easier that way.

Furthermore, if your link uses multimode fiber at high bit rates (or single mode on long links at very high bit rates), there will be dispersion. Dispersion spreads out the pulses, causing a power penalty. That's why high speed Ethernet at 10G has a loss budget of 2dB while the power budget calculated from transmitter and receiver specifications is about 6dB.

Calculating Cable Plant Link Loss Budget

Loss budget analysis is the calculation of a fiber optic cabling system's estimated loss performance characteristics. This is sometimes confused with the communication system "power budget" which is a specification of the dynamic range of the electronics, the difference between the output power of the transmitter coupled into the fiber and the minimum received power required at the receiver for proper data transmission. The communications system power budget will set a limit for the loss of the cable plant.

The cable plant loss budget needs to consider transceiver wavelength, fiber type, and link length plus the losses incurred in splices, connections and other passive devices like FTTH or OLAN PON splitters. Attenuation and bandwidth/dispersion are the key parameters for the cable plant loss budget analysis.

Analyze Link Loss in the Design Stage

Prior to designing or installing a fiber optic cabling system, a loss budget analysis is recommended to make certain the system will work over the proposed link. That same loss budget will be used as to compare test results after installation of the cabling to ensure that the components were installed correctly. Both the passive and active components of the circuit have to be included in the loss budget calculation. Passive loss is made up of fiber loss, connector loss, and splice loss. Don't forget any couplers or splitters in the link. Active components are system gain, wavelength, transmitter power, receiver sensitivity, and dynamic range. Prior to system turn up, test the circuit with a source and FO power meter to ensure that it is within the loss budget.

The idea of a loss budget is to insure the network equipment will work over the installed fiber optic link. It is normal to be conservative over the specifications! Don't use the best possible specs for fiber attenuation or connector loss - give yourself some margin!

The best way to illustrate calculating a loss budget is to show how it's done for a typical 0.2 km multimode link. The link may be analyzed and tested in two ways, with or without the patch cords that connect the equipment. With the patch cords, the cable plant has 5 connections (2 connectors at each end for the transmitter and receiver), 3 connections at patch panels in the link) and one splice in the middle. Without the patch cords, the cable plant has 3 connections (2 connectors at each end for the transmitter and receiver), 1 connection at a patch panel in the link) and one splice in the middle.

See the drawings below of the link layout and the instantaneous power in the link at any point along it's length, scaled exactly to the link drawing above it.

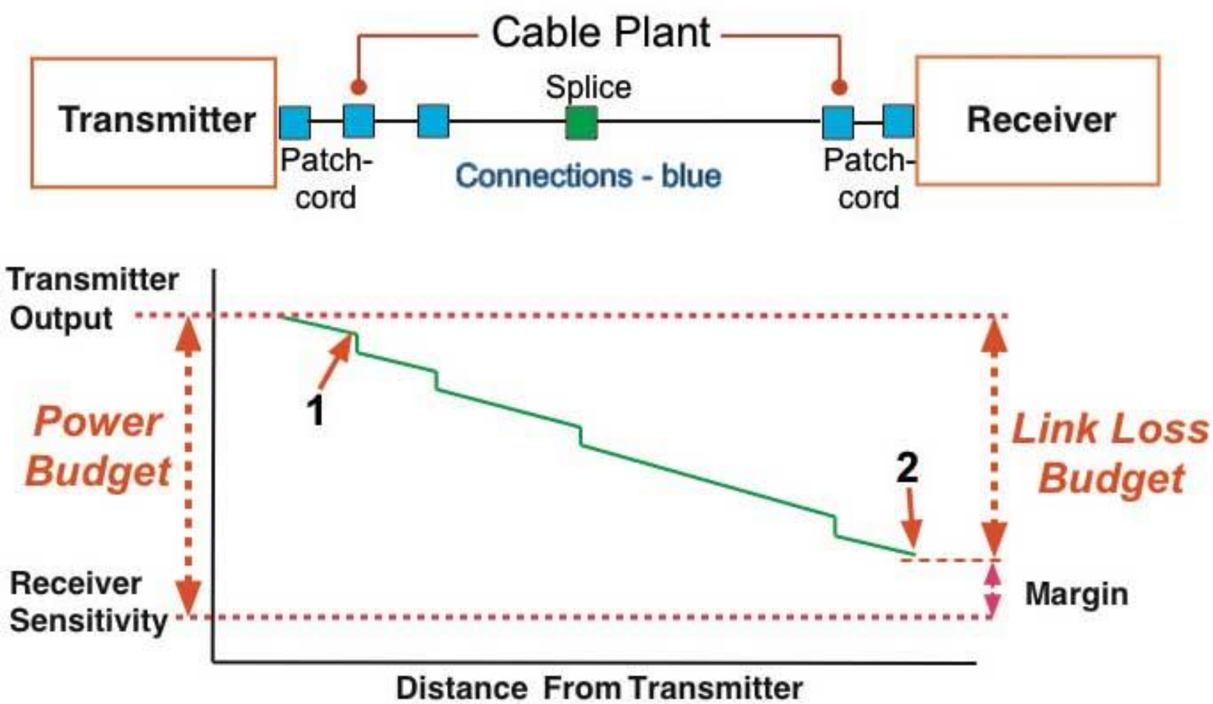


Figure 3:16: Power Sensitivity

At the top is a fiber optic link with a transmitter connected to. a cable plant with a patch cord. The cable plant has 1 intermediate connection and 1 splice plus, of course, "connectors" on each end which become "connections" when the transmitter and receiver patch cords are connected. At the receiver end, a patch cord connects the cable plant to the receiver.

My observation, a connector is the hardware attached to the end of a fiber which allows it ti be connected to another fiber or a transmitter or receiver. When two connectors are mated to join two fibers, usually requiring a mating adapter, it is called a connection.

Below the drawing of the fiber optic link is a graph of the power in the link over the length of the link. The vertical scale (Y) is optical power at the distance from the transmitter shown in the horizontal (X) scale. As optical signal from the transmitter travels down the fiber, the fiber attenuation and losses in connections and splice reduces the power as shown in the green graph of the power.

That graph looks like an OTDR trace. The OTDR sends a test pulse down the fiber and backscatter allows the OTDR to convert that into a snapshot of what happens to a pulse going down the fiber. The power in the test pulse is diminished by the attenuation of the fiber and the loss in connectors and splices. In our drawing, we don't see reflectance peaks but that additional loss is included in the loss of the connector.

On the left side of the graph, we show the power coupled from the transmitter into its patch cord, measured at point #1 (the end of the transmitter patch cord) and the attenuated signal at the end of the patch cord connected to the receiver shown at point #2. We also show the receiver sensitivity, the minimum power required for the transmitter and receiver to send error-free data.

The difference between the transmitter output and the receiver sensitivity is the power budget. Expressed in dB, the power budget is the amount of loss the link can tolerate and still work properly - to send error-free data. The difference between the transmitter output (point #1) and the receiver power at its input (point #2) is the actual loss of the cable plant experienced by the fiber optic data link.

The difference between the power coupled into the cable plant and the power at the receiver is the loss of the cable plant. That's what we estimate when we calculate a loss budget.

It's also what is called "insertion loss" tested with a test source and power meter.

Note: This concept gets many questions - but two are most common. Why do you include the loss of the connectors on the ends if they are connected to a transmitter and receiver? And what about testing a permanently installed cable plant from patch-panel (or wall outlet) to another patch panel, not including the final patch cords used to connect equipment.

Why do you include the connectors on each end? Depending on the design of the transceivers (and especially if they have pigtailed lasers or detectors), practically every factor in connector loss affects coupling to a transmitter or receiver as well. Whether these connections are included in the loss budget should depend on whether the margin for the link to be use on the cable plant was specified to include these connectors. As far as we know almost all system specifications are considering connection losses at both ends. Unless you know the system was not specified for loss including the end connectors, include them in calculations of the loss budget.

Testing is another issue. When the cable plant is tested, the reference cables will mate with those end connectors and their loss will be included in the measurements but the results depends on the method used to set the "0dB" reference.

If the "0dB" reference for the insertion loss test was done with only one reference test cable attached between the light source and power meter which is the most common way, the connectors on the end of the cable will be included in the loss so the loss budget should include both connectors. Most tests are specified and done with the one cable reference when the test equipment is compatible with the connectors.

If the "0dB" reference for the insertion loss test was done with three cables, the launch reference cable, a receive reference cable and a third reference cable between them, a method used for many plug and jack (male/female) connectors such as MPOs, the loss budget should not include the connectors on the end. When making the "0dB" reference with three cables, two connections are included in setting the reference so the measured value will be reduced by the value of those two connections. If the loss budget is calculated without the connectors on the ends, the value will more closely approximate the test results with a 3-cable reference. The three cable reference is generally done with plug/jack or male/female connectors like the MPO or when doing a "channel" test specified in some standards that includes the permanently installed cable plant with patch cords attached but excludes the connectors on each end that attach to transceivers.

While the two-cable reference method is rarely used, it includes only one connector. Thus you could use the same approach when calculating loss budgets for this test method.Whatever test method is presumed, it must be documented when the loss budget is calculated.Cable Plant Passive Component Loss - Calculating a Loss Budget For this analysis, we'll use our 0.2 km cable plant without the patch cords so it has 3 connections and one splice

Step 1. Fiber loss at the operating wavelength over 200m (0.2 km)

Cable Length (km)0.2 0.2

Fiber Type	Multimode		Single mode	
Wavelength (nm)	850	1300	1310	1550
Fiber Attend. DB/km	3 [3.5]	1 [1.5]	0.4 [1/0.5]	0.3 [1/0.5]
Total Fiber Loss	060 [0.7]	0.2 [0.3]		

(All specs in brackets are maximum values per EIA/TIA 568 standard. For single mode fiber, a higher loss is allowed for premises applications.)

Step 2. Connector Loss

Multimode connectors will have losses of 0.2-0.5 dB typically (see note about "connector" vs. "connection" loss). Single mode connectors, which are factory made and fusion spliced on will have losses of 0.1-0.2 db. Field terminated single mode connectors may have losses as high as 0.5-1.0 db. Let's calculate it at both typical and worst case values.

Remember that we include all the components in the complete link, including the connectors on each end.

Connector Loss	0.3 dB (typical adhesive/polish conn)	0.75 dB (TIA-568 max acceptable)
Total # of Connectors	3	3
Total Connector Loss	0.9 dB	2.25 dB

Note: When we say connector loss, we really mean "connection" loss - the loss of a mated pair of connectors, expressed in "db." Thus, testing connectors requires mating them to reference connectors which must be high quality connectors themselves to not adversely affect the measured loss when mated to an unknown connector. This is an important point often not fully explained. In order to measure the loss of the connectors you must mate them to a similar, known good, connector. When a connector being tested is mated to several different connectors, it may have different losses, because those losses are dependent on the reference connector it is mated to.

(All connectors are allowed 0.75 max per EIA/TIA 568 standard)

Remember that we include all the components in the complete link, including the connectors on each end. In our example above, the link includes patch cords on each end to connect to the electronics. We need to assess the quality of these connectors, so we include them in the link loss budget and if we test the link end to end, including the patch cords, these connectors will be included in the test results when connected to launch and receive reference cables. On some links, only the permanently installed link, not including the patch cords, will be tested. Again, we still need to include the connectors on the end as they will be included when we test insertion loss with reference test cables on each end.

Step 3. Splice Loss

Multimode splices are usually made with mechanical splices, although some fusion splicing is used. The larger core and multiple layers make fusion splicing about the same loss as mechanical splicing, but fusion is more reliable in adverse environments. Figure 0.1-0.5 dB for multimode splices, 0.3 being a good average for an experienced installer. Fusion splicing of single mode fiber will typically have less than 0.05 dB (that's right, less than a tenth of a dB!)

Typical Splice Loss 0.3 dB

Total # splices 1

Total Splice Loss0.3 dB

(All splices are allowed 0.3 max per EIA/TIA 568 standard)

Step 4. Total Passive System Attenuation

Add the fiber loss, connector and splice losses to get the link loss.

Typical TIA 568 Max

850 nm 1300 nm 850 nm1300 nm

Total Fiber Loss (dB) 0.6 0.2 0.7 0.3

Total Connector Loss (dB) 0.9 0.9 2.25 2.25

Total Splice Loss (dB)0.3 0.3 0.3 0.3

Other (dB) 0 0 0 0

Total Link Loss (dB) 1.81.43.25 2.85

My observation, the big difference between the typical values and the TIA worst case values. Which should be used for evaluating the cable plant? If you use typical field installed connectors of the adhesive/polish type or SOCs - fusion splice on connectors, the lower/typical values are probably a good choice. If you use MPO or republished splice connectors with mechanical splices, the TIA values may be closer.

In either case it is important to realize that these are estimates, just estimates, and some judgment is required. Remember these should be the criteria for testing. Allow +/- 0.2 - 0.5 dB for measurement uncertainty and that becomes your pass/fail criterion.Equipment Link Power Budget Calculation: Link loss budget for network hardware depends on the dynamic range of the electronics, the difference between the sensitivity of the receiver and the output of the transmitter into the fiber. You need some margin for system degradation over time or environment, so subtract that margin (as much as 3dB) to get the loss budget for the link.

Step 5. Data from Manufacturer's Specification for Active Components (Typical 100 Mb/s link)

Operating Wavelength (nm) 850

Fiber Type MM

Receiver Sens. (dBm@ required BER)-21

Average Transmitter Output (dBm) -13

Dynamic Range (dB) 8

Recommended Excess Margin (dB) 3

Step 6. Power Margin Calculation

Dynamic Range (dB) (above) 8 8

Cable Plant Link Loss (dB) 1.8 (Typ) 3.25 (TIA)

Link Loss Margin (dB) 6.2 4.75

My observation, that a link like this may have dispersion penalties, common for MM links at 1G or above. As a general rule, the Link Loss Margin should be greater than approximately 3 dB to allow for link degradation over time. Sources in the transmitter may age and lose power, connectors or splices may degrade or connectors with multiple mating’s or may get dirty if opened for rerouting or testing. If cables are accidentally cut, excess margin will be needed to accommodate splices for restoration. The 3dB rule, of course, is irrelevant if the power budget is ~2dB like some of the 10G multimode links. Then the need for the best quality installation is critical!

Chapter 4

4. Application of FTTH Service:

4.1 Urban Security Monitoring Application:

While planning a network to address Urban Security Monitoring, "digital monitoring" is a key factor and must be taken into account. Numerous digital video recorders will be dispersed throughout the urban area requiring long transmission distances and high bandwidth.

If an EPON / GPON system is used to implement the digital monitoring service, the above requirements can easily be satisfied

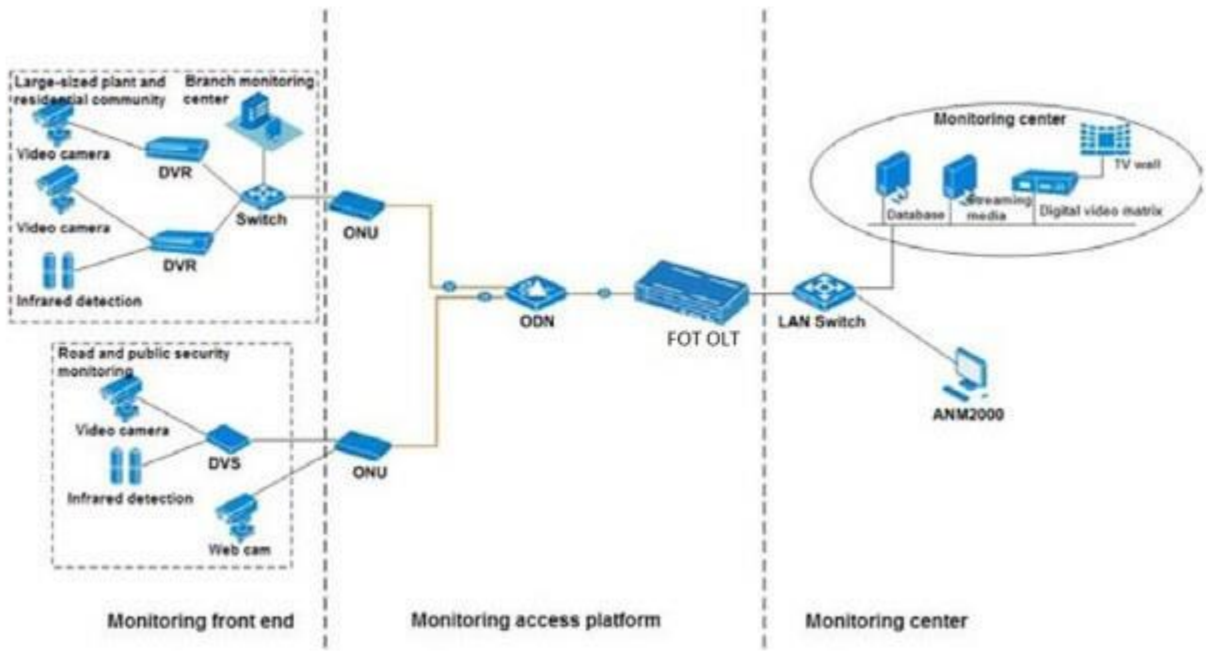


Figure 4.1: Urban Security Monitoring Application

- Monitoring front end
- Monitoring access platform
- Monitoring center

4.2 PON equipment's maintainability and manageability

The GEPON/GPON solution provides four network management functions: configuration management, security management, performance management and fault management.

Together these functions fully guarantee network QoS and facilitate users' routine maintenance and fault diagnosis.

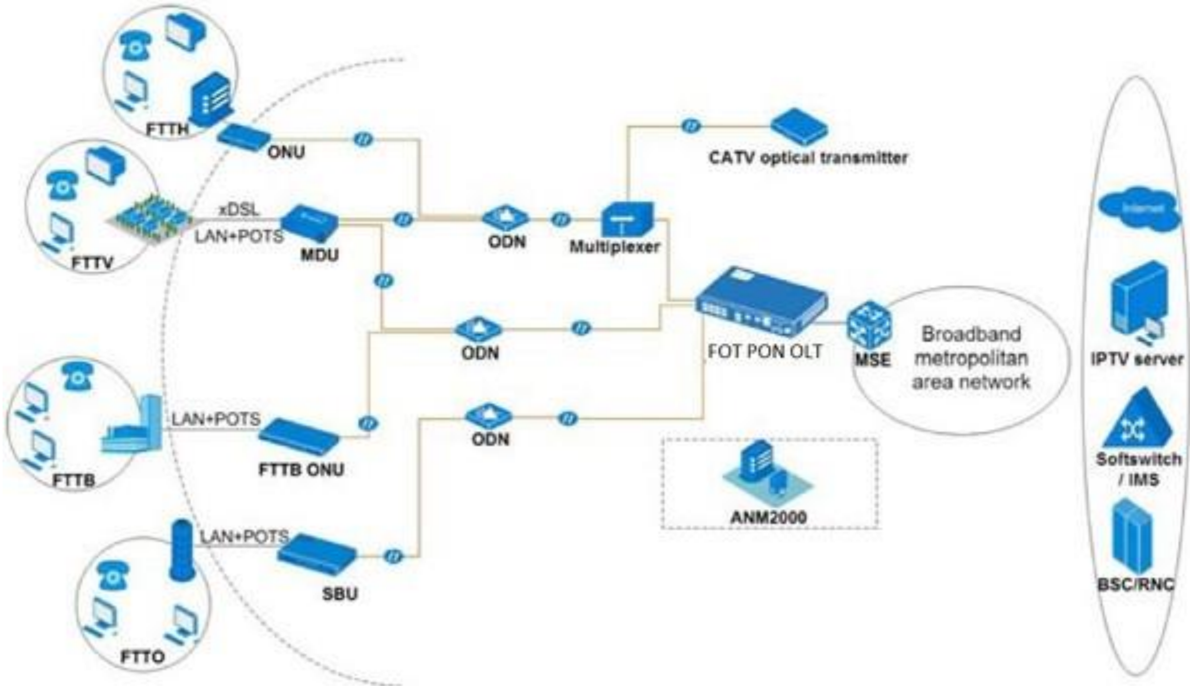


Figure 4.2: PON equipment's maintainability and manageability

- Maintenance measures
- Terminal management
- Fault Management
- Performance Management
- Security management
- Environment supervision

4.3 QinQ VLAN application in FTTH PON network

The OLT series support QinQ VLAN application to overcome restriction on VLAN number resource in network, and allow separation and unique identification of subscribers as well as classification of service types.

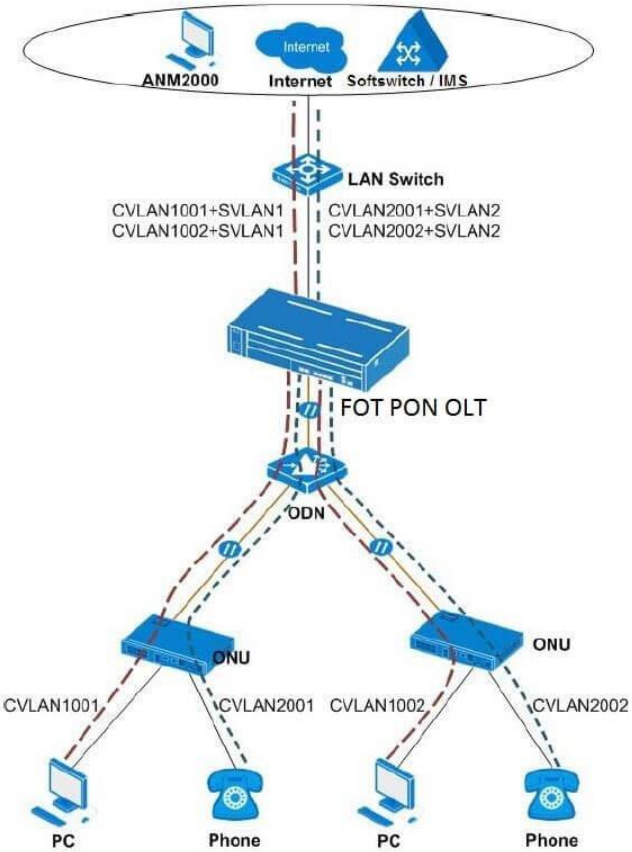


Figure 4.3: QinQ VLAN application in FTTH PON network

Data messages transferred in an IP backbone network have two layers of VLAN tags. On the internal layer is Customer-VLAN tag, and on the external layer is Service-VLAN tag.

4.4WiFi service in FTTH PON application

The OLT supports Wi-Fi service application. It allows access of wireless terminals and wired terminals via home gateway device, so as to meet various demands of subscribers.

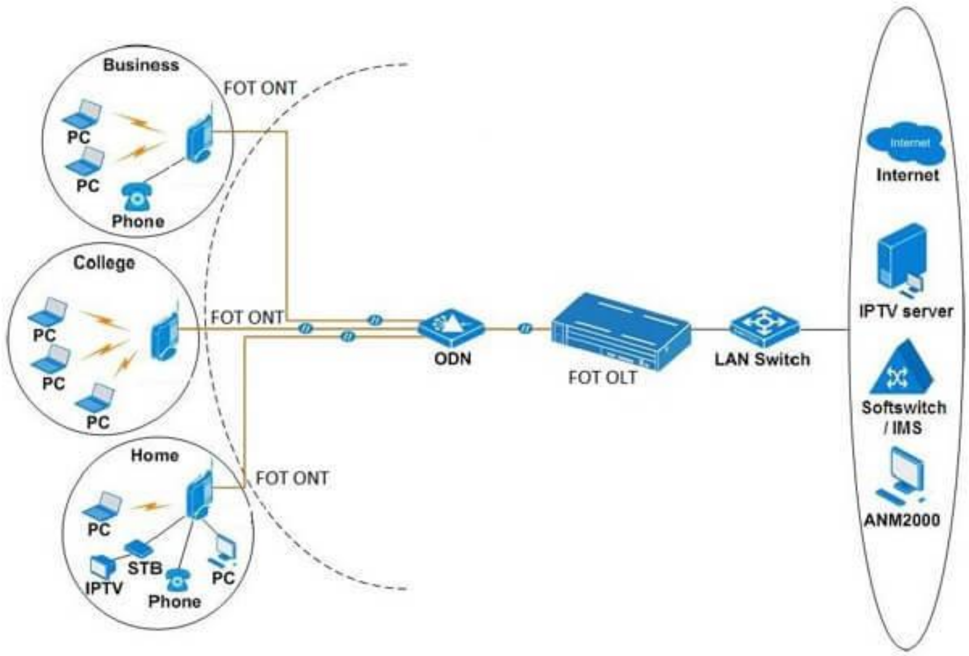


Figure 4.4: Wi-Fi service in FTTH PON application

The OLT supports two types of home gateway: GPON uplink interface or EPON uplink interface. The home gateway covers homes, schools and public areas via wireless network, to allow wireless access of terminal devices such as laptops and mobile phones. The home gateway supports simultaneous access of data, voice and multicast services to allow Triple Play. See following figure for an illustration of the OLT's Wi-Fi service application network.

4.5VoIP Service Application

The OLT supports VoIP functions, providing voice services with carrier class quality, and allowing IP-based voice service access.

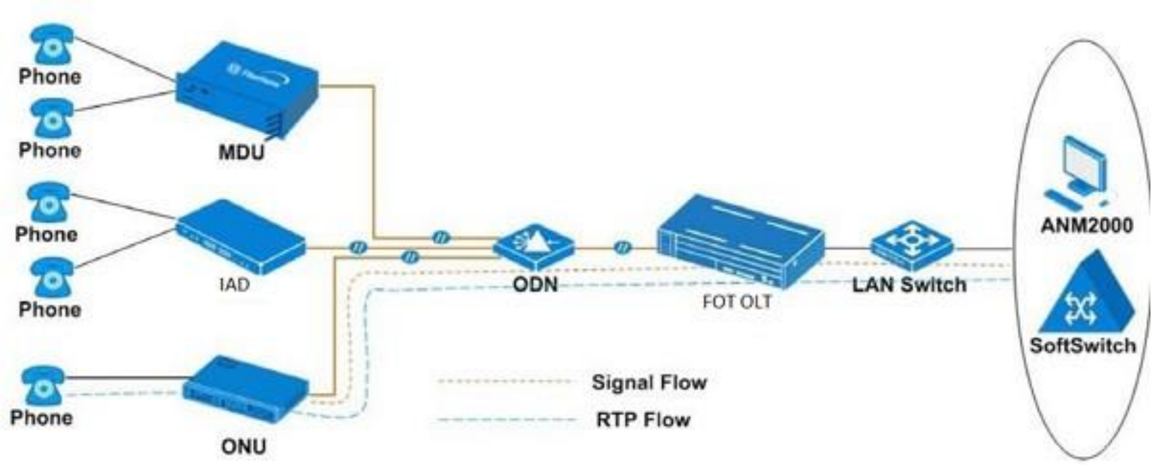


Figure 4.5: VoIP Service Application

The OLT product series support MGCP, H.248 and SIP, and its soft switch interface can be connected to MGC gateways produced by various mainstream manufacturers. See following figure for an illustration of the FOT OLT's VoIP service application network.

4.6IPTV Service Application

The FOT OLT transmits multicast service in SCB+IGMP mode, and performs multicast service control and management via multicast control messages. The IPTV service application for the FOT PON OLT is illustrated in following figure.

- Multicast service working modes
- IGMP Proxy mode
- IGMP Snooping mode
- Controllable mode

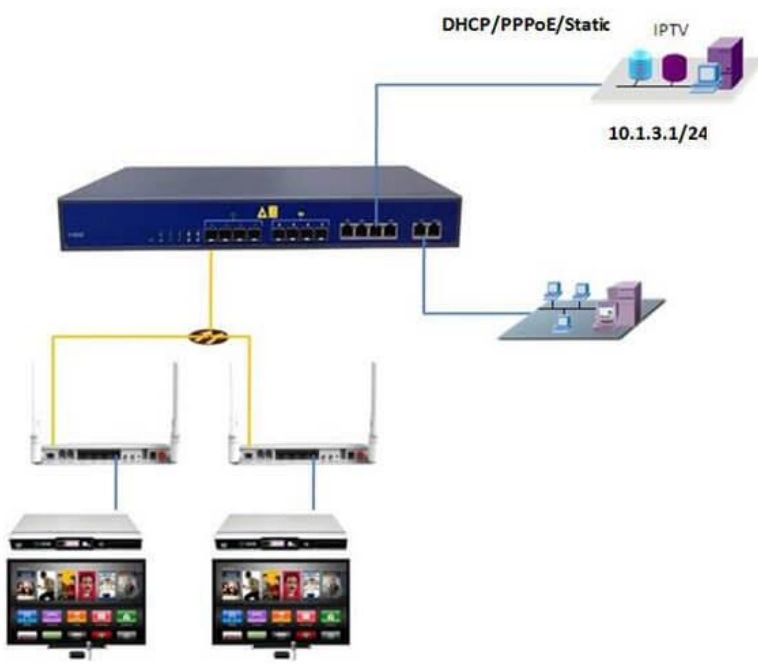


Figure 4.6:IPTV service Application

Chapter 5

5. Comparative analysis between EPON vs GPON

5.1 EPON vs GPON

There are some distinct differences between EPON and GPON at Layer 2. However, these aren't the only differences between the technologies. Designers will also find differences in terms of bandwidth, reach, efficiency, per-subscriber costs, and management. Let's look at each of these elements in more detail

Table 5.1: EPON VS GPON[3]

	GPON(ITU-T G.984)	EPON(IEEE 802.3ah)
Downlink/Uplink	2.5G/1.25G	1.25G/1.25G
Optical Link Budget	Class B+:28dB;Class C: 30dB	PX20: 24dB
Split ratio	1:64 --> 1:128	1:32
Actual downlink bandwidth	2200~2300Mbps 92%	980Mbps 72%
Actual Uplink bandwidth	1110Mbps	950Mbps
OAM	Complete OMCI function + PLOAM + embed OAM	Flexible and simple OAM function
TDM service & synchronized clock function	Native TDM, CESoP	CESoP
Upgradeability	10G	2.5G/10G
QoS	DBA schedule contains T-CONT,PORTID; fix bandwidth/guarantee bandwidth/non-guarantee bandwidth/ best-effort bandwidth	Support DBA, QoS is supported by LLID and VLAN

Cost	10%~20% higher cost than EPON currently, and almost same price in large volume	--

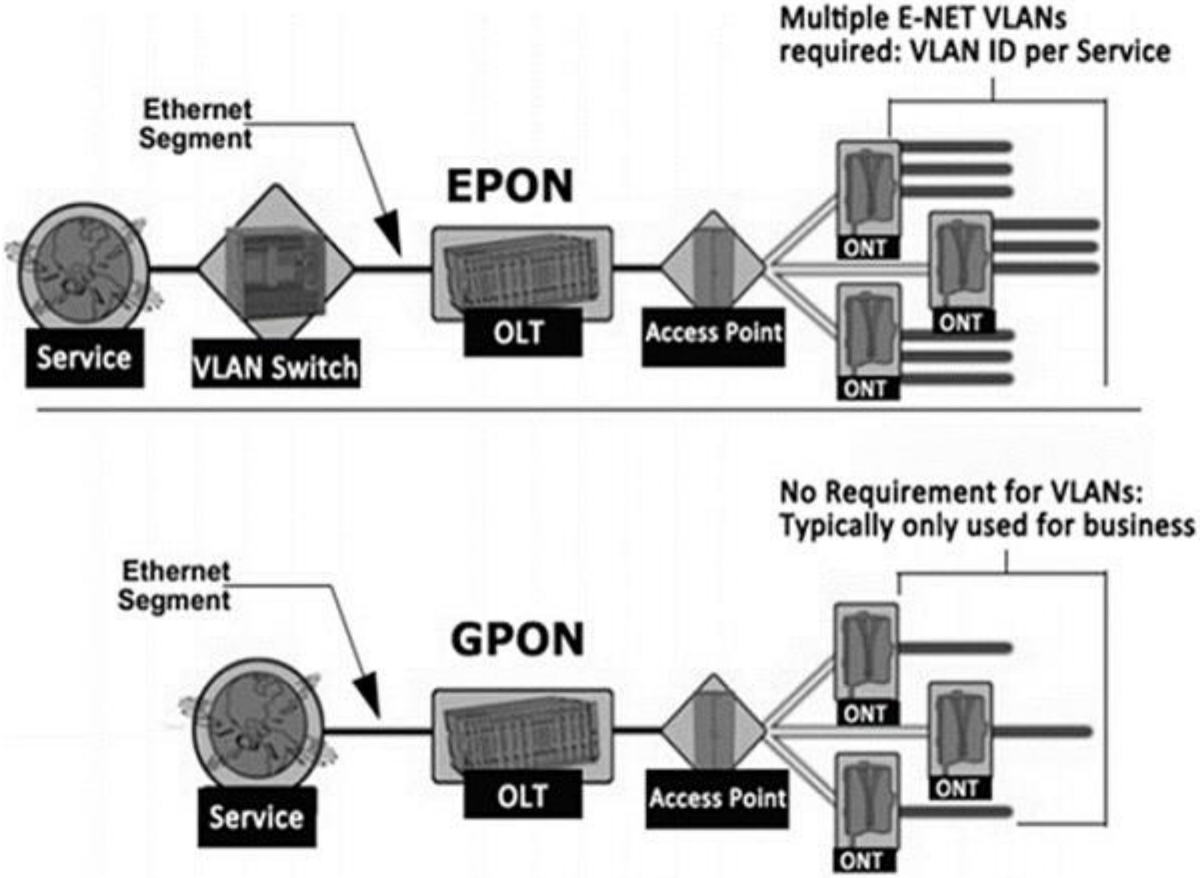


Figure 5.1: EPON VS GPON

1. Usable Bandwidth

Bandwidth guarantees vary between the two protocols: GPON promises 1.25-Gbit/s or 2.5-Gbit/s downstream, and upstream bandwidths scalable from 155 Mbit/s to 2.5 Gbit/s. EPON delivers 1-Gbit/s symmetrical bandwidth. EPON's Gigabit Ethernet service actually constitutes 1 Gbit/s of bandwidth for data and 250 Mbit/s of bandwidth for encoding. The approach of EPON, as part of the Gigabit Ethernet standard, parallels that of Fast Ethernet, which also uses 25 percent for encoding.

GPON's 1.25-Gbit service specifies a usable bandwidth of 1.25 Gbit/s, with no requirement for encoding. Will the additional 250 Mbit/s promised by GPON promoters stand as a clear advantage for GPON? The answer may lie not in the sheer bandwidth comparisons, but in the practicality of 1.25-Gbit uplinks.

Gigabit Ethernet interfaces to the aggregation switch, central office, and metro are currently the cost-effective way to aggregate 1-Gbit ports for transport. With no cost-effective switches for 1.25 Gbit available, the added bandwidth promised by GPON, although measurable, could come at a significant premium over the price of EPON equipment. In other words, the low-cost uplink for the foreseeable future is likely to be Gigabit Ethernet, which is the exact bit rate of EPON. In that light, GPON's "added" bandwidth may not prove advantageous for carriers.

2. Host Capacity:

With either protocol, the practical limitation to reach comes from the optical-link budget. With the reach of both protocols currently specified at approximately 20 kilometers, the difference in split rates — the number of optical network units (ONUs) supported by one optical line terminal (OLT) — is a point of differentiation.

GPON promises to support up to 128 ONUs. With the EPON standard, there is no limit on the number of ONUs. Depending on the laser diode amplitude, when using low-cost optics, EPON can typically deliver 32 ONUs per OLT, or 64 with forward error correction (FEC).

3. Per-subscriber Costs

The use of EPON allows carriers to eliminate complex and expensive ATM and Sonnet elements and to simplify their networks, thereby lowering costs to subscribers. Currently, EPON equipment costs are approximately 10 percent of the costs of GPON equipment, and EPON equipment is rapidly becoming cost-competitive with VDSL.

4. Efficiencies of Each Standard

With both PON protocols, a fixed overhead is added to convey user data in the form of a packet. In EPONs, data transmission occurs in variable-length packets of up to 1518 bytes according to the IEEE 802.3 protocol for Ethernet. In ATM-based PONs, including GPONs, data transmission occurs in fixed-length 53-byte cells (with 48-byte payload and 5-byte overhead) as specified by the ATM protocol. This format makes it inefficient for GPONs to carry traffic formatted according to IP, which calls for data to be segmented into variable-length packets of up to 65,535 bytes.

For GPONs to carry IP traffic, the packets must be broken into the requisite 48-byte segments with a 5-byte header for each. This process is time-consuming and complicated and adds cost to the central-office OLTs as well as the customer premise-based ONUs. Moreover, 5 bytes of bandwidth are wasted for every 48-byte segment, creating an onerous overhead that is commonly referred to as the "ATM cell tax". (This is the case with GPON's ATM encapsulation mode. In its other encapsulation mode, called GEM, the ATM cell tax does not apply.)

By contrast, using variable-length packets, Ethernet was made for carrying IP traffic and can significantly reduce the overhead relative to ATM. One study shows that when considering trim ode packet size distribution, Ethernet packet encapsulation overhead was 7.42 percent, while ATM packet encapsulation overhead was 13.22 percent.1

In addition, since Ethernet frames contain a vastly higher ratio of data to overhead than GPON, that high utilization can be reached while using low-cost optics. The more precise timing required with GPON results in more expensive optics. High-precision optics are mandatory as part of the GPON standard.

5. Management Systems

EPON requires a single management system, versus three management systems for the three Layer 2 protocols in GPON, which means EPON results in a significantly lower total cost of ownership. EPON also does not require multiprotocol conversions, and the result is a lower cost of silicon.

GPON does not support multicast services, which makes support for IP video more bandwidth-consuming.

6. Support for CATV Overlay

Both protocols support a cable television (CATV) overlay, which meets requirements for a high-speed downstream video service. EPON wavelengths are 1490 nanometers downstream and 1310 nanometers upstream, leaving the 1550-nanometer wavelength for a CATV overlay — similar to the wavelengths for BPON and GPON.

7. Encryption

With GPON, encryption is part of the ITU standard. However, GPON encryption is downstream only.

EPON, on the other hand, uses an AES-based mechanism, which is supported by multiple silicon vendors and deployed in the field. Furthermore, EPON encryption is both downstream and upstream.

8. Network Protection

Both protocols provide vendor-specific and carrier-specific protection. This includes support for vendor-specific and carrier-specific operations, administration and maintenance (OAM).

9. Wrap Up

While pundits are lining up in opposite corners of the ring, it's still unclear whether EPON or GPON will prevail — or if each will take its own share in a burgeoning market. One thing is clear: fiber deployments will continue expanding, and at the expense of copper, as consumer demands for "triple-play" (video, voice and data) grow.

5.2 Troubleshooting cases of EPON/GPON equipment

As we know, FTTH PON equipment's have been in used for certain time today, and there are more or less some faults, which is headache. The following four common PON equipment faults case was chosen as the examples for our troubleshooting case. Hopefully our readers can learn some basic PON equipment troubleshooting idea, that we can solve PON device's problem more efficiently.

Case 1: Network Management System Disconnected

NMS system's disconnection problem is quite frequency, let's start with idea to debug and troubleshoot this No.1 PON equipment faults issue. What we need to do is just check the list step by step as following, if we found our OLT/ONU disconnected to the NMS system unluckily.

1. Check cable status.

2. Check the IP address setting.

3. Check the subnet number and network settings.

4. in-band and out of band management IP cannot be set on the same IP address.

5. Restart OLT after modifying the subnet or network number.

6. Check NMS VLAN configuration, if in-band NMS disconnected.

Case 2: Fail To Detect ONU/ONT

1. Input command: display running-configuration
2. Check ONU type
3. Check if any abnormal event logs and alarm.
4. Connect ONU with PON port in OLT directly, check whether can detect ONU (Note: Be careful the over-high optical power when ONU connect with PON port directly)
5. Connect to another PON line card or PON port and check whether can detect the ONU
6. Replace with another authenticated ONU to check whether it's ONU problem
7. Check ODN, whether there is problem in optical network.

Case 3: Fail To Access Internet

"Fail to connect" is another big issue for our end users, no worries, we can follow those steps one by one to fix it.

1. Check ONU register status in ONU management interface.
2. If register is ok, check the VLAN configuration in OLT and ONU.
3. Check whether bandwidth setting is too small.
4. Configure spare Ethernet port in switch line card in untag mode and add to VLAN, modify PVID value to the corresponding VLAN number, then connect a PC with ONU and test network access.
5. If fail to access internet, the problem maybe in uplink network. Check the uplink port status and uplink switch VLAN configuration.
6. If network is ok, then the uplink network is ok. Connect only 1 pc ONU with PON port, after registering, set the ONU VLAN number and test internet access.
7. If it's ok to connect 1pc ONU, then connect other ONUs one by one and see whether there is problem when connect an ONU.
8. If the ONU connect to LAN or several cables, in order to eliminate the LAN problem, disconnect them and connect to only 1 PC to do test.

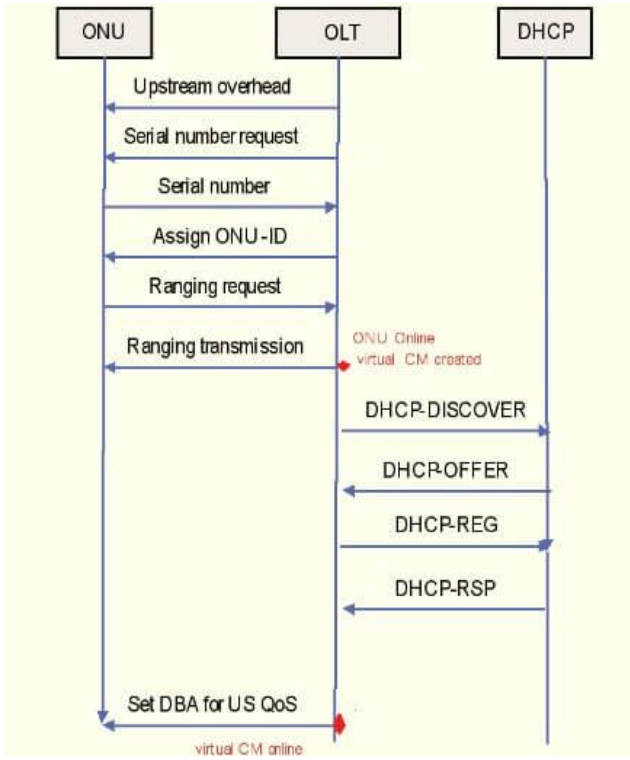


Figure 5.2: Access Internet

Case 4: VoIP Function Problem

For those CPE equipment which support the Voice/VoIP function, it is also a very headache problem of call issue. We have to fix it as soon as possible if the analog/sip phone fault to call.

1. If the link between VoIP FXS port/chipset and SIP Server/IP PBX is ok.
2. Whether can ping VoIP IP address via SIP server, if it is failed then got to check port configuration on VoIP card on EPON and related connection status.
3. For static IP access, please check IP address and Port ID on the service card on EPON;
4. For DHCP/Domain access, please check if the configuration on terminal and server side match or not.
5. Luckily ONU/ONT terminal successfully register, but fail to make a call, what we need to check is the USER TID and RTP TID configuration between
6. Clients and sip server.
7. Imaging all the configuration mentioned above is correct, the best way to debug is using the protocol flow analytics via sip sever

- Trouble facing between EPON and GPON shifting
  Fiber layout Diagram

5.3 Challenges against FTTH Solution:

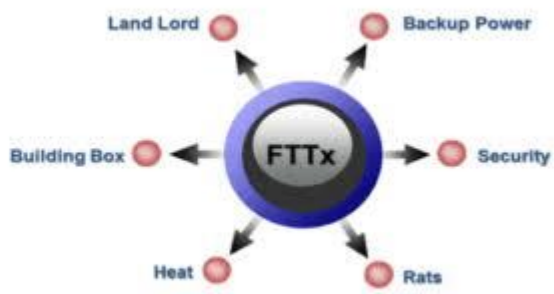


Figure 5.3: Challenges against FTTH Solution

Land Lord Problem:

Most of the Land lords do not agree to put ONU in their building premises. Most of them think it as an extra hassle. But, nowadays, awareness is growing and many of them have realized the good sides of GPON technology and some of house owners are willingly request to put BDB in their building premises.[2]

Power Backup Problem:

Commercial power is another big challenge of FTTH service providers. An ONU consumes very little electrical power. If an ONU is ON 24 hours a days for a month, so, it will cost only 50 to 80 taka .But in our country, most of house owners/land lords do not agree. In Bangladesh. Load shading is regular matter. During load shading client will not be able to get service. But, nowadays most of the client get power back up from their own UPS or IPS.

Building Distribution Box Problem:

Building Distribution Box problem is another main problem .Many land load are not agreeing to install BDB in his building. After BDB box installation, BDB key is broken by thieves or bad people. When we hang or distribute the all fiber in the local area , then the fiber rearrange .[2]

Security:

Security is another concern issue for FTTX Development. ONTs, BDBs and sometimes Fiber stolen.EPON equipment developers and manufacturers are adding some security mechanisms to their OLT and ONT offerings because Ethernet protocol doesn't provide any built-in security solution. Most of the mechanisms are standard multilayered security solutions, such as firewalls, virtual private networks, Ip security and tunneling.

The GPON networks are using point-to-point encryption mechanism called Advanced Encryption Standard (AES). The AES is using cipher keys of 128, 192 or 256 bits to encrypt the data blocks of 128-bits. The result of inscription is unintelligible and is extremely difficult to compromise. Decrypting of the information is changing information to its original state

Heat:

In case of Asian country like Bangladesh, heat is a major problem for ONUs. Sometimes service provides have to install ONUs in outdoor. After some Moments, it is damaged due to heat and dust.

Rats:

Sometime patch cords are cut by rats. Practically, Bangladesh has faced this type of problem continuously

Weak planning for Deployment:

The process of laying Fiber Involves securing approvals from multiple which agencies which is a key challenge. The lack of government intervention in addressing this issue is a major roadblock.

To deploy FTTX in Bangladesh there are some other problem like-

- Charges for laying fiber in towns and cities are very high
- The return on investment in FTTH networks is realized only when subscriber uses services at the connected location. The returns are impacted when subscribers shift from their locations unlike wireless connections. The FTTH network deployed at premises remains idle until the next user occupies it. Wireless connections allow operators to provide services to customers irrespective of their location.

- The high cost of the related consumer premise equipment and optical network terminals is another challenge. Currently, most of these equipment's are imported, which accounts for a significant part of overall costs.
- Others issues the efficient transportation of the huge bandwidth, selecting the FTTX access mode and design, ensuring quality of experience for multi play services, fiber resourcing saving long distance coverage, reliable fiber transporting and rational planning of the optical distribution network.
- Currently the ROW within housing projects or resident welfare associations is controlled by the builder, which generally gives access to one or two operators. Rolling out FTTH in these areas is viable for an operator, if it is guaranteed a subscriber base. Otherwise an operator can expect.

5.4 Real life implement on GPON Project

My real life GPON project in Bangladesh Army in Dhaka cantonment which is based on Triple Play system like Internet, Dish TV and Telephone exchange. We take 7 days for those preparation. Their backbone fiber condition was not so much good .then we hanging new fiber to signal battalion. Then we collect all those service from different source. Then we prepare our project

Require Device:

1. GPON OLT
2. GPON Multiport Multiservice ONU
3. Splitter
4. 1550 transmitter
5. 26 dB output PON EDFA
6. Splitter
7. Telephone set

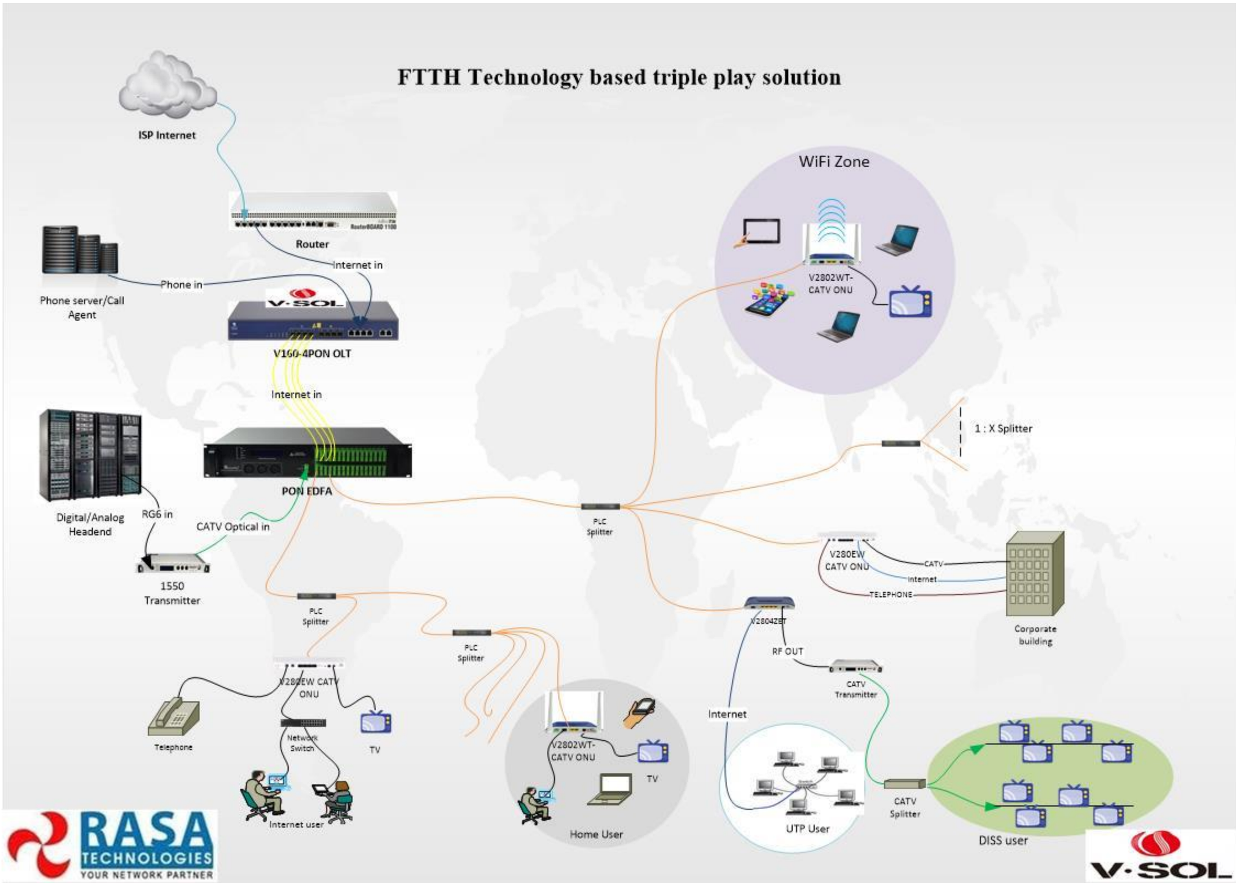


Figure 5.4: FTTH technology based triple play solutions

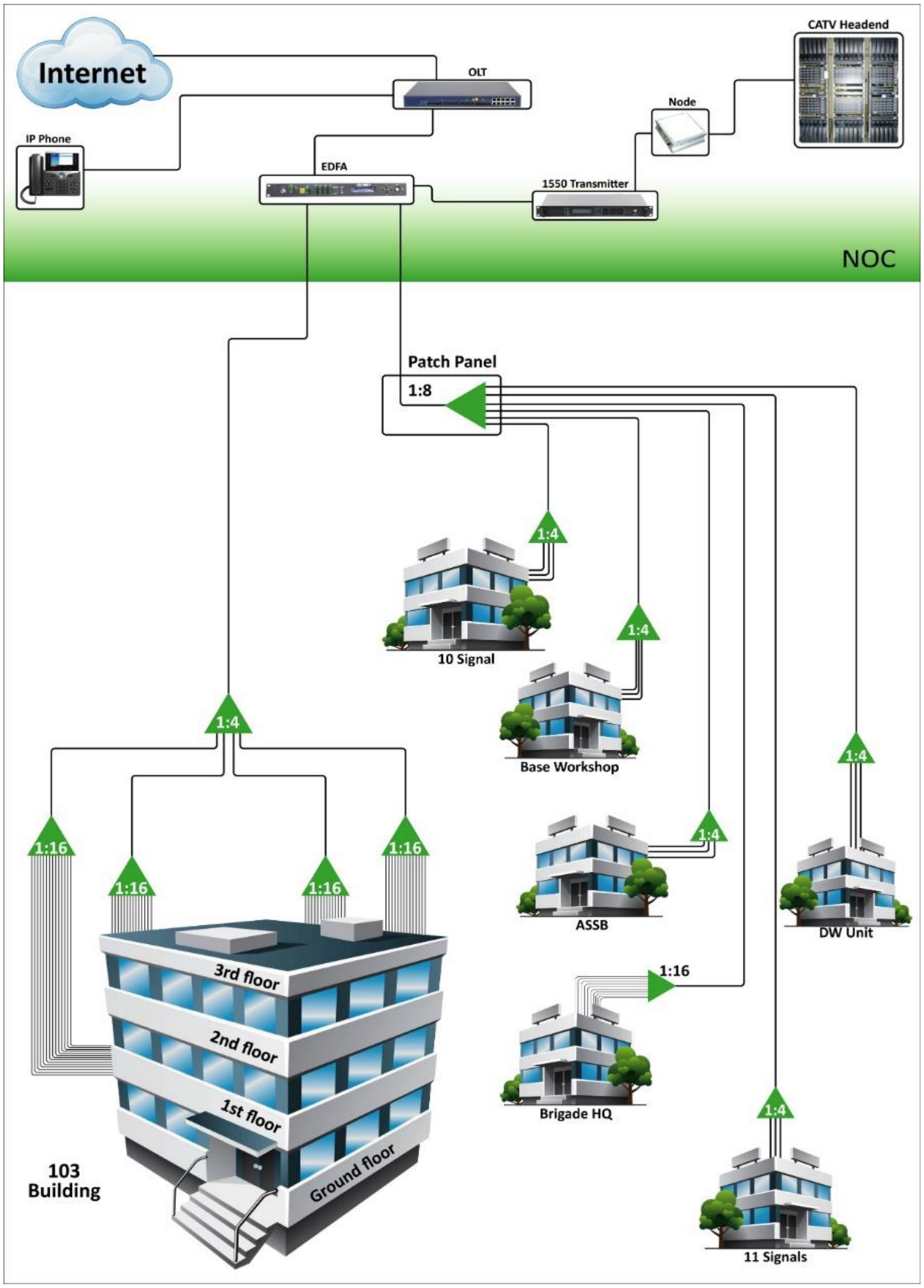


Figure 5.5: Bangladesh Army triple Play Solution (Internet,Dish and Telephone)

Figure 5.6: My working Photo on Bangladesh Army

Why it is better and Price cost:

1. Low cost
2. Faster than others like DSL, Dial Up
3. Virtually unlimited bandwidth
4. Single fiber to the end user with triple play
5. FTTH features local battery backup and low power consumption.
6. Reliable, scalable, and secure
7. Easy to troubleshoot
8. No active components from the CO to the end user

Cost analysis between Traditional Network vs FTTH

If I think about the cost effectiveness between traditional network vs FTTH. Then I have to must say tradition network is an unarranged network. Traditional cannot give us a proper satisfaction. In Tradition network, we need many managed or unmanaged network switch. Network switch is cost effective. Then we calculated about the cost of LAN cable. LAN cable is more expensive, in the traditional network electric power is more important. If one area electric power is down .then the upper area internet connection is DE touch. Another importance issue is cost of optical fiber and unused of optical fiber core. We miss use optical fiber in the Traditional network.

- So many network use in the traditional network
- So many Optical Fiber core is unused in the network
- Electric power is more important. If I place has no internet, then the upper places cannot get internet.
- So many LAN Cable is use in the network. So, Network traffic carrying capacity gradually down compare to fiber. So, that is more important. If we use so many hope in a same network then the traffic travelling time or latency gradually high and then the browsing speed and net speed gradually slow.

Cost estimations for PON-Based FTTH development:

This section measures and compares the development cost of additional optical monitoring, switching and protection systems for PON-based FTTH with different splitting ratio in order to select the most cost efficiency configuration. The main development cost of conventional PON can be broadly divided in 2 categories, namely labor cost and electronic equipment's. The labor necessary to deploy the Outside Plant (OSP) includes the cable, ducts and civil work represents the biggest piece of conventional PON-based FTTH first-installed cost. Labor costs come in two parts: the time to deploy, test and troubleshoot and the hourly rate of the installer. That hourly rate depends on the skill set and equipment required to install the components. The active electronic equipment's in CO or Head End (HE) and at customer premises, where the equipment is shared among multiple subscribers and no active components are deployed in the field. The remaining is the passive components installed in the Head end as well as Outside Plant. NSPs need to keep capital and operational expenditures low in order to be able to offer economical solutions for the customers. A full protection offers relatively high connection availability but unfortunately it requires duplication of all network resources and investment cost to realize the protection, which may result in CAPEX that is too

Product	Quantity	Price(bdt)
8 port GPON OLT	1 pcs	1,25000 /=
1 port ONU	1 pcs	1,400/=
1:8 splitter without connector	1 pcs	500/=
TJ BOX	1 pcs	80/=
C++ PON Module	1 pcs	4,000/=
Patch Cord	1 pcs	100/=
1:16 splitter without connector	1 pcs	800/=
Fiber	1 meter	13/=

high for the cost-sensitive access networks.

Table 5.2: GPON Device Unit Price

Budget Analysis:

The study divided fiber deployments into two segments. The first was the infrastructure from the last active point (CO or S/C) to the branching point, which gives the calculation per HP (Home Passed). The second was the infrastructure from the branching point to the terminal outlet at the subscriber premises. Lower costs were sometimes encountered in 'transport' segments of the network between the Central Office and the first street cabinet. Subscriber connection costs, however, resulted in some negative surprises, but still the budget was not exceeded. Small additional costs incurred during the course of a deployment project are generally evened out by activities that go more smoothly than planned. Furthermore, estimates tend to be cautious, which means projects are more likely to be realized below budget.

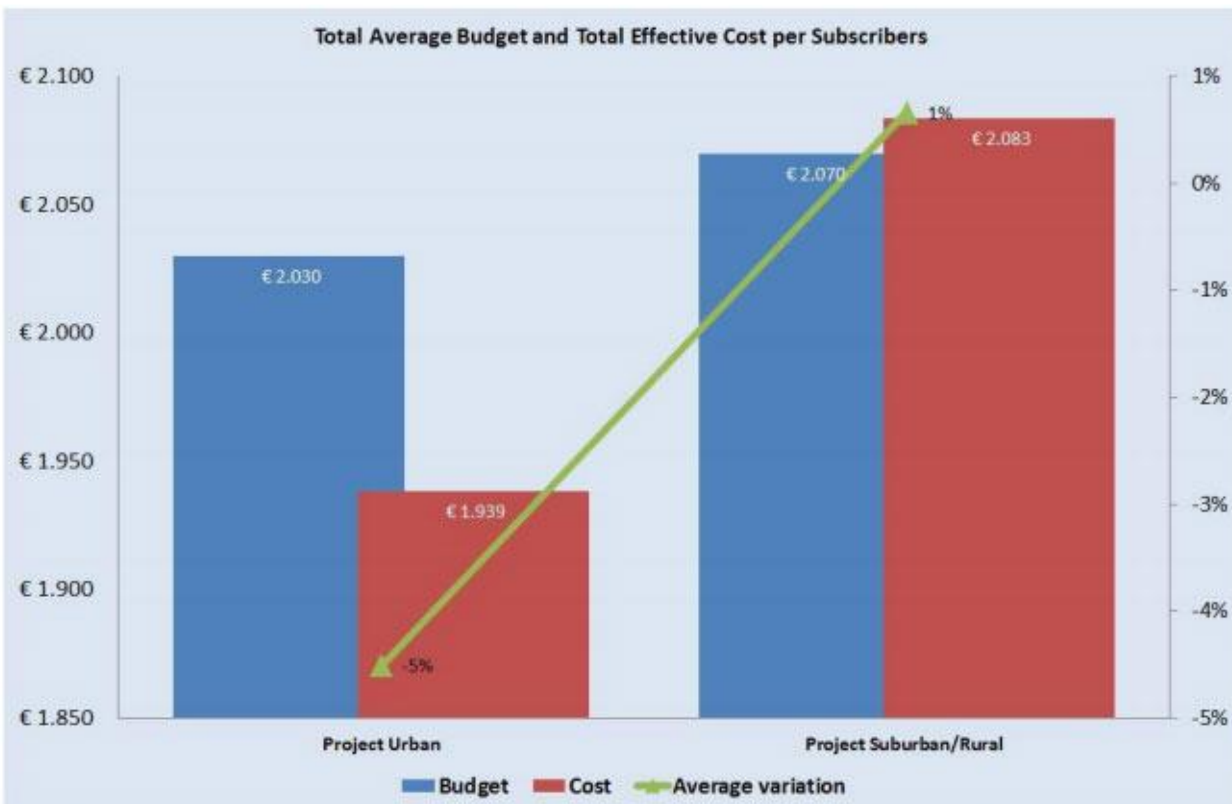


Figure 5.7: Budget and cost analysis

Building the business case

"We also found that, whenever the real costs are lower than the budgeted costs, there is a tendency to spend the entire budget and thereby slightly enlarge the area to be covered.

This, in turn, results in an increase the number of Homes Passed. Another interesting finding is the fact that different types of budgeting bodies come up with similar estimates. Areas in which gaps might occur are identical, regardless of the source of the costing. Independent consulting firms are just as reliable as the design offices of operators or integrators."

In the past, potential investors, advisors and consultants have frequently voiced concerns about a lack of clarity when it comes to the cost of fiber rollouts. It appears that FTTH rollouts have left the 'experimental' phase and are now a highly standardized industrial process. They are becoming an accepted investment category without major risk. Today, operators, banks and other stakeholders in various countries consider fiber to be a reliable investment. This growing understanding and acceptance will accelerate rollout and opens up new possibilities in economically challenged areas that may become less dependent on government funding.

6 ways to reduce FTTH implementation costs

1. Eliminating blowing
2. Use existing infrastructure
3. Use the right construction techniques
4. Pick the right equipment
5. Focus on deployment speed
6. Minimize the skills required

Benefits of FTTx Network in Bangladesh:

1. User Driven Network – Any Time Any Service
2. Single 24/7 Call Center for all ISP
3. Easy & Centralized O&M
4. Cost Effective – Minimum 40% Less.
5. Service Concentric Network

5.5 Drawback of EPON and GPON

ONU Redundancy:

In FTTH network all type of redundant is not possible. Uplink redundancy, power backup redundancy, PON port redundancy is possible in EPON/GPON technology. But ONU level redundancy is not till possible. If we need ONU level redundancy, then we need two PON port in one ONU. And every ONU should be RSTP Protocol enabled.

Security:

EPON equipment developers and manufacturers are adding some security mechanisms to their OLT and ONT offerings because Ethernet protocol doesn't provide any built-in security solution. Most of the mechanisms are standard multilayered security solutions, such as firewalls, virtual private networks, IP security and tunneling.

The GPON networks are using point-to-point encryption mechanism called Advanced Encryption Standard (AES). The AES is using cipher keys of 128, 192 or 256 bits to encrypt the data blocks of 128-bits. The result of inscription is unintelligible and is extremely difficult to compromise. Decrypting of the information is changing information to its original state

Chapter 6

6. Summary

According to the contents above, we can see that there are own advantages and disadvantages of EPON and GPON. In performance comparison, GPON is better than EPON, while EPON has much advantages on time and cost. And now, EPON is still the mainstream of PON, and meanwhile, GPON is catching up with it. Going forward to the broadband access market, maybe it is not substitution between EPON and GPON. It is more likely that they are co-exist to complement each other. For the users who have demands of multi-service, high QoS and security, as well as ATM backbone network, GPON seems to be an ideal. And for the one who is much care about the cost and has less security requirements, EPON may be better.

The intention of this paper is simply to develop a simulation model that can be used in PON technology design analyses. After PON link performance requirements were established, the proper components could be selected and their simulation results are used as a feedback to change the architecture, components, and/or these requirements. The design process thus becomes iterative. The impact of fiber nonlinearities and the use of different fiber types can be addressed in the simulation which makes the design process fairly simple. With the different PON technologies and configurations in terms of line rates, split ratios, and triple play broadband services, the use of simulation helps us to focus on identifying the right design and making decisions regarding how to deploy PONs to address the service needs without getting bogged down on a technology debate. In conclusion, FTTH networks using PON technologies can be characterized and maintained at every stages of the design layout using the simulation which reduces the requirement of expensive test and measurement equipment in complex test beds.

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