International Journal of Trend in Scientific Research and Development (IJTSRD)
Volume 3 Issue 5, August 2019 Available Online: www.ijtsrd.com e-ISSN: 2456 – 6470

Design and Fiber Installation for University Campus System

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How to cite this paper: Naing Naing Kyaw "Design and Fiber Installation for University Campus System" Published in International Journal of Trend in Scientific Research and Development (ijtsrd), ISSN: 2456-6470, Volume-3 | Issue-5, August 2019, pp.1918-1924,
https://doi.org/10.31142/ijtsrd26812

IJTSRD26812

ABSTRACT

The health of a network depends on the quality of proper installation of the network infrastructure. The main aim of this research is to understand the basic aspects of a modern telecommunication network structure. Signal degradation dominants the performance of the fiber installation. By using MATLAB software, simulation results for signal degradation such as attenuation, dispersion and nonlinear effects are discussed. OTRD (Optical Time Domain Reflectometer) is a valuable tool for field engineers and service providers to monitor and detect the faults between access network and CO (Central Office) in real world analysis. In this paper, an overview related to the operation and function of a PON (Passive Optical Network) and required components to implement the fiber communication system are also described.

KEYWORDS: *degradation, OTDR, access network, CO, PON*

I. INTRODUCTION

Over the last decade the world has been a great transformation in telecommunications with various advances in high speed, high-capacity broadband telecommunications technologies. Nowadays, optical fiber communication system plays an important role in global telecom infrastructure. [1]

Passive optical network (PON) makes use of optical fiber as the transmission medium, lasers and photodiodes as transmitters and detectors.

There are two types of optical fiber: single mode fiber and multimode fiber. One of the purposes of this paper is to provide a balanced coverage of networking technologies, fiber-optic transmission technologies, and the electronics involved in PON system development [2].

Designing and deploying FTTP networks requires careful evaluation of all communication links between the transmission equipment in the central office (CO) and the ONT at the customer's premises [13].

II. FTTx OVERVIEW

The general structure of a modern telecommunication network consists of three main portions: backbone (or core) network, metro/regional network, and access network as shown in Figure 1.

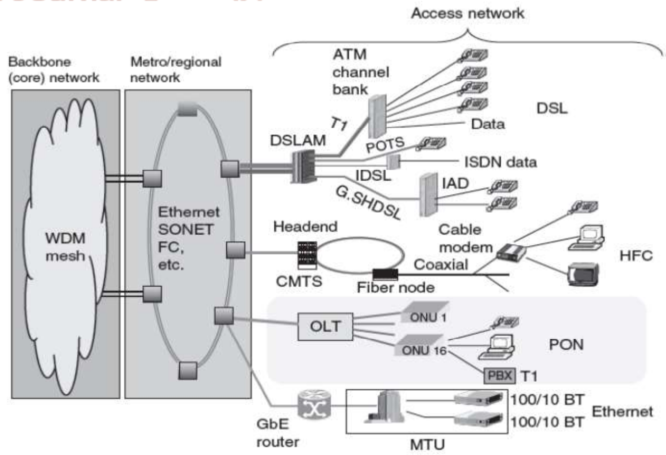

Figure 1 Generic structure of a modern telecommunication network [2]

On a very high level, core backbone networks are responsible for long-distance transport and metro/regional networks are used for traffic grooming and multiplexing functions. Structures of backbone and metro networks are usually more uniform than access networks and their costs are shared among large numbers of users.

These networks are built with state-of-the-art fiber optics and wavelength division multiplexing (WDM) technologies to provide high-capacity connections. Access networks provide end-user connectivity. They are placed in close proximity to end users and deployed in large volumes. In a fiber-to-the-home (FTTH) system, fiber is connected all the way from the service provider to household users [2].

A. Fiber Access Systems

Optical fiber has the advantage of high bandwidth, low loss, and low noise. Local loops using optical fiber for access connections are called fiber-in-the loop (FITL). Compared to the coaxial cable plant, which usually requires many cascaded RF amplifiers, fiber plants are in general much cleaner and require very little maintenance. Fiber access systems are also referred to as fiber-to-the-x (FTTx) system, where x can be home, curb, premises, neighborhood, etc., depending on how deep in the field fiber is deployed or how close it is to the user.

In an optical access network, the final drop to customers can be fiber (FTTH), coaxial cable (as in an HFC system), twisted pairs or radio (FTTC). In fact, a PON system can be used for FTTH or FTTC/FTTP depending on whether the optical fiber termination (or the ONU location) is at the user, or in a neighborhood and extended through copper or radio links to the user [2].

B. Passive Optical Networks

In a PON there are no active components between the central office and the customer's premises.. The three main PON alternatives are known as broadband PON (BPON), Ethernet PON (EPON), and gigabit PON (GPON).

Table 1 Major PON Technologies and Their Characteristics

	Passive Optical Network Type		
Characteristic	BPON	EPON	GPON
Standards family	ITU-T G.983	IEEE 802.3ah	ITU-T G.984
Protocol	ATM	Ethernet	ATM and Ethernet
Transmission speeds (Mbps)	622/1244 downstream, 155/622 upstream	1244 upstream, 1244 downstream	155 to 2488 upstream, 1244 or 2488 downstream
Span	20 km	10 km	20 km
Number of splits	32	16 nominal, 32 allowed	64

An architecture consisting of point-to-point Ethernet links is a competing access network technology. Ethernet use in access networks is referred to as Ethernet-in-the-first-mile (EFM). Some of the characteristics of each methodology and the standards to which they adhere are listed in Table 1 [13].

III. DESIGN CONSIDERATIONS FOR FIBER INSTALLATION

Network layout considerations within the CO include where to place the WDM coupler that combines the triple-play services, minimizing the number of connector interfaces, and allowing flexibility in connecting both FTTP and non-FTTP services to available fibers in the feeder cables. Installing the outside cable plant (OSP) is a major expense of an FTTP implementation [13].

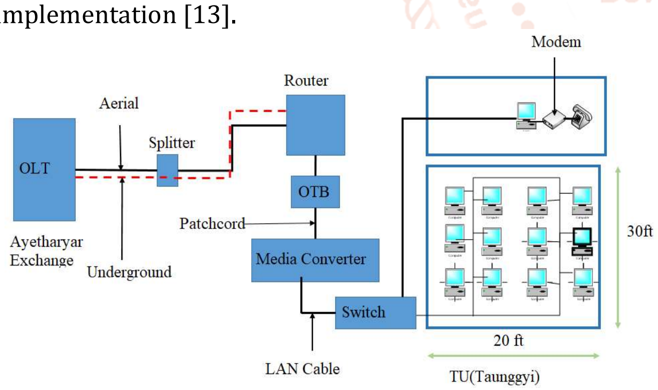

Figure 2 Design of FTTx for Electronic Engineering Department of Technological University (Taunggyi)

The red line in Figure 2 represents the overhead installation and the black line refers to aerial installation where electrical poles are used to carry fiber cables. The optical splitter splits the power of signal that is each fiber entering the splitter into a given number of fibers. Fiber Optic Terminal Box (OTB) is mounted to inside and outside of building to distribute and connect optical cable for distribution of subscribers. It supports termination, splicing and storage functions for fiber cable. It has excellent performance for aerial installation and it can be installed rapidly and easily in the field.

The type of cable choosing from CO to the University is G-652.C single mode fiber. It is optimized for operation in the 1310 nm and 1550 nm wavelengths with zero-dispersion. The simulation area is chosen at the distances 1.6 km and 3.1 km. OTDR test is made at Fiber Optic Terminal Box (OTB). Most single mode fibers have a loss factor of between 0.25dB/km at 1550 nm and 0.35dB/km at 1310 nm. Fusion splice loss is calculated at 0.1 dB per splice for 1310 nm sources. For each connector, 0.75 dB loss is used for fusion splice on connectors. Most system designers add a loss budget margin of 3 to 10 dB.

Link Loss = [fiber length (km) x fiber loss per km] + (splice loss ×number of splices) + (connector loss ×number of connectors) + (safety margin)

By using the above link loss equation, an estimated 6.24 dB of power would be required to transmit across this link [14]. The maximum distance of a particular fiber optic link can be estimated by using the following equations:

Fiber Length = (Optical budget - Link loss) ÷ (Fiber loss/km)

Fiber Length = {(mint power) -(RX sensitivity)- (splice loss ×number of splices)- (connector loss number of connectors) - (safety margin)}÷ (Fiber loss/km)

In this installation a fast Ethernet single mode link at 1310 nm with 2 connector pairs and 5 splices are used. So,

min.TX power-RX sensitivity= -0.8dB-(-7.04dB) = 6.24dB
Splice loss × number of splices = 0.1 dB×5= 0.5dB
Connector loss × number of connectors = 0.75dB×2 = 1.5dB
Safety margin = 3.0dB
Fiber loss/km = 0.4 dB/km
Fiber Length = {(6.24dB) - (0.5dB) - (1.5dB) - (3.0dB)} ÷ (0.4 DB) = 3.1km

End-to-end tests of fiber optic cable loss include the losses caused by splices. If the cable loss exceeds the calculated maximum value, test the cable with an OTDR to analyze the loss of individual components (fiber, connectors, and splices) in the cable. Required components for installation from CO to a university campus network are described in the next section.

IV. ACCESS NETWORK FOR A UNIVERSITY

Access networks have been traditionally called last-mile networks as they comprise the last segment connection from service providers' central office (CO) to end users. Figure 3 shows an access network which consists of local mikrotik CCR1036-8G-2S+ firewall router, cisco Catalysts 3550 series layer 3 switch and fiber media converter FT-806A20 for Ethernet cable based University campus system.

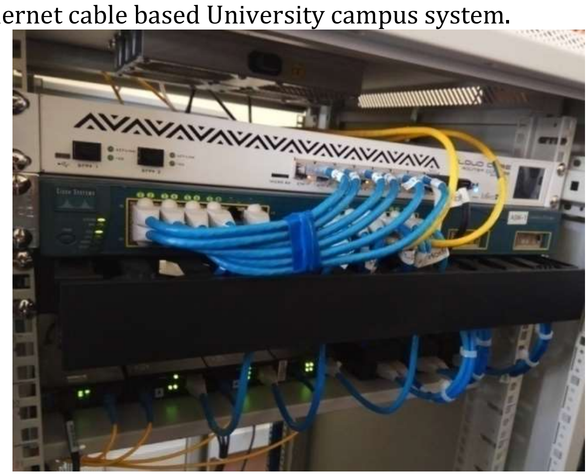

Figure 3 University access network

They are also called first-mile networks in recent years as they are the first segment of the broader network seen by users of telecommunication services. Traditionally, optical fibers have been widely used in backbone networks because of their huge available bandwidth and very low loss [2].

A. WDM in Optical Access Networks

The basis of wavelength division multiplexing (WDM) is to use multiple sources operating at slightly different wavelength to transmit several independent streams simultaneously over the same fiber. Figure 4 shows the basic WDM concept [3].

WDM increases system capacity by transmitting multiple wavelengths on a single fiber. Coarse WDM techniques have already been applied in PON systems to separate upstream and downstream signals, and provide analog video overlay. An important advantage of the optical fiber is its virtually unlimited bandwidth from an access viewpoint. Coarse WDM overlay on a power-splitting PON is an obvious way to provide different services and increase system capacity [2].

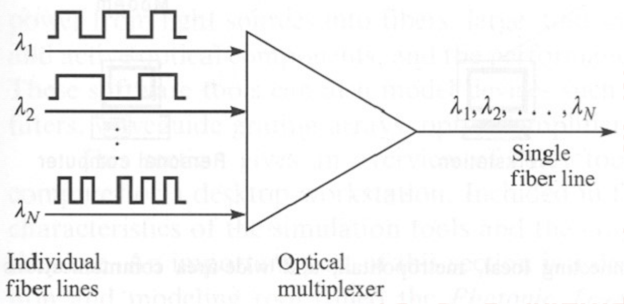

Figure 4 Basic concept of wavelength division multiplexing

Dense Wavelength Division Multiplexing (DWDM) module depicted in Figure 5 is an optical multiplexing technology used to increase bandwidth over existing fiber networks. DWDM works by combining and transmitting multiple signals simultaneously at different wavelengths on the same fiber. The technology creates multiple virtual fibers, thus multiplying the capacity of the physical medium [7].

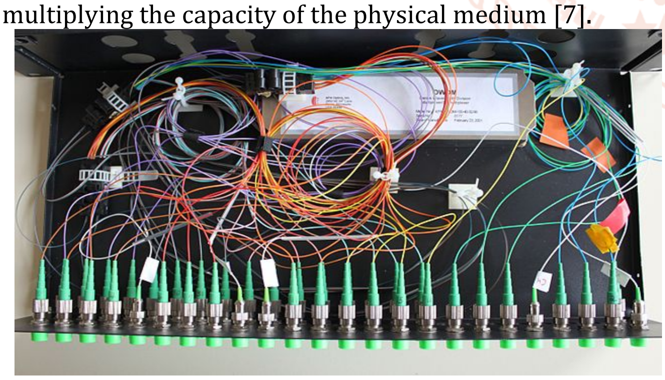

Figure 5 DWDM module

B. Media Converter

A media converter, in the context of network hardware, is a cost-effective and flexible device intended to implement and optimize fiber links in every kind of network. Among media converters, the most often used type is a device that works as a transceiver, which converts the electrical signal utilized in copper unshielded twisted pair (UTP) network cabling to light waves used for fiber optic cabling. A media converter offers fiber-to-fiber conversion as well, from multi-mode fiber into single-mode fiber. It also converts a dual fiber link to single fiber with the help of bi-directional (BIDI) data flow. [8]

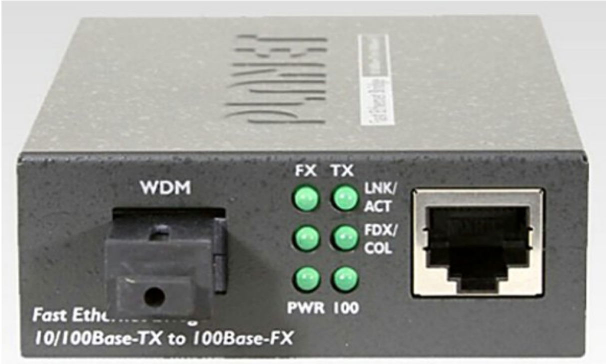

Figure 6 Media converter

A fiber media converter is a simple networking device that makes it possible to connect two dissimilar media types such as twisted pair with fiber optic cabling. They are important in interconnecting fiber optic cabling-based systems with existing copper-based, structured cabling systems. They are also used in metropolitan area network (MAN) access and data transport services to enterprise customers [9]. Figure 6 shows a Fast Ethernet bridge fiber converter (10/100BASE-TX to 100BASE-FX).

C. Splicing

Splicing in fiber optics as shown in Figure 7 is the physical joining of two separate optical fibers with the goal of having 100-percent signal transfer. Splicing connections are meant to be permanent, non-reconfigurable connections. There are two basic splicing methods in use today: mechanical and fusion splice.

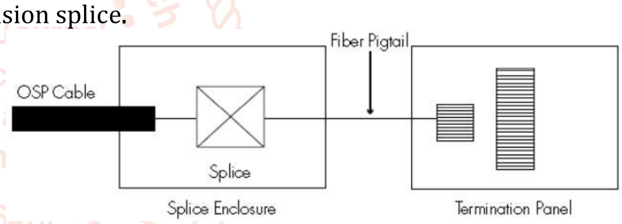

Figure 7 Fiber Splicing

Mechanical splicing involves the use of an alignment fixture to bring and hold two fibers in alignment. Mechanical splices typically give insertion loss values of <0.15dB with return loss values of >35dB and involve the use of an index-matching gel.

Fusion splicing as shown in Figure 8 uses an electric arc to "weld" two fibers together. Fusion splices typically have insertion loss values of <0.05dB and return loss values of >70dB. Whichever splicing type is used, the ODF needs to provide a location to store and protect the splices.

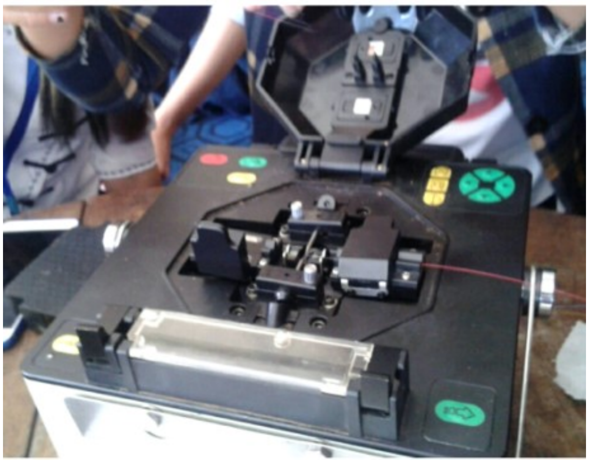

Figure 8 Fusion splicing

When fusion splicing is done, the alignment of two connecting fibers can be observed on the screen as depicted in Figure 9.

Figure 9 Monitoring fiber alignments

D. Optical Distribution Frame

An Optical Distribution Frame (ODF) is a frame used to provide cable interconnections between communication facilities, which can integrate fiber splicing, fiber termination, fiber optic adapters and connectors and cable connections together in a single unit. It can also work as a protective device to protect fiber optic connections from damage. According to the structure, ODFs can mainly be divided into three types, namely wall mount ODF, floor mount ODF and rack mount ODF. Figure 10 shows the wall mount ODF [6].

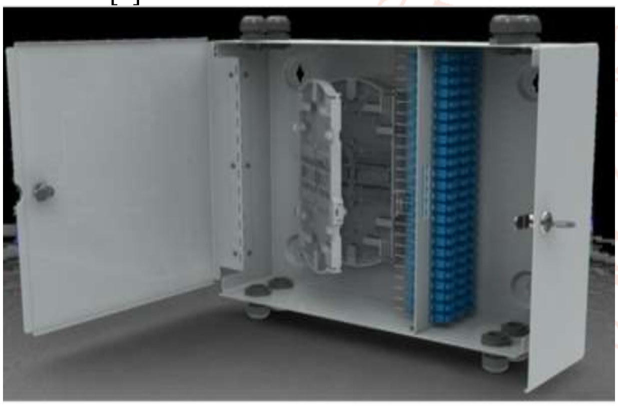

Figure 10 Wall mounts Optical Distribution Frame

E. Optical Line Terminal

An optical line terminal (OLT) is the device which serves as the service provider endpoint of a passive optical Network (PON). The OLT is located in a central office and controls the bidirectional flow of information across the ODN. In the downstream direction the function of the OLT is to take in voice, data, and video traffic from a long-hual network and broadcast it to all the ONT modules on the ODN. In the upstream direction, OLT accepts and distributes all the traffic from the network users [13].

Figure 11 EPON OLT FD2000S

Figure 11 shows EPON OLT FD 2000S which can be applied to Fiber to the Building / Point / Home (FTTB/ FTTP/FTT H) Access solution.

F. Optical Network Unit

FTTH FD204HW ONU as shown in Figure 12 is a broadband access device and can be used with OLT FD2000S to build a system EPON.

Figure 12 EPON ONU FD204HW

V. SIGNAL DEGRADATION IN OPTICAL FIBERS

Signal attenuation is one of the most important properties of an optical fiber, because it largely determines the maximum repeaterless separation between a transmitter and a receiver. Of equal importance is signal distortion. The distortion causes the optical signal pulses to broaden as they travel along a fiber.

The signal distortion mechanisms thus limit the information carrying capacity of a fiber. The basic attenuation mechanisms in a fiber are absorption, scattering, and radiation losses of the optical energy. Absorption is related to the fiber material, whereas scattering is associated both with the fiber material and with structural imperfections in the optical Waveguide [3].

A. Attenuation

Attenuation of a light signal as it propagates along a fiber is an important consideration in the design of an optical communication system, since it plays a major role in determining the maximum transmission distance between a transmitter and a receiver.

Figure 13 illustrates the relationship of wavelength and attenuation of optical fiber. As channel attenuation largely determined the maximum transmission distance prior to signal restoration, optical fiber communications became especially attractive when the transmission losses of fibers were reduced below those of the competing metallic conductors (less than 5 dB km^{-1}) [4].

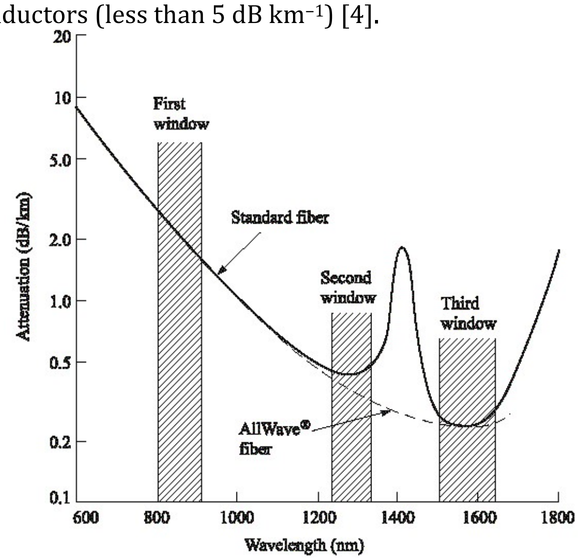

Figure.13 Optical fiber attenuation[3]

B. Dispersion
Dispersion of the transmitted optical signal causes distortion for both digital and analog transmission along optical fibers.

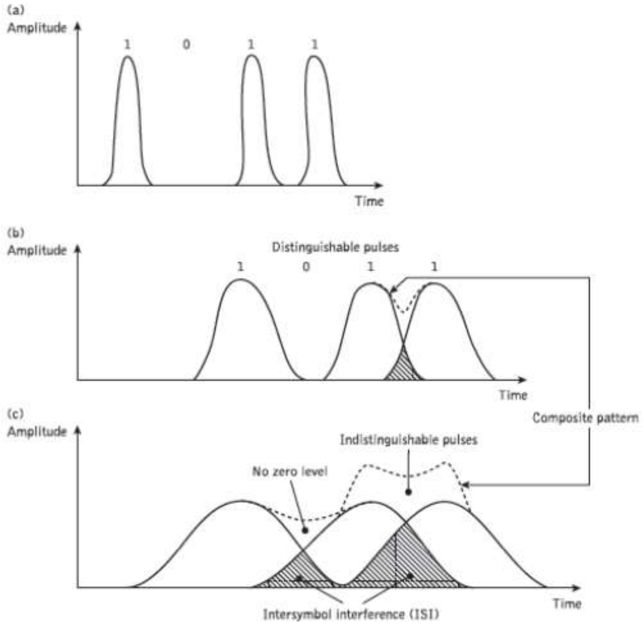

Figure14. Dispersion (a) fiber input;(b) Fiber output at a distance L1;(c) fiber output at a distance L2 > L1 [4]

When considering the major implementation of optical fiber transmission which involves some form of digital modulation, then dispersion mechanisms within the fiber cause broadening of the transmitted light pulses as they travel along the channel. There is an illustration using the digital bit pattern 1011 of the broadening of light pulses as they are transmitted along a fiber.

This phenomenon is illustrated in Figure 14, where it may be observed that each pulse broadens and overlaps with its neighbors, eventually becoming indistinguishable at the receiver input. The effect is known as inter symbol interference (ISI).

Thus an increasing number of errors may be encountered on the digital optical channel as the ISI becomes more pronounced. The error rate is also a function of the signal attenuation on the link and the subsequent signal-to-noise ratio (SNR) at the receiver.

C. Nonlinear effects
Usually light waves or photons transmitted through a fiber have little interaction with each other, and are not changed by their passage through the fiber (except for absorption and scattering). There are exceptions, however, arising from the interactions between light waves and the material transmitting them, which can affect optical signals.

These processes are normally referred to as nonlinear effects or phenomena because their strength typically depends on the square (or some higher power) of the optical intensity. Hence nonlinear effects are weak at low powers but they can become much stronger at high optical intensities. This situation can result either when the power is increased, or when it is concentrated in a small area such as the core of a single-mode optical fiber.

Although the nonlinear effects in optical fibers are small, they accumulate as light passes through many kilometers of single-mode fiber. The small core diameters, together with the long transmission distances that may be obtained with these fibers, have enabled the occurrence of nonlinear phenomena at power levels of a few milliwatts which are well within the capability of semiconductor lasers.

Furthermore, the optical power levels become much larger when wavelength division multiplexing packs many signal channels into one single-mode fiber such that the overall power level is the summation of the individual channel optical powers. [4]

VI. OPTICAL FIBER CABLE INSTALLATIONS
Before installation, site survey should be done to recognize circumstances or locations in need of special attention. A cable pulling plan is also necessary because part of pulling tension can impact performance of the system process.

Fiber optic cables are designed to withstand bending both during installation where tension is applied to the cable and after installation. During pulling stage, fiber bending should not exceed the cable bend radius because fiber optic cable can be broken when kinked or bent too tightly.

The installation of optical fiber cables can be either aerial, in ducts, undersea, or buried directly in the ground, as Figure 15 illustrates. As a result of installation and/or manufacturing limitations, individual cable lengths will range from several hundred meters to several kilometers for long distance applications.

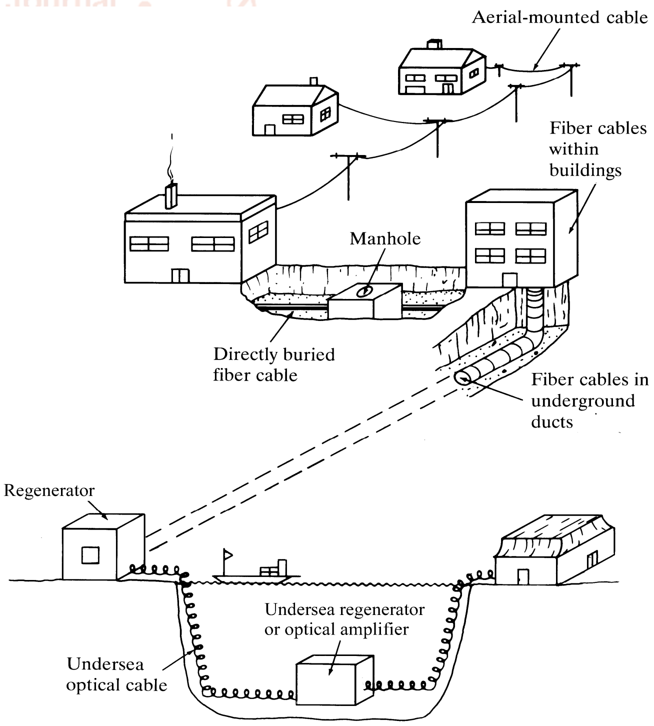

Figure 15 Types of installation of optical fiber cables [3]

The Optical line terminal (OLT) is the main element of the network and it is usually placed in the local exchange (Central Office). In this thesis, aerial fiber installation is used. Aerial fiber installation is cheaper than the underground fiber installation.

Aerial fiber installations are one of the most cost effective methods for installing fiber cables rather than digging up roads, operators can simply use existing pole infrastructure to deploy the cables. Aerial fiber installation is reliable and flexible at most 5.5 km. The poles are placed at each 50 ft (15.24 m). After the link is installed, it needs testing from end to end. The end-to-end loss as illustrate in Figure 16 includes the connectors on each end, the loss of the fiber in each link, the connectors or splices on the splitter and the loss of the splitter itself [14].

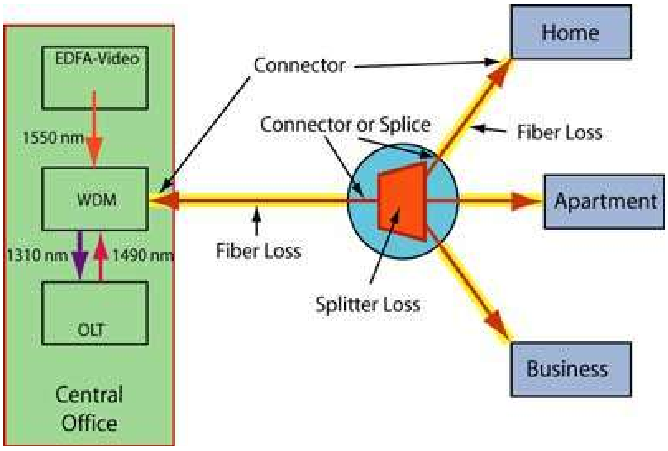

Figure 16 Types of losses in installing optical fiber cables

VII. SIMULATION RESULTS

Simulation results for performance in optical fiber installation concern with attenuation, dispersion and nonlinearity are discussed in this section.

The data signal in a single mode optical fiber link is simulated by using MATLAB software. In the simulation Gaussian pulse has taken as an input signal and studies all effects that change its shape due to attenuation, dispersion and nonlinearly.

In first simulation, the output is taken at a distance 1.6 km, while in second simulation, the output is taken at 3.1 km. Figures 17 to 22, illustrate the effects of attenuation, dispersion, and nonlinearity of the fiber for the two distance.

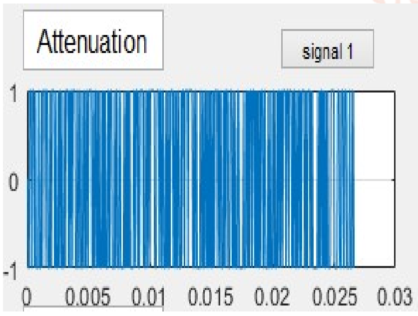

Figure17 Attenuation effects at 1.6 km distance from local exchange

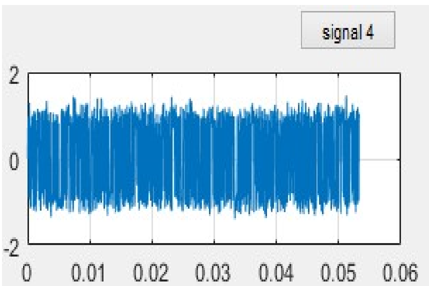

Figure18. Attenuation effects at 3.1 km distance at TU (Taunggyi)

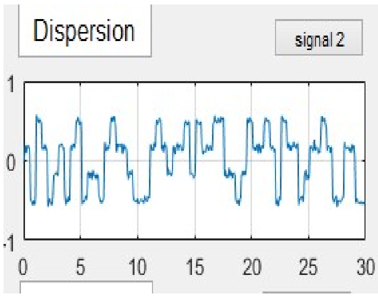

Figure 19 Dispersion effects at 1.6 km distance from local exchange

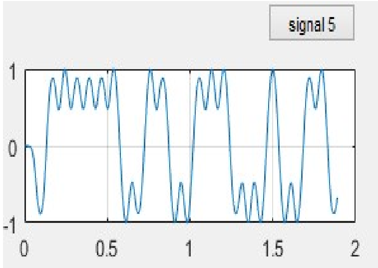

Figure 20 Dispersion effects at 3.1 km distance at TU (Taunggyi)

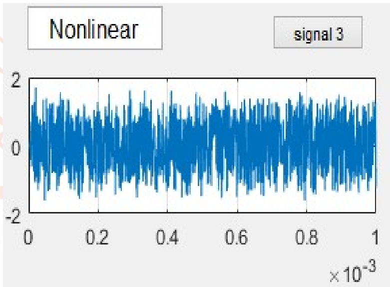

Figure 21 Nonlinear effects at 1.6 km distance from local exchange

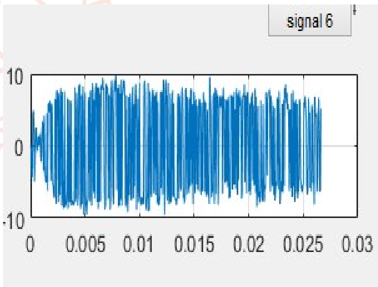

Figure 22 Nonlinear effects at 3.1 km distance at TU (Taunggyi)

It is clear that from the above results the attenuation, the dispersion and nonlinearly effects increase when the distance of communication through the fiber optics is increase. Therefore, repeaters are necessary for long-distances fiber optic systems when the signals are very weak.

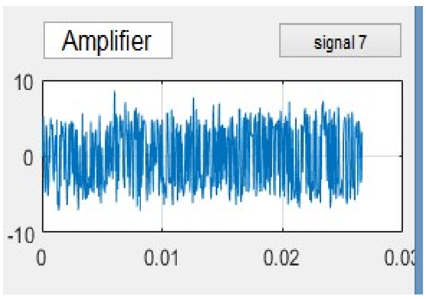

Figure 23 Output using ideal amplifier

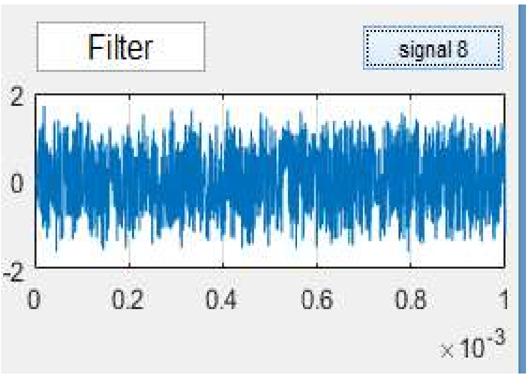

Figure 24 Output using amplifier and filter

Optical in-line amplifiers as shown in Figure 23 and 24 must be used as the repeaters for compensating the attenuation affects. The amplifiers and noise are dependent, so it is necessary to use filters after the amplification of the signal. Filter removes the effects of noise.

VIII. ANALYSIS RESULT

Optical Time Domain Reflectometers (OTDRs) can be used to test the performance of newly installed fiber links and detect problems that may exist in them. Its purpose is to detect, locate, and measure elements at any location on a fiber optic link. Simply by connecting one end of the fiber, OTDR can calculate fiber attenuation, uniformity, splice and connector losses, then provides pictorial trace signatures [11].

Testing of OTDR is performed by transmitting and analyzing pulsed laser light traveling through an optical fiber. The measurement is said to be unidirectional as the light is insert at extremity of a fiber optic cable link.

Using information obtained from the resultant light signature reflected or scattered back to the point of origin, the OTDR acts as an optical radar system, providing the user with detailed information on the location and overall condition of splices, connections, defects and other features of interest. Figure 25 shows an example image for a OTRD result [12].

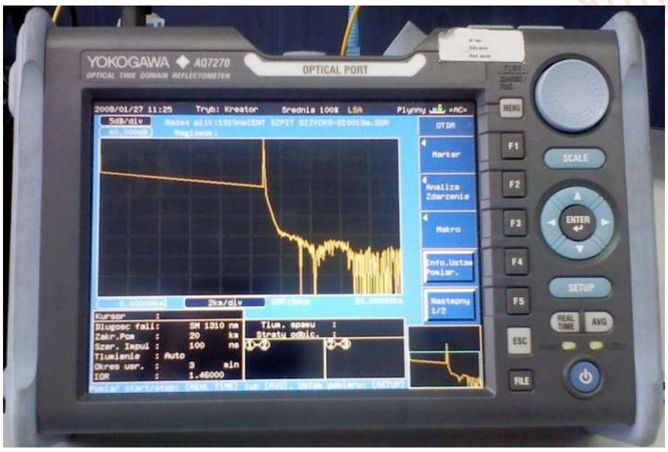

Figure 25 Example of OTDR testing result

The distance between local exchange to TU (Taunggyi) is approximately 3.1 km. For this distance, simulation test has to be implemented before installation. After installation, the losses must be tested by OTDR. The result for real world analysis is shown in Figure 26.

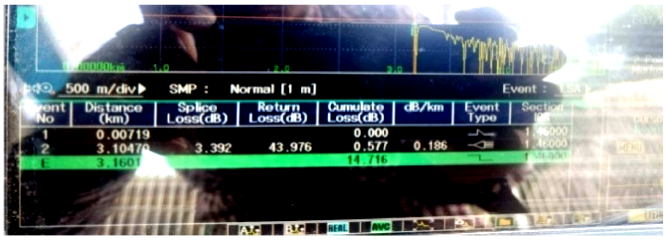

Figure 26 OTDR test at 3.1 km distance from local exchange

IX. CONCLUSION

Designing and planning are the first stage for implementing a network system. The second stage is to choose proper equipments and follow the instructions in cable installation. In the final stage, quality and performance of the entire system must be tested. In this research, most of the components used in modern communication system are discussed. Signal degradations which are mostly dominant on performance level are also described. By observing OTRD testing results, it can be concluded that the overall performance of the optical link is in good condition.

ACKNOWLEDGMENT

The author wishes to express her heartfelt thanks to her parents U Kyaw Thaung and Daw Mya Nyunt for their noble support throughout her life. The author would also like to express her deepest gratitude to all teachers who taught her everything from childhood till now and to her student Mon Myat Thu who helped her collecting the required data.

REFERENCES

[1] C. Lin, "Broadband – Optical Access Networks and Fiber-To-The-Home", England : John Wiley & Sons Ltd,2006.

[2] C. F. Lam, "passive optical networks: principles and practice", Elsevier Inc, 2007.

[3] G. Keiser, "Optical Fiber Communication", Second edition, McGraw-Hill, Inc, 1991.

[4] J. M. Senior, "Optical Fiber Communications Principles and Practice", Third edition, Pearson, 2009.

[5] Commscope, "Fundamentals of Fiber Cable Management", white paper.

[6] https://community.fs.com/blog/basic-of-icaldistribution frameodf.html

[7] https://www.advaoptical.com/en/products/technology/ dwdm

[8] https://www.techopedia.com/definition/20651/mediaconverter-network-hardware

[9] https://en.wikipedia.org/wiki/Fibermediaconverter

[10] [https://upload.wikimedia.org/wikipedia/commons/0/08 /OTDR-Yokogawa_AQ7270_-_1.jpg

[11] https://community.fs.com/blog/understandingotdrdead-zone-specifications.html

[12] https://www.viavisolutions.com/en-us/workingprinciple-characteristics-otdrs

[13] G. Keiser, "FTTX Concepts and Applications", JohnWiley & Sons Ltd, 2006.

[14] https://www.thefoa.org

[15] https://www.mikrotik.com.