Jimma University

Jimma Institute of Technology

School of Graduate Studies

Faculty of Electrical and Computer Engineering

Comparative Topology Study on a Fiber Optics Local Area Network in Jimma Institute Technology

A Thesis Submitted to the School of Graduate Studies of Jimma University in Partial Fulfilment of the Requirements for the Degree of Master of Science in Electrical Engineering (Communication)

By:

Teka Desta

April 2018

Jimma, Ethiopia

Jimma University

School of Electrical and Computer Engineering

Comparative Topology Study on a Fiber Optics Local Area Network in Jimma Institute Technology

By:

Teka Desta

Main Advisor: Dr.Ing.Towfik Jemal

Co-Advisor: Dr.Kinde Anley

A Thesis Submitted to the School of Graduate Studies of Jimma University in Partial Fulfilment of the Requirements for the Degree of Master of Science in Electrical Engineering (Communication)

April 2018

Jimma, Ethiopia

Approval Sheet

Jimma University

School of Graduate Studies

As thesis research advisor, we here by certify that we read and evaluated this thesis prepared under our guidance, by **Teka Desta**, entitled **'Comparative Topology Study on a Fiber Optics Local Area Network in Jimma Institute Technology.**

I recommend that it be submit as fulfilling the thesis requirement.

Dr.-Ing.Towfik Jemal	_____	_____
Advisor	Signature	Date
Dr.kinde Anley	_____	_____
Co .advisor	Signature	Date

As member of the board of examiners of the master of sciences thesis open defence examinations, we certify that we have read and evaluated the thesis prepared by Teka Desta and examined the candidate. We recommended that the thesis to be accepted as fulfilling the thesis requirement for the degree of Master of Science in communication engineering.

_____	_____	_____
Chairperson	Signature	Date
_____	_____	_____
Internal examiner	Signature	Date
_____	_____	_____
External Examiner	Signature	Date

DECLARATION

I, the undersigned, declare that this thesis is my original work, has not been presented for a degree in this or any other university, and all sources of materials used for the thesis have been dully acknowledged.

Name: Teka Desta _____

Signature

Place: Jimma

Date of Submission: _____

This thesis has submitted for examination with my approval as a university supervisor.

Dr.Ing. Towfik Jemal _____ _____

Advisor's Name Signature Date

Dr.Kinde Anley _____ _____

Co .advisor Signature Date

ACKNOWLEDGEMENTS

First, I would like to give special thanks and glory to the Omnipotent, Omnipresent, and the Omniscient Almighty God who is the wonderful source of my strength. He gave me the grace, wisdom, good health and guided me in all the ways of my life.

I would like to express my sincere gratitude to my adviser Dr:-ing.Towfik Jemal and Co adviser Dr.Kinde Anley, for their guidance, support, advice and encouragement right the way throughout the research. This thesis would not have been possible without their help, and their experiences have been valuable during this thesis.

I would also like to the staffs of electrical engineering schools especially communication stream at Jimma university who through their guidance and support has served as a driving force throughout the thesis.

I owe a great deal of thanks to my family, for their constant support and encouragement throughout the duration of my study.

Lastly but not the least I would also like to thank my co-workers who have contributed with their experience as well as shown an interest in the thesis work and the results.

Finally, I would like to thank all my friends (too many to list here but you know who you are!) whom I respect and love dearly. Thank you for the constant encouragement during all these years.

Thank you ALL!!!

ABSTRACT

Local area network is a small area computer network by interconnecting devices; they are data terminal equipment and data converting equipment. LAN is the end connection it may be logically or physically after router to client with different topology. Therefore multimode optical fiber is the logical choice for Storage Area Networks and Local Area Networks. In JIT LAN for backbone transmission implemented by optical fiber, but is not efficient work and there is some resource wastage and less fault protection topology. There is design gap in network; it needs high emphasis to design and implementation.

JIT campus has many buildings each building should connected by LAN network, totally optical fiber backbone, seventy-four switches, eleven hubs, and nine access points are used. To ensuring this LAN, it needs parameters analyses such as cost, bandwidth with distance, reliability, better fault protector, and power consumption. Then design best LAN by considering all parameters and evaluate it with existence LAN.

Reliability or failure-free operations of the system evaluate by sample of five times per month each downtime interval is for six hour at one-year time, in power consumption there is difference between LED and LASER optical light source, bandwidth based on JIT demand from ISP and internal communication, cost evaluate from online price. For customer, data prediction is depending on user categories such as light, medium and heavy users. According to these considerations, I proposed new better topology design and evaluate the performance relative to existing LAN.

The proposed scheme is better due to cost difference between single mode and multimode fiber; LED has less power consumption than LASER, length of optical fiber affect reliability, needed bandwidth achieve at both topology and fiber modes. Therefore, there are two mechanisms used to mitigate it, using multimode as much as possible and change topology from extended star to ring-star.

Table of Contents

Content **page**

List of Figures

Figures **Page**

List of Tables

Tables **Page**

List of Abbreviation

ACL	Applications Connection-Less
ADSL	Asymmetric Digital Subscriber Line
CATV	Cable Television
CD	Collision Detection
CDMA	Code Division Multiple Access
CSMA	Carrier Sense Multiple Access
DWDM	Dense Wavelength Division Multiplex
EDFA	Erbium-Doped Fiber Amplifier
EMI	Electromagnetic Interference
FCS	Frame check sequence
FDDI	Fiber Distributed Data Interface
FEP	Fluorinated Ethylene Propylene
FIT	Failure in Time
FOS	Fiber Optic Sensor
FTTD	Fiber to the Desk
GMII	Gigabit Media Independent Interface
IEEE	Institute of Electrical and Electronic Engineers
IEC	International Electro technical Commission
ISP	Internet service provider
ITU	International Telecommunication Union

LLC	Logical Link Control
MAN	Metropolitan Area Network
MAP	Medium Access protocol
MTBF	Mean Time Between Failures
MTTF	Mean Time to Failures
MTTR	Mean Time to Repair
NAC	Network Admission Control
NT	Network Termination
OEO	Optical-electrical-optical
O/E	Optical Signal-to-Electrical Signal conversion
QoS	Quality of Service
PBX	Private Branch Exchange
POE	Power over Enter net
POF	Plastic Optical Fiber
PON	Passive Optical Network
PSTN	Public Switched Telephone Network
PVC	Permanent Virtual Circuit/Connection
SANs	Storage Area Networks
SOAs	Semiconductor optical amplifiers
TIA	Trans-Impedance Amplifier
WAAS	Wide Area Application Service

1. Introduction

1.1 Background

Local area network is computer networks that interconnect computers within a limited area such as a company, campus, schools, organization; its network equipment, and connection manage locally. Wide area network from local area network cover wide geographic area and make logical local or private networks. The impacts of LAN in computers system to achieve local network for fast data transmission between workgroups and resource sharing out of cost. [1]

In 1960s, the demand of computers and interconnected system increase that needs to provide high-speed connections in computer systems. As well as in 1970 the Lawrence Radiation Laboratory releases the developments of the Octopus network achieve best direction for the network by using number of experiment finally latest LAN technologies developed. [3]

The development of computers using the operating system grew in the 1970s after that DOS based systems started in 1981. The first networks provided to share file storage resource and printers it was costly at that time. There is much interest in the attitude for many years onward 1983, computer network companies by professionals disciples claimed year of the LAN [10].

In real world the concept that spread out but not compatible in physical layer and protocol, to share resource that used plethora mechanism. Usually every vendors has different own operating system, network cards, protocol, and cabling. Novell NetWare gave a handling method to resolve incompatible that support for many network card, cable standards, and rather than complex operating system of its competitors. Netware after introduced in 1983 became dominate in market by the individual computer for LAN. In the mid1990s Microsoft announced Windows NT for servers and windows for personal computer users.

Many LANs now based partly or wholly on wireless technologies. Smartphone's, tablet computers and laptops typically have wireless networking support built-in. In wireless local area network to users gives movement without restrict in the coverage area. [2]

Physical topology of network emphasizes the hardware association with the systems includes remote terminals, workstations, servers, and the associated wiring between devices. Physical topologies define the systems are physically interconnected. This means arrangement of devices in a network through backbone cables that transreceive data.

Topology refers to the way in which the network of computers is connected. Each topology is suited to specific tasks and has its own advantages and disadvantages. The choice of topology is dependent upon type and number of equipment being used, planned applications and rate of data transfer required, response time, and cost. The topology also define as the geometrically connection pattern by which the stations may be nodes or computers are connect using suitable transmission media, which can be point-to-point and broadcast [23].

The need for higher speeds by the client has created by a demand for faster access to larger files from the Server. This potential client was involved with heavy drafting and multimedia applications that require more bandwidth through the cabling system. End-user organizations planning cabling upgrades still face tough decisions about which cabling type is the best overall value for their current and projected future needs. Copper-based systems present the same stepladder upgrade path that they have for years, while fiber-optic proponents continue to advocate the "once-and-you are-done" philosophy. In this thesis, I do Comparative Topology Study on a fiber optics local area network in Jimma Institute of technology campus.

1.2 Statement of the problem

JIT is huge technology institute so it need best Ethernet infrastructure. This campus implemented fiber optics backbone for LAN; it is not much effective and not efficient. Fiber optics and optical devices is more expensive. Therefore, this network needs high emphasis to design and implementation. JUICT design LAN for JIT by using fiber backbone with redundancy in front of and behind the building by using extend-star topology.

In this network there is resource wastage so it is not economically effective; it need some improvement in design. Fiber backbone redundancy used to fault preventive, but to Administration, Workshop, and Male dormitory without redundancy. This without redundancy transmission is exposed to easily fault because it gets only one side. So it needs analyses JIT implemented LAN is it feasible or not according to topology.

1.3 Objective

1.3.1 General Objective

To analyses the feasibility of optical fiber backbone topology transmission line in Jimma Institute of Technology local area network.

1.3.2 Specific Objectives

- ✓ Evaluate system of the LAN service with capacities
- ✓ Propose better LAN topology design for Jimma institute of technology
- ✓ Analyse the cost between existing and proposed LAN
- ✓ To analyse the power consumption according to topologies
- ✓ Compare the reliability of the topologies
- ✓ Determine the proposed topology design is efficient than existing LAN

1.4. Scope and Limitation of study

This research focused on the comparative study for Jimma institute of technology LAN topology. According to buildings place, service, and other parameters design new topology for JIT. For ensuring compare, it with existence network topology bases on power consumption, cost, bandwidth and reliability.

There is some limitation such as to take practical measurement in real time of installed fiber not permit for technical intervention, JUICT have not has well written document about all. Compare fiber cost is difficult, because in our country optical fiber cable and some other devices cannot get easily in market, like as copper cat cables. Therefore, I took price from ecommerce sites. Although this thesis well done through challenge and another option.

1.5 Significance of the study

This research work done by detail analysis so it gives many benefits. The first one is give better proposed design of fiber optics LAN for JIT. The second and special one is gives best knowledge for effective LAN infrastructure designing which parameters should take emphasis. The feasibility study of about JIT LAN proposed new design of fiber optics backbone to become smart network. JU ICT gets feedback to improvement of their works and for next new works.

1.6 Methodology of the Study

The method be used to achieve the objectives of this work has some steps

- Study about LAN network, topologies. its equipment, media, properties, Fiber backbone and related topics.
- Data gathering from JUICT about data rate, users, failure, topology and so on.
- Design another LAN topology for JIT campus
- Make comparison of cost, bandwidth with distance, reliability, and power consumption analyses for existing and proposed.
- Finally evaluate the performance of proposed topology relative to existing LAN.

THESIS ORGANIZATION

This thesis consists by six chapters. Chapter one introduces LAN and topology, problem of statement, methodology, scope and limitation of study and significance of the research. Chapter two deal about general literature reviews on local area network.

While chapter three provides about local area network such as fiber Optic technology, focusing on fiber network topology, the physical media used, and the various advantages and disadvantages of using a fiber optic LAN. Chapter four deal about explanations of the existing system and proposed system of JIT LAN Network. Chapter five presents the results, finally chapter six concludes the thesis work and indicates future work.

2. Literature Review

2.1 Local Area Network

The proliferation of electronic and computer technologies in the 1970s made it feasible to place small personal computers at locations where users needed them. Before this, computational tasks had been performed by large computers in centralized locations. The widespread use of personal computers prompted the need for a communication method that could link this equipment. This led to the creation of local area networks (LANs). These networks facilitated the decentralization of computing tasks by allowing network-connected computers to exchange information among themselves, without having to go through a central location[2].

In the modern office environment, each worker is equipped with a personal computer, containing its own disk drives and processor. Each of these computers can communicate with another by the way of a local area network (LAN), which is a computer network that covers a small area, usually a single building or group of buildings. In addition, the LAN may also connect the network of computers with a series of printers, a mainframe computer or file server with even greater processing power and memory storage, and with other devices that can send messages from the network over telephone lines to another location.

As the name suggests, a LAN is local, meaning that it is a proprietary system limited to a finite number of users. It generally serves an area of less than one mile. It is also a network, affording users both functional and communicative diversity through a distribution of resources. A LAN permits workers isolated in separate offices to operate off the same system, as if they were all sitting around a single computer.

One of the great attributes of a LAN is that it may be installed simply, upgraded or expanded with little difficulty, and moved or rearranged without disruption. LANs are also useful because they can transmit data quickly. Perhaps most importantly, anyone familiar with the use of a personal computer can be trained to communicate or perform work over a LAN. But despite their great potential and capabilities, LANs have yet to demonstrate an increase in office productivity. They have certainly eliminated paper and speeded the flow of information, but in many cases they have also created additional work in terms of organization, maintenance, and trouble-shooting.

The advent of personal computers changed the type of information sent over office computer networks. Terminals were no longer "dumb," but contained the power to perform their own instructions and maintain their own memories. This took considerable pressure off mainframe devices, whose energies could now be devoted to more complex tasks.

LANs allowed for the transmission of data between workers. In turn, they enabled this shared data to be directed to a common printer, serving a larger group of users. This eliminated the need for each worker to have a printer and ensured that the one printer provided was not underutilized. In addition, LANs allowed data to be called up directly on other workers' computers, providing immediate communication and eliminating the need for paper. The most common application was in interoffice communications, or electronic mail (e-mail). Messages could be directed to one or several people and copied to several more over the LAN. As a result, an e-mail system became something of an official record of communications between workers. Addressees became obligated to respond to e-mail messages in a timely manner because their failure to answer could be easily documented for supervisors.

Personal computers transformed LANs from mere shared processors to fully integrated communication devices. With processing power distributed among several computers, the mainframe's main role was eclipsed and complex processing, administrative functions, and data file storage became the job of a new device, the file server. Today, there are many different types of LANs. For example, many Macintosh computers use AppleTalk, while IBM computers commonly use Ethernets.

Network topology determine physical connection of assemble equipment’s. The OSI model layer1 and layer2 are essential elements to describe network as bus, ring, star and mesh. In the higher layers layer4 topology of network characterize by the Internet Protocol, it now the transport standard.

LANs basically at minimum consist from one or more hosts and layer2 switches within cabling. This layer2 switch connected to WAN by a router, ADSL modem optical fiber, or cable modem, for Internet access. A LAN functionally consists from different equipment for different application these network equipment’s are gateway, firewalls, servers, switches and hosts. LANs are characterize by their use of repeated links with interconnection by using the spanning tree protocol to protect loops and increase managing ability in difference transmission types through quality of service and to separate transmissions with VLANs.

2.2 Guided Transmission Media

In guided transmission, media the traffic capacity determine in terms of data rate or bandwidth. It measure on the travelling distance and state of the medium is point to point or point to multipoint most guided media in networks are coaxial cable, twisted pair and optical fiber [3].

Transmission Characteristics

Twisted pair used to transmit both analogy and digital transmission. In digital transmission use digital signals and analogy transmission use analogy signal it required amplifiers every 2 km up to 3 km and 5 to 6 km respectively.

According to performance of guided transmission media rank by bandwidth, distance, speed parameters optical fiber, coaxial cable, and twisted pair respectively. Twisted pair is a high strong function of frequency that exposes it for attenuation. These medium is less sensitivity to noise and interference in the reason of electromagnetic fields simple coupling. It can install parallel to an AC power line and impulse noise also simply produce in twisted pair. To reduce the wire interference shielding the cable is one mechanism, twisting cable use to reduce low frequency interference and crosstalk.

For point-to-point analogy signalling, a bandwidth of up to about 1 MHz is possible. This can serve a number of voice channels and long distance digital single end to end-signalling data rates. For very short distances, data rates of up to 1Gbps have achieved in commercially available products.

2.3 Fiber properties

An optical fiber is a thin (2um to 125um), flexible medium capable of guiding an optical ray. Different plastics and glasses type can make optical fiber cables and less loss of fibers by ultrapure silica. Ultrapure fiber cable is difficult to production of glass fibers are better in economical and has good performance. Plastic fibre cable is low costly and used for short haul links. [3]

Optical fiber consists of three concentric parts inner to outer the core, the cladding, and the jacket. The core is the inner part and contain of one or more core strands, it made of plastic or glass. The core diameter for single mode and multimode is in range of 8um to 100um. Cladding is a coating for core, which has optical characters in variety from of the core surround fiber. The cladding surrounds use as reflector to maintain light propagation out of

the core. The outer layer is jacket that manufacture from plastic to prevent from external crushing or damages.

The significant technology invented in data traffic is the growth of practical optical fiber communications system. For long distance telecommunications and military applications is develop highly that use optical fiber for best traffic. The consistent development in performance and degrade of prices within the transparent of the pros of optical fiber increasable interesting for LAN.

Capacity: The bandwidth and data rate of optical fiber is data rates in Gbps over kilometres are claim. Compare this to the real time maximum Mbps over 1 km for coaxial cable and few Mbps over 1 km, twisted pair to 100 Mbps to 1Gbps over a few of meters but fiber t0 10Gbps up to 100Gbps for long kilometres.

Smaller weight and size: Optical fiber cables are thinner than coaxial cables or twisted pair cables. In cramped conduits in building walls, underground in city and across country, the pros of small size is reduction in weight reduces structural provide requirements.

Lower attenuation: Attenuation is necessarily less in fiber optics than for twisted pair or coaxial cable and it is approximately constant over a long distance range.

Electromagnetic isolation: An optical fiber cable in transmission is not affect by other electromagnetic fields and not exposed to interference. Fibers do not emit energy so that little interference in other device and there is a high level of security and difficult to tap.

Transmission Characteristics

Optical fiber transmits a signal-encoded beam of light by means of total internal reflection. The internal reflection may within large refraction index than surround media. In this case, the optical fibers just like a waveguide media in the range of visible and infrared spectrum.

Light from a source enters the cylindrical glass or plastic core. The rays at some extent angles has propagated and reflected in the optical fiber; the surrounding material absorbs other rays. This is step-index multimode propagation indicates to the various angles which would reflect. Multiple paths propagation in multimode transmission takes time to pass through the fiber within different path length. In other hand, the demand to move spacing among the light pulses limits data rates which type of fiber is better performance for short distances transmission. Optical fiber core radius minimized light reflects is angles fewer. A single mode means single angle reflection penetrates to the axis ray in the fiber core. The single

mode support high performance propagation for this reasons there is a single transmission path in single fiber and distortion not occur. Single mode fibers has usually used for long distance purpose such as telecom and cable televisions. Graded-index at multimode fiber that propagates within various refraction indexes in the core.

There are two light sources in optic fiber communication they are the light emitting diode (LED) and laser diode (LD). They are manufacture from semiconductor material when a forward bias voltage applies on it, it can emit light. The pros of LED operate in a high temperature, low costly and better durability but LD emits high power.

Table 2.1: Frequency utilization for fiber applications

Wavelength(Frequency Range vacuum) (nm)	Range (THz)	Band Label	Fiber Type	Application
820 to 900	366 to 333		Multimode	LAN
1280 to 1350	234 to 222	S	Single mode	Various
1528 to 1561	196 to 192	C	Single mode	WDM
1561 to 1620	192 to 185	L	Single mode	WDM

There is a relationship between the wavelength employed, the type of transmission, and the achievable data rate. Single mode and multimode can provide many different wavelengths of light spectrum. Table 2.1 shown optical fiber properties transmission windows based on the attenuation, band and application types and often use modes.

In attenuation, values of optic fiber traffic that optic fiber performance has determine in terms of wavelength better than frequency. The wavelengths respect to transmit in a vacuum that wavelengths state in tabular and graphical. The velocity of propagation in fiber is low speed relative to light speed in vacuum. Because of the frequency of the light signal in fiber is not change so that the wavelength is no change in case of window attenuation.

Several local applications in nowadays-used LED light sources in 850nm window. In this scenario, it is low costly, support distances in few kilometres and it limits data rates are up to 100Mbps. To success, high data rates within long distances that 1300nm so laser source

rather than LED also need but for highest data rates and longest distances applications 1500nm laser sources is highly perform. The mainly loss introduce in transmission are absorption means material sink lights and scattering means in the signal travels in fibers that change direction of light rays by impurities in the medium.

2.4 Local area network equipment

Local area networking equipment's are routers, switches, LAN cards, and hubs. The major condition in LAN devices sending data frames in packet switching in same way as to circuit switches use to sending voice data. A protocol used for communications between from a sender to a receiver. This protocol has work by signal travels in physical medium through copper wire, fiber optic cable and airwaves. The physical links among every sender and receiver of information exchange, data transmission in the medium via nodes, which as circuit switch in the network infrastructure. [4]

LAN equipment support exchanging data between computers, file sharing and browsing with worker group environment. LANs always used to interconnect by groups of users, are may place physically approach and any user in LAN want to shared resource just like a printer. Users out of LAN may group not only physically additionally remote user can access LAN by virtual private network by establish tunnel across networks that act like as same LAN.

When an email has sent from a computer, the computer breaks the message into some frame then frame has send to the network interface card that through cable goes to switch. The frame goes to switches then it act as filters to identify to send a frame next hope.

The switches send the data to a router that oversees in the local network and routers has intelligent out of local network. A router is a complex device that make path that packets should transmit in the network. If the data desire to send in LAN worker the router returns to local network.

The differences in the methods between routers and switches work principles routers has more functionality features than switches in any aspect. Routers can understand network data traffic and analysis better path for sending frame from source to destination. Network management use routers to determine traffic congestion through network. Security features in routers to assure networks secure from undesired access.

2.5 Cabling Lifetime and Total Cost of Ownership

There are several factors that must take into consideration when determining the category or class of cabling that be used in a network infrastructure: Time the end-user will occupy a facility, Expected installed lifetime of the cabling plant. Applications that will run on the cabling plant over its useful life, Timeframe during which standards, applications and electronics manufacturers will support the cabling plant, Cost of active electronics, Warranty length and covered components and Price as it relates to performance[5].

Standards to network

With the IEEE 802.3an 10GBASE-T standard complete, performance demands on cabling infrastructures will continue to increase, with the most significant activity occurring in the move from 10/100/1000 Mb/s to 10Gb/s over the next few years. When looking at how this application performance progression influences cabling choices, it is important to put cabling in perspective. Typically representing 2 - 3% of an overall network hardware budget, cabling has nonetheless expected to perform for 10 years, supporting 2 - 3 generations of active electronics. It is the most difficult, labour intensive and disruptive piece of the infrastructure to replace. With such long-term implications, relying on initial price as the sole deciding factor for the cabling plant is rarely a wise decision. Overall lifecycle costs are closely considered.

Cabling standards have regularly written and reviewed. For instance, ANSI/TIA/EIA (Now TIA) standards have reviewed every 5 years. At the end of the 5-year period, they may be reaffirmed, rescinded or revised. ISO/IEC standards have written with a target lifespan of 10 years. IEEE application performance standards are written, revised or amended based on current manufacturing and product capabilities, application needs and contributions from companies, including cabling manufacturers that participate in the standards process.

In some instances, overall network capabilities change at a greater pace than originally expected. This can shorten the lifecycle of a cabling system. Category 4 is a good example. This cable had a very short lifecycle due to expanding network performance requirements and the capabilities of higher performing category 5, category 5e and then category 6. Predating the ratification of 10GBASE-T, 10Gb/s capable category 6A cabling was introduced to the market and subsequently standardized in ISO/IEC 11801:2002 Amendment 1 and TIA/EIA-568-B.2-10. Although available for some years prior to category 6A, category 7A/Class FA is also a standards approved solution, capable of supporting speeds of 10Gb/s

and beyond. So with all of these available options, the question is how do maximize cabling investment, and what category of cabling should install in facility.

Based on estimates from the major chip manufacturers, each of a chip costs a developer approximately $1,000,000.00 and requires roughly 18 months from conception to market. Facing costs like these, most equipment producers are hesitant to venture too far from the standards. As standards eliminate or rescind support for cabling systems, the active equipment manufacturers will as history shows, follow suit. There is an intricate balance between forward movement in technology and addressing the needs of legacy systems. In discussions within the original 10GBASE-T study group, all categories, including 5e, category 6, category 6A and category 7A/Class FA, were examined to determine what the cabling would support and market share percentage held by each category. While category 5e had a greater market share, it is not capable of supporting 10 GB/s and had written out of the standard. The final cabling choices for the 10GBASE-T standard are category 6A and category 7A/Class FA at the full 100 meters distances and previously installed legacy category 6 over supported distances of 37 meters, with 55 meters possible under best-case alien crosstalk conditions.

It is important to note that the TIA 942 Data Centre standard states that all horizontal cables shall be run to accommodate growth so that the horizontal does not need to be revisit. This is due to the significant cost and risk of downtime. It has estimated that a data centre will be in service for a period of 20 years and 10GBASE-T electronics will be add within 2-5 years. As such, both TIA 942 and ISO/IEC 247643 data centre standards specify category 6A/Class EA as the minimum grade of cabling to deploy in data centres.

Part of the cabling system selection process should include the cost of the cabling itself as well as other factors that contribute to the overall cost over its lifetime. As mentioned previously, a cabling infrastructure should last a customer 10 years and support 2 - 3 iterations of active equipment and applications. A costly factor in these calculations is labour, which may vary depending on geographic location; therefore, national averages will be use.

The following analysis compares the total cost of ownership for a 24 channel cabling system ranging from category 5e through category 7A/Class FA. Riser-rated cable has used in all instances. Initial installation cost includes the cost of components, installation and testing.

System life cycles have based on current standards developments, pending revisions, and the category’s ability to support upcoming applications. For example, non-augmented category 6

systems will have a lesser lifecycle than augmented category six (6A) systems capable of supporting 10GBASE-T up to 100 meters. Category 7 or Class F-systems has longest lifecycle and expecting to support future applications beyond 10GBASE-T such as 40 GB/s. The lifecycle costs for category 7or class F systems do not include the TERA's ability to run multiple 1 or 2-pair applications over one 4-pair cable and outlet which would make the TERA figures more attractive.

The previous idea demonstrates that due to the shortened lifecycle of category 5e, the annualized cost of cat 5e (total installed cost divided by number of useful years) is near 10G 6A UTP. It is expected that during the next 2 -5 years, new 10GBASE-T copper electronics will be available and a cabling upgrade from 5e to at least augmented cat 6 (6A) will be necessary to support 10GBASE-T. It has fully expected that in the next 5-7 years, category 5e systems will move to an archive annex in their respective standards documents and will no longer be support in the active equipment standards. Such was the case with category 3, 4 and 5 systems.

If a category 5e cabling plant had installed prior to adoption of additional performance parameters specified to support Gigabit Ethernet, the cabling plant should be retest for these parameters according to the latest standards. If a factor in the added labour to retest a legacy category 5e cabling plant, the total annualized cost increases.

It becomes clear that over time, installation of a 5e system would cost significantly more. The figures above assume normal hours of operation and do not take into account overtime or other premiums that may be charge if the work is perform after hours to minimize disruption of the operation.

It is important to note that category 5e is not included in IEEE 802.3an 10GBASE-T standard. In order to upgrade to support 10GBASE-T applications, additional labour will be required for both installation of a higher performing category 6A cabling system as well as removal of abandoned category 5e cable as now required by fire codes and legislation in many countries. In the category 6 UTP model, incremental labour is also added to test and verify 10GBASE-T support for channel lengths up to 55m as outlined in IEEE 802.3an and the corresponding TIA and ISO/IEC standards. According to the standards, 55m will only be viable with some type of mitigation to reduce alien crosstalk. This are not accounting for after-hours installation or tracing cables if the labelling and documentation on the system.

The cost to replace or run new conduit or drill new cores as needed to accommodate the new circuits due to increased cable diameters is also included.

If consider downtime costs while testing and replacing the non-compliant 10G systems, the category 5e and 6 total costs of ownership figures continue to increase. As cable testing is intrusive of the device at the other end must be disconnect in order to test, some downtime will occur at each line testing and remediation.

3. Local Area Network overview

3.1 Introduction to Local Area Network

Local area networks first emerged in companies and their utilization was mainly associated with the office premises, but recent trends are pushing them more towards home environments. The main benefit of having a LAN is that it provides a possibility for sharing resources, like printers, drives and databases, and exchanging the information processed by individual computers. Resource sharing is important for enabling cost cutting [6].

LANs can be distinguish from the other network types by geographical area of coverage, data transmission rates, ownership, government regulation, data routing and the type of information transmitted over the network. This area can range in scope from the group located in an office building to the department located on several floors in the building, or to several buildings on the university campus. The size of the coverage area will depend on the physical transmission limitations regarding cable distance between the devices connected to the LAN.As far as transmission rate is concerned, LANs normally operate at a megabit per-second rate, while MANs and WANs operate at gigabit-per-second and terabit-per-second rates, respectively. Although the latest LAN implementations already accommodate gigabit-per-second rates, data rates in MANs are still much higher, going to 10Gbps or 40Gbps in the lab per channel.

In difference with the other types of networks, LANs has usually own by the organization that installed it. Since they cover a relatively small area, no special governmental regulations are necessary. Instead, building regulations determine the type of the wiring that can be installing in a building and whether the wiring must be aligning in a conduit. Another important feature of the LANs is that data has routed along a path that defines the network. That path is usually a bus, ring or a star. More complex topologies like the mesh commonly use in WANs. The types of the information transported on the LAN are data, voice and video.

3.2 Network Topology

The topology of a LAN refers to the shape of a network, or the network's layout. How different nodes in a network are connecting to each other and how they communicate is determine by the network's topology. Topologies are either physical or logical. LAN is the end connection it may be logically or physically after router to client [6].

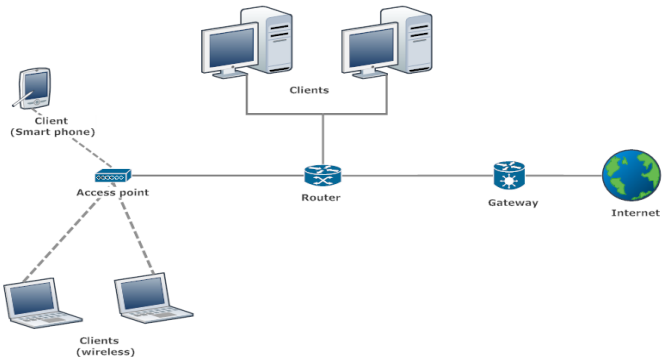


Figure 3. 1: Physical internet network orientation

Client: It is a user access network. Usually such as computer, smart phone. Clients may be mobile or fixed.

Router: The router connects different subnets and forwards information to the correct destination.

Access point: In a wireless network client, connect to the rest of the network through an access point. The access point transmits and receives radio frames for WLAN equipped devices enabling them to communicate. The difference between an access point and a router is that an access point only connects clients within a subnet, rather than interconnecting subnets. However, one can think of an access point as interconnecting a wireless subnet with a wired subnet.

Gateway: The gateway has used to connect the network to another network, usually the Internet. A computer with two or more network interfaces can use as a gateway. However, today the gateway has often implemented as a combination of a router and a firewall, with optionally many local server functions, such as acting as a DHCP server, DNS server, VPN end, etc.

The most common physical topologies used in LANs are bus, ring, star and tree. They have illustrated in Figure 3.2.

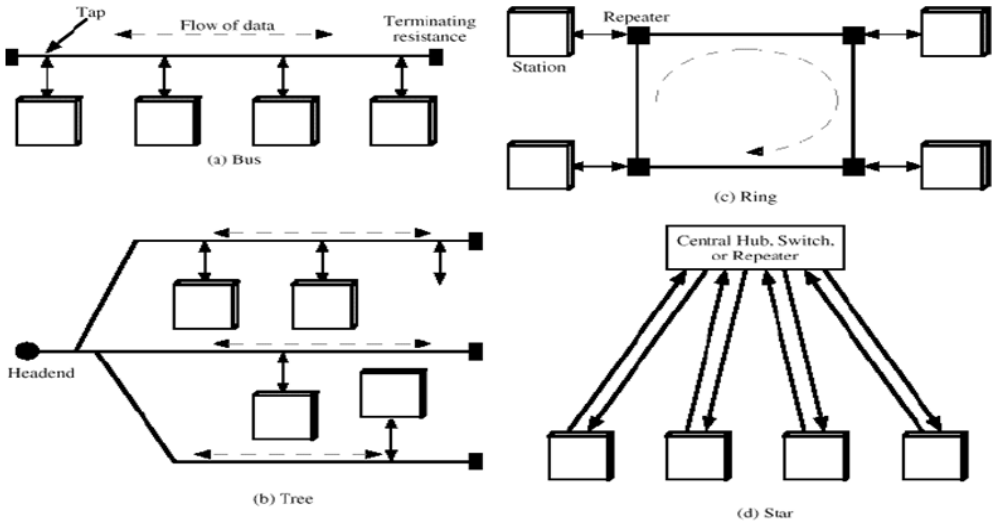


Figure 3. 2: The most common geometric layouts of local area network topologies

Bus

In Bus Topology, all stations attach through appropriate hardware interfacing known as a *tap*, directly to a linear transmission medium, or bus as shown in Figure 3.2.a. Full-duplex operation between the station and the tap allows data to be transmitted onto the bus and received from the bus. A transmission from any station propagates the length of the medium in both directions and can be received by all other stations. At each end of the bus there is a terminator, which absorbs any signal, preventing reflection of signal from the endpoints. If the terminator is not present, the endpoint acts like a mirror and reflects the signal back causing interference and other problems.

Key characteristics of this topology are flexible, expandable, moderate reliability, moderate performance. A shared link is used between different stations. Hence it is very cost effective. One can easily add any new node or delete any node without affecting other nodes; this makes this topology easily expandable. Because of the shared medium, it is necessary to provide some extra information about the desired destination, i.e. to explicitly specify the destination in the packet, as compared to mesh topology. This is because the same medium is shared among many nodes. As each station has a unique address in the network, a station copies a packet only when the destination address of the packet matches with the self-address. This is how data communications take place among the stations on the bus [23].

As there are dedicated links in the mess topology, there is a possibility of transferring data in parallel. But in bus topology, only one station is allowed to send data at a time and all other stations listen to it, as it works in a broadcast mode. Hence, only one station can transfer the

data at any given time. Suitable medium access control technique should be used so as to provide some way to decide “who” will go next to send data. Usually a distributed medium access control technique, as discussed in the next lesson, used for this purpose.

As the distance through which signal traverses increases, the attenuation increases. If the sender sends data (signal) with a small strength signal, the farthest station will not be able to receive the signal properly. While on the other hand if the transmitter sends the signal with a larger strength (more power) then the farthest station will get the signal properly but the station near to it may face over-drive. Hence, delay and signal unbalancing will force a maximum length of shared medium, which can use in bus topology.

Ring

In the ring topology, the network consists of a set of repeaters joined by point-to-point links in a closed loop as shown in figure 3.2.c. The repeater is a comparatively simple device, capable of receiving data on one link and transmitting them, bit by bit, on the other link as fast as they are receive, with no buffering at the repeater. The links are unidirectional; that is data are transmit in one direction only and all are oriented in the same way. Thus, data circulate around the ring in one direction (clockwise or counter clockwise) [23].

Each station attaches to the network at a repeater and can transmit data onto the network through that repeater. As with the bus and tree, data are transmit in frames. As a frame circulates past all the other stations, the destination station recognizes its address and copies the frame into a local buffer as it goes by. The frame continues to circulate until it returns to the source station, where it is remove. Because multiple stations share the ring, medium access control is need to determine at what time each station may insert frames.

How the source knows whether it has to transmit a new packet and whether the previous packet has been received properly by the destination or not. For this, the destination change a particular bit (bits) in the packet and when the receiver sees that packet with the changed bit, it comes to know that the receiver has received the packet.

This topology is not very reliable, because when a link fails the entire ring connection is broken. Nevertheless, reliability can be improved by using wiring concentrator, which helps in bypassing a faulty node and somewhat is similar to star topology.

Repeater works in the following three modes; **Listen mode** is the station listens to the communication going over the shared medium, **Transmit mode** is the station transmit the data over the network and **By-Pass mode** means when the node is faulty then it can be

bypassed using the repeater in bypass mode. It does not care about what data is transmit through the network. In this mode there is no delay introduced because of this repeater.

Star

A star topology is one of the most used LAN topology within office premises. It became very popular because of the low cost and ease of troubleshooting. In this topology, each end station has connected to a central node using a point-to-point connection. Access from any end station on the network to any other end station has accomplished through the central node. The networks presented in this thesis are also based on a passive star topology but suffer no echo problem due to a special construction of the star coupler and the access method used CSMA/CD. The advantage of the star topology is that if one computer fails then only that computer is unable to send or receive data. The remainder of the network functions normally. The disadvantage of using this topology is that the entire network fails when the central node fails [23].

In general, there are two alternatives for the operation of the central node.

- One approach is for the central node to operate in a broadcast fashion. A transmission of a frame from one station to the node is retransmitting on all of the outgoing links. In this case, although the arrangement is physically a star, it is logically a bus; a transmission from any station received by all other stations, and only one station at a time may successfully transmit. In this case, the central node acts as a repeater.
- Another approach is for the central node to act as a frame-switching device. An incoming frame is buffer in the node and then retransmitted on an outgoing link to the destination station. In this approach, the central node acts as a switch and performs the switching or routing function. This mode of operation can be compared with the working of a telephone exchange, where the caller party is connected to a single called party and each pair of subscriber who needs to talk have a different connection.

Very High speeds of data transfer can achieve by using star topology, particularly when the star coupler is use in the switch mode. This topology is the easiest to maintain, among the other topologies. As the number of links is proportional to n, this topology is very flexible and is the most preferred topology.

Tree

A tree network structure consists of a combination of bus and star topologies. In fact, groups of star-configured networks have connected to a linear bus backbone. Tree topologies allow for the expansion of an existing network. A disadvantage of this structure is the propagation delay since the two stations located at the opposite ends of the network require a signal to propagate twice the length of the longest network segment. A passive optical network (PON) is one of the examples of the tree topology networks [23].

This tree topology is very good in an organization as incremental expansion can do in this way. It is commonly use in cascading equipment. Main features of this topology are scalability and flexibility. Because, when the need arises for more stations that can accomplished easily without affecting the already established network.

3.3 Gigabit technology

Gigabit Ethernet appeared as the extension to the existing Ethernet and Fast Ethernet standards. Interest in introducing this standard came from the fact that computer speed increased such that transferring the files among computers and servers became a bottleneck. Moreover, video conferencing demands more bandwidth than the existing local area networks support [7].

3.3.1 Gigabit design structure

The design objectives for Gigabit Ethernet were to offer 10-fold increase in bandwidth with respect to the Fast Ethernet standard, to support both full and half-duplex operation and to be compatible with the previous Ethernet standards. To achieve this most changes had to make in the Physical layer. Three different standards were specific depending on the types of media used to transmit data, namely 1000BASE-SX, 1000BASE-LX and 1000BASE-CX. The main difference with respect to the previous Ethernet standards are introducing carrier extension and frame bursting [7].

Carrier extension had to be introducing due to collision detection. It means the small time to detect collision at the time that takes delay of the signal to propagation from source to destination. However, increasing the speed requires proportional decrease in the network span. Keeping in mind that the maximum network span for the Ethernet network is 2.5 km,

increasing the speed 100 times would limit the span of Gigabit Ethernet network to about25 m only.

The remedy to increase the network span was to increase the Slot Time and at the same time increase the minimum frame size. Nevertheless, in order to maintain compatibility with the previous Ethernet standards, the minimum frame size could not be increase. This particularly regards networks using half-duplex transmission and CSMA/CD at gigabit rates. For full-duplex transmission networks, this is of no importance since the Slot Time does not limit the network span. To increase the Slot Time keeping the minimum frame size unaltered a carrier extension technique is implemented. According to the standard, the use of this technique increases the Slot Time from 64 bytes to 512 bytes. A composition of the Gigabit Ethernet MAC packet using the carrier extension technique has presented in Figure 3.3.

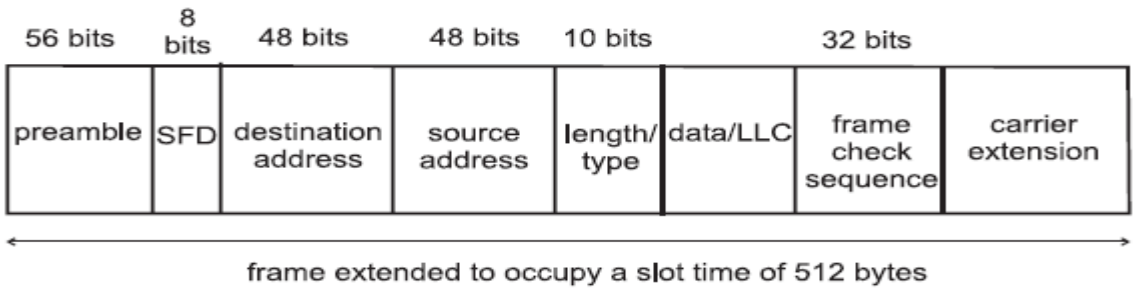


Figure 3. 3: A Gigabit Ethernet packet composed using carrier extension technique.

Whenever the Gigabit Ethernet packet size is shorter than 512 bytes the packet is pad with the extension symbols that do not appear in the payload. The packet size increases, but as far as both transmitter and receiver are concerned the packets are normal Ethernet packets. The Frame Check Sequence is to calculate on the part of the packet before padding. The LLC sub-layer is not aware that carrier extension is being use. The carrier extension is a technique that provides a simple solution to increase the network span when Gigabit Ethernet is accommodate but it has also a drawback. It is very bandwidth inefficient, especially for the short packets. For example, for the shortest Ethernet packet of 64 bytes, 448 bytes of padding have to be adding, resulting in a low throughput.

The solution for increasing the throughput is frame bursting. This feature distinguishes Gigabit Ethernet from the other Ethernet standards. This technique allows stations to send a number of short packets such that full available bandwidth utilization can be achieve. If the end station has several short packets to send, the first packet has padded to 512 bytes and the other packets have just attached to the first one keeping the interframe gap between the two

consecutive packets of 96bits. Instead of allowing the medium to go idle between frames, the transmitting station fills the interframe gaps with extension bits. Extension bits are no data symbols that maintain an active carrier, and are readily distinguished from data bits by receiving stations. The total burst length can be up to 1500 bytes, which is the maximum frame size defined in the Ethernet standard. The frame bursting technique, shown in Figure 3.4, considerably increases the throughput.

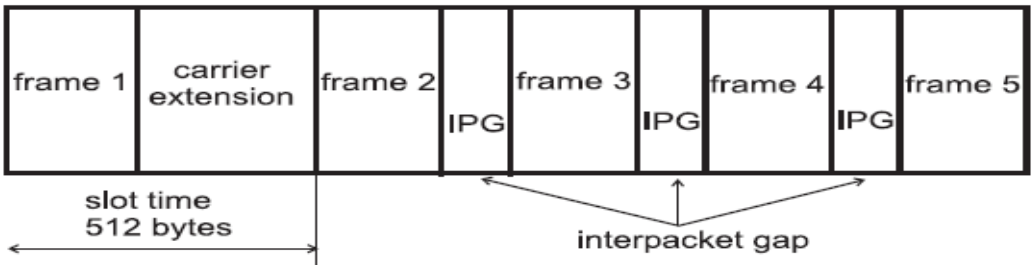


Figure 3. 4: Frame bursting in Gigabit Ethernet.

Important to add about the Gigabit Ethernet is that it defines a gigabit media independent interface (GMII) that supports 10-, 100- and 1000 Mbpsdata rates. It provides an 8-bit bus for both transmission and reception, so it can support both full duplex and half-duplex modes of operation. The encoding scheme in Gigabit Ethernet has changed from 4B/5B to 8B/10B. Although this technique allows for good error detection and reliable synchronization of bits, it is bandwidth inefficient, introducing 25 % of overhead. The actual signalling speed has thus increased from 1Gbps to 1.25Gbps.

3.3.2 Gigabit Ethernet over Fiber

1000Base-X Gigabit Ethernet has originally designed as a switched technology, using fiber optic cable for uplinks and for connections between buildings. Fibers typically used to connect network facilities spread over wide area; IEEE standards specify fiber for cabling distances greater than 100 meters[7].

Even when long distances are not involved, environment can play a part in the choice of fiber over copper. For example, fiber is less susceptible to the electro-magnetic interference that can affect data transmission over copper.

Special Considerations

Security: Fiber may be the best option for intra-building applications and other situations where cabling runs must be leave expose. Fiber-optic cable cannot be splice except under clean-room conditions, making it nearly impossible for a hacker to tap into the cable.

Related Expense: Installation of fiber-optic cable can be difficult, and therefore more expensive than Cat-5 copper cable. The termination and connectors, as well as optical receivers (switch ports), are costly such equipment have reduced significantly.

Desktop Deployment: It appears that unless security or interference is concerning, deploying of fiber to the desktop may be still costly as switch ports need to be replace. Also current fiber technology is not capable of powering network-attached devices at the desktop level.

3.3.3Advantages of a Gigabit Network

Gigabit is 100 times faster than regular 10Mbps Ethernet and 10 times faster than 100Mbps Fast Ethernet. Advantages as a networking technology include:

• Increased bandwidth for higher performance and elimination of bottlenecks

• Power to transfer large amounts of data across a network quickly

• Ability to aggregate network bandwidth to multiple-Gigabit speeds

• Quality of Service (QOS) features to help configure network traffic and optimize critical data

3.4Fiber technology

A basic fiber optic cable is made up of a thin, highly transparent strand of glass, or sometimes plastic, and guides lights. A fiber optic cable consists of the following [8]:

Core: The centre of the fiber is glass or plastic where the light is transmission.

Cladding: The outside optical layer is glass, but a different density then the core of the fiber that traps the light in the core and guides it along even through curves.

Buffer coating or primary coating: it is hard plastic coating on the outside part of fiber, to protect the glass from moisture or physical damage.

Basic Fiber Optic Communication System

Fiber optics is a medium for carrying information from one point to another in the form of light. A basic optic fiber system contains of light transmitter, light detector and light transmission media. The light source diode converts electrical signal to light then light signal pass through optical fiber cable when light signals arrive to receive detector converts it into electrical signals. Optical fiber in transmission different concept from copper cable is not electrical in nature. The complex system of an optic fiber system can support local area network, long distance telecom, and extremely sophisticated [8].

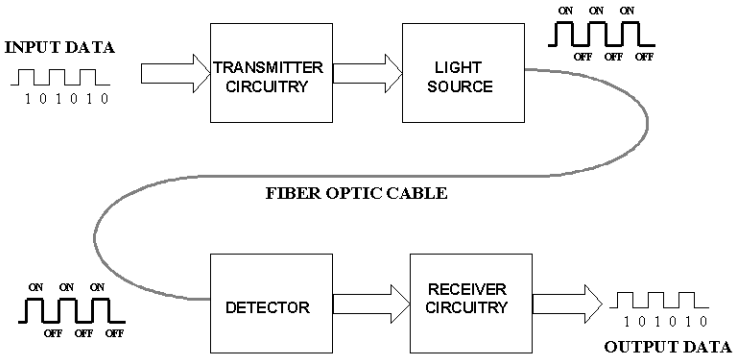


Figure 3. 5: Basic fiber optic communication system

The above figure shows the built within LED or laser source, silicon photo detector, plastic fiber, and transmit and receive circuit. It means these system used to long distance, high bandwidth telecommunication that for needed wavelength-division multiplexing, erbium-doped fiber amplifiers, modulation by using DFB lasers with temperature compensation, and high speed infrared photo detectors. The different components make a fiber optic communication system and the considerations should done in the design of such systems.

Transmission Windows

Optical fibers transmission support wavelengths that are in the near-infrared spectrum, they are not understandable to eye, it just above the visible light waves. LEDs used to multimode purpose it transmits light on 850 or 1300nm. Lasers emitters have usually used for for single mode applications on 1310 or 1550nm.

The ranges of windows wavelength at which the fiber operation is best. In each window the entered value is typical value for operational wavelength, as shown below in Table 3.2.

Table 3.1: Fiber Optic Transmission Windows

Windows	Operating Wavelength
800nm – 900nm	850nm
1250nm – 1350nm	1310nm
1500nm – 1600nm	1550nm

Fiber Optic Source

The main light sources used to fiber optic system are laser diodes and light emitter diodes. Optic fiber cable sources should operate in the low loss of transmission windows in glass fiber. Both sources have their own advantages and disadvantages LED's are large numerical aperture, wide spectrum width, easier to operation, slower in data rate, emit low power and low cost. Laser sources are smaller numerical aperture, narrow spectrum width, difficult for operation; fast data rate speed and emit high power.

LED: use for high data rate for short distance. Two basic structures for LEDs used in fiber optic systems: surface emitting and edge emitting. In surface-emitting LEDs, the radiation emanates from the surface. LEDs typically have large numerical apertures, which makes light coupling into single-mode fiber difficult due to the fiber's small N.A. and core diameter. LEDs most of the time used to multimode fibers. LEDs operate in a linear method than do laser diodes. The output spectrum of LED value is around 40nm, this limits its performance because of severing chromatic dispersion. The LED has a more linear output power that makes it more suits for analogy modulation. This makes the system more suits for analogy modulation. Always these devices are pigtailed, having a fiber attached during on the manufacturing. General applications are closed circuit TV, local area networks, and transmitting information in areas where EMI may be a problem. Some LEDs allow a connection fiber directly attach that are available with connector ready housings.

Laser diodes (LD) have a much higher output power than an LED, it is capable of over longer distances to transmitting information. Laser diodes used in applications in which

higher data rates longer distances are required. To drive current and temperature fluctuations in that causes their output wavelength to become disperses. The LD's has smaller numerical aperture, also it allow being more effectively couple with single mode fiber. In wavelength division multiplexing (WDM) the many wavelengths transmit signals in fiber with stability of light source. The advantages of laser diodes are for transmission to high speed over long distance. This always need mechanisms to detect and correct error and in large circuits disperses in wavelength.

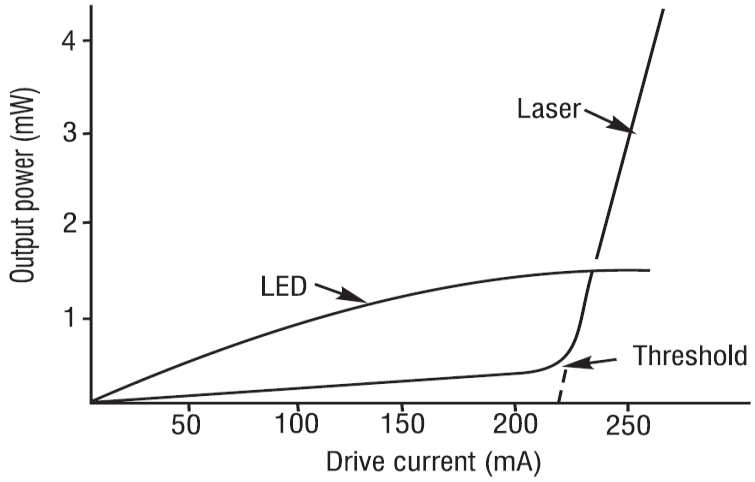


Figure 3. 6: Drive current versus output power for LED and laser

Single mode Advantages

Single mode cable provides less signal attenuation, higher transmissions speeds, and up to 50 times greater transmission distance than multimode cable. Single mode cable can transmit data at terabits per second over 100km without requiring reamplification of the signal [9].

Single mode fiber typically has a diameter of only 8.3 to 10 microns, which is much narrower than multimode fiber, which is usually 50 to 100 microns in diameter. The small core of a single mode fiber allows for the propagation of only one light wave, so there is no possibility of distortion due to overlapping light pulses. In addition, single mode is more stable than multimode for systems that have branching devices, such as couplers.

Multimode Advantages

Multimode fiber optic cable and components are less expensive and easier to work than single mode. This is due largely to the fact that the multimode fiber core is larger, and alignment tolerances are much less critical than they are for single mode fiber. Like single

mode, multimode fiber provides high bandwidth at high speeds, but transmission is limited to shorter distances than single mode. In longer cable runs, the multiple paths of light in a multimode fiber tend to create signal distortion.

Multimode cable core is made of glass fibers; diameter usually 50 up to 100 micron in the common is 62.5micrometers. Multimode cable is also available as low-cost plastic optical fiber (POF), which offers performance similar to glass cable for very short runs.

When deciding whether to use multimode or single mode fiber to proper topology, a lot depends on a system's current and future bandwidth requirements. As a general multimode bit rate as being limited to 100Mbps over distances up to 40km, with shorter links allowing for bit rates up to 10Gbps.

If system is comprised of, relatively short fiber links and bandwidth requirements not expected to exceed multimode capacity over the system's lifetime, then multimode may be the logical choice. It is less expensive to purchase, install and maintain.

Today, multimode fiber optic systems are lagging behind single mode systems in terms of growth. In addition to supporting high data throughput, single mode systems are attractive because they are easy to upgrade and help to "future proof" installations. Multimode is still the fiber of choice for many applications. For example, multimode fiber optic cable is well suited for systems that have short fiber optic links, such as local area networks and storage area networks.

3.5 LAN structure

3.5.1 Hierarchical Design Model

This architecture uses a hierarchical design model to break the design up into modular groups or layers. Subsiding of the network design by different layers that layer consider all functions each and specific that used to simplify the network design, to simple implementation and management.[10]

Hierarchical networks have advantages over flat network designs. The significant of divide a flat platform network to smaller and easy for management of hierarchical sector in internal system. The data exchange destination on going to another network by pass to higher layer.

Layer2 equipment in a flat platform network support minimum opportunity to control broadcasts service or selection of undesired data. Applications and equipment's add to a network platform, that reply time minimize up to the network becomes stable.

At meshed and flat platform network structures of the network within small, simple to understand elements also organize resiliency by fault isolation. Advance working change for a subpart of the network in hierarchical design that makes it simple to management and better resilience. There are three layers of hierarchical design:

• Core layer: support applications with connection all distribution for large networks.

• Distribution layer: the aggregates access layers and support connectivity to core layer.

• Access layer: it supports end user to communicate with the network.

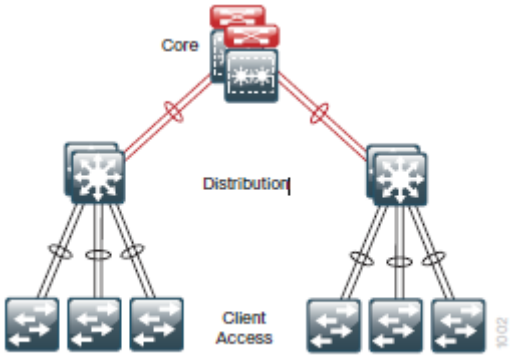


Figure 3. 7: Hierarchal network design structure

Core Layer

In multiple distribution layer switches case access layer switches are placed in multiple geographic areas then it can runs by setting a distribution layer switches.

Networks expand above the distribution layers in a single location; that optimize the design. To increase the performance of the network using multiple distribution layer switches is better than use of a single distribution layer. A reliable and scalable network design can aggregate distribution layers to data centre and internet connectivity services. In network multiple distribution layer switches system deploy is closest and fiber optics support high data rate in interconnection as well as core layer minimize the network complexity.

The core layer is a main sector is to scalable network; it is one of the options by design. The distribution layer supports core layer for fault management and control system in the latest user to share resources and effective work.

Distribution Layer

Distribution layer makes most necessary services for the local area network. The first function is to make aggregation from different points for multiple access layers for desired place or organization. Where network connection needs to transparency in the LAN end to end, among different access layer equipment's or from access layer equipment to the WAN, the distribution layers ensure this connection.

Multiple access layer devices exist in all networks at a place to make end user connection. It comes unreal to interconnect every access switch in the access layer exceed above two or three access layer switches. Distribution layer support virtual points within addressing and make a restriction for features are important protocols in the access layer process. The other use of the distribution layer restriction makes fault domains that have network failures in which sector of the network. The distribution layer gives less cost of operation and increase efficiency the network that needed processing resources and less memory. Network availability assure by distribution layer that make failures to small or affected part. The distribution layer support connection to become networked, for different services from internet it connect WAN.

Access Layer

The access layer is the point at which user-controlled and user-accessible devices connected to the network. Access layers supports wireless and wired connection. It's all features of services that assure resilience and security for the network.

Access layer supports high speed user accessibility and user control in equipment connectivity. End user equipment in many cases it will not use the whole capacity of this connectivity for long time of interval, the able to damage. More expensive alternative way of high speed access technologies such as gigabit Ethernet and 802.11 wireless families are known standard for end user equipment. The routine in high speeds used to increase the network performance in subpart of end users.

It is common for many different types of devices to connect at the access layer. In the same access layer, switch device of these cases to partition these different devices for the access layer connection. By physical infrastructure, it provides most logical networks within high performance, easy management, and strong security.

The aim of the security and resiliency services in the network is to assurance of the network that is available for purpose out of denial for any user that needs service. It issued on assuring the network protection from human mistakes and from another attack. It means the access layer is the connection point between the network provider and user equipment. This security includes making certainty that equipment connect to the network done not only assume to provide application services to everyone end users.

Access layer support of network application services that provide had better innovation technologies. Video and voice are often use in now days the network and organizations should support application services which enable these innovated technologies. This includes providing perfect access on those equipment, that assuring another do not unpaired the traffic from those equipment, and supporting acceptance efficiently for traffics which needed by most equipment's in the network.

Quality of Service (QoS)

The network should assure that the type of channel signals has process with priority in this case the streaming of audio or video signals has not interfered each other. It takes bandwidth from one section this is generally the default traffic section to deliver bandwidth to another section. In this design the approach to applying QoS potential is to maintain the QoS, significantly to achieve the objectives for providing applications which need prior deliverance. To design uses a three step options to deploying QoS through the network:

• making a limited number of traffic sections that is one to eight sections in the network which desire best processing for interactive traffic, real-time voice, high priority data, batch traffic, real-time video, and default sections.

• Subsidize applications into the traffic sections.

• Make best processing to the traffic section to achieve needed network character.

In the design, QoS configurations are as easy much as possible and make only to those applications that need best processing within modular framework to implement QoS in the network.

3.5.2Fiber Optic System Design Considerations

When designing a fiber optic communication system some of the following factors must be taking into consideration [8]:

- Which modulation and multiplexing technique is best suited for the particular application
- power budget: enough power available at the receiver
- Rise-time and bandwidth characteristics
- Noise effects on system bandwidth, data rate, and bit error rate
- Amplifier: such as Erbium-doped fiber amplifiers
- What type of fiber is best for the desired application
- Cost

Fiber modulation

Lasers and LEDs used in telecommunication applications modulated using one of two methods: direct modulation or external modulation.

- External modulation is making modulation by external device. Modulation methods work on the light signal phase or intensity. The external modulation usually done in high speed needed applications may cable TV or back-haul telecommunication. The pros of this modulation used for higher power laser signals with faster speed. The cons are more costly and it requires complexity circuitry to process high radio frequency modulation signal.
- Direct modulation is the input to the output in the processor, from both light signal sources signals can modulate. The main pros of direct modulation are being less costly and simple. The cons are slower compute time than indirect modulation due to limitations of less capability if frequency greater than 3GHz.

Fiber Multiplexing

The multiplexing is to share the bandwidth in a single channel for many transmit data's by one tunnel. There are two mechanism of multiplexing that used in optics fiber:

Time Division Multiplexing

Time division multiplexing is time based on the information channel in fiber that shared among the various data sources. The multiplexer at high speed of individually connection to every input to the communicate channel for a limited interval of time. The demultiplexer is the inverse process into the output with a device. Each channel by sequence connects the process cycles itself. Frame is one complete cycle. To assure each channel connected on the input to its correspondent channel on the output. It starts and stops packet entering to synchronize the input with the related output. This multiplexing system transmits information by using time slot to the digital and analogy modulation schemes.

Wavelength Division Multiplexing

In wavelength division multiplexing is data channel transmit by slightly different wavelengths. Different wavelengths for multi-channel without interruption channels transmit by single fiber. This method used to increase capacity of optic fiber. Dense wavelength division multiplexing is the transmission of multiple rarely separate wavelengths via the one fiber. ITU release standard for frequency spacing Δf as 100GHz, that means $\Delta\lambda$ of 0.8nm wavelength spacing. The relationship $\Delta\lambda=\lambda\Delta f/f$. DWDM systems work in the 1550nm because of the less attenuation of glass behaviour at 1550nm and the erbium doped fiber amplifiers (EDFA) work in the 1530nm up to 1570nm range. It is available systems in nowadays to multiplex up to 32 individual wavelengths within 10Gbps and 128 individual wavelengths within 2.5Gbps. ITU grid specifies each transmit wavelength in DWDM system spacing by 100GHz systems now development on progress have claim that minimize the channel separation to 50GHz and should below <0.4 nm. The channel separations reduce the number of channels, which can be, transmits increases for the transmission capacity of the system.

Bandwidth and Rise Time Budgets

The transmission data rate of a digital fiber optic communication system is limit by the rise time of the various components, such as amplifiers and LEDs, and the dispersion of the fiber. The total effect of whole components in the system by own different rise time, that didn't restrict the bandwidth.

4. JIT LAN Network Analyses and Design

Jimma University (JU) is a public research university located in Jimma, Ethiopia, the city of Jimma, situated around 352 kilometres southwest of Addis Ababa. Its grounds cover some 167 hectares. The establishment of Jimma University dates back to 1952 when Jimma college of Agriculture founded. It recognized as the leading national university, as ranked first by the Federal Ministry of Education for four successive years (2009 - 2012).

Jimma University is one of the largest and comprehensive public research universities in Africa. The university graduates innovative professionals through its community oriented educational philosophy in the fields of agriculture, environment, health and medical sciences, natural and social sciences, technology and information sciences, business and economics, and education. The University has more than 4,000 faculty and staff members. It also has twelve research facilities, a modern hospital, a community school, and a community radio station (FM 102.0), an ICT centre, libraries and revenue generating enterprises. The university is operating on four campuses and it is on the phase of establishing its fifth campus at Agaro. Currently, the university educates more than 43,000 students in 56 undergraduate and 103 postgraduate programs in regular, summer and distance education with more enrolments in the years to come. The university has many national and international linkages and collaborations in the area of research, education and community service. Its innovative educational philosophy, staff commitment, motivation, and availability of better research facility have helped the university in attracting both national and international partners. Jimma Institute of Technology campus is Engineering and ICT learning and research centre located in KitoFurdisa, it also called KitoFurdisa campus.

Figure 4. 1: Jimma University Institute of Technology campus map

4.1 Existing LAN and Component

JIT local area network implemented based on the hierarchical model architecture. This hierarchical model is core, distribution and access layers. To communicate those devices media needed. In JIT LAN router or core, switch use for gateway as well as firewall purposes. Distribution layer used for provide connectivity and aggregate access layers to services. Access layer provide workgroup access to the network to achieve number of host in LAN. These devices interconnect by indoor and outdoor cables. To implement copper LAN or fiber LAN the only difference is transmission media other equipment is the same for example 1000BaseT copper modelled switches has fiber port so there is no switches differences because it depends on vendor. In transmission media design, the concerning issues are cable, terminators, repeaters and connectors. Therefore, in this chapter, detail discussion area for integrated copper to desktop and fiber for backbone LAN is design issues. Generally, let us see used devices such as switches, access point and hub to achieve desirable services for JIT LAN and repeaters may be implementing in LAN in case of for extending cable length but not applied there.

Internet network concern of JIT staffs and students to give enough service for those who need more devices with cost effective feasibility of fiber optics LAN implemented by considering the existing infrastructure. The existing network device settlement listed below.

Totally 74 switches, 11 hubs and 9 access points are available in JIT LAN. Below there is detail physical configuration or placement explanation.

- **Administration building**: in the building there are three blocks (Block A, Block B, Block C) each block has three floors. Each floor has one switch and in each block, there is one access point. Totally, there are nine switches and three-access point.
- **Library** in ground floor there are four switches, one hub and one access point, on ground plus one there are two switches.
- **In Rama** class room building except wing three all floors have two switches but in wing -3 only one switch at ground plus one. Totally, there are twenty-five switches.
- **In Varnero**classroom building there are thirty-one switches, nine hubs and one access point. Wing -5 has three switches and one hub on ground and one switch and one hub on ground plus one, ground plus two and ground plus three. In wing -6 four switch and one access point in ground floor, two switches on each ground plus one and ground plus three and one switch and one hub on each ground plus two and four. Wing seven has three switches on ground, two switches on ground plus three, and one switch and one hub on each ground plus one and four. Last wing eight has two switches on each ground, ground plus one and ground plus two. In ground plus three one switch and one hub is there.
- **Student dormitory** there are two destination female dormitory and male dormitory. For females dormitory there is one switch and one access point and for males' dormitory one switch and two-access point are available.
- **Student clinic** has one switch, one hub and one access point.
- **Student café** has one switch
- **Workshop** building now pending but only one single mode fiber installed.

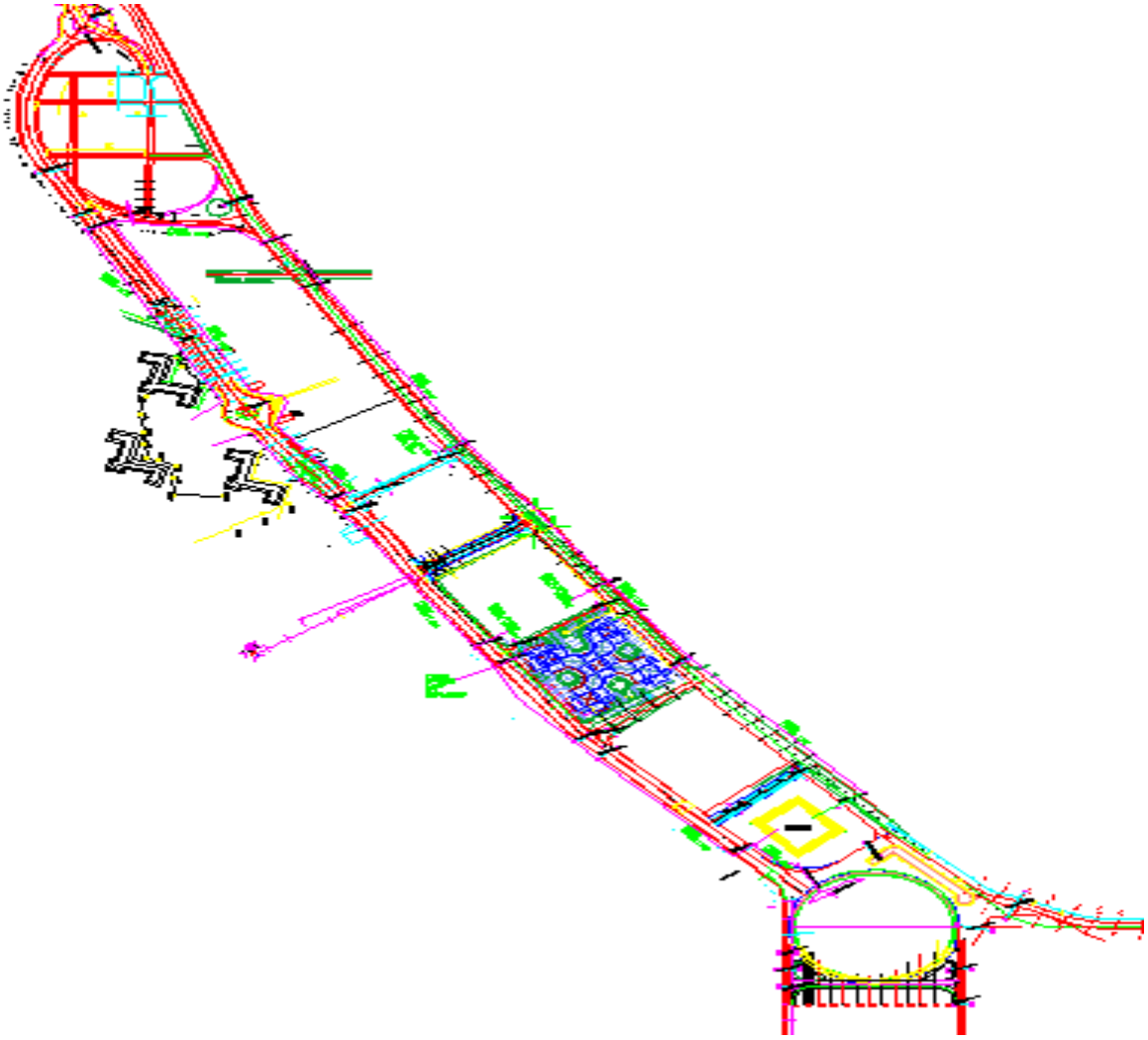


Figure 4. 2: Autocad optical fiber layout of JIT LAN

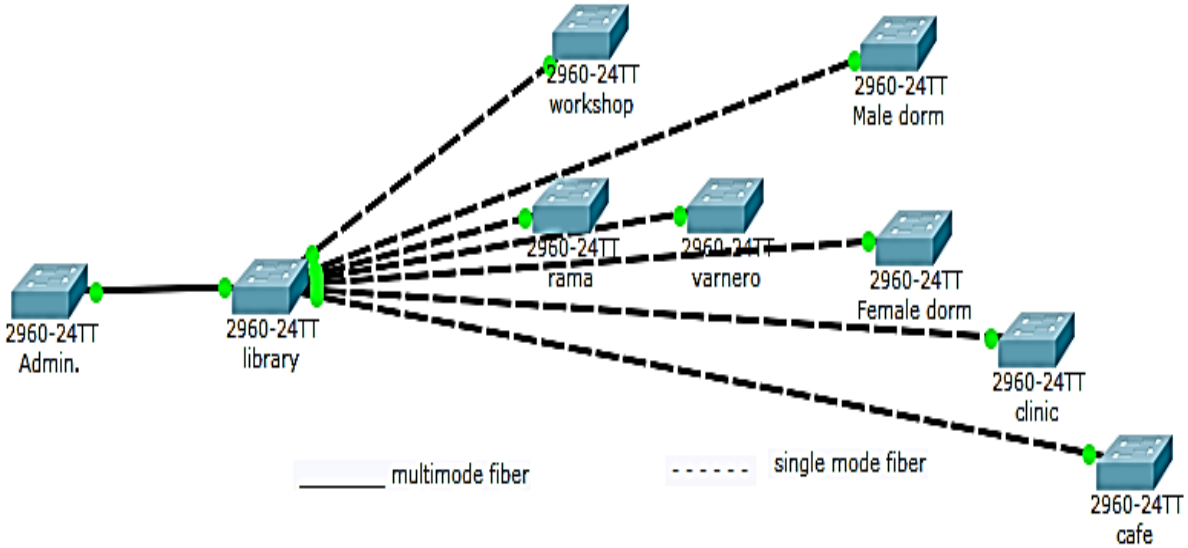


Figure 4. 3: Existing LAN extended star topology without fiber redundancy

Ethernet is a multi-access, packet−switched system. The stations themselves provide access to the network, and all devices on an Ethernet LAN can access the LAN at any time. Ethernet signals are transmitted serially, one bit at a time, over a shared channel available to every attached station. Network system contains number of sub system with number of devices such as switches, hub, repeater, and access point.

Switches

Switches provide the benefit of LAN segmentation and distribution it means that every node will connected to a switched port receives its own dedicated bandwidth. Also, with switching can segment the network into logical or virtual LANs such as staff and student.

Such bridges or switches usually operate on the link layers of the OSI reference model and in the case of Layer3 switches, it extend into the network layer. The similar mechanisms have used to build dynamic route table that associate MAC addresses with switched port. Whatever, bridges may implement store-and-forward bridging through software; switches that implement either cut-through switching or store and- forward through hardware, within marked improve of speed.

The main benefit of micro segmentation in LAN is to switches. Most common organizations either in the process of doing or complete phased out hubs so to achieve the throughput requirements for multimedia application. Although switches become good affordable range in price, the price may not prevent organizations to migrate for complete switched infrastructures. At a minimum, servers and workgroups linked via switched ports. Implemented switches model in JIT LAN are Cisco catalyst 2960 series switches.

Repeaters

It used for extend the distance to cover large area and overcome other limitation on this type of installation. Generally, a repeater consists from a pair of back to back transceivers. The transmit line on one transceiver is hooked to the receive line on the other; in this case bits receive by one transceiver are as soon as retransmitted by the other.

Repeaters work principle is done by recreate the signals from one segment to another, and it allows networks to over face distance limitations and another factors. Repeaters also amplify the signal and transmit it on the next segment because it is a loss in signal energy cause by

the length of the wiring. When signal travels via the physical wire, it loses strength the through it travels, loss of the signal strength is attenuation.

This can introduce propagation delay, when there are several repeaters in a row, which can affect communication of network. In this case the number of repeaters that used in a row limit in network architectures.

Although repeaters have many pieces of equipment, they have few drawbacks. The signal receive at one segment is exactly transmit to the other segment this is disadvantage associated with repeaters is in transparent nature. Repeater cannot separate noises and signal because of it does not understand the language of frame. If collisions occur on one segment, it does same along with noise produced then reproduced collision on the other segment by repeater. The main drawback is that they generate a small amount of time delay it takes a signal become lag propagation through a network.

No repeater is needed in JIT fiber LAN because the first nodes data centre in library building ground floor, JIT campus is small area not exceeded out of fiber capability for those distance. Multimode fiber installed only for library to administration but for others Rama, Varnero, Workshop, Dormitory, Clinic and student Cafe are installed fiber is single mode.

Hubs

A hub is a device containing a grouping of repeaters. Same to repeaters, hubs also found at the Physical layer of the OSI Model. These devices connect multiple cable runs, simply collect, and retransmit bits in a star wired network topology. There are many benefits derive from this type of device such as from any pair of nodes on the network to extending the maximum distance and improve the ability in the rest of the network.

Fast Ethernet switches are relatively expensive devices. Hubs act as any 10BASE-T equipment's connection then the whole network need to process by 10Mbit/s. There is a challenge between a switch and a hub to grew, it known as a dual speed hub. These devices use as bridge the 10Mbit/s, exist two-port switch work on 100Mbit/s segments. When a network device goes active on every of the physical ports which the device linked on it to either the 100Mbit/s segment or the 10Mbit/s segment, as appropriately. This mostly need of the in all nothing improve to go Fast Ethernet networks. These devices target hubs because of the data traffic between devices, which linked within the same speed.

Repeater hubs describe for Ethernet when the companies transit to switching gigabytes but broadly deploy products has failed. Case of switch scarcity there are nine hubs in JIT LAN for end users it share one port of switch bandwidth. Hubs contain twenty-four ports but can access only 100Mbs because of catalyst 2960 switch support 100Mbs for each twenty-four fast Ethernet port.

Access point

In networking a wireless access point is a part of networking at hardware device that allows a Wi-Fi match device to connect without a wired network. Wireless networks should have prior, setup a computer network in a home, school or business usually require running in order to deliver network access that many cables through ceilings and walls to connect all of the network devices in the building. Network users are now able to add devices with the creation of the wireless access point, which accesses the network with some or no cables. A WAP commonly connect to a wired Ethernet connection directly and the WAP finally provides wifi connections using radio frequency links. Mostly WAPs support connects of multi wireless devices at the same time to one wired connection. Current WAPs built to support more standard for receiving and sending data by using radio frequencies. The frequencies they use from IEEE it defines those standards, WAPs use mostly IEEE 802.11 standards.

JIT use Cisco AIR-AP1252AG-A-K9 AP 1253AG 802.11a/b/g/n Access Point. The Cisco Aironet 1250 Series is the first organization class access point to support the IEEE 802.11n standard. Especially 802.11n gives combined data rates of up to 600 Mbps it provide user with mobility access within high-bandwidth voice, video and data applications regardless of their location. Through the use of multiple-input multiple-output technology, 802.11n also provides predictable and reliable WLAN coverage to improving the end-user experience for both existing 802.11a/b/g clients and new 802.11n clients.

4.2 JIT Fiber LAN

JIT implemented LAN by JU ICT organization, it design by using fiber backbone for better transmission rate and reliability. Transmission media components used for implementation are list below.

Optical Fiber

The single mode fiber provides higher transmissions speeds, less signal attenuation, and up to 50 times greater transmits distance than multimode fiber. Single mode fiber can transmit data by terabits per second over a hundred kilometres without require of amplification of signal. The smallest core of a single mode fiber allow for the propagation of one light wave, so there is no possible way of distortion due to overlapping light pulses. Also single mode is highly stable than multimode in systems that such as couplers, have branching devices. Multimode fiber optic cable and components are easier to work and less expensive than the single mode counterpart. This is due largely to the fact that the multimode fiber alignment tolerances are much less critical and core is larger than they are for single mode fiber. Multimode fiber provides wide bandwidth at high speeds, but transmission is limited to shorter distances than single mode. The multiple paths of light in a multimode optical fiber tend to create signal distortion in longer cable runs. Standard multimode fiber is made of glass fibers often 50-to-100 micron in diameter common is 62.5. Multimode fiber is also avail as low-cost Plastic Optical Fiber (POF) that gives performance similar to glass cable for very short runs.

The multimode optic fiber systems are lags after single mode systems in terms of develop. Also it support high data throughput, single mode fiber system are attractive because they are easy to help and upgrade to future proof installations. Multimode is the fiber optic of choices for application. For instance, multimode optic fiber is well suit for system which has short optic fiber links in LAN.

Multimodes continue to be cost effective for short reach with in dominates link of power consumption and cost of optics transceivers multimode optics is less than SM [11]. A large data centre within thousands of links use transceiver, power and cooling and multimode solution can provide substantial cost savings. Input source of LED power for multimode is 3watt.

Table 4. 1: Cost and power consumption between multi-mode and single mode [11]

	Fiber Type	Relative Transceiver Cost	Power Consumption (watts, max)
10GBASE-SR	MM	1	1
10GBASE-lR	SM	2	1.5
40GBASE-SR4	MM	3	1.5
40GBASE-Lr4	SM	10	3.5
100GBASE-SR10	MM	18	3.5
100GBASE-LR4	SM	60	8

Implemented fiber in JIT LAN is 12 core outdoor standard fibers. Outdoor 12-core Fiber Optic Single Mode cable; Jelly-Filled with 2-wire Armored jacket, Price is per meter cut; Full drum is 1500m, If buy full drum, get 20% discount, model 12C-SM-OT and cost $12.00 per meter.

There is redundancy cabling for fault prevention grounded the one is in front of building street ditch the other one is behind building street ditch. Multi-mode fiber installed to library and varnero for other buildings Rama, dormitory, workshop, clinic and student café installed fiber is single mode due to distance. For each building fiber installed from library building data centre room.

To install fiber for each building start from Library building data centre with redundancy network. Optical fiber cable length depends on the sum of each cable from building to building because there is no repeater needed. Library to Administration 124m, Library to rama355m, Library to varnero396m, Library to Male dorm780, Library to Female dorm 619,Library to Workshop 650, Library to clinic 961m, Library to café 1066m. Total cable length is multimode fiber and single mode fiber is 124m and 3397m respectively.

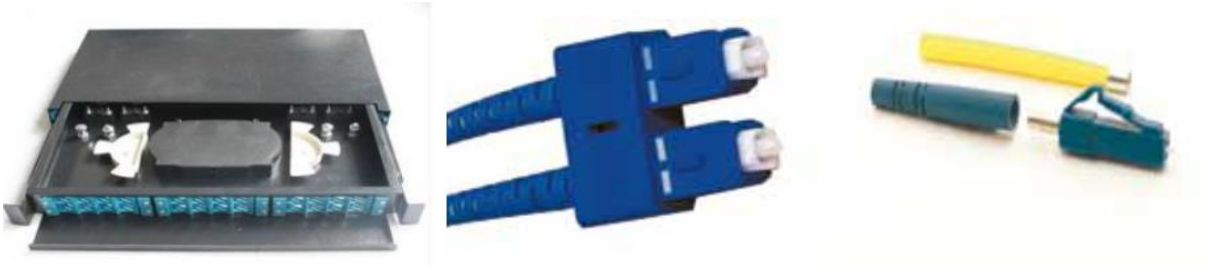
Connector and termination

At the end of optic fiber need termination because of strands in single optic fiber cannot direct connect or plug to switch. Below is a description of each of the termination and connectors, it use in fiber to the implementation LAN. The ones needs here are terminal box, SC and LC.

Available for termination box for this communication system, compact and reasonable structure, rack or wall mounting, harmonized with device room. The cabinet is consisting of two parts, one links with optics fiber for fusion connection links with patch cord and between optical cable and fiber pigtail. It provides storage and fusion appliance earthling and stripping for optical cables and for optical fibers reliable and protection appliance of fixing. All range protects design for fiber lays to ensure the bends radii ≥40mm and it provides various accessories to reduce any unexpected fault to the fiber.

LC- stands from Local Connector or Lucent Connector. It is a small form factor connector within good performance and is use mainly for single mode. LC connectors are excellent panel packing density and smaller size and push-pull design supplanting. It also use extensively under small factor from pluggable transceiver. Average the insertion loss is 0.1dB for both modes, generally use for high density interconnections.

SC- stands from Standard Connector or Subscriber Connector. SC fiber connector has use generally for Gigabit and Fast Ethernet. They have use in new network application at single mode optic systems. SC connector also gives a push pull design that avoids the possibility of overcome fault when provide and connecting good packing density. They are still used in telecom and datacom applications. Average the insertion loss for single mode 0.15dB and for multimode 0.1dB usually for datacom.



a b c

Figure 4. 4: End to end component: a) 24 port terminator b) duplex SC connector c) simplex LC connector

Figure 4.4 (a) show that fiberterminator, it contain 24-port Fiber Optic Distribution Box, 19" Rack mountable; slide out tray, Supports 24pcs fiber flange (not included), Includes cabling rack for reliable protection, model is FDB524 and $300.00 cost.

Figure 4.4(b) shows SC connector the specification is Housing material: Plastic (UL 94V-0), Ferrule: Ceramic (ceramic ferrule provides the highest durability for repeated mating), Temperature range: -40°C to +80°C, Mating cycles: 1000, Set with cable boot and crimp sleeve for cable Ø3.0mm, Dust caps, Model: FAST-SC and Cost: $20.00.

Figure 4.4(c) shows LC connector the specification is Housing material: Plastic (UL 94V-0), Ferrule: Ceramic Temperature range: -40°C to +75°C, Mating cycles: 1000, Set with cable boot and crimp sleeve for cable Ø0.9mm, Dust caps, Model: FAST-LC and Cost: $20.00. Easy to use, require only simple fiber tools [12].

Its thick layer of protection will use to connect the optical receiver, transmitter, and the terminal box. Patch cords are classified by construction of the connector's insert core cover and by transmission medium short or long distance, by connector constructing. Patch cables are used for computer fiber optic networks, connections to telecommunication networks, and fiber tester. An application includes communication rooms, FOS (Fiber Optic Sensor), LAN (Local Area Network), FTTH (Fiber to The Home), FOCS (Fiber Optic Communication System), Defense combat readiness; optical fiber connected and transmitted equipment, etc.

For each building 2fiber transmission line install it can terminate in one termination box, if it has 12 ports, totally 9termination boxes have needed. Patch chord cable with connector install to interconnect termination box to switches, 54 duplex patch chord cables are need.

4.3 JIT LAN Topology Analyses

A fiber optic end user concerns reliability of system as the trustworthiness within a measurements is make and transparently interface to some type of monitoring computer systems. In the particular cases of structural health monitoring to reduce lifetime cost is of primary importance, sensors should not only record physical parameters in a dependable ways. It should an element of an assets management technique that gives potential to improve lower failure security, and environmental risk, reduced maintenance costs, extended service life, and reduced downtime. In these aspects, the reliability of sensors directly relates to the operational effectiveness at the system.

Generally, reliability on the system plays important roles in the conceptual of system and cost effectiveness. System and cost effectiveness are a measurement to the ability of an item to meets service requirement of demand quantitative and qualitative characteristics within the better possible value of usefulness to lifetime cost and it is a prerequisite for sustainable and profitable technical system according to the market.

In a complex system, higher reliability always lead to higher lower operating cost, and development cost, these means the appropriate life time cost between extreme high and low reliability figures.

At quantitative term, the reliability of item components, assembly and system is the probability that is item will performs on a certain functions within a set of defines specification for a given time. The numerical statements of reliability is accompanies by the definition of the operating conditions, the required function, and the mission duration.

The reliability theory, τ represent the failure-free operating times, this τ is nonnegative value at random variable, its distribution function $(t) = 0$ for $t < 0$, and i.e. $\tau \geq 0$ or a positive random variable, $F(0) = 0$ and i.e. $\tau > 0$. $R(t)$represent a expresses the probability and survival functions Pr that an item will operate out of failure in the interval $(0,t)$, usually in the assume $R(0) = 1$, i.e. the item is operating when "switched on" at time $t = 0$. The reliability function write $R(t)$ as

$$R(t)= Pr\{\tau > t\}=1- F(t)$$

A main assumption on investigate failure-free operating time is at $t = 0$ the items will be free of systematic failures and defects. However, τ can be short, because of a transient event will at turn-on.

The distinction has to be makes between estimated and predicted or assessed reliability. The first one is the calculation based on the predicted failure rate of its components and the items reliability structure; the second is obtain from field data with known environmental or from a statistical evaluation of reliability tests and operating conditions [13].

Network Reliability

Reliability can be determining the probability of failure free operation. Also unprotect spliced fiber may have a lower strength than unspliced fiber after period if time it introduce reliability decrement but the design is not include such as parameter in reliability. The different parameter will affect the whole network reliability that have described. Reliability terms are MTTR, MTTF, MTBF, and FR based on procedures and methods for lifetime predictions for service. Customers usually must add reliability data when determine what product will buy for their applications. MTTR (Mean Time to Repair), MTTF (Mean Time to Failure), MTBF (Mean Time between Failures), and FR (Failure rate) are ways to provide a numeric value based on the result time of expected performance and a compilation of data to quantify a failure rates. The numeric values express by using any measurement of time, but hours are the common unit for practice [14].

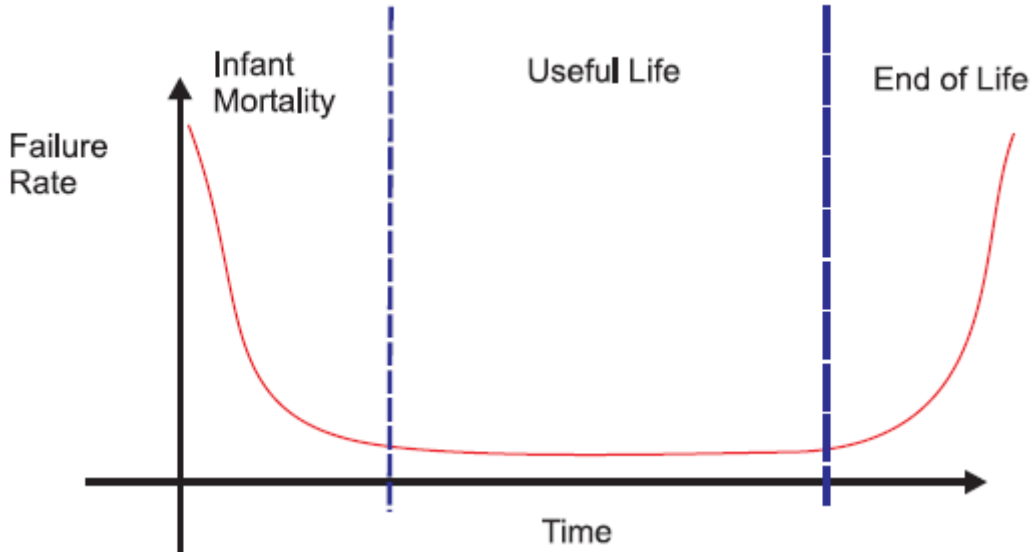


Figure 4. 5: Network failure rate state vs. time

Failure Rate (FR)

The Failure rate always varies within period. FR reports many of expected failures per one billion hours of operation of that device. These terms will use particularly for semiconductor industry even it is also use by components manufacturer. FR quantify in a number of ways: 1 million devices for 1000 hours or 1000 devices for 1 million hours each and other combinations. FR and Confidence Limits (CL) are always providing together. In most common usage, at claim of 95% confidence in something is normally taken as indicates virtual certainty. In statistics, a claim to 95% confidence simply means that the researcher

should see something occur that exactly happen one times in twenty or less. For instance, component manufacturer will taken a small sample of a devices, that test x number of hours, and then determining there was any failure in the test. Based on the number of failures that occur, the CL will continue to provide as well.

Mean Time to Repair (MTTR)

On operational system, repair means replacing a failed software and hardware part. Those, devices MTTR viewed as minimum time to replace failed devices. Taking long time to repair a material drives increase the cost of the installation in the long process, due to failure time until the new part reach and the possible interval of time require the scheduling of installation. To reduce MTTR, companies purchase spare part products so they replacement fault device quickly. Generally, customer will inquire for the turn-right time of repair products, and this can fall into the MTTR section.

Mean Time between Failures (MTBF)

The MTBF is the average mean times that expect between failures, it measured in hours. The constant failures rate system and MTBF is the inverse of the FR.

MTBF=1/FR

The reliability term use to provide the total amounts of failures per million hours on a product. This is the common inquiry for important in the decision making process and a product's life cycle, for end user. MTBF is highly important for integrators and industries than consumers. More consumers are price for driven and will not concern MTBF, nor is a data always readily avail. On the other hand, if equipments such as switches or media converters installed into critical mission application, MTBF's become very important. Also, MTBF may be expecting line item in Request for Quote (RFQ). Out off the proper data, manufacturer pieces of equipment will be immediately disqualified.

Mean Time to Failure (MTTF)

MTTF is time of period the expect time before first any whole or partial failure equipment. It is a basic measurement value of reliability on non-repairable system. Generally, MTBF often use only in reference of repairable items, while MTTF would be use on non-repairable item. MTBF mostly use for both non-repairable and repairable items.

Reliability(R)

Reliability is the describe value of performance capacity or probability of failure-free operation over a period of time [15].

$$MTBF = \int_0^\infty R(t)dt$$

$\boldsymbol{R(t) = e^{(-\frac{T}{MTBF})}}$, *where T is the number of hours*

MTBF and R for multiple components

MTBF=1/(FR1+FR2+FR3+……+FRn), where 'n' is the number of components in the system.

Therefore,$R(T) = \prod_{i=1}^{n} R_i(T)$

Availability

Availability is the probability of a system will be operational at any time, when upon to perform its function.

A=MTBF/(MTBF+MTTR)

Bends in Reliability

In fiber installation, fiber will be bending around under staples and corners as well as coiled for reserve purposes. For this scenario, the convenient express fiber bends by using per turn. Bending in a corner is traditionally a single 90° round turn. The bends created by stapling can varies, but it will be less than a 90° round turn. Coiling for reserve should best express in terms of a complete 360° round turn. By using per turn base can be facilitate the process of

failure probability in case of fatigue failures. Table 1 shows the prediction on probability of failure for at single 360° round turn for several bends radii [16].

Table 4. 2: Failure probability predictions over a 25-year lifetime

Radius (mm)	Probability of Failure or Turn(ppm)
5.0	3
7.5	1
10	0.5
15	0.1

• Twenty permanent 90° round turns around each bent and corners to a radius of 5mm. This is equivalent with five full 360° round turns. Using 3ppm per turn, the failure probability on corners is 15ppm.

• Twenty full 360° round reserve turns at a 15mm bend radius. These translate to a reserve failure probability of 2ppm (20x0.1).

• Another 70 staples cause for the equivalent of approximately three full round turn at 5mm radii. These translate for a total staples failure probability of 9ppm (3x3).

Total installed failures probability for this is better severe installation sample at less than 30ppm. One can decide that risks of fatigue relate a failure due to premises installations and bending in FTTH is low. At assumption the entire hypothetical FTTH network, consist of a hundred thousand homes installed within the bending scenario. The estimate number of fatigue relates a break is less than three of the entire FTTH network over twenty-five years of operation. This low estimate failure rate is not significant when compare to other source a fiber failure be simple excavations. The short length has subjected to light bends; the reliability of fiber is more than adequate.

Component Failure Rates

Components failure rate are always sensitive information, which were difficult to find out from the literature. The samples of some components failure rate refer from educated guesses and previous publications. When, this study does not support perfect value for components availability, but to give consistent or reliant estimates, which allow verifying fiber links on the connections availability and the joint impacts of nodes architecture.

The repair or departure and arrival of component failures are less memory process within permanent means, and the failure rate in FIT; FIT is a failure rate of one failure in one billion hour of a series system in the sum of the failures rate in FIT of the constitute components.

The failures rate of components prediction according to the detail assumptions [17]:

MUX/DEMUX: The assumed the number of supported wavelengths proportional to failure rate. The main value obtained from 200 FIT for 8 wavelengths and 100 FIT for four wavelengths.

EDFA: The failure rate of inline EDFAs is added in the link fault on failure rate of node to internal erbium doped fiber amplifiers.

Optical Switch 1: Optical Switch 1 is optical switch matrix with add or drop capability based on both dimensional micro electro-mechanical systems (2D-MEMS). An optical add or drop multiplexer (OADM) which used such switch matrix with WxM switch mirrors, where M is the number of add or drop ports, and W is the number of incoming light paths to be switch. Assume M =W/4 since only part of the traffic may be dropped. It verify an predict of less than 21 FIT for the random failure rates of a switch elements on static reliability check up, when let's assume a failure rate of 21*W*W/4 FIT.

Optical Switch 2: The Optical Switch 2 is an optical 3D-MEMS base switch devices suit for optical cross connections (OXCs) with wavelength selection architectures. The major of commercial 3D-MEMS switch design to use a number of mirrors which is twice the number of input port. The wavelengths selection architecture each optical switch devices has 2N output and input ports to allow full drop or add capability, let N is the number of incomes optical fiber. A failure rate of 21*2*2N FIT in assumed.

Coupler 1: Coupler 1 is a 1: 2 power splitter. The failures rate of couplers assume proportional to the number of output. This concern a failure rate of 50 FIT for a 1:2 splitter.

Coupler 2: Coupler 2 is a 1: W/4 power splitter, let W is the number of wavelengths support by each incomes optical fiber.

Coupler 3: Coupler 3 is a 1: (N-1) power splitter, let N is the number of incomes optical fibers to the OXC tuneable transmitter.

Fix Transmitter and Fix Receiver: The Fix transmitter is the sensitivity part of detector error correction and optical power adjustor part according receive signal bit respectively.

Tuneable Receiver: The tuneable receiver is able to filter and to select a specific channel others.

Digital Switch 1: The Digital Switch 1 is a digital switch matrix with add or drop capability, suit for opaque OADMs support W wavelength. The failure rate is proportional to the number of input channels that 3500 FIT for a 4x4 switch.

Digital Switch 2: The Digital Switch 2 is a matrix with add, drop, and cross connect capability, suit for opaque OXCs support WxN channels, let W is the number of wavelengths carried by each of the N incomes optical fibers.

Wavelength Blocker: This scenario assumes that the failure rate is directly to the number of support wavelengths for a demultiplexer and a multiplexer, which are important components of wavelength blockers. Another function of wavelength blockers additionally used as channel equalizers. Let W: Number of wavelengths per optic fiber N: Number of incomes optical fibers.

Table 4. 3: Component failure rates

Component	Symbol	Failure Rate
MUX/DEMUX	MUX	25*W
EDFA	EDFA	2850
Optical Switch1	OSW1	21*W*W/4
Optical Switch2	OSW2	21*2*2N
Coupler 1	COUP1	25*2
Coupler 2	COUP2	25*W/4
Coupler 3	COUP3	25*(N-1)
Tuneable Transmitter	TTx	745
Tuneable Receiver	TRx	186
Fix Transmitter	FTx	470
Fix Receiver	FRx	70
Digital Switch 1	DSW1	875*W
Digital Switch 2	DSW2	875*W*N
Wavelength Blocker	WB	50*W

Derivation of Link Reliability

In the reliability of network parts and component of links has three different parameter are use. (1) Component failure in time (FIT) rate, it is measured in one billion operating hours of the component, optional values vary from few tens or simple coupler to few thousands or complex switch. (2) Mean time between failures (MTBF) it derived from the FIT rate. (3) Mean failure time (MFT), it determines how time spent on average a failed component remains off-line [15].

The Fiber and Amplifier availability or Reliability found as follows:

Fiber unavailability= (Length*FIT*MFT) / (1*10^9)

=>Fiber availability=1- Fiber unavailability

Amp unavailability= (FIT * MFT) / (1*10^9)

=>Amp availability=1- Amp unavailability

Link availability=Fiber availability*(Amp availability) N

N is the number of Amplifiers in that link. These components other than the link's reliability calculated and amplifiers also considered in a similar manner. Apply link availability equation in the network topology in study, the reliability amount calculated for any network topology through the link found to be often above 0.999. This indicates that few of the links across the network do not fulfil the availability requirements that most common in operators. The value of link reliability or, availability, it derived, can be sets as link parameters in the VPI tools.

4.4 Network Accessibility Analysis

In JIT LAN Ethernet, any host can communicate each other with in high speed 100Mbs depend on devices network interface card but all fiber optic cable and copper cat 5e can transfer 1Gbs data rate. There is internet service accessibility can access 150Mbs in JIT and 260Mbs by using main campus path. Generally, this LAN speed is good but not enough; there is a Wi-Fi customer compliant according to data rate. Access point ports plug on one port of switches, there is no additional bandwidth allocation it just like one host. Another problem is frequent network unavailability in different cause. There are switches and hub to support 2020 ports avail for RJ45 connection device, in Wi-Fi, each 9-access point can deliver 253 IP. It means in JIT 4297 user can get IP but all users not active at the same time the probability is very less. If active user reach maximum(70%)for each device can access 50Kbs it achieve light user class and 87Kbs it achieve medium user class respectively 150Mbs and 260Mbs.

Figure 4.6 shows some long outage but there were many outages in any time for short period in a year. It indicates connectivity break down around first days of August, December, first

days February, and last days of April. Very all faults occur by fiber cut from JIT to ISP side. Daily average data rate in a year 169.78Mb incoming traffic and 14.06Mb outgoing traffic, total usage is 704.82Tb last year. This data rate is more essential to design and forecast demand respect to congestion.

Figure 4. 6: One year In and Out data rate LAN traffic

Internet data traffic on 09/05/2017 at 3:40 up to 9:40 figure 4.7 show Ethernet outage for 20min at lunch time (6:20 up to 6:40), 237.78Mb in and 22.93Mb out traffic. The time highly traffic flow in JIT that peak data rate from 3:00-5:00 and 9:00-11:00[22].

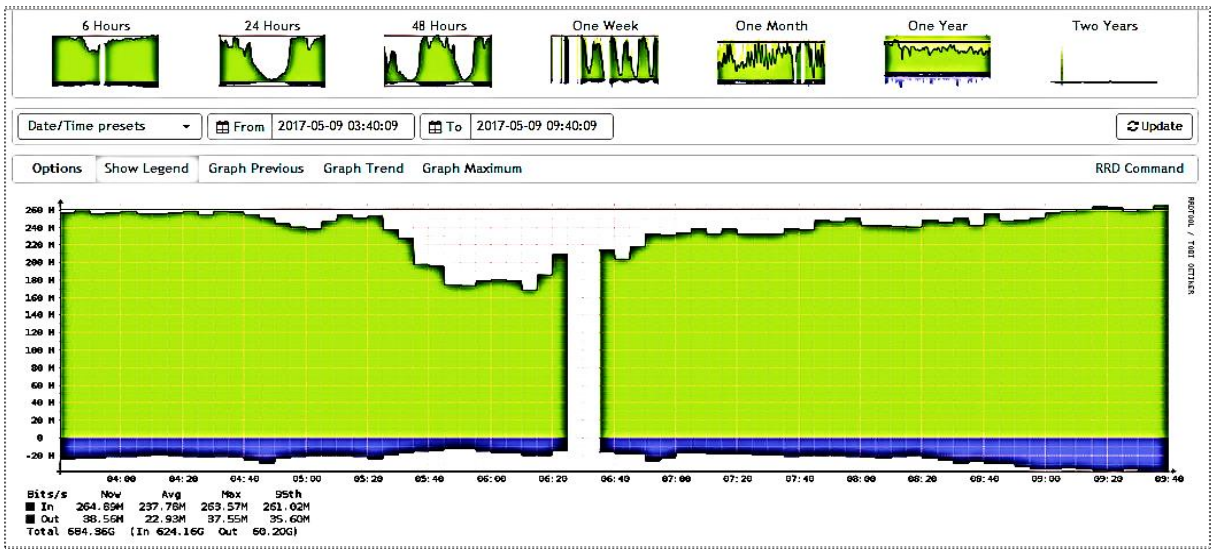


Figure 4. 7: Six hour In and Out LAN traffic

In average LAN support 237.78 IN and 22.93 OUT data rate totally 260.71 JU has 260Mbs service but 0.71 increment score by CIR of provider. Current users average are 286 fixed port user 649Wi-Fi user totally 900 users, each device can access 279KBps simultaneously. It means it support heavy user privilege for each. It is good service without any other problem occurs but there is wastage resource.

4.5 Proposed LAN Model for JIT

The equipment used for JIT LAN communications over multi-mode optical fiber is less expensive than that for single-mode optical fiber so for cost effective proposed another topology for JIT. Typical transmission speed and distance limits are 1 GB (1000 Mb) Ethernet 1000BASE-LX for distances up to 550 m. Because of high reliability and capacity, multi-mode fiber usually use for backbone transmission inter buildings. In ring topology one node can access in two directions, if one transmission line will be disconnect it can communicate with another path. Therefore, this topology could achieve efficient LAN in JIT network without redundancy cabling, without using much single mode fiber and within cost minimize.

All users from any buildings want access network, frames come to library building switch and go to ISP it can only support 150Mbs or 260Mbs, so others frame wait there queue level. Therefore, the new design topology does not crowd traffic because multimode fiber 4 times greater than allowed IN and OUT traffic from ISP side based on 260Mbs. For internal LAN communication the reset, 740Mbs bandwidth above needed even if very less demand in internal connection. It means unused resources install in JIT LAN, it is fallacy in economics many now and many later thought. This design can get service efficiently for many years until JIT LAN IN and OUT traffic become 1Gbs. For bending building workshop also, I proposed multimode fiber from varnero it far between 300m-500m to any room.

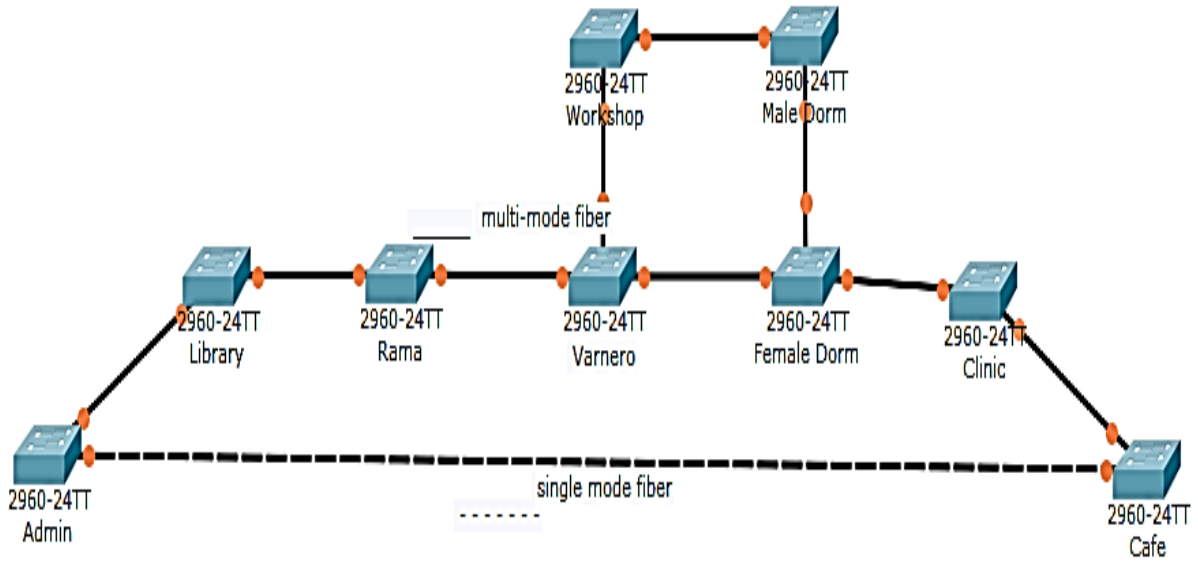


Figure 4. 8: Proposed LAN ring star topology in JIT

Customers Bandwidth Predict

In JIT level internet setup parameters are similar but mainly it has professional gauge need lot accuracy. After here more of a guiding way to evaluate an office what would likely need sufficient bandwidth. In addition, do not think that getting this estimation right on many times it adjusts a bandwidth subscription level depending on real life usage testing.

Users represent different types of service for different application at residential internet customers. Streaming video and social media are high bandwidth load, but in most cases it should be control within certain levels. All offices workers are embedded on few of the following online tasks: cloud services (hosted CRM, hosted accounting, hosted email, etc.), Email, VOIP in place of PBX phone systems, online research, downloading and uploading large files, online banking, and online backup.

Resources are need wise management for proper use, it estimate be highly accuracies, rise out documentation from online network by monitoring system. Above items of interesting in all play key role finally how much bandwidth should require for a company.

The provide service determine way to calculate bandwidth needs: where: N=Numbers of users; T=Traffic estimate based on usage weight; BN=Bandwidth Needed

BN =N x T

There is different user weight by different application; However, as weights are consider depend on the usage data per second in what the whole office worker use. The following user weights are appropriate today:

- ✓ Light user: 50Kbps
- ✓ Medium user: 80Kbps
- ✓ Heavy user: 120 Kbps

Congest state means all bandwidth occupy by users, an office may have a mixture of users. If 2000 users access internet at the same time it can afford for 500 heavy users who are the VoIP and video streaming, 500 medium users whom are the admin assistants and audio streaming. The remaining 1000 users are light office workers and student use browser and email [22]. Estimate calculation in the following manner: Available Bandwidth = 150Mbps

500 (heavy users) x 120 (Kbps usage weight) = 60Mbps

500(medium users) x 80 (Kbps usage weight) = 40Mbps

1000 (light users) x 50 (Kbps usage weight) = 50Mbps

These factors could affect bandwidth need, because of like high bandwidth utilizes application such as VOIP will use at a time; there will large emails are being sent and received in same time. Another issues with bandwidth usage time in any different application frequently in office, that become peak usage time, it may be horrendous during mid-day hours and level off in the morning and afternoon.

Table 4. 4: Assumption of congested condition data usage summery without CIR

	Users at a time	User type with data rate	Total usage by user type
1	500	Heavy; 120Kbs	60Mbps
2	500	Medium; 80Kbs	40Mbps
3	1000	Light; 50Kbps	50Mbps
Total	2000		150Mbs

5. Result and Discussion

5.1Comparison of JIT Fiber LAN over Proposed LAN in JIT

The main decision points for LAN network are so many concern issues for effective plan and implementation. The purpose of the proposed system is to improve the feasibility of the JIT LAN system. This model tries to satisfy customer demand and supplier organization JIT bandwidth, reliability, power consumption, and cost on Ethernet connectivity.

1. Bandwidth with Distances

Investing in fiber optic Ethernet can significantly increase bandwidth potential. Multimode optical fiber, whether it or not carrying laser power, it can readily transmit large bandwidth data within moderate distance; a typical bandwidth-distance product for multimode fiber is 500MHz/km, with appropriate modulation. Signal losses over 500-600m with 10Gbs are negligible; the bandwidth has limited by dispersion of signals

Installed fibers were single mode 9/125 and 62.5/125 micron both has capable for needed bandwidth. Single mode used for far distance on proposed scheme, it is from admin to café. Bandwidth consideration based on JIT demand very less than installed and proposed fiber capacity. This network can support users demand with in satisfy, until demand rate reach 10Gbs. There is problem due to slow rate but the problem not from JIT LAN side; it need data rate increment from provider because only 2000 user at a time to reach congestion according to previous sample without CIR.

2. Reliability

There are a many factors that can cause out off services when an organization is utilize on fiber optic cable-based Ethernet such as weather conditions, device temperature fluctuations, and moisture can be a cause to loss connectivity. Proposed LAN performance evaluation done by using fiber length, by average failure those assume 6hr failure 5 times per month from average rate.

Fiber unavailability= (Length*FIT*MFT) / (1*10^9)

ExistingJIT LAN fiber length = 8,348m; MFT=6hr; FIT =0.41;

*Fiber unavailability=8348*0.04167*6/10^9=2087167/10^9*

*Fiber availability= 1-2.087*10^-6=0.99999791*

Proposed JIT LAN fiber length = 3,206m; MFT=6hr; FIT =0.41;

Fiber unavailability=3206*0.04167*6/10^9=801.56/10^9

Fiber availability= 1-0.80156*10^-6=0.9999992

Reliability difference between existing and proposed is

=Proposed fiber availability -Existing fiber availability

=0.9999992 - *0.99999791*

=0.00000129

Reliability value should be above 0.999 for any network, so proposed LAN reliability satisfy it and exceeded by 0.00000129 this much reliability has a proposed LAN within a month that means a proposed LAN has 0.00001548within a year so that proposed LAN reliability is more preferable than existing.

3. Power Consumption

Single mode fibers in the existing system are change to multimode fibers in the proposed system; due to that, Multimode transceivers also consume less power than single-mode transceivers an important consideration specially in assessing cost of cooling and powering a data centre.

Table 5. 1: Comparison of consumption power

In the existing system	In the proposed system
7-single mode	1-single mode
1-multimode	9-multimode
14-Laser transmitter	2-laser transmitter
2-LED	18-LED

Power consumption for 10Gbs between multimode fiber and single mode fiber ratio is 1 to 1.5 respectively. Power consumption is based on length for this scenario to existing LAN SM is 8,224m and MM is 124m; for proposed LAN SM is 1,126 and MM is 2,080.

In existing LAN8.224*3*1.5+0.124*1*3= 37.38watt

In proposed 1.126*3*1.5+2.08*3*1= 11.307watt,

It reduces power consumption by 26.073watt or 44.16dbm.

4. Cost

Investing in fiber Ethernet will cost more in the short period costs are frequently decreasing as these option becomes more commonplace. The dominant cost of the laser system is the laser itself, which is not present in the electrical system. Ultimately, the total cost of ownership over the lifetime of fiber is lower. It is more durable, cheaper to maintain, and requires less hardware. The advantages of fiber make it overall, a more cost-effective investment for organizations of all sizes.

Multimode optical fiber continues to be the more cost-effective choice over single-mode optical fiber for these shorter reach applications. On average, single-mode transceivers continue to cost from 1.5 to 4.5 times more than multimode transceivers, depending on data rate. As faster optoelectronic technology matures and volumes increase, prices come down for both, and the cost gap between multimode and single-mode decreases. Transceiver cost variation is for existing 23 up to 65 according to 14 Laser and 2 LED, but for proposed 21 up to 27 according to 18 LED and 2 Laser. If just, take average for both existing to proposed ratio is 44:24, SFP module almost twice costly. However, single-mode optics has always been more expensive than their equivalent multimode counterparts have. This fact is support by the difference in multimode vs. single-mode 10G optics, a common Ethernet speed used today.

Additionally electricity cost due to consume power, multimode transceivers also less power than single-mode transceivers, an important consideration especially when assessing the cost of powering and cooling a data centre. In this scenario, 26.073-watt consumption is wastage, totally 26.073watt*24hr*30day/10^3=18.8KWh per month.

Table 5. 2: Cost analysis of existing and proposed model fiber

Fiber type	Existing fiber length	Proposed length	Unit cost
Single mode Outdoor 12 core strand	Library-Rama 355m Library-Varnero396m Library-workshop 650m Library-Female dorm619 Library-Male dorm 780 Library-Clinic 961m Library-Café 1066m	Admin -Café 1126m	$12.00 per meter
Multi-mode Outdoor 12 core strand	Admin to Library 124m	Admin-Library 124m Library-Rama 355m Rama-Varnero 91m Varnero-Femaledorm293m Female dorm-Male dorm 170m Varnero-Workshop 300m Workshop-Male dorm 250m Dorm-Clinic 372m Clinic-Café 125m	$6.00 per meter
SM total with redundancy	8,224	1,126	
MM total	124	2,080	
Total cost	$99,432	$25,992	

This table summarize relative to existing LAN proposed LAN model has $73,440discount. Finally, the fact that multimode optical fiber is low cost and easier to install in the field is an important consideration for enterprise environments, with their frequent moves, ads and changes.

6.1 Conclusion

Fiber Optic Ethernet is very important idea in every aspect. Implementing fiber in JIT is very feasible in case of all except power consumption, cost and reliability. Using fiber backbone with redundancy to LAN is very important for high data rate and fault prevention. However, installation cost for this LAN has some wastage because of design topology. It used muchlength single mode fibers as well as high power, high cost and less reliability.

Implemented extended star topology exposed LAN to use much single mode fiber because of fiber layout design with redundancy in front and behind of building, for each building install fiber from data centre or Library then distributed to each block and floor. For all buildings, installed fiber is single mode except library to admin. Proposed LAN is ring-star topology, all transmission by using multimode fiber without redundancy can prevent fault by ring, only one single mode optical fiber used to administration to student café for ringing. Proposed fiber design is better bsed on parameters such as reliability, less fault opportunity, power consumption and minimizing fiber and transreceiver cost but it is same for bandwidth.

There are analysed differences between implemented and proposed fiber backbone system. The existence LAN, reliabilityis 0.99999791, power consumption by transreceiver is 37.38watt and optical fiber cost is $99,432 but for proposed LAN topology reliability is 0.9999992 it increase by 0.00000129, power consumption is 11.307watt and fiber cost is $25,992. Additionally transreceiver and power consumption has value in cost.Any working network reliability is start from 0.999 so if u improve network in many necessary aspect the increase value in digits is small but it is not mean meaningless.

This LAN fiber backbone design will be effective for future, up to JIT data transfer demand reach above 10GBs. This demand will be reach after many years of next century,at that time there will be latest technology than now and economically provide above demand is wastage, until congestion occur at the end of estimation period.

6.2 Recommendation

The benefits of fiber optic Ethernet are making it an increasingly common choice for high and long data transmission. Ethiopia is one of the developing countries So many universities are building in it. To success the goal of the country, all universities can use the proposed system because the system has high performance than the existing one. When the universities in the country use the proposed system the technologies in the country can be develop within a short period.

Above half of JIT, users are Wi-Fi users but only share one switch port bandwidth. So that JIT LAN should improve it by bandwidth allocation on switch port for access points and hub, creating smart group port, or increase Wi-Fi VLANs bandwidth; because those contain many users

Finally, any organizations who want to invest in fiber firstly find that the total cost, power consumption, bandwidth demand by users, and reliability are noticeable. Proposed fiber design is best by three parameters such as reliability, power consumption and minimizing material cost but it is same for bandwidth.

Reference

[1] https://en.wikipedia.org/wiki/Local_area_network, May 2017.

[2]http://www.referenceforbusiness.com/small/Inc-Mail/Local-Area-Networks LANS.html#ixzz4k5HP6pjK, 2017 Advameg, Inc

[3] William Stallings, “Data and Computer Communications”, 7th Edition, May 2007.

[4] Mark Doms and Chris Forman “Prices for Local Area Network Equipment”June 2003

[5] Siemon, “Cabling Lifecycles and Total Cost of Ownership”, revised February 2012

[6] Radovanovic, “Optical local area networks new solutions FiberToThe Desktop application”, Twente University Press, december 2003.

[7] Chai Chuan, Ee, “The feasibility study of implementing a fiber optic local area network in software metrics labratory in Ingersool 158”,March 2004

[8] Nick Massa, “Fiber Optic Telecommunication’, Springfield Technical Community College, Springfield, Massachusetts, 200

[9] Tessco, “Fiber optics LAN”, march 2008.

[10] Cisco Systems, “Campus Wired LAN Technology design guide” August 2013

[11] Cost References:www.sanspot.com, www.cdw Power Consumption References: www.finisar.com www avagotech com Oct. 2014

[12] Conec, “Fiber optics connector”, www.conec.com

[13] F. Berghmans, S. Eve and M. Held, “An introduction to reliability of optical Components and fiber optic sensors, August 2014.

[14] Susan Stanley, MTBF, MTTR, MTTF & FIT Explanation of Terms, 2011 IMC Networks.

[15] Chinmayananda Panda et al, Link Reliability in WDM Optical Network, Vol. 3 No. 1 Feb-Mar 2012

[16] G. Scott Glaesemann, Paulo Dainese, Merrion Edwards &JabulaniDhliwayo "The Mechanical Reliability of Corning Optical Fiber in Small Bend Scenarios", December 2007.

[17] Jitendrasaxena and AdityaGoel "Reliability and Maintainability of Passive optical

Component", *2011*

[19] Sean Odom and Hanson Nottingham "Cisco Switching Black Book", The Coriolis Group, LLC, http://www.coriolis.com/, 2001.

[20] M. Norris, "Gigabit Ethernet, Technology and Application", Artech House, 2003.

[21] Belco, wholesaler of security system products; Price / specifications / design subject to change without prior notice. Cable, power & accessories price list, 25 November 2016.

[22] JUICT, monitoring software-ICINGA

[23] Nitin, Ajit Pal, "Module 5: Broadcast Communication Networks" Version 2 CSE IIT, Kharagpur