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DESIGNING A LOCAL AREA NETWORK FOR TELEMEDICINE

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ABSTRACT

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The purpose of this thesis was to design and implement communication equipment used for telemedicine in Shisong Cardiac Center by hiring bandwidth from Camtel using optical fiber as the transmission medium. Plastic optical fibers known to be very cheap and very fast was able to produce quality signals that can be used for video conferencing.

A VSAT link was created as a standby to the optical fiber so that if any destruction occurred on the optical fiber the VSAT link will be use to transmit the signals while the repairs on the fiber were going on. To produce quality signals and to maintain the functionality of the Cardiac Center, the following steps were taken in to consideration.

Firstly, very high bandwidth of plastic optical fiber was hired from Camtel and these signals were given priority over any other signals provided by Camtel. Secondly, the network was encrypted in such a manner that only two persons can have access to the signals. Intruders cannot be able to have access to the network to cause confusion within the signal transmission since all the finger prints of the two users are snapped and an alarm is set to produce a sound if the finger prints presented on the equipment are not the right finger prints registered.

Key words
Design, equipment, networking, telecommunication, telemedicine.

LIST OF ABBREVIATIONS

ATM: Asynchronous Transfer Mode

ASICs: Application Specific Integrated Circuits

BAN: Body Area Network

Camtel: Cameroon telecommunications

CDMA: Code Division Multiplex Access

CPU: Central Processing Unit

CSU: Channel Service Unit

DECnet: Digital Equipment Corporation Network

DSU: Data Service Unit

FDMA: Frequency Division Mmultiplex Access

HTTP: Hyper Text Transfer Protocol

IDU: In Door Unit

IPX: Internet Protocol Exchange

ISDN: Integrated System Digital Network

LLC: Logical Link Control

MAC: Media Access Control

NIC: Network Interface Card

ODU: Out Door Unit

OSI: Open System Interconnection

POF: Plastic Optical Fiber

POTS: Plain Old Telephone Services

SCPC: Single Channel per Carrier

SMTP: Simple Message Transmission Protocol

SNMP: Simple Network Management Protocol

TCP: Transmission Control Protocol

TDMA: Time Division Multiplex Access

TMC: Telemedicine Centre

UTP: Unshielded Twisted Pair

VLAN: Virtual Local Area Network

VSAT: Very Small Aperture Terminal

ABSTRACT
LIST OF ABBREVIATIONS
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1 INTRODUCTION

Shisong Cardiac center is located in the North West region of Cameroon and it is referred to as reference hospital in the entire central Africa. Shisong Cardiac Center was initiated by Don Claudio Maggionia’s who became very interested to give heart solutions to developing countries after the death of his sister due to a heart problem; he worked in collaboration with the president of the Bambini Cardiopatici nel Mondo. The main objective of Shisong Cardiac Center is to offer affordable, quality medical attention to cardiac patients of all status and works of life in Cameroon and the neighboring countries by providing sustainable services from facilities in St Elisabeth's Catholic General Hospital, in Shisong, Cameroon.

Shisong Cardiac Center has one main surgeon and the rest of the surgeons and operating team comes every month from abroad for consultation and operation of patients with heart problems. During the period when the surgeons comes to Shisong, information is passed to the communication media so that more patients could come to Shisong for consultation and finally to be treated on their cardiac problems, thereby making the cardiac center to be very crowdy. This makes the consultation team to over work themselves. In order to maintain this cardiac center for a longer period, the administration has to ensure that it is cost effective by minimizing the cost and maximizing profits. Presently too much money is wasted in the transportation and accommodation of surgeons every month for the operation and consultation of patients. Also, the time wasted for traveling to and from Shisong by the surgeons cannot be compensated.

In order to solve these problems, a local area network should be designed for telemedicine in Shisong Cardiac Center so that surgeons can stay at a distance and carry on operations on the patients with the collaboration of the cardiac doctor in Shisong Cardiac Center. Also, it will be very cheap and easy for the consultation team to consult patients from a distance without necessarily moving to Shisong. This will reduce the operation cost on each patient thereby making many cardiac patients to be interested in finding the solutions to their health problems since it will be affordable. Also, time will no longer be wasted by the surgeons to travel and money will not be used in the transportation of surgeons every month. This will minimize the cost and maximize profit in the cardiac center.

This thesis work is going to design and implement the communication equipment used for telemedicine in Shisong Cardiac Center by hiring bandwidth from Camtel (Main telecom operator in Cameroon that provide network bandwidth for private and business purpose) in their center in Tobin and creating a Local Area Network in Shisong Cardiac Center. Thus this thesis will be aimed at extending the optical fiber transmission link from Camtel Tobin to Shisong and creating a network in order to interconnect the two theaters I and II, the ICU (Intensive Care Unit), the Angiograph, the technical office, the general wards (male and female wards,) pediatrics ward, the consultation area, the doctor's and the manager's office. It is made up of six chapters. Firstly, introduction which contains the presentation of Shisong Cardiac Center and reason for the need of a telemedicine design in the hospital. Secondly, the transmission medium used for telemedicine is presented in chapter two which explains the two types of communication media (Optical Fiber and VSAT) that will be used to create the Local Area Network.

The characteristics and advantages of optical fiber as a medium of transmission are explained in this chapter. In case of any distortion on the optical fiber link, the VSAT link will be used to transmit the signals while the maintenance on the optical fiber link is being carried. Thirdly, chapter three goes further to design and implement the telemedicine equipment. This is the main part of the thesis where the design methodology and analysis, the equipment used for telemedicine, the network equipment used for the telemedicine and the power supply for this network are explained. Also, in this chapter, a review of telemedicine in Finland an example of that of Oulu hospital is explained. Furthermore, chapter four explains the network protocol used for the telemedicine design, the cost estimate for designing a Local Area Network in Shisong Cardiac Center, the security maintenance and how network security is managed. Chapter four goes further to explain how the design will be planned and scheduled and the necessary technical specifications needed in a telemedicine room. Moreover, chapter five brings out discussion about the Network Provider in Cameroon (Camtel) as being capable of providing fast bandwidth to Shisong Cardiac Center that can be used for video covering. Lastly, chapter six is the conclusion of the thesis which summaries the thesis and gives recommendation to the administration of Shisong Cardiac Center in order to ensure that the art of telemedicine is well practiced in the hospital

2 TRANSMISSION MEDIUM FOR TELEMEDICINE

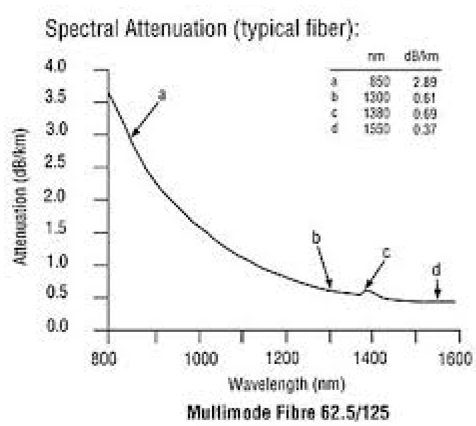
The design of a local area network for telemedicine involves a high usage of network bandwidth with no signal distortion in order to transmit quality signals that will be used for video conferencing. The high bandwidth can be obtained by hiring them from Camtel and instructing Camtel to set this link as a priority link to all the links distributed to customers. Plastic optical fiber is going to be used to transmit the optical fiber signal to the cardiac center because it is very cheap and easy to install. If there is a fault on the optical fiber link, then the signals will be switched to the VSAT link while maintenance is being carried on the optical fiber link. All these equipment will be connected to the main power circuit of the cardiac center to ensure constant availability of electric current. This chapter is going to explain the various communications medium used to transmit signals and the reason why plastic optical fiber will be the best transmission medium to carry the signal to the cardiac center. (Bill 2005, 51.)

2.1 Optical Fiber

The purpose of an optical fiber is to convert a signal to light, move the light over a long distance and then reconstruct the original signal from light. Optical fiber links consist of four basic components. Firstly, the transmitter which converts the signal to light and send the light into the optical fiber. Secondly, the receiver to capture the light and convert it back to a signal. Thirdly, the optical fiber that carries the light and lastly, the connectors that link the cable to the transmitter and the receiver. During the transmission of signals, problems can be encountered and thus there will be a need of a standby to all the components used for the transportation of signals. (Bill 2005, 51.)

A fiber optic link is a signal pathway between two points using a generic cable; this path way includes a means to send the signal in to the cable and a way to receive it at the other end in a useful way. Links are often described in terms of their ability to send and receive signals as part of a communication system. This ability to send and receive signals could either be referred to as the simplex or duplex means. With the simplex means, the link can only send and receive at each end while the transmission of signal using the duplex means involves the use of a transmitter and a receiver at each end. A half-duplex system allows signals to be sent only one way at a time and a full-duplex system allows users to send and receive at the same time. (Bill 2005, 51.)

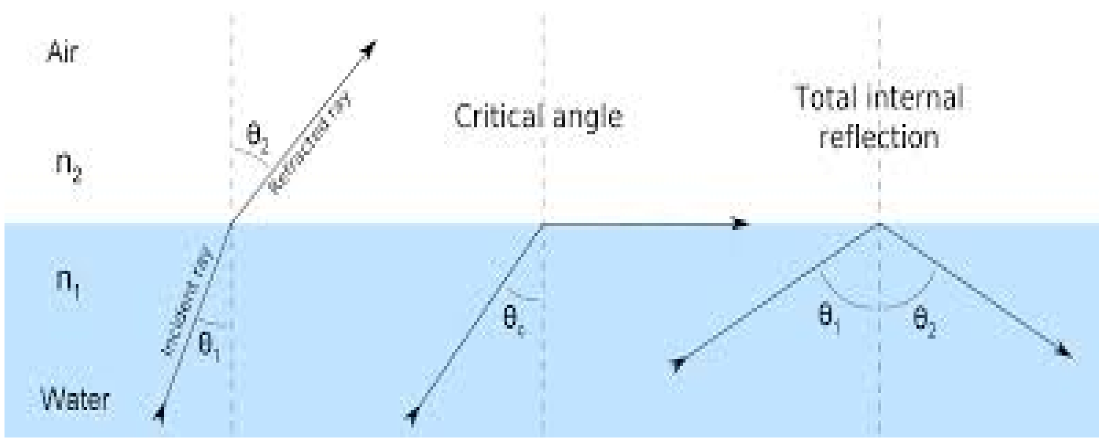
Fiber optics as a medium of transmission has a comparatively unlimited bandwidth. It has excellent attenuation properties as low as 0,25dB/km. A major advantage that fiber has when compared with coaxial cable is that no equalization is necessary. Also, repeater separation is on the order of 10-100 times that of coaxial cable for equal transmission bandwidths. Order advantages of optical fiber include electromagnetic immunity, ground elimination, and light weight. Optical fiber was developed by physicists called Claude Chappe in 1790 and following the convention in optics, wavelength rather than frequency is used to denote the position of light emission in the electromagnetic spectrum. The optic fiber of today uses four wavelength windows; 850nm,1310nm, 1550nm, 1620nm or near-invisible infrared. The wavelength used by Camtel is 1310 because it waves division multiplex the windows below it. As the optical signal propagates over a long stretch of fiber, it becomes attenuated because of scattering and absorption by material impurities. The attenuation is measured in dBs (10* log of power ratio) and is proportional to the length of the fiber. Fiber attenuation or fiber loss is therefore specified in dB/km. Attenuation reduces as the wavelength bands increases; this is illustrated in graph 1 below. (Sackinger & Eduard 2005, 11.)



Graph 1. Attenuation Versus Wavelength Window.. (Sackinger & Eduard 2005, 12).

Optical fibers consist of core, a cladding and coating. The core is the light transmission area of the fiber, either glass or plastic. The larger the core, the more light will be transmitted in to the fiber. The cladding is a dielectric material that surrounds the core of the optical fiber and its function is to provide a lower refractive index at the core interface in order to cause reflection within the core so that light waves are transmitted through the fiber. The coatings are usually multi-layers of plastics applied to preserve fiber strength, absorb shock and provide extra fiber protection. These buffer coatings are available from 250microns to 900microns.(Sackinger & Eduard 2005, 29.)

The practical propagation of light through an optical fiber is explained by the Snell's law which states that the ratio of the sine of the angle of incidence to the sine of the angle of refraction is constant. When light passes from a medium of higher refractive index (n1) in to a medium of lower refractive index (n2) the refracted ray is bent away from the normal. As the angle of incidence becomes more oblique, the refracted ray is bent more until the refracted energy emerges at an angle of 90 degrees with respect to the normal. (Sackinger & Eduard 2005, 50.)

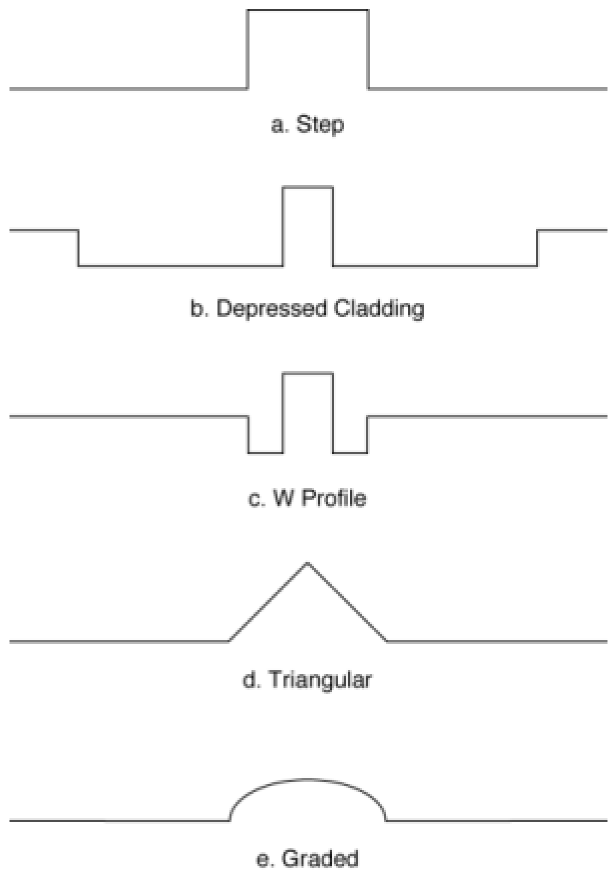


Graph 2. shows various incident angles of light entering a fiber (Sackinger & Eduard 2005, 55).

The first case in graph 2 is the normal situation where the incident rays of water are refracted away from the normal, the second case illustrates the critical angle, where the refracted ray just grazes the surface. The last case is an example of total internal reflection, this occurs when the angle of incidence exceeds the critical angle. A glass fiber for the effective transmission of light requires total internal reflection. (Sackinger & Eduard 2005, 55.)

2.1.1 Optical Waveguide Profiles

The optical waveguide profiles describes the refractive change as the radius changes from the axis of the fiber in the core glass outwards towards the cladding glass. The propagation of modes in an optical waveguide depends on the following shapes of the refractive index profile.



Graph 3 Optical Waveguide Profile (Okamoto & katsunari 2005, 19).

The optical waveguide profile is triangular and symmetrical about an axis and inverted curve symmetrical about the same axis or rectangular about the same axis depending on the value of g where g is the profile exponent. This results in a power law function given by the following expression. (Okamoto & katsunari 2005, 19.)

$n^2 (r) = n^2 1 [1- 2\Delta (r/a)^g]$

$n^2 (r) = n^2 2 =$ constants

This is only possible when the distance from the axis of the fiber in micrometer is less than the core radius in micrometer in the core and the distance from the axis of the fiber in micrometer is greater than the core radius in micrometer in the cladding respectively. (Okamoto & katsunari 2005, 19.)

n1 = refractive index along the axis of the fiber

D = Normalized refractive index difference

r = Distance from the axis of the fiber in micrometer

a = core radius in micrometer

g = profile exponent

n2 = refractive index of the cladding

The normalized refractive index difference is related to the Numerical Aperture (NA) by

$D = NA^2/2n^21 = (n^21- n^22)/2n^21$

With some special values of g it can be deduce specific results as follows

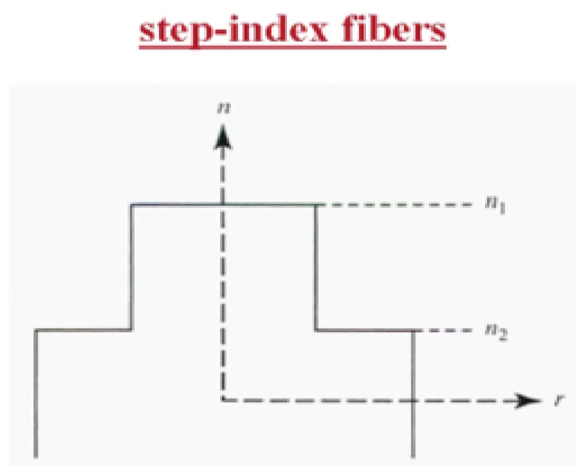
g = 1 triangular profile

g = 2 parabolic profile

$g \rightarrow \infty$ step profile

It is only in the case $g \rightarrow \infty$ that the refractive index remains constant that is n(r) = constant in the core glass for all other cases of profile, the refractive index n(r) in the core glass rises gradually from the value n2 of the cladding glass to the value n1 at the axis of the fiber where its value is maximum. These profiles are therefore called graded index profile and have become particular for the parabolic profile when g = 2 because the optical fiber with these profiles have technically very good light guiding qualities.(Okamoto & Katsunari 2005, 23.)

2.1.2 Step Index Profile



Graph 4. Step Index Profile (Mendez & Morse 2006, 563).

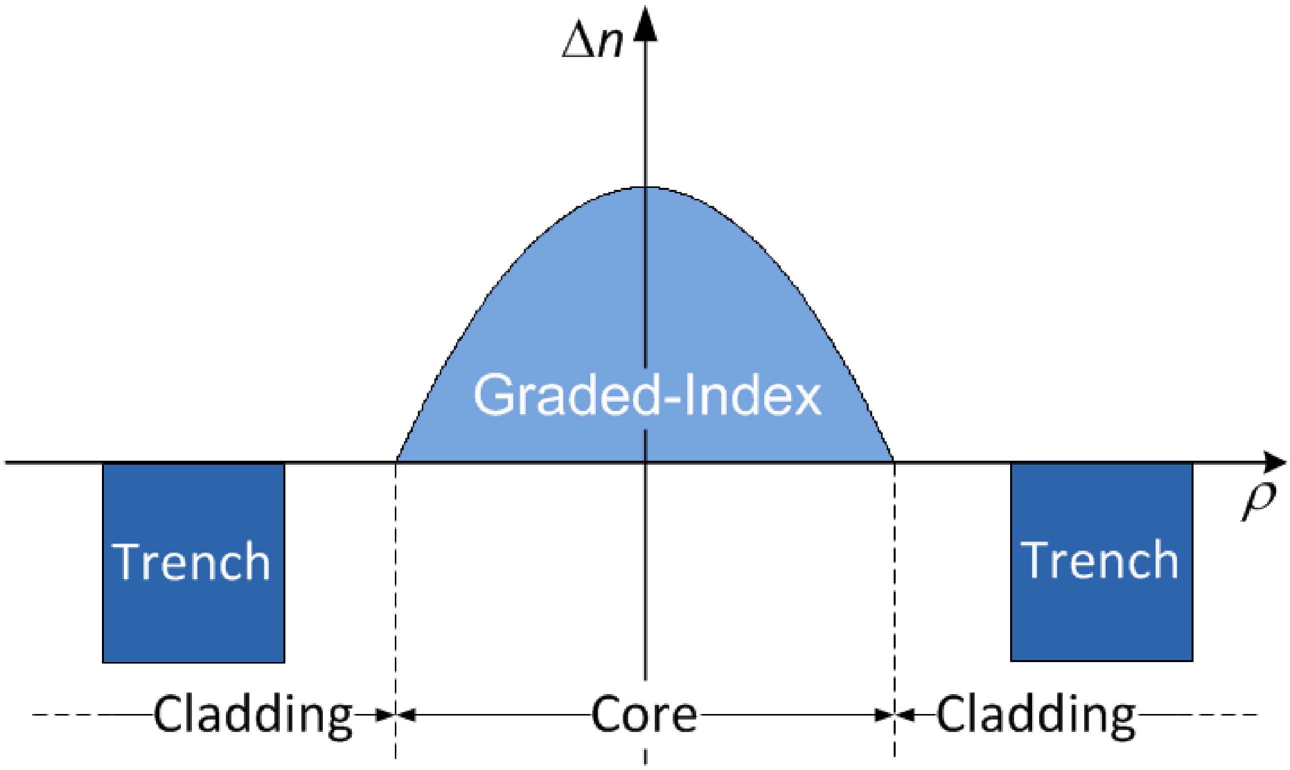
In order that light can be guided in the core glass of an optical fiber with step index profile due to total internal reflection, the refractive index n1 of the core glass must be slightly higher when compared with the refractive index n2 of the cladding glass at the interface of the two glasses. If the refractive index n1 maintains the same value over the entire cross section of the core then the refractive index is known as a step profile. These types of optical fibers are easily manufactured for today's use. A light pulse propagated in it will be composed of many partial light pulses which are guided in the individual mode of the fiber. If the core is not constant along its length then it becomes assimilated to multimode. Each of these modes is excited at the beginning of the fiber as If it was with a different launch angle and is guided through the fiber in a corresponding different path. The delay time distortion of the individual mode is called modal dispersion. This is disadvantageous for optical transmission because it reduces the transmission speed (bit rate and the transmission bandwidth). This means that modal dispersion can be minimized when there is only one mode guided in the fiber namely; the LPO1 mode. This mode becomes broaden in time as it passes through such a fiber resulting to chromatic dispersion. In comparison to modal dispersion chromatic dispersion is relatively minor or zero in the wavelength range from 1200nm and 1630nm. (Mendez & Morse 2006, 563.)

The mode field diameter is used to improve the radial field amplitude of the fundamental mode. Therefore in order to manufacture a low attenuation step index fiber with only one mode in the wavelength range above, the mode field diameter must be reduced to about 9-10nm. Such a step index fiber is known as a single mode fiber or a mono mode fiber. Since the core diameter, the NA and the acceptance angles are very small, it is very difficult to launch into a single mode fiber compared to a multimode fiber. (Mendez & Morse 2006, 32.)

2.1.3 Multistep Index Profiles

The dispersion in a single mode fiber is composed of two types; firstly, the material dispersion caused by the wavelength dependence of the refractive index $n = n(\lambda)$ and therefore of the light speed $c = c(\lambda)$. Secondly, the wave guide dispersion which results from the wavelength dependence of the light distribution of the fundamental mode Lp01 over core and cladding glass and therefore of the refractive index difference $\Delta(\lambda)$. When material and waveguide dispersions are combined, It results to chromatic dispersion. With the wavelength range that is higher than 1310nm, the two dispersions in fused silica glass have opposite signs. The material dispersion can only be changed through the use of the other dopants glass, By contrast the waveguide dispersions can be greatly influenced by the use of another structure of the refractive index. (Mendez & Morse 2006, 560.)

2.1.4 Graded Index Profiles



Graph 5. Graded-Index Fiber (Mendez & Morse 2006, 564).

In the step index fiber with numerous modes, these modes propagate along parts of varying lengths and therefore arrive at different times at the end of the fiber. This situation of modal dispersion can be greatly reduced when the refractive index of the core gradually diminishes parabolically towards the cladding from the core with maximum value “n”, at the axis and minimum value n^2 at the cladding boundary, as with the case of graded index fiber shown above in graph 4. Such a fiber has g = 2 this implies n^2 (r) = n^21- $NA^2(r/a)^2$ for r ≤ a in the core and n^2 (r) = n^22 for r ≥ a in the cladding. (Mendez & Morse 2006, 563.)

Another optical waveguide with the graded index profile is also called the graded index fiber. Due to the continuous change of the refractive index n(r) in the core glass, the rays are refracted continuously and hence their direction of propagation is changed, therefore propagating in different wave paths. The result is that the time delay difference of the various rays disappears almost completely. The minimal time delay difference in graded index fiber is caused by profile dispersion in addition to material dispersion. The optimal profile exponent of the parabolic graded index profile can be calculated on a theoretical basic from g = 2-2p-D(2-p) whereby both the parameters p<<1 and the refractive index difference D are dependent on the wavelength λ and therefore the profile exponent g. It is only with a given λ range (g = 2), that it can be possible for all guided modes to have almost the same time delay. The launch angle θ is dependent on r and n(r). (Mendez & Morse 2006, 563.)

2.1.5 Plastic Optical Fiber (POF)

This is the type of optical fiber that will be used in cabling the LAN in Shisong Cardiac Center. Plastic Optical Fiber is extremely reliable and rugged, which has led to its recent adoption in the residential, commercial and industrial networking market. With super-fast rates of up to one gigabit per second and assured high service quality levels, POF is the most robust technology for 100 Mbps optical fast Ethernet and next 1 Gbps optical giga bit Ethernet networks. POF offers all advantages of Glass Optical Fiber (GOF) without any of its challenges. POF is also ideally suited for delivering high-bandwidth emerging applications like IPTV and other triple play services. Some advantages of Plastic Optical Fiber include the following. (Ivan & Tingye 2008, 19.)

Plastic Optical Fiber is quick, easy and inexpensive to install in such a manner that it can reduce the cost of truck rolls for broadband service providers. It can be deployed by a home builder, either a professional or do-it-yourself installer, using very basic tools. POF offers simple connectivity which makes installations simple, easy, quick and far more straight-forward than other copper and optical networking technologies. Also, Plastic Optical Fiber has a very high bandwidth. The data rates of up to 100Mbps are currently offered by Plastic Optical Fiber and in the future it will cover to 1Gbps, ensuring high quality of service to every home and office device. This makes POF the most robust technology for 100Mbps optical fast Ethernet networks in residential, commercial and industrial environments. (Ivan & Tingye 2008, 19.)

Plastic Optical Fiber is small and convenient. At the ultra-thin diameter of 2.2mm, POF can easily be deployed in new construction or retrofit installations, either inside wall cavities in the same ducts of electricity cables or outside the wall along baseboards, under carpets or anywhere cables are typically run. Moreover, Plastic Optical Fiber is a very rugged and durable technology that can bend and flex without any loss of service, loss of bandwidth or damage to the cabling. It is also a proven technology in the markets and is already widely used in the automotive industry. There are over 20 million cars using POF to deliver high speed in-car infotainment. (Ivan & Tingye 2008, 20.)

Plastic Optical Fiber transmits data optically, which makes it completely immune to electrical noise. POF can even be installed next to electrical wiring without having any effect. This is an important advantage of POF for bandwidth- intensive applications, for example in the case of multimedia data transmission where the signal deliver over POF will not degrade or be negatively impacted by external noise. It has a simple design making it ideal for architects and home/offices designers, as one POF cable satisfies all network media needs. Currently, POF can be used for point-to-point links up to 75meters for 100Mbps with 0.5NA cables and up to 100meters for 100Mbps with more powerful POF cables with 0.3NA. Repeaters that extend the optical network are also available. (Ivan & Tingye 2008, 20.)

Plastic Optical Fiber has a very quick and easy troubleshooting method since POF uses a visible eye-safe red light to transfer data from one device to another. POF is the only interconnecting technology allowing signal to be seen at both ends which makes troubleshooting very easy. A quick glance inside the cable will indicate successful connectivity to the network, shown by a red light. No telemedicine equipment has more than 100Mbps speed disparity. This enables the speed of the equipment to be compactable with those of the network components, thereby enabling real time services. (Ivan & Tingye 2008, 25.)

2.2 Very Small Aperture Terminal (VSAT)

In order to avoid a single point of failure, a VSAT link will be designed as a standby for the optical communication link. In case of poor signal transmission, the VSAT link will be used to transmit the signals. It is a very small satellite transmitting and receiving station that is installed at each local agency to replace the modem for data transfer. VSAT links are able to reliably transfer data, video, and voice through the satellite. VSAT consist of two units; the Out Door Unit (ODU) and In Door Unit (IDU). (Bruce & Elbert 2008, 70.)

2.2.1 Out Door Unit

The Out Door Unit is made of a dish-shaped antenna that is typically 3 to 5 feet in diameter and it is the electronic which receives or transmits data, video, or voice signal to and from the satellite. This VSAT dish typically weighs no more than 150 pounds. The ODU is mounted outdoors, typically on top of the building roof with a non-penetrating mount. It could also be mounted on the wall or on a pole away from the building. This ODU is connected to the IDU (inside the building) by a coaxial cable. (Bruce & Elbert 2008, 71.)

2.2.2 In Door Unit

An IDU is a telecommunication device that is used in satellite television and Internet service to receive and decode satellite transmissions. It is a box that connects to the user's television or router and contains a built-in satellite receiver that may also be connected to a satellite dish on the roof or exterior wall of the user's home. IDU is responsible for receiving the satellite signals broadcasted by the user's satellite service provider and decoding them in order to provide the user with satellite television and internet access. It is an electronic device that is about the size of a small video cassette recorder. It transfers data, voice and video images between the computer and the Out Door Unit and it also facilitates the interactive distance learning training capacity. (Bruce & Elbert 2008, 71.)

The VSAT Link enables the broadcast link to transmit bulk information to all receiving points and these points in turn transmit their individual requests or replies back to the originating points over the same satellite. In order to achieve high quality signals for files and video streaming, information should be transferred from a large earth's station. VSATs are defined by their antenna aperture (diameter of parabolic dish) which varies from 0.5m to 2.5m. A VSAT network consist of one comparatively large hub earth's terminal and remote VSAT terminals. VSAT terminal have transmitter output powers ranging from 1W to 50W, depending on the service characteristics. Receiver noise performance using a low-noise down converter is about

1.5dB. G/T values for 12.5GHZ downlinks are between +14dB/K and +22dB/K, depending greatly on antennae aperture. This is in order to make a VSAT terminal as inexpensive as possible (Joseph & Edward 2003,140.)

A multipoint interactive connectivity provides two-way communications because the remote VSATs receive the broadcast from the central hub station and can transmit back typically at a much lower throughput data rate. This is different from a point- to-point network because the remote stations cannot communicate directly with one another but must do so through the hub. The principle applied here is that of the data broadcast called the forward link which continuously transmits information to all VSATs which in turn utilizes burst transmissions called return links. This will enable several VSATs can share a common frequency channel. The forward link is at high power level to permit reception by small VSAT antennas. There is therefore an economical balance between the high cost of the hub (which is shared among the VSATs) and the low cost per VSAT (installed at each remote served location). The best application of VSAT star networks are where there is a need for remote locations to access a headquarter host computer or LAN as in the case of Shisong Cardiac center. (Elbert & Bruce 2008,105.)

2.2.3 Access Techniques

Inbound refers to traffic from VSAT(s) to hub and outbound refers to traffic from hub to VSAT(s). The outbound link is commonly a time division multiplex (TDM) serial bit stream often 56kbps with some high-capacity systems of 1.544Mbps or 2.048Mbps. The inbound links can take on any one of a number of flavors, typically 9600bps. More frequently, VSAT system supports interactive data transaction, which is very short in duration. One application is to deliver, in near real time, point -of-sale information by forwarding it to headquarters where the VSAT hub is located. In this system design, low delay, simplicity of implantation and robust operation are generally of important than the bandwidth efficiency achieved. Message access on any shared system can be of three types: fixed assigned, contention (random access) or reservation (controlled access). In the fixed assigned multiple access, the VSAT protocols are Single Channel Per Carrier (SCPC) / Frequency Division Multiples Access (FDMA), Code

Division Multiples Access (CDMA) and Time Division Multiples Access (TDMA). All three are comparatively inefficient in the populated environment with hundreds of thousands of potential users. (Joseph & Edward 2003, 150).

3 THE DESIGN METODOLOGY AND ANALYSIS

Various network designs depend upon their applications in order to provide necessary requirements to reliably transmit the type of information involved. For example, to monitor a ventricular tachycardia patient requires regular transmission of ECG and heart information to ensure that any risk of the ventricular fibrillation will be promptly detected. In designing any telemedicine system, it is very important to ensure that the communication network used is capable of supporting the required data. In this chapter, the technologies and challenges of setting a body area network that is suitable for the implementation on both patients and health services will be explained. The application of remote patient monitoring using wireless communication technologies will also be explained. (Fong& Bernard 2010, 37.)

3.1 Preliminary Studies

To design a LAN for Shisong Cardiac Center made of 14 departments, the physicians in these departments/units need to communicate whenever a patient visits more than one of the units. The proposed LAN will follow the hierarchical structure of the hospital. The decision to make the selection of the various LAN technologies is done based on certain factors. Firstly, the expected application to run on the network and their traffic patterns. Secondly, the physical locations of the offices and users to be connected in the hospital. Thirdly, the rate of network growth. Furthermore, the abundance of network technology in the market and lastly, the simplicity of installation and maintenance. (Fong& Bernard 2010, 37.)

3.1.1 Expected Application to Run on the Network and their Traffic Patterns

A web-based telemedicine application is expected to run on the network. The application will use a central database server where all the user and patient information will be stored. This database will only contain the basic information of the patient such as the day of admission and discharge of the patient while the rest of the information will be written in the patient's hospital book and in case of any reference by the doctor, the hospital book will be use as a reference. This will help to maintain the patient's privacy. The type of data to be transmitted on the network shall be in the text and image formats. (Fong& Bernard 2010, 37.)

3.1.2 Physical Locations of the Offices and Users to be connected in the Campus

Shisong Cardiac Center is built on 1600-2000 square meters, with each office located 5m away from the other. The critical area is located 10m away from the administration block, while the pediatric and adult wards are located 5m away from the administrative block. The technical department is located 10m away from the critical area and 20m away from the pediatric and adult wards. With these distance specifications, it will be easier to calculate the total length of cable that will be used to connect to the different areas of the hospital. (Fong & Bernard 2010, 37.)

3.1.3 The Rate of Network Growth

The rate of hospital LAN growth depends on level of computerization in the hospital. Currently in the hospital, there is a LAN that connects few offices and computer room. The network uses star topology, using a centrally located hub and Unshielded Twisted Pair (UTP) cables forming a peer-peer LAN. The purpose of this LAN was to enable offices share printer and staff get access research documentations. In this documentations. In this design it is anticipated that as the web based application is used and becomes familiar, there is a chance to add more applications and connect more computers and offices to the LAN. The switches/routers selected in this design have many free ports to help cascade the growing number of connection in the future. (Fong& Bernard 2010, 38.)

3.1.4 Simplicity of Installation and Maintenance

To design the LAN architecture the hierarchical model is selected, which enables the design and arrangement of the inner-network device in layers. It is a model preferred by most of network design experts for its ease of understanding, expandability and improved fault isolation characteristics. The model required the following three layers. Firstly, the core layer which is made up of switches that is capable of switching packets as fast as possible. This layer connects the LAN backbone media and the outside world to WAN through firewall. In this design, the devices in the core layer will be placed at the central location of the Cardiac Center and they will be connected with high-speed cables such as fiber optics. The servers will be connected to switches in this layer shielded by a firewall. Secondly, the distribution layer which contains switches and routers capable of VLAN switching and allowing define departmental work groups and multicast domains. The devices support connectivity of different LAN technologies since they also serve as the demarcation point between the backbones connections in the core layer and the access layer. In this hospital, the switches/routers will be used as the distribution layer. Lastly, the access layer where the end users are allowed in to the network. This layer contains switches/hubs from which PCs in each department get access to the hospital LAN. (Pasricha & Harpreet 2004, 319.)

3.2 Conception of the Project

Implementing a telemedicine program can be very challenging due to the associated costs such as hardware, software, networking, administration and clinical expertise. To maximize potential and minimize costs, it is important to study the existing information technology infrastructures in telemedicine and make the program based on the infrastructures. The parameters considered in the information technology infrastructure for telemedicine are the geographical coverage, bandwidth, mode of communication, rental cost of WAN connection and capacity to add more LANs. (Reponen & Martilla 2004, 81.)

Table 1. Existing ICT infrastructure for telemedicine. (Reponen & Martilla 2004, 81).

Parameter	Internet	DDN	School Net	Woreda Net	BMN
Coverage	Telephone coverage area only	The capital and regional urban areas only	About 500 schools covered. There are woredas that do not have schools	571 woredas out of 594 are covered	The capital city and 13 regions
Bandwidth	Maximu of 56k dialup and 1mbps in leased line	Maximum of 1Mbps	Can be upgraded to 384k upstream	Downstream / Upstream 45Mbps/256k downlink	ADSL Service variable Bandwidth Downstream /Upstream 512k/128k 1024k/256k
Interactivity	Two way	Two way	One way broadcasting	Two way	Two way
Cost	0.11birr/min dialup	1000birr/month leased line	Free for schools	Free for woredas	Not yet determine under development
Capacity to scale	Not scalable	Not scalable	Not scalable	Will have more than 10 ports free at each woreda	Can be expanded

From the above table it is seen that WoredaNet have a good coverage area with bandwidths used for Downstream/Upstream being 45mbps/256kbps and it is a two way broadcast having more than 10 ports free Woreda. Shisong Cardiac Center will therefore use Woreda ICT infrastructures to connect their LAN network. WoredaNet interconnect over 600 woredas offices and 11regional headquarters with high speed broadband to greatly increase the flow and speed of information needed to administer the decentralized system. (Pasricha & Harpreet 2004, 320.)

3.3 A Review of Telemedicine in Finland

Telemedicine was introduced in Finland as a result of patients lacking specialized treatments on health as it was difficult for them to visit the Oulu District Hospital for special care. Teleradiology was the first telemedicine application started in northern areas of Finland that improved the health care system and eventually benefited patients, heading towards Finland's goal for the completion of ubiquitous health care dream. The current application of telemedicine in Finland include. Teleradiology, telelaboratory, telepsychiatry, telepsychiatry, teleop-thalmology, teledermatology and teledentistry (Ignatius & Makela 2004, 958.)

3.3.1 Teleradiology

In 1969, Initial experiments took place when radiological images were transmitted between Helsinki hospital district and Oulu hospital district using the broadcasting network of Finnish national television. Some hospitals started teleradiology services utilizing existing copper telephone lines to transmit X/ray images, but later up graded to using Integrated Systems Digital Network (ISDN) lines as transport medium. The teleradiology and telemedicine applications network expanded widely along with the passage of time, Asynchronous Transfer Mode (ATM) dominated data transport technology, replacing ISDN lines and the YLE broadcast network there. While ATM was a dominated data transport technology, some hospitals also utilized Ethernet 10Mbps connections, because of compatibility issues, the equipment did not support any ATM cards as an interface. The imaging database can be viewed in three ways: regional database, regional Picture Archiving and Communication System or EPR having e-referral and e-discharge letters. (Ignatius& Makela 2004, 958.)

3.3.2 Teleboratory

Telelaboratory refers to electronic distribution of laboratory results from one location to another location and these applications between hospitals are very common nowadays. According to a 2005 survey, 90% of the hospital districts were using electronic methods of distribution of laboratory results where as 27% of the primary care centers were receiving daily laboratory results electronically through a regional database and the rest were either at planning or testing stage. In 2005, Integrated Services Digital Network (ISDN) lines were used for inter-laboratory communication, this was later on replaced by ATM connections along with the data transport technology up gradation. (Reponen & Martilla 2004, 81.)

3.3.3 Telepsychiatry

Telepsychiatry refers to interactive psychiatric consultation over long distance that enables simultaneous sound and video connections between two or more interested parties (patient-psychiatrist or patient, nurse/physician-psychiatrist). The primary communication method used in telepsychiatric consultation is teleconferencing. This is because the psychiatrist tries to understand the problem through therapy and observing a patient. These observations include physical movement, thoughts, reaction to certain actions expressions and many other factors of patient that are often difficult to quantify but are known indicators in psychiatry. Initially, 3 pairs of ISDN lines (384Kbps) were used for teleconferencing, as the technological revolution continued, Finland switched to using ATM connections. (Reponen & Martilla 2004,81.)

3.3.4 Teledentistry

Finland has a shortage of dental health care professionals, lacking odontology services in sparsely populated regions. Odontology is a branch of dentistry that deals with the teeth, their structure, development, and their diseases. Teledentistry refers to provision of dental services at remote end using videoconferencing, but it is mostly used for distance learning specialist education and clinical consultation purposes in dentistry. Turku university hospital odontological Clinic hosts specialist training, which is distributed to various health care centers and hospitals in Western Finland.

Videoconferencing is made possible through standard videoconference equipment and wireless intraoral camera technology, utilizing ISDN as well as TCP/IP network connections. Wireless intraoral camera is a tiny digital camera that fits comfortably in one's mouth and shows a clear real time view of one's smile and teeth to dentist for analysis and diagnostic purpose. In some health care centers computer aided consultation is also utilized for patient diagnosis and treatment planning. For a patient, some photographs using digital camera or digital images for x-ray films are obtained and sent through email for consultation, saving patient's time and effort. Teledentistry is expected to develop further in the near future. The data transport technology used in telemedicine services is compared in the table below. (Reponen & Martilla 2004, 81.)

Table 2. Data technology used in telemedicine services. (Reponen & Martilla 2004, 81).

Application	Transport Technology
Teleradiology	YLE Network, POTS, ISDN, ATM
Telelaboratory	ISDN, ATM
Telepsychiatry	ISDN(3 pairs 384kbps) ATM
Teledentistry	ISDN, TCP/IP

3.4 Characteristic of Equipments and Materials

The practice of telemedicine can be divided into real time and store-and-forward. Real time telemedicine involves synchronous interaction between the parties concerned. This type of telemedicine practice is often effective in terms of consultation and patient satisfaction. In contrast, the store and forward type of telemedicine is an asynchronous interaction between the parties concerned. Email is a common example of this type of telemedicine. Although diagnostic accuracy is lower in store-and-forward telemedicine, it is advantageous from the point of view of cost, complexity and convenience.(Garcia & Huerta 2012, 1488.)

Equipment used for telemedicine can be broadly divided in to the following. Firstly, The Information hardware which comprises of the equipment that helps to run the software interface, the examples of IT hardware equipment include computers, multimedia devices, scanners, security devices, daughter boards and handheld devices. Secondly, the connectivity hardware which consist of devices used for connectivity, they include items such as VSATS, routers, hubs, switches and structured cabling. Furthermore, the video conferencing hardware that permits full screen TV, plasma TV or Projection TV, live two way audio and video conferencing. Lastly, the medical hardware which comprises of all the clinical instrumentation that would be attached to the telemedicine system to capture data from the patients.(Garcia & Huerta 2012, 1489.)

The equipment used for telemedicine are many in number but the most common ones are digital 12 lead ECG, digital BP, digital glucometer, electronic stethoscope, digital microscope, digital PTR, pulseoxymeter, electronic ENT fundoscope, skin camera, multiple parameter monitors, Doppler ultrasound, CT scanner and MRI. Equipment as above comes in various configurations, sizes and shapes and capabilities and varying costs. Based on the necessity and affordability, a careful assessment has to be made with regard to each instrument to ensure right fittings. (Garcia & Huerta 2012, 1489.

3.5 Design Goal

The overall goal of nationwide telemedicine network design is to provide an affordable and low-cost system that facilitates communication between physicians and healthcare professionals across the country. The system implements connectivity among rural clinics and urban area hospitals to be used mainly for tele-consultation and maintaining patient information. As the main design goals, the network should be cost effective, expandable, secure which provides state-of-the art ICT access scheme to rural area clinics. Existing ICT infrastructure will be given priority to minimize cost of implementing the network. In this design the following specific design goals were given priority. (Blobel & Gunnarsdottir 2010, 238.)

3.5.1 Expandability

Expandability is concern in the telemedicine network design for the following reasons: firstly, the number of hospitals built in the country is few in number. However, there are more clinics being added to the health system of the country every year. There is also a chance to incorporate private hospitals in the nationwide telemedicine network if necessary, which will ultimately increase the number of sites to be connected in the future. Secondly, the area of telemedicine application will not be limited only to specific diseases, but will be expected to increase in type and number in the future. Lastly, the network should also support advanced applications, which require real time connectivity such as video conferencing in the future. (Blobel & Gunnarsdottir 2010, 238.)

3.5.2 Security

During consultation or patient referral, most of the data exchanged over the network is sensitive patient information. Confidentiality of patient information must always be respected. For a secure communication, protocols such as Secure Socket Layer (SSL) can be used. SSL permits users to conduct secure communication over web-based applications. This provides the ability to safely exchange patient information across the network. When doctors exchange patient information, they should adhere to medical protocol that defines the rules to be followed during this process. In addition to these the network and the involved servers should be protected by firewall against external invader. A Firewall can be software or hardware for the sole purpose of keeping digital pests such as viruses, worms and hackers out of the network. (Blobel & Gunnarsdottir 2010, 238.)

3.5.3 Cost

Implementing a nation-wide telemedicine network may seem to be more expensive than building clinics or equipping existing regional clinics with medical personnel and medical instruments. A cost benefit analysis and a comparison on various approaches have to be done to produce a lower cost solution to the problem of delivering proper health care to rural areas. However, network connectivity among the health care facilities, both in the urban and rural areas over an existing ICT infrastructure is considered as an effective cost. (Bartz & Robert 2012, 600.)

3.6 Elements of LAN Design

The elements used to design a LAN include the following: firstly, locating the equipment to have the maximum security and gathering application services to determine the software. Secondly, foreseeing the need of an expansion on the network in the future. Thirdly, determining port access speed for switch and hosts (>= 100mbps). Furthermore, choosing hosts (PCs) Pentium IV. Lastly, foreseeing software security needs (firewalls) to protect your network. (Lammle & Todd 2008, 320.)

3.7 Network Components Used for the Design

Computers must share media to communicate successfully. Network media can be media or it can be a physical cable or it can be wireless. Regardless of the media type, its main function is carrying data from one device to the next. To access the network or communicate with other computers, a network interface card (NIC) is needed, these comes with different variety of specifications and depending on the network setup, it may not be interchangeable in all machines. From the equipments specification above, the following network components will be used to design a local area network for telemedicine. (Lammle & Todd 2008, 321.)

To start with, a H3CS5120-48P-EI Layer 3 Ethernet Switch -48ports-54-watts power-96GBps which support diversified services and enables IPV6 forwarding will be used. Secondly, a WSC424 CISCO Fast Hub. Thirdly, a transceiver which will be used at the interface of the router and signals from the VSAT link to convert the VSAT signals to electrical signals. Furthermore, a CISCO-Linksys WRT160 N-RM Wireless Router to distribute the network to the switches. Moreover, an optical to electrical converter used to convert the optical signals to electrical signals. In addition, an access router will be used to encapsulate frames into packet by appending a destination network address, source network address console port used for network set up configuration performance monitoring and checking, security features such as firewall, encryption and authentication and allocation of WAN bandwidth to allow a better quality of service to higher priority application such as time sensitive communication. Lastly 2 switches of 48 ports and 24 ports will be used to connect the equipment and personal computers. (Rajarsh & Koel 2004, 400.)

3.7.1 Connection of Switches to the Equipment and Personal Computers

A 48 port switch will be used in the critical area as follows. 8 ports used to connect the various telemedicine equipment, 2 ports used to connect the network to the two theatres, 10 ports used to connect the network to other locations like Angiography I and II, Blood blank I and II, 2 ports used to connect the doctors resting apartments and 20 ports will be left for future expansion of the network in the critical area. A 24 port switch will be used to extend the network to the adult ward and consultation ward. A hub will be connected to the 24 port switch in order to distribute the network to non-traffic generation departments such as the technical department, changing room and the pressing room. The functions of routers, switches and hubs are explained below. (Rajarsh & Koel 2004, 400.)

3.7.2 Hubs

A hub is a multiport repeater that retransmits a signal on all ports. When a packet arrives at one port, it is sent to the other ports so that all segments of the LAN can see it. Since it operates at Layer 1 of the OSI model, it can connect segments on a network but cannot segment a network. Most hubs are produced with a minimum of 4 ports but can have as many as 48 ports. There are two basic types of hubs: active and passive. Active hubs are the type described previously in this paragraph. A passive hub allows the signal to pass through without any amplification or regeneration. Intelligent or manageable hubs add features to active hubs that enable each port to be configured and the traffic passing through the hub to be monitored. A switching hub is a type of active hub that reads the destination address of packets and forwards it to the correct port. Most hubs require no configuration and passive hubs does not require power. The devices connected to the hubs all share the same bandwidth. For instance, if there is a 10-Mbps hub and three devices are transmitting at the same time, each device gets one third of the bandwidth. (Rajarsh & Koel 2004, 400.)

3.7.3 Switches

The concept of switching is identical to bridging: they both forward, flood, and filter traffic using the same rules. Both bridges and switches create multiple collision domains as well one collision domain per port. The advantages of switches over bridges are as follows. Firstly, switches have a higher port density. Secondly, switches have faster packet-processing capabilities. Furthermore a good quality-of-service capabilities and usage of virtual LAN technology is performed with the use of switches that bridges. (Rajarsh & Koel 2004, 410.)

Early bridges typically had two ports and some had as many as four. It was rare and very expensive to find a bridge with a total of six or more ports. Most early switches came with a minimum of eight ports, with some having as many as 16 or 24 ports. Some of the switches used in today's network environment are expandable to more than 350 full duplex 100-Mbps ports. Each is in essence a single bridging device that creates its own collision domain and uses port-based memory for buffering incoming and outgoing data. Switches achieve faster packet-processing capabilities than bridges in a number of different ways as explained below. (Lammle & Todd 2008, 310.)

The bridges has Application-Specific Integrated Circuits (ASICs) where they accomplish their decision-making process almost exclusively through software. Although it was adequate for its time, today's networking applications and services require much faster processing capabilities. This is achieved by imbedding the decision routines into hardware ASICs installed on each port on switch. Deciding how to manage a packet is handled at the lowest level possible, allowing switches to achieve packet throughput in excess of 150 million packets per second, which was inconceivable 10 years ago. (Lammle & Todd 2008, 309.)

Switches use the latest and the most powerful CPUs in the market that help to process all the port-based ASIC decisions. There is also a process of cut-through switching which enables switches to forward packets immediately after receiving the destination MAC address. Bridges manage frames by using store-and-forward processing whereby the bridge receives the entire frame in memory before forwarding it to a different interface. The cut-through processing allows the switch to forward frames much more quickly because the destination MAC address is received in the first six bytes of a frame. The major drawback to cut-through switching is that malformed frames from collisions or a misbehaving network interface card (NIC) are also forwarded. (Lammle & Todd 2008, 300.)

Switches have a fragment-free switching, a technique similar to cut- through switching except the fact that it eliminates the forwarding of collision packets and still achieves a faster processing capability than store-and-forward bridge behavior. In the fragment-free switching technique, the frame is forwarded after receipt of the 64^{th} because Ethernet requires that collisions are detected prior to this byte being transmitted. A successful transmission to the 64^{th} byte ensures a high probability that the frame is a good (not a collision). (Lammle & Todd 2008, 301.)

Switches are rapidly becoming more popular than hubs when it comes to connecting desktops to the wiring closet. Switches operate at data link layer of the OSI model. Their packet-forwarding decisions are based on MAC addresses, a switch simply looks at each packet and determines from the physical address which device a packet is intended for and then switches it out toward that device. Switches allow LANs to be segmented, thereby increasing the amount of bandwidth that goes to each device. A switch sent data only to the specified port, whereas a hub sends the data to all ports. For instance if a switch of 10Mpbs is used to connect three devices, all the three devices can use the 10Mpbs one after another but if this bandwidth was given to the hub, it will be divided equally to the ports with regardless to whether there is traffic there or not. In this context, it is said that each segment is a separate collision domain but all segments are in the same broadcast domain. The basic functions of a switch include filtering and forwarding frames, learning media access control addresses and prevention of loops. In wide area networks such as the internet, the destination addresses requires them to be looked up in a routing table by a device known as a router. Some recent switches also perform routing functions. These switches are sometimes called IP switches or layer 3 switches. (Lammle & Todd 2008, 290.)

3.7.4 Routers

Routers operate at the network layer of the TCP model. They forward information to its destination on the network or the internet. Routers maintain tables that are checked each time a packet needs to be redirected from one interface to another. The routes may be added manually to the routing table or may be updated automatically using various protocols. Although primarily used to segment traffic, routers have additional useful features. One of the best is its ability to filter packets either by source address, destination address, protocol, or port. A router may create or maintain a table of the available routes and their conditions, and then use this information along with distance and cost algorithms to determine the best route for a given packet. Typically, a packet may travel through a number of network points with routers before arriving at its destination. On the internet, a router is a device that determines the next network point to which a packet should be forwarded toward its destination. The router is connected to at least two networks and decides which way to send each information packet based on its current understanding of the state of the networks to which it is connected. A router is located at any gateway, including each internet point of presence. The connection from a router to the internet is through a device called a Channel Service Unit/Data Service Unit (CSU/DSU). (Rajarsh & Koel 2004, 390.)

3.8 Body Area Network (BAN)

Body Area Network (BAN) is also referred to as Personal Area Network. It is the ability of installing very tiny radio transmitting devices on human body. These devices are so small that some can even be implanted inside the body. They provide the underlying technology for monitoring various signs of the body and to issue an alert if an abnormal behavior is detected. They also provide a convenient means of logging daily activities and determining whether a user has met a pre-determined target for workout during a session. Bio sensors are attached to the user's body for remote health monitoring offering extremely high mobility. A BAN consists of two major components: Intra- BAN and Extra-BAN.(Fong& Bernard 2010,38.)

3.8.1 Intra-BAN

This component is used for internal communication around the body of the patient, where sensors and actuators are connected to a mobile base unit that serves as a data processing center. This mobile base unit can be any consumer electronics device such as a cellular phone. Blue-tooth and Zigbee are currently the wireless technologies use for Intra-BAN communication. The choice of communication technology depends on the application and sensors sets involved such as the amount of data that a sensor set produces and the power consumption needed for a certain communication technology. The BAN that will be used in Shisong Cardiac Center will use wired connections between the sensors and the sensor front end with a wireless (blue-tooth) to link the mobile base unit. (Fong& Bernard 2010, 38.)

3.8.2 Extra-BAN

This component is used for external communication between the components surrounding the body and the outside world. This is normally a telemedicine system that conveys the collected data for processing and analyzing. The Extra-BAN device has a sensitive receiver and transmitter that are ready to receive and transmit signals to and from the body of the patient. (Fong& Bernard 2010, 38.)

BAN devices have properties of very low power consumption of less than 10mW and a low data throughput of less than 10kbps. Various considerations taken in implementing a BAN design. Firstly, the quality of service assurance for an individual device must be provided to ensure that all devices remain in contact since no data protection mechanism is employed in most situations. Secondly, the base mobile unit should be connected within two meters in order to successfully cover each signal and lastly, an Omani-directional antenna coverage should be used to ensure a high degree of mobility and the effects of absorption by human body on signal propagation needs to be thoroughly investigated. (Fong& Bernard 2010,38.)

3.9 Remote Patient Monitoring Using Wireless Communication

The monitoring of patients for long periods during their normal daily activities is essential for the management of various pathologies. This includes sleep monitoring in the normal home environment for apnea patients, the continuous personal monitoring of brain signals and long-term cardiac monitoring. In addition to monitoring specific parameters, the patient monitoring equipment has to comply with additional specific design requirements such as portability and/or wear-ability (light weight, specific sensors, body compatibility), long-term signal or parameter monitoring (battery consumption, long-term electrodes), capable of continuous signal acquisition, real-time processing and feature extraction, transmission capability, data integrity and security. It should also comply with medical device regulations. (electrical safety, electromagnetic compatibility). (Maeder & Smith 2010, 57.)

3.9.1 Continuous Biomedical Signal Monitoring

Long-term monitoring of body energy requires specific design requirements in order to achieve accurate sense signals over a long period of time. Dry electrodes such as conductive rubbers are used as conducting devices since they are easily tolerated by the skin, flexible and tolerant to sweat. This type of electrode has higher impedance than standard electrodes and therefore needs higher input impedance for the amplification stage. Other measures are taken in to consideration. Firstly, enabling a stable connection between the electrode and skin in order to reduce the variations in electrode potential. Secondly, maintaining a low power consumption in order to extend the monitoring lengths. By using a power circuit of Ni-MH 3.6 V battery, a biomedical front-end will provide very high input impedance with selectable gain feature of about 1000 V/V for EKG/EMG application and up to 70000 V/V for EEG applications in conjunction with an adjustable monitoring bandwidth (0.02/0.5[Hz] up to 40Hz for EEG application, 5Hz up to 400Hz for EMG application).The current consumption of the front end is less than 1mA powered by a single 3.6V supply, and it includes over current protection. (Maeder & Smith 2010, 59.)

3.9.2 Body Motion Sensing and Posture Assessment

A micro-electronic-mechanical system (MEMS) is required to record concise information about patient motion to estimate physical activity. MEMS accelerometer sensors are small (few mm) and light-weight (few grams) and when combined with their low power consumption, such a sensor is known to be a convenient choice for personal biomedical devices design. Since the MEMS sensor is able to detect the static acceleration due to gravity, it is possible to know the position of the sensor (and body or anatomical segment where the sensor is linked), in the gravity field. (Maeder & Smith 2010,59.)

3.9.3 Photoplethysmograph and temperature sensors

Plethysmograph (PPG) and Sp02 sensors are mostly integrated in most patients' monitors. The use of light (red and infrared) through the patient's skin to estimate the changes in artery diameter that in turn depends on blood pressure, provides a noninvasive way to gather information such as heart rate, percentage of oxygenated hemoglobin and qualitative data about blood pressure. These types of sensors are very sensitive to motion and usually require relatively high power consumption. Integrated temperature sensors provide a reliable intrinsically linear voltage (or current) proportional to temperature, absorbing extremely low currents. Un calibrated-sensors usually offer accuracy of one tenths of a degree. Temperature sensors can be easily integrated with other circuitry and can provide information about a patient's skin temperature, which in turn depends on local peripheral circulation and muscle activity. (Maeder & Smith 2010, 60.)

3.9.4 Signal Acquisition and Transmission

An integrated, commercially available Blue-tooth transmitter is used. This transmitter has different characters of 25 meters operative range, a data rate up to 115200 bits/s in 8 channels sampled at 12 bits with a maximum threshold of 4 kHz. The Blue-tooth transmitter draws high current (30 mA) from batteries, reducing their life to a few hours of continuous transmission. To solve this problem of battery discharge, data should be stored temporarily in the internal memory. (Maeder & Smith 2010, 60.)

3.10 Power Supply for Telemedicine Equipment

The operation of telemedicine equipment requires a constant power supply. A huge power backup system such as an Uninterrupted Power Supply (UPS) with large batteries, standby generators and solar polar systems are required at the equipment sites to keep the Base Station (BTS) of the mobile telecommunication operators of Shisong Cardiac Center function for 24 hours. Presently, the Cardiac Center is well equipped with power backup and the telemedicine equipment will be connected to this power back up in order for them to have a power supply. Computers, cameras and microscopes will be switched off when the telemedicine services are not in used in order to allow for low investment on power supply in the Cardiac Center. (Shearer & Findlay 2007, 202.)

3.11 Risk Management of Patient's Information

High- risk organizations such as hospitals are expected to manage any unexpected situation in their everyday activities. Modern medicine has led to increasingly complex forms of treatment and processes of care, but it has also increased the risk of adverse events and patient harm. For example, treatment toxicity to a patient who has been given treatment and thought to be competent but later found to be unsafe. Another example is that of a patient who has been treated inadequately resulting in failure to cure or a reduce chance of be healed. To reduce this risk, the patients should try on their own part to find out the following transparency from their doctors. Firstly, the patients should ask about his/her treatment options, including active surveillance or watchful waiting, surgery or medication. All of these options should be disclosed to the patients to get at the problem of over treatment and under treatment. Secondly, the patient should know about a mistake as soon as it happens and lastly, patients should have access to their medical reports rather than paying a certain amount of money before their reports are given to them. In this way, the risk of patient harm can be reduced though it cannot be completely eliminated. Clinical risk management plays a crucial role in enabling hospitals to enhance patient safety. The clinical risk management outlines certain solutions to this hospital risk management. Firstly errors should be avoided by the doctors and nurses. Secondly, concentrating on key elements in the case history will influence a better treatment. Thirdly, conclusions should be written before plans are made. Furthermore, specific questions should be defined in order to be answered by the chosen tests and in the case of invasive tests, the risk to benefit ratios should be considered. This will solve the problem of inappropriate use of tests. Lastly, when discharging the patients from the hospital, arrangements should be made with him/her in case the symptoms arose again. (Vincent & Charles 2001, 202.)

4 PROJECT IMPLEMENTATION

The stages required to design the LAN for telemedicine will be discussed in this chapter. They include Project Planning, Project Scheduling, Installation guide and training, technical specifications and cost estimates. Also, the type of internet protocol used for the LAN design, access control method, network security policies and security maintenance will be studied in this chapter. (Tomczyk & Catherine 2005, 15.)

4. 1 Project Planning

To successfully handle a project and makeup with the project goals and objectives, planning has to be made. Certain planning stages are required for the design to be successful. Firstly, the study of telemedicine equipment and the calculation of total bandwidth required. Secondly, the ordering of equipment and shipment. Thirdly, the hiring of bandwidth from Camtel. Furthermore, the purchase of the network components and lastly the installation of network components and testing of these components. The initial phase is when the project manager is introduced to other team managers. Also this is when the goals and the objectives of the project are outlined. The project manager meets team members and determines whether they require additional training or not. (Tomczyk & Catherine 2005,17.)

4.2 Project Scheduling

This is the tool that communicates what work needs to be performed, which resources of the organization will perform the work and the time frames in which that work needs to be done. This involves planning the work associated with delivering the project on time. Without a full and complete schedules, the project manager will be unable to communicate successfully in terms of the cost and resources necessary to deliver the project. The various activities considered in order to design the LAN in Shisong Cardiac Center will be practice in the following order of importance. (Demeulemeester & Erik 2002, 28.)

TABLE 3 The Telemedicine Schedule Program In Shisong Cardiac Centre. (Demeulemeester & Erik 2002, 28).

Number	Activity to be carried out	Duration
1	The study of telemedicine equipment	2 weeks
2	Calculation of the total bandwidth required	3days
3	Order of equipment and shipment	3-6 months (12-24 weeks)
4	Installation of optical fiber by CAMTEL	3weeks
5	Choosing Network Components	2days
6	Installation of Network components and testing	4 weeks
7	Closure of project	2 days

The network components can be chosen alongside the installation of optical fiber by Camtel. From the above table, it is noticed that the project can be completed within 22 weeks to 34 weeks (5 months 2 weeks to 8 months 2 weeks.) with the latter being the maximum duration to finish the project. (Demeulemeester & Erik 2002, 30.)

4.3 Installation Guides and Training

Once the equipment has been completely assembled and tested offline with the software, connectivity with the test center at the implementer's HQ should be made. As the video-conference equipment would be implemented, there should be an assurance of network connectivity for the data section. At least 10 tests specialist consult of requests should be sent using different sizes of files and the results sent are tested for errors. This would confirm readiness of the 'store and forward mode', testing desktop video-conference for quality, clarity of sound, picture and frame rate should then precede after checking for errors. Real time viewing of data from equipment like ECG, X-Ray scanner, microscope and ultrasound should be tested and finally, a combination of live VC with high resolution data capture and transfer should be tested. Once the equipment is live, the local staff can be trained by the technician. The client's staff should then perform similar exercises using test and non-patient data. (Mcmillan &Troy 2011, 300.)

4.4 Technical Specification

The telemedicine room should be sufficiently large to accommodate placement of two computers with 17" monitors each, a printer, and connectivity (VSAT indoor) equipment rack and few chairs. Telemedcine room at patient's end should be slightly larger to accommodate medical diagnosis equipment such as the X-ray, scanner, pathological microscope and a bed for taking ECG. Since the video conferencing equipment is also going to be used for treatment of patients, a larger room of 29" will be used. The doctor's room dimension should be at least 12' x 20' and that of the patient at least 15' x 30'. If the patient's room also has an ICU as the case of Shisong Cardiac Center, then the minimum square required for the room is 1500 Square feet. In case of medical college hospitals a standard class room size of at least 30" x 50" is required with good provision for placement of audio/video system as a virtual classroom. (Marilyn 1996, 72.)

The room temperature should be maintained between 18 to 25 degree Celsius, preferably with the use of a A/C for less background noise during video-conferencing and the room should have electrical outlets for connecting various equipment and a very good earthing's pit. Five 15Amp sockets for UPS and five 5AMP sockets for other diagnostic equipment could be good examples of electrical outlets, with a proper arrangement of power supply during emergency. The UPS should at least be of 3KVA capacities depending on the equipment load and the room should have a good acoustics, using sound absorbing panels or heavy curtains for noise free environment during video-conferencing. The curtains in the room should be light blue or gray in color to give good contrast view for video-conferencing and the room should have good illumination to provide good picture quality for video conferencing. Also, the room should have good flooring, preferably vinyl or ceramic floor, to reduce noise. (Marilyn 1996, 72.)

Where ever a VSAT is used, it should be ensured that the antenna size is 1.8 meters in diameter for remote end and 3.8 meters for specialty end and weight of 500 – 2000 kg. Ideally, the antenna should be located at top of the building and should be within a distance of 40 m (cable length) from three telemedicine rooms. The Antenna should have unobstructed field of view to the satellite low time /high time power lines. (Marilyn 1996, 72.)

4.5 Cost Estimate

The cost estimate of establishing telemedicine in Shisong Cardiac Center is as follows. Firstly, the cost of hiring 2 mbps from CAMTEL is equal to 36769,9221 Euros per year. Therefore in a month, the Cardiac Center will be expected to pay 3064,161 Euros as the amount used for hiring bandwidth. Secondly, the cost of a CISCO LINKSYS SRW2048 and 48-port Gigabit Managed Switch is 136 Euros. Thirdly, the cost of a CISCO SFS 7000-P 24-port full duplex infinite band server switch (SFS7000P-SK9) is 221 Euros. In addition, the cost of a level one internet hub with 5 ports is 24 Euros. Moreover, the cost of a CISCO 3700 Series CISCO3725 3725 Access Router is 23 Euros and lastly, The cost of a YAESU FT-2900R VHF 75W 2M Transceiver New Radio FT-2900 is 180 Euros. This total amounts to 37,353.9221 Euros. (Sicotte & Lehoux 2004, 79.)

When this is converted to Cameroon currency, it amounts to 24,466,818.9755frs to start with for the first year of telemedicine implementation and during the following years only the money for hiring the bandwidth will be paid. The above cost is not taken in consideration with the cost of buying and shipping the equipment for telemedicine, the number of rolls of cables used in the network connection and the payments made to the technicians for configuring the network. This might seem expensive, but considering the amount of money spent every month for the transportation of each doctor to and from Shisong in addition to their payments, it will be cost effective. (Sicotte & Lehoux 2004, 80.)

4.6 Internet Protocol Used

The internet protocol that will be used is TCP (Transmission Control Protocol). This will ensure real-time services. The window size is the bandwidth of communication through segmentation of data. This protocol also permits service prioritization. TCP is a model consisting of the 5 layers which are application, transport networking, data layer and physical layer. (Krawetz & Neal 2006, 20.)

4.6.1 Physical Layer

The physical layer (layer 1) handles the mechanical and electrical communications; it translates bits (0s and 1s) in to data that can be transmitted. Layer 1 specifications determine the shape, size and pin-out of connectors, the type of voltages and currents used. It also determines the function of the physical media and electrical components. Devices that operate at the physical layer include network interface cards, hubs, repeaters, multistation access units, media filters and transceivers. The physical layer operates independent of the data sent or received. It only ensures that the data is transmitted and received properly, it does not determine whether the data itself is correct or not. For example, the program calling the physical device driver could be a Web request or just sending random bits. The physical layer ensures that the transmitted data is not corrupted but it does not validate the content of the transmitted information. (Krawetz & Neal 2006, 125.)

Depending on the type of medium, the physical link may also require activation and deactivation. The transmission and reception of data on the physical layer follows a five-step cycle. Firstly, a program generates data and sends it to the physical device driver. Secondly, the physical device driver uses the Network Interface Card (NIC) to transmit data and sends it to the physical device driver. Furthermore, the NIC on the recipient system receives the data and the data is passed to the recipient's physical device driver. Lastly, the physical device driver passes the data to higher OSI layers for processing.(Krawetz & Neal 2006, 125.)

4.6.2 Data Link Layer(Network interface layer)

The Data link layer (also known as the network interface layer) provides flow, error control and synchronization for the physical layer. It takes information from the network layer and sends it to the intended device through the physical layer on the same network. The specifications defined at this layer are network and protocol characteristics. This includes physical addressing, network topology, error notification, sequencing of frames and flow control. Physical addressing defines how devices are addressed; network topology determines the specifications that define how devices are to be physically connected. Error notification alerts upper-layer protocols that a transmission error has occurred and sequencing reorders frames that are transmitted out of order. Flow control monitors the transmission of data so that the receiving device is not overwhelmed with more traffic than it can handle at one time. (Krawetz & Neal 2006, 177.)

The IEEE 802.2 specification has divided the data link layer into the Logical Link Control(LLC) and Media Access Control (MAC) layers. The logical link control layer manages communications between devices over a single link. This includes checking for errors and flow control. The LLC also supports both connectionless and connection-oriented services used by higher-layer protocols. The media access control sub layer of the data link layer to manage protocol access to the physical network medium (the MAC controls access and network adapter card drivers). Media access control addresses enable multiple devices to uniquely identify one another. These unique addresses are assigned by the manufacturer. The data link layer cannot route to other networks, it can only pass on packets in its own segment. Devices that operate at this layer are bridges, switches and routers. (Krawetz & Neal 2006, 178.)

4.6.3 Network Layer

The network layer (layer 3) manages the routing of packets that are to be forwarded on to different networks. The network layer relies on the use of routable protocols to deliver packets to distant networks. The network layer defines the network address, which is different from the MAC address. MAC address is considered the physical address and the network address is considered the logical address. Since the network layer defines the logical network layout, routers can use it to determine how to forward packets. The design and configuration of a network is made in the network layer. (Krawetz & Neal 2006, 226.)

Routers are network nodes that span two distinct data link networks. Any node that spans two distinct data link networks may act as a router. A router that connects two networks is dual-homed. A multihomed router connects many different networks. Routers span that supports the same addressing schemes. Two networks may use different physical layer mediums and data link protocols but a router can span them if the address convention is consistent. For example, a multihomed router may support IP over Wifi, 10Base-T, 100Base-T and a cable modem connection. Multiprotocol routers may offer support for different network layer protocols such as Internet Protocol (IP), Internet Protocol Exchange (IPX) and Digital Equipment Corporation Network (DECnet) but cannot convert traffic between the protocols. Gateways of the transport layer are required to convert this traffic. (Krawetz & Neal 2006, 227.)

4.6.4 Transport Layer

The transport layer (layer 4) manages the connection between the source and the destination to ensure that the data has reliable delivery. The transport layer accepts data and segments it for transport across the network. The transport layer is responsible for making sure that the data is delivered error free and in the proper sequence. Flow control generally occurs at the transport layer to manage data transmission between devices so that the transmitting devices should not be able to send more data than the receiving device can process. Reliable delivery involves error checking and recovery. Error checking includes detecting transmission errors while error recovery includes acting to resolve any errors that occurs. (Krawetz & Neal 2006, 305.)

Transport protocols can be characterized as being either connection-oriented or connectionless. Connection-oriented services must first establish a connection with the desired service before handing over any data. A connectionless service can send the data without any need of establishing a connection. Connection-oriented services involves three phases such as establishing the connection, transferring the data, and terminating the connection. The protocol is also responsible for arranging the packets in the correct sequence before handing over the data. Connection-oriented network services must negotiate a connection, transfer data and terminate the connection, whereas a connectionless transfer can simply send the data without the added overhead of creating and terminating the connection. (Krawetz & Neal 2006, 306.)

4.6.5 Application Layer

The application layer (layer 5) provides the user interface for communication. The application layer is the TCP layer closest to the end user. The TCP application layer and the user interact directly with the software application. The application layer functions typically include: file transfer, file management, message handling and database query functions. The application layer also determines the availability of an application with data to transmit and decides weither sufficient network resources for the communication exist. The application layer is not itself an application that is communicative, rather it is a layer that provides application services. (Krawetz & Neal 2006, 463.)

The application layer is based on the push or pull technologies which allow one system to initiate a data transfer to another system without a request from the recipient. Application layer push-oriented protocols include email (SMTP) and VoIP. In contrast to push systems, pull technologies require the recipient to issue a request for information retrieval. An example of pull-oriented protocols include Web (HTTP), newsgroups and remote login protocols such as SSH and Telnet. Most network protocols are pull technologies, although some may have push elements. For example, DNS (OSI layer 5) allows users to pull data, but servers can push data to other servers. Similarly, the Simple Network Management Protocol (SNMP) allows clients to push configuration change to servers or pull values from server. (Krawetz & Neal 2006, 464.)

4.7 The Access Control Method

The access control provided for this network will be the use of biometrics. Biometrics are automated methods of recognizing a person based on a physiological or behavioral characteristic. Physiological characteristics include hand or finger images, facial characteristics and iris recognition while behavioral characteristics are traits that are learned or acquired. Dynamic signature verification, speaker verification and keystroke dynamics are examples of behavioral characteristics. Biometrics is expected to be incorporated in solutions to provide an increased homeland security, including applications for improving airport security, strengthening the national borders, in travel documents and visas and preventing ID theft. The biometrics with physiological characteristics of finger images capture will be used in Shisong Cardiac Center. (Vacca & John 2007, 32.)

Among all the biometric techniques, fingerprint-based identification is the oldest method that has been successfully used in numerous applications. Everyone is known to have a unique, immutable finger prints. A finger print is made of series of ridges and furrows on the surface of the finger. Finger image capture is the acquisition and recognition of a person's finger print characteristics for identification purposes. This allows the recognition of a person through quantifiable physiological characteristics that verify the identity of an individual. There are two different types of finger scanning technologies which includes optical method which starts with a visual image of a finger and the semiconductor-generated electric field to image the finger. (Vacca & John 2007,145.)

The two categories of finger print matching techniques are minutiae-based and correlation-based. Minutiae-based techniques first find minutiae pints and then map their relative placement on the finger but some difficulties are encountered when using these approaches such as, the difficulty of extracting the minutiae points accurately when the finger print is of low quality and also, this method does not take into account the global pattern of ridges and furrows. The correlation base's method is able to overcome some of the difficulties of the minutiae-based approach but its main shortcoming is that of requiring the precise location of a registration point. (Vacca & John 2007,146-147.)

4.8 Establishing Network Security Policies

It is important to establish clear and detailed network security policies that are supported by the hospital management. The management has an ethical and legal responsibility to provide security for all assets of the hospital. Investors, board members, officers and employees can all be held liable in a lawsuit involving a breach in security. Insurance companies now place a great deal of weight on the security policy and perform audits. It is also important that the users are aware of the policies and follow them. The most crucial part of a security policy is planning. The quality of the policy indicates how sophisticated a hospital is as well as how it can cope with the security threats. (Preetham 2002, 50.)

The first step in establishing a network security policy is to appoint a planning committee. This should be a joint administrative-IT's committee. This committee should designate the information security analyst or officer, a security administrator and the security team. When the management hierarchy is established, planning can begin. One way to begin is by examining the network for security risks or risk assessment. Risk is the potential of a threat to exploit a vulnerability found in an asset. Risk assessment refers to how likely the scenarios listed might actually occur. The security policy team must perform a detailed risk assessment to determine what assets must be protected by the policies and then identify the users and vendors who must abide by the policies. By identifying assets, threats, and vulnerabilities and comparing them with the probabilities and costs, it is important to specify to the administration the policies that are acceptable to the hospital and inform them of their expectation and how to handle network access. This will include e-mail. (Preetham 2002, 51.)

4.9 Managing Network Security

It is often found in financial institution that in order to violate the security controls, all of the participants in the process would have to agree a compromise on the system. For security purposes, it is necessary to avoid giving one individual complete control of a transaction or process from beginning to end. Also, policies such as job rotation, mandatory vacations and cross-training are implemented. Users should have access to only the resources and information necessary to perform their roles. This part of the policy outlines the manner in which a user is associated with necessary information and system resources. There must be justification for any request to access information. Each person must have a unique ID and password to access a secure system. It is of importance to give users only the minimum possible level of access necessary to perform normal duties. Weak passwords are security risks that may be exploited by an attacker. (Herzog & Shai 2001, 24.).

In addition to the password duration and complexity requirements, the password policy should recognize the following practices. Firstly, a password based on personal information can be guessed easily. Secondly, short words or common acronyms are easy to crack and provide very little security and lastly, hard-to-remember passwords tempt users to write down the password. The password policy needs to spell out that passwords such as, god, password, sex, names of children, pet names, birthdays should not be used. It is important that users are made aware of these requirements and that existing passwords are tested using auditing tools to ensure that users are in compliance with these policies. Proper disposal of data and equipment should be part of the security policy. Outdated hardware and discarded paper may be used by attackers to obtain access to a network. (Herzog & Shai 2001, 25.)

4.10 Security Maintenance

Maintaining security is an ongoing process. A plan cannot be implemented and just forgotten about it. As the business needs and the network requirements change, so most the security plan changes. A security plan is a living document, just like a disaster recovery or incident response plan. When the plan is in place, it may be found that certain parts do not work the way they should and thus need modification. There should be a policy describing the method for change control so that when it has been decided that the policy should be changed, these changes are documented and communicated to the employees concerned. Sensitive data must be tightly controlled to ensure that the information does not fall in to the wrong hands. (Liley & Christopher 2010, 43.)

5 DISCUSSIONS

Communication networks play a vital role in all the different types of telemedicine systems. It is not possible for medical entities to build their own communication networks for the purpose of telemedicine. Network infrastructure sharing should be done with the telecom's service providers. Telemedicine equipment often requires a longer and stable connection to a fixed number of systems. An example is that of the telemedicine equipment used in Shisong Cardiac Center to connect to a super specialist hospital in Italy. Leased line connection suits this type of network requirement for both real-time and store-and-forward type of telemedicine applications. Since optical fiber is a fast and cheaper medium of communication in Cameroon, the utilization of telemedicine services will be easier if the leased connection can be provided through an optical fiber medium provided by Camtel. In order to ensure constant availability of the network, A VSAT link should be used as an alternative to optical fiber.

Cameroon Telecommunication (Camtel) is the only main telecoms operator in Cameroon and this operator operates in each of the 10 region in Cameroon including the North West region where the Cardiac Center is located. Camtel provide bandwidths to other telecommunication operators in Cameroon such as MTN, ORANGE and Vietel. Camtel was established in 1998 by the government of Cameroon and it provide services like voice(Telephone), data and internet services. With the introduction of Leap Billing(end-to-end billing), Camtel is presently able to deliver new and exciting services to its customers while at the same benefiting from creative billing schemes. The key benefit to the customer is a single unified bill that outlines the different services they have used from across the package that they were subscribed in the beginning. The details of the bills includes all the services that the customers have been charged for, from wire-line telephony and internet services to wireless CDMA usage. The customer management solution also provides all Camtel's customers with a single point of contact for all their inquires or problems

For this type of leased line service for telemedicine network, a major role will be played by the Camtel. Camtel in Kumbo should be ready to provide leased bandwidth service through their transmission network from Camtel. The telecoms operators have to ensure reliability in the leased network by constantly monitoring and maintaining the optical fiber medium in times of damage. Also, the operator have to ensure that a particular technician should be assigned to monitor and correct the signals provided to the Cardiac Center.

6 CONCLUSIONS

Plastic Optical Fibers are used for LAN cabling though they have a high attenuation; the distance from Camtel office in Kumbo to Shisong Cardiac Center is very small in such a manner that attenuation is not introduced on the optical fiber. In the design of a telemedicine network, the LAN/WAN protocol and the utilization allocation of bandwidth are taken into consideration. The concept of communicating patient's information electronically and the needs for developing medical protocol to be used in the day-to- day activity using telemedicine network are equally taken into consideration. High speed devices are used to design the Local Area Network for telemedicine and the network have to be constantly available in order to avoid failure during operations and consultation. Therefore the continuous monitoring and maintenance of the equipment is very important. Designing and implementing telemedicine in Shisong Cardiac Center is not sufficient to solve the problem of inadequate doctors. There is also a need to secure the network so that intruders should not have access to the network and cause signal distortion there by disrupting the consultation and operation of patients. In order to solve this problem, it necessary that the finger prints of the two doctors both in Shisong and abroad should be imprinted on the computer so that only two of these doctors can have access to the signals.

Telemedicine is of necessity in the presence African medication than before. Considering the many deadly diseases presently in Africa, many doctors will not like to go there for the treatment of patients since they are scared to die in the process of helping the patients. To improve the living conditions of these patients, a situation should be made in a way that doctors can sit in their various home countries and perform the treatment on patients in this way, the patients will be healed and the doctors will not have any physical contact with the patients. Looking at the example of telemedicine in Finland, a situation where patients were not able to travel to and fro to Oulu Hospital, the health of the patients were gradually degrading because the distance was too far for the patients to travel. This condition continued till when telemedicine was introduced and doctors were able to monitor their patients from home, which has now made the health and the living standard of Fins to be wonderful.

During the process of writing this thesis, a limitation was encountered in knowing the exact bandwidth of signal needed by the hospital. This is because the hospital handle a lot of privacy and have to be very careful with the people they share information with. The bandwidths used in this thesis were estimated from the existing telemedicine equipment and from the traffic pattern of the hospital. A recommendation is therefore made to the Shisong Cardiac Center Administration that constant availability of signals should be ensured by monitoring the equipment on a daily basis and writing down the daily reading and performance of each telemedicine equipment. Also, The administration of Shisong Cardiac Center should send some of their staff's for training concerning the monitoring and maintenance of telemedicine equipment in order to ensure quality signal transmission. It will be a good suggestion to the Shisong Hospital Administration to extend this telemedicine from the cardiac center to the general hospital. Therefore a study of network traffic and total bandwidth needed by the general hospital should be made and given to the Cameroon telecommunications. With this, they will be able to provide the required bandwidth to both the cardiac center and general hospital with no distortion on the signal.

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