UNIVERSITY OF EDUCATION, WINNEBA

COLLEGE OF TECHNOLOGY EDUCATION, KUMASI

DEPLOYMENT TECHNIQUES AND LINK BUDGET ANALYSIS OF FIBER BACKBONE NETWORKS IN GHANA

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DECLARATION

STUDENT'S DECLARATION

I, Frank Appiah Aboegye declare that this dissertation with the exception of quotations and references contained in published works which have all been identified and duly acknowledged, is entirely my own original work, and it has not been submitted, either in part or whole, for another degree elsewhere.

SIGNATURE …………………….……………..

DATE: ………………………………………….

SUPERVISOR'S DECLARATION

I hereby declare that the preparation and presentation of this work was supervised in accordance with the guidelines for supervision of thesis as laid down by the University of Education, Winneba.

NAME OF SUPERVISOR: PROF WILLIAM K. OFOSU

SIGNATURE: …………..………..……………

DATE: ……………….……………………………

DEDICATION

This piece of work is dedicated to my lovely wife, Mrs Vesta Sakyi Appiah Aboagye and my father Rev. Stephen Aboagye.

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TABLE OF CONTENT

Title page i

Declaration.. ii

Dedication... iii

Acknowledgement.. iv

Table of Contents.. v

List of Tables viii

List of Figures ix

Abstract... x

CHAPTER ONE: INTRODUCTION..1

1.1 Overview 1

1.2 Problem Statement...1

1.3 Objectives of Research..2

1.4 Significance of Project...3

1.5 Scope of the Project...3

1.6 Limitation of Project...3

1.7 Research Organisation..3

CHAPTER TWO..4

LITERATURE REVIEW 4

2.1 The Optical Fiber 7

2.2 Advantages of Fiber 9

2.3 Types of Fiber Cables 10

2.4.1 Aerial cable ……………………………………………………………………..12

2.4.2 Armored cable……………………………………………………………………..13

2.4.3 Underwater cable…………………………………………………………………..13

2.4.4 Military cable………….……………………………………………………………..13

2.5 Fiber Deployment Techniques..14

2.5.1 Direct-burial installations………..……………………………………..……..14

2.5.2 Pulling into ducts………..……………………………………………..…..15

2.5.3 Aerial installation………..…………………………………………………..…..16

2.5.4 Submarine installation………..…………………………………………..…..16

2.5.5 Blowing ……………………..…………………………………………………..…..17

2.6 Optical Backbone Networks...18

2.7 Link Budget Analysis...21

2.7.1 Link margin ……………………………………………………………………....22

2.7.2 Cable attenuation……………………………………………………………..…..23

2.7.3 Connector loss……………………………………………………………..…..23

2.7.4 Splice loss……………………………………………………….……………..23

2.7.5 Repair splice loss…………………………………………………………..…..23

2.8 Measurement and Testing..24

CHAPTER THREE

METHODOLOGY ……………………………………………………………………..25

3.1 Link Budget Analysis…………………………………………………………...25

3.2 Parameter Definitions……………………………………………………………28

3.2.1 Practical external losses……………………………………………………..28

3.2.2 Internal loss ……………………………………………………………………30

3.3 Installation ……………………………………………………………………….31

CHAPTER FOUR

4.1 Network Topology ……………………………………………………………32

4.2 Type of Cable Used…………………………………………………………… 33

4.3 Methods of Installation ……………………………………………………….34

4.4 Comparison of Direct Burial and Duct Methods ………………………………35

4.5 Factors Affecting Fiber Performance……………………………………………36

4.6 Link Budget Analysis…………………………………………………………..37

4.6.1 Estimated link budget for MTN and TIGO………………………………..39

4.6.2 Real or actual link budget for MTN and TIGO…………………………….40

4.6.3 Final tabulation of results……………………………………………...40

4.6.4 Graphical analysis of results (losses) ……………………………………..41

CHAPTER FIVE

CONCLUSION ………………………………………………………………… 43

5.1 Recommendation ……………………………………………………………… 44

References ……………………………………………………………… 45

LIST OF TABLES

Table 1: Types of connectors and their losses …………………………………………………..29

Table 2: Types of fibers, their losses and applications ………………………………………30

Table 3: Parameters for link budget for MTN and TIGO…………………………………….38

Table 4: Parameters for estimated loss budget for MTN and TIGO for the three hops ……..38

Table 5: Estimated total loss for MTN and TIGO for all three hops ………………………..39

Table 6: Real link budget for MTN and TIGO for all three hops ……………………………40

Table 7: Optical Power Budget (OPB) difference for MTN ……………………..…………40

Table 8: Optical Power Budget (OPB) difference for TIGO …………………….………..40

LIST OF FIGURES

Figure 1: Power Budget ……………………………………………………………24

Figure 2: Diagram of an OTDR measuring a transmit power ……..……………….27

Figure 3: Splicing technique using the fusion splicer……………………………28

Figure 4: Layout of backbone for TIGO (Nationwide)…………….………………32

Figure 5: Layout of backbone for MTN (Nationwide)………………..…………33

Figure 6: Sample of a Fiber cable ……………………………………………..34

Figure 7: Duct installation method (TIGO)…………….…………………….…..34

Figure 8: Direct buried installation method (used by MTN) ……………………35

Figure 9: Hops from Accra to Nkawkaw ……………….……………………….37

Figure 10: A graph of total splice loss in the link of

MTN and TIGO for the three hops...41

Figure 11: A graph of estimated total link loss for MTN and TIGO……………41

Figure 12: A graph of real or actual link loss for MTN and TIGO.......................42

Figure 13: Losses in the fiber backbone link for MTN and TIGO ………………42

ABSTRACT

Fiber backbone is almost at the verge of replacing the microwave link completely owing to the high demand for capacity. To achieve this high capacity with fiber in other to reduce complaints of poor quality of service, proper deployment techniques must be employed by network operators. This project delves into the network elements, their installations and their interconnection topologies of the various fiber backbones deployed by all the network operators in Ghana. The analytic method was used for the work. Link budget analysis was done over the existing links of the backbone of all the network operators to obtain the losses in the links. After the analysis it was observed that the duct method of installation had lesser losses than the direct buried method due to it being less prone to fiber cut.

Both duct and direct buried methods of installation should be used depending on the environment between two nodes. This will help cut down the cost of installation. Also engineers should comply with regulations on deployment. They should ensure that factors which will lead to a reduced performance of the fiber such as poor termination of the cable, splicing fallen outside its defined range of 0- 0.05dB, shallow burial depth, bends, absence of warning tapes and poor laying of cable are avoided.

CHAPTER ONE

INTRODUCTION

1.1 Overview

Telecommunication networks are basically in two sections, access and core networks (backbone). Access networks connect end users or nodes to the core networks. Due to the ever increasing number of users of telecommunication networks with services like live streaming, video calls and conferencing, e-banking and high speed internet access there is a need for higher core network capacity to carry this integrated traffic from several users. Network operators thought it wise and technical to migrate onto optical communication systems in other to harness its wide range of carrier frequency typically about 200 THz, in contrast with microwave carrier frequencies. There are three elements of an Optical link which are the transmitter consisting of the light source and associated electronic circuitry, the optical fiber placed in a cable offering mechanical and environmental protection.

Next is the receiver, inside which there is a photodiode that detects weakened and distorted optical signal emerging from the end of an optical fiber and converts into an electric signal (Gerd Keiser, 2003)

1.2 Problem Statement

As the trend of changing from micro wave to fiber optic mobile communication systems in Ghana started, mobile operators find it difficult to fully cater for complains from subscribers making their services less quality, the traffic management system on the other hand is becoming a serious challenge from time to time. More over the hand over from micro wave link to fiber optic net work is generally not smooth for mobile communication network in Ghana. Specifically, high demand of data traffic in Ghana is highly increasing putting pressure on mobile operators to increase data rate and capacity on their networks, Quality of service in the urban areas where there are lots of buildings and other obstacles that cause transmission problems is becoming the main issue for the Ghanaian mobile operators

The Topology of the country is also highly scatted where rural settlement is more dominant, accessing these scatted areas with the required data rates and quick latency time by the existing technology is almost impossible.

In summary, Ghanaian Telecom operators have been challenged by high network congestion, lack of coverage and scarcity of band width availability (Harrie, 2012), which need to be resolved in the years to come. Therefore the trust of this study is to analyze the possibility of Deployment Techniques and Budget Analysis of Fiber Backbone Networks in Ghana.

Some network operators after migrating onto fiber core network have not fully catered for complaints from subscribers making their services less quality. This is due to losses in the existing links of the backbone arising from poor deployment techniques employed by them.

1.3 Objectives of Research

The ultimate goal of this study is to deploy techniques and link budget analysis of fiber backbone networks in Ghana.

This project seeks to:

1. Determine techniques for the installation of fiber core networks to reduce frequent fiber cuts.
2. Analyze the various link budgets of the existing links of the fiber backbones for all the network operators in Ghana.
3. To determine the best techniques based on the losses incurred in their deployment.

1.4 Significance of Project

The project reveals the most efficient and effective techniques for the installation of fiber backbone network in order to help engineers in the field to minimize losses in their fiber backbones, reduce fiber cut and to ensure a required capacity.

1.5 Scope of the Project

The project is centered on fiber backbone networks in some areas of the nation and also based on their link budgets.

1.6 Limitation of Project

The prime limitation of the project was the securing of data from the various network operators.

1.7 Research Organisation

This paper is organized as follows: chapter 2 reviews all literature, followed by the Research Methodology in chapter 3. Results of the research are further discussed in the fourth chapter. The fifth and final chapter looks at the conclusions drawn from the research as well as recommendations.

CHAPTER TWO

LITERATURE REVIEW

Fiber backbone deployment involves the connection of several technologies and the incorporation of techniques in order to ensure the provision of good quality of services. Below are reviewed literature based on technologies for higher capacity demand as well as techniques that result in proper harnessing of the capacity of the fiber core network.

Robert C. Bray et all presented a fact in their contribution (Robert C. Bray and Douglas M. Baney, 1997) that Communications traffic in the world's fiber-optic backbone network is growing more than 10% per year and the growth rate is accelerating. The ever-increasing bandwidth demands are being met by an array of technological innovations including higher time-division multiplex (TDM) transmission rates combined with wavelength-division multiplex (WDM) overlays. They then talked about the convergence of high-speed millimetre-wave wireless communications and high-capacity fibre-optic backhaul a network which provides tremendous potential to meet the capacity requirements of future access networks. In the paper a point was made that, long-haul core networks, ultra-high-speed optical communication systems which can support 1Terabit/s per channel transmission would soon be required to meet the increasing capacity demand in the core networks. According to (STICNE, 2003) an optical fiber defined by ITU-TG.655 and called NZ- DSF (Non-Zero Dispersion Shifted Fiber) which is also branded by Corning as LEAF (Large Effective Area Fiber) is proposed. It is optimized to support higher speed and dense wave division multiplexing (DWDM) in the 1550 nm and 1625 nm bands where the optical lost is lowest. It is designed to have small positive dispersion at 1550 nm to reduce signal distortion caused by fiber non-linear effects. The optical fiber has a low PMD (Polarization Mode Dispersion) at 1550 nm.

In this same paper another type of NZ-DSF which has a negative dispersion slope was proposed. Corning calls this negative dispersion fiber Metro Cor. It is recommended for large metropolitan DWDM applications with the use of directly modulated positive – chirp lasers in 1550 nm band. An alternative installation was provided to cater for the high cost of DWDM equipment. That is, to run extra optical fibers to avoid the need for DWDM. In the paper (Optic Association Inc, 2010) general guidelines for installing fiber optic cable are presented. It presents several processes required for both indoor and outdoor installations. From the paper, outdoor cable may be direct buried, pulled or blown into conduit or inner duct, or installed aerially between poles. Indoor cables can be installed in raceways, cable trays above ceilings or under floors, placed in hangers, pulled into conduit or inner duct or blown though special ducts with compressed gas. It further makes a point that installation process will depend on the nature of the installation and the type of cable being used. Fiber cable is designed to be pulled with much greater force than copper wire if pulled correctly, but excess stress on the cable may harm the fibers, potentially causing eventual failure. Particular care should be taken during installation to prevent kinking the cable which can harm the fibers. In paper (Rajendran Partheban, 2004), Automatically Switched Optical Network (ASON) to address the limitations of the first one. A linear algorithm was developed to design an ASON in other to determine its bottlenecks and afterwards the cost compared to that of point – to – point WDM network. A scheme was later developed to perform waveband grooming for several different topologies of an ASON that uses single-layer multigranular Optical Cross-Connects (MG-OXCs). Investigation on how different traffic grooming schemes could be used to eliminate the bottlenecks in an ASON was done. Also in this paper, a new modeling approach for ASONs was developed, and evaluated the cost and scalability of different architectures of point-to-point WDM networks and ASONs as a function of traffic load.

Through this modeling approach, it was identified that an ASON is lower in cost *than a point-to-point WDM network for low traffic loads. It was further demonstrated that an*ASON needed IP routers to be lower in cost for high traffic loads. Later analysis on how the cost of an ASON is affected by other factors such as the use of 40 Gb/s versus 10 Gb/s light paths, and reductions in network element cost over time was made.The focus of the contribution (Lim, C et al, 2001) was on the realization that wavelength conversion may be the first obstacle in realizing a transparent WDM network and among numerous wavelength conversion techniques reported to date, only a few techniques offered strict transparency. It was pointed out that optoelectronic conversion (O/E-E/O) techniques achieve limited transparency, yet their mature technologies allow deployment in the near future and also, the majority of all-optical wavelength conversion techniques also offer limited transparency but they have a potential advantage over the optoelectronic counterpart in realizing lower packaging costs and crosstalk when multiple wavelength array configurations are considered. A proposal that wavelength conversion by difference-frequency generation offers a full range of transparency while adding no excess noise to the signal was made. The paper [17] reveals that recent experiments showed promising results including a spectral inversion and a 90 nm conversion bandwidth. Investigation on network capacity limitations for star-tree WDM mm-wave fiber-radio systems incorporating wavelength-interleaving technique to increase optical spectral efficiency was made. A model was developed based on link budget calculations to provide estimations of the network capacity which can also be utilized to find the optimum network architecture in conjunction with other factors such as cost. It was found that a completely passive feeder network offers simplicity however is limited by a maximum network reach of 9 km. A proposal, pre-amplification, arrangement enables centralized control architecture, however amplifier saturation effects limit the system capacity to 100 channels with a network reach of 50 km.

Incorporating an amplified RN architecture(post-amplification) significantly increases the overall capacity however increases cost and network management complexity trade-offs must be also taken into account.

From the above reviews it is vivid that selecting some specific technologies and techniques increases the capacity and performance of the core network. This project on the other hand seeks to know the losses incurred as a result of the techniques used in the deployment of the core network and how prone the network is to fiber cut.

2.1 The Optical Fiber

A fiber consists of a solid glass cylinder called the core. This is surrounded by a dielectric cladding, which has a different material property from that of the core in order to achieve light guiding in the fiber. Surrounding these two layers is a polymer buffer coating that protects the fiber from mechanical and environmental effects. In its simplest form an optical fiber consists of a cylindrical core of silica glass surrounded by a cladding whose refractive index is lower than that of the core. Because of an abrupt index change at the core–cladding interface, such fibers are called step-index fibers. In a different type of fiber, known as graded-index fiber, the refractive index decreases gradually inside the core.

The refractive index of pure silica varies with wavelength, ranging from 1.453 at 850nm to 1.445 at 1550nm. By adding certain impurities such as germanium or boron to the silica during the fiber manufacturing process, the index can be changed slightly, usually as an increase in the core index. This is done so that the refractive index n2 of the cladding is slightly smaller than the index of the core (that is, $n2 < n1$), which is the condition required for light traveling in the core to be totally internally reflected at the boundary with the cladding. The difference in the core and cladding indices also determines how light signals behave as they travel along a fiber.

Typically the index differences range from 0.2 to 3.0 percent depending on the desired behavior of the resulting fiber. Only a finite set of rays at certain discrete angles greater than or equal to the critical angle is capable of propagating along a fiber. These angles are related to a set of electromagnetic wave patterns or field distributions called modes that can propagate along a fiber. When the fiber core diameter is on the order of 8 to 10µm, which is only a few times the value of the wavelength, then only the one single, fundamental ray that travels straight along the axis is allowed to propagate in a fiber. Such a fiber is referred to as a single-mode fiber. Fibers with larger core diameters e.g greater than or equal to 50µm support many propagating rays or modes and are known as multimode fibers. Single-mode fibers are used for long-distance communication and for transmissions at very high data rates. The larger-core multimode fibers typically are used for local-area network applications in a campus environment, particularly for gigabit or 10-Gbit rate Ethernet links, which are known popularly as GigE and 10GigE, respectively. Here the word campus refers to any group of buildings that are within reasonable walking distance of one another. Light traveling in a fiber loses power over distance. The fiber loss is referred to as signal attenuation or simply attenuation. Basically, there are just two ways of losing light. Either the fiber is not clear enough or the light is being diverted in the wrong direction (John Crisp, 2001). The first problem is due to material absorption. In absorption, impurities (hydroxyl ions and metallic traces) that remain in the fiber after manufacture will block some of the light energy. The second is due to Rayleigh scattering. This is the scattering of light due to small localized changes in the refractive index of the core and the cladding material. Also a sharp bend in a fiber can cause significant losses as well as the possibility of mechanical failure. It could be a macro bend or a micro bend. The problem of macro bend loss is largely in the hands of the installer whiles that of the micro bend is in the hand of the manufacturer.

With careful choice of the fiber to be installed, these are less likely to be a problem than the bending losses caused during installation since fiber optic cables are readily available with a wide range of operating temperatures from –55°C to +85°C.Attenuation is an important property of an optical fiber because together with signal distortion mechanisms, it determines the maximum transmission distance possible between a transmitter and a receiver(or an amplifier) before the signal power needs to be boosted to an appropriate level above the signal noise for high-fidelity reception. The degree of the attenuation depends on the wavelength of the light and on the fiber material.

Fiber losses are considerably higher for shorter wavelengths and exceed 5dB/km in the visible region, making it unsuitable for long-haul transmission.

2.2 Advantages of Fiber

The motivation for developing optical fiber communication systems started with the invention of the laser in the early 1960s. The operational characteristics of this device encouraged researchers to examine the optical spectrum as an extension of the radio and microwave spectrum to provide transmission links with extremely high capacities. As research progressed, it became clear that many complex problems stood in the way of achieving such a super broadband communication system. However, it also was noted that other properties of optical fibers gave them a number of inherent cost and operational advantages over copper wires and made them highly attractive for simple on/off keyed links.

Included in these advantages are;

- Optical fibers have lower transmission losses compared to copper wires and hence data can be sent over longer distances, thereby reducing the number of intermediate repeaters needed for these spans.
- Wider bandwidths than copper wires, which means that more information can be sent over a single physical line.

- Low weight and the small dimensions of fibers offer a distinct advantage over heavy, bulky wire cables in crowded underground city ducts or in ceiling-mounted cable trays.
- They consist of dielectric materials and as such do not conduct electricity. This makes optical fibers immune to the electromagnetic interference effects seen in copper wires, such as inductive pickup from other adjacent signal-carrying wires or coupling of electrical noise into the line from any type of nearby equipment.
- Optical fiber offers a high degree of data security, since the optical signal is well confined within the fiber and any signal emissions are absorbed by an opaque coating around the fiber. This makes fibers attractive in applications where information security is important, such as in financial, legal, government, and military systems (Gerd Keiser, 2003).

2.3 Types of Fiber Cables

Optical cables are essential elements of an optical communications link. In addition to providing protection to the optical fibers contained within the cable, the construction of an optical cable determines whether it can withstand the environments in which it will be used. If engineers select the wrong cable configuration, the cost of retrofitting installed cable can be prohibitively high. Although we could insist on buying a cable containing almost any number of fibers, it is generally less expensive and easier to buy standard sizes. Small cables usually have a fiber count of 1, 2, 4 or 6. Medium size cables have counts increasing in multiples of 6 to give sizes of 12, 18, 24, 30 and 36. Larger cables increase in steps of 12 to give 48, 60, 72 etc. The degree of protection depends on the conditions under which the cable is to operate. Some cables will live a luxurious life, warm, dry and undisturbed asleep in a duct in an air-conditioned office while others are outside in the real world.

These may well be submerged in water or solvents, attacked by rodents, at sub-zero temperatures or being crushed by earthmovers on a construction site (John Crisp, 2001). The cable structure will vary greatly depending on whether the cable is to be pulled or blown into underground or intra building tubes called ducts, buried directly in the ground, installed on outdoor poles, or placed underwater. Different cable configurations are required for each type of application, but certain fundamental cable design principles will apply in every case. The objectives of cable manufacturers have been that the optical fiber cables should be installable with the same type of equipment, installation techniques, and precautions as those used for conventional wire cables. This requires special cable designs because of the unique properties of optical fibers such as their strength, dielectric nature, small size, and low weight. There are two distinctly different methods used to protect the optic fibers. They are referred to as loose tube and tight buffer designs. Cables with tight-buffered fibers nominally are used indoors whereas the loose-tube structure is intended for long-haul outdoor applications. A ribbon cable is an extension of the tight-buffered cable. In all cases the fibers themselves consist of the normally manufactured glass core and cladding which are surrounded by a protective 250-μm-diameter coating. In loose tube construction, there is room for more than one fiber and as many as twenty-four optic fibers can run through the same tube. Heavy duty versions are available with up to 144 fibers. The main feature is that the optic fiber is thus free to move about as it wishes. The benefit of this is that its natural springiness allows the optic fiber to take the path of least strain and allows the fiber to expand and contract with changes of temperature. Indoor cables can be used for interconnecting instruments, for distributing signals among office users, for connections to printers or servers, and for short patch cords in telecommunication equipment racks. The three main types are Interconnect cables, Breakout cables and Distribution cables.

Outdoor cable installations include aerial, duct, direct-burial, underwater, and tactical military applications. Many different designs and sizes of outdoor cables are available depending on the physical environment in which the cable will be used and the particular application. Some important designs are described here.

2.4.1 Aerial cable

An aerial cable is intended for mounting outside between buildings or on poles or towers. The two main designs that are being used are the self-supporting and the facility-supporting cable structures. The self-supporting cable contains an internal strength member that allows the cable to be strung between poles without implementing any additional support to the cable. For the facility-supporting cable, first a separate wire or strength member is strung between the poles, and then the cable is lashed or clipped to this member. There are three common self-supporting aerial cable structures known as OPGW, ADSS, and figure 8.

- In addition to housing the optical fibers, the optical ground wire (OPGW) cable structure contains a steel or aluminum tube that is designed to carry the ground current of an electrical system. The metal structure acts as the strength member of the cable. OPGW cables with up to 144 fibers are available.
- The all-dielectric self-supporting (ADSS) cable uses only dielectric materials, such as aramid yarns and glass-reinforced polymers, for strength and protection of the fibers. An ADSS cable typically contains 288 fibers in a loose-tube stranded-cable-core structure.
- A popular aerial cable is known as a figure 8 cable because of its shape. A key feature is the factory-attached messenger, which is a support member used in aerial installations. The built-in messenger runs along the entire length of the cable and is an all-dielectric material or a high-tension steel cable with a diameter between 0.25 and 0.625in (0.64 and 1.6cm). This configuration results in a self-supporting structure that allows the cable to be installed easily and quickly on low-voltage utility or railway poles.

2.4.2 Armored cable

An armored cable for direct-burial or underground duct applications has one or more layers of steel-wire or steel-sheath protective armoring below a layer of polyethylene (PE) jacketing. This not only provides additional strength to the cable but also protects it from gnawing animals such as squirrels or burrowing rodents.

2.4.3 Underwater cable

Underwater cable, also known as submarine cable, can be used in rivers, lakes, and ocean environments. Since such cables normally are exposed to high water pressures, they have much more stringent requirements than underground cables. For a cable that can be used in rivers and lakes, they have various water-blocking layers and a heavier armor jacket. Cables that run under the ocean have further layers of armoring and contain copper wires to provide electric power for submersed optical amplifiers or regenerators. In addition, if such a cable is damaged, the ruptured portion needs to be lifted to the surface for repair.

2.4.4 Military cable

Extremely strong, lightweight, rugged, survivable tight-buffered cables have been designed for military tactical field use. That means they need to be crush-resistant and resilient so they can withstand being run over by military vehicles, including tanks, and they need to function in a wide range of harsh environments. In addition, since often they are deployed in the field from reels attached to the back of a rapidly moving jeep, they must survive hard pulls. As a result of being developed for such hostile environments, these cables also have found use in manufacturing, mining, and petrochemical environments.

2.5 Fiber Deployment Techniques

Workers can install optical fiber cables by pulling or blowing them through ducts (both indoor and outdoor) or other spaces, laying them in a trench outside, plowing them directly into the ground, suspending them on poles, or laying or plowing them underwater. Although each method has its own special handling procedures, they all need to adhere to a common set of precautions. These include avoiding sharp bends of the cable, minimizing stresses on the installed cable, periodically allowing extra cable slack along the cable route for unexpected repairs, and avoiding excessive pulling or hard yanks on the cable (Gerd Keiser, 2003).

2.5.1 Direct-burial installations

For direct-burial installations a fiber optic cable can be plowed directly underground or placed in a trench which is filled in later. The cables are mounted on large reels on the plowing vehicle and are fed directly into the ground by means of the plow mechanism. Since a plowing operation normally is not feasible in an urban environment, a trenching method must be used. Trenching is more time-consuming than direct plowing since it requires a trench to be dug by hand or by machine to some specified depth. However, trenching allows the installation to be more controlled than in plowing. Usually a combination of the two methods is used, with plowing being done in isolated open areas and trenching being done where plowing is not possible, such as in urban areas.

During direct-burial installations, a bright (usually orange) warning tape normally is placed a short distance (typically 18in) above the cable to alert future digging operators to the presence of a cable. The tape may contain metallic strips so that it can be located from above ground with a metal detector.

In addition, a warning post or a cable marker that is flush with the ground may be used to indicate where a cable is buried. Besides indicating to repair crews where a cable is located, these precautions are intended to minimize the occurrence of what is known popularly in the telecommunications world as backhoe fade (the rupture of a cable by an errant backhoe).

2.5.2 Pulling into ducts

Most ducts are constructed of a high-density polyurethane, PVC, or an epoxy fiberglass compound. To reduce pulling tensions during cable installation, the inside walls can have longitudinal or corrugated ribs, or they may have been lubricated at the factory. Alternatively, a variety of pulling lubricants are available that may be applied to the cable itself as it is pulled into a long duct or into one that has numerous bends. A duct also can contain a pulling tape running along its length that was installed by the duct manufacturer. This is a flat tape similar to a measuring tape that is marked every meter for easy identification of distance. If the duct does not already contain a pulling tape, the tape can be fished through or blown into a duct length. After the fiber optic cable is installed in a duct, end plugs can be added to prevent water and debris from entering the duct. Similar to direct-burial installations, a warning tape may be placed underground above the duct, or warning posts or markers may be placed aboveground to alert future digging operators to its presence. Using forced air to blow a fiber cable into a duct is an alternative method to a pulling procedure. The cable installation scheme of utilizing the friction of the air moving over the cable jacket is referred to as either a cable jetting or a high-air-speed blown (HASB) method. Cable jetting must overcome the same frictional forces to move cable as in a pulling operation, but it does this differently and with much less stress on the cable. The advantage of cable jetting is that the cable moves freely around bends whereas the pulling method puts a high lateral stress on the cable when it is passed through bends in a duct.

2.5.3 Aerial installation

Cable crews can install an aerial cable either by lashing it onto an existing steel messenger wire or by directly suspending it between poles, if it is a self-supporting cable. Several different methods can be used to install the fiber optic cables. The primary method for installing self-supporting cable is a stationary reel technique. This method stations the payoff reel at one end of the cable route and the take-up reel at the other end. A pull rope is attached to the cable and is threaded through pulleys on each pole. The take-up reel gradually pulls the cable from the payoff reel, the pulleys guide it into position along the route, and it is then attached to the poles. If a messenger wire is used, first this wire is installed between poles with an appropriate tension and sag calculated to support the fiber optic cable. The messenger wire must be grounded properly and should be kept on one pole side along the route whenever possible. One of at least three techniques then can be used to attach the fiber optic cable to the messenger wire. Each of these methods uses a special lashing machine that hangs on the messenger and attaches the cable as it moves along the messenger.

2.5.4 Submarine installation

Specially designed cable-laying ships are used to install an undersea cable. The ships have several large circular containers inside of them called cable tanks. In modern cable ships these tanks together can hold up to 8000 km of underwater cable. Such a length of cable is assembled onshore in a factory environment along with underwater signal amplifiers that need to be located every 60km or so. The amplifiers are housed in large beryllium-copper tubes that are about a meter long and 50cm in diameter. After being assembled, this cable unit is coiled by hand into the cable holding tanks on the ship at a rate of around 80km/day.

During installation, near the shore a sea plow buries the cable to a depth of about 1m under the ocean floor to protect it from fishing nets and other factors that might damage the cable. In the middle of the ocean the cable simply lays exposed on the ocean floor.

2.5.5 Blowing

Blowing involves the installation of a cable empty of any optic fibers and these are added afterwards. It is an alternative technique available for distances up to about 2 km. This has three real advantages. It defers much of the cost since only the optic fibers actually required at the time need to be installed. It allows the system to be upgraded by the replacement of individual optic fibers. Finally, as a bonus, the installation of the optic fiber is completely stress free. The first step is to install the empty loose tube cable. No commitment to use any particular number or types of fibers to be made at this stage in the proceedings. The next stage is to take a prepared bundle of fibers, usually four, contained in a tight jacket of foamed polyethylene. This jacket of foamed polyethylene produces a white coating which is very light in weight and slippery to the touch. It is reminiscent of a slippery version of expanded polystyrene. Its diameter of about 3mm is a very loose fit inside the tubes that we have installed in the duct. A small compressor, called a blowing head, is attached to the end of the loose tube and blows air through it. The fiber is then fed in through the same nozzle as the air and it is supported by the airstream. The fiber is blown along the tube and happily round bends in the duct, like a leaf in the wind, at a rate of about two meters a second. No stress is felt by the fiber as it is supported by the movement of the air all along its length. Other fibers can be blown in at any time to suit the customer. The fibers are equally easy to remove if the fiber needs to be upgraded at a future date.

Only one fiber bundle can be installed in each tube so the system can consist of seven tubes each containing a single bundle of four fibers, twenty-eight fibers in all (John Crisp, 2001).

2.6 Optical Backbone Networks

Data from the customers reach the backbone network through local routers. The local routers exchange data using light paths, which are provided by the backbone optical network. These light paths form the internal traffic of the optical network. Some nodes of the network are directly connected to the local routers. These are called nodes edge nodes. The local routers can also communicate with networks of other carriers or external networks through selected nodes in the optical network. The traffic associated with this communication is called external traffic. Some nodes of the backbone network are directly connected to local routers. The traffic to or from a local router may traverse several nodes in the backbone network. Pass-through traffic is the amount of traffic that goes through a node whose source or destination is not the node. Some nodes are not directly connected to local routers, and are used in the network to manage pass-through traffic. We call these nodes core nodes. In the most advanced form of the present optical network, the nodes have IP backbone routers and the links have WDM fibers. This network is known as a point-to-point WDM network. This network has three main disadvantages; the bottleneck in the capacity of electronic switching in IP routers. For an increase in traffic, the WDM link capacity can be vastly expanded, whereas the same is not true for the switching capacity of IP routers; the high cost of switching which can be reduced by using express links. The third disadvantage of a point-to-point WDM network is that it takes a long time to reconfigure light paths for changes in traffic.

An Automatically Switched Optical Network (ASON) provides faster switching of light paths than a point-to-point WDM network. It has OXCs in the nodes of the optical network and uses signaling mechanisms that enable each network element to identify the updated network topology and automatically reconfigure the light paths.

It has the potential to eliminate the capacity bottleneck of network nodes caused by electronic processing in IP backbone routers, thus providing scalability which allows for continuous traffic growth and network expansion. Despite having these advantages, there is a critical drawback in an ASON. Traffic from a local router to an ASON is generally at a much lower level granularity than a light path. For this reason, IP backbone routers might have to be included in an ASON to aggregate the traffic from local routers, so that it is close to the granularity level of light paths. An ASON with IP backbone routers is known as an IP-over-Optical Transport Network (IP-over-OTN).

As traffic demand increases, the number of light paths in an ASON will also increase. This means that each OXC will have to switch a large number of light paths. However the number of ports that can be switched in an OXC has an upper limit. In ordinary OXCs, a light path is switched using a single port. When a large number of light paths need to be switched in an OXC, the number of ports in the OXC may become a bottleneck. In these circumstances, two approaches can be used to improve scalability. The first approach is to use the ports in OXCs more efficiently. Specifically, we can aggregate light paths into a waveband, or wavebands into a fiber and then switch a waveband or a fiber using a single port in an OXC. For this purpose, we use multigranular OXCs (MG-OXCs) rather than ordinary OXCs. In an MG-OXC, we can switch a group of light paths using a single port. This enables an ASON to manage a large number of light paths or a high traffic volume. We call an ASON capable of performing waveband grooming a Waveband Groomed Optical Network (WGON). The second approach to deal with limited number of ports in an OXC is to increase the effective number of ports, by interconnecting several OXCs together to form a multi-stage OXC with a large number of effective ports (Rajendran Partheban, 2004).

As backbone traffic increases, telecommunication carriers must decide what type of backbone network to deploy to meet this growing demand. In order to be able to make this decision, the following challenges need to be addressed:

- For a given traffic scenario, how can we find the number of network elements and their interconnection topology for these network types while taking into consideration any constraints on the use of each type of network elements?
- How can we evaluate these alternatives to identify the most cost-effective network type for future?

We model each network type and evaluate their cost benefits and scalability for a range of traffic scenarios. By means of this evaluation, we gain insights on how a future optical network can be built in order to achieve a sub-linear cost increase with increasing traffic demand. A significant factor in any fiber optic system installation is the requirement to interconnect fibers in a low-loss manner. These interconnections occur at the optical source, at the photodetector, at intermediate points within a cable where two fibers join and at intermediate points in a link where two cables are connected. The particular technique selected for joining the fibers depends on whether a permanent bond or an easily demountable connection is desired. A permanent bond (usually within a cable) is referred to as a splice, whereas a demountable joint at the end of a cable is known as a connector. Every joining technique is subject to certain conditions that can cause varying degrees of optical power loss at the joint. These losses depend on factors such as the mechanical alignments of the two fibers, differences in the geometric and waveguide characteristics of the two fiber ends at the joint and the fiber-end-face qualities.

2.7 Link Budget Analysis

The link analysis and its output, the link budget, consist of the calculations and tabulation of the useful signal power and the interfering noise power available at the receiver. It is a balance sheet of gains and losses and outlines the detailed apportionment of transmission and reception resources, signal attenuators and effects of processes throughout the link. From a quick examination of a link budget and its supporting documentation, one can judge whether the analysis was done precisely or if it represents a rough estimate (Bernard Sklar, 2001).If the signal is too weak when it reaches the far end of the system, the data will be difficult to separate from the background noise. This will cause the number of errors in the received data bits to increase. If an error occurs once in every thousand million bits it would be said to have a bit error rate (BER) of 10^{-9} and is the usual upper limit of acceptability. The received power must be high enough to keep the BER to a low value and must be low enough to avoid damage to the receiver. Also, on cost and safety grounds it is good to keep the transmitter power to the minimum acceptable value. Having decided on the receiver and the system, the transmit power can be found following the steps below;

Find the minimum power losses due to the fiber, connectors and the splices. These figures are obtained from the manufacturer.

Find the maximum likely losses. This will include the: Minimum losses calculated above.

Aging losses: Many components of a system deteriorate during their lifetime and it is important to know how much to allow for this, otherwise the system will crash at some future date. The aging loss is slight in fibers but the transmitter and the connectors, mechanical splices, couplers etc. will need to be investigated.

Repairs: This is a matter of judgment depending on the environment and stress to which the fiber will be subjected. It is clearly of little use to design a system that, although it works when first switched on, has so little spare power capacity that the extra loss incurred by a simple repair would be enough to make it fall over. A battlefield system would need more repair allowance than an installation in a building.

Spare: Keep a little extra in reserve just in case. About 3 dB is a usual amount. Select a transmitter light source with enough power to enable the system to operate under the worse case conditions with the maximum losses considered above. Then check to see if it would damage the receiver in the conditions of minimum loss. If necessary, an attenuator could be added with a view to removing it at a later date should repairs become necessary.

2.7.1 Link margin

Also called a loss margin or a system margin is an optical-power safety factor for link design. This involves adding extra decibels to the power requirements to compensate for possible unforeseen link degradation factors. These degradations could arise from factors such as a dimming of the light source over time, aging of other components in the link, the possibility that certain splices or connectors in the actual link have a higher loss than anticipated, or additional losses occurring when a cable is repaired. ITU-T Recommendation G.957 specifies that a link margin ranging from 3.0 to 4.8dB should be allowed between the transmitter and the receiver to offset possible equipment degradation. In an actual system, designers typically add a link margin of 3 to 10 dB depending on the performance requirements of the application, the number of possible repairs and the system cost.

To calculate the link budget, subtract all losses from the available power. Losses include, cable attenuation, connector losses and splice losses.

2.7.2 Cable attenuation

It is the decrease in light power during light propagation along an optical fiber. The basic causes of attenuation or signal loss include absorption, scattering and bending which could be macro and microscopic. Fibre loss is the ratio of power output at the end of a fibre to power launched into the fibre. We measure attenuation in decibels (dB).

Loss (dB) = -log (Pout/ Pin)

The attenuation per unit of fiber length, A is given as;

A (dB/km) = loss (dB)/ fiber length (km)

It is obtained by multiplying the cable attenuation with the total length of the network (km).

2.7.3 Connector loss

Connectors are devices that join fibre optic cable to electronic devices. Since most transmitters, multiplexers, receivers etc. are electronic devices. A typical network will have six connectors. The total loss is obtained by multiplying the total number of connectors with the loss of each.

2.7.4 Splice loss

Splicing is simply the joining of a fibre optic cable to the other. This is done since it is impossible to obtain one long fibre cable for the entire network. Each splice introduces some loss at that joint. The total loss is obtained by multiplying the total number of splices with the loss of each.

2.7.5 Repair splice loss

In the life of the network possible repairs are anticipated as well as possible fibre cut which needs splicing. Hence we estimate and calculate for a possible number of splices due to repairs.

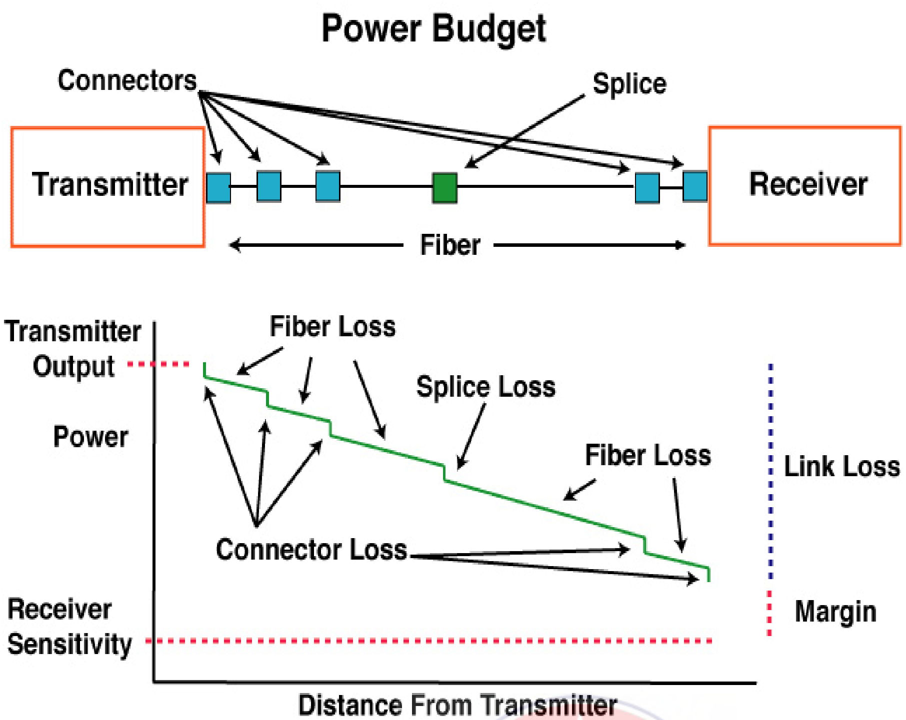

Figure 1: Power Budget

2.8 Measurement and Testing

The installation and powering up of an optical fiber communication system requires measurement techniques for verifying that the link has been configured properly and that its constituent components are functioning correctly. The basic test equipment for measurements on optical fiber components and systems includes optical power meters, attenuators, tunable laser sources, spectrum analyzers, and optical time-domain reflect meters. These come in a variety of capabilities, with sizes ranging from portable, handheld units for field use to sophisticated briefcase-size bench-top or rack-mountable instruments for laboratory and manufacturing applications.

More sophisticated instruments, such as polarization analyzers and optical communication analyzers, are available for measuring and analyzing polarization mode dispersion, eye pattern diagrams and pulse waveforms. Most test and measurement instruments enable a variety of statistical performance readings to be made at the push of a button, after the user has keyed in the parameters to be tested and the desired measurement range. Optical power measurement is the most basic function in fiber optic metrology. However, this parameter is not a fixed quantity and can vary as a function of other parameters such as time, distance along a link, wavelength, phase and polarization. Therefore two standard classes of power measurements in an optical system are the peak power and the average power. The peak power is the maximum power level in a pulse, which might be sustained for only a very short time. The average power is a measure of the power level averaged over a relatively long time period compared to the duration of an individual pulse. The long-term workhorse instrument in fiber optic systems is the optical time-domain reflect meter (OTDR). In addition to locating faults within an optical link, this instrument measures parameters such as attenuation, length, connector and splice losses and reflectance levels (Gerd Keiser, 2003)

CHAPTER THREE

METHODOLOGY

Two telecommunication network operators (TIGO and MTN) were visited to check the techniques they employ in the deployment of their fiber backbone. Their existing links were considered for link budget analysis and sites were visited to observe the installation of fiber cables. Records of splice losses, connector losses as well as other losses and the number of fiber cuts were secured and those locations visited to analyze how the fiber cable was installed to know whether precautions in the deployment were fully obeyed. The deployment of the two links based on cost effectiveness, total losses incurred and how prone the link is to fiber cut were compared.

3.1 Link Budget Analysis

In the installation of fiber, external losses are always incurred due to splicing, the use of connectors, bending, pressure on the buried cable and others. Aside the external losses the fiber itself has an internal loss which varies based on the fiber type and the wavelength of operation. Gains are normally introduced in the installation in order to boost the power to compensate partially for the losses. This is done by the introduction of amplifiers at required points in the link. Since the power at the receiver end must fall within a defined range (receiver sensitivity) before it can effectively recover signals an analysis is done to know the total losses throughout the link for compensation. This is known as link budget analysis. In the transmission rooms of both telecommunications companies the OTDR was used to launch a known power into the link at one end of the link and the receiver power at the other end noted, subtraction between the launched power and the received power was done to know the total losses of the link.

The OTDR produced a graph of distance against power which we used to check the actual points where losses were incurred.

Total link loss (Ls) = fiber loss (Fl) + total splice loss (Sl) + total connector loss (Cl) + other losses (Ol). All loss parameters are measured in decibel (dB). With the existing links the operating transmits power was recorded and a received power within the receiver sensitivity range was also recorded. To calculate for link budget we subtracted all the losses from the available transmit power. A power margin (Pm) is normally added to the budget to compensate for unforeseen losses that may occur. The transmit power and system margin are measured in (dBm).

Link budget in dBm = transmit power (Tp) – Total losses (Tl)

Figure 2: Diagram of an OTDR measuring a transmit power

3.2 Parameter Definitions

All the parameters used in the calculation of the link budget are defined and also how their values were obtained from the sites and the transmission rooms explained.

3.2.1 Practical external losses

Splice loss**:** Is simply the loss incurred by joining of a fiber optic cable to the other permanently. It is measured in decibel (dB)**.** This is done since it is impossible to obtain one long fiber cable for the entire network. Each splice introduces some loss at that joint. If 'n' number of joints are done to achieve the maximum link length and the average splice (joint) loss is As then the total splice loss will be nAs. The splicing is done with a tool known as fusion splicer, which displays the splice loss on its display unit after the splicing. Splice loss is not constant throughout the link; it must fall within a defined range of 0 - 0.05dB. When the splice loss is exactly zero, it is known as a perfect splice.

Figure 3: Splicing technique using the fusion splicer

Connector loss: Connectors are devices that join fiber optic cable to electronic devices such as transceivers, multiplexers and so on. There are different types of connectors with different losses and strength. The losses are always in decibel (dB). A typical network will have six (6) connectors. The total loss is obtained by multiplying the total number of connectors with the loss of each. Eg. Six connectors each with loss of 0.5dB will total 3.0dB

Table 1: Types of connectors and their losses

Connector types	**Mode**	**Loss**	**Design Perspective Loss**
LC	Single/Multi-Mode	0.25 dB	0.5 dB
SC	Single/Multi-Mode	0.25 dB	0.5 dB
ST	Single/Multi-Mode	0.25 dB	0.5 dB
FC	Single/Multi-Mode	0.25 dB	0.5 dB
MT-RJ	Single/Multi-Mode	0.25 dB	0.5 dB
MTP/MPO	Single/Multi-Mode	0.25 dB	0.5 dB

Other losses: In the process of installation losses are introduced due to sharp bends, pressure on the cables, dust entering the core and so on. These losses are summed up as other losses. They are normally taken care of by the power margin. The power margin also caters for the losses which might occur in the future after the installation.

3.2.2 Internal loss

Fiber cables for long haul communications are typically single mode fibers. There are types of single mode fibers which are used in different applications. They have same internal losses but differ due to their manufacturing components and some additional losses introduced in the process of manufacturing.

We measure fiber attenuation in decibels (dB). Loss (dB) = -log (Pout/ Pin)

The attenuation per unit of fiber length, **A** is given as;

A (dB/km) = loss (dB)/ fiber length (km)

It is obtained by multiplying the cable attenuation with the total length of the network (km).

Table 2: Types of fibers, their losses and applications

FIBER TYPES	MODE	LOSS/KM	APPLICATION
G.651	Multimode	0.8 dB/km	For short-reach optical transmission system
G.652	Singlemode	0.2 dB/km	Most commonly used Singlemodefiber, mostly used in SDH deployment
G.652C	Singlemode	0.2 dB/km	Good for Metro DWDM applications
G.654	Singlemode	0.2 dB/km	Mostly used as submarine longhaulfibers
G.655	Singlemode	0.2 dB/km	Mostly for longhaul DWDM applications

3.3 Installation

The two techniques employed by the two network operators in the underground deployment of their fiber cables are; duct and the direct burial methods. The duct method makes use of a plastic tube for extra protection of fiber. The tube is laid after the trenching and the fiber cable is blown through it. For the direct buried the fiber cable is laid directly after the trenching. Both have advantages and disadvantages which were analyzed to come up with technical conclusion.

CHAPTER FOUR

This section provides a careful analysis of collected results identifying various observed phenomena and highlighting the importance of observations made.

4.1 Network Topology

The major topology used nationwide is ring with some bus extensions. The various topology used with their hops are shown diagrammatically below.

Figure 4: Layout of backbone for TIGO (Nationwide)

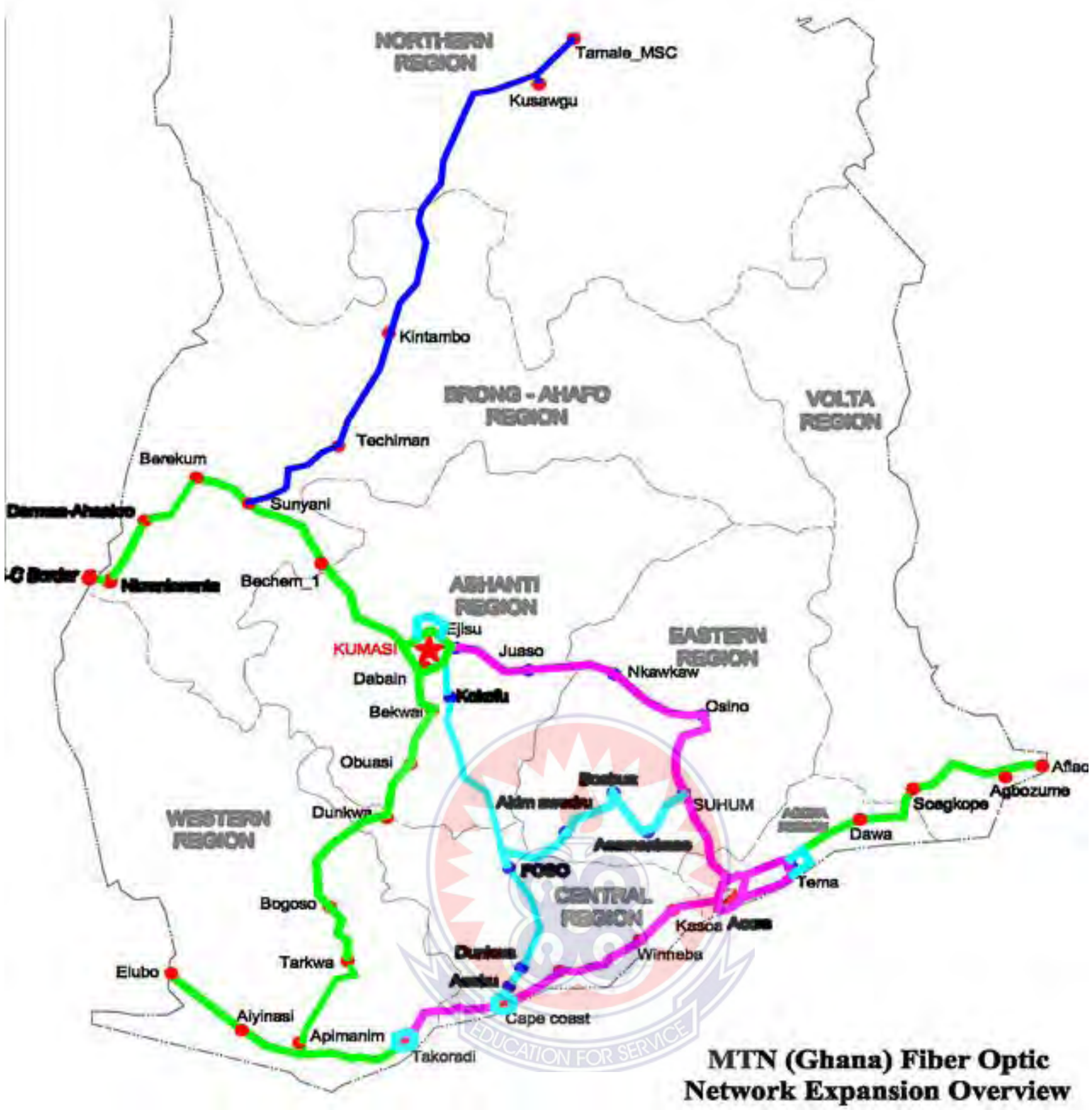

Figure 5: Layout of backbone for MTN (Nationwide)

4.2 Type of Cable Used

The type of cable used by the two telecommunications companies is G652 which has major application in SDH deployment. This is made up of an outer sheath surrounding the buffer within which the real fiber lies identified by colours. The size of the fiber cable depends on the number of fiber core within it. There are the 96 core, 48 core and 24 core fiber cables and the range of services that can be supported is directly proportional to the size.

Figure 6: Sample of a Fiber cable

4.3 Methods of Installation

MTN and TIGO use two different forms of deployment for their underground cabling. MTN uses direct burial and TIGO uses duct method. The two were compared and the best method of installation proposed.

Figure 7: Duct installation method (TIGO)

Figure 8: Direct buried installation method (used by MTN)

4.4 Comparison of Direct Burial and Duct Methods

Results on comparison of the duct method and direct burial method:

Cost: It was observed that direct burial is cost effective than the duct method. This is because the duct method makes use of a plastic tube for extra protection of fiber. The tube is laid after the trenching and the fiber cable is blown through it which increases the cost of the deployment. For the direct burial the fiber cable is laid directly after the trenching; there is no need for additional cost of duct.

Maintenance: Cost of maintenance of duct method of installation is higher than the direct burial method. During repairs on the duct; for instance when there is fiber cut, more materials are needed. Both the fiber cable and the duct have to be repaired. More materials needed for repair means increased cost.

Pressure: Pressure on the fiber leads to loss in the system. The higher the pressure, the more the loss incurred in the system. The duct method reduces the pressure on the cable since the plastic tube gives extra protection to the fiber cable. On the other hand, direct burial of fiber cable is more susceptible to pressure.

Fiber Cut: Fiber cable experiences cut owing to certain activities such as road constructions, digging, etc. Certain links can have frequent fiber cuts. It was observed that the duct method is prone to fiber cut than the direct burial. Because of the plastic tube (duct) for extra protection of fiber, the fiber cable is not easily cut. Frequent fiber cuts leads to a low system performance since the fibers have to be spliced and splicing introduces some loss into the link.

Re- Installation: It is easier and less cost effective to re-install in duct method than in direct burial. For direct burial, the whole cable system should be changed which means a whole lot of digging to be done across the nation whiles in duct method, only the old cable is pulled out and a new pulled in by the process of blowing. There is no need to dig around in order to change the cable.

4.5 Factors Affecting Fiber Performance

Losses are introduced in the link if deployment is not done well. This leads to low performance of the fiber. Some of the factors which affect the performance of the fiber are discussed below:

- Poor termination of cable: The end of the fiber must be terminated using connectors at the transmission room. More losses are incurred if termination is not done well.
- Poor Splicing: Splicing could be done poorly. In this case the loss per splice falls outside its defined range of 0 – 0.05dB. Re- splicing is done if loss per splice is exceeded. If not the overall splice loss in the system is increased.
- Sharp bends: A sharp bend in a fiber can cause significant losses as well as the possibility of mechanical failure. It is easy to bend a short length of optic fiber to produce higher losses than a whole kilometer of fiber in normal use. The tighter the bend, the worse the losses.

- Poor lying of fiber cable: The fiber cable has to be laid well. If not, the possibility of bends and pressure will be high.
- Shallow burial depth: Fiber cable should be buried to a depth of 1.2m or more. Cables which are laid below this depth are more susceptible to frequent cuts leading to reduced system performance.
- Absence of warning tapes: During direct-burial installations, a bright (usually orange) warning tape normally is placed a short distance (typically 18in) above the cable to alert future digging operators to the presence of a cable. The tape may contain metallic strips so that it can be located from above ground with a metal detector. In addition, a warning post or a cable marker that is flush with the ground may be used to indicate where a cable is buried. Besides indicating to repair crews where a cable is located, these precautions are intended to minimize the occurrence of what is known popularly in the telecommunications world as backhoe fade (the rupture of a cable by an errant backhoe).

4.6 Link Budget Analysis

Analysis of the link budget from Accra to Nkawkaw in hops is done to know how much total unbudgeted loss was incurred in the installation. Estimated budget is compared to the actual budget of the existing links.

DATA OBTAINED

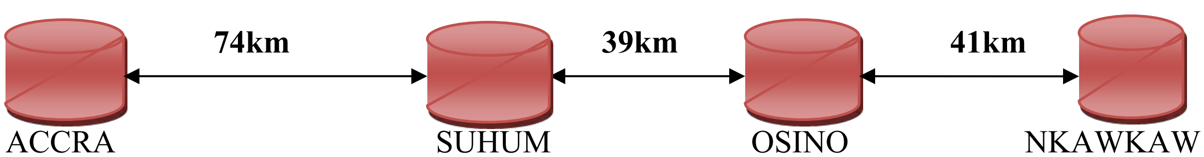

Figure 9: Hops from Accra to Nkawkaw

Table 3: Parameters for link budget for MTN and TIGO

PARAMETERS FOR LINK BUDGET	MTN(DIRECT)	TIGO(DUCT)
Connector-Pair Loss	1.0dB	1.0dB
Splice Loss	0.00 - 0.05dB	0.00 - 0.03dB
Link Margin	3 – 10 dB	3 – 10 dB
Length of a Continuous Fiber Cable	3km	6km

Table 4: Parameters for estimated loss budget for MTN and TIGO for the three hops

Parameters	Hop 1		Hop 2		Hop 3	
	MTN	TIGO	MTN	TIGO	MTN	TIGO
TOTAL CABLE DIST. IN Km	74	74	39	39	41	41
FIBER LOSS PER Km	0.2dB	0.2dB	0.2dB	0.2dB	0.2dB	0.2dB
CONNECTOR LOSS(PAIR) IN dB	1	1	1	1	1	1
NO. OF CONNECTOR PAIRS	2	2	2	2	2	2
SPLICE LOSS (dB)	0.05	0.03	0.05	0.03	0.05	0.03
NO. OF SPLICE	25	13	13	7	14	7

4.6.1 Estimated link budget for MTN and TIGO

Table 5: Estimated total loss for MTN and TIGO for all three hops

PARAMETERS	HOP 1		HOP 2		HOP 3	
	MTN	TIGO	MTN	TIGO	MTN	TIGO
TOTAL FIBER LOSS(FL) IN dB	14.8	14.8	7.8	7.8	8.2	8.2
CONNECTOR LOSS(CL) IN dB	2	2	2	2	2	2
TOTAL SPLICE LOSS(LS) IN dB	1.25	0.39	0.65	0.21	0.7	0.21
LINK MARGIN(LM) IN dB	10	10	10	10	10	10
ESTIMATED TOTAL LOSS IN dB	28.05	27.19	20.45	20.01	20.9	20.41

Estimated Link Budget = FL +CL +SL +LM

4.6.2 Real or actual link budget for MTN and TIGO

REAL LOSS= Transmit Power – Received Power

Table 6: Real link budget for MTN and TIGO for all three hops

PARAMETERS	HOP 1		HOP 2		HOP 3	
	MTN	TIGO	MTN	TIGO	MTN	TIGO
TRANSMIT POWER IN dBm	-2	-3	-4	-5	-4	-4
RECEIVED POWER IN dBm	-39	-38	-29.6	-28	-31	-29
REAL LOSS IN dB	37	35	25.6	23	27	25

4.6.3 Final tabulation of results

Table 7 : Optical Power Budget (OPB) difference for MTN

HOPS	REAL OPB (dB)	EST. OPB (dB)	DIFF OPB (dB)
1	37.00	28.05	8.95
2	25.60	20.45	5.15
3	27.00	20.90	6.10

Table 8: Optical Power Budget (OPB) difference for TIGO

HOPS	REAL OPB (dB)	EST. OPB (dB)	DIFF OPB (dB)
1	35	27.19	7.81
2	23	20.01	2.99
3	25	20.41	4.59

4.6.4 Graphical analysis of results (losses)

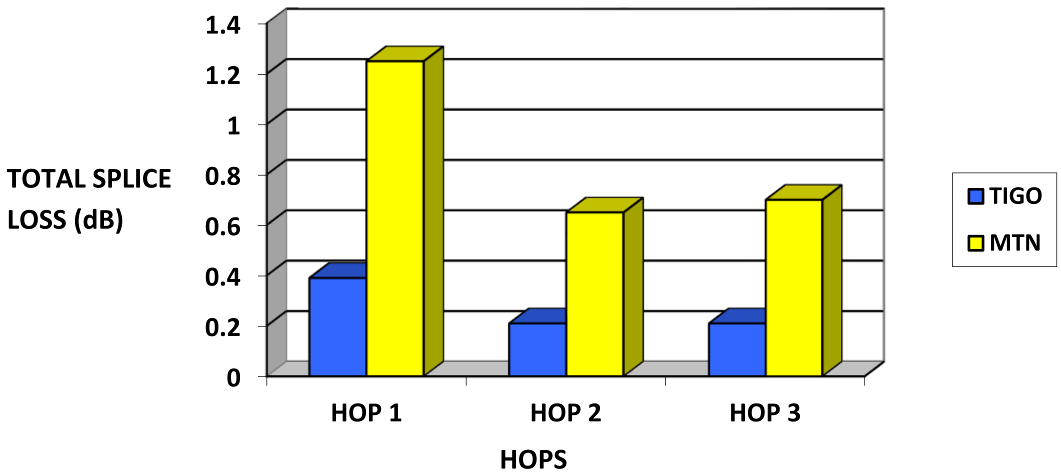

Figure 10: A graph of total splice loss in the link of MTN and TIGO for the three hops

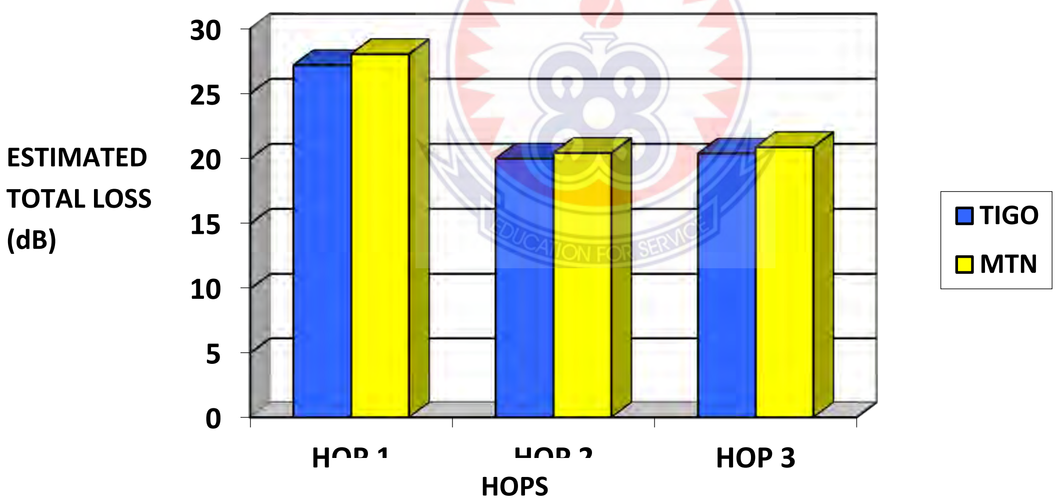

Figure 11: A graph of estimated total link loss for MTN and TIGO

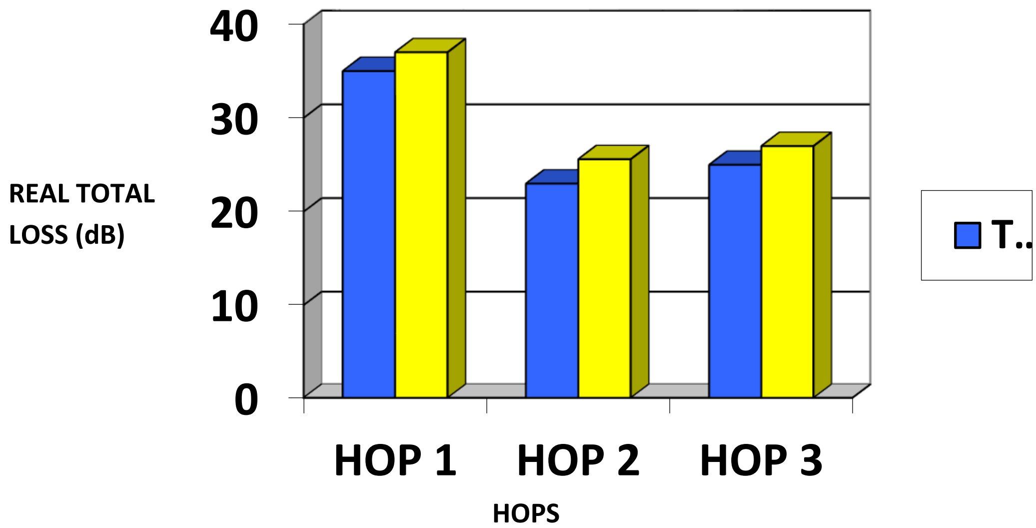

Figure 12: A graph of real or actual link loss for MTN and TIGO

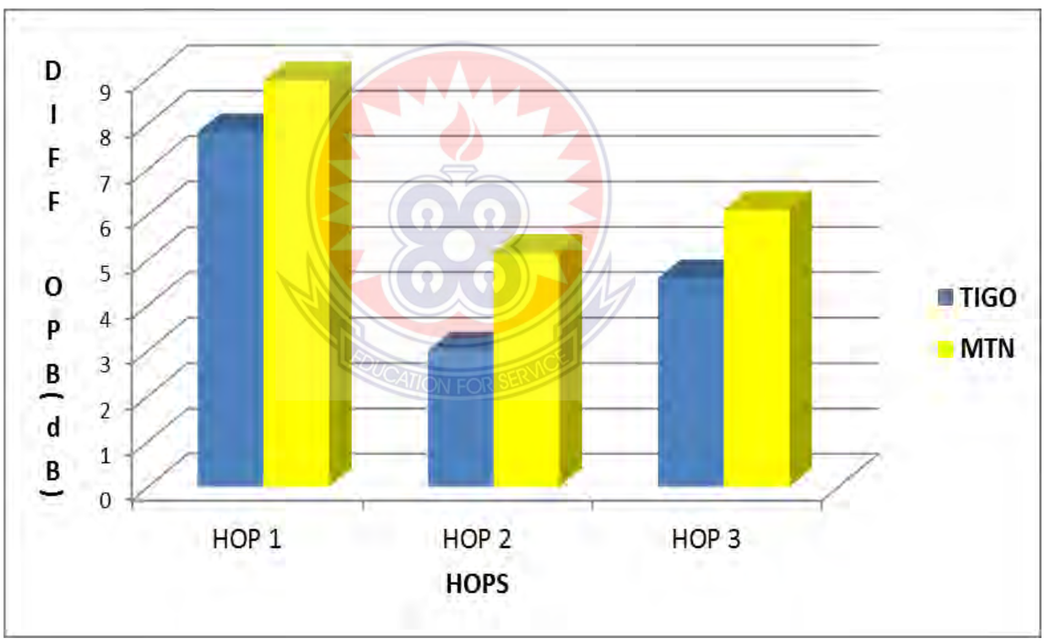

Figure 13: Losses in the fiber backbone link for MTN and TIGO

CHAPTER FIVE

CONCLUSION

The Conclusions and the Future Work sections summarize the project, draw conclusions about the proposed solution and chart future directions of the research.

At the end of the research, it was observed that for the three hops considered the losses in the link increased with distance and that the amount of losses incurred by TIGO was lesser than MTN. After comparison of the two methods of installation, the duct method which is used by TIGO was more advantageous making their link less prone to sources of loss. Hence TIGO has a better installed backbone than MTN. These high losses in the backbone could likely be as a result of poor deployment and monitoring of the fiber backbone cable. In the case of MTN, these high losses could be strongly attributed to the fact that they have been in the system for long and the fiber is gradually degrading. Also more splicing has been done on the link since at every 3km they do splice, increasing the losses in the link, but is minimal with TIGO which does splicing at every 6km. It was noted that the backbone of MTN has had many issues of frequent fiber cuts which has led to poor service delivery and complaints from most subscribers. Finally, it was observed that most regulations governing the deployment of the fiber was not held onto. Some places which had experienced fiber cuts had no warning tapes to keep constructors off from interfering with the cable. The future work can be the design of sensors and alarm systems which will prompt the office of any attempt on the fiber and the necessary actions to take in order to reduce the rate of fiber cuts which is resulting in low quality of service.

5.2 Recommendation

The following recommendations are proposed to combat the issue of poor performance of the fiber. Both duct and direct buried methods of installation should be used depending on the environment between two nodes. This will help cut down the cost of installation. Also engineers should comply with regulations on deployment. They should ensure that factors which will lead to a reduced performance of the fiber such as poor termination of the cable, splicing fallen outside its defined range of 0- 0.05dB, shallow burial depth, bends, absence of warning tapes and poor laying of cable are avoided. Re- installation should be done for places where installation was done poorly. For places where there are unbearable and uncontrollable cuts, aerial cabling can be used; where the cable is passed on poles. Engineers should focus on securing the fiber cable making it less prone to these external factors which introduces losses into the link.

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