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Fiber Cut Impacts and the Scientific Analysis of its Financial Losses

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Abstract: *The Mobile Telecommunication Network (MTN) among many other telecommunication industries embrace the use of fiber optic technology to deploy their networks to offer services to their customers based on its numerous advantages. The advantages are not limited to its immunity to electromagnetic wave pick up, high capacity of bandwidth for data and voice activities, and immunity to cross talk. It is without doubt that the fiber optic network infrastructure deployed by the MTN has suffered frequent fiber cuts. In addition, these cuts have had impactsnegatively on the quality of service delivery to its numerous customers across the length and breadth of Ghana. Furthermore, the cuts have had negative effects on the financial status of the aforementioned telecom industry. Hence, research was embarked on to delve into the most serious impacts that resulted from the frequent fiber cuts. The negative effects such as the increase of the operational expenditure, the decline of the revenue thrown on the finances of the MTN were also analyzed. The research was conducted using MTN Ghana (Western and Central Region) as a case study. A purposive survey was administered to obtain information about the impacts. Also, Pareto and Ishakawa analytical tools were applied to the primary source data for the analysis.Based on the primary data evaluated, it was established that the total network unavailability attributed to fiber cut for the period under study, that is, from 2014 to 2016 was about 540 hours equivalent to about twenty two and one half days.Again, it was concluded that the organization losses tremendous amount of revenue to this fiber cut menace in respect to the operational cost incurred to restore and relocate damaged fiber cut.*

Keywords: *Fiber optic, Telecommunication, Financial, Scientific, Network, expenditure*

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I. Introduction

In the field of telecommunication and others, the most popular medium of transmission is fiber optics. The technology of fiber optics has advanced largely and the popularity keeps increasing. A fiber-optic cable is made from thin strands of plastic or glass that carry light instead of electricity. The advantages of using fiber optics as a medium of transmission supersedes most of the transmission lines. Some of the advantages include the very high bit rates (greater than 1Gb/s), immunity from electromagnetic pickup and cross talk, low attenuation for signals. Other advantages are gained when data needs to be sent through severe environments such as nuclear radiation, chemical or explosive vapors, electrical noise, salt water, high humidity and dust, and so forth. In instrumentation and control systems, fiber-optic links are mostly selected because they can solve electrical isolation and interference problems typical in industrial environments. Fiber optics are applied in divers areas such as positioning systems, object-sensing, counting, connections between controllers and production equipment, electrical speed-control links, and connections from computer-control systems and the units they control.

As indicated by Dhliwayo, fiber optic is the most fastest and widely used medium of backhaul transmission that offers the required capacity and capability to meet the required telecom needs of customers in the industry today (Dhliwayo, 2012). The high bandwidth capacity, high network reliability and resiliency, and high quality of service delivery are some of the demands on the Mobile Telecommunications Network (MTN), a major telecommunication operator in Ghana. This telecom operator moves various voice and data services on the mobile cellular network technologies such as Second Generation (2G)/Global System for Mobile Communication (GSM), Third Generation (3G)/Universal Mobile Telecommunication Service (UMTS) and Fourth Generation (4G)/Long Term Evolution (LTE). These operations are conducted using fiber optics network technology.

As stated earlier on, fiber optic technology provides an enhanced features and advantages that is superior over copper-based and wireless backhaul transmission solutions. The MTN has deployed many lengths

of fiber optic network infrastructure across Ghana to provide quality services to its numerous customers. It is undoubtedly that the good intentions and efforts made by the MTN to provide excellent services to its customers is fraught with a menace that in one way or the other can be combated. And this impediment originates from the frequency of the cuts of the deployed fiber optics network infrastructure. Besides, the poor service delivery emanating from the persistent fiber cuts, there has been tremendous pinching financial impact against the MTN.

As regards to that, the research was embarked on to investigate the impacts of persistent fiber cuts in the telecom industry in Ghana (Case study in MTN Ghana, Western and Central Region), and to scientifically analyze the financial losses that the fiber cuts bring to bear. It is believed that the analysis will enable the telecommunication managers to have insights in the causes of the financial losses stemming from the fiber cuts and assist them to take measures that will curb this needless loss. Furthermore, the managers can use the outcome of the research to improve upon the service delivery to their customers.

Problem Statement

The Mobile Communication Network (MTN) company in Ghana has embraced the use of fiber optic technology as its primary transmission medium on its backhaul network design infrastructure because of its advantages over other transmission mediums such as microwave, copper wires, and the rest. The advantages are not limited to large capacity of bandwidth, the immunity to cross talk, immunity to electromagnetic wave interference. Fiber optics technology can transport more information over longer distance in less time than any other communication medium.

Furthermore, the maintenance cost of the fiber is less as compare to the conventional microwave transmission system and the other transmission mediums. According to Xiong, the cost of transmitting a single phone conversation or data over fiber optics is only about 1% the cost of transmitting it over the conventional medium of communication (Xiong, 2013). It is quite obvious that fiber optics technology is rapidly taking over the traditional transmission systems in the telecom landscape due to its superior and attractive features.

It is in this regard that almost all the telecommunication network operators in Ghana have and continue to make significant investment in rolling out more fiber optics network infrastructure across the country. This is to enable them expanding network coverage and building network capacity to drive both voice and data service utilization on the various generation or evolution of mobile communication technology such as 2G/GSM, 3G/UMTS and 4G/LTE within the telecom landscape in Ghana.

However, despite the advantages that fiber optic technology has over the conventional transmission techniques, the telecom industry is confronted with problems such as fiber cuts, loss of revenues and other related challenges. Furthermore, the industry faces a number of challenges both in the deployment as well as maintenance of the infrastructure

The frequent fiber cut has had a big impact on the mandatory key performance indicators (KPI) relative to industrial standards set by the regulator. In addition, these are availability, reliability, call set-up success rate (CSSR), call congestion rate, drops call rate (DCR) as well as subscriber connectivity for both voice and data.

Objectives

The main objectives of this paper is to present the following:

- The investigation of the impacts offrequent fiber cut on the availability of services and the quality of service delivery by the MTN Company in Ghana.
- The determination of the fiber cut impacts on the financial status of the telecommunication industry.

II. Methodology

- Solicited information about the design of fiber optic network design from the managers of Mobile Telecommunication Network in Ghana
- Issued questionnaires to some MTN employees to obtain information on fiber cut and its related problems experienced by the company
- Pareto and Ishakawa analytical tools were applied to the primary source data for the analysis

Scope of Work

The research was limited to ascertaining the impacts of fiber cuts, and the analysis of the financial losses incurred because of these occurrences.

Justification

If the analysis of the research is studied carefully and prudently applied, it will reduce the cost of operations of the telecom companies in Ghana, and increase their revenues. In addition, it will improve network quality of service delivery in the telecom industry in Ghana in terms of high network availability.

III. Literature Review

Socio-Economic Benefit of Optical Fiber Technology

Globally, optical fiber network technology is recognized as progressive innovation in the telecommunication technology that provides enormous bandwidth required to support continues growing demand for data traffic. In recent study conducted in Nigeria in an article written by William (2010), shows that the expansion of broadband service beyond cities and major town and encouraging the use of ICT in primary, secondary and tertiary institutions, potentially contributed about USD 1.1 billion (representing a GDP growth of about 1.2 per cent) to the Nigerian economy as at 2015.According to Gelvanovska et al, the phenomenon of optical fiber technology has been accepted globally as the fundamental driver of economic growth and social development. He cited this in a selected case study conducted in Middle Eastern and North Africa. In his research he revealed that broadband internets is crucial to the effort of reducing poverty and the creation of job opportunities.

In a similar related study in Poland by Romaniuk (2010), he stressed that globally, many countries including Africa are making huge investment into the telecom sector to build optical fiber infrastructure in a bid to bridge digital divide across continent and also to meet the increasing high demand for high bandwidth capacity to drive high data utilization. According to him the main forces of the fast development of the optical fiber network globally is the explosive growth of internet demand. He indicated further that the infrastructure enhance optimal efficiency in services such as email, world wide web (www), file transfer protocol (FTP), catalogue service, information storage, internet telephony and video telephony (VoIP), internet TV, teleconferencing, distant learning, e-trading, e-banking, distant working, tele-immersion and tele-medicine which are very essential to socio-economic development of every country.

Global Deployment Statistics

In a study carried out by Hoffman (2002), to ascertain the root causes of cable cut, he noted that the world's total optical fiber infrastructure deployment was estimated at 455million km as off late 1980s. Due to the increasing trend of demand for high bandwidth capacity to drive data utilization in the various sectors of the world's economy, he projected that an additional 539,130 km of optical cable would be rolled out unto the existing optical fiber infrastructure by 2006. Out of this, the United States alone contributed 321,870 km of both underground and overhead optical fiber infrastructure, representing 0.07% of the world's total estimated figure.

Gelvanovska et al (2016), also carried out a similar research, summary in the Table 1 below shows inland optical fiber infrastructure deployment in some selected African countries specifically in the North African and the Middle East.

Table 2.1 Optical Fiber Coverage for Six Selected Countries

SN	Country	Inland Optical Fiber Coverage (kilometers)
1	Algeria	40000
2	Egypt	26000
3	Morocco	18000
4	Libya	24000
5	Tunisia	12000
6	Jordan	1270

Source: (Writer of this Paper)

In line with same subject matter, Dahunsi (2015) also examined the relationship between major player of the Nigerian market using the broadband ecosystem module to analysis the relation between the different ties of the system in terms of competition, information and symbiosis. In his studies he cited that over 38,000 km inland optical fiber infrastructure has been deployed in Nigeria to support the ICT ecosystem and information society.

The deployment of the optical fiber cable continue to increase for both long haul backbone transmission and short distant implementation for metro fiber, due to high demand for data services in the telecom market to address the telecom needs of the end user (Ezel et al, 2013).

Like any other countries, Ghana started deploying optical fiber network infrastructure in the late 1990's. In the late 2007, Ghana established the National Communication Backbone Company (NCBC), under the auspices of Ghana Telecom (now Vodafone, Ghana) to manage and drive expansion of optical fiber network infrastructure in the country targeted at the following strategic objectives according to Asior (2011):

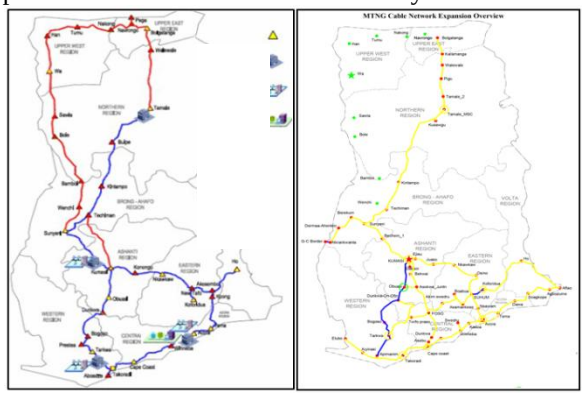
- Promote socio-economic development
- Provide high quality and competitively priced services to ISPs and Operators
- Provide high capacity bandwidth to the hinterlands and under-served regions of Ghana
- Facilitate international connectivity

Progressively, under the auspices of Ministry of Communication, the Government of Ghana has deployed over 1,350 km of inland optical fiber backbone network infrastructure linking the Southern part of Ghana to the North through the Eastern corridor and other regions such as Western, Central and Greater Accra Region.

And since the liberalization of the sector in respective of fiber optics network deployment in 2009, many private investigators in the telecom industry has contributed to the significant growth of the infrastructure in Ghana. In Ghana's telecom market, over 90% of the mobile network operators have either build their own optical fiber network infrastructure across the country or co-located other competitors to extend fiber coverage to other parts of the country where they are not physically covered.

In responds to a questionnaire, MTN, the leading mobile telecommunication network operator in Ghana indicated that it has built over 5,000 km of optical backbone link across the country. Vodafone, Ghana (formerly Ghana Telecom) has also deployed over 1,350 km of optical backbone link across the country (Ibrahim, 2016). Whiles TiGO, Airtel, Glo and Expresso have also deployed quite significant amount of cable in some part of the countries. Figure 1. Below shows the layout plan for fiber footprint or coverage for the top two telcos leading the delivery of optical fiber network rollout in Ghana.

Figure 2.1 Optical Fiber Network Infrastructure Layout for MTN and Vodafone



Source: (Vodafone left [Ibrahim, 2016] and MTN right [MTN data bases])

In a research conducted by a Ghanaian based internet researcher, summarized in Table2.2 below, demonstrate clearly significant growth in internet usage for top 10 countries in Africa and their respective trend of penetration rate over the past 6years.

Comparatively, it is evidently clear from the articles reviewed so far that, there is direct correlation between high data utilization, high bandwidth capacity and optical fiber network infrastructure deployment across the globe

Table 2.2 Internet Utilization for Top 10 African Countries

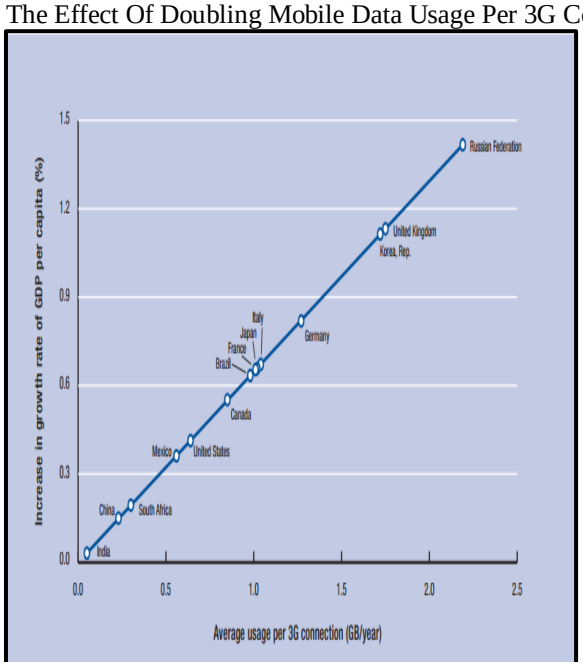
AFRICA 2016 POPULATION AND INTERNET USERS STATISTICS FOR 2016					
AFRICA	Population (2016 Est.)	Internet Users (31st Dec 2000)	Internet Users (30th June 2016)	Penetration (% Population)	Internet (% Africa)
Nigeria	181,562,056	200,000	92,699,924	51.10%	28.00%
Egypt	90,067,793	450,000	33,300,000	37.00%	10.00%
Kenya	45,925,301	200,000	31,985,048	69.60%	9.70%
South Africa	54,777,809	2,400,000	26,841,126	49.00%	8.10%
Morocco	33,322,699	100,000	20,207,154	60.60%	6.10%
Sudan	36,108,853	30,000	9,307,189	25.80%	2.80%
Uganda	37,101,745	40,000	11,924,927	32.10%	3.60%
Tanzania	51,045,882	115,000	7,590,794	14.90%	2.30%
Algeria	40,263,711	50,000	11,000,000	27.30%	3.30%
Tunisia	11,037,225	100,000	5,408,240	49.00%	1.60%

Source: Internet World Stats http://www.internetworldstats.com/stats1.htm, (2016).

It has also been established that, broadband and optical fiber network infrastructure are key drivers for higher data utilization in the information and communication world. And consequently this translate into high gross domestic product (GDP) growth for both developed and under-developed countries of the world economy. This was well elaborated on in the global information technology report, 2013. The report further emphasize that, in developing markets, increase in mobile penetration benefit GDP growth per capita and boost country productivity.

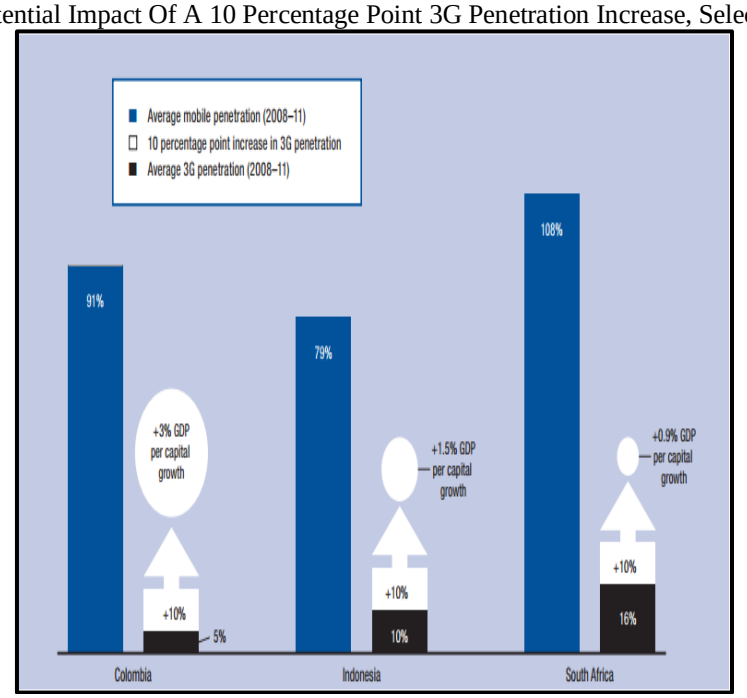
Figure 2. Below shows a trend analysis in increasing growth rate in GDP per capital against average usage per 3G cellular mobile technology connections for some selected countries. Similarly, figure 3 below shows an increase in GDP per capita growth due to the 10 percentage point increase in 3G cellular mobile technology penetration for selected countries.

Figure 2.2 The Effect Of Doubling Mobile Data Usage Per 3G Connection



Source: (Global Information Technology Report, 2013)

Figure 2.3 Potential Impact Of A 10 Percentage Point 3G Penetration Increase, Selected Countries



Source: (Global Information Technology Report, 2013)

Ghana is an evolving market with a lot of potential for growth in the telecom space in Africa. Though it did not show up in the top 10 African countries with high internet utilization, it has made significant progress in terms of growth since the liberalization of the telecom industry and subsequent introduction of the fiber optic technology and further involvement of the private sector in Ghana. According to NCA report (2009) by a Ghanaian base researcher indicates that, Ghana's internet users between the year 2000 and 2016 stood at 30,000 and 7,958,675 respectively representing 29.6% of penetration growth over the period. And this is largely supported by the enabling environment of a continuous evolution of the mobile cellular network technology as well as continuous growth in the deployment of optical fiber network infrastructure.

Environmental Protection Agency

The permit obtained at a fee is a confirmation that, the proposed route per organizations engineering drawings to deploy the infrastructure is approved. Normally, the conditions for obtaining ROW for the various method or techniques differs. This paper shall discuss only ROW related to overhead and underground optical cable deployment.The framework for issuing and regulating ROW varies across the globe and this, either enforces compliances or non-compliances in the deployment of the infrastructure. Though in many circumstance the optical cable are deployed in accordance with approved ROW, the deployed infrastructure has still suffered from many cable cut.

As a result, in many jurisdiction such as Australia, Denmark, Czech Republic, Canada, Finland, Germany, Japan, France, Korea, New Zealand, Norway, etc., have adopted many reformed to enhance the ROW acquisition process and regulation to protect the infrastructure (Anon, 2008). Some of the lead factors driving these reforms includes inconsistences and high price rate that fiber optic companies pay for utilizing rights of way (Valentin and Hodge, 2011). Similar reforms is been consider in Africa due to similar challenges, according to William (2010), obtaining rights-of-way is often very difficult because of the lack of a clear legal framework and the multiple jurisdictions involved. In a related study in Nigeria by Juwah (2011), he stressed on regulatory difficulties involved in obtaining right of way permits for access to streets, roads, and other public land.

Afzal (2005) discussed the effect of fiber cut in Pakistan. In his report he gave an account of a fiber cut incident which occurred on a 39,000 km stretch of submarine cable which connect 33 countries in the Asia Pacific, Europe and Australia. In his account, the fiber cable was cut 35 km nautical miles (69km) South-West of Hawksbay, Karachi deep sea and it took 11days to restore services.Though Afzal did not establish the root cause of that fiber cut in the deep sea incidence, he however indicated the commercial impact of the outage on both voice and data activities as highlighted below; e-Commerce: no business on webOnline banking: On line transactions were not possibleLiability-Driven Investors (LDI) Operators: LDI operators were unable to continue their servicesInternet Service Delivery (ISD) Calls: Unable to make calls to and from Pakistan for 2 days.

- Data Services: General Packet Radio Service (GPRS) services went down along with Internet
- Airlines: Online Reservation system of Airlines was badly effected
- Stock Exchanges: Online trading system of stock exchanges came to a halt
- Call Centers: An estimated loss of US$ 1million to call center industry

In a paper titled "cable cut", Hoffman (2002), sort to profile and ascertain the root cause of cable cut in the communication industry in the united State of America. He focused on examining the critically, the frequency at which the cut incidence are occurring, the commonality in the locations of the incidence, the various activities resulting into these cuts and the real root causes accounting for them and further determine the impact of the optical fiber cable failure to the operations of telecom companies.

According to Hoffman's research over 455million km of optical fiber infrastructure has been deployed globally as of late 1980's. Due to the increasing trend of high demand for capacity to drive data activities, he projected that by 2006 an additional 539,130 km more would be rolled out in addition to the existing infrastructure, bringing the global figure to 455,539,130 km. Out of this, United States alone contributes about 321,870 km of both underground and overhead cable, representing 0.07% of global estimate. Approximately 67% of the optical communication cable in the United State are buried underground and whiles the remaining 33% are layered overhead. From his analysis it was revealed that most underground cable failure were experienced in rural areas than in the urban. He further classified the finding of the causes of the incidence into three categories. Namely: human error, accident and malicious act. Statistically, it was noted that 40% of the incidences were as a result of human error which occurred through constructional activities. Moreover, between 1992 and 2001, constructional activities accounted 50-70% of the underground optical cable failure. Of which digging errors, inadequate notification of cable location prior to digging were cited for some of the root cause accounting constructional incidences.

Furthermore, floors, falling trees, activities of rodent, bush fires and other causes such as vandalism and sabotage (though very rare) all together account for the remaining 60%.In conclusion, Hoffman noted that there were 386 count of fiber cuts (representing 25%) of the total network outage experienced in United State in

the year 1993 to 2001. And the trend continue to increase as growth in deployment also increases.Finally, among other recommendation, he cited the creation of additional redundancy on the optical network infrastructure to serve as an alternative path to re-route traffic to mitigate traffic affecting fiber cut.

However, the challenge to this recommendation is that telecom companies would have to invest additional capital expenditure (CapEx) to create these additional redundancies which heeder-to could have been invested in other project. On the contrary, this paper holds the view that a holistic approach of getting all the relevant stakeholder; including state agencies for granting permits and regulating the utilization of the or the road reservation (i.e. Ghana Highway Authority [G.H.A] and Department of Urban Roads [D.U.R], Association of Road Contractors, Regional Coordinating Council (R.C.C), utility services provides such as Electricity Company of Ghana (E.C.G), Ghana Water Company Limited (G.W.C.L), Metropolitan and Municipal Assembly, National Communication Authority (N.C.A), the telecom chamber and the respective telcos, to agree on a common framework or modality for engaging the road reservation should be the way forward.

In related study previously discussed, a similar research was conducted by Neumayer et al, which assessed the vulnerability of optical fiber network infrastructure to disaster. They analyzed in details the impact of natural disaster such as earthquakes, floods, tornadoes and electromagnetic pulse as well as physical attack on the optical network infrastructure in specific geographical location(s). In the discussion, a three model approach for the assessment was cited; bipartite graph model, vertical cut assumption and the generic model. However, the analysis centered on the generic model where nodes on the optical fiber infrastructure can be arbitrarily located on the plan and can equally suffer a disaster which could result in a linear segment cut.

In Neumayer's analogy to arrive at a network model and the formulation of the geographical network model to address both the line segment and circular cut, he further argue that out that though, both the physical and the logical layer of the network infrastructure are very important in the scheme of design, one has to consider first the effect of the cut on the physical layer to that of the logical link of the optical fiber network infrastructure. This is simply because the logical link directly depends on the stability and reliability of the physical lays for it optimal performance.

Theoretically, the principle worked when simulated experimentally but it is quite unclear whether the model will yield the same results when introduced to a live network. Technically, this paper also suffers the same limitation as that conducted by Shake et al (1999) in terms of empirical or historical data to justify gravity of that aspect of the fiber cut phenomenon. Ezeh et al (2013) conducted a related research in South-Eastern Nigeria to establish the severity index of the problem associated with the deployment of optical fiber network infrastructure. The objective of his research was to identify and statistically evaluate and appraise the main factors accounting for the root causes of fiber cut menaces on the optical communication infrastructure in Nigeria. His research analysis and evaluation led to the identification of 17 problems accounting for the root causes of the fiber cut.

In the root cause analysis, he further grouped the problem into four main category, namely; Governmental, Fabricated, Planning and Design related issue and Natural problems as shown in Table 2.3 below. The outcome of the research formulated on the bases of the data collected from questionnaire administered by 26 telecom operators and 23 Nigeria Communication Commission personnel. The information was then analyzed statistically to establish the severity index and the degree of ranking for each category of the problem identified.

Table 2.3 Severity Indices and the Ranking of the Four-Problem Category

		NCC PERSONNEL		OPERATORS	
CATEGORIES	PROBLEM CATEGORY	INDEX (%)	RANK	INDEX (%)	RANK
A	GOVERNMENTAL PROBLEMS	72.1	1	76.93	1
B	MAN-MADE PROBLEMS	62.03	2	67.69	2
C	PLANNING AND DESIGN RELATED PROBLEMS	49.85	3	55.90	4
D	NATURAL PROBLEMS	47.34	4	62.39	3

Source: (Ezeh et al, 2013)

Though his findings and conclusion were consistent and coincide, they were more of reactive recommendation than proactive. However, this paper is of the view that all various institutions and organizations who are actors and key plays in the acquisition and regulation of the ROW need to be well resourced and empowered in order to drive a common framework aimed at eliminating or reducing the occurrence of the

incidence. This is important because once the infrastructure is deployed and carries traffic, any network outages or failure because of the fiber cut compromises national security.

Finally, Crawford (1993) also conducted a similar research to ascertain the causes of optical fiber cable dig –up in the telecom industry and further recommend measure to cure it or reduce the menace.

Crawford's investigation was centered on establishing the factors that responsible for frequent fiber optics cable failure caused by dig –up. In his approach, he setup a focused group to collect data on optical fiber cable failure for analysis from selected telecom companies, surveyed existing utility damage prevention legislation and held discussion with key representatives from damage prevention industry.

During the investigation he established that between 1990 and 1992, optical fiber cable failures was the single largest causes of network outages which affected over 50,000 customer for over 30 minute per each incident. Further analysis lead to the classification of the data analyzed to immediate causes and root causes.The immediate causes are the direct causes accounting for the cable cut (eg dig-up). Figure 2.4 and Table 2.4 below illustrate the various percentage contribution captures in the analysis with dig –up accounting for the highest.

Figure 2.4 Immediate Cause of failure

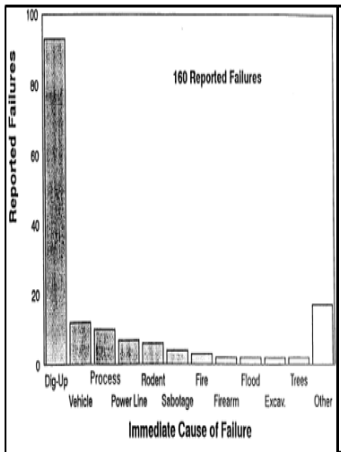


Table 2.4. Immediate Causes of Failure

Cause	# of Reports	% of Total
Dig-ups	93	58.1
Vehicle	12	7.5
Process Error	11	6.9
Power Line	7	4.4
Rodent	6	3.8
Sabotage	4	2.5
Fire	3	1.9
Firearm	2	1.3
Flood	2	1.3
Excavation (non dig-up)	2	1.3
Fallen Trees	2	1.3
Other	16	10.0
Totals	160	100.0

Source: (Crawford, 1993)

The root causes are the critical event such as lack of proper notification, which lead to the failure. Figure 2.5 and Table 2.5 below illustrate the various percentage contribution captured in the analysis with digging errors accounting for the highest.

Figure 2.5. Root Causes of Fiber Dig-up

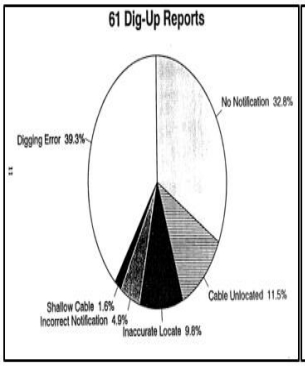


Table 2.5. Root Causes of Fiber Dig-up

Root Cause	# of Reports	% of Total
Digging Error	24	39.3
No Notification	20	32.8
Cable Unlocated	7	11.5
Inaccurate Locate	6	9.8
Incorrect Notification	3	4.9
Shallow Cable	1	1.6
Totals	61	100.0

Source: (Crawford, 1993)

The general outcome of the entire investigation established weak laws as one of the primary reasons for the continuing cutting or damaging of the optical fiber cable. He said, this is because 40% of the total cable failure recorded happened in locations or areas with accurate cable location, proper temporal markers of sub-surface cable route (in order words proper prior notification were made to the excavator). On the other hand, 33% of the 60% attributed to fiber dig-up in the industry was as a result of excavation activities such government and private property owns.

In the final analysis, Crawford applied Pareto analysis tool to identify the most significant failure cause and on the bases of his finding made some significant and relevant recommendation that when implement could go a long way to curb the optical fiber cut menace if not eliminated. However, he could have complemented the

Pareto tool with Ishakawa tool, which is an analytical tool, used for identifying the causes and effect of a problem to make his conclusion more focused on the actual root causes of the contributing to the fiber cut menace in the jurisdiction under discussion.

Impact of Fiber Cut

Grover (2004) and Hoffman (2002) defines an outage and an optical cable cut respectively as an event that arises from a failure that has actually occurred. Moreover,an incident where a communication cable is damaged, effectively disrupting normal operations and typically requiring an emergency repair response.

Hence, the phenomenon of fiber cut in the telecom industry can be described as an act of interrupting an active optical cable connected to network element resulting from specific activities, which is/are, carried out close to the location(s) where these optical cables are deployed.

The occurrence of this phenomenon often disrupt or causes network outages and the level of the impact of the network outage is dependent on the numbers of cut(s) and the location(s) of the cut in a given time.

Additionally, the effect of this menace in the telecom industry has significant effect on the network quality delivery (on both voice and data traffic) as well as the cost of operation and revenue margin.There are a different variety of impacts on the end user and the telcos themselves that results from fiber optic cable failures. These includes brand reputation, financial and socio-economic impact as well as impact on network quality of service delivery.

Financial Impact

In terms of financials, the phenomenon is draining the purse of the telecom operators. According to Grover (2004), the Gartner research group attributes up to $500 million in business losses to network failures by the year 2004. There are three cost component which are occasioned whenever a fiber is cut which affect the general operational expenditure (OpEx) as well as the revenue margins of the telcos and these are;

Cost of splicing Optical fiber Cable

Whenever an optical fiber is cut, it is repaired or fixed (ie spliced) as soon as possible usually within 1 to 4 hours depending on the extent of the cut, and this involves huge cost to the telcos. According to Hoffman (2002), in 1986, AT&T estimated it optical cable cuts cost at about $4000 to physically repair only.

Cost of replacement of fiber due to degradation

Frequent cut on an optical cable within a particular segment degrades the quality of the optical cable overtime, hence will require replacement.

Revenue Lost

From voice and data traffic point of view, whenever there is a traffic affecting fiber cut, subscribers on that network are unable to make or receive calls or even browse the internet and this impacts on revenue generation of the telcos. According to Hoffman (2002), it is estimated that the cost of each fiber optic cable cut is approximately $2,500 per minute in Portland. Similarly, AT&T estimated its revenue lost to optical fiber cut per minute at $3,600. Moreover, Grover (2004) also argued that direct voice-calling revenue loss from failure of major trunk groups is frequently quoted at $100,000/minute or more.

Socio-Economic Impact

Economy

In this era, many organization and business completely depend on the web base transaction system for the business operations. Hence, frequent fiber cuts results in poor network quality of service, which has a ripple effect on our many consumers who conduct businesses through our services. This ultimately leads to loss of revenue to the economy and retards the gross domestic product (GDP) growth as well. Research has proven that doubling broadband speeds for an economy can add 0.3 percent to GDP growth (Little, 2013), as this translated into increase in innovation and high productivity of businesses (i.e. the economic effect), improves better access to services and healthcare (i.e. Social effects), and enhances effectiveness and efficiency in energy consumption (i.e. environmental effects). Implicitly, a consistent degradation in quality of service on the very infrastructure that enable information and communication companies to provide such high bandwidth capacity to enable these business function optimally, could gradually erode the gain in GDP growth overtime due to instability, unreliability and high unavailability of the optical fiber network infrastructure resulting from frequent fiber cut.

National Security

Lack of stable network service presents serious security implications such as lack of secure and guaranteed access to emergency service numbers. According Hoffman (2002). In 1998, an 8-month-old baby died when an optical fiber cable cut disabled 911 and phone service, preventing his parents from calling for help when he stopped breathing.

Impact on Network Quality Delivery

Fiber cuts seriously affect the quality of service delivery that telcos are required to provide to subscribers on their network. In addition, as result quality of customer satisfaction and customer experience is negatively impacted. Customers become frustrated with time because of the incessant disruptions to their service and could contemplate switching to another network.

IV. Research Methodology

The method adopted for this research was both quantitative and qualitative approaches. According to Burns and Grove (1993), a quantitative research is defined as a formal, objective, systematic process to describe and test relationships and examine cause and effect interactions among variables. Whiles Allwood (2011) defined the term qualitative to mean that a studied phenomenon is related to (associated with) one or more categories (for example as done in content analysis) and further defined quantitative to be that entities that are dealt with in terms of an ordinal, interval or quote scale level of analysis.

A combined method of approach was adopted to accomplish this research because the research aimed at identifying main factors and their corresponding root causes accounting for the frequent fiber cutson the optical fiber network infrastructure and its associated financial impact on the telecom industry in the Western and the Central Regions.

The Background of theStudy Organization

This research was carried out in the South-West Business Districts of MTN Ghana. MTN Ghana is one of the 22 operating countries (OpCo) under MTN Group in Africa, Asia and the Middle East connecting to over 232.5 million subscribers across it footprint. The organization is a leading provider of telecommunications services in the telecom landscape in emerging markets such as Afghanistan, Benin, Botswana, Cameroon, Cote d'Ivoire, Cyprus, Ghana, Guinea Bissau, Guinea Republic, Iran, Liberia, Nigeria, Republic of Congo (Congo Brazzaville), Rwanda, South Africa, Sudan, South Sudan, Swaziland, Syria, Uganda, Yemen and Zambia, with the mission of providing a world-class telecommunications products and services, through innovative and sustainable corporate social investment initiatives. The company was founded in 1994 and is based in Johannesburg in South Africa.

Ghana become part of the MTN Group following the acquisition of Scancom Limited in 2006, which operated under the trade name Spacefon. MTN has the widest, most robust 2G, 3G and 4G coverage across the length and breadth of Ghana with over 50% market share of the telecom industry in Ghana. Presently, MTN Ghana has deployed over 5,000 km of nationwide optical fiber network infrastructure connecting to over 2,500 operational cell sites and three state-of-the-art switch and data center. Besides the traditional voice and data services which the organization provides, it also provides tailor made product and service such as mobile financial services, ICT solution for SME, assets tracking devices,etc., which are designed to address the specific telecom needs and lifestyle of it subscribers.

Its operations in Ghana is sub-divided into three Strategic Business Unit (SBU); Northern Business Unit which is a composite of the Northern Region, Upper-Easts Region, Upper-West Region, Brong Ahafo Region and Ashanti Region; part of Eastern Region, Volter Region, and Greater Accra Region also constitute the South-East Business Unit; whiles South-West Business Unit is made up of part of Eastern Region, Central Region and Western Region.The various function of the organization under the respective SBU's are further divided into division, department and section, which drives the overall strategic objectives and goals of the entire MTN Ghana organization.

The divisions and departments that drives the comprehensive operational activities of the organization includes; The Marketing, Sales & Distribution, Mobile Financial Service and Enterprise Business Division. These divisions are technically responsible for creating the route to the market as well as communicating to the customers and corporate institution about MTN's tailor made product and services such as Network Solutions, Internet & Messaging Solutions, Data Center Services, Calling Solutions, Security Solutions Cloud Services,etc., besides the traditional voice and data services on offer, through advertising, pricing and promotions. The Human Resource Division/Department plays a critical role in the function of the entire organization. It is responsible for supporting and creating an enabling environment for learning and the development of employees who are already on the job as well as talented individuals who have joined MTN.

Another important division in the organization is the Capital Group Division and Network Group. These two divisions are responsible for building and maintaining the fix and physical assets (e.g. cell sites, switches and data centers, branch offices etc.) of MTN respectively. The maintenance and enhancement of the integrity and the controls over the company's financial assets and liabilities as well as the financial statements of the organization is the full responsibility of the Finance and Services Division.

The Customer Care Division is responsible for attending to the needs of MTN customers at the respective branch network offices across the country. The Information Services Division focuses on creating an

enabling business environment to grow profitablyby providing cost-effective technological platforms that effectively manages information flow both internally and externally and supports the various solutions the organization provides. Finally, the Corporate Service Division is responsible to ensure that good corporate governances such as communication, regulatory and foundation activities are strictly embraced.

The Study Population and Sample

Two set of population was utilized for the consolidation of data for the discussion and analysis. The first targeted population is MTN, the organization under study and the owners of the optical fiber network infrastructure. The second targeted population was the third party vendor; they provide managed service for MTN on their optical fiber network infrastructure. Their core responsibility is to conduct preventive and corrective maintenance activities on MTNs optical fiber network infrastructure. Furthermore, they make recommendation to MTN with respect to areas on the network that require optimization to enhance the resiliency of the fiber optics network infrastructure, where applicable.

The sample space for the analysis of this study was a derivative of MTN and its vender in the South-West Business Unit (i.e., Western & Central Regions), the jurisdiction under study.The method or technique applied for the selection of the sample space was a direct and purposive, targeted at specific key staff(s) of these organizations who has the technical "know-how" or has the requisite expertise to provide the required information on the problem statement under study. According to Babbie (2007), purposive sampling is the selection of a sample space based on the knowledge of the population, its elements, and the nature of the researcher's aims.

Data Collection/Sources of Data

In this research study,questionnaires and direct interviews were used as the techniques for collecting data. These were adopted in order to fully establish a clear case for the defined problem.The secondary data was obtained through the administering of questionnaires for analysis and discussion in line with the objectives of the study. Prior to secondary data analysis, a data on major network outages recorded within the period of this study, which the fault reasons for the respective outages were established to be as a result of fiber cuts shall also be thoroughly evaluated and analyzed in line the objective study using Microsoft excel. And this major network outages data shall become the primary sources of data for this research study.

Primary Data Sources

As earlier mentioned, the primary source of data for this research shall be an obtained data from the organization on major network failure attributed to fiber cut on the optical network infrastructure for the jurisdiction under study, between the periods of January 2014 to August 2016. Below are some of the relevant information on the data to aid in the discussion and analysis; the duration for each outage accounted for by fiber cut.

The various network technologies that are impacted during each outage (i.e. only 2G or only 3G, only 4G, or only 2G & 3G or all).Whether or not a particular network outage resulting from fiber cut was traffic affecting or non-traffic affecting.The network type (backbone or metro/FTTx) on which a particular fiber cut incidence occurs.The activity(s) that accounts for a particular fiber cut. Whether or not the various cell sites are classified or categorized. In addition, if yes what are the categories and what is the impact of the each cut on the respective categories.

Secondary Data Sources

Secondly, in order to obtain some specific information which was not available in the primary data, a purposive sampling in the form of a questionnaire was administered on the Regional Senior for Network Field Operation of MTN for Southern Ghana, Fiber Implementation Manager for MTN Ghana and the Regional Manager of the Manage Service Provider (WR&CR) to sources further information in the following areas; The fiber population in MTN Ghana (i.e. WR&CR).The network type deployed in that jurisdiction; whether or not they were inter-cite/backbone or metro fiber route.The type of network topology deployed whether or not fiber network deployed in regions were operational on the ring topology, star topology, mesh topology or linear topology. The frequency at which the fiber cut incidence were occurring (i.e. once, twice, thrice or more). The nature of the fiber cut, whether or not they are single cut, double cut or triple cut. In addition, whether or not they are occurring at the same time or different time or at a specific time interval.Establish the gravity of the impact when it's a single fiber cut, double fiber cut and/or triple fiber cut.The causes of the fiber cut along the various corridor of the regions. Whether or not the occurrence were deliberate or accidental.

Limitation

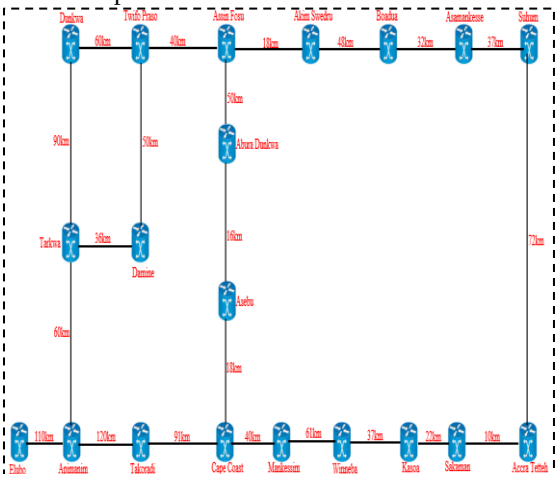
Although the study was comprehensively put together as regards to the available information in the subject area researched, it was not without some encountered limitation; firstly, there were not enough books, articles, and journals in the subject area. Secondly, the study could not secure absolute figures from the organization under study in respect of revenue generated per site to able to quantify the actual revenue loss to the organization as a result of the impact of the menace. Hence, available figures already in the public domain in addition estimated figures provides in the questionnaire were extrapolated and utilized for the analysis to arrive at a reasonable estimated cost.

ANALYSIS AND DISCUSSION

In Ghana MTNhas deployed an excess of about one thousand two hundred and four kilometers of fiber optic network infrastructure as said by the Senior Manager for Network Field operations in charge of Southern Ghana, ie, (WR & CR). Figure 2.6 below shows a sketch of MTN's fiber layout coverage deployed in the utility corridor or road reservation as acquired in the form of right-of-way in the jurisdiction under study. The layout provides further details showing the backbone footprint of the optical fiber backbone network infrastructure in WR&CR generally.

The right-of-ways procured for optical fiber cables deployment in Ghana are developed within the existing corridors or the reservations.

Figure 2.6 WR&CR Optical fiber Backbone Network Infrastructure Layout



Source: MTN

The Senior Manager for Network Operation further indicated that traffic affecting fiber cuts incidences on both backbone and metro fiber infrastructure happens due to double or triple fiber cuts. Generally, double or triple fiber cut is a situation whereby the fiber network infrastructure suffers more than one fiber cut incident, either simultaneously or at separate, but very short time interval at different locations on the infrastructure within a particular jurisdiction. According to the objectives ofthis study, the analysis and discussion of this research will be focused on the causes of fiber cut and their main factors accounting for them. Furthermore, the analysis and discussion of this research willalso be focused on the assessment of the financial impact of the causes of fiber cut.

Part one shall analyze the primary source data for this study manually using Microsoft Excel and establish the various categories or classification, accounting for the fiber cut incidences on the fiber network infrastructure and further apply Pareto analytical tool to evaluate the top 20% category(s) that ought to be further analyzed to establish their respective root causes as well as main factors responsible for the phenomenon and further recommend mitigation action to address 80% of main factors of the root causes accounting for the fiber cut phenomenon.

Subsequently, Ishikawa diagram, also known as Causes-and-Effects diagram shall be applied to the results of the above analysis to identify actual factors accounting for the said root causes of the various categories identified.In part two, the analysis shall focus on evaluating the impact of the fiber cut on the operation of the organization based on the primary sources data. Then further evaluation shall seek to analyze and establish the quantitative impact of the incidences in relation to organizations operational expenditure as well as revenue loss attributed to fiber cut menace within the period and the jurisdiction under study. Moreover, possibly assess the translational effect of the incidences on quality of service delivery to the customers of MTN

(i.e. customer experience). Incidences on quality of service delivery to the customers of MTN (i.e. customer experience).

The Impact of Fiber Cut on the Operations

In this section of the paper, the discussion shall center on evaluating and assessing the impact of the fiber cut phenomenon on the operation of the organization with focused on the jurisdiction under study. The discussion will seek to establish the financial cost relative to the organizations operational expenditure (OpEx) as well as revenue loss to the organization within the period and the jurisdiction under review.

***Impact Analysis on Organizational Operational Expenditure (OpEx*)**

As discussed in the early on, MTN has deployed over five thousand kilometers (5000 km) of optical fiber cable infrastructure across the length and breadth of Ghana. Out of this total fiber population, One Thousand, Two Hundred and Four kilometers (1,204km) representing 24.08% of its total fiber coverage in the WR&CR. The optical fiber network infrastructure is in this part of the Strategic Business Unit has been deployed to form a ring network topology which serves as protection for all the services which depends on the infrastructure. Besides this, additional redundancies has been created or provided to ensure that the network is resilient enough to withstand any challenges such fiber cut, with very minimal or no impact on active services.In spite of the huge capital investment been made by the organization in it fiber optic network infrastructure to ensure a robust network with high network quality and reliability, fiber cut continues to be the highest network challenges accounting for the root causes, eroding the many gains made in this respect.

According to Mr. Bernard Avor, Senior Manager, Network Field Operation, up to about fifty kilometers (50km) of optical fiber cable are relocated annually in the WR&CR. These sections or areas on the fiber route, which are earmarked annually for relocation, are often location identified to be prone to frequent fiber cut due to activities mentioned in the earlier discussion under the root cause of fiber cut. He cited that continues splicing of any particular section of the fiber route (that is introducing more joint) increases the attenuation level, thereby degrades the quality of the fiber cable. Over a certain period, the level of attenuations renders the optical cable inefficient to the extent that it is unable to perform optimally, hence the need for it replacement and/or relocation.

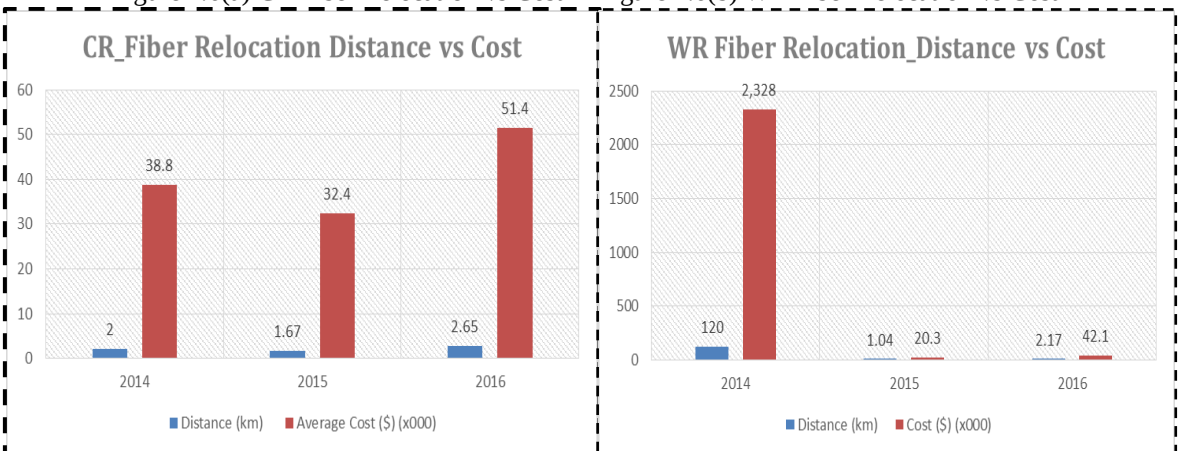
He further mentioned that cost of replacing and/or relocating a kilometer of fiber cable various from rural to urban. However, he indicated that its cost the organization up to about Fifty Thousand Ghana Cedis (GHC50, 000) to relocate a kilometer of fiber cable.

Figure 2.6(**a** and **b**) show a statistical analysis on fiber relocation effected in WR&CR between 2014 and 2016 (August ending) and their corresponding cost associated with it. The data used for the statistical analysis below was obtained from the primary sources data. From the data, it was estimated that, a total of One Hundred and Twenty Nine point Fifty Three kilometer (129.53km) of optical fiber cable was relocated in WR&CR at a total cost of Two Million, Five Hundred and Twelve Thousand, Six Hundred Ghana Cedis (GHC2,512,600) over the two years and eight months period under study. Out of this, a total of 123.31km, representing 95.12% of fiber cable relocation project were executed in Western Region (WR) at a total cost GHC 2,390,000. Similarly, a total of 6.32km representing 4.88% of fiber cable relocation project were carried out in Central Region (CR) at a total cost GHC 122,600.

From the above analysis though WR recorded the highest relocations over the two years eight months period, a year-on-year comparative analysis in figure 2.6b shows a significant reduction in the total number of relocation done from 2014 to 2016.

In the Central Region, the trend is opposite; between 2014 and 2015 there was a marginal drop in the total number of fiber relocations. However, between 2015 and 2016 there was a significant increase in fiber cut from a total relocation of 1.67km in 2015 to 2.65km in 2016 as of August ending as shown in figure 2.6a.

Figure 2.6(a) CR Fiber Relocation vs Cost Figure 2.6(b) WR Fiber Relocation vs Cost



Source: Primary Source Data

Besides the cost incurred for relocation, the company also spend additional cost in repair works for each fiber cut that occurs. According to the Senior Manager for Network Field Operation, it cost the company up to about GHC10, 000 to repair a damaged fiber cable. Meaning if the company experienced a total fiber cut count of 849 in WR&CR for the period under study, then it's estimated in present value that the organization expends approximately GHC 8,490,000 on repair works between the years 2014 to 2016 year to date.

In summary the organization expends approximately GHC11, 002,600 as part of it operational expenditure to repair and relocate optical fiber cable.in Western and Central Region between 2014 and 2016 year to date.

Revenue Loss

At a typical MTN cell sites one could find either of the following cellular network technology deployed at the cell sites according to the survey conducted;

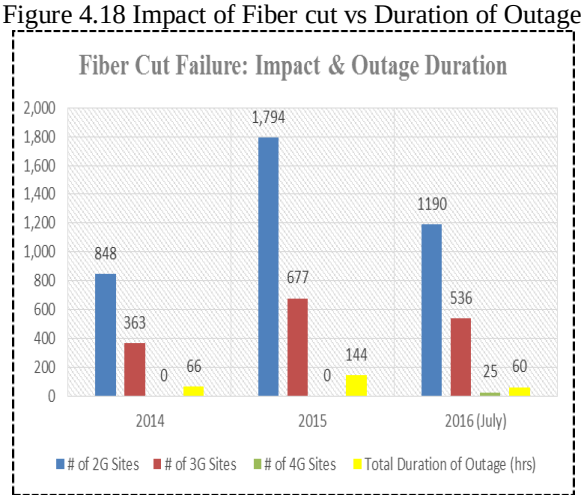
- Only 2G cellular network technology
- Both 2G and 3G cellular network technology
- Both 2G, 3G and 4G cellular network technology

2 G cellular network technology does the traditional voice services, whiles 4G cellular network technology doses purely data services. However, for 3G cellular network, the technology has the capability to does both the voice and data services, implying that traditional MTN's revenue generation channels are through voice and data activities on their network infrastructure

Moreover, in order to optimized its operational efficiencies and quality of services delivery to its various market segmentation, MTN has categorized all its cell sites into five priorities namely; Hub sites (Hub), Priority one (P1) sites, Priority Two (P2) sites, Priority Three (P3) sites and Priority Four (P4) sites in that order of importance; based on the criteria enumerated below, The location of the cell sites within a strategic business unit. The revenue generation per the sites take into consideration the various cellular network technology deployed. The number of dependent cell sites. According to the description provided, Hub sites are sites with more than 10 dependent sites irrespective of the geographical location of the sites. Priority one (P1) and Priority two (2) are sites, which are located in the city centers or the metropolis with high revenue generation and services high valued customers. Priority three (P3) are sites on the peripheral of city center and metropolis whiles Priority four (P4) sites are often sites located in the rural areas with comparatively low revenue generation.

Figure 4.18 shows the impact of fiber cut on the various network technologies over the three year period for which the study is been conducted. Its further shows the total hours lost or network unavailability (in hours) lost to fiber cut annually.

Figure 4.18 Impact of Fiber cut vs Duration of Outage



Source: Primary Data

On the bases of the primary data evaluated, it was established that the total network unavailability attributed to fiber cut for the period under study (2014 -2016) was 270hrs, equivalent to about 11day of total network unavailability for the entire jurisdiction under study. Out of this, the year 2015 recorded the highest network outage with a total of 144hrs of downtime, equivalent to 6days of network unavailability in the entire jurisdiction, which involved 1794 2G cell sites and 677 3G cell sites in Western and Central Region.Similarly, in 2014, a total of 66hrs of network unavailability equivalent to 2days of total network downtime in WR&CR was experienced, involving 848 2G sites and 363 3G sites in the SBU.For the year 2016, though it has not ended yet, a total of 60hrs of network downtime attributed to frequent fiber cut has been recorded already as of July ending. This is equivalent to 2 days of total network outage in WR&CR involving 1190 2G-cell sites, 536 3G cell sites and 25 4G cell sites.

Unfortunately this paper could not secure a confirmed estimated revenue generated by the respective priority cells sites either on daily, monthly or yearly bases in order to establish the actual revenue loss to fiber cut year-on-year by the organization. Without any speculation, this paper is however of the view that the organization losses a lot of revenue to this fiber cut menace in addition the operational cost incurred to restore and relocation damaged fiber cut.

V. Conclusion

Based on the primary source data reviewed relative to the jurisdiction under study and further subjecting it to thorough analysis and interpretation, it was established that fiber cut incidences have hadnegative impacts on the organization's revenue generation ability, increases its operational expenditure exponentially as well as dwindled its commercial fortunes in strategic market places within the strategic business unit. The fiber cuts have had a gross negative effect on the availability of services and reduced the quality of services to its customers. The research obtained its objective in respect of the impact of the fiber cut on the service delivery. The duration of the unavailability of network services to the customer was about five hundred and forty hours, which is equivalent to about twenty-two and one half days, ranging from 2014 to 2016.

The analysis of the finances proved that the organization under study expends approximately GHC11, 002,600 as part of its operational expenditure to repair and relocate optical fiber cables in Western and Central Region between 2014 and 2016 year to date.In the nutshell, if the MTN and other telecommunication companies need to look through this paper and consider the analysis, it is believed that they can take steps to seize the expenditure that arise because of fiber cut, increase revenue, and use this analysis to provide quality and continuous services to their numerous customers.

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