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Mobile Network Backbone Upgrade: How Mobile Operators Can Solve Future Bandwidth Demands

Hilary Ackah-Arthur [1] Winfred Adjardjarh [2] George Essien [1]
1.Department of Computer Science, Takoradi Polytechnic, P. O. Box 256, Takoradi, Ghana
2. Department of Electrical Engineering, Takoradi Polytechnic, P. O. Box 256, Takoradi, Ghana

Abstract
The advent of 3G and 4G mobile services brings with it a surge in data traffic, which in turn puts a strain on existing mobile networks. Nowhere is the demand for more bandwidth felt more than in the Backbone.The backbone of a mobile network contributes to the bandwidth of mobile signals. Therefore the more efficient or effective the mobile network backbone is the more mobile operators can solve current and future demands for higher bandwidths. The main objective of this paper is to research into the best possible way to improve the network backbone of mobile operators, in order to provide the best bandwidth for current and future use.The research was conducted on four mobile operators in Ghana at their branches in Takoradi, Kumasi and Accra Metropolitan areas because of the high population at these areas and the consequent high use of mobile services. Takoradi, also known as the twin-city, is fast developing and turning into a highly industrial area not to mention the recent oil find. Kumasi is the second most industrial area in Ghana and is one of the most populated areas in Ghana. The capital city, Accra is the most populated and the most industrial area in Ghana.Among the numerous challenges of mobile operators in Ghana is how the increasing demands for mobile bandwidth can be solve in the future. Evidently, this is an uphill task that confronts most mobile operators in Ghana.The paper took cognizance of the following factors in respect of the network backbone of mobile operators; the transmission media used for the network backbone, regulations on mobile telecommunications in Ghana, the backbone infrastructure of mobile operators, continuous increase in mobile subscribers, and future demands for network bandwidth.The central questions revolved around identifying the current generation technologies for backbone mobile networks, the current situation of microwave technology being used as backbone by mobile operators in Ghana and the future market demands for network backbone. This was done in terms of their characteristics such as bandwidth capacity, susceptibility to noise and the subsequent error rate, distance required between repeaters and security cost. For an upgrade of a network backbone to solve future bandwidth demands, the aforementioned characteristics of the transmission medium are of utmost importance. A mixed data collection approach was employed. Thus, through observation, it was discovered that some mobile operators are currently upgrading their backbone networks using fiber optics. An interview with workers of some mobile operators in Ghana resulted in such views as: each mobile network operator should have its own network backbone to enhance reliability and to promote effective competition; and the network backbone of most mobile operators should consists more of fiber than microwave.It was also realized, through the analyses of questionnaires that the network backbone of most mobile operators in Ghana are primarily made up of both microwave and fiber technologies; there will be a market demand for backbone networks in Ghana in the near future; and finally, fiber is chosen as the best technology to use for a mobile network backbone in the future.The paper recommends that mobile operators should upgrade their network backbone to fiber and also there must be a common underground conduits or ducts for all mobile operators to lay their fiber cables. An alternate parallel microwave network backbone for mobile operators is also recommended.
Keywords: Fiber optics, Microwave, Mobile bandwidth, Mobile operators in Ghana, Network backbone and Telecommunication.

1. Introduction

Mobile telecommunications over the years in Ghana has been seen as one of the most progressive sectors in the telecommunication industry, and also one of the economic backbones of the country's income generation. Ghana is one of the first countries in Africa to introduce Telecommunication service, and has also taken steps in making sure service providers and citizens get value for their money. By giving license to five different major service providers, Ghana has provided the mobile operators a good platform for stiff competitions among themselves which has created a robust and aggressive market for the explosion of mobile communication, whose growth over the years has grown rapidly that it has spread all over the regions of the country.

Over the years, the number of mobile users in the country has increased dramatically, and making information easily accessible to all citizens. Research has shown that both public and private investment in mobile telecommunications in Ghana has double over the years surpassing the investment in agriculture and natural resources such as gold, diamond and bauxite which were the main export commodities of the country.

In Ghana development in mobile telecommunications are radically and rapidly moving the country towards an economy where there is continuous and ubiquitous availability of information. Recent advances in

mobile telecommunications technology have been an important vehicle in permitting information exchange to develop. Countries and sectors equipped with requisite mobile telecommunications system have been rapidly moving into post-industrial information-based economy growth. For the developing world, a modern mobile telecommunications infrastructure (especially a high capacity network backbone) is not only an essential for domestic economic growth, but a prerequisite for participation in increasingly competitive world markets and for attracting new investment.

With a number of African undersea fiber cables such as the SAT-3/WASC, WACS, Main One, GLO-1 and ACE (Source: http://manypossibilities.net/african-undersea-cables) constructed for the sole purpose of improving voice and data capacity across countries and across continents, mobile operators especially in a country like Ghana where these undersea fiber cables have their landing points will eventually need to upgrade their internal or country-wide network backbone in order to provide higher bandwidth to cater for current and future network bandwidth demands.

Over the past few years, most mobile operators in Ghana have experienced a significant growth in their subscriber base, longer call durations, the emergence of new services and a significant increase in the demand for mobile Internet. Therefore, the demand for mobile services has increased and continues to increase. Mobile Operators in Ghana rely on copper, microwave or fiber as their network backbone technology which determines their network capacity.

There have been a lot of developments or innovations in the mobile market over the years such that voice transmissions which were the main purpose of mobile communication is now shifting more to data transmissions. The increase in voice and data transmissions due to new mobile innovations and increase in the number of mobile subscribers has resulted in the constant demand for network bandwidth. Therefore, mobile operators must make the investments necessary to boost the capacity of their networks. One optimal way for mobile operators to solve the current and future demands for higher bandwidth is to upgrade their mobile network backbone to a technology that is reliable and that can provide higher speed and performance. With the demand for mobile speeds and performance, mobile operators may have no option but to upgrade their network backbone for higher bandwidth in the near future. To address the need for greater bandwidth; mobile operators need to implement a nationwide mobile network backbone that enables simultaneous voice and data transfers through different channels and at different speeds. This must be done using the best technology for optimum results. The available technologies for a mobile network backbone must be investigated and compared to determine the best technology that can be used.

In this paper, we focused on evaluating the current mobile network operators and their backbone networks in Ghana. Depending on the coverage of mobile operators considered for this study, each operator has its own network backbone and the transmission technology varied from operator to operator although the variations were not much. The regulations on mobile services were also considered. The country is saddled with such problems as consistent increase in telecommunication towers as most mobile operators are always expanding their coverage areas. We then identified the developments that are taking place in the mobile telecommunication market. These developments in the mobile market included wholesale markets in backbone capacity, increase in the use of smartphones, advent of new innovative mobile contents/services, and increase in competition in the mobile market.

Our objectives in this paper include identification of the current generation technologies for mobile backbone networks, determination of the current situation of microwave technology being used as backbone by mobile operators in Ghana and last but not least, an assessment of the future market demands for backbone networks in Ghana.

The primary significance of this paper will include an increase in network bandwidth, a reduction in the number of towers used for backbone transmissions, provision of better mobile services, and extra backbone capacity for commercial purposes.

2. Methodology

This section outlines the procedures involved in the research. The methods used for the research activities and the problems encountered are discussed. Because the researchers were determined to cover a wider area, about 80% questionnaires were distributed to technical staff of mobile operators in Ghana and a number of interviews and observations were made. The importance of this section is to give an overview of the general planned procedure used for executing the research work. It also explains how data was gathered and the methods used in achieving the objectives of the research work.

The study was carried out in three most developed and industrial Regions of the ten Regions of Ghana. These three regions are the Western, Ashanti and the Greater Accra Regions of Ghana. The researchers are residents of Takoradi (the capital of the Western Region), so the choice of study location facilitated proximity. The researchers could therefore move in and around these areas quite frequently for field study. The regions selected for the study were considered due to their high use of mobile services and also since they are the most

populated of all the ten regions of Ghana. Their high population has over the years resulted in their high rate of demand for fast and efficient mobile services. This has put more pressure on Mobile Operators in Ghana to continuously upgrade their telecommunication infrastructure to meet the increasing demand of their customers especially in these three well populated areas in Ghana where they have their highest market shares.

The researchers resorted to both primary and secondary data. Primary data refers to data expressly collected for a particular or a specific purpose. In this direction, it was meant to answer the research problem. Instruments employed include questionnaire, interviews and observation. Questionnaire was chosen for this particular study because it is very effective in securing factual information which the respondents are familiar with and also for inquiring into existing opinion and attitude in relation to the subject in question. It also provides a standard procedure for collecting primary data that are comparable, irrespective of who collects them. It also enhances the accuracy of recording and makes data processing easier. Questionnaire is easy to complete and takes less time as compared to other methods. The respondent completes at his own convenience and it offers considerable and objective view on an issue since many respondents prefer to write rather than discuss issues. Questionnaire enables data (concrete or conceptual) to be collected, measured and compared with a standard. (Louis Cohen, Lawrence Manion, Keith R. B. Morrison)**.** The questionnaire used consists of close and an open ended question. The closed questions provided alternative options or answers for respondents to choose from. The open question provided no alternative, but rather the respondents have to answer in their own words.

A useful method that was used to check the questionnaire for a problem was piloting. This usually involves testing it on small selected respondents, interviewing them to get their impressions and to confirm whether the questions have accurately been captured and if the options could elicit the required response. In addition to the questionnaire, the researchers carried out one-on-one interview, which is a personal interaction with some respondents to obtain additional information to supplement that obtained through the questionnaire. The researchers used interview since it is a good method for in-depth probing of personal opinions, beliefs and values. Interviews actually have a comparative flexibility. This involves the researcher and the interviewee in a one-to-one situation and may be quite time consuming. The researcher may interview several people at different time using the same interview question schedule (Harvey Russell Bernard). Patton (1990) noted that observation is a technique that involves systematically selecting, watching and recording behaviour and characteristics of living beings, objects or phenomena. The researchers periodically visited some selected areas where mobile telecommunication infrastructure can be found to observe and have an eye witness account of what actually takes place on the ground. The researchers visited several working areas of some Mobile Operators in Ghana to gain more insight on the technology of their infrastructure. The researchers also observed these operators to observe the activities of mobile operators, rather than what they claim during interviews or in the completion of Questionnaire. With regards to secondary data, various literatures were read and reviewed for this study. For the completeness of this paper, the researchers consulted published documents like magazines, journals and textbooks. Internet references were made including regular visit to the library to consult books and information relating to fiber networks. Secondary data gave the researchers background knowledge and more insight about the topic.

The purpose of sampling is to enable the researchers estimate some unknown characteristics of the population. As a result of the greater number of operators having their outfits mainly in the Takoradi, Accra and Kumasi metropolitan areas, there was the need to select a sample from each of these metropolitan areas. The researchers therefore deemed it expedient to adopt a simple random sampling in these areas. This allowed for members of a specific population to have an equal chance of being selected.

The sample frame refers to the target group from which the researchers can pick the sample size. A sample size of sixteen (16) was selected for the purpose of this study. This consists of sixteen (16) technical staff of some mobile operators in Ghana. This consists of at least three technical staff from each of the four selected mobile operators in Ghana being studied (MTN Ghana, Vodafone Ghana, Tigo Ghana and Airtel Ghana). These are made up of at least one technical staff each from each selected mobile operators in each selected areas of study (Takoradi, Accra and Kumasi). The sample size of sixteen (16) was chosen because the sample frame or the target group consist of technical staff of four (4) leading mobile operators in Ghana. Responses to questionnaire from technical staff of a particular mobile operator will be the same; hence a sample size of only 16 (4 staff from each of the selected mobile operators) was chosen.

We used percentages, pie charts, bar charts and tables to interpret the data collected. These interpretations of the data were made possible with the use of software packages like Microsoft Excel and Statistical Package for Social Sciences (SPSS). A manual coding was also used for all responses which were tallied accordingly. After that the responses were decoded. Answers were assigned numbers for each item and all responses that bear the same numbers were summed up to get the total number of response for each answer. The responses were then grouped and tabulated. Percentages were also used to get the relationship between the variables used in the data. This gives a visual impression of many of the basic properties of the data set as a whole. The data, after it has been analysed, was interpreted by the use of instructive reasoning that is from

general to specific and from specific to general.

Every activity, social, political or economic, has its own difficulties. An academic work like this research is no exception. The main problems the researchers encountered are:

- Funding: The exercise requires a lot of financial commitments. The researchers had to gather their own resources in order to finance the work.
- Time factor: Most respondents could not complete the questionnaire on time, thus slowing down the process.
- For fear of intimidation, some respondents were a bit hesitant and apprehensive in responding to some key questions.

Nonetheless, we tried as much as possible to ensure objectivity in the research, being very systematic and accurate in the process of investigation so as to validate all conclusions.

3. Discussion of Results

The section seeks to critically discuss the opinions of the experts concerning mobile services provided by mobile operators and whether the future developments in the industry require an upgrade of existing backbone technology.

Those who were interviewed included engineers, supervisors and managers. Mr. Charles Weredu, the Radio and Transmission Engineer of MTN Ghana at Takoradi said that each mobile network operator should have its own network backbone. He said there should not be a common network backbone for all mobile operators in the country. He pointed out that, this would avoid the situation whereby a breakdown in the network backbone would affect services of all mobile operators to a particular area. He also highlighted that problems would arise as to who will be responsible for the maintenance of the network backbone in case it breaks down as most of the operators have their own technicians working on their network backbone with different technical competence.

The view of Mr. Charles Weredu that there should not be a common network backbone for all mobile operators in the country is somehow debatable since a common backbone network is less costly to implement and maintain if there is alternative network backbone to support it when there is a breakdown in the common network backbone. With effective maintenance plan supported by all mobile operators and the government, a common network backbone will be operated in the future.

Another interview with Mr. Godwin Diamewu, an Assistant Engineer (Maintenance Section) at Takoradi branch of Vodafone Ghana brought to bear that currently, their network backbone consists more of fiber than microwave. Fiber optics, according to him, forms 70% of their backbone network and microwave forms 30% of their backbone network. He claimed that the choice of fiber for their backbone network is based on the following factors: It has low cost of maintenance, it has larger bandwidth, hence a higher transmission capacity for multimedia purposes such as video, picture or audio transmissions and it is fast and reliable since it transmits on terahertz range as compared to microwave which transmits on a gigahertz range. He then said that the only problem about the fiber network backbone is the splicing or joining of the fiber. If it is not properly done, there will be higher resistance at that joint. He reiterated that the installation cost for fiber is high but the maintenance cost is low. On the issue of microwave network backbone, he said the microwave is weather dependent. It is affected by attenuation, lightening and land topology. He said that Vodafone currently has a nationwide ring topology forming their network backbone in Ghana. This allows calls to be re-routed when there is a break in a particular area.

The view of Mr. Godwin Diamewu about the choice of fiber over microwave for a network backbone is in line with the report by *Heavy Reading* (July 2009).

We also had an interview with Mr. Bright Asare, a Radio and Transmission Engineer at MTN Ghana, Takoradi branch. On the question of whether mobile operators in the country prefer a common network backbone or not, he stated that MTN like other mobile operators prefer having their own separate network backbone although most of their towers are now being managed and maintained by TowerCo Ghana, a joint venture between American Tower Corporation with 51% share and MTN Group Limited ("MTN Group") with 49% share (www.mtn.com.gh). Having their own backbone network will minimize cost, enhance their reliability and promote effective competition. He also gave an example of a network operator in Nigeria called Globacom (Glo), who is responsible for providing the network backbone for most mobile operators in that country. He said that, if the network backbone of Glo breaks down almost all the networks in Nigeria will be down. Hence, mobile network operators should have their own network backbone.

On the question of whether there will be an upgrade of their network backbone, he said that MTN are currently upgrading their Base Transceiver Stations using multiplexing techniques to meet the demands of their subscribers. And also MTN is currently laying fiber cables from tower to tower in each region in Ghana. In analysing the opinion of Mr. Bright Asare that each mobile operators should have its own separate network backbone, we were of the opinion that it will be more costly and uneconomical if each mobile operator have its

own separate network backbone. A common network backbone will rather minimise cost (especially the cost of digging) and increase its reliability if effectively maintained by a dedicated body. Also, competition will depend on the services provided by the mobile operators whether they own their backbone or not.

The researchers observed that a high percentage of the population in the various study locations (i.e. Takoradi, Accra and Kumasi) in one way or the order use mobile services or have subscribed to one or more mobile services. Another observation was that there were new services provided by mobile operators in Ghana that will require higher bandwidth from their network if a lot of people subscribe to those services. Mobile Money provided by MTN is an example. Another example is the mobile Internet that is provided by almost all mobile operators in Ghana.

The researchers also observed that telecommunication masts can be found almost everywhere and most of these masts have been placed at areas of high altitudes (see Picture1).

It was observed also that some mobile operators in Ghana are currently and gradually upgrading their backbone network using fiber across the whole country. Each operator is laying its own fiber cables between its cell-sites. MTN is in the process deploying fiber cable between cell sites in a ring topology at various locations in the country. Vodafone and tigo are also deploying fiber cables in their network backbone. Vodafone Ghana which is operating both mobile and fixed line telecommunication, already has some underground tunnels which are used for fixed line transmissions. Vodafone is currently running fiber cables through these existing underground tunnels thus reducing the cost of digging. These underground tunnels of vodafone are not found everywhere in Ghana, therefore some locations must be dug to lay the fiber cables. The type of fiber cable being used in a particular location depend on the bandwidth demand in that location. Fiber cables with 24, 48, 64 or 96 fiber lines are being used by MTN Ghana, Vodafone Ghana and Tigo Ghana for their network backbone upgrade. The fiber cables being used by these mobile operators are from different manufacturers and therefore can only be identified by the number of fiber lines in each fiber optic cable. Pictures 2 and 3 below shows a fiber cable with 24 fiber lines being deployed in the existing underground tunnels of Vodafone by staff of vodafone Ghana. Pictures 4 and 5 also shows conduits for fiber cables being burried between various cell-sites by MTN Ghana and junctions where the fiber cables can be accessed, joined and monitored.

From the field observation made, we were impressed by the way some mobile operators have began laying fiber cables to upgrade their network backbone. We were, however, not impressed about the way each of these mobile operators is digging and laying their fiber cable beside each others along-side roads. Having common conduits or tunnels for their fiber cables will be more beneficial.

During the fieldwork, sixteen (16) questionnaires were distributed to technical staff of mobile operators in the three selected regions of Ghana. Out of this number, fourteen (14) responses were received. Table 1 below shows the groupings and results obtained:

There were 3 respondents each from MTN and Airtel. Also 4 respondents each from Vodafone and Tigo also filled the questionnaire as can be seen in Table 1.

It can be observed (Figure 1) that every questionnaire sent to Vodafone and Tigo were filled and returned. For the ones sent to MTN and Airtel, only three out of four were filled and returned. Therefore, there were three respondents each from MTN and Airtel whiles there were four respondents each from Vodafone and Tigo. The responses from staff of these mobile companies were used for the analysis. Any propositions and conclusions drawn, will be based on the responses given by staff of these mobile companies in Ghana. That is 29% each from Vodafone and Tigo and also 21% each from MTN and Airtel.

Out of the 14 respondents, 12 respondents (86%) were Engineers whiles 2 respondents (14%) were Managers of the various mobile operators under study. Figure 2 gives a graphical display of the percentage of managers and engineers.

From Table 2, it is known that the respondents were either Engineers or Managers of the various selected mobile companies. The target group for this research was technical staff of selected mobile operators in Ghana and all the respondents to the questionnaire fall in this category. Specifically, the number of respondents from each mobile company who were either Engineers or Managers are demonstrated. There were 3 Engineers from MTN and four engineers from Tigo. There were 3 Engineers and 1 Manager from Vodafone and also 2 Engineers and 1 Manager from Airtel.

The engineers and managers of mobile companies are in a better position to explain their views of the current trend and future of mobile network backbone. Since the questionnaires were responded by people in the telecommunication field, the propositions and conclusions from this research will be the results of views from experts in the field.

In our quest to identify the existing transmission technology used by mobile operators for their network backbone in Ghana, we present the results in Table 3. It can be indicated that 8 respondents (57%) chose Microwave and Fiber Optic as their current transmission technology for their mobile network backbone. Six respondents (43%) chose only Fiber as their current transmission technology for their mobile network backbone. None of the respondents chose Copper or only Microwave. This result is not in line with the recent report by

Heavy Reading (July, 2009), which estimates that microwave represents nearly 50% of global backbone deployments. The analysis indicates that majority (57%) of the mobile operators are currently using Microwave and Fiber for their network backbone but the question is "to what extent are they using the fiber or the microwave?" Fiber technology provides very high bandwidth but how is it being implemented by these mobile operators for their network backbone? In a nutshell, mobile operators in Ghana use microwave and fiber for their network backbone although fiber is used more than microwave.

We further made an investigation into the reasons for mobile operators' option for the type of transmission technology used for their network backbone in Ghana. Infer from Figure 3 that six respondents (43%) identified the reason for the choice of their transmission technology to be Bandwidth Capacity. Four respondents (29%) gave their reason to be both Reliability and Bandwidth Capacity. Two of the respondents (14%) gave their reason to be Reliability. One respondent (7%) gave his reason to be Cost and Bandwidth Capacity and another respondent also gave his reason to be Reliability and Cost. This reveals that Bandwidth capacity and reliability contributes to the choice of the particular transmission technology. This responses stress the importance of higher Bandwidth Capacity and reliability in the provision of a network backbone for the future. Bandwidth Capacity and reliability thus constitute the most vital factors in a mobile network backbone upgrade.

We probed into the cost effectiveness of the current transmission technology for the network backbone. 100% of the respondents were of the view that their current technology is cost effective as can be seen in Table 4. This is a clear evidence that the network backbone technologies being used by mobile operators in Ghana are cost effective due to the relatively high percentage of microwave technology for their backbone networks. This is in line with the report by Tzvika Naveh (October, 2009).

The results in Table 4 indicates how long mobile operators have been using their current transmission technology for their network backbone. Ten respondents chose 1-5years whiles 4 respondents chose 6-10years. Infer that majority (71%) of the correspondents have been using their current backbone technology for at least one year and at most five years. Only (29%) have been using their backbone technology for between six to ten years. The choice of 1-5 years that majority of operators have been using their network backbone shows the constant efforts by mobile operators to upgrade their network backbone in Ghana. Therefore, majority of the currently existing mobile operators in Ghana have been using their backbone technology for between one (1) to five (5) years.

To demonstrate whether or not microwave backbone can provide the best bandwidth for mobile networks in the future, we make reference to the results in Table 5. One of the respondents (7%) did not answer this question leaving thirteen respondents to this question. Out of the 13 respondents, ten representing 71% were of the view that microwave backbone cannot provide the best bandwidth for their mobile network in the future whiles 3 respondents (21%) thought otherwise. The result depicts the views of experts in telecommunications in Ghana. The result of the analysis implies that microwave network backbone has its limits and cannot provide the best or very high bandwidth for a mobile network if the demand for bandwidth increases. This is in line with the paper by Williams (2004), which chooses fiber networks as the optimum solution for higher volumes of traffic, although microwave networks are the most cost-effective technology for a network backbone. It is evident that microwave cannot provide the best bandwidth in the near future; moreover it can be used as an alternative network due to its cost-effectiveness and especially to provide services in areas that require lower traffic.

The question as regard to the certainty about future increase in demand for network capacity in Ghana has been answered by the empirical result as displayed by Table 9. The 71% of the respondents were of the view that there will certainly be a rise in the demand for network capacity in the near future, whilst the remaining 29% did not answer because they were not sure. Thus, the respondents were very sure that the demand for network capacity will increase in the future.

Factually, the cost of installing fibre is very high relative to that of microwave backbone. Although the installation cost of a transmission technology constitutes an important cost component, it is incurred but once. What becomes a more significant constituent of cost is the maintenance cost after installation. We performed another investigation to compare how expensive it is to maintain fibre network backbone relative to microwave backbone. From the result in Figure 6, 79% of the respondents were of the view that it is not expensive to maintain fiber network backbone as compared to that of microwave. Three (3) respondents (21%) thought otherwise. Fiber network backbone is found to be less expensive to maintain relative to microwave. Although it is costly to install fiber (cost of digging), it is less costly to maintain as compared to microwave which requires expensive towers and repeaters for signal transmission.

We found it expedient to advance an interrogation to establish the urgent need of mobile operators to upgrade their network backbone. All 14 respondents, as evinced in Table 6, supported the view that mobile network operators need to upgrade their network backbone to meet future market demands in Ghana. The results prove that an upgraded of a mobile network backbone to cater for higher network bandwidths will be a solution to future market demands for network backbone. The report by Scanbi-Invest (2007) stated that 'Mobile

operators build their networks gradually as the traffic grows'. Gradually the network traffic grows as the number of mobile subscribers, mobile services and also new mobile operators who lease lines increase. Since there are continuous emergence of new and small mobile operators in Ghana increase in mobile services and subscribers, there will certainly be a market demand for network backbone in Ghana in the near future.

In so far as the need to upgrade network backbone in Ghana is concerned, it has become imperative to advance an empirical establishment in respect of the type of transmission mechanism mobile operators would prefer to upgrade their current transmission technology to. From Figure 6, 7 respondents (50%) preferred to upgrade their network backbone technology to fiber whiles 6 of the respondents (43%) preferred an upgrade using both fiber and microwave technologies. Only one respondent (7%) opted for both fiber and copper. Therefore, more than 50% of the respondents prefer to use fiber technology for an upgrade of their mobile network backbone. The results of this analysis indicate that fiber is most preferred by mobile operators if they were to upgrade their network backbone. Fiber may have been preferred as the technology for future network backbone because of its advantages over microwave and copper especially due to its high bandwidth. Also, as stated in the Heavy Reading Research (July, 2009), fiber is expected to take the place of copper based wire-line connections, and increase its overall share (albeit not at the expense of Microwave). In a nutshell, fiber technology is most preferred for future network backbone upgrade.

The responses for the network backbone ownership were diverse although most of the respondents preferred both ownership by all mobile operators in Ghana (36%) and also ownership by government and mobile operators (36%). Three respondents (21%) preferred the ownership of the network backbone to be entirely owned by government. Only one of the respondents (7%) was of the view that mobile operators should construct their own individual network backbone (see Table 7). We analyse that a single unified network backbone that is financed by all mobile operators in Ghana or financed by a partnership between mobile operators and the government, will be most appropriate to be implemented in Ghana. A single robust network backbone used by all mobile in the country and managed or maintained by a dedicated body will reduce cost of mobile services, reduce the number of base stations, provide optimal network bandwidth to cater for increasing bandwidth demands, reduce costs of transmission by mobile operators and enable easy implementation of telecommunication regulations by the NCA since all the mobile operators will have a common network backbone in the country.

The results of the analysis (shown in Table 8) above depict that 71% of the respondents answered the negative whilst 29% affirmed in respect of whether the current network backbone can provide adequate bandwidth in the future. This establishes that the current network cannot provide adequate bandwidth in the future.

4. Conclusions

The network backbone technologies that were considered revealed that fiber optic is the medium with more advantages as compared to other media like microwave or copper used for mobile network backbone. More importantly, fiber provides the highest bandwidth capacity.

Ghana currently has five mobile operators that are in operation. The mobile operators in operation include MTN, Vodafone, Airtel, Tigo, and Globacom (Glo). The number of mobile subscribers in Ghana continuously increases every quarter of a year as stated in the report by Business Monitor International (BMI) that in the first six months of 2010, the number of mobile subscribers increased by 7.3%. Currently there are close to 17,000000 mobile subscribers in Ghana with MTN having the highest market share of 56%. Other research such as that of Heavy Reading Research (July 2009), revealed that the use of fiber for network backbone is on the increase while the use of microwave and copper are on a decline. The researchers found out in a book by Schiller, 97(*Mobile Telecommunications*), that there is continuous increase in mobile network traffic and also when there is very high traffic on the network, fiber is preferred for transmissions more than microwave. Telecommunication towers are found to make up 70% of the total capital cost of mobile operators using microwave for their backbone network (Source: www.scanbi-invest.com, 2007).

The analysis revealed that many mobile operators in Ghana prefer to use fiber for their network backbone because of its greater reliability, cost-effective and higher bandwidth capacity. It was also been established that, since fiber provides a higher bandwidth than microwave it is preferred for a future network upgrade. It is also realized that, although fiber network is costly to install, it is less expensive to maintain. The demand for network bandwidth is also found to increase currently and will increase in the future, but the network backbone of most mobile operators cannot provide adequate bandwidth in the future. Therefore, there is urgent need for mobile operators to upgrade their mobile network backbone to meet future bandwidth demands.

Conclusively, mobile operators can solve bandwidth demands in future by upgrading their network backbone to a fiber optic technology due to the extremely high bandwidth of fiber optic cable.

5. Recommendations

In order for mobile operators to solve the problem of bandwidth demands in the future, the following measures are recommended:

- All mobile operators should upgrade their mobile network backbone using fiber as a medium of transmission since fiber provides higher bandwidths.
- There must be a common underground tunnels or conduits where the fiber cables can be laid and should be large enough to accommodate a lot of fiber optic cables of mobile operators and also accommodate dark fibers. This fiber tunnels or conduits can be installed by mobile operators and the government.
- There should be an alternative parallel microwave network backbone that can be used when natural disasters such as earthquake causes a break or affects the fiber backbone. Microwave is also a medium of transmission with high bandwidth but not as that of fiber optic.
- There must be a policy to ensure that road contractors lay fiber cables along-side new roads they construct. Fiber must also be laid along-side water pipes.

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Table 1: Number of questionnaire distributed and received from respective mobile companies

No.	Mobile Operator	Number of questionnaire distributed	Percentage %	Number of questionnaire received	Number of received questionnaire percentage
1	MTN Ghana	4	25	3	18.75
2	Vodafone Ghana	4	25	4	25
3	Tigo Ghana	4	25	4	25
4	Airtel Ghana	4	25	3	18.75
Total		16	100	14	87.5

Table 2: Cross tabulation of Respondents against position within mobile companies

		Position of respondent in the mobile company		
		Engineer	Manager	Total
Respondents from respective mobile companies	MTN	3	0	3
	Vodafone	3	1	4
	Tigo	4	0	4
	Airtel	2	1	3
Total		12	2	14

Table 3: Frequency Distribution of type of transmission technology used for network backbone.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Fiber	6	43	43	43
	Microwave & Fiber	8	57	57	100
	Total	14	100	100	

Table 4: Frequency distribution of the cost effectiveness of the preferred technology.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	14	100	100	100

Table 5: Frequency distribution of whether microwave can provide the best bandwidth in future.

		Frequency	**Percent**	**Valid Percent**	**Cumulative Percent**
Valid	No	10	71	77	77
	Yes	3	21	23	100
	Total	13	93	100	
Missing		1	7		
Total		14	100		

Table 6: Frequency distribution of the need for mobile operators to upgrade their network backbone in the future.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	14	100	100	100
	No	0	0	0	

Table 7: Frequency distribution of the preferred network backbone ownership.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Mobile operators constructing their own individual network backbone	1	7	7	7
	Government constructing a mobile network backbone for all mobile operators in Ghana	3	21	21	29
	All mobile operators in Ghana coming together to construct a common network backbone	5	36	36	64
	Government and mobile operators in Ghana coming together to construct a common network backbone	5	36	36	100
	Total	14	100	100	

Table 8: Frequency distribution of whether the current network backbone can provide adequate bandwidth in the future

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No	10	71	71	71
	Yes	4	29	29	100
	Total	14	100	100	

Table 9: Frequency distribution of whether network capacity will be of demand in future

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	10	71	100	100
Missing		4	29		
Total		14	100		

Picture 1: Telecommunication masts of Mobile Operators in Ghnana

Picture 2: A fiber cable being deployed in an existing tunnel by Vodafone Ghana

Picture 3: Fiber cable being pulled by Vodafone staff as it arrives at a junction

Picture 4: Fiber Conduits of MTN Being Connected at a Junction

Picture 5: Junction of Fiber Conduits Being Laid Between Cell-Sites of MTN

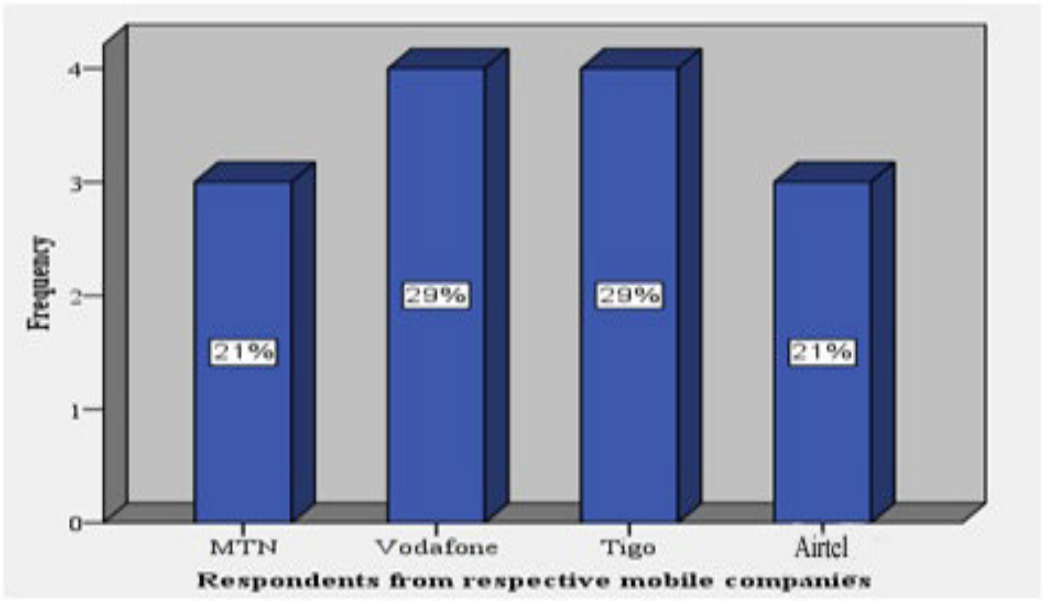

Figure 1: Number of Respondents from respective mobile companies

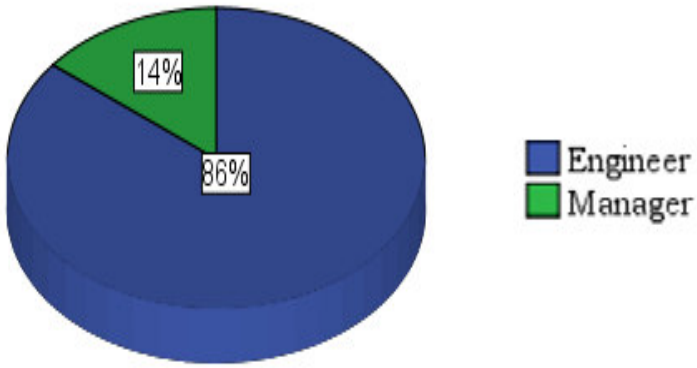

Figure 2: Percentage of position of respondents

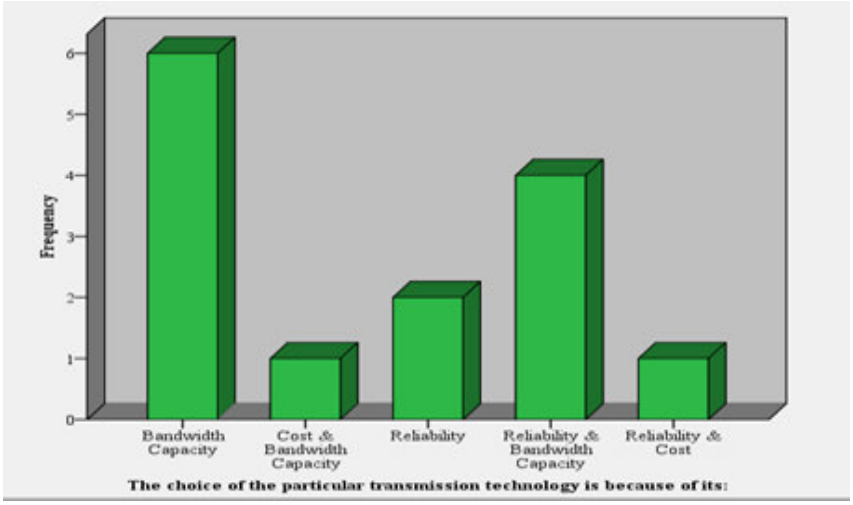

Figure 3: Reasons for choice of a particular network backbone technology

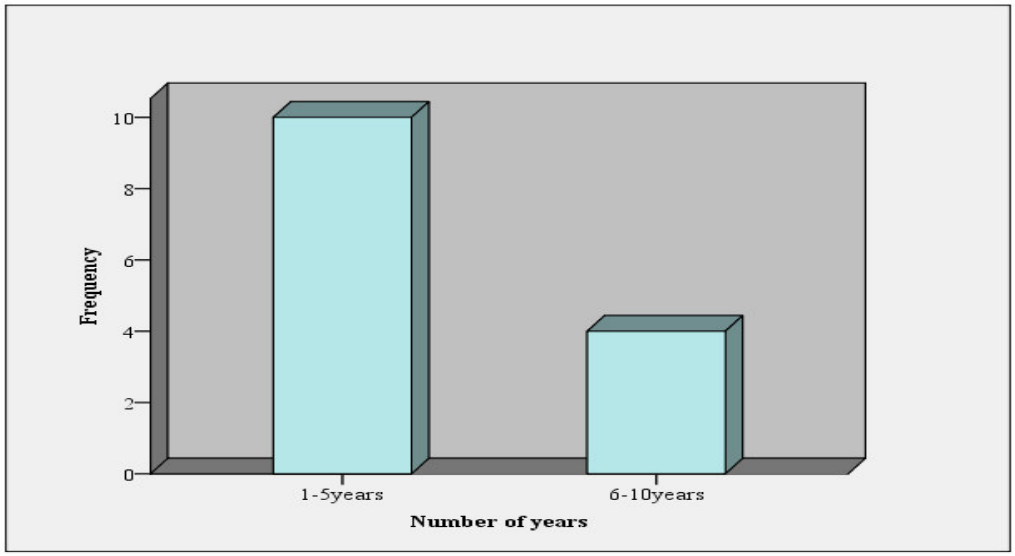

Figure 4: How long mobile operators have been using their network backbone

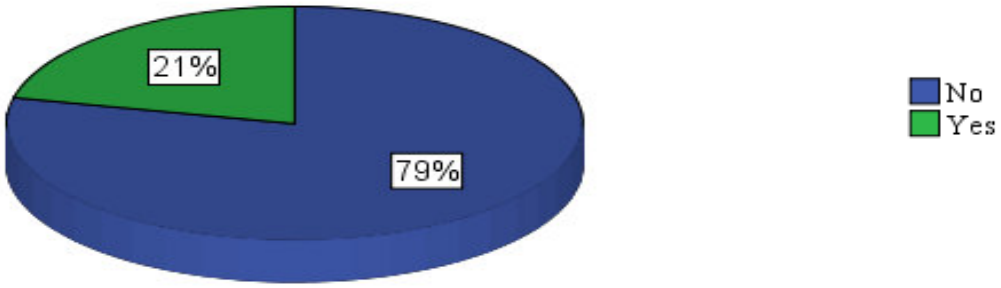

Figure 5: Is it is expensive to maintain fiber network backbone as compared to that of microwave.

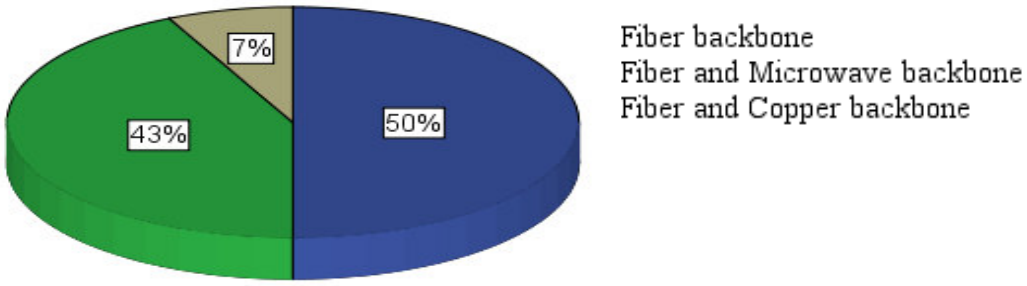

Figure 6: Technologies preferred for an upgrade of a mobile network backbone.