PERFORMANCE EVALUATION OF MOBILE NETWORK SERVICES IN SHIRORO POWER STATION, NIGERIA

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LIST OF ABBREVIATIONS

AC	Attempted Call
ATC	Automated Test Calls
BCH	Broadcast Channel
BS	Base Station
BTS	Base Transceiver Station
CDMA	Code Division Multiple Access
CSS	Call Setup Success
CCS	Call Completion Success
CSF	Call Setup Failure
CHSR	Call Handover Success Rate
CSSR	Call Setup Success Rate
CST	Call Setup Time
DC	Drop Call
CDR	Call Dropped Rate
DTA	Drive Test Area
DT	Drive Test
TEMs	Transmission Environment Monitoring Software
GPS	Global Positioning System
MS	Mobile Station
EMF	Electromagnetic Wave Or Field
GIS	Geographical Information System
GSM	Global System for Mobile Communication
SQMS	Square meters

ABSTRACT

In this work, performance of four mobile network operators (MNOs) was measured, analysed, and evaluated in Shiroro Power Station and recommendation were made to improve the quality of their voice and data services. Drive test was performed using transmission environment monitoring softwares (TEMs) and statistical analysis was done for performance evaluation. The results shows that the received signal strength level was between the ranges of -50 dBm to -110 dBm as against the standard range values of -30 dBm to -70 dBm, recommended by the Nigerian Communication Commission (NCC) and the received quality for Mobile Network A , Mobile Network B and Mobile Network C were observed to be Excellent. This implies that MNO A, B and C met the NCC recommendation in terms of received quality level. Received quality level of Mobile Network D was observed to be poor. MNO C offered the best quality of service in term of call setup time (CST), Call setup success rate (CSSR), Call completion success rate (CCSR) whereas in term of dropped call rate (DCR) MNO A and MNO B were the best. Mobile Internet service of MNO B with latency of 2.75 ms and throughput of 6731.8 kbps was observed to be the best in term of Latency and Throughput follow by MNO C with Latency of 121 ms and throughput of 153kbps but in term of data rate, MNO A with data rate of 38.85 kbps was observed to be the best followed by MNO C 10.55 kbps data rate. Technical issues that were observed to be responsible for poor performances are; Terrain problem, low transmit power, absence of booster amplifiers at the base stations, Insufficient coverage and absence of 4G wireless technology.

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the Study

Telecommunications is fundamental for development of any economy; it is a vital infrastructural element that increases the growth and expansion of other sectors. It is necessary in day to day activities and essential in times of national crisis or natural disasters; it also minimizes the hazard and rigors of travel. Therefore, the availability of efficient telecommunications facilities is good for any country that wants to compete in today's economy as most economy becomes handicapped in the absence of sound communication system (Aliyu *et al.*, 2018).

Telecom regulatory body in Nigeria, the Nigeria Communication Commission (NCC) knew that Nigeria had a very few telephone lines for several years, before the liberalization of the Telecommunication system in 2001 by the Federal government of Nigeria. The number of subscribers seeking to be connected through the then Nigeria Telecommunication (NITEL) was projected at over ten (10) million (Dahunsi *et al.*, 2018). The story has changed dramatically today with the lunch of Wireless Mobile Communication (WMC) also known as Global System for Mobile Communication (GSM) in 2001 in Nigeria (Dahunsi *et al.,* 2018). Its acceptance was likely and projected to provide a feasible alternative to the analog system operated at that time in Nigeria. The main objectives during its launching in 2001, was to offer efficient and valuable telecommunication services that will maintain good speech quality, minimize interference, roaming, minimum drop call, maximum handoff, spectral efficiency, and good interconnectivity (Alabi *et al.,* 2017). Four Mobile Network Operators (MNOs) are in Nigeria presently competing for mobile subscribers for Telecom services namely; Airtel, 9mobile, Globalcom and MTN (Aliyu *et al.*, 2018).

The unprecedented number of subscribers witnessed by the telecommunication industries led to poor quality of service been provided by the Mobile Service Providers (MSPs) (Al-Imran *et al.*, 2010). In Nigeria for the past years, the problem of poor quality of service (QoS) has been an issue to both mobile network service Providers and Mobile Users. Fundamentally, every subscriber to mobile network in Nigeria is affected in one way or the other on services provided by the Mobile Telecommunication operators (Al-Imran & Ajayi , 2010). Subscribers of Mobile Network have been complaining and suffering from terrible quality of service (QoS), ranging from problem of network congestion, incessant dropped calls, failed calls, poor voice clarity, and failed handover, among others (Al-Imran & Ajayi , 2010). The challenge is how to sustain good, secure, uninterruptible Mobile Service for public health, safety, military control in the face of poor QoS such as: Call Setup Failure, dropped call and poor voice clarity. The need to tackle the problem of failed calls, dropped calls and poor mobile internet service on the mobile network is important, as this will be of advantage to both operators and users.

According to United Nations Consultative Committee for International Telephony and Telegraphy (CCITT) recommendation E.800 Quality of Service is defined as “The combined effect of service Performance which determines the level of contentment or agreement of a user of the service” (Edy & Oki , 2016). QoS upholds customers' confidence and is good for a competitive advantage. In telecommunication system, Network coverage (availability of services), Network Accessibility (receiving or getting on the network), Network Retain ability (holding on the network) and connection Quality (having a good service experience while using the network) are the four major factors considered in evaluating quality of service (QoS) of a Mobile Network Provider (Daniel & Joshua , 2018).The most important element to the mobile service providers are connected to Network Performance and Quality Service for income generation and subscriber contentment (Galadanci *et al.,* 2018).

However according to Gordon et al (2016), for Mobile Network Telephony services to be of good quality, it has to meet up with some criteria such as, good speech quality, minimum call blocking, minimum dropping, appropriate loudness level, good signal strength, and high data rate for multimedia application. Mobile service also has to be delivered to the customers as at when needed.

Call setup time (CST), Call Setup Failure Rate (CSFR), Call Drop Rate (CDR), Call setup success rate (CSSR), Call Completion Success Rate (CCSR), Call Handover Success Rate (CHSR) and Standalone Dedicated Control Channel (SDCCH) are some key performance indicator (KPIs) considered by Telecommunication regulatory organ in Nigeria for monitoring and rating (QoS) of Mobile Network Service. The three common methods used to monitor and evaluate these KPIs are; Network Statistics, Drive Test and Customer complaint/Questionnaire. Nevertheless, drive test trial is the best method to analyze Mobile Network Performance as it provides the subscriber experience of the service provider (Yusuf *et al.,* 2016). In order to measure and evaluate network performance of Mobile network, Data ara needed. This research work made use of eight KPI parameters which are: Call Setup Time (CST), Call Setup Failure Rate (CSFR), Call Drop Rate (CDR), Call Setup Success Rate (CSSR), and Call Completion Success Rate (CCSR), data rate, Data throughput and Latency.

1.2 Statement of the Research Problem

The Poor QoS experienced by mobile network users is one of the challenges confronting mobile network operations. Mobile networks therefore need to be under constant monitoring. Therefore, the need to carry out this investigation to assess and monitor the

Mobile Network operations in order to quantify the degree of quality service deviation from the acceptable standard and identify the challenges that are responsible for the problem of poor quality of service and hence make recommendations for possible improvements. Ability to identify the root cause will enable us to address the problem.

1.3 Aim and objectives of the Study

This research aims to evaluate the quality of voice and data services and make recommendations for improvement on mobile network operations in Shiroro power station

The specific objectives to achieve this aim include to:

i. Conduct drive tests for data collection using Transmission environment monitoring software (TEMs)
ii. Analyze the collected data to determine the network coverage and various KPI parameters for all the Mobile Network operators in Shiroro power station
iii. Determine the Mobile Network Provider with the best Quality of Service (QoS) through comparative process of various KPI parameters with the KPI benchmark set by NCC and Minimum standard for data communication
iv. Investigate network transmission impairment and offer useful recommendations.

1.4 Motivation for the Study

The socio-economic setting of Nigeria has been positively transformed after the rollout of wireless Mobile Services across Nigeria. The growth and the general acceptance of wireless telecommunication system by Nigerians bring about giant income to the Mobile Service Providers and to the Government in the course of issuing license and tax fees. Equally, the citizenries are not also left behind in terms of benefit from the Services of Wireless Telecommunication, not just as a way of passing information thousands of people had also benefited in terms of job opportunities in Nigeria. Nonetheless, the Service.

rendered by these Service providers have continued to witness series of complains from the subscribers concerning poor Quality of Services (QoS) provided in the country. The lamentable part of these circumstances is the reality that all the Mobile subscribers are continually affected. On account of this situation, many subscribers are undecided on which Mobile Service Provider to subscribe to and thus making the Subscribers to migrate from one Mobile Network Provider to the other in search of a better services.

The main motivation of this research is that the subscribers not only in Shiroro power station but also everywhere like to see fast and reliable telecommunication activities and get values for their money. This study was undertaken based on the poor quality of voice and data service experience by the Subscribers in Shiroro power station. To find out the cause of unreliable voice and data service and provide some useful recommendations.

1.5 Scope of the Study

The scope of this research was limited to using eight (8) KPIs parameters to evaluate voice and data Services provided by the Mobile Network Providers in Shiroro power station. Five of the KPIs being voice centric and the remaining three data centric.

1.6 Justification of the Study

The workforce and inhabitant of Shiroro Power Station need voice and data services for social, industrial, educational and economic purposes. A qualitative voice and data service in this location will ensure employees in this locality can easily use their telecommunication devices such as smartphone, modem to send and receive emails, participate in multimedia conferences and efficient voice service, collaboration between departments will be more easier and effective, Network operators will get good returns on their investment and there will be a positive impact on the economy of this location and the national economy in general It is therefore important to monitor and evaluate the mobile network operations in this location to understand nature of the service being provided and investigate network transmission impairment and to make recommendations for improvement.

1.7 Limitation of the Study

One of the most challenges that militate against the Quality of Service Evaluation of this Research and probably in Nigeria is abruptly refusal from the side of Telecom Network Providers (TNPs) to authorize researcher's contact to database. This makes this research to resort to comparative analysis of Data obtained from the Drive test with that of NCC KPIs threshold and minimum standard for data communication instead of using real-live Network Statistics from the MNP in evaluating the accuracy of QoS been provided by the Wireless Service Providers WSP.

1.8 Thesis Outline

The remaining part of this thesis is arranged as follows: Chapter two presents the Literature reviewed in the course of the research work while the methodology adopted in this research is presented in chapter three. The results obtained from the Drive Test and performance analysis and are discussed in chapter four and chapter five contains conclusion and recommendations.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 KPIs benchmark by NCC for MNOs

Telecommunications industry in Nigerian is basically governed by the Nigerian Communication Act, issued by Nigeria communication commission (NCC) in 2007. By means of section 4(d) of the NCA, the NCC was saddled with job of issuing license to telecommunication operators, regulating and monitoring the activities of the telecommunication operators, protecting and satisfying the customers of mobile users, enforcing and penalizing any mobile operators contravening the regulations. In an effort to satisfy consumers of mobile networks the NCC issued Regulations on Quality of Service and Nigerian Communications regulations, 2005, for all the telecommunication operators to comply with (Ernest, 2009). In this research, focus is on the following KPIs and minimum standard for data communication; Call Setup Time (CST), Call Drop Rate (CDR), Call Setup Failure Rate (CSFR), Call Setup Success Rate (CSSR), Call Completion Success Rate (CCSR), Data rate, Latency, Data Throughput, Table 2.1 and 2.2 show NCC regulations on QoS issued to telecommunications service providers and minimum industrial standard for data communication.

Table 2.1: KPIs parameters considered by NCC Benchmark for Mobile services (https://www.ncc.gov.ng/technology/standards/qos#measuring-voice-quality%202019).

S/N	KPIs	STANDARDS
1	CST	≤6s for local/international call
2	CSSR	≥98% of attempted calls
3	CSFR	≤10% of the attempted calls
4	CDR	≤1% of the attempted calls

5	CCSR	≥97% of the attempted calls

Table 2.2: Industrial Standard for data communication (Dahunsi *et al.,* 2018).

S/N	KPIs	STANDARDS
1	Data Rate	500-5000kbps3G, 1-50Mbit/s 4G
2	Latency	100-500ms 3G, <100ms 4G
3	Data Throughput	3.1mbps 3G, 10-300 mbps 4G

2.2 QoS in GSM networks

The Quality of service definition may vary from situation to situation and from person to person. Quality refers to the standard of something when compared to other things like it, while, service means application, system or amenities, or any combination of these services, that is provided significantly for communications between Network Termination. According to Wikipedia (en.wikipedia.org/wiki/Quality_of_service), quality of service is the description or measurement of the overall performance of a service, such as a telephony or computer network or a cloud computing service, particularly the performance seen by the users of the network. To quantitatively measure quality of service, several related aspects of the network service are often considered. The definition of Quality of Service only vary in wording but in general involves determining whether perceived service delivery meets, exceeds or fail to meet subscriber expectation. It is basically the level of guaranteed service to a user. Meanwhile, Settapong et al (2016) defined QoS from the perspective of users as the level and trend of difference among the Mobile Users perceptions and prospect, or the scope to which a service meets or exceeds opportunity. Therefore, Quality of Service is the differences between Subscriber's expectations and perceptions of service delivered by a service provider (Aliyu *et al.,* 2018) Fundamentally, Quality of Services (QoS) includes absence of interference and tones on the circuit, good quality speech, proper loudness point, high signal strength, minimum call blocking, minimum call dropping, maximum handoff and good data rates for multi-media applications (Suhail *et al.,* 2107). Meanwhile, all these factors have not been achieved perfectly in the Telecommunication system. Making a successful call without interruption is a major dream of all mobile Subscribers. This, however, had not been possible due to poor quality of service been experience by the Subscribers of the mobile users (Suhail *et al.,* 2017)

2.3 Quality of service estimation perspective

Quality of Service in wireless mobile services is classified into four different perspectives. These are; planned QoS by the Mobile Service Provider, the required QoS by the Mobile Users, QoS achieved by the Service Provider and QoS perceived by the Mobile Users (Aliyu *et al.,* 2018).

2.3.1 QoS planned by the mobile service providers

Normally, the mobile service provider should define the QoS planned or expected to offer to the mobile users. However, it is conveyed through assessments that are assigned to specific QoS parameters (Aliyu *et al.,* 2018).

2.3.2 QoS required by the mobile users

This expresses the QoS levels the mobile users requires or expects from the mobile service provider. These requirements or expectation can be stated in untechnical terms by means of descriptive terms which h the service provider must translate into QoS parameters fitting the service (Aliyu *et al.,* 2018).

2.3.3 QoS achieved by service providers

This is obtained through some key performance indicators assessed and gathered from the network. It has to do with the class or stage of quality really attained and rendered to the Mobile Users. It is stated through rates that are given to some specific factors of QoS. For instance, within 1G Network and 2G Networks such as GSM and CDMA, there was only one aspect of QoS which is voice. In 3G networks, QoS had to be maintained for voice and as well as for data (Gopal & Kuppusamy, 2015)

2.3.4 QoS perceived by the mobile users

This expresses the mobile user's perception of the service quality levels that have been received or experienced, which are usually indicated by the degree of approval and not in the technical terms. Therefore, the levels of QoS as perceived by the mobile users should be interpreted into QoS factors to fit the rest of perspectives.

Call Setup Time (CST), Call Drop Rate (CDR), Call Setup Success Rate (CSSR), and Call Setup Failure Rate (CSFR) are some of the KPI parameters used in evaluating and estimating the QoS alleged by the mobile user for a mobile service provider as it seriously affects the users experience and expectation. (Gopal & Kuppusamy, 2015)

2.4 Measurement of quality of service

Measurement of Quality of service involves assessing and monitoring the Mobile Network to see if the required value set by the telecom regulatory body and the Wireless Mobile Network Planned is achieved and delivers to the mobile users. However, there are four (4) factors considered in measuring QoS of Mobile network services. Meanwhile, three of these factors that are considered in assessing and monitoring the

Networks' performance are subjected to regular change depending on the growing Coverage and Capacity requirement. These three factors are: Network Accessibility, Network Retain-Ability and Connection quality. The fourth factor is the network coverage (Aliyu *et al.,* 2018; Segun *et al.,* 2017).

For the purpose of this research, focus is only on four factors, the Network Coverage, Network Accessibility and Network Retain-ability and data services. However, measurement and evaluation performance of some of these factors are based on a test or assessment conducted on matrices called key performance indicators (KPIs).

The metrics on which the Mobile Services are observed include: Call Set-up Time (CST), Call Set-up Success Rates (CSSR), Call Completion Success Rates (CCSR), Call Drop Rate (CDR), Call Set-up Failure Rate (CSFR), and Handover Failure Rate (HFR) (Aliyu *et al.,* 2018)

2.4.1 Call setup time

This is the time required to establish a circuit-switched call between users. This KPI parameter measures the time required or duration taken to connect a call between mobile phone users. According to Encyclopedia (encyclopedia2.thefreedictionary.com/ call+setup+time), call setup time is the period of time between the lifting of a handset to make a telephone call and the start of voice or data transmission. Meanwhile, the Telecom regulatory organ the NCC has set a benchmark of less than or equal to six seconds ($\leq$ 6s) for local and international calls as a satisfactory value for which all GSM service providers have to meet and comply with (Ukhurebor *et al.,* 2018). For instance, if a mobile user spent 8 seconds before been connected by a service provider, it means the quality of that service provider is poor. The higher the period a subscriber spend before accessing the network, the poor the service and the lower the time a subscriber spend in accessing service the better the service. (CST) can be express mathematically as:

$$CST = T2 - T1 \quad (2.1)$$

where $T1$ is a point of time where the subscriber presses the send button on Mobile Station (MS) and $T2$ is a point of time where connection is established.

The following are some of the reasons that accounts for a low or poor call setup time in a call making process. These are:

Poor coverage

Low BTS output power

Downlink or uplink low signal strength

Lack of best server

Antenna problems

Faulty hardware units.

Bad dimensioning

Radio interface congestion.

Effects of Interference and fading (Ukhurebor *et al.*, 2018)

2.4.2 Call setup success rate

This KPI parameter measures simplicity or easiness at which calls are connected by the mobile Service user. According to Klipfolio (klipfolio.com/resources/kpi-examples/call-center/call-setup-success-rate), call setup success rate measure the total number of calls that make it successfully through to the dialed number. The lower the value of CSSR, the difficult it is to connect a call and the higher the value of CSSR the better, as this enable mobile users to connect easily. For example, if a CSSR is 85%, this implies that out of every 100 call attempts by the mobile user, only 85 are successful while the remaining 15 are unsuccessful and unsuccessful calls are either blocked (failed) or dropped. The Telecom regulatory organ, NCC set a standard of greater than or equal to ninety-eight percent (≥ 98%) of attempted calls for local and national as a satisfactory value that all GSM operators have to meet. CSSR is calculated using the expression:

$$\frac{\text{CSSR = Number of unblocked call attempts}}{\mathit{Number\ of\ attempted\ calls}}\ X\ 100 \qquad (2.2)$$

CSSR = (1- blocking probability) X 100 (2.3)

The following are some likely reasons that accounts for a low or poor call setup success rate in a mobile network.

Poor coverage.

Faulty hardware units.

Bad dimensioning

Radio interface congestion.

Effects of Interference and fading.

High antenna position

Increasing traffic demand

Congestion in the Network.

Low handover activity (Ukhurebor *et al.,* 2018)

2.4.3 Call setup failure rate

This KPI parameter measure the rate at which calls unexpectedly fails by the mobile service user during pre-connection process. The higher the value of CSFR, the more difficult it is to connect a call by the user. For example, if a CSFR is 15%, this implies that out of every 100 call attempts by the mobile user, only 85 are successful whereas the remaining 15 are unsuccessful (failed). The Telecom regulatory organ, NCC set a benchmark of less than or equal to ≤ 10% of attempted calls as an satisfactory value which all GSM operators have to meet. It is expressed as:

$$\frac{\text{CSFR = Number of Fail call attempts}}{Number\ of\ attempted\ calls} \quad X \quad 100$$

(2.4)

The following are some likely reasons which accounts for call setup failure rate in a cell of mobile network.

Poor Coverage

Bad dimensioning

Low Signal Strength

Faulty hardware units.

Radio interface Congestion

CM Service Reject

TCH Failure Assignment (Aliyu *et al.,* 2018).

2.4.4 Call drop rate

This KPI parameter measures the failure of networks to hold on to ongoing call when it has been connected by the Subscriber of GSM Service. According to Wikipedia (en.wikipedia.org/wiki/Dropped call_rate), call drop rate is the fraction of the telephone calls which, due to technical reasons, were cut off before the speaking parties had finished their conversational tone and before one of them had hung up (dropped calls). For instance, when CDR is 7%, this implies that, for every 100 calls connected 7 calls will drop before the ongoing conversation is terminated by any of the calling parties (Subscribers). NCC set a standard of less than or equal to one percent (≤ 1%) of attempted calls for local and national as a satisfactory value which all GSM operators have to meet. The indicator (CDR) can be calculated using the expression:

$$\frac{\text{CDR = Number of dropped calls}}{Total\ Number\ of\ attempted\ calls} \text{ X } 100 = (1 - \text{Call Complete probability}) \text{X } 100 \qquad (2.5)$$

However, call drop occurred in mobile networks are due to some of the following reasons.

Low BTS output power

Lack of best server

Poor quality on downlink or uplink

Antenna problems

Mobile station battery flaw

Too high timing advance

Congestion in neighboring cells

Unsuccessful outgoing handover

Unsuccessful incoming handover (Ukhurebor, 2018)

2.4.5 Call completion success rate

This KPI parameter measures the amount of call initiated, get connected and conversation successful completed by both users of the mobile network. According to

Customer contact week digital (customercontactweekdigital.com/glossary/call-completion-rate-ccr), call completion success rate is ratio of the number of completed calls to the total number of attempted calls. This ratio is typically expressed as either a percentage or a decimal fraction. The CCSR is one of the KPI parameters considered for evaluating the Network Retainability as it determines Customer satisfaction. The higher the value of CCSR, the better the Network. For instance, if a CCSR is 95% it means that out of every 100 call attempts by the mobile user, only 95 are completed while the remaining 5 are unsuccessful. Meanwhile, the organ responsible for the regulation of telecom Services, the NCC set a standard of greater than or equal to ninety-seven percent (≥ 97%) of attempted calls for local and national as a satisfactory value which all GSM operators have to meet. The KPI can be calculated using the expression:

$$\frac{\text{CSFR} = \text{Number of completed calls}}{Number\ of\ attempted\ calls} \quad \text{X} \quad 100$$

(2.6)

2.4.6 Data rate

This is defined as transmission speed, or the number of bits per second transferred over channel (Telecom ABC., 2005). Data rate is the speed at which data is transferred within the computer or between a peripheral device and the computer, measured in bytes per second (pcmag.com/encyclopedia/term/data-rate). According to Traficom, (2019) data transfer technology, other users and poor coverage tends to affect data rates

2.4.7 Latency

This is the amount of time it takes a bit to be transmitted from source to destination. Latency is a measure of delay in a network, latency measures the time it takes for some data to get to its destination across the network. It is usually measured as a round trip delay - the time taken for information to get to its destination and back again (sas.co.uk/blog/what-is-networklatentcy-how-do-you-use-a-latancy-calculator-to-calculate-throughput). This according to RF Wireless world, (2012) network latency can be expressed mathematically as;

$$\text{Network Latency} = \text{Propagation delay} + \text{Serialization delay} \quad (2.7a)$$

$$\text{Propagation delay} = \frac{Distance}{Speed} \quad (2.7b)$$

$$\text{Serialization delay} = \frac{Packets\ size\ (bits)}{Transmission\ Rate\ (bps)} \quad (2.7c)$$

2.4.8 Data throughput

This is the actual measured performance of a system when delay is considered or the rate at which messages are delivered successfully over a communication channel. Throughput is the amount of a product or service that a company can produce and deliver to a client within a specified period of time. The term is often used in the context of a company's rate of production or the speed at which something is processed (https://www. inap.com/blog). According to Telecom Hall Forum, (2017) the causes of low throughput are:

Poor coverage, Availability issue, Uplink Interference, Downlink Interference, Problematic Users Equipment, Transmission instability and bottleneck, Accessibility issue, High radio errors and Link Adaptation

2.5 Factors affecting quality of service

The service provided by the mobile network providers involves generation, transmission and reception at different points and therefore not free from hitches. There are many factors that affect the QoS provided by the service Providers in Nigeria. Some of these factors are:

2.5.1 Bandwidth allocation

Bandwidth Allocation is one of the major factors that affect QoS in wireless mobile communication. According to Wikipedia (en,wikipedia.org/wiki/Bandwidth_computing), bandwidth is the maximum rate of data transfer across a given path. Bandwidth may be characterized as network bandwidth, data bandwidth and digital bandwidth. Bandwidth Allocation problem is a situation whereby a telecommunication operator witness more Mobile subscribers than it can handle at that particular moment. What this means is that there is no enough channels to route call through, which leads to call setup failure or congestion and queuing in the network thereby affecting the QoS provided by the Wireless Telecom Providers (Gopal *et al.,* 2015).

2.5.2 Network congestion

Network Congestion is one of the factors that affect the quality of service in Wireless Mobile Services. Network Congestion basically means 'full of traffic' Congestion happens when there are many Subscribers in search of facilities that is inadequate. Network congestion is therefore defined as the unavailability of Mobile Networks for use by the subscriber at the time of making or receiving calls in mobile communication (Suhail *et al.,* 2017)

2.5.3 Handoff failure in mobile communication

Handoff in wireless mobile telecommunication is a phenomenon when the mobile telephone network automatically switches an active call from one cell to another of the same Base Station or from one Base Station (BS) to another BS without disturbing or terminating the ongoing call. Handoff is the process of changing the channel (frequency, time slot, spreading code, or combination of them) associated with the current connection while a call is in progress. It is often initiated either by crossing a cell boundary or by a deterioration in quality of the signal in the current channel (cis,temple.edu/2wu/ teaching/spring%202013/handoff.pdfinvestopedia). However, handoff failure occur in wireless mobile communication when the mobile station (MS) is moving and fail to switch an active call from one cell to another of the same Base Station or to another BS which lead to termination of an ongoing call.

2.5.4 Call setup failure

Call Setup Failure is a phenomenon that occurs in telecommunication system when a mobile user initiates a call and access is granted but the call could not be established successfully thereby affecting the QoS. Theoretically, during a mobile call setup, a communication call is allocated from a SDCCH (standalone dedicated channel) to a TCH (traffic channel). If the TCH chosen suffers from cross talk, after that the mission resolve to fail and the assignment failure communication will be sent to the Mobile Switching Controller (MSC). The task will then be reestablished back. Call Setup Failure is an important KPI parameter used in evaluating Network performance to determine network accessibility and therefore is one of the major factors that affect the QoS in Telecommunication system (Yusuf *et al.,* 2016)

2.5.5 Call retention

Call retention in telecommunication system is a phenomenon when a call is being held automatically by the Mobile Service Provider after it has been initiated and established while conversation is still ongoing. This simply implied that the duration or lengthy a mobile user hold on a Mobile Network after a call has been connected. However, if a mobile call terminates while conversation is ongoing, a drop call is said to have occurred. Therefore, dropped call is a phenomenon whereby a call that is connected is surprisingly ended while conversation is still ongoing. It is a frequent incidence in Nigeria's telecommunication system as conversation is concluded unpredictably while communication is still ongoing. Call retention is the ability to hold calls or not. To hold calls is one of essential parameters considered in evaluating Network Retain-ability in wireless telecommunication sector and therefore one of the major KPI factors that affect the QoS in Telecommunication system (Aliyu *et al.*, 2018; Segun *et al.*, 2009)

2.5.6 Wave propagation effects and parameters

A Base station (BS) or transmitting antenna radiates or transmit wireless mobile network signals in form of electromagnetic wave or field (EMF) into the free space. These signals are open to variety of man-made natural structures and are made to go through different types of terrain, and it appears that these signals are affected by an amalgamation of transmission environments. All these factors contributed in one way or the other to the variation in the mobile signals level transmitted and unstable signal coverage received as well as quality in the network provided. Theses parameters includes: free space loss, signal fading and interference.

2.5.6.1 Free space loss.

This is a situation or phenomenon whereby a signal that is transmitted by the Base Station will experience degradation and reduction during its transmission in free space before reaching the Mobile Station (MS) or receiving antenna. According to Radartutorial (radartutorial.eu/o/.basics/Free-space%path%20Loss.eu.html) free space loss is the loss in signal strength of electromagnetic wave that would result from a line of sight path through free space, with no obstacles nearby to cause reflection or diffraction.

Figure 2.1: An isotropic antenna radiating EMF (Aliyu *et al.,* 2018).

2.5.6.2 Fading of the Signal

This is a process at which transmitted signal moving from the transmitting antenna (BS) to the receiving antenna, loses signal strength. This might be due to the trend of path loss, or it may be due to interference in the transmission (Al –Imran & Ajayi, 2010).

2.5.6.3 Interference

According to Wikipedia (en.wikipedia.org/wiki/interferenc_communication), an interference is that which modifies a signal in a disruptive manner, as it travels along a communication channel between its source and receiver. The term is often used to refer to the addition of unwanted signals to a useful signal. As the transmitted signals from the transmitting Station move over a distance during the transmission process, the signals at the receiving station can be affected by the virtue of obstruction in the signal. These obstructions of signals can be from the similar Mobile Network or might be due to man-made materials. The occurrences of interference in the transmitted or received signals affect the QoS provided by the Mobile Service Providers in Wireless Telecommunication System. Figure 2.2 shows interference and some factors affecting wave propagation in wireless communications (Gopal *et al.,* 2015).

2.6 Maintaining good QoS in mobile communication

Despite the increase in the number of wireless mobile users in Nigeria, there is need for the Mobile service providers to maintain good quality of service for their customers. According to Chron (chron.com/quality.important-business-54470.html), quality products help to maintain customer satisfaction and loyalty and reduce the risk and cost of replacing faulty goods. Companies can build a reputation for quality by gaining accreditation with a recognized quality standard. Presently, there are four major Wireless Mobile operators in Nigeria namely; Airtel, 9mobile, Globalcom and MTN. Meanwhile, complaint is usually made by the subscribers of the mobile services on any of the following channels: calling the customer call center number, going to the customer care unit, and visiting or checking a website for the Network providers.

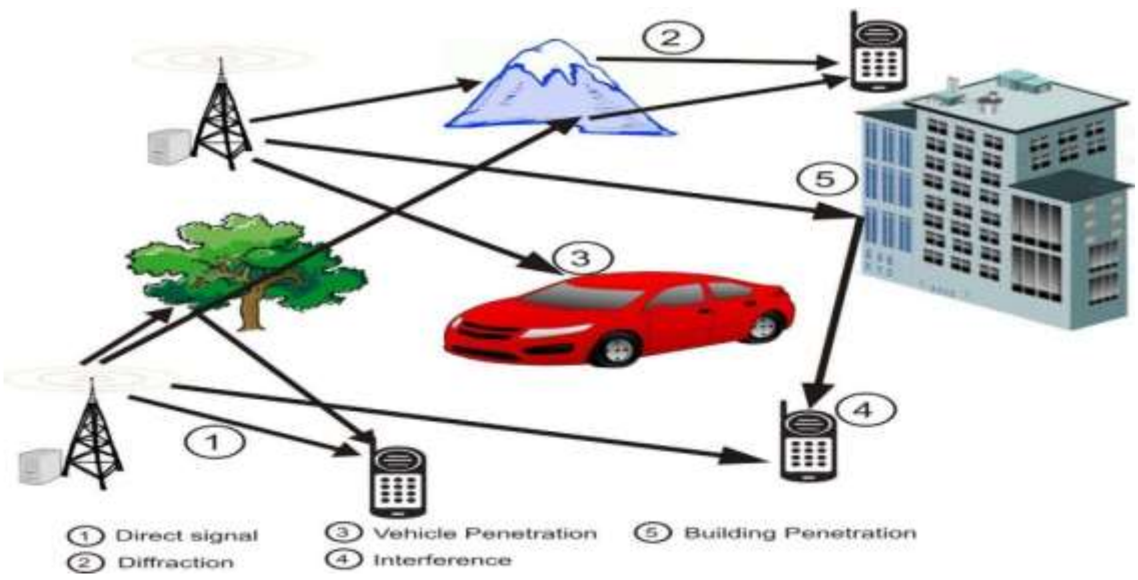

Figure 2.2: Factors affecting wave propagation (Aliyu *et al.,* 2018).

However, some major problems confronted by the Mobile Users before making a call includes: Inability to make a call, failure to recharge, send SMS, check balance and any other related MS problems (Settapong *et al.,* 2016)

2.7 Related works

Many research had been carried out on quality of service (QoS) measurement, evaluation and performance on various KPI parameters of Mobile Network Operators, causes and how to improve on such QoS. These are some of the reviewed research papers.

Al-Imran *et al.* (2010) evaluated the performance of existing quality of service for voice and video transmission over a 3G/UMTS networks. From the simulation the voice and video quality of service over a 3G/UMTS network are influenced by several factors such as delay, throughput, packet loss and jitter. The tool used is OPNET Modeler (Networks simulator). Though this work is both voice and data centric but connection quality is not covered in the work as against this work.

Marhamat *et al.* (2013) worked on the quality of service and its importance in service organizations. It was stated in this work that supply of high quality products and services to customers on continuous basis, make creating higher competitive advantages such as competitive barriers, increase customer loyalty, production and supply differentiated products, reduce marketing costs and determine higher prices for companies possible and that providing continuous high quality service is one of basic ways that an services organization can differentiate itself from other competitors.

Aliyu *et al.* (2015) used drive test techniques to conduct a study on performance Analysis of GSM Networks in Minna Metropolis of Nigeria. All the networks studied in this work experienced one type of degradation or the other in terms of the KPIs. The research then suggested the required physical optimization measures in order to resolve the problems identified. This work was voice centric in comparison with this new work that is voice and data centric.

Agubor *et al.* (2016) used drive test method to evaluate quality of service of mobile network operators in Lagos state in which three major towns Ikoyi, Abule – Egba and Agege were covered. Call Drop Rate (CDR), one of the performance indicators was measured in this work. It was observed that Etisalat had the least value of 0.6% of all the calls initiated during the test. The weaknesses of this work is that one performance indicators was evaluated as against this work where eight performance indicators were measured.

Yusuf *et al.* (2016) assessed the GSM quality of service provided by MTN to eagle square Abuja before, during and after PDP presidential primary election .The results show that the values of the KPIs from the three base transceiver station (BTS) on a normal day rarely meet up with NCC recommended values but deviation were observed during the event. The method used is network statistic. This work only evaluated one mobile network whereas this work evaluated four mobile network for improvement and it is both voice and data centric as against the work done by (Yusuf *et al;* 2016).

Gordon *et al.* (2016) investigated services render by four major mobile network operators (mtn, airtel, glo and 9mobile) in Owerri metropolis, Nigeria. The services render are evaluated to determine the best operator with minimal call pattern variations. The results show that all the operator failed to comply with stipulated performance threshold as recommended by NCC for all the network operators in Nigeria. Etisalat displayed a fair performance among the four mobile network operators considered in this study area. The methodology was drive test techniques. The tools used include: inverter, battery, laptop and transmission environment monitoring system technology. Gordon *et al.* (2016) did not include mobile internet service evaluation in their work as against this work.

Alabi *et al.* (2017) carried out a study on the GSM quality of service performance in Abuja Nigeria. The study investigate network transmission impairment and offers some useful remedies. Sony Ericson phone and transmission environment monitoring system are used to gather data on physical network impairments in selected densely populated areas of Abuja. The method used is drive test. The results obtained indicate that the quality of service performance of Airtel is slightly better than the other three GSM service providers tested within Nyanya, Gwagwalada and Wuse areas in Abuja. The test was conducted on 2G and 3G technology across four major telecom service providers. The study was voice-centric whereas this work is both voice and data centric.

Segun *et al.* (2017) investigated the quality of service offered by mobile network operators in Nigeria. Information are collected from NCC database network operating center base station controller. The analysis show that relative to the quality of service target set by NCC, all the mobile network operators maintain a good QoS across board. The tools used are: MATLAB, Microsoft, Excel and ANOVA. The method used is network statistics. This work is both voice and data centric as against the work done by (Segun *et al;* 2017).

Suhail *et al.* (2017) evaluated VoIP traffic's quality of service deterioration while traversing through heterogeneous networks. The average value of jitter of the VoIP transversing through the wifi - wimax networks was observed to be higher than that of utilizing wifi alone at some point in time. The tool used is OPNET simulation software. Suhail *et al.* (2017) did not include evaluation parameters such as CST, CSSR, CCSR, CDR, CSFR, Data Rates, Latency and Throughput for improvements as against this work.

Aliyu *et al.* (2018) carried out a study on the quality of service of mobile network operators within the Federal Polytechnic Bida campus. This evaluation was undertaken using some KPIs of mobile network services. These KPIs are: Call Setup Time (CST), Call Setup Failure Rate (CSFR), Call Dropped Rate (CDR) and Call Completion Rate (CCSR). Drive test method was used in this study. Drive test was performed using the Mobile Station (MS) software package called My Mobile Coverage Pro (MMC Pro). The results of the study show that Network Accessibility and Network retainability in the area were below Nigerian Communication Commission (NCC) KPIs standard for the considered metrics. The work shows that the QoS rendered in the area of study for Mobile Users is not sufficient, unreliable and unsatisfactory. Recommendation was made in the paper on how to improve the QoS of Mobile Network Providers in this area. What make this work different from (Aliyu *et al;* 2018) is that, in this work connection quality and mobile internet service are examined.

Dahunsi *et al.* (2018) evaluated the performance of mobile network operators in Akure metropolis, Nigeria. The result show that the quality of voice service offered by MNOs is not optimal and there is need for improved quality of service. Drive test approach and statistical method are used. The tools used includes; post processing software, Transmission environment monitoring software (TEMs), laptop, USB cables, car inverter, GPS. What makes this work different from (Dahunsi *et al;* 2018) is that, in this work mobile internet service are evaluated for improvements.

Galadanci *et al.* (2018) investigated the performance of GSM networks (P, Q, R and S) in Kano Metropolis, Kano state, Nigeria. The result showed that the four carriers failed to achieve the NCC minimum targets for CSSR and HOSR and call blocking respectively. The Ericson W995 phone with built-in transmission environment monitoring system (TEMs Pocket) software package was used to generate log file from the active GSM networks. The tools used include: Ericson w995 phone, Laptop, four different types of subscriber's identity module (SIMs) for P, Q, R and S networks, USB cables, Ms Excel 2013. The method used is drive test. What makes this work different from (Galadanci *et al;* 2018) is that, and mobile internet services are evaluated for improvements.

Daniel *et al.* (2018) conducted a study on four mobile network operators (MTN, Vodafone, Tigo and Airtel) in some selected cities of Accra, Tema and Kumasi in Ghana. Some of the measured KPIs values were fairly close to the standard set by local (NCA) and the international regulator (ITU) indicating customer experienced fairly good service in those locations, while other values (Traffic channel congestion and call set up time were outside the standard set by NCA and ITU which mean customer experienced poor QoS in these area. Measurements are collected over network peak time in each area in order to best capture the effects of congestion on call blocking, CSSR and CDR. The method used is network statistics. Daniel *et al.* (2018) did not include mobile internet service evaluation as against this work.

Network statistical method was use by Ukhurebor, (2018) for the evaluation of the quality of service of an operational cellular network service providers that cover the Redeemed Christian Church of God (RCCG) at redemption camp, Lagos –Ibadan express, Lagos state, Nigeria. The tool used include: network management system, raw data, base transceiver station. The results show that the KPIs fall short of the recommended values by NCC especially during traffic intensity. Ukhurebor, (2018) did not include mobile internet service evaluation as against this work.

Opele *et al.* (2020) examined the influence of service quality on preference for mobile telecommunication (GSM) service providers among students of tertiary institutions in Lagos State. Specifically, the study determined the influence of service assurance on preference for GSM service provider and assessed the influence of service empathy on preference for GSM service providers among students of tertiary institutions in Lagos

State. Findings from the study revealed that service assurance positively and significantly influenced preference for mobile telecommunication (GSM) service providers among students of tertiary institutions. The study concluded that increased service quality led to increased preference for GSM service providers among students of tertiary institutions in Lagos State. Therefore GSM service providers should improve on service assurance and service empathy to enhance consumers' preference.

The papers reviewed adopted different approaches to collect data from the Mobile Network Operators for QoS, Network performance evaluation namely; Statistical Network data collection from Network Operation Centre's (NOCs), Drive Test models aimed at evaluating network performance of wireless mobile networks in order to suggest ways of improvements on quality of service (QoS).The related works that are reviewed also vary in terms of; Geographical locations, Methodology, Focus, Tools, Scope and Data Coverage.

In this new research, transmission environment monitoring softwares (TEMs) Mobile was used to replicate the research work done by Aliyu *et al.* (2018) in Federal Polytechnics, Bida, Niger state, Nigeria. Aliyu *et al.* (2018) presented a research work that determined the call drop Rate (CDR), Call setup Time (CST), Call setup Success Rate (CSSR), Call setup Failure Rate (CSFR), Call Completion Success Rate (CCSR) and Signal Strength of Mobile Network operators in Federal Polytechnics, Bida, Niger State, Nigeria. Four Mobile Network Operators namely: Network A, Network B, Network C and Network D and eight (8) KPI parameters namely; Call Setup Time (CST), Call Completion Success Rate (CCSR), Call Setup Failure Rate (CSFR), Call Setup Success Rate (CSSR), Call Drop Rate (CDR), Data Rate, Latency and Data Throughput were considered for this research as against the use of only Five (5) KPIs parameters by Aliyu *et al.* (2018).This Implies that this work is both voice and data centric whereas Aliyu *et al.* (2018) is voice centric and did not measured the connection quality of the mobile network operators.

CHAPTER THREE

3.0 RESEARCH METHODOLOGY

3.1 Description of the research methodology

The methodology used in this research work to achieve the objectives is presented in the Block diagram of figure 3.1. Also in this chapter, a test area was selected and data were collected for different mobile network parameters for Network performance evaluation.

3.2 Drive test area

Since the aim of this research was to measure, evaluate and improve on the Quality of voice and data Service (QoS) rendered by the Mobile Network Operators (MNOs), Shiroro power station and its environs was chosen being the one of the area where these services are most needed and useful for, industrial, economic, social, self development and business purposes. The Shiroro power station is an hydroelectric power plant of the Kaduna River in Niger state. It has a generating capacity of 600megawatts (800,000hp) enough to power over 404,000 homes. It coordinates is 9º58’30” N, 6º50’04” E. It began operation in 1990. Figure 3.2 shows map of Shiroro Power station showing the base stations of mobile network operators. The Shiroro power station presently has the four major mobile network operators operating in Nigeria. Figure 3.2 shows that there are four Base Stations (BS) serving the Shiroro power station one for each Mobile Service Provider. The distance of three of the base stations (Network A,B,C) to the drive test area is within 2.82 km and the distance of the basestation for network D to the drive test area is within 13.32km.

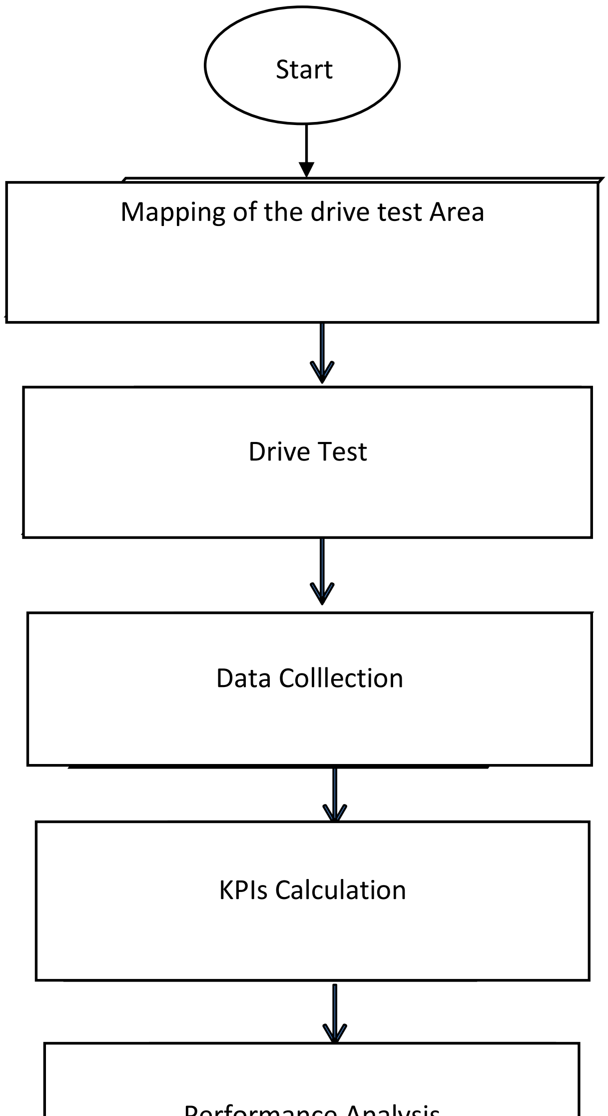

Figure 3.1: Flowchart of the Research

3.3 Materials and tools

For the purpose of this Research, the following materials and tools were used. Sony Ericson phone and Samsung phone , Subscribers Identification Modules (SIMs) Card for all the networks under consideration (Network A, Network B, Network C and Network D).Network A,B,C and D are represented by MTN, GLOBACOM, AIRTEL and 9MOBILE respectively. The location of MNO A (MTN), MNO B (GLOBALCOM), MNO C (AIRTEL) is $9^0\ 57^I\ 7.6^{II}$N, $6^0\ 49^I\ 40.8^{II}$ E and the location of MNO D (9MOBILE) is $9^0\ 50^I\ 47^{II}$N, $6^0\ 48^I\ 49^{II}$ EInverter, Car battery, Car, Laptop, GPS, Transmission Environment monitoring softwares (TEMs) and Stopwatch.

Figure 3.2: Map of Shiroro power station showing base stations

3.4 Precautions

For the purpose of this research, the followings measures were taken before, during and after the drive test. These are;

i. Ensured that the Mobile stations used were in good working condition and high quality that is compatible with the software package acquired.

ii. Ensured that the power or the batteries of the mobile stations used were fully charged before the commencement of drive test. This is to ensure that mobile stations did not off due to insufficient power in the batteries during drive test as this will interrupt the test.

iii. Functional Subscribers Identification Modules (SIMs) Card for all the networks were used

iv. The mobile stations used were loaded with enough credits/recharge cards.

v. Ensured that a functioning Car was used throughout the period of drive test.

vi. The Transmission environment monitoring softwares (TEMs) was, installed successfully.

3.5 The drive test

In order to acquire sufficient data to estimate Quality voice and data Service (QoS) rendered by the MNOs, it was important to perform a Drive Test (DT). Transmission environment monitoring software (TEMs) was installed on the Laptop to take the measurement of the Mobile Network Operators. Two mobile stations were used for each of the mobile network operators during the drive test. One for voice and the second for data. The mobile stations have SIM cards installed on each one of them in such a way to put a call and to download simultaneously. The Mobile Stations and the Laptop were placed inside the car and driven through the Drive Test Area (DTA) in order to capture data for collections as shown in Figure 3.3. Calls and downloading were performed at the same time as the drive tests were conducted.

Transmission Environment monitoring software (TEMS) is used by telecom operators to measure, analyse and optimise mobile networks. It is a basic tool in wireless network drive testing. The KPI parameters were stored in the Map event file of the TEMs. The drive test route started at the Shiroro power station first gate which is along Gwada - Minna road and ended at the Shiroro power station work centre.

Figure 3.3: Experimental setup during drive test

3.6 Collection of data

In this research, collection of data was obtained by means of drive test using the software package called TEMs investigation for all the Networks under consideration.

It is considered as basic tool to perform wireless network drive testing. Figure 3.4 shows TEMs investigation platform.

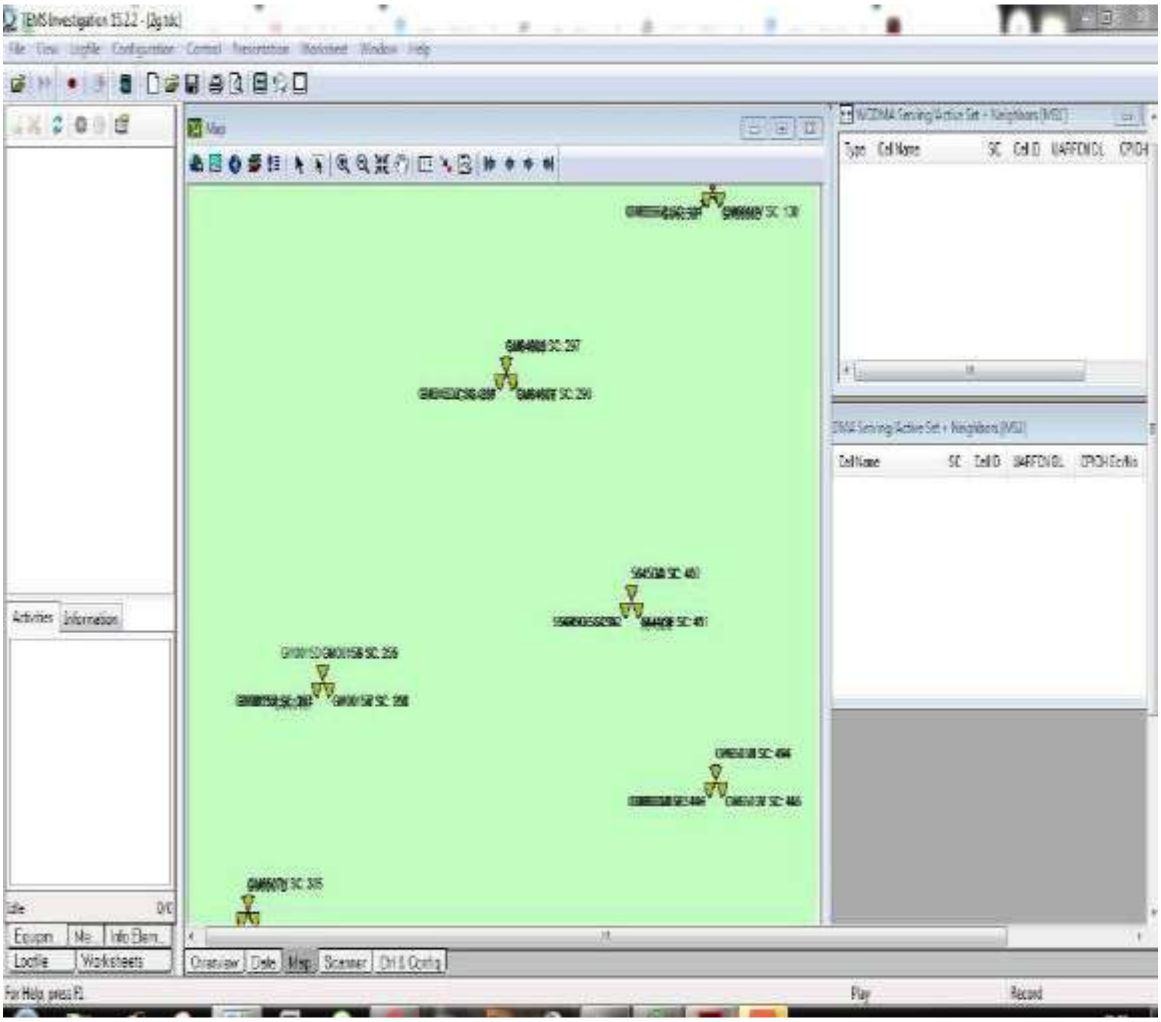

Figure 3.4: TEMs Investigation Platform

During the drive tests, the received signal level or signal penetration (Rex-Lev) information and received signal quality were received and displayed on the status window of the application package.

3.7 Calculations of key performance indicators (KPIs)

The QoS of any Mobile Network Provider is been accessed by Key performance indicators (KPIs). KPIs in Telecommunication industry is a tool used to set standard or threshold on wireless mobile operators.

The KPIs are used to determine telecom operators' progress in achieving its planned and outfitted goals and to also evaluate company performance against others rendering the same or similar services. This research considered the following KPIs parameters for evaluation; Call Setup Time (CST), Call Setup Failure Rate (CSFR), Call Drop Rate (CDR), Call Setup Success Rate (CSSR) ,Call Completion Success Rate (CCSR), Data Rate, Latency and Data Throughput.

TEMs discovery was used to processed the raw data obtained during drive test to determine the received signal strength, quality and various KPIs. TEMS Discovery provides insight into network performance as perceived by the users at the device, network and application level. TEMS Discovery works with TEMS Investigation as well as network test solutions from other vendors. Network issues are hard to identify. TEMS Discovery is used to expose issues affecting subscribers such that you can get to the root cause quickly to fix the issues. Figure 3.5 shows Transmission Environment monitoring software (TEMs) discovery platform.

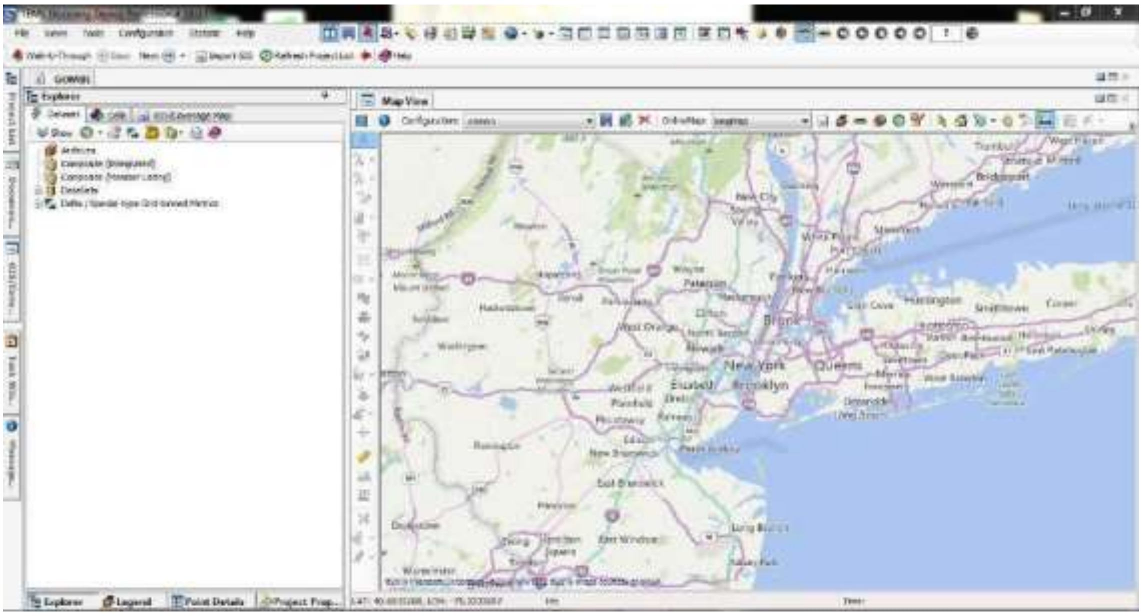

Figure 3.5: TEMs discovery platform

The KPI parameters on each Mobile Network were calculated from the data obtained from the drive test using the following KPI equations defined by NCC. These are:

3.7.1 Call setup time (CST)

This KPI parameter measures the length of time required or duration taken to connect a call between users of mobile phone. It is expressed mathematically as shown in Equation 2.1 and Equation 3.1

$$\frac{\text{CST} = \sum \text{Calls} \le 6s}{Attempted\ calls} \quad \text{X} \quad 100 \qquad (2.6)$$

3.7.2 Call setup success rate (CSSR)

The KPI parameter measures easiness to connect calls by the mobile service user. It is expressed mathematically as shown in Equation 2.2 and Equation 2.3

3.7.3 Call setup failure rate (CSFR)

The KPI parameter measure the rate at which calls unexpectedly fails by the mobile service user during pre-connection process. It is expressed mathematically as shown in Equation 2.4

3.7.4 Call drop rate (CDR)

The KPI parameter measures the failure of network to hold on to ongoing call when it has been connected by the subscriber of GSM Service. It is expressed mathematically as Equation 2.5

3.7.5 Call completion success rate (CCSR)

This KPI parameter measures the amount of call initiated, get connected and conversation successful completed by both users of the mobile network. It is expressed mathematically as shown in Equation 2.6

3.7.6 Data rate and data throughput

These were obtained directly after the collected data has been processed by Transmission environment monitoring software discovery (TEMs discovery).

3.7.7 Network latency

Equation 2.7 was used to determined the Network Latency .Packet size in bytes and data transmission rate and were obtained from the result of Transmission Environment Monitoring software discovery (TEMs discovery).Transmission medium speed is the speed of Light in m/s.

3.8 The received power

The received power at various distance from the base station are calculated using equation3.2 and equation 3.3

$$P_r = \frac{P_t G_t G_r \lambda^2}{16\,\pi^2 d^2 L} \tag{3.2}$$

$$P_r\,(d) = P_r\,(d_o) + 20\log\frac{d_o}{d} \tag{3.3}$$

Where Pt is the transmitted power from the base stations, Pr is the received power which is a function of the transmitter and receiver separation, Gt is the transmitter's antenna gain, Gr is the receiver's antenna gain, d is the transmitter and receiver separation distance in meters ,L is the system loss factor not related to propagation ($L \geq 1$), do is the reference distance and s is the wavelength which is equal to c/f where c is the speed of light in m/s and f is the carrier frequency or operating frequency in MHz.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

In this chapter, the results obtained from the drive test for the eight KPIs parameters and performance analysis for all the four Mobile Network Providers considered are presented. Comparative analysis through graphical representation was used in selecting the Network Quality from the performance test on each KPI parameter. Table 4.1 is the power profile of all the basestations under study.

Table 4.1: Power profile of the base stations

Base stations	$\boldsymbol{Pt}$(dBm)	$\boldsymbol{Pt}$(watt)	$\boldsymbol{Gt}$	$\boldsymbol{Gr}$	$\boldsymbol{fc}$ (MHz)	L≥1	s (m)	$\boldsymbol{do}$(km)
Network A	11	0.01	2.82	1	1	2100	1	0.143
Network B	47	50	2.82	1	1	2100	1	0.143
Network C	22	0.16	2.82	1	1	2100	1	0.143
Network D	23	0.20	13.32	1	1	2100	1	0.143

Table 4.2: Received power at reference distance and other distances from the base stations

MNOs	$\boldsymbol{Pr\ at\ do}$km (dBm)	$\boldsymbol{Pr}$at 3km (dBm)	$\boldsymbol{Pr}$ at 5km (dBm)	$\boldsymbol{Pr}$ at 14km (dBm)
Network A	-98.0	-99.0	-103.0	-112.0
Network B	-61.0	-62.0	-66.0	-75.0
Network C	-86.0	-87.0	-91.0	-100.0
Network D	-128.0	-115.0	-120.0	-128.0

4.1 Network performance evaluations

4.1.1 Network coverage

Network coverage is considered in this study as the first factor in evaluating the performance of Mobile Network Services because without the presence of Network, there is nothing to test or to evaluate. Network Coverage is the amount of power transmitted or delivered in form of an electromagnetic wave or field (EMF) from the Base Transceiver Station (BTS) or Base Station (BS) to Mobile Station (MS). Technically, and under standard operational situation, all Base Transceiver Station (BTSs) are likely to function and generate a Broadcast Channel (BCH) which is turned ON all the time. The Broadcast Channel (BCH) signal which is received by all the Mobile Stations in the cell, whether they are on call or not, in order to be connected to the Network. Naturally, this makes the Network Coverage to formed the sensitive part of Mobile Communication as no availability of the network on a Mobile Station implies no connectivity of the Mobile Station to the BTS. Based on the significance of network coverage on network performance evaluation, a Drive Test (DT) was conducted to determine the availability of Network and also to measure the Signal Strength and received voice quality of the networks under the area of study. The results from the drive test are presented in a mobile station google map plot.

4.1.1.1 Mobile network A signal strength and received voice level

Figure 4.1 shows the signal strength received for Mobile Network A by the Mobile Station (MS) from the Base Station (BS) by using the Transmission Environment Monitoring software investigation (TEM Investigation) through the drive test within the Shiroro Power Station. Colour Red in the map indicates while it is below -110dBm this is regarded as poor signal strength. Colour yellow indicates while it is between -110dBm and -95dBm this is regarded as fair signal strength. Light green in the map indicates while it is between -95dBm and -85dBm this is regarded as good signal strength. Dark green in the map indicates while it is between -85dBm and -70dBm this is regarded as excellent signal strength. The Aqua color indicates while it is below -70dBm and this legend is applicable to all other mobile networks in this work. This result show that some of the transmitted signals from the base station are obstructed before getting to the drive test area. The areas with color yellow in Figure.4.1, indicates that the difference between the transmitted and received signals in this areas was high whereas areas with light green indicate that, the difference between transmitted signal and the received signal was not that high compare with areas with color yellow. The terrain profile of this location is the major observable factor that is responsible for substandard received signal strength in this location. The signals radiating from the base stations are observed to be opened to elements such as trees. rocks, engineering structures. Insufficient base station is another factor that is responsible for substandard received signal strength on mobile network A. Table 4.2 shows that the received signal strength is inversely proportional to the distance from the base station.

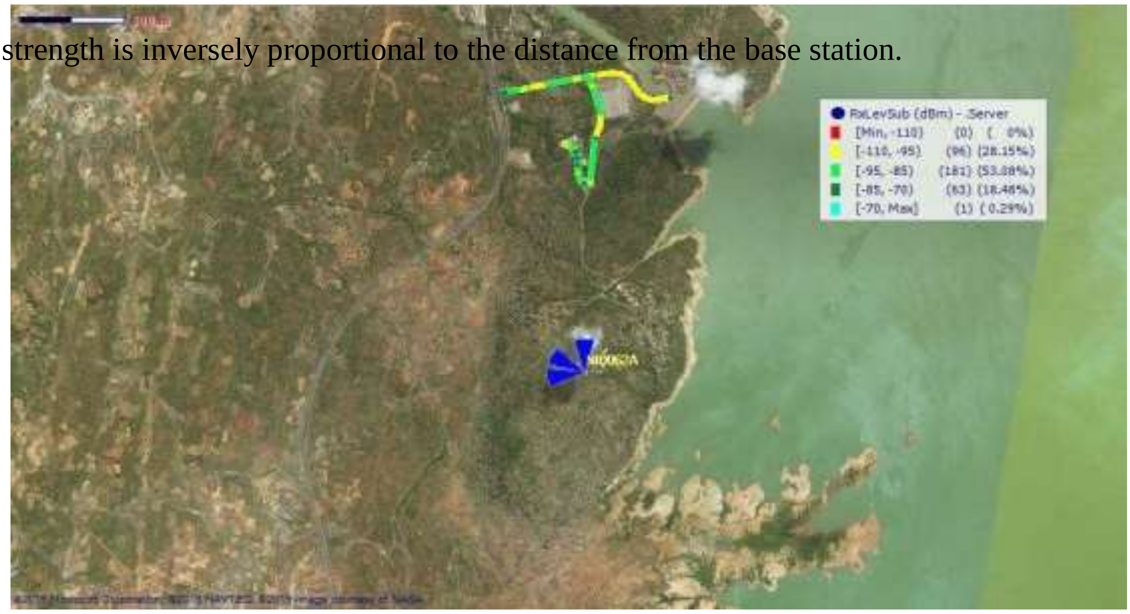

Figure 4.1: Received signal strength for Network A

Figure 4.2 shows the received voice quality of mobile Network A. Voice quality refers to the clearness of speakers' voice as perceived by a listeners. It is measured on the scale of 1 to 7 with 1 to 4 represent excellent voice quality,4 to 5 represent good quality,5 to 6 is fair and above 6 poor voice quality. Colour Red in the map indicates while it is above 6 this is regarded poor received quality level. Colour Yellow indicates while it is between 5 and 6 this is regarded as fair received quality level. Light Green colour indicates while it is between 4 and 5 this is regarded as good received quality level. Dark green indicates while it is below 4 this is regarded as excellent received quality level and this legend is applicable to other mobile network in this work. As shown in Figure 4.2, the part of the drive test area with color yellow and red is characterize with more elements such as trees, rocks than part with light green and dark green. The terrain profile of this location is observed to be the major cause of substandard received voice quality. It appears that the signals coming from the base station are obstructed by the amalgamation of elements in the transmission environments. Insufficient transmit power on mobile network A is another factor observed to be responsible for substandard received voice quality.

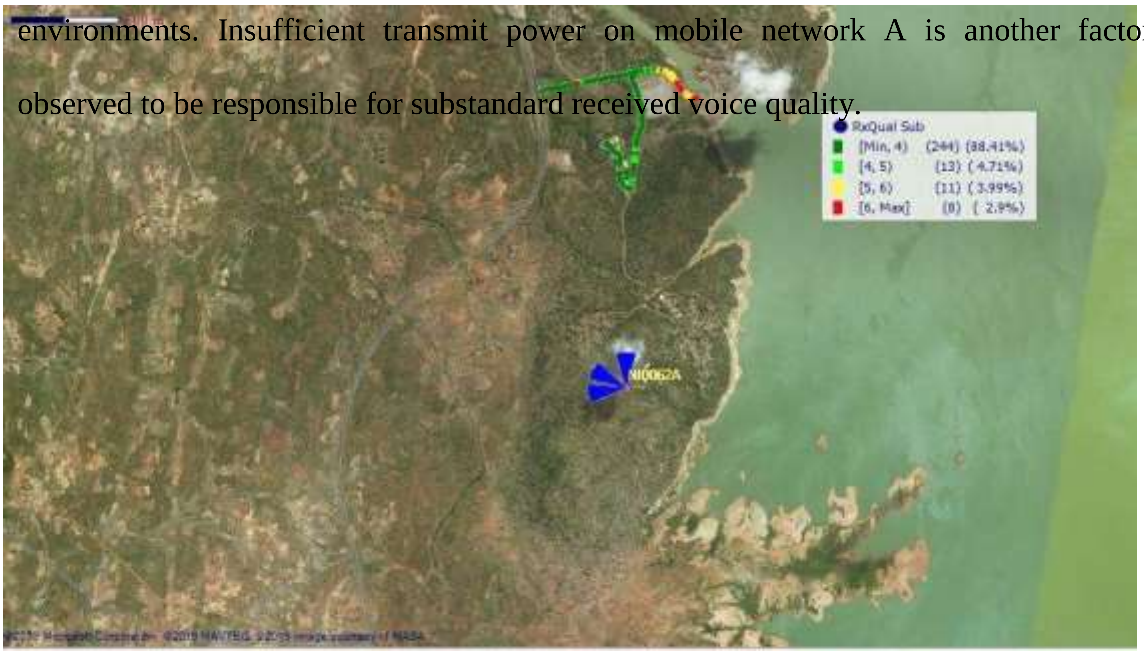

Figure 4.2: Received voice quality for Network A

4.1.1.2 Mobile network B signal strength and received voice quality

Figure 4.3 shows the received signal strength. Trees, rocks and engineering structures were observed to be primarily affecting the integrity of the received signal strength of mobile network B among others in this location.

Figure 4.3: The received signal strength for network B

Figure 4.4 shows the received voice quality for network B. Received voice quality is measure on the scale of 1 to 7. Areas with color red indicate poor received voice quality ,areas with color yellow indicate fair received voice quality, areas with light green indicate good received voice quality and areas with dark green indicate excellent received voice quality .Majority of the areas in the drive test area appeared to have excellent received voice quality as shown in Figure 4.4. The terrain profile of this location is observed to be responsible for substandard received voice quality and insufficient base station is another.

Figure 4.4: Received voice quality for Network B

4.1.1.3 Mobile network C signal strength and received voice quality

Figure 4.5 shows the received signal strength for Network C. The received signal strength on mobile network C, appeared to the mixture of excellent, good and fair received signal strength. All the received signal strength are expected to be excellent base on the standard. The factors observed to be responsible for substandard received signals strength in this location are terrain profile and insufficient base station.

Figure 4.5: The received signal strength for Network C

Figure 4.6 shows the received voice quality for network C. The received voice quality for network C is excellent. As shown in Figure 4.6 the percentage by composition of the dark green colour is 95.08%.

Figure 4.6: The received voice quality for Network C

4.1.1.4 Mobile network D signal strength

Figure 4.7 shows the received signal strength (RSS) for Network D. The received signal strength for mobile network D is good in the study area. It lies between -95 dBm and -85 dBm.

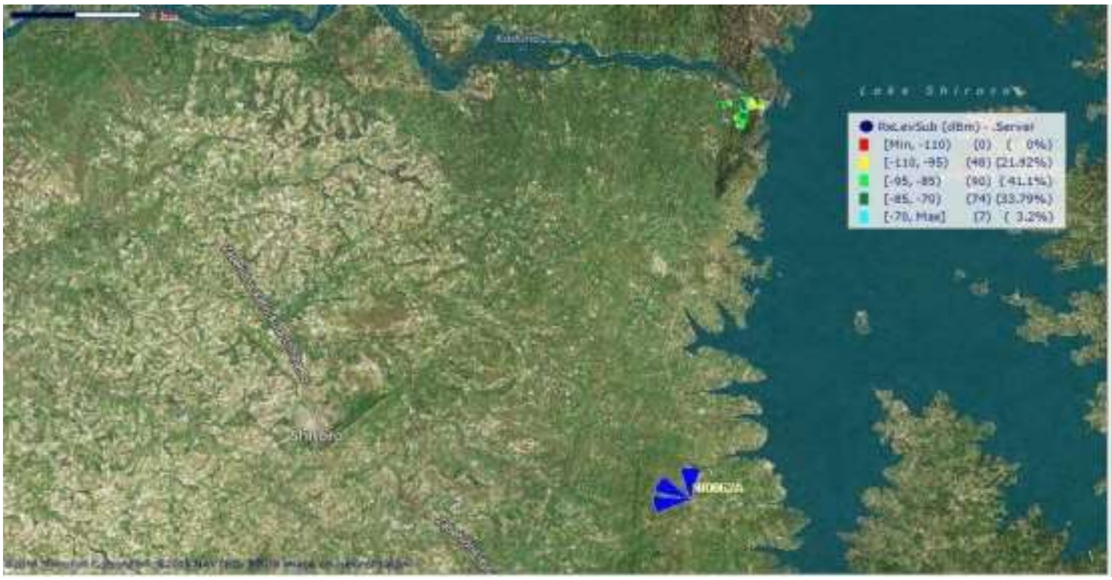

Figure 4.7: The received signal strength for network D

Figure 4.8 shows the servicing site distance of Network A,B and C to the drive test area. Figure 4.9 shows the servicing site distance of Network D to the drive area. Table 4.2 shows that the received signal strength at any location is inversely proportional to the distance of that location from the base station.

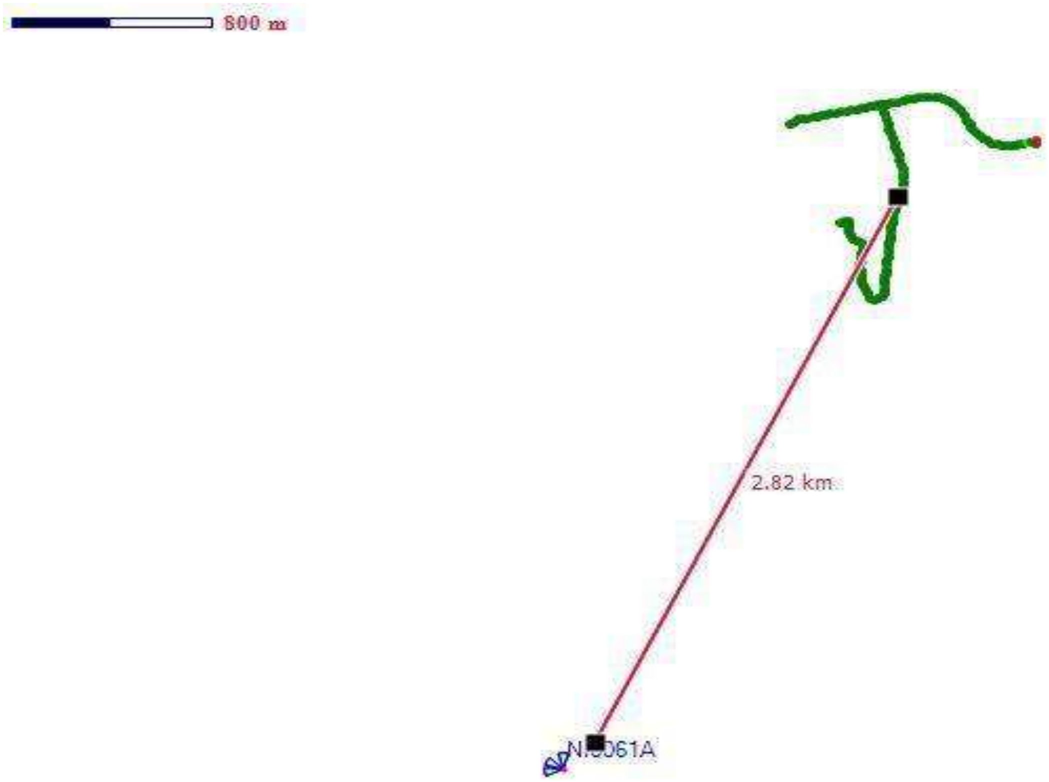

Figure 4.8: Servicing site distance for Network A,B and C

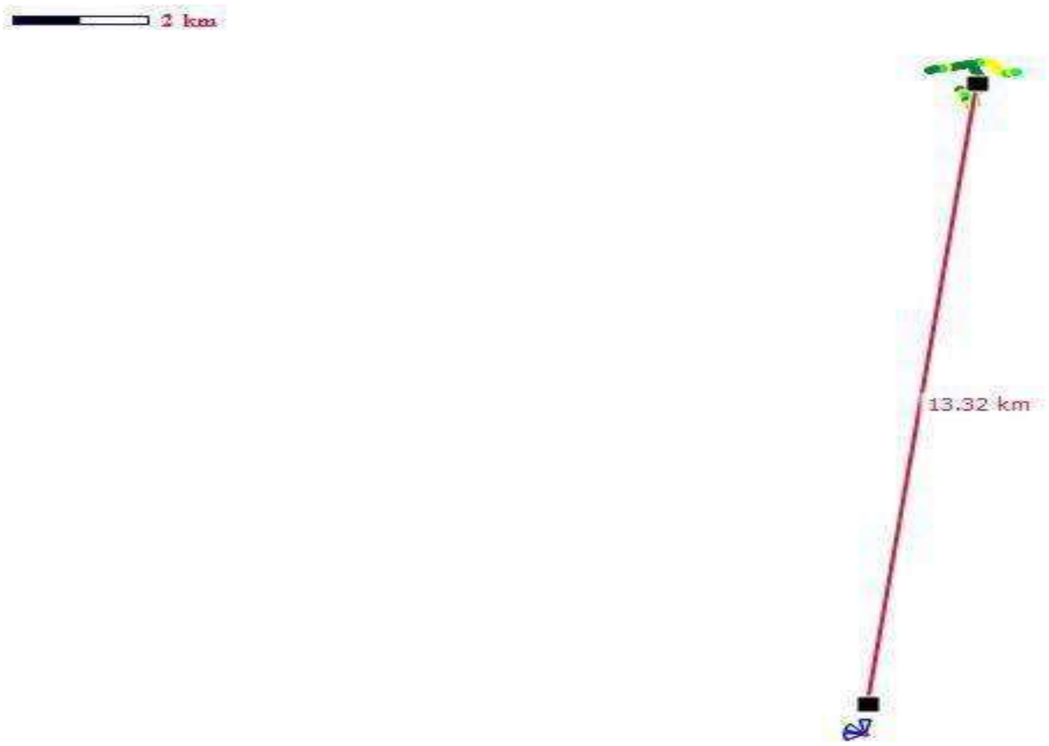

Figure 4.9: Servicing distance for network D

4.2 Performance analysis of the signal strengths for all the networks

The coverage penetration level of signals received voice quality for all the networks studied are shown in Figure 4.1 to Figure 4.7. The Rx-Level values, between 0 to -65dBm indicate excellent coverage; between - 65 to - 75dBm for very good coverage; between -75 to -85dBm for good coverage; between -85 to - 95dBm for average coverage and between -95 to -110dBm for poor coverage and below - 110dBm it is considered as no coverage penetration. The normal range Rx-Level is from - 30dBm to -70dBm. However, it was observed that the range of Rx-Level during the drive test of this research was between -70dBm to -95dBm. The RX voice quality values between 0 and 4 indicate excellent voice quality; between 4 and 5 indicate good voice quality; between 5 and 6 indicate fair voice quality and above 6 indicate poor voice quality. It was observed that the range of RX voice quality during the drive test of this research was between 0 and 4 and $[6, max]$. It was observed from the drive test that Network D have poor Rx voice quality whereas Network A, B and Network C have excellent Rx voice quality.

4.3 The Results of the drive test

During the test, transmission environment monitoring software investigation (TEMs investigation) was used to capture data for different MNO parameters (either in idle mode or in dedicated mode) and transmission environment monitoring software discovery (TEMs Discovery) was use to processed the data. Drive test approach was used for the measurements and statistical methods for the presentation of the results. The drive test was performed in the morning, afternoon and evening. The data obtained for a period of 3days. A total of 78 calls were made from the networks under study. The data collected on each mobile network are presented on Tables 4.3 to Table 4.10 while the KPIs values for each mobile network were calculated using the expression earlier defined from equations 3.1 to 3.7.

Data Rate, Throughput were obtained from the result generated after processing the data collected with the transmission environment monitoring software discovery (TEMs Discovery). Latency was obtaining by using equation 2.7 and the results for calculated KPI parameters was presented on Table 4.6 while results for each KPIs are presented on Tables 4.3 to 4.10. However, a graphical presentation of various KPIs was presented and performance evaluation for each KPI was done on Figure 4.12 to 4.19 respectively. The Result for Performance Test and Network Quality was presented on Table 4.11

The KPI Parameters meant for analysis at this point are: Call Setup Time (CST), Call Setup Failure Rate (CSFR), Call Setup Success Rate (CSSR), Call Drop Rate (CDR), and Call Completion Success Rate (CCSR), Data Rate, Throughput and Latency.

Table 4.3: Data Collected for Mobile Network A

DAYS	Call Setup Time (CST)	Call Setup Success (CSS)	CallSetup Failure (CSF)	Dropped Calls (DC)	Call Completion Success (CCS)	Attempted Calls (AC)
1	3calls ≥6s 4 calls≤ 6s	3	4	0	3	7
2	calls ≥6s calls≤ 6s	9	0	0	9	9
3	2 calls ≥6s 3calls≤ 6s	5	0	0	5	5
Total	9calls ≥6s 12 calls≤ 6s	17	4	0	17	21

Table 4.4: Average Data Rate, Throughput and Latency for Network A

Days/KPIs	**Data Rate (kbps)**	**Throughput (kbps)**	**Latency (ms)**
1	69.21	37.53	392.83

2	25.84	0	Nil
3	12.50	190	97.35
Average	38.85	75.84	243.88

Packet size for Network A is 2312 bytes .Equation 2.7 was used to obtained Network latency.

Table 4.5: Data collected for Network B

DAYS	Call Setup Time (CST)	Call Setup Success (CSS)	CallSetup Failure (CSF)	Dropped Calls (DC)	Call Completion Success (CCS)	Attempted Calls (AC)
1	3calls ≥6s 4 calls≤ 6s	0	7	0	0	7
2	2 calls ≥6s 4 calls≤ 6s	6	0	0	6	6
3	2 calls ≥6s 4 calls≤ 6s	6	0	0	6	6
Total	7 calls ≥6s 12 calls≤ 6s	12	7	0	12	19

Table 4.6: Average Data Rate, Throughput and Latency for Network B

Days	Data Rate(kbps)	Throughput(kbps)	Latency(ms)
1	0	0	Nil
2	8.16	11027.58	1.68
3	2.02	9167.82	2.02
Average	3.39	6731.80	2.75

Table 4.7: Data collected for Network C

DAYS	Call Setup Time (CST)	Call Setup Success (CSS)	CallSetup Failure (CSF)	Dropped Calls (DC)	Call Completion Success (CCS)	Attempted Calls (AC)
1	5 calls ≥6s 2 calls≤ 6s	7	0	0	7	7
2	5 calls ≥6s 2 calls≤ 6s	6	1	1	5	7
3	3 calls ≥6s 1 calls≤ 6s	4	0	0	4	4
Total	13 calls ≥6s 5 calls≤ 6s	17	1	1	16	18

Table 4.8: Average Data Rate, Throughput and Latency for Network C

Days/KPIs	Data Rate (kbps)	Throughput (kbps)	Latency (ms)
1	10.87	271.82	68.05
2	12.63	25.64	721.37
3	8.14	161.54	114.50
Average	10.55	153	121

Packet size in bytes for Network C is 2312. Equation 2.7 was used to determine the Network Latency.

Table 4.9: Data collected for Network D

DAYS	**Call Setup Time (CST)**	**Call Setup Success (CSS)**	**CallSetup Failure (CSF)**	**Dropped Calls (DC)**	**Call Completion Success (CCS)**	**Attempted Calls (AC)**
1	7 calls ≥6s 0 calls≤ 6s	0	7	0	0	7
2	6 calls ≥6s 0 calls≤ 6s	0	6	0	0	6
3	7 calls ≥6s 0 calls≤ 6s	0	7	0	0	7
Total	20 calls ≥6s 0 calls≤ 6s	0	20	0	0	20

Table 4.10: Average Data Rate, Throughput and Latency for Network D

KPIs/Average	Data Rate (kbps)	Throughput (kbps)	Latency (ms)
1	o	o	Nil
2	0	0	Nil
3	0	0	Nil
Average	0	0	Nil

4.3.1 Calculation of kpi parameters for mobile network A

The various KPI parameters values were calculated using the expression earlier defined from equations 2.1 to 2.7 and 3.1 for the entire Mobile Network Providers and results were presented in Table 4.10.

i. To Calculate for CST

Recall that call Setup Time (CST) was given as:

Percentage of CST (≤ 6s) = $\sum \frac{Calls \leq 6s}{Attempted\ calls}$ x 100

Total number of Call Setup Time less than or equal to six (6) second is:

CST (≤ 6s) = $\sum calls \leq 6s$

$\sum$ CST ≤ 6s = 4+5+3 = 12calls

Therefore, percentage of calls less than six seconds

CST ≤ 6s = $\frac{12}{21}\ X\ 100 = 57\%$

CST ≤ 6s = 57% of the attempted calls

Percentage of CST (≥6s) =$\sum \frac{Call \leq 6s}{Attempted\ \ calls}\ X\ 100$

Total number of Call Setup Time greater than or equal to six (6) second is:

CST ≥ 6s = $\sum calls \geq 6s$

CST ≥ 6s = 3+4+2= 9 calls

CST ≥ 6s = 9calls

Percentage of CST ≥ 6s = $\frac{9}{21}$ x 100 = 43%

Percentage of CST (≥ 6s) = 43% of the attempted calls.

ii. To Calculate for CSFR

Recall that call Setup Failure Rate (CSFR) was given as:

CSFR= $\frac{Number\ of\ ailed\ call\ attempts}{Total\ Number\ if\ atempted\ calls}$ X 100

CSFR= $\frac{4+0+0}{21}$ X 100

CSFR= $\frac{4}{21}$ X 100 = 19%

iii. To Calculate for CSSR

Recall that Call Setup Success Rate (CSSR) was given as:

CSSR= $\frac{Number\ of\ unblocked\ call\ attempts}{Total\ Number\ of\ calls\ atempt}$ X 100

CSSR= $\frac{3+9+5}{21}$ X 100

CSSR= $\frac{17}{21}$ X 100 = 81%

iv. To Calculate for CSSR

Recall that Dropped Call Rae (DCR) was given as:

CDR= $\frac{Number\ of\ dropped\ calls}{Total\ Number\ of\ atempted\ calls}$ X 100

CDR= $\frac{0+0+0}{21}$ X 100

CDR= $\frac{0}{21}$ X 100 = 0%

v. To Calculate for CSSR

Recall that Call Completion Success Rate (CCSR) was given as:

CCS R= $\frac{Number\ of\ Completed\ Cals}{Total\ Number\ of\ Attempted\ calls}$ X 100

CCSR = $\frac{3+9+5}{21}$ X 100

CCSR = $\frac{17}{21}$ X 100 = 81%

The same procedures above were adopted for various KPI parameters calculations for Mobile Network B, Mobile Network C and Mobile Network D and results presented on Table 4.3, 4.5, 4.7, Table 4.11 shows data related KPIs the mobile Networks A, B, C and D.

Table 4.11: Calculated KPI Parameters for Mobile Network Providers

NO	NETWORS	CST		CSFR	CSSR	CDR	CCSR	CA
1	NCC (Target)	CST (E) ≤6s	CST (D) >6s	≤ 10%	≥ 98%	≤ 1%	≥ 97%	CA
				0	0	0	0	
2	Network A	57%	43%	19%	81%	0%	81%	21
3	Network B	63%	37%	37%	63%	0%	63%	19
4	Network C	72%	28%	6%	94%	6%	89%	18
5	Network D	0%	100%	100%	0%	Nil	0%	20

Table 4.12: Shows the results for data related KPIs Parameters for Mobile Network Providers

NO	NETWORKS	Data Rate (kbps)	Throughput (kbps)	Latency(ms)
1	Target	500-5000(3G)	3100(3G)	100-500(3G)
2	Network A (2G)	35.85	75.84	244
3	Network B	3.39	6731.8	2.75
4	Network C (3G)	10.54	153	121
5	Network D	0	0	Nil

Mathematical Relationship Between KPIs

$$CCS = CSS - DC \quad (4.1)$$

$$CSF = CA - CSS \quad (4.2)$$

$$CDR \alpha \frac{1}{CCSR} \quad (4.3)$$

Where CCS represents call completion success, CSS represent call setup success, DC represent dropped calls, CSF represent calls setup failure and CA represent calls attempt

4.3.2 Network accessibility

Network accessibility is a measure of how ease or difficult the mobile service is obtained within a specified threshold and derivable when requested by the Mobile Service User. Network Accessibility simply determines mobile station's capability to ascertain and maintain calls. It simplified the capability to successfully commence and set up a voice communication between a mobile network terminal and a fixed network terminal. It is also the ability of network providers to sustain this call throughout a pre-establish period of time. When it is difficult or not possible to set up communication or communication dropped in the process of conversation, the cause for this difficulty have to be identified. The most common KPIs connected to Network Accessibility for the purpose of this Research are: Call Setup Time (CST), Call Setup Failure Rate (CSFR) and Call Setup Success Rate (CSSR). The responses on the Network Accessibility from the study are shown in Figure 4.12 to 4.14 respectively.

Table 4.13: KPIs data calculated for CST

Network Providers	**Network A**	**Network B**	**Network C**	**Network D**	**Target**
CST ≤ 6s (E)	57 %	63%	72%	0%	100%
43%		37%	28%	100%	
CST ≥ 6s (D)					0%

4.3.2.1 Performance analysis of call setup time

Figure 4.10 shows the Call Setup Time or Call Accessibility to each of the Mobile network provider. CST measures the length of time required to establish a circuit switched call between users of mobile phone. CST (≤ 6s/E) means easy call setup time while CST (≥ 6s/D) means difficult call setup time. Figure 4.10, shows that among all the Mobile Networks studied, Mobile Network C is with the highest easy Call Setup Time, which is CST (E/≤ 6s) of 72% with calls difficult CST (D/≥ 6s) of 28%. This simply implies that the Call Accessibility into Mobile Network C in terms of Call Setup Time is the easiest and follow by Mobile Network B with CST (E/≤ 6s) of 63% and with call difficult CST (D/≥ 6s) of 37%. Also, the Call Accessibility of Mobile Network A with CST (E/≤ 6s) of 57% with calls difficult of CST (D/≥ 6s) 43% in terms of call setup time is easier than that of Network D with CST (E/≤ 6s) of 0% and CST (D/≥ 6s) 100%. The following factors are observed to be responsible for substandard call setup time; Interference due to obstructions in the the area under study, poor coverage, Low base stations output power, Antenna problems and insufficient base station. However, from Figure 4.10, it shows that all the Mobile Network Operators under study performed below the minimum standard (which represent Target in this study) of 100% (≤ 6s) CST benchmark set by the regulatory organ the NCC for all telecom operators to comply with.

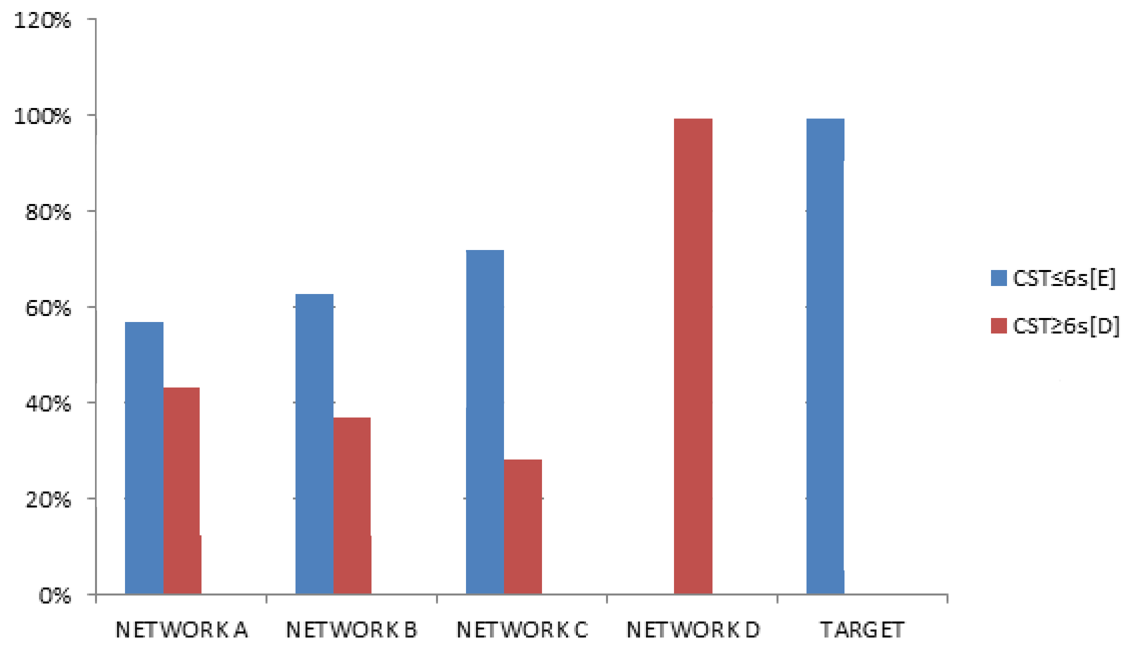

Figure 4.10: Call Setup Time

Table 4.14: KPIs data calculated for CSFR

Network Providers	Network A	Network B	Network C	Network D	Target
Call setup Failure Rate(CSFR)	19%	37%	6%	100%	≤10%

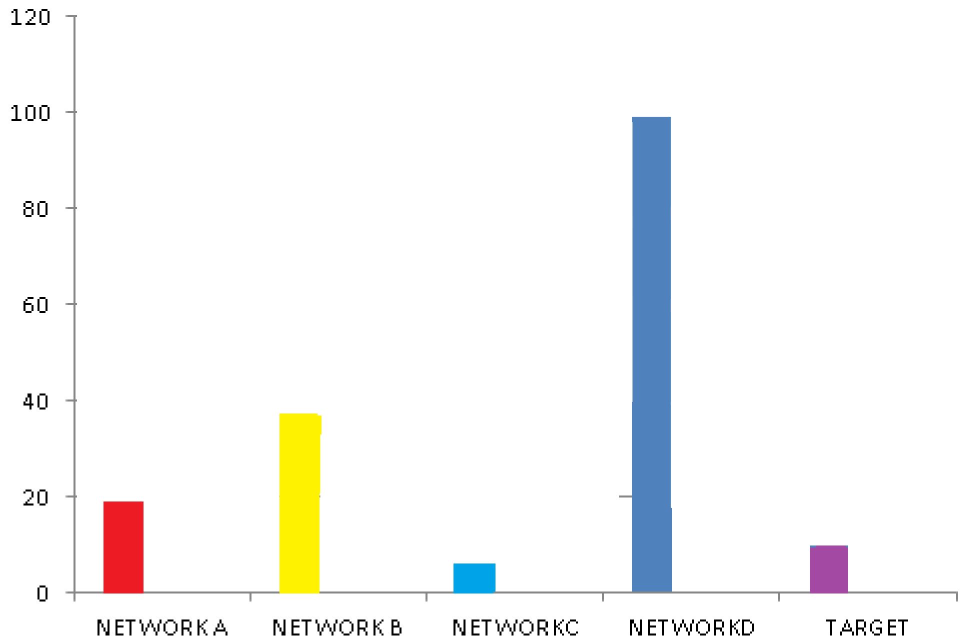

Figure 4.11: Call Setup Failure Rate

4.3.2.2 Performance analysis of call setup failure rate

Call Setup Failure Rate (CSFR) measure the rate at which call set-up fails by the mobile service provider. Figure 4.11 shows the rate at which call setup failed for each of the Mobile Networks. The Figure 4.11 shows that for the entire Mobile Networks studied Mobile Network C has the best call setup failure rate of 6%. This implies that for every 100 calls made to Mobile Network C 94 calls are likely to be successful without interruption or termination with only approximate 6 calls unsuccessful or blocked (CSFR) followed by Mobile Network A with CSFR of 19%. Mobile Network D has the worst network failure of 100% followed by Mobile Network B with 37% calls failure. From the study, it was only mobile Network C that met with NCC minimum standard whereas Network A, B and D did not meet up with the NCC CSFR minimum standard of $\leq$ 10%. The following factors are observed to be responsible for substandard call setup failure rate; Signal interference due to obstructions in the environments, low transmit power, insufficient basestations and low signal strength as shown in Table 4.2.

Network Providers	Network A	Network B	Network C	Network D	Target
Call Setup Success Rate (CSSR)	81%	63%	94%	0%	≥98%

Table 4.15: KPIs data calculated for CSSR

4.3.2.3 Performance analysis of call setup success rate

The level of accessibility into each network is shown in Figure 4.12, which indicates the rate at which calls setup were successful. From Figure 4.12, Mobile Network C has the best mobile network in establishing or connecting calls of 94% CSSR. These implies that for every 100 calls made to Mobile Network C, 94 calls are likely to be successful with CSSR of 94% and with 6% unsuccessful or blocked calls followed by Mobile Network A with CSSR of 81%. Similarly, the Call Setup Success Rate of Mobile Network B with 63% is better than that of Mobile Network D with success rate of 0%. Meanwhile, Figure 4.12 also reveals that calls accessibility to Mobile Network C can be established very successfully and calls accessibility to mobile Network A is not as strong as that of mobile Network C. However, all the Mobile Networks studied performed below the minimum standard which is (Target) of either less than or equal to ninety eight percent of attempted calls (≥ 98%) benchmark set by the telecom regulatory body the NCC. Mobile Network C almost meet up with this standard.

The following factors are observed to be responsible for substandard call setup success rate; poor coverage, low transmit power, antenna problems, signals interference due to obstructions in the transmission environments and insufficient base stations.

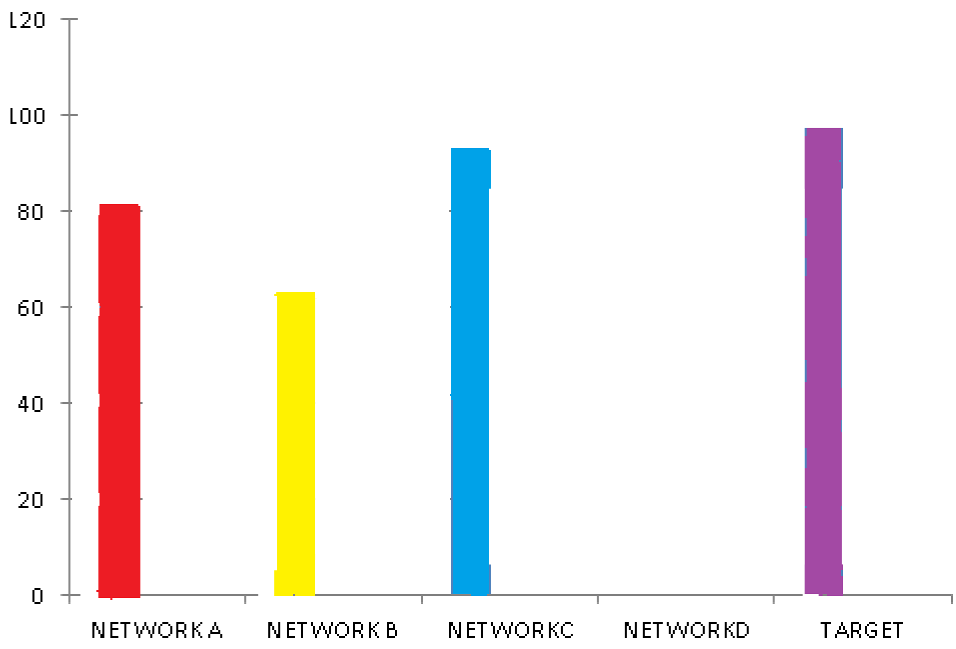

Figure 4.12: Call Setup Success Rate

4.3.3 Network retainability

Network retainability indicates how long a mobile user is sustained on a network after the call has been successfully connected. Normally, it is evaluated as the probability that a connected call will not end at the same time as conversation is ongoing. The KPIs connected for evaluating the Network retainability on a Mobile Network for the purpose of this study are the Dropped Call Rate (DCR) and Call Completion Success Rate (CCSR). The results on the Network Retainability are presented in Figure 4.13 and 4.14 respectively.

Table 4.16: KPIs data Calculated for CDR

Networks Provides	**Network A**	**Network B**	**Network C**	**Network D**	**Target**
Call dropped Rate (CDR)	0%	0%	6%	Nil	≤ 1%

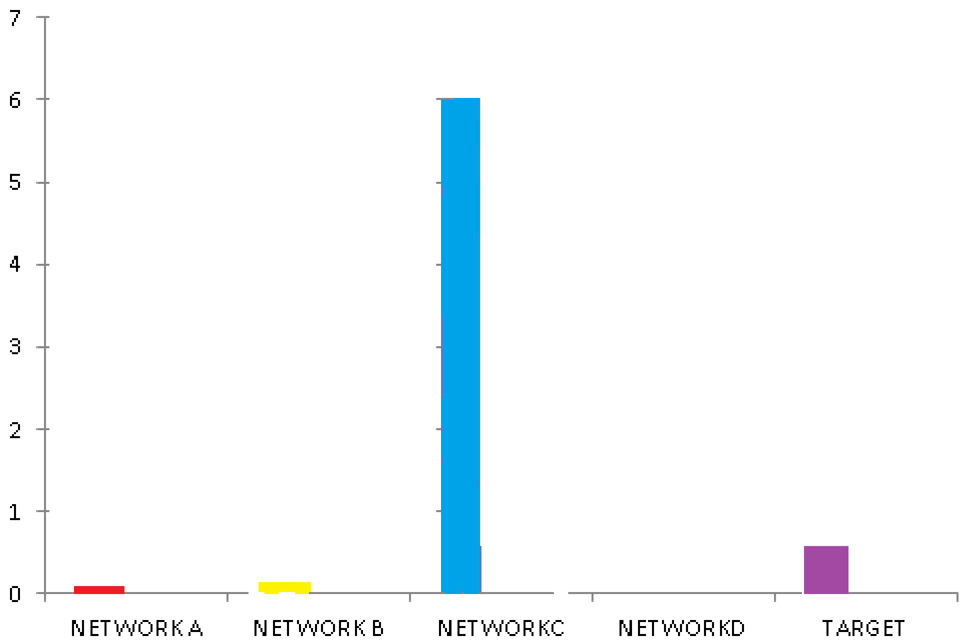

Figure 4.13: Call Drop Rate

4.3.3.1 Performance analysis of call drop rate

Call Dropped Rate is said to be among the worst and highest performing metric that affect QoS in Nigeria. Call Drop is a phenomenon that angers all the mobile subscribers especially when an important conversation is ongoing. The result from Figure 4.13 shows that Mobile Network C has the highest call drop rate (CDR) of 6 %.Call could not be made on Mobile Network D. While Mobile Network A and B has the lowest call drop rate (CDR) of 0%. From Figure 4.13, it shows that Mobile Network A and B met the NCC minimum standard of ≤ 1% whereas Mobile Network C and D performed below the minimum standard. The following factors are observed to be responsible for substandard drop call rate; Low base station output power, signal interference due to obstructions in the transmission environments, poor quality on downlink and uplink and insufficient base stations.

Table 4.17: KPIs data Calculated for CCSR

Network Providers	Network A	Network B	Network C	Network D	Target
Call Completion Success Rate (CCSR)	81%	63%	89%	0%	≥ 97%

4.3.3.2 Performance analysis of call completion success rate

From Figure 4.14, with Mobile Network C has highest Call Completion Success Rate value of 89%.This indicates that mobile subscribers on Mobile Network C will cover higher probability of finishing discussion before call terminate as compare with mobile users on Mobile Network A,B and D followed by Mobile Network A and Mobile Network B. However connection quality of Mobile Network D was observed to be poor. Moreover , all the mobile networks studied performed below the minimum standard of either less than or equal to ninety seven percent of attempted calls, CCSR (≥ 97%) benchmark set by the telecom regulatory organ, the NCC for all mobile network operators to complied with. Mobile Network C nearly meet this target. The following factors are observed to be responsible for substandard call completion success rate; signals fluctuation, signals interference due to obstructions in the transmission environments, low transmit power from the base stations and insufficient base stations.

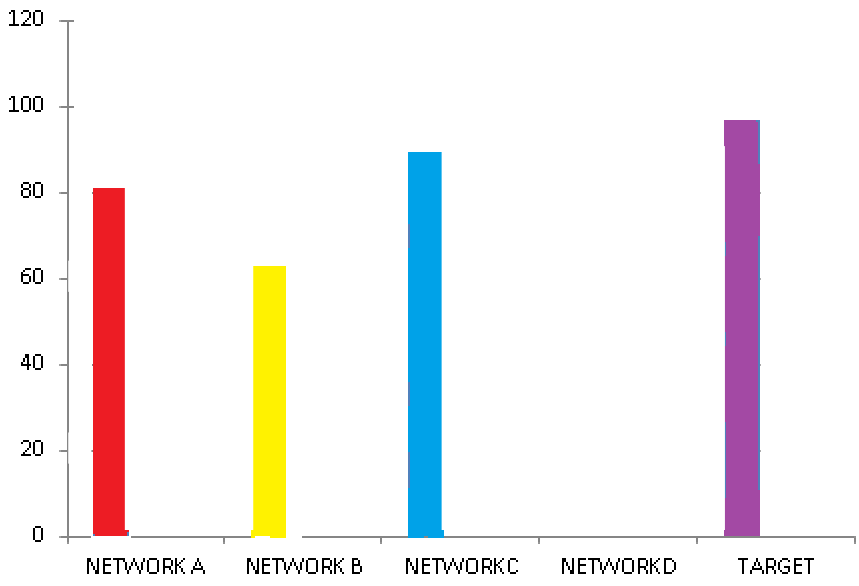

Figure 4.14: Call Completion Success Rate

4.3.4 Mobile internet service

Mobile data service is the internet access through an internet-enabled mobile phone. Mobile broadband is the wireless Internet access delivered through cellular towers to computers, tablets, smartphone and other digital devices using portable modems. The KPIs for evaluating the mobile internet service on a Mobile Network for the purpose of this study are the data rate, Throughput and Latency. The results on the mobile internet service are presented in Figure 4.15 to 4.17 respectively.

Table 4.18: KPIs data Calculated for Data Rate

Network Providers	**Network A**	**Network B**	**Network C**	**Network D**	**Target**
Data Rate (kbps)	35.85	3.39	10.54	0	500 for 3G

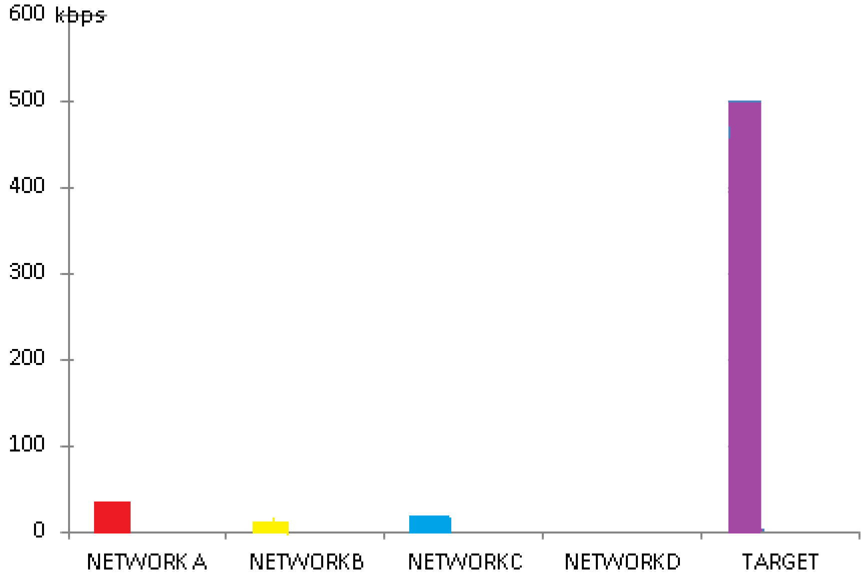

Figure 4.15: Networks Data rate

4.3.4.1 Performance analysis of data rate

The data rate denote the transmission speed, or the number of bits per second transferred. The result from Figure 4.15 shows that Mobile Network A has best data rate with value of 35.85 kbps. Followed by mobile Network C with the data rate of 10.54 kbps. Mobile Network B has data rate of 3.39 kbps. Mobile Network D has no mobile internet services as at the time of this test. From Figure 4.15, it shows that all the Mobile Network studied performed below the industrial standard for data communication which is 500 -5000 kbps for 3G network there is therefore need for improvement. The following factors are observed to be responsible for substandard data rate; absent of 4G wireless technology, signals fading due to obstructions in the transmission environments and insufficient base stations.

Table 4.19: KPIs data Calculated for Throughput

Network Providers	Network A	Network B	Network C	Network D	Target
Throughput (kbps)	75.84	6731.8	153	0	3100 for 3G

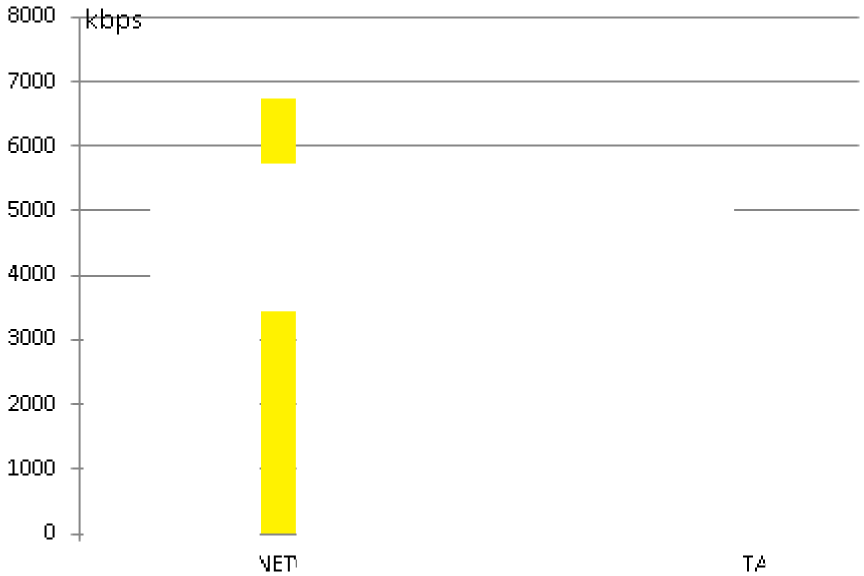

Figure 4.16: Networks Throughput

4.3.4.2 Performance Analysis of Throughput

Throughput is the amount of material or items passing through a system. Throughput is the rate of successful message delivery over a communication channel. It is the amount of information that actually pass through a communication channel. The result from figure 4.16 shows that Mobile Network B has best throughput with value of 6731.8 kbps. Followed by Mobile Network C with the throughput of 153 kbps. The next was Mobile Network A with throughput of 75.84 kbps. Mobile Network D has no mobile internet service as at the time of this research. From figure 4.16, it shows that mobile Network A ,B and C performed below the data communication minimum standard (which is Target) 3100 mbps for 3G network while mobile network D has poor connection quality. The following factors are observed to be responsible for substandard data throughput; absent of 4G wireless technology, signal fading due to obstructions caused by elements in the transmission environment, insufficient base station

4.3.4.3 Performance analysis of latency

Latency measures the time it takes for a bit to get to its destination across the network. A few ways to measure network latency include Ping, Traceroute, Matt's Traceroute (MTR).In this research network latency Equation 2.7 was used. Figure 4.17 shows that Mobile Network D has no latency. Mobile network A has latency of 244 ms as against minimum standard of 100ms for 3G network. Mobile network B has latency of 2.75 ms which is not against the minimum standard of 100ms for 3G network. Moreover, Mobile Network C has latency of 121 ms which above the minimum industrial standard of 100 ms for 3G technology. The following factors are observed to be responsible for substandard latency; Absent of 4G technology, low transmit power, insufficient base stations, obstructions due to elements in the transmission environments, distances the base station to the drive test area, It was only Mobile Network B that met the minimum industrial standard for data communication.

Table 4.20 : KPIs data Calculated for Latency

Network Providers	**Network A**	**Network B**	**Network C**	**Network D**	**Target**
Latency(ms)	244	2.75	121	0	100 for 3G

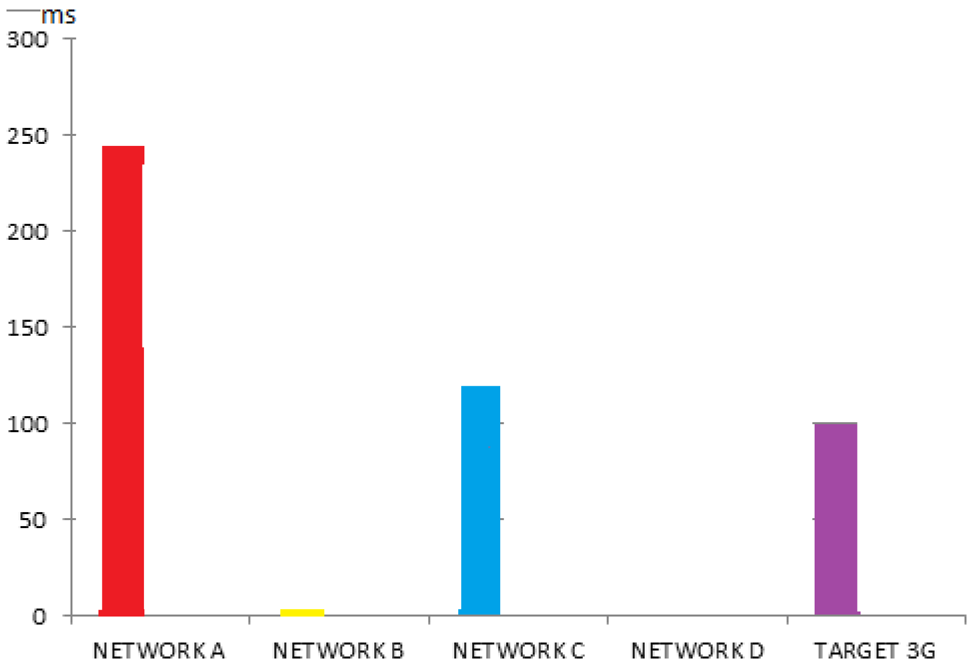

Figure 4.17: Networks Latency

4.4 The result for performance test and network quality

The performance analysis for each of the KPI parameters were done as shown from Figure

4.10 to 4.17 based on the data collected during the drive test. However, these results simply at hand present a comparative study of the Networks. Table 4.21 shows the result for performance test compare with the NCC benchmark, industrial standard for data communication and Network Quality.

Table 4.21 shows that the whole performance of the Mobile Network Operators is not satisfactory. It further reveals that in the entire Mobile Networks studied Mobile Network D has the worst QoS.

Table 4.21 Result for Performance Test and Network Quality

S/No	KPIs	Target	Best	Worst Results
1	Call Setup Time (CST)	≤ 6s for local & international calls	Network C; 72%	Network D; 0%
2	Call Setup Failure Rate (CSFR)	≤ 10% of attempted calls	Network C; 6%	Network D; 100%
3	Call setup Success Rate (CSSR)	≥ 98% attempted calls	Network C; 94 %	Network D; 0%
4	Dropped Call Rate (DCR)	≤ 1%	Network ; A an B; 0%	Network D; Nil
5	Call Completion Success Rate (CCSR)	≥ 97% of attempted calls	Network C; 89%	Network D; 0%
6	Data Rate(kbps)	500 for 3G	Network A; 35.85kbps	Network D; Nil
7	Though (kbps)	3100 for 3G	Network B; 6731.8kbps	Network D; Nil
8	Latency (ms)	100 for 3G	Network B; 2.75ms	Network D; Nil

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

This study was undertaken to evaluate mobile network voice and data services for improvement in Shiroro Power Station. Various KPIs Parameters of Mobile Network Services are used these KPIs are: Call Setup Time (CST), Call Setup Failure Rate (CSFR), Call Setup success Rate (CSSR), Call Dropped Rate (CDR), Call Completion Rate (CCSR), Data rate, Throughput and Latency. The methodology used was Drive Test using the transmission environment monitoring software (TEMs)

The results of the research shows that the Network Coverage (Coverage penetration level of Signals) by the Mobile Network Operators for the Mobile Users in the area of study were below Nigerian Communication Commission (NCC) threshold and the industrial standard for data communication. The range of Rx-level during the drive test was between -50dBm to -110dBm as against the normal range values of -30dBm to -70dBm. Rx-levels lower than -70dBm shows poor Network Coverage. The Rx quality for mobile Network A,B and C were observed to be better .This implies that MNO A,B and C met the NCC recommendation in term of Rx quality level which state that “A Voice Quality Impairment of less than 2%, means that the total number of “Bad Speech” Samples (resulting in only noise) throughout entire conversation must not be up to 2%. This means that the entire conversation must result to predominantly ‘Excellent and Good’ speech Samples’’ (NCC,2019). Although footprint for mobile network D was seen, the study revealed that Mobile Network D has poor receive quality.

The Network Accessibility into the Mobile Networks studied was below standard. In that none of the networks evaluated for improvement has network accessibility of hundred percent. The duration time spent on each of the Networks by Subscribers to get a call established or connected vary across the Networks. Network retainability was also below standard as shown in the result and discussion. The mobile internet service was not up to the industrial standard. The results shows that all the Mobile Network Operators are extreme from providing satisfactory and sufficient Mobile voice and data Services to the Subscribers in the study area. Technical issues that were identified to be responsible for poor performance include; Terrain problem, Signal fluctuation or fading due to various factors such as obstructions from (buildings and trees), signal path loss, insufficient coverage, Increase in subscribers base and introduction of new services, low transmission power, absent of signal boosters at the base stations, insufficient base transceiver station and absent of 4G wireless technology.

This result show the degree of deviations of the key performance indicators from the acceptable standard and technical issues that are responsible for it.

5.2 Recommendations for network improvement

Since no system is designed to continue to function forever and since there are so called environmental factors always affecting its behaviors, plan and efforts should always be put in place to improve performance. The results obtained, poor receive voice quality, low call setup success rate, not good enough call setup time, high call setup failure rate, fair call completion success rate ,low data rate, throughput and latency which affects the Quality of Service of a Wireless Mobile Networks are indicators of the need for optimization in Mobile services around Shiroro Power Station. The Networks therefore need optimization. It is also on this foundation that the following recommendations are made for each of the mobile network in order to improve the observed defects:

5.2.1 Recommendations for mobile network A

i. Deployment of more base transceiver stations
ii. Deployment of 4G wireless technology
iii. Increase transmit power
iv. Installation of the signal boosters at the base station
v. Environmental survey of this area should be adequately carried out before the installation of any other BS/BTS as presently terrain profile is account for Network Coverage Problem around Shiroro Power Station.
vi. Antennas should be checked periodically and be realign for better coverage Conducting periodic performance test on the their network

5.2.2 Recommendations for mobile network B

i. Deployment of more base transceiver stations
ii. Deployment of 4G wireless technology
iii. Increase transmit power
iv. Installation of the signal boosters at the base station
v. Environmental survey of this area should be adequately carried out before the installation of any other BS/BTS as presently terrain profile is account for Network Coverage Problem around Shiroro Power Station.
vi. Antennas should be checked periodically and be realign for better coverage
vii. Conducting periodic performance test on the their network

5.2.3 Recommendations for mobile network C

i. Deployment of more base transceiver stations
ii. Deployment of 4G wireless technology
iii. Increase transmit power
iv. Installation of the signal boosters at the base station
v. Environmental survey of this area should be adequately carried out before the installation of any other BS/BTS as presently terrain profile is account for Network Coverage Problem around Shiroro Power Station.
vi. Antennas should be checked periodically and be realign for better coverage
vii. Conducting periodic performance test on the their network

5.2.4 Recommendations for mobile network D

i. Deployment of more base transceiver stations
ii. Deployment of 4G wireless technology
iii. Increase transmit power
iv. Installation of the signal boosters at the base station
v. Environmental survey of this area should be adequately carried out before the installation of any other BS/BTS as presently terrain profile is account for Network Coverage Problem around Shiroro Power Station.
vi. Antennas should be checked periodically and be realign for better coverage.
vii. Conducting periodic performance test on the their network

5.3 Suggestions for future Studies

In this work, Quality of voice and data Service Evaluation of mobile network services was done on seven factors; Network Coverage, Connection Quality, Network Accessibility, Network Retainability, Data rate, Throughput and Latency. I would recommend that a future work could be carried out on measuring quality of service for mobile internet service in the same location including jitter, Bit error rate and other mobile broadband KPIs that are not included in this thesis.

5.4 Contribution to knowledge

The information needed on quality of service (QoS) and some KPIs values of different Mobile Network Providers studied was made available. This research shows the degree of deviation of the KPIs values of Mobile Network Operators from the acceptable standard, technical issues that are responsible for poor performance were also made available and the recommendations also provide recommendations for improvements. Mobile Subscribers are better informed about the QoS been provided by the MNOs in the study area hence; mobile subscriber can determine which MNP to subscribe to. Mobile Network providers can as well use this thesis as a reference to improve the quality of their service.

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