American Journal of Engineering Research (AJER)
e-ISSN: 2320-0847 p-ISSN : 2320-0936
Volume-7, Issue-5, pp-69-79
www.ajer.org
Research Paper Open Access

Performance Analysis of GSM Networks in Kano Metropolis of Nigeria

G.S.M Galadanci[1], S.B. Abdullahi[2]
Email: ggaladanci.phy@buk.edu.ng sba_elt.bch@outlook.com

[1](Department of Physics, Bayero University, Kano, Nigeria)
[2](Department of Physics, Bayero University, Kano, Nigeria)
Corresponding author: G.S.M Galadanci

Abstract: *This work examined the performance of GSM networks (P, Q, R and S) in Kano Metropolis, Kano State, Nigeria, where the Key Performance Indicators (KPIs) were used as a key asset for carriers and subscribers alike. The Ericson W995 Phone with built-in Transmission Environmental Monitoring System (TEMS POCKET) software package was used to generate the log files from the active GSM networks. The post analysis of these log files identified problems of parametrical issues. The research results revealed out that the four carriers failed to achieve NCC minimum targets for CSSR, HOSR and call blocking respectively. More than 40% of the samples had poor quality and the five coverage groups were defined in terms of RXLEV and RXQUAL, while group 1 and 5 were the best and worst groups respectively since it comprised both the best and poor RXLEV and RXQUAL. The drive test maps were inspected and found out that the four carriers experienced one or more type of signal interruptions. The work validated the claim made by the NCC; Nigeria Communication Commission, that the carrier P had the best network coverage nationwide. Parametrical optimization was given as a way of network improvement for better reception and huge amount of revenue generation.*

Keywords: *GSM network, Drive Test, KPIs, Network optimization, RXLEV, and RXQUAL*

Date of Submission: 18-04-2018 Date of acceptance: 03-05-2018

I. INTRODUCTION

Mobile communication is all about sending and receiving a signal message while on move [1]. This was actualized through various developmental processes: first generation of the system was into being in 1978 by the USA government [2]. The system consisted of distributed transceivers that provides a platform of communication while on move [3]. The system was analogue and could only be adopted for voice traffic. The Frequency Division Multiplexing (FDM) was employed and the capacity of the network was increased by implementing the frequency reuse [1]. The geographical area of the network is divided into small sectors, called cells. It was from this idea, the network was named Cellular and the phones were called cell phones [4]. Among the disadvantages of analogue systems were incompatible with each other as each network had its own standard, limited capacity, mobility issues, frequent use, security, and roaming among others [1]. Thus, resulted in a very low market and coverage penetration and mandated a significant effort to develop the second generation (2G) cellular networks. It was deployed in 1991 in Finland and based on digital communication system [1][5]. The digital system improved the network quality, capacity, cost, power, speed, security and so on. Unlike the predecessor, various technologies were developed some based on Time Division Multiple Access (TDMA), Code Division Multiple Access (CDMA), and Global Systems for Mobile Communications (GSM) etc. The characteristics of 2G were quite evident that it would accommodate multiple users and provide good communication platform with high security integrity[1]. The system introduced data transfer through mobile rather than only voice and text messages. 2G utilizes any of the available three frequency bands, could either be 900, 1800 and 1900 MHz respectively[1]. The GSM is the most widely used standard due to its capability for international roaming under one subscriber directory number, superior speech quality, ISDN compatibility, high level of security and many more [6]. The GSM 1800 uses 25 MHz and bandwidth of 1805-1880 MHz from mobile to base station and 1710-1785 MHz from base station to mobile[6]. However, several signal problems were increasingly found in this network. At the present time, these problems are being greatly increased in several cities [7] such as Kano. The research location is Kano metropolis, Nigeria. It is situated between latitudes 11º 25' N to 12º 47' N and longitude 8º 22' E to 8º 39' E east and 472m above sea level. Kano metropolis is bordered by Madobi and Tofa Local Government Areas (LGAs) to the South West, Gezawa LGA to the East, Dawakin Kudu LGA to the South East, and Minjibir LGA on the North East. The study area is made up of eight (8) LGAs. They include Dala, Fagge, Gwale, Kano Municipal, Nassarawa, Tarauni and parts of Ungogo and Kumbotso local governments. Kano metropolis is the third largest town in Nigeria after Lagos and Ibadan. It has a population of 2,826307 people. Kano is referred to as the Center of Commerce in the Country due to long flourished marketing activities. This is based on the fact that marketing and trading has been the dominant economic activity of the Populace of the Metropolitan Kano [8]. However, the challenge that defeats the benefits of GSM networks in Kano is the aggressive complaints raised by the GSM subscribers regarding abysmal quality of service rendered by the GSM operators [9]. Thus, a steady and reliable mobile phone communication is more of a necessity rather than a luxury in Kano Metropolis. With the rapid growth and the need for high quality and high capacity cellular networks, accurate examination and optimization of the networks has become extremely important. To more accurately optimize the modern GSM cellular networks, signal strength measurements must be taken in the service area of the active GSM network [10]. In order to achieve the best performance, carriers have to monitor and optimize their network continuously [11]. Network Operating Centers (NOCs) with an online database is responsible for the collection of data on active GSM network [11].The presented KPIs below are crucial for carriers who are concerned with maintaining a reliable and steady network, while maintaining an acceptable QoS based on NCC targets. Thus, the Drive Test (DT) is a test performed in cellular networks regardless of technology (GSM, CDMA, UMTS, LTE, etc.) usually Performed in order to Analyze and optimize the Network Quality [12]. It is an appealing solution for cellular networks quality as well as performance viral content. Although by the analysis of KPIs' we can identify problems of Parametrical Issues e.g. (CDR, Interference, CSSR, TCH congestion rate etc.). Identifying areas of each sector of coverage, interference, evaluation of network changes and various other parameters. This work generated measurement data from a live network with the sole aim of analyzing and evaluating the generated result so as to undertake possible network optimization for performance improvement [7]. This paper made the following contributions:

(1) Systematic examination of GSM mobile networks performance and end user experience using four NCC KPIs metrics.
(2) Indoor measurements and measurements in some areas that are difficult to cover during a typical drive testing were considered.
(3) The use of unique tool (TEMS POCKET+ Scanner + GPS) was adopted for the DT as compared with the typical drive testing. The four leading GSM carriers were investigated at the same locations, using the same phone, with each SIM card for the GSM networks in consideration.
(4) Standard mathematical relations for the four KPIs using the generated call logs were developed and adopted in the research.

1.1 Key Performance Indicators (KPIs)

Quality of Service of mobile cellular networks was defined by (ITU-T E.800, 2008) Rec as "the collective effect of service performance that determine the degree of satisfaction of a user of the service," has many performance metrics which have continue to give telecommunication experts and operators lot of keen considerations for continual optimality [13].

The quality of performance feels by the mobile cellular network will be captured using the KPIs [13]. KPIs are used for parameters related to voice and data channels. The most important KPIs that are used by NCC for grading the QoS of GSM networks in Nigeria [7] are:

1.1.2 KPIs connected to accessibility

(1) Call Setup Success Rate (CSSR): measures successful TCH assignments of total number of TCH assignment attempts [14]. It is calculated as the number of the unblocked call attempts divided by the total number of call attempts[7]. The reasons for low CSSR were TCH congestion and interference & poor coverage. See Table 1.0 for this NCC metrics target. It can be found using:

$$\text{CSSR} = \frac{\textit{Number of unblocked call attempts}}{\textit{Total number of call attempts}} \times 100\% \qquad (1.0)$$

(2) Standalone Dedicated Control Channel (SDCCH) access success/drop rate: Is a percentage of all SDCCH accesses received in the BSC [14]. It measures the ease with which a call can be setup, the ease to recharge an account, send SMS, location update, paging etc.[7]. Reasons for poor SDCCH were too high timing advance, congestion, low signal strength on downlink or uplink, false accesses due to high noise floor. SDCCH congestion ratio can be found using:

$$SDCCH\ Cong.rate = \frac{1-CSSR}{TCH\ assignment\ rate} \times 100\% \quad (2.0)$$

(3) TCH Congestion Rate: This provides the percentage of attempts to allocate a TCH call setup that was blocked in a cell [14]. In a properly dimensioned network the value of this statistics should not be more than 2%[7]. Table 1.0 indicates the NCC metrics for this. The reasons for this block is high increase in traffic demand, bad dimensioning, high mean holding time, low hand over activity and high antenna position etc. Traffic channel availability can be found using:

$$\text{TCH Cong.} = \frac{Number\ of\ calls\ blocked\ due\ to\ unavailable\ resources}{Total\ number\ of\ requests} \times 100\% \quad (3.0)$$

1.1.3 KPIs Connected to Retainability:

Retainability is the ability of a service, once obtained, to continue to be provided under given conditions for a requested duration. These KPIs are:

(1) Call Drop Rate (CDR): Is the percentage of TCH dropped after TCH assignment completed [14]. It is a call that is prematurely terminated before being released normally by either the caller or the calling party. It is calculated as the number of dropped calls divided by the total number of call attempts[7]. See Table 1.0 for this NCC metrics. Reasons for CDR are low signal strength on downlink or uplink, lack of best server, congestion in neighboring cells, too high timing advance, low BTS output power, missing neighboring cell definitions, unsuccessful incoming or outgoing handovers etc. CDR can also be found using:

$$\text{CDR} = \frac{Number\ of\ dropped\ calls}{Total\ number\ of\ call\ attempts} \times 100\% \quad (4.0)$$

Call Drop Probability can be computed using equation below, assuming the number of handovers during a call, and depends on one or more factors such as cell size, call duration, speed and direction [15]:

$$\text{CDP}^{AB} = \sum_{I=1}^{hAB} HDP \times (1-HDP)^{i\text{-}1} \quad (5.0)$$

$$= 1\text{-}(1\text{-HDP})\text{\textasciicircum hAB} \quad (6.0)$$

Where HDP is the handover dropping probability, hAB is the total number of handover between two points A and B in space.

(2) Hand over Success Rate (HOSR): gives the percentage of successful handovers of all handover attempts. A handover attempt is when a handover command is sent to the mobile [14]. The possible reasons for poor HOSR are congestion, link connection, incorrect handover relations, incorrect locating parameter setting, bad radio coverage, high interference, co-channel or adjacent etc. HOSR can be found using:

$$\text{HOSR} = \frac{Number\ of\ successfully\ completed\ handovers}{Number\ of\ initiated\ handovers} \times 100\% \quad (7.0)$$

1.1.4 KPIs Connected to Service Integrity:

(1) Receive Quality (RXQUAL): Is the average received signal quality of the serving cell measured on all time slot and subset of time slots. It is measured on basis of BER. The range of RxQual is 0 to 7. The higher value of RxQual show the worse communication services [16].

(2) Speech Quality Index (SQI): This measure is dedicated to reflecting the quality of speech. SQI is updated at 0.5 seconds intervals. It is computed on basis of BER and FER [16]. It also estimates how codec type and radio link parameters such as BER, FER, DTX and handover rates affect voice quality.

(3) Frame Erasure Rate (FER): Is a speech quality degrade factor that indicates fading and interference. Voice quality is judged upon the FER[7].

(4) Received Signal Strength Indicator (RSSI)

The RSSI for an individual cell can be formulated as in [15] to be:

$$\text{RSSI (dB)} = Ro - \varepsilon \log d + \xi \quad (8.0)$$

Ro is constant determined by transmitted power, wavelength, and antenna gain of cell.

ε Is a slope index (typically 40 for microcells in a city)

ξ Is the logarithm of the shadowing component, and d is the distance between the MS and BS of cell.

1.3 Review of Related Works

In recent years, attention has been paid to the planning, evaluation and optimisation of mobile cellular networks [17]. There are several research works that addressed the evaluation and optimisation of operational GSM networks. Thus, the performance evaluation and improvement on quality of service of GSM network in

Federal Capital Territory (FCT), Abuja and some selected cities in all the six geo-political zones is presented in [18]. With a review of the most common networks quality of service (service retainability, network accessibility, connection quality and network coverage). The relationships between these qualities of service (QoS) metrics were introduced and thresholds for some QoS metrics were suggested so that the GSM carriers should not exceed them. In [19], the KPIs for QoS evaluation in GSM networks are identified. Four assessment parameters for evaluating the QoS from the mobile carriers' perspective were applied on four GSM networks in Nigeria. In [20] evaluated the cellular mobile networks from the data collected from Network Operating Centre (NOC) and compared with the measurement samples taken representing a particular KPI in Abuja and Kaduna BSC. The iManager M2000 was used to pull the KPI measurements. But the work is limited to Visafone mobile network. [6] Addressed the performance analysis of GSM networks in Aligarh City, India. Network dimensioning such as BSC, MSC and other related parameters are addressed and the top ten wireless parameters are listed which are the most important from the authors' point of view. The optimization process is adopted in cyclic nature till the best performance for the network is reached. The study in [21] aimed at presenting the comparative analysis of the received signal strength (RSSI) measurement of GSM networks in Owo, Ondo state Nigeria. Software was developed to create an interface for the computer to aid in the measurement of the RSSI from different networks in Owo at random sampling. The mean value of the signal strength received using the developed software for the four carriers were computed, the methods of improvements were also suggested. [7] Used KPIs to evaluate the performance of an operational live GSM networks in Minna. The network performance assessment is based on CSSR, CDR, SDCCH congestion rate and TCH congestion rate. All the KPIs are explored and improvement methodologies were suggested. However, the work is not hundred percent on the drive test results. The result of that study showed that the QoS of GSM networks in Nigeria is unreliable and the network accessibility and retainability are unsatisfactory. In [15] used three months call record sample data to analyzed and optimized intercell handover dynamics of Airtel networks in Kano. Investigated the cells performance using standard mathematical relationships of HOSR, CSSR, blocking probability and CDR which are relevant KPIs. The data was simulated using JAVA variant NETBEANS 6.1. An optimal solution was provided using dynamic cutoff priority channel allocation scheme, but the data was collected from NOC not from the drive test.

From the literature reviewed above, some researchers have suggested several approaches to improve the available KPIs. However, most of these approaches were not evaluated for a live GSM networks. Other authors have used the drive tests to evaluate the performance of live GSM networks in terms of QoS. Nevertheless, to the best of my knowledge, there are no comprehensive research works in Kano that evaluate and optimize the live GSM networks based on these KPIs (CSSR, CDR, SDCCH congestion rate, and TCH congestion rate). In this work, a comprehensive research study was carried out on the performance analysis of four GSM mobile carriers (P, Q, R and S) in Kano where Kano Metropolis is selected as a case study. The paper profiles performance of GSM networks with particular attention on the impact of call drop rates, call block rates, handover failure rates and interference ratio. The research result was used to point out the main challenges for achieving good and quality networks based on the NCC KPI metrics and how to derive the required changes and the technological performance road map for improved GSM QoS.

II. MATERIALS AND METHODS

The following materials and equipment are employed: Personal Laptop computer (PC), W995 Sony Ericson with built-in TEMS software package (TEMS POCKET), MapInfo professional version (16.0.0), Baffo cable, USB 2.0 cable, MS Excel 2013 package, GlobalSat BT-359 GPS, four different types of Subscriber Identity Modules (SIMs) for P, Q, R and S networks respectively, Complete Inverter system, built-in Scanner and USB MODEM.

2.1 Transmission Ecosystem/Environmental Monitoring System Pocket (TP)

TP is a convenient and powerful product for verification, monitoring and troubleshooting of mobile networks and also for basic cell-planning tasks [22]. The tool is installed in a range of phone models. TP professional as used in this research is installed on the superb new Sony Ericson W995. TP collects measurements and event data for immediate monitoring or for processing by other tools at a later time. It can capture data in areas that are difficult to cover during traditional drive-testing. The tool provides options to perform indoor-environment measurements quickly and easily. Another valuable option that was added to TP professional is a powerful scanner that places extensive data-gathering capabilities in the palm of the user's hand. Thus, present detailed information about the surrounding networks [22]. Among the solution and benefits of TP professional are [22]:

- Interfaces with a wide range of user terminals, scanners, and positioning equipment, collecting data from these devices and recording it in log files.

- Supports the following major technologies:

GSM/EDGE/ WCDMA/HSDPA/HSUPA/WiMAX/GPRS.

- Network analysis and reporting: full decoding of metrics and events etc.
- Efficient use of engineering time: automatic data processing, background post processing and customized reporting capabilities.

Figure 1.0: W995 Sony Ericson Test Phone with built-in TEMS (TEMS POCKET)

2.2 MAPInfo Software

Is a comprehensive computer mapping tool that lets you perform complex geographical analysis such as redistricting, accessing your remote data, dragging and dropping map objects into your applications, creating thematic maps that emphasize patterns in your data, and much more [23].

2.3 Method

To date many methods have been employed in an attempt to evaluate and assess the performance of GSM mobile networks. These methods include pure speculation, mathematical derivations, statistical estimations as well as methods based upon laboratory measurements. Unfortunately, none of the above methods can be said to be rigorous or conclusive. The idea of statistical physics helps solve the hard network problems in an efficient manner. The techniques of statistical physics have been successfully applied to represent emerging macroscopic phenomena in cellular networks; mean field approaches, percolation theory, a parallelism with interacting fermionic particle systems, and message passage algorithms. The main advantage offered by statistical physics methods is in the range of tools developed to address large scale problems of a non-linear nature, through the study of typical case behavior and relying on approximation techniques that are well established within the physics community[24][25]. The disadvantages of these methods are that many of them are non-rigorous and that some tend to fail in small-scale systems. Thus, the drive test. The Drive Test (DT) is a test performed in cellular networks regardless of technology (GSM, CDMA, UMTS, LTE, etc.) usually Performed in order to Analyze and optimize the Network Quality. Although by the analysis of KPIs' we can identify problems of Parametrical Issues e.g. (CDR, Interference, CSSR, TCH congestion rate etc.) while the drive tests allow a deeper analysis in the field [12]. Identifying areas of each sector of coverage, interference, evaluation of network changes and various other parameters [7]. One of the shortcomings of simulation with TEMS software is the configuration of external GPS and scanner/spectrum analyzer among others, reliability and validity of such information is not certain. Some areas are very difficult to cover during traditional drive-testing. Hence, the TP is employed in this research, as it captured data and information in areas that are difficult to cover in TEMS software simulation and also perform indoor-environment measurements quickly and easily among others.

The research's method employed three key characteristics as follows:

(1) Measurements reflect four aspects (CSSR, CDR, HOSR and Call blocked rate) that impact the quality of service.

(2) Measurements are carried out in the same locations, conditions and the same phone for the four carriers (P, Q, R and S) in consideration.

(3) Tests are carried out completely automatically, thus eliminating the subjectivity inherent to human intervention or decision.

The KPI data was obtained through a drive test over the coverage area of the respective base stations under monitoring, during which the following information was collected for each data; RXLEV (received signal strengthpower level), RXQUAL (received signal quality), Interference, Dropped calls, blocked calls, HO (Hand over) information, six neighboring cell information, GPS location coordinates, call events, BSIC (base station identity code), ARFCN (absolute radio frequency channel number), LAC (location area code), TA (timing advance), FER (frame erasure rate), etc. while the GlobalSat BT-359 GPS was configured to access the location information of the site/cells: Latitude (LAT), Longitude (LONG) and other topographical data. The data was generated for a period of six months from 02/03/2017 to 08/08/2017. The drive test routes are defined using Mapinfo software as shown in Fig. 2.0.

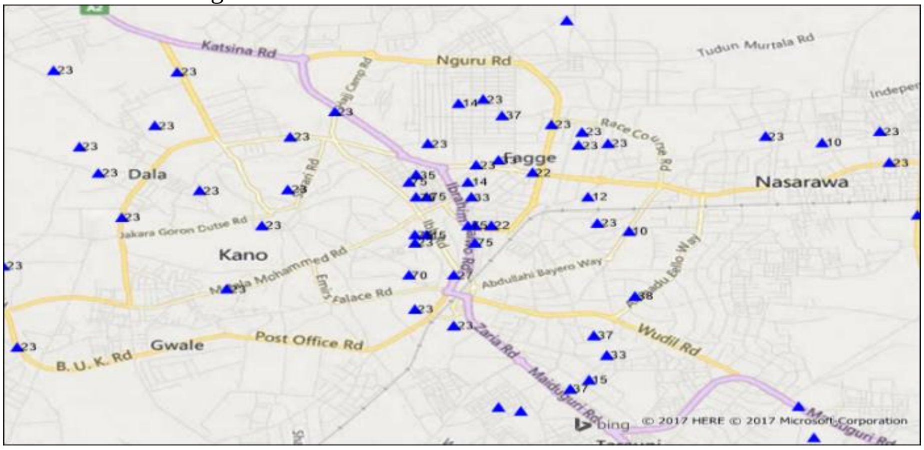
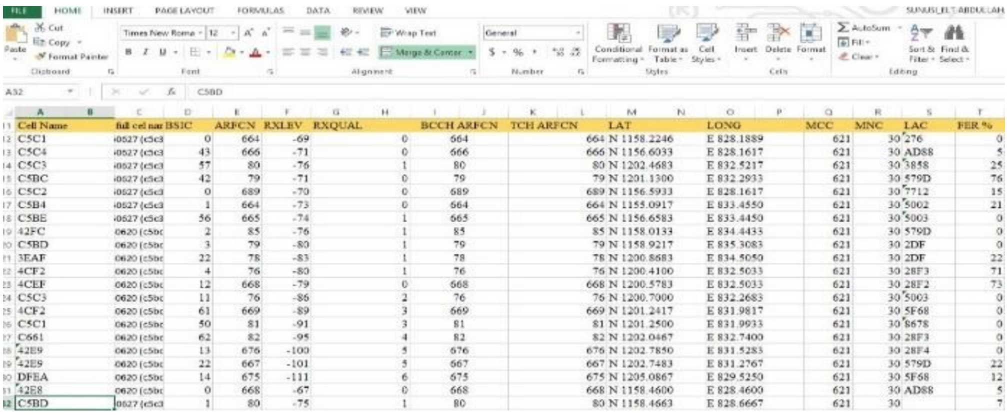


Figure 2.0: Screenshot showing the driving routes

The log files data was generated by making use of full functioning and equipped Sony Ericson W995 test phone with built-in TEMS software plus Scanner (TEMS Pocket), containing the subscribers Identification Modules (SIMs) for different networks under investigation. The experimental setup was shown in Fig. 3.0.

Figure 3.0: The experimental Setup

The SIM card was inserted into the slot of W995 phone, after successful registration/installation of the card, the DT was started till the last point where the last sample was predefined in the driving routes was obtained. The card was removed, another one from different carrier was slotted and tested, till all the four SIM cards were tested using the same procedures and at the same predefined routes as it was plotted in the MAPINFO. All the values extracted for both intra and inter calls were recorded on a research's designed form, as shown in Fig. 4.0. Averages of the various data was calculated and recorded in appropriate tables, also line graphs were plotted using Microsoft Excel Office 2013 software package to determine the performance of each network relative to each KPI for different collection areas. The comparison of the type of networks was done by calculating the mean averages of each KPI and recorded on tables and their bar charts were plotted respectively.



Cell Name	full cel nar	BSIC	ARFCN	RXLEV	RXQUAL	BCCH ARFCN	TCH ARFCN	LAT	LONG	MCC	MNC	LAC	FER %
C5C1	i0527 (c5c3	0	664	-69	0	664	664	N 1158.2246	E 828.1889	621	30	276	0
C5C4	i0527 (c5c3	43	666	-71	0	666	666	N 1156.6033	E 828.1617	621	30	AD88	5
C5C3	i0527 (c5c3	57	80	-76	1	80	80	N 1202.4683	E 832.5217	621	30	3858	25
C5BC	i0527 (c5c3	42	79	-71	0	79	79	N 1201.1300	E 832.2933	621	30	579D	76
C5C2	i0527 (c5c3	0	689	-70	0	689	689	N 1156.5933	E 828.1617	621	30	7712	15
C5B4	i0527 (c5c3	1	664	-73	0	664	664	N 1155.0917	E 833.4550	621	30	5002	21
C5BE	i0527 (c5c3	56	665	-74	1	665	665	N 1156.6583	E 833.4450	621	30	5003	0
42FC	0620 (c5bc	2	85	-76	1	85	85	N 1158.0133	E 834.4433	621	30	579D	0
C5BD	0620 (c5bc	3	79	-80	1	79	79	N 1158.9217	E 835.3083	621	30	2DF	0
3EAF	0620 (c5bc	22	78	-83	1	78	78	N 1200.8683	E 834.5050	621	30	2DF	22
4CF2	0620 (c5bc	4	76	-80	1	76	76	N 1200.4100	E 832.5033	621	30	28F3	71
4CEF	0620 (c5bc	12	668	-79	0	668	668	N 1200.5783	E 832.5033	621	30	28F2	73
C5C3	0620 (c5bc	11	76	-86	2	76	76	N 1200.7000	E 832.2683	621	30	5003	0
4CF2	0620 (c5bc	61	669	-89	3	669	669	N 1201.2417	E 831.9817	621	30	5F68	0
C5C1	0620 (c5bc	50	81	-91	3	81	81	N 1201.2500	E 831.9933	621	30	8678	0
C661	0620 (c5bc	62	82	-95	4	82	82	N 1202.0467	E 832.7400	621	30	28F3	0
42E9	0620 (c5bc	13	676	-100	5	676	676	N 1202.7850	E 831.5283	621	30	28F4	0
42E9	0620 (c5bc	22	667	-101	5	667	667	N 1202.7483	E 831.2767	621	30	579D	22
DFEA	0620 (c5bc	14	675	-111	6	675	675	N 1205.0867	E 829.5250	621	30	5F68	12
42E8	0620 (c5bc	0	668	-67	0	668	668	N 1158.4600	E 828.4600	621	30	AD88	5
C5BD	0527 (c5c3	1	80	-75	1	80	80	N 1158.4663	E 828.6667	621	30		7

Figure 4.0: The sample of the Excel sheet

3.2 Call Procedures

Short calls: 50/10, 50 (fifty) seconds dedicated mode, 10 (ten) seconds idle mode. It enable accessibility measurement (SDCCH, CSSR, TCH Cong. Rate, and PSR). Call counters (CC; call attempt, call established and call end) were generated every time the W995 phone trigger a new call attempt/setup.

Long calls: 120/10, 120 (one hundred and twenty) seconds dedicated mode, 10 (ten) seconds idle mode. It enable retainability measurement (HOSR, and CDR). Call counters (CC; call dropped, call blocked and call end) were generated every time any of these happens.

3.3 Standard Mathematical relationships

The following mathematical relations were developed to calculate the crucial KPIs' parameters; CSSR, CDR, HOSR and TCH Congestion/block rate respectively:

$$CSSR = \left[\frac{(CC1+CC2)}{CC3}\right] \times 100\% \quad (9.0)$$

Where CC1 metric successfully seized layer for terminated layer;
CC2 metric successfully seized layer for originated call;
CC3 metric seized requests.

$$CDR = \left[\frac{(CC4+CC5)}{CC6}\right] \times 100\% \quad (10)$$

CC4 metric TCH drops due to RR problems;
CC5 metric TCH drops due to RRC problems;
CC6 metric successfully assigned TCH.

$$HOSR = \frac{[(CC7+CC8)]}{[(CC9+CC10)]} \times 100\% \quad (11)$$

CC7 metric number of successful incoming handovers;
CC8 metric number of successful outgoing handovers;
CC9 metric number of requested outgoing handovers;
CC10 metric number of requested incoming handovers.

$$TCH\ Cong. = \frac{(CC11)}{(CC12)} \times 100\% \quad (12)$$

CC11 metric number of assignment failures due to the unavailable TCH;
CC12 metric number of assignment requests due to the available TCH.

III. RESULTS AND DISCUSSIONS

The distributions of the collected signal samples of RXLEV and RXQUAL are depicted in Figures 5.0 and 6.0 respectively. The coverage penetration of the signal samples as shown in Figures 9.0 to 12.0, were analyzed in MAPINFO with 0 to -65dBm(Excellent), -65 to -75 dBm(Good), -75 to -85 dBm(Fair), -85 to -95 dBm (Poor), and -95 to -110 dBm (Non-existent; means at -110 to below there is no coverage) respectively. The values of SQI between 23-30 is excellent, between 16-23 is good, between 9-16 is acceptable, between 4-9 is poor and bad speech, while below 2% resulted in totally impaired voice message. The overall DT data was analyzed in five coverage groups defined with respect to RXLEV and RXQUAL as tabulated in Table 2.0.

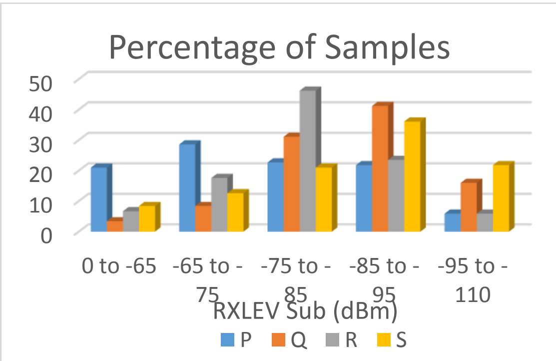


Figure 5.0: RXLEV Sub (dBm) Distribution

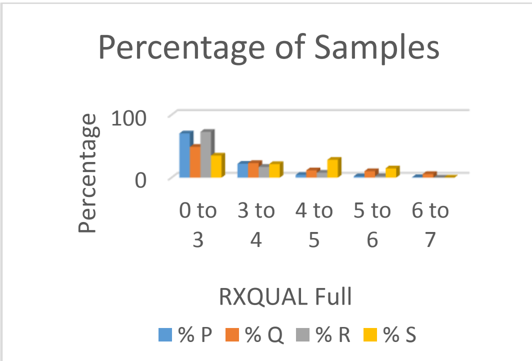


Figure 6.0: RXQUAL Distribution

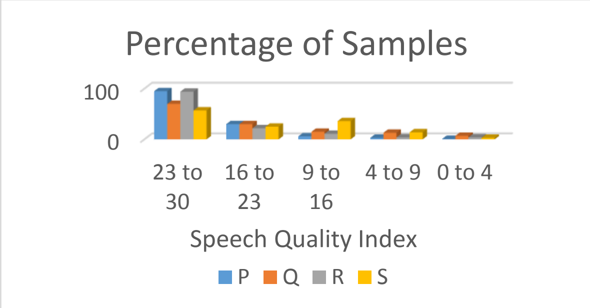


Figure 7.0: Speech Quality Index

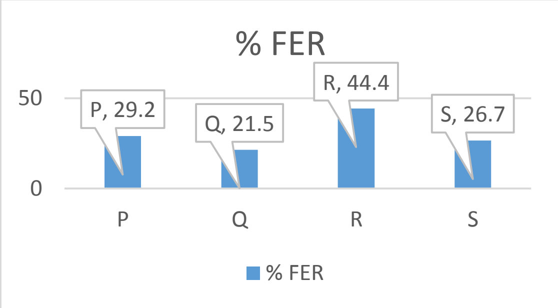


Figure 8.0: Frame Erasure Rate

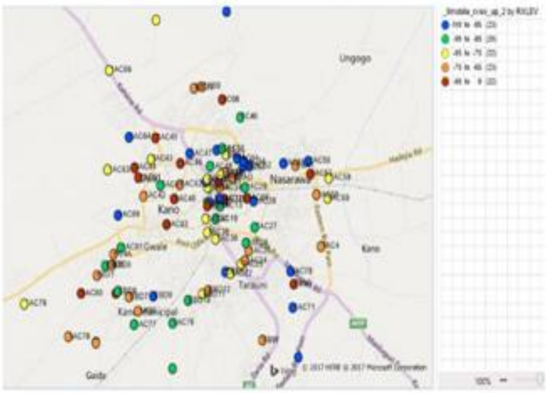


Figure 9.0: P network coverage penetration

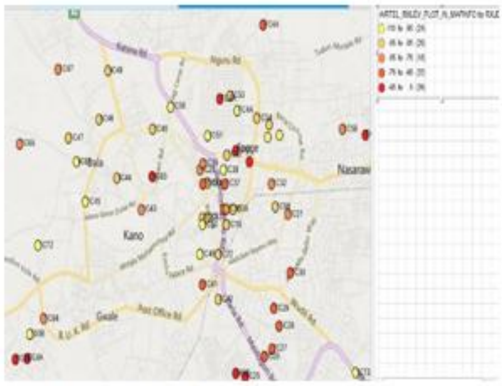


Figure 10.0: S network coverage penetrations

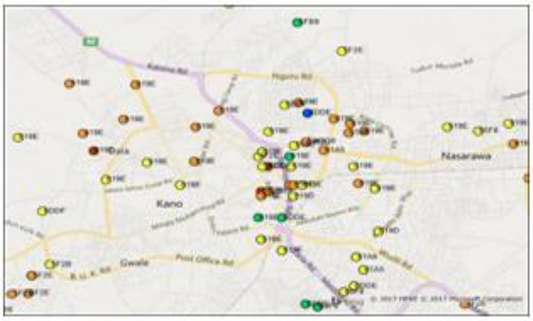


Figure 11.0: R network coverage penetration

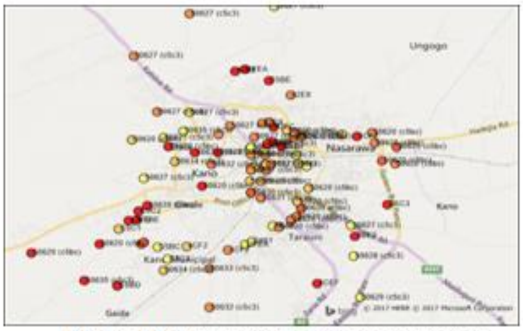


Figure 12.0: Q network coverage penetration

IV. DISCUSSIONS

Observing Figure 5.0, about 21%, 3.4%, 6.7% and 8.4% for P, Q, R and S respectively of the collected samples have excellent quality corresponding to RXQUAL value between 0-3, and about 21.8%, 41.2%, 23.5%, and 36.1% for P, Q, R and S have poor quality which equivalent to the RXQUAL values of 5-6, while 5.9%, 16%, 5.9% and 21.8% for P, Q, R and S respectively have no coverage corresponding to RXQUAL values between 6-7. By inspecting drive tests of each locality in the Metropolis proved that S has the worst network quality followed by Q and R, while P has the best network quality as compared to the aforesaid. The various network ranking according to NCC database was tabulated for the considered carriers in Table 3.0. Let critically examine the sample performances of the four GSM networks in consideration. And to compare the values obtained with the NCC 2017 benchmark (as in Table 1.0); tabulated various recommended parameters with their targets.

Table 1.0: NCC KPIs Target for GSM Network [26]

Key Performance Indicator	CSSR	DCR	HSR	SQI	SDCCH CONG	TCH CONG
NCC Target (%)	>= 98	<= 1	>= 98	>= 3.8	<= 0.2	<= 2

In Table 2.0 the results for the four networks in consideration are grouped into five coverage groups, defined in terms of RXLEV and RXQUAL. Started from the best group (group 1; comprises of the best RXLEV and RXQUAL respectively) through the worst group (group 5; contained worst RXLEV and RXQUAL respectively).

Table 2.0: Data Group Coverage with respect to RXLEV and RXQUAL

GROUP	STATE
1	RXLEV <= 0 to >= -65 RXQUAL >= 0 to <= 3
2	RXLEV >= -75 to <= -65 RXQUAL >= 3 to <= 4
3	RXLEV >= -85 to <= -75 RXQUAL >= 4 to <= 5
4	RXLEV >= -85 to <= -95 RXQUAL >= 5 to <= 6
5	RXLEV >= -95 to <= -110 RXQUAL >= 6 to > 7

Table 3.0 presents the research results based on the NCC general ranking. The system will normally initiate handover when the signal strength is less than or equal to -100 dB, the call is handed over or dropped. In Table 3.0 computed mean average of HOSR was presented, where P network achieved 91.31% slightly below the NCC recommended minimum target, it is ranked first based on the NCC KPIs general ranking, followed by R, S and Q networks with 85.43%, 84.05% and 82.58% respectively, it is not so impressive because all the three networks above performed below NCC recommended minimum targets. Thus, yielded negative intra/inter cell handover effect. Qualitatively, to reinforce and justify the computed results of HOSR for the samples, Table 1.0 indicate the NCC recommended minimum handover target. Therefore significant number of samples performed below the desired target, hence optimization is necessary.

CSSR is a parameter that evaluate the accessibility and retainability of the network as perceived by the end user. Table 3.0 presented the average computed mean of CSSR, only P network achieve a mean value close to the NCC minimum target and was ranked first based on the general ranking. These means that averages of 90.51%, 89.80%, and 87.3% for R, Q, and S networks respectively did not meet the NCC minimum target (as in Table 1.0). Based on the sample performances, CSSR failures were due to call drops and unsuccessful call set-ups, therefore the retainability of the network is very poor. Minimization of dropped calls will greatly improve the CSSR.

The CDR parameter is directly tied to handover and also evaluate the retainability of the network. As in Table 3.0, average values for P and R networks performed close to the NCC minimum target (as in Table 1.0). While the computed average values for Q and S networks respectively did not meet up. Therefore, it is highly significant to note that the retainability of the network is hampered. Optimizing the cell handover and proper selection of values for paging and periodic update can greatly improve the network retainability. With general ranking P is the best followed by R networks, while Q is the worst followed by S networks.

Table 3.0: Summary of the Various Ranking Network Quality Using NCC KPIs Target

OPERATION	P	Q	R	S	GENERAL RANKING	RANKING			
						P	Q	R	S
RXLEV (>-75 dBm)	49.6	11.8	24.3	21	P	1ST	4TH	2ND	3RD
RXQUAL (0-5)	97	85.2	94	87.4	P	1ST	4TH	2ND	3RD
SQI (16-30)	95	70	94	57	P	1ST	3RD	2ND	4TH
CSSR	93.08	89.80	90.51	87.33	P	1ST	3RD	2ND	4TH
HSR	91.31	82.58	85.43	84.05	P	1ST	4TH	2ND	3RD
CDR	1.78	4.86	2.89	5.05	P	1ST	3RD	2ND	4TH
CALL BLOCKING	3.45	5.48	3.71	7.45	P	1ST	3RD	2ND	4TH

3.3 Optimization:

Optimization is a procedure through which the best possible values of decision variables are obtained under the given set of constraints and in accordance to a selected optimization objective function [27]. It is a continuous process. All available information about the network and its status is required as input for the optimisation. Some necessary components like statistical figures, alarms and traffic have to be monitored carefully. Complaints from the customers are also a source of input to the network optimisation team. For indicating potential problems and analyzing problem location both network level measurements and also field test measurements are included in the optimisation process [14].Due to the unwillingness on the part of network carriers to allow researchers to have access to their database, the manual optimizations will only be possible to the four networks in Kano Metropolis. Table 4.0 below contained the proposed parametrical optimization to the networks.

Table 4.0: Some of the parametrical optimizations Recommended

CELL ID	SIGNAL INTERRUPTIONS	DIAGNOSIS	RECOMMENDATIONS
C5C1, 4C6F, 5FB9, 474E…..	Less than -100 dBm	Holes	The previous tilt should be adjusted
61A7, 4C67, 619D, 566B, 2AC2…..	Call Setup Failures	Missing Neighbors	Establish a best server everywhere to clear the Dominance
28E6, 4F72, C5BF, 5727, 1ABF…..	Overshooting of cell & the MS miss the air interface message	Interference	Improve best server area, thereby strong dominance
C5C3, EBD7, 1C08, 1ABF, ……	RRC T3213 and T3226 Timeout	Lack of dominance	Establish a best server everywhere
28E6, 6DDF, EBD9, FCDC, 60D1, ….	Voice Quality degradation	Ping-Pong Handover	The Azimuth & present Tilt should be adjusted. Or to increase the Hysteresis value & introduce a high averaging length for the SS measurement.
566E, 2A32, 2736, FCE1, …..	Suspect signal with center frequency, similar to an analog signal is found	External interference Source	. Solve the internal interference via checking frequency planning . Locate the external interference frequency with Scanner or Spectrum analyser. Finally, adjust the frequencies.

V. CONCLUSION

The research results indicated that the performance of GSM networks in Kano metropolis is still far behind subscribers' expectation and also below the NCC benchmark. The severe network problems were due to signal interference, dropped calls and the congestion rate, that the proposed optimization has removed. The needed KPI values were attained on completion of the three research's techniques. Causes for every fault is identified optimum solution is provided as best way of improvement. The work also helps to validate the claim made by the NCC QoS audit report which said that P Network has the best network quality nationwide as obtained from network operating center (NOC) Statistics. The recommendations above need to be actualized in a live network so that post-drive test can be done to evaluate the performance improvement that is achieved in the network quality. In a nutshell, the research largely achieved the set objectives.

REFERENCES

[1]. Webb, W. (1998). *Understanding Cellular Radio* (1st ed.). Norwood: Artech House, Boston, London.

[2]. Patzold, M. (2002). *Mobile Fading Channels* (1st ed.). West Sussex, England: John Wiley & Sons, LTD.

[3]. Legend Technical Team. (2011). *GSM Radio Network Planning & Optimization*. New Jersey.

[4]. Theodore Rappaport, S. (2001). *Wireless communications: principles and practice* (Vol. 207). Washington, USA: Prentice Hall, Inc.

[5]. Library, D. E. (2004). *Introduction to Wireless Telecommunications, Network Architecture and Functions* (2nd ed.). New york, USA: The McGraw-Hill Companies.

[6]. Upadhyay, R. K., Singh, V. K., & Kumar, R. (2014). Performance analysis of gsm network. *International Journal of Advanced Research in Science and Engineering*, *8354*(3), 244–253. Retrieved from http://www.ijarse.com

[7]. Ozovehe, A., & Usman, A. . (2015). Performance Analysis of Gsm Networks in Minna Metropolis of Nigeria. *Nigerian Journal of Technology (NIJOTECH)*, *34*(2), 359–367. Retrieved from www.nijotech.com

[8]. Ayila, A. E., Oluseyi, F. O., & Anas, B. Y. (2014). Statistical Analysis of Urban Growth in Kano Metropolis , Nigeria. *International Journal of Environmental Monitoring and Analysis*, *2*(1), 50–56. https://doi.org/10.11648/j.ijema.20140201.16

[9]. Nochiri, I. U., Osuagwu, C. C., & Okafor, K. C. (2014). Empirical Analysis on the GSM Network KPIs Using Real- Time Methodology for a Novel Network Integration. *Progress In Science and Engineering Research Journal*, *2*(3), 092–107.

[10]. Andleeb, M., & Ali, S. A. (2015). A Study on the Hourly Behavior of Key Performance Indicators of Global System for Mobile Communications, *6*(3), 169–173.

[11]. Boulmalf, M., Abrache, J., Aouam, T., & Harroud, H. (2009). Traffic Analysis for GSM Networks. In IEEE/ACS (Ed.), *International Conference on Computer Systems and Applications* (pp. 498–503). IEEE/ACS.

[12]. Mkheimer, B., & Jamoos, A. (2012). Evaluation and optimisation of GSM network in Jenien City, Palestine. *International Journal of Mobile Network Design and Innovation*, *4*(4), 201–213. https://doi.org/10.1504/IJMNDI.2012.054458

[13]. Olabisi, P. O. (2014). Trend Analysis of Key Cellular Network Quality Performance Metrics. *International Journal of Engineering Sciences & Research Technology*, *3*(7), 916–925. Retrieved from www.ijesrt.com.

[14]. Alam, M. A. (2013). *Mobile Network Planning and KPI Improvement*. Linnaeus University, Sweden.

[15]. Galadima, A. A. (2014). *Analysis and Otimisation of Inter Cell Handover Dynamics In a GSM Network (A Case Study of Airtel Kano, Nigeria)*. Ahmadu Bello University, Zaria, Nigeria. Retrieved from www.abu.edu.ng.
[16]. Yuwono, T., & Ferdiyanto, F. (2016). RF measurement and analysis of 2G GSM network performance, case study: Yogyakarta Indonesia. *2015 IEEE International Conference on Smart Instrumentation, Measurement and Applications, ICSIMA 2015*, *4*(3). https://doi.org/10.1109/ICSIMA.2015.7559010
[17]. Mishra, A. R. (2007). *Advanced Cellular Network Planning and Optimisation: 2G/2. 5G/3G... Evolution to 4G*. *John Wiley & Sons Ltd*. (second). West Sussex, England: John Wiley & Sons Ltd. https://doi.org/10.1002/9780470057629
[18]. [18]Popoola, J. J., Megbowon, I. O., & Adeloye, V. S. A. (2009). Performance Evaluation and Improvement on Quality of Service of Global System for Mobile Communications in Nigeria. *Journal of Information Technology Impact*, *9*(2), 91–106.
[19]. Adegoke, A. S., & Babalola, I. T. (2011). Quality of service analysis of GSM telephone system in Nigeria. *American Journal of Scientific and Industrial Research*, *2*(5), 707–712. https://doi.org/10.5251/ajsir.2011.2.5.707.712
[20]. Idigo, V. E., Azubogu, A. C. O., Ohaneme, C. O., & Akpado, K. A. (2007). Real-Time Accessments of Qos of Mobile Cellular Networks in, *1*(6), 64–68.
[21]. Oluwajobi, E., & Idowu, F. (2015). Comparative Analysis of The Received Signal Strength Measurement of GSM Network in Owo , Ondo State Nigeria. *International Journal of Emerging Technology and Advanced Engineering*, *5*(7), 305–311.
[22]. Ascom, N. T. I. (2013). *TEMS Pocket 7.2/10.2 for Sony Ericsson W995 and W995a-User's Manual*. 1943 Isaac Newton Square, Reston, USA.
[23]. Inc., P. B. S. (2016). *US patent 5,710,835*. California: US and International Patent.
[24]. Lehtimaki, P. (2008). *Data Analysis Methods for Cellular Network Performance Optimization*. Helsinki University of Technology, Espoo, Finland.
[25]. Ghoraishi, M., Takada, J., & Imai, T. (2013). *Radio Wave Propagation Through Vegetation* (5th ed.). Tokyo: Tokyo Institute of Technology Press, Japan. https://doi.org/10.5772/52571
[26]. www.ncc.gov.ng
[27]. Ali, M. H., & Ibrahim Yusuf (2016). Dynamic Estimation of Photovoltaic Module Parameters Using Differential Evolution (DE) Algorithm. Bayero Journal of Physics and Mathematical Sciences, 7 (1), 170-181.
[28]. ITU-T E.800. (2008). *Definition of Terms related to quality of service*. Melbourne.

S.B. Abdullahi" Performance Analysis of GSM Networks In Kano Metropolis Of Nigeria"American Journal of Engineering Research (AJER), vol. 7, no. 5, 2018, pp.69-79.