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Comparative Analysis of GSM Networks Communication Congestion in Zaria

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ABSTRACT-The study of congestion on GSM networks in Nigeria is necessary as congestion remains a major challenge to telecommunications services provision both to service providers and subscribers. The subscribers are compelled to quit the service provider who fails to meet up with the services required by them. This occurs at a time when the wide spread use of mobile communication has heightened consumers' demand for quality of service anytime, anywhere. Today, network operators face challenges of improving the quality of services. Operators are fast realizing that they are in a highly competitive environment, where subscribers can easily quit them. Dissatisfaction by subscribers gives rise to a high rate of subscriber churn (a situation of stopping doing business with the company or service) and low revenue for the operator. Congestion is a problem all GSM service providers are facing and trying to resolve. Drive test was conducted using Transmission Evaluation and Monitoring System (TEMS) software and congestion was analyzed to check the performance of Etisalat, and MTN Networks in Zaria and methods for its improvement were suggested.
Keywords- QoS, KPIs, ITU, Cellular Network and Congestion

I. INTRODUCTION

A cellular telephone is designed to give the user maximum freedom of movement. As a result of this freedom, the number of mobile users keep growing at an alarming rate. The role of cellular phones has risen with the improvement in services, reduction in service cost, and the ever increasing range of services available through cell phones and as a result, subscribers possess multiple lines on the same or various networks, all of which have contributed to the challenge of congestion (Kuboye etal, 2010).The cellular system began in the United States of America with the release of the Advanced Mobile Phone Service (AMPS) system in the year 1983, Asia, Latin America, and Oceanic countries adopted the AMPS standard
creating the largest potential market in the world for cellular service (Mehrotra, 2015).

GSM was introduced to solve the problem of capacity, high-level of interference, high power consumption, signaling issues, inefficient use of radio spectrum and so on, which were faced in the analogue mobile system. The technology was embraced by everybody considering the advantages a GSM has, such as increase in the number of simultaneous user and clarity of voice communication, in addition to those problems of AMPS it resolved. GSM revolution in Nigeria started in August 2001, and this brought a great change in the ICT. The Nigerian telecommunications industry is rapidly growing, and many operators and their operations put forth different services, but in the diverse services provided, most of the subscribers do not receive satisfaction due to the poor nature of services available on these networks. With the rapid growth of the wireless industry, GSM networks are rolling out and expanding at a high rate. The industry is also becoming intensely competitive. In this environment, high quality service is a competitive advantage for service providers. A lot of effort is made by a network operator to monitor the network and maintain current, comprehensive and accurate status of its quality. This status together with new traffic demand data is used by the operators to improve the Quality of Service (QoS) of their networks and adjust their Operations QoS of mobile cellular networks which was defined by ITU-T Rec E. 800 as "the collective effect of service performance that determine the degree of satisfaction of a user of the service" has many performance attributes or metrics which have continue to give telecommunications experts and operators lot of keen consideration for continual optimality. In GSM, parameters used include network accessibility, retain-ability, mobility, and service integrity. According to ITU standard, all these are affected by system configuration or/and dimensioning. Since the QoS is very important, then researching into factors affecting this QoS is equally very important. This research work focuses on carrying out investigation on the parameters that determine the QoS in GSM technologies for the mutual benefits of both subscribers and network operators.

II. RELATEDWORKS

Popoola *et al.*, (2012) evaluated the network performance and QoS of GSM cellular system in Nigeria using Key Performance Indicators (KPIs). The result of the study showed that the QoS of GSM system in the country was unreliable, poor, and unsatisfactory. The limitation in their work was the fact that the assessment and the performance evaluation were carried out by using structured questionnaire which could not be appropriate for standard QoS measurement analysis.

Shoewu *et al*., (2011) presented a report on the QoS of network optimization and evaluation of KPIs provided by GSM operators considering the ability to establish and maintain call connections, call retention, handover, inter and intra network call setup. The work consequently developed a model of service quality and a set of dimensions for comparative evaluation which were opined to direct regulators and service providers. The major problem of this work was that, the ability to establish and maintain call connections, call retention, handover, inter and intra network call setup could not be used for the comparison of the QoS Performance of various GSM Operators.

Louge, (2011) used subscribers' perception of the quality of service of GSM services in Nigeria to determine the network performance through a questionnaire titled "user perception of the QoS of GSM Service providers in Ibadan, Nigeria to gather responses from users. The responses were presented using descriptive statistics and data collated using inferential statistics. Finding from the questionnaire showed that a significant number of respondents were not satisfied with the QoS provided by the operators. They experienced epileptic services, call drops, low voice call quality, poor interconnectivity, and poor reception on the network. The major problem of this work was that the work seemed like work that was carried out based on sample opinion. Just using questionnaire to take statistics by sample opinion could not establish or justify assessment or performance evaluation of QoS.

Agago *et al*., (2012) optimized GSM network performance with respect to efficiency by developing a pilot study. Simulations were carried out to assess various parameters and recommendations were made on how to improve the efficiency of the wireless communication network. The limitation of this work was the fact that the work was based on optimizing the efficiency of wireless communication network which could not be used to determine or compare the QoS of GSM Network.

Ndife *et al.*, (2013) carried out an evaluation and optimization of QoS of mobile cellular networks in Nigeria using drive test but without considering the KPIs. With this, a holistic network optimization model using an Adaptive Network-based Tuzzu Inference System (ANFIS) algorithm was developed. The limitation of this work was that drive test could not give a standard performance measurement of QoS Analysis in a GSM network.

Innocent(2015) uses ANFIS and ANN features to evaluate the performance of GSM network Call Set-up Success Rate(CSSR) of MTN Kano region. Innocent's paper focused only on corporate analysis of the measured (CSSR) to that of estimated using (ANFISS) and (ANN) model.

Marshal, (2015) carried out the assessment ofQoS over GSM network using KPIs, in his work Marshal,2015 selected Etisalat Nigeria in Kano and Katsina as a case study, only that the study covers virtually the areas mentioned and the results may not be specific.

Having observed the limitations of the above literatures reviewed, this research came up with a better method in accordance with the standard for Congestion Comparative Analysis and measurement of the QoS in GSM Cellular network. The work considered the major KPIs such as TCH and SDCCH that were used in Congestion Comparative Analysis in GSM Cellular Network. The data used in this research were obtained directly from network operators through drive testnot through opinion sampling. The data were directly from BSC and BTSs of Etisalat, and MTN in Zaria. The research also described the causes and impacts of TCH and SDCCH congestion rate and provided measures to reduce the congestion rate and optimize the KPIs. The research also provided the models for allocation of calls within GSM network based on the network capacity and traffic, distribution procedure and optimization method and algorithm for implementing the models to manage congestion of calls in GSM network. All these are what the operator needs to use to improve service level of a GSM Communication Network.

III. Methodology/Materials

The methodology adopted in carrying out this research included the following;

Collection of data(by means of drive test) from BSC and BTSs of Etisalat and MTN-Zaria from 1st January to 30th June,2017

Generating the data collected to a MapInfo-format for the purpose of plotting drive test information, view a cellular network with sites and cells and for analysing key performance indicators(KPIs) of the system.

Analysis and Extraction of relevant parameters from the data collected for comparing the performance of the two networks.

Transmission Evaluation and Monitoring System (TEMS) investigation software was used to analyse the data to achieve the improved voice quality, increased accessibility, more successful call attempts and better service performance.

Materials

The drive test equipments required in performing cluster test and data collection are;

- Laptop as a user interface that displays all information during RF drive testing. It is the user interface where drive test software such as Transmission, Evaluation and Monitoring System (TEMS), MapInfo and MS-excel are installed and hardware such as scanner, external GPS and mobile phone are connected
- Dongle as a small modem that enables a user to connect to the Internet using mobile phone.
- TEM software from ASCOM as the backbone of RF drive testing optimization tool. It is used to obtain all RF parameters for data collection and data analysis.
- Laptop as a user interface that displays all information during RF drive testing. It is the user interface where drive test software such as Transmission, Evaluation and Monitoring System (TEMS), MapInfo and MS-excel are installed and hardware such as scanner, external GPS and mobile phone are connected
- Dongle as a small modem that enables a user to connect to the Internet using mobile phone.
- TEM software from ASCOM as the backbone of RF drive testing optimization tool. It is used to obtain all RF parameters for data collection and data analysis.
- External GPS (Global Positioning System) as a device connected externally to Laptop collecting the data of latitude and longitude of each point/measurement data, time, speed, etc.
- MS-Sony Ericsson TEMS phone used for collecting data such as signal strength, best service, etc. It is also used for making short call and long call during RF drive testing for drop call rate optimization evaluation.
- Scanner that is used in collecting data through the network because mobile radio is limited and does not handle all the necessary data for complete RF analysis.

Figure 1. Laptop

Methods of Data Collection

The data were obtained from Etisalat and MTN Nigeria, Zaria Metro-police, comprising TCH, SDCCH, CSSR, CCR, CDR, CST, and TCHASR for the period of 6 months (from 1st January to 31st June 2017). Test routes were planned to include all the roads(around PZ) which are covered by different sectors of the sites under study. Also, the main streets around the BTSs, BSC were included. The test routes reached the overlapping areas of surrounding neighbour cells. This ensured the proper verification of the actual coverage area of the sites and the handover functions.

Drive Test

Drive test is the process of data collection from the GSM network so as to check the network performance by means of coverage evaluation, system availability, network capacity, network retain-ability and call quality. This is accomplished by checking the status of KPIs like receive level, receive quality, Speech quality and so on, in order to make appropriate recommendations where necessary for effective optimization. The drive test was carried out in a dedicated manner to identify the eventual black spots(radio coverage, holes) present within Zaria Metropolis. The logs recorded during the test were analysed and recommendations were made to improve the QoS in the City. The drive test investigated what the mobile users experienced on the radio network in the area. This was done by collecting data related to the radio network itself, services running on the network, radio frequency scanner information, and geographical positioning data to enable mobile station location logging.

Benchmarking drive test involves comparing the network performance in terms of network accessibility, retain-ability, mobility, data throughput and service integrity. This enables the network operator to know its rank among other competitors and where necessary improvement action needed. After drive test data collection using TEMS software, the data were analysed to check the event summary such as call attempts, call completion, drop calls, and blocked calls. Also, graphical representation of the data was drawn to be able to understand how the network plots of 2G and 3G signal levels, 2G and 3G signal quality, and other events summary that were represented graphically.

TEMS Investigation Interface

TEMS investigation is the industry-leading solution for troubleshooting, verification, optimization, and maintenance of wireless networks. TEMS investigation has powerful, versatile features that are essential throughout the network's lifecycle. Using TEMS investigation, operators can achieve improved voice quality, increased accessibility, more successful call attempts, and better service performance. Support for GSM, GPRS, EDGE, WCDMA, HSPA, and GAN (UMA), CDMA (IS-95 to EV-DO Rev A),and now the addition of WiMAX technology functionality, further demonstrates that TEMS investigation is the ideal choice for network operators. TEMS investigation also offers true multi-vendor support in addition to its multi-technology infrastructure support. It supports handsets from all major vendors across multiple technologies. Its measurement and reporting functions have general features that can be applied to any event or radio parameter that is measured. These features include a real-time map display and a report generator, allowing quick verification of the cell coverage. The map functionality in TEMS investigation provides basic statistics and the distribution of an arbitrary area selection plotted on the map. The route analysis module allows the user to work with multiple log files when post-processing the data by performing tasks such as statistical binning and benchmarking. TEMS investigation offers operators one tool with the ability to collect, analyse, and post-process the net-work data used on a daily basis for network monitoring, troubleshooting, and optimization. This complete solution eliminates the need for multiple tools, reducing costs and saving time, and effort for operations staff. In addition, TEMS investigation gives operators a way to utilize all the benefits of network data while at the same time protecting its integrity. TEMS Investigation collects data beyond the abilities of other tools on the market. In addition to all standard parameters, it employs specialized developed algorithms to collect unique information not available in other vendors' tools. For example, the Sony Ericsson Z750 (Triband HSDPA/WCDMA, Quadband GSM/EDGE) now offers powerful WCDMA scanning capabilities. This model is a cost-effective, conveniently slim tool for solution for the agile field engineer. TEMS investigation gives efficient work processes that allow operators to focus on network quality.

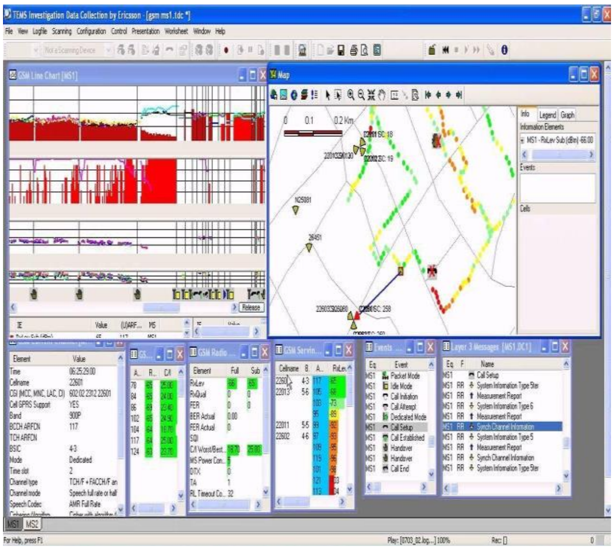

Figure 2 TEMS Investigation Interface

TEMS Discovery

TEMS discovery is the wireless industry's most holistic network analytical and optimization platform, providing mobile operators and their service providers with unparalleled insight into network performance as it is perceived by subscribers at the device, the application and the network level. This holistic approach is unique to TEMS Discovery, empowering operators to lock-in premium subscribers by validating that customers receive the service levels they demand, around-the-clock, from any location, and across voice, data and integrated media services. TEMS Discovery automatically analyses drive-test, User Equipment (UE), network OSS, crowdsourced, and application data, providing actionable intelligence via a Web-based management dashboard. TEMS Discovery enterprise offers a variety of analytical packages for customer experience, VoLTE, indoor, capacity (traffic hotspots and small cell); SON; handset analysis; subscriber KPIs, and benchmarking. TEMS Discovery is available in its flagship enterprise edition, as well as desktop editions that enables engineers to drill down into UE (collected from TEMS and third-party tool vendors) and OSS data (collected from Ericsson, Nokia Siemens Networks and Huawei).

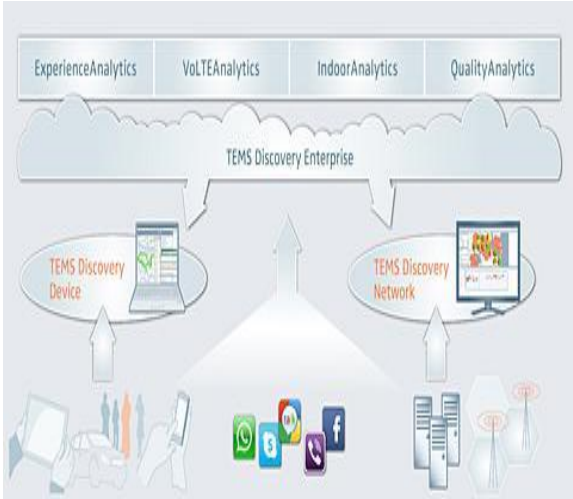

Figure 3 TEMS Discovery

Drive Test Route

Quality routes are pre-defined pathways and that must be performed periodically, usually 2 to 2 months. These routes should cover the relevant areas of the network, such as large customers and companies, bridges and major Avenues, etc. long ago. These routes were marked in printed maps and delivered to the staff responsible for performing the Drive Test. Currently, it is more common the creation and use of these routes in vector files, lines drawn on GIS programs such as Map-info and Google Earth.

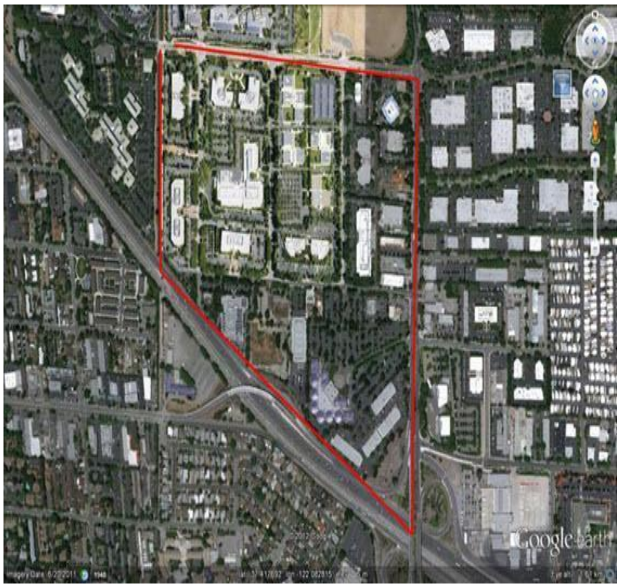

Figure 4 Drive Test Route

Figure 5 Zaria Test Route

IV. Results and Discussion

From the data obtained in the site, the Tables 1 and 2 show the call events statistics results which compare the performance of the two networks.

Table 1 Summary of 2G Call Events Statistics Overall Voice

Event details	Etisalat	MTN
Call attempt	153	334
Call attempt retry	02	31
Call initiation	152	335
Call end	152	321
Call established	150	321
Call setup	150	1
Blocked call	0	1
Dropped call	1	3
Handover	559	526
Handover failure	0	13
Location area update	42	49

Table 2 Summary of 3G Call Events Statistics Overall Voice

Event detail	Etisalat	MTN
Call attempt	170	356
Call attempt retry	2	34
Call initiation	170	361
Call end	169	323
Call established	168	332
Call setup	169	332
Blocked call	0	21
Drop call	0	9
Handover	83	396
Handover failure	0	10
Location area update	42	112

Speech Quality Index

Speech Quality Index (SQI) is a quality of speech of a network. It is designed to cover all factors that Received Signal Quality (RxQual) lack to measure. SQI computation considers the Bit Error Rate (BER), the Frame Erasure Rate (FER) and data on handover events. The Figures4.1 and 4.2 show the speech quality index for Etisalat and MTN network operators from data collected.

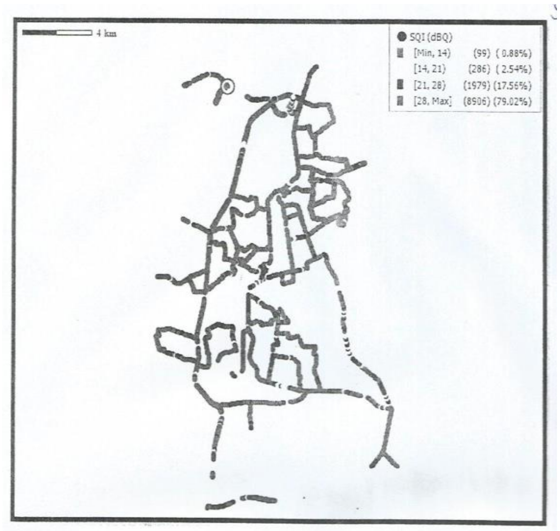

Figure 6 Etisalat 2G SQI Drive

Figure 6 shows the speech quality index of Etisalat 2G network the best SQI is 28 and above whose measurement counts of 8906 points and it also has the highest proportion of counts. Below 14 represent or bad SQI and it has the smallest measurement point of 99. This indicates that the SQI of this network is strong and better than MTN.

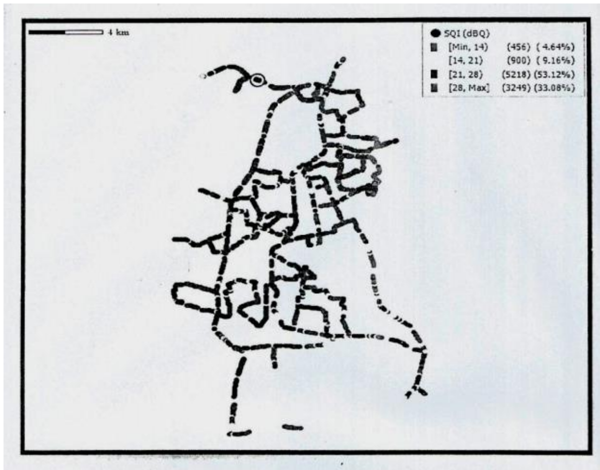

Figure 7 MNT 2G SQI Drive

Figure 7 shows the SQI of MTN 2G network. The best SQI is 28 and above whose measurement counts of 3249 point while the SQI with the highest proportion of counts falls within 21-28 with a point of 5218. Below 14 represent a bad SQI and it has the smallest measurement point of 456. This indicates that the SQI of this network is strong but not as strong as Etisalat.

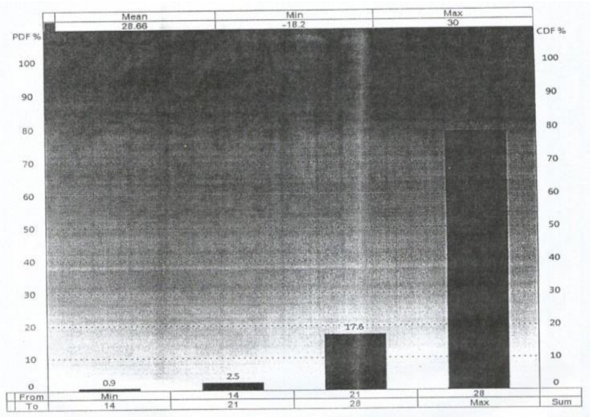

Figure 8 Etisalat 2G SQI Histogram Plot

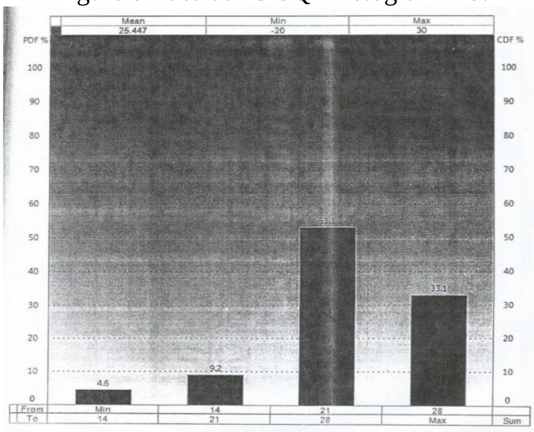

Figure 9: MTN 2G SQI Plot

Figures 8 and 9 show SQI histogram plots for Etisalat and MTN networks, respectively. From the histogram it is observed that the SQI for Etisalat network is the best because it has higher percentage of maximum SQI. The congestion rate of MTN network is higher than that of the Etisalat network.

Signal Quality

For 2G network, it is denoted as received signal quality (Rx Qual) and for 3G energy per chip per noise density (Ec/Lo). It is the measure of signal quality and the unit is dBm. The Figure 10 shows the signal quality for Etisalat and MTN network operators from the data collected.

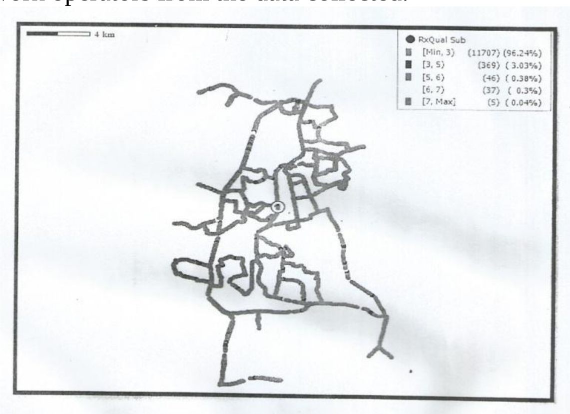

Figure 10 Etisalat 2G RxQual Drive Test

Figure 10 shows the received signal quality level Etisalat 2G network, measured base on BER. The value is between 0 and 7, the lower it is the better. The received signal quality of a larger proportion of the measurement point (11707) falls within the range of 0-3. Also the best received signal quality level of the lowest received signal quality falls into 7 and has the measurement points 5.

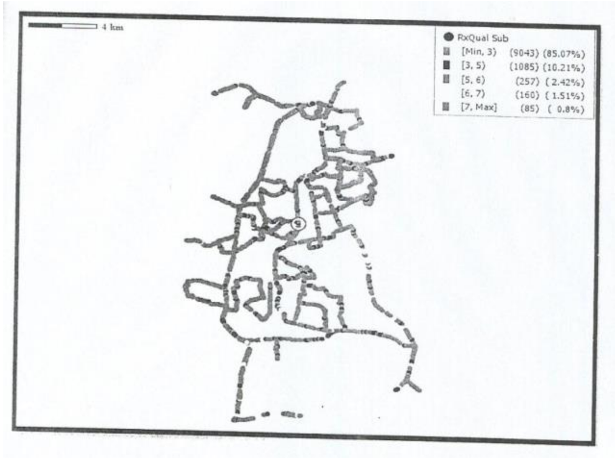

Figure 11 MNT 2G Rx Qual Drive

Figure 11 shows the received signal quality level for MTN 2G network, measured based on BER. The value is between 0 and 7. The RxQual of a larger proportion of the measurement point (9043) falls within the range of 0-3. Also the best received signal quality level and the lowest received signal quality falls into 7 and has the measurement point 85.

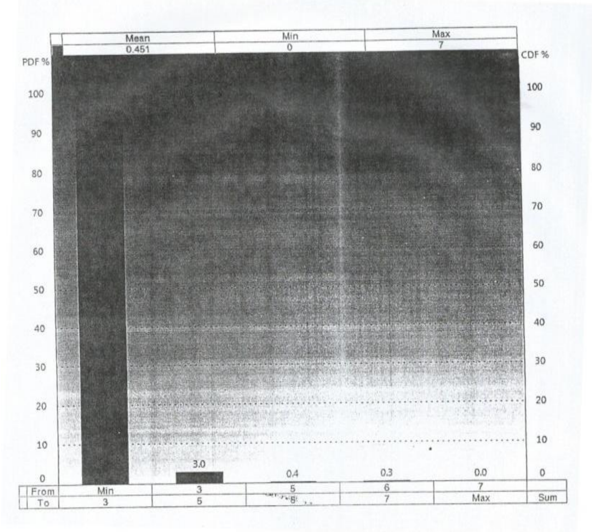

Figure 12 Etisalat2GRxQualPlot

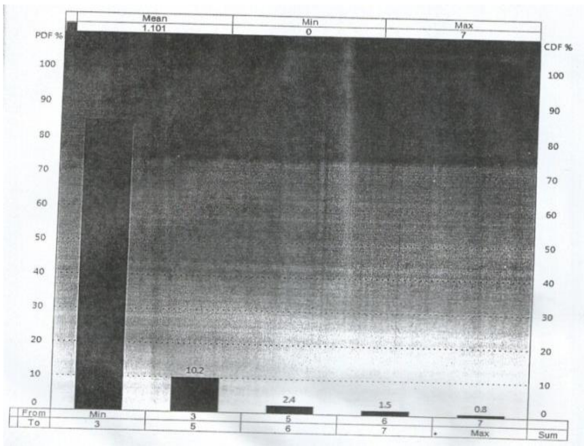

Figure 13 MTN “2G RxQual Plot

Figure 12 and 13 show RxQual histogram plots of Etisalat and MTN 2G networks, respectively. The plots show how the comparison of RxQual between Etsialat and MTN networks. It is observed that the RxQual of Etisalat is the better because it has highest percentage of minimum BER. Thus, it implies that Etisalat subscribers experience better received signal quality and low congestion compared to MTN subscribers in the area.

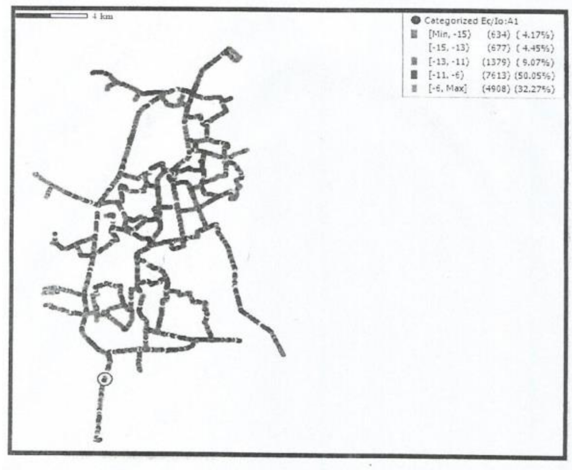

Figure 14 Etisalat 3G Ec/Lo Drive

Figure 14 show the received signal quality level Etisalat 3G network Ec/Lo, measured base on BER. The value is between -15 and - 6, the it is higher the better. The received signal quality of a larger proportion of the measurement point (7613) falls within the range of -11 to –6, and it is a good received signal quality level of the lowest received signal quality that falls into-15 and has the measurement point of 634.

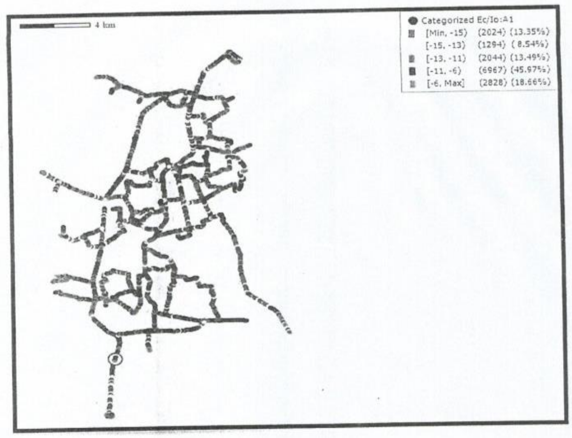

Figure 15 MNT 3G Ec/Lo Drive

Figure 15 shows the received signal quality level for MTN 3G network Ec/Lo, measured base on BER. The value is between -15 and -6. The received signal quality of a larger proportion of the measurement point of 6967 falls within the range of -11 to -6 and it is a good received signal quality level and the lowest received signal quality that falls within the range of -15 to -13 and has the measurement point of 1294.

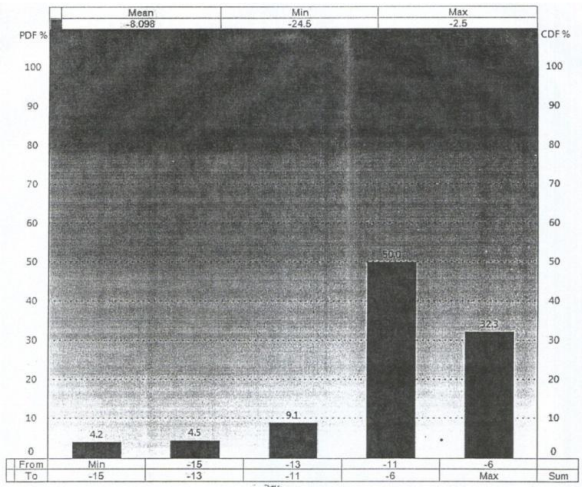

Figure 16 Etisalat 3G Ec/Lo Plot

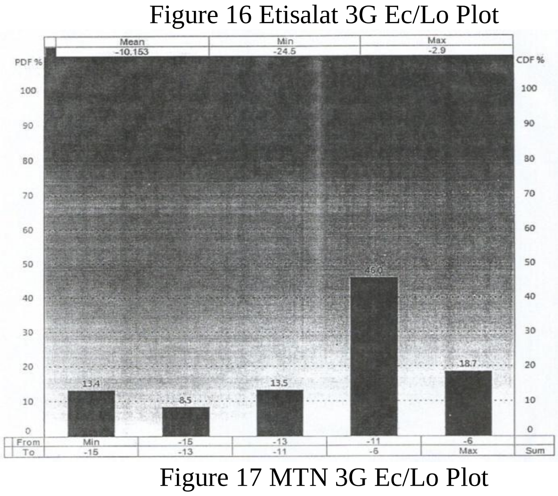

Figure 17 MTN 3G Ec/Lo Plot

Figure 16and 17 show energy per chip per noise density Ec/Lo histogram plots of Etisalat and MTN networks, respectively.

It can be observed that the Ec/Lo for Etisalat network is better than MTN network because it has higher percentage of best Ec/Lo level. Thus the network quality of Etisalat is better than MTN network.

Network Coverage

This determines the area that a network can cover. For 2G networks it is termed as Received Signal Level (Rx Level) and for 3G networks it is termed as Received Signal Code Power (RSCP). This is the signal power level (signal strength).The pilot channel of a cell is received and usually expressed in dBm. With this parameter different cell using the same career can be compared and handover or cell reselection decision can be taken. Figures 16 and 17show the network strength for Etisalat and MTN network operators from data collected.

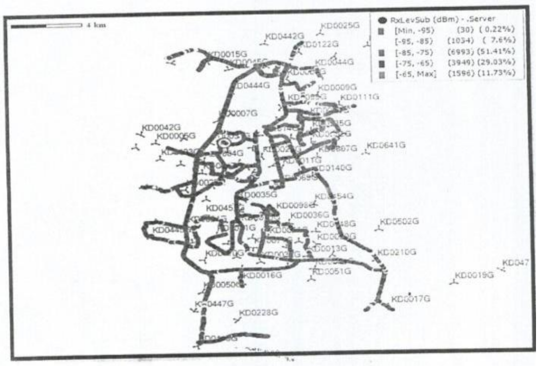

Figure 18 Etisalat 2G Rx Level Drive

Figure 18 shows the coverage plot of the received signal level obtainable on the networks at different mobile user locations for Etisalat 2G network. The analysis of this result revealed that approximately 13,600 measurement points were collected during the drive test. The received signal strength of a larger proportion of the measurement points (6993 points) fell within the range of -85 to -75 dBm. Higher signal values of -65 to 0 dBm were received at 1596 measurement points. The lowest received signal level range of below – 95dBm was experienced at 30 measurement points within the coverage area.

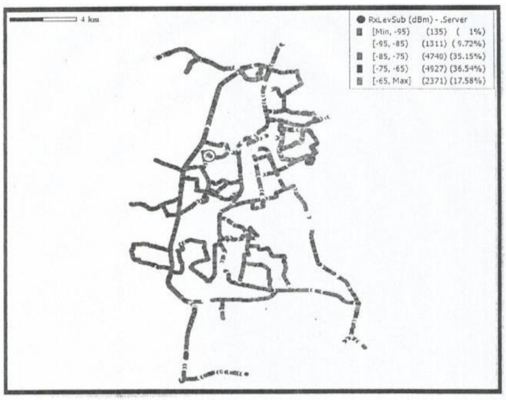

Figure 19 MTN 2G Rx Level Drive

Figure 19 shows the coverage plot of the received signal level obtainable on the networks at different mobile user locations for MTN 2G network. The analysis of this result revealed that approximately 13, 480 measurement points were collected during the drive test. The received signal strength of a larger proportion of the measurement points of 4927 points fall within the range of -75 to -65 dBm. Higher signal level values of -65 to 0 dBm were received at 2371 measurement points. The lowest received signal level range of below -95dBm was experienced at 135 measurement point within the coverage area.

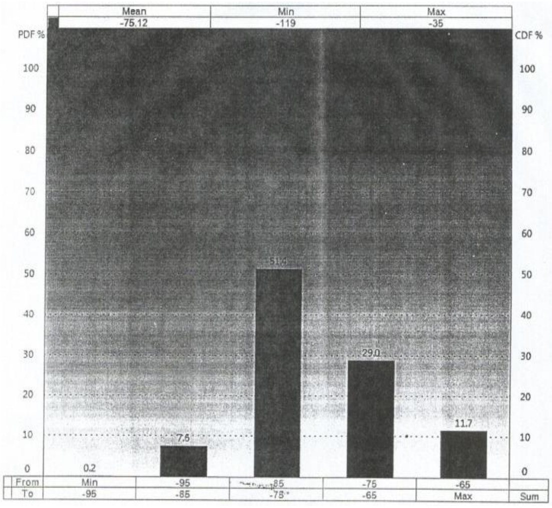

Figure 20 Etisalat 2G Rx Level Plot

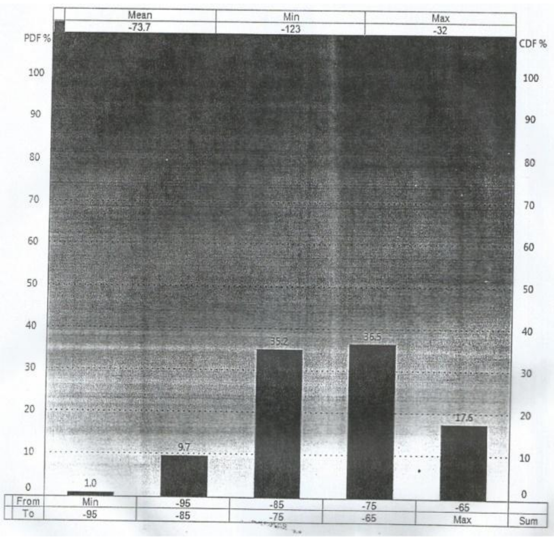

Figure 21 MTN 2G Rx Level Plot

Figure 20 and 21 show Rx Level histogram plots of Etisalat and MTN networks, respectively. From the plots it was deduced that the Rx Level of MTN network is better than Etisalat because it has higher percentage of best Rx Level.

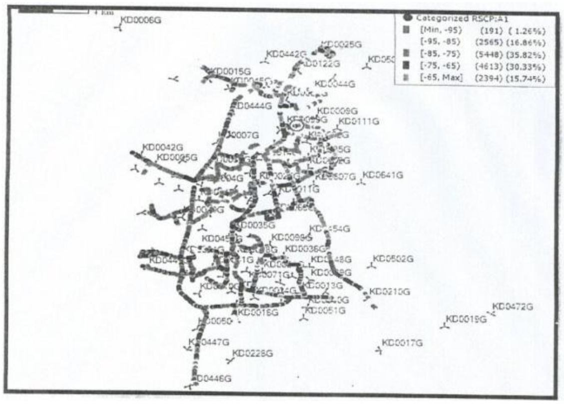

Figure 22 Etisalat 3G RSCP Drive

Figure 22 shows the coverage plot of the received signal level obtainable on the networks at different mobile user locations for Etisalat 3G network RSCP. The analysis of this result revealed that approximately 15,200 measurement points were collected during the drive test. The received signal strength of a larger proportion of the measurement points of 5448 fall within the range of -85 to -75 dBm. Higher signal level value of -65 to 0 dBm were received at 2394 measurement points. The lowest received signal level range of below -95dBm was experienced at 191 measurement points within the coverage area.

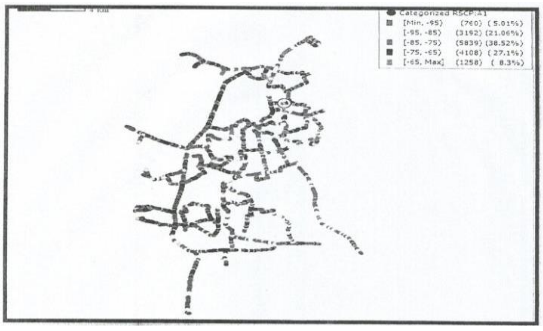

Figure 23 MTN 3G RSCP Drive

Figure 23 shows the coverage plot of the received signal level obtainable on the networks at different mobile user locations for MTN 3G network RSCP. The analysis of this result revealed that approximately 15,100 measurement points were collected during the drive test. The received signal strength of a larger proportion of the measurement points of 5839 fall within the range of -85 to -75 dBm. Higher signal level values of 65 to 0 dBm were received at 1258 measurement points. The lowest received signal level range of below -95 dBm was experienced at 760 measurement points within the coverage area.

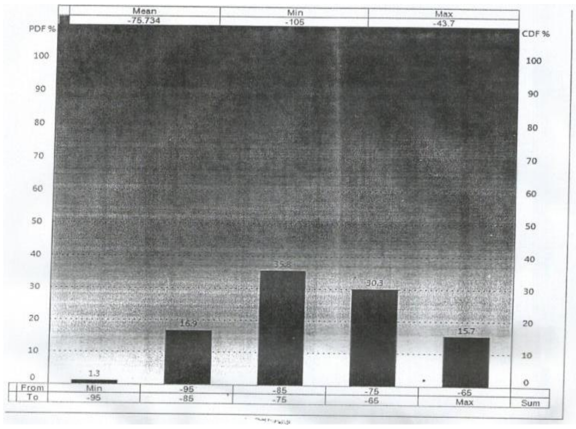

Figure 24:Etisalat3GRSCPPlot

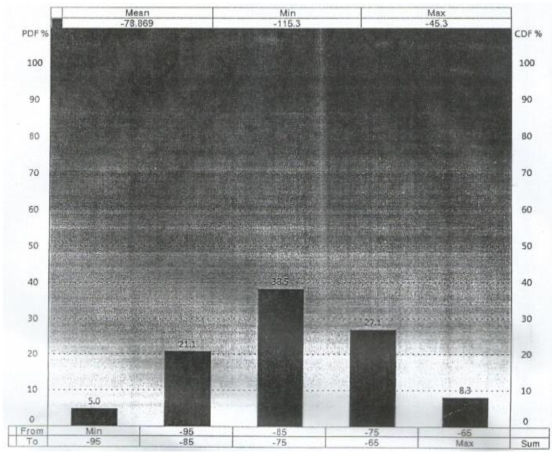

Figure 25 MTN 3G RSCP Plot

Figure 24 and 25 show received signal code power histogram plots of Etisalat and MTN networks respectively. It is observed, from the plots that RSCP for Etisalat network is better than MTN network because it has the high percentage of best RSCP and this has significant effect on the network performance in general.

Discussion

From the results analysed, the received signal code power and energy per chip per noise density for 3G Etisalat network is better than that 3G MTN network. Also, signal quality index received signal level and received signal quality for 2G ETISALAT network is better than that of 2G MTN network.
In general, the ETISALAT network performance is the better in the area where the drive test was conducted which implied that subscribers on ETISALAT network experienced low congestion.

V. Conclusions

With technological advancement in this age, 2G and 3G planning has been a very interesting task due to availability of updated digital terrain data. 0Subscribers' growth has posed a great demand for network rollout and expansion, software and hardware upgrade basically towards coverage and capacity expansion. In order to achieve the best performance, service providers have to monitor and optimize their network continuously. Therefore, good optimization models will go a long way in helping the GSM operators to deliver good and qualitative service to the subscribers.

KPI monitoring schedule should be done in such a timely manner of routine checks on networks, network audit, performance test, cluster acceptance test, and analysis to ensure compliance with NCC regulations.

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