International Journal of Engineering and Environmental Sciences | *ISSN 1694-4372*
Published by ACADEMIC INK REVIEW | *https://airjournal.org/ijees*
12011 WestBrae Pkwy, Houston, TX 77031, United States
airjournals@gmail.com; enquiry@airjournal.org

Performance Analysis of 3G and 4G LTE Networks and the Need for Automatic Mobile Number Portability

Onuigbo, C. M.[1], Onoh, G. N.[2] and Inyiama, H. C.[3]

[1&2]Department of Electrical/Electronic Engineering
Enugu State University of Science and Technology, Enugu, Nigeria

[3]Department of Computer Engineering
Baze University, Abuja, Nigeria

Publication Process	*Date*
Accepted	***December 23rd, 2021***
Published	***December 31st, 2021***

ABSTRACT

Experimental work was carried out to establish the features of three out of four networks operators in Nigeria; MTN, GLO, and AIRTEL using TEM Navigation 16 equipment. The results of these comparisons were used to buttress the need for automatic mobile number portability (AMNP) and also establish the conditions that must be met for AMNP to take place. The experimental setup and data collection were achieved in extensive drive tests in both 3G and 4G LTE environments in the three networks within the Metropolitan City of Port Harcourt in Rivers State, Nigeria. Key performance Indicators evaluated were Stand Alone Dedicated Channel (SDCCH), Call Setup Success Rate (CSSR), Call Drop Rate (CDR), Call Block Rate (CBR), and Handover Success Rate (HOSR) for the 3G networks, and Reference Signal Received Power (RSRP), Reference Signal Received Quality (RSRQ), and Through put analysis for the LTE networks respectively. Data presentation showed how these KPIs varied, presenting need for AMNP to ensure seamless interconnectivity between networks. The results showed that all the operators at one time or the other did not comply with the stipulated performance threshold values as recommended by the Nigerian Communications Commission for all the Network operators in Nigeria. This led to the articulation of some conditions upon which porting was predicated to ensure network availability no matter the location.

Keywords: *Key Performance Indicators, Mobile Number Portability, Network Operators, 3G and 4G LTE*

1. Introduction

A swift turnaround has been recorded in Nigeria's wireless communications industry from predominantly analog technology to digitized technology in the past two decades. Owing to this growth, statistics have ranked Nigeria as one of the fastest-growing countries in the telecommunications industry in Africa. With this growth, the industry has been grappling with the ever-increasing challenge of satisfying the number of subscribers who hope to enjoy the services offered by the communication operators. The increase in the number of subscribers on the various communication operators in Nigeria has resulted in the admission of more subscribers thereby causing congestion. As a result, blocked calls, dropped calls, degraded signal quality, unsuccessful handover attempts to neighboring cells, and occasional service outages, among others, were the observed challenges faced by subscribers (Ozovehe et al., 2015). It has also been observed that calls across different networks are always difficult to connect; sometimes they are diverted and also attract unnecessary costs. From the analysis carried out, the three main network operators in the country, at one time or the other, were found to perform Call setup failure which is the inability of a subscriber to initiate a call and establish access. Unfortunately, the number of subscribers keeps increasing. The direct consequence was that most subscribers resorted to carrying multiple phones with different SIM cards to enable them to maintain communication with one another should any of the networks fail at any point in time. Even with the emergence of handsets with multiple SIM slots, subscribers still find it difficult to establish calls through the other routed network as a result of poor connectivity. To avoid this, the completion of calls should be established using a network with a better quality of service at every particular point in time.

In finding an enduring solution to this problem, a body saddled with the regulation of telecommunications services in Nigeria, the NCC, in the second quarter of 2013, introduced mobile number portability scheme in the country. Mobile Number Portability (MNP) is the capability of subscribers to maintain their old telephone numbers when changing from one service provider, service type, and service locations to another (Nnochiri, 2016).

In this presentation, it is intended to bring the need for the implementation of automatic mobile number portability (AMNP). This is in a bid to technically obviate the shortcomings of MNP. In itself, Automatic Mobile Number Portability is a technology in which ported mobile subscribers are automatically switched to any network with the best quality of service at a particular time and back to the originating network when the network improves. Implementing AMNP in the country will enable subscribers to automatically switch over to the service provider with a better quality of service at that time while retaining the same mobile number. The subscriber automatically switches back to the original network when the service quality improves without going to the originating network provider for reconnection.

This paper offers relative assessment, performance evaluation, and analyses of three out of the four major 3G/4G LTE network operators in Nigeria using the drive test (DT) method in Port Harcourt metropolis, Rivers state. The DT was carried out to present the need for automatic mobile number portability as a panacea to inherent problems of MNP and conditions warranting automatic porting. The performance of these three networks was evaluated using four assessment considerations namely service accessibility, service retainability, coverage reliability, and throughput for the 3G and 4G LTE networks. This was achieved using Transmission Equipment Monitoring Systems (TEMS Navigation 16 equipment) investigation technology to determine and analyze the key performance indicators (KPIs) of the three mobile networks under consideration (Aye and Zar, 2019). It allowed the use of typical 4G mobile phones as test user equipment, and data was obtained without affecting the normal functionality of the networks. The results of the empirical tests are compared with the standard key performance indicators threshold specified by the Nigeria Communication Commission, NCC.

2. Review of Related Literature

Empirical Review

Onuigbo et al, (2019), in "Developing Automatic Number Portability Scheme for Mobile Networks Operating in Nigeria Using Border Gateway Protocol Intelligent Technique," carried out a series of Drive Tests (DT), using TEM Navigation 16 equipment to characterize the features of 3G and 4G LTE networks of MTN, GLO, and AIRTEL. Comparing the DT results for the real-time monitoring and analysis of the performance of the networks with that of NCC targets, showed that at one time or the other, most of the networks did not meet the required Key Performance Indicator (KPI) threshold values as recommended by the NCC. The work concluded that there is a need for automatic mobile number portability (AMNP) in other to ensure seamless communication. The DT results helped the researchers in establishing the conditions that should necessitate porting. The research suggested that all mobile network operators and subscribers should adopt AMNP. With AMNP, mobile subscribers are automatically switched to any network with the best quality of service at a particular time and back to the originating network when the network improves. Thus, the problem of subscribers being in possession of multiple SIM cards will be eliminated.

Nnochiri, (2016), in "An Improved Model for Key Performance Indicators Analysis for Mobile Number Portability Scheme for GSM Subscribers in Nigeria," carried out drive tests to examine the Key Performance Indicators (KPIs) of the four network providers in the country. Comparing their KPIs with those of NCC targets concluded that there is no uniformity in the delivery of Quality of Service (QoS) among the network providers. The author suggested that for a uniform and efficient quality of service delivery by network providers to customers, there is a need to develop a platform for subscriber migration in mobile networks in other to ensure improved QoS by network operators. The research suggested that all mobile network operators and subscribers should adopt Mobile Number Portability (MNP) JAVA VSIM Suite. However, the VSIM approach provided no lasting solution to the problem of subscribers going about with multiple SIMs since mobile network data is needed to access the network and hence ensure porting as required.

Alor, et al, (2019) in "Characterization of LTE Parameters Relevant for Mobile Number Portability in Nigeria," carried out a drive test in Port Harcourt metropolitan city, Rivers State, Nigeria, using Transmission Equipment Monitoring System (TEMS) to demonstrate the performance level of the two LTE networks under study. The research was carried out using GLO and MTN LTE networks running on the frequency band of 900/1800 MHZ respectively. Different LTE key performance indicators such as Reference Signal Received Power (RSRP), Throughput analysis, Channel Quality Indicator (CQI), Reference Signal Received Quality (RSRQ), and Signal to Noise Ratio (SRN) was measured and analyzed. The measured KPIs of the two networks were compared and presented in bar charts. From the results, the measured LTE KPIs of the two networks, MTN and GLO, was less when compared to the expected theoretical LTE network values, and this calls for improvement, thus, the need for automatic mobile number portability. However, this work did not determine the extent of improvement but only suggested the need for portability. The technical implementation on portability used was not discussed.

Kadioglu et al, (2015) in "Quality of Service Assessment: A case study on Performance Benchmarking of Cellular Network Operators in Turkey" carried out evaluation analyses on network Statistical analysis of the voice signal quality of Universal Mobile Telecommunication Systems and GSM networks of three cellular network operators in Ankara metropolis, Turkey. The evaluation was done using performance benchmarking techniques based on customer perception. Probability distribution function/cumulative distribution function, chi-square, and Fisher's exact test were used to conduct surveys on the importance of KPIs from the user's point of view. Drive test method on specified routes was used to measure KPIs with standard test equipment measuring relevant indicators related to QoS of a cellular radio network in a given geographical area. There was one measurement device for each network operator in the mobile vehicle and two subscriber identity module (SIM) cards for each equipment set for voice and data services, respectively. The result presented the best network operator in Ankara with the best voice quality performance. This study effectively shows the penetration level of the wireless signals and the experiences of mobile users when roaming within the network area. The author suggested that periodic benchmarking should be conducted in order to reduce customer complaints and confusion about services. To increase customer satisfaction, the regulatory body should take more commitments in the valuation of networks and services given.

From the foregoing reviews of related works, there is an obvious need for AMNP implementation to improve the desire for seamless connectivity in mobile network communication.

3. Methodology

This work adopted the methodology as discussed in this section.

Characterization of Port-Harcourt Environment

Port Harcourt metropolis was chosen because of its high mobile telephone density; it is one of the areas where the three networks under study have the operation of both 3G and 4G LTE networks. Table 3.1 shows the demography of Port Harcourt municipality where the research was carried out, while Figure 3.1 shows the map of the metropolitan city of Port Harcourt with eight Locations where the drive test was carried out.

Table 3.1 Port Harcourt City Demography

Port Harcourt	Details
Population	2,596,000
Area	369 km^2
Population Density	7,035 people per km^2

Source: (Historical Population Data, United Nation World Population Prospect, 2017)

Drive Test (DT) Route

The total distance covered in the drive test was approximately 280km. The areas covered included

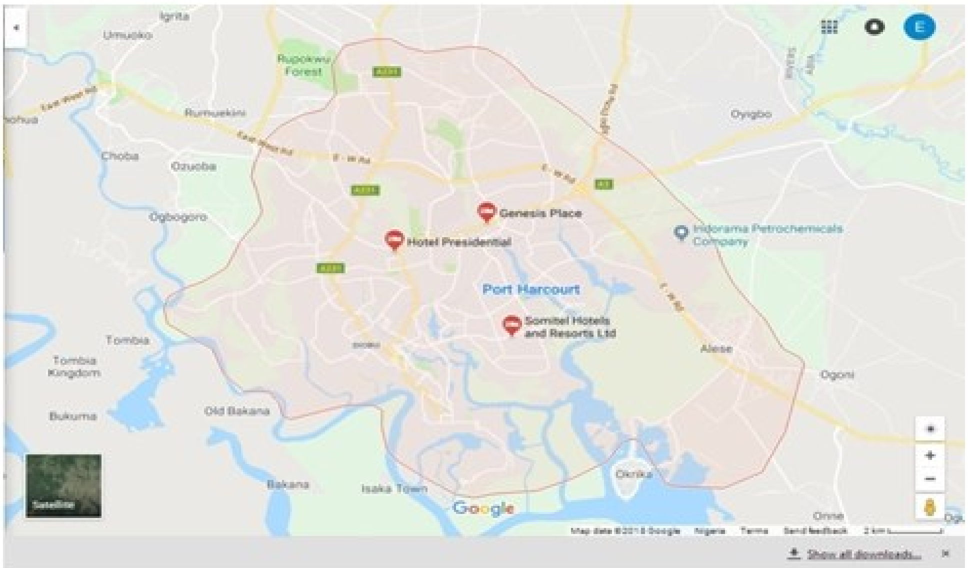

Figure 1: Map of drive test route (Nigeria Google Satellite Maps, 2017)

The area covered in figure 1 defines the route followed during the drive test.

Figure 2: Map of Metropolitan City of Port Harcourt with eight Locations(Nigeria Google Satellite Maps, 2017)

The experiment was carried out to evaluate the performance levels of the three mobile networks. During the drive test, measurements were carried out on key performance indicators and their measurements were recorded. The user equipment was used to measure the experience of customers in their everyday usage of the services.

The block diagram of the measurement setup is shown in Figure 3, while the equipment setup is shown in Figure 4 below:

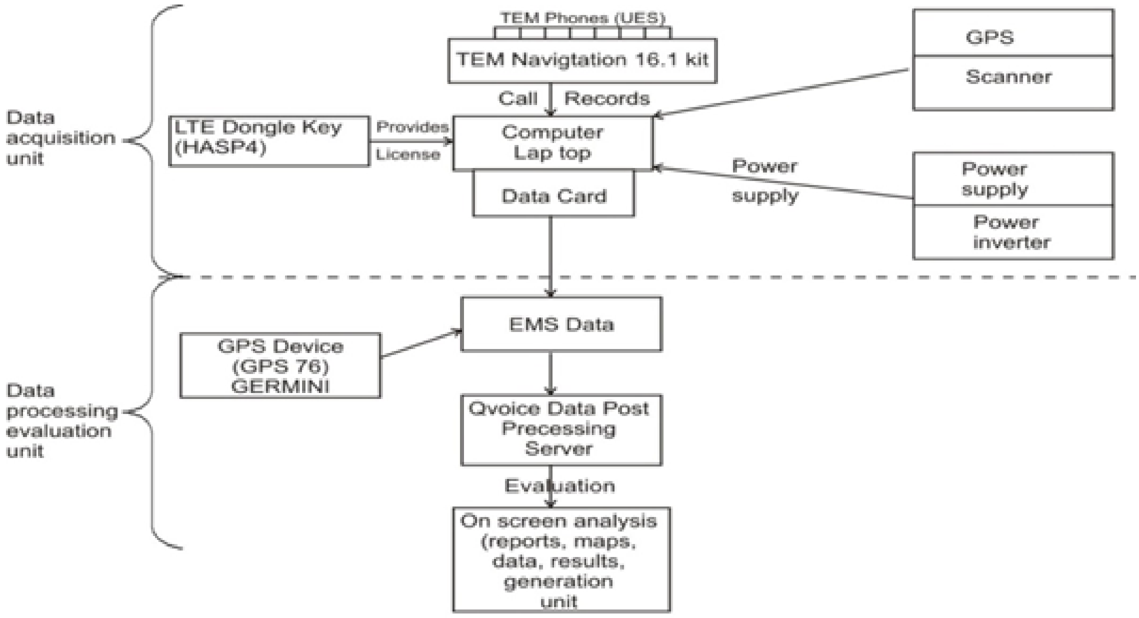

Figure 3: Block diagram of the measurement setup

Figure 4: Equipment setup diagram for the Drive Test

Explanation of the Setup

The setup equipment was placed inside a car during the drive test with an external antenna mounted on the car. Dongle key in the form of flash memory was connected to the laptop as security for unlocking the software. Data collection software known as Element Management Software (EMS) was installed in the laptop, also GARMIN GPS 76 (Global Positioning System) was connected for the geographical location of predefined routes which is a worldwide navigation system that uses information received from orbiting satellites. GPS collects the longitude and latitude values at every point of measurement and other topographical data and setup time. TEM phone (Sony Ericsson KS001) was used to prepare call reference and this was equipped with Net-monitor which allows access to base transmitter station (BTS) information over the air interface. For call initiation at regular intervals through a predefined frequency, the TEM phone was connected to the laptop and was able to record data values like handover success rate, call attempts, answered calls, call drops, call blocks, call setup time, throughputs, Reference Signal Received Power (RSRP) coverage, Reference Signal Received Quality (RSRQ) coverage and hand over attempts. TEM drive test tools were used to collect log files from live Networks of the three mobile operators under study.

Schedule of Drive Test

The drive test conducted was both on 3G and 4G LTE networks. This technical comparability provides a basis for determining the level of compliance of these networks with the benchmark set by the Nigerian Communication Commission. A total of about 8100 calls were made by the operators during the test. The DT was carried out in six sessions of different months of the year to accommodate possible variations regarding seasons of the year. Relevant KPIs were measured and subsequently compared. Measurements of these KPIs of the networks were done at specific intervals along the routes. The measurements were from 7 am to 11 am in the morning hours and 4 pm to 6 pm in the evening periods. This was to accommodate heavy traffic hours in the mornings and evenings of each day. The data used in this analysis was based on the traffic pattern of the networks.

For performance analysis, short calls and long calls were used. The short calls were used to collect accessibility statistics. A short voice call attempt was done every 50 seconds including the idle time of 20 seconds between two consecutive calls. The TEM tool initiates the short calls and generates an event "Call Attempt" each time a number was dialed and "Blocked Call" any time the call setup procedure failed. For retainability statistics, the TEM tools initiated the long calls and generated an event "Drop Call" every time the connection dropped or "Complete Call" for normal user release. This was established automatically and was programmed in the command sequence to end after 110 seconds. The data was viewed and analyzed in real-time allowing a view of network performance on the field. Data from all units were grouped by collection software and stored. The log files were further analyzed by post-processing of the collected data using the QVoice data processing server. The results of these comparisons were used to buttress the need for automatic mobile number portability and also established the conditions for automatic porting. For any automatic porting to be successfully carried out, conditions that must be met for porting to take place must be spelled out hence, the need for this presentation.

Key Performance Indicators (KPI)

For this paper, the recorded 3G KPIs during the DTs were evaluated under major headings such as Accessibility (%), Retainability (%), and Mobility (%). These are presented as follows:

1. **Accessibility:** This measures the ability of a user to obtain the requested service from the network with minimum effort. Call setup success rate (CSSR) was measured and used to monitor accessibility
2. **Retainability:** Retainability occurs when a service, having been established and sustained, continues to be available and thus be provided over a given period and under specified conditions for a requested duration. Retainability was measured during the drive test when a call made by subscriber "A" to subscriber "B" has a successful setup and was held for a time duration of 90 seconds to 120 seconds. If the call had dropped, it would have been considered a dropped call. Call dropped was measured and used to monitor retainability.
3. **Mobility:** A base station only has a limited coverage area in a cellular system, thus presenting a situation when a subscriber could be said to be out of range of a particular base station during a call. Handover is the process of transferring calls from one base station to another as the subscriber passes the cell boundary. Handover Success Rate (HOSR) was measured and used to monitor mobility. Table 4.1 shows the results of the six sessions of drive tests carried out for the 3G networks.

Parameters of 3G measured

Considering cellular mobile license obligations with the regulatory body in Nigeria, the NCC, the QoS indicators as outlined below were evaluated using the measured parameters obtained from the drive test.

1. Stand-Alone Dedicated Control Channel (SDCCH) Congestion Rate (NCC Target: ≤0.2%)

This measured the probability of failure of accessing a stand-alone dedicated control channel during call setup.

$$\text{SDCCH (\%)} = \frac{N_o c_f}{T_{ca}} \qquad (3.1)$$

Where $N_o c_f$ = Number of Connect Call Fails due to Immediate Assignment Failure, and

T_{ca}= Total Number of Call Attempts.

2. Call Setup Success Rate (CSSR)
This measures the ratio of established calls to the number of call attempts, mathematically,

$$CSSR\ (\%) = \frac{\varepsilon_c}{T_{ca}}\ x\ \frac{100}{1} \qquad (3.2)$$

Where ε_c = Established calls,

T_{ca}= Total Number of Call Attempts, and

CSSR = Call Setup Success Rate.

3. Call Drop Rate
This measured the active voice calls that were dropped or terminated during the process of an engagement without any of the party's will. Its recommended threshold value stands at ≤ 2%. Its mathematical expression is shown as follows:

$$CDR\ = \frac{C_d}{T_{ca}}\ x\ \frac{100}{1} \qquad (3.3)$$

Where C_d = Number of Calls Unwillingly Terminated (Drop calls), and

T_{ca}= Total Number of Call Attempts.

4. Call Blocked Rate
This measures the ratio of total calls blocked to the total number of calls attempted.

$$BCR\ (\%\ ) = \frac{C_b}{T_{ca}}\ x\ \frac{100}{1} \qquad (3.4)$$

Where C_b = Number of Call Blocks

T_{ca}= Total Number of Call Attempts.

5. Hand Over Success Rate (HOSR)

This measures the ratio of total handover success to total handover attempts which is the measurement of the network mobility.

$$HOSR\ [\ \%] = \frac{h_s}{h_a}\ x\ \frac{100}{1} \qquad (3.5)$$

Where h_s = Hand over success

h_a = Hand over attempt

Measurement of 4G LTE Performance Indicators
The operational 4G LTE networks used in this report are MTN, GLO, and AIRTEL. They were seen to run on frequency bands of 900/1800 MHZ, which are the best propagation frequencies for the deployment of 4G LTE technology.

1. Reference Signal Received Power (RSRP) coverage analysis. This measures the linear average power (in watts) of the downlink reference signals (RS) across the channel bandwidth for the resource elements that carry cell-specific reference signals. RSRP is utilized in both connected and idle states and it provides the user equipment (UE) with data about cells strength through which path loss was premeditated and used in the algorithms to determine the peak power settings for network operation. It ranges from -44 to -140 dBm. This is presented in Table 4.4 and figure 4.6. This parameter is normally measured.

2. Reference Signal Received Quality (RSRQ) Coverage Analysis.
The measurement of RSRQ is utilized only in a connected state. This is the quality of real-time voice transmission of the network to the end-user. It indicates the Signal Quality of a network and ranges from -3 to -19.5 dB. The Cumulative Distribution Function (CDF) for the RSRQ for the three networks under study is shown in table 4.5.

3. Throughput

International Journal of Engineering and Environmental Sciences | IJEES
Vol. 4, No. 3 | December, 2021 | pp. 27-43
https://airjournal.org/ijees

Throughput measures how many units of information or data a system can process in a given time. It is the rate of successful data transfer over a communication channel. It is measured in Megabits per second, Mbit/s (Mbps). Both downlink and uplink throughputs were measured.

Downlink throughput values measured indicate the amount of data a UE processed from the internet in a given time while uplink throughput measures the amount of data that is uploaded into the internet from a UE in a given time.

Conditions for Automatic Porting

After the series of drive tests, the results were used to establish the network features with which automatic porting conditions were determined. This means that without those conditions being met, porting would not take place.

These conditions listed below were established based on the measured KPIs of the three networks. The measured data were compared with threshold values given by NCC to decide on conditions for automatic porting.

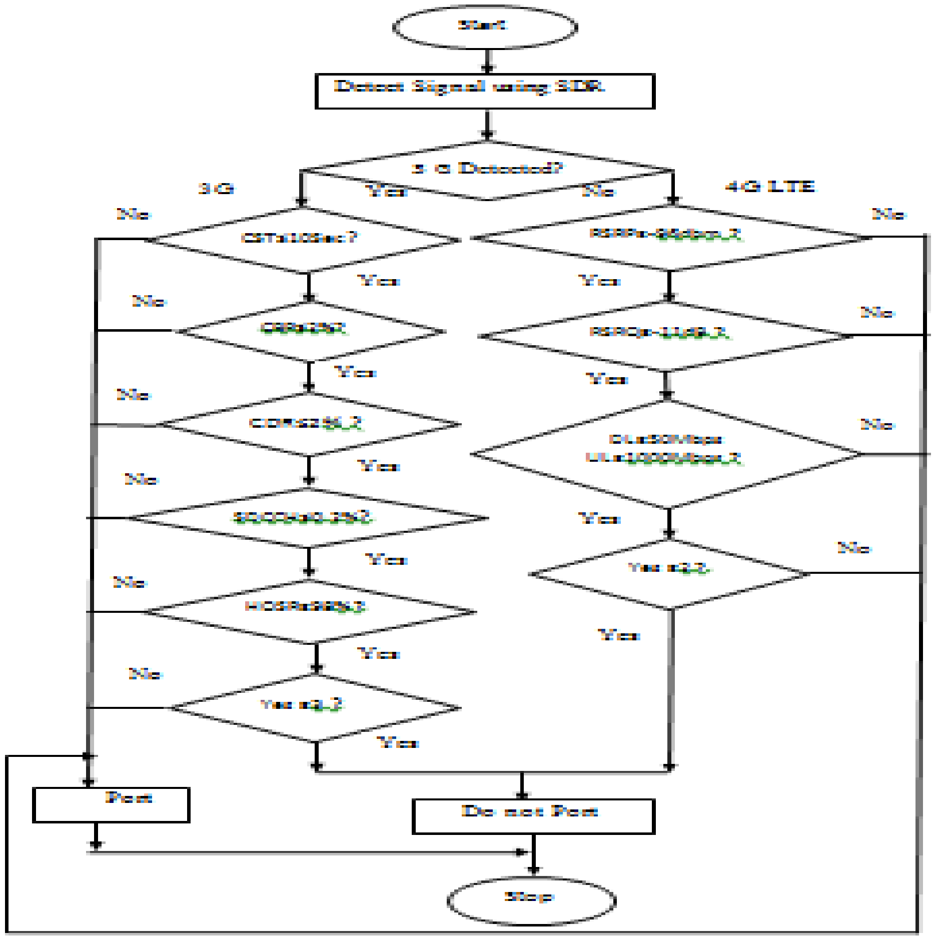

Figure 5: Flowchart for the Conditions that Warrant Porting

GSM Porting Conditions

1. Call Set-Up Time (CST): This is the period of time between the moment when an alerting signal is sent to the receiver's terminal address and the moment when the SEND button is pressed on the calling terminal. This means the time between the pressing of SEND button and the receiving of a call signal by the receiver's User Equipment (UE). The maximum allowable CST according to NCC standard is 10 seconds. This means that any call not connected between 1 second to 10 seconds is experiencing a delay in connectivity and thus is not regarded as a seamless call. This also means that any initiated call that does not connect for possible completion after 10 seconds is deemed to be experiencing network delay and thus requires automatic porting for more speedy call completion. This phenomenon is represented as follows:

<080-0001-1000> SEND

$$CST(s) = t_{alerting\ signal} - t_{address\ sending} \quad (3.6)$$

2. Call Block Rate (CBR): This KPI is normally ≤ 2%. A higher value of call block rate calls for porting to ensure successful completion of initiated calls.

3. Call Drop Rate (CDR): The higher the call drop rate, the more there presents a need for portability to forestall already established calls from dropping.

4. Stand Alone Dedicated Channel (SDCCH): Its recommended threshold value stands at ≤ 0.2%. Any value higher than this initiates porting.

5. Handover Success Rate (HOSR): Its recommended threshold value stands at ≥98%.

4G LTE Porting Conditions

In 4G LTE technology, porting conditions are similar to what obtains in the GSM phenomenon. Thus, the strength and quality of the reference signal play a significant role in determining when porting should become necessary during the process of data transfer. Additionally, the magnitude of the single-user throughput in the downlink and uplink categories is also of great importance. These three conditions are presented accordingly:

a. Reference Signal Received Power (RSRP). (-44dbm to -140dBm)

b. Reference Signal Received Quality (RSRQ). (-3dB to-19.5dB)

c. Single User Throughout: Downlink: (50Mbit/sec < DL ≤ 100 Mbit/sec)

d. Uplink: (0 Mbit/sec < UP ≤50 Mbit/sec)

Reference Signal Received Power (RSRP)

The RSRP is the average received power of a single Reference Signal (RS) resource element. The RSRP has a range of which varies from -44dBm to -140dBm. When the RSRP approaches the value of -44dBm, an excellent value of QoS is attained. Conversely, when RSRP approaches the value of -140dBm, QoS drops to a poor and unacceptable value. Specifically, the following situations are meant to determine when porting should be initiated. When RSRP≥-75dBm, that is, from -44dBm to -75dBm, QoS is acceptable and no porting is required. When the RSRP lies in the range of -76dBm to -95dBm, the QoS becomes slightly degraded with a decline throughout to the rate of 30% to 50%. Porting would still not be necessary. However, when the RSRP lies in the range -96dBm to -99dBm, the QoS becomes completely unacceptable while throughout declines to zero. At that stage, porting becomes the only way to continue to sustain the transaction and hence ensure data transfer.

Reference Signal Received Quality, (RSRQ)

The RSRQ provides an indication of signal quality. It is used only during connected states and ranges between -3dB to-19.5dB. Increasing range magnitude signifies increased QoS while the reverse is the case with a decreased magnitude of the range. This brings about the following further analysis:

RSRQ > -5dB results in excellent quality; porting not required.

-6dbB ≤RSRQ ≥ -10dB result in good quality; still, no porting is required.

RSRQ < -11dB results in poor quality; an immediate porting process should be initiated.

From the analysis presented above, RSRQ can present three quality conditions namely, excellent signal quality, good signal quality, and poor signal quality. Both in excellent and good signal quality conditions, network performance for data transfer is deemed good and acceptable, thus, there would be no need for porting. However, when the value of RSRQ drops to RSRQ ≤ -11dB, poor QoS results. Under this condition, porting becomes necessary; a failure in which data transfer operations could no longer be possible within the network.

Single User Throughput

The downlink throughput for an LTE network can peak at 100Mbit/sec while the uplink component is 50Mbit/sec. For porting to be initiated, if the throughput in the downlink and uplink category falls below 40%, the AMNP should initiate porting procedures. However, other KPIs should be jointly considered before this action is initiated such that even if a 40% drop in throughput is noticed, other favourable KPIs may still adjudge the network as the best in that particular instant and so no porting would be required to be initiated.

4. Data Presentation and Analysis

The various data and results realized during the implementation of the research objectives were presented, analyzed, and subsequently discussed for a clearer understanding and appreciation

Table 4.1 Six Months Drive Test Average Results

Drive Test	Total Call Attempts (T_{ca})			Established Calls (E_c)			Total number of Call Blocks (C_b)			Total number of Call Drops (C_d)			Total No. of connect fail Calls. ($N_o c_f$)		
MONTHS	MTN	GLO	AIRTEL	MTN	GLO	AIRTEL	MTN	GLO	AIRTEL	MTN	GLO	AIRTEL	MTN	GLO	AIRTEL
January	450	450	450	444	442	439	8	10	11	7	9	6	3	2	1
March	450	450	450	440	441	442	10	9	8	9	6	7	4	1	3
May	450	450	450	441	443	439	9	7	11	8	7	11	1	2	4
July	450	450	450	441	444	440	9	6	10	9	8	9	2	1	3
Sept.	450	450	450	442	440	441	8	10	9	7	9	8	1	3	2
Dec.	450	450	450	440	441	441	10	9	9	9	6	9	1	2	1
Total	2700	2700	2700	2646	2651	2642	54	51	58	49	45	50	12	11	14

These parametric measurements tabulated in table 4.1 were further used to evaluate five KPIs of the three networks using equations 3.1 to 3.5 and were presented in table 4.2.

Table 4.2 Summary of Calculated KPIs

Drive Test	CBR(%) $\leq 2\%$			CDR $\leq 2\%$			SDCCH (%)$\leq$ 0.2%			CSSR (%) $\geq 98\%$		
MONTHS	MTN	GLO	AIRTEL	MTN	GLO	AIRTEL	MTN	GLO	AIRTEL	MTN	GLO	AIRTEL
January	1.78	2.22	2.44	1.58	2.04	1.37	0.67	0.44	0.22	98.67	98.22	97.56
March	2.22	2.00	1.78	2.05	1.36	1.58	0.89	0.22	0.67	97.78	98.00	98.22
May	2.00	1.55	2.44	1.81	1.58	2.51	0.22	0.44	0.89	98.00	98.44	97.56
July	2.00	1.33	2.22	2.04	1.80	2.05	0.44	0.22	0.67	98.00	98.67	97.78
September	1.78	2.22	2.00	1.58	2.04	1.81	0.22	0.67	0.44	98.22	97.78	98.00
December	2.22	2.00	2.00	2.05	1.36	2.04	0.22	0.44	0.22	97.78	98.00	98.00
Average	2.00	1.81	2.15	1.85	1.70	1.89	0.31	0.41	0.52	98.00	98.35	97.85

The different evaluated network's KPI data in Table 4.2 were further analyzed using graphs in figure 1 to fig 6 showed the level of accessibility of the networks under study to their teeming subscribers.

Stand Alone Dedicated Congestion Channel (SDCCH) ≤0.2%

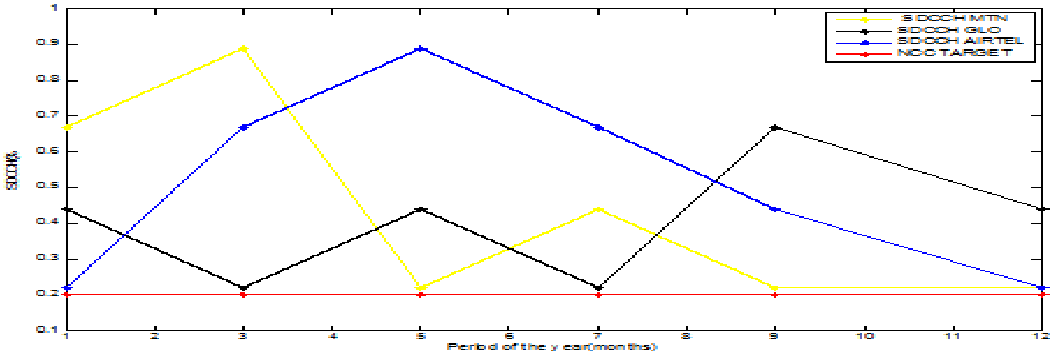

Figure 6: Graph representation of the Stand-Alone Dedicated Congestion Channel.

During the first drive test in January 2017, the three networks respectively presented SDCCH KPI values of 0.67%, 0.44%, and 0.22% for MTN, GLO, and AIRTEL respectively. These values were higher than the NCC target KPI of ≤0.2%. In March, the KPI values of MTN, GLO, and AIRTEL were 0.89%, 0.0.22%, and 0.0.67% respectively. The values for the months of May, July, September and December, showed results of 0.22%, 0.44%, 0.22%, 0.22% for MTN; 0.44%, 0.22%, 0.67%, 0.44% for GLO and 0.89%, 0.67%, 0.0.44%, 0.22% for AIRTEL. Thus, in the first DT period, none of the three networks had a good SDCCH. This calls for automatic porting to increase the QoS of the network providers for seamless communication.

Call Setup Success Rate (CSSR).

The graphical representation of the Call Setup Success Rate (CSSR) for the three networks under study is shown in Figure 7.

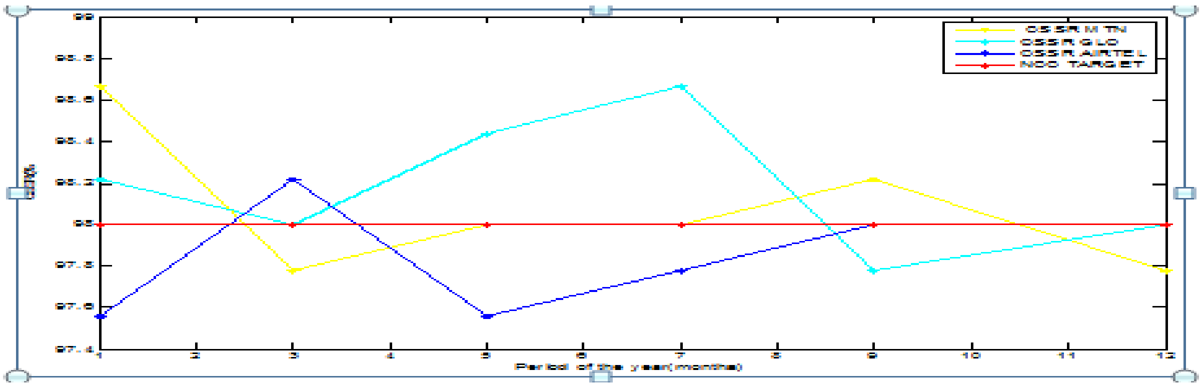

Figure 7: Graph representation of the Call Setup Success Rate.

In the first month of January 2017, MTN, GLO, and AIRTEL had values of 98.67%, 98.22%, and 97.56% respectively. Only one network was unable to meet the target value of ≥ 98%. Subsequent DTs carried out in May, July, September and December, presented results of 97.78%, 98.00%, 98.00%, 98.22% and 97.78% respectively for MTN; 98.00%, 98.44%, 98.67%, 97.78% and 98.00% respectively for GLO while results of 98.22%, 97.56%, 97.78%, 98.00% and 98.00% were presented for AIRTEL. With these results, there was a need for automatic porting so that subscribers can switch over to networks with a better quality of service at any time.

International Journal of Engineering and Environmental Sciences | IJEES
Vol. 4, No. 3 | December, 2021 | pp. 27-43
https://airjournal.org/ijees

Call Drop Rate (CDR)

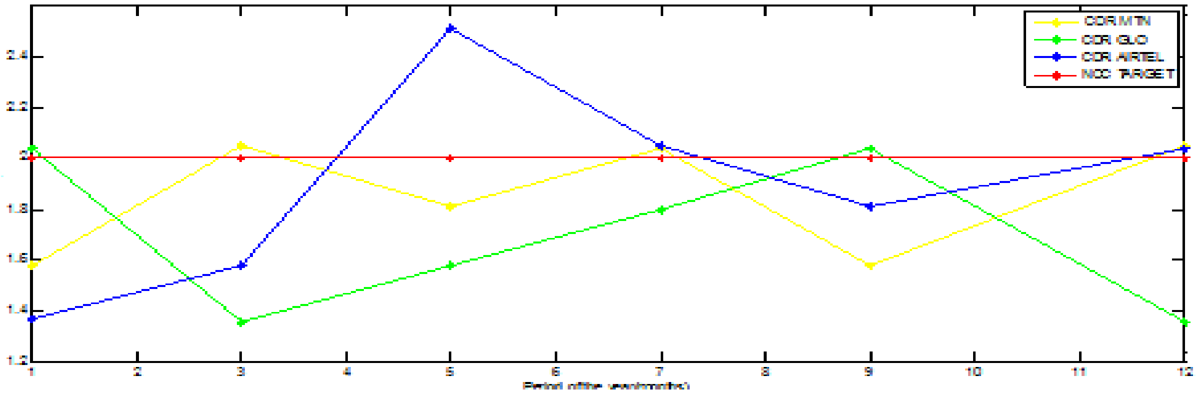

Figure 8: Graphic representation of the Call Drop Rate for the three Networks.

Figure 8 shows the graphic representation of the Call Drop Rate (CDR) of the three networks under study and their NCC set target. The Call Drop Rate is the ratio or fraction of the telephone calls which were cut off or dropped before the two parties undertaking a call session had finished their conversation due to technical reasons. This normally occurs before either party had hung up willingly. The fraction is usually measured as a percentage of the total number of calls unwillingly terminated over several attempted calls. Plotting the values of this KPI for the three networks, MTN, GLO, and AIRTEL presented DT results of 1.58%, 2.04% and 1.37% during the first drive test carried out in January. Subsequent results of DTs carried out in March, May, July, September, and December, 2017, were 2.05%, 1.81%, 2.04%, 1.58% and 2.05% respectively, for MTN; 1.36%, 1.58%,1.80%, 2.04% and 1.36% respectively, for GLO and 1.58%, 2.51%, 2.05%, 1.81% and 2.04%, respectively for AIRTEL. With these values, it was obvious that for all the networks to meet the KPIs standard value of ≤ 2% as stipulated by the NCC at any point in time there is a need for a better QoS for the networks. This is because the lower the CDR, the better the network and the more assurance it is that calls made in that network environment will be completed. To achieve this standard, porting would be necessary among these networks.

Call Block Rate (CBR)

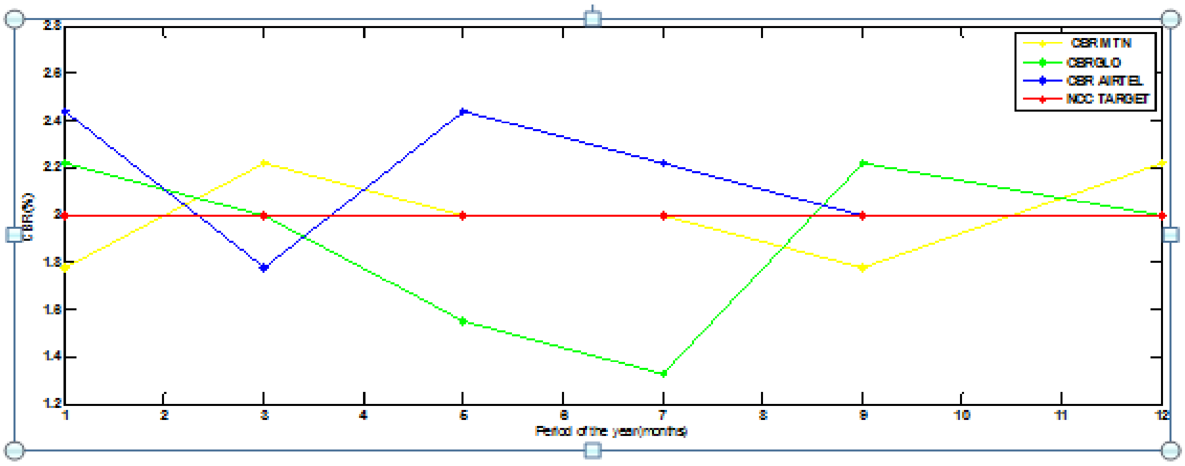

Figure 9: Graphical representation of the Call Block Rate (CBR) for the three networks.

Figure 9 shows the graphical plots and relationships of the Call Block Rates in the three networks. During the drive tests, several KPI values of the CBR were measured and recorded according to the months of the DT exercise. In January, MTN, GLO, and AIRTEL had CBR KPI values of 1.78%, 2.22%, and 2.44% recorded. During subsequent DTs carried out in March, May, July and September, and December, the following values were recorded for the networks: 2.22%, 2.00%, 2.00%, 1.78% and 2.22% for MTN, respectively; 2.00%, 1.55%, 1.33%, 2.22% and 2.00% for GLO, respectively and 1.78%, 2.44%, 2.22%, 2.00% and 2.00% for AIRTEL, respectively. Analyzing the plots of the graph, the three networks were only able to meet up with the NCC target of ≤ 2% on a few occasions requiring the need for porting to bring about an improved QoS and hence, better communication

Handover Success Rate (HOSR)

From the summary of HOSR data of the three networks in table 4.3, Handover Success Rate (HOSR) which is more than 98% were considered to be reasonably good. This is based on the NCC Target of ≥98%.

Table 4.3 Mobility of the Networks.

Drive Test	Total Hand over attempts (h_a)			Total Hand Over Success (h_s)			HO Success Rate (%)			Call Setup Time (s) (CST)		
	MTN	GLO	AIRTEL	MTN	GLO	AIRTEL	MTN	GLO	AIRTEL	MTN	GLO	AIRTEL
July	850	853	652	833	839	634	98.00	98.36	97.24	11	11	9
Sept.	831.	842	769	814	825	756	97.95	97.98	98.31	10	6	13
Nov.	810	790	662	793	782	649	97.90	98.99	98.04	7	9	12
Dec.	910	897	512	893	887	501	98.13	98.89	97.85	9	8	10
Jan.	790	811	792	773	798	771	97.85	98.40	97.35	7	8	10
March	910	927	525	893	897	519	98.13	96.76	98.86	8	6	10
Average	850	854	652	833	838	638	98.00	98.23	97.95	9	8	11

Figure 10 shows a graphical representation of the Handover Success Rate for the three networks. Since the Handover success rate measures network mobility, this shows the movement of calls from one cell to another thereby sustaining call conversation and preventing call drop on the network. This means that if there is a drop-in handover success rate, there will be an increased call drop rate.

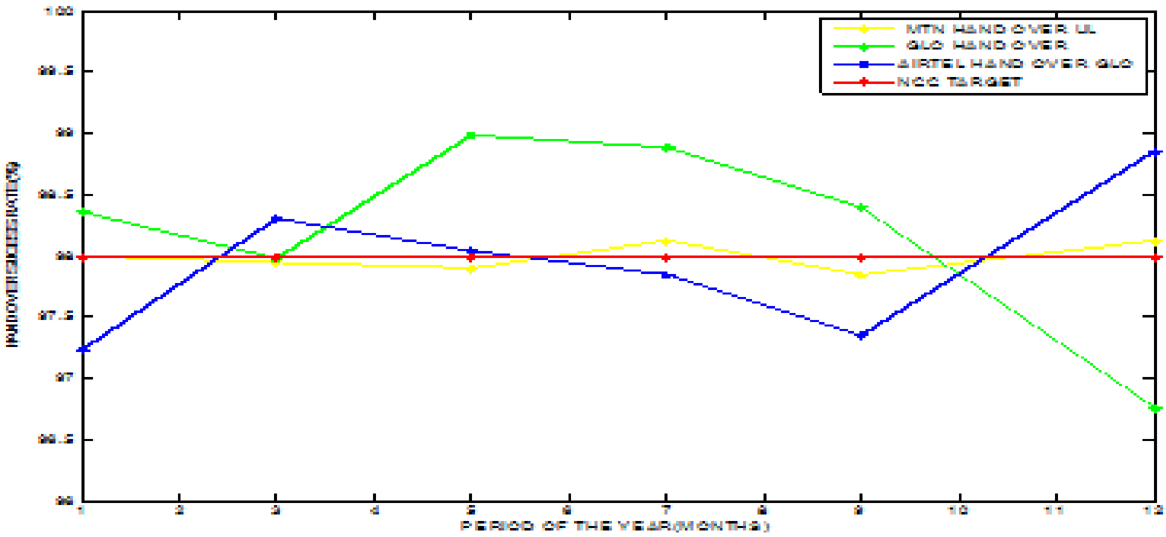

Figure 10: Graphic presentation of the three networks for Handover Success Rate

The three networks under study presented different values of HOSR during different periods of the year. For MTN network, these were 98.00%, 97.95%, 97.90%, 98.13%, 97.85% and 98.13%. The GLO network presented handover values of 98.36%, 97.98%, 98.99%, 98.89%, 98.40% and 96.76%. The recorded handover for AIRTEL was 97.24%, 98.31%, 98.04%

97.85%, 97.35% and 98.86%. Relating these to the NCC target values of 98%, it is seen that porting is necessary given that none presented complete satisfactory handover values.

Characterization of 4G LTE Networks.

Reference Signal Received Power (RSRP)

When multiple runs were made along the same route the following result statistics of RSRP were obtained. Brief statistical values for the RSRP measurements for the sites in the three networks are shown in Table 4.4. Mean values for the three networks were within the acceptable limits of -44 to -140 dBm.

Table 4.4 RSRP Statistics for Multiple Runs along the Same Route.

Statistics on RSRP	Run 1			Run2			Run 3		
	MTN	GLO	AIRTEL	MTN	GLO	AIRTEL	MTN	GLO	AIRTEL
Min (dBm)	-122.1	-118.6	-120.4	-122.3	-116.7	-120.6	-121.5	-119.4	-120.4
Max (dBm)	-70.8	-65.7	-68.6	-73.3	-71.6	-72.4	-70.9	-68.8	-69.4
Mean (dBm)	-102.1	-101.6	-100.4	-102.7	-100.2	-101.3	-101.7	-100.1	-101.2

The graphical representation of the Reference Signal Received Power (RSRP) for the three LTE networks under is seen in figure 11

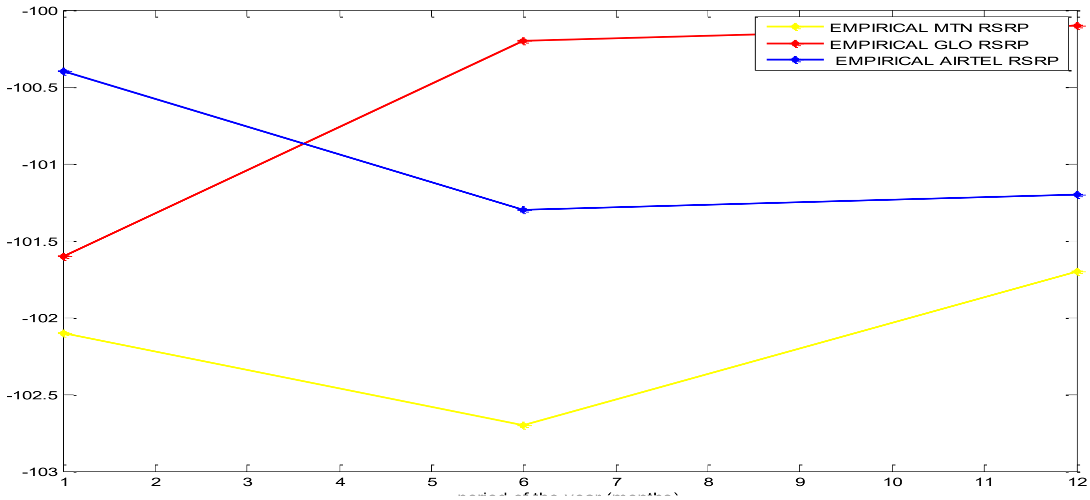

Figure 11: Graphical representation of the Reference Signal Received Power (RSRP)

Recall that when the RSRP approaches the value of -44dBm, an excellent value of QoS is attained, on the other hand, when RSRP approaches -140dBm, the QoS drops to a poorer and unacceptable value. From the mean values, it was noticed that in the first run, the RSRP values for AIRTEL were better followed by GLO. In the second run, the RSRP values for GLO were better followed by AIRTEL. MTN has the poorest value of RSRP. The three networks under study could be seen to have met average required values within the acceptable range, but the RSRP values were poor showing poor signal received power. Hence, automatic porting is required.

Reference Signal Received Quality (RSRQ).

RSRQ provides an indication of Signal Quality and is used only during connected states. It ranges from -3 to -19.5 dB. The Cumulative Distribution Function (CDF) for the RSRQ for the three networks under study is shown in table 4.5

Table 4.5 CDF Statistics for RSRQ of MTN, GLO& AIRTEL

RSRQ Statistics	PCI 110			PCI 111			PCI 112		
	MTN	GLO	AIRTEL	MTN	GLO	AIRTEL	MTN	GLO	AIRTEL
Minimum (dB)	-26.9	-24.8	-25.2	-24.1	-23.8	-24.0	-12.1	-11.9	-12.2
Maximum (dB)	-9.2	-9.0	-9.1	-6.2	-6.0	-5.9	-4.9	-4.6	-4.7
Mean (dB)	-12.0	-11.9	-11.7	-12.1	-12.0	-11.9	-9.1	-8.9	-9.2
Median (dB)	-11.2	-11.0	-10.9	-12.0	-11.8	-12.1	-9.3	-9.1	-9.6

Figure 12 shows the graph representation of the Reference Signal Received Quality for the three LTE networks under study based on the data presented in Table 4.5.

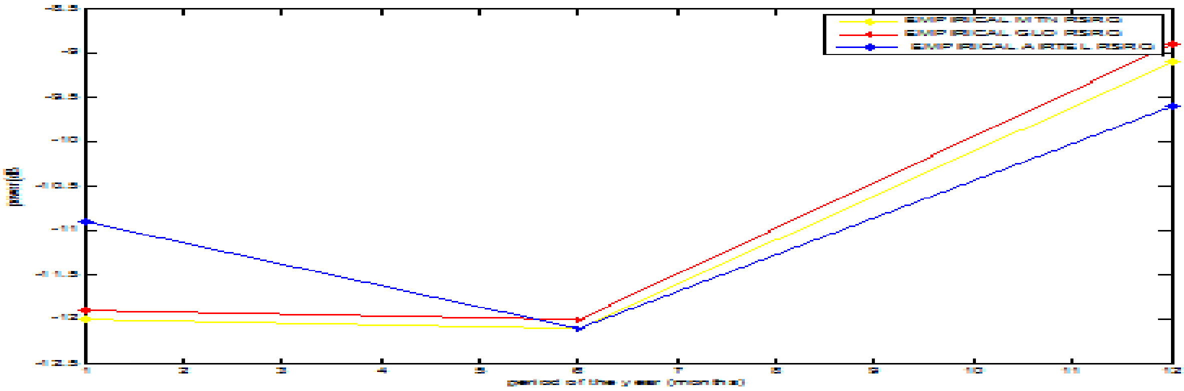

Figure 12: Graphical representation of the Reference Signal Received Quality (RSRQ)

As shown in table 4.6, Physical Cell Identity (PCI) 112 offers the best signal quality in its coverage area with -9.1dB, -8.9dB, and -9.2 of RSRQ while the worst was PCI 111 with -12.1dB, -12.0bB and -11.9dB mean RSRQ respectively. In the PC110 and PC111, the RSRQ values for AIRTEL were better followed by GLO. MTN has the poorest value of RSRQ. In the PC112, the RSRQ values for GLO were better followed by MTN. AIRTEL has the poorest value of RSRQ. The inference of this resulting condition is that automatic mobile number portability is feasible in the Nigerian telecommunication environment among the three networks under study.

Throughput

The single-user throughput results are shown in Table 4.6 for the three networks. The data in the table combines with other KPIs to produce a better and more reliable analysis as could be seen. Figures 4.7 show the graphical representation of the single user throughputs for the MTN, GLO, and AIRTEL networks at different outdoor locations.

Table 4.6 Single User Throughput Results

Scenario	Distance from site	MTN throughput (Mbits/s)		GLO throughput (Mbits/s)		AIRTEL throughput (Mbits/s)	
		Downlink	Uplink	Downlink	Uplink	Downlink	Uplink
Outdoor	90m	51.50	22.80	50.5	21.0	49.3	20.60
Outdoor	410m	23.00	1.92	24.5	16.3	22.4	1.74
Outdoor	510m	15.50	0.87	14.5	1.87	13.7	1.53

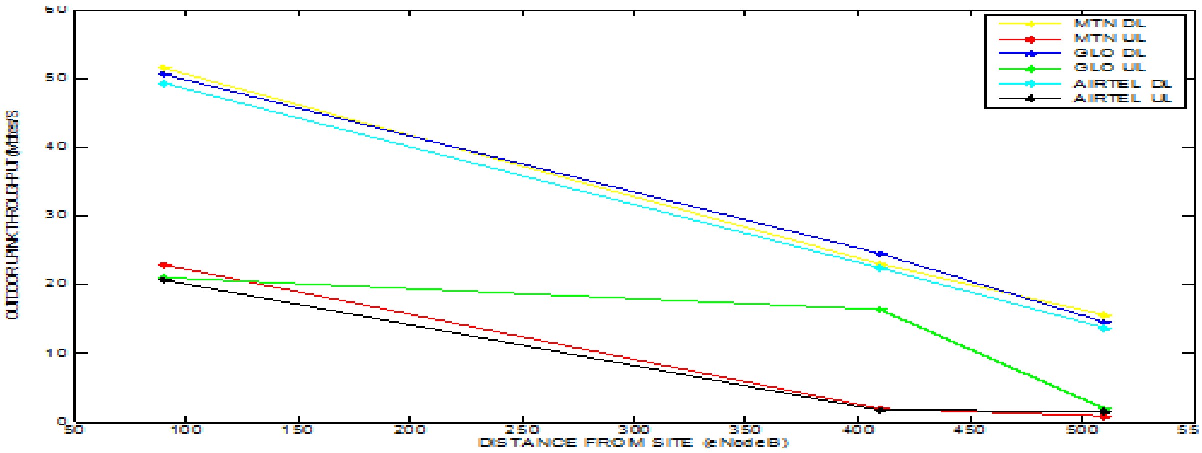

Figure 13: Single User Throughput for the three Networks

Both downlink and uplink values are shown. The values for all three networks are less than the expected theoretical values of Downlink: (50Mbit/sec < DL ≤ 100 Mbit/sec), except that of MTN (51.50) and AIRTEL (50.9) 90m distance from the site. Also, for Uplink with the threshold of (0 Mbit/sec < UP ≤50 Mbit/sec) for 4G LTE networks, all three networks are less than the expected theoretical values, which call for an enhancement and can be realizable if automatic mobile number portability is efficiently implemented.

5. Conclusion

The Drive Test (DT) results of the real-time monitoring and analysis of the performance of the three networks showed that at one time or the other, most of the networks did not meet the required KPI threshold values of the NCC in order to ensure seamless communication. The results showed that after the DT, average values of SDCCH, CDR, and CBR for 3G networks were 0.457%, 1.814%, 2.005%, respectively. These values were not within the NCC threshold values of 0.2%, 2%, and 2% respectively. Similar results were recorded for throughput values of 50.43Mbits/sec downlink and 21.466Mbits/sec uplink as against the NCC threshold of 100Mbits/sec and 50Mbits/sec respectively. This led to the articulation of some conditions upon which porting was predicated. With AMNP in place, the tendency of subscribers experiencing call block, call drops, high call setup time and low throughput operations arising from network congestion will be eliminated. Thus, there would be no need for multiple mobile telephone numbers or multiple handsets. Network operators would also be forced to distinguish themselves by the quality of service they provide to their customer.

References

Alor M.O., Onuibgo C.M., Eze M. N., (2019), "Characterization of LTE parameters Relevant for Mobile Number Portability in Nigeria". *International Journal of research in Engineering and Science,* 3(13). ISSN (P) 2572-4274 (O) 2572-*430 Available online on* http://rspublication.com/IJRES/IJRE.html.

Aye MyatMyatMyo and Zar Chi Soe (2019).3G Drive Test Analysis for Long Call in University Campus. *International Journal of Trend in Scientific Research and Development (IJTSRD)*, 3(5). August 2019. Available Online: www.ijtsrd.com e-ISSN: 2456 – 6470

Kadioglu R, Yaser D and Ali, (2015) "Quality of Service Assessment: A case study on Performance Benchmarking of Cellular Network Operators in Turkey". *Turkey Journal of Electrical Engineering and Computer Sciences*, 23: 548-559.

Nigeria Google Satellite Maps, (2017) https://www.drivingdirectionsandmaps.com/nigeria-google- map/#Google-maps

Nnochiri I.U., Osuagwu C.C., Okafor K.C. (2013), Empirical Analysis on the GSM Network KPIs Using Real-Time Methodology for a Novel Network Integration. *In Progress in Science and Engineering Research Journal,* 2(02/06): 092-107.

Nnochiri, I. U. (2016), An Improved Model for Key Performance Indicators Analysis for Mobile Number Portability Scheme for GSM Subscribers in Nigeria. A PhD Thesis Submitted in Partial Fulfilment of the requirement for the Award of Doctor of Philosophy in the Department of Electronic Engineering University of Nigeria, Nsukka.

Onuigbo, C.M., (2019), Developing Automatic Number Portability Scheme for Mobile Networks Operating in Nigeria Using Border Gateway Protocol Intelligent Technique. Enugu State University Science and Technology.

Ozovehe, A., &Usman., A. U. (2015). Performance Analysis GSM Networks in Minna Metropolis of Nigeria. *Nigerian Journal of Technology,* 34(2).