COMPARATIVE ANALYSIS OF QUALITY OF SERVICE OF GSM NETWORKS IN NIGERIA: CASE OF IKORODU AND BADAGRY

Akinola O. A. [1] and Allison M. A. [2]

[1,2]Department of Electrical and Electronic Engineering, Federal University of Agriculture. Abeokuta, Ogun State, Nigeria.

ABSTRACT

The problem of poor quality of services as well as congestion in channels includes call setup failure, call retention/call drop and traffic congestion. In this study, the quality of services (QOS) of some selected operators of global system for mobile communications (GSM) networks in Ikorodu and Badagry network regions of Nigeria were investigated for six months. A benchmarking drive test method was employed in the collection of call data which included accessibility, retainability, mobility, coverage reliability, and coverage quality and call completion rate. Erlang and poison probability distribution models of call blocking rate and congestion control respectively were employed in the analyses to determine the probability of calls blocked and profound a solution to traffic congestion. The study of quality of services and a set of dimensions for comparative evaluations were analysed and compared with NCC targets. During Ikorodu region test, a total of 90 calls were made with operator A in which 69 were established and 21 were blocked, 90 calls were made with operator B, 49 established 41 blocked, a total of 88 calls were made with operator C in which 62 established and 26 blocked, 90 calls were made with operator D, 89 established and 6 blocked. At Badagry region a total of 274 calls were made with operator A in which 255 were established and 19 were blocked, 274 calls were made with operator B, 212 established 62 blocked, a total of 274 calls were made with operator C in which 191 established and 83 blocked, 274 calls were made with operator D, 205 established and 69 blocked. All calls event were recorded by the TEMS software, Molina lost calls held trunking formula (poison formulas) were established to compare and confirm these calls value. Generally the quality of services of the operators met up to NCC targets as well as that of the Molina lost call formulas in some KPI while some performs below the expected NCC targets, The overall ranking of operator's KPI revealed that operator C, operator D, operator B and operator A performed in every category of the key performance index (KPI) in that order.

Keywords: Quality Of Service (QOS), Key Performance Index (KPI), Drive Test, GSM operators, Nigeria communication commission (NCC).

INTRODUCTION

The world is fast becoming a global village and a necessary tool for this process is communication of which telecommunication is a key player. Telecommunication is powerful and it empowers, with far reaching consequences. It has demonstrated the potential to transform society and business, and the evolution has only just begun. With the invention of telephone, human communication and commerce were forever changed; time and distance began to melt away as a barrier to doing business, keeping in touch with loved ones and being able to respond immediately with major world event (Akinboboye, 2010). Communication without doubt is a major driver of any economy. Emerging trends in socio-economic growth shows a high premium being placed on information and communication technology (ICT) by homes, organizations, and nations. Sixteen years ago, Nigeria embraced the global system for mobile communication. Telecommunication operators in Nigeria have grown into a subscriber base of 60 million with five GSM operators. Each of the operators operates at the GSM licensed frequency ARFCN (Absolute radio frequency channel number) range between (945MHz to 949.8MHz) uplink and (895.0MHz to 899.8MHz) downlink. Although every nation in the world is entitle to 25MHz Bandwidth which represent the GSM frequency range. This 25MHz is to be shared among all the GSM operators in the nation. In the case of Nigeria, only 5 operators is operating on GSM frequency .Therefore this 25MHz was shared equally among these five operators (M-TEL, ZAIN, MTN, GLOBACOM and ETISALAT) (Akinboboye, 2010). The deployment of GSM system into Nigerian market was universally embraced and found to be relatively efficient at the inception. With time, operators in the industry experienced an unprecedented growth in customer base which later incapacitated the networks to function efficiently. Although, this explosive growth has brought huge revenue to both the operators and government through tax and license fee. As revolutionary as GSM may seems to be, many problems bedevil the sector in recent past. Some of the problems are instability in power supply, security of infrastructure, internetwork connectivity, network congestion, call setup failure and call retention/call drop. All these factors contribute in one way or the other to the poor quality of services rendered by GSM operators in Nigeria. Worried by the spate of development in the industry, nation's lawmakers (Senate) in 2007 set up a committee to investigate the inefficiency of the service providers. While this was going on, the house of representative invited the service providers to appear before its ad hoc committee mandated to investigate the activities of the service providers. They maintained that this became necessary due to public outcry on the epileptic services, as well as its economic and social implications. The NCC on their part made a statement in 2009 at a forum on QoS issue that their focus is to administer and monitor closely a performance management program to ensure that operating companies maintain minimum performance levels jointly agreed between the GSM operators, consumer representatives and NCC, in consistent with the world class standards (NCC, 2005). At this forum, the commission outlined a benchmark of QoS indicators in form of technical parameters that must be followed by all operators. This, according to NCC will be closely monitored and evaluated on quarterly basis while stiff penalties were also spelt out for any erring operators for non-compliance (Kuboye et al., 2009). In order to ensure universality and interoperability across the globe in telecommunication services, the International Telecommunication Union (ITU) has set specific standards and regulations in various aspects of information and communications technologies. The ITU has provided benchmarks for equipment and services. The NCC has adopted the ITU standard so that the country can be totally integrated into the entire globe. Conventional Voice Quality of service (QoS) is a means of measuring customer experience of voice telephone service through the voice quality scores known as Mean Opinion Score (MOS) standardized on a scale of 1 to 5 by ITU. The Quality Scores are 5-Excellent, 4-Good, 3-Fair, 2-Poor, 1-Bad (Marc, 2004).

2 LITERATURE REVIEW

There has been much research concerning quality of service (QoS) of global system for mobile communication (GSM). Quality of Service (QoS) is a set of technologies for managing network traffic in a cost effective manner to enhance user experiences for home and enterprise environments. The traffic engineering term quality of service (QoS) refers to resource reservation control mechanisms rather than the achieved service quality. QoS is sometimes used as a quality measure, with many alternative definitions, rather than referring to the ability to reserve resources. Quality of service sometimes refers to the level of quality of service, i.e. the guaranteed service quality. High QoS indicates to a large extent a high level of performance or achieved service quality. QoS are critical for providing high quality network services and for being able to meet the SLA's (Service Level Agreements) that all network operators must have with their customers (Goleniewski, 2003). In the field of telephony, quality of service was defined in the ITU standard X.902 as a set of quality requirements on the collective behavior of one or more objects (ITU, 2003). Quality of Service comprises requirements on all the aspects of a connection, such as service response time, loss, signal-to-noise ratio, cross-talk, echo, interrupts, frequency response, loudness levels, and so on. A subset of telephony QoS is Grade of Service (GoS) requirements, which comprises aspects of a connection relating to capacity and coverage of a network, for example guaranteed maximum blocking probability and outage probability (Yuksel et al., 2007). Poor performance of a telecommunication network would induce customer complaints and faults, thereby leading to customer dissatisfaction towards the operator; it is evident from this presentation that the quality of service rendered by these operators is far below expectation (Adegoke and Babalola, 2011). There have been numerous complaints from all parts of the country regarding call and voice quality, interconnectivity, billing integrity, inability to make calls, poor network reception and total lack of service, etc. (Abayomi-Alli et al., 2012). The Element Management Software (EMS) provided the platform for report generation in the various formats within the Microsoft Excel package, data was collected over a period of twenty-three weeks, parameter analysis were Call Set-up failure rate, Call drop rate, Stand-alone dedicated control channel congestion (SDCCH), Traffic channel availability and Handover failure rate. It can be deduced from the investigation that the bad quality of service encountered by these operators is not as a result of the traffic channel which is readily available but from other factors which include the congestion of the SDCCH (Konstantinopoulou et al., 2000). The QoS constraints are expressed in terms of a delay bound, which is the same as the period of packet arrivals, and a user-defined delivery ratio lower bound (Hou, I-H et al., 2009). GPRS is still immature and several issues need to be considered. Indirectly GPRS performance can be increased if the cellular system is working more efficiently (Kyriazakos et al., 2002). Analyses carried out indicate that the timeslot capacity, and more generally EGPRS performance, varies significantly with frequency reuse and path loss, which directly affect the average system rate (Furuskär, 2001). The use of both ATM and mobile networks will enable us to extend our investigation of QoS issues and resource reservation to specific networking technologies (Davies et al., 1993). GPRS users with a QoS profile allowing a throughput degradation of at most 50%, was concluded for 2% GPRS users among all incoming calls, the reservation of 4 PDCHs is sufficient up to an GSM/GPRS call arrival rate of 1 call per second. However, for the case of 5% and 10% GPRS users, the QoS profile can only be guaranteed up to a call arrival rate of 0.5 and 0.3 calls per second, respectively. The impact of the number of packet data channels reserved for GPRS users on the performance of the cellular network was investigated. Furthermore, three different QoS profiles modeled by a weighted fair queuing Scheme were considered (Lindemann and Thümmler, 2007). Multidimensional Markovian model, which would have been a natural approach for modeling a system with multi-class data traffic, can be decomposed into single linear Markov chains and combined into an approximate "conditional product-form model" (Nogueira, et al., 2008). A DiffServ based approach has been proposed for use at the edge of a network with limited bandwidth resources and it ensures QoS and performance guarantees without needing bandwidth over provisioning to the users (Chaudhuri, 2012). Quality of service (QOS) profile describes the performance evaluation of a system from the consumer perspective, using specific parameters. In telephony, parameters used include call failure rate, call drop, call throughput, and voice quality. All of these are affected by system configuration or dimensioning. All failure is the inability of a call to access the trunk usually due to full trunk occupancy (Ayeni, 2005).

3 METHODOLOGY

In this study, various call quality parameters were evaluated for four global system for mobile communication (GSM) mobile operators: Operators A, Operator B, Operator C and Operator D, with existing network infrastructures within Ikorodu and Badagry network regions. A total of five parameters were evaluated which include Call Setup Failure Rate, Call Drop Rate, standalone dedicated control channel SDCCH congestion rate, TCH availability and Inter and Intra public land mobile network PLMN handover. The most commonly used method to collect call data within a network public land mobile network (PLMN) by obtaining these parameters from a central monitoring center called the Operation and Maintenance Centre (OMC), Network Operation Centre (NOC) was used. The NOC connects directly to the Base Station Controller (BSC) and Mobile Switching Center (MSC) which are the most sensitive equipment within the GSM infrastructures. Reports were then generated from these data via enterprise software applications referred to as Element Management Software EMS. This software provides platforms for reports generation in various file formats with the Microsoft Excel. This study investigated the Quality of Services provided by the four GSM service operators within Ikorodu and Badagry Regions by collecting and analyzing call data from drive test. The result of the analysis is then compared with those specified by the Nigerian Communication Commission NCC (Regulator, 2013). Molina lost calls held trunking formula (poison formulas) were used to establish, compare and confirm the calls blocked value for each operator in the two regions.

Method of Data Collection and Analyses

A benchmark drive test method was used to test the network performance of the study area as well as the quality of service (Dahlman et al., 2008).

Drive Test Requirements

The following accessories were used to perform a drive test.

Hardware requirements

Laptop (for mobility), Measurement Phone, Dual serial port PCMCIA card, GPS Navigator with external serial port connection, External Antenna for both the measurement phone and the GPS navigator. Dual connection box for combining Trace and Data ports on phone, This is also known as a 'Break Out' box, Cables and Connectors as required (DB9 serial cable X 2, Serial connection cable for Navigator, Charger for Measurement phone) (Davies et al., 1993).

Software requirements.

Operating System on the laptop. Windows 98 or higher, TEMS investigation software Version 9.3.1. USB Dongle, which is the TEMS software license needed before software can be used for GPRS measurements, GPRS phone driver software (for phone setup as a modem), Driver software for Dual Serial I/O Card (PCMCIA).

Hardware Connections.

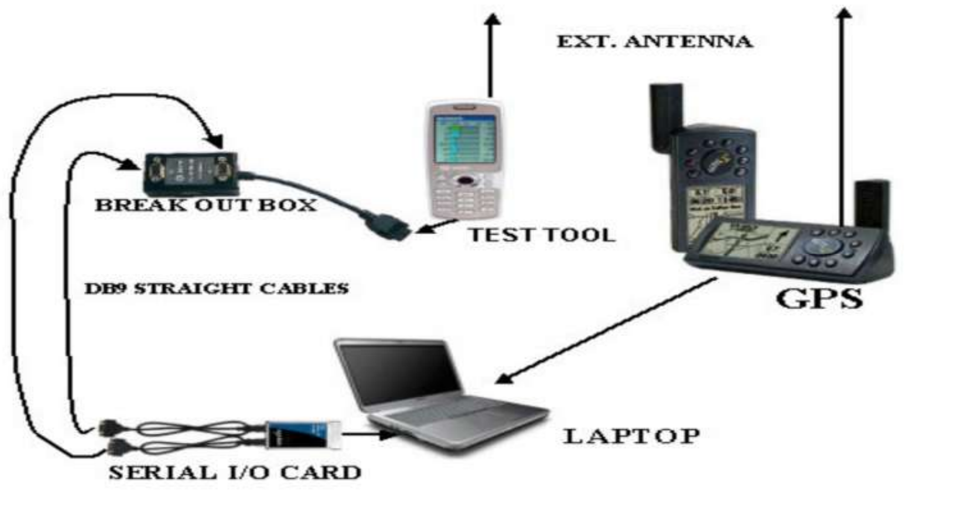

Figure.1: Hardware connections

Methods and Materials

i. Call Set-Up Success Rate (CSSR) = $\frac{\text{no of SD seizures}}{\text{total no SD request}}$ (1)

ii. Call Drop Rate (CDR) = $\frac{\text{no of TCH Drops}}{\text{No of successful TCH assignment}}$ (2)

iii. TCH Congestion Rate (TCH – CR) = $\frac{\text{no of drops due to resource unavailability}}{\text{Total no of TCH requests}}$ (3)

iv. SDCCH Congestion Rate = $\frac{\text{no of SDCCH Drops}}{\text{Total no of SDCCH assignments}}$ (4)

v. Call Retention Rate: (CRR) = (100- CDR) % (5)

vi. Call Completion Rate: (CCR) = (CSSR –CDR) % (6)

vii. Conversion of percentage to decibel, 1dB = 10LOG (1 + X), where X = 1,2,3,4,5,……..[%] (7)

viii. Poison blocking probability (Molina lost calls held trunking formula)

$$P(x) = \frac{A^x e^{-A}}{x!} \quad (8)$$

Where e = 2.71828 and x! is the factorial of x, $1\cdot2\cdot3\ldots\cdot x$. Now the average number of occupied channels is A in erlangs and (1) gives the probability that x number of channels is occupied at a time when a subscriber makes a call. Blocking occurs if all n channels are occupied or there may even be a need for a larger number of channels. This probability is given by:

$$P(x \geq n) = P(n) + P(n+1) + P(n+2) + \ldots \quad (9)$$

On the other hand, one number of channels is always in use, giving this probability for

$$P(0) + P(1) + P(2) + \cdots + P(n) + P(n+1) + \cdots = P(x < n) + P(x \geq n) = 1 \quad (10)$$

Re-writing equation (9) in this form:

$$P(x \geq n) = 1 - P(x < n) \quad (11)$$

Substituting equation in (10) gives:

$$P(x \geq n) = 1 - [P(0) + P(1) + P(2) + \cdots + P(n-1)]$$

$$= 1 - [\frac{A^0 e^{-A}}{0!} + \frac{A^1 e^{-A}}{1!} + \cdots + \frac{A^{n-1} e^{-A}}{(n-1)!}] \quad (12)$$

This is the Poisson formula, which is also known as the Molina lost calls held trunking formula, for blocking probability and is analysed as follows:

$$P(x \geq n) = 1 - \sum_{x=0}^{n-1} \frac{A^x e^{-A}}{x!} \quad (13)$$

From equation 10 above $P(x) = \frac{A^x e^{-A}}{x!}$

The following expressions illustrate a poison probability distribution function, given an offered traffic A = 1 and n total channel, n = 3; x gives the tolal occopied channel.

When x = 0 A = 1 $P(0) = \frac{1^0 0.271828^{-1}}{0!} = 0.37$

x = 1 $P(1) = \frac{1^1 0.271828^{-1}}{1!} = 0.37$

x = 2 $P(2) = \frac{1^2 0.271828^{-1}}{2!} = 0.18$

4 RESULTS OBTAINED

Benchmarking Drive Test of Lagos Ikorodu and Badagry Region

The following results were obtained from a drive test process which took the following procedure, firstly TEMS software was installed on t he laptop with a corresponding operating system of window 7 and other hardware devices such as measurement phone, dongle, GPS, phone cables were connected to the laptop. During Ikorodu region test, a total of 90 calls were made with operator A in which 69 were established and 21 were blocked, 90 calls were made with operator B, 49 were established with 41 blocked, a total of 88 calls were made with operator C in which 62 established and 26 got blocked, 90 calls were made with operator D, 89 were established and 6 were blocked. In Badagry region, a total of 274 calls were made with operator A in which 255 were established and 19 were blocked, 274 calls were made with operator B, 212 were established and 62 blocked, a total of 274 calls were made with operator C in which 191 got established and 83 blocked, 274 calls were made with operator D, of which 205 were established and 69 blocked. All calls event were recorded by the TEMS software for a period of six months of operation and the results analysed.

In this paper, the voice network of OPERATOR A was benchmarked against those of 3 other competing networks, namely OPERATOR B, OPERATOR C, and OPERATOR D. In particular, the drive-test campaign was conducted for the Lagos Ikorodu and Badagry region and the overall performance of the four operators networks were described in terms of accessibility, retainability, mobility, coverage reliability, coverage quality and call completion rate.

Call Statistics and Event-Based KPI Analysis

In this section, call statistics were presented and analysed for all the benchmarked networks. The resulting KPIs were subsequently compared for the benchmarked networks in question. The results of these comparisons were presented in tabular formats. However, the radio coverage were analysed in terms of the coverage reliability and quality. The network KPIs considered were accessibility, retainability, and mobility. The coverage and quality metrics represented as maps in this report were Ec/No, RSCP, and UE Tx Power.

First Region: Lagos Ikorodu Voice Benchmarking Report

The results of the analysis of Ikorodu region were summarized based on coverage reliability, coverage quality, accessibility and key performance (KPI) ranking in Table 1, Table 2, Table 3 and Table 4, respectively. Each operator was represented as Operator A, Operator B, Operator C and Operator D.

Coverage Reliability

Table 1: Showing Reliability Quality of Lagos Ikorodu Region

% Coverage Reliability	Operator A	Operator B	Operator C	Operator D
NCC TARGET % RSCP > (-90dbm)	18.22	30.44	56.68	74.02
RANKING	4th	3rd	2nd	1st

Table 2: Showing Coverage Quality of Lagos Ikorodu Region

% Coverage Quality	Operator A	Operator B	Operator C	Operator D
NCC TARGET -11dB <= Ec/No < 0 dB	49.26	71.49	88.04	97.15
RANKING	4th	3rd	2nd	1st

Accessibility

Table 3: Showing Accessibility Quality of Lagos Ikorodu Region

Event Details	Operator A	Operator B	Operator C	Operator D
Call Start Results				
Call Attempt	0	50	74	90
Call Attempt Retry	17	5	27	2
Call Initiation	90	90	88	90
Call Setup Results				
Block Call	21	41	26	1
Call Established	69	49	62	89
Call Setup	90	90	88	90
% Call Setup Rate	88.46%	96.00%	86.49%	100.00%
% Block Call Rate	23.08%	42.00%	35.14%	1.11%
% Established Call Rate	88.46%	94.00%	83.78%	98.89%
RANKING				
Poison blocking probability distribution (Molina lost call)	**0.2308**	**0.4200**	**0.3514**	**0.0111**
Offered traffic (A, unit in erlang)	**2%**	**1%**	**0.5%**	**1%**
Number of occupied channels	**2**	**3**	**3**	**1**
Block Call Rate	2nd	4th	3rd	1st

It is obvious that OPERATOR D out performs all the other operators in terms accessibility due to good received signal power of the antennas and lesser number of occupied traffic channels. OPERATOR B, unfortunately recorded the worst performance in this region due to too many occupied traffic channels, overshooting of sites and high interference spot, and these causes very low reliability and quality values (74.02%, 71.49% and 18.22%, 49.26% respectively).

Key Performance (KPI) Ranking [For Lagos Ikorodu]

Table 4: Showing of Key Performance (KPI) Ranking of Lagos Ikorodu Region

OPERATOR RANKING BY KPI's						
Coverage- or Event-Based	**KPI Category**	**KPI Definition**	**OPERATORS**			
			Operator A	**Operator B**	**Operator C**	**Operator D**
Coverage-Based	Coverage Reliability	%(CPICH RSCP>-90dBm)	4th	3rd	2nd	1st
	Coverage Quality	%(-11dB <= CPICH Ec/No < 0dB)	4th	3rd	2nd	1st
Event-Based	Accessibility	Blocked Call Rate	3rd	1st	2nd	. 4th
	Retainability	Dropped Call Rate	4th	3rd	1st	2nd
	Mobility	Soft/Softer HOSR	1st	1st	1st	1st
	Integrity	%(DL BLER<2%)	4th	3rd	2nd	1st

It was obvious that OPERATOR D and OPERATOR C both have better performances above other operators. OPERATOR A, unfortunately recorded the worst, chiefly due to its very low coverage reliability and quality values (18.22% and 49.26%, respectively).

Second Region: Lagos Badagry Voice Benchmarking Report

The results of the analysis of Lagos Badagry region were summarized based on coverage reliability, coverage quality, accessibility and key performance (KPI) ranking in Table 5, Table 6, Table 7 and Table 8, respectively. Each operator was represented as Operator A, Operator B, Operator C and Operator D.

Coverage Reliability

Table 5: Showing Reliability Quality of Lagos Badagry Region

% Coverage Reliability	**Operator A**	**Operator B**	**Operator C**	**Operator D**
NCC TARGET % RSCP > (-90dbm)	56.66	42.72	57.66	76.74
RANKING	3rd	4th	2nd	1st

Coverage Quality

Table 6: Showing Coverage Quality of Lagos Badagry Region

% Coverage Quality	Operator A	Operator B	Operator C	Operator D
NCC TARGET -11dB <= Ec/No < 0 dB	79.74	75.91	86.18	91.43
RANKING	3rd	4th	2nd	1st

Accessibility

Table 7: Showing accessibility Quality of Lagos Badagry Region

Event Details	Operator A	Operator B	Operator C	Operator D
Call Start Results				
Call Attempt	271	228	247	240
Call Attempt Retry	21	36	29	13
Call Initiation	274	274	274	274
Call Setup Results				
Block Call	19	62	83	69
Call Established	255	212	191	205
Call Setup	274	274	274	274
% Call Setup Rate	94.46%	93.86%	93.93%	91.67%
% Block Call Rate	2.95%	6.58%	6.07%	12.50%
% Established Call Rate	94.10%	92.98%	77.33%	85.42%
RANKING				
Poison blocking probability distribution (Molina lost call)	**0.0295**	**0.0658**	**0.0607**	**0.1250**
Offered traffic (A, unit in erlang)	**3%**	**10%**	**10%**	**1%**
Number of occupied channels	**1**	**1**	**1**	**2**
Block Call Rate	1st	3rd	2nd	4th

It is obvious that OPERATOR A out performs all the other operators in terms accessibility due to good received signal power of the antennas and lesser number of occupied traffic channels. OPERATOR D, unfortunately recorded the worst performance in this region due to too many occupied traffic channels, overshooting of sites and high interference spot, and the effects are low reliability and quality values (76.74, 42.72%, and 91.43%, 75.91% respectively).

Key Performance (KPI) Ranking [Lagos Badagry Region]

Table 8: Showing of Key Performance (KPI) Ranking of Lagos Badagry Region

OPERATOR RANKING BY KPI's						
Coverage- or Event-Based	**KPI Category**	**KPI Definition**	**OPERATORS**			
			Operator A	**Operator B**	**Operator C**	**Operator D**
Coverage-Based	Coverage Reliability	%(CPICH RSCP>-90dBm)	3rd	4th	2nd	1st
	Coverage Quality	%(-11dB <= CPICH Ec/No < 0dB)	3rd	4th	2nd	1st
Event-Based	Accessibility	Blocked Call Rate	1st	3rd	4th	2nd
	Retainability	Dropped Call Rate	2nd	3rd	4th	1st
	Mobility	Soft/Softer HOSR	1st	1st	1st	2nd
	Integrity	%(DL BLER<2%)	2nd	4th	3rd	1st

It was obvious that OPERATOR D outperformed all the other operators in terms of the KPIs.

Table 9: Performance Analysis of Lagos - Ikorodu and Badagry Regions

LAGOS REGIONS RANKING BY OPERATOR's KPI					
Coverage- or Event-Based	**KPI Category**	**KPI Definition**	**LAGOS REGIONS**		
			FIRST REGION : IKORODU	**SECOND REGION :BADAGRY**	
Coverage-Based	Coverage Reliability	%(CPICH RSCP>-90dBm)	1st Operator D	2nd Operator D	
	Coverage Quality	%(-11dB <= CPICH Ec/No < 0dB)	1st Operator D	2nd Operator D	
Event-Based	Accessibility	Blocked Call Rate	1st Operator D	2nd Operator A	
	Retainability	Dropped Call Rate	1st Operator C	2nd Operator D	
	Mobility	Soft/Softer HOSR	2nd Operator A, B, C,D	1st Operator A, B, C	
	Integrity	%(DL BLER<2%)			

Overall Key Performance (KPI) Ranking [Lagos Ikorodu, Badagry Region]

The overall ranking of operator's KPI in the studied regions revealed that OPERATOR C, OPERATOR D, OPERATOR B and OPERATOR A performed in every category of the key performance index (KPI) in that order as shown in Table 9.

5 CONCLUSION

This study analysed a drive-test campaign within Lagos Ikorodu and Badagry regions. The methodology employed for the analysis took the following form; the overall KPI performances, along with the coverage reliability, accessibility and quality, compared with Nigeria Communication Commission (NCC) standard and a Poison distribution of blocking probability (Molina lost calls held trunking formula for blocking probability). As a final point, comparative analyses were performed for the two regions to verify the performance of quality of service offered by the four operators. Generally the quality of services of the operators met up to NCC targets in some KPI as well as the Molina lost calls held trunking formula for blocking probability while some performs below the

expected NCC targets. The analysis of the study revealed that the performance of Operator C network, based on coverage reliability (RSCP) was observed to be the best and Operator D reveals to be 2nd
best.The performance of Operator D based on cove rage quality (Ec/No) was also observed to be the best and Operator D was the 2nd best, the performance of Operators A, B, C were observed to be the best in terms of mobility (soft/softer handover). Likewise, in terms of both accessibility (Blocked Call Rate) and retainability (Dropped Call Rate), Operator D and C performances revealed to be the overall best. Irrefutably, Operator C and D have proven their loyalty to customers about the quality of services (QoS) they render. The overall ranking of operator's KPI revealed that operators C, D, B, A performed in every category of the key performance index (KPI) in that order. The poor quality of services by the operators could be improved by proposing new sites, adjustment of antenna azimuth, BTS equipment's filter change, improvement in base radio power supply, retuning of interference frequencies, measure of control over promotion on services and attenuation add/removal processing.

REFERENCES

Abayomi-Alli, A., Ezomo, P. I., Etuk, D. J., Ogbogho, I. and Izilien, F. (2012), Performance Evaluation of GSM Service Providers around Igbinedion University Campuses. Advanced Materials Research published by Trans Tech Publications, Switzerland, 367(2012):177-184.

Adegoke, A.S and Babalola, I.T. (2011), Quality of Service Analysis of GSM Telephone System in Nigeria. American Journal of Scientific and Industrial Research 5(2):707-712.

Akinboboye, K. O. (2010), M.Eng. Thesis, Department of Electrical Engineering. University of Ilorin, Ilorin. Nigeria.

Ayeni, A. (2005). Performance Evaluation Of The Nigerian Cellular Mobile. Phd Thesis, Department of Electrical Engineering, University of Ilorin, Ilorin,Nigeria.

Chaudhuri, S. G. (2012), Design and Implementation of a Differentiated Service Based QoS Model for Real-Time Interactive Traffic on Constrained Bandwidth IP Networks. Cornell University Library, Computer Scince, Networking and Internet Architecture [arXiv: 1205.3319 v 1 cs.NI].

Dahlman, E., Parkvall, S., Sköld, J and Beming, P. (2008), 3G Evolution HSPA and LTE for Mobile Broadband. Second edition, 2008. pp45-55.

Davies, N, Coulson, G and Blair, G. S. (1993), Supporting Quality of Service in Heterogeneous Networks: from ATM to GSM. Internal Report MPG-93-26, Department of Computing, Lancaster University, Bailrigg, Lancaster, UK.

Furuskär, A. (2001), Statistical QoS Requirements, Timeslot Capacity and Dimensioning for Interactive Data Services in GERAN–The GSM/EDGE Radio Access Network, in proceedings of the Nordic Radio Symposium, Sweden.

Goleniewski, L. (2003), Telecommunication

Essentials. Addison Wesley. Boston, U.S.A.

Haider, B, Zafrulla, M and Islam, M. K. (2009), Radio Frequency Optimization and Quality of Service Evaluation in Operational GSM Network. Proceedings of the World Congress on Engineering and Computer Science. 20th-22nd October, San Francisco, USA. Vol. l.

Hou, I-H, Borkar, V and Kumar, P. R. (2009), A Theory of QOS for Wireless. Department of Computer Science, University Of Illinois Urbana, IL 61801, USA.

ITU, (2003), ITU-T Study Group 2, Teletraffic Engineering Handbook. Available at http://www.com.dtu.dk/teletraffic/handbook/telenook.pdf

Konstantinopoulou, C. N., Koutsopoulos, K. A., Lyberopoulos, G. L and Theologou, M. E. (2000), Core Network Planning, Optimization and Forecasting in GSM/GPRS Networks. IEEE Symposium, Communications and Vehicular Technology, 2000-SCVT-200. pp51-61.

Kuboye, M. B., Alese, B. K and Fajuyigbe, O. (2009), Congestion Analysis on the Nigerian Global System for Mobile Communications (GSM) Network. The Pacific Journal of Science and Technology. 10(1):262-271.

Kyriazakos, S, Papaoukakis, N, Nikitopoulos, D, Gkroustiotis, E, Kechagias, C, Karambalis, C and Karetsos, G. (2002), A Comprehensive Study and Performance Evaluation of Operational GSM and GPRS Systems under Varying Traffic Conditions.1st Mobile and Wireless Telecommunications Summit, Thessaloniki, Greece.

Lindemann, C. and Thümmler, A. (2001), Evaluating the GPRS Radio Interface for Different Quality of Service Profiles. In Proc. 12th GI/ITG Fachtagung Kommunication Verteilten Systemen (KiVS), Feb. 2001. Hamburg, Germany. pp 291-301.

Marc, K. (2004), Pocket Guide For Fundamentals and GSM Testing. Wandel and Goltermann GmbH & Co, Berlin, Germany, 2:30-36.

Nogueira, G., Baynat, B. and Ziram, A. (2008), An Efficient Analytical Model for QoS Engineering in Mobile Cellular Networks. IEEE International Symposium on World of Wireless, Mobile and Multimedia Networks (WoWMoM), Newport Beach, CA. pp 1-12.

Regulator, (2013), Regulations on Quality of Service. Available online: www.ncc.gov.ng/index.php?option=com_content&view=aeticle&id=74&itemid=89. Retrieved on Sept. 10, 2013.

Yuksel, M., Ramakrishnan, K. K., Kalyanaraman, S., Houle, J. D. and Sadhvani, R. (2007), IEEE International Workshop on Quality of Service (IWQoS'07). Pp. 109-112. Available at http://iwqos07.ece.ucdavis.edu