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Performance Evaluation of WCDMA Networks in Selected Geolocations Using Structured Questionnaire and Empirical Analysis Methods

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ABSTRACT

High influx in the number of cellular subscribers is observed to be one of the constraints to incessant poor network performance which results to increased congestion challenges. This work is attributed towards executing network performance evaluation to ascertain the levels of degradation on the WCDMA networks from selected geographical locations in Owerri, the capital city of Imo State, Nigeria. The methods adopted are structured questionnaire and empirical analysis. Structured questionnaires were administered to survey 250 customers from the two (2) major and dominant network providers in Owerri metropolis: MTN and AIRTEL, on their Quality of Service (QoS) delivery and to determine their network satisfactory performance rates. Empirical analyses were conducted on the two networks to evaluate their network performances using the selected Key Performance Indicators (KPIs). Aba road, FUTO road, Onitsha road, Orlu road and Wetheral road were selected for the analysis owing to the high density of the network subscribers within these regions. The Selected KPIs which include Call Drop Rate (CDR), Call Setup Success Rate (CSSR), Call Completion Success Rate (CCSR), network accessibility, network retainaibility and Receive Signal Level (RXLEV) were deployed to evaluate the various performance characteristics of the networks based on the QoS. From the result assessments, none of the networks met the Nigeria Communication Commission (NCC) thresholds based on the KPIs selected except for MTN network along FUTO, Wetheral and Onitsha roads marginally agreed with the NCC target value on CCSR. Also MTN network along Onitsha road slightly met the NCC target value on CSSR and network accessibility.

Key Words: *WCDMA, KPI, QoS, MTN, AIRTEL, NCC.*

1. INTRODUCTION

The introduction of mobile telephone systems was one of the advancements in wireless technology which had created ease in mobile communication and in various levels of transactions. Its benefits to human and capacity developments, was perceived as one of the factors that influences the high demand. The increasing need for efficient high speed internet and multimedia applications further resulted to the invention of Universal Mobile Telecommunication Services (UMTS), a 3rd Generation network (3G), widely known as Wideband Code Division Multiple Access (WCDMA), operating at 2.1GHz. This was developed to improve the limitations of the GSM network especially in multimedia applications.

In [1], it was observed that the high traffic evident in the network due to the increased number of subscribers had led to persistent poor quality service delivery. Due to the influx of subscribers, the network performance of WCDMA systems began to deteriorate ranging from poor network coverage, constant drop calls, call/network congestion and poor internet services. These highlighted issues created lots of complaints from the end users and hence the need for adequate evaluation of the percentage degradation for suitable mitigation measures.

This study considered basically two prominent networks viz MTN and Airtel in the South Eastern part of Nigeria (Owerri metropolis in Imo State), characterized with greater number of subscribers. Evaluation of their network performances will be

achieved in the study using two analysis tools - Structured Questionnaire and Empirical Analysis. The selected geo-locations for the study include Aba road, FUTO road, Onitsha road, Orlu road and Wetheral road observed with high density of cellular subscribers. A prominent criterion known as Key Performance Indicators (KPIs) was further deployed for adequate valuation. In [2], classified KPI as a minimum set of metrics used for tracking system progress towards a performance target. Usually, the essential tools for the KPI assessment are the Quality of Service (QoS) and Grade of Service (GoS). For this study, QoS is solely considered. Quality of Service is defined as the collective effect of service performance, which determines the degree of satisfaction of a user[3]. Selected KPIs for the study include Call Drop Rate (CDR), Call Setup Success Rate (CSSR), Call Completion Success Rate (CCSR), Network Accessibility, Network Retainaibility and Receive Signal Level (RXLEV).

2. LITERATURE REVIEW

In [4], entitled "Performance Analysis of GSM network in Minna metropolis of Nigeria", compared the performance of various KPIs used by NCC for rating QoS which include Call Setup Success rate (CSSR), Call Completion Success rate (CCSR), Call Drop Rate (CDR) and TCH Congestion Rate. The network operators evaluated were designated as W, X, Y, and Z. The results obtained were used to compare NCC KPIs target, which was observed that only operator X had the best network quality, followed by W while Y had the worst network quality followed by Z in the area of study. The result also showed that Y had the best planned network requiring minimal handover which means 100% handover success rate. The authors further did an in-depth analysis on W network, problem that affects the sites were identified and optimization measures required to resolve the problems were recommended. The authors of [5], on quality of service assessment, studied the benchmarking of cellular network in Ankara, Turkey, by comparing the GSM and UMTS network operators represented as A, B, and C to determine which network renders the best network performance in Ankara. The study was carried out using some selected KPIs which include CSSR, Call Setup Time (CST), CDR, Speech Quality (SQ) Perceptual Evaluation of Speech Quality (PESQ) and Received Signal level (RxL). The results obtained from both field test and survey from customers, comparison was done according to the operator's value of weighted and equivalent weighted score. For GSM; operator B was the overall best followed by A and C with 73.00, 74.14 and 72.57scores respectively. When KPIs for RX level were compared, operator B had the highest signal strength. Operator C follows operator B with better signal level than operator A. Their results showed that operator B had the best performance for accessibility and retainability. The authors further carried out analysis on measurement conducted on speech quality using Perceptual Evaluation Speech Quality (PESQ). They analyzed the speech quality (SQ) of the network operators using Probability Density Function and Cumulative Density Function (PDF/CDF) analysis, which according to them was the most popular KPI. They used PESQ to measure the SQ and evaluated with Chi-Square and fisher's exact tests. The researchers therefore were able to determine which network operator provided the highest Speech quality in Ankara. Their results after comparing UMTS and GSM networks showed that UMTS had better signal levels and voice quality than GSM.

A compromise between network performance and end user satisfaction over UMTS Radio interface was carried out by [6]. An empirical investigation in Asaba Delta state." The authors empirically assessed and analyzed the compromise between network performance and end-user satisfaction. The KPIs used were CDR, CSSR, HOSR, ESA and NRR. Five clustered ranging from 1-5 were considered in their analysis. Drive test was used to conduct measurements in the cellular network of study. The research work assessed the End User satisfaction by estimating the blocked calls probability (Pblock) and dropped calls probability (Pdrop) data by Psatisfied = 1- Punsatised, where Punsatisfied = Pblock + Pdrop. The results obtained when compared with the NCC performance benchmark, made 20% in cluster 1-3 and 60% in cluster 4-5 respectively. The authors observed that the network performance in the five clusters were generally below expectation and unsatisfactory. The work of [7], carried out a study on "End-User Satisfaction Assessment Approach for Efficient Network Performance Monitoring in Wireless Communication Systems". A data mining process was introduced which was also referred to as nontrival technique of extracting implicit and potentially useful information from existing data sets. The performance statistical data was obtained from NCC QoS KPIs database. A total of eight months data within the periods of February to September 2013 were obtained and the selected network were named A, B, C, and D. The results obtained showed that none of the operators except operator D in the month of March to September met the NCC target of 98% of CSSR standard within the evaluation period. Relative to the related works, the various authors conducted good research work on the related issue.

This research study tends to evaluate the field measurements conducted with the structured questionnaires to establish the present conditions of the quality of service offered by the two dominant networks. Some Selected KPIs were applied to analyze the various performance characteristics of the networks.

2.1 Selected Key Performance Indicators [8]

1. **Call Drop Rate (CDR)**: It is the total number of calls dropped (not ending as desired by the user)or forced call disconnection by the network due to various reasons within the licenses own network.

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$$CDR = \frac{\text{Number of Dropped Calls} \quad X\ 100}{\text{Number of Successfully Completed Call Setup}} \quad (1)$$

2. **Call Completion Success Rate (CCSR):** This indicator can be derived either from network statistics or from drive test statistics. The indicator takes into account the fact that all failures are either drops or unsuccessful call set ups. It is a good parameter for evaluating the network accessibility and retainability as perceived by the customers. The indicator is derived using the expression:

$$CCSR = \frac{\text{Total Number of Completed Call} \quad X\ 100}{\text{Total Number of Call Attempted}} \quad (2)$$

3. **Call Success Setup Ratio (CSSR)**: This is ratio of total number of completed calls to the total number of call attempts.

$$CSSR = \frac{\text{Successfully Completed Call Setups} \quad X\ 100}{\text{Call Setups Attempts}} \quad (3)$$

4. **Network Accessibility Ratio (NAR)**: This is the probability that a mobile user will establish a successful voice communications between the two ends of the network within a given condition. It is also expressed as the call setup rate. It is expressed as:

$$NAR = \frac{\text{Number of Successful Call Setup} \quad X\ 100}{\text{Number of Call Attempted}} \quad (4)$$

5. **Network Retainability Ratio (NRR)**: It is the ratio between the number of successful calls and number of normally terminated calls. It is also the probability that an active call come to an end successfully in a network.

$$NRR = \frac{\text{Number of Successful Calls} \quad X\ 100}{\text{Number of Call Terminated}} \quad (5)$$

6. **Received Signal Level (RXLEV)**: This is referred to as the received signal level at the input of the mobile device. For WCDMA network it is in RSCP

$$RSCP = \frac{\text{Summation of all data that fall in >-85dBm} \quad X\ 100}{\text{Summation of all data}} \quad (6)$$

2.2 NCC's KPI Benchmark for Network Providers

Table 1 shows some of the Network Performance KPI's and their percentage threshold levels by the Nigeria Communications Commission (NCC).

Table 1: Threshold for Network performance KPI's [1-9]

Key Performance Indicators	CDR (%)	CSSR (%)	CCSR (%)	CSFR (%)	HOSR (%)	HOFR (%)	RSCP (dBm)	Ec/lo (dBm)
NCC Threshold value in %	2	98	96	4	98	2	-85	-9

3. METHODOLOGY

Structured Questionnaire was implemented in the study to ascertain how satisfied customers are with the WCDMA networks while Empirical Analysis was incorporated to evaluate the actual levels of network performance based on field measurements. The hardware materials used for the study include Laptop, TEMS Phone(SONY ERRICSSON W995 TEMS POCKET), Global Positioning System (GPS) and data cable while the software tools are TEMS Investigation Software, MapInfo Professional and Statistical Packages for Social Sciences (SPSS). Figure 1shows the TEMS Phone and data cable configuration while Figure 2 shows the Mapinfo Professional environment.

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Fig 1: Sony Erricsson W995 Tems Pocket.

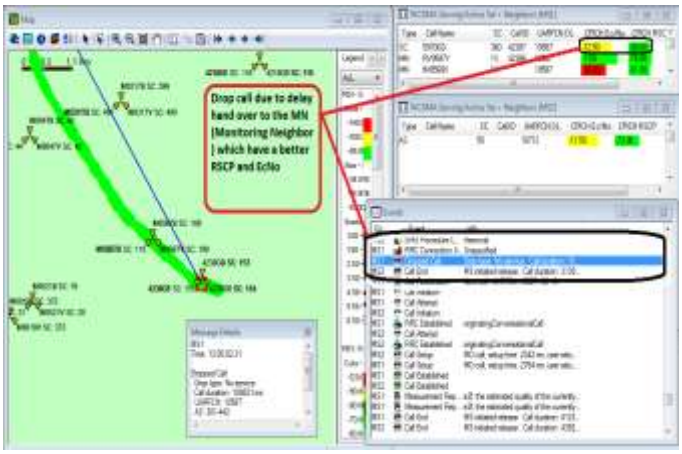

Figure 2 MapInfo Professional

A HP labtop of core i3, 2GB, 500GB was used to install softwares such as MapInfo Professional and TEMS Investigation for the simulation analyses.The data cable, Sony Erricson Phone, and GPS were all connected on the the labtop. Sony Erricsson W995 TEMS Pocket is a phone-based test tool for measuring the performance and quality parameter of wireless networks. The tool collects measurements and event data for network monitoring. TEMS Phone was used to access the services of WCDMA from the End users. Data cable was used to connect the Sony Erricson W995 TEMS pocket to the Labtop. Global Positioning System (GPS) was used to calculate the exact position, speed and time at the vehicles location. Hence it was implemented to determine the position of the mobile station to an accuracy of ± 5 meters. TEMS Investigation Software was used to verify, optimize and troubleshoot the WCDMA services from a subscriber testing scenario. It gives a good knowledge of the availability of the WCDMA network, and features about the quality of service for WCDMA network. MapInfo Professional is a geographical information software for mapping and location analysis of the network. It was used to visualize, analyze, interpret and output WCDMA network data to reveal quality of service relationships, pattern and treads. It also enabled the maps formation for interpretation of the network services, analyse drop calls due to delay hand over to the monitoring neighbor. These parameters remain paramount for the system simulation. The research study deployed is a widely used program for statistical analysis known as Statistical Packages for Social Sciences (SPSS) version 20.0 to compute the obtained descriptive statistics.

3.1 Measurement Environment

The measurements were carried out in the following areas within Owerri municipal namely Aba road, Federal University of Technology Owerri road, Onitsha road , Orlu road and Wetheral road as shown in Figures 3-7 respectively.

Figure 3: Measurement Environment for Aba Road.

Figure 4: Measurement environment of FUTO Road

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The measured area in Figure 3 comprised mainly farmland, moderately populated, scattered low houses, with both long and short trees. It consists of flat terrain with houses clustered apart. Figure 4 is characterized with plain environments, low level vegetation, more of moderate high buildings, scarcely populated with dwarf trees.

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Figure 5: Measurement Environment for Onitsha Road.

Figure 6: Measurement Environment for Orlu Road.

Figure 5 is made up of plain environments, densely populated and comprised bungalows, few high rise buildings. Orlu Road as shown in Figure 6 is characterized with low plain environment, densely populated with lots of bungalows and moderate short trees. Figure 7 is composed of plain environments, densely populated with moderate high buildings and very few low short trees.

Figure 7: Measurement Environment for Wethral Road.

3.2 Analysis of the MTN and Airtel Networks using Structured Questionnaire

Structured questionnaires were deployed to survey 250 network subscribers of MTN and Airtel networks on the perceived service delivery by the respective service providers, to determine their satisfaction rate.The study implemented a mean distribution approach to determine the state-of-the-art performance of the WCDMA network for MTN and Airtel at various locations namely Aba road, Federal University of Technology Owerri road, Onitsha road, Orlu road and Wetheral road. The study was conducted from 9th of September 2016 to 21st of Nov 2016.

The questionnaires were administered to persons from the age of 18yrs and above to staff in offices along Aba road and at the car dealers market. Along FUTO Road, it was administered to staff and students in FUTO. Also administered to staff in offices and institution along Onitsha Road. Orlu Road was administered at Imo High court and Alvan Ikoku Federal College of Education Owerri (AIFCE).

In this research work the critical mean was generated from using Mean Opinion Score (MOS). The MOS is basically used for arithmetic mean calculation for quality evaluations. The following are the decision rules:

1. if calculated mean = μ < critical mean= 3.5, Disagree to the statement
2. Else if calculated mean = μ > critical mean= 3.5, Agree to the statement

Where μ represent the mean distribution.

3.3 Experimental Test Set Up

The required components were connected fittingly to the laptop. A dongle which gives a license to the TEMS interface on the system was first connected to the laptop. The next step requires powering ON the laptop after which the dongle was connected to it through one of the Universal Serial Bus (USB) ports. Further step aided to connect the TEMS phone through the phone's USB

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cable and the GPS. The dongle allows accessibility to these two pieces of equipment. One quality about TEMS is the embedded audio capability which enables quick detection of any disconnected component. After the successful connection of these tools, the next step was the commencement of the drive test. A folder was created for data saving (Log file) during the measurement.

3.3.1 Outdoor Measurement Analysis

Drive test is a process used to ascertain and measure the quality of service and coverage capacity. It is performed on wireless network irrespective of the technology. Data was collected on a motion vehicle at an average speed of 30m/s. Statistic information of the network was obtained to enable further optimization of the network performance. Drive test was used to obtain call statistics for the KPI's computation.

The measurements obtained from drive test were used to analyze the characteristics performance of WCDMA signals from the selected geolocations. The NCC threshold (as presented in Table 1) remains the benchmark used for the KPIs.

4. RESULTS AND DISCUSSION

Mean distribution of customer perceived service delivery and the mean distribution using the Call drop rate performance indicator

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Table 2 Mean distribution of Customer Perceived Service Delivery by providers of WCDMA networks within Owerri

	Customer Perceived Service Delivery	**OwerriMetropolis**				
S/N	**Statement**	**FUTO Road (µ)**	**Orlu Road (µ)**	**Onitsha Road (µ)**	**Wetheral Road (µ)**	**Aba Road (µ)**
1	**The network is always available and there is network coverage at all times**	3.0000	3.3600	2.8800	3.7600	3.1633
	Decision	Disagreed	Disagreed	Disagreed	Agreed	Disagreed
2	**Call initialization is always very good and satisfactory**	2.8200	2.7800	2.7000	3.4400	2.9796
	Decision	Disagreed	Disagreed	Disagreed	Disagreed	Disagreed
3	**The Network is satisfactory for internet browsing & multimedia usage**	2.9000	2.6600	2.5800	3.7000	3.0612
	Decision	Disagreed	Disagreed	Disagreed	Agreed	Disagreed
4	**Service providers are truthful in keeping promise**	3.5700	3.44	2.94	3.88	4.0816
	Decision	Agreed	Disagreed	Disagreed	Agreed	Agreed
5	**Service providersare usually eager in solving network issues**	3.1633	3.2600	3.5	4.24	3.8367
	Decision	Disagreed	Disagreed	Agreed	Agreed	Agreed
6	**Service providers understand customer's specific needs**	3.4082	3.1000	3.24	3.8800	4.1020
	Decision	Disagreed	Disagreed	Disagreed	Agreed	Agreed
	Critical Mean	3.5				

Metropolis

are represented in Tables 2 and 3 respectively.

Table 3 Mean distribution performance of the network using Call Drop Rate criteria

	Call Drop Rate	**OwerriMetropolis**				
S/N	**Statement**	**FUTO Road (µ)**	**Orlu Road (µ)**	**Onitsha Road (µ)**	**Wetheral Road (µ)**	**Aba Road (µ)**
1	**Call clarity on my network is always high and good**	2.5	2.3	2.3	3.3	2.8
	Decision	Disagreed	Disagreed	Disagreed	Disagreed	Disagreed
2	**The rate of call failure on my network is low**	3.6	3.3	3.5	3.4	3.3
	Decision	Agreed	Disagreed	Agreed	Disagreed	Disagreed
3	**The network is always available and there is network coverage at all times**	2.2	2.4	2.2	3.0	2.2
	Decision	Disagreed	Disagreed	Disagreed	Disagreed	Disagreed
4	**There is active call till the end**	3.0	3.0	2.6	3.8	3.4

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	Decision	Disagreed	Disagreed	Disagreed	Agreed	Disagreed
	Satisfactory Rating of Service Provider	**Owerri Metropolis**				
	Statement	**FUTO Road (μ)**	**Orlu Road (μ)**	**Onitsha Road (μ)**	**Wetheral Road (μ)**	**Aba Road (μ)**
5	**I am satisfied with the network**	2.76	3.06	3.42	2.84	3.35
		Disagreed	Disagreed	Disagreed	Disagreed	Disagreed
6	**My network is often poor in making calls.**	3.98	3.56	4.04	2.84	3.35
		Agreed	Agreed	Agreed	Disagreed	Disagreed
	Critical Mean	3.5				

The Call setup, Dropped Calls, Call Attempt, Call End, Call Established and Call Initialized as shown in table 4 were obtained from the drive test measurements, while Call Drop rate, Call Completion Success Rate, Call Setup Success Rate, Network Accessibility and Service Retainability were evaluated using equations (1-5).

Table 4 call statistics summary for the inclusive voice quality

	Orlu Road		**Aba Road**		**FUTO Road**		**Wetheral Road**		**Onitsha Road**	
Event details	**MTN**	**MTN**	**MTN**	**Airtel**	**MTN**	**MTN**	**MTN**	**Airtel**	**MTN**	**MTN**
Call Setup	87	89	81	79	81	93	81	93	82	91
Dropped Call	5	3	4	3	5	2	4	3	3	2
Call Attempt	96	95	95	87	98	96	97	96	94	93
Call End	73	69	83	76	83	92	83	92	82	89
Call Established	81	84	75	78	79	80	79	80	81	77
Call Initiation	96	95	95	87	98	96	97	96	94	93
Call drop rate	5.7	3.4	4.9	3.8	6.2	2.2	4.9	3.2	3.6	2.2
Call Completed Success Rate	76.0	72.6	87.4	87.4	84.7	95.8	85.6	95.8	87.2	95.7
Call Setup Success Rate	90.6	93.7	85.3	90.8	82.7	96.9	83.5	96.9	87.2	97.8
Network accessibility	90.6	93.7	85.3	90.8	82.7	96.9	83.5	96.9	87.2	97.8
Service retainability	76.0	72.6	87.4	87.4	84.7	95.8	85.6	95.8	87.2	95.7

Shown in Figures 8-12 are for the comparison of Call Drop Rate , Call completed success rate, Call Setup Success Rate, Call Network Accessibility, and Service Retainability respectively along Aba road, FUTO road, Onitsha road, Orlu road, Wetheral road with the NCC threshold.

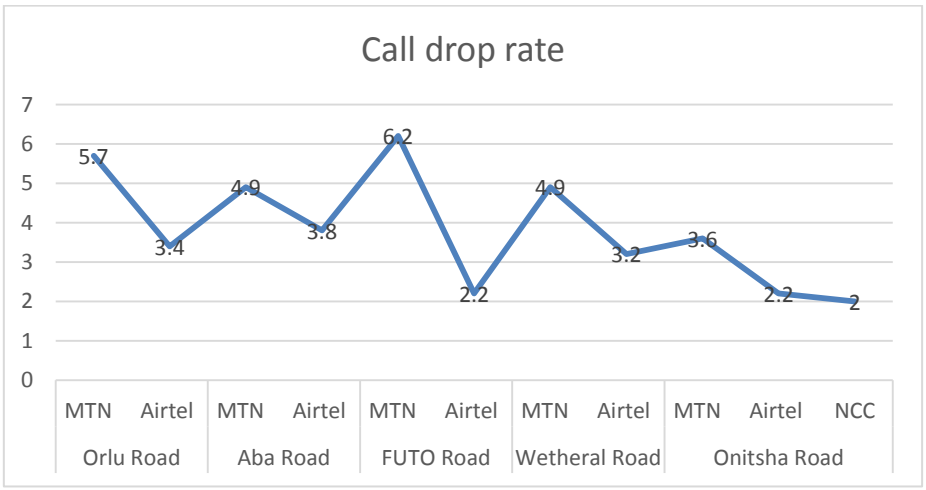

Figure 8 The Call Drop Rate from the selected regions versus the NCC Target Value

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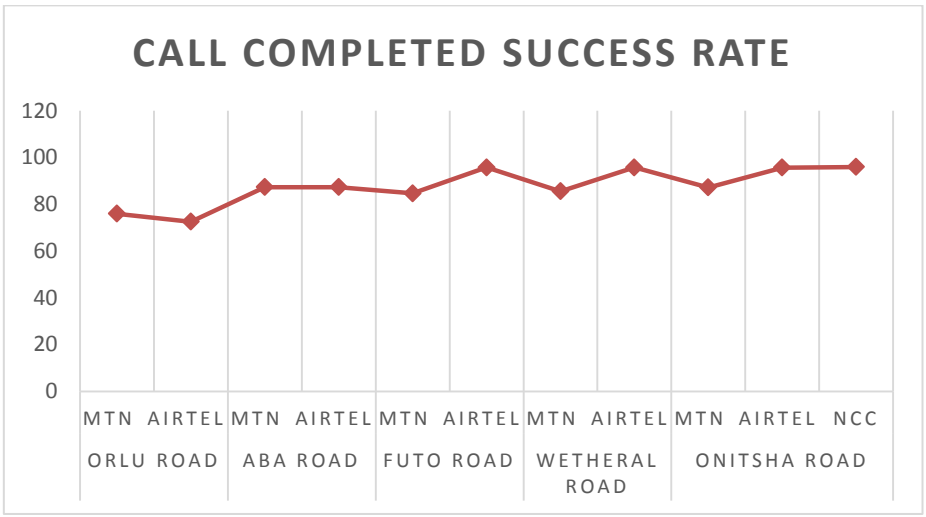

Figure 9 Call Completed Success Rate from the selected geolocations versus the NCC Target Value

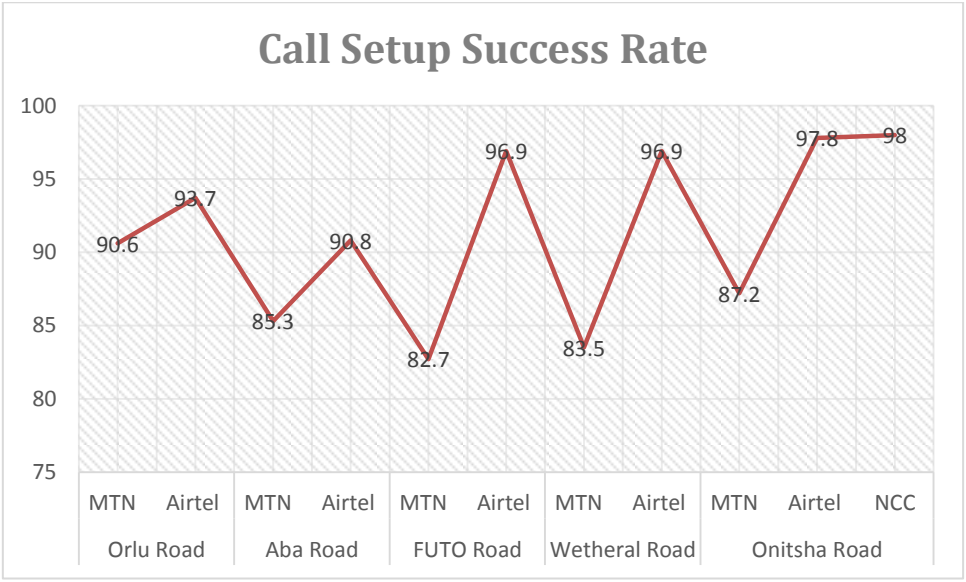

Figure 10 Call Setup Success Rate along the designated regions versus NCC Target value.

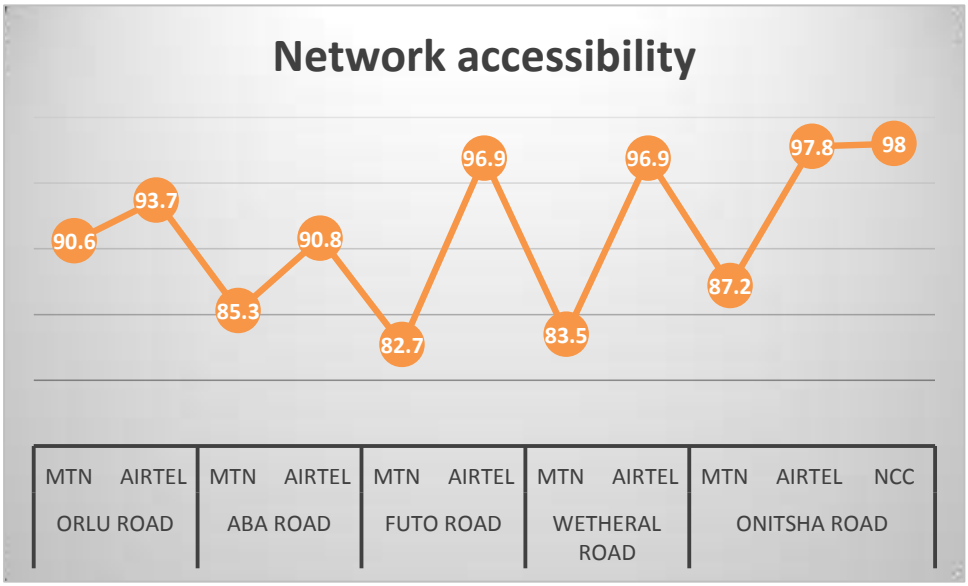

Figure 11 Call Network Accessibility along the designated regions versus NCC Target Value

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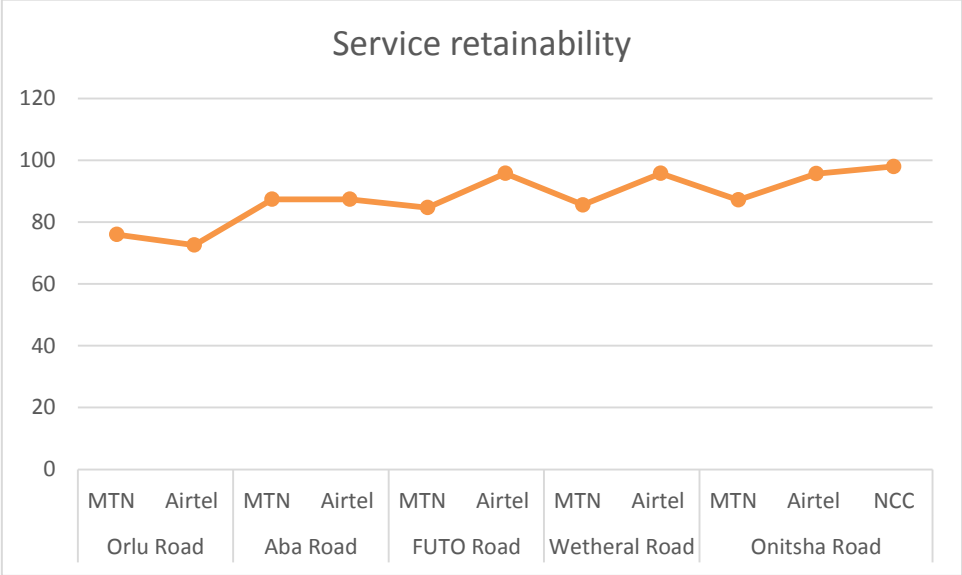

Figure 12 Service Retainability performance along the selected regions versus NCC Target Value.

Table 5 illustrated the analysis of Benchmark drive test of UMTS on the Received Signal Coded Power of the MTN and Airtel networks along the selected geographical regions. The ranges in dBm of -55 to 0 and -85 to -55 indicated very good and good signal strength, while -95 to -85, -100 to -95, and -120 to -100 indicated fair, poor, and very poor signal strength. The addition of the signal strengths between those ranges gave the value of Coverage Reliability of the networks.

Table 5 Drive test results of the WCDMA networks on the Received Signal Coded Power along the designated regions

	Orlu Road		Aba Road		FUTO Road		Wetheral Road		Onitsha Road	
Ranges (dBm)	MTN	Airtel	MTN	Airtel	MTN	Airtel	MTN	Airtel	MTN	Airtel
(-55 to 0)	2.5	2.2	3.8	2.0	1.1	2.2	1.9	1.3	3.9	2.8
(-85 to -55)	44.9	35.4	46.2	33.9	25.1	31.6	45.3	38.9	34.9	44.1
(-95 to -85)	2.6	19.1	0.0	13.5	16.7	19.8	2.4	9.8	9.9	3.1
(-100 to -95)	0.0	0.9	0.0	0.6	2.8	2.7	0.4	0.0	1.3	0.0
(-120 to -100)	0.0	0.0	0.0	0.0	4.3	0.0	0.0	0.0	0.0	0.0

Figure 13 explained the level of coverage quality of service obtained on the designated networks from the average mean valuations along the selected geolocation.

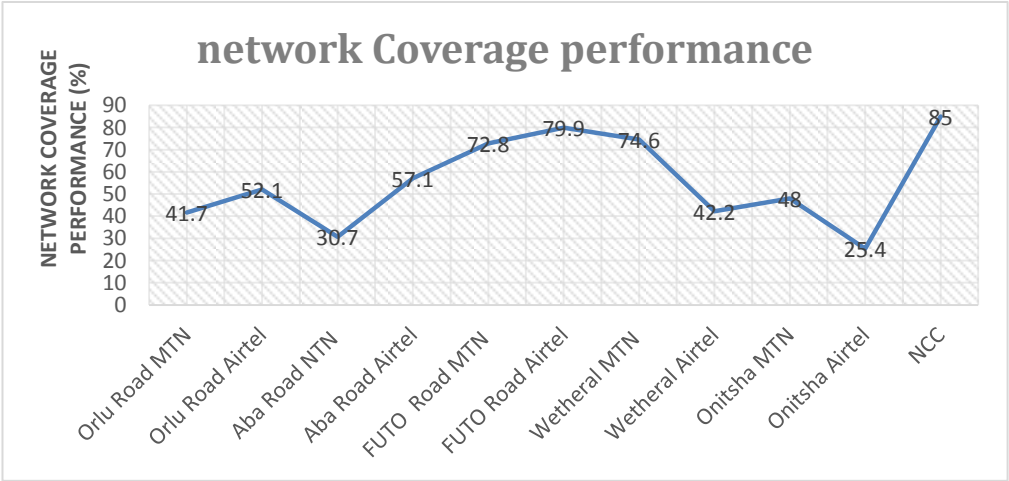

Figure 13 showed the coverage network performance versus the NCC target value

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4.1 Discussion

In Table 2, Customer Perceived Service Delivery from the network providers compared with the critical mean showed averagely poor performance of the network. Table 3 clearly expressed that the satisfactory assessment of the service provider from the end user was not favorable. The outcome of the survey generally indicated the evident dwindling network performance experienced by the subscribers. Figure 8 illustrated that none of the networks met the NCC target value for the CDR, for CCSR as shown in Figure 9, only the MTN along FUTO road, Wetheral road and Onitsha road marginally agreed with the NCC target value. In CSSR as presented in Figure 10, only MTN network along Onitsha road slightly met the NCC target value. For network accessibility in Figure 11, only MTN network along Onitsha road was close to the NCC target value while for service retainiability as shown in Figure 12, none amongst the networks met the NCC threshold. The overall network coverage performance as shown in Figure 13 showed that none of the network demonstrated a marginal performance relative to the NCC target value. Hence, results obtained generally proved that there exist poor quality of service amongst the two dominant networks along the designated regions.

4.2 CONCLUSION

The study evaluated the performance characteristics of two selected and dominant networks in Owerri metropolis to ascertain the network satisfactory levels to customers. Structured questionnaires and empirical analyses were conducted for adequate evaluation of the present operational conditions of the networks. Structured questionnaires were administered to survey 250 customers from the two (2) major network providers in Nigeria (MTN and AIRTEL) while the empirical analyses were conducted on same designated networks due to the observed high network traffic density within the regions. Five geographical locations within Owerri metropolis were selected for the measurements, they are Aba road, FUTO road, Onitsha road, Orlu road and Wetheral road. The Selected KPIs were used to evaluate the state-of-the-art conditions of the rollout networks and compared it with the standard specified by the Nigerian Communications Commission (NCC). It was observed that none of the obtained values from the KPIs met the NCC threshold which obviously established the degraded nature of the networks. The study was of importance because it helped to ascertain the actual level of quality of services provided to end users by the network providers and further provides a guide and benchmark for the mitigation.

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