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Evaluation of Quality of Voice Service (QoVS) Offered by Mobile Network Operators in Akure, Nigeria

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ABSTRACT
Voice communication is the transfer of audio signal from one person to another. If the parties involved are at distance apart to each other, it becomes telecommunication. In Akure, mobile customers have been experiencing poor Quality of Voice Service (QoVS) which has affected their social and economic activities. This study evaluates the QoVS offered by the four (4) Mobile Network Operators (MNOs) – MTN, GLO, 9MOBILE and AIRTEL in Akure, Nigeria, as well as determines their level of compliance with Nigerian Communications Commission (NCC) benchmarks. Data was collected using the drive test technique. The drive test was carried out for seven days between 6th November, 2023 and 12th November, 2023. The test consisted of two sessions for each day – morning and evening. The morning sessions took place between 9 am and 11 am while the evening sessions were from 5 pm to 7 pm. Six Key Performance Indicators (KPIs) measured and evaluated include: Call Setup Success Rate (CSSR), Call Success Rate (CSR), Call Drop Rate (CDR), Handover Success Rate (HoSR), Received Signal Strength Level (RSSL) and Received Voice Quality (Rx Qual). The results of the study showed that the QoVS offered by the MNOs in Akure in the morning and evening sessions differed by about 1% - 2%. MTN, AIRTEL, 9MOBILE met the benchmark of NCC in term of CSSR which was ≥98%. GLO's CSSR performance was 95.3% which is about 3% less than the benchmark. In addition, the research findings reveal that area topography and time of the day affect the QoVS. The RSSL average values for AIRTEL and MTN were within NCC's benchmark of – 30 dBm to - 70 dBm while GLO and 9MOBILE's networks did not meet the benchmark. It is recommended that the MNOs should build more base stations to reduce blind spots and coverage gaps caused by lack of network in some of the areas covered as this will increase the network coverage areas.

General Terms
Drive Test (DT): A technique of determining the level of network performance through information collection when driving through certain locations.

Quality of Service (QoS): QoS is the overall performance of the mobile network as perceived by the users benchmarked against set standards.

Key Performance Indicators (KPIs): Particular measurements that are employed to measure QoS, including call success, drop rates, and signal strength.

Call Setup Success Rate (CSSR): Indicates the ability to access the network- how frequently the calls are connected.

Call Drop Rate (CDR): This is a measure of the retainability of the service- how infrequently the calls are dropped.

Call Setup Time (CST): A measure of responsiveness of how fast calls connect.

Handover Success Rate (HoSR): Measures the performance of mobility--how well calls handover between cell sites.

Received Signal Strength Level (RSSL): Signal power (greater dBm = stronger signal).

Received Signal Quality (RxQual): It shows signal clarity (0 = best, 7 = worst).

The Nigerian Communications Commission (NCC) is the regulatory body that stipulates and oversees these QoS standards to the mobile operators in Nigeria.

Keywords
Telecommunication, Drive test, Quality of Voice Service (QoVS), Key Performance Indicator (KPI), Exploratory Data Analysis (EDA)

1. INTRODUCTION
Voice communication involves the transfer of spoken words or auditory human voice from one person to another. When it is done at distance it becomes telecommunication. Telecommunication facilities in Nigeria were first established in 1886 by colonial administration. The telephone system during that period was expensive, congested and unreliable. Also, service was unsatisfactory (Surajudeen-Bakinde *et al*., 2021). Modern voice service in Nigeria dates to the era of Post and Telecommunication (P and T) and Nigeria Telecommunications Limited (NITEL). It was further improved with the advent of a Global System for Mobile Communication (GSM). Voice service quality started improving as the GSM starts evolving. The launch of GSM in Nigeria in 2001 significantly influenced the lives of Nigerians (Olawoye *et al*., 2020). Mobile networks have raised the economic activities in Nigeria and upgraded the standard of life of Nigerians (Ukoette and Chibuzor, 2021). Over time, MNOs in the country have experienced substantial growth in their subscriber base (Obe *et al*., 2020). As the number of subscribers expanded, the need for high quality of voice service became more pronounced. Consequently, MNOs had to monitor and evaluate their service quality accurately to enhance efficiency, optimize costs, ensure customer satisfaction, and maintain a competitive advantage. Quality of Service (QoS) refers to level of satisfaction a customer or end-user derives from a service (Tunde *et al*., 2020). In telecommunications, QoS is defined as the degree to which a set of inherent characteristics fulfil the end users' requirements (Adikpe *et al*., 2022). QoS is typically

evaluated using KPIs, which are derived from measurements of various network parameters. These KPIs establish specific benchmarks that a network must meet to ensure the proper functioning of a service and define its overall performance. Each of the four major MNOs in Nigeria provides voice service. The telecommunications industry in Nigeria has grown remarkably. Nigeria has become one of the fastest-growing GSM markets in the world since the GSM was launched. The growth of the GSM telecommunications industry in Nigeria has been explosive, with a significant number of people relying on mobile telephony as their preferred method of voice communication. The historical evolution of cellular voice service in Akure has shaped the city's connectivity and communication landscape. Initially, voice service in the region has been characterized by traditional means, such as landline telephones and limited infrastructure. Over the years, advancements in technology have played a pivotal role in the expansion and diversification of voice service in Akure. As the demand for voice service grew, so did the expansion of network coverage and the establishment of more robust communication infrastructure in Akure. This development likely contributed to increased connectivity, enabling residents to communicate more efficiently and facilitating socio-economic activities. Challenges such as network congestion and call drops prompt operators to invest in infrastructure upgrades. Regulatory bodies play a crucial role in setting standards and ensuring compliance, shaping the operational landscape of mobile services. It has been difficult to establish calls successfully in some locations in Akure due to lack of network coverage, this problem can be resolved when MNOs build more base stations. This study focused on evaluating the QoVS provided by MNOs in Akure, Nigeria. Akure, the capital city of Ondo State has witnessed substantial growth in its telecommunication infrastructure, leading to intense competition among MNOs. The study provides insights into the performance of the voice service achieved by the four (4) major MNOs in Akure.. Understanding various parameters such as CSR, CSSR, CDR, RSSL and Rx Qual are crucial for a comprehensive assessment. Previous research by Jiennitte (2020) and Okolie (2021) emphasized the importance of consistent and reliable voice service on the user experience. Poor QoVS can result in dropped calls, interrupted conversations, and user frustration. MNOs also will face challenges retaining customers if QoVS falls below NCC's benchmark.

2. REVIEW OF RELATED WORKS

Ukoete and Chibuzo (2022) conducted a comparative assessment of GSM and Universal Mobile Telecommunication System (UMTS) networks in Calabar, Nigeria. It is widely recognized that the evolution of mobile networks from one generation to another aims to enhance network QoS. Based on this understanding, the researchers assumed that the UMTS would outperform the GSM, which served as the motivation for their study. The results showed no significant overall improvement in QoS, with noticeable fluctuations in service quality across the MNOs. In addition, Ajayi *et al*., (2021) conducted a study on the performance evaluation of GSM and Wideband Code Division Multiple Access (WCDMA) networks, using the University of Ilorin as a case study. The study focused on assessing the performance of four MNOs, referred to as Operator A, Operator B, Operator C, and Operator D, which provide voice communication service within the University of Ilorin, Ilorin, Nigeria. A drive test method was employed to collect KPIs Findings revealed that the WCDMA network performed significantly below both the NCC-defined KPI targets and customer expectations in both locations. In contrast, GSM network met the acceptable performance threshold. Furthermore, Ahinoy *et al*., (2022) conducted a performance assessment of the QoS of a GSM network in Jigawa State, Nigeria.. This study utilized statistical data on call traffic from the Base Station Controller (BSC_KNBHO2) in Jigawa State, analyzing KPIs collected from 34 Base Transceiver Stations (BTSs). The evaluation revealed that 89% of CSSR failed to meet the NCC benchmark (>98%), leading 10% of Call Setup Failure Rate (CSFR) exceeding the NCC threshold (<2%). Similarly, the CCR showed that 2% of its dataset was below the NCC benchmark (>96%), while 9% of the CDR deviated from the NCC's recommended limit (<2%). Kubau *et al*., (2021) conducted a study on the performance evaluation of MNOs in Nigeria using Data Envelopment Analysis (DEA). The research focused on applying DEA to assess the efficiency of MNOs in the country. The existing performance evaluation methods for MNOs were examined and analyzed, after which the DEA model was utilized to compute and compare the technical efficiency of major MNOs in Nigeria over a six-year period (2015 – 2020). The results categorized MNOs into efficient and inefficient groups, followed by a ranking of their performance. Among the four major mobile operators in Nigeria: MTN, 9MOBILE, GLO, and AIRTEL. MTN was identified as the most efficient.

Dahunsi *et al*. (2018) conducted a study on the performance MNOs in Akure Metropolis, Nigeria. The findings revealed that the quality of voice services provided by MNOs was suboptimal, and there is the need for improved QoS. The study employed a drive test approach and statistical methods, utilizing tools such as post-processing software, Transmission Environment Monitoring software (TEMs), a laptop, USB cables, a car, an inverter and GPS. Ukoette and Iloke, 2022) studied the performance evaluation of four UMTS networks in Calabar, Nigeria, using KPIs including Call Setup Success Rate (CSSR), Drop Call Rate (DCR), Handover Success Rate (HoSR), Call Success Time (CST) Signal Received Code Power (RSCP), and ratio of received energy and interference level (Ec/Io). The results were compared with NCC standards. Notably, all networks excelled in CST, with MTN leading, and AIRTEL had no blocked calls. However, 9MOBILE network fell short in CSSR, and GLO's DCR was below the threshold. HOSR was excellent for all networks, and RSCP showed positive performance. Also, Tunde *et al*, (2020) conducted a performance evaluation of mobile network services at Shiroro Power Station, Nigeria. The study assessed, analyzed, and evaluated the performance of four MNOs in the area and provided recommendations for improving the quality of their voice and data services. A drive test was carried out using TEMS, and statistical analysis was employed for performance evaluation. The findings revealed that the RSSL ranged from -50 dBm to -110 dBm, which deviated from the standard range of -30 dBm to -70 dBm recommended by NCC.

Surajudeen-Bakinde *et al*., (2020) worked on an assessment of the QoS of GSM networks in the Ilorin metropolis, Nigeria. GSM growth in Nigeria faces challenges due to subscriber complaints about poor QoS. In this study, three KPIs (SCCR), (RSL) (CDR) were used in assessing the performance of two of the major GSM networks in the Ilorin metropolis of Nigeria. MNOs A and B monitored are far from providing reliable services to Nigerians. The study was limited to two network providers in the country.

In a similar work, Adikpe *et al*, (2022) assessed the QoS of a GSM network in Kaduna State, Nigeria, focusing on subscriber satisfaction and Quality of Experience (QoE). Using statistical

data from the base station controller (BSC-KDBH14) and evaluating KPIs from 48 BTSs, the research found that CSSR was 96% which was 2% below NCC's benchmark (>98%). This resulted in a corresponding 2% failure for the CSFR benchmark (<2%). Despite these, the Call Completion Rate (CCR) met NCC's benchmark (>96%). Adikpe *et al*., (2021) analyzed GSM network congestion in Kaduna State, Nigeria, revealing 6% traffic channel congestion exceeding NCC benchmarks, while stand-alone dedicated control channel congestion met the benchmark at 4.2%. Focused on one MNO in Kaduna, the study compared congestion and KPIs. Using File Transfer Protocol and MATLAB, the research found unreliable QoS with unsatisfactory network accessibility and retainability. However, call voice quality was satisfactory across the four network providers.

3. RESEARCH METHODOLOGY

Generally, there exist three prominent methods of evaluating whether the QoS offered by a network provider meets the required industry benchmark or not. These methods include: network statistics, drive test and customers' feedback (Adikpe *et al*., 2022). The drive test approach was employed in achieving the stated objectives of this study. Figure 1 shows the flow diagram of the study.

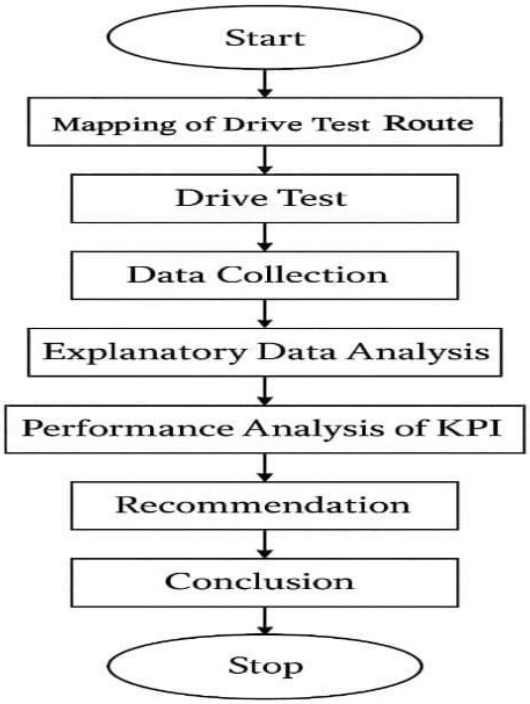

Fig 1: Flow Diagram of the Research

3.1 Drive Test Design

This research utilized the drive test technique for data collection. The drive test setup included: the Transmission Environment Monitoring software (TEMs) investigation tools, including a Laptop with TEMs investigation software fully installed, four (4) Sony Ericsson W995 phones, a Garmin GPS, an inverter, and a vehicle. The collected data (log file) was processed, and a report was generated using MapInfo software. The research focused exclusively on four MNOs: GLO, 9MOBILE, AIRTEL and MTN. Figure 2 shows the typical block diagram of a drive test. In the diagram, Global Position System (GPS) and mobile phones were connected to a computer with TEMs. The setup is put in a Mobile Vehicle. Calls generated from the phones are routed to the Public Switch Telephone Network (PSTN) to Public Line Mobile Network (PLMN) and then transmitted via the Base Tranceiver Station (BTS) to the receiving end.

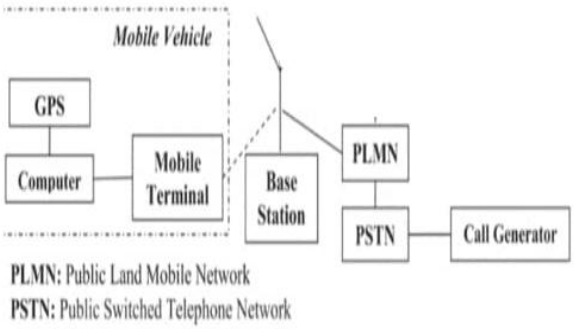

Fig 2: Typical Block Diagram of Drive Test

The drive test took place from the 6th November, 2023 to 12th November, 2023 spanning through morning and evening sessions. The morning session of day 1 started from The Federal University of Technology, Akure, North Gate (FUTA North Gate) through Shasha, Owo road to Airport Junction, Oba- Ile, Oja-Oba and back to FUTA North Gate. The evening session of day 1 started from FUTA North Gate to Agbogbo, Ijapo, Alagbaka, Oja-Oba and back to FUTA North Gate. For day 2, the morning session started from FUTA South Gate to Cathedra, Ondo Road, Agagu road, Ilesha garage, Oloko and FUTA North Gate. The evening session of day 2 started from FUTA South gate to Aule road, Agagu road, Isikan, Arakale, Nepa Junction, High Court Road, Oja-Oba and back to FUTA North gate. On the remaining days, several places like Oke-Ogba, Mechanic Village, Danjuma, Oke -Aro, Oshinle and Oluwatuyi were covered. The route map for the drive test is shown in Figure 3.

Fig 3: Route Map of the Drive Test

3.2 Data Analysis

The data collected in this research was analysed using Microsoft Excel, TEMS discovery and Python software. Based on the KPIs already measured, the performances of the MNOs were compared. The TEMS Discovery platform was utilized to pre-process the raw data collected during the drive test, allowing for the evaluation of voice quality across the different MNOs. This TEMS Discovery platform provided valuable insights into network performance from the users' perspective.

4. RESULTS AND DISCUSSION

The results obtained from the measurement of six (6) KPIs and the performance analyses of the MNOs tested in this study are presented in this section. EDA of the drive test dataset was used

in ascertaining the QoVS offered by the MNOs to mobile customers in the coverage area.

4.1 Comparison of MNOs' KPIs

Table 1 shows the overall average of the KPIs for each MNO. For MTN, the KPIs: CSSR, DCR, CSR and HoSR were 99%, 0.8%, 98% and 86% respectively while for AIRTEL, the KPIs were 98%, 1.8%, 100%, and 98% respectively. For 9MOBILE, they were 99%, 0.9%, 100% and 100% respectively. While that of GLO were 95%, 3.4%, 82% and 97% respectively. RxQual, which refers to the clearness of a speaker's voice as perceived by the listener, was calculated in the range of 0 to 7. RSSL refers to the strength of received signal. It has a range of values from 0 to -110 dBm. These KPIs indicate the MNOs performance during the drive test. The performance analysis of each KPI for the MNOs is summarized in Table 1.

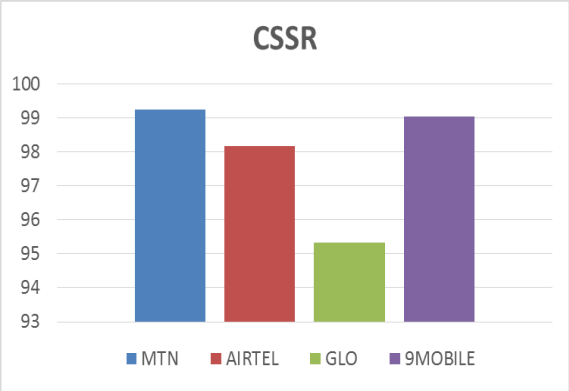

Fig 4: Overall Average of CSSR

4.2 Performance Analysis of CSSR

The CSSR of each network presented in Figure 4 shows the success rate of call setups. According to the Figure, MTN and 9MOBILE had the highest performance in establishing or connecting calls, with a 99% CSSR each. This means that out of every 100 calls made through MTN and 9MOBILE, 99 were successfully connected, while one call was either unsuccessful or blocked. AIRTEL followed closely with a CSSR of 98%, while GLO recorded a CSSR of 95%. This implied that out of every 100 calls made through AIRTEL, 98 were successful and 2 were not successful. In case of GLO, out of 100 calls, 95 were successful and 5 were unsuccessful. It also indicated that call accessibility on the MTN, 9MOBILE and AIRTEL networks were highly successful, whereas, GLO network accessibility was not as strong in comparison.

Table 1: Overall Average of the KPIs Measured for the Week

MNOs	KPI (%)			
	CSSR	DCR	CSR	HoSR
MTN	99.2	0.8	98.2	85.9
AIRTEL	98.1	1.8	100.0	98.1
GLO	95.3	3.3	82.3	95.2
9MOBILE	99.0	0.9	100.0	97.2

4.2.1 Performance Analysis of CDR

The CDR is one of the most critical KPI affecting the QoS in Nigeria. Call drops are particularly frustrating for mobile subscribers, especially when an important conversation is interrupted. As shown in Figure 5, GLO recorded the highest CDR of 3.4% followed by AIRTEL with 1.8% while 9MOBILE and MTN had 0.9% and 0.8% respectively. The overall average of CDR for morning and evening sessions measured during the drive test was represented in Figure 5

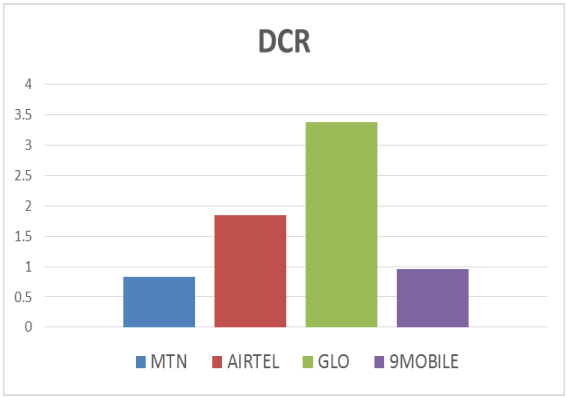

Fig 5: The Overall Average of CDR Measured During the Drive Test

4.2.2 Performance analysis of CSR

The overall average of CSR measured during the drive test for morning and evening sessions was represented in the Figure 6. CSR is an important KPI that affects QoS of MNOs. This KPI determined that a successfully established call was maintained and ended according to the user's will during a specified period. The results from Figure 6 show that MTN had the highest value of 99.3%, followed by 9MOBILE with 99%. AIRTEL had 98 %, GLO had the least with 95.4%.

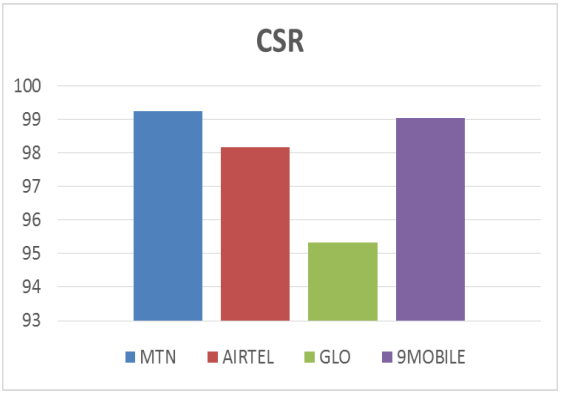

Fig 6: Average CSR of the MNOs Measured during the Drive Test

4.2.3 Performance analysis of HoSR

The overall average of HoSR for both morning and evening sessions measured during the drive test was represented by Figure 7.. HoSR is another important KPI for determining the performance of MNO. It evaluated the performance of network operator relative to user's mobility. Figure 7 shows that AIRTEL had the highest value 98% followed by 9MOBILE with 97% and GLO network with 95%. MTN had the least HoSR with 85%.

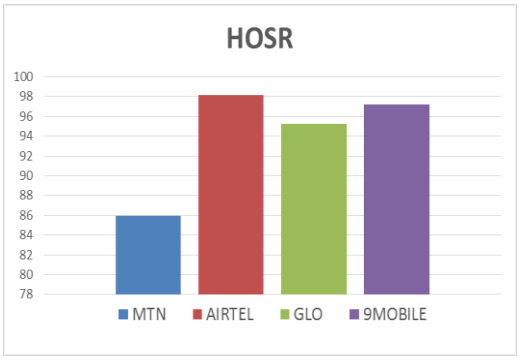

Fig 7: Average HoSR for Measured during the Drive Test

4.2.4 Performance analysis due to Rx Qual

The Rx Qual has a grouping from:0 – 3, 3.1 – 4, 4.1 – 5, 5.1 – 6, 6.1 – 7 as shown in Table 2.

Table 2: Rating of Rx Qual

RATING	GROUPING
Excellent	0-3
Very Good	3.1-4.0
Good	4.1-5.0
Fair	5.1-6.0
Poor	6.1-7.0

As shown in the table, RxQual values between 0 and 3 indicated excellent voice quality; between 4 and 5 indicate good voice quality; between 5 and 6 indicate fair voice quality and above 6 indicate poor voice quality. It was observed that the range of RxQual during the drive test of this research was between 0 and 4 and [6, *max*]. GLO network had poor Received voice quality whereas MTN, AIRTEL and 9MOBILE had excellent Received voice quality.

4.2.5 Performance analysis of RSSL

RSSL can be classified as shown in Table 3.

Table 3: Rating of RSSL.

RATING	GROUPING
Excellent	0 to 65
Very Good	- 66 to-75
Good	-76 to -85
Fair	-86 to -95
Poor	-95 to -110

RSSLs for all the MNOS studied were measured. The RSSL values, between 0 to – 65 dBm indicated excellent coverage; between – 66 dBm to – 75 dBm for very good coverage; between - 76 dBm to – 85 dBm for good coverage; between – 86 dBm to – 95 dBm for average coverage and between – 95 dBm to – 110 dBm for poor coverage and below – 110 dBm was considered as no coverage penetration. It was observed that the range of RSSL during the drive test of this research was between -70 dBm to – 95 dBm.

4.3 Comparison of MNOs' KPIs with NCC's Benchmark

The NCC's benchmark for CSSR, CSR, CDR and HoSR are :> 98%, > 98%, ≤ 2% and >98% respectively as shown in Table 4. MTN, AIRTEL and 9MOBILE with CSSR 99%, 98% and 99% respectively complied with NCC's benchmark for CSSR and GLO with 95% was lower than the benchmark by 3%. CDR for MTN, AIRTEL, 9MOBILE and GLO were: 0.8%, 1.8%, 0.95% and 3.3% respectively. This implied that MTN, AIRTEL and 9MOBILE met NCC's benchmark for CDR. GLO was below the benchmark by 1.3%.CSR for MTN, AIRTEL, 9MOBILE and GLO were: 98%, 100%, 100% and 82% respectively. It means GLO was below the benchmark by 16%. Other MNOs met NCC's benchmark for CSR. For HoSR, MTN, AIRTEL, 9MOBILE and GLO had 85%, 98%, 97% and 95% respectively. Only AIRTEL met NCC's benchmark for HoSR. MTN, 9MOBILE and GLO were below the benchmark by 13%, 1% and 3% respectively. The KPIs for all the MNOs was represented in Figure 8. It gave the overview of all the KPIs for all the MNOs and their level of compliance with NCC's benchmark. A line was drawn across the upper part of the graph; it shows NCC's minimum benchmark for CSSR, CSR and HoSR. The line drawn at the lower part of the graph shows the maximum NCC's benchmark for CDR .RSSL for MTN and AIRTEL during the test lies between – 64 dBm to – 70 dBm which is in compliance with NCC's benchmark of – 30 dBm to – 70 dBm. For 9MOBILE and GLO it ranged between – 65 dBm to – 88 dBm. RxQual more than 7 show poor voice quality. The RxQuals for MTN and AIRTEL were observed to be better. This implies that MTN and AIRTEL met the NCC's standard in terms of RxQual. Several factors identified as contributing to their performance below the benchmark, include poor network coverage, low transmission power, antenna malfunctions, signal interference caused by obstructions in the transmission environment, and an insufficient number of base stations

Table 4: Comparison of MNOs PKIs with NCC' Benchmark

MNOs	KPI (%)			
	CSSR	DCR	CSR	HoSR
MTN	99	0.8	98	85
AIRTEL	98	1.8	100	98
GLO	95	3.3	82	95
9MOBILE	99	0.95	100	97
NCC Benchmark	≥98	≤ 2	≥98	≥98

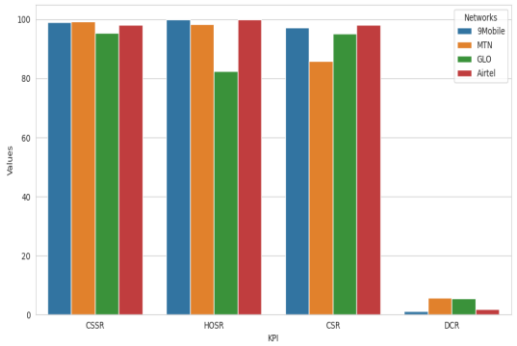

Fig 8: KPIs for All the MNOs

4.4 KPIs at Selected Locations

KPIs like CSSR, CDR, CSR and HoSR were measured at some locations in Akure. This was done to compare the performance of the MNOs in these areas. The average values of the KPIs for

each operator were recorded at these locations. The locations were: FUTA North Gate, Shasha, Oja-Oba and Isikan in Akure.

4.4.1 CSSR at Selected Locations

The CSSR measured at the selected locations is shown in Table 4.5. For MTN, the CSSR measured at FUTA North Gate, Oja-Oba, Shasha and Isikan were: 99.25%, 99.54%, and 95.24% and 98.43% respectively. For AIRTEL, the values of CSSR measured at FUTA North Gate, Oja-Oba, Shasha and Isikan were: 98.15%, 98.63%, 95.35% and 99.26% respectively. For GLO the CSSR measured At FUTA North Gate,Oja-Oba, Shasha and Isikan were 95.33%, 98.67%, 94.35% and 98.63% respectively. For 9MOBILE the CSSR measured at FUTA North Gate, Oja-Oba, Shasha and Isikan were: 99.05%, 99.05% 92.35% and 98.53% respectively. This implied that at Oja-Oba and Isikan all the MNOs met the NCC's benchmark for CSSR of ≥98%. At FUTA North Gate, MTN AIRTEL and 9MOBILE met the NCC's standard. GLO was below the benchmark at this location by 2.7%. At Shasha all the MNOs were below the NCC benchmark for CSSR by 2.74%, 2.65%, 5.65% and 3.65% respectively. The following factors were observed to be responsible for the subpar performance of the MNOs at Shasha: the topography of the area and insufficient sub stations. The area was characterized by tall hill and rocks causing obstruction to transmitted signals. This can be corrected by mounting substation on the mountain top. The factors observed to be responsible for the subpar performance of GLO's network at FUTA North Gate are poor quality of signal on downlink and uplink and insufficient base station. For ease of comparison, the CSR measured at the locations for each MNO was represented in Figure 9. This implied that it was easier to make call at FUTA North Gate, Oja-Oba and Isikan than at Shasha with all the MNOs. To make call with GLO network was a little bit difficult compared to other network.

Table 5: Overall Average of CSSR Measured for the MNOs at the Selected Locations

LOCATIONS	CSSR (%)			
	MTN	AIRTEL	GLO	9MOBILE
FUTA NORTH GATE	99.25	98.15	95.33	99.05
OJA OBA	99.54	98.63	98.67	99.05
SHASHA	95.24	95.35	94.35	92.35
ISIKAN	98.43	99.26	98.63	98.53

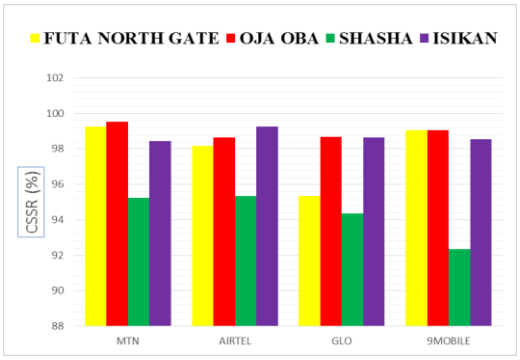

Figure 9: CSSR for the MNOs at the Selected Locations

4.4.2 CDR at selected locations

DCR measured at the selected locations was shown in table 4.6. For MTN the CDR measured at FUTA North Gate, Shasha, Oja-Oba and Isikan were: 0.83%, 1.83%, and 0.52% and1.53% respectively. For AIRTEL the CDRs measured were: 1.83%, 2.01%. 1.55% and 1.36% respectively, For GLO network, the CDRs measured at the locations were: 3.37%, 5.94%, 1.34% and 3.45% respectively. For 9MOBILE, the values measured were: 0.94%, 3.00%, and 0.64% and1.53% respectively. This means MTN, AIRTEL and 9MOBILE met the minimum benchmark of ≤ 2% recommended by NCC for CDR at FUTA North Gate and Isikan. All the MNOs met the benchmark at Oja-Oba. At Shasha only MTN met the minimum benchmark. AIRTEL, GLO and 9MOBILE did not meet the benchmark for CDR at this location. GLO network did not meet the benchmark at Isikan. For easy comparison CDR measured at the selected locations was represented in Figure 10.This implied that the rate of call drop for MTN was minimal at the locations, At Shasha, GLO, AIRTEL and 9MPBILE had more drop call.

Table 6: Average CDR for MNOs at the Locations

LOCATIONS	DCR (%)			
	MTN	AIRTEL	GLO	9MOBILE
FUTA NORTH GATE	0.83	1.85	3.37	0.94
SHASHA	1.83	2.01	5.94	3.00
OJA OBA	0.52	1.55	1.34	0.64
ISIKAN	1.53	1.36	3.45	1.53

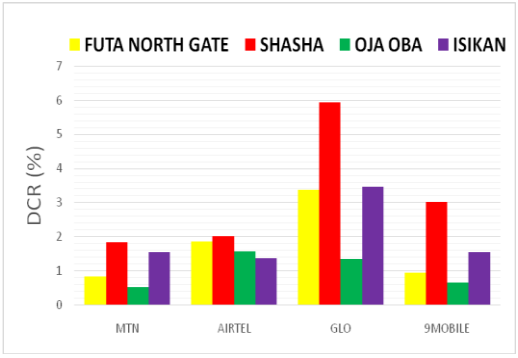

Fig 10: CDR for MNOs at the Selected Locations

4.5 Comparison of MNOs' KPIs during Morning Sessions of the Drive Test

During the morning sessions of the drive test, the values of KPIs for each day were recorded for all the MNOs. The overall average value of the KPIs measured for each MNO were shown in table 7. For MTN, the values of CSSR, CDR CSR and HoSR were: 98.85%, 1.8%, 98.90% and 89.9% respectively. For AIRTEL, the values were: 98.15%, 1.85%, 100.00% and 98.15% respectively. For GLO network the values were: 95.33%, 1.97%, 82.35% and 95.22% respectively. For 9MOBILE the values were: 99.05%, 0.96%, 100% and 97.22% respectively. MTN, AIRTEL and 9MOBILE networks met NCC's benchmark for CSSR and CSR. All the MNOs met NCC's benchmark for CDR. Only AIRTEL met NCC's benchmark for HoSR MTN, GLO and 9MOBILEwere below the benchmark by 10.1%,3.78% and 0.78% respectively. Figure 11 shows the overall average of the KPIs for the MNOs

during morning session of the drive test

Table 8: Shows the Overall Average of all the KPIs for the MNOs during Morning sessions of the Drive Test

MNOs	KPI's (%)			
	CSSR	DCR	CSR	HOSR
MTN	98.85	1.8	98.15	89.90
AIRTEL	98.15	1.85	100	98.15
GLO	95.33	1.95	82.35	95.22
9MOBILE	99.05	0.96	100	97.22

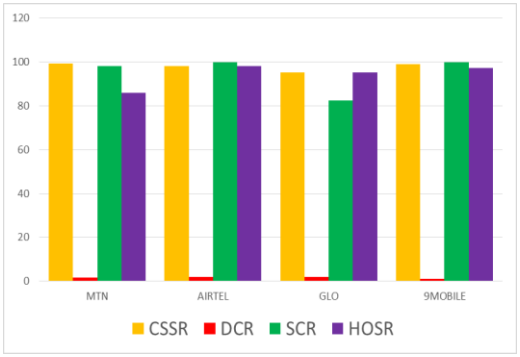

Fig 11: Overall Average of the KPIs for the MNOs during Morning Sessions of the Drive Test

4.5.1 Comparison of MNOs' KPIs during Evening Sessions of the Drive Test

During the evening sessions of the drive test, the values of KPIs for each day were recorded for all the MNOs. The overall average value of the KPIs measured for each MNO were shown in table 8. For MTN, the values of CSSR, CDR CSR and HoSR were: 98.75%, 2%, and 98.30% and 80.9% respectively. For AIRTEL, the values were: 98.25%, 2.89%, 99.00% and 98.90% respectively. For GLO network the values were: 94.30%, 3.94%, 80.45% and 95.20% respectively. For 9MOBILE the values were: 98.00%, 2.5%, 98.50% and 95.4% respectively. MTN, AIRTEL and 9MOBILE networks met the minimum standard for CSSR and CSR. Only MTN met the standard for CDR, other networks were below the benchmark by 0.89%, 1.94% and 0.5% respectively. All the networks were below the minimum standard for HoSR. Figure 12 shows the overall average of the KPIs for the MNOs during evening session of the drive test.

Table 8: Shows the Overall Average of all the KPIs for the MNOs during Evening sessions of the Drive Test.

MNOs	KPI's (%)			
	CSSR	DCR	CSR	HOSR
MTN	98.75	2	98.3	80.9
AIRTEL	98.25	2.89	99	98.7
GLO	94.3	3.94	80.45	95.2
9MOBILE	98	2.5	98.5	95.4

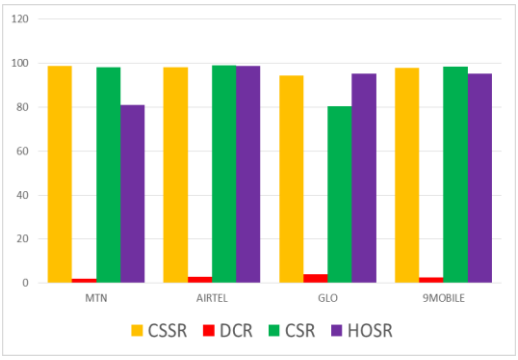

Figure 12: Overall Average of the KPIs for the MNOs during Evening Sessions of the Drive Test.

In the morning session, the call drops were minimal and in compliance with NCC Benchmark. The evening session witnessed more drop calls and only MTN network met the NCC's benchmark of ≤ 2%. The higher rate of drop calls in the evening can be attributed to network congestion. Most people will be at their offices or places of work or market during the morning session. Consequently, the number people making call were reduced. Hence the rates of drop calls were minimal. In the evening, most people were at home, they had time to make calls as such, and networks were congested. Hence, making call was a little bit difficult.

5. CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

This research evaluated the QoVS offered by MNOs in Akure, Nigeria. Six (6) KPIs were measured. The method employed for data collection was Drive Test using TEMs.The results of the research show that MTN, AIRTEL and 9MOBILE met the benchmark of NCC in all the KPIs. GLO fell short of the benchmark by 3% for CSSR, 1.3% for CDR, 16% for CSR and 3% for HoSR. Overall average RSSL values for MTN and AIRTEL during the test period lies between -64 dBm and -70 dBm which is in compliance with NCC's benchmark of -30dBm to -70dBm. On the other hand, the average RSSL for 9MOBILE and GLO range lies between -65dBm and – 88dBm. Analysis of the RxQual values reveals better voice quality for MTN and AIRTEL users. This implies that MTN and AIRTEL met the NCC's benchmark in terms of RxQual. GLO on its part had poor RxQual. Reasons that were identified to be responsible for sub standard performance by the MNOs in some areas include terrain,signal flunctuation or fading due to various factors such as obstruction from rocks and trees, signal path loss, insufficient coverage and inadequate number of base stations.

5.2 Recommendations

The null values and blind spots observed in the analysis were due to lack of network coverage. Consequently, it is recommended that the MNOs should build more base stations to increase their coverage areas. In addition, MNOs should also review their networks and effect optimization measures. Drop calls should be reduced by incorporating soft handover during break and make of hard handover. Transmission power should be increased. Signal boosters should be installed at the base stations. Handover parameters on neighboring cells should be well defined in order to retain connection and reduce dropped calls. Wrong antenna azimuth and swap sectors should be checked. Antenna should be checked periodically and be realigned for better coverage.cNCC should periodically

publicize all MNOs' KPI results which are obtained by unbiased researcher and sanction any non-complying MNO.

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