COMPARATIVE ANALYSIS OF THE PERFORMANCE OF 3G NETWORKS VOICE SERVICE IN IBADAN METROPOLIS

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Abstract: This paper aims to offer a comparative analysis of the main Nigerian mobile network service provider with reference to 3G voice service. Drive tests were engaged in Ibadan metropolis to acquire some KPI parameters used for the analysis. The findings show that not a single service provider was in good standing across all the KPIs. Thus, the performance of a particular operator is purely a function of the desired KPI parameter.

Keywords: drive test, KPI, service provider

1. INTRODUCTION

According to the Nigerian Communication Commission (NCC), Nigeria is the largest mobile telecommunications market in Africa. This may be as a result of self-made auction of the Digital Mobile licenses in 2001 [1]. The Nigerian wireless communication industry has expanded at a full speed over the past decade, with markets doubling approximately every two years. This growth has additionally been attributed to the public's ever increasing demand for mobile telephones, and a lot of recently, wireless knowledge systems. The increasing diversity of wireless users has spurred communication engineers to enhance the service quality and optimize available spectrum resources.

Telecommunication has been around for a relatively long time and has evolved a lot recently. This is accurate regarding the advancement of mobile communication networks, which has been dubbed the most sophisticated form of human communication to date [2]. The whole systems and services of Third Generation (3G) mobile network rely on the quality of International Telecommunication Union (ITU) underneath International Mobile Telecommunication 2000 (IMT-2000) developed by 3G Partnership Project (3GPP) [3]. Universal Mobile telecom equipment (UMTS) is an element of the IMT-2000 family. In a communication system based on multiple access, various users need to access the channel at the same time, thus, several techniques that allow users to share the channels are deployed. UMTS employed Wideband Code Division Multiple Access (WCDMA) and includes the High Speed Packet Access (HSPA) specifications [4] as well as novel Packet Switched (PS) domain as multiple access technique.

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3G is mostly characterized to own high frequency spectrum utilization to support top quality voice services, multimedia system and internet services like electronic mail (e-mail), internet browsing, video streaming, interactive games and mobile e-commerce. It additionally permits the supply of adequate information about a particular environment such as weather forecast, location of schools, hotels, markets, airports, churches and mosques. These are some of the importance of 3G networks in people's lives and their day to day activities [2].

The information flows that make up voice and data calls between 3G mobile networks have a variety of limitations on the required Quality of Service (QoS). As radio network resources advance, QoS restrictions are now being resolved continuously. The distribution of network resources can be improved to maximize use [5]. In essence, QoS evaluation and network performance measurement are crucial for ensuring that customers are happy with the services they receive. As a result, per [6], a network operator or service provider that offers more superior QoS in comparison to a network service provider that offers inferior QoS will be guaranteed of acquiring new consumers while keeping existing ones for longer length of time. Furthermore, assessing and monitoring QoS is a difficult task for cellular network service providers, according to [7].

Among the Key Performance Indicators (KPIs) that are widely deployed in evaluating and assessing QoS in mobile networks are; Call Setup Success Rate (CSSR), Call Block Rate (CBR), Call Completion Rate (CCR), Call Drop Rate (CDR), Handover Success Rate (HOSR), Received Signal Code Power (RSCP) and Ec/Io or Ec/No.

Call Setup Success Rate (CSSR)**:** Call Setup Success Rate is a measure of the impact of congestion during a call attempt. It indicates the probability of successful calls initiated by the mobile station. CSSR is usually deployed as performance assessment tools for mobile operator. It is expressed in percentage as in equation (1) [8].

$$\text{CSSR} = \frac{\text{Number of successful call setup}}{\text{Total number of call attempts}} \times 100\% \tag{1}$$

Call Completion Rate (CCR): The Call Completion rate refers to the total number of calls that are initiated connected and ends successfully, in comparison to the number of calls attempt. Equation (2) depicts the mathematical expression of CCR in percentage. The recommendation of NCC is that for a network to be in good standing, its CCR value must be greater than 96%.

$$\text{CCR} = \frac{\text{Number of normally ended calls}}{\text{Total number of call attempts}} \times 100\% \tag{2}$$

Call Drop Rate (CDR): CDR is as well given in percentage. It is a measure of the calls that are prematurely ended before being released normally by either the caller or called party [1]. According to NCC, the CDR must be less than or equal to 1% for a network to be adjudged good equation (3) depicts the mathematical expression of CDR in percentage;

$$\text{CDR} = \frac{\text{Number of dropped calls}}{\text{Total number of call attempts}} \times 100\% \tag{3}$$

Call Block Rate (CBR): Call Block Rate is the ratio of the number of blocked calls to the total number of attempted calls. It is expressed in percentage as in equation (4). The NCC standard value for CBR is$< 2\%$. The lesser the CDR to the given standard value, the better the network.

$$\text{CBR} = \frac{\text{Number of blocked calls}}{\text{Total number of call attempts}} \times 100\% \tag{4}$$

Handover Success Rate (HOSR): Handover Success Rate is the ratio of successful handover calls to total number of attempted handover calls. It is also expressed in percentage. NCC recommends a standard value of greater than or equal to 98% for a qualitative mobile network. Equation (5) gives the mathematical representation of HOSR;

$$\text{HOSR} = \frac{\text{Number of successful completed handovers}}{\text{Total number of attempted handovers}} \times 100\% \tag{5}$$

Some other parameters used to measure the QoS of a mobile network are Received Signal Code Power (RSCP) and Ec/Io (or Ec/No). RSCP is signal strength of a network that donates the power measured by a receiver. It serves as a handover criterion, a downlink power control parameter, and a pathloss estimation [9]. Table 1 indicate rough guidelines as to what constitutes a particular level of performance (RSCP), ranging from excellent to unusable. Moreover, Ec/Io is the ratio of received energy per chip (Ec) and the interference level (Io), usually given in decibel (dB). It is a signal to noise ratio and a measure of equipment capacity. A payload is spread across several chips, so as Ec/Io declines, some chips might not reach their destination or might need to be sent more than once before the message can be successfully decoded. The mobile network employs Ec/Io or Ec/No as a factor to precisely time handovers. Table 2 gives key guidelines defining each quality level (Ec/Io), from excellent to unusable.

Table 1. Received Signal Code Power (RSCP) indication [10]

RSCP	Quality	Description
≥ -60 dBm	Excellent	Strong signal enabling maximum data capacity
≥ -75 dBm	Good	Good signal and speed with no dropouts expected
≥ -85 dBm	Fair to Poor	Fair/usable signal with possibility of dropouts and slowdowns
≤ -125 dBm	Unusable	No usable signal (expect frequent disconnections and sluggish performance

Table 2. Ec/Io signal strength indication [10]

Ec/Io	Quality	Description
≥ -6 dB	Excellent	Strong signal enabling maximum data capacity
≥ -10 dB	Good	Good signal and speed with no dropouts expected
≥ -15 dB	Fair to Poor	Fair/usable signal with possibility of dropouts and slowdowns
≤ -20 dB	Unusable	No usable signal (expect frequent disconnections and sluggish performance)

2. EXPERIMENTAL SETUP

2.1. Drive test setup

Test Mobile Systems (TEMS), a drive test package, was used as the method for data collection in the study. TEMS is a system that evaluates the accessibility and quality of wireless network signals and it includes several Mobile Test Units (MTUs), also known as Mobile Stations (MSs) [11]. Figure 1 presents the experimental setup for the drive test. Just as PSO (Particle swarm optimization) explores the solution space to find the optimal solution, TEMS allows for the exploration of various network conditions, configurations, and parameters to optimize the performance of mobile networks [12]. However, Figure 2 gives the breakdown of the equipment's used during the drive test.

The data collection exercise was repeatedly done on daily basis and lasted for two weeks. This was to ensure more accurate predictions and better optimization strategies for ensuring quality of service (QoS). By identifying long-term trends and issues, network administrators can proactively address potential bottlenecks, optimize resource allocation, and improve overall QoS for users [13]. Additionally, long-term analysis can uncover underlying factors contributing to congestion, allowing for more effective long-term solutions to be implemented [14].

The version of the TEMS investigation software is 15.2.2. Samsung galaxy S5 was the mobile station deployed and the studied area were Bodija, Eleyele and Sabo all in Ibadan metropolis, Oyo State, Nigeria. The GPS was included for geographical positional information and the examined networks were MTN Nigeria (MTN), Globacom (GLO), Airtel Nigeria (AIRTEL) and 9MOBILE.

During the test, a number of calls were made followed by an idle period of 20 seconds. The short calls were used to capture the cluster statistics voice data of the network. On the other hand, long lasting calls were used to capture both the mobility and signal strength of the network. The measurement procedure was repeated for all the mobile operators under consideration, along the Bodija-Eleyele-Sabo pre-determined test cluster route. Figure 3 depicts the drive test route. The collected dataset was later processed using TEMS discovery 10.0.3 to determine the intensity and the quality of the signal, the number of successful call setup, the number of unsuccessful call setup, the number of dropped calls, the number of blocked calls and handover information, for each of the four mobile operators.

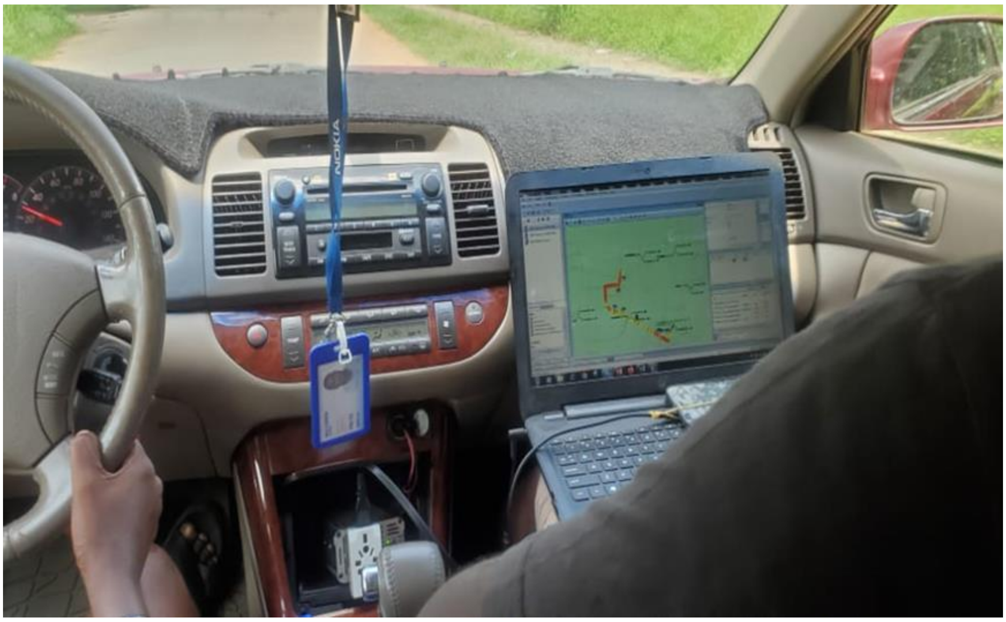

Fig. 1. Experimental Setup for Drive Test.

Fig. 2. Equipment used for the project.

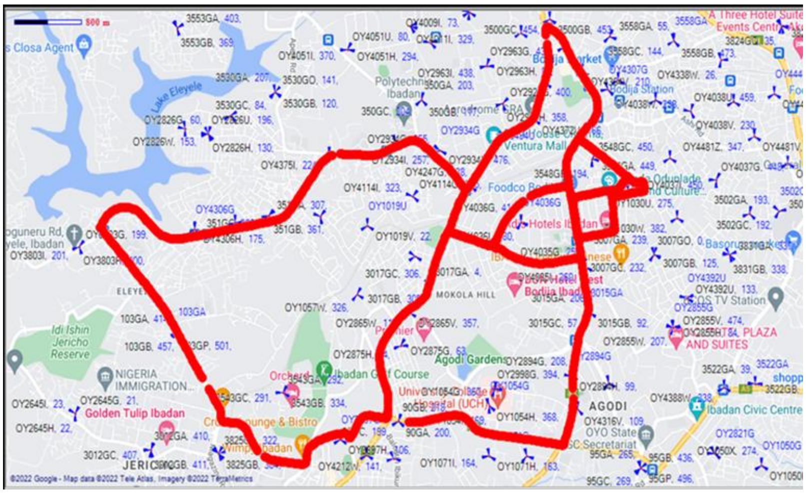

Fig. 3. The drive test route cluster.

3. RESULTS AND DISCUSSION

Figures 4 ÷ 7 present the 3G network coverage performance for the four mobile operators showing the RSCP values. However, Figures 8 ÷ 11 depict the 3G network performance quality for the four considered operators in terms of Ec/Io (or Ec/No).

Data extractions of the categorized RSCP and Ec/Io in terms of network range and percentage total calls are presented in Table 3 ÷ 10. Bar plots for the extracted RSCP and Ec/Io for the four operators are presented in Figures 12 and 13.

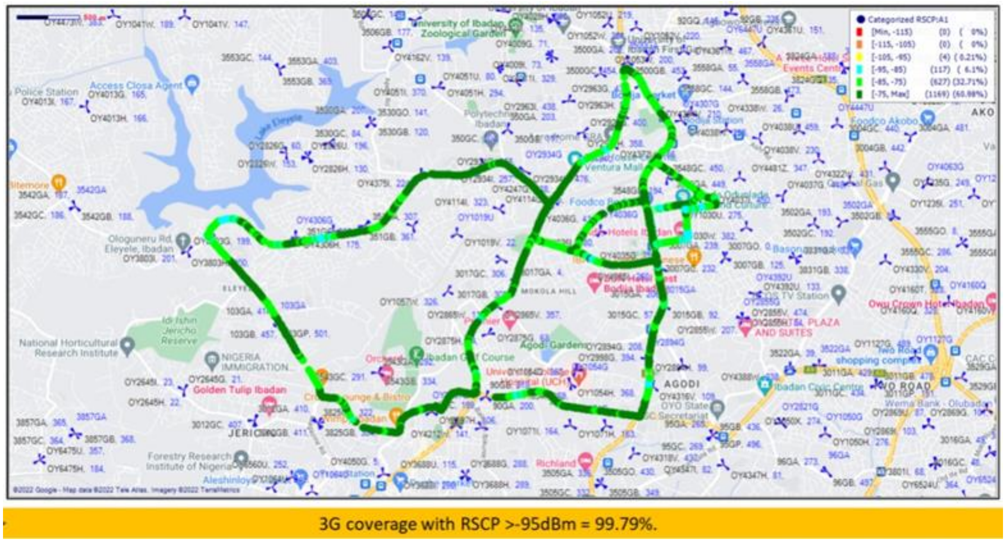

Fig. 4. MTN Network Coverage Performance (RSCP).

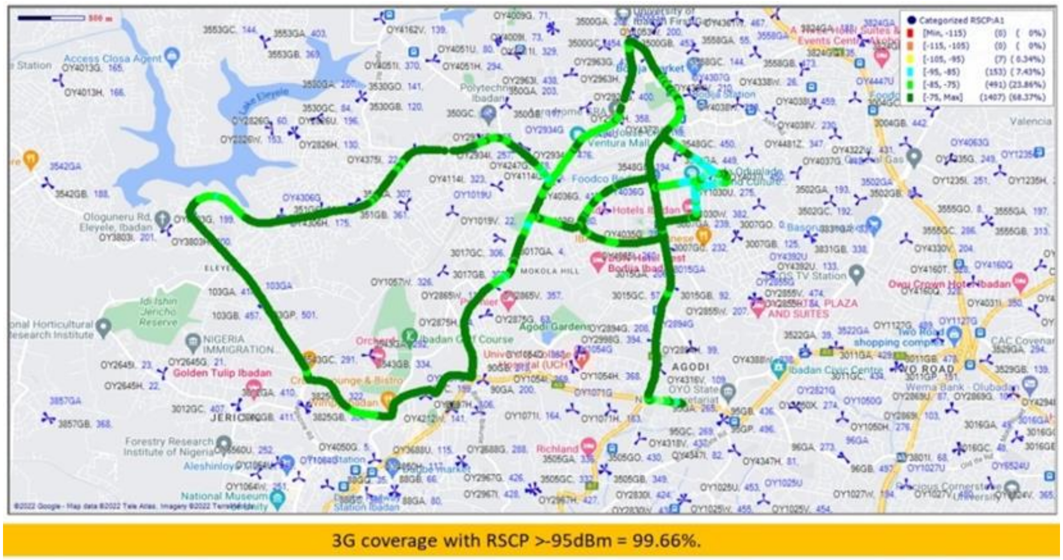

Fig. 5. GLO Network Coverage Performance (RSCP).

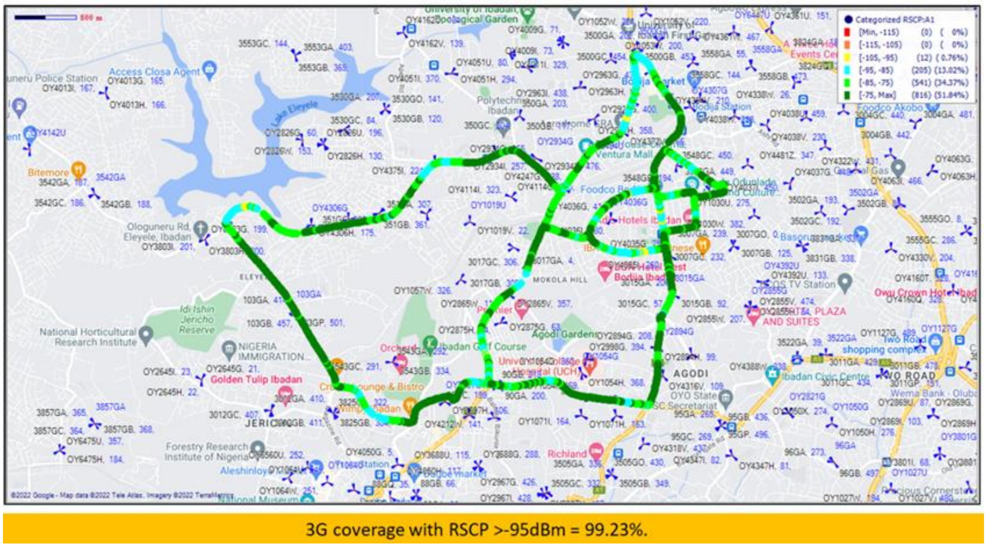

Fig. 6. AIRTEL Network Coverage Performance (RSCP).

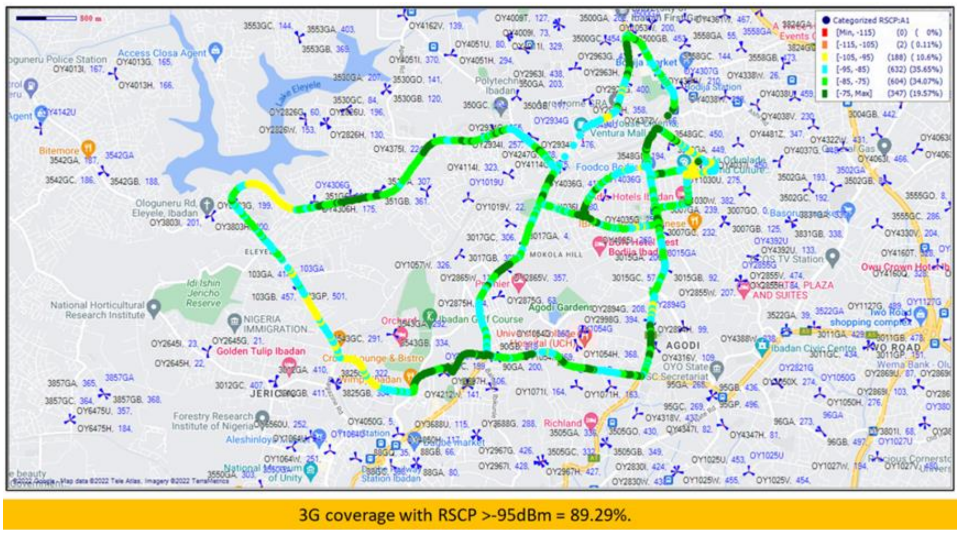

Fig. 7. 9MOBILE Network Coverage Performance (RSCP).

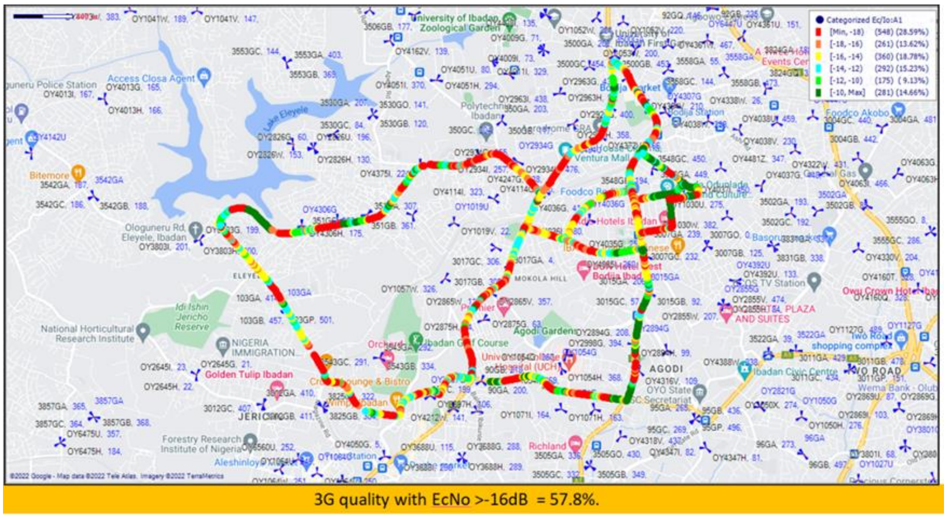

Fig. 8. MTN 3G Network Quality Performance (Ec/Io)

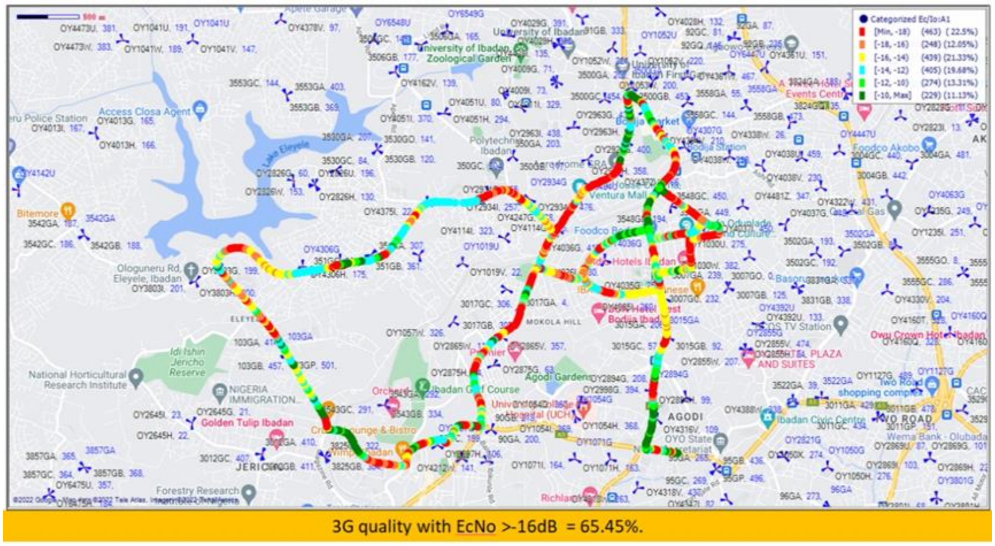

Fig. 9. GLO 3G Network Quality Performance (Ec/Io).

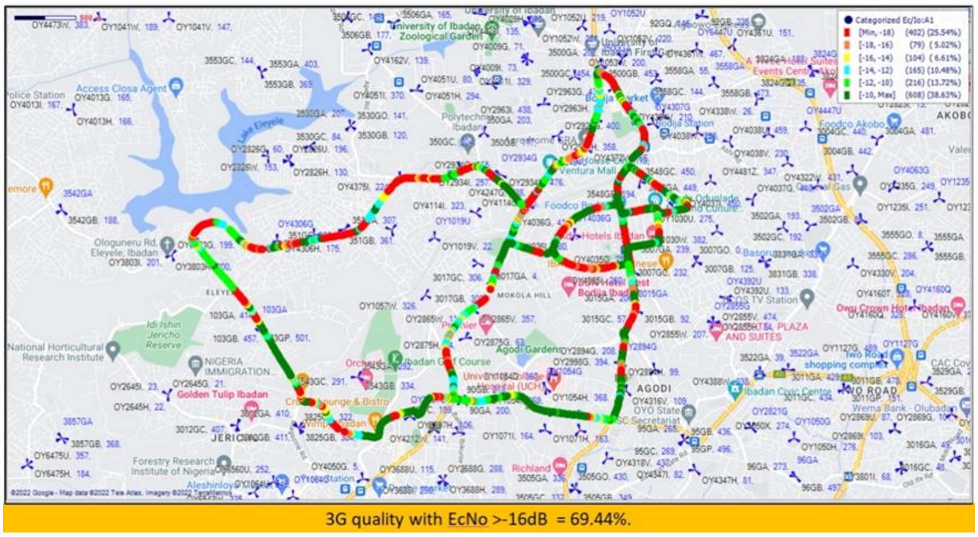

Fig. 10. AIRTEL 3G Network Quality Performance (Ec/Io).

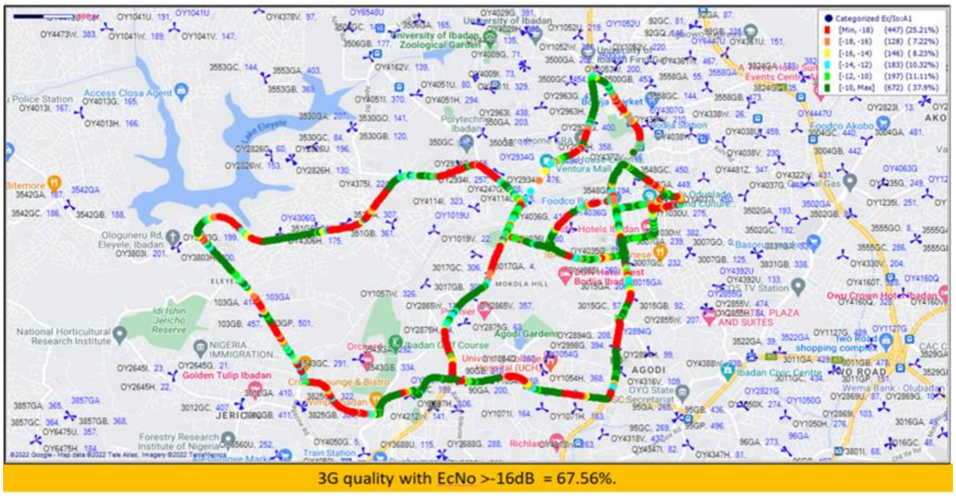

Fig. 11. 9MOBILE 3G Network Quality Performance (Ec/Io).

Table 3. Extracted Categorized RSCP for MTN

RSCP Color code	Range (dBm)	Corresponding no of calls	Percentage
	[min, -115]	0	0%
	[-115, -105]	0	0%
	[105, -95]	4	0.21%
	[-95, -85]	117	6.1%
	[-85, -75]	627	32.71%
	[-75, max]	1169	60.98%

Table 4. Extracted Categorized RSCP for GLO

RSCP Color code	Range (dBm)	Corresponding no of calls	Percentage
	[min, -115]	0	0%
	[-115, -105]	0	0%
	[105, -95]	7	0.34%
	[-95, -85]	153	7.43%
	[-85, -75]	491	23.86%
	[-75, max]	1407	68.37%

Table 5. Extracted Categorized RSCP for AIRTEL

RSCP Color code	Range (dBm)	Corresponding no of calls	Percentage
	[min, -115]	0	0%
	[-115, -105]	0	0%
	[105, -95]	12	0.76%
	[-95, -85]	205	13.02%
	[-85, -75]	541	34.37%
	[-75, max]	816	51.84%

Table 6. Extracted Categorized RSCP for 9MOBILE

RSCP Color code	Range (dBm)	Corresponding no of calls	Percentage
	[min, -115]	0	0%
	[-115, -105]	2	0.11%
	[105, -95]	188	10.6%
	[-95, -85]	632	35.65%
	[-85, -75]	604	34.07%
	[-75, max]	347	19.57%

Table 7. Extracted Categorized Ec/No for MTN.

Ec/Io Color code	Range (dB)	Corresponding no of calls	Percentage
	[min, -18]	548	28.59%
	[-18, -16]	261	13.62%
	[-16, -14]	360	18.78%
	[-14, -12]	292	15.23%
	[-12, -10]	175	9.13%
	[-10, max]	281	14.66%

Table 8. Extracted Categorized Ec/No for GLO.

Ec/Io Color code	Range (dB)	Corresponding no of calls	Percentage
	[min, -18]	463	22.50%
	[-18, -16]	248	12.05%
	[-16, -14]	439	21.33%
	[-14, -12]	405	19.68%
	[-12, -10]	274	13.31%
	[-10, max]	229	11.13%

Table 9. Extracted Categorized Ec/No for AIRTEL.

Ec/Io Color code	Range (dB)	Corresponding no of calls	Percentage
	[min, -18]	402	25.54%
	[-18, -16]	79	5.02%
	[-16, -14]	104	16.61%
	[-14, -12]	165	10.48%
	[-12, -10]	216	13.72%
	[-10, max]	608	38.63%

Table 10. Categorized Ec/No for 9MOBILE.

Ec/Io Color code	Range (dB)	Corresponding no of calls	Percentage
	[min, -18]	447	25.21%
	[-18, -16]	128	7.22%
	[-16, -14]	146	8.23%
	[-14, -12]	183	10.32%
	[-12, -10]	197	11.11%
	[-10, max]	672	37.9%

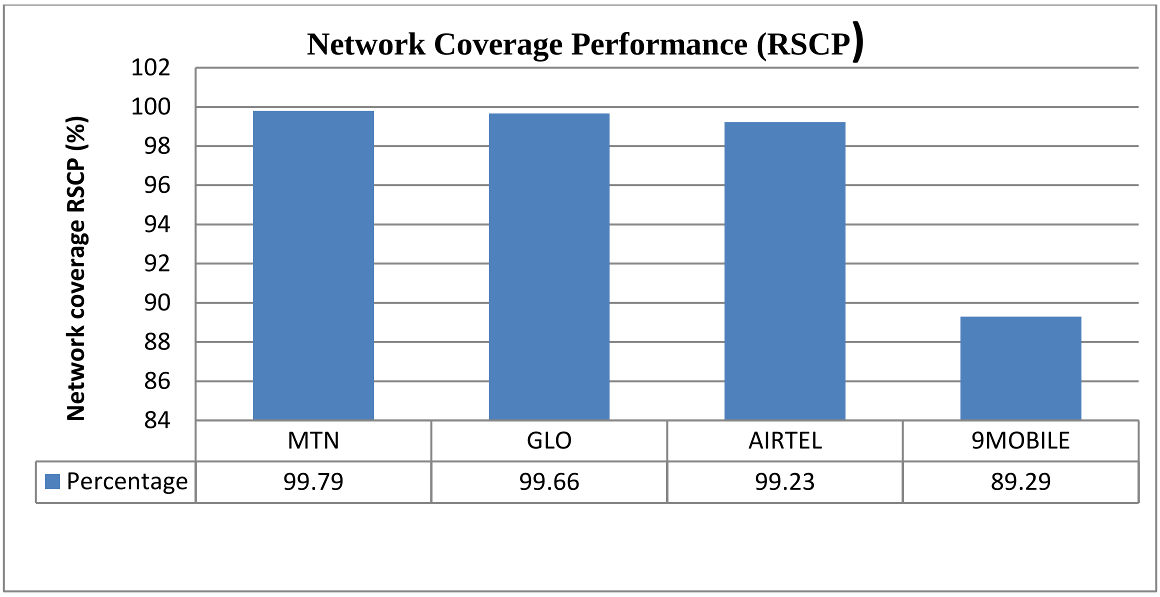

Fig. 12. Network Coverage Performance (RSCP).

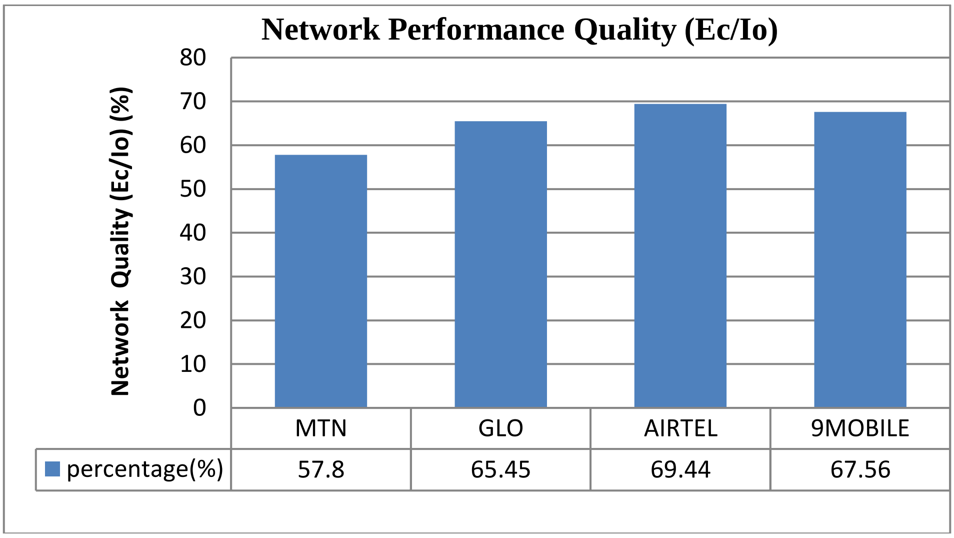

Fig. 13. Network Performance Quality (Ec/Io)

Statistics of the event of the four mobile operators is displayed in Table 11.

Table 11. Statistics of the event of the four mobile operators.

EVENTS	MTN	GLO	AIRTEL	9MOBILE
Call Attempts	58	54	45	39
Call Set up Success	56	41	45	39
% Call Set up Success	96.55%	75.93%	100%	100%
Blocked Calls	2	13	0	0
% of Blocked calls	3.45%	24.07%	0%	0%
Drop Calls	0	9	3	1
% of Drop Calls	0%	16.67%	6.67%	2.56%
Handover Attempts	870	323	650	449
Handover Success	865	287	590	394
% of Handover Success	99.42%	88.85%	90.77%	87.75%
Handover Failure	5	36	40	55
% of Handover Failure	0.58%	11.15%	9.23%	12.25%

Evaluation of the quality of service (QoS) results with respect to NCC target that were obtained on CSSR, CCR, CBR, CDR, and HOSR is shown in Table 12. Figure 14 shows the 3D graphical representation of all the four mobile operators with respect to NCC target.

Table 12. KPI summary of the four mobile operators with respect to NCC target.

KPIs	Qos Metrics	NCC	MTN	GLO	AIRTEL	9MOBILE
CSSR (%)	$\frac{\text{call established}}{\text{call attempt}}$	≥ 98	96.55	75.93	100.00	100.00
CCR (%)	$\frac{\text{no of completed calls}}{\text{call attempts}}$	> 96	96.43	59.25	93.33	97.40
CBR (%)	$\frac{\text{no of blocked calls}}{\text{call attempts}}$	< 2	3.45	24.07	0.00	0.00
CDR (%)	$\frac{\text{no of drop calls}}{\text{call attempts}}$	≤ 1	0.00	16.67	6.67	2.56
HOSR (%)	$\frac{\text{no of successful handover}}{\text{no of handover attempts}}$	≥ 98	99.43	88.85	90.77	87.75

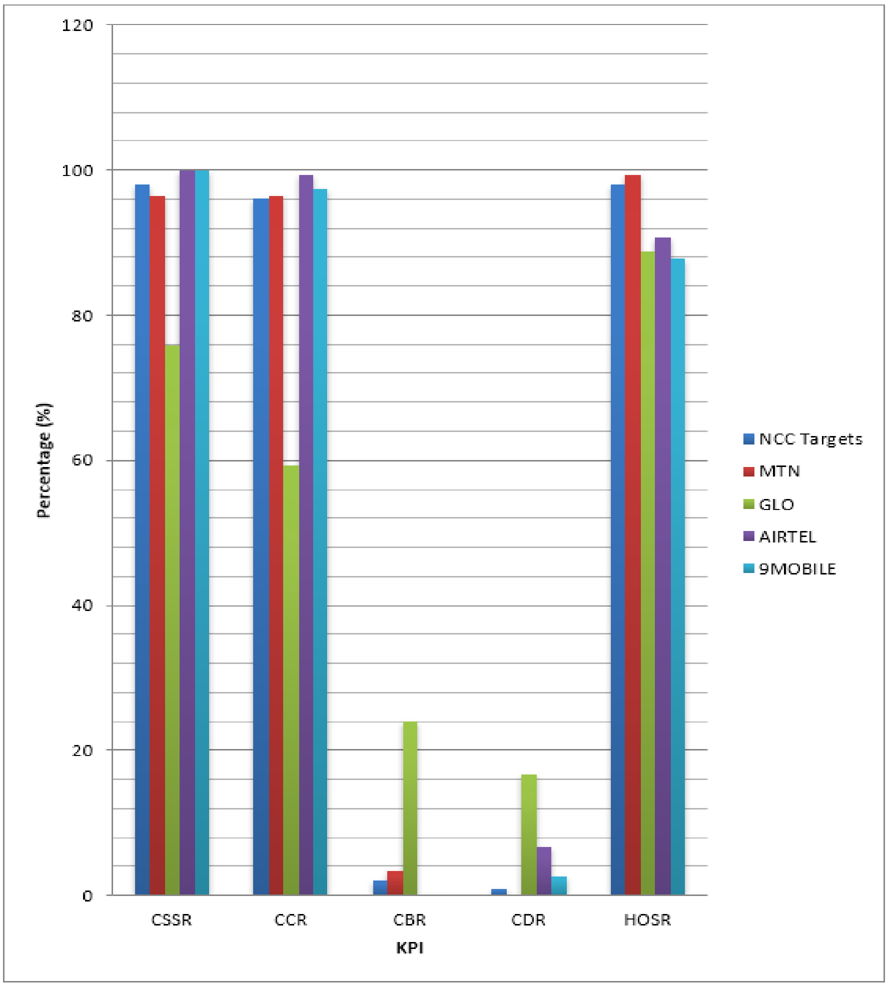

Fig. 14. Bar plot of each Mobile Operator’s performance.

The findings of this research work base on the earlier mentioned KPI parameters: RSCP, Ec/Io, CSSR, CBR, CDR, CCR and HOSR.

RSCP: Considering RSCP as shown in Figures 4 ÷ 7 and 12, and Tables 3 ÷ 6, one may observe that MTN has RSCP values of 0 corresponding call, 0% in the range of [-min, -115] dBm; 0 corresponding call, 0% in the range of [-115, -105] dBm; 4 corresponding calls, 0.21% in the range of [-105, -95] dBm; 117 corresponding calls, 6.1% in the range of [-95, -85] dBm; 627 corresponding calls, 32.71% in the range of [-85, -75] dBm; 1169 corresponding calls, 60.98% in the range of [-75, max] dBm. Thus in overall, MTN has a value of 1913 corresponding calls that were above the minimum NCC standard of -95dBm RSCP value amounting to 99.79% of the total calls.

However, GLO has RSCP values of 0 corresponding call, 0% in the range of [-min, -115] dBm; 0 corresponding call, 0% in the range of [-115, -105] dBm; 7 corresponding calls, 0.34% in the range of [-105, -95] dBm; 153 corresponding calls, 7.43% in the range of [-95, -85] dBm; 491 corresponding calls, 23.86% in the range of [-85, -75] dBm; 1407 corresponding calls, 68.37% in the range of [-75, max] dBm. Thus in overall, GLO has a value of 2051 corresponding calls that were above the minimum NCC standard of -95dBm RSCP value amounting to 99.66% of the total calls.

Furthermore, AIRTEL has RSCP values of 0 corresponding call, 0% in the range of [-min, -115] dBm; 0 corresponding call, 0% in the range of [-115, -105] dBm; 12 corresponding calls, 0.76% in the range of [-105, -95] dBm; 205 corresponding calls, 13.02% in the range of [-95, -85] dBm; 541 corresponding calls, 34.37% in the range of [-85, -75] dBm; 816 corresponding calls, 51.84% in the range of [-75, max] dBm. Thus in overall, AIRTEL has a value of 1562 corresponding calls that were above the minimum NCC standard of -95dBm RSCP value amounting to 99.23% of the total calls.

Accordingly, 9MOBILE has RSCP values of 0 corresponding call, 0% in the range of [-min, -115] dBm; 2 corresponding call, 0.11% in the range of [-115, -105] dBm; 188 corresponding calls, 10.6% in the range of [-105, -95] dBm; 632 corresponding calls, 35.65% in the range of [-95, -85] dBm; 604 corresponding calls, 34.07% in the range of [-85, -75] dBm; 347 corresponding calls, 19.57% in the range of [-75, max] dBm. Thus in overall, 9MOBILE has a value of 1583 corresponding calls that were above the minimum NCC standard of -95dBm RSCP value amounting to 89.29% of the total calls.

Ec/No: Considering Ec/No as shown in Figures 5 ÷ 8 and 13, and Tables 7 ÷ 10, it was observed that MTN has Ec/No values of 548 corresponding call, 28.59% in the range of [-min, -18] dB; 261 corresponding call, 13.62% in the range of [-18, -16] dB; 360 corresponding calls, 18.78 in the range of [-16, -14] dB; 292 corresponding calls, 15.23% in the range of [-14, -12] dB; 175 corresponding calls, 9.13% in the range of [-12, -10] dB; 281 corresponding calls, 14.66% in the range of [-10, max] dB. Thus, in overall, MTN has a value of 1108 corresponding calls that were above the minimum NCC standard of >-16dBm Ec/No value amounting to 57.8% of the total calls.

However, GLO has Ec/No values of 463 corresponding call, 22.5% in the range of [-min, -18] dB; 248 corresponding call, 12.05% in the range of [-18, -16] dB; 439 corresponding calls, 21.33% in the range of [-16, -14] dB; 405 corresponding calls, 19.65% in the range of [-14, -12] dB; 274 corresponding calls, 13.31% in the range of [-12, -10] dB; 229 corresponding calls, 11.13% in the range of [-10, max] dB. Thus in overall, GLO has a value of 1347 corresponding calls that were above the minimum NCC standard of >-16dBm Ec/No value amounting to 65.45% of the total calls.

Furthermore, AIRTEL has Ec/No values of 402 corresponding call, 25.54% in the range of [-min, -18] dB; 79 corresponding call, 5.02% in the range of [-18, -16] dB; 104 corresponding calls, 6.61% in the range of [-16, -14] dB; 165 corresponding calls, 10.48% in the range of [-14, -12] dB; 216 corresponding calls, 13.72% in the range of [-12, -10] dB; 608 corresponding calls, 38.63% in the range of [-10, max] dB. Thus in overall, AIRTEL has a value of 1093 corresponding calls that were above the minimum NCC standard of >-16dBm Ec/No value amounting to 69.44% of the total calls.

9MOBILE has Ec/No values of 447 corresponding call, 25.21% in the range of [-min, -18] dB; 128 corresponding call, 7.22% in the range of [-18, -16] dB; 146 corresponding calls, 8.23% in the range of [-16, -14] dB; 183 corresponding calls, 10.32% in the range of [-14, -12] dB; 197 corresponding calls, 11.11% in the range of [-12, -10] dB; 672 corresponding calls, 37.9% in the range of [-10, max] dB. Thus in overall, 9MOBILE has a value of

1198 corresponding calls that were above the minimum NCC standard of >-16dBm Ec/No value amounting to 67.56% of the total calls.

CSSR, CBR, CCR, CDR, and HOSR: For CSSR only AIRTEL and 9MOBILE of the operators have their CSSR values of 100% respectively above the standard NCC value of ≥ 98%.MTN and GLO have values of 96.55% and 75.93% respectively.

The NCC standard value for CBR is < 2%. AIRTEL and 9MOBILE have values of 0.00% respectively. MTN and GLO have CBR values of 3.45% and 24.07% respectively.

The standard NCC value for CCR is < 2. MTN and 9MOBILE have values of 0% respectively, while GLO and Airtel have respective values of 59.25% and 93.33%.

For CDR the standard NCC value is ≤ 1. MTN has a CDR value of 0.00%. GLO, AIRTEL and 9MOBILE have respective values of 16.67%, 6.67% and 2.56%.

For HOSR, the standard NCC value is ≥ 98. MTN has a value of 99.43%. GLO, AIRTEL and 9MOBILE have values of 88.85%, 90.77% and 87.75% respectively.

4. CONCLUSIONS

MTN achieved; 99.79%, 57.8%, 96.55%, 96.43, 3.45%, 0.00%, 99.43%, GLO achieved; 99.66%, 65.45%, 75.93%, 59.25%, 24.07%, 16.67%, 88.85%, AIRTEL achieved; 99.23%, 69.44%, 100.00%, 93.33%, 0.00%, 6.67%, 90.77%, 9MOBILE achieved; 89.29%, 67.56%, 100.00%, 97.4%, 0.00%, 2.56%, 87.75% of RSCP, Ec/No, CSSR, CCR, CBR, CDR and HOSR respectively.

The findings show that, when all the seven KPI parameters were considered together, there were always trade-offs in the service provider’s performance. A service provider may be good when some KPIs are considered, but perform poorly in others. No service provider was in good standing across all the KPIs. Thus, the performance of a particular operator is purely a function of the desired KPI parameter.

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