International Journal of Computer (IJC)
ISSN 2307-4523 (Print & Online)
http://ijcjournal.org/

Performance Evaluation Of Quality Of Service Of A 4g Network In A Tropical Environment

Solomon N. Ogili, G. N. Onoh*

Abstract

The Nigerian Communications Commission (NCC), which is a communication regulatory Authority sets some key Performance Indications (KPIs) that the GSM network providers need to adhere to in order to deliver an efficient and quality network services in the country [1]. In this paper, Transverse Electromagnetic Wave Simulator (TEMS) was used in collecting data (Drive Tests) related to – call setup success rate (CSSR), call drop rate (CDR), paging success rate (PSR), grade of service (GOS), handover success rate (HOSR) etc; from 30 Base transceiver stations (BTS or BS) within Enugu metropolis during a specified period of fifteen working days. The Path Loss Exponent of the Test-Bed was verified to ascertain if it is in agreement with the environment of interest and the Operation and Maintenance Centre Resources (OMCR) statistics and drive test data gathered were analyzed using different graphs. The results of the Investigation of performance of Quality of Service offered by the network provider, Mobile Telecommunications Nigeria (MTN) in Enugu metropolis showed high performance as the network was deployed in the appropriate environment – Shadowed Urban Environment with Path Loss Exponent of 3.12.

Keywords: environment; network.

1. Introduction

Poor Quality of Service (QoS) leads to customer dissatisfaction, loss of revenue and credibility to the service provider. Traffic congestion in a mobile radio communication system is a challenge in terms of the number of subscribers that can successfully access the network at a particular period of time due to limited availability of transmission channels [2]. When the number of subscribers in a network exceeds the maximum installed network capacity, users are bound to experience frequent call blockings/droppings. This implies that some subscribers accessing the network will be denied access into the network at that particular period of time especially during busy hours (peak period) as a result of congestion on the network. Congestion deteriorates network service quality, resulting in queuing delay, interference, frames or data packet loss, degradation of signal strengths and blocking of new calls with reduced network throughput. Mobile users are bound to experience increase in blocked/dropped calls in the network due to inability to access the Exchange (mobile switching centre - MSC) through the Air interface. The poor quality of service could also be traced to lack of adequate number of BS, and provision of additional services by the network provides without recourse to system upgrade and adequate dimensioning which leads to capacity problems [3].

----

* Corresponding author.

Users usually experience poor quality service while trying to make calls by getting frustrating voice prompts (signal responses), like ‘’the number you have dialed is currently switched off, not reachable, network or number busy, not available’’ etc., whereas the phone is actually on and active (indicating full service). During festive periods (example Christmas and Easter) in some Regions in Nigeria, mobile radio network usage is usually higher (stretched) than in any other month of the year and as such, subscribers experience a lot of challenges due to limited availability of radio resource (channels). However, the motivation of this work was based on the need to reduce the loss of revenue by the service provider and increase subscriber perception of reliability which enhances customer retention. “Reliability” when technically distinguished from “quality” refers to the expected length of time that a System/service or network will meet customers need before failing [4]. Reliability affects both the subscribers and the network providers. When the users (subscribers) migrate from one network to another, the provider tends to lose their customers patronage to other competitors and their income adversely affected. While on the other hand, the providers of the new network subscribers migrated to will have increase in their income with more number of subscribers to access their own limited available channels. Thus, the rate of call blocking/dropping and delay in data transmission will also increase as a result of poor quality of services in the network the subscribers migrated to. Hence, the problem still remained unsolved. In Nigeria, service providers are more interested in introduction of additional services and the amount of profit they will make instead of providing better and reliable services in order to satisfy their customers. Despite many researchers’ contributions towards improving the quality of network services, there is still need for further improvement. Need to ascertain and verify test-bed of network deployment and Path Loss Exponent of the environment intended to host the network is not considered before installing or developing a network. Efficient Path loss and Path loss Exponent prediction is important for proper design of wireless network. Efficiency of present Path loss models suffers when they are used in the environment other than that, for which they have were designed [5]. Propagation models that predict the signal strength for an arbitrary transmitter – receive (T-R) separate distance are useful in estimating the radio coverage area of a transmitter [6] and the Radio transmission in a mobile common system often takes place over irregular terrain. The terrain profile of a particular area needs to be taken into account for estimating the path loss and Path loss Exponent [7].

2. Overview of Cellular Network System

First Generation of Mobile Systems catered on speech services and was based on analogue transmission techniques. Facilities such as roaming within continents were impossible and most countries have only one operator. The first generation or 1G analogue systems started with frequency band of NMT450 and later NMT900 (NMT – Nordic mobile Telephony). There was no encryption on the voice services and cell ranges from 2km to 30km. This later moved to AMPS (Advanced mobile phone system) that operate at 900MHZ and operate on FDMA (Frequency division multiple access) which allow multiple users in a cell or cell sector.The challenges of incompatibility of different systems, capacity and insecure speech lead to the development of 2G (GSM Global System for Mobile, PDC – Personal Handling Cellular, PHS – Personal handy Phone System, CDMA – Code division multiple access, Short Message signal and CSD – circuit switched data are available in 2G system which operate in TDMA –Time division multiple access. Most GSM systems operate at radio frequency of 900MHZ and 1800MHZ. The uplink frequency band in the 900MHZ is 935 -960MHZ and the downlink frequency band is 890-915MHZ. Both the uplink and downlink has a frequency band of 25MHZ which is divided into 124 carriers to get 200KHZ apart. Each frequency channel contains 8 speech channels [8].

Before a GSM network is commercially launched, the radio network optimization process starts and continues during the life of the network. GSM network operators are worried about the quality of their network services as perceived by the end users – subscribers. The GSM operators' competitiveness relies closely on radio network quality in parallel with the pricing policy. GSM standards offer the possibility of monitoring network by statistics. In the BSC or BTS, each cell reports thousands of statistics about number of attempts, failures, successes, during calls, handover, setup etc are reported to the Network Management System (NMS) as counters. Each GSM network operator chooses its own Key Performance Indicator (KPIs) and sets, according to specific criteria and objectives to be met in order to achieve a good end user perception of the service offered and also in order to benchmark one network with other operators. Drive Test field measurements tool is able to report measurements like Mean Opinion Score (MOS), Frame Error Rate (FER), and Bit Error Rate (BER), in addition to standard reporting of the signal level, quality and site information, cell identity, BCCH, mobile allocation list and best neighbours. In addition to statics and drive test, tracing catches the behaviour of TRX, cell, BTS or BSC during a period and regarding a specific event like SDCCH allocation, conversation phase of a voice call. Tracing also catches events like call setup, paging and location update. Network switching subsystem (NSS) performance follow-up, alarm monitoring and transmission network auditing are used in finding out hardware problems/parameter errors that effect end users perception of the GSM network.

All these above (KPI, drive test, tracing network auditing) field knowledge, frequency planning review are all key step in GSM optimization process. The following statistics/KPIs are very important for GSM optimization and benchmarking to achieve remarkable Quality of Service (QoS):

3. Methodology

3.1 Field Work Experiment -Measurement in Enugu Urban Environment

A drive test was conducted in Enugu on MTN Network to ascertain the major properties of the network under consideration and to collect a log file (data) which was used for the analysis. Before the drive test, the different base stations were monitored using our compass to check the direction of the cells from the BS and to know where the connecting radios are facing or coming from, and the latitude and longitudinal directions.

Drive testing results were used for determining the receive signal level with distance variable. The period of data reading is between 05/07/2020 to 23/07/2020 weekdays only and 30 Base Stations were considered. To get started, we launched the TEMS software for TEMS 19.0 and clicked professional. After booting, the TEMS investigation page is displayed as shown in Figure 2. The measurement instrument for gathering of Data is displayed in Figure 1 and the Drive Route, and Test Sites is shown in Figures 3 below. The overall scenario consists of couple of base station sites, each of them with three sectors having different azimuths that are placed in order to cover the defined area. The distance between the sites is approximately 600 meters which corresponds to typical setup of commercial UMTS antennas. All sites are synchronized using a defined GPS-clock. The cell diameter is approximately 350 meters.

Figure1: TEMS Measurement Tool used for Field gathering of RSSI Data.

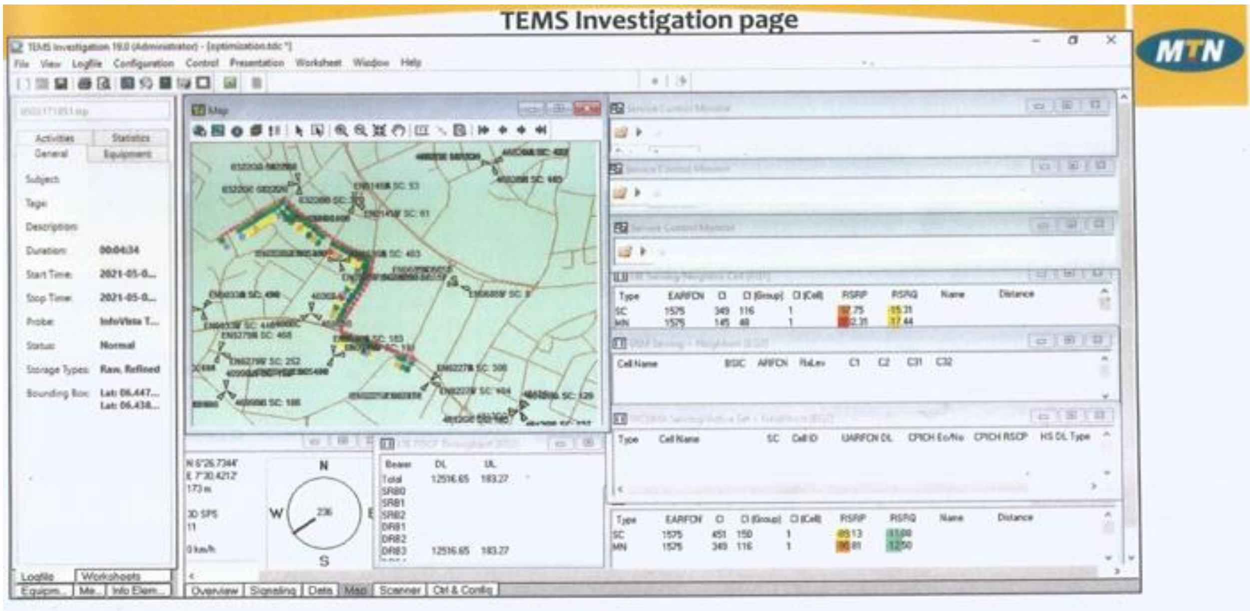

Figure 2: TEMS Investigation Page.

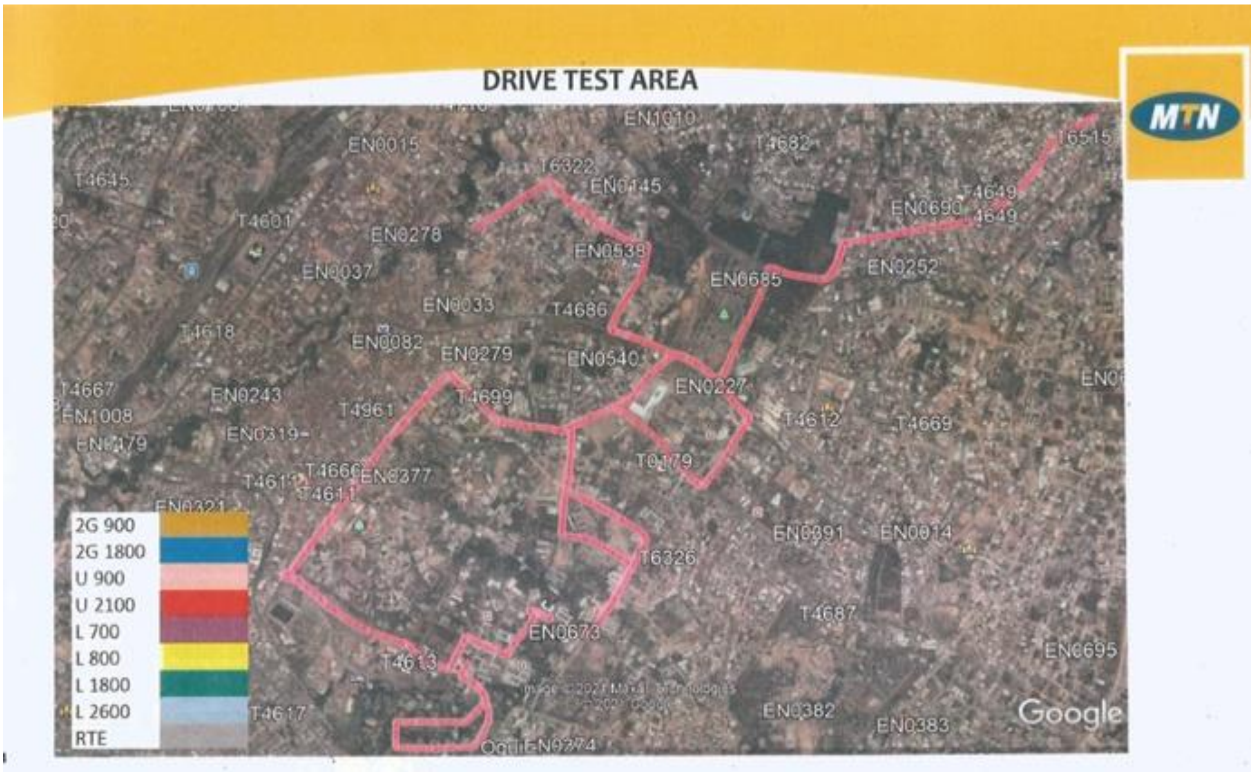

Figure3: Drive Test Area – Enugu Urban Environment.

A predefined route was driven where the 4G network is already installed in an MTN network and data was collected. Collected data includes diverse information of parameters such as Network frequency, RSSI, SNR, Call setup, Call Establishment, Call Drops, Uplink and Downlink Physical layer, Throughput, Handover, and Packet Latency (Round Trip Delay) and this work will concentration mainly on the KPIs (CSSR, Paging Success Rate, effect of Traffic Load on successful handover), and Path Loss Exponent of Enugu Environment.

3.2 Path loss Exponent

Table 1: Path Loss Exponent for Different Environment [9].

Environment	**Path Loss Exponent (n)**
Free Space	**2**
Urban Area Cellular Radio	**2.7 – 3.5**
Shadowed Urban Cellular Radio	3 – 5
In building Line-of-Sight	1.6 – 1.8
Obst6ructed in building	4 – 6
Obstructed in factory	2 – 3

3.2.1 System Design/Specification

The following is the system design of a 3G GSM Base Transceiver Stations (BTS) for the field test:

i. Transmitter Power 30W

ii.	Antenna gain	20dB
iii.	Transmit Frequency	800MHz
iv.	Average height of BTS antenna	45m

The Mobile Terminal (TEMS) has the following parameters:

i.	Transmit Power	30W
ii.	Sensitivity	104dBm
iii.	Antenna gain	0dB
iv.	Transmit Frequency	800.2MHz
v.	Average height of MT antenna mounted in Car	1.6m
vi.	Average cell radius	5km

4. Results and Discussions

This paper characterized the 4G network using TEM devices and analyzed the results gathered.

Table 2: Summary of KPIs.

	Average Calls Attempted	**Average Completed Calls**	**Average Blocked Calls**	**Average Answered Calls**	**Average Unanswered Calls**	**Average Handover Attempted**	**Successful Handover**
ENU001	455863	390037	6582	350344	39693	9293	9192
ENU002	419731	234190	18554	194354	39836	6271	6031
ENU003	279830	193839	8599	173932	19907	9289	8728
ENU004	479465	398002	8146	298022	99980	10393	10293
ENU005	53955	40573	1338	34529	6044	3827	3111
ENU006	80208	54058	2615	48293	5765	3634	2989
ENU007	69103	51019	1808	49832	1187	4352	4028
ENU008	132691	106016	2667	93839	12177	8934	8732
ENU009	678566	597331	8123	530728	66603	4723	4273
ENU010	1038491	940585	9790	894032	46553	8373	7832
ENU011	147067	109101	3796	93032	16069	4582	3829
ENU012	108595	87809	2078	78392	9417	3839	3028
ENU013	109534	98231	1276	109634	1011	9278	8713
ENU014	143641	108543	1163	287103	2076	10821	9887
ENU015	176678	254876	1462	264071	11754	2801	2413
ENU016	234987	234869	2374	303109	17010	9476	8501
ENU017	324678	812423	2729	271912	21872	8709	8127
ENU018	412890	79543	2479	38901	29043	7234	6729
ENU019	213456	121845	2712	87293	12003	6903	4417
ENU020	89453	103542	1730	28345	34860	7923	7731
ENU021	79354	304786	910	73192	32876	3489	2989
ENU022	67453	237201	1375	69173	17012	6100	5087
ENU023	54830	564908	1521	39601	39491	3890	2906
ENU024	76987	127512	1073	47145	13009	5189	4781
ENU025	41854	219753	1384	29803	19023	3978	905
ENU026	6751	98419	1747	26309	18723	2758	2703
ENU027	67513	98419	1747	26309	18723	2758	2703
ENU028	87311	319683	1853	41876	16234	3219	1954
ENU029	78613	40725	1638	33809	17609	4156	3840
ENU030	67500	66540	6,00	550370	3678	10750	10750
Average	**210165.03**	**240180.8**	**3539.483**	**172602.8**	**23600.9**	6329.9	5772.7

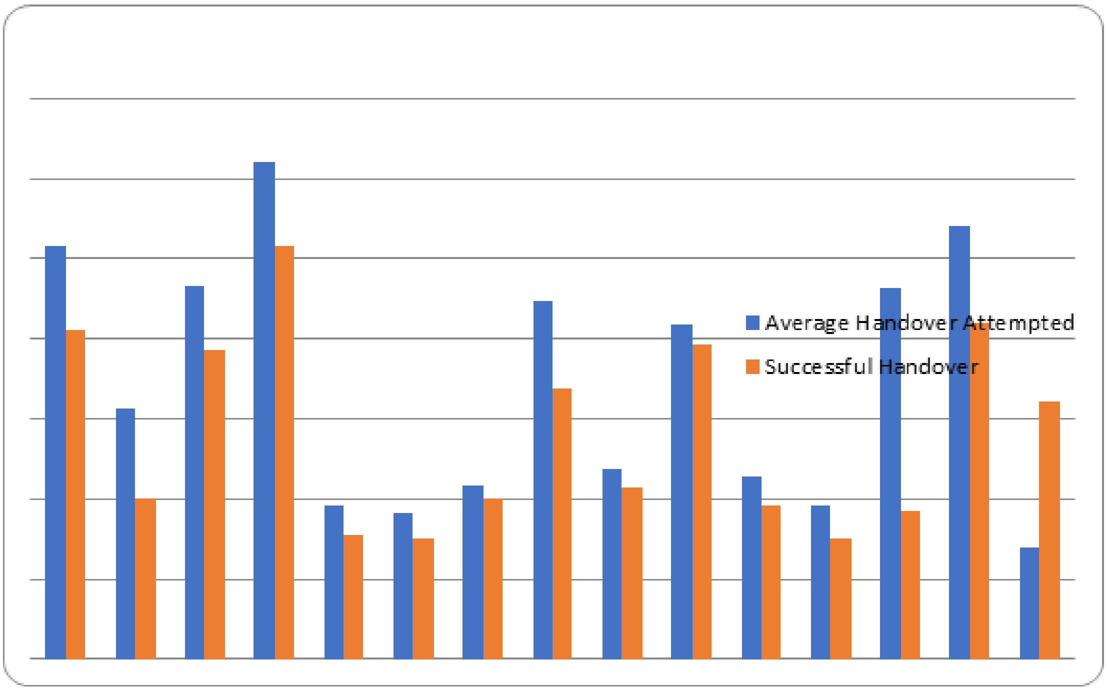

Figure 4a: Effect of traffic load on Handover for the first set 15 BTS.

ENU005, ENU006 and ENU012 recorded the lowest successfull handover in the first set of 15 BTS under review.

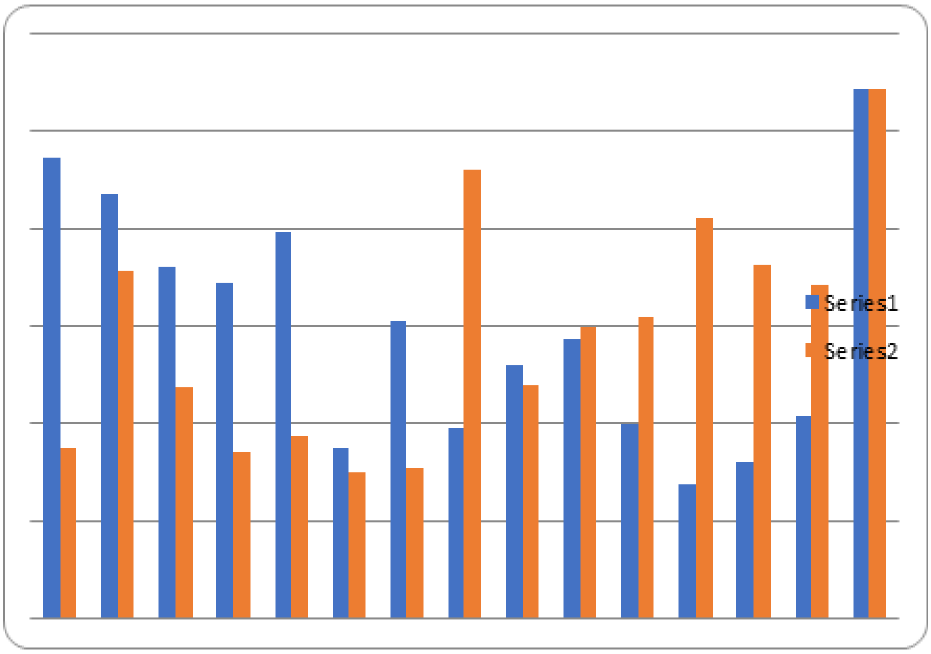

Figure 4b: Effect of traffic load on Handover for the second set of 15 BTS.

ENU030 has the best handover success rate in the second set of 15TS.

Table 3: Average Paging Success Rate for 30 BTS for the period of experimentation.

S/N	**Base Transceiver Station**	**Paging Success Rate (%) before optimization**	**Paging Success Rate% after optimization**
1	HENU BSC1_RNC(AWK001)	60.65	98.3
2	HENU BSC1_RNC(AWK002)	61.58	99
3	HENU BSC1_RNC(AWK003)	59.98	98.7
4	HENU BSC1_RNC(AWK004)	60.15	98.1
5	HENU BSC1_RNC(AWK005)	61.22	98.6
6	HENU BSC1_RNC(AWK006)	60.8	98.4
7	HENU BSC1_RNC(AWK007)	60.45	98.2
8	HENU BSC1_RNC(AWK008)	62.27	98.9
9	HENU BSC1_RNC(AWK009)	59.94	99
10	HENU BSC1_RNC(AWK010)	60.49	98
11	HENU BSC1_RNC(AWK011)	62.67	99
12	HENU BSC1_RNC(AWK012)	60.68	98.43
13	HENU BSC1_RNC(AWK013)	60.27	98.76
14	HENU BSC1_RNC(AWK014)	60.39	98.53
15	HENU BSC1_RNC(AWK015)	61.2	98.73
16	HENU BSC2_RNC(AWK016)	61.22	98.41
17	HENU BSC2_RNC(AWK017)	62.1	99
18	HENU BSC2_RNC(AWK018)	62.45	99
19	HENU BSC2_RNC(AWK019)	62.29	99.1
20	HENU BSC2_RNC(AWK020)	62.57	98.8
21	HENU BSC2_RNC(AWK021)	63.45	98
22	HENU BSC2_RNC(AWK022)	62.95	99
23	HENU BSC2_RNC(AWK023)	64.11	98.6
24	HENU BSC2_RNC(AWK024)	63.66	99
25	HENU BSC2_RNC(AWK025)	63.75	99
26	HENU BSC2_RNC(AWK026)	64.48	98.4
27	HENU BSC2_RNC(AWK027)	64.08	98.56
28	HENU BSC2_RNC(AWK028)	63.46	98.4
29	HENU BSC2_ RNC(AWK029)	63.94	98.2
30	HENU BSC2_RNC(AWK030)	64.63	98.7
	AVERAGE	**62.1%**	**98.6%**

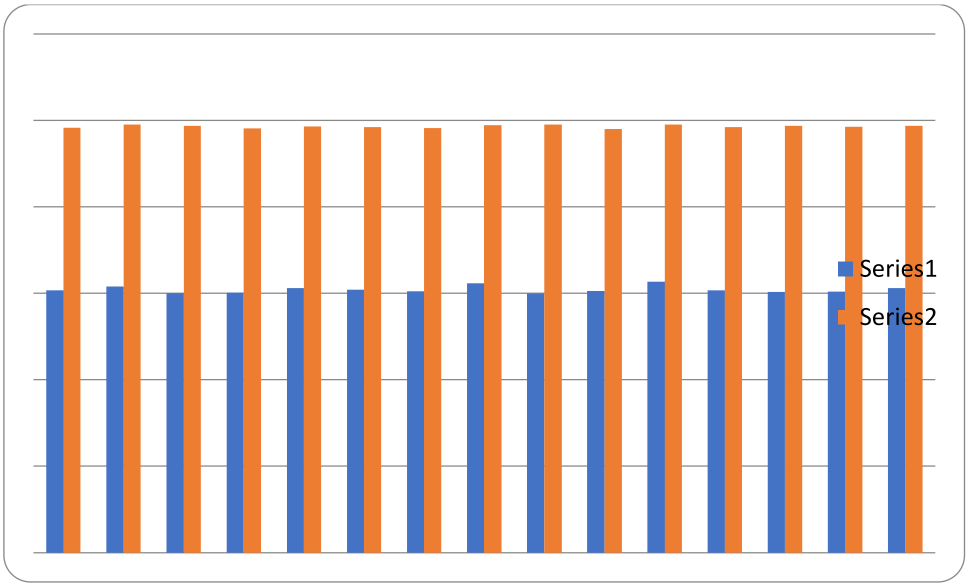

Figure 5a: Paging Success Rate for the first 15 BTS.

ENU009 recorded the lowest paging success rate during the period of experimentation and investigation showed that there was a transceiver failure at the BTS for 3 days during the period of experimentation.

ENU011 recorded the best paging success rate for the first 15 BTS during the period of experimentation.

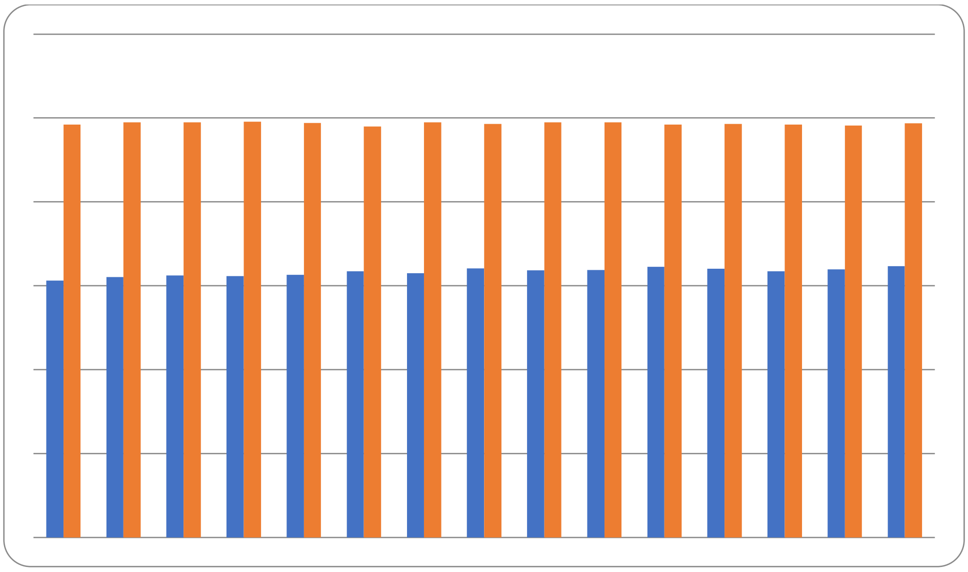

Figure 5b: Paging Success Rate for the second set of 15 BTS.

ENU016 has the lowest paging success (low income) rate and ENU030 has the highest success rate (generate more income) during the period of review.

Investigation showed that only one generator set is working at ENU016 and that servicing of generator took place twice during that time.

Table 4: Average RSSI generated for the coverage area of 1250metres for 15.

Distance (m)	R_{xav} (dBm)
100	-44
150	-45
200	-47
250	-49
300	-51
350	-53
400	-55
450	-57
500	-60
550	-62
600	-63
650	-65
700	-67
750	-69
800	-71
850	-73
900	-75
950	-77
1000	-79
1050	-80
1100	-83
1150	-84
1200	-85
1250	-87

Received Power is in dBm unit (decibel relative to milliwatt), the Received Power P_r is expressed as:

P_r (dBm) = 10 Log $[\frac{P_r(d_o)}{1mW}]$

Where $P_r(d_o)$ or R_{xav} is in unit of Watts, converted to decibel (dB) and d_o is the close-in reference distance.

P_r can hence be evaluated from the RSS measured data. For any distance, (d_i) and so:

P_r(dBm) = 10 Log $P_r(d_o)$

Where d_o is the close-in distance of 100 metres.

Recall that the gradual reduction of the signal strength (Power) as the Transmitter and Receiver (T-R) distance increases is called **Path Loss**.

Path Loss = L_P (d_i) = 10 Log $[\frac{P_t}{P_r}]$(dB)

From Table 4 at d_o of 100m, Power (R_{xav}) = -44dBm

That is, -44 = 10 Log P_r or Log P_r = -4.4

Hence $P_r = 10^{-4.4}$ = 3.981* 10^{-5}dB and from System Design/specification P_t 30W =14.77dB

Working with decibel (dB) unit, the measured Path Loss value becomes:

$L_P\ (d_i) = 10\ \text{Log}\ [\frac{P_t}{P_r}](\text{dB}) = 10\ \text{Log}\ \frac{14.77}{3.981*\ 10^{-5}} = 55.69\text{dB}$

Subsequent values of Path Losses for specified distances, 0.1km ≤ d_i ≤ 1.25km are evaluated, using the same procedure and presented in Table 5 below.

Table 5: Average Measured Path Loss for Enugu Urban Area.

Distance (km)	Median R_{xav} (dBm)	Measured Path Loss Lp (di) (dBm)
0.10	-44	56
0.15	-45	57
0.20	-47	59
0.25	-49	61
0.30	-51	63
0.35	-53	65
0.40	-55	67
0,45	-57	69
0.50	-60	72
0.55	-62	74
0.60	-63	75
0.65	-65	77
0.70	-67	79
0.75	-69	81
0.80	-71	83
0.85	-73	85
0.90	-75	87
0.95	-77	89
1.00	-79	91
1.05	-80	92
1.10	-83	95
1.15	-84	96
1.20	-85	97
1.25	-87	99

From measurement, at close-in distance, d_o of 100m or 0.1km:

$$n = \frac{\sum_{i=1}^{k}[\text{Lp (di)} - \text{Lp (do)}]}{\sum_{i=1}^{k} 10\ \text{Log}(\frac{d_i}{d_o})} = 56\ \text{dB}$$

Estimates or Predicted values of Path Loss at specified distances are calculated as follows:

At d_i = 0.1km = d_o

Equation 2.12: Lp (di) = Lp (do) + 10n Log $(\frac{d_i}{d_o})$

$L_P\ (d_i) = 56 + 10n\ \text{Log}\ (\frac{d_i}{d_o}) = 56 + 10\ \text{Log}\ \frac{0.1}{0.1} = 56$

At $d_o = 0.1$km and $d_i = 0.15$km

$L_P\ (d_i) = 56 + 10n\ \text{Log}\ \frac{0.15}{0.1} = 56 + 1.8n$

Subsequent evaluations were carried out in the same manner.

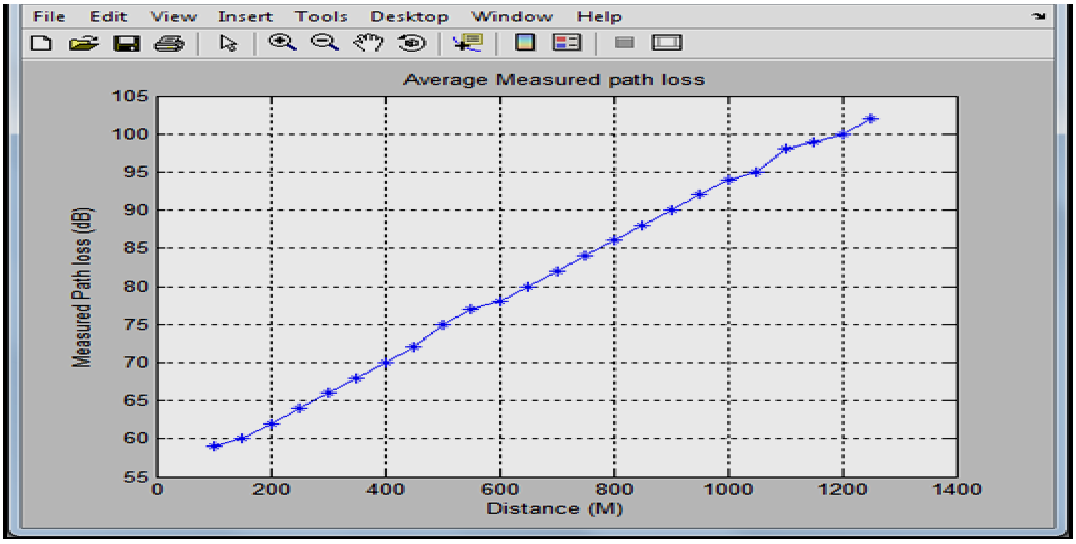

Figure 6: Simulation of Average Measured Path Loss for Enugu Urban.

Table 6: Evaluation of Mean Square Error (MSE) – Generated by Researcher.

Distance (km)	Measured Path Loss [Lp (do)]	Predicted Path Loss [Lp (di)]	Lp(do) – Lp(di) (Error Term)	$[Lp(do) – Lp(di)]^2$ MSE
0.10	56	0	0	0
0.15	57	56+1.8n	1-1.8n	$3.6n^2$-3.6n+1
0.20	59	56+3.01n	3-3.01n	$9.06n^2$-18.06n+9
0.25	61	56 + 3.98n	5-3.98n	$15.84n^2$-39.80n+25
0.30	63	56+4.77n	7-4.77n	22.75n2-66.78n+49
0.35	65	56+5.44n	9-5.44n	$29.59n^2$-87.92n+81
0.40	67	56+6.02n	11-6.02n	$36.24n^2$-131.44n+121
0.45	69	56+6.53n	13-6.53n	$42.64n^2$-219.70n+169
0.50	72	56+6.99n	16-6.99n	$48.86n^2$-223.68n+256
0.55	74	56+7.40n	18-7.40n	$54.76n^2$-266.40n+324
0.60	75	56+7.78n	19-7.78n	$60.52n^2$-295.64n+361
0.65	77	56+8.13n	21-8.13n	$66.10n^2$-341.46n+441
0.70	79	56+8.45n	23-8.45n	$71.40n^2$-388.70n+529
0.75	81	56+8.75n	25-8.75n	$76.56n^2$-437.50n+625
0.80	83	56+9.03n	27-9.03n	$81.54n^2$-487.62n+729
0.85	85	56+9.29n	29-9.29n	$86.30n^2$-538.82n+841

0.90	87	56+9.54n	31-9.54n	$91.01n^2$-591.48n+961
0.95	89	56+9.78n	33-9.78n	$95.65n^2$-645.48n+1089
1.00	91	56+10.00n	35-10.00n	$100.00n^2$-700.00n+1225
1.05	92	56+10.21n	36-10.21n	$104.24n^2$-735.12n+1296
1.10	95	56+10.41n	39-10.41n	$108.37n^2$-811.98n+1521
1.15	96	56+10.61	40-10.61n	$112.57n^2$-848.80n+1600
1.20	97	56+10.79n	41-10.79n	$116.42n^2$-884.78n+1681
1.25	99	56+10.97n	43-10.97n	$120.34n^2$-943.42+1849

$$\sum_{i=1}^{24}[(1554.36n^2 - 9708.18n + 15783)]^2$$

$$e(n) = \sum_{i=1}^{k}[Lp\ (di) - Lp\ (do)]^2$$

The value of n, which minimizes the Mean Square Error (MSE) is obtained by equating the derivative of Equation 2.16 to zero and solving for n.

$$\frac{\partial e(n)}{\partial n} = 0$$

$$\sum_{i=1}^{k}[Pm - Pr]^2 = 1554.36n^2 – 9708.18n + 15783$$

2[1554.36n] -9708.18 = 0

Hence 3108.72n – 9708.18 = 0

Therefore $n = \frac{9708.18}{3108.72} = 3.12$

Then the Path Loss of Enugu Urban Environment is Lp (d) = 56 + 31.12 log (D), while the Path Loss Exponent (n) for Enugu Urban Environment (Metropolis) is 3.12

Path Loss Exponent indicates the rate at which Path Loss increases with distance. Path Loss can therefore, be Estimated or Predicted, using data obtained from field measurements as above.

5. Conclusion

In this paper, the parameters necessary for evaluation of the QoS offered by Service Providers were investigated and the environment of network deployment verified to ascertain if in conformity to standard. The results of the Investigation of performance of Quality of Service offered by the network provider, Mobile Telecommunications Nigeria (MTN) in Enugu metropolis showed high performance as the network was deployed in the appropriate environment – Shadowed Urban Environment with Path Loss Exponent of 3.12 and shows that Call Setup Success Rate (CSSR) is 96.3% far above NCC standard of 80%. The Paging Success Rate is 98.6% as against NCC standard of 80%. Call Drop Probability shows that the Work done gave a better result of 0.1% against NCC standard of 0.3%.

References

[1] Nigeria Communication Commission – NCC; Retrieved June 12, 2021 from http://www,ncc.gov.ng/index.php]

[2] Wang, C.; Li, B.; Sohraby, K.; Daneshmand, M.; Hu, Y. (2007) Upstream Congestion Control in Wireless Sensor Networks through Cross-Layer Optimization. *IEEE J. Sel. Area. Commun.* **2007**, *25*, 786-79

[3] Irland, E.A, (1988), "Assuring Quality and Reliabilityof Complex Electronic Systems: Hardware and Software", Proceedings of the IEEE, Vol. 76, No. 1,, pp5-18

[4] *Kuboye,2010, Optimization model for minimizing GSM congestion in Nigeria. Journal media and communication studies vol2(5) pp122-126.*

[5] Jorgan A.B, et al,(1996) " propagation Measurements and models for wireless communication channels, IEEE communication magazine, Vol.33 no 1, pp 42

[6] Guptel V, et al, (2008) " Efficient path loss prediction in mobile wireless communication Networks, proceeding of world Academy of science, Engineering and Technology, Vol. 36

[7] Waltisch, J. et al,(1988) "A theoretical model of uhf propagation in urban environments", IEEE Transactions on Antenna and propagation pp 1788 – 1796. [3] Jorgan A.B, et al,(1996) " propagation Measurements and models for wireless communication channels, IEEE communication magazine, Vol.33 no 1, pp 42

[8] Misra, A., Das, S., Dutta, A., McAuley., Das, S, K, "IDMP-based fast handoffs and paging in IP-Based 4G mobile networks", IEEE Communications Magazine, Vol. 4, No. 3, March 2002; pp136-145

[9] Sharma S (2007),"Wireless and Cellular Communications", S. K. Katan and Sons Publishers, pp12-98, 265; 2007