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Assessment of Quality of Service of G.S.M. Networks in Ilorin Metropolis, Nigeria

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Abstract: *Following the rollout of GSM services across Nigeria, the socio-economic landscape of the country has been positively altered. Its explosive growth has brought huge revenues to the operators, as well as the government and at the same time benefited the citizens in many ways. However, the principal developmental factors that has continued to mar these benefits is the aggressive complaints from GSM subscribers regarding the horrible Quality of Service (QoS) rendered by the GSM operators across the country. As the number of subscribers of GSM in Nigeria increased, congestion rates also increased and there has been a huge demand for a decent QoS in the country. In this study, three key performance indicators (KPI) parameters, call setup success rate (CSSR), received signal level (RSL) and call drop rate (CDR) were used in assessing the performance of two of the major GSM networks in Ilorin Metropolis of Nigeria, which have been tagged Network "A" and Network "B". A and B monitored are far from providing reliable services to Nigerians. None of the networks in the study met the* $\geqslant$ *98% CSSR required by the N.C.C. regulations, and none met the* $\leqslant$ *2% CDR required by the N.C.C. regulations. The problems GSM operation encountered have been attributed to a number of challenges, with cited faults ranging from the Network providers, to regulatory agencies, and even to the Nigerian Government.*

Keywords: *Global System for Mobile Communication, Quality of Service, Key Performance Indicators, Network Congestion, Received Signal Level.*

1. INTRODUCTION

One of the challenges faced by the cellular network operator globally is the issue of improving the quality of services (QoS) while increasing capacity. Under-utilization of available resources and inadequate provision of needed resources leads to degradation of the quality of service due to network congestion. In the absence of the interference problem and hardware fault, the insufficient number of radio channels in network elements could lead to network congestion [1]. One of the challenges of QoS in telecommunication is congestion [2], congestion in telecommunication engineering means the unavailability of network resources (bandwidth: frequency, time and code slots or power) when the subscribers requested the resources for use to initiate call in GSM network. Network congestion is a major challenge in networks limited in resources, particularly those with limited bandwidth to provide high-volume data transmission. It deteriorates QoS of the network with effects such as packet loss, time delay, low throughput, and decrease the quality of wireless communication [3-4].

The first telecommunication facilities in Nigeria were established in 1886 by the British colonial administration [5], only about 18724 phone lines were available for use for a population of roughly 40 million in 1960 when Nigeria got independence. The telephone system during this period was expensive, congested and unreliable. Also, service was not satisfactory.

In 2001, the story of Nigeria telecommunication industry changed dramatically with the birth of GSM under the rule of civilian president Olusegun Obasanjo. By May 2005, Nigeria with an estimated population of 128,771,988 had more than 9 million GSM subscribers, making the country one of the fastest growing GSM markets in the world [6]. Presently four

active GSM operators exist in Nigeria: MTN, AIRTEL, 9MOBILE and GLOBACOM. The competition among the operators is getting fiercer by the day as operators have to compete desperately for the same potential subscribers.

The GSM has contributed positively in boosting economic activities in Nigeria. It has also significantly improved the quality of living of Nigerians. The affordable advanced Internet that it provides, has allowed Nigerian citizens to work online in a variety of jobs, opens up lot of economy opportunities and provides for their families. Owing to the mobile Internet that the GSM provides, Nigerians also enjoy services like terrestrial television on mobile devices, live feeds for security management, electronic payment, Internet banking and mobile banking [7-8].

Received signal level on a mobile device is an important parameter to measure the QoS of a network service provider, as it is expected to meet the specified standard set by the approved regulators. The minimum usable signal strength value is specified between -85 dBm and -105 dBm for it to be sensitive and usable for a mobile device [9].

In this research, three key performance indicators (KPI) parameters, call setup success rate (CSSR), received signal level (RSL) and call drop rate (CDR) were used in evaluating the performances of the two major GSM networks in Ilorin Metropolis of Nigeria, which have been tagged Network "A" and Network "B". Also, twenty subscribers were randomly selected for data collections, their opinions on QoS experienced from their respective network providers were also documented for analysis.

2. RELATED WORKS

A research work carried out on the factors that affect GSM congestion in Nigeria [10], suggested several ways through which this can be significantly minimized. This publication was very clear and detailed in its recommendations for better QoS in Nigeria [11], researched on the method to address the problem of congestion at the access layer of the GSM network through the use of traffic class prioritization. This research was very explicit in its explanation of traffic class prioritization and how it can solve GSM congestion in the country.

In [12], a careful study of congestion in GSM networks was made. The points where congestion occurred in the GSM networks were identified through observation of GSM base transceiver stations (BTSs), and through the administering of questionnaires. This research was very detailed in the findings obtained from the various KPI parameters that were studied, and it gave a clear picture on the extent of the problem. The seminar work "Congestion Control Mechanisms in GSM Telecommunication Networks (The case of MTN Nigeria)" by [13], adequately determined the causes of congestion and evaluated congestion control mechanisms adopted by service providers in Nigeria using MTN Nigeria as a case study. This work was very detailed in its research on the causes of congestion in GSM networks. Recommendations on how the problems can be solved were discussed.

Another study showed that the accessibility and retainability of the mobile networks at Ilorin is unreliable and below the threshold sets by the regulator based on the statistics obtained [14].

Furthermore in [15], the authors discussed the performances of the mobile networks at Ilorin based on the signal strength of the networks. Data used was obtained at every interval of 100 meters from the BTSs which were arranged in an array. The results showed that users experienced call drops, signal fluctuations and user experiences cannot be classified as satisfactory.

In the work of [16], a combined scheme was designed to incorporate a known Adaptive Call Admission Control (CAC) scheme and a load balancing strategy to further minimize the New Call Blocking Probability (NCBP) and the Handoff Call Dropping Probability (HCDP). The input to the system (i.e. calls) is made to pass through the CAC part of the combined scheme where calls are either rejected or accepted based on bandwidth availability which depends on the condition of the network system. The work was very comprehensive in its research on CAC, and a load balancing strategy that can solve congestion problems.

3. MATERIALS AND METHODS

3.1 Materials

The three KPI parameters, CSSR, RSL and CDR were used in obtaining data for two of the major GSM networks in Nigeria which are labelled as Network "A" and Network "B" respectively. Data collected during the course of the study were obtained through a mobile application called *RantCell Pro* and were obtained from networks "A" and "B" of twenty (20) subscribers of these two networks, in different parts of the Ilorin metropolis. The data were collected for a total period of two (2) weeks, within the month of May 2018. A total of about two thousand calls were monitored during the cause of this research, from which the QoS data were obtained. Another developed mobile application called *SignalDetect* on Android platform was used to obtain data of signal strength values for network "A" and "B" in a 10 seconds interval to predict the behaviour of the networks.

3.2 Methods

The analysis in this research is based on the comparison of the results of the analysis of the data obtained from *RantCell Pro* and *SignalDetect*, with the network performance specified by the Nigerian Communications Commission (NCC) regulations. Graphs and charts were used to clearly explain the analyses of all the KPI parameters and to show a clear picture of what the QoS are, from the network operators. Possible suggestions were given on how to increase the QoS, as well as, to reduce the congestion rates amongst the G.S.M. networks in Nigeria.

3.3 Area of Study

The investigation in this project focused on the GSM QoS within Ilorin metropolis, Kwara State as shown in Figure 2, where calls were monitored for two (2) weeks. Ilorin is one of the major cities in Nigeria, situated in the west-central part of Kwara state. It is the capital of the state, which is classified in the North-Central geopolitical zone of Nigeria. It has a total area of 765 km^2 (295 sq mi) and located within coordinates: 8º30'N 4º33'E [17].

Ilorin is subdivided into three (3) Local Government Areas (LGAs), namely: Ilorin East, Ilorin South and Ilorin West. As of 2006 census, its three LGAs had a total population of 777,667, making it the 6th most populated city in Nigeria. As of 2011, the population is estimated at 908,490. The average yearly temperature range is between 19.0 ºC and 35.9 ºC; with about 6.5 hours of daily mean sunshine [17].

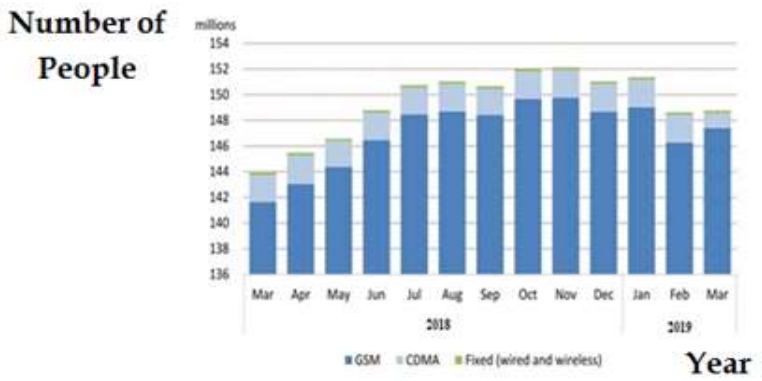

Figure 1: Total number of active mobile subscribers in Nigeria from 2018 to 2019

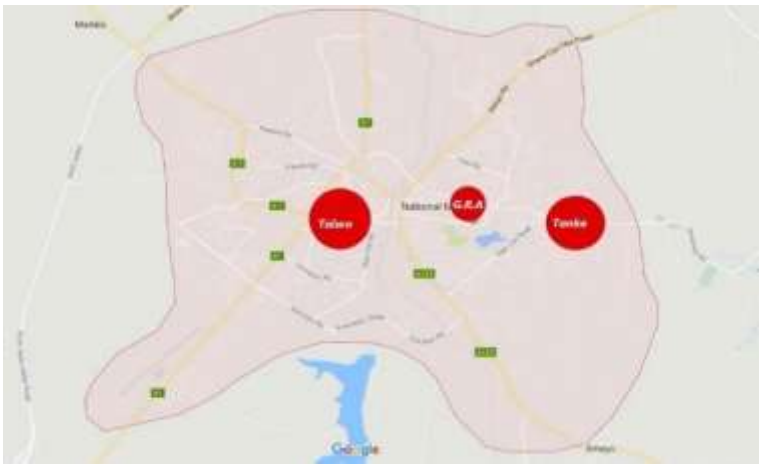

Figure 2: Map of Ilorin, indicating the approximate areas monitored

3.4 Network Performances Required by NCC

Table 1 states the minimum standard for CSSR and CDR KPI parameters required from telecommunication operators by the 2011 NCC regulations, to ensure acceptable QoS within the telecommunications sector [18].

Table 1: Network performance standards required by N.C.C. [18]

S/N	Title	Parameter	% of Attempted calls
1	Network Performance KPI	CSSR	≥ 98
2	Network Performance KPI	CDR	≤ 2
3	Network Node Performance	TCH congestion	≤ 2
4	Network Node Performance	SDCCH congestion	≤ 0.2

- **Network Performance KPI:** Measured at Mobile Station (MS) level. i.e, mobile devices.
- **Network Node Performance:** Measured at Base Station Controller (BSC) level.
- **TCH:** Traffic Channel
- **SDCCHC:** Stand-alone Dedicated Control Channel Congestion.

4. RESULTS AND DISCUSSION

Figure 3 shows that the average KPI results from networks A and B are very similar, achieving an overall average of 99.2% similarity; both networks' parameters follow similar trends and are both well below NCC specified standards, with a 20% deviation from the standard. The highest CSSR rate achieved by network A was 86.8% on 28th May 2019, while the highest achieved by network B is 86.9% on 15th May 2019. The lowest CSSR rate achieved by network A is 65.1%, while the lowest rate by network B is 56.5%, both on 21st May 2019. It was also deduced from the trend that KPI parameters are worst during weekends, due to high number of call attempts on GSM phones throughout the days of weekends. The CSSR data gotten from this research can be used to deduce the CDR, as represented in Figures 4 and 5.

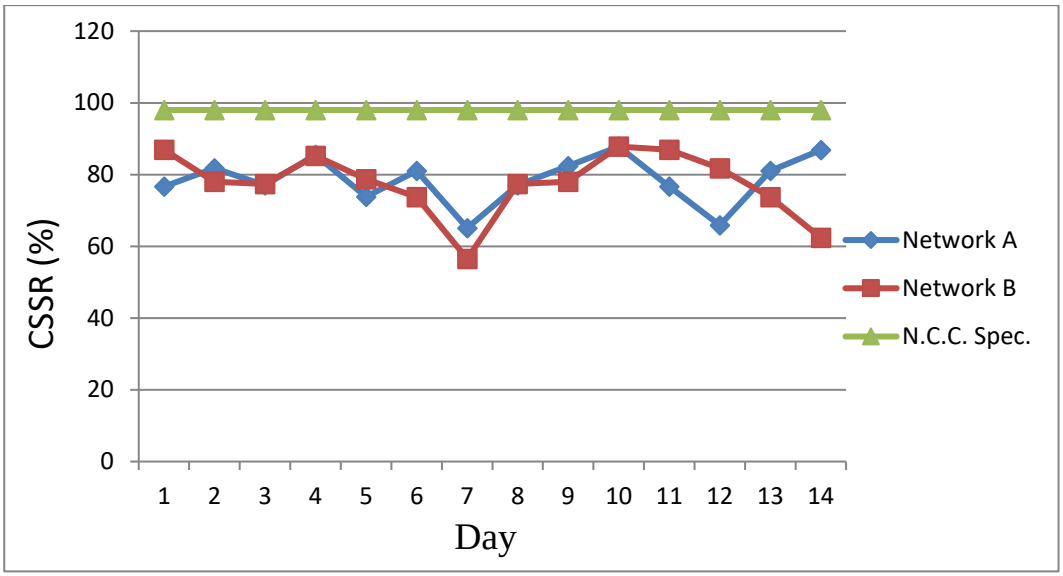

Figure 3: Daily Call Setup Success Rate (CSSR) per network

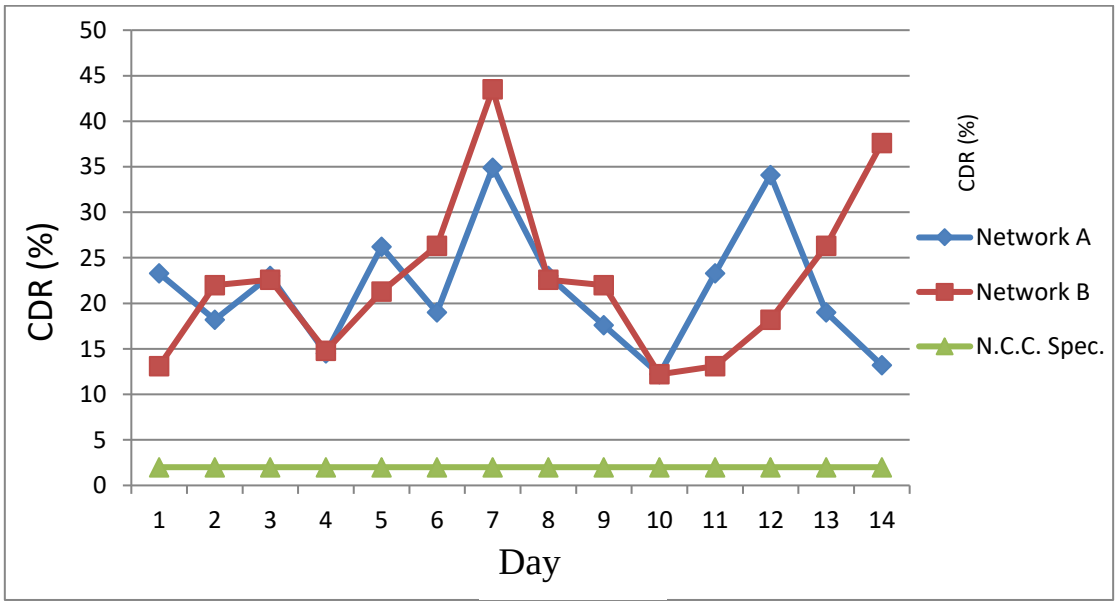

Figure 4: Daily Call Drop Rate (CDR) per network

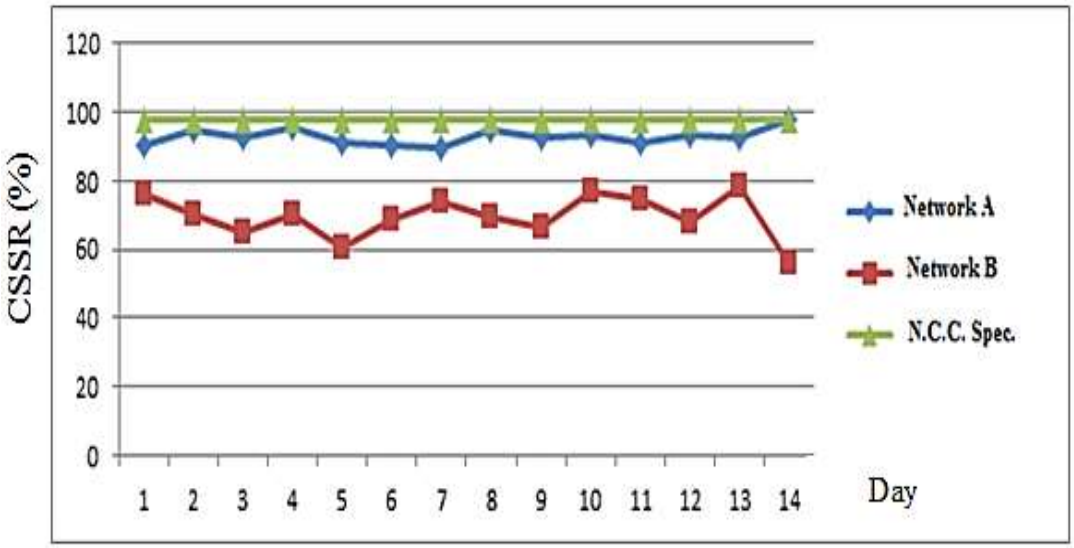

Figure 5: Average daily Call Setup Success Rate (CSSR) per call period

Furthermore, the commercial nature of neighbourhoods also seems to play a significant role on the CSSR data gotten from such neighbourhoods. Solely residential neighbourhoods like government reserved area (GRA) for instance, experience better QoS, compared to more commercialized districts like Taiwo and Tanke. It can also be explained that the CSSR data obtained indicates that, areas with high density of students are at high risk of poor CSSR. This is because, compared to the middle-aged and older people, young students, tend to be more inclined towards accessing a wider range of multimedia services from network providers, thereby straining the availability of good QoS within these areas. As a result of the demographic skew, CSSR data is best in GRA, where the student population is relatively lower, while CSSR is worst in Tanke, where there's a high density of university students.

The developed application was used to take samples of signal strength values for the two networks over a 10 seconds interval after taking into consideration the distance of BTS for the respective networks to the mobile devices used in taking the measurements. Two mobile smartphones of the same specifications as shown in Table 2 were used as they both have the same hardware structure. Hence, the performance of the receiver sensitivities on the smart phones due to thermal noise and degradation are similar which means they are expected to deliver almost the same signal strength values for a network.

Table 2: Smartphone specification used to obtain data of received signal level.

S/N	Smartphone	Specification
1	Samsung A-5	**OS:** Android 9.0 (Pie) **Chipset:** Exynos 9610 (10nm) **CPU:** Octa-core (4x2.3 GHz Cortex-A73 & 4x1.7 GHz Cortex-A53) **GPU:**Mali-G72 MP3 **Memory:** 64GB, 4GB RAM

As shown in Figure 6, the plot of RSL for network A and B, the values obtained as shown on the plot indicates the RSL for the two networks meet the specified threshold set by the NCC which is between -85 dBm and -105 dBm to engage in a voice call. Furthermore, network A fluctuates more rapidly over time when compared to network B which remains stable. This is as a result of the variation in the numbers of users connected to the BTS for the two networks, number of mobile devices using data services on the networks, the pathway of the signals from the BTS to the devices and a chance of the mobile device to be at an equal distance from two BTS which led to the decision of performing hand-off process.

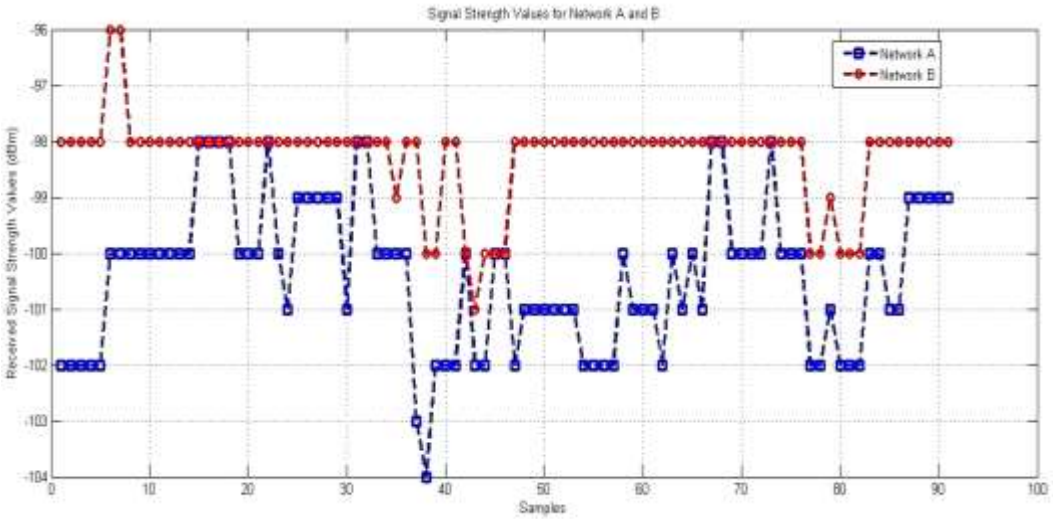

Figure 6: Signal strength plot for network A and B respectively

4.2 Surveys of Customers' Satisfaction

During the cause of this research, the twenty (20) consumers that were selected for data collection were also surveyed, to give their personal opinions on the QoS that they experienced from their network providers. They were advised to look at service delivery, as a whole; which includes: call congestion, Internet speed, bundle pricing, call packages and customer care support, amongst others. Out of the 20-customer's surveyed; only three (3) customers claimed to be enjoying excellent service delivery from their network providers, while eight (8) customers claim to be enjoying only average QoS. The other nine (9) customers claimed that QoS is extremely bad. With only 15% customer satisfaction as shown in Figure 8 shows that indeed, there's a need for improvement of the QoS delivery amongst network providers within Nigeria.

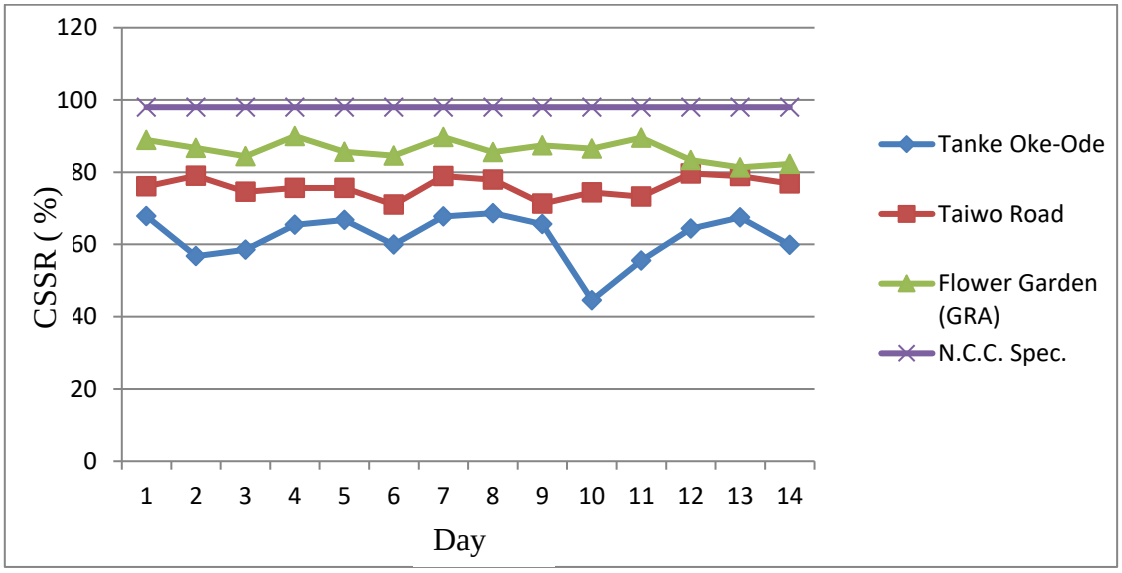

Figure 7: Average daily Call Setup Success Rate (CSSR) per neighborhood

Figure 8: Customers' personal opinions on the Quality of Service experienced from their network providers

5. CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

At the end of this study, it can be concluded that network providers in Nigeria need to improve on the QoS offered to their customers. At the time of the study, it was observed that none of the two (2) networks monitored offer KPI parameters (CSSR and CDR) that are acceptable, based on the NCC regulations except for the RSL. From the results of this study, it is evident that the two (2) GSM operators, A and B monitored are far from providing reliable services to Nigerians. None of the networks in the study met the ≥ 98% CSSR required by the N.C.C. regulations, and none met the ≤ 2% CDR required by the N.C.C. regulations.

This is a clear indication that the service retain-ability of the GSM networks operating within the country is very low, and that the congestion rates on the networks are still quite high. One of the very apparent reasons for this is that GSM operators generally have huge number of subscribers which continue to rise, but lack sufficient equipment to support their daily increasing customer base. In addition, the results of the analysis showed that the network coverage of these networks is not sufficient in certain circumstances. Although RSL performances for both network A and B are not stable, network B has a better performance with stability. The overall assessment of call parameters and RSL, coupled with the satisfaction survey carried out on customers, is an indication of poor QoS delivery, and that Nigerians are yet to optimally enjoy the impact of GSM as an efficient means of telecommunication.

5.2 Recommendations

In order to correct this unacceptable situation in the country, suggestions on how to improve the QoS of GSM Networks operating within the country need to be made. It is on this basis that the following recommendations are made in order to ameliorate the observed defects. Recommendations that have been carefully drafted in this study are split into three sections:

1. Recommendations for GSM Network Operators.
2. Recommendations for Nigerian Federal and State Governments.
3. Recommendations for Nigerian Communications Commission (N.C.C.).

5.2.1 Recommendations for G.S.M. Network Operators

i. *Provision of Adequate Base Stations:* To guarantee efficient network quality, there must be adequate number of Base Stations to be able to drive the network. Also, the size/rating and quality of these Base Stations must be in tandem with the subscribers' base. When subscribers' base outgrows the capacity of the available base stations, then congestion is inevitable. In Nigerian situation, operators have been playing down on expansion of all cell sites, which of course is the strength of call quality. The rate of service rollout in the country has never been the same with the rate of base stations' rollout, and this often leads to Network Congestion and inability to successfully initiate communication on phones. Upgrading and optimizing existing base stations across the country, as well as, installing new ones of adequate ratings and quality, will definitely help significantly in improving the QoS problems in Nigeria.

ii. *Deployment of Repeaters:* In certain situations in base station installations, there are two separate base stations and in between them is an area that is not within the network coverage. This area is referred to as a *dead spot*. Instead of providing a base station site to cover such a small area, network providers can mount a repeater in order

to maximize the capacity of both sites; the use of repeater is actually cheaper in terms of cost and maintainability, than to install separate BTS equipment.

iii. *Improving on Channels' Sufficiency:* Since there are not enough infrastructural equipment (base stations), automatically there will be lack of adequate channels to support network functionality. Recall that channels are normally used to determine total number of subscribers that can be allowed to use a base station. Therefore, making channels more sufficient will definitely have a direct impact on improving network congestion.

iv. *Deployment of Extended Cell Site Range:* A GSM cell is typically limited to a range of 35 km; however, a cell site can beat this limit with a slight modification. In fact, an optimized cell can cover up to 120 km. This method of extending the range of cell site helps to reduce the problem of dead spot.

v. *Upgrading the Capacity of Some Cell Sites:* Another way to efficiently improve QoS would be to upgrade the site capacity of cells that are situated in neighbourhoods that are badly affected with the problem of congestion. It was also observed during the cause of this research that few base station sites of the network providers are badly impaired; example of such site was observed in a street called Taiwo Road. A congestion control mechanism in such circumstances can be temporarily applied in order to reduce congestion of calls. However, a permanent solution would be to fix the damaged sites, and also to upgrade aged facilities in other areas.

vi. *Developing Appropriate Channel-loading Models:* This is a congestion control mechanism which makes sure the number of channels allocated to subscribers does not result into the operator's deficit. Using this mechanism, appropriate algorithms should be used to manage calls within the network. The recommended algorithm must have a prioritization scheduled to maintain un-interrupted communication during emergency. It should also provide a location for temporary memory to cater for incessant frequent callers within a specified period. This gives them a higher priority over a new entrant call. This algorithm should be implemented at every base station. The advantages of this kind of algorithm according to [12] are: it gives priority to highly essential duties calls that need immediate attention; it gives priority to the most denied calls to grab the channel when they appear within a specified time; it does not allow any call to occupy the channel more than necessary when there are calls waiting to grab the channel; it does not pre-empt the subscriber if there is no call waiting unlike the block-time that will pre-empt even if there is no call waiting; and it allows dynamic allocation of channel when there is equal priority calls.

vii. *Investment in Efficient Network Development and Radio Planning:* This would ensure increased network resilience, improved bandwidth utilization and alleviation of capacity bottleneck. A proper network development and radio planning can be achieved through a combination of several network and transmission models, some of which include: Cell Splitting, Multi-band operations, Micro-cell (in areas prone to sudden surge in populations. e.g; stadiums, religious camps, etc.), and so on.

5.2.2 Recommendations for Nigerian Federal and State Governments

i. *Provision of Adequate Public Infrastructure:* Incessant power failures have been a major hindrance to the operation of all kinds of businesses across the country, and this should be addressed by the government as a matter of national emergency. An uninterrupted power supply will stop the over-dependence of network providers on generators for their power supply. If this is achieved, cost of operation would drastically go down, making the operators to be able to appropriately direct their spending towards improving the QoS of their networks.

ii. *Improve the Ease of Doing Business:* The Government also needs to make the country much more conducive for doing business. This can be in form of tax rebates, favourable policies, relaxed service registration processes, and so on. Improving the business environment within the country can significantly compensate for the poor infrastructures, making the operators to have available income to spend towards improving QoS.

iii. *Provision of Employment for the Citizens:* If the Government can create more jobs for the citizens, poverty level would be reduced and a lot of boys and girls will be taken off the streets. Hence, we would have a secured environment, and network providers would have to worry less on the cost of fixing vandalized Base stations, and focus on improving QoS that they offer to their customers.

iv. *Provision of Adequate Security:* The Government should adequately equip and train security agencies in the country, in order to ensure public safety and security. This will prevent vandalism of network facilities situated in public spaces. Again, this will in-turn ensure network providers worry less on the cost of fixing vandalized Base stations, and instead make them to focus on improving QoS that they offer to their customers.

v. *Ensuring Proper Town Planning for Developing Areas within the City:* During the cause of the study, it was observed that neighbourhoods that are well planned experience better QoS, than areas that don't follow a specific master plan. This makes absolute sense; as proper arrangement of buildings does ensure proper propagation of network signals. Therefore, ensuring there's a master plan for new and developing neighbourhoods in the city will make sure that network providers will have to spend less effort and funds on ensuring provision of great service quality.

5.2.3 Recommendations for the Nigerian Communications Commission

i. *Active Enforcement of its Regulations:* NCC has formulated appropriate policies, in regards to QoS standards. However, like most other things in the country, it seems enforcement of such policies is a major issue. It would go a long way if NCC sanctions these networks for failures to meet up with the requirements set by NCC regulations. Sanctions can be in form of fines, license seizures, issuing ultimatums, liquidation, etc. This line of actions will make the network providers to sit-up and give their best in the services that they render to their customers.

ii. *Proper Education of the Consumers:* Another issue that makes it easy for network providers to get away with their poor QoS is because consumers are quite docile in the manner with which they react to this unacceptable service delivery. NCC must intensify it efforts in educating GSM customers on ways to deal with poor service quality. Mobile numbers and e-mails dedicated to the issuance of complaints should be readily available for the consumers. Other government sister agencies like the Consumer Protection Council (CPC) must partner NCC in protecting GSM customers from poor service delivery by network providers.

REFERENCES

[1] Božidar, V. (2006). Modeling and Characterization of Traffic in a Public Safety Wireless Network, Master of Applied Science Thesis, Simon Fraser University, Canada.

[2] Chughtai, O., Badruddin, N., Rehan, M., & Khan, A. (2017). Congestion Detection and Alleviation in Multihop Wireless Sensor Networks. *Wireless Communications and Mobile Computing*, 2017, 1-13. doi: 10.1155/2017/9243019

[3] Aimtongkham, P., Nguyen, T., & So-In, C. (2018*).* Congestion Control and Prediction Schemes Using Fuzzy Logic System with Adaptive Membership Function in Wireless Sensor Networks. *Wireless Communications and Mobile Computing, 2018*, 1-19. doi: 10.1155/2018/6421717

[4] Hac, A. (1997). Reducing congestion in wireless network. *Proceedings of ICC'97 - International Conference on Communications.* doi: 10.1109/icc.1997.595027

[5] Akinsola, O. S., Herselman, M.E and Jacobs, S. J. (2005). ICT provision to disadvantaged urban communities: *A* study in South Africa and Nigeria, *International Journal of Education and Development using Information and Communication Technology*, 1(3), 19-41.

[6] Ajala, I. (2005). GIS and GSM network quality monitoring: A Nigeria Case study. Directions Magazine. [Online]. Available: https://www.directionsmag.com/article/3081.

[7] Adeniji, K., Ikpeze, O., Ejidokun, T., & Alli, K. (2017*).* Analysis of Propagation Models for Base Station Antenna: A Case Study of Ado-Ekiti, Nigeria. *ABUAD Journal of Engineering Research and Development*, 1(1), 124-129.

[8] Okafor, P. (2016). 10 Years of GSM Mobile in Nigeria. [Online]. Available: https://www.naijatechguide.com/2011/08/10-years-of-gsm-mobile-in-nigeria.html.

[9] Nsikan, N., Olatunbosun, J., Bob-Manuel, I., & Omotayo, O. (2016). Analysis of Mobile Networks Signal Strength for GSM Networks. *In WCECS* (pp. 90-93). Berkeley, San francisco: IAENG. Available: http://www.iaeng.org/publication/WCECS2016/WCECS2016_pp90-93.pdf

[10] Kuboye, B.M. (2010). Optimization models for minimizing congestion in Global System for Mobile Communications (GSM) in Nigeria. *Journal Media and Communication Studies*. 2(5), 123-126.

[11] Omotoye, K. O., Akogbe, M. A., Olaniyi, O. M., Inyiama, H. C. (2014). Congestion Management on GSM Networks using Traffic Class Prioritization. *International Journal of Engineering Research & Technology.* 3(12): 474-478.

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

[13] Ikenna, G. (2018). Congestion Control Mechanisms in GSM Telecommunication Networks (The Case of MTN Nigeria). [Online]. Available: https://afribary.com/works/congestion-control-mechanisms-in-gsm-telecommunication-networks-the-case-of-mtn-nigeria-7374

[14] Ayanda, R., Musa, A., & Ahmed, M. (2019). A Comparative Study and Performance Evaluation of GSM in Urban Settlements in Nigeria. *ABUAD Journal of Engineering Research and Development*, 2(1), 26.

[15] Mufutauabiodun, S. (2014). On the Practical Assessment of Signal Strength of GSM Network Service Providers. *Global Journal of Science Frontier Research: A Physics and Space Science*, 14(2), 21-27.

[16] Alarape, M.A., Akinwale, A.T., Olusegun, F. (2011). A Combined Scheme for Controlling GSM Network Calls Congestion. *International Journal of Computer Applications.* 14(3), 47-53.

[17] KWARA. (2011). Kwara State Map. [Online]. Available: http://www.citypopulation.de/php/nigeria-admin.php?adm1id=NGA024

[18] NCC. (2013). Nigerian Communications Act No. 19 of 2003: Quality of Service Regulations. [Online]. Available: http://www.ncc.gov.ng/documents/731-legal-regulations-quality-of-service-regulation-2013/file.