A Comparative Study and Performance Evaluation of GSM in Urban Settlements in Nigeria

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Abstract: *With the rapid growth of the wireless industry, GSM networks are expanding at high rates with many network operators bringing forth different services. However, most of the subscribers are not satisfied due to poor nature of services available on these networks in form of blocked and dropped calls. In this paper, Quality of Service (QoS) for circuit switched calls in Ilorin, Kwara State, Nigeria using two different networks (A and B) as case study in three characteristically different locations was investigated. The network performance was assessed in terms of Key Performance Indicators (KPIs) based on statistics generated from drive test measurements and customer feedbacks. The result shows that the network accessibility and retainability of Ilorin is unreliable and below regulatory agency's requirements. We concluded with recommendations on how to improve the QoS in Ilorin to enhance the telecommunication system which could be adapted in Nigeria.*

Keywords: *Quality of Service (QoS), GSM, Key Performance Indicators (KPIs), Optimization, Base Station (BS), Performance Evaluation.*

1. INTRODUCTION

Global System for Mobile Communication (GSM) technology was introduced to solve the problem associated with earlier mobile phone services which included the inability to handle the growing capacity needs in a cost-efficient manner. The GSM uses Time Division Multiple Access (TDMA) which divides a radio channel into 8 time slots i.e. a user per time slot. It also uses digital data which comes with ease of signalling, lower levels of interference, integration of transmission and switching, and increased ability to meet capacity demand.

Over the years after the start of GSM era in Nigeria, focus shifted from providing coverage to providing quality of service (QoS) and the euphoria of owning a phone is now gradually giving way to complaints of dropped calls and blocked calls mostly caused by congestion [1]. Congestion occurs when the call emanating or terminating from a network is more than the capacity of a network at a time i.e. all channels are occupied [2] – [3]. Maintaining of good, secured, uninterruptible network in disaster response, military control, public health, safety and law enforcement command in the face of this congestion is of great importance to network operators in Nigeria [4]. Besides, the best way to acquire more subscribers and keep them satisfied is to make the service flexible and reliable. The need to satisfy the subscribers of wireless services and keeping them is paramount to the operators as they can make or break them thus the need to tackle the problem of congestion is an important consideration for both the operators and the users.

In this research work, a study and analysis of GSM congestion in Ilorin West is carried out and optimization is made based on the log files obtained from benchmarking network operator A and network operator B for 2G network. Questionnaire was also administered to users to compare Quality of Experience (QoE) with QoS. The study is limited to voice only as all GSM subscribers be it enlightened or unenlightened, young or old use voice. The Key Performance Indicators (KPIs) used for the study are Call Setup Success Rate (CSSR), Call Drop Rate (CDR) and Call Completion Success Rate (CCSR).

2. METHODOLOGY

A benchmarking drive test was conducted on three locations in Ilorin which are highly populated area with enlightened people (College of Education, Ilorin), highly populated area with unenlightened people (Oja Oba) and low populated area (Airport Road) between network operators A and B to find which performance profile is better and where necessary improvement action is needed. Some of the procedures adopted were guided by the research works conducted in the past [5] – [7] but with necessary modifications.

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2.1 Drive Test Procedure

To perform the benchmarking drive test, the first thing that was done was to define the test routes of the location to be accessed, know the test methods to be used and have a CellRef file to have complete information of the site. The drive route definition is important to identify the route that best defines the characteristics of interest in those locations and to prevent hinderances (road traffic congestion and unplanned road diversion) to successful data capturing.

Before starting the drive test, the following equipment were required some of which were then connected: Laptop, Dongle, Transmission Evaluation and Monitoring System (TEMS), Inverter 300W, 12V DC (Direct Current) to 220V AC (Alternating Current), 1 GPS (Global Positioning System), 2 MS (Sony Ericsson p900), USB, D-Link Hub, Vehicle, 2 Network operator A SIM and 2 Network operator B SIM.

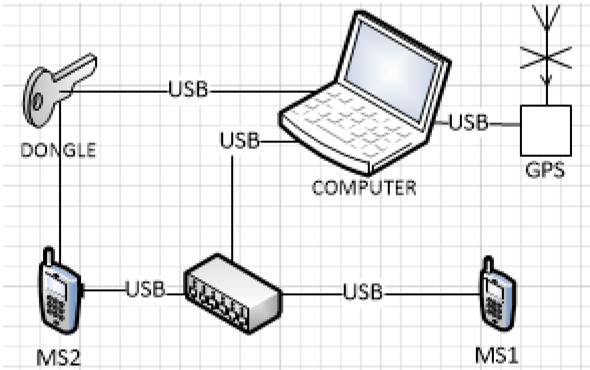

Figure 1: Drive test connection setup

Some of the step by step connections of the equipment are such that the dongle was connected to the laptop with installed TEMS (investigation software); the SIM of the network to be accessed inserted into the TEMS Mobile Stations (MSs); GPS and hub with TEMS MSs were well connected to the laptop. The connection is as shown in Figure 1.

A test script was then loaded to the TEMS which automatically initiated both the short and long calls. The script used during drive testing is as shown in Figure 2. Running through the same points in a route multiple times was strictly avoided as can be seen in Figure 3, Figure 4 and Figure 5, which show the route of our drive test for the three locations in context.

MS1 was used for short call to collect accessibility statistics. According to the script, a short voice call attempt was performed every 2mins including 10s of idle time between two consecutive calls. MS2 was used for long call to collect retainability statistics. A long voice call attempt was performed every 5mins including 10s of idle time between two consecutive calls.

2.2 Drive Test Route

The route along the Airport road lies on a straight path without a need to run through the path multiple times. While running the path as shown in Figure 3, our parameters on context where measured. The colour coding of the path represents different degrees of received signal quality. Similar code notation was used in the measurement of received signal strength. The green represents greatest signal quality and strength, while the red represents the minimum signal strength and yellow lies in-between.

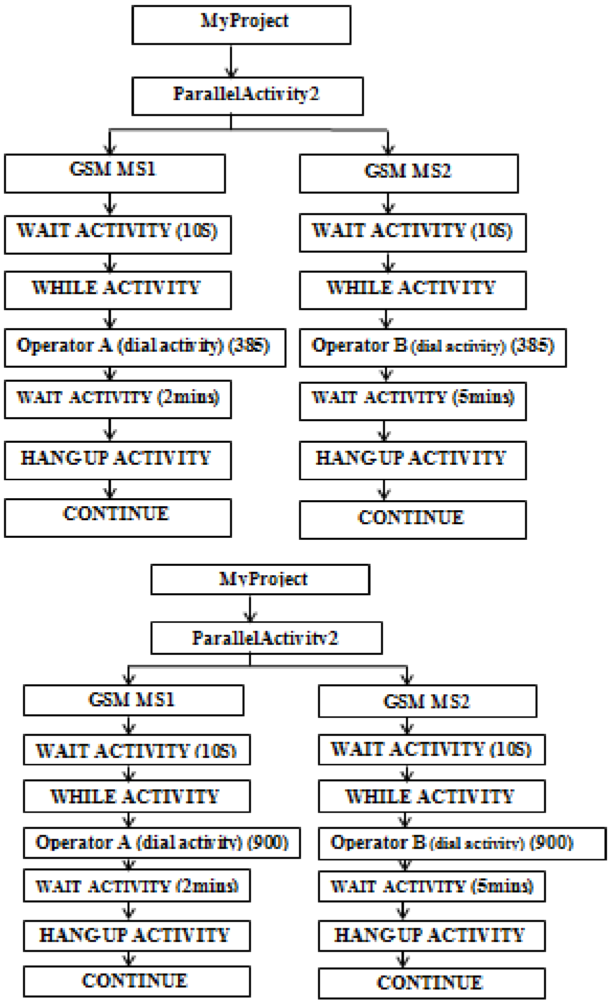

Figure 2: Script used during drive testing

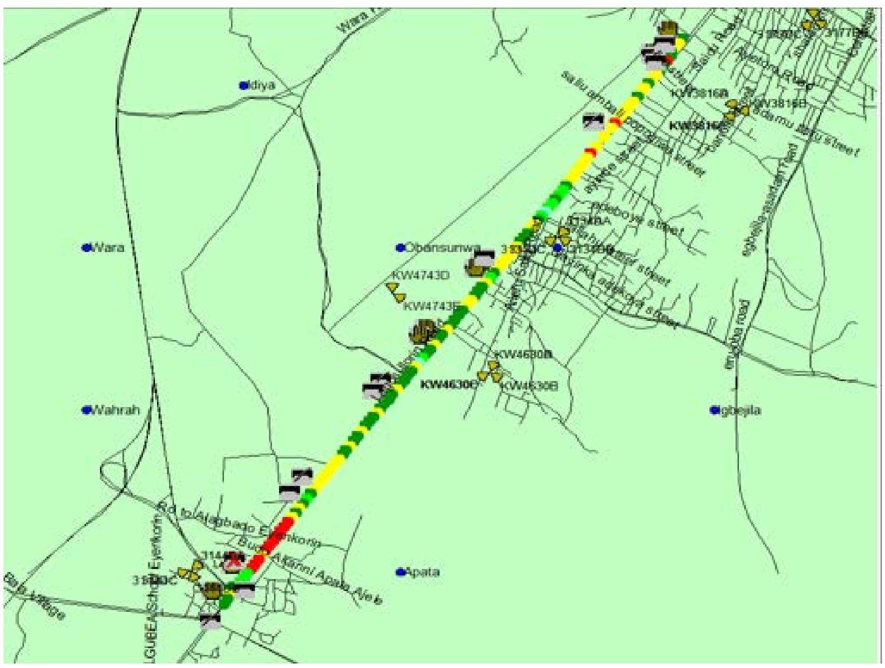

Figure 3: Drive Test Route in Airport Road

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College of Education drive test measurements were taken in a route of a pattern different from that of the Airport road. The same colour code scheme was adopted for received signal strength and received signal quality as can be observed in Figure 4. The route has been surveyed prior to drive test measurement to avoid the effects of unpredicted occurrences on measurements. Points that were unavoidably plied multiple times were not captured multiple times. Capturing was paused in subsequent plying of such route.

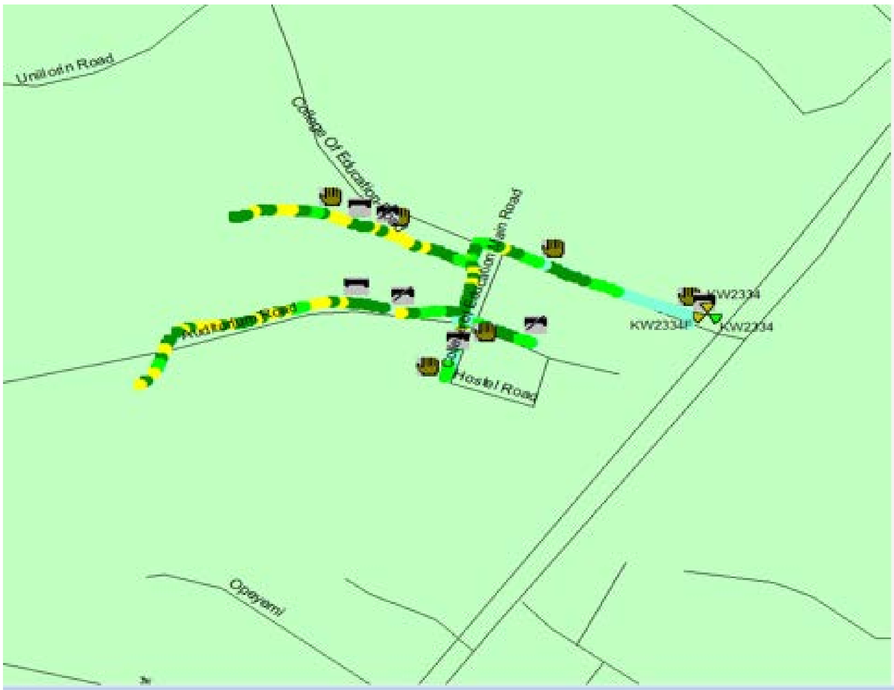

Figure 4: Drive Test Route College of Education

A drive test around Oja Oba was made with its corresponding received signal strength and signal quality observed along the drive route as depicted in Figure 5. The colour code is similar to other locations and it is apparent that no multiple capturing was observed.

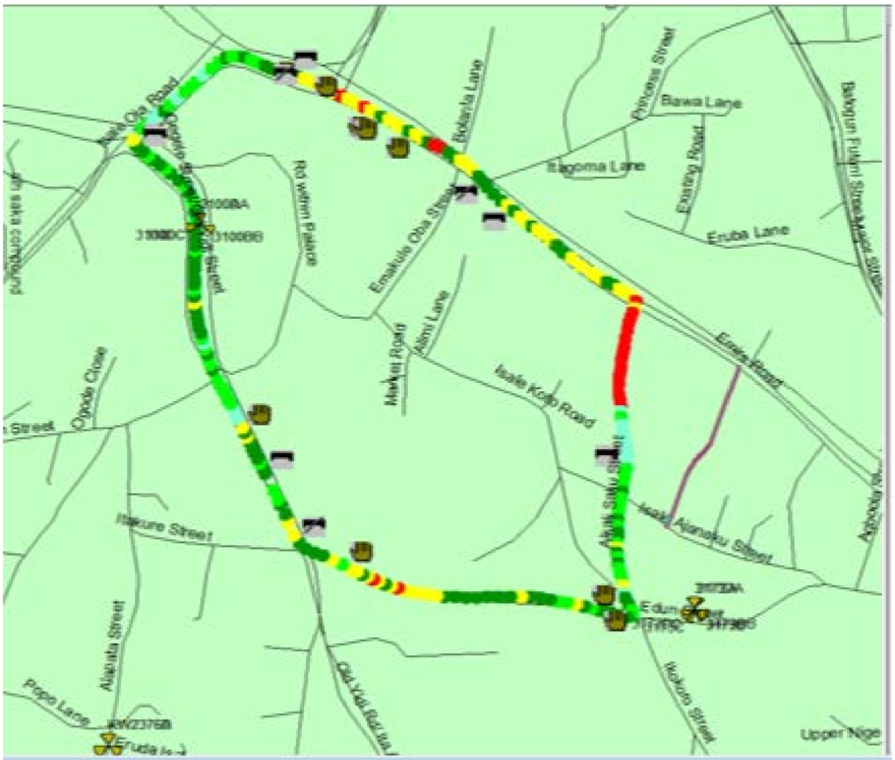

Figure 5: Drive Test Route Oja Oba

During the test run, no site was observed to be experiencing a downtime, however a significant drop in received signal strength and/or signal quality was observed in very few occasions.

2.3 Customer Feedback

A brief questionnaire shown in Figure 6 was administered to the network operators A and B users between the age of 18 to 60 years of the locations under study to have feedback on the performance of the network i.e. ease of setting a call, rate at which calls get completed without any form of interruption with availability of airtime, quality of speech received etc.

Customer Feedback on GSM Technology

This is a study to get your feedback on the services rendered by your network operator (e.g. Mtn, Airtel etc.) regarding voice call with your participation being voluntary and your response being anonymous and confidential.

First, we will like to ask a few questions about you

What is your age range? ________ A) 18 – 25yrs B) 25 – 40yrs C) 40 – 60yrs D) 60yrs above

What is your gender? Male ( ) Female ( )

What is your education qualification? A) PhD/MSC B) B.Sc C) HND D) SSCE E) Others

Now, let's talk about your network operator and your feedback on the services rendered

1. What network operator do you use frequently for voice calls? ________________ (operator A or B)
2. At an average, how many times do you place a call per day? (e.g. 5 times, 10 times etc.) __________
3. At an average, how many times do you receive a call per day? (e.g. 2 times, 8 times etc.) __________
4. At an average, for what duration are you always on call? (e.g. 30seconds, 1 minute, 2 minute etc.) ________
5. Is the call tariff friendly to you? (Yes/No) ________________________________

For the next set of questions to be asked, please rate the statements/questions in percentage (0 to 100) indicating how much you agree with it or your view towards it.

90 – 100%	85 - 89%	70 – 84%	50 – 69%	0 – 49%
Excellent	Very Good	Good	Fair	Worst

6. Rate the ease at which your call is easily established by your network operator? ____________
7. When you have successfully established a call, at what rate does your call suddenly drop before you intentionally terminate it with airtime still available ________________
8. At what rate do you complete a call successfully without having any form of interaction? ________
9. How will you rate the speech quality of your calls? ________________________
10. In a brief description, Why did you choose the particular network operator in (1) for voice call?

____

____

11. At what rate are you satisfied with the quality of service offered to you by your network operator? ______ and will you be willing to pay for more tariff for a better quality of service? (Yes/No) ______

Thanks for your participation

Figure 6: Questionnaire used to obtain customer feedback; Mean Opinion Score (MOS)

3. RESULTS

From the data obtained from site, Table 1 and Table 2 show the call events statistics results of two networks which compare high populated area with enlightened people, high populated area with unenlightened people and low populated area. From Table 1 and Table *2*, the following KPIs which are CSSR, CDR, CCSR can be calculated using their respective formulas.

For the Call Setup Success Rate (CSSR),

$$CSSR\ (\%) = \frac{No\ of\ Successfull\ Call\ Setup}{\text{Total No of Call Attempts}} * 100$$

- Airport Road

From Table 1, for Network Operator A,

$CSSR\ (\%) = \frac{6}{8} * 100 = 75.00\ \%$

For Network Operator B,

$CSSR\ (\%) = \frac{6}{8} * 100$ = 75.00%

- College of Education, Ilorin

From Table 1, for Network Operator A,

$CSSR\ (\%) = \frac{4}{4} * 100$ = 100.00 %

For Network Operator B

$CSSR\ (\%) = \frac{4}{4} * 100$ = 100.00%

- Oja Oba

From Table 1, for Network Operator A,

$CSSR\ (\%) = \frac{4}{4} * 100$ = 100.00 %

For Network Operator B,

$CSSR\ (\%) = \frac{5}{5} * 100$ = 100.00%

Table 1: 2G Short Call Event Statistics Summary

	Airport road (Low populated area)		**College of Education (High populated area with enlightened people)**		**Oja Oba (High populated area with unenlightened people)**	
EVENTS	Network operator A	Network operator B	Network operator A	Network operator B	Network operator A	Network operator B
Blocked Call	2	2	-	-	-	-
Call Attempt	8	8	4	4	5	4
Call Established	6	6	4	4	3	4
Call Setup	6	6	4	4	5	4
Call End	6	5	4	3	4	5

Table 2: 2G Long Call Event Statistics Summary

	Airport road (Low populated area)		**College of Education (High populated area with enlightened people)**		**Oja Oba (High populated area with unenlightened people)**	
EVENTS	Network operator A	Network operator B	Network operator A	Network operator B	Network operator A	Network operator B
Call Attempt	6	6	3	4	3	4
Call Established	6	6	3	4	3	4
Dropped Call	2	2	1	1	1	1
Handover	9	7	6	37	9	6
Handover Intracell	-	-	-	-	-	3
Handover Failure	1	-	-	-	-	-
Call End	4	4	2	3	2	3

In the case of Call Completion Success Rate (CCSR),

$$CCSR\ (\%) = \frac{No\ of\ Successfully\ Completed\ Call}{\text{Total No of Call Attempts}} * 100$$

- Airport Road

From Table 2, for Network Operator A,

$CCSR\ (\%) = \frac{4}{6} * 100$ = 66.67%

For Network Operator B,

$CCSR\ (\%) = \frac{4}{6} * 100$ = 66.67%

- College of Education, Ilorin

From Table 2, for Network Operator A,

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$$CCSR\ (\%) = \frac{2}{3} * 100 = 66.67\%$$

For Network Operator B,

$$CCSR\ (\%) = \frac{3}{4} * 100 = 75.00\%$$

- Oja Oba

From Table 2, for Network Operator A,

$$CCSR\ (\%) = \frac{2}{3} * 100 = 66.67\%$$

For Network Operator B,

$$CCSR\ (\%) = \frac{3}{4} * 100 = 75.00\%$$

For the Call Drop Rate (CDR),

$$CDR\ (\%) = \frac{No\ of\ Dropped\ Call}{\text{Total No of Call Attempts}} * 100$$

From Table 2, we can get the CDR (%) using the equations above for each location. The KPI analysis from the drive test and from customers are as shown in Table 3 and Table 4.

Table 3: KPI Analysis from Drive Test (QoS)

	Airport road (Low populated area)		**College of Education (High populated area with enlightened people)**		**Oja Oba (High populated area with unenlightened people)**	
KPI	Operator A	Operator B	Operator A	Operator B	Operator A	Operator B
Rx Qual (%)	93.20	83.95	97.26	98.88	94.35	89.97
Rx Level (%)	90.52	94.00	95.59	100.00	87.50	92.21
CSSR (%)	75.00	75.00	100.00	100.00	100.00	100.00
CDR (%)	33.33	33.33	33.33	25.00	33.33	25.00
CCSR (%)	66.67	66.67	66.67	75.00	66.67	75.00

Table 4: KPI Analysis from Customers (MOS)

	Airport road (Low populated area)		**College of Education (High populated area with enlightened people)**		**Oja Oba (High populated area with unenlightened people)**	
KPI	Operator A	Operator B	Operator A	Operator B	Operator A	Operator B
Rx Qual (%)	81.17	78.50	76.33	83.00	78.85	91.50
Rx Level (%)	80.83	85.78	71.50	81.11	88.14	89.75
CSSR (%)	84.67	86.00	77.17	87.00	69.50	83.13
CDR (%)	8.83	9.67	20.00	12.56	17.00	11.13
CCSR (%)	81.49	81.78	74.67	87.89	79.71	89.20

4. DISCUSSION

Comparing the main KPIs (CSSR, CDR, CCSR) values in Table 3 and Table 4, MOS > QoS in the sense that, when administering the questionnaire, most of the customers mentioned that they use non smart phones such as Techno T430, Nokia 105, BLU Tank 1 T193 for their voice call as they could provide better signal performance for making calls and sending texts not to mention the battery capacity. According to [14], test conducted by industry regulator Ofcom in the laboratory showed that despite being packed with technologies, smart phones are not as good at picking up weak signals as cheaper devices. Also, Ofcom findings claims that glass and metal used in smart phones as opposed to the plastic used in cheaper mobiles are sometimes responsible for call cutting off which explains the large difference between the MOS and QoS CDR. The MS used in collecting data during drive test is Sony Ericson p900 which is a smartphone from Sony Ericson.

From Table 3, Table 4, Figure 7 and Figure 8, the same value of KPIs was recorded in both and network operators A and B for Low Populated Area (Oja Oba) therefore the reasons for those values will be generalised. Comparing the low populated with the high populated area, expectations was to have a higher CSSR, lower CDR and higher CDR in the low populated area but reverse was the case due to the following:

1. Lack of BTS Infrastructure: Network Operators prefer to install more BTS in an area where there are many users in order to run at a profit as acquiring of BTS Infrastructure and its maintenance is expensive. Due to limited number of BTS, there are wide swaths of dead zone leading to CDR drop as the MS receives no reception from the BTS.
2. Cityscape Changes - In low populated areas such as Airport road, new buildings come up and adjacent building subscribers loose cell reception causing rapidly changing cityscape which calls for routine network data analysis from service providers.

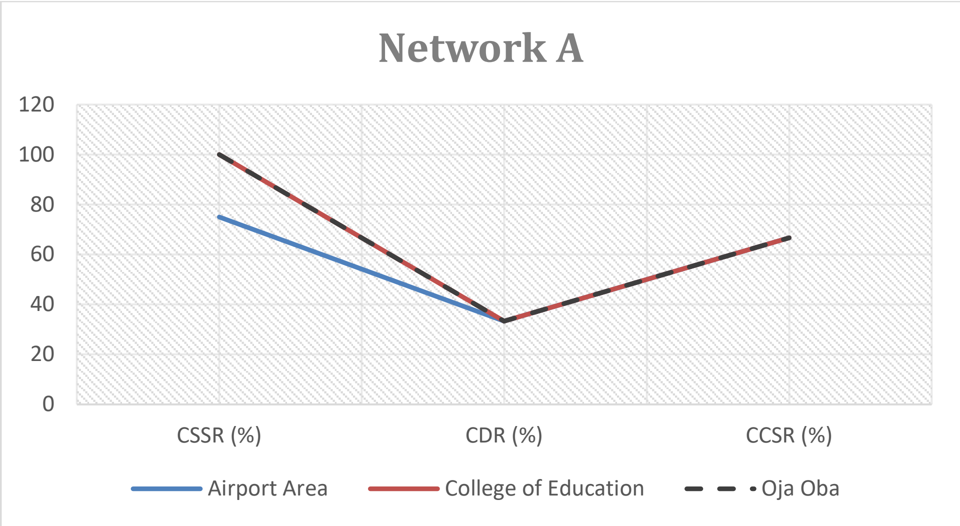

Figure 7: Graph showing the KPIs of Airport Road, College of Education, Ilorin and Oja Oba of Network Operator A

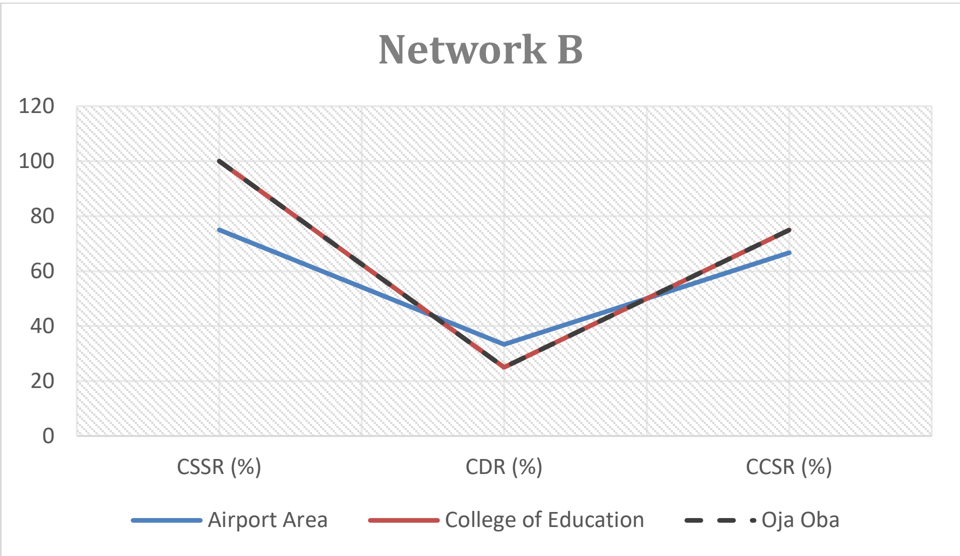

Figure 8: Graph showing the KPIs of Airport Road, College of Education, Ilorin and Oja Oba of Network Operator B

Comparing the high populated area with enlightened people (College of Education) and the high populated area with the unenlightened people (Oja Oba), for network operator A, same KPIs values were recorded as well as for network operator B which means the network performance of any high populated will be equivalent regardless of majority of the habitants being enlightened or unenlightened.

5. CONCLUSION AND RECOMMENDATION

From the results of the study, it is evident that both network operators A and B are far from providing reliable services in Ilorin West as recommended by the Nigerian Communication Commission (NCC). None of the location considered in the study has up to 95% Call Completion Success Rate which is an indication that the service retainability of both network operators considered in Ilorin West is very low. From the Mean Opinion Score (MOS), less than 90% of the customers in each of the network accessed get their call completed before the call drops. This is an indication that Call Drop Rate (CDR) is high compared to the threshold value provided by NCC (<=2%).

Likewise, the network accessibility for both networks in high populated area regardless of whether it is of enlightened or unenlightened people at peak, is high but for low populated area (from QoS measured). From the MOS, the network accessibility for both networks in all locations considered is low with half of the subscribers of each of the network saying they need to dial more than one time before having access to the network. This indicates that the congestion rates are high as the network accessibility is below the threshold value given by NCC (>=98).

It shows that both networks considered have more subscribers but lack enough equipment to support daily increasing customer. The study however reveals better performance of the network in terms of service integrity most especially in voice quality. With these findings, it can be concluded that QoS and GSM performance profile in Ilorin West is poor especially in low populated area which shows some users are yet to enjoy the full impact of GSM as a new effective means of communication.

To correct this congestion situation in Ilorin West and any other areas with similar situation, suggestion on how to improve the QoS of the GSM operators in the country is made. It is on this basis that the following recommendations are made to correct the observed defects. The NCC is advised to inspect the GSM performance profile in the country regularly. This will aim the GSM operator to improve their network base to meet the ever-increasing need of the subscribers. Secondly, the GSM operators should focus on more BTS sites to be built to close access gaps and improve QoS. Besides, routine network data analysis in the low populated areas by the service providers is recommended since the cityscape of such areas changes from time to time. Finally, an application such as the one proposed in Figure 9 can be implemented. It can be installed in dual SIM phones at the point of manufacturing in which users and subscribers automatically select the network with better coverage at the point of use. With this, the network operators will compete to provide excellent coverage in many areas.

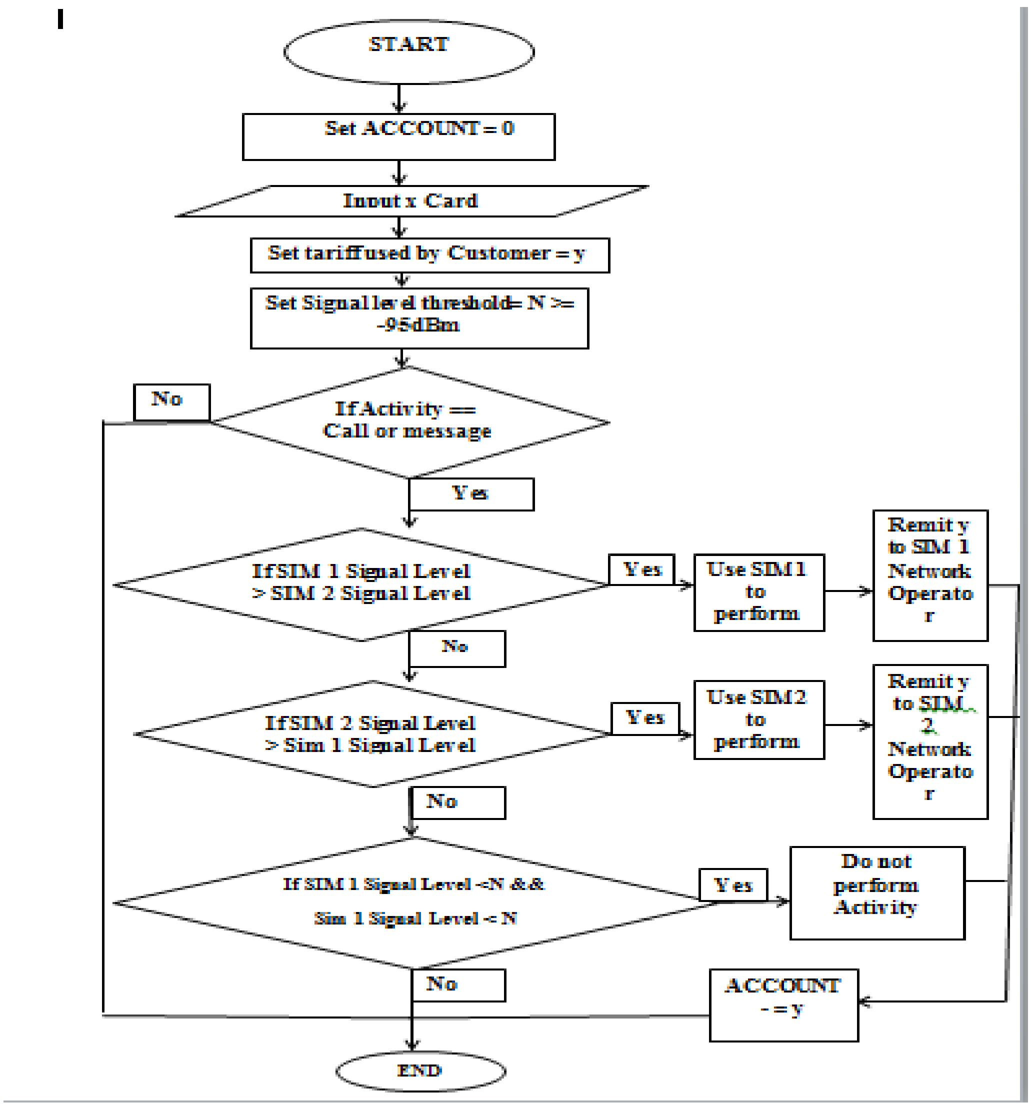

Figure 9: Algorithm for the recommended application

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