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REAL-TIME ASSESSMENT OF CELLULAR NETWORK SIGNAL STRENGTHS IN CALABAR

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ABSTRACT

This research is aimed assessing and comparing the performance of four cellular networks (MTN, Airtel, 9mobile and Globacom) operating in Calabar, using their Received signal Strengths (RSS). An extensive measurement of RSS was conducted and collected over base stations in Calabar, through a benchmarking drive test. This was possible with the aid of a TEMS investigation software running on a Windows 10 operating system laptop. A total of 8,640 RSS measurements were taken for 3 months (April to June, 2021). Graphs and bar charts were plotted and statistical analyses (calculations of standard deviations and standard errors of mean) made for a better visualization and understanding of RSS data trends. Average signal levels for the three months was obtained as -65dBm for MTN, -70dBm for 9Mobile, -72dBm for Airtel and -68dBm for Globacom, while the most obtained signal level was -68dBm for MTN, -70dBm for 9Mobile, -72dBm for Airtel and -67dBm for Globacom. Results obtained shows good signal coverage for the four mobile networks. However, the four networks experienced signal fluctuations which could be attributed to meteorological factors and terrain. This result is useful to the network operators and RF planners for the assessment of their network performance, planning and optimization.

KEYWORDS: Signal Strength, Cellular Network, Drive Test, SIM cards, Quality of Service

1. INTRODUCTION

In 1896, Guglielmo Marconi, using a Morse code operating at a frequency of 1 MHz, demonstrated radio's ability to provide continuous contact with ships and this laid a foundation to the various evolutions of mobile technology [1]. After the Second World War, wireless telephone, assumed with zero generation (0G), proceeded to the first generation (1G), second generation (2G), third generation (3G), fourth generation (4G) and presently the fifth generation (5G) [2-12].

Mobile phones play a vital role in our daily lives. We make use of them unceasingly in watching movies, in sending e-mails, in making voice calls, in sending short message services (SMS), in e-learning, in e-commerce and in e-banking [13], however, the services of mobile network operators in Nigeria is very poor, due to drop in signal strength, which is evident in series of dropped calls, traffic congestion, failed internet services, failed message delivery, failed e-banking transactions and even the noticeable failed voters' accreditation exercises [14-16].

As at May 2021, the teledensity of the major mobile networks in Nigeria was 187,026,517 [17]. As a result, there is an exponential increase in the number of mobile applications, wireless devices and services that require connectivity to mobile networks in different scenarios. With the emerging trends in Machine-to-Machine and Internet of Things (IoT) communication technologies, billions of smart devices and sensors are expected to be connected to cellular networks globally. However, the capacity of the mobile network operators may not be enough to meet with the high user requirements of future cellular communications. The plain sailing way of increasing cellular network capacity is to install more base stations in a given coverage area. This is done to guarantee good signal reception at every point within the coverage area. To achieve these set targets, mobile network operators are to provide the infrastructures for interconnection and digital inclusion [18]. In addition, a

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correct knowledge of electromagnetic wave propagation is required for efficient radio network planning and optimization [19–23].

Received Signal strength (RSS) data are useful for the design, formulation, and establishment of radio propagation models. These models are required for the forecast of the mean received signal strength of a mobile network at a given distance away from the transmitter. These path loss models are indispensable for signal power forecast at different points within the coverage area during radio network planning and optimization [24–25]. Radio network engineers depend on RSS data to estimate radio coverage, determine the needed transmission power, determine optimal locations of base stations, achieve best possible data rates, aid appropriate selection of antenna height and pattern, perform efficient frequency allocation, conduct radio network optimization, perform interference feasibility studies and ensure an acceptable level of Quality of Service (QoS) without the need of expensive and time consuming measurements [26–27].

A lot of researchers have investigated RSS of mobile networks in various terrains using different methods. [28] presented a comparative analysis of the Received Signal Strength (RSS) of some cellular networks in Port Harcourt, Nigeria. Radio Frequency (RF) signal tracker was used to measure received signal strength of three GSM networks (Airtel, MTN, and Globalcom) at five locations (Old Government Residential Area, Aba Road. Borokiri, Rivers State University and Ikwerre Road). Result shows that MTN has the highest received signal strength of -61.9dBm in Borokiri, at Old GRA, Airtel has the highest received signal strength of -61.3dBm. Globacom had the highest received signal strength of -68.3dBm and -64.9dBm respectively, at Rivers state University and Ikwerre Road while at Aba Road, MTN had the highest received signal strength of -63.0dBm. Results were further analyzed using least square method and standard deviation to approximate the measurement data and a path loss model was developed using ordinary least square regression technique.

[29] x-rayed the diurnal variation of signal strength generated by Orient 94.4 FM transmitter along six (6) selected route in Imo State, Nigeria. At a distance of 20 Km, signal strength measurements were collected with the aid of a constructed signal strength meter. Arrangement was made with the management of the base station to ensure that the transmitting parameters were kept constant throughout the period of signal strength measurement. The average results of these measurements were taken. Graphs were plotted to establish the diurnal variation in signal strength along the different routes of signal strength measurement. It was observed that transmission and reception of signals are dependent on the time of the day. High signal strength was recorded between 8 am to 11 am, low signal strength was recorded between 1 pm to 5 pm, while stronger signal strengths were recorded at night. The result of this study shows that signal strength generated by FM transmitter vary with time of the day and the prevalent weather conditions.

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GSM networks' signal strength coverage in rural communities in South-Eastern Nigeria was x-rayed by [31]. To carry out measurement of the signal strength received from the transmitting stations of various GSM networks, a Network Cell Info Lite application was installed into two Gionee M5 phones. Signal strength obtained from the application was compared with the Gionee android inbuilt signal meter for authentication purposes. The obtained data was analyzed to determine, the availability of the networks, GSM networks coverage levels and the quality of the network provided in the aforementioned rural communities. Result shows that most rural communities in the South-East region of Nigeria, like Amaigbo and Amasa, experiences a lot of periods of out of service as a result of poor network coverage level. In Uli, a rural community with high population density, network coverage level was relatively high, therefore, quality network services was recorded. More booster stations was recommended to be sited to enhance good network coverage level in rural communities within the South-Eastern region of Nigeria.

The received signal strength and path loss of a GSM (Globacom) Network operating at a frequency of 900MHz in Umuahia, Nigeria using drive test was evaluated by [32]. During the period of investigation, low signal quality was discovered. Results from simulation of the acquired data using Matlab reviewed a considerable decline in the Received Signal Strength Level (RSSL), mainly due to increase in vegetation, population and building heights. An increase in the frequency band was recommended to remedy the effect of path loss within this study area.

[33] examined five experimental broadcast models- Egli's model, free space model, ECC model, COST 231 Hata model and ERICSSON Model for path loss performance in Owerri, Imo State, Nigeria. A drive test was carried out to obtain the real-time field data on the Long Term Evolution (LTE) operating at a frequency of 700MHz. A TEMS Investigation tool was used to obtain log files while a TEMS Discovery software was used in the analysis of the log files. Results obtained shows that Ericsson model was found to best predict the environment with a minimum deviation of 10.11dB being closest to the measured path loss with 2.01dB compared to the other models. [34] in a research carried out in Lagos, analyzed received signal strength in a macrocell using Finite Element Method (FEM). Six different site locations were investigated. They were classified as dense urban, open urban, peri-urban, open suburban, suburban and exurban areas. Using 2D Maxwell's wave equation, simulation was achieved. It was deduced that the experimental values obtained was favourable with the FEM predicted values with the mean prediction error ranging between 6.66dB to 12.89dB while that of standard deviation error is 2.99dB to 8.09dB.

Signal level of frequency modulated radio spectrum measured by cognitive radio and signal level calculated from some existing models were analyzed and compared by [35]. Received signal of frequency modulated radio spectrum for four campuses (Igbinedion University, University of Benin, Well Spring University and Benson Idahosa University) in Edo State, Nigeria, was measured by the aid of a cognitive radio. Also, three path loss models were used to determine the prediction for the path loss, which was used to determine the received signal level of FM radio spectrum respectively. Received signal power levels measured using cognitive radio were observed to be lower than that of the existing models. This is because received signal power levels predicted from existing models do not account for variations in terrain, structural blockage and other factors peculiar to the investigated environment, which affects the frequency modulated radio stations transmitting signal. Hence, the results of the signal level of FM radio spectrum for the four locations derived using cognitive radio provide a better result than that obtained from existing empirical models. The measured results was proposed to be used in estimating the signal level of FM radio spectrum for locations within Nigeria with similar environmental conditions to the investigated environment.

This research is aimed at assessing the quality of signal strength provided by mobile network operators in Calabar, comparing the received signal strengths to know the network with the best QoS. This is done to put the network operators in the know about their QoS for efficient network planning and optimization.

2. MATERIALS AND METHODS

The central idea of this research is to investigate the RSS of the major mobile networks and to further make comparative analyses, so as to deduce which network performs best. The study location of this research is Calabar and the cellular networks investigated are MTN, Airtel, Globacom and 9Mobile. A Garmin Global Positioning System (GPS), four W995 TEMS mobile phones, four SIM cards, one for each network, TEMS 15.1 investigation software, a laptop, a USB hub, a car inverter and a car are the materials used for this study.

The SIM cards were slotted into the TEMS phones while the TEMS investigation software was installed in the laptop. The TEMS phones were powered by connecting them to the USB hub which is plugged to the laptop. The GPS, which is also powered by the laptop, gives the location for the drive test. An extensive drive test measurement was conducted and RSS data were collected over base stations in Calabar, using TEMS investigation software running on a Windows 10 operating system laptop. A total of 8,640 RSS measurements were taken for 3 months (April to June, 2021).

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Graphs and bar charts were plotted and statistical analyses (calculations of standard deviations and standard errors of mean) made for a better description and understanding of RSS data trends.

3. RESULTS AND DISCUSSION

Comparative analysis of Airtel, 9mobile, Globacom and MTN was analyzed based on their RSS data recorded in April, May and June, 2021. The monthly mean values of the RSS are represented in a bar chart in Figure 1.

Figure 2 and Figure 3 while the average RSS for the study period for each network was presented in a bar chart as Figure 4. The weekly mean RSS was presented in Figure 5, graphically. For further analysis, the most received monthly signals were presented as Figure 6, Figure 7 and Figure 8, for the months of April, May and June respectively. Figure 9 displayed the frequently RSS for the 3 months in study while the weekly frequently RSS was displayed in a graph as Figure 10.

In each graph and bar chart, MTN was represented by a yellow colour, Airtel was represented by the red colour, 9mobile was represented by a dark green colour while Globacom was represented by a light green colour. Values of standard deviation and standard errors for the four networks is presented in Table 1. This was done for a better visualization and understanding of data trends across the weeks and months of study.

Table 1. Result of statistical analysis for the four networks

MOBILE NETWORK	STANDARD DEVIATION	STANDARD ERROR OF MEAN
MTN	2.63	0.76
Airtel	3.65	1.05
9Mobile	5.07	1.46
Globacom	4.32	1.25

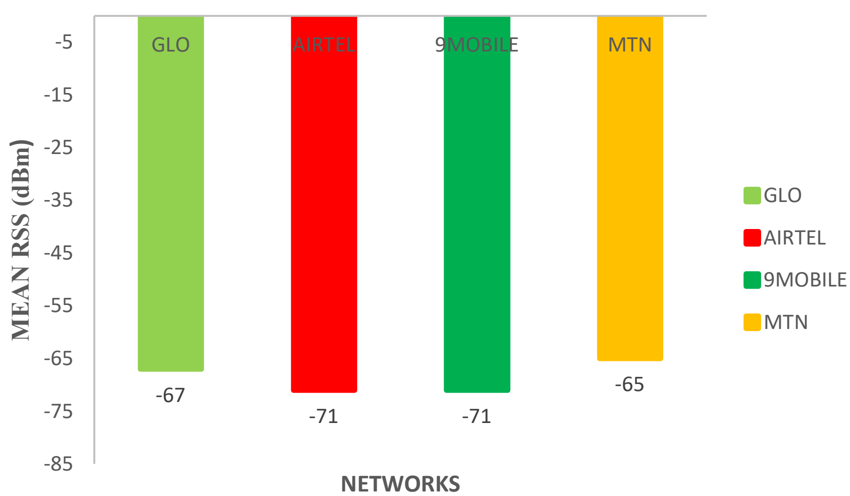

Figure 1: Bar chart of mean RSS for April 2021

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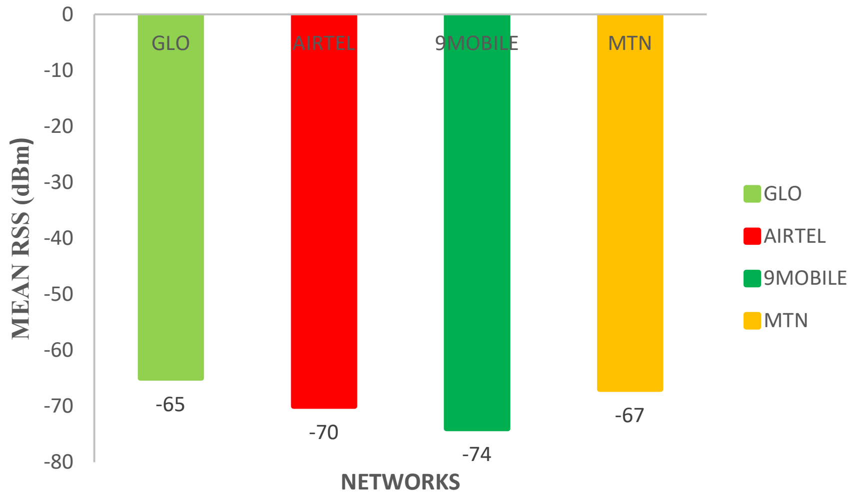

Figure 2: Bar chart of mean RSS for May 2021

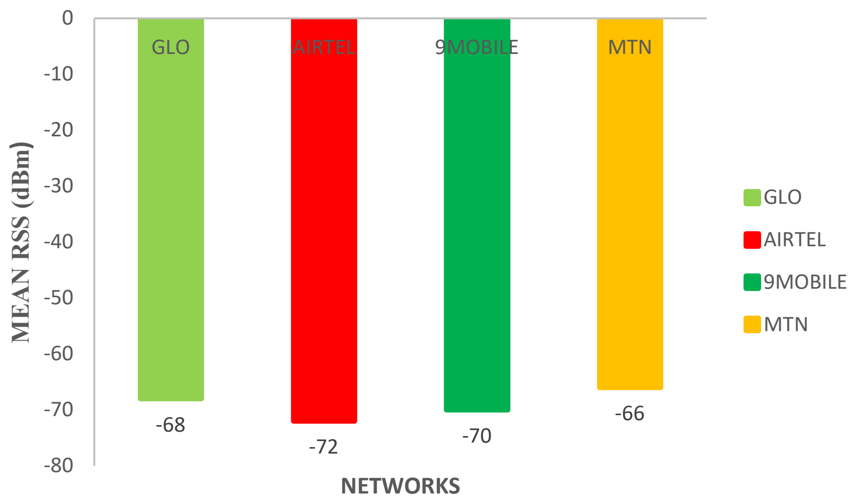

Figure 3: Bar Chart of mean RSS for June 2021

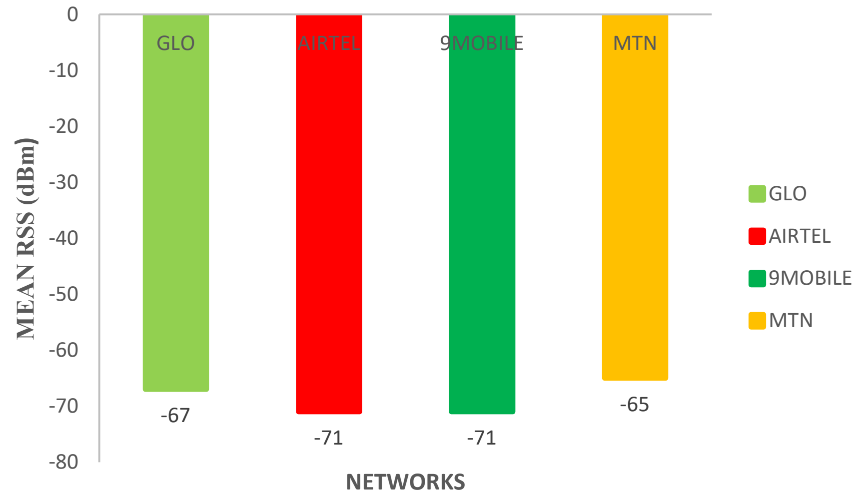

Figure 4: Bar Chart of mean RSS from May to June 2021

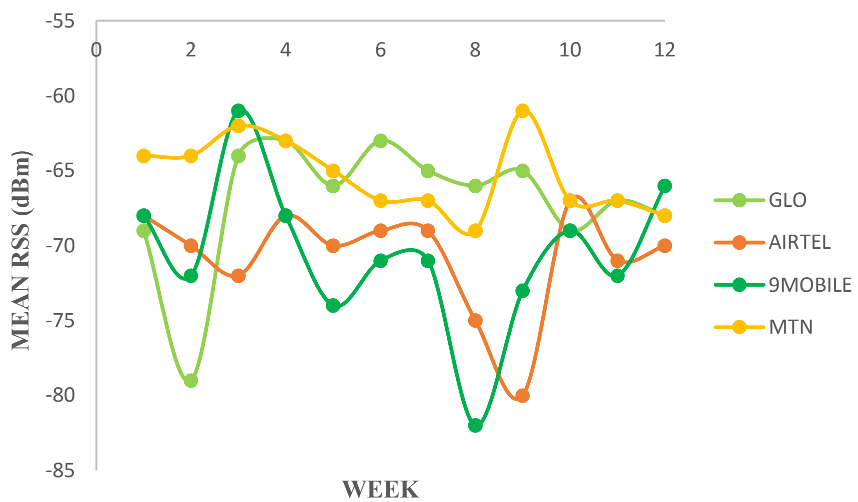

Figure 5: Graph of weekly mean RSS against weeks

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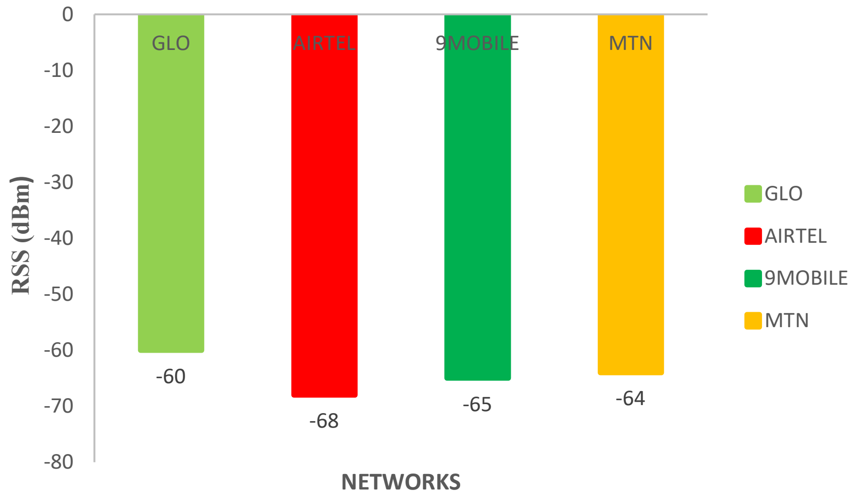

Figure 6: Bar chart of frequently RSS in April 2021

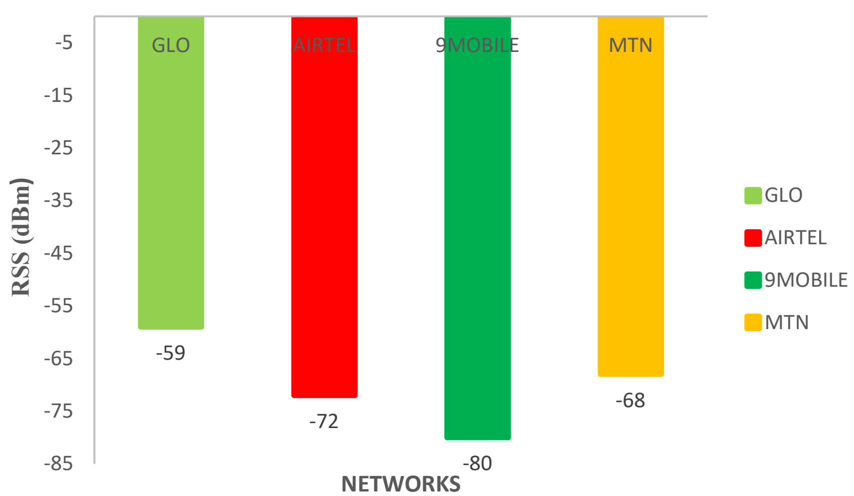

Figure 7: Bar chart of frequently RSS in May 2021

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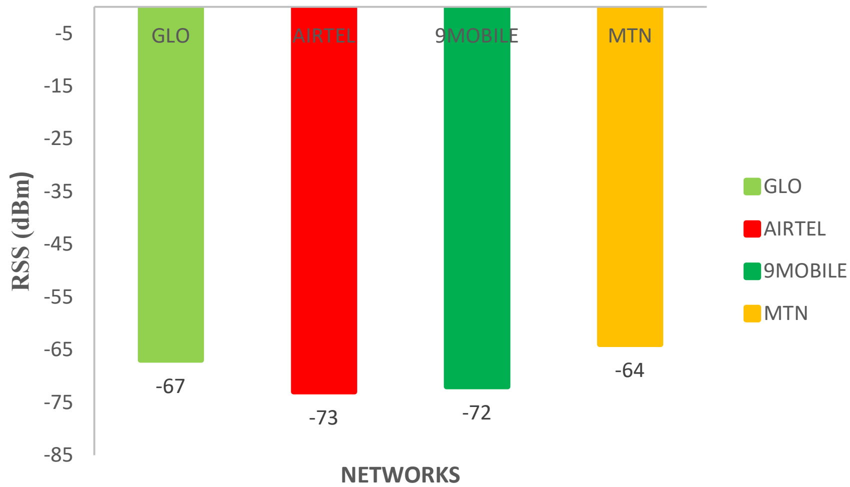

Figure 8: Bar chart of frequently RSS in June 2021

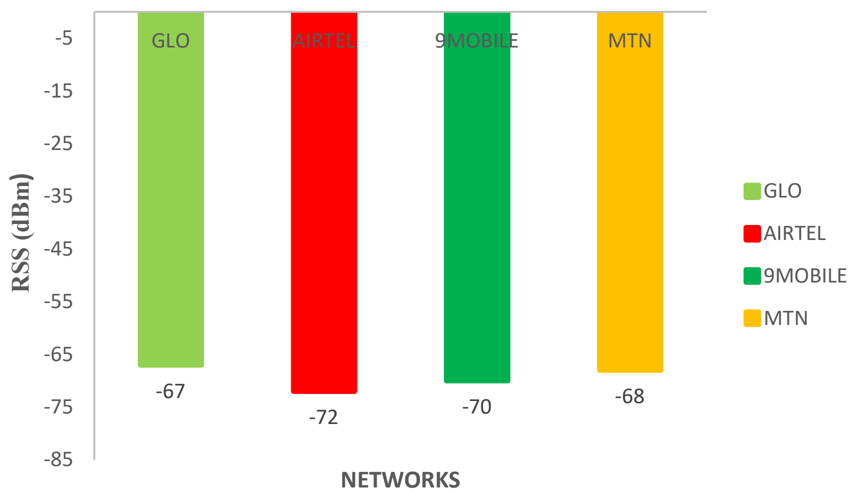

Figure 9: Bar chart of frequently RSS from April to June 2021

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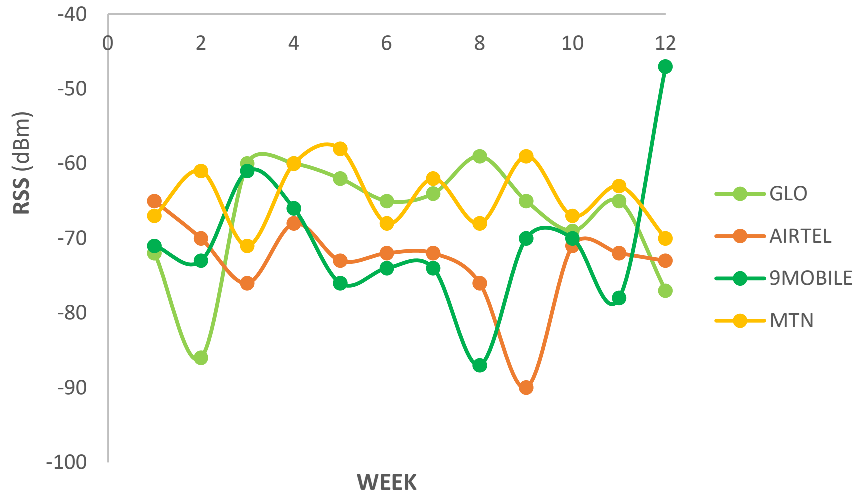

Figure 10: Graph of weekly frequently RSS against weeks

In Figure 1, MTN has the strongest signal coverage in the month of April. However, other networks had good coverage. This result is affirmed in Figure 6 where the frequently received signal level is -64dBm for MTN, -65dBm for 9Mobile, -68dBm for Airtel and -60dBm for Globacom. In the month of May, Globacom produced the best network. Their subscribers were remarkably satisfied with their coverage, hence, they had the strongest signal strength as shown in Figure 2 and Figure 7. This was followed by MTN, Airtel and then 9mobile network. A serious fluctuation in signal level was observed for 9mobile network, though it was still good enough for mobile services.

In June, MTN had the best signal coverage. This was followed by Globacom, 9mobile and then Airtel, as seen in Figure 3 and Figure 8. Average signal levels for the three months, as depicted in Figure 4. Results of Figure 1 to 3 and Figure 6 to 8 was further affirmed by bar charts in Figure 4 and Figure 9 respectively. Average signal levels for the three months was obtained as -65dBm for MTN, -70dBm for 9Mobile, -72dBm for Airtel and -68dBm for Globacom as shown in Figure 4 while the most obtained signal level as obtained in Figure 9 is -68dBm for MTN, -70dBm for 9Mobile, -72dBm for Airtel and -67dBm for Globacom.

Irrespective of how good the performance of the mobile networks appear to be, a weekly analysis of the RSS in Figure 5 and Figure 10 show fluctuations in signal levels for the four networks. The worst received signal was -86dBm in week 2 for Globacom, -90dBm for Airtel in week 9 and -87dBm for 9mobile. In this period, many subscribers were dissatisfied with the performance of these networks because they received fair coverage due to interference. During this period, dropped calls, inability to initiate calls, handover failure, channel congestion and poor data services were experienced. In week 12, an excellent signal level of -47dBm was obtained in 9mobile network, this depicts strong coverage, which means good quality voice and data services.

Low values of standard deviation were obtained for the four cellular networks. Airtel had the value 3.65, 5.07 for 9mobile, 4.32 for Globacom and 2.63 for MTN. This low values show that the data points tend to be very close to the mean RSS for each network. In addition, low values of standard errors were obtained for the four networks. 1.05 was calculated for Airtel, 1.46 for 9mobile, 1.25 for Globacom and 0.76 for MTN. This was an affirmation of the reliability of their mean RSS. It is an indication that the mean RSS is an accurate reflection of the data trends. This result is useful to the network operators and RF planners, for the assessment of their network performance, planning and optimization of their networks.

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4. CONCLUSION

A benchmarking drive test to compare the RSS of the major networks in Calabar has been conducted. The collected data was analyzed statistically. Average signal levels for the three months was obtained as -65dBm for MTN, -70dBm for 9Mobile, -72dBm for Airtel and -68dBm for Globacom, while the most obtained signal level was -68dBm for MTN, -70dBm for 9Mobile, -72dBm for Airtel and -67dBm for Globacom. MTN and Globacom had excellent signal strengths while 9mobile and Airtel had good signal strengths. A summary of the analysis show that the four networks have very good signal coverage but are experiencing fluctuations due to interference caused mainly by meteorological variables and terrain. Mobile network operators will find the result of this work very useful and are advised to frequently investigate their QoS for efficient optimization of their networks.

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