Available online

JOURNAL OF CONTEMPORARY RESEARCH (JOCRES)

RESEARCH ARTICLE VOL. 1 (1) ISSN:2814-2241

www.unicrossjournals.com

Date Accepted: 30th June, 2022

Pages 88 - 98

MEASUREMENT AND PERFORMANCE ASSESSMENT OF GSM NETWORKS USING RECEIVED SIGNAL LEVEL

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Abstract

This research appraises the performance of MTN, Airtel, Globacom, and 9mobile networks, with the view to determining the network with the best coverage, taking its received signal level (RxLev) as the key performance indicator (KPI) under consideration. The log files obtained during the driving test were made possible through TEMS 15.1 investigation software. A post-processing software, TEMS 15.1 discovery, analyzed the collected data in the form of coverage plots. The collected data was further put through a few measures of central tendency and dispersion, with a view to understanding the spread, shape, and accuracy of the computed data. It was observed that 96.50%, 93.60%, 95.40%, and 93.70% of the drive test routes for MTN, Airtel, Globacom and 9mobile network had good signal quality and met the regulatory threshold of at least -85dBm for RxLev. The GSM networks investigated had excellent coverage. The best coverage was from MTN network, followed by Globacom network, 9mobile network, and lastly Airtel network. This result will save as a guide to the network operators, the regulatory body, the network engineers, and those in academics, for the purpose of developing a propagation model for the accurate transmission of GSM network signals over Calabar South and Calabar Municipality.

Keywords: Network coverage, Received signal level, GSM network, Mobile network, Radio signal

1. Introduction

The received signal level, conventionally denoted as RxLev, is an assessment of the downlink coverage penetration in a 2G mobile network (Ozovehe and Usman, 2015; Ekah and Emeruwa, 2021). It is the mean RxLev received by the mobile station of the base station, measured on all-time slots and the subset of time slots (Yuwono and Ferdiyanto, 2015), classified under the Key Performance Indicator (KPI) called coverage reliability (Ajayi, *et. al.*, 2021; Ekah and Iloke, 2022). In Nigeria, it is given a benchmark of at least – 85dBm by the agency supervising telecommunication services, the Nigerian Communication Commission (NCC). Data, Short Message Services (SMS), and voice services rely on the downlink coverage penetration (Ajayi, *et. al.*, 2021; Ekah and Emeruwa, 2022) and a location is considered to be within the coverage area if the RxLev can be measured in that location (Ekah *et. al*, 2022a).

At different locations in a given terrain, RxLev of propagated signals is usually measured for the purpose of network optimization, network design, network planning, channel characterization, and deployment of a precise and effective propagation model. By so doing, the average RxLev of a radio network at a given distance away from the transmitter can be accurately predicted (Popoola *et. al.*, 2018; Faruk *et. al.*, 2013; Oseni *et. al.*, 2014; Faruk *et. al.*, 2017; Adeyemo *et. al.*, 2016). To ascertain optimal data rates and base station positions, to establish exact transmission power and frequency allocation, to aid accurate selection of antenna types and orientation, to conduct feasibility studies on interference and to conduct RF optimization, RF planners rely on the RxLev (Popoola *et. al.*, 2018; Popoola *et. al.*, 2017a; Popoola *et. al.*, 2017b; Popoola *et. al.*, 2017c; Abdulrasheed *et. al.*, 2017; Sikiru *et. al.*, 2017, Ekah *et. al.*, 2022c).

RxLev is often affected by several environmental and technical factors like the transmitter height, receiver height, terrain, number of base stations, foliage, meteorological variables, transmitting frequency and the distance between the receiver and the transmitter (Aprillia *et. al.*, 2020; Mishra, 2007; Helhel *et. al.*, 2008; Ewona and Ekah, 2021; Ekah and Onuu, 2022; Ekah *et al.*, 2022b; Iloke *et. al.*, 2018). In urban areas, RxLev decreases as the transmitter-receiver distance increases, especially in areas behind tall buildings and indoors. In rural areas where the capacity of the cell site is low, RxLev becomes critical (Galadanci, and Abdullahi, 2018). Low RxLev arises due to wrong antenna orientation and tilt, high VSWR value and low transmitting power. This requires immediate scrutiny of the antenna location, height and tilt, checking RF connectors and RF cables and checking the DRX power and connector. If low RxLev persists after optimization, the building of new sites are recommended (Galadanci, and Abdullahi, 2018; Kumar *et. al.*, 2011).

Galadanci, & Abdullahi, 2018 expresses the RxLev of a cell mathematically as:

$$\text{RxLev (dBm)} = A - B \log d + C \quad (1)$$

Where A is constant determined by the transmitted power, antenna gain and wavelength of the cell, B is the slope index, C is the logarithm of the shadowing component while d is the distance between the mobile station and base station of the cell.

An assessment of mobile networks is always necessary for the optimization of the network's QoS and this has been carried out by many researchers in various terrains. Emeruwa and Onuabuchi (2018) through a drive test, assessed the RxLev of a 2G network located in Calabar South, Nigeria and the MatLab analyzed data showed a decrease in RxLev which was attributed to tall buildings, foliage and density of people in the assessed location. Shoewu *et. al.*, (2015) evaluated the RxLev of 6 base stations situated in different terrains using the Finite Element Method (FEM). The experimental value was seen to be favorable with the FEM predicted values which had a mean prediction error ranging between 6.66dB to 12.89dB while the standard deviation error ranged between 2.99dB to 8.09dB.

In Obi *et. al.*, (2021), a measurement campaign was carried out through a driving test and analyzed to obtain the network with the best coverage. Though path loss was observed due to terrain and tropospheric variables, the four networks investigated had good coverage at the time the of study. In Isabona and Azi (2013), 3G networks transmitting at 800MHz and 1900MHz through drive tests were investigated to ascertain how the RSCP responds to antenna adjustment. An enhancement in the QoS and coverage of the mobile networks was achieved.

Emeruwa and Ekah, (2018a) through a drive test, assessed the RxLev of a Globacom GSM network located in Umuahia, Nigeria and the MatLab analyzed data showed path loss in the RxLev which was attributed to storey buildings, foliage and the high number of people in the investigated location. Bakare *et. al.*, (2018) carried out a comparative study of RxLev of selected networks in the city of Port Harcourt, Nigeria. Subscribers in the measured locations had good RxLev, though path loss in the measured signal was observed. The authors used the measured mean RxLev of each network and their corresponding distances to develop an enhanced free space path loss model to suit signal transmission for each of the networks.

In Ogunsola *et al.*, (2021) RxLev emanating from GSM networks transmitting at different bands in the 900MHz frequency, penetrating houses in the University campus in Ibadan were measured during busy hours. This was done using specialized software installed on a smart mobile phone. It was observed that RxLev was stronger in the passage than inside the buildings due to path loss resulting from materials used in the building. The authors recommend increasing the transmission power of the networks, which will account for signal attenuation and ill increase coverage. Emeruwa and Ekah, (2018b) through an intensive RxLev measurement during a drive test, examined five empirical propagation models to ascertain which path loss model will give better signal transmission in an LTE network operating in Owerri. The Ericsson model, set side-by-side with other empirical models, was suitable for the Owerri environment, having a measured path loss of 2.01dB with a minimum deviation of 10.11dB.

The central idea of this research is to investigate the RxLev of four major mobile networks operating in Calabar South and Calabar Municipality, to make comparative analyses, so as to deduce the network with the best coverage, using the NCC benchmark of at least – 85dBm.

2. Methodology

Materials Used

Materials used in this study is a Garmin Global Positioning System (GPS), four subscriber identity module (SIM) cards (one for each network), a laptop, a car, a car inverter, a universal serial bus (USB) hub, four W995 TEMS mobile phones, TEMS 15.1 investigation software and TEMS 15.1 discovery software.

2.2 Measurement Setup and Data Collection

A windows 10 operating system laptop is powered by connecting it to a car inverter. Installed on the laptop are the TEMS investigation and TEMS discovery software. Plugged to the laptop is a USB hub. The four cards, each being a SIM card for each network under investigation (9mobile, MTN, Airtel and Globacom) are inserted into the four TEMS phones. The TEMS phones are powered by connecting them to the USB hub. Also connected to the USB hub is the GPS.

A measurement campaign is established by dialing the TEMS phones for short calls of 180 seconds, while the TEMS investigation software collects the RxLev of GSM networks. The GPS gives the geographic positions of the drive test routes.

2.3 Data Analysis

The log files are subjected to statistical analysis using the TEMS discovery software which gives an insight of the network's QoS at the subscribers' end in the form of coverage plots. Further statistical treatment in the form of calculations of standard deviations, averages, modes, standard errors, skewness and kurtosis using Excel spreadsheet.

3. Results and Discussion

This section gives a picture of the analyzed data for the four mobile networks investigated. First, we introduce the significance of the data ranges analyzed by the post-processing software, the TEMS discovery. This is done for a proper understanding of the various data ranges. At – 65dBm and above, subscribers are remarkably satisfied because of the excellent coverage and this is denoted by the cyan color in the coverage plots. At - 75dBm to – 65dBm, subscribers are very satisfied because there is very good coverage and this is denoted by a dark green colour in the coverage plots. At – 85dBm to – 75dBm, subscribers in that region are also satisfied because they had good coverage and this is denoted by the light green colour in the coverage plots. At – 95dBm to – 85dBm, the region is characterized by dissatisfied subscribers, fair coverage with moderate interference and this is denoted by the yellow colour in the coverage plots. Finally, at – 105dBm to – 95dBm, the region has poor coverage, higher interference and the subscribers are very dissatisfied and this is denoted by a red colour in the coverage plots.

3.1 Result of Findings for MTN Network

During the measurement campaign for MTN network, 10382 RxLev data were collected, out of which 4935 were within the range of -65dBm to -47dBm, 4016 were within the range of -75dBm to -65dBm, 1067 were within the range of -85dBm to -75dBm, 310 were within the range of -95dBm to -85dBm while 54 were within the range of -110dBm to -95dBm. This is presented in the coverage plot in Figure 1.

An average, standard deviation and most occurring RxLev of -66dBm, 11.62 and -67dBm was calculated. This average computed value implies that the center of the data is -66dBm. The calculated standard deviation means that 68% of the distribution lies between -66 ± 11.62dBm, 95% of the distribution lies between -66 ± 23.64dBm, and 99.7% of the distribution lies between -66 ± 34.86dBm.

To estimate the accuracy of the measured data, the standard error of the collected data was calculated and a low value of 0.11 was obtained, implying that the data set used in this study was precise and not forged. To determine the shape of the distribution, excess kurtosis and skewness of the distribution were calculated and the values obtained were 0.51 and -0.38. The value of the excess kurtosis implies that the data distribution is leptokurtic, hence there is a variance in the data distribution due to infrequent deviations. For skewness, the computed result shows that the distribution is nearly symmetrical.

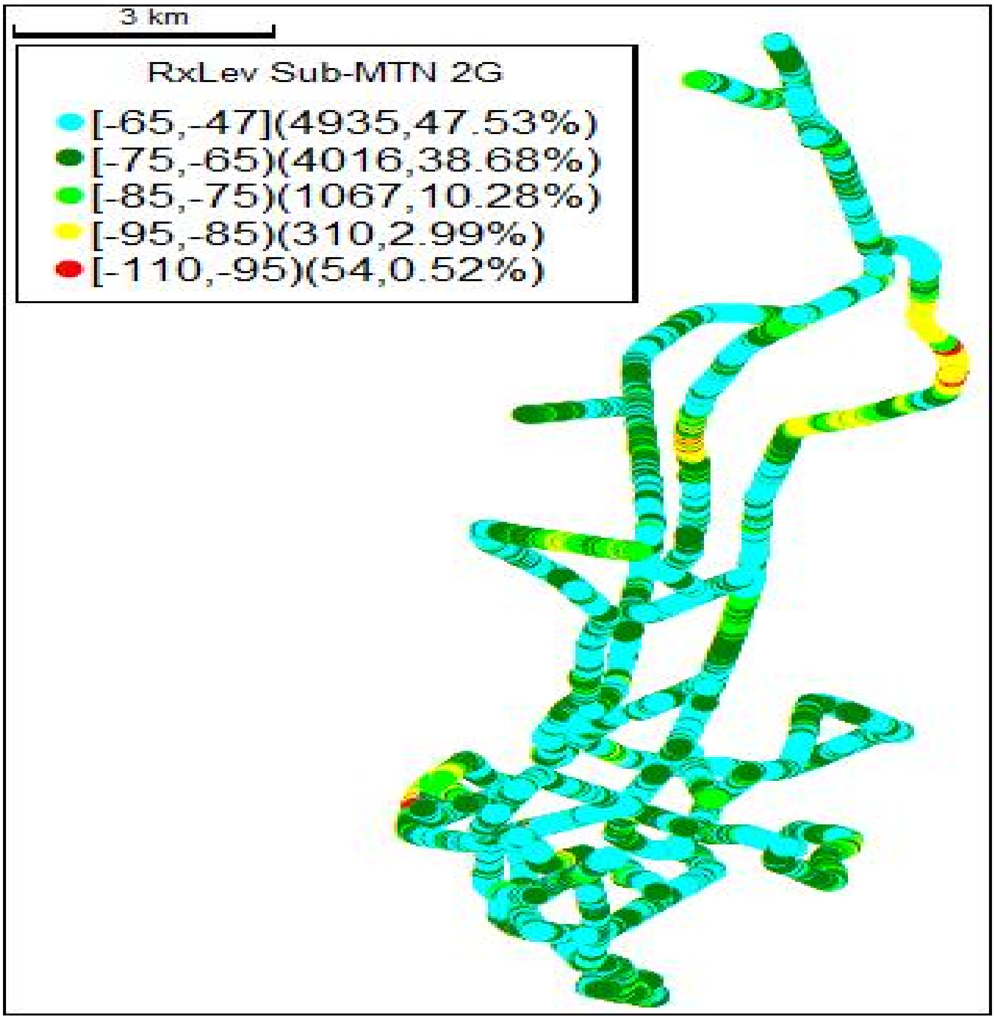

Fig 1: Coverage Plot for MTN Network

3.2 Result of Findings for Airtel Network

An Assessment of the log files for Airtel network shows that 10415 RxLev data were collected, out of which 2532 lies within -65dBm to -47dBm, 4739 lies within -75dBm to -65dBm, 2482 lies within the range of -85dBm to -75dBm, 613 lies within -95dBm to -85dBm while 49 lies within -110dBm to -95dBm. This is presented in the coverage plot in Figure 2.

An average, standard deviation, and most occurring RxLev of -71dBm, 9.00, and -73dBm were calculated. This average computed value implies that the center of the data is -71dBm. The calculated standard deviation means that 68% of the distribution lies between -71 ± 9.00dBm, 95% of the distribution lies between -71 ± 18.00dBm, and 99.7% of the distribution lies between -71 ± 27.00dBm.

To estimate the accuracy of the measured data, the standard error of the collected data was calculated and a low value of 0.08 was obtained, implying that the data set used in this study was precise and not forged. To determine the shape of the distribution, excess kurtosis and skewness of the distribution were calculated and the values obtained were 0.25 and -0.08. The value of the excess kurtosis shows that the data distribution is slightly leptokurtic. For skewness, the computed result shows that the distribution is approximately symmetrical.

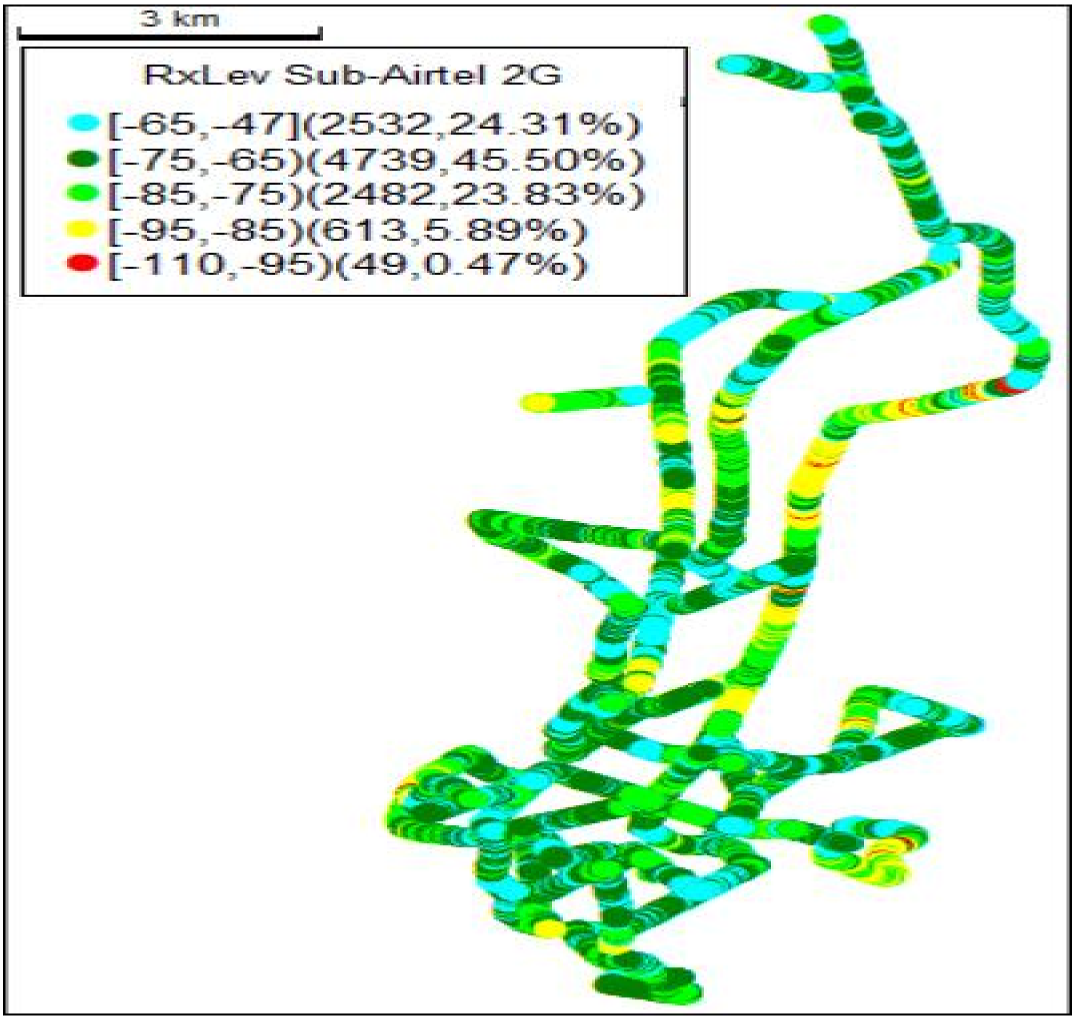

Fig 2: Coverage Plot for Airtel Network

3.3 Result of Findings for Globacom Network

An analysis of the log files for Globacom network shows that 10680 RxLev data were collected, out of which 3271 were within -65dBm to -47dBm, 4710 were within -75dBm to -65dBm, 2213 were within -85dBm to -75dBm, 455 were within -95dBm to -85dBm while 31 were within -110dBm to -95dBm. This is presented in the coverage plot in Figure 3.

An average, standard deviation, and most occurring RxLev of -70dBm, 11.62, and -

70dBm were calculated. This average computed value implies that the center of the data is -70dBm. The calculated standard deviation means that 68% of the distribution lies between -70 ± 9.20dBm, 95% of the distribution lies between -70 ± 18.40dBm, and 99.7% of the distribution lies between -70 ± 27.60dBm.

To estimate the accuracy of the measured data, the standard error of the collected data was calculated and a low value of 0.09 was obtained, implying that the data set used in this study was precise and not forged. To determine the shape of the distribution, excess kurtosis and skewness of the distribution were calculated and the values obtained were 0.02 and -0.12. The value of the excess kurtosis shows that the data distribution is mesokurtic. For skewness, the computed result shows that the distribution is nearly symmetric.

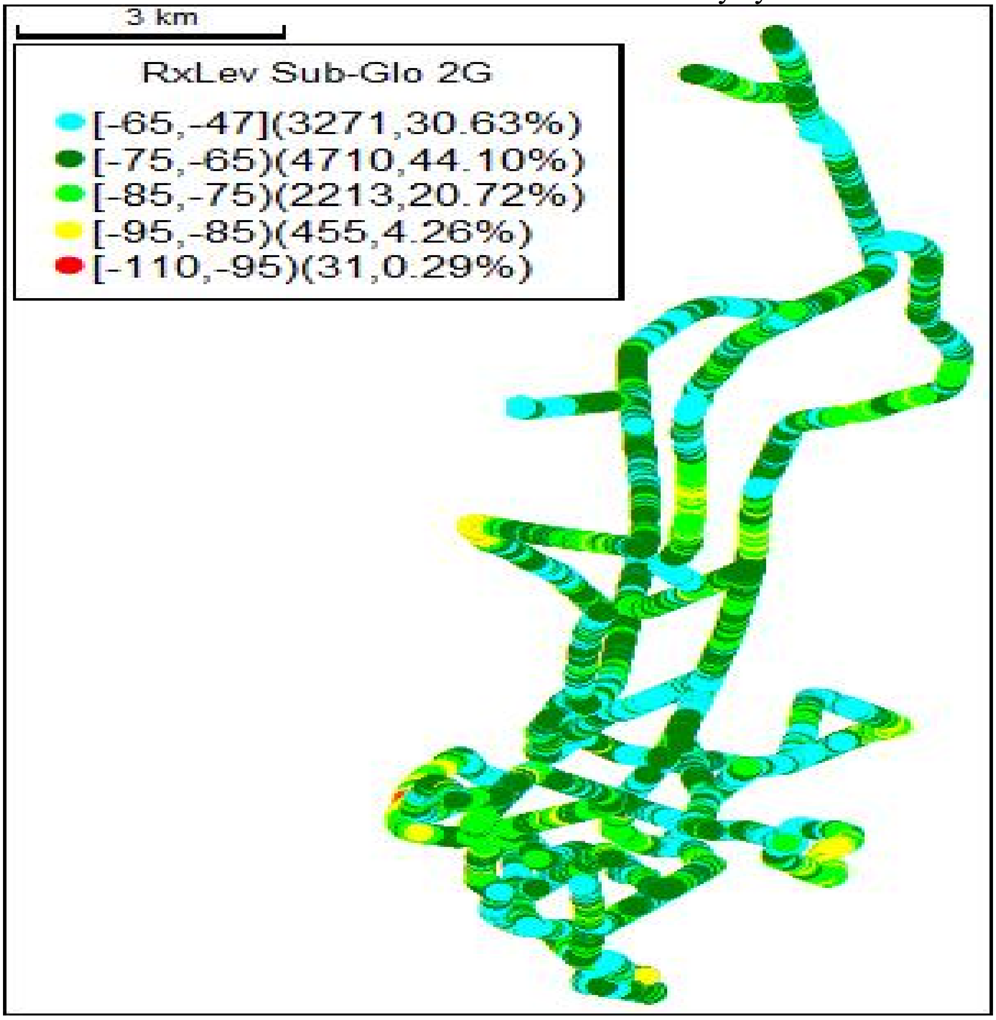

Fig 3: Coverage Plot for Globacom Network

3.4 Result of Findings for 9mobile Network

A measurement campaign carried out on the RxLev of the 9mobile network shows that 10137 RxLev data were collected, out of which 2726 were within the range of -65dBm to -47dBm, 4039 were within the range of -75dBm to -65dBm, 2732 were within the range of -85dBm to -75dBm, 501 were within the range of -95dBm to -85dBm while 139 were within the range of -110dBm to -95dBm. This is presented in the coverage plot in Figure 4.

An average, standard deviation, and most occurring RxLev of -71dBm, 10.10, and -,73dBm were calculated. This average computed value implies that the center of the data is -71dBm. The calculated standard deviation means that 68% of the distribution lies between -71 ± 10.10dBm, 95% of the distribution lies between -71 ± 20.20dBm, while and of the distribution lies between -71 ± 30.30dBm.

To estimate the accuracy of the measured data, standard earth or of the collected data was calculated and a low value of 0.10 was obtained, implying that the data set used in this study was precise and not forged. To determine the shape of the distribution, excess kurtosis and skewness of the distribution were calculated and the values obtained were 0.56 and -0.09. the value of the excess kurtosis shows that the data distribution is leptokurtic. For skewness, the computed result shows that the distribution is approximately symmetric.

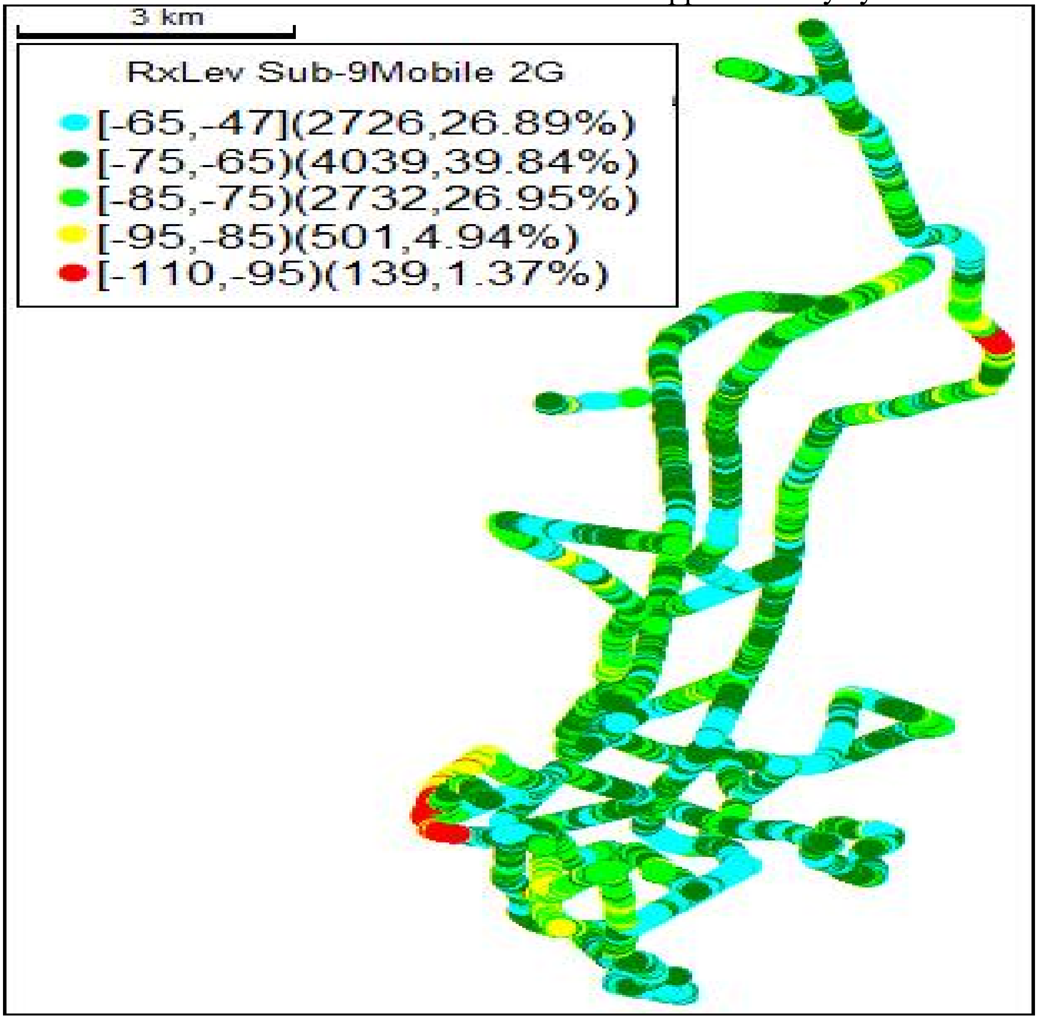

Fig 4: Coverage Plot for 9mobile Network

Conclusion

This research examines the performance of MTN, Airetel, Globacom and 9mobile networks, taking its received signal level (RxLev) as the key performance indicator (KPI) under consideration. This is done to ascertain the GSM network with the best coverage. The log files obtained during the drive test has a total of 10382, 10415, 10680 and 10137 RxLev measurements for MTN, Airtel, Globacom and 9mobile network. A TEMS discovery software was used to analyze the collected data in the form of coverage plots and was further put through a few measures of central tendency and dispersion, with a view to understanding the spread, the shape and the accuracy of the computed data. It was observed that 96.50%,93.60%, 95.40%and 93.70% of the drive test routes for MTN, Airtel, Globacom and 9mobile network met with the regulatory threshold of at least -85dBm. To check the spread of the distribution, the mean and standard deviation of each distribution was calculated. Mean values of -66dBm, -71dBm, -70dBm and -71dBm were obtained for MTN, Airtel, Globacom and 9mobile network. For MTN network, 68% of the measured data were within the range -66.00 ± 11.62dBm, 95% were within the range -66.00 ± 23.24dBm while 99.7% were within the range -66.00 ± 34.86dBm. For Airtel network, 68% of the measured data were within the range -71.00 ± 9.00dBm, 95% were within the range -71.00 ± 18.00dBm while 99.7% were within the range -

71.00 ± 27.00dBm. For Globacom network, 68% of the measured data were within the range -70.00 ± 9.20dBm, 95% were within the range -70.00 ± 18.40dBm, while 99.7% were within the range -70.00 ± 27.60dBm. Finally, for 9mobile network, 68% of the measured data were within the range -71.00 ± 10.10dBm, 95% were within the range -71.00 ± 20.20dBm, while 99.7% were within the range -71.00 ± 30. 30dBm. To examine the shape of the distribution, excess kurtosis and skewness of the distribution was calculated. MTN, Airtel, Globacom and 9mobile network had calculated values of excess kurtosis as 0.51, 0.25, 0.02 and 0.56, showing that the data distribution for MTN, Airtel and 9mobile network were slightly leptokurtic, while that of Globacom network was mesokurtic. Again, MTN, Airtel, Globacom and 9mobile network had calculated skewness values of -0.38, -0.08, -0.12 and -0.09, implying that the distribution was approximately symmetric. The low standard error values calculated is an indication that the data used in this study was not manipulated. The mobile networks investigated has shown excellent coverage from the results obtained and this will save as a guide to the network operators, the regulatory body, the network engineers and those in academics, to develop a propagation model for the accurate transmission of mobile network signals over Calabar South and Calabar Municipality.

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