Original Research Article

Quality of Service Reliability:A Study of Received Signal Quality in GSM Networks

Abstract

Every radio frequency (RF) design, after its implantation, should be regularly evaluated. The kernel of this article is to evaluate the performance of four GSM networks, taking its received signal quality (RxQual) into consideration. A total of 10501, 10140, 10415 and 10690RxQual measurements were obtained for MTN, 9mobile, Airtel and Globacom network. These generated data were subjected to statistical analysis in the form of bar charts, quality plots and calculations of measures of central tendency and dispersion. Result shows that 78.43%, 92.18%, 90.68% and 86.93% of the drive test route for MTN, 9mobile, Airtel and Globacom network had good signal quality and met with the Nigerian telecommunication regulatory benchmark of at least 4dB for RxQual. It is therefore deduced that in terms of RxQual, 9mobile was the best GSM network, followed by Airtel network, Globacom network and then MTN network. The result provided in this article will help mobile network operators to improve signal quality, ensure improved network coverage and increase network capacity in the future.

Keywords: Interference, received signal quality, GSM network, wireless networks, bit error rate

Introduction

Cellular networks are regulated in Nigeria by the Nigerian Communication Commission (NCC) and their performance is judged using specific telecommunication key performance indicators (KPIs) whichare segmented into categories; service integrity, service accessibility, service retainability, service mobility and service reliability [1-4]. One KPI investigated under service reliability in a cellular network is the received signal quality (RxQual).

RxQual is the measure of the signal quality in a GSM network during a call. It is a parameter which measures the amount of bit errors received by the MS that did not pass error checking [5]. The MS determines the bit error rate of the signal and reports it back to the network. It is the average received signal quality of the serving cell measured on all time slot and subset of time slots, measured on basis of bit error rate (BER)before channel decoding [3][6].These bits may have been garbled along the RF path or lost due to fading or interference.

It is given by a GSM scale of 0 to 7, where 0 is the best quality and 7 is the worst [7].The higher the value of the RxQual, the worse the communication services [6]. It is used to identify thequality of a voice call or data session and are logarithmically mapped to the BER percentage as shown in the table below [7].

Table 1: RxQualcodes with corresponding BER values

Received Signal Quality codes	Bit Error Rate (BER) in %
0	<0.2%
1	0.2% to 0.4%
2	0.4% to 0.8%
3	0.8% to 1.6%
4	1.6% to 3.2%
5	3.2% to 6.4%
6	6.4% to 12.8%
7	>12.8%

The quality of a radio network is dependent on its coverage, capacity and frequency allocation. Most of the severe problems of RxQual in a radio network can be attributed to signal interference. For uplink quality, bit error rate (BER) statistics is used and for downlink quality, frame error rate (FER) statistics is used. The problems may be caused by flaws in the frequency plan, configuration plans (e.g antenna tilts) and inaccurate correction factors used in propagation models [8]. Other causes are low received signal level, handover failure, assignment failure ratio and hardware problems[9].

When the RxQual is distorted in a network, the source has to be traced. The entire frequency plan is scrutinized to detectif the source is internal or external. This is done bydefining proper neighbours, checkingdiscontinuous reception (DRX) power and connectors, checkingbroadcast control channel (BCCH) andmobile allocation index offset (MAIO) frequency, reducingthe height of the antenna, orientation and tilt, checking the neighbouring list and definition, checking the neighbouring parameters, checking DRX, checking thevoltage standing wave ratio(VSWR) and RF cableconnectivity, checking DRX hardware[9], checking the transmitter-receiver distanceandfrequency reuse[10].

Researchers, in the world over, have investigated cellular network Quality of Service in various locations [11-22]but only a few is been centredonRxQual[23-30].The authors in [30] evaluated the quality of signal of UMTS radio access technology of three cellular networks (MTN, 9mobile and Airtel network) over two cities in Nigeria. A total of 10958, 11075 and 11109 Ec/Io measurements were obtained for MTN, 9mobile and Airtel network. These generated signals were subjected to statistical analysis in the form of bar charts, quality plots and calculations of measures of central tendency and dispersion. Result shows that only 59.64%, 50.45% and 17.02% of the drive test route for Airtel, 9mobile and MTN network had good signal quality and met with the Nigerian telecommunication regulatory benchmark of at least -9dB for Ec/Io. Also, 40.36%, 49.55% and 82.98% of the drive test area for Airtel, 9mobile and MTN network fell below the regulatory benchmark and subscribers in this region experienced dropped calls, blocked calls, handover failures and degraded signal quality due to interference. Airtel network was adjudged the best network while the worst network was MTN network.

The authors in [31] analyzed WCDMA network in both rural and urban areas of Mwanza, Tanzania. The parameters analyzed were Received Signal Code Power (RSCP), Transmitted Power (TX), Speech Quality Index (SQI) and the ration of received power to noise (Ec/No). The data collected shows that only 24.02% of the region had good coverage, 23.24% had poor coverage and 52.74% had fair coverage. Also, further analysis of the study area shows that only 27.61% of the region has good QoS, while the poor QoS was recorded in 2.76% of the region.

A well-established real 3G radio network performance evaluation is presented by the authors in [32] on the basis of Receive Signal Code Power (RSCP) and Signal-to-Interference Ratio (Ec/Io). Their focus was to analyze live indoor network performance of 3G network within the confines of Distributed Antenna Systems (DAS). The Tests was carried out by TEMS Investigation, one of the most powerful tools for measuring GSM/3G/LTE mobile wireless network Performance. Practical deployment has proved that Distributed Antenna System is a promising technology for improving indoor coverage and capacity in 3G mobile wireless technology. Installation of DAS in high traffic areas like hotels, malls, railways, public buildings can improve QoS by minimizing call blocking probability and Bit Error Rate (BER). The study shows how DAS can improve both RSCP and Ec/Io which are two important key performance indicators in delivering quality 3G services that leads to better user Quality of Experience (QoE).

In this article, a reliability-based performance analysis is carried out using the RxQual as the KPI. Four GSM operators are considered; MTN, 9mobile, Airtel and Globacom network. Thisresearch is carried out in two cities in Nigeria through an intensive drive test. The RxQual log files of the four networksare analyzed by a post-processing software and further put through statistical analysis for a comprehension of the collected data.The remaining part of this article is divided into three parts; first, we shall discuss the method at which this research was carried out, followed by the display and discussion of results and finally go into a conclusion.

Materials and Method

This study investigates the RxQual of fourGSM network operators in Calabar South and Calabar Municipality and to further make comparative analyses, so as to deduce the network with the best received signal quality, based on the NCC benchmark of at least – 4dB. The cellular networks investigated are MTN, Airtel, 9Mobile and Globacom network.

A measurement campaign was carried out through a drive test and RxQual data were collected over base stations in Calabar South and Calabar Municipality. The collected data were analyzed by a post-processing network tool in the form of quality plots using the TEMS discovery software. Furthermore,bar charts and measures of central tendency and dispersion (mean, standard deviations, standard errors of mean, kurtosis and skewness) were calculated for a better description and understanding of the RxQual in the terrain investigated.

Results and Discussion

An intensive measurement was conducted to evaluate the performance of fourGSM networks transmitting signals over Calabar, based on generated RxQual data during drive test. A total of 10501, 10140, 10415and 10690 RxQualdata were obtained for MTN, 9mobile, Airtel and Globacomnetwork. These generated data were subjected to statistical analysis whose summary is given in table 2. Figure 1 to 5 are bar charts comparing the RxQual of the networks at various range and finally, quality plots of the networks based on the drive test route are shown in Figure 6, 7, 8 and 9 for MTN, 9mobile, Airtel and Globacom network.

Table 2: Summary of Measures of Central Tendency and Dispersion

Mobile Networks	MTN	Globacom	9Mobile	Airtel
Mean (dB)	1.49	0.96	0.59	0.72
Minimum (dB)	0	0	0	0
Maximum (dB)	7	7	7	7
Kurtosis	-0.07	1.92	6.58	4.14
Skewness	1.19	1.80	2.75	2.29
Population Std. dev (dB)	2.19	1.80	1.53	1.60
Std. error of mean	0.02	0.02	0.02	0.02

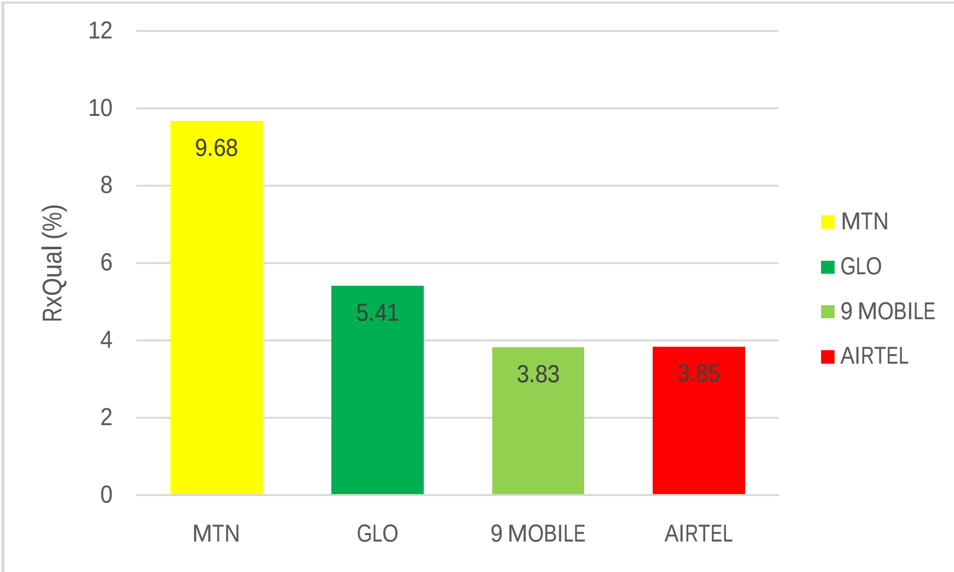

Figure 1: Percentage of RxQual at 6dB to 7dB for the networks under study

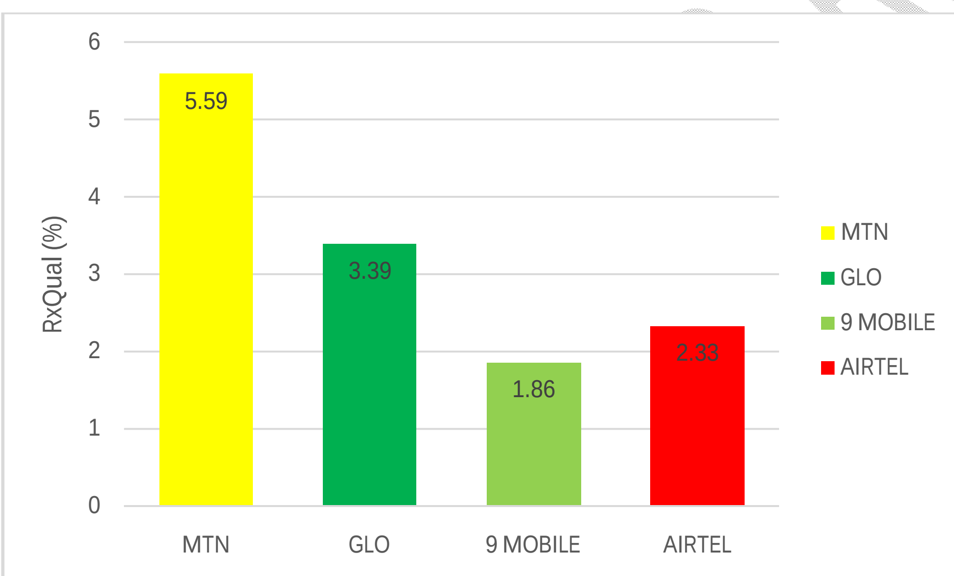

Figure 2: Percentage of RxQual at 5dB to 6dB for the networks under study

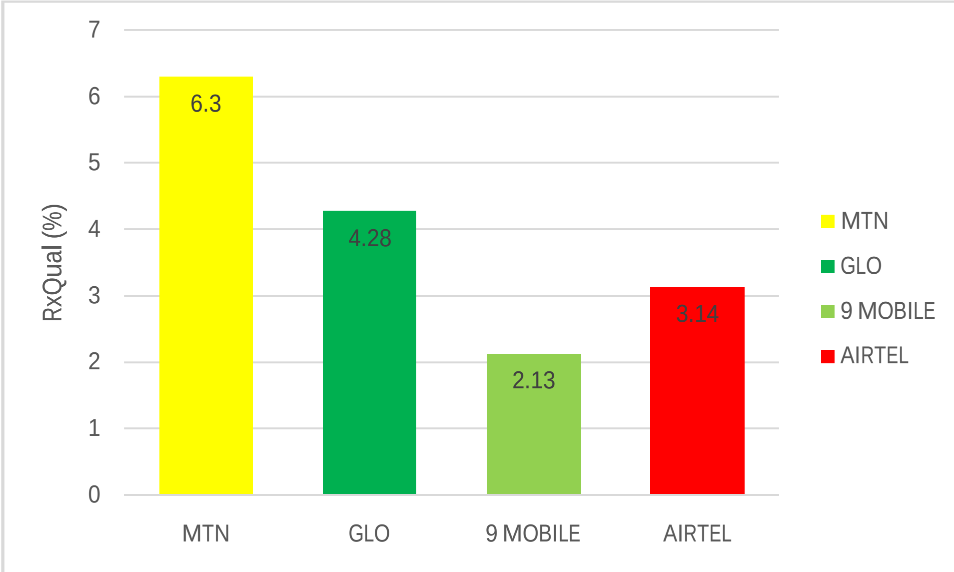

Figure 3: Percentage of RxQual at 4dB to 5dB for the networks under study

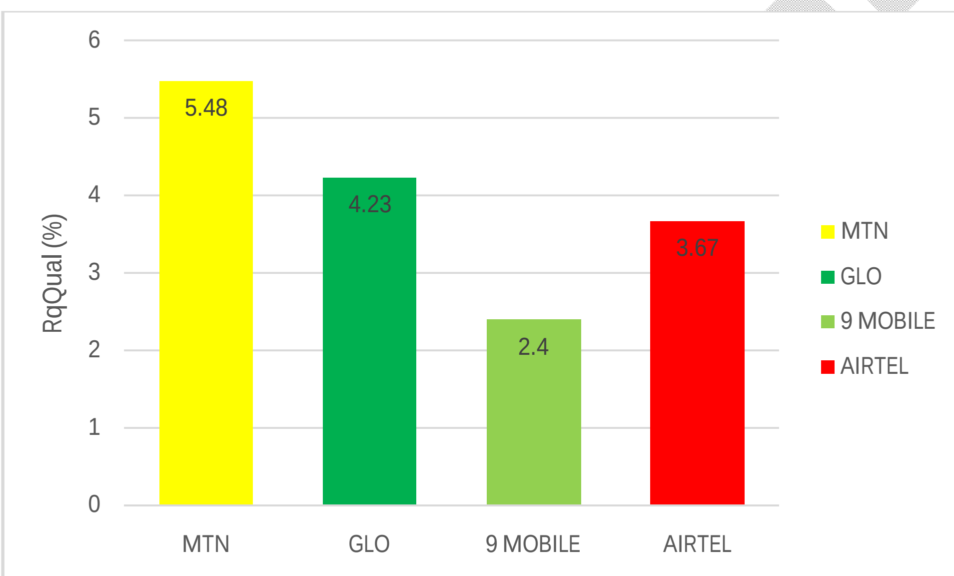

Figure 4: Percentage of RxQual at 3dB to 4dB for the networks under study

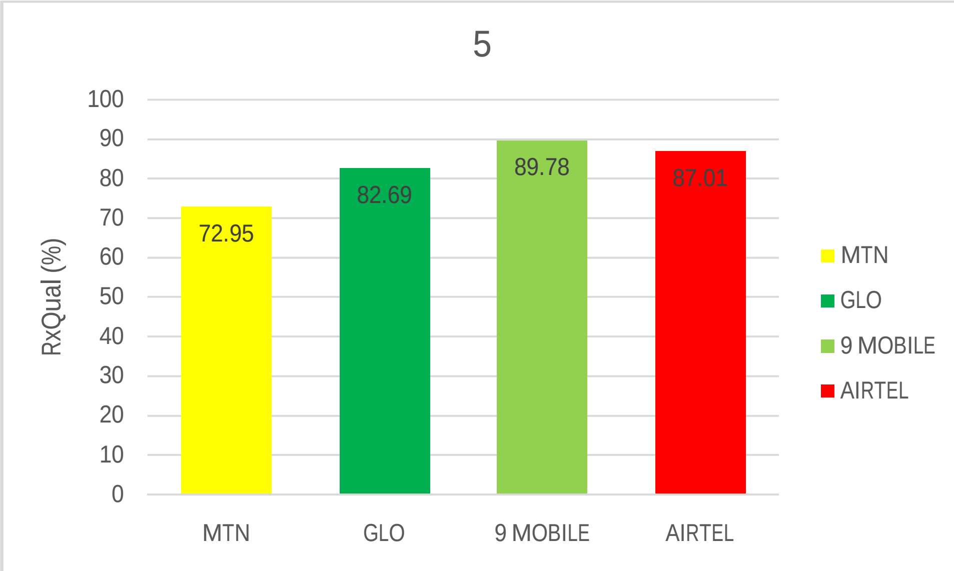

Figure 5: Percentage of RxQual at 0dB to 3dB for the networks under study

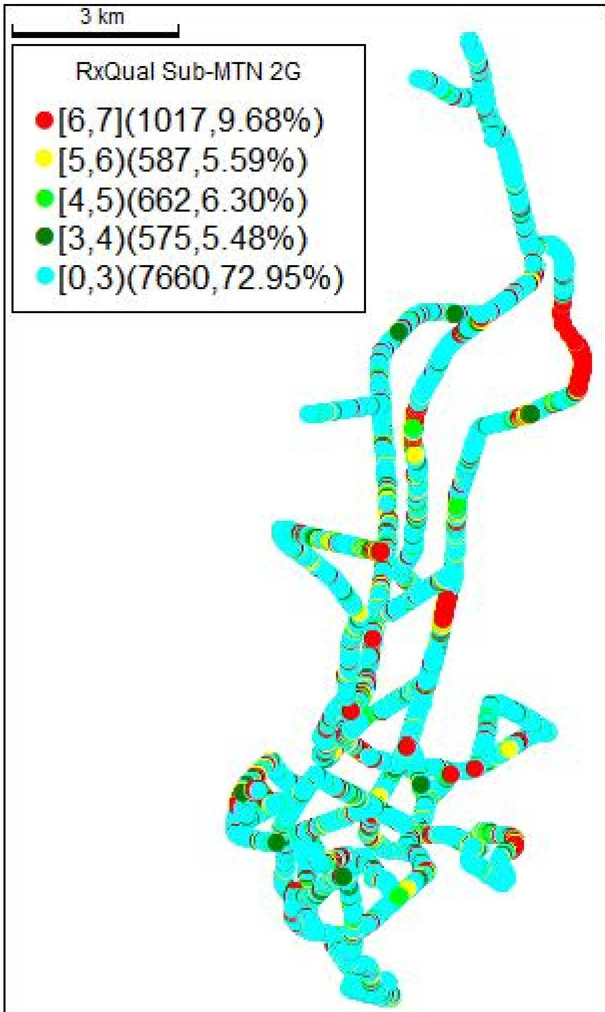

Figure 6: Quality plots of RxQual for MTN Network

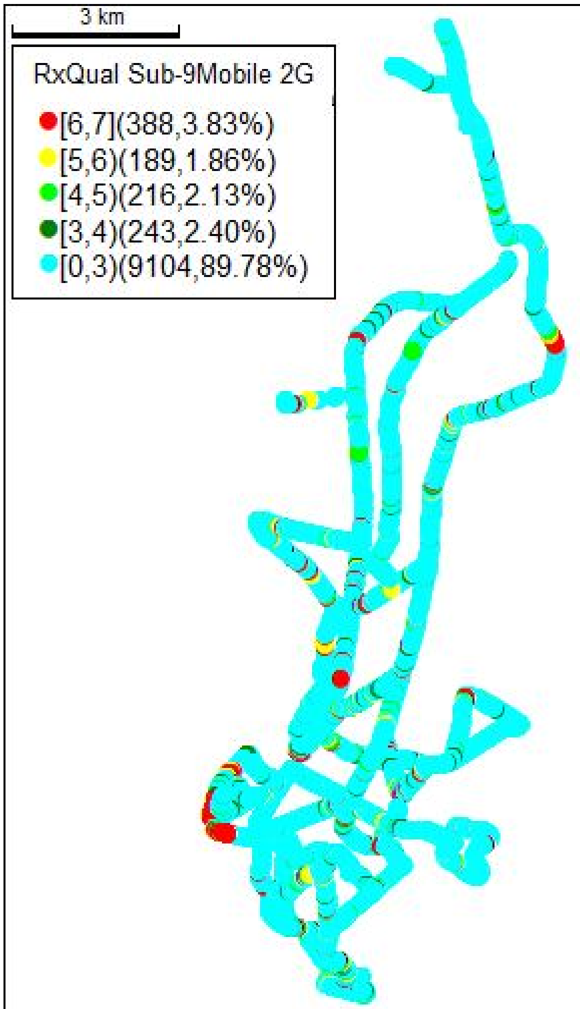

Figure 7: Quality plots of RxQual for 9mobile Network

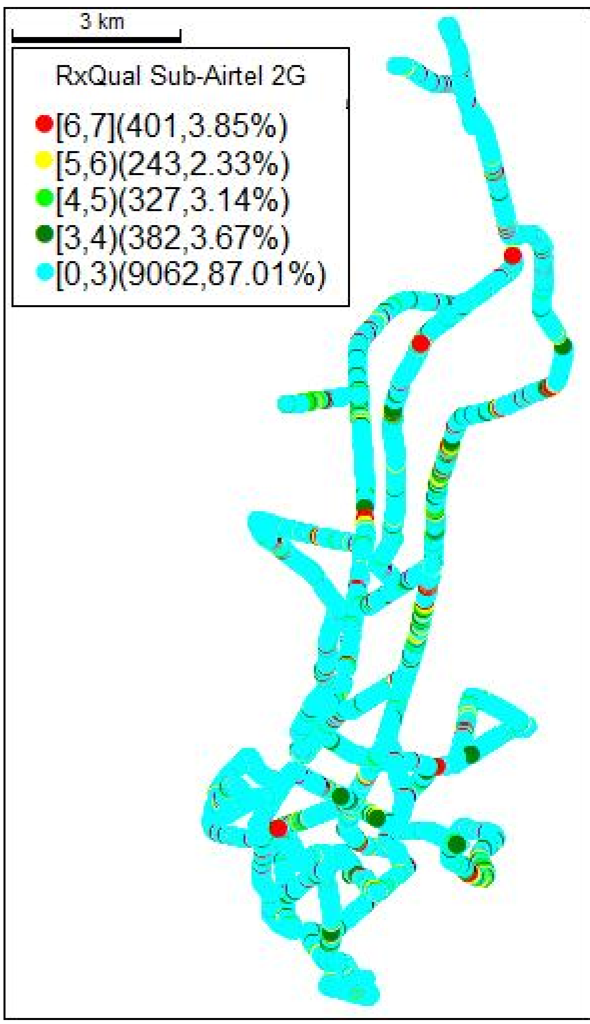

Figure 8: Quality plots of RxQual for Airtel Network

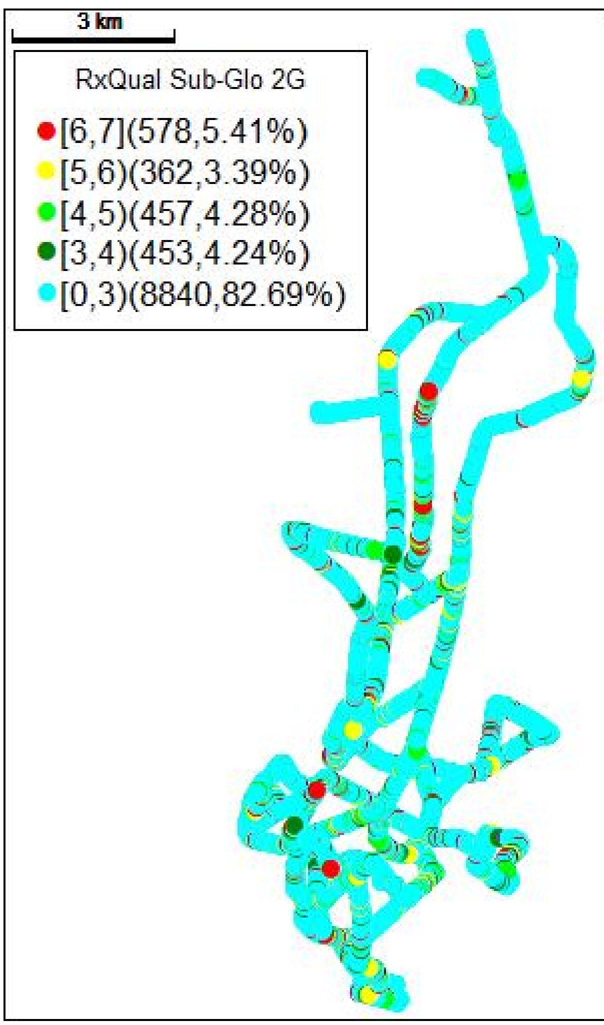

Figure 9: Quality plots of RxQual for Globacom Network

To estimate the efficiency, accuracy and consistency of the measured data, standard error of the collected data were calculated.A low value of 0.02 was obtained for the four networks, showing that the data used in this study were precise and not forged.

To consider the shape of the distribution, the kurtosis and skewness of the distribution was calculated. MTN, 9mobile, Airtel and Globacomnetwork were seen to have excess kurtosis of -0.07, 6.58, 4.14 and 1.92. This shows that the data distribution in MTN network was slightly platykurtic, the distribution for 9mobile and Airtel network were heavily leptokurtic while that of Globacom network was moderately leptokurtic. Again, MTN, 9mobile, Airtel and Globacomnetwork had skewness valuesof1.19, 2.75, 2.29 and 1.80. This means that the data distribution for the four networks were highly skewed.

To check forthe spread of data, the mean and the standard deviation of each distribution was calculated. Mean values of 1.49dB, 0.59dB, 0.72dB and 0.96dB were obtained for MTN, 9mobile, Airtel and Globacomnetwork as shown in table 2. Result from the computed standard deviationshowsthat for MTN network,68% of the measured data were within the range of 0dB to 4dB, 95% were within therange of 0dB to 6dB while 99.7% were within the range of 0dB to 7dB. For 9mobile network, 68% of the measured data were within the range of 0dB to 2dB, 95% were within the range of 0dB to 4dB while 99.7% were within the range of 0dB to 5dB. For Airtel network,68% of the measured data were within therange of 0dB to 2dB, 95% were within therange of 0dB to 4dB while 99.7% were within the range of 0dB to 6dB. Lastly, for Globacom network,68% of the measured data were within therange of 0dB to 3dB, 95% were within therange of 0dB to 5dB while 99.7% were within therange of 0dB to 6dB.

Figure 1 gives a picture of data values within therange of 6dB to 7dB for the four networks. 9.68%, 3.83%, 3.85% and 5.41% of the measured data werewithin this category for MTN, 9mobile, Airtel and Globacomnetwork. This means that only 1017, 388, 401 and 578 samples in the 10501, 10140, 10415 and 10690 distributions were in this category. This region is denoted by a red colour and the subscribers are very dissatisfied as a result of very high interference due to poor signal quality.

Figure 2 gives a bar chart of data values within therange of 5dB to 6dB for the four networks. 5.59%, 1.86%, 2.33% and 3.39% of the measured data werewithin this category for MTN, 9mobile, Airtel and Globacomnetwork. This means that only 587, 189, 243 and 362 samples in the 10501, 10140, 10415 and 10690 distributions were in this category. This region is denoted by a yellowcolour and the subscribers are dissatisfied as it is characterized by poor coverage and interference.

Figure 3 gives a bar chart of data values within therange of
4dB to 5dB for the four networks. 6.30%, 2.13%, 3.14% and 4.28% of the measured data were within this category for MTN, 9mobile, Airtel and Globacomnetwork. This means that only 662, 216, 327 and 457 samples in the 10501, 10140, 10415 and 10690 distributions were in this category. This region is denoted by a light greencolourand subscribers are dissatisfied as it is characterized by fair coverage with moderate interference.

Figure 4 gives a bar chart of data values within therange of3dB to 4dB for the four networks. 5.48%, 2.40%, 3.67% and 4.24% of the measured data were within this category for MTN, 9mobile, Airtel and Globacomnetwork. This means that only 575, 243, 382 and 453 samples in the 10501, 10140, 10415 and 10690 distributions were in this category. This region is denoted in dark green. The subscribers are very satisfied since the signal quality is very good.

Figure 5 gives a bar chart of data values within therange of0dB to 3dB for the four networks. 72.95%, 89.78%, 87.01% and 82.69% of the measured data were within this category for MTN, 9mobile, Airtel and Globacomnetwork. This means that only 7660, 9104, 9062 and 8840 samples in the 10501, 10140, 10415 and 10690 distributions were in this category. In this region, network quality was excellent and the subscribers were remarkably satisfied.

Conclusion

A performance evaluation of GSM networks in Calabar South and Calabar Municipality has been conducted, taking the RxQual as the key performance indicator in consideration. The four networks had satisfactory RxQual, with 9mobile network being the best, followed by Airtel network, then Globacom and finally MTN network. However, a fewspots in the area under study had poor coverage and this was characterized by several blocked calls, failed handovers, slow data services and dropped calls. The areas with poor quality of service were mainly due to the introduction of bit errors which introduces interference in GSM networks. The network operators are advised to optimize their networks frequently to enhance the Quality of Service (QoS) the render to subscribers.

COMPETING INTERESTS DISCLAIMER:

Authors have declared that no competing interests exist. The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

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