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Investigation of Received Signal Quality of 3G GSM Networks in Yenagoa – Southern Nigeria

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Abstract

After implementation, every radio frequency (RF) design should be assessed on a regular basis. The core of this article is to assess the performance of four GSM networks while taking received signal quality (RxQual) into account. RxQual readings of 10211, 10170, 10275, and 10523 were recorded for the MTN, Globacom, Airtel, and 9mobile networks. These collected data were statistically analyzed using bar charts, quality plots, and the generation of measures of central tendency and dispersion. The results reveal that for MTN, Globacom, Airtel, and 9mobile networks, 70.14%, 81.34%, 90.13%, and 88.52% of the driving test route had high signal quality and fulfilled the Nigerian telecommunication regulatory threshold of at least 4dB for RxQual. As a result, it can be concluded that Airtel had the best GSM network in terms of RxQual, followed by 9mobile, Globacom, and MTN. The results presented in this paper will assist mobile network operators in the future in improving signal quality, ensuring enhanced network coverage, and increasing network capacity.

1. Introduction

The Nigerian Communication Commission (NCC) regulates cellular networks in Nigeria, and their performance is measured using specific telecommunication key performance indicators (KPIs) divided into five categories: service integrity, service accessibility, service retainability, service mobility, and service reliability [1]. Under service reliability, a major KPI is the Received Signal Quality (RxQual). RxQual is a parameter that represents the quantity of bit errors received by the MS that did not pass error checking during a call [1, 2, 5]. The MS evaluates the bit error rate of the signal and reports it back to the network. There are several factors that affect the RxQual, firstly, the signal quality can be influenced by the distance between the transmitter and the receiver [3,4]. As the distance increases, the signal strength tends to weaken, resulting in a lower received signal quality. This is known as path loss. Additionally, the presence of obstacles such as buildings, trees, or even weather conditions like rain or fog can also impact the received signal quality [1,4]. These obstacles can cause signal attenuation or reflection, leading to signal degradation. Furthermore, the frequency at which the telecommunication network operates plays a crucial role in signal quality [5,9]. Higher frequency signals tend to have shorter wavelengths, making them more susceptible to attenuation and interference. On the other hand, lower frequency signals can travel longer distances and penetrate obstacles more effectively [6]. Another important factor is the presence of interference from other devices or networks operating in the same frequency band. This interference can degrade the received signal quality and result in data loss or dropped calls [8]. Telecommunication networks also employ various techniques to improve the received signal quality. For example, they may use signal amplification or repeaters to boost the signal strength over long distances [7, 10, 11].

Additionally, advanced modulation and coding schemes are used to enhance the signal robustness and minimize errors. It's worth mentioning that different telecommunication technologies have their own specific considerations for signal quality [10,12]. For instance, in cellular networks, signal quality is often measured using metrics like signal-to-noise ratio (SNR) or bit error rate (BER). These metrics provide insights into the overall quality of the received signal.

When the RxQual in a network is distorted, the source must be tracked down. The complete frequency plan is examined to determine whether the source is internal or external. This is accomplished by defining proper neighbors, inspecting discontinuous reception (DRX) power and connectors, inspecting broadcast control channel (BCCH) and mobile allocation index offset (MAIO) frequency, lowering the antenna height, orientation, and tilt, inspecting the neighboring list and definition, inspecting the neighboring parameters, inspecting DRX, inspecting the voltage standing wave ratio (VSWR) and RF cable connectivity, inspecting DRX hardware [9], inspecting the transmitter-receiver distance and frequency reuse. This study is aimed at filling several knowledge gaps and to contribute to various aspects of network optimization, performance improvement, and technological advancements. Some of the possible knowledge gaps that this study addresses include:

1. Network Optimization: with this study, areas with poor signal quality will be identified which will help in optimizing network coverage and capacity in those regions. It will also assess the performance of base stations and their configuration to ensure the highest signal quality across the network.

2. Quality of Service (QoS) Improvement: As the factors affecting voice and data quality in GSM networks are analyzed, it will enhance the overall user experience. It will also study the effects of signal quality on call drops, call setup time, and data transfer rates to reduce service disruptions.

3. Interference and Noise Mitigation: It will provide a better understanding of the sources of interference and noise, such as adjacent channel interference or co-channel interference, to develop strategies for mitigating their effects. It will further investigate the techniques for reducing interference from other electronic devices or environmental factors.

4. Handover and Roaming: An Evaluation of the handover mechanisms between cell towers and the impact of signal quality on seamless handovers will be achieved while assessing the quality of service during international or national roaming and identifying areas for improvement.

5. Power Efficiency: The Study will show how variations in signal quality affect power consumption in mobile devices and base stations to optimize energy usage which will ultimately lead to Developing energy-efficient strategies for maintaining signal quality while conserving battery life.

6. Location-Based Services: An Investigation on how signal quality can impact the accuracy of location-based services (LBS), such as GPS or location tracking, to improve their precision is also achieved in this study which gives a framework for developing algorithms and technologies that utilize signal quality data for better positioning.

7. Security and Privacy: this study also shows a preliminary examination of how signal quality metrics can be used for security and privacy purposes, such as detecting unauthorized network access or eavesdropping attempts which helps in developing techniques to secure GSM networks against signal quality-related vulnerabilities.

8. Spectrum Management: Understanding the correlation between signal quality and spectrum utilization to make informed decisions regarding spectrum allocation and utilization. This is achieved by studying the potential for spectrum sharing and dynamic spectrum access based on signal quality data.

9. Future Network Evolution: Using signal quality data to inform the deployment and optimization of next-generation mobile networks, such as 5G and beyond. This helps in anticipating the challenges and opportunities presented by evolving network technologies and standards.

10. User Experience and Service Quality: The study also Investigates how signal quality impacts user satisfaction and the overall quality of GSM services which assist in incorporating signal quality metrics into service-level agreements (SLAs) to improve customer service.

1.2. Previous Studies

Researchers from all around the world have researched cellular network Quality of Service in diverse settings, but only a few have focused on RxQual.
The authors of [1] investigated the WCDMA network in both rural and urban Mwanza, Tanzania. Received Signal Code Power (RSCP), Transmitted Power (TX), Speech Quality Index (SQI), and the ratio of received power to noise (Ec/No) were the metrics studied. According to the statistics gathered, only 24.02% of the region had strong service, 23.24% had poor coverage, and 52.74% had acceptable coverage. Furthermore, additional examination of the research area reveals that just 27.61% of the region has acceptable QoS, while 2.76% has bad QoS.
In similar manner [7] propose a well-established actual 3G radio network performance evaluation based on Receive Signal Code Power (RSCP) and Signal-to-Interference Ratio (Ec/Io). Their primary goal was to examine the live indoor network performance of a 3G network inside the limits of Distributed Antenna Systems (DAS). TEMS Investigation, one of the most powerful tools for analyzing GSM/3G/LTE mobile wireless network performance, conducted the tests. The practical deployment of the Distributed Antenna System has demonstrated that it is a viable solution for boosting indoor signal strength and capacity within 3G mobile wireless technology. DAS installation in high-traffic locations such as hotels, malls, trains, and public buildings may enhance QoS by lowering call blocking percentage and Bit Error Rate (BER). The study demonstrates how DAS may increase both RSCP and Ec/Io, two significant key performance metrics in providing quality 3G services, resulting in an improved subscriber Quality of Experience (QoE).
The authors of [1] assessed the signal quality of three cellular networks across two cities in Nigeria. The produced signals were statistically analyzed using bar charts, quality plots, and the generation of measures of central tendency and dispersion. Only 59.64%, 50.45%, and 17.02% of the driving test route for Airtel, 9mobile, and MTN networks had satisfactory signal quality and satisfied the Nigerian telecom regulatory guidelines of at least -9dB for Ec/Io, respectively. Furthermore, 40.36%, 49.55%, and 82.98% of the driving test area for Airtel, 9mobile, and MTN networks came beneath the regulatory threshold, resulting in lost calls, blocked calls, handover failures, and decreased signal quality owing to interference. Airtel's network was deemed the most reliable, meanwhile MTN's network was ranked the least satisfactory.
In this paper, a reliability-based performance evaluation is conducted with the RxQual as the key performance indicator (KPI). MTN, Globacom, Airtel, and 9mobile network are the four GSM providers under consideration. This study is being conducted across two towns in Nigeria via an intense drive test. The RxQual log files from the four networks are evaluated by post-processing applications and then statistically analyzed to have a better understanding of the obtained data.

2.0. Materials and Method

This study examines the RxQual of four GSM network providers in Yenagoa, Bayelsa State - Nigeria and conducts comparative assessments to determine which network has the best received signal quality, based on the NCC standard of at least - 4dB. Cellular networks analyzed include MTN, Globacom, Airtel, and 9mobile.
Materials used are

1. TEMs investigation 20.0 installed in a computer system
2. A Samsung SM-G900V mobile phone
3. A Global Positioning System (GPS)
4. A Car for mobility

A driving test was used to conduct a measurement campaign, and RxQual data was gathered using TEMs Investigation 20.0 from base stations in Yenagoa. The test was done within the peak hour period (11:30am – 2:00pm) and the routes taken was Tombia Roundabout through Melford Okilo Road (Mbiama-Yenagoa Road) through Alamiesiye Road Through Isaac Adaka Boroh Express way Through Ebis Road Through Melford Okilo Road Through Azikoro Road Through Berger Roundabout Through Sani Abacha Express Way Through Lambert Eradiri Road Through Bayelsa State Government House Through Hospital Road Junction Through Sani Abacha Way Through Isaac Adaka Boroh Express Way Back to Tombia Roundabout. Call initiation was done at a regular interval of 3mins. The obtained data was examined by a post-processing network tool in the form of quality charts. For a better description and comprehension of the RxQual in the landscape studied, bar charts and measurements of central tendency and dispersion (mean, standard deviations, standard errors of mean, kurtosis, and skewness) were created.

3.0. Results

Based on RxQual data collected during the driving test, an elaborate measurement was performed to evaluate the performance of four GSM networks sending signals over Yenagoa. RxQual data for MTN, Globacom, Airtel, and 9mobile networks totaled 10211, 10170, 10275, and 10523. These produced data were subjected to statistical analysis, the results of which are summarized in Table 1. Fig. 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 Figs. 6, 7, 8 and 9 for MTN, Globacom, Airtel and 9mobile network.

Table 1. Summary of Measures of Central Tendency and Dispersion

Mobile Network	MTN	GLO	AIRTEL	9mobile
Mean (dB)	0.38	0.90	0.58	0.63
Maximum (dB)	7.25	7.38	7.20	7.28
Minimum (dB)	-0.12	-0.04	0.00	-0.07
Kurtosis	-0.10	0.09	1.11	3.24
Skewness	1.23	1.44	2.68	1.96
Population Std. dev (dB)	2.17	1.16	1.47	1.60
Std. error of mean (dB^2)	0.02	0.03	0.02	0.02

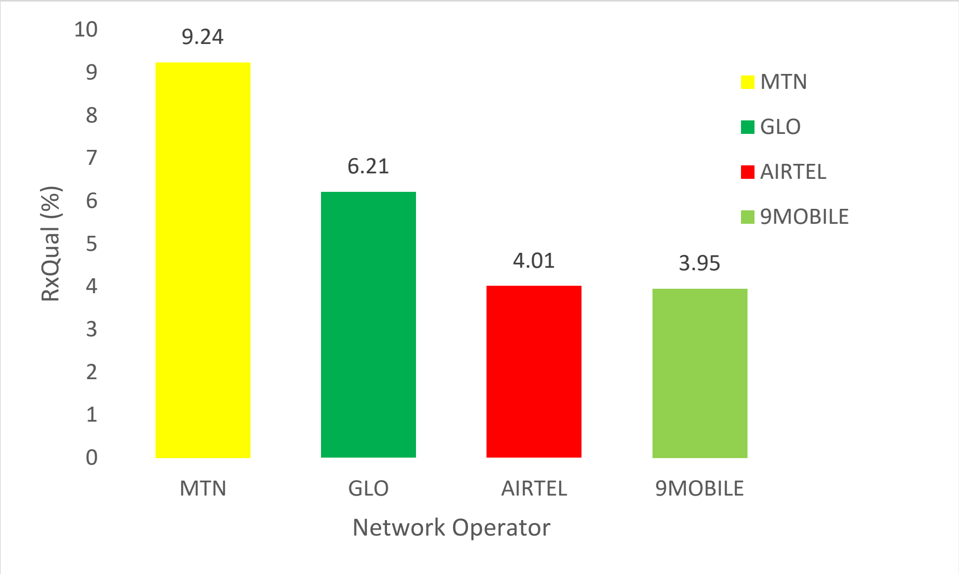

Fig. 1. Percentage of RxQual at 6dB to 7dB for the networks under study

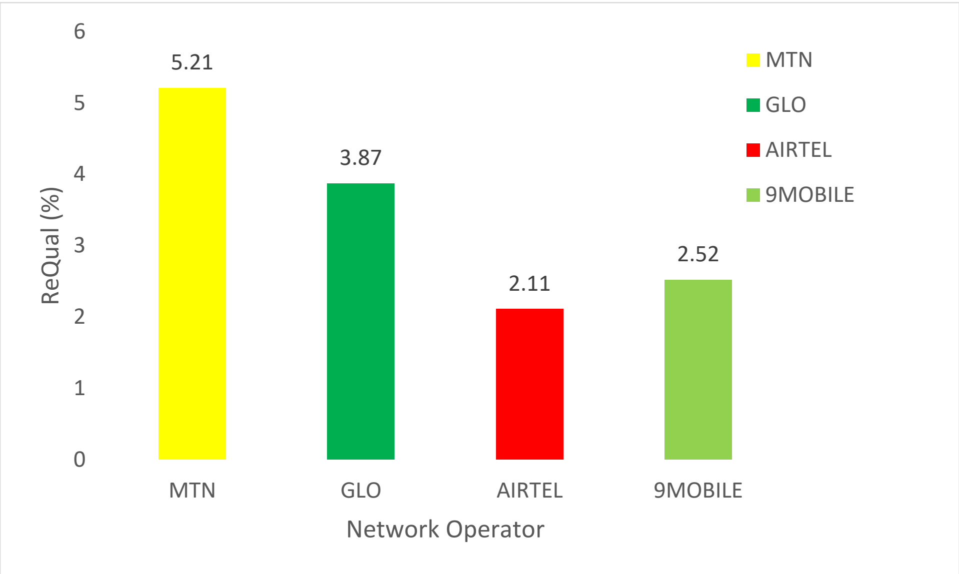

Fig. 2. Percentage of RxQual at 5dB to 6dB for the networks under study

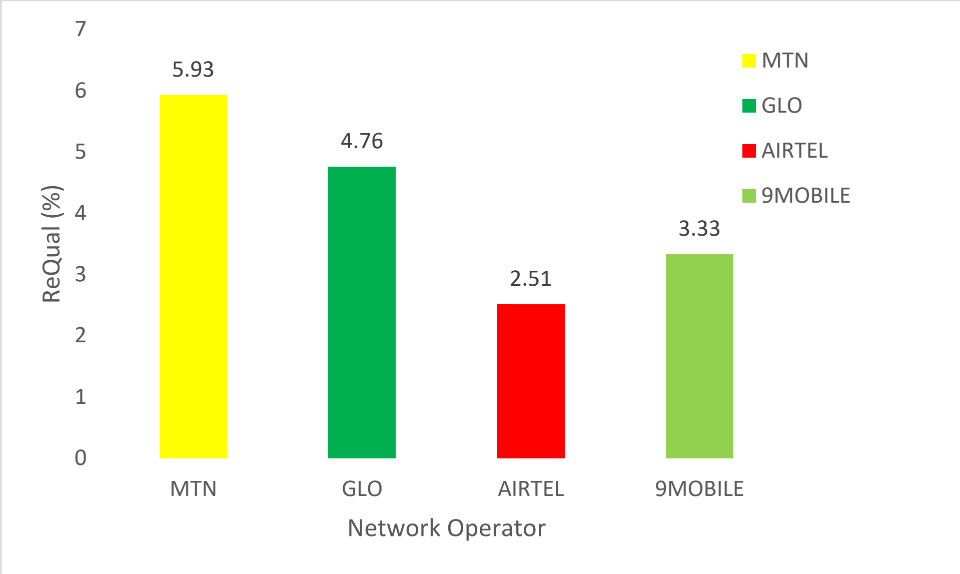

Fig. 3. Percentage of RxQual at 4dB to 5dB for the networks under study

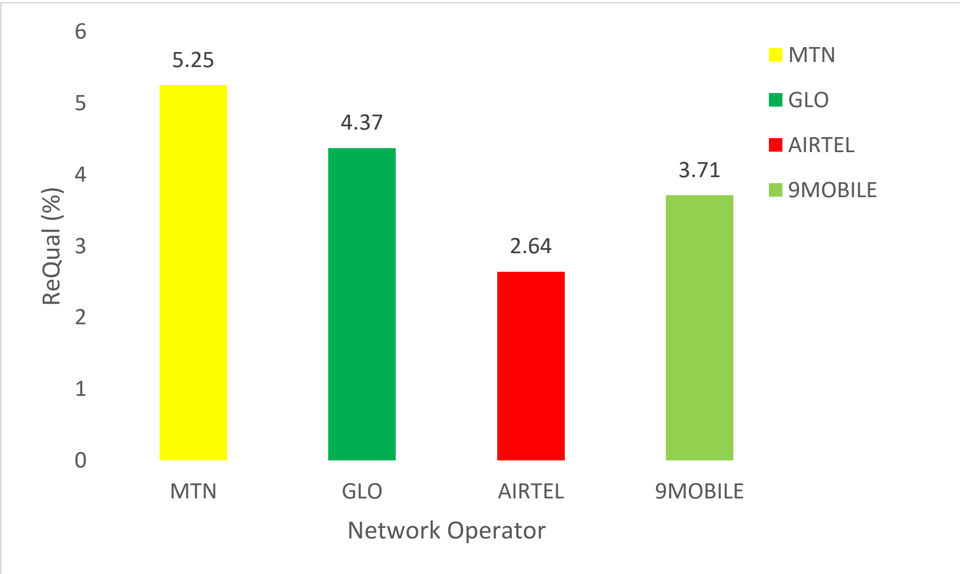

Fig. 4. Percentage of RxQual at 3dB to 4dB for the networks under study

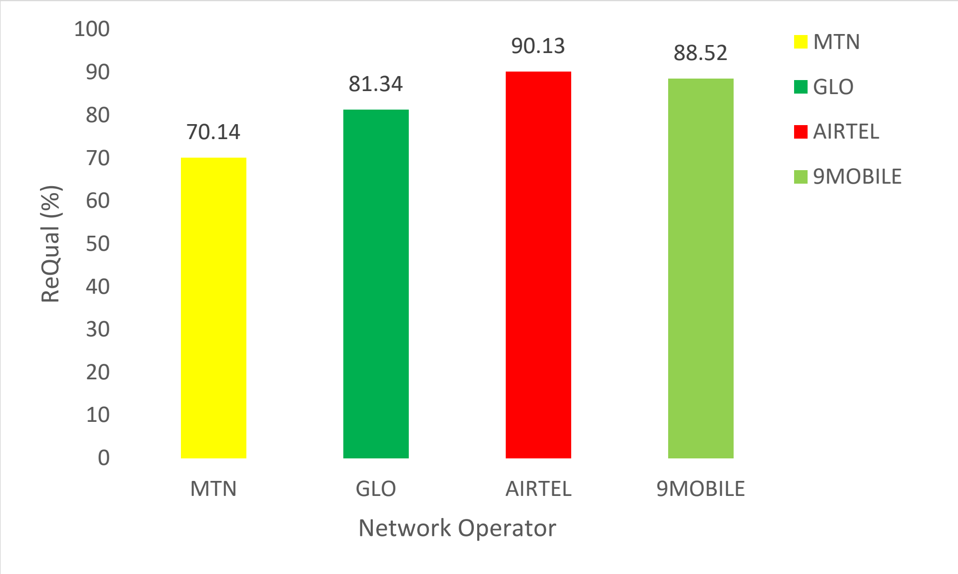

Fig. 5. Percentage of RxQual at 0dB to 3dB for the networks under study

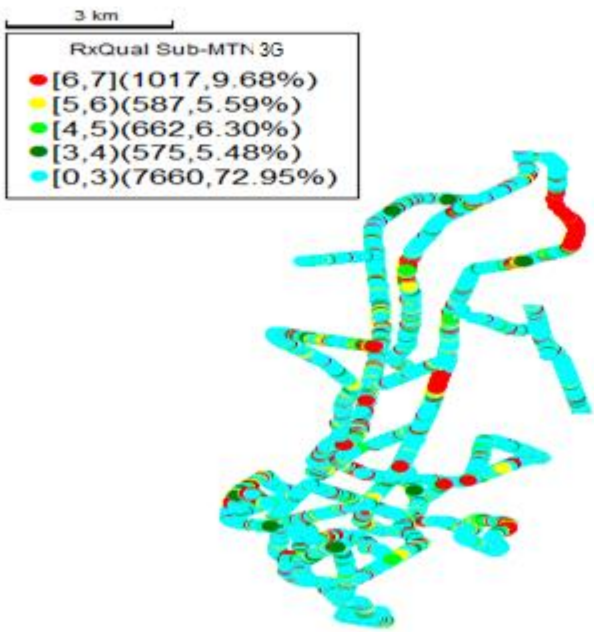

Fig. 6. Quality plots of RxQual for MTN Network

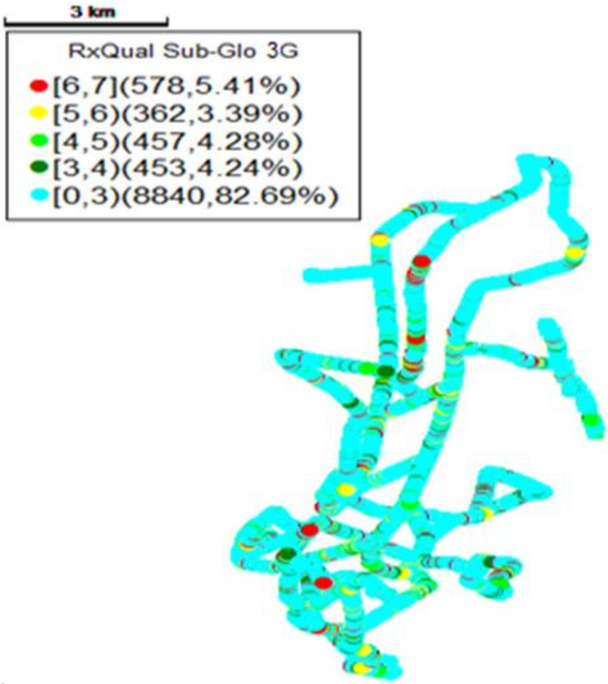

Fig. 9. Quality plots of RxQual for Globacom Network

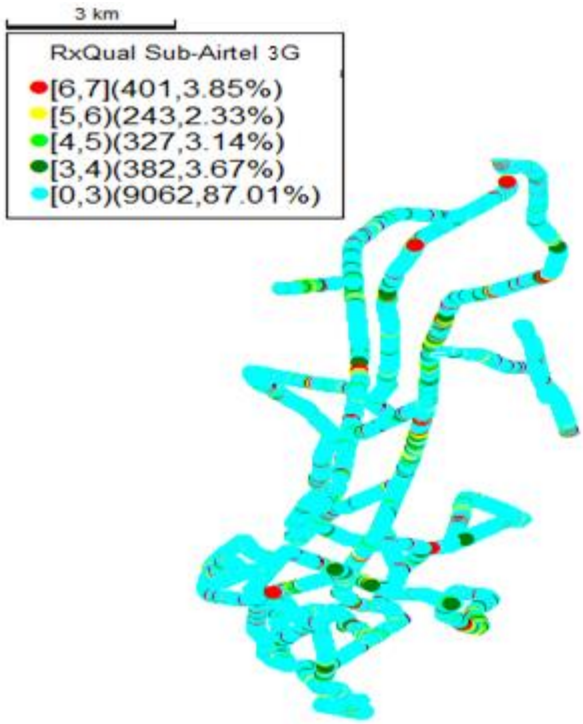

Fig. 8. Quality plots of RxQual for Airtel Network

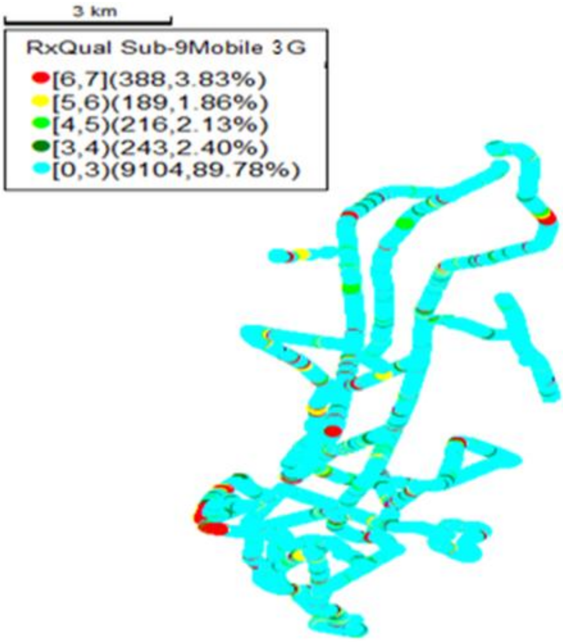

Fig. 7. Quality plots of RxQual for 9mobile Network

The kurtosis and skewness of the distribution were determined to examine the form of the distribution. Excess kurtosis was observed on the MTN, Globacom, Airtel, and 9mobile networks, with values of -0.10, 0.09, 1.11, and 3.24. This demonstrates that the data distribution in the MTN network was somewhat platykurtic, while the distributions in the Globacom and Airtel networks were highly leptokurtic and the distribution in the 9mobile network was moderately leptokurtic. MTN, Globacom, Airtel, and 9mobile networks showed skewness values of 1.23, 1.44, 2.68, and 1.96 respectively. This suggests that the distribution of data across the four networks was extremely skewed. The mean and standard deviation of each distribution were computed to check for data dispersion. Table 1 shows mean values of 0.38dB, 0.90dB, 0.58dB, and 0.63dB for MTN, Globacom, Airtel, and 9mobile networks. According to the computed standard deviation, 63% of the measured data for MTN network were within the range of 0dB to 4dB, 92% were within the range of 0dB to 6dB, and 99.9% were within the range of 0dB to 7dB. Regarding the Globacom network, 67% of the observed data fell within the 0dB to 2dB range, 95% fell within the 0dB to 4dB range, and 99.8% fell within the 0dB to 5dB range. For the Airtel network, 70% of the observed data fell within the 0dB to 2dB range, 97% fell within the 0dB to 4dB range, and 99.9% fell within the 0dB to 6dB range. Finally, on the 9mobile network, 67% of the observed data fell within the 0dB to 3dB range, 94% fell within the 0dB to 5dB range, and 99.6% fell within the 0dB to 6dB range.

Figure 1 depicts data values for the four networks in the 6dB to 7dB range. This category contained 9.24%, 6.21%, 4.01%, and 3.95% of the measured data for MTN, Globacom, Airtel, and 9mobile networks, respectively. This indicates that only 943, 632, 412, and 416 samples from the distributions 10211, 10170, 10275, and 10523 fell into this group. This location is marked by a red color, and subscribers are extremely unsatisfied as a result of extremely high interference caused by poor signal quality.

Figure 2 shows a bar chart of data values for the four networks ranging from 5dB to 6dB. This category contained 5.21%, 3.87%, 2.11%, and 2.52% of the measured data for MTN, Globacom, Airtel, and 9mobile networks, respectively. This indicates that only 532, 394, 217, and 265 samples were included in the 10211, 10170, 10275, and 10523 distributions, respectively in this category. This location is marked by a yellow color, and subscribers are unsatisfied because of inadequate coverage and interference.

Figure 3 shows a bar chart of data values for the four networks ranging from 4dB to 5dB. This category contained 5.93%, 4.76%, 2.51%, and 3.33% of the measured data for MTN, Globacom, Airtel, and 9mobile networks, respectively. This indicates that only 606, 484, 258, and 342 samples from the distributions 10211, 10170, 10275, and 10523 fell into this group. This location is marked by a light green color, and subscribers are disappointed since it provides fair coverage with mild interference.

Figure 4 depicts a bar chart of data values for the four networks ranging from 3dB to 4dB. This group contained 5.25%, 4.37%, 2.64%, and 3.71% of the measured data for MTN, Globacom, Airtel, and 9mobile networks, respectively. This indicates that of the 10211, 10170, 10275, and 10523 distributions, only 536, 444, 271, and 390 samples fell into this group. This area is highlighted in dark green. Subscribers are quite pleased since the signal quality is excellent.

Figure 5 shows a bar chart of data values for the four networks ranging from 0dB to 3dB. 70.14%, 81.34%, 90.13%, and 88.52% of the measured data for MTN, Globacom, Airtel, and 9mobile networks fell into this group. This indicates that only 7161, 8272, 9261, and 9315 samples from the distributions 10211, 10170, 10275, and 10523 fell into this group. The network quality in this region was exceptional, and customers were quite delighted.

4.0. Conclusion and Recommendation

A performance evaluation of GSM networks in Yenagoa was carried out, with the RxQual as the key performance indicator. The four networks had acceptable RxQual, with Airtel network being the best, followed by 9mobile network, Globacom network, and lastly MTN network. However, a few sites in the research region had inadequate coverage, as evidenced by multiple blocked calls, unsuccessful handovers, delayed data services, and lost calls. The areas with poor service quality were mostly caused by the introduction of bit errors, which cause interference in GSM networks. It is recommended that network operators optimize their networks on a regular basis in order to improve the Quality of Service (QoS) they provide to subscribers.

When conducting a study on the received signal quality of GSM networks in a suburban setting like Yenagoa, it's essential to consider various factors that can impact the quality of service. Below are some recommendations for further study:

1. Site Selection: Choose study sites that represent different suburban environments, such as residential areas, commercial districts, and open spaces, to capture a diverse range of signal quality conditions.

2. Data Collection: Use specialized equipment or mobile devices with signal measurement capabilities to collect signal quality data. Collect data at different times of day and on different days of the week to account for variations in network traffic.

3. Signal Quality Metrics: Measure and record key signal quality metrics, such as signal strength (RSSI), signal-to-noise ratio (SNR), and bit error rate (BER), to assess the overall quality of the received signals.

4. Location Data: Collect GPS coordinates or other location data for each measurement point to create geospatial maps of signal quality variations across the suburban area.

5. Benchmarking: Compare the signal quality of the GSM network under study with that of other wireless networks (if available) to provide a context for performance evaluation.

6. Network Analysis: Analyze the data to identify areas with weak or strong signal quality and investigate potential causes, such as cell tower placement, interference sources, or geographical features. Examine handover performance between neighboring cell towers, as suburban areas may have complex handover requirements due to varying signal strengths.
7. Interference Sources: Identify sources of interference, including nearby electronic devices, buildings, or natural obstacles like hills and trees, and assess their impact on signal quality.
8. Coverage Maps: Create coverage maps that illustrate signal quality across the suburban area. These maps can be used to identify coverage gaps and areas with degraded service.
9. Network Planning: Provide recommendations for network planning and optimization, such as the need for additional cell towers, adjusting antenna tilt, or optimizing frequency allocation.
10. Environmental Factors: Consider how environmental conditions, such as weather or seasonal changes, can affect signal quality, especially in suburban areas.
11. Future Technologies: Anticipate the potential impact of emerging technologies like 5G on suburban signal quality and recommend strategies for a smooth transition.
12. Security and Privacy: Evaluate any security and privacy implications associated with signal quality data collection and storage, and ensure compliance with relevant regulations.
13. Community Engagement: Engage with local communities, authorities, and mobile network operators to foster collaboration and gather insights into specific suburban challenges and needs.
14. Reporting and Recommendations: Present findings in a clear and actionable report, including recommendations for improving signal quality, enhancing user experiences, and optimizing network performance in the suburban setting.

Disclaimer

The materials employed in this study are frequently and mostly used in our field of study and nation. There is no conflict of interest between the author and the makers of the items because the intention is not to utilize these products as a tool for litigation but rather to promote knowledge. Furthermore, the study wasn't funded by the production firm, but rather by the author's own efforts.

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