EVALUATION OF MOBILE COMMUNICATION NETWORK PERFORMANCE IN DELTA STATE, NIGERIA

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ABSTRACT
This research offers an assessment of the performance of the mobile communication network conducted in Delta State, Nigeria. The assessment is based on Quality of Service characteristics. Blocks, lost calls, speech quality, and Received Signal Strength (RSS) were all taken into account for the Quality of Service in three distinct mobile communication networks in Nigeria, which were designated as NET A, NET B, and NET C. With the help of Android Version 2.3.5 and TECNO mobile equipment (model number TECNO N3), the RSS data were collected. RF network tracker software was utilized to assess the mobile communication network providers in Nigeria that use the 900/1800 MHz spectrum. To ascertain the degree of speech quality, Mean Opinion Score (MOS)-based subjective testing techniques were also used. The subjective method was carried out in a calm setting at various times, using approved words for each of the three cell networks under examination at unique lengths. Examined were the speaking qualities of men and women. Different causes of dropped calls and low (bad) speech quality degrees were also emphasized. The complete average root mean square error (RMSE) score of the male speech excellent obtained from the three networks considered is found to be 0.601. On the other hand, invariance was the correlation coefficient value found between the male and female speech qualities. Additionally, compared to Net B and Net C, Net A has greater (better) voice quality. Furthermore, in feamobile communication networks, a large percentage of dropped calls has been attributed to voice distortions. These results will contribute to the enhancement of mobile communication in Nigeria.

Keywords: Evaluation, Mobile Communication Network, Network Performance, GSM

INTRODUCTION
It is impossible to overstate how beneficial mobile communication networks are for boosting economic growth in any nation. In terms of employment, training for human empowerment, mobile communication networks that facilitate information sharing and collecting, and other

aspects of human development and capacity building, this fundamental technology has made a significant contribution. These days, there are a number of mobile communication protocols with different generational acronyms connected, such GSM, CDMA 20001X, EGDE, GPRS, UMTS, and LTE. The concept behind many mobile communication standards emerged from the premise that increasing technical performance will improve the quality of service (QoS) in the mobile communication network [1, 2, and 3].

Furthermore, due to the disparities in mobile communication protocols, as well as the use of various mobile network providers and operators, users continue to endure declining service quality. The number of Nigerian users who are claiming that their mobile communication providers are giving them short change has increased recently. In order to ascertain the effectiveness of the quality of service being provided to Nigeria's terming population, the mobile communication network must be put through a litmus test by assessing the QoS criteria. Recent mobile communication network outages, poor speech quality, dropped calls, blocked calls, and low signal levels have all been reported by users as indicators of poor service quality. Subscribers are compelled to end calls due to poor speech quality or distortion, which increases the frequency of calls dropped. They may also choose to redial the calling party in an effort to get clearer speech. The speech (digital audio) quality provided by speaker phones, earbuds, cell phones, etc. consistently dissatisfies subscribers. [4]. Significant call quality loss occurs when voice signals are conveyed across telecommunication networks due to several factors such as channel noise, interferences, echo, codec utilized, speech volume, noise level, and bit error ratio. These deficiencies are now a significant hindrance to the mobile communication system. Every language that humans have adopted has some significant components with intrinsic meanings.

Phonemes are used and are thought to be important in helping to distinguish between words. The philosophy of the human vocal tract depends on a number of speaker restrictions, including voice pitch, accent, and speaking tempo. Speaking involves the use of airflow to create pressure waves. These wave patterns are created in the speaker's lungs during exhalation. To stop this airflow, the vocal fold inside the larynx can open and shut almost rhythmically. Voiced speech is the final product, which is distinguished by its periodicity. The most noticeable kind of voiced speech is a vowel. Vowels show unusually high power in addition to periodicity when evaluated with all possible phoneme teachings. This is because air may freely skip during the emission of a vowel since the vocal tract is left open at this time. When measured one meter away from the speaker, the usual range for human voice volume is 55–65 dB [5, 6, 7].

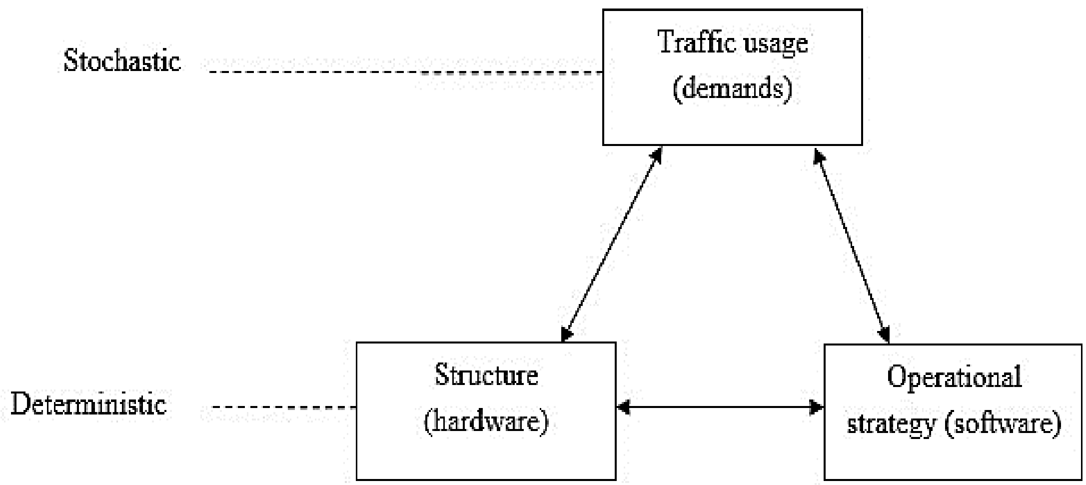

Fig. 1. Mobile communication system

In terms of perception, speech exceptionality is a complex psycho-acoustic phenomena. It is therefore always subjective (everyone has a different interpretation of what constitutes high-quality speaking). Thus, a MOS is typically used to indicate speech quality. Measurement of speech quality offers a framework for measurement to define the requirements that network operators must meet [8,], [9], [10]. The three main parts of the mobile communication system shown in Fig. 1 are the deterministic elements of the structure (hardware), operational strategy, and traffic consumption (traffic needs), which are random in character.

Structure: Identical channels (servers, trunks, and slots) operating in parallel are examples of what is regarded as the system's hardware. We call these channels homogeneous groups. Signal energy in telecommunications, primarily in radio, refers to the electrical area's significance at a reference point that might be rather far from the transmitting antenna. Less than -100 dBm, which is regarded as poor coverage, is unacceptable for the signal intensity; -50 dBm is regarded as full signal strength. Optimization of network performance predictions, reduction of interference issues, and effective operation of communication channels might result from ongoing improvements to signal strength prediction algorithms and link produce simplification [11], [12], [13], [14], and [15].

Fig. 1 breaks down the modeling of a mobile communication network into three primary sectors: traffic user (demand), hardware structure, and operational strategy (software).

Method: The sequence or process by which clients are chosen for service is known as the queue discipline [18]. Here are some examples of queue discipline: Among these are Priority service, Last-Come-First-Served (LCFS), First-Come-First-Served (FCFS), and Service in Random Order (SIRO). If at least one channel is empty when a call enters the system, it is accepted for service. If the system is free, a call cannot be stopped unless every channel in the system is in use. The arrival rate and service time displayed in Fig. 2 are components of the traffic, which is initiated by the subscribers.

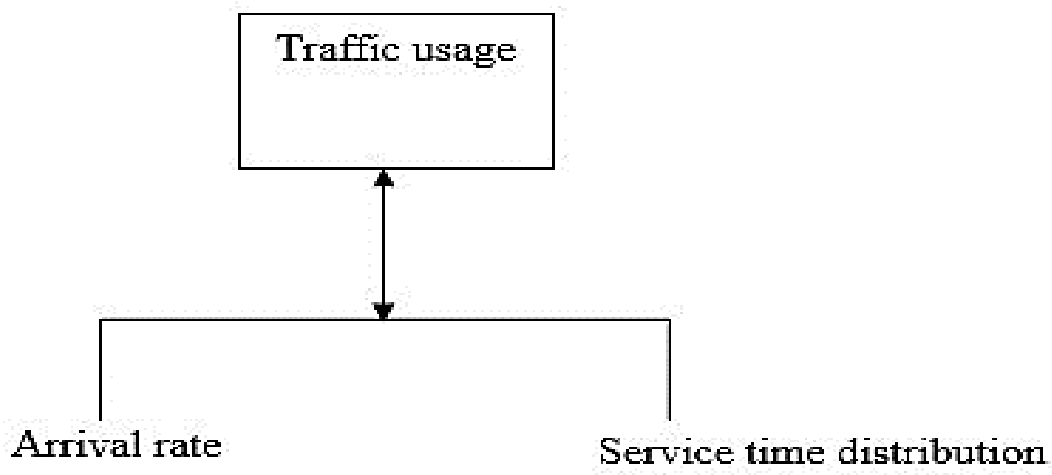

Fig. 2. Traffic random components

Quantities vary over time during random distribution, making it possible to forecast the immediate value associated with a quantity with some degree of accuracy. These amounts are referred to as random variables [16]. The arrival rate and service time distribution, which are modeled by statistical features, include a traffic user demands component [17], [18], and [19].

Arrival Rate in Interaction

The percentage of subscribers that arrive at the service facility within the allotted time frame is referred to as the arrival process. However, the total number of subscribers during a certain time frame may be used to calculate the arrival rate. The arrival rate is thought to be independent of one another and subject to arbitrary fluctuations throughout time. In mobile communication, the number of calls is used to measure arrival rate. The arrival rate is expressed using the Greek term Lambda (λ) [17]. Arrival rates at the service facility follow probability distributions such the Erlang, Poisson, and exponential distributions [20]. The arrival process, which is the queue system's input, is defined by the following elements [21], [22]. The size of the calling population, arrival patterns, and behavior are all influenced by the arrival processes in the queuing system. These processes can be examined using the average inter-arrival time (the average interval between two consecutive arrivals) or the average arrival rate (the average number of arrivals per unit of time).

A Poisson distribution, which is a statistical probability distribution, may be used to study the frequency of unplanned arrivals to a service facility within a certain time frame [18]. One of the following probability distributions can be used to approximate the arrival process distribution: Erlang distribution, Poisson distribution, and exponential distribution [20], [23].

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Distribution of Service Time

The service time is the amount of time that the server (mobile equipment) needs to spend serving a client from the beginning to the end. It is also taken into account as the call overhead time, the communication time or name's duration, and any queue time that may exist. The total amount of time necessary to serve a buyer who needs a carrier in the system (call duration and readiness time). The length of time required to serve a customer is indicated by the service time. An exponential probability distribution might be the cause of a variable service time. A service facility (or facilities) provides the service. This might involve one person working alone or in a group and could take the form of a machine, bank teller, barber, or area such as an airport runway, parking lot, or hospital bed [20], [21], [23]. A service system consists of two fundamental parts. These setups depend on the service system and service speed [20]. These service configurations demonstrate how the service facilities are set up (in terms of the number of servers or channels). Single server-single queue, single server-many queues, numerous (parallel) servers-single queue, several servers-several queues, and service facilities in a series are the various configurations of service systems. There are two methods to represent the pace at which services are rendered in a queue system [20]

The number of clients served during a specific time period is shown by the service rate, while the time required to service a customer is indicated by the service time.

Characteristics of Statistics

Mathematical random point processes or counting processes can be used to characterize the arrival process at the communication exchange (switches). Point procedures are explained as follows. Two fundamental characteristics of point processes are as follows:

Orderliness is the chance that two or more arrivals appear simultaneously and are insignificant.

Memoryless is the state in which the method's future evolution is statistically independent of its history at any point in time. By use of Markovian theory or Markovian chain, the two houses are in possession. Due to the stochastic character of the limitations connected with mobile communication, mobile communication dependability is crucial.

Review of Literature

While Thomas Locher et al. focused on the users' current logical position, Lee Ee foong et al. examined the behavior of radio signals in both indoor and outdoor environments. Along with developing a sequential interference cancellation technique, Yasamin Mostofi and Pradeep Sen also created a map of the received signal intensity to a stationary station. This study takes into account the degree of Received Signal Strength encountered in Nigerian mobile communication networks. Additionally, this study took voice quality into account. In order to measure the quality of speech in GSM networks, [7] first looked at Perceptual Evaluation of Speech Quality (PESQ), and [24] created parametric models to estimate MOS speech level. A subjective approach was then used to assess the quality of speech in the mobile communication networks that were the subject of the investigation [7], [24].

Materials and Method

This study evaluated the performance of mobile communication networks in Nigeria. First, the metrics pertaining to quality of service were identified and established using data from OMC collected from many networks, including NET A, NET B, and NET C. The quality of service took Received Signal Strength (RSS), speech distortion, lost calls, and banned calls into account. A eleven (11) months-long study employing MOS and the Received Signal Strength (RSS) method—which is expressed in decibels—was conducted at the University of Delta Campus area from around January, 2023 to November, 2023.

The ITU-T standard recommends utilizing suggested phrases to assess speech quality at different times and periods in a calm setting. The suggested phrases are: I'd like to speak with the inspector for a moment; did he require any money; you will need to be extremely quiet; there was nothing to see; they worshipped wooden gods. For a duration of one year, both male and female speaking voices were employed in this investigation. The three mobile communication networks made use of five different models of TECNO mobile equipment, with the model number TECNO N3 and Android Version 2.3.5.

The RSS was ascertained at six distinct locations, including College Junction, Main Campus, Owa Oyibu Campus, Owa Alero Campus, Alihame Area, Agbor Town, along with the corresponding signal strength and both latitude and longitude, for the three mobile communication networks, using network monitor software installed in TECNO N3. The voice quality on mobile networks and the difference in speech quality between men and women were assessed using statistical methods like RMSE and Correlation Coefficient. On the basis of the RSS gathered from three mobile communication networks, an empirical model was created. Additionally, the chisquare goodness of fitness was used to calculate the adjustment between the proposed benchmark and signal strength. Furthermore, the constructed Empirical model was used to estimate the MSE value.

Data Display

In this analysis, three distinct Nigerian mobile network carriers are being taken into account. First, Table 1 listed the cumulative reasons for missed calls, various causes of dropped calls from three networks were highlighted

S/N	Causes of dropped calls	Average Occurrence
1	Forceful termination due to speech distortion	56
2	InsuffiClient Credit	32
3	Electromagnetic causes	21
3	Battery outage	10
4	Handover process	5

The subjective measurement method of three different mobile network operators in Nigeria,- using Mean Score values with recommended sentences was shown in Table 2

Table 2: The Mos Results Obtained From Initialing Calls from the Basic Three Networks

S/N	Recommended Sentences from ITU-T				MALE									FEMALE					
		NetAtoNetA	NetAtoNetC	NetAtoNetB	NetBtoNetA	NetBtoNetC	NetBtoNetB	NetCtoNetA	NetCtoNetC	NetCtoNetB	NetAtoNetA	NetAtoNetC	NetAtoNetB	NetBtoNetA	NetBtoNetC	NetBtoNetB	NetCtoNetA	NetCtoNetC	NetCtoNetB
1	You will have to be very quiet	4.7	5.0	4.0	5.0	4.3	4.7	4.0	4.0	4.3	4.7	5.0	5.0	5.0	4.3	4.7	4.7	5.0	4.3
2	There was nothing to be seen	4.7	4.3	4.7	5.0	4.0	4.7	4.3	4.0	4.0	5.0	5.0	5.0	5.0	5.0	5.0	4.7	5.0	5.0
3	They worshipped wooden idols	4.7	4.7	5.0	4.7	3.3	4.7	3.0	3.0	3.3	4.0	4.7	4.3	4.7	4.3	4.0	4.3	3.6	4.3
4	I want a minute with the inspector	5.0	5.0	4.3	5.0	4.3	5.0	4.0	4.6	4.3	4.7	5.0	5.0	5.0	4.3	4.7	4.7	5.0	4.3
5	Did he need any oney	5.0	3.6	4.3	4.7	4.7	5.0	5.0	4.3	4.7	4.3	4.7	4.7	4.7	4.0	4.3	5.0	4.3	4.0

The Received Signal Strength (RSS) DBM Obtained At University of Delta Campus, Agbor.

S/N	Investigated location position	Received Signal Strength (RSS) DBm			Mobile Latitude	Mobile Longitudes
1	College Junction	NET A	NET B	NET C		
		-59	-92	-59	6^0 44′ 5.5″	6^0 4 ′51.2″
2	Main Campus.	-73	-89	-71	6.44′57.23″	6.4′ 48.09 ″
3	Owa Oyibu Campus	-95	-97	-77	6^0 43″52.0″	60 4 ′42.6″
4	Owa Alero Campus	-67	-89	-69	6^0 44′57.4″	60 5 ′9.2″
5	Alihame Area	-97	-79	-91	6 44′37.3″	6^0 52.9 ′
6	Agbor Town	-63	-81	-107	6^0 44′ 14.8′	$6^0$4′ 46.8 ″

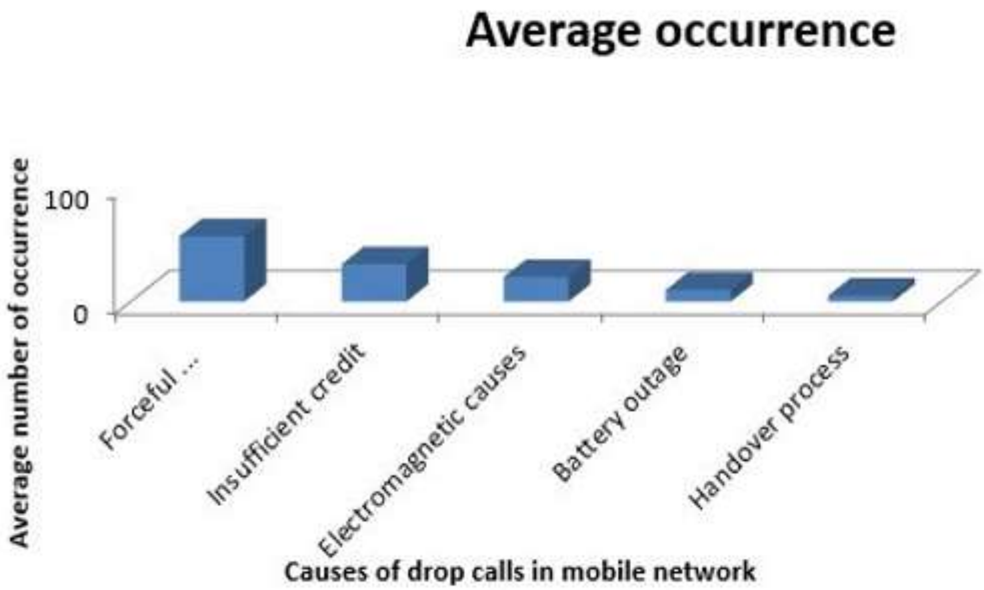

Fig. 3. The causes of dropped calls and level of occurrences in mobile communication network

First, a number of reasons for dropped calls in Nigeria were examined from Network A. It was found that the most frequent cause of dropped calls in mobile communication networks was forcible termination resulting from voice distortion. Dropped calls have an impact on service quality, which increases the amount of redial calls and congests traffic in mobile networks. As a result, it is essential to assess speech quality using the subjective measuring technique based on the MOS values shown in Table 2. Equation 1 presents a statistical technique known as the root mean square deviation (RMSE), which is utilized to quantify the discrepancy between the values seen from the environment being modeled and the values projected by the modeled

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(X_{Obs,i} - X_{MODEL,i})^2}{n}} \quad (1)$$

where Xmodel is the modeled value at time and location i and Xobs is the observed value.

Where n is the number of occurrences, and XObs is supposed to be the MOS calls values collected from Network A to Network A mobile communication networks. Additionally, the XModel is taken to represent MOS call values from Network A to the mobile communication networks of Network B and Network C.

From the MOS data from Network A to Network C, the RMSE value is 0.559.

However, 0.665 is the RMSE number derived from the MOS values from Network A to Network B.

The MOS data from Network A yielded an average RMSE value of 0.612.

Using the MOS values from Network B to Network C, the RMSE value is 0.7987.

From the MOS values from Network B to Network C, the RMSE value is 0.2324.

Comparable, the mean RMSE value derived from Network B's MOS data is 0.51556.
From the MOS values from Network B to Network C, the RMSE value is 0.5916.
The MOS data from Network C to Network B yielded an RMSE value of 0.7563.
Additionally, Network C's average RMSE value (derived from MOS values) is 0.674.
The following is the overall average RMSE value for male speech quality derived from MOS values:
The MOS value yielded the overall average RMSE value.

The r-value of the coefficient is $\frac{\sum_{i=1}^{n}(X_i - \bar{X}).(Y_i - \bar{Y})}{\sqrt{\sum_{n}^{i=1}(X_i - \bar{X})^2.(Y_i - \bar{Y})^2}}$ (2)

The correlation coefficient was deployed from Equation

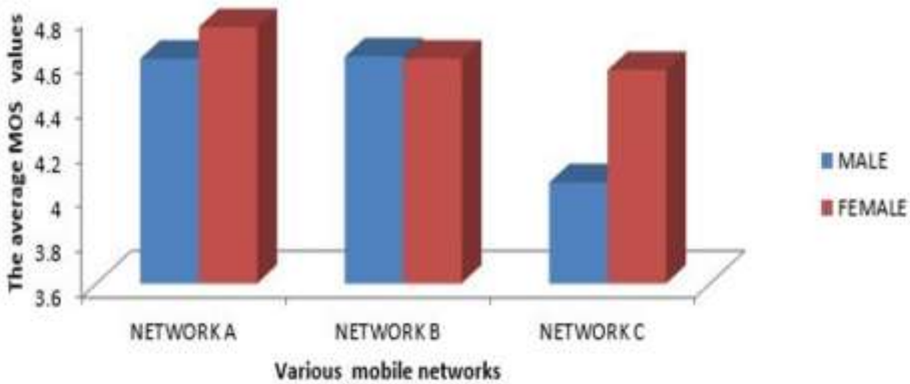

Fig. 4. The causes of dropped calls and level of occurrences in mobile communication networks

Secondly, using the same networks to ascertain the linear association and intensity between the male and female speech quality levels.
where Yi is the female and Xi is the male
The MOS value x¯ = 4.82 yielded the average male value, whereas the MOS value y¯ = 4.54 yielded the average female value.
The Correlation Coefficient (r) values that were acquired from different networks had a MOS value of 0 (zero). This suggests that the degree of male speech quality differed from that of female speech quality. Figures 4 and 5 illustrate this comparability of the speech quality levels of men and women. Figure 4 shows a comparison of the cumulative MOS values for male and female users from each of the three mobile networks—Net A, Net B, and Net C.. It was noted that the speech of women sounded superior to that of their male counterparts. Additionally, Figure 5 illustrates that, according to calls initiated from network A to other mobile communication networks, the male speech quality is 49% and the female voice is 51% better.

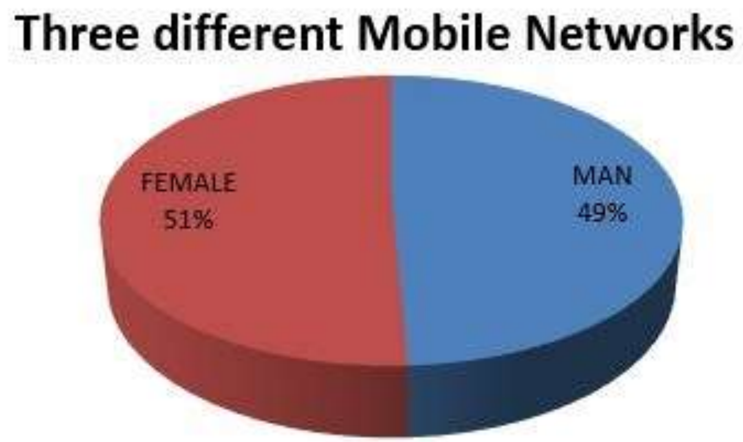

Fig. 5: Male and female speech quality comparison based on MOS values acquired using suggested ITU phrases

The related average MOS values comparison of different networks for the male and female voice quality levels on various mobile communication networks under research is displayed in Figures 4 and 5. The average MOS value for the male and female speech quality levels on Net A is 4.67, the average MOS value for the female speech quality levels on Net B is 4.605, and the average MOS value for the male and female speech quality levels on Net C is 4.3. These observations suggest that while the MOS values for the various mobile networks are good and satisfactory, the mobile operators still need to improve the speech quality level. Table 2, as depicted in Figure 4, revealed that low values detected in the male speech corresponded to low (bad) voice quality from calls initialed from Net C to Net C.

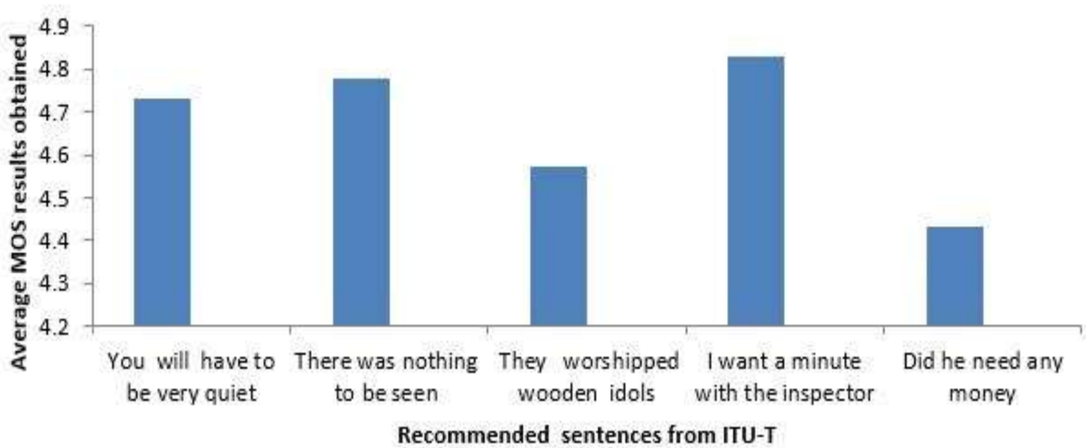

Figure 6: A range of subjectively suggested ITU words

Based on the suggested ITU sentences, it can be seen in Fig. 6 that there are still differences amongst the five suggested phrases. However, two of the suggested sentences exhibit significant variance from the first three phrases in Fig. 6, whereas three of the suggested sentences show strong connection. As a result, such phrases have to be given another look in order to properly analyze speech quality. The risk associated with this approach is that the subjective speech technique takes longer to complete because to the large number of listeners needed for the test. The objective approaches aim to eliminate those issues and present a human-unbiased manner of first-rate speech. Mathematical computational models and algorithms may be used to accomplish this Nonetheless, because they offer a number of important benefits over subjective assessments, objective measurements are frequently employed.

Additionally, the results of the subjective measurement should be compared with the objective approach for future research. Furthermore, the following aspects are emphasized as they impact or result in bad voice quality: bit error ratio, handover rates, mobile terminal (MT) orous transmission (DTX), channel noise, interferences, echo, codec utilized, speech level, and noise level. Pitch, speaking tempo, and accent are additional speaker-dependent factors.

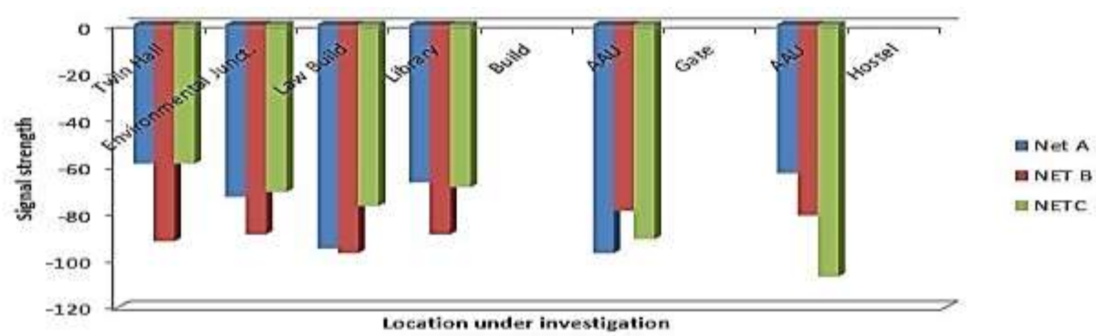

Figure 7: Three distinct mobile network carriers' Received Signal Strength (RSS) dBm

The data were obtained using network monitor software installed in TECNO N3 to determine the RSS level at six different locations, such as Twin Hall, Environmental Junction, Law Build, Library Build, AAU Gate, and AAU Hostel, along with the corresponding signal strength and both latitude and longitude, for the three mobile communication networks. The Received Signal Strength (RSS) in dBm for the three different mobile network operators under investigation was presented in Figure 7. The six studied University of Delta, Agbor sites shown in Fig. 7 served as the basis for the comparison.

Additionally, based on the graphical display, it was noted that, at 0.043 MSR, the signal strength of Net A is more linearly distributed than that of other GSM networks. This suggests that despite outside influences and obstructions under the studied region, the signal strength value was (strong) constant. Furthermore, during the distance under investigation, Net B's maintenance is robust and its signal strength remains steady. Due to obstructions, reflections, and diffraction of the received signal intensity at the Mobile Station (MS) ends, it is noted that the signal strength level in Net C, as depicted in Fig. 7, is gradually decreasing

Because the transmitted network is not powerful enough to provide positive dBm values, signal strengths for mobile networks are always negative dBm values. The average received signal strength from Net A is -75.67 dBm, whereas Net B's received signal strength is -87.83 dBm. The recommended signal level is -50 dBm.

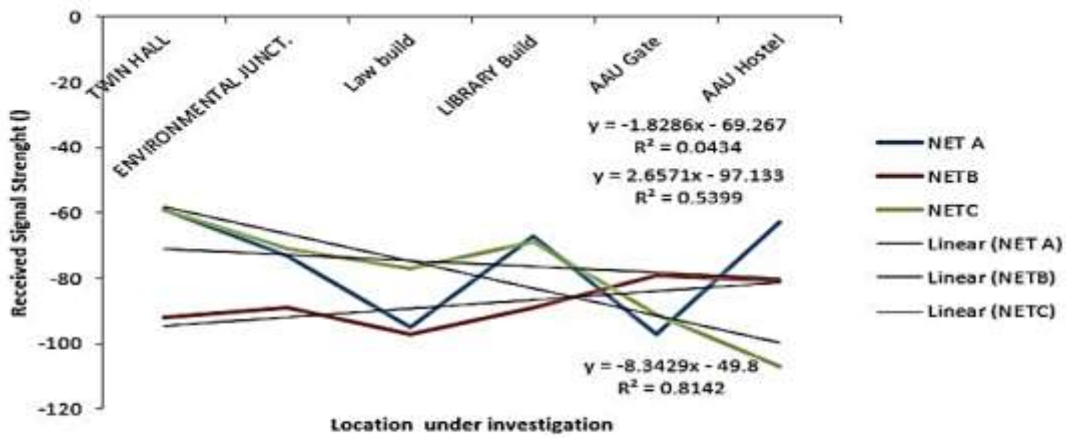

Figure 8: A comparison of the signal strength received at different points on the University of Delta, Agbor Campus.

Net C at -79.00 dBm was smaller and less strong than the -50 dBm seen in Fig. 8. Inadequate signal strength will result in inconsistent audio due to frequent signal disappearance from the mobile station, persistent audio buffering, and disconnections.

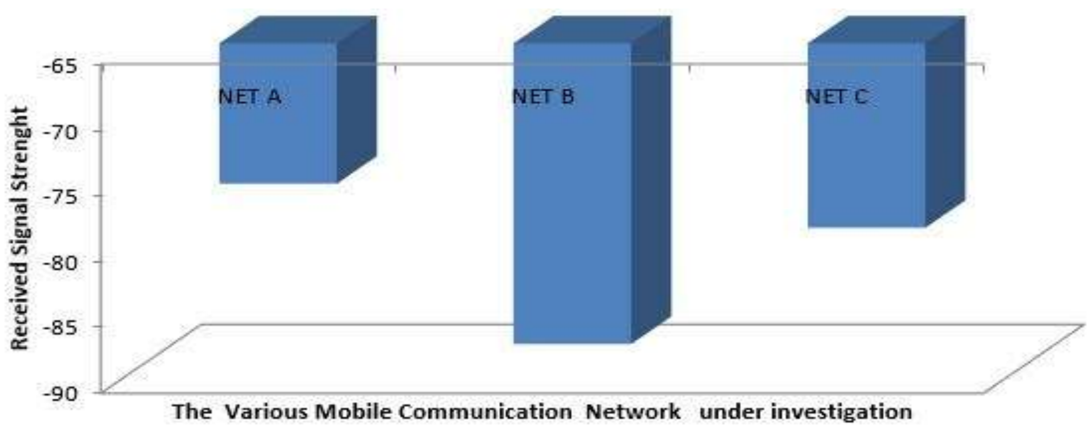

Figure 9 shows the RSS linear regression distribution model for the three networks that are being studied

Empirical Model of Signal Strength Received

The empirical method is based on measuring data, which may be used to compute signal levels when shown as regression curves or analytical formulas. The benefit of using an empirical model is that it provides a framework for measurement; all of them account for both known and unknown radio propagation parameters. The empirical model based on the Received Signal Strength pattern of several mobile communication networks depending on the places under research was determined using the Microsoft Excel application. It was noted that the linear distribution for NET A yielded the lowest Mean Square Root (MSR) value of 0.043, followed by Net B and Net C from Fig. 9 shown in Table 4. The logarithmic and polynomial distributions, together with their corresponding values, were compared with the linear distribution.

Table 4: The Empirical Model Distribution Pattern Of The Mobile Communication Network Using Mean Square Roots

S/No	**Networks Operators**		**Mean Square Roots**	
		Linear Distribution	Logarithmic Distribution	Polynomial Distribution
1	Net A	0.043	0.122	0.425
2	Net B	0.539	0.388	0.654
3	Net C	0.814	0.697	0.870
	Mean value	0.465	0.402	0.650

Equation 3 presents the empirical model that was produced using the relative Mean Square Error (MSE) of 0.043 and the Received Signal Strength acquired from the examined networks corresponding to Net A as shown in Table 4.

$R2 = 0.043\ Y = -1.828x - 69.26$ (3)

A scalar dependent variable (y) and one or more explanatory variables (X) are modeled using the linear regression technique in statistics. Equation 3 expresses the linear regression distribution model, where x is the signal intensity and y the various locations (distance). On the other hand, according to Okumura, the signal intensity is said to diminish with distance at a far faster rate than that which is anticipated by free space loss. With a value of 0.043 MSR, it was found that the signal strength of Net A is more linearly distributed than that of Net B and Net C networks. This suggests that despite outside influences and obstructions in the region under investigation, the Net A signal strength value was (strong) constant.

This study's linear distribution of received signal intensity was consistent with theory, allowing the mobile network to successfully cover the cell's active customers. Furthermore, barriers, reflections, and diffraction of the received signal intensity at the Mobile Station (MS) endpoints caused attenuation of Net B and Net C. This led to a logarithmic distribution of RSS, which was based on the total least average or mean value derived from the logarithmic distribution of 0.402.

Summary and Recommendation

But given the declining Quality of Service (QoS) that Nigerian mobile phone subscribers are experiencing, this study, "Evaluation of mobile communication network performance," is necessary to ascertain the reasons behind poor speech quality, dropped calls, blocked calls, and low Received Signal Strength (RSS) on mobile networks. An arbitrary Mean Opinion Score (MOS) approach was employed. This study took into account three mobile networks and looked at the quality of speech in each of those networks for both men and women. Additionally, a comparative analysis was conducted between the different networks to ascertain the degree of voice quality, employing statistical approaches like the Root Mean Square Error (RMSE) and Correlation Coefficient. Additionally, three mobile communication network carriers in Nigeria had their signal strengths and causes for lost calls analyzed. The investigation was done on several sites, taking into account the relevant latitudes and longitudes. The three networks' average RMSE speech quality score is 0.601, and the correlation between the male and female voice excellencies is variance.

Additionally, Network A's voice quality is superior to that of Networks B and C. Additionally, a large percentage of lost calls in Nigerian mobile communication might be attributed to voice distortion. It is noted that the average signal intensity is between -50 and -100 dB, and that Net B, Net C, and Net A have the highest average sign strengths. With an average signal strength value of 75.7dBm, Net A is the network with the most appropriate received signal strength from the inquiry, followed by Net C. Additionally, it was noted that, at 0.043 MSR, Net A's signal intensity exhibited features of a linear distribution when compared to the networks of Net B and Net C. This suggests that despite outside influences and obstructions in the area under investigation, the Net A's signal strength value was (strong) constant.

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