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Evaluation Of The Quality Of Service Of Global System For Mobile Telecommunication (GSM) Operators In Nigeria

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***Abstract*—Excellent Quality of service sustains customers' confidence and is essential for a competitive advantage. It is an important key performance indicator (KPI) that is used in determining the efficiency of an industry in terms of services rendered. Poor performance of a telecom network would provoke customer complaints and faults, thereby leading to customer dissatisfaction towards the operator. This paper has therefore aimed at evaluating the quality of service rendered by Telecom Operators in Nigeria and also suggest on how to improve on their services.**

Keywords—Quality, Service, Telecommunication, Indicator

1. INTRODUCTION

The GSM network services in Nigeria was introduced with a view of meeting the urge and high demand for communication with increased ability to meet services capacity and subscription demand in order to satisfy the common subscriber of GSM network communication services and the opportunity of integrating herself to a public cellular phone system within and outside its locality[1]. The invention of GSM was a product of international cooperation in the telecommunication industry. Before the liberalization of the telecommunication industry in 2001, the NCC admits that Nigeria had a very limited telephone network for many years, and the waiting list is estimated at over 10 million people, who have applied to the Nigeria Telecommunications Limited, NITEL, for services. Today, the story has changed dramatically.

Since the GSM launch, mobile telephony has rapidly become the most popular method of voice communication in Nigeria. Growth has been so rapid that Nigeria has been rightly described in various forms as "one of the fastest growing GSM markets in the world". Indeed these developments have been truly explosive:

Quality of Service (QoS) remains a major concern to telecommunications service subscribers. Quality service sustains customers' confidence and is essential for a competitive advantage. In telecommunication system, accessibility, retainability and connection (voice) quality are three major factors used in evaluating quality of service of an operator. Service is a key component of value that drives any company's success. To the customer, value is the benefits received for the burdens endured-such as price, an inconvenient location, unfriendly employees, or an unattractive service facility. Quality of Service (QoS) refers to the state of nature of services rendered by the telecommunication operator, which can either be good or bad quality. For the service to be considered as good, it has to satisfy the demand expectation of the customers.

Technically speaking, QoS was defined in the ITU standard X.902 as a set of quality requirements on the collected behavior of one or more objects. Quality of service comprises requirements on all the aspects of a connection, such as service response time, loss, signal-to-noise ratio, cross-talk, echo, interrupts, frequency response, loudness level, etc [2]. QoS helps a company maximize benefits and minimize non-price burdens for its customers. Excellent service is a profit strategy because it results in more new customers, more business with existing customers, fewer lost customers, more insulation from price competition, and fewer mistakes requiring the re-performance of services.

Global System for Mobile Communication was introduced to Nigeria in 2001. This launch liberated Nigerians from the telecom monopoly of NITEL. GSM has boosted the economic activities in Nigeria and improved the quality of life for the Nigerians. They are now able to enjoy services such as mobile television, affordable Internet service, cheaper international calls, and even Internet banking. As the number of services and subscribers of GSM in Nigeria increases, the demand for good QoS has become an issue in the country. The agitation has become a national issue which had been brought before the country House of Representative on July 18, 2007 and the Nigerian Communication Commission (NCC) [3]. In finding the lasting solution to the problem, the NCC, body responsible for the regulation of GSM in Nigeria, on 6th July 2007 issue out the threshold levels on the key performance indicators (KPIs) for ascertaining QoS of all the GSM networks in the country. The KPIs on which the GSM networks were tested according to include: call set-up success rates (CSSR), call drop rate (CDR), call completion success rates (CCSR), handover success rates (HSR) and traffic channel congestion rate

(TCHR) [4]. The NCC is further threatening to sanction any operator that fails to pay attention to quality. It therefore behooves all the operators to ensure that the subscribers enjoy the best of service.
As innovative as GSM may seems to be, many problems militating against the sector in recent past include: instability in power supply, security of infrastructure, inter-Network connectivity, network congestion, call setup failure, call retention / call drop, increased failure to access and engage communications channels, increased dropped calls, and general poor quality of services are some of the persistent problems encountered in cellular networks in Nigeria.

2. BRIEF HISTORICAL BACKGROUND

The development of the GSM technology started in 1982 when the conference of European Post Telecommunication (CEPT 1982) formed a study group called Group Special Mobile (meaning GSM). The group was to study and develop a Pan European Public Cellular Systems that uses 900MHZ frequency bandwidth range using spectrum that had been previously allocated. At that, there were many incompatible analog tele-based system in various part of Europe, some of the basic criteria for their proposed systems were; Good subjective sound or speech quality, low terminal and service cost, support handheld terminals, support for range of new service, ability to handle high volume of users and spectral facility efficiency.
In 1989, the responsibility of GSM was transferred to the European Telecommunication Standard Institute (ETSI, 1989) and phase one recommendation was published in 1990. At that time, the United Kingdom requested specification based on GSM but for high use densities with low-power mobile stations operating at 1.8GHZ. The specification for the system was called Digital cellular system (DCS, 1800). By 1991, GSM network technology started commercial operations within European countries with different bandwidth equipment. By 1995, there were over sixty (60) countries with operational facility on GSM networks in the Middle East, the far East, Australia, Africa and South America with a total of over 20.4 million subscribers[5]. The GSM technology feature a cell broadcast with D channel for call set up and B channel for transferring data with different base station subsystem network[6]. The development of GSM technology came to Nigeria in 2001, when the Federal Government saw the need to privatize, liberalize some shares in order to break the monopoly of its network operations and also to improve in the communication services rendered to subscribers by issuing license to other private telecommunication operator.

3. ANALYSIS OF GSM SYSTEM ARCHITECTURE

In GSM system, the mobile handset is called Mobile Station (MS). A cell is formed by the coverage area of a Base Transceiver Station (BTS) which serves the MS in its coverage area. Several BTS together are controlled by one Base Station Controller (BSC). The BTS and BSC together form the Base Station Subsystem (BSS). The combined traffic of the Mobile Station in their respective cells is routed through a switch called Mobile Switching Center (MSC) connection originating or terminating from external telephone (PSTN) are handled by a dedicated Gateway Mobile Switching Center (GMSC). Several databases are used for the purpose of call control and network management. These databases are Home Location Register (HLR), Visitor Location Identity (VLR), the Authentication Center (AUC) and Equipment Identity Register (EIR). Home Location Register (HLR) stores the permanent (such as user profile) as well as temporary (such as current location) information about all the users registered with the network. A VLR stores the data about the users who are being serviced currently. It includes the data stored in HLR for faster access as well as the temporary data like the location of the user. The AUC stores the authentication information of the user such as the keys for encryption. The EIR stores data about the equipment and can be used to prevent calls from a stolen equipment [7]. All the mobile equipment in GSM system are assigned unique identity called IMSI (International Mobile Equipment Identity) and is allocated by equipment manufacturer and registered by the service provider. This number is stored in the EIR. The users are identified by the IMSI which is stored in the Subscriber Identity Module (SIM) of the user. A Mobile Station can be used only if a valid SIM is inserted into equipment with valid IMSI. The “real” telephone number is different from the above identities and is stored in SIM.

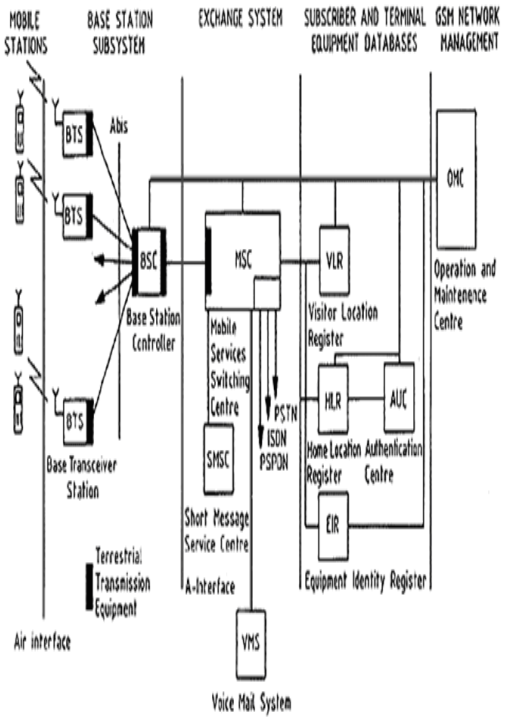

Figure 1: General Architecture of a GSM Subsystem

3.1. Quality of Service and Key Performance Indices (KPI) for GSM Networks

Generally, the term Quality of Service (QoS) in various context and applications could have various definitions, but most definitions point towards end user satisfaction, expectations or fulfill requirements. According to [8], the International Organization for Standardization (ISO) gave an initial general definition of quality in ISO 8402 as "the totality of characteristics of an entity that bear on its ability to satisfy stated and implied needs" and in the year 2000 it was replaced by ISO 9000 which defines quality as the "degree to which a set of inherent characteristics fulfils requirements.

For a new framework in GSM telephony to work, Monitoring QoS of any telecommunication network requires continuous processes that measure values of the Key Performance Indictor (KPI) parameters in real-time, its analysis of measured empirical data to determines quality of service rendered to the subscribers. There are many network parameters that evaluate the quality of delivered network service [9] viz: Call Setup Success Rate, Call Setup Failure Rate.

Call Success Rate, Call Drop Rate, Call Retention Rate, System Response Time, Handover Statistics, Number of Handovers per call, and Voice Quality as a MOS value and Airtime Recharge Performance.

In 2007, the NCC held a Public Forum [10] to identify issues affecting QoS in Nigeria while seek a lasting remedy to the current QoS challenges in the 2G/3G industry and make recommendations on way forward. The forum identified the following issues as factors that require attention in order to improve the unacceptable QoS delivered on the various networks.

- Network Congestion
- Limited Transmission Infrastructure.
- Security of Telecommunications Equipment or Facilities.
- Unreliable Public Power Supply.
- Lack of Information to the Consumer on downtime.

The Nigerian Communications Commission (NCC) conducted QoS audit of the four networks in Nigeria for a period of 21 days from September 21, 2004 to October 11, 2004 [11]. The tests were in two categories namely; voice network performance/quality and Prepaid Performance Test while investigating on the above KPI's [12].

In their work, the authors in [13] investigate and analyze the Quality of Service (QoS) of cellular mobile networks in Nigeria using some Network Key Performance Indicators (KPI). There study though was limited to Visafone Mobile Network which is licensed to provide fixed wireless access telecommunications services on State by State basis in Nigeria under the license category classified as Private Network Links (PNL).

Their results obtained showed that busy hour TCH Congestion Ratio was 0.0062 (which is lower than the NCC stipulated value of ≤ 2%). Also, the busy hour CDR was 0.7129 (below the NCC threshold of ≤ 2%) and the Busy hour CSSR was 98.7267 which is within the expected threshold set by NCC. However, the carried out its study on CDMA network service.

The work in [14] presented a precise analysis of mobile users behavior in terms of mobility and traffic that would help to optimize capacity for both circuit and packet switched services. Their research work employed the multiplicity of techniques for the capacity analysis of GSM network in Nigeria. In the work, enhanced stochastic knapsack was evaluated for resource sharing approach in multi-services while using erlang Loss Model for SMS capacity analysis. The authors used offered traffic ie Lost Traffic based to dimension the system resources. The work was actualized by the characterization of a typical representation of the Northern part of Nigeria. The work observed that traffic modeling is the critical part of networks modeling, it is the key point on performance evaluation for any communication network and thus group traffic Model grouped into two series, namely, smooth and non smooth model.

Firstly, the work examines source, volume and type of data generation by analytical method, then investigated the kind of channel allocation with respect to the frequency hopping types and proposes the best spectral efficiency. They further used grade of service (GoS) parameters in the multiservice GSM network to ascertain (fairer source allocation, a QoS metric) in the traffic mix environment.

Finally, in its model derivation, a multiservice Traffic model for an enhanced Knapsack of capacity C, with steady state probability of process was used to satisfy the conditional probability of occurrence of state in Stochastic Knapsack. The work then developed a traffic model for a GSM network designed to meet heterogeneous service requirements of different applications. The work showed a lower service rate for homogenous services.

A study in [15] evaluated the significance of price (call rate), service quality, service availability, promotion and brand image and it affect in users' perception in selecting a mobile telecommunication services provider in the Nigerian telecommunication market, using Ibadan, a Nigerian municipality as a case study.

The author observed that the paramount interest of mobile service providers is to achieve optimum consumers satisfaction so as to retain them, as evaluating the perception of a mobile user in a highly competitive telecommunication market is very a crucial factor leading toward competitiveness and success. In their work, it was gathered that no work have carried an investigation to assess the influence of the attributes of the mobile operators on users' choice of mobile service operators in the life of the Nigerian mobile users. This formed their focal point of study, which was to understand the factors that influence mobile phone users in their choice of a mobile phone service provider in the Nigerian mobile telecom market. The work then examined the

influence of call rate (price), service quality, service availability, promotion, and brand image on mobile phone users' perception in selecting a service provider using structural equation modelling (SEM).A conceptual model shown in figure 2.

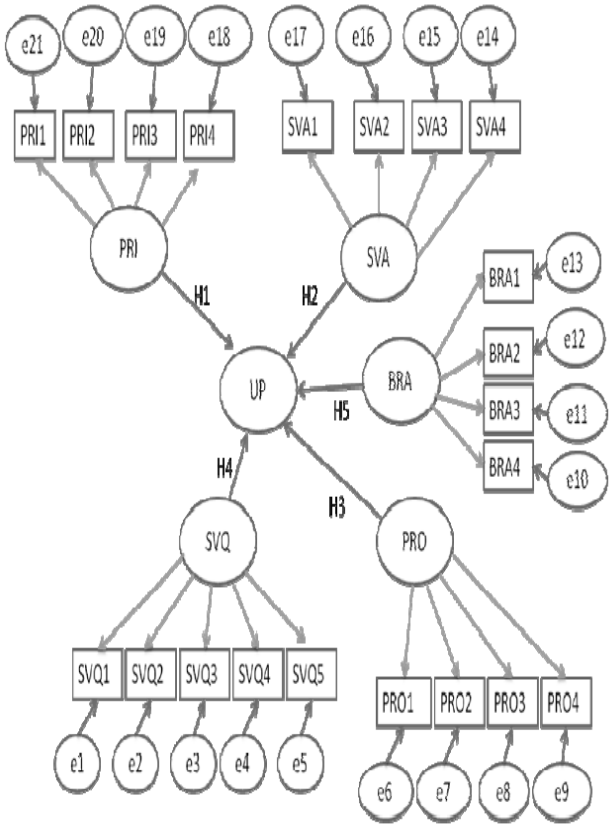

Figure 2: Structural Model specification [16].

In Figure 2, the author explained that the first four constructs (price, service availability, service quality and promotion) were adopted from a similar study carried out in [17] using the Malaysian experience whereas, the last construct brand image, was from empirical literature [18]. In the centre of the model are the latent variables (PRI = Price/Call rate, SVA = Service availability, BRA = Brand image, SVQ = Service quality, PRO = Promotion, UP = User perception) represented with circles, and towards the perimeter are manifest variables (PRI1...PRIn, SVA1...SVAn, BRA1...BRAn, SVQ1...SVQn, PRO1...PROn) represented with squares. The lines with an arrow in one direction show a hypothesized direct relationship between the variables. It should originate at the causal variable and point to the variable that is caused.

For every endogenous variable, a residual term is added in the model. Generally, a residual term is a circle with the letter E written in it, which stands for error.

Based on the conceptual model in Figure 2, the work then formulated the following hypotheses viz:

H01: Call rate (Price) has no significant influence on mobile phone user perception in selecting a mobile telecommunication service provider.

H02: Service availability has no significant influence on mobile phone user perception in selecting a mobile telecommunication service provider.

H03: Promotion has no significant influence on consumer perception in selecting a mobile telecommunication service provider.

H04: Service quality has no significant influence on mobile phone user perception in selecting a mobile telecommunication service provider.

H05: Brand image has no significant influence on mobile phone user perception in selecting a mobile telecommunication service provider.

After a questionering survey, factor analysis and factor loading was carried out while testing the above formulated hypothesis leading to figure 3.

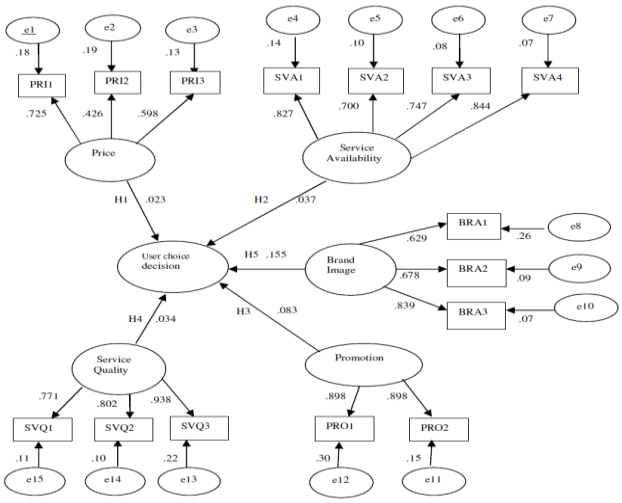

Figure 3: Structural Equation Model diagram of the degree of relationship in Consumer Perceptions towards Service Quality (SVQ), Call rate/Price (PRI), Service Availability (SVA), Promotion (PRO), and Brand image (BRA).

In the first formulation, their result in Figure 3, showed that Call rate (price) emerged as the most important factor that affects customers' perception in selecting mobile operator with the results ($r^2 = .023$, $p<0.05$) showing the degree of significance. In the second case, the result ($r^2 = 0.037$, $p<0.05$) in Figure 3, showed that Service availability directly affects customers' perceptions in selecting mobile telecommunication services provider. In the third case, the result in Figure 3 showed that Promotion does not have a significant effect on users' intention in buying telecom service and therefore, no positive impact on the users' perceptions in selecting a mobile operator, In the fourth case, Service quality emerged as the most important factor next to Call rate (price) that affects customers' perception in selecting telecom service (see Figure 3). Their study showed that service quality has positive impact on users' perceptions. This work strongly agrees on these deductions which lead to the following recommendations in [19] viz:

1. The Nigerian Communication Commission should, by way of policy, assume the control and management of base stations from the network

operators such that all mobile network operators would make use of same base stations but operate on different frequencies and pay rental fees to NCC or her designated agent. This would eliminate the high cost of building and maintaining base stations incurred by the various operators and consequently reduces operational cost.

2. The network operators should reduce their expenditure on promotional activities and brand building, but rather invest on network extensions, quality service delivery and product and services outlets infrastructures, while also concentrating on price reduction strategies as a way of increasing subscribers' base.

3. With the planned introduction of Mobile Number Portability (MNP) by Nigerian Communication Commission (NCC), which favours mobile operators with the best customer satisfaction, the finding of this study would provide these operators with the indicators to focus their business and marketing strategies [20].

4. METHODOLOGY

The method used in this research is called passive method. Passive method involves the gathering of real traffic data at one or more points on the network. I measured call procedures on definite Base Transceiver Station (BTS) for a period of three (3) days. The total number of accepted calls, successful calls and dropped calls by the network under study were recorded. The observed and recorded data from measurement forms part of the primary data for the research. To obtain the required data for analysis, simulation and measurement were limited to one Base Transceiver Station (BTS) in Osisioma area of Aba switching center, and the result recorded forms part of the secondary data which are presented in tables1-3

Table 1
DAY ONE (1)

Time(per minute)	Number of successful calls	Number of dropped Calls
7.00-7.30am	401	400
7.30-8.00am	441	400
8.00-8.30am	431	433
8.30-9.00am	433	431
9.00-9.30am	390	391
9.30-10.00am	431	422
10.00-10.30am	389	290
10.30-11.00am	341	340

TABLE 2
DAY TWO (2)

Time(per minute)	Number of successful calls	Number of dropped Calls
7.00-7.30am	461	400
7.30-8.00am	341	330
8.00-8.30am	451	460
8.30-9.00am	433	431
9.00-9.30am	397	391
9.30-10.00am	421	422
10.00-10.30am	383	350
10.30-11.00am	338	340

Table3
DAY THREE (3)

Time(per minute)	Number of successful calls	Number of dropped Calls
7.00-7.30am	455	400
7.30-8.00am	341	342
8.00-8.30am	451	460
8.30-9.00am	433	431
9.00-9.30am	381	369
9.30-10.00am	421	422
10.00-10.30am	383	350
10.30-11.00am	398	340

5. ANALYSIS OF THE RESULTS

There were about 24 radio channels between the base transceiver station and the base controller station. From the tables, each observation period lasted for 30 minutes; total observation time for the 8 period is 4 hours.

The plots of the results obtained from the observation are shown in figures 4-6. From the results, it can be seen that within the period of the observation, the grade of service anticipated at three different times and days indicate a significant variation. The simulated data exposes the authentic performance of the network under study, on the assumption that all enabling conditions and infrastructures are in place, the number of successful calls is a little bit higher than the number of dropped calls.

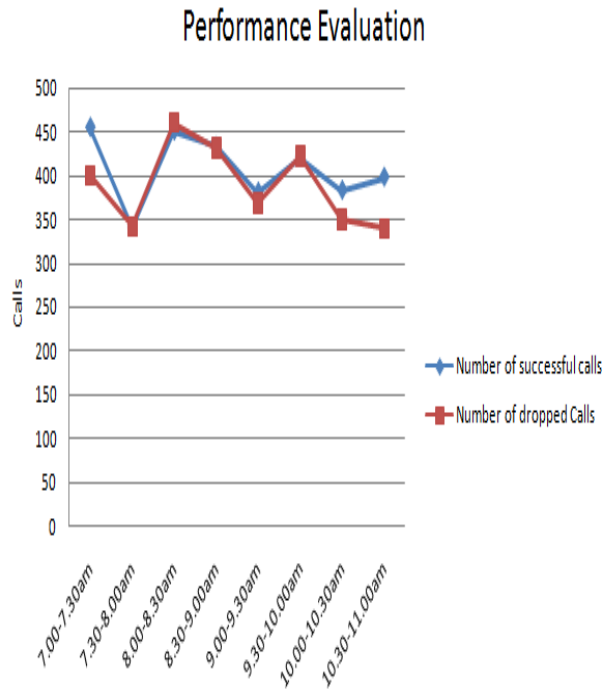

Figure4: Result of day one observation

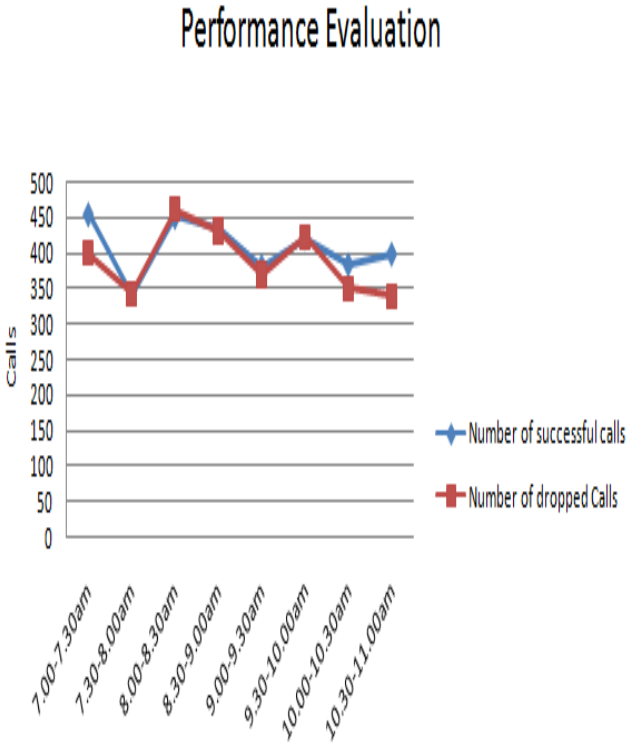

Figure5: Result of day two observation

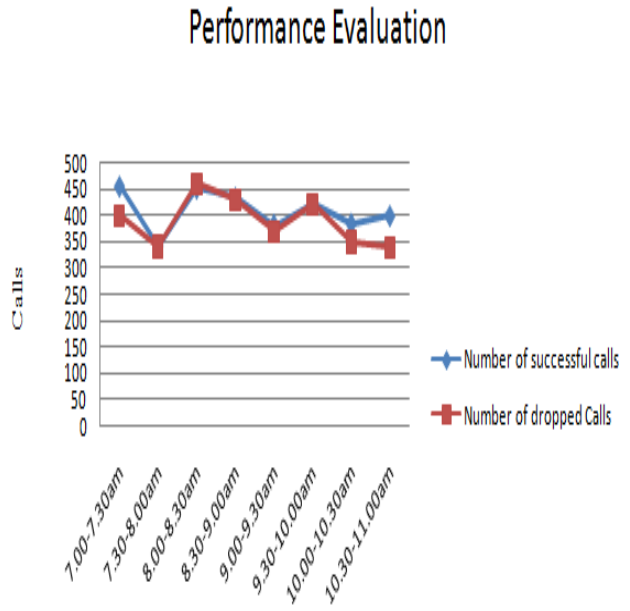

Figure6: Result of day three observation

6. FACTORS AFFECTING QUALITY 0F SERVICE

Below are some of the major factors affecting quality of service of telecommunication in Nigeria:

A. Bandwidth Allocation

When the telecommunication operator takes more users than it can handle, the consequential outcome is jamming on the network. What it means is that there are no available channels to route call through.

B. System Frequency harmonization

Lack of Base Transceiver Station (BTS) harmonization effects GSM handover performance, resulting to some degradation of quality of service. The speech quality of calls between two handsets, undergoing handover between two BTSs harmonized with variable frequency offset, was measured in terms of Mean Opinion Score (MOS) and speech clipping. The result shows that without the network harmonization, there is about 40% performance degradation. The Mean Opinion Score is a measure of listening quality with score ranging from bad; poor; fair; good; excellent according to the scale defined in ITU-T Rec. Speech Clipping is a measure to indicate the loss of speech segment.

C. Instability in Power Supply

Recent study revealed that 80% of the total cost of operations by telecommunication operators goes into provision of generators and its fueling. The epileptic nature of our power supply system in Nigeria had necessitated the over-dependence on generators.

The direct connotation of this is that call tariff will significantly shoot up. Apart from this, it is obvious that the cost of procurement and fueling is so enormous. If our power supply system is stable, this huge amount could have been used in upgrading and

optimizing existing base stations in order to improve service efficiency.

D. Security of infrastructure
Due to the volatile nature of some parts of the country, telecommunication equipments are not safe from vandalisation. There have been many reported cases of theft and vandalisation at base station sites. This development has prompted telecoms operators to invest heavily on recruitment of security personnel at their base station sites. One direct implication of this is that the cost incurred on these security guards goes into the total cost of operation and subsequently leading to increase in call tariff.

E. Call set up failure
This is the ability of a subscriber to initiate a call and granted access. Technically, during a GSM call setup, a speech call is assigned from a SDCCH (stand alone dedicated channel) to a TCH (traffic channel). If the TCH selected suffers from interference, then the mission will fail. And the mission failure message will be sent to the MSC. The call will then be reestablished back.

F. Call retention
Call retention is the ability to retain a GSM call after it has been established while dropped call is a situation whereby an established call is abruptly terminated while conversation is ongoing. It is a common occurrence in Nigeria's GSM system that communication is terminated unexpectedly while conversation is ongoing.

G. Congestion
Congestion is a phenomenon in telecommunication system that occurs when more subscribers attempt simultaneously to access the network than it is able to handle. This is a situation where subscriber numbers has completely overgrown network capacity.

H. Coverage Problems
The BTS coverage can stretch 30Km as maximum diameter depending on the traffic in urban or rural areas. Coverage problem appears if waves transmitted by the mobile can not reach the nearest BTS or if waves transmitted by the BTS are not received with sufficient power which can be detectable by the mobile. Sufficient coverage can be caused by antennas special disposition, we can consider the case of an obstruct between the antenna and the mobile (building, mountain.
To resolve this problem, operators have to take many actions in concerned sites :
i. Adding sites: This solution is preferred in the case of coverage absence or if waves transmitted by BTS antennas cannot reach the nearest area with sufficient power,
ii. Antennas change such as tilting, changing antennas orientation.
ii. Configuration change: This action aims to rise many antenna parameters such as transmission power (BS_TXPWR_MAX).

I. Interference
The signal at the receiving antenna can be weak by virtue of interference from other signals. These signals may be from the same network or may be due to man-made objects. However, the major cause of interference in a cellular network is the radio resources in the network. Indeed, high capacity increases interference because of reuse of frequency technique.
There three kinds of interference:
i. Co-Channel interference: occurs when radio transmitters from two adjacent cells transmit on the same channel, in the same TDMA timeslot. When this happens, the signal is temporarily distorted. The result will be poor speech quality, drop-outs or even complete call losses in voice calls, GPRS data connections will slow down significantly. Co-channel interference cannot be avoided, since the same channels must be re-used in other cells not far apart. In GSM various techniques have been developed to reduce the problem, for example discontinuous transmission, frequency hopping, power control and adaptive multi-rate coding. However, the problem remains the ultimate limiting factor for network capacity.
ii. Adjacent channel interference: This phenomenon is due to the use of two frequencies having adjacent bandwidth by sites not well separated,
iii. Co-site interference: occurs when two neighbouring frequencies are used in the same site. To avoid this problem, many actions can be taken: Operators should choose an adequate cluster for frequency reuse technique, change antenna direction and reduce the BTS transmission power

7. SUGGESTED METHODS 0F IMPROVEMENT

Having evaluated the parameters that attributed to poor quality of service by operators, the following under listed methods are suggested towards improving the quality of service of Telecom Nigeria.

A. The engineers of Telecom should design their works having good quality of service at the back of their minds. The network should be designed in such a way that it will never fail. That is it should be able to create alternative links to resolve transient changes over the network. Protocols, gateways and backbone for the network should be wisely chosen or decided upon.

B. Telecoms should invest heavily in transmission network development and have a proper radio planning. This would ensure increased network resilience, improved bandwidth utilization and alleviation of capacity bottleneck.

C. Build additional switching centers across the country and increase capacity to handle more traffic.

D. Telecom should upgrade and optimize all existing base stations. If this is done, it will stem call set up failures due to rise in traffic volumes.

E. They should install additional base stations across the country. This would create room for the network to handle more traffic.

F. If a particular base station is to be taken "offline" (either for schedule maintenance, repairs, upgrades etc.), all neighboring base stations should have their communication power level increased. This will increase their coverage area, thereby reducing congestion and dropped calls.

G. Incessant power failures should be addressed by the government. This will stop the over-dependence on generators for power supply. If this is achieved, call tariff would drastically go down.

H. As technologies emerge rapidly, Telecom Nigeria should be very proactive in the acquisition and deployment of new electronic when they come onboard. The network should be accessible to the largest number of users. The land mass of the country should be taken into serious consideration, Knowing that greater part of the population reside in the rural areas.

I. The use of Automated Test Calls and GIS (geographic information system) based tool is highly recommended. Automated Test Calls overcomes all the limitations of manual Test Calls in monitoring quality of service.
However, the use of GIS-based tools becomes imperative as it helps to make informed technical decision in resolving network issues. It shows areas experiencing low quality of service.

J. Telecom operators in Nigeria should continue to give back to the society aimed at enhancing social security. Because no amount of security personnel can deter hoodlums from attacking base station sites. Also, if government can create more jobs for its citizens, poverty level would be reduced and a lot of boys and girls will be taken off streets. Hence we would have a secured environment.

8. CONCLUSION

Quality of service is seen as a key performance indicator that is used in determining the efficiency of an industry in terms of services rendered. This paper has explored different factors affecting quality of service of telecommunication industries in Nigeria and also suggested different methods of improving them.

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