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Evaluating the Effectiveness of Mobile Telecommunication Network in APAPA Lagos South-West, Nigeria

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ABSTRACT: Quality of service and customer satisfaction in a cellular communication system is the major concern for real time applications. In order to fulfill the users' demand, it is important for mobile network operators to ensure stability and efficiency by delivering a consistent, reliable and high quality end-user satisfaction. In this paper, a performance evaluation of a cellular network provider is presented. The data for the research was collected from Mobile Telecommunication Network (MTN), a leading telecom operator in Nigeria. The parameters of the network and operational data were collected from 10 arbitrary selected base stations from Apapa area of Lagos state covering a period of six months. The research was developed by holistically exploring the Key Performance Indicators (KPIs) covering all aspects of network planning and development. It was found that the call blocking probability for all the base stations except BTSs 2, 8and 10 fell below the NCC stated benchmark of 2% signifying good performance. Also the trunking efficiency of BTSs 2, 4, 1, 8, 3, 10, 5 and 6 in increasing order were slightly above the 60% benchmark prescribed by NCC. The results of the analysis of drop-call probability performance at all the 10 base stations were also found to be within acceptable limits. On the whole, the results revealed that the MTN subnetwork in the Apapa area was performing satisfactorily. However further optimization is required at the affected BTSs for improved trunking efficiency and call blocking probability.

KEYWORDS: Quality of Service, Call blocking Probability, Channel Utilization rate, KPI and Drop-call probability.

I. INTRODUCTION

Day by day communication through technological means has become more popular over the past decade due to the numerous developments in the area of wireless technologies. During the past decades the evolution of these wireless technologies has enabled the development to better achieve users' satisfaction. New innovations in cellular networks are also emerging subject to the demand of users. At present, with increasing number of demands driven applications, different types of services are available to fulfill the expectation of users. Against this backdrop, efficient Quality of Service (QoS) method is required to sustain and improve the quality of the multifarious services aspiring to satisfy users' satisfaction. This need is much more expedient in real-time application such as voice and video telephony, QoS has enormous importance in providing efficient services in order to fulfill the users' expectation. QoS is a term which has been widely used in modern telecommunications. QoS is the ability to provide different priorities to different applications or flows to guarantee a certain level of performance. QoS guarantees are especially important when the network capacity is insufficient or the network is exposed to congestion. Quality of service refers to traffic-dependent performance metrics—trunking efficiency, call blocking probability, and drop- call probability A network's admission-control mechanisms, which are invoked whenever a new connection is initiated, provide assurance that QoS requirements will be met; a new connection is aborted if its QoS requirements cannot be met. Attention to QoS issues is increasing because of at least two converging trends: the growing market for applications (e.g., video) that require real-

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time service, and the evident interest in using the Internet for a range of activities that are critical to both the public and private sectors

Key Performance Indicators (KPIs) have been extensively investigated and widely used in accessing the quality of services generally by the service providers. [16] used KPIs to evaluate the performance of an operational GSM network. The network performance evaluation is based on four major KPIs, i.e., call setup success rate, call drop rate, handover success rate and traffic congestion. In [15], the authors evaluate the handled traffic and network utilization of an operative GSM network during eight months. They developed a regression-based forecasting model for the traffic. The performance of GSM and GPRS operational network is presented in [18] with a review of the most common KPIs that are used to evaluate the performance of GSM and GPRS networks. The relationships between these KPIs are introduced and thresholds for some KPIs are suggested so that the GSM operators should not exceed them. [17] addressed the optimization of GSM network, data sorting and analyzing, implementing the optimization and system fine tuning. Network dimensioning such as BSC, MSC and other related parameters are addressed and the top ten wireless parameters are listed which are the most important from the authors' point of view. In [23], the KPIs for QoS evaluation in GSM network are identified. Four assessment parameters (network accessibility, service retainability, connection quality, and network coverage) for evaluating the QoS were applied on four GSM networks in Nigeria. The results of that study showed that the QoS of GSM networks in Nigeria is unreliable and the network accessibility and retainability are unsatisfactory. The study in [24] aimed at presenting the QoS of network optimization and evaluation of KPIs provided by GSM operators in terms of the ability to establish and maintain call connections, call retention, handover, inter and intra network call set-up. [19] carried out comparative analysis of network congestion. In their research, they proposed a combine and non – combined model for managing the congestion control. The research proposed a new scheme that can control congestion in GSM network. The network performance evaluation was based on four major key performance indicators (KPIs) which include call setup success rate, CDR, handover success rate and traffic channel congestion rate. The KPIs were explored and the performance of the new model was compared with that of the non-combined (existing) model. Finally, improvement methodologies were suggested. [25] carried out traffic congestion audit of MTN cells located within Dutse metropolis, which involves following routes between the cells and assessing the quality of service (QoS). Drive test was conducted to collect traffic data, the base transceiver station (BTS) power throughput was measured and the maximum carrying capacity of mobile stations (MSs) was identified which enabled him to determine the amount of deviation from the expected power. He identified the channels and/or interface(s) that habitually contributed to this traffic congestion by comparing the outcomes with the KPIs. Conclusively, he found out that the channels that are greatly involved in call setup are simultaneously played a vital role toward congestion effect. The work of [20] investigated the causes of congestion using a survey research design methodology, live data from MTN BTS and BSC, as well as customer feedback. The study showed that a major cause of MTN network congestion is lack of adequate network resources to cope with the demand of its teeming subscribers. Similarly, [21] simulated some traffic models in MATLAB environment for evaluating performance of GSM networks using Call Completion Ratio (CCR) and Answer Seizure Ratio (ASR) on four mobile network's BTS and BSC in Nigeria. The result showed that the QoS is not reliable as a result of network congestion. However, the work did not identify the cause or proffer solution to the congestion problem. Similarly, [22] established traffic pattern for 6 BSCs over 24 hours in Nigeria for a period of five months and the analysis showed that the busy hour is 20:00 on five of the BSCs and 14:00 on one of the BSCs.

II. THEORY OF WORK

In this research work, our primary focus is to appraise the service quality being rendered by mobile telephone operator in Apapa Lagos State South-West, Nigeria from the end user satisfaction perspective, using Mtn GSM network operator as case study. The intention is to investigate the how Quality of Service (QoS) provided by the GSM network operator impact the end user satisfaction. Particularly, we intend to quantitatively assess the end users' satisfaction rate from the general network performances of the studied GSM telephone operator.

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The evaluation of the network is done by looking at the Key Performance Indicators (KPI) [1] of the network. Typical KPIs are metrics for measuring QoS. QoS is most commonly measured by the following metrics: call blocking probability, trunking efficiency and drop-call probability

III. CALL BLOCKING PROBABILITY

In a wireless mobile network, CBP or GoS is among the key performance measures in mobile communication network. Usually this parameter is specified in the design. To evaluate the performance of a wireless network, the concept of traffic offered, traffic carried, and traffic lost is illustrated in Figure 1

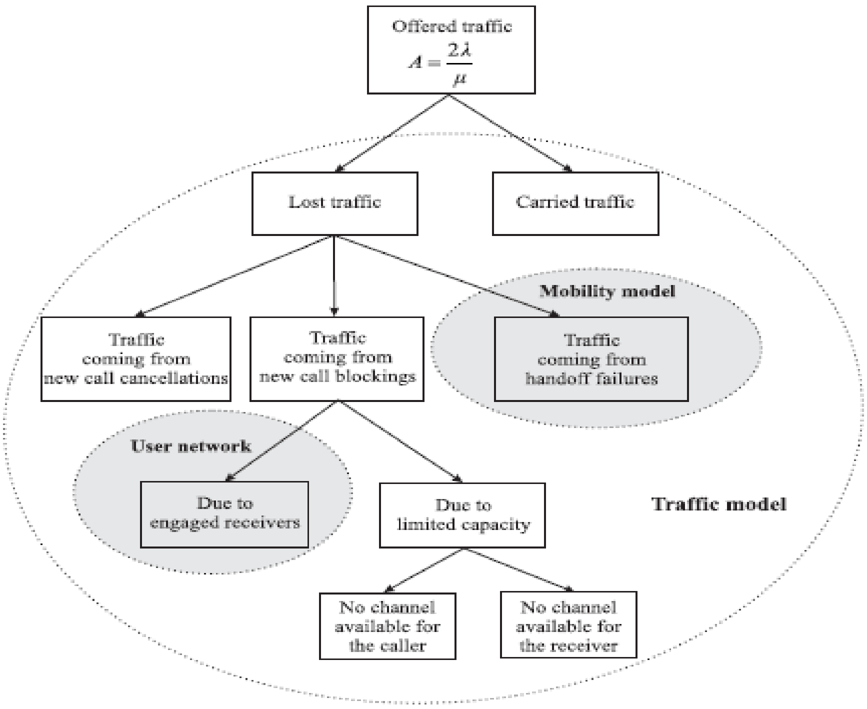

Figure 1: Network Traffic scenario [11]

The term of GoS is donated by PB is used and it is defined in [4] as;

$$P_B = \frac{\text{Traffic lost}}{\text{Traffic offered}} \tag{1}$$

In general, $GoS = P - A_O / P$

Where, P = offered traffic, A_o = carried traffic and $P - A_o$ = lost traffic

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[2] also defined GoS as:

$$GoS = \frac{\text{Served}}{\text{Existing}} \tag{2}$$

Served is the total number of served users in a defined target area and existing is the total number of users in this area. The GoS denotes the probability that a specific service is available. The operator of GSM networks usually tries to guarantee a minimum GoS of about 90 percent.

IV. TRUNKING EFFICIENCY OF THE CELLULAR NETWORK

Another important parameter which is usually used to characterize the efficiency of cellular network is called trunking efficiency (channel utilization efficiency). Trunking efficiency is the maximum traffic intensity that a system can provide for a given GoS which is determined by the amount of traffic per channel [6]

Trunking Efficiency $$(\eta_T) = \frac{\text{Carried traffic in Erlangs}}{\text{number of channels}}[0,1] \tag{3}$$

Trunking efficiency is also measured by the channel usage efficiency (or loading factor) [12]. The channel utilization depends on the total traffic and call arrival rate. In the Erlang B model

$$(\eta_T) = \frac{P(1 - P_B)}{N} Erlang / channel \tag{4}$$

The Erlang-B formula is not entirely applicable to cellular systems, because it does not account for handoff calls. Furthermore, the total offered traffic per cell may be time-varying due to the spatial movement of the subscribers, whereas the offered traffic in the Erlang-B formula is assumed to be constant. The Erlang-B formula

$$P_B = \frac{\frac{P^N}{N!}}{\sum_K^N = 0 \frac{P^{K_O}}{K_o!}} \tag{5}$$

Where, P is the offered traffic (capacity) $[Erlang]$, P_B is the blocking probability, N is the total number of traffic channels and K_o is number of users.

To calculate the capacity of the given cell using blocking probability and the number of carriers, we need the well-known Erlang B table or formulas and the number of traffic channels for different number of carriers. The result we get is the traffic capacity in Erlangs, which can easily be transferred into the number of subscribers and formulation as:

$$\text{Erlangs} = \frac{\nabla \times t}{3600} \tag{6}$$

where, ∇ = number of calls attempted and t = total duration in seconds. Also to determine the traffic per subscriber using Equation 35 ([5] recommends traffic per subscriber between 0.025Erlang and 0.033Erlang when planning GSM network).

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V. DROPPED- CALL PROBABILITY

Dropped call is the common term for describing the rate of calls which end due to technical reasons. The probability of such an event is known as drop- call probability [10]. Drop-call probability is given by [13] as:

$$P(\mathrm{Y}=n)=\frac{(V_d t)^n}{n!}e^{-V_d t} \qquad n \geq 0 \qquad (7)$$

Here, V_d is the drop-call rate, *t* the call duration, while Y is a random variable that counts the number of drops and *n* is the confirmed calls dropped. Call dropping events constitute a Poisson probability distribution function. This model, there are no assumption in a particular technology, it is worthwhile to note that the model can be exploited to predict the drop-call probability in different networks (e.g. GSM, PCS, UMTS). The drop-call probability is one of the most important QoS index used to monitor the performance of cellular networks. Wireless service providers have to design the network to minimize the call dropping probability for customer care. Generally, more than 50% of the reasons for dropped calls by [13] in a cell, are reported to be mainly due to electromagnetic causes, and other factors are; the prepaid account balance, service plan subscribed, power supply of the mobile devices, the users' mobility mechanism, and handoff. There are different ways to calculate DCR. It can be calculated as dropped calls per Erlang, dropped calls over originated calls and dropped calls over all calls handled by each cell, including incoming handovers. In this work, we will use dropped calls over originated calls only, since it is the most common way in which operators calculate DCR. Furthermore, studying call dropping behaviors as a function of other network parameters (e.g. traffic load, utilization factor, call arrival rate and call duration) would aid the optimization of the system's performance and guarantee excellent quality of service delivery as well as improved revenue. Moreover, [13] showed that the number of dropped calls due to inadequate radio link quality and other similar reasons is calculated from the relation

$$\text{Drop-call rate} = \frac{\text{No. of dropped calls}}{\text{No. of call attempts}} \qquad (8)$$

The application of the above formula (equations 5, 7 and 8) in probability analysis as carried out in various literature [13] and [14] shows that dropped-call probability decreases with an increasing number of channels.

i. Call Arrival Rate

Call arrival rate λ_t, refers to the traffic offered expressed as the number of call attempts per unit time which is given by [26] as:

$$\lambda_t = \frac{\text{Number of Call Attempts/busy hour}}{\text{14400 seconds/busyhour}} \qquad (9)$$

ii. Call Duration

Call duration is another parameter that can affect the quality of service in a cellular network, hence it is considered when planning the network [7]. Call duration or mean call holding time is defined as the time a mobile station takes to complete a call connection. Mathematically, call duration is given by [8] as:

$$t = \frac{P}{\lambda_t} \qquad (10)$$

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Where; P = traffic intensity in Erlang, λ_t = call arrival rate

iii. **Channel Utilization Factor**

The utilization factor is the ratio of the time that the network is in use to the total time that it could be in use. Utilization factor is the traffic load in the cellular network. Traffic load signifies the strength of the offered traffic in the network [9]. By definition, the traffic load is the ratio between the arrival rate of calls and the service rate of the calls arriving. Utilization factor gives the product of total traffic offered and the mean service time

$$Utilization\ \text{factor} = P \times t \quad (11)$$

Where P is an Average Traffic Intensity, t is the Mean Holding time

Therefore, we can simply analyze the impact on model results of the call-arrival rate and of the call duration.

VI. METHODOLOGY

Traffic analysis plays an important role in the planning and network design in cellular communication system, particularly in network resource allocation, performance evaluation of network in terms of utilization capacity and coverage.

An average Busy Hour Traffic (BHT) data for six months is presented in Table 1 using the busy hour for Ten different GSM base stations in Apapa Lagos, south western part of Nigeria in order to evaluate the performance making use of data obtained for three key performance indicators. The primary data for this study were obtained from the OMC are; number of call attempts, number of successful call and service time (calls duration). These traffic parameters were used to determine the offered traffic, block traffic (loss traffic), traffic channel and other traffic performance parameters also called Traffic Key Performance Indicator (KPI). They are Calls Completion Rate (CCR), Grade of Service (GoS), Channels Utilization Rate (CUR), drop- call rate (DCR), call arrival rate and drop-call probability etc., by improving these parameters, we improve the quality of network from using Table 1 and equations (3), (6), (7), and (8) were presented in Table 2 and Table 3.

VII. DATA ANALYSIS AND RESULTS

Average busy hour key performance indicator for the ten base transceiver stations were shown in Table 2 and Table 3.

Table 1: KPIs data Obtained from OMC for the Ten Base Transceiver Stations for six months

S/N	Base Station	Call attempt Based on (BHT)	Successful call Based On (BHT)	Call in duration (s)
1	BTS1	7800	7796	103
2	BTS2	11104	10298	119
3	BTS3	5016	4936	34
4	BTS4	11871	11647	113
5	BTS5	2830	2799	22
6	BTS6	2124	2094	20
7	BTS7	928	922	28
8	BTS8	1123	998	103
9	BTS9	195	193	15
10	BTS10	370	362	114

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Table 2: Calls Analysis of 10 Base Transceiver Stations Indicators for six months

Base Station	Number of Channel	Call attempts based on (BHT)	Calls Completed Based on (BHT)	Call Blocking Probability (%) C-D / C	Call completion rate (CCR) D / C	Offered Traffic in Erlang	Carried traffic in Erlang FxG	No of Dropped Call C – D	Trunking Efficiency (Utilization rate, %) H / B
A	B	C	D	E	F	G	H	I	J
BTS1	238	7800	7796	0.05	0.999	223.17	223.06	4	93.72
BTS2	400	11104	10298	7.26	0.927	367.05	340.40	806	85.10
BTS3	58	5016	4936	1.59	0.98	47.37	46.62	80	80.38
BTS4	400	11871	11647	1.89	0.98	372.62	365.59	224	91.40
BTS5	25	2830	2799	1.10	0.989	17.29	17.10	31	68.40
BTS6	19	2124	2094	0.94	0.991	11.80	11.69	20	61.53
BTS7	13	928	922	0.65	0.994	7.22	7.17	6	55.15
BTS8	42	1123	998	11.13	0.889	32.13	28.55	125	60.74
BTS9	4	195	193	1.03	0.99	0.81	0.80	2	20
BTS10	19	370	362	2.16	0.978	11.72	14.47	8	76.16

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Table 3: Evaluation of Drop Call Rates, Call Arrival Rate and Drop Call Probability

Base Station	No. of Call Attempt (BHT)	Call in duration (s)	Number of Channels	Channel Utilization Factor	Drop call rate In BHT (%)	Call Arrival Rate (Call/s)	Drop call probability (%)
BTS1	7800	103	238	0.94	0.05	0.54	$4.46x10^{-5}$
BTS2	11104	119	400	0.85	7.83	0.77	$1.44x10^{-5}$
BTS3	5016	34	58	0.80	1.62	0.35	$41.10x10^{-5}$
BTS4	11871	113	400	0.91	1.92	0.82	$1.77x10^{-5}$
BTS5	2830	22	25	0.68	1.11	0.20	$20.69x10^{-5}$
BTS6	2124	20	19	0.62	0.96	0.15	$11.57x10^{-5}$
BTS7	928	28	13	0.55	0.65	0.06	$1.38x10^{-5}$
BTS8	1123	103	42	0.61	12.53	0.08	$0.015x10^{-5}$
BTS9	195	15	4	0.20	1.04	0.01	$9.56x10^{-10}$
BTS10	370	114	19	0.76	2.21	0.03	$6.08x10^{-5}$

Analysis of Call Blocking Probability of Cellular Network

The blocking probability as function of traffic is shown Table 1 and Figure 2. It shows a bar chart displaying the call blocking probability level attained in each base transceiver stations. It is observed from the chart that only base stations 1, 3, 4, 5, 6, 7 and 9 met this standard 2%. This means that congestion experienced by the users in these base stations are low. Other base transceiver stations 2, 8 and 10 fail to meet this target and this could imply that congestion by the users in the subnetwork is high and so optimization is needed. The effect of high number of block calls experience in mobile network, especially during the Busy Hour (BH) has leads to poor Quality of Service (QoS) delivering in mobile network. Therefore, higher blocking probability for user network is caused by call concentration by a number of users who might majorly be mobile. This is because in addition to inadequate channel capacity, the user behavior has a profound influence on call blockings and this high call blocking probability may be attributed to poor network monitoring by the network operators to match the ever changing traffic intensities. Therefore, for improved quality of service, the call blocking probability must be minimized to a certain level less than or equal to 2%.

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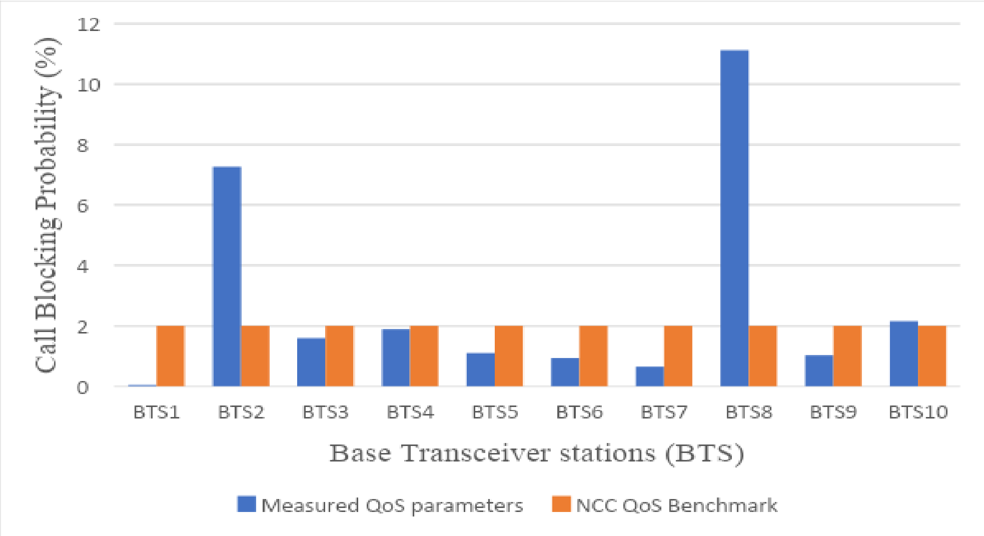

Figure 2: Comparison of NCC QoS Benchmark and estimated Call Blocking Probability

Analysis of Trunking Efficiency of the Cellular Network

In the case of MTN network in Apapa, the trunking efficiency performance is presented in Table 1 and plotted in Figure 3. It can be seen that the best performing base stations are 7 and 9 having the lowest trunking efficiency. Base transceiver stations 2, 4, 1, 8 and 3 followed by 10, 5 and 6 trunking efficiencies is above 60% benchmark stated by NCC. These will result in loss of calls or blocked calls in affected base transceiver stations. Effort should be made by the mobile communication operator to provide good quality of service (QoS) and monitoring agency (NCC) should ensure that they conform to recommended standard to avoid blocked calls during the busy hour. Thus appropriate optimization measure is required to increase capacity.

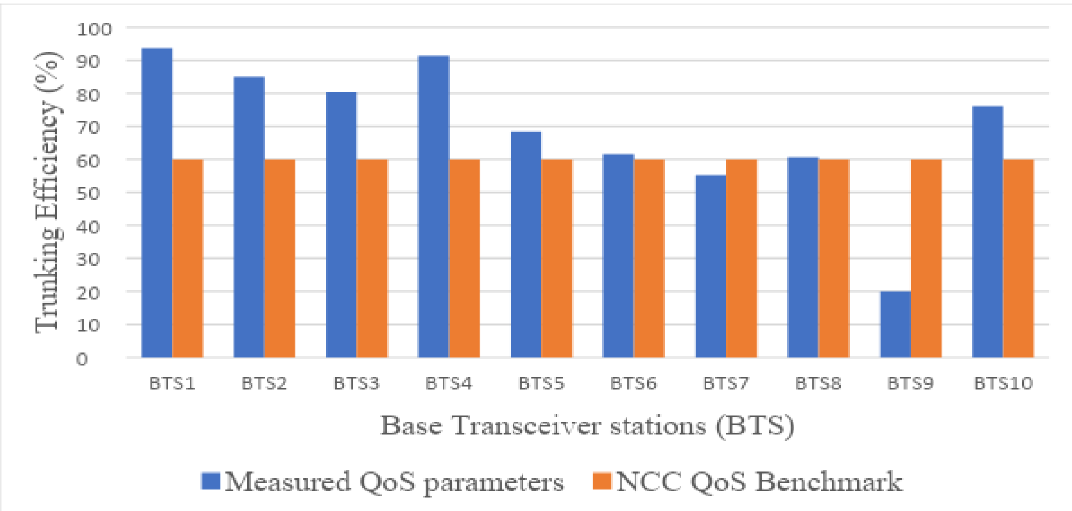

Figure 3: Comparison of NCC QoS Benchmark and estimated Trunking Efficiency

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Analysis of Drop Call Probability of the Cellular Network

The drop-call probability is one of the most important parameter for assessing the quality of service (QoS) in a cellular network. Table 2 and Figure 4 confirms that MTN network in Apapa is performing satisfactorily. This is because the estimated values of drop-call probabilities were well below the benchmark at all the 10 base stations.

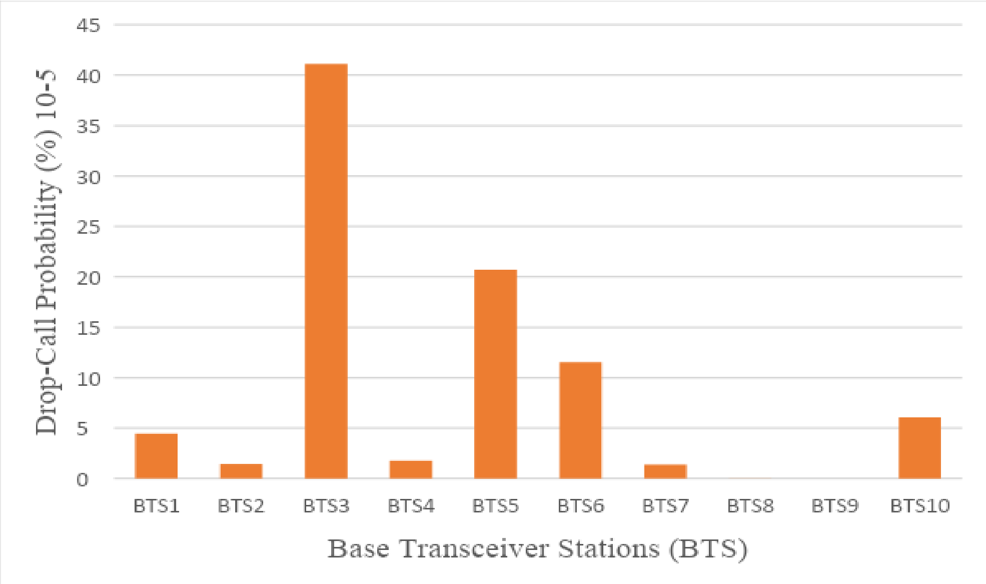

Figure 4: Comparison of Drop-Call Probability at Base Transceiver Stations

VIII. CONCLUSION

The main goal of our research work is to evaluate the existing QoS performance for Mtn network. The evaluation is made based on some performance metrics such as call blocking probability, trunking efficiency and drop-call probability. On basis of the results and literature review, the performance of the network was satisfactory.

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