Evaluation and Analysis of Key Performance Indicators Which Affect QoS of Mobile Call Traffic

Owusu Nyarko-Boateng (Ph. D Candidate) *owusu.nyarko-boateng@uenr.edu.gh*
School of Science/Dept. of Computer Science & Informatics
University of Energy and Natural Resources
Sunyani, Ghana

Adebayo Felix Adekoya (Ph. D) *adebayo.adekoya@uenr.edu.gh*
School of Science/Dept. of Computer Science & Informatics
University of Energy and Natural Resources
Sunyani, Ghana

Abstract

Mobile communication is ubiquitous and its usage cut across all sections of human activities. This service has become a necessity in the daily activities of humans across the globe; from communications within organizations, health care educational institutions, government agencies, the judiciary, etc, all these human driven activities rely on mobile communications for prompt information delivery. Ensuring quality service delivery by the mobile network operators (MNOs) in the mobile communication space to meet the demands of the loyal users is essential. Poor quality of service in mobile communications such as call setup failures, signals loss, congestion, jitters call drops are some of the key indicators which usually measure network quality and the experience of mobile service users. This paper investigated how the quality of mobile communications are affected by Key Performance Indicators (KPI) such as Call Setup Success Rate (CSSR), Call Drop Rate (CDR), Traffic Channel (TCH) Availability, Stand-alone Dedicated Control Channel (SDCCH), and Call Setup Time (CST). These KPIs are mostly affected by severe congestions due to several factors. The paper also evaluates and analyze these factors which causes severe congestions on the mobile call traffic, the paper also sought the views of users and their perception on the quality of service delivery. The paper then provided suggestions and recommendations on how the MNOs could improve and upgrade their infrastructure and ensure the users always have the most efficient and quality of service delivery.

Keywords: Quality of Service, Key Performance Indicators, Call Setup Success Rate, Call Setup Time, Call Drop Rate, Traffic Channel.

1. INTRODUCTION

In telecommunication services, it is strongly expected that industry players such as the MNOs, provide quality services to its subscribers while the regulating agencies set the framework for standards and monitoring compliance. In most cases the MNOs are not able to meet these targets of ensuring subscribers are given efficient and quality voice, data and other value added services such as mobile banking services, cloud storage service, contents service delivery, etc. These inefficiencies tend to affect subscriber's quality experience with the MNO services. Provision of quality call traffic requires that the MNOs meet certain industrial parameters, which are robust and efficient transmission system, Base Transceiver Station (BTS), switching and billing infrastructure. There are several factors that contribute to inefficient delivery of QoS by the MNOs (Kar & Sanyal, 2017). These include but not limited to packet loss, error bit rate, throughput, transmission delay, availability, jitters, limited facility vis-à-vis the large number of subscribers which mostly result in high-level congestion. This paper evaluates the possible areas in services of which the KPIs affect the quality of service provided by the MNOs. The paper further performed comparative analysis of the impact of congestions and other indicators on call traffic which affect subscribers' quality of experience (Shinkuma, Tanaka, Yamada, Takahashi & Onishi, 2018).

Kar & Sanyal (2017) established that quality of service is an important KPI used in determining the efficiency of MNOs in terms of services rendered. In telecommunication system, accessibility, retainabilty and connection (voice) quality are three major factors used in evaluating the KPIs of an operator. Consumers in the industry expect maximum satisfaction from any services paid for. The maximum satisfaction factor has now become a difficult task to achieve especially in the telecommunication industry; some major evidence which can be attributed to this are the mismatch of hardware component, expansion in customer base and infrastructural expansion.

1.1 Mobile Service Subscription

At the end of September 2018, the total number of mobile voice subscriptions in Ghana was 40,089,004. This represents a percentage increase of 1.83% from June 2018's figure of 39,367,236. The total penetration rate for the month under review was 137.38% as shown in figure 1. MTN's voice subscriptions for the period was 19,073,969 representing a percentage increase of 1.83% from June 2018's figure of 18,730,632. MTN's market share for the month under review was 47.58%. Vodafone's mobile voice subscriptions increased from 9,342,496 as at the end of June 2018 to 9,534,186 as at the end of September 2018. This represents a percentage increase of 2.05%. Vodafone's market share for September 2018 was 23.78%.

Tigo's voice subscriptions increased from 5,158,375 as at the end of June 2018 to 5,337,668 as at the end of July 2018 indicating a percentage increase of 3.48%. Their market share for the month under review was 13.31% as compared to 13.10% in September 2018.

Airtel's voice subscriptions decreased from 5,392,707 as at the end of June 2018 to 5,390,704 as at the end of September 2018, a percentage decrease of -0.04%. Their total market share for the month under review was 13.45%. Voice subscriptions of Glo increased from 743,026 as at the end of June 2018 to 752,477 at the end of July 2018. With a percentage increase of 1.27%, their total market share for the month under review was 1.88% as compared to 1.89% in September 2018.

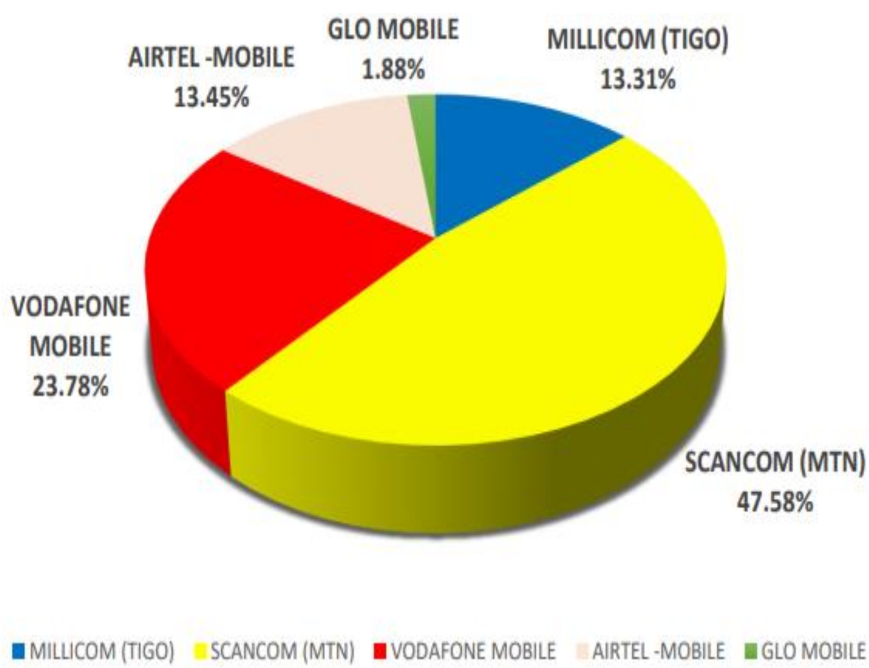

FIGURE 1: Market share of the mobile network operators (NCA, 2018).

2. RELATED WORK

Popoola, Megbowon, Adeloye (2009) in their research on the GSM networks, selected four (4) MNOs as their primary sources of data. These MNOs were Celtel, MTN, Glo and M-Tel. They conducted the research on three KPIs which were Call Drop Rate (CDR), Call Setup Success Rate (CSSR) and Call Completion Success Rate (CCSR). Pavan, Anuradha, Vivek, Naresh (2010), also did a work which was an improvement over what Popoola et al (2009) did. Their work additionally discussed SDCCH KPI as a factor which affected QoS. According to Pavan et al (2010), call initialization goes through three thematic processes, which also suffered inefficiencies (Nasralla, Khan & Martini, 2018).

Popoola, Atayero, Faruk & Badejo, (2018) collected data from four telecom companies and used it for QoS analysis. These comprehensive data were obtained from the Nigerian Communications Commission (NCC). In their work, Popoola et al, 2018, conducted ANOVA test on the data obtained. Significant differences in each of the KPIs for the four quarters of each year were presented and the values of the KPIs were plotted against the months of the year for better visualization and understanding of data trends across the four quarters of the year 2017. Multiple comparisons of the mean-quarterly differences of the KPIs were also presented using Tukey's Post Hoc test. The authors also gave a useful information that will assist the network providers, Nigerian government, local and international regulatory bodies, policy makers, and other stakeholders in ensuring telecommunication companies provide high quality service (Nasralla et al., 2018).

Osahenvemwen & Ikheba, (2015) and Soudani, Divoux &Tourki (2012) conducted a study which aimed at evaluating the QoS of the MNOs. The authors investigations were based on quality of service and relative parameters such as the traffic load, successful calls, attempted calls, traffic congestion and causes of drop calls in mobile communication network which were part of the four thematic process underlined by Naranlla et al., (2018) and Popoola et al., (2018) and were analyzed as established by (Kim, Kim & Park, 2018). They undertook comprehensive analysis of data obtained from an Operational and Maintenance Centre (OMC) over a one-year period. It was observed that the number of attempted calls increased, the number of blocked calls also increased in proportional rate (Zhou, Liu, Wang, Deng & Oh, 2016). Osahenvemwen & Ikheba, (2015) concluded their study by providing a clear Analysis on why the key performance indicators lead to the poor QoS.

3. QOS OF MOBILE CALL TRAFFIC

Mobile Call traffic (MCT) is the process of regulating the incoming and outgoing volumes in voice communications, particularly in wireless mobile networks and in VoIP (voice over Internet Protocol, also known as Internet telephony). MCT can also be used to maintain certain level of audio quality in voice communications networks, or certain level of performance in Internet nodes and servers where VoIP traffic exists (Kim et al, 2018).

MCT works by regulating the total utilized bandwidth, the total number of calls, or the total number of packets or data bits passing a specific point per unit time. If a defined limit is reached or exceeded, a new call may be prohibited from entering the network until at least one current call terminates (Nasralla et al., 2018). Alternatively, a graceful degradation methodology can be implemented. This means that the audio quality of individual calls can deteriorate to a certain extent before new calls are denied entry (Zhou et al., 2016). Another method involves the regulation of calls according to defined characteristics such as priority descriptors. Another method prevents new calls from entering the network only if the resources of the Base Transceiver Station (BTS) are not overburdened by several call initialization (Shinkuma et al., 2018).

In order to have quality of service in the end-to-end MCT management, hardware capacity constraints and transmission imbalance of uplink and downlink paths are properly controlled with an enhanced matching software upgrade and balanced system configurations. According to Kim et al (2018), QoS helps to control the delay, jitter and packet loss experienced by individual resources of the network (jitter refers to the variability in delay). Since MCT is a limited resource, it is important to ensure that all network components that are most sensitive to delay, congestion, jitter and packet loss are given priority over less sensitive traffic in MCT management.

In order to ensure quality service delivery in MCT, delayed voice packets must be re-transmitted as soon as possible when the network is congested. Network congestion is the reduced quality of service that occurs when a network node or link is carrying more data than it can handle. Typical effects include queuing delay, packet loss or the blocking of new connections. The consequence of congestion is the decrease in network throughput. QoS guarantees a steady and continuous stream of voice packets from the source (speaker) to the destination (listener) involved in the conversation, resulting in a high-quality phone call (Kar & Sanyal, 2017).

3.1 Key Performance Indicators (KPIs)

In Ghana, the regulatory body that measures the performance of the key indicators of mobile call quality is National Communication Authority. NCA is mandated by the laws of the nation to sanction any MNO whose performance within a specific measuring period falls below the required threshold. Table 1 shows the five (5) KPIs that NCA deploys in judging the performance of the MNOs. The given thresholds are to be met by all MNOs at all time. In situation where MNO fail to meet the threshold for a particular KPI, it means there were some form of congestions which affected the performance of those KPIs. For instance, if there was CCR rate of less than 70%, it means call retention rate did not measure up to 70% for that period.

TABLE 1: KPIs Used To Determine QoS in Ghana.

KPI	**SDCCH CONGESTION RATE (%)**	**TCH CONGESTION RATE (%)**	**CALL DROP RATE (%)**	**CALL SETUP TIME (sec)**	**CALL COMPLETION RATE (%)**
Threshold	**≤ 1%**	**≤ 1%**	**≤ 3%**	**<10 sec**	**KPI ≥70%**

3.2 KPIs Which Affect QoS of Mobile Call Traffic

According to NCA (2018), QoS of voice calls are performed in series of 2 attempts within 10 seconds for a delay of 10 seconds between the defined series. A successful call initialization is to last for a maximum of 60 seconds and must be completed in a window of 90 seconds. The minimum time required for a call set up and before the end of a call window is 30 seconds. The maximum call set up time is 30 seconds.

Popoola et al, (2018) and Idigo, Azubogu, Ohaneme & Akpado, (2012), established that in order to enable regulators and operators to measure call handling of MCT for benchmarking and compliance, certain KPIs must be met. This paper defines six (6) significant KPIs in accessing QoS of mobile call traffic (NCA, 2018).

3.2.1 Stand-alone Dedicated Control Channel (SDCCH) Congestion Rate

SDCCH Congestion Rate should be equal or less than one per cent (1%). SDCCH Congestion is defined as the probability of failure of accessing a stand-alone dedicated control channel during call set up. For analysis and calculations,

$$SDCCH = \frac{Number\ of\ connect\ failures\ due\ to\ immediate\ assignment\ failures}{MOC\ call\ attempts} x\ 100\%$$

3.2.2 Call Setup Time (CST)
CST should be less than ten seconds (<10sec) in 95% of cases. Call Setup Time is the difference of the time when the mobile station (MS) sends a channel request message to the time when the MS receives the alerting message from the mobile switching controller (MSC).

$$CST = t_{alerting\ signal} - t_{address\ sending}$$

Where, $t_{\text{alerting signal}}$ is the moment when an alerting signal is sent to the called terminal and $t_{\text{address sending}}$ is the moment the user presses send on the calling terminal

3.2.3 Call Congestion Rate (CCR)
Traffic Channel Congestion should be equal or less than one per cent (1%). Call Congestion Rate is the probability of failure of accessing a traffic channel during call setup;

$$CCR = \frac{Number\ of\ connect\ failed\ calls}{Total\ number\ of\ call\ attempt}\ x\ 100\%$$

3.2.4 Call Drop Rate (CDR)
Call drop rate should be equal or less than three per cent (3%). Voice Call Drop Rate is the probability of a call terminating without any of the users' will;

$$CDR = \frac{Number\ of\ call\ terminated\ unwillingly}{Total\ number\ of\ call\ attempt}\ x\ 100\%$$

3.2.5 SDCCH Call Drop Rate (SCDR)
The SDCCH call drop rate is one of the accessibilities KPIs and it indicates the probability of call drops when the MS occupies the SDCCH. This KPI reflects the seizure condition of signaling channels. If the value of this KPI is high, user experience is adversely affected.

$$SCDR = \frac{Call\ Drops\ on\ SDCCH}{Successful\ SDCCH\ Seizures + Successful\ SDCCH\ Seizures\ in\ the\ signaling\ channel\ handover}\ \mathrm{x}\ 100\%$$

3.2.6 Traffic Channel (TCH)
TCH is the probability of failure of accessing traffic channel(s) or radio access bearers during call connections

$$\text{TCH availability } (100\%) = \frac{\text{Mean Number of Available Channels}}{\text{Mean number of dynamically configured Channels}}\ \mathrm{x}\ 100\%$$

4. RESEARCH METHODOLOGY
The data used for the evaluation and analysis in this paper were categorized into two, which were the primary data and the secondary data. The primary data was obtained from MNOs by using monitoring software called U2000. The data collected from MNOs were SDCCH, CSSR and TCH availability values. The values of the other KPIs such as CDR and CST were not easily assessable at the time the evaluation and analysis was conducted. Another primary data was obtained from NCA.

This data was the result of a drive test the agency conducted in September 2018. The secondary data was obtained by the assessment of quality of experience of subscribers through the use of questionnaires. These data were evaluated and then comparative analyses of the various KPIs which affect the quality of service of the MNOs were done.

4.1 Target Population and Sampling Technique of the Secondary Data
The target population was the total number of subscribers of the five MNOs in Ghana which stood at 40,089,004 for period under consideration. The regional capitals of the five major regions out of

the total sixteen regions in Ghana were selected for the subscriber's QoE measurement. The regional capitals are Accra in the Greater Accra region, Kumasi in the Ashanti region, Koforidua in the Eastern region, Takoradi in the Western region and Tamale in the Northern. For the sake of anonymity, the MNOs have been labelled as MNO1, MNO2, MNO3, MNO4 and MNO5.
In order to reach all the sample size for the study, a convenience sampling technique was used because participants (Subscribers) were selected based on availability and willingness to take part.

The sample size was calculated through Slovin`s formula (Osunsan et al, 2015) by using a confidence level of 95%.

$$n = \frac{N}{1 + Ne^2}$$

n = 40,089,004 / (1+ (40,089,004) $(0.05)^2$

n= 40,089,004/ 100223.51

n= 400

In the formula N is the total population, e is the error of tolerance and n is the sample size. The total population consists of 40,089,004 which represent the total number of subscribers for the five MNOs.

4.2 Data Collection Instrument and Procedure

To ensure the study meet its objectives, relevant questionnaires were given to the respondents (subscribers) and a well-defined pre-test was conducted with five senior managers of the selected MNOs. The results obtained from the pre-test helped reshaped the questionnaire to suit the expected purpose of the study. Data for the study composed of both primary and secondary data sources. The primary data source includes drive test results conducted by NCA (NCA, 2018). The secondary data includes the opinion of the subscribers' representation of questionnaires administered online to respondents using google forms.

The questionnaire had a cover letter seeking the consent of respondent and also stating the voluntary nature of the survey, and a statement of secrecy of the respondent's data. Using the Likert scale approach, the questionnaire was divided into three sections. Section A was on Personal Information; Section B call success rate; Section C focused on service satisfaction. The questionnaires were basically focused on subscriber's experience on their MNOs in September 2018. At the end of the survey which last for a period of 10 days, only 157 subscribers who were at the five selected cities in September, responded appropriately instead of 400 targeted sample size.

4.3 Drive Test Result

Quality call benefit evaluation depends on Mean Opinion Score (MOS). MOS is measurement of quality of service used to evaluate the subscribers' view of quality call, testing the quality of call traffic and estimating call degradation. The standard for estimating MOS is an International Telecommunications Union (ITU) approved standard. The MOS is communicated as a single number in the range 1 to 5, where 1 is most minimal evaluated quality, and 5 is the most evaluated quality. According to the permitted conditions of ITU, MNOs are required to meet an MOS score of at least 3.5 for over 95% of calls.

Table 2 shows the percentage of calls within the permit range and the compliance status of the MNOs measured in five towns in five regions of Ghana. Per the license score and the ITU standard, all the MNOs were able to meet the targeted standards in most of cities where the evaluation was conducted. This situation indicates that some KPIs of the MNOs were met and there were failures in most instances which resulted in the abysmal performance of the compliance status failure. For instance, in table 2, MNO3 obtained a test result of 10.20sec for CST in Accra but the ITU standard was <10sec.

TABLE 2: Drive Test Report**.**

	KPIs	**SDCCH CONGESTION RATE (%)**	**TCH CONGESTION RATE (%)**	**CALL DROP RATE (%)**	**CALL SETUP TIME (SEC)**	**CALL COMPLETION RATE (%)**
City	**THRESHOLD**	**≤1%**	**≤1%**	**≤3%**	**<10sec**	**>70%**
Accra	MNO1	0.00	0.03	0.00	11.40	96.77
Accra	MNO2	0.00	0.26	0.00	9.20	96.12
Accra	MNO3	0.00	0.35	0.00	10.20	83.48
Accra	MNO4	0.00	0.14	0.00	9.51	98.02
Accra	MNO5	0.03	0.11	0.00	7.40	95.80
Koforidua	MNO1	0.00	0.06	0.03	7.90	95.80
Koforidua	MNO2	0.00	0.00	0.00	6.17	98.00
Koforidua	MNO3	0.00	0.06	0.00	9.70	37.20
Koforidua	MNO4	0.00	0.06	0.00	7.40	98.30
Koforidua	MNO5	0.00	0.00	0.00	8.67	96.09
Takoradi	MNO1	0.04	0.02	0.00	8.60	96.72
Takoradi	MNO2	0.08	0.02	0.00	8.73	93.25
Takoradi	MNO3	0.00	0.00	0.00	10.92	22.43
Takoradi	MNO4	0.00	0.00	0.00	7.90	99.28
Takoradi	MNO5	0.04	0.00	0.00	8.40	97.93
Tamale	MNO1	0.00	0.00	0.00	7.60	99.28
Tamale	MNO2	0.00	0.27	0.00	7.90	91.45
Tamale	MNO3	0.00	0.53	0.00	7.71	72.48
Tamale	MNO4	0.00	0.63	0.00	8.20	98.19
Tamale	MNO5	0.00	0.00	0.00	9.30	98.04
Kumasi	MNO1	0.00	0.02	0.00	9.30	91.41
Kumasi	MNO2	0.00	0.03	0.00	7.90	96.42
Kumasi	MNO3	0.00	0.22	0.00	8.08	65.20
Kumasi	MNO4	0.00	0.00	0.00	9.10	96.40
Kumasi	MNO5	0.00	0.00	0.00	9.10	98.06

5. SURVEY RESULTS AND ANALYSIS

The survey ended with only 157 users responding as indicated in table 3; out of these respondents' 32 were below the ages of 20 which represent 20.4%. The age range between 20 and 30 years represented 72 respondents', which is 45.9%. According to the survey, the age group between 0-30 years which were the youthful age represented 66.3%.

This results strongly confirms the notion that the use of mobile devices are prevalent among the youth (Shinkuma et al., 2018). The respondent above 31 years were 53, which represented 33.8%.

TABLE 3: The Age Range of The Respondent.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Below 20	32	20.4	20.4	20.4
	20-30	72	45.9	45.9	66.2
	31-40	21	13.4	13.4	79.6
	Above 40	19	12.1	12.1	91.7
	5	13	8.3	8.3	100.0
	Total	157	100.0	100.0	

When asked what their mobile network operator was, 57 respondents' representing 36.3% said they were MNO5 subscribers as shown in table 4. MNO4 subscribers were 29.9% of the respondents. MNO2 and MNO1 subscribers among the respondents were 31.2%. MNO3 had its subscriber base at 2.5%. This figure confirms the market share data provided by NCA that MNO5 is the largest telecommunication company in Ghana and MNO3 is the least patronized service in Ghana because the company do not have nationwide coverage and even had few subscribers at the location where the drive test and the survey was conducted.

TABLE 4: What is Your Mobile Network Operator (MNO)?

		Frequency	**Percent**	**Valid Percent**	**Cumulative Percent**
Valid	MNO5	57	36.3	36.3	36.3
	MNO4	47	29.9	29.9	66.2
	MNO2	21	13.4	13.4	79.6
	MNO3	4	2.5	2.5	82.2
	MNO1	28	17.8	17.8	100.0
	Total	157	100.0	100.0	

When respondents were asked how often they experienced congestions, when calls were initialized, 5.7% said they have never experienced any form of call congestion. This question was posed in order for the authors to know if users mostly make several attempts to get their calls through. 45.9% respondents experience congestions very often while 26.1% said they always experience call congestion. This results strongly suggest that more than half of the respondents sometimes, very often or always experience congestion; the frustration subscribers may have gone through as a result of congestions was enormous. As indicated in table 5, 8.9% said they rarely experience congestion.

TABLE 5: How often did you experience any form of congestion when you initialized calls?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Never	9	5.7	5.7	5.7
	Rarely	14	8.9	8.9	14.6
	Sometimes	21	13.4	13.4	28.0
	Very Often	72	45.9	45.9	73.9
	Always	41	26.1	26.1	100.0
	Total	157	100.0	100.0	

Table 6 shows the mean opinion score for each of the nineteen questions posed to the respondents. The respondents were given a close-ended five (5) Likert scale degree options to choose. The Likert scale options were 1, 2, 3, 4, 5 with 1 being the lowest and 5 was the highest. MOS of 3 indicate a neutrality of the respondent and the MOS below 3 indicate the respondents' perception on the MNO services is bad. MOS above 3 indicate a good service from the MNO. The MOS of the entire survey was 2.84; this value represents the perception index of the respondent based on the quality of service provided by the MNOs. On the Likert scale, 1=Strongly Dissatisfied, 2=Dissatisfied, 3=Neutral, 4=Satisfied and 5=Strongly Satisfied. The MOS value 2.84 indicate that even though the respondents were dissatisfied with the poor quality of service from the MNOs, their perception scale moved closer to the neutrality point.

TABLE 6: Mean Opinion Score (MOS) of Respondents.

Focused study area which determines excellent KPIs	N	Minimum	Maximum	Mean (MOS)	Std. Deviation
Q1. What is your age	157	1	5	2.42	1.183
Q2. What is your mobile network operator (MNO)?	157	1	5	2.32	1.341
Q3. Where were you in September 2018?	157	1	5	2.49	1.357
Call Congestion Rate					
Q4. How often did you experience any form of congestion when you initialized calls?	157	1	5	3.78	1.107
Q5. How severe was the congestion if there was any?	157	1	5	3.34	1.047
Q6. How many call attempts did you make before your call went through?	157	1	5	2.30	1.222
Call Drop Rate (CDR)					
Q7. Did you experience any form of call drop in September?	157	1	5	3.15	1.139
Q8. How often did your call drop?	157	1	5	3.45	1.106
Q9. How often did you experience call drop when you initialized the call or during active communication?	157	1	5	3.24	1.087
Q10. How often did you have a good network signal on your phone?	157	1	5	2.71	1.312
Call Setup Time (CST)					
Q11. How long did it take your initialized calls to go through successfully?	157	1	5	3.17	.966
Q12. How often did you experience regular long CST over the period?	157	1	5	2.70	1.268

Q13. How often did you at any point in time had a weak signal on your phone when you initiated calls?	157	1	5	3.19	1.326
Call Completion Rate (CCR)					
Q14. How often did you ever complete talking on phone over the period?	157	1	5	2.59	1.405
Q15. How often did you experience any call breaks or intermittent silence from the recipient end?	157	1	5	3.61	1.054
Quality of Experience (QoE)					
Q16. How satisfied were you, considering the quality of service rendered by your MNO?	157	1	5	2.07	1.297
Q17. In your view, do you think the services provided by your MNO met your expectations?	157	1	5	3.00	1.064
Q18. I will recommend the services of my MNO to others	157	1	5	2.37	1.355
Q19. How will you rate your MNO based on your QoE	157	1	5	2.03	1.242
Valid N (listwise)	157			2.84	

Table 7 shows the measurement of the strength of the association between the three variables thus, Q4, Q5 and Q6. The t-test was used to establish the correlation coefficient which was significantly close to zero (0). There was an evidence of an association between the three variables. Pearson correlation of normal and hypervent = -0.521. P-Value = 0.000. The strength of association between the variables was very high (r = -0.521). The correlation coefficient was very highly and significant as P< 0.01, hence P-Value =.000

TABLE 7: Pearson Correlations between Q4, Q5 and Q6.

		How often did you experience any form of congestion when you initialized calls?	How severe was the congestion if there was any?	How many call attempts did you make before your call went through?
How often did you experience any form of congestion when you initialized calls?	Pearson Correlation	1	-.521**	-.367**
	Sig. (2-tailed)		.000	.000
	N	157	157	157
How severe was the congestion if there was any?	Pearson Correlation	-.521**	1	.381**
	Sig. (2-tailed)	.000		.000
	N	157	157	157
How many call attempts did you make before your call went through?	Pearson Correlation	-.367**	.381**	1
	Sig. (2-tailed)	.000	.000	
	N	157	157	157

**. Correlation is significant at the 0.01 level (2-tailed).

5.1 ANOVA Test

An ANOVA test is an analytical approach to find out whether a survey or experiment results is significant. The significance level determines either to accept or reject a hypothesis. This paper analyzed the significance of the responses of the respondents using a one-way ANOVA. Table 8 shows the significance level of 0.970, of the responses. The significance level indicates an acceptability of the test. The result of the ANOVA test strongly concludes that most respondents were not satisfied with the kind of services rendered by the MNOs.

TABLE 8: How satisfied were you, considering the quality of service rendered by your MNO?

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.110	2	.055	.030	.970
Within Groups	280.324	154	1.820		
Total	280.433	156			

Figure 2 shows the scatter analysis of three variables representing the measurement of QoE of the respondents. The location of the respondent during the period of research and the MNO of the respondents largely depends on the expected quality of service from the subscribers. The diagram indicates the expectations of the respondents against their chosen MNO and their location.

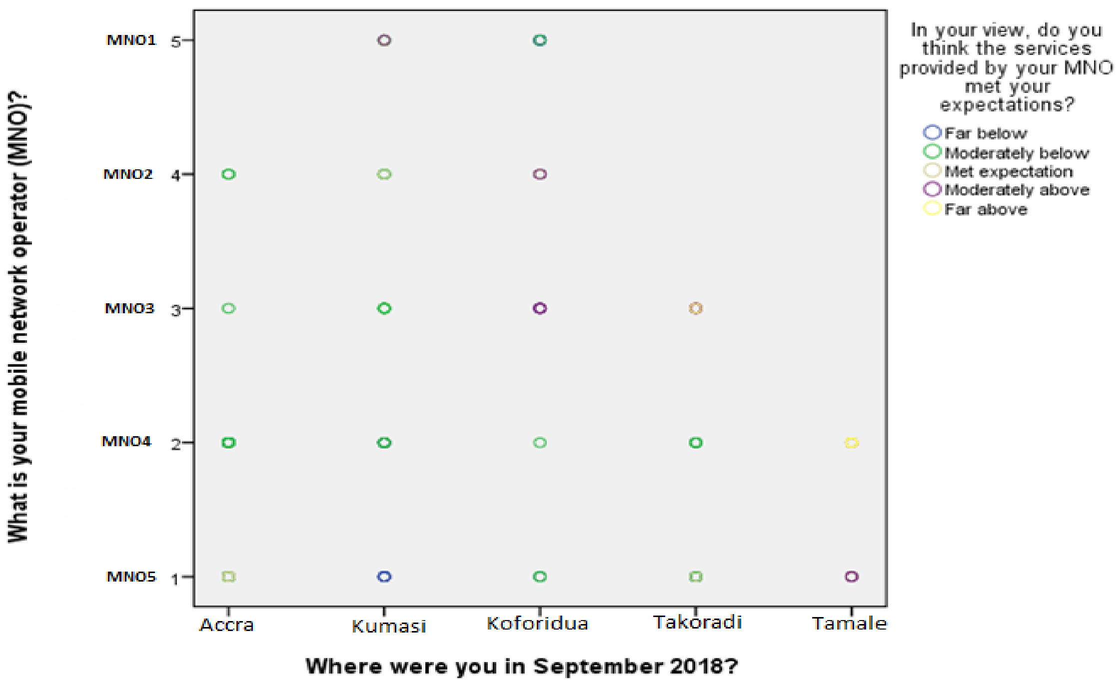

FIGURE 2: Scatter Statistical Analysis.

In table 9, the Pearson's chi-square test conducted indicate that the p-value was .000 with the resulted 95% confidence level. The degree of freedom was 4. The chi-square test concludes that the variables are not independent of each other and that there is a statistical relationship between the categorical variables Q1 and Q2 which defines the respondent's perception about the QoS of the MNOs.

TABLE 9: Pearson's Chi-Square test of Q2, Q3 and Q16.

	What is your mobile network operator (MNO)?	Where were you in September 2018?	How satisfied were you, considering the quality of service rendered by your MNO?
Chi-Square	42.140[a]	23.350[a]	44.497[a]
df	4	4	4
Asymp. Sig.	.000	.000	.000

a. 0 cells (.0%) have expected frequencies less than 5. The minimum expected cell frequency is 31.4.

5.2 MNOs Data

To achieve an in-depth analysis, several data were collated from other sources for that purpose. The MNOs were contacted to release the graphical representation of the mobile call traffic flow for the period the drive test was conducted. This data was crucial in this study because a comparative analysis needed to be done to ensure high throughput value for the inbound and outbound traffic were obtained by the various MNOs. Only one MNO released its data presented graphically on *Call Setup Success Rate (CSSR), Traffic Channel congestion (TCH) rate* and *Stand-alone Dedicated Control Channel (SDCCH) congestion rate.*

SDCCH Call drop rate determines the count of active calls that are dropped within the evaluation period as indicated in figure 3. Generally, the drop was minimal and on significant occasions the drop rate increased intermittently within the period. High concentrations of call retention were observed throughout the evaluation period. In figure 3, CSSR were measured for a period of eleven (11) days. Six (6) out of these days had high call setup failure rate but generally there was an extremely high concentration of call success rate which was a direct reflection of call quality within the period. Congestions and the degradation of many other KPIs were the cause of these drops within the period.

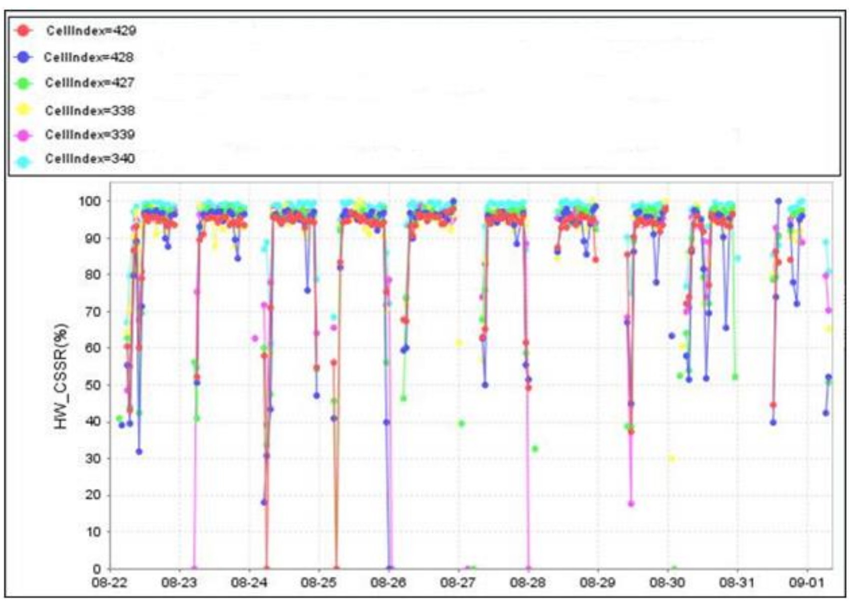

FIGURE 3: Call Setup Success Rate (CSSR).

TCH is a critical KPI in telecommunications industry. The availability of dynamically configured traffic channels determines call success rates. Figure 4 shows the TCH traffic penetration for each cell. The cell index measured showed how call traffic allocated available channels for quality communication. The indexes showed high TCH availability except in some few instances that there was high congestion rate in the traffic channels which accounted for high SDCCH drop and call setup failure as indicated in figure 5.

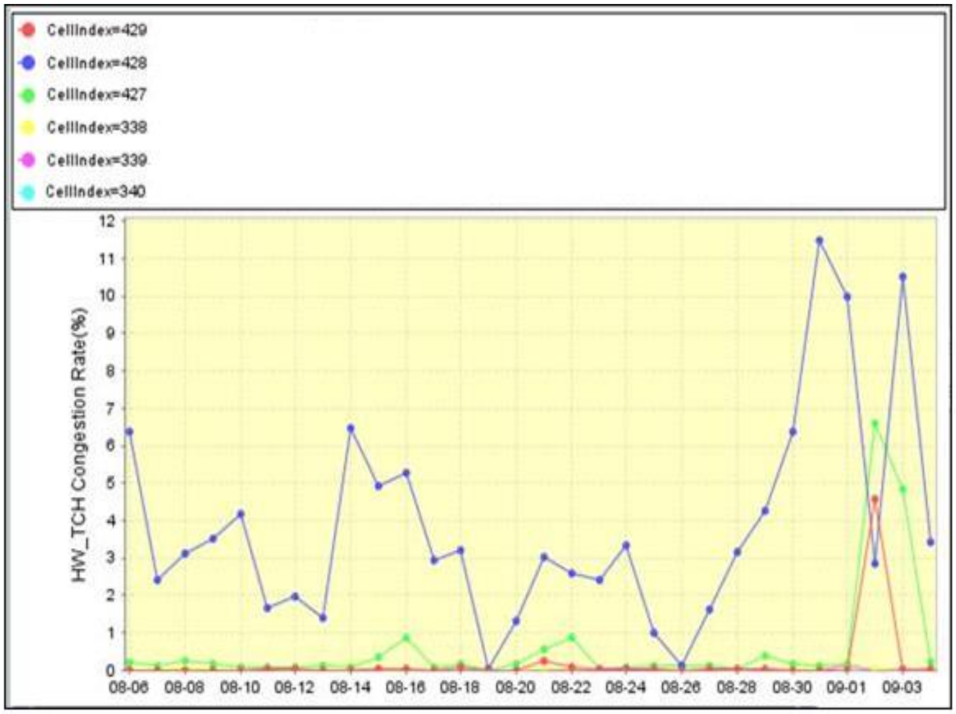

FIGURE 4: TCH Congestion Rate.

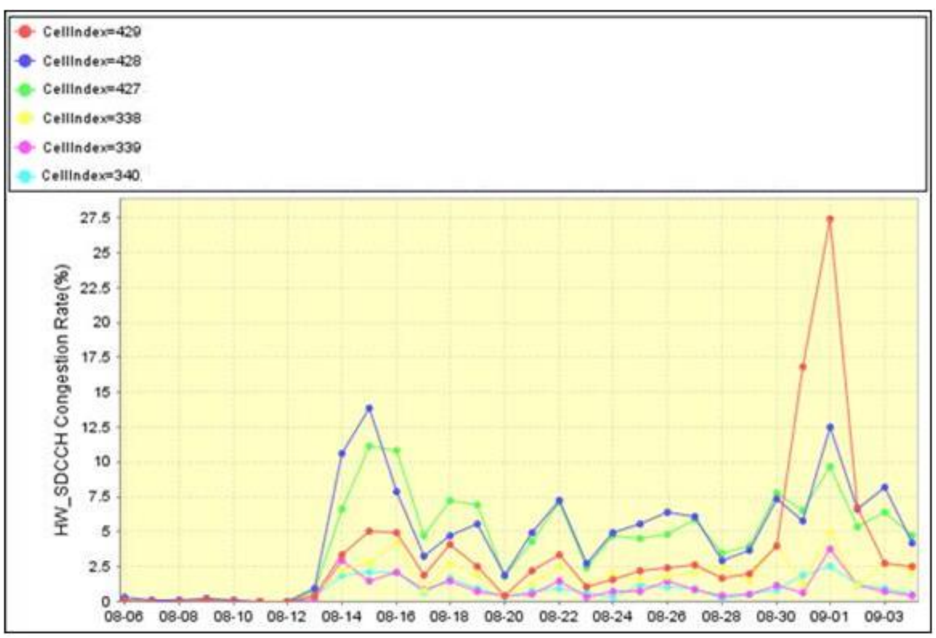

FIGURE 5: SDCCH Congestion Rate.

6. DISCUSSION

Table 10 represent the relations matrix of network elements which and KPIs which determines QoS in the mobile communication space. In comparative analysis many research work as published by Eghonghon, (2017); Idigo et al., (2012) and Nasralla et al., (2018) have been carried out to evaluate the quality of service performance of mobile telecommunications network. In order to achieve the aim of their assessment, Idigo et al., (2012) used three KPIs to match against the industry best practice. The authors deployed descriptive statistics to analyze the Traffic Channel Congestion Ratio, Call Drop Ratio and Call Setup Success Ratio on hourly and daily basis and it was found that the busy hour TCH Congestion Ratio target of below 2%, the busy hour CDR target of below 2% and the busy hour CSSR target value of above or equal to 98% were obtained (Idigo, Azubogu, Ohaneme & Akpado, 2012) and (Eghonghon, 2017).

The previous works on the QoS measurement were silent on the user experience and other key elements such insufficient hardware capacity, software incompatibility, etc. were not given the required attention. These elements which act as the determinants of the KPIs has been presented in Table 10 in a matric index to compare the various KPIs against the required network element factors.

TABLE 10: Network QoS and KPI Comparative Matrix.

Network factor	SDCCH Congestion	TCH Congestion	Call Drop	Call Setup Rate	Call Completion
Poor coverage	√	√			
Congestion	√	√			
Hardware and transmission fault	√	√		√	
Tx imbalance of UL and DL Path			√		√
Software incompatibility		√		√	
Insufficient hardware capacity		√	√	√	

Congestion of the various KPI has been a major contributing factor to the quality of service by the MNOs. TCH and SDCCH congestion rate has been shown to have heavily impacted on the call drops, call setup time and call complete rate in Ghana. TCH configuration largely depends on the capacity that MNO's physical or local infrastructure support. In order to achieve a high TCH availability MNOs creates huge volumes of logical TCH capacity to accommodate large number of user within a specified enclave. High TCH availability drastically reduces TCH congestion which results in improved QoS (Delgado & Santiago, 2013). In table 2, the drive test conducted in the cities indicated high TCH availability hence the low TCH congestion rate. In a situation where TCH congestion falls below that threshold of ≤1%, subscribers do not mostly struggle to initialize a success call if the SDCCH congestion rate is also with the ≤1% threshold. In other to achieve QoS in mobile call traffics by MNOs, these KPIs need to properly managed, especially the factors that causes KPIs congestions must be given a top priority to ensure transmission uplink and downlink packets reaches its destinations appropriately (Sánchez, Toril, Solera, Luna-Ramírez & Gómez, 2018).

According to Adegoke et al., (2008) and Kumar, Singh & Kharab (2017), the effect of KPIs congestion have a severe impact on call time setup, call drop, and call completion rate which results in industry standard compliance failure. In table 2, all the MNOs failed in standard compliance due to poor KPIs as measured in figure 3, figure 4 and figure 5. Traffic congestion in mobile networks occurs for various reasons depending on switching facilities, TRX equipment and Transmission infrastructure. Kim et al, (2018) and Adegoke et al, (2008) further stated that traffic congestion mainly occurs due to inadequate capacity of equipment and improper mobile traffic management. Causes of congestion may be categorized as congestion due to faulty equipment, congestion due to improper configuration of network and congestion due to generation of high traffic. In our evaluation of the performance of the MNOs, it was observed that the cell had high congestion rates, mostly recorded high level of temperature.

7. CONCLUSION AND RECOMMENDATION

Achieving high QoS requires huge investment into MNOs communication infrastructures. Transmission systems, BTS, Switches and other network critical systems such as software and configuration mismatch which have great tendency to affect KPIs must be addressed. Critical KPIs could be targeted to reduce congestion which occurs as a result of high temperature in hardware device, errors on transmission path, high transmission frequencies and transmission power. In our measurement, evaluation and analysis, we have provided recommendations for real world implementation which will significantly reduce delays, congestion and errors in order to improve KPIs such as CSSR, SDCCH, TCH, minimal call setup time, call retention. Improvement in these KPIs obviously impact positively on the QoS.

It is strongly recommended that, MNOs ensures these are fully implemented: Hardware infrastructure must be given critical attention concerning it durability, usability configuration. Faulty hardware and malfunction devices in the communication infrastructure must be quickly identified and swiftly replaced. Mostly MNOs finds it extremely difficult to replace such devices whose fault tolerance threshold has elapse, but still keep them in use. This adversely affect the performance of the device; this situation results in poor measurement of KPIs of the cell as indicated in figures 5.

The transmission infrastructures are design to operate in well ventilated environment because the hardware generate huge amount of heat. If hardware devices operating in an enclosed environment are not well ventilated, the performance of the device is hugely affected due to increase in temperature. In the evaluation process of most the cell sites visited, it was observed that most hardware device were not having enough ventilation due to dirt in the ventilation holes. Devices must be well ventilated and properly cleaned. Operational software versions must be upgraded and updated on regular basis in accordance with manufacturing and ITU standards. Configurations of these devices must be done by professionals in order to avoid poor parameter settings, interference (both inter-network and intra-network) and configuration mismatch. MONs must increase channel capacity to improve QoS. Implementation of these recommendations shall improve the QoS of MNOs in Ghana, may restore subscriber confidence in the services the MNOs provide.

8. FUTURE WORKS

The telecommunication industry has serious issues when it comes to quality service delivery. The issues as identified in this research work really have severe impact on the users. This phenomenon defines user perception of the QoS in the telecommunication industry. In the future, researchers can further look into the medium of transmission which mostly result in poor quality of service. Even though hardware challenges largely account for the poor QoS, further research into the mode of transmission and the study of data transmission rate will ensure proper understanding of the mobile traffic communications space.

9. ACKNOWLEDGMENT

We fully acknowledge the data we used which was a published result from a drive NCA conducted in some region in Ghana in the second quarter of 2018. We are also grateful for all the MNOs in Ghana for the data they made available to us during our KPIs measurement and evaluation.

10. REFERENCE

[1] Adegoke, A. S., Babalola, I. T., & Balogun, W. A. (2008). Performance evaluation of GSM mobile system in Nigeria. *Pacific Journal of Science and Technology*, *9*(2), 436-441.

[2] Adel Soudani, Thierry Divoux, Rached Tourki (2012), Data traffic load balancing and QoS in IEEE 802.11 network: Experimental study of the signal strength effect, Computers & Electrical Engineering, Volume 38, Issue 6, 2012, Pages 1717-1730, ISSN 0045-7906, https://doi.org/10.1016/j.compeleceng.2012.07.016.

[3] Almudena Sánchez, Matías Toril, Marta Solera, Salvador Luna-Ramírez, Gerardo Gómez (2018), Performance assessment of three-dimensional video codecs in mobile terminals, Computer Communications, Volume 125, 2018, Pages 56-64, ISSN 0140-3664, https://doi.org/10.1016/j.comcom.2018.04.016.

[4] Delgado, J. D., & Santiago, J. M. (2013). Key Performance Indicators For Qos Assessment In Tetra Networks. arXiv: Networking and Internet Architecture, 3(6), 1-18. Retrieved 12 6, 2018, from https://arxiv.org/abs/1401.1918.

[5] J. J. Popoola, I. O. Megbowon, V. S. A. Adeloye (2009); Performance Evaluation and Improvement on Quality of Service of Global System for Mobile Communications in Nigeria; Vol. 9, No. 2, pp. 91-106, 2009; Journal of Information Technology Impact.

[6] Kim, S., Kim, D.-Y., & Park, J. H. (2018). Traffic management in the mobile edge cloud to improve the quality of experience of mobile video. Computer Communications, 118, 40–49. doi:10.1016/j.comcom.2017.09.001.

[7] Moustafa M. Nasralla, Nabeel Khan, Maria G. Martini (2018), Content-aware downlink scheduling for LTE wireless systems: A survey and performance comparison of key approaches, Computer Communications, Volume 130, 2018, Pages 78-100, ISSN 0140-3664, https://doi.org/10.1016/j.comcom.2018.08.009.

[8] NCA (2018). QUALITY OF SERVICE (QoS) MONITORING OF CELLULAR MOBILE VOICE SERVICES. Retrieved from: https://www.nca.org.gh/assets/Uploads/QoS-Trends-for-April-2013.pdf. Retrieved on: 27th Nov. 2018.

[9] Osahenvemwen, O. A., & Ikheba, O. S. (2015). Evaluation of QoS in Mobile Communication Networks. International Journal of Computer Science and Telecommunications [Volume 6, Issue 11, December 2015]. ISSN 2047-3338.

[10] Osunsan, O. K., Nowak, J., Mabonga, E., Pule, S., Kibirige, A. R., & Baliruno, J. B. (2015). Firm age and performance in Kampala, Uganda: A selection of small business enterprises. *International Journal of Academic Research in Business and Social Sciences*, *5*(4), 364-374. DOI:10.6007/IJARBSS/v5-i4/1588

[11] Peng Zhou, Yanheng Liu, Jian Wang, Weiwen Deng, Heekuck Oh (2016), Performance analysis of prioritized broadcast service in WAVE/IEEE 802.11p, Computer Networks, Volume 107, Part 2, 2016, Pages 233-245, ISSN 1389-1286, https://doi.org/10.1016/j.comnet.2016.04.011.

[12] Popoola, S. I., Badejo, J. A., Ojewande, S. O., & Atayero, A. A. (2017). Statistical evaluation of quality of service offered by GSM network operators in Nigeria. Proceedings of the World Congress on Engineering and Computer Science 2017 Vol I WCECS 2017, October 25-27, 2017, San Francisco, USA.

[13] Popoola, S. I., Atayero, A. A., Faruk, N., & Badejo, J. A. (2018). Data on the key performance indicators for quality of service of GSM networks in Nigeria. Data in brief, 16, 914-928.

[14] Popoola, J. J., Megbowon, I. O., & Adeloye, V. S. A. (2009). Performance evaluation and improvement on quality of service of global system for mobile communications in Nigeria. Journal of Information Technology Impact, 9(2), 91-106.

[15] Pravin Kumar, Rajesh K. Singh, Karishma Kharab (2017), A comparative analysis of operational performance of Cellular Mobile Telephone Service Providers in the Delhi working area using an approach of fuzzy ELECTRE, Applied Soft Computing, Volume 59, 2017, Pages 438-447, ISSN 1568-4946, https://doi.org/10.1016/j.asoc.2017.06.019.

[16] Ryoichi Shinkuma, Yusuke Tanaka, Yoshinobu Yamada, Eiji Takahashi, Takeo Onishi (2018) User instruction mechanism for temporal traffic smoothing in mobile networks, Computer Networks, Volume 137, 2018, Pages 17-26, ISSN 1389-1286, https://doi.org/10.1016/j.comnet.2018.03.008.

[17] Ukhurebor Kingsley Eghonghon (2017). Evaluation of the quality of service of a cellular network using the network statistics. International Journal of Advanced Engineering and Technology ISSN: 2456-7655 Impact Factor: RJIF 5.54 www.newengineeringjournal.com Volume 1; Issue 5; Pg No. 01-07.

[18] U.N. Kar, D.K. Sanyal (2017), An overview of device-to-device communication in cellular networks, ICT Express (2017), Science Direct ICT Express. https://doi.org/10.1016/j.icte.2017.08.002.

[19] V.E.Idigo, A.C.O.Azubogu, C.O.Ohaneme & K.A.Akpado (2012), Real-Time Accessments of Qos of Mobile Cellular Networks in Nigeria; International Journal of Engineering Inventions ISSN: 2278-7461, www.ijeijournal.com Volume 1, Issue 6; PP: 64-68 64.