Quality of Service and Performance Analysis of A GSM Network In Eagle Square, Abuja and Its Environs, Nigeria

Lawal B. Y., Ukhurebor K. E., Adekoya M. A., Aigbe E.E

Abstract— Quality of Service (QoS) and Quality of end-user Experience (QoE) are the two major techniques used for judging the performance of GSM services. While the former is adjudged by service providers, the latter is determined by reactions from end-users (subscribers). Assessment of GSM services from service providers' perspective is usually based on some Key Performance Indicators (KPIs). This paper utilize the five major KPIs (CCSF, TCH-CR, CSSR, DCR, HOSR) to assess the GSM QoS provided by MTN, Nigeria to cover Eagle Square Abuja before, during and after PDP presidential primary election. The results show that the KPIs deviate from the recommended values both during the event and non-event period thus the QoS requires an uncompromising improvements inorder to curtail further degradation in the services derived by the rapidly increasing subscribers' rate..

Index Terms— CCSF, Cell, CSSR, DCR, GSM, HOSR, QoE, QoS, Suscriber, TCHCR

1 Introduction

THIS introduction of Global System for Mobile communication (GSM) in Nigeria which was launched in 2001, has no doubt impart meaningfully in the life Nigerians. Government Agencies, Ministries, Industries, Organizations, Institutions are all beneficiaries of this meritorious revolution. Apart from voice call which is the primary aim of GSM, other mouth-watering value added services such Short Message Service (SMS) and Internet services have opened door for a number of applications ranging from e-learning, mobile banking, e-mail, social networking, teleconferencing etc. The internet and web have further raised the revolutionary tempo especially through the enhancement of e-learning. E-learning is one that encompasses a wide set of applications and processes, such as Web-based learning, computer-based learning, virtual classrooms, and digital collaboration. It includes the delivering of content via internet, intranet/extranet (LAN/WAN), audio and video tape, satellite broadcast, interactive TV, and CD-ROM [1]. GSM services globally has also witness a number of transformations ranging 1G, 2G, 3G to the current 4G. It is obvious that the reasons for this transformation are qualitative voice calls, high speed data and internet connections e.t.c.

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's House of Representative on July 18, 2007 and the Nigerian Communication Commission (NCC) [2]. More users are connected to the existing network on daily basis; hence the need to continuously monitor the Quality of Service (QoS) delivered by service providers. With the growth of mobile services, it has become very important for an operator to measure the QoS and Quality of end-user Experience (QoE) of its network accurately and improve it further in the most effective and cost-efficient way to achieve customer loyalty and maintain competitive edge [3]. Since GSM services are locally provided by Base Transceiver Stations (BTS), it is pertinent to carry out performance analysis of a number of cells (BTSs) covering a community or a particular location. This paper presents the performance analysis and the quality of service delivered to a famous national historical event center called Eagle Square and its environ within Abuja metropolis, Nigeria. Service Providers and Regulatory authorities usually base the QoS and performance analysis of GSM services on Key Performance Indicators (KPIs). KPIs are parameters measured and obtained directly from network infrastructures such as Base Transceiver Station (BTS) and Base Station Controllers (BSC).

- *Lawal, B.Y is a Teaching Assistant and currently pursuing his Ph.D degree program in Communication Physics in Federal University of Technology, Akure, Nigeria. His areas of interest are Tropospheric/Ionospheric Radio Waves Propagation, Satellite Communications, GSM networks and Electronics Engineering. PH -2348032412347. E-mail: lawalyusuf.b@gmail.com*
- *Ukhurebor K.E. is a Lecturer at Edo University, Iyamho, Edo State, Nigeria. Presently, a PhD student in Electronic Physics at University of Benin, Nigeria. His research interests are Telecommunication Engineering, Environmental Physics and Electromagnetic waves. PH-2348035383194. E-mail: ukeghonghon@gmail.com*
- *Adekoya, M.A is a Lecturer at Edo University, Iyamho, Edo State. Presently, a Ph.D student in Condensed Matter Physics in Federal University of Technology, Akure, Nigeria. His research interest includes Material Physics, Synthesis and characterization of materials for device utilization. PH-2347038891545. E-mail: mathewadekoya14@gmail.com*
- *Aigbe, E.E. holds a Masters degree in Control System Engineering from University of Sheffield, United Kingdom. He has over eight years experience in Network Planning and Optimization and he currently works with LM Ericsson Nigeria. PH-2348036194573. E-mail: jefosaaigbe@gmail.com*

2 Evaluation of Quality of Service (QoS)

The Quality of Service generally can be described as the level of satisfaction a customer or an end-user obtained from a service. Customer satisfaction is critical to gain a sustainable competitive edge in the market [4]. It plays an important role in the growth rate and development of any business. Telecommunication regulatory agencies and the service providers are usually concerned in measuring quality of service so as to protect the customers' and service providers' interest respectively. QoS parameters are not always directly measurable. The fundamental concept about QoS measurement is based on the traffic over the network [5]. In voice telephony, QoS majorly depends on some properties such as voice clarity, call set-up time delay, traffic congestion and network failure which can prevent setting-up calls or prematurely terminate a live call. These are properties are exclusive to the last network terminal equipment i.e Base Transceiver Stations at service providers end which directly interact with Subscribers' Equipment (SE). Thus, QoS can be measured based on the operations and capacity of BTSs within a location. KPIs are parameters retrieved from BTS for the analysis of QoS provided over a period of time. They are data measured and data-logged usually on hourly basis and then retrieved from BSC when desired. The values of KPIs recommended by Nigeria Communications Commission (NCC) for effective communication in Nigeria are shown in table 1. The following are the major KPIs used for analyzing QoS.

2.1 Traffic Channel (TCH) Congestion Rate (TCHCR)

It is a measure of how busy a cell is in setting up a call due to traffic congestion. A higher TCH congestion rate indicates difficulty in establishing a channel. Every BTS has a definite number of channels that can run simultaneously. Once the channels are exhausted, it becomes impossible for a new caller or callee to establish a call with the other party. BTS are usually configured with high number of TCHs which must outweigh the expected maximum number of users within the BTS coverage zone. The maximum NCC recommended TCH congestion rate is 2% or less. It should be noted that higher TCHCR does not imply call cannot be set up unless if the TCHCR is 100% which is practically impossible.

.

2.2 Call Set-up Success Rate (CSSR)

It is the ratio of the number of successive calls initiated by callers to the total number of attempted calls. The higher the CSSR, the better the performance of a cell. High call setup success rate is achieved when standalone dedicated control channel (SDCCH) seizures and traffic channel (TCH) allocation are easily achieved to set up a call [6].

2.4 Drop Call Rate (DCR)

It is the ratio of number of live calls prematurely terminated by network to the total number of live calls within a particular time. It is usually calculated on hourly basis. It is commonly caused by poor HOSR, high TCH congestion rate, interference, frequency reuse, fluctuations in received signal strength or sudden network breakdown. Service providers are always conscious of DCR status because an astronomical increase in DCR is an indication of serious network problem; thus, requires urgent attention.

2.4 Hand Over Success Rate (HOSR)

This is the ability of live calls (established channels) on a particular network core to be successfully transferred to another network core. Handover success rate directly affects the user performance and is an important KPI of hold call type. When the user traverses different cells, this KPI enables user to communicate continuously. It is the ratio of successful handover to the total handover requests [7].

2.5 Control Channel Set-up Failure (CCSF)

Every BTS has a specific maximum number of traffic channels that can be set up at a time. When a subscriber attempts to make a call, a Dual Tone Multi-Frequency (DTMF) signal must be returned to the potential caller indicating there is or are free channels available to begin the phone call process at the moment otherwise no call can be initiated. The percentage of unsuccessful control channel set up in a given period (usually 60mins) is referred to as CCSF.

3. Materials and Research Method

In carrying out a study like this, there are three methods normally use to collect data to monitor, analyze and evaluate QoS and take corrective actions. They are drive tests, network statistics and customer complaints [8]. The drive test method is suitable when measurements covering a large number of cells are required such as QoS evaluation for a whole country, state, local government area or a city. In this research, the network statistics method is preferred because its data are obtained through in-situ measurements that do not require any pre-mathematical processes thus they are more reliable and subjected to less error. A predominant GSM service provider, MTN Nigeria was chosen being the operator with the largest number of mobile subscribers in the country as at June 2016 according to [9]. Traffic data of their three BTSs covering Eagle

- *Lawal, B.Y is a Teaching Assistant and currently pursuing his Ph.D degree program in Communication Physics in Federal University of Technology, Akure, Nigeria. His areas of interest are Tropospheric/Ionospheric Radio Waves Propagation, Satellite Communications, GSM networks and Electronics Engineering. PH -2348032412347. E-mail: lawalyusuf.b@gmail.com*
- *Ukhurebor K.E. is a Lecturer at Edo University, Iyamho, Edo State, Nigeria. Presently, a PhD student in Electronic Physics at University of Benin, Nigeria. His research interests are Telecommunication Engineering, Environmental Physics and Electromagnetic waves. PH-2348035383194. E-mail: ukeghonghon@gmail.com*
- *Adekoya, M.A is a Lecturer at Edo University, Iyamho, Edo State. Presently, a Ph.D student in Condensed Matter Physics in Federal University of Technology, Akure, Nigeria. His research interest includes Material Physics, Synthesis and characterization of materials for device utilization. PH-2347038891545. E-mail: mathewadekoya14@gmail.com*
- *Aigbe, E.E. holds a Masters degree in Control System Engineering from University of Sheffield, United Kingdom. He has over eight years experience in Network Planning and Optimization and he currently works with LM Ericsson Nigeria. PH-2348036194573. E-mail: jefosaaigbe@gmail.com*

Square and its environment located within the Federal Capital Territory (FCT) of Nigeria were retrieved through the Base Station Controller (BSC) which serves as the parent base station for these BTSs. The traffic data span from 10th of January to 15th of January 2011. The justification for the traffic period employed was to study and analyse the performance of the GSM voice service before (10th, 11th and 12th), during (13th) and after (14th and 15th) People's Democratic Party (PDP) presidential primary election in 2011. The primary Election Day is a D-day usually characterize with massive political party members from all the 36 states of the federation, hence a heavy traffic is ascertained. The data which contained major Key Performance Indicators (KPIs) such as TCH, CSSR, DCR, HOSR and CSSF were used for statistical analysis and the results obtained are presented and discussed below.

4 Results and Discussion

A thorough analysis was carried out using various statistical tools and observation of the time series of the KPIs. Average values of the five KPIs for each cell (BTS) on normal days and event period were computed and compared with the NCC recommended values as shown in tables 1 to 3. Generally, the measured KPIs on ordinary days fall below standard especially the Drop Call Rate (DCR) while worst values were observed for all the BTSs during the event period i.e from 16:00 to 23:00hrs on 13th of January 2011. However, it is crucial to note that these average values for normal days correlate with the work of [10] where he obtained 94.17% for CSSR, 5.83% for DCR, and so on for MTN network. QoS within the studied period was estimated using three major KPIs that relate directly to service availability, reliability and call quality. The three KPIs are Call Set-up Success Rate (CSSR) also known as service ability, Hand Over Success Rate (HOSR) also called Inter-cell link rate and Drop Call Rate (DCR). The plots of the KPIs against are showed in figures 1 to 18. According to [11], these three parameters exclusively describe network: accessibility (i.e. getting on the network), retainability (i.e. staying on the network) and connection quality or service integrity (i.e. having a good service experience while using the network).

Table1: Comparison of KPI values for cell A

KPIs	NCC Rec. (%)	NORMAL DAY OCCURENCE (%)	STATISTICS DURING EVENTS %
CCSF	≤ 1.2%	0.98	0.75
DCR	≤ 2.0%	3.22	50.85
HOSR	≥ 99.0%	94.27	77.24
TCHCR	≤ 2.0%	0.12	0.33
CSSR	≥ 98.0%	95.45	90.23

Table2: Comparison of KPI values for cell B

KPIs	NCC Rec. (%)	NORMAL DAY OCCURENCE (%)	STATISTICS DURING EVENTS %
CCSF	≤ 1.2%	0.96	0.82
DCR	≤ 2.0%	2.19	17.51
HOSR	≥ 99.0%	96.3	70.11
TCHCR	≤ 2.0%	0.12	9.2
CSSR	≥ 98.0%	96.8	74.39

Table3: Comparison of KPI values for cell C

KPIs	NCC Rec. (%)	NORMAL DAY OCCURENCE (%)	STATISTICS DURING EVENTS %
CCSF	≤ 1.2%	2.44	2.1
DCR	≤ 2.0%	5.23	30.1
HOSR	≥ 99.0%	92.14	79.82
TCHCR	≤ 2.0%	0.08	0
CSSR	≥ 98.0%	94.08	90.34

Figures 1 to 3 show the performance report of the three cells on the first day of observation. The three cells performed fairly well even though the KPIs deviate unfavourably from the recommended values. The CSSRs for the three cells swing between 71% and 99.9% which indicate a functional successful call rate. This implies that, on the average, subscribers were able to set up voice calls with less than 11.5% percent difficulty. Minimum values of 78% were observed for both cells A and B around 16:00 which falls within the peak periods while 71% was recorded late in the night for cell C. DCR were generally high throughout the day except for early morning off-peak period which is normally charaterise with less number of calls. The HOSR exhibit almost same the trend with the CSSR for all the cells.

On the second day, cells A and B performed similarly with CSSR and HOSR moderately below the standard values as shown in figures 4 to 6. The DCR normally rise from around 7am in the morning and maintain a fairly maximum value of 6% and 5% respectively throughout the peak period until off-peak late evening. However, the DCR of cell C possesses excessively high values during the day time. Although an average increase of about 5% was observed between 7:00 to 18:00 which falls under the peak period, an anomalous increase of up to 19.2% was observed from 18:00 to 23:00. This is a worst case scenario as almost 20% of calls initiated during this period would be prematurely terminated. The behavior of the three Cells on the third can be likened to that of the precious day but cell C possess a high DCR late in the night. Hence, we can conclude that late night DCR high value is customary to cell C.

The fourth day of observation has similar trends for all the cells until around 4:00pm in the afternoon when the three KPIs begin to deviate rapidly from the NCC recommended values as shown in figures 10 to 12. The DCR for all the cells rise drastically which indicate heavy traffic on the network. All-time peak values of 95% for cell A, 50% for cell B and 42% for cell C were observed between 8:00pm and 9:00pm after which it begins to fall gradually. Similarly, the HOSR and CSSR are low from 4:00pm to 11:00pm with minimum values of 61.29% at 8:00pm and 84.72% at 9:00pm respectively. These poor values are obviously due to massive inflow of political party members in this area (PDP primary election held at Eagle Square, Abuja) resulting in network traffic congestion. Normal daily occurrences for all the cells were gradually restored till early morning hours of the fifth day. Thus, the values of CSSR and HOSR for the fifth and sixth days are approximately same for the first two days of the observation. Although the values fall a bit below the standards, proximity to the standards and consistency make them fair for communications. However, figures 13 to 18 show that DCR for these last two days are always greater than the maximum permissible value (2%) especially during the peak hours. For instance, the DCR for cell A around mid-day on 14th of august 2011 is greater than 20% while that of cell B around 8:00pm on 15th is greater than 8%.

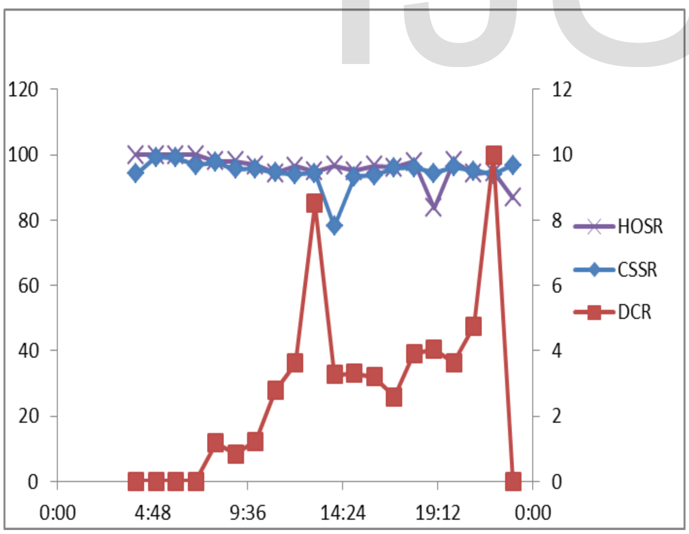

Fig 1: Graph showing KPIs for cell A on 10th January 2011

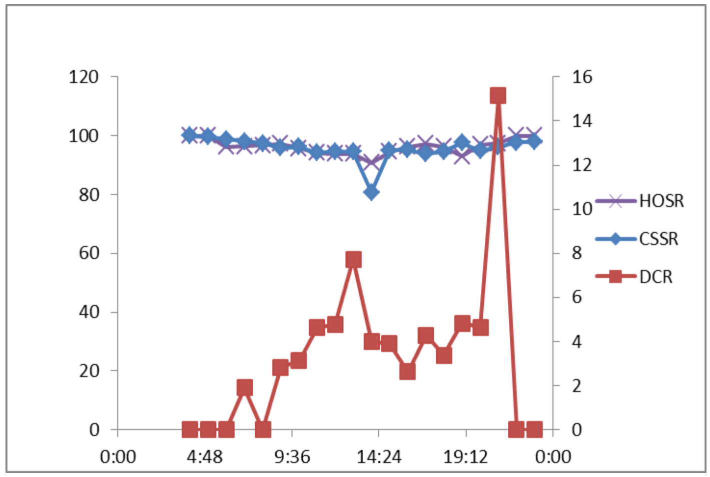

Fig 2: Graph showing KPIs for cell B on 10th January 2011

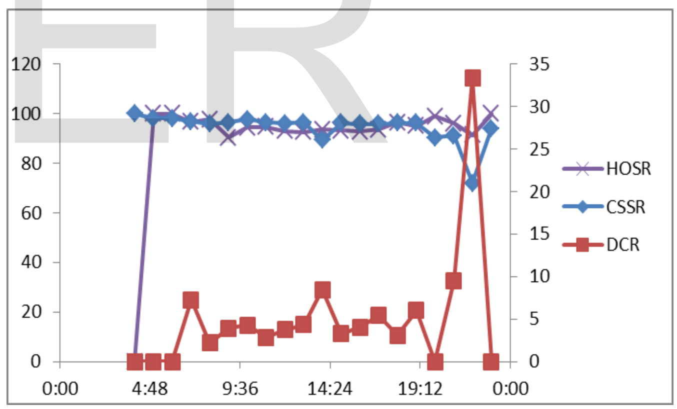

Fig 3: Graph showing KPIs for cell C on 10th January 2011

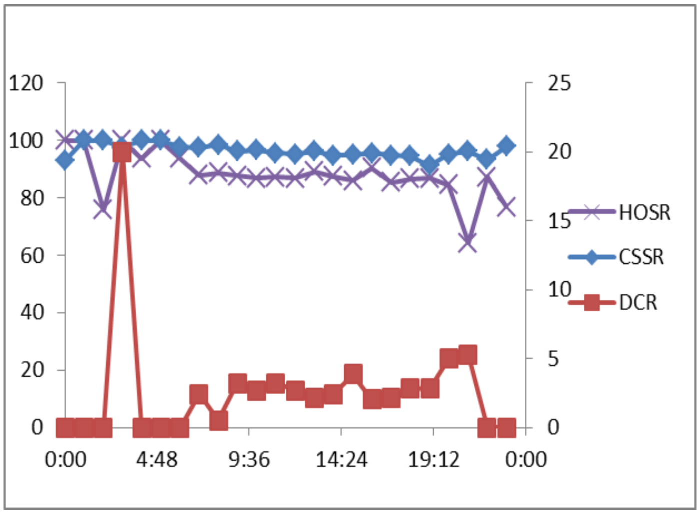

Fig 4: Graph showing KPIs for cell Aon 11th January 2011

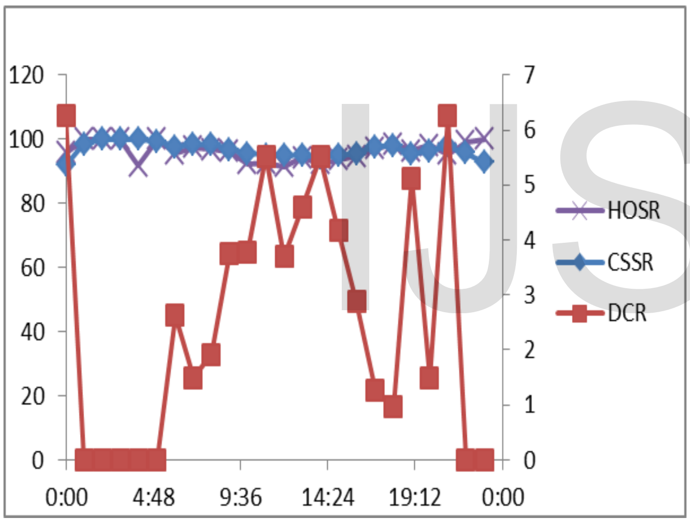

Fig 5: Graph showing KPIs for cell Bon 11th January 2011

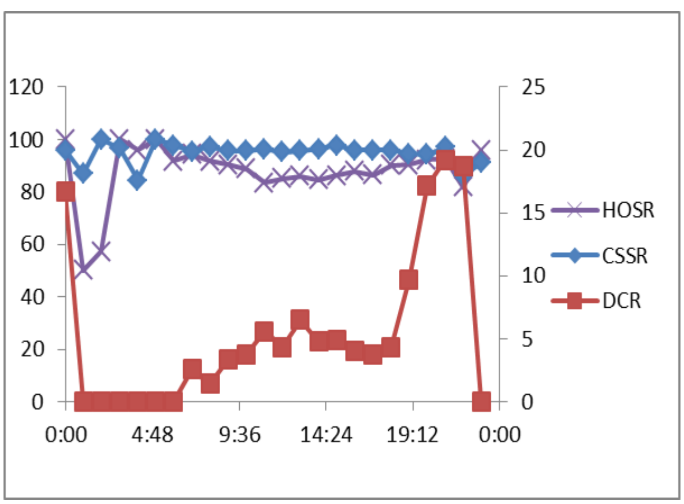

Fig 6: Graph showing KPIs for cell C on 11th January 2011

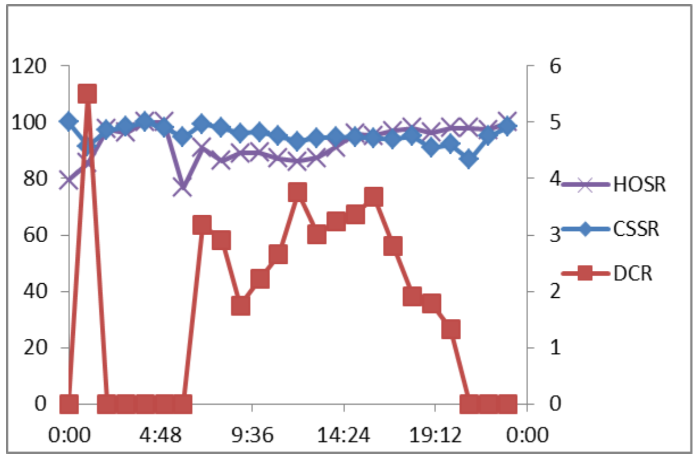

Fig 7: Graph showing KPIs for cell A on 12th January 2011

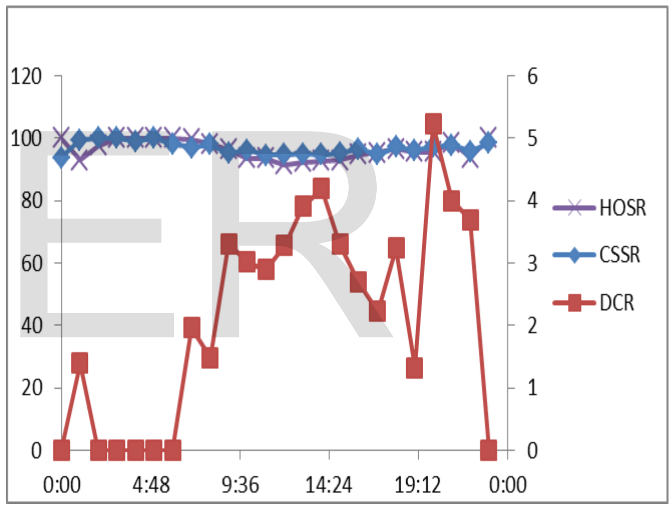

Fig 8: Graph showing KPIs for cell B on 12th January 2011

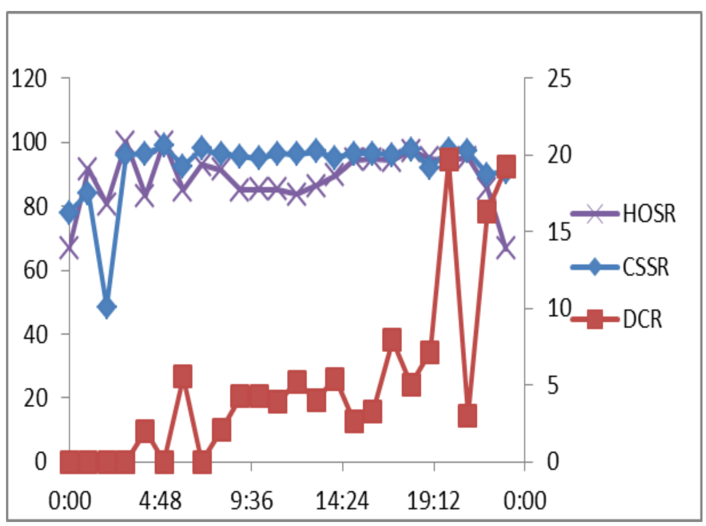

Fig 9: Graph showing KPIs for cell C on 12th January 2011

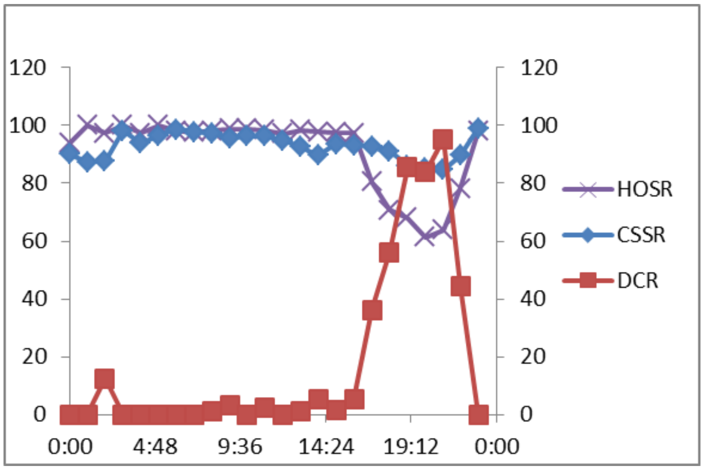

Fig 10: Graph showing KPIs for cell A on 13th January 2011

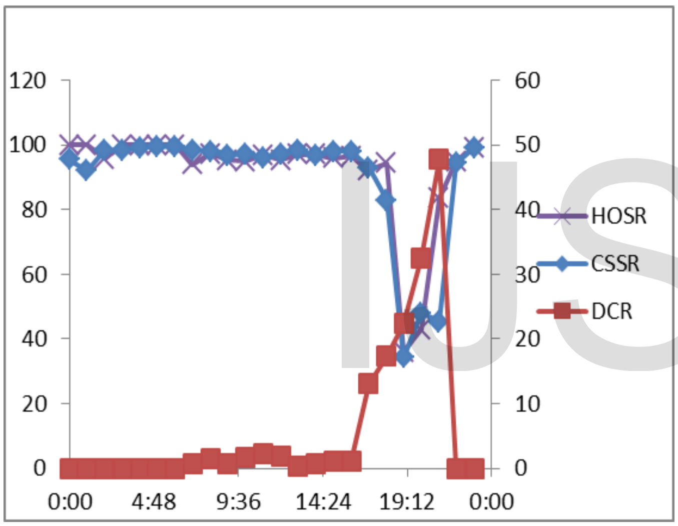

Fig 11: Graph showing KPIs for cell B on 13th January 2011

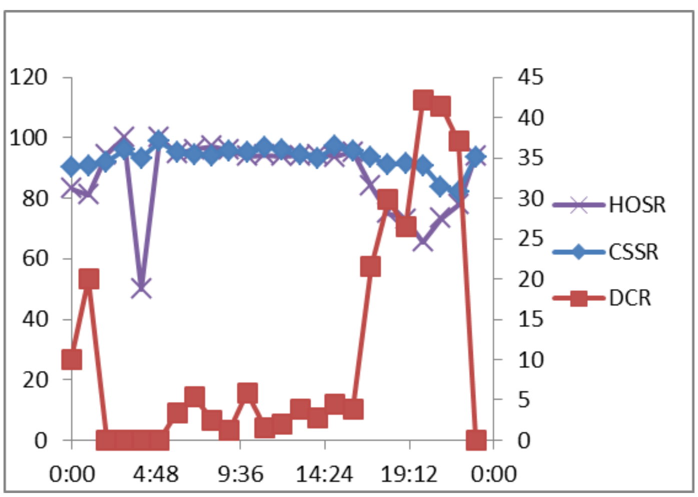

Fig 12: Graph showing KPIs for cell C on 13th January 2011

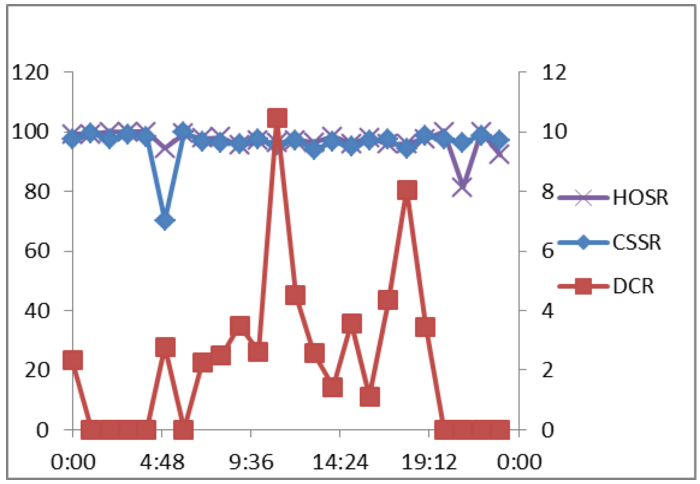

Fig 13: Graph showing KPIs for cell A on 14th January 2011

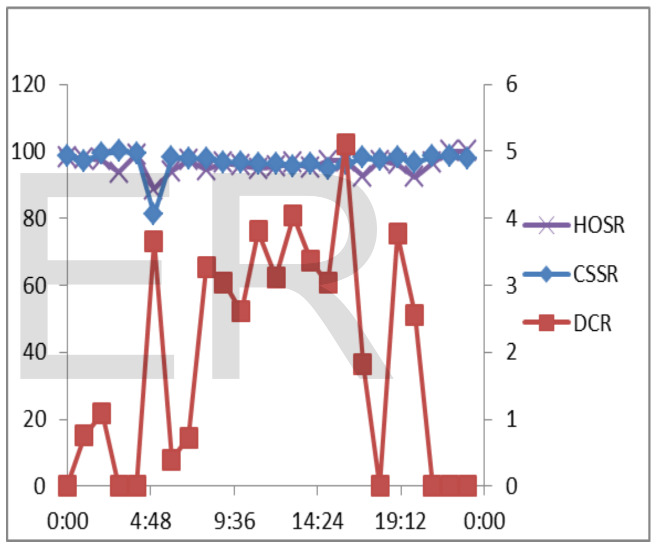

Fig 14: Graph showing KPIs for cell B on 14th January 2011

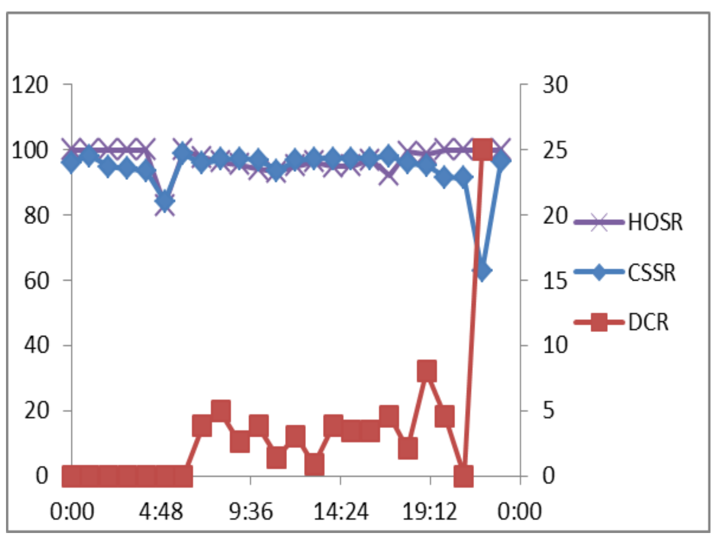

Fig 15: Graph showing KPIs for cell C on 14th January 2011

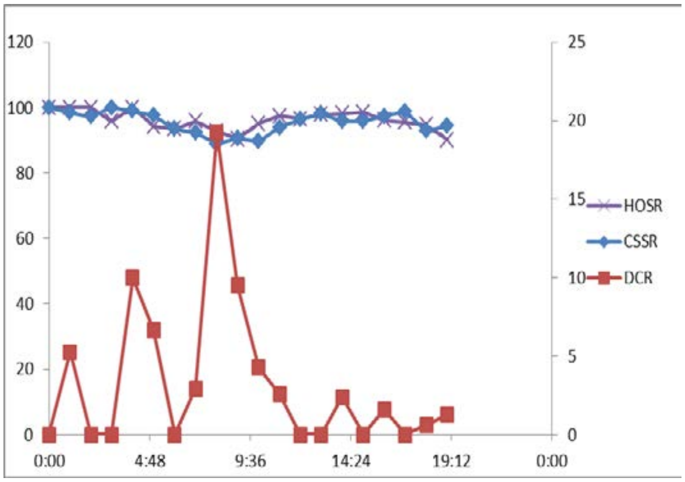

Fig 16: Graph showing KPIs for cell A on 15th January 2011

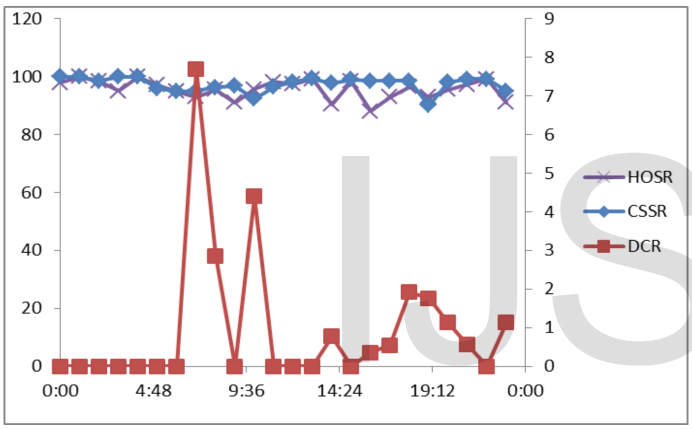

Fig 17: Graph showing KPIs for cell B on 15th January 2011

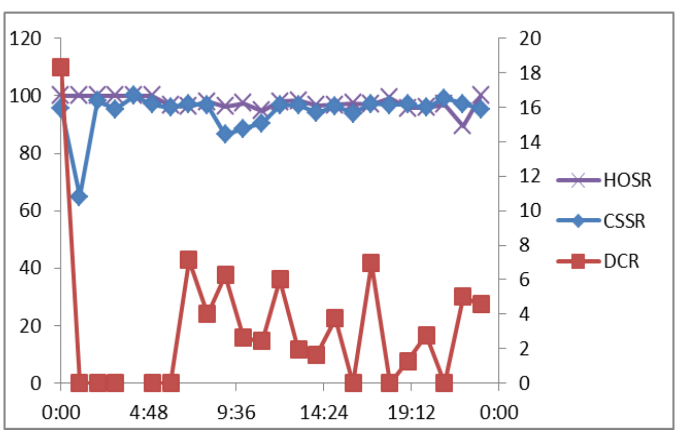

Fig 18: Graph showing KPIs for cell C on 15th January 2011

5 Conclusion

Generally, the values of the KPIs from the three BTS on a normal day rarely meet up with the NCC recommended values. Consequently, worst deviations were observed during the event period. It is pertinent to stress that the HOSR values among the BTS are not ideal; it is recommended that antennas with wider coverage area should be deployed so as to boost the overlapping area between the cells. The NCC should continuously retrieve network statistics data for towns, cities and states from operators and carry out network drive test to ensure compliance with their recommended standards.

REFERENCES

[1] M.T. Islam, "Education Technology for 21st Century," Observer Magazine, Dhaka, pp. 3-4, 1997

[2] A.S. Adegoke, I.T. Babalola, and W.A. Balogun, "Performance Evaluation of GSM Mobile System in Nigeria," *Pacific Journal of Science and Technology*, *9*(2), pp. 436-441, 2008.

[3] S. David, "Means and Methods for Collecting and Analyzing QoE Measurements in Wireless Networks," *Proceedings of the International Symposium on a World of Wireless, Mobile and Multimedia Networks*, IEEE CS, 2006.

[4] R. Kadioglu, Y. Dalveren, and A. Kara, "Quality of Service assessment: a case study on performance benchmarking of cellular network operators in Turkey," *Turkish Journal of Electrical Engineering and Computer Sciences*, vol. 23, pp. 548-559, February 2015.

[5] O.E. Caroline, A.A. Adeola, and S.A. Oluwatosin, "Assessment of GSM Network Failures, Quality of Service Evaluation and Its Impacts on E-Learning," *International Journal of Scientific Engineering and Applied Science (IJSEAS)*, vol 1, Issue-5, ISSN: 2395-3470. Pp. 121, Aug, 2015.

[6] A. Ozovehe and A.U. Usman, "Performance Analysis of GSM Networks in Minna Metropolis of Nigeria," *Nigerian Journal of Technology (NIJOTECH)*, vol. 34, no. 2, pp. 359 – 367, Apr. 2015.

[7] M. Andleeb and S. Abbas Ali, "A Study on the Hourly Behavior of Key Performance Indicators of Global System for Mobile Communications," *Journal of Emerging Trends in Computing and Information Sciences*, vol. 6, no. 3, ISSN 2079-8407, pp. 170, March 2015.

[8] M. Pipikakis, "Evaluating and Improving the Quality of Service of Second-Generation Cellular Systems," *Bechtel Telecommunications Technical Journal*, vol. 2, no. 2, pp. 1-8, 2004.

[9] Subscriber/Operator Data for July 2015-June 2016 www.ncc.gov.ng/index.php?option=com_content&view=article&id=68&Itemid=67 August, 2016. (URL for Nigerian Communications Commission).

[10] B.M. Kuboye, B.K. Alese, and O. Fajuyigbe, "Congestion Analysis on

the Nigerian Global System for Mobile Communications (GSM) Network," *The Pacific Journal of Science and Technology*, vol. 10, no. 1, pp.262-271, 2009.

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