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On The Compromise between Network Performance and End-User Satisfaction over UMTS Radio Interface: An Empirical Investigation

Michael Atenaga

Department of Physics,
Western Delta University, Oghara Delta State, Nigeria
michaelatenaga@hotmail.co.uk

Joseph Isabona

Department of Basic Sciences,
Benson Idahosa University, Nigeria
jisabone@biu.edu.ng

Abstract: *The wide adoption of smart phones and other mobile devices such as smart tablets and e-readers has spurred rapid growth in wireless mobile communication. In order to meet user performance expectations and enhance user experiences, effectively monitoring and managing of the wireless mobile communication networks is imperative. It is remain one of the most effective ways of gaining insight into the status and performance of the network over the air interface across the user population experience. This paper, which was a part of a large study, seeks to empirically assess and anaylise the compromise between network performance and end-user satisfaction over UMTS radio interface in Nigeria. Some of the service quality-based network performance indicators investigated in the radio across the area of study are call block rate, call drop rate, call setup success rate, call success rate and call handover success rate. From the results, we observed that as the end user satisfaction rate decreases as each of the service quality-based network performance indicators decreases and verse versa. This implies that there is one-to-one relationship between the quality of service (QoS) being provided by the network operator and the end user satisfaction. Hence, proper care should be taken while formulating any long term policy for end user satisfaction.*

Keywords: *Network performance, end user satisfaction, Quality of Service, Key Performance Indicators*

1. Background to Study

Radio networks represent one of the most fast-growing technology markets since the introduction of the Global System for Mobile communications (GSM) [1]. As an implementation of the second generation of mobile networks (2G), GSM appeared more than twenty years ago. Its successor, the Universal Mobile Telecommunications System (UMTS) [2] marks an evolution from 2G, representing a milestone for the third generation of mobile radio networks (3G). The concept of 3G systems is based on the global International Mobile Telecommunications (IMT- 2000) initiative sponsored by the International Telecommunications Union (ITU) to create a unified global set of standards that will lead to commercial deployment of advanced wireless services. In the standardization forums, UMTS has emerged as one of the most widely adopted third generation air interface. However, the introduction and roll-out of 3G networks is costly and happens within a very competitive and mature 2G environment. Therefore, operators are using their existing GSM network to the fullest possible extent, with co-siting 3G sites with existing 2G sites to reduce cost and overheads during site acquisition and maintenance.

Recently, in Nigeria, the 3G-based WCDMA air interface for UMTS is being deployed on existing GSM core network with the goal of supporting more efficient data services. The introduction of 3G wireless networks has brought some new services such as video and data services that were not available in 2G GSM networks. The acceptance of these services is heavily based on quality of service (QoS) experienced by the user.

Specifically, in 2007, four applicants were successful in obtaining a 10MHz lot each in the 2GHz band for third generation (3G) mobile services in Nigeria. The successful operators were: Alheri Engineering Celtel, now Airtel Nigeria, GloMobile and MTN Nigeria Communications. In early 2008, GloMobile launched the first commercial 3G service on their UMTS/HSPA network, followed closely by MTN.

One of the key challenges confronting these Telecom companies is how they manage their service quality, which holds a great importance to customer satisfaction. The contentment level of different customers depends on different quality services (QoS) level based key performance indicators.

Recently, in line with no 19 of the Nigeria Communication Act, 2003, the national assembly mandated the Nigeria Communication Commission (NCC) to ensure provision of good QoS by licensed telecommunication operators and service providers. The obligation to provide quality services is further reinforced by the respective licenses under the QoS obligation. Based on this act, the NCC published a QoS Regulations document for the benchmark evaluation of wireless network performance (see Federal Republic of Nigeria Official Gazette, 2012) [3]. The document serves as a regulatory watch dog for benchmarking telecom services provider's operations in Nigeria. It also serves as a reference document for various stakeholders, research agencies and analysts.

2. Main Contribution

The main focus of this paper has been on the empirical investigation of the compromise between network performance and end-user satisfaction over UMTS radio interface. To that end, the following contributions were made:

(i) Analysis of QoS in UMTS Network using a pioneer 3G telecom service provider operating in South-South Nigeria at the cell cluster level

(ii) Assessment of the level of network performance compliance of the pioneer 3G based service provider against the QoS benchmarks notified by Nigeria Communication Commission (NCC).

(iii) Estimation the rate of subscribers' satisfaction with Quality of Services (QoS) provided by the service provider at the cell cluster.

3. Research Methodology

Firstly, we will start by presenting the location of study and its description. Secondly, the method used for data collection is looked into. This is closely followed by presentation of the drive test data used for the study.

4. Study Location

Our location of study is Asaba. Asaba is the capital of oil rich Delta State of Nigeria. It is strategically located on a hill at the western edge of the majestic River Niger. The historic River Niger is a trans-African link beginning from West Africa and down into the Atlantic Ocean. Asaba forms a connector between western, eastern and northern Nigeria through the River Niger from the north and via the Asaba Niger Bridge, an east west link and a Nigeria landmark.

Asaba is situated at 6.2° North latitude, 6.73° East longitude and 55 meters elevation above the sea level; and about the same distance east of the meridian; about 100 miles north of where the River Niger flows into the Atlantic Ocean. The greater Asaba occupies an area of about 300 square kilometers. It maintains an average tropical temperature of 90 degrees during the dry season and an average fertile rainfall of 6 inches during the rainy season.

5. Method of Data Collection

Measurements were conducted with Drive test tools that could generate calls automatically and uniformly within the cellular network of study. Drive test is performed to assess network performance from a moving subscribers' point of view. The tools consisted of a Vehicle, Global Positioning System, a Laptop with installed data collection software (ERICSSON TEMS Investigation 8.0), Sony Ericsson TEMS pocket Mobile Phone, Dongle, Data Card, Compass and Inverter. All the components were connected appropriately to the laptop which serves as the communication hub for all other equipments in the system. The GPS operates with global positioning satellites to provide the location tracking for the system during data collection position on a global map which has been installed on the personal computer. The compass help to determine the various azimuth angles of the base station transmitters. Average height of transmit antenna is about 28 – 42 meter above ground level, with comparatively same transmit power. After the successful connection of these tools, sequences of test calls were made along the selected routes which cover main roads, public access and hot spot areas. Five cell clusters namely cluster 1, 2, 3, 4 and 5 were identified for the drive test in the study locations.

6. PERFORMANCE INDICATORS ASSESSED IN THE MEASUREMENTS

A wide range of key performance indicators (KPIs) are available in literature for radio network performance monitoring to achieve remarkable QoS. The most essential KPIs include ([4], [5], [6]:

a. Call Success Setup Ratio (CSSR)
b. Call Drop Ratio (CDR),
c. Call Block Ratio (CBR).
d. Handover Success Ratio (HOSR).
e. End points Service Availability (ESA).
f. Network Retainability Ratio (NRR)

These KPIs can be computed in different ways depending on the network vendor and the operator, but in general, they are computed in the following ways as provided in table 1. For concision of purpose in this paper, we are focusing on all the listed KPIs above.

Table 1. *KPIs, Definitions and Formulations*

	Indicator	Definition	Formula	NCC Benchmark
(a)	CSSR	This is the ratio of total number of completed calls to the total number of call attempts. This is the ratio of total number of completed calls to the total number of call attempts	$\frac{\text{successfully completed call setups}}{\text{call setups attemps}}$ x 100 (1)	98%
(b)	CDR	This is the ratio of total number of completed calls to the total number of call attempts. This KPI indicates the total number of calls dropped (not ending as desired by the user) or forced call disconnection by the network due to various reasons within the licensees own network	$\frac{\text{No.of dropped calls}}{\text{No.of Successfully Completed Call Setups}}$ x 100 (2)	2%
(c)	CBR	Rate of blocked calls due to resource unavailability. This is the ratio of total number of blocked calls to the total number of call attempts or offered.	$\frac{\text{No.of calls blocked}}{\text{number of offfered calls}}$ x 10 0 (3)	2%

(d)	HOSR	This is the ratio of handover calls to the total number of call attempts. This KPI is intended to give an indication of user mobility in the network.	$\frac{\text{No.of handover calls}}{\text{number of offfered calls}}$ x 100 (4)	0.2%
(e)	ESA	This indicator measures service availability, which is the QoS during service use. It is defined as the percentage of time a usable call can be established and maintained between two end points	$\text{ESA} = \frac{Nattempt-\text{Nblock}-\text{Ndrop}}{Nattempt}$ x 100 (5) where *Nattempt* = No. of call attempts *Nblock* = No. of call blocks *Ndrop* = No. of call drops	99%
(f)	NRR	Retainability is described This indicator is describes as a probability that an active call come to an end successfully in a network. It is estimated as the ratio between the number of successful calls and number of normally terminated calls.	$(1-\text{DCR})$ x 100 (6) *w*here DCR is defined by equation (3)	Not Applicable

Note: NCC stands for Nigeria Communication Commission. Recently, in line with no 19 of the Nigeria Communication Act, 2003, the national assembly mandated the NCC to ensure provision of good quality services (QoS) by licensed telecommunication operators and service providers. Based on this act, the NCC published a QoS Regulations document for the benchmark evaluation of wireless network performance (see Federal Republic of Nigeria Official Gazette, 2012). The document serves as a regulatory watch dog for benchmarking telecom services provider's operations in Nigeria. It also serves as a reference document for various stakeholders, research agencies and analysts.

7. END USER SATISFACTION ASSESSMENT METHODOLOGY

End user satisfaction is a customer's feeling of either contentment or discontent resulting from the evaluation of the services provided by the organization to the customer in respect to expectations. In communication networks, the customer satisfaction on the service is directly dependent on the quality and the performance of the network [7]. So, how the end-user perceives the service quality, i.e. his satisfaction with the service as a function of the measured parameters, is highly dependent on the service level (QoS– parameters) he is accustomed to. In this section, the end user satisfaction is estimated from the blocked calls probability, P_{block} and dropped calls probability, P_{drop} data by:

$$P_{satisfied} = 1 - P_{unsatisfied} \tag{7}$$

Where $P_{unsatisfied}$ is the probability of a user or call being unsatisfied and it is defined by [8]:

$$P_{unsatisfied\ being} = Pblock + Pdrop.\ (1-Pblock) \tag{8}$$

8. RESULTS AND ANALYSIS

In this section, we will first present the results of the studied 3G network performance data in tabular form using the various KPIs formulas that were defined in chapter three. This is followed by presenting the performance results of the network graphically in each cell cluster. Later, we will provide analysis of the six KPIs based data results, before conclusion is drawn.

9. Network Performance Data across the Cell Clusters

Presented in table 2 below is a summary of 3G network performance Data from the studied five cell clusters

Table 2. *Summary of 3G network performance Data*

Event Details	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5
% Dropped Call Rate	15.66	22.3	9.18	11.53	13.33
% Call Setup Rate	96.50	93.00	96.93	100.00	98.90
% Blocked Call Rate	3.48	6.94	3.06	0.00	1.09
% Established Call Rate	96.50	93.00	96.93	100.00	98.90
% Soft Handover Success Rate	100	100	100	100	100

10. Analysis of Results with KPIs

The plots in figures 1-5 show the performance trends of the investigated 3G network in cell cluster 1-5, within assessment period. It can be observed from the plots the network performance fluctuates with CSSR, BCR, DCR and ESA KPIs, except with HOSR that is stable across the five cell clusters. The fluctuation may be attributed to different loads or traffic and antenna configuration in each cluster.

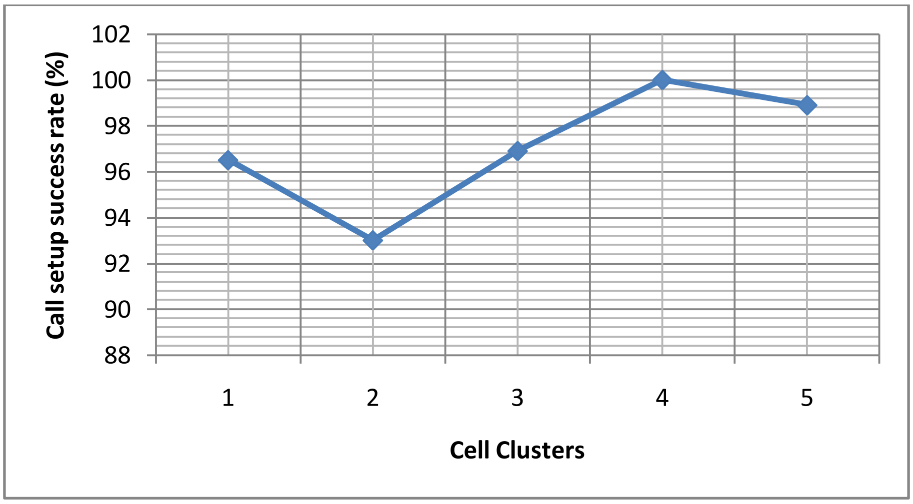

Figure 1. *Network performance evaluation with CSSR indicator in Cluster 1-5*

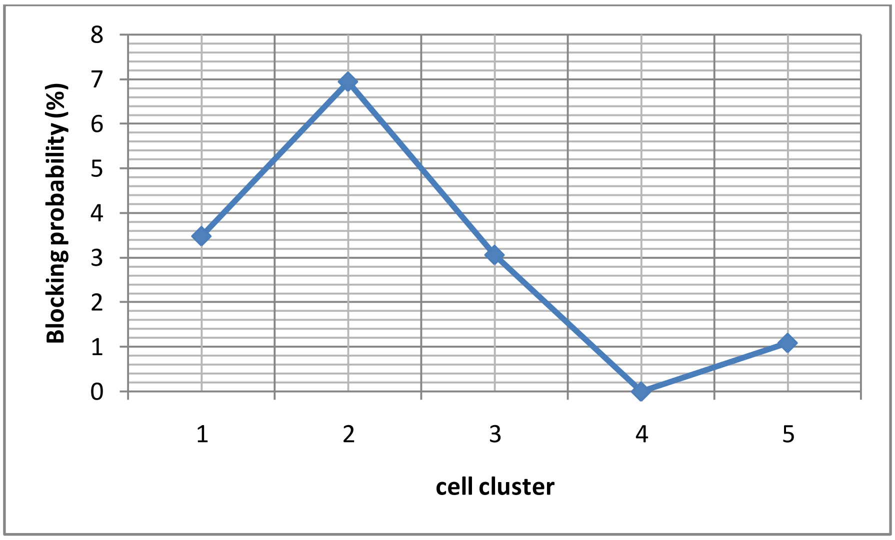

Figure 2. *Network performance evaluation with BCR indicator in Cluster 1-5*

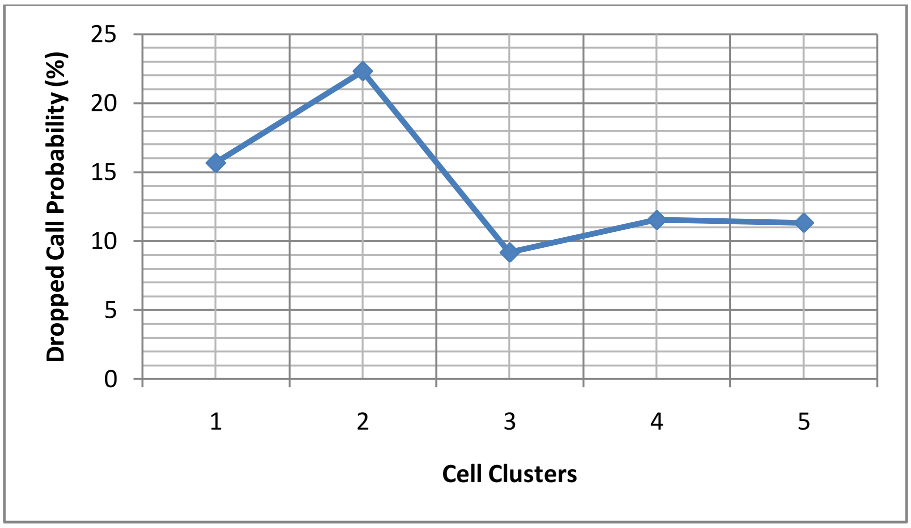

Figure 3. *Network performance evaluation with DCR indicator in Cluster 1-5*

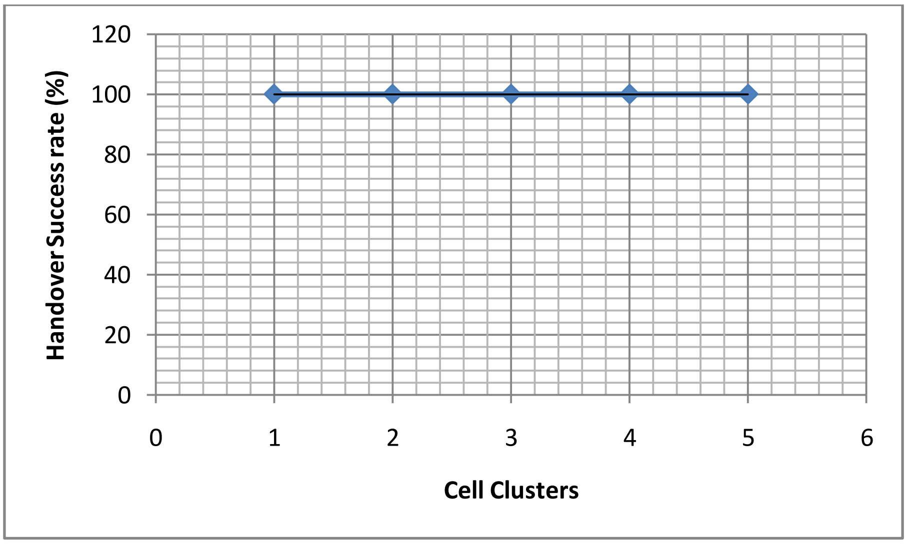

Figure 4. *Network performance evaluation with HOSR indicator in Cluster 1-5*

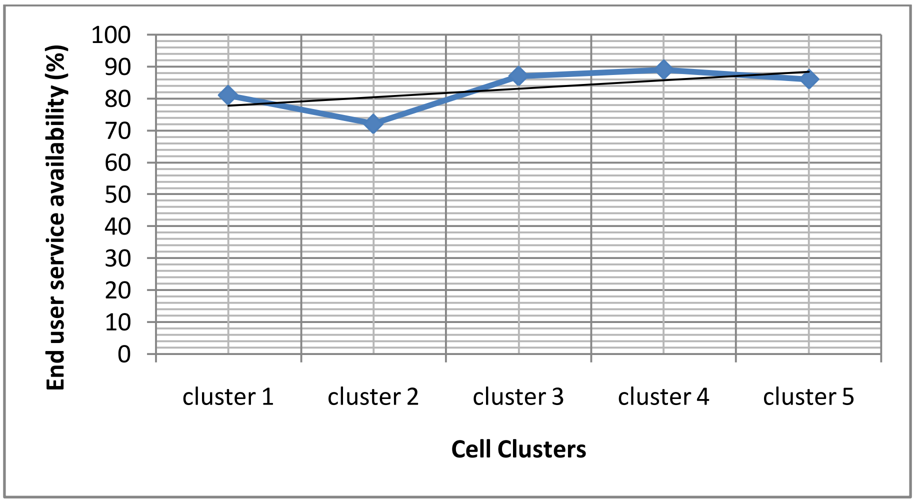

Figure 5. *Network performance evaluation with ESA indicator in Cluster 1-5*

The summary of the overall network performances are arising from the specific QoS level-based KPIs in comparison with NCC performance benchmark are summarized in the tables 3-7 for further analysis. We observed from the tables that the 3G network provider only met the NCC performance bench mark with HSR indicator across the five cell clusters. In order words, the operator fell below the NCC performance target with other KPIs. On the average, the operator only made 60% and 20% out 100% each in clusters 1-2 and 3-5 respectively in terms of performance compliance level with the NCC performance bench marks. This again shows that the general network performance is below expectation and unsatisfactory.

Table 3. *Network Performance compliance result with NCC Benchmark, in Cluster 1*

No.	KPI	NCC Benchmark (%)	Performance (%)	Compliance Status
1	CSSR	≥ 98	96.5	Not Compliant
2	BCR	≤ 2	3.48	Not Compliant
3	DCR	≤ 2	16.66	Not Compliant
4	HOSR	≤ 95	100	Compliant
5	ESA	≥ 99	81	Not Compliant
Compliance level		100%	20%	Not Compliant

Table 4. *Network Performance compliance result with NCC Benchmark, in Cluster 2.*

No.	KPI	NCC Benchmark (%)	Performance (%)	Compliance Status
1	CSSR	≥ 98	93	Not Compliant
2	BCR	≤ 2	6.94	Not Compliant
3	DCR	≤ 2	22.3	Not Compliant
4	HOSR	≤ 95	100	Not Compliant
5	ESA	≥ 99	72	Compliant
Compliance level		100%	20%	Not Compliant

Table 5. *Network Performance compliance result with NCC Benchmark, in Cluster 3.*

No.	KPI	NCC Benchmark (%)	Performance (%)	Compliance Status
1	CSSR	≥ 98	96.9	Not Compliant
2	BCR	≤ 2	3.06	Not Compliant
3	DCR	≤ 2	9.18	Not Compliant
4	HOSR	≤ 95	100	Compliant
5	ESA	≥ 99	87	Not Compliant
Compliance level		100%	20%	Not Compliant

Table 6. *Network Performance compliance result with NCC Benchmark, in Cluster 4.*

No.	KPI	NCC Benchmark (%)	Performance (%)	Compliance Status
1	CSSR	≥ 98	100	Compliant
2	BCR	≤ 2	0	Compliant
3	DCR	≤ 2	11.53	Not Compliant
4	HOSR	≤ 95	100	Compliant
5	ESA	≥ 99	81	Compliant
Compliance level		100%	60%	Not Compliant

Table 7. *Network Performance compliance result with NCC Benchmark, in Cluster 5.*

No.	KPI	NCC Benchmark (%)	Performance (%)	Compliance Status
1	CSSR	≥ 98	98.9	Compliant
2	BCR	≤ 2	1.09	Compliant
3	DCR	≤ 2	11.33	Not Compliant
4	HOSR	≤ 95	100	Compliant
5	ESA	≥ 99	86	Not Compliant
Compliance level		100%	60%	Not Compliant

Figures 6 –8 are plotted to examine the correlation between each QoS-based KPI and end user unsatisfaction rate. From the figures, we observed that as the end user unsatisfaction rate increases as each of the QoS-based performance indicators decreases. This implies that the QoSs provided by the network operators are directly proportional to the end user satisfaction. Therefore, we can conclude here that a network can be rated as performing when end-users satisfaction rate is high. This is, a network is said to be performing when the end users are able to access its applications and carry out given task without undue perceived irritation

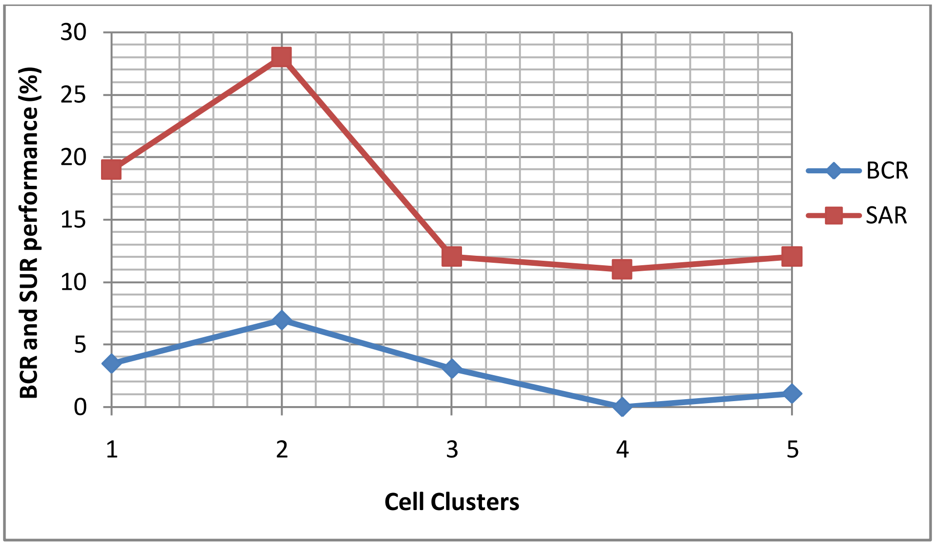

Figure 6. *Network performance evaluation with CSSR and SUR indicators in Cluster 1-5*

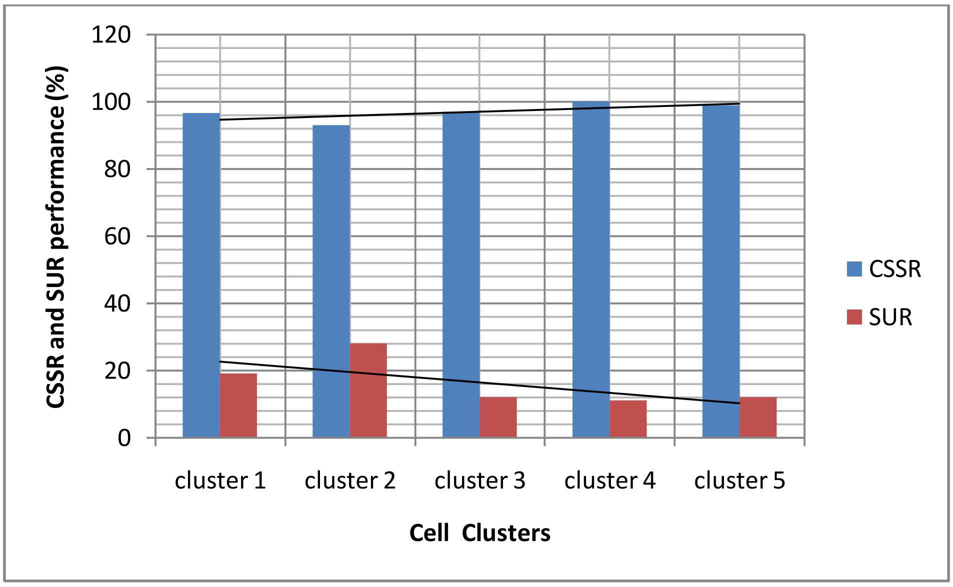

Figure 7. *Network performance evaluation with CSSR I and SUR indicators in Cluster 1-5*

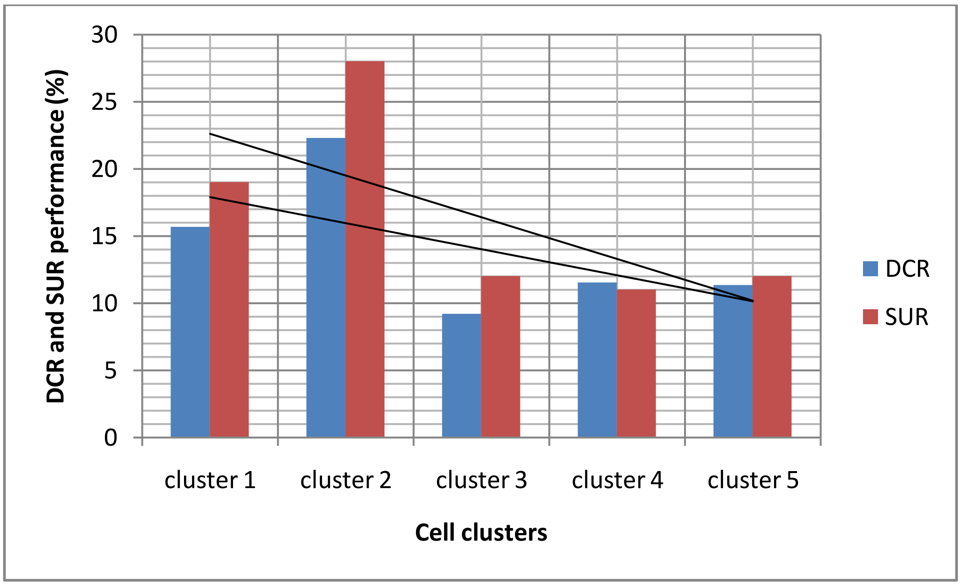

Figure 8. *Network performance evaluation with DCR and SUR indicators in Cluster 1-5*

Figure 9 is plotted to examine the correlation between ESA and SAR. From the figures, we observed that SAR increases as ESA improves. This also implies that there high correlation the two indicators.

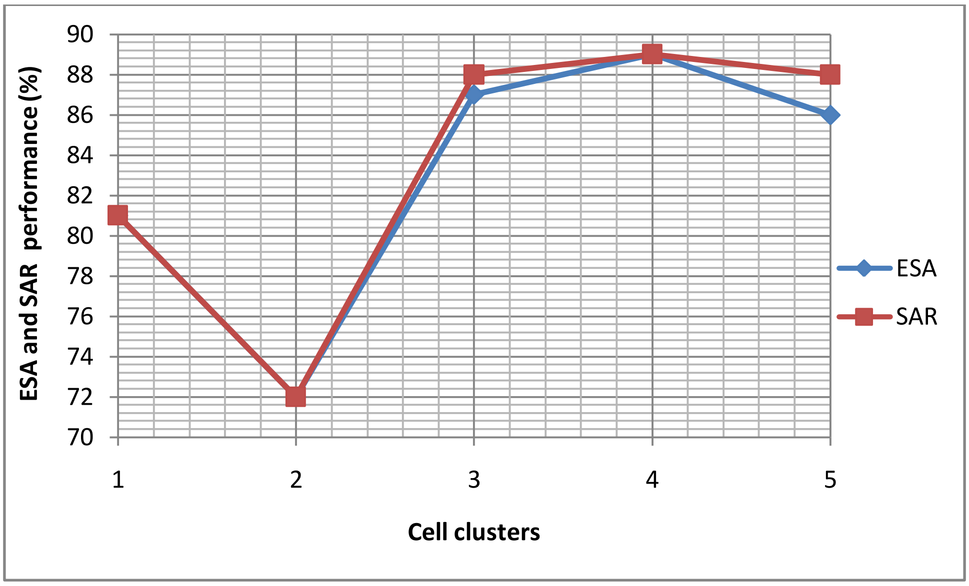

Figure 9. *Network performance evaluation with ESA and SAR indicator sin Cluster 1-5*

11. Conclusion

The current evolution of 3G networks worldwide is driven by new and faster data services and the introduction of HSDPA technology to support it. This growth adds more constraints to the Radio Access Network (RAN) configuration in order to offer the required transmission capacity while maintaining the Quality of Service (QoS) indicators above acceptable levels.

The main focus of this paper has been on the empirical investigation of the compromise between network performance and end-user satisfaction over UMTS radio interface. From the results, we observed that as the end user satisfaction rate decreases as each of the QoS-based network performance indicators decreases and verse versa. This implies that there is one-to one relationship between the QoSs being provided by the network operators and the end user satisfaction. It also implies that both service quality and end user satisfaction have some things in common. Hence, proper care should be taken while formulating any long term policy for end user satisfaction.

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AUTHORS' BIOGRAPHY

Mr Michael Atenaga is an Assistant lecturer in the department of Physics and Energy, Western Delta University, Oghara, Delta State, Nigeria. He received Masters Degrees in 2011 and 2009 in Telecommunications Technology and in Physics Electronics, from Aston University and University of Benin respectively. He has a Bachelors degree in Applied Physics from Ambrose Alli University Ekpoma, which he received in 2001. He is currently enrolled into a Ph.D programme at the University of Benin, with interest in Wireless/Mobile Telecommunications. He is a student member of Institute for Electrical and Electronics Engineers **(IEEE)** and Institute Of Engineering and Technology ***(IET-uk)***. His overall research interest areas spans from wireless communications to optical fiber and Electronics.

Dr. Joseph Isabona is a Senior lecturer in the department of Basic Sciences (Physics Unit), Benson Idahosa University, Benin City, Nigeria**.** He received Ph.D and M.Sc. degrees in Physics Electronics, 2013 and 2007 from the University of Benin and Uyo respectively, and a B.Sc in Physics in 2003, from Ambrose Alli University, Ekpoma, Edo State. He is a member of the Nigerian Association of Mathematical Physics (NAMP) and Nigeria Institute of Physics. He has published both nationally and internationally in the area of wireless communications. His area of interest is signal processing and radio resource management in wireless networks.