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Assessment of Interdependence of Key Performance Indicators in Voice Traffic of Glomobile Network in Akure, Nigeria

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ABSTRACT : *Global System for Mobile Communications (GSM) operators use Key Performance Indicators (KPIs) such as Call Setup Success Rate (CSSR), Handover Success Rate (HSR), Traffic Channel availability (TCH), Stand Alone Dedicated Control Channel Success Rate (SDCCH-SR), Call Drop Rate (CDR) and Call Success Rate (CSR) to assess the performance and evaluate the Quality of Service (QoS) of their network. In this work, assessment of interdependence of Key Performance Indicators in voice traffic of Glomobile Network in Akure was carried out considering five different KPI's which are CSSR, HSR, SDCCH-SR, DCR and CSR. Three local government areas (Ifedore, Akure North and Akure South) were considered for Akure. Voice traffic data of Glomobile Network in Akure for a period of two and a half years was collected, and analysis of the KPIs for each Local Government Area (LGA) was performed to determine their interdependence on the performance of the network. It was found out that SDCCH is nearly maximized within the three local governments, even though its average values are all still below 99.8% minimum stipulated by Nigeria Communications Commission (NCC). Increase in its success rate can only marginally improve the performance of the network. Other KPIs showed interdependence in the three LGAs of varying degree. CSR, CSSR and HSR showed strong interdependence in all the LGAs. These KPIs need to be improved for better performance of Glomobile Network in Akure. CSSR should not be less than 98% and CSR should not be less than 97% as stipulated by NCC. CSSR was observed to be at an average value of 97.26%, 97.16% and 97.27% in Ifedore, Akure North and Akure South local government area respectively. This should be improved. Given their respective Drop Call rates which are all below the 1% maximum by NCC, CSR was observed to be at an average value of 97.08%, 96.97% and 96.99% in Ifedore, Akure North and Akure South local government area respectively. Traffic Channel availability should also be improved for the three local government areas.*
KEYWORDS: *key performance indicator, traffic channel, networks, correlation, handover.*

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I. INTRODUCTION

Mobile telephone systems in the 1980s were mostly analog which were unable to handle the increasing capacity needs being experienced efficiently. Their limitations became obvious with increased number of subscribers, hence, digital technology and systems were introduced [1]. This then brought into place the Global System for Mobile Communications (GSM). GSM is a digital cellular network that uses advanced technology and can handle large number of subscribers. This technology increased the number of subscribers beyond expectation. The increasing demand for unlimited and broadband information access makes wireless and mobile systems the most intensively evolving area in telecommunication [2].

The deployment of GSM in Nigeria over a decade ago has made communications in the country to witness a tremendous growth. Although this growth has brought many advantages, nevertheless, many problems are still facing the sector. According to Oladeji et al., (2013), some of the problems are: poor inter-network connectivity, call setup failure, instability in power supply, poor security of infrastructures, network congestion, call drop [3]. All these factors contribute in one way or the other to the poor Quality of Service (QoS) rendered by GSM operators in the country [4]. As commented by Ajiboye et al., (2007), GSM performance is degrading due to the astronomical growth of subscribers; therefore, an operator has to keep the subscribers satisfied with the delivered QoS in order to grow and retain her subscriber base [5]. Delivering acceptable QoS to GSM subscribers has now become a difficult task for the operators due to many reasons. One of such reasons is the

mismatch between the explosive growth in the number of subscribers and the expansion of the network equipment; which therefore leads to traffic congestion, drop calls and hence poor QoS [6].

As of today there are four different GSM operators in Nigeria: MTN, AIRTEL (formerly ECONET), GLOBACOM, and 9MOBILE (formerly ETISALAT). The GSM service is available in 900 MHz, and 1800 MHz frequency bands. All the GSM operators use Key Performance Indicators (KPIs) such as Call Setup Success Rate (CSSR), Handover Success Rate (HSR), Traffic Channel availability (TCH), Stand Alone Dedicated Control Channel Success Rate (SDCCH-SR), Call Drop Rate (CDR), Call Success Rate (CSR), etc. to access the performance of their network and evaluate the Quality of Service. Again, according to Oladeji et al., (2013), all these parameters aim at measuring the level of consumers' satisfaction, which to an average consumer is the measure of how easy it is to get connected to the network when a call is initiated, the voice quality when the call is in progress and the call retain-ability on the network despite the user's mobility [3]. The Nigeria Communications Commission (NCC) is empowered to establish minimum QoS standards in service delivery for the Telecommunications Industry in Nigeria [7]. A benchmark on KPIs is issued to all network operators to ensure mobile users have access to quality service [8].

Popoola et al., (2009), in an insight into network performance and QoS improvement of GSM cellular system in Nigeria, considered four assessment parameters, namely: network accessibility, service retain-ability, connection quality and network coverage for evaluating QoS on the network of four GSM operators in Abuja and some selected cities in Nigeria [9]. Also, Kuboye (2010) presented the causes and effects of congestion as it relates to QoS provided by operators. He listed factors that led to congestion and an overview of the congestion, and where it occurs on the GSM network. Some optimization models for minimizing congestion problem on the GSM network in Nigeria were also presented [10].

Biebuma et al., (2010) attributed high demand of GSM services (voice, data, and multimedia) and limited capacity to be the causes of congestion in a mobile network. They looked into six (6) northern states in Nigeria: Taraba, Adamawa, Gombe, Bauchi, Yobe and Bornu in their analysis [11]. Idigo et al., (2012) presented a real time assessment of a Visafone mobile network in Abuja, with the aim of investigating and analyzing the quality of service of the networks [12].

Omasheye and Kolagbodi (2012) carried out performance evaluation of a GSM Network provider in Lagos, Nigeria based on six major Key Performance Indicators CDR, Handover failure rate (HFR), HSR, Call complete rate (CCR), CSSR and Call setup failure rate (CSFR). The result of the research showed that the GSM network provider failed to achieve the QoS benchmark setup by NCC in all the KPIs parameters measured [13]. Ozovehe and Usman (2015) used KPIs to evaluate the performance of operational live GSM networks in Minna, Nigeria. The result of the study showed that the QoS of GSM network in Nigeria is unreliable [14]. Oluwajobi and Idowu (2015) presented the comparative analysis of the received signal strength measurements of GSM networks in Owo, Nigeria [15].

Ononiwu et al., (2016) considered and evaluated the service rendered by four major operators (MTN, Airtel, Glo and Etisalat) in Nigeria to determine the best operator with minimal call pattern variations. The performance evaluation was based on five KPIs measured by drive technique in Owerri, Nigeria. The results showed that all the operators failed to comply with the stipulated performance threshold by NCC [7]. Galadanci and Abdulahih (2018) examined the performance of GSM networks (P, Q, R and S) in Kano Metropolis, Kano State, Nigeria, where the KPIs were used as a key asset for carriers and subscribers alike. The research results revealed out that the four carriers failed to achieve NCC minimum targets for CSSR, HOSR and call blocking respectively[16].

In this work, we aimed at examining the interdependence of some predominant KPI's of voice traffic in Glomobile Network (Globacom) in Akure (CSSR, HSR, SDCCH-SR, DCR and CSR), with a view to assessing their effect on the general performance of the network, with appropriate recommendations. Voice traffic data of Glomobile Network in Akure for a period of two and a half years for three local government areas (Ifedore, Akure North and Akure South) were collected and analysed.

II. CONGESTION IN GSM AND KEY PERFORMANCE INDICATORS

2.1 Congestion Areas on GSM Network

The GSM radio link uses both Frequency Division Multiple Access (FDMA) and Time Division Multiple Access (TDMA) technologies. The frequency bands for the GSM downlink signal and the uplink signals are 935-960MHz and 890-915MHz respectively. The frequency band is divided into 124 pairs of frequency duplex channels with 200 kHz carrier spacing.

According to [17], and as reported in [18], Common Control Channel (CCCH) is a group of control channels that supports the establishment and maintenance of communication links between the mobile stations and base stations. It consists of Random Access Channel (RACH), Paging Channels (PCH), and Access Grant Channel (AGCH). RACH is used to make request for network assignment, PCH is used to alert the mobile station of incoming calls, and AGCH is used to assign Mobile Station (MS) to a specific SDCCH for onward

communication. When any of these three control channels is congested, there cannot be any call establishment between the sender and the receiver [19].

Traffic channel (TCH) is the channel allocated to a subscriber for the duration of call after the successful seizure of SDCCH channel. TCH is used to transfer voice, data, and control information and when there is no vacant TCH, the voice communication on the GSM network cannot be established. Traffic Channel Congestion (TCHC) occurs when an AGCH cannot get any free TCH to allocate to the request of the mobile terminal through the RACH [18].

To initiate a call setup, the MS sends a signaling channel request to the network through the RACH. The Base Station Controller (BSC) informs the MS of the allocated signaling channel (SDCCH) through the AGCH. Then the MS sends the call origination request via the SDCCH. The Master Station Controller (MSC) instructs the BSC to allocate a Traffic Channel (TCH) for this call. Finally, both the MS and the Base Station Transceiver (BTS) tune to the TCH.

2.2 Some Key Performance Indicators

According to [20] and [21 - 24], the KPIs for QoS used in evaluating the GSM networks includes: Call Set-up Success Rate (CSSR), Call Drop Rate (CDR), Call Success Rate (CSR), Handover Success Rate (HSR) and Traffic Channel Assignment (TCH).

(a) Call Setup Success Rate (CSSR): This indicator measures the ease in which calls are established or set up. The higher the value of CSSR, the easier it is to set up a call. For instance a CSSR of 81% means that out of every 100 call attempts, only 81 are successful while the remaining 19 are unsuccessful. The indicator is calculated using the expression in Eq. (1)

$$\text{CSSR} = \frac{N_S}{N_{CA}} \times 100\% \quad (1)$$

where N_S is the number of successful dials/successful establishments and N_{CA} is the number of call attempts. NCC stipulates that CSSR must be ≥ 98% [21 – 24].

(b) Call Drop Rate (CDR): A dropped call is a call that is prematurely terminated before being released normally by either the caller or the called party. This KPI measures the network ability to retain call conversation when it has been established or set up. The Call Drop Rate (CDR) is the number of dropped calls divided by the total number of call attempts. A value of 8% of CDR means that, out of every 100 call attempts, 8 will drop before any of the calling parties voluntarily terminate the set up call. The indicator is calculated using the expression in Eq. (2):

$$\text{CDR} = \frac{N_{DC}}{N_{CA}} \times 100\% \quad (2)$$

where N_{DC} is the number of dropped calls and N_{CA} is the number of call attempts. NCC stipulates that Call Drop should be ≤ 1% [21 – 24].

(c) Call Success Rate (CSR): This is the rate of ongoing calls until normal release by either party. It is expressed in Eq. (3).

$$\text{CSR} = \text{CSSR} - \text{CDR} \quad (3)$$

where CSSR is the Call Set up Success Rate , and CDR is the Call Drop Rate. CSR should be ≥ 97% as stated by NCC [21 – 24].

(d) Stand Alone Dedicated Control Channel (SDCCH): This is the channel used for signaling messages. It is concerned with call setup, location update message and Short Message Services (SMS), authentication, ciphering etc. SDCCH Success Rate (SDCCH-SR) is expressed in Eq. (4).

$$\text{SDCCH} - \text{SR} = \frac{N_{SS}}{N_{SA}} \text{ X } 100\% \quad (4)$$

where N_{SS} is the number of successful SDCCH seizures, and N_{SA} is the number of all SDCCH seizures. SDCCH Success Rate (SDDCH-SR) has been stipulated by the NCC to be ≥ 99.8% [21 – 24].

(e) Handover Success Rate (HSR): This is the ratio of the number of successfully completed handovers to the total number of initiated handovers. It is expressed as a percentage in Eq. (5).

$$\text{HSR} = \frac{N_{SH}}{N_{IN}} \text{X } 100\% \quad (5)$$

where N_{SH} is the number of successful handovers and N_{IN} is the number of initiated handovers. NCC stipulates that HSR should be ≥ 98% [21 – 24].

III. RESEARCH METHODOLOGY

The methodology for this research work is in two stages: Data Collection, and Data Analysis.

3.1 Brief Description of Akure

Akure is the capital of Ondo State, in the south western part of Nigeria. It is located on Latitude 7.25°N and Longitude 5.19°E; at an elevation of 353 meters above sea level. Akure is the largest city in Ondo State, and an urban city in terms of development. This city is important in terms of economy and the commercial profile of the state. Fig. 1 shows the map of Ondo State in Nigeria [25].

Fig. 1: Map of Nigeria showing Ondo State and Akure [25].

3.2 Data Collection and Analysis

Data for top level Key Performance Indicators (KPIs) such as total call request, total successful call request, total handover request, total successful handover request, total stand alone dedicated control channel (SDCCH) request, total successful stand-alone dedicated control channel, total drop calls and traffic channel (TCH) at the BTS level for Glomobile Network in Akure was obtained at the Network Management Center (NMC) Lagos, using Alcatel Lucent Network Server Statistics. The data were for three Local Government Areas (Ifedore, Akure North and Akure South). Fig. 2 shows the three LGAs within Ondo State [25].

Ifedore local government has a plain topography and is sparsely populated with majority of the people being farmers and petty traders. Akure North local government is sparsely populated. Most of them engage in the trade of farm products; while some are artisans. The topography is hilly. Akure South local government is densely populated having a plain topography with commercial centers, small scale industries, and tertiary institutions.

The collected data which are for 38 base transceiver stations spread over two and a half years. The numbers of antenna sectors of all the base stations were also obtained. Tables 1 - 3 show the base transceiver stations sites in Ifedore, Akure North, and Akure South LGAs respectively, indicating the site number, site codes, site names and the number of antenna sectors.

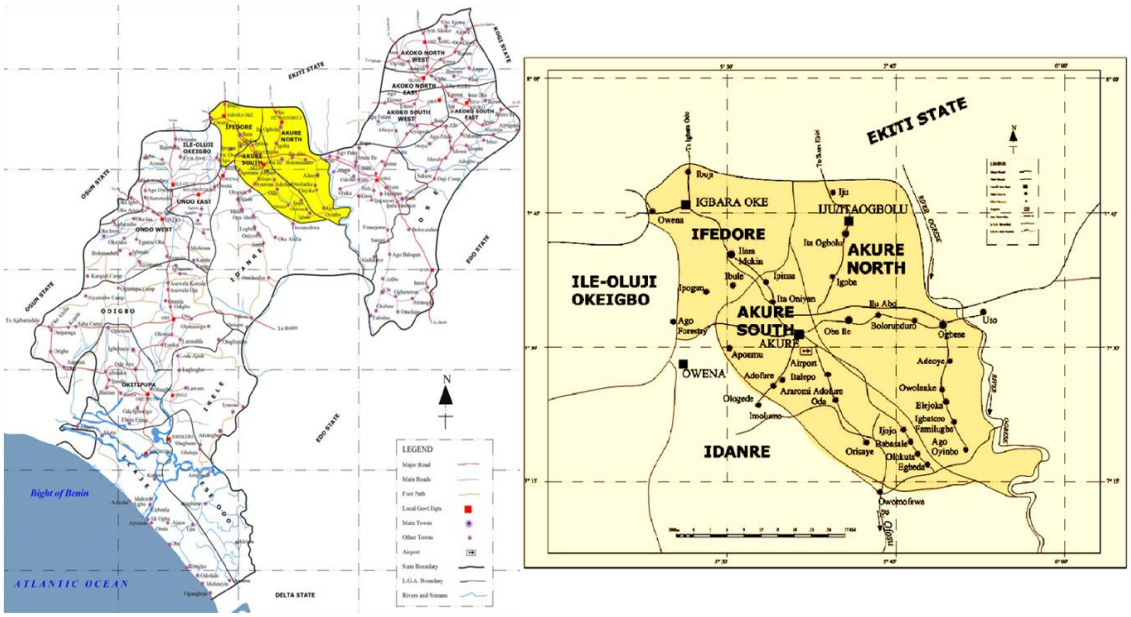

Fig. 2(a): Map of Ondo State showing its LGAs. (b): Akure region showing Ifedore, Akure North and Akure South LGAs [25].

Table 1: Ifedore Local Government BTS sites with Antenna Sectors

Site No	Site Code	Site Name	No of Antenna Sector
1	IIN001	Igbara Oke	S6
2	IMK001	Ilara Mokin	S6
3	IMK002	Elizade University	S6
4	INS001	Isarun	S6
5	AKR024	Ero Town	S6
6	AKR023	Ibule Town	S6
7	IJA001	Ijare	S6
8	AKR010	FUTA	S6
9	ONB001	Orisumibare	S6
10	AKR027	Futa South Gate	S6

Table 2: Akure North Local Government BTS sites with Antenna Sectors

Site No	Site Code	Site Name	No of Antenna Sector
1	JGL001	Ilado	S6
2	IJA801	Igoba	S6
3	AKR013	Oba-Ile Estate	S3
4	USO001	Uso Town	S6
5	AKR015	Ikere-Ekiti	S3
6	AKR801	Bolorunduro	S4
7	AKR031	Federal Secretariat	S4
8	AKR026	Oba-Ile Road	S6

Table 3: Akure South Local Government BTS sites with Antenna Sectors

Site No	Site Code	Site Name	No of Antenna Sector
1	AKR029	Ipinsa	S6
2	AKR022	Orita Obele	S6
3	AKR014	Adejuyigbe	S3
4	ILS802	Local Govt	S3
5	AKR009	Alewi	S6
6	AKR001	Iroko, Akure	S6
7	AKR002	Adesida 1	S6
8	AKR003	Conoil	S6
9	AKR005	Adesida 2	S6
10	AKR006	Ijoka	S6
11	AKR007	Ijapo	S6
12	AKR008	Bolajoko	S6

13	AKR016	Oluwatedo	S3
14	AKR017	Adebowale	S3
15	AKR019	Davog Area	S6
16	AKR020	Afunbiowo Estate	S6
17	AKR021	Awule	S4
18	AKR028	Oda Road	S6
19	AKR030	School of Health Tech.	S6
20	AKR025	State Secretariat	S3

Ifedore, Akure North and Akure South local government area has 10 BTS, 8 BTS and 20 BTS respectively. The sites in Ifedore Local Government Area are all six-sectored antennas. Four of the base station sites in Akure North Local Government Area have six (6) antenna sectors, two has four (4) antenna sectors, and two has three (3) antenna sectors. In Akure South Local Government Area, fourteen base stations have six (6) sector antennas; five has three (3) sectors while there is a site with four (4) sector antennas. The higher the number of sectors, the better the signal reception and the better the voice call quality. For each local government, the KPIs were analysed and correlated with each other with respect to their contributions to the performance of the network.

IV. RESULTS AND DISCUSSION

4.1 KPI Analysis

4.1.1 Ifedore Local Government

Figure 3(a) shows the DCR and the average traffic channels for the BTS sites in Ifedore LGA. From Figure 3(a)(i), the site with the highest DCR is observed to be Site No 1 (IN001, Igbara Oke) while Site No 5 (AKR024, Ero Town) has the lowest DCR which may be due to well defined handover parameters on the cells and with few subscribers. DCR of all the sites were below the 2% NCC maximum value.

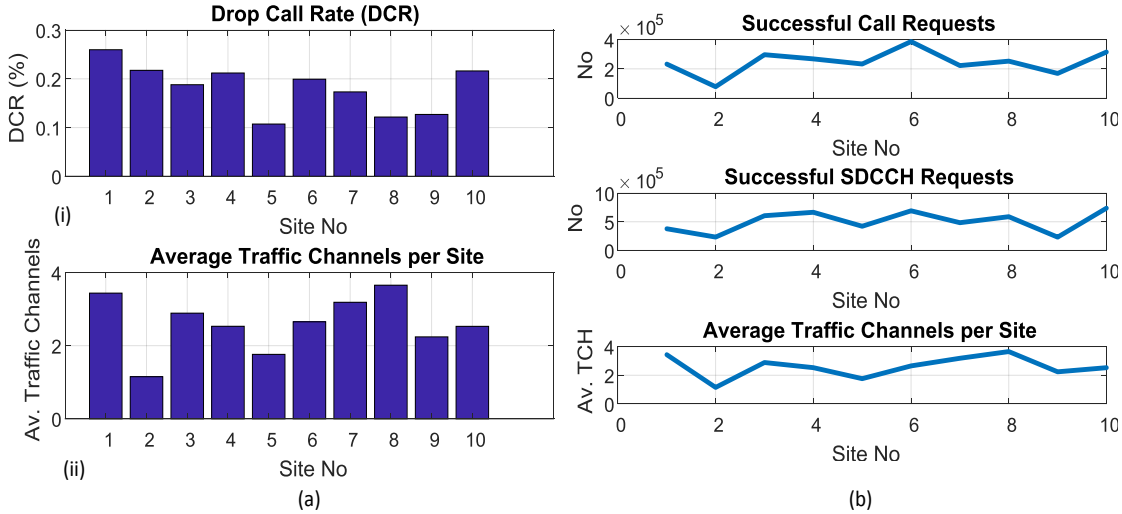

Figure 3: (a)(i) DCR, (ii) average TCH, and (b) Number of successful call requests, number of successful SDCCH requests with average traffic channels for the BTS sites in Ifedore LGA.

Figure 3(a)(ii) shows the traffic channels with Site No 8 (AKR010, FUTA), Site No 1 (IIN001, Igbaraoke) and Site No 7 (IJA001, Ijare) observed to have high number of traffic channels being a road coverage site for travellers, the only base station in Igbara-oke and Ijare town respectively. The site with the lowest traffic channel is seen to be Site No 2 (IMK001, Ilara Mokin) as a result of its sparsely populated density.

Traffic Channel is expected to be configured or upgraded based on the increase in number of subscribers on the particular base station in order to ease channel congestion and to improve call set up success rate. Figure 3(b) shows the average traffic channels with respect to the number of successful call requests, and the number of successful SDCCH requests for each site.

Observing Figure 3(b), it can be observed that the relative apportioning of traffic channels for the sites does not follow closely the successful SDCCH requests or successful call requests. Site No 8 (AKR010, FUTA) with the highest number of average traffic channel is not the site with the highest total number of successful SDCCH or call requests.

Figure 4 shows the CSR, CSSR, HSR and the SDCCH-SR for the BTS sites in Ifedore LGA.

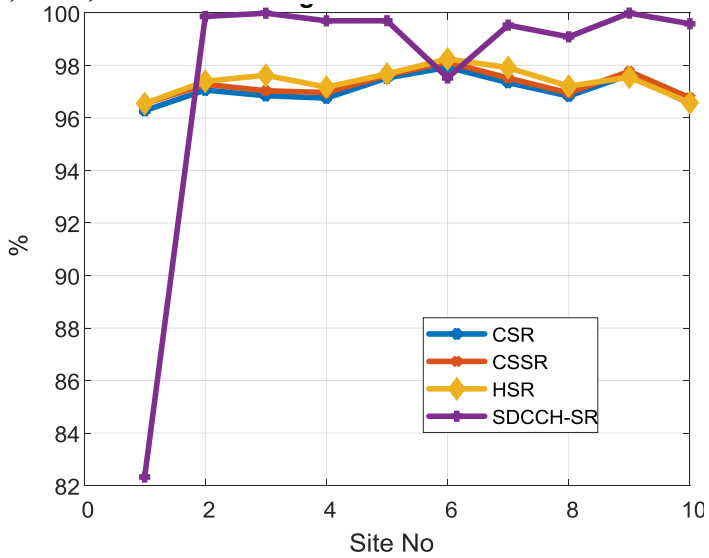

Fig. 4: CSR, CSSR, HSR and SDCCH-SR for the BTS sites in Ifedore LGA.

The site with the highest CSSR is Site No 6 (AKR023, Ibule town). This site is also the site with the highest HSR. Interestingly, the site is not the site with the highest SDCCH-SR but is the site that is second to the least in SDCCH-SR. The site with the lowest CSSR is Site No 1 (IN001, Igbara Oke) due to poor SDCCH-SR value (82.33%). This site also happened to be the site with the lowest HSR.

CSR values for all the BTS sites in Ifedore LGA are expectedly lower than CSSR and follows it closely. The trend of HSR also follows close to CSSR. Most of the sites have values of SDCCH-SR greater than 99% but still fall short of the NCC minimum value of 99.8%.

4.1.2 Akure North Local Government Area

Figure 5(a) shows the DCR and the average traffic channels for the BTS sites in Akure North LGA. Figure 5(a)(i) shows Site No 1 (JGL001, Ilado) having the highest DCR which is likely due to the hilly topography, undefined handover parameters on the neighboring cells, and insufficient channels to handle the handover calls. Site No 3 (AKR013, Oba Ile) is seen to have the lowest DCR. DCR of all the sites were below the 2% NCC maximum value.

Figure 5(a)(ii) shows Akure North LGA traffic channel with Site No 8 (AKR026, Oba Ile road) seen to have the highest traffic channel as a result of its location along Oba Ile /Alagbaka environs because of the number of subscribers. Site No 3 (AKR013, Oba Ile) and Site No 4 (USO001, Uso town) is observed to have the lowest TCH due to its sparsely populated density.

Figure 5(b) shows the average traffic channels with respect to the number of successful call requests, and the number of successful SDCCH requests for each site. For this LGA, as shown in Figure 5(b), it can be observed that the relative apportioning of traffic channels for the sites follows closely the successful SDCCH requests or successful call requests.

Figure 6 shows the CSR, CSSR, HSR and the SDCCH-SR for the BTS sites in Akure North LGA. The site with the highest CSSR is Site No 7 (AKR031, Federal Secretariat). This site is also the site with the highest HSR. Interestingly, the site is the site with the lowest SDCCH-SR of 97.64%. The site with the lowest CSSR is Site No 1 (JGL001, Ilado). Site No 5 (AKR015, Ikere-Ekiti) has the lowest HSR of 95.28% due to the hilly topography. Site No 3 (AKR013, Oba Ile), Site No 6 (AKR801, Bolorunduro) and Site No 8 (AKR026, Oba Ile Road) have SDCCH-SR values of 100%, 99.99% and 99.96% respectively due to available TCH and high signal strength of uplink and downlink signals. The highest is Site No 3 (AKR013, Oba Ile).

CSR values for all the BTS sites in Akure North LGA are expectedly lower than CSSR and follows it closely. The trend of HSR also follows close to CSSR. All the sites have values of SDCCH-SR greater than 99% except one, and some are able to meet the NCC minimum value of 99.8%.

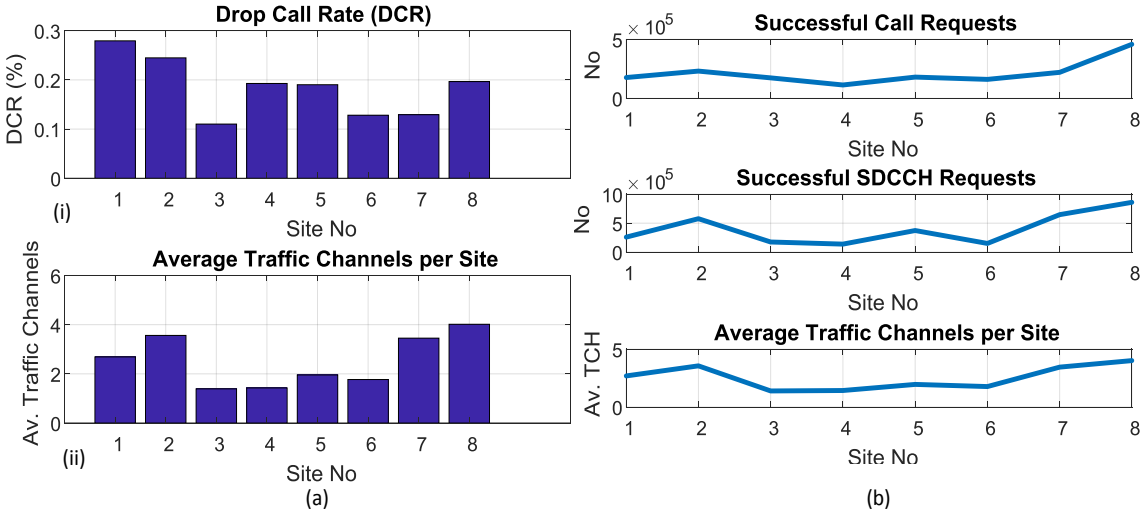

Figure 5: (a)(i) DCR, (ii) average TCH, and (b) Number of successful call requests, number of successful SDCCH requests with average traffic channels for the BTS sites in Akure North LGA.

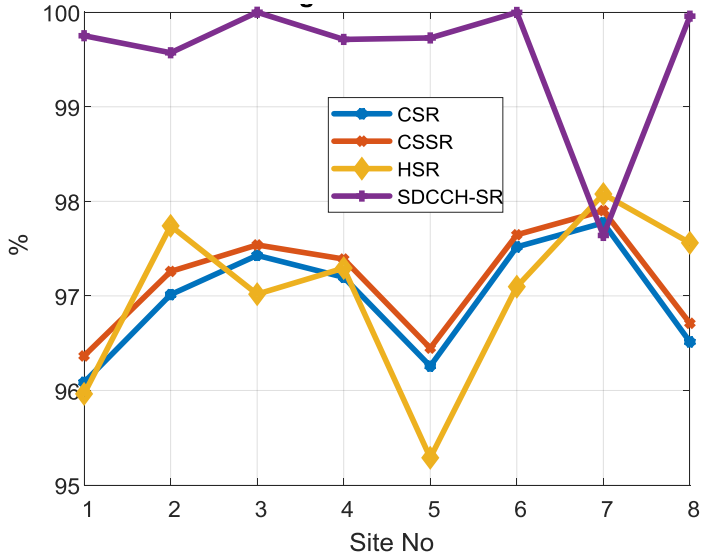

Fig. 6: CSR, CSSR, HSR and SDCCH-SR for the BTS sites in Akure North LGA.

4.1.3 Akure South Local Government Area

Figure 7(a) shows the DCR and the average traffic channels for the BTS sites in Akure South LGA. Figure 7(a)(i) shows the DCR with Site No 6 (AKR001, Iroko Akure) having the highest DCR. Site No 14 (AKR017, Adebowale) has the lowest DCR being road coverage base station site with less number of users. DCR of all the sites were below the 2% NCC maximum value.

Figure 7(a)(ii) shows the traffic channel of Akure South LGA where a larger part of the sites are clustered. Site No 14 (AKR017, Adebowale) is observed to have the lowest TCH being a road coverage base station site with less number of users while Site No 9 (AKR005, Adesida 2) has the highest traffic channel because it is located in the heart of the town where there are commercial activities with larger percentage of subscribers.

Figure 7(b) shows the average traffic channels with respect to the number of successful call requests, and the number of successful SDCCH requests for each site. Observing Figure 7(b), it can be observed that the relative apportioning of traffic channels for the sites does not follow exactly the successful SDCCH requests or successful call requests. Site No 9 (AKR005, Adesida 2) with the highest number of average traffic channel has the highest total number of successful call requests with Site No 5 (AKR009, Alewi), but is not the site with the highest total number of successful SDCCH requests which is Site No 5 (AKR009, Alewi).

Figure 8 shows the CSR, CSSR, HSR and the SDCCH-SR for the BTS sites in Akure South LGA.

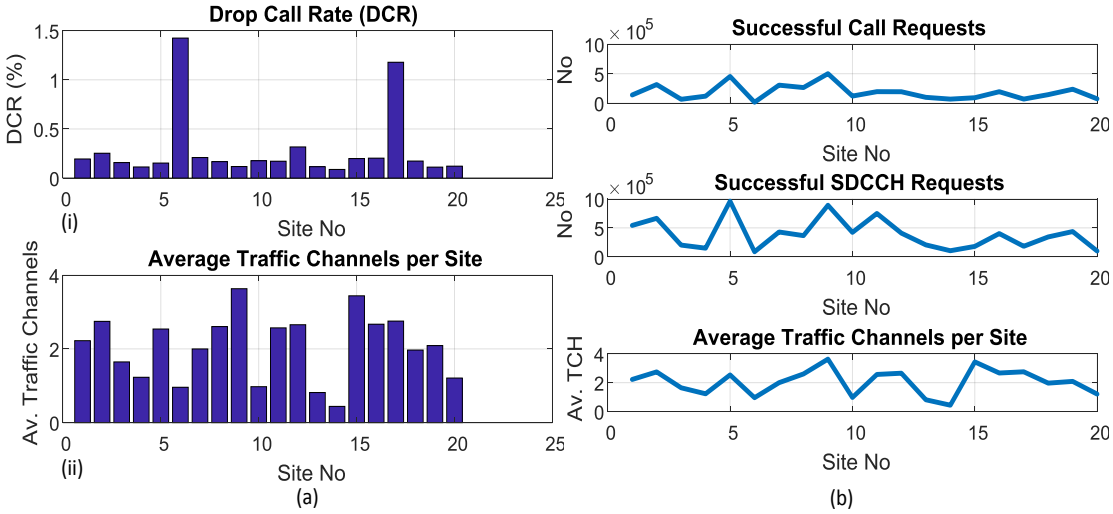

Figure 7: (a)(i) DCR, (ii) average TCH, and (b) Number of successful call requests, number of successful SDCCH requests with average traffic channels for the BTS sites in Akure South LGA.

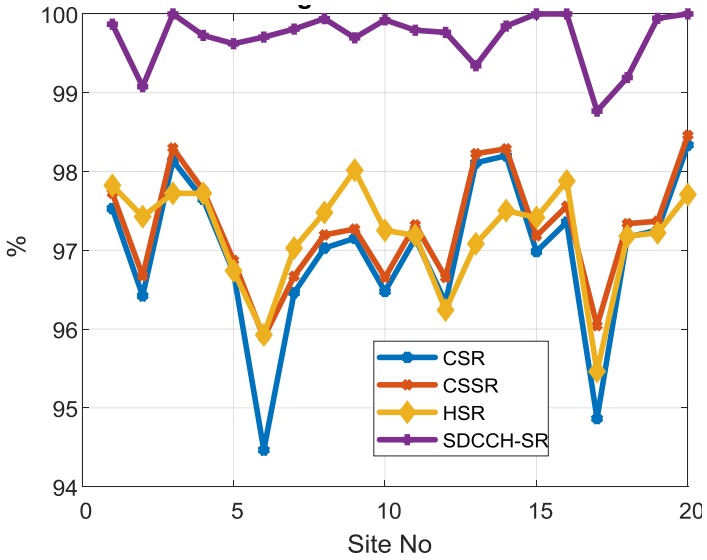

Fig. 8: CSR, CSSR, HSR and SDCCH-SR for the BTS sites in Akure South LGA.

The site with the highest CSSR is Site No 20 (AKR025, State Secretariat) having a CSSR of 98.46% due to successful SDCCH seizure. This site is one of the sites with 100% SDCCH-SR. Other sites with 100% SDCCH-SR are Site No 3 (AKR014, Adejuyigbe), Site No 15 (AKR019, Davog) and Site No 16 (AKR020, Afunbiowo) owing to their different locations and the number of subscribers. The site with the lowest CSSR is Site No 6 (AKR001, Iroko Akure) which is likely due to degraded hardware. The site with the highest HSR is Site No 9 (AKR005, Obanla) having a HSR of 98.01% due to a good radio coverage and well defined handover relations. The site with the lowest HSR is Site No 17 (AKR021, Awule) which is also the site with the lowest SDCCH-SR of 98.77%.

CSR values for all the BTS sites in Akure South LGA are expectedly lower than CSSR and follows it closely. The trend of HSR also follows close to CSSR. All the sites have values of SDCCH-SR greater than 99% except one, and some are able to meet the NCC minimum value of 99.8%. Four of them have 100%.

4.1.4 Summary of the KPIs

The foregoing analyses show the values of the Call Success Rate (CSR), Call Set up Success Rate (CSSR), Handover Success Rate (HSR) and SDCCH-SR; as well as their interdependence. In all the LGAs, CSR follows CSSR closely which is expected. Also, the trend of HSR follows close to CSSR. SDCCH-SR is expected to be 100% in all the LGAs, but only very few sites were able to exactly meet this value. The trend of SDCCH-SR does not follow either CSSR or HSR. From figures 4, 6 and 8, the SDCCH-SR of most of the sites

in each LGA is observed to be almost 100%, though still fall short of the NCC minimum value. Owing to this, further improvement of SDCCH-SR in Glomobile Network, Akure would have only marginal effect on its overall network performance. This was also observed by [26].

Table 4 shows the average values and standard deviations of the KPIs for the three LGAs.

Table 4: Average values and Standard Deviations of the KPIs for the three LGAs

KPI	Ifedore LGA		Akure North LGA		Akure South LGA	
	Average (%)	S.D.	Average (%)	S.D.	Average (%)	S.D.
CSSR	97.2585	0.50	97.1572	0.58	97.2727	0.73
HSR	97.3922	0.54	97.0050	0.94	97.2012	0.67
SDCCH-SR	97.7310	5.46	99.5450	0.79	99.7009	0.34
DCR	0.1821	0.05	0.1839	0.06	0.2824	0.35
CSR	97.0764	0.52	96.9733	0.62	96.9903	1.00

From Table 4, it can be observed that the average values of CSSR in all the LGAs are above 97% but fall short of the NCC minimum value of 98%. Therefore, CSSR needs to be improved in all the LGAs. Likewise, the average values of HSR in all the LGAs are above 97% but fall short of the NCC minimum value of 98%. This also needs to be improved in all the LGAs. The average values of SDCCH-SR are very close to the NCC minimum value of 99.8% except for Ifedore LGA having an average value of 97.731% with a wide standard deviation. Therefore, SDCCH needs to be improved upon in Ifedore LGA. The average values of DCR in all the LGAs are below the NCC maximum value of 1%. Akure South LGA has the highest average DCR of 0.2824% with a wide standard deviation compared to others. The population of Akure South LGA is the highest of all the three LGAs; therefore, DCR needs to be improved upon in the LGA.

Notwithstanding the situation of the above mentioned KPIs, the average value of CSR of 97.0764% in Ifedore LGA (which is the highest) was able to meet the NCC minimum value of 97%, while others were almost. Improvement in CSSR, DCR and HSR will lead to further improvement in CSR.

4.2 Correlation of KPIs

4.2.1 Ifedore Local Government

The scattered plots in Fig. 9 show the relationship between CSR and CSSR, HSR, SDCCH-SR and DCR for Ifedore Local Government Area. In Ifedore Local Government, CSR has a linear relationship with CSSR, likewise HSR. SDCCH-SR does not seem to have a linear relationship with CSR. This KPI seems to have been nearly maximized except for the fact that some values are far away from 100% making their correlation to be low. This can be observed in Table 4 with a high standard deviation for SDCCH-SR. CSR and DCR seem to have a negative relationship which is expected. CSR is significant with respect to CSSR, but the significance of HSR is not as that of CSSR.

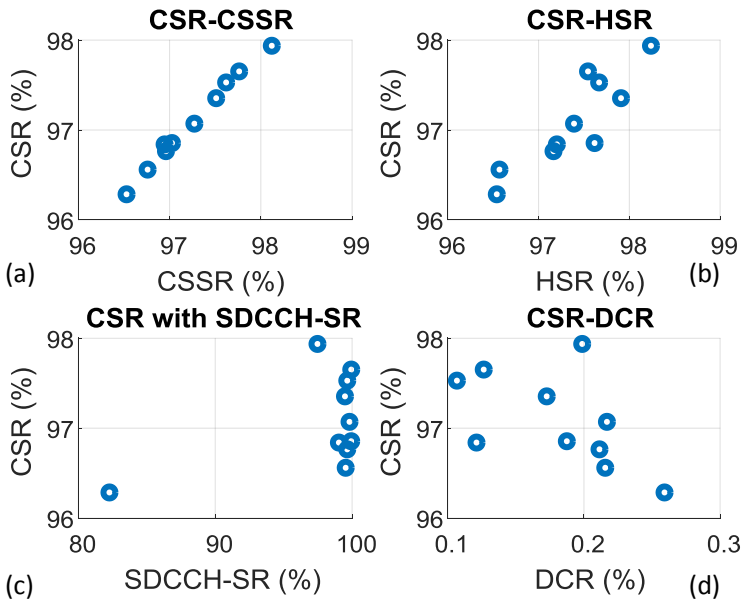

Fig. 9: Scatter plots of CSR with (a) CSSR, (b) HSR, (c) SDCCH-SR, and (d) DCR for Ifedore LGA.

4.2.2 Akure North Local Government

The scattered plots in Fig. 10 show the relationship between CSR and CSSR, HSR, SDCCH-SR, and DCR for Akure North Local Government Area. In Akure North Local Government, CSR has a linear relationship with CSSR, and HSR. SDCCH-SR does not seem to have a linear relationship with CSR. CSSR is significant with respect to CSR in this local government. The significance of HSR with CSR in this LGA is not as that of Ifedore LGA. CSR with DCR has a negative linear relationship which is expected.

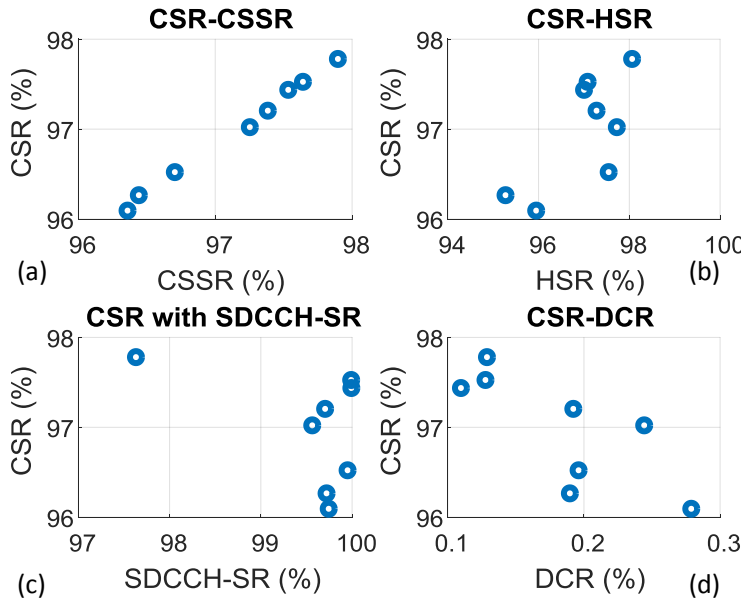

Fig. 10: Scatter plots of CSR with (a) CSSR, (b) HSR, (c) SDCCH-SR, and (d) DCR for Akure North LGA.

4.2.3 Akure South Local Government

The scattered plots in Fig. 11 show the relationship between CSR and CSSR, HSR, SDCCH-SR, and DCR for Akure South Local Government Area. In Akure South local government, CSR has a linear relationship with CSSR and HSR. SDCCH-SR seems to somehow have a linear relationship with CSR but not significant. In this local government, CSR with DCR has an expected negative linear relationship, but in this case is very significant.

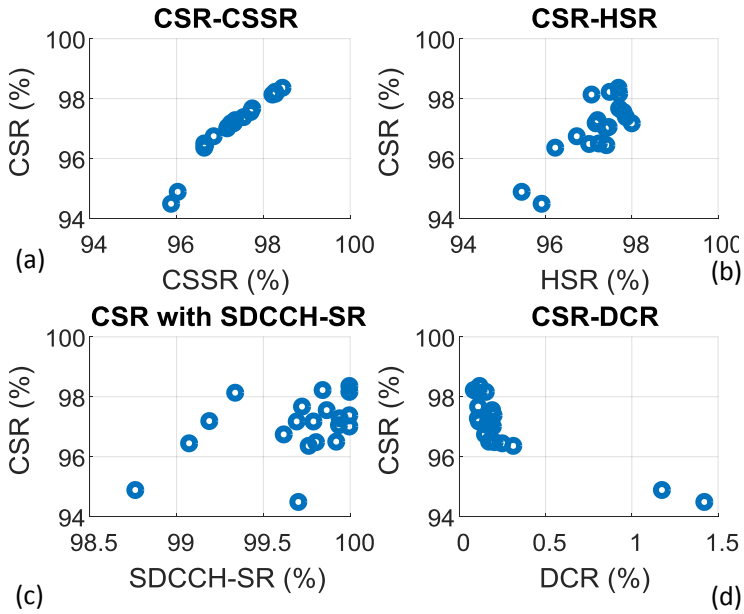

Fig. 11: Scatter plots of CSR with (a) CSSR, (b) HSR, (c) SDCCH-SR, and (d) DCR for Akure South LGA.

4.2.4Summary of Correlations

Table 5 shows the values of correlations between CSR and other KPIs for the three LGAs. Values between DCR, HSR, TCH and SDCCH-SR are also shown.

Table 5: Correlations of the KPIs for the three LGAs

KPIs	Correlation		
	Ifedore LGA	Akure North LGA	Akure South LGA
CSR/CSSR	0.9965	0.9978	0.9662
CSR/HSR	0.8880	0.7138	0.8033
CSR/SDCCH-SR	0.4798	-0.4489	0.4373
CSR/DCR	-0.5548	-0.7679	-0.8498
DCR/HSR	-0.4462	-0.3103	-0.7922
TCH/SDCCH-SR	-0.4180	-0.3908	-0.1157

The Table shows high correlation of almost one (1) between CSR and CSSR for all the three LGAs. Also, high correlation can be observed between CSR and HSR, but not as high as that of CSSR, and with Akure North LGA having the least correlation. CSR with DCR has a negative correlation in all the three LGAs as expected, with the highest correlation in Akure South LGA. DCR/HSR and TCH/SDCCH-SR can be observed to have negative correlations with Akure South LGA having the highest for DCR/HSR, and Ifedore LGA having the highest for TCH/SDCCH-SR.

V. CONCLUSION

This work has been able to assess interdependency of predominant KPI's in the voice traffic data of Glomobile Network, Akure for three local government areas. Of all the KPIs considered, DCR was the only KPI that met Nigerian Communications Commission (NCC) requirement. CSR and SDCCH were nearly able to. Other KPIs need to be improved for a better performance of Glomobile Network in Akure. For Call Success Rate (CSR) to be maximally improved, Call Setup Success Rate (CSSR) should be above 98% as stipulated by NCC, and its average value was observed to be 97.2727% only in Akure South Local Government Area. CSSR in the two other local government areas have lower values and they should be improved upon. Handover Success Rate (HSR) and Traffic Channel availability should also be improved for the three local government areas. SDCCH is nearly maximized and any further improvement would have marginal effect on the success of a call in Glomobile Network, Akure. From this work, CSR can be improved in Akure North Local Government area and Akure South Local Government area. Drop Call Rate should be further decreased in Akure South Local Government Area.

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