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Performance Evaluation Of Selected Gsm Networks In Nigeria

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***Abstract*— In this paper, performance evaluation of selected GSM networks in Nigeria is presented. The performance evaluation of the networks is based on requisite datasets pertaining to those networks and some key performance indicators (KPIs) which are applicable for Quality of Service (QoS) assessment of GSM networks. Specifically, seven (7) KPI parameters were computed, namely; Call Setup Success Rate (CSSR), Call Drop Rate (CDR), Standalone Dedicated Control Channel (SDCCH) congestion rate, Traffic Control Channel (TCC) congestion rate, Call Block Rate (CBR), Handover Success Rate (HOSR) and Handover Failure Rate (HOFR). The results show that from June, 2020 to May, 2022, MTN has the highest CSSR value of 99.73 % followed by Airtel with 99.41% then 9mobile with 99.19 % and Globacom 99.06 %. Also, MTN has lowest Call Drop Rate (CDR) value of 0.28, followed by Globacom with CDR value of 0.32, Airtel had CDR value of 0.35 and 9mobile had CDR value of 0.43. Again, only the network of MTN and Airtel have Standalone Dedicated Control Channel (SDCCH) < 0.2% as mandated by the Nigerian Communications Commission (NCC) while Globacom had SDCCH > 0.2% in October and 9mobile had SDCCH > 0.2% in about 13 month. In addition, Airtel, 9mobile, Globacom and MTN satisfied the NCC requirement of Traffic Control Channel (TCCH) ≤ 2%. Similarly, only Airtel and MTN have call blocked rate (CBR) ≤ 2.0% while Globacom exceeded 2% in October 2021 and 9mobile exceeded 2% in about 6months. Also, only MTN network was able to meet the Handover Success Rate (HOSR) ≥ 98 % requirement in all the months, while Airtel had HOSR < 98% for about 5 months, Globacom had HOSR < 98% for all the months and 9mobile had HOSR < 98% for about 17 months. In all, among the four GSM networks considered in the study, the best performance was recorded for the MTN network.**

Keywords: GSM Networks, Call Setup Success Rate (CSSR), Call Drop Rate (CDR), Standalone Dedicated Control Channel (SDCCH) congestion rate, Traffic Control Channel (TCC) congestion rate, Call Block Rate (CBR), Handover Success Rate (HOSR) and Handover Failure Rate (HOFR).

1. INTRODUCTION

Since the inception of Global System for Mobile communication (GSM) in Nigeria in 2001, the number of users has continued to rise [1,2,3]. The number of subscribers increased from 1.57 million in 2002 to 18.56 million in 2005, then to 81.08 million in 2010, 132 million in 2014, and 184.7 million in 2015. Nigeria now has 226.84 million active GSM subscribers, according to the Nigerian Communications Commission [4]. However, in respect of the increasing subscriber base, the GSM communication provider's service quality (in terms of dropped calls) is poor and unreliable [5,6,7,8]. To ensure that Nigerians have improved GSM communication service, much work needs to be done. Four (4) percent of all calls on the country's GSM networks are dropped early. Given the country's current GSM line count of over 226 million active lines, this corresponds to hundreds of thousands of daily call losses [9,10,11].

Generally, the service quality supplied by GSM operators in Nigeria, on the other hand, has remained terrible. Essentially, every GSM subscriber in the country is affected. The Nigerian Communication Commission (NCC), the country's main GSM regulator, established a baseline for Key Performance Indicators (KPIs) in order to enforce greater service quality [12,13,14]. The KPIs are measurements for assessing the GSM network's service quality. Call Setup Success Rate (CSSR), Call Drop Rate (CDR), Handover Success Rate (HOSR), Handover Failure Rate (HOFR), Standalone Dedicated Control Channel

(SDCCH) Congestion Rate, Traffic Control Channel (TCCH) Congestion Rate and Call Block Rate (CBR) are just a few of the KPIs available[15,16,17,18].

According to research into the quality of GSM KPIs in Nigeria, the CDR is the country's worst performing indicator [9,10]. By distributing questionnaires to the six regions of Nigeria, [11] substantiated [11] assertion in their driving time test in Abuja, the Federal Capital Territory. According to their results, the CSSR and CDR are the two essential KPIs for which most operators have not yet fulfilled the NCC target [11]. Accordingly, this work is set to analysis the KPI parameters of four major GSM networks in Nigeria based on 2021 to 2022 datasets obtained with respect to the four networks. The essence of the study is to provide recent performance of the networks and highlight the areas that require performance improvement.

2. METHODOLOGY

This work set to conduct performance evaluation of four major Global System for Mobile Communications (GSM) networks in based on requisite datasets pertaining to those networks and some key performance indicators (KPIs) which are applicable for Qaulity of Service (QoS) assessment of GSM networks.

2.1 Data Collection

In order to evaluate the performance of the four case study mobile communication network service providers in Nigeria, requisite datasets are collected from the Communications Commission (NCC) website and also from the cellular networks Operation and Maintenance Centre (OMC). Notably, in Nigeria, the Nigerian Communications Commission (NCC) is the regulator agency for all telecommunications companies and operations. The NCC Key Performance Indicators (KPI) benchmarks from their May, 2020 Quality of Service (QoS) requirements are shown in Table 1 [20,21,25]. Specifically, the fours GSM networks in Nigeria considered in this work includes Airtel, 9mobile, Globacom and MTN.

2.2 Mathematical models for the computation of the Key Performance Indicators (KPI)

Specifically, seven (7) important major Quality of Service (QoS) KPI (shown in Table 1) are considered in this work; the analytical models for computing each of the 7 KPIs are presented, as well as their mathematical correlations. The analytical models are useful for assessing the influence of inter-cell handover dynamics on Quality of Service (QoS). Accordingly, the following key GSM network KPI parameters were computed; Call Setup Success Rate (CSSR), Call Drop Rate (CDR), Standalone Dedicated Control Channel (SDCCH) congestion rate, Traffic Control Channel (TCC) congestion rate, Call Block Rate (CBR), Handover Success Rate (HOSR) and Handover Failure Rate (HOFR).

Table 1: Nigerian Communications Commission (NCC) KPIs Benchmarks.

S/N	Key Performance Indicators (KPI)	NCC Benchmarks
1	Call Setup Success Rate (CSSR)	≥ 98%
2	Call Drop Rate (CDR)	≤ 1%
3	Standalone Dedicated Control Channel (SDCCH) Congestion Rate	≤ 0.2%
4	Traffic Control Channel (TCCH) Congestion Rate	≤ 2%
5	Call Block Rate (CBR)	≤ 2%
6	Handover Success Rate (HOSR)	≥ 98%
7	Handover Failure Rate (HOFR)	≤2%

A. Handover Rate

Typically, in a Base Station Controller (BSC) and Base Transceiver Station (BTS), handover rate can be expressed as: [19]

$$HSR = \frac{HO_{SUCC\,BSC}}{HO_{SUCC\,BSC} + HO_{UNSUCC_R} + HO_{UNSUCC_L}} \quad (1)$$

Where:

HSR_{BSC} = Handover Success Rate

$HO_{SUCC\,BSC}$ = Successful Inter-Cell Handover in a BSC

HO_{UNSUCC_R} = Unsuccessful Inter-Cell Handover with Re-connection per BSC

HO_{UNSUCC_L} = Unsuccessful Inter-Cell Handover with Loss of Connection per BSC.

$$HSR_{cell} = \frac{HO_{succ\,out}}{HO_{total}} \quad (2)$$

Where:

HSR_{CELL} = Successful Inter-Cell Handover per Cell

$HO_{\_SUCCout}$ = Successful Outgoing Handover per Cell

$HO_{\_total}$ = Total Outgoing Handover per Cell.

B. Call Setup Success Rate (CSSR)

This is the ratio of the number of unblocked call attempts to the total number of call attempts. When a service request is made from a mobile terminal, the request may be granted or it may be denied, such service denial is termed call blocking [22];

$$Call\ Setup\ Success\ Rate\ (CSSR) = \frac{Number\ of\ Unblocked\ Call\ Attempts}{Total\ Number\ of\ Call\ Attempts} * 100\% \quad (3)$$

C. Call Drop Rate (CDR)

The Call Drop Rate (CDR) is the ratio of the number of dropped calls to the total number of call attempts. A mobile user may cross various cell boundaries throughout the course of a call, necessitating multiple successful handoffs. If there isn't a successful handoff at

any point along the path, the service provider is forced to stop providing service to the user. This is referred to as call dropping or forced call termination [22];

$$Call\ Drop\ Rate\ (CDR) = \frac{Number\ of\ Drop\ Calls}{Total\ Number\ of\ Call\ Attempts} * 100\% \quad (4)$$

D. Standalone Dedicated Control Channel (SDCCH) Congestion Rate: -

The Standalone Dedicated Control Channel (SDCCH) congesting rate is the ratio of the number of assignment related connect fails to the mobile originating call attempts. It also serves as both a control and a signalling channel. Call setup, location update messages, and Short Message Services (SMS) are all covered [23];

$$SDCCH = \frac{Number\ of\ Assignment\ Related\ Connect\ Fails}{Mobile\ Originating\ Call\ Attempts} * 100\% \quad (5)$$

E. Traffic Control Channel (TCCH) congesting rate

The Traffic Control Channel (TCCH) congesting rate is the ratio of the total number of call connect fails to the total number of call attempts. The traffic channel is the communication channel utilized by Mobile Station. Traffic channel availability as a measure of traffic channel congestion during peak hours [22];

$$Traffic\ Control\ Channel(TCCH) = \frac{Number\ of\ Call\ Connect\ Fails}{Total\ Number\ of\ Call\ Attempts} * 100\% \quad (6)$$

F. Call Block Rate (CBR)

The Call Block Rate (CBR) is the ratio of the total number of blocked calls to the total number of call attempts.

$$Call\ Block\ Rate\ (\text{CBR}) = \frac{\text{Number of Block Calls}}{\text{Total Number of Call Attempts}} * 100\% \quad (7)$$

G. Handover Success Rate (HOSR)

Handover Success Rate (HOSR) is the ratio of the number of successfully handover calls to the total number of attempted handover calls.

$$\text{Handover Success Rate (HOSR)} = \frac{\text{Number of Successefully Handover Calls}}{\text{Total Number of Handover Call Attempts}} * 100\% \quad (8)$$

H. Handover Failure Rate (HOFR)

The Handover Failure Rate (HOFR) is the ratio of the number of fail handover calls to the total number call attempts. This Key Performance Indicators (KPIs) is intended to indicate user failure mobility in the network [24];

$$Handover\ Failure\ Rate\ (\text{HOFR}) = \frac{Number\ of\ Failed\ Handover\ Calls}{Total\ Number\ of\ Call\ Attempts} * 100\% \quad (9)$$

In occasions where mobile active terminal moves from one cell where it is on active call to another cell while still on the call, successful handoff is required from the previous cell of the mobile terminal to the new cell. In this case, the handoff is said to be successful if the required resources from the mobile terminal are available and allocated to it in the new cell.

I. Endpoints Service Availability (ESA)

This shows the Quality of Service (QoS) measures for the currently offered services. It is described as the proportion of time it takes for two endpoints to establish and sustain a useable call [24];

$$Endpoints\ Service\ Availability\ (ESA) = \frac{Nattempts - Nblock - Ndrop}{NAttempts} * 100\% \quad (10)$$

Where:
Nattempts = Number of call attempts
Nblock = Number of call blocks
Ndrop = Number of call drop

3. RESULTS AND DISCUSSIONS

3.1 The results for the Call Setup Success Rate (CSSR)

The results for the Call Setup Success Rate (CSSR) are given in Table 2 and Figure 1. According to NCC benchmark, CSSR should be equal to or greater than 98% .The results in table 2 show that from June, 2020 to May, 2022, MTN has the highest CSSR value of 99.73 % followed by Airtel with 99.41% , then 9mobile with 99.19 % and Globacom 99.06 %.

Again, from the results plotted in Figure 1, it can be seen that only the network of MTN and Airtel have an appreciable Call Setup Success throughout the periods of two years showing monthly description rate with values above the threshold mark of 98% while Globacom and 9mobile show serious setback of monthly description for the period of two years below 98%.

Table 2: Performance Threshold of Call Setup Success Rate (CSSR).

MONTHS	AIRTEL	9MOBILE	GLOBACOM	MTN	MONTHS	AIRTEL	9MOBILE	GLOBACOM	MTN
Jun'20	98.89	99.05	98.50	99.71	Jun'21	99.40	95.30	98.03	99.65
Jul'20	99.05	99.19	98.58	99.72	Jul'21	99.31	98.98	98.53	99.69
Aug'20	99.13	99.14	98.42	99.72	Aug'21	99.41	98.18	98.46	99.62
Sep'20	99.02	98.64	98.30	99.69	Sep'21	99.08	98.98	99.06	99.62
Oct'20	98.98	99.00	97.95	99.65	Oct'21	98.94	98.43	98.61	99.65
Nov'20	98.96	99.00	98.18	99.66	Nov'21	99.18	93.76	98.38	99.66
Dec'20	99.21	98.74	98.04	99.70	Dec'21	99.10	98.72	98.38	99.66
Jan'21	99.21	98.70	98.23	99.69	Jan'22	99.16	97.51	98.42	99.71
Feb'21	99.28	98.81	98.27	99.72	Feb'22	99.19	98.08	98.42	99.72
Mar'21	99.40	99.00	98.32	99.71	Mar'22	99.31	97.18	98.61	99.71
Apr'21	98.98	99.02	98.17	99.71	Apr'22	99.18	97.57	98.37	99.73
May'21	99.19	98.94	98.10	99.68	May'22	99.22	97.36	98.33	99.71

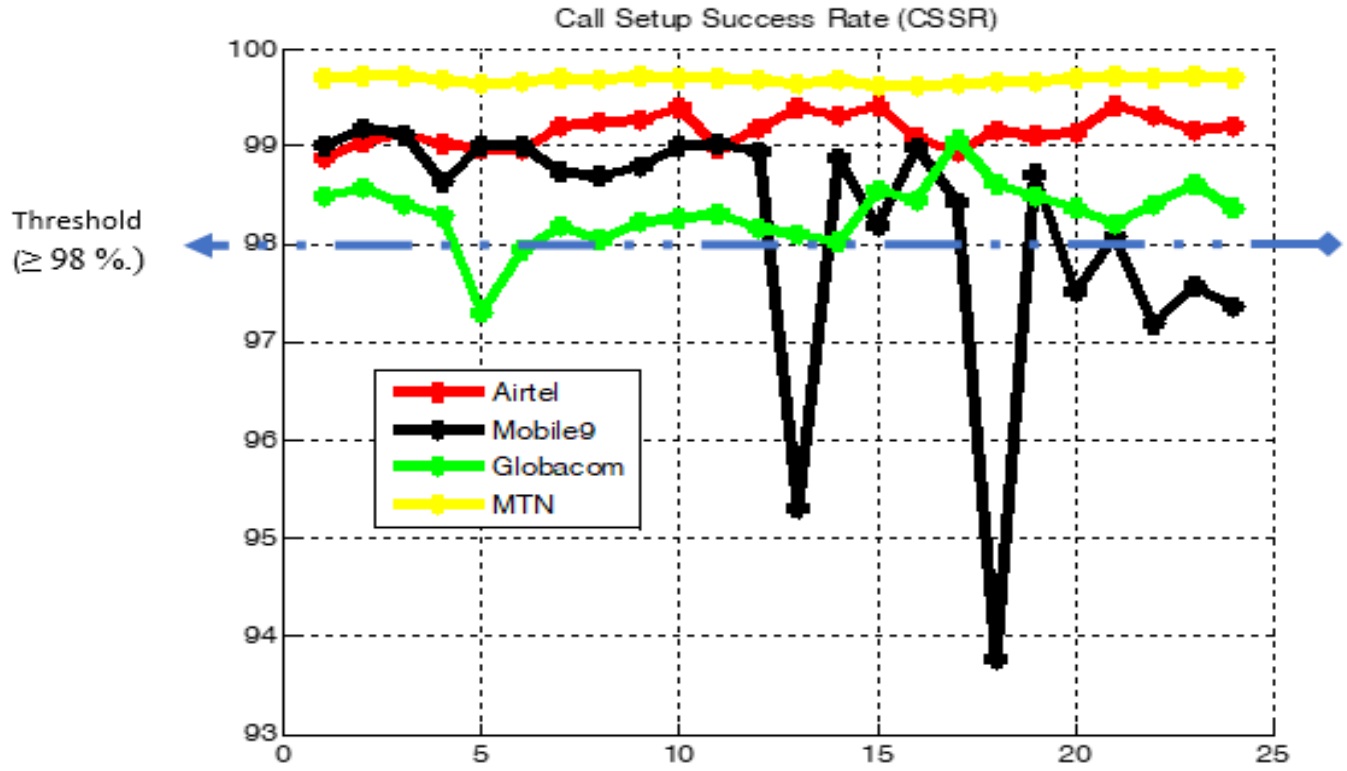

Figure 4. 7: Call Setup Success Rate (CSS) ≥ 98 %.

3.2 The results for the Call Drop Rate (CDR)

The results for the Call Drop Rate (CDR) are given in Figure 2. According to NCC benchmark, CDR) should be equal to or less than 1%. The results show that from June, 2020 to May, 2022, MTN has lowest CDR value of 0.28, followed by Globacom with CDR value of 0.32, Airtel had CDR value of 0.35 and 9mobile had CDR value of 0.43.

Notably, the results as presented in the graph analysis point to the facts since all the network fall below the ≤ 1% bench mark, it shows that all the communication networks of Airtel, 9mobile, Globacom and MTN for the 24 months' period there is very minimal call drop rate which is appreciable for sustaining subscribers across the different networks.

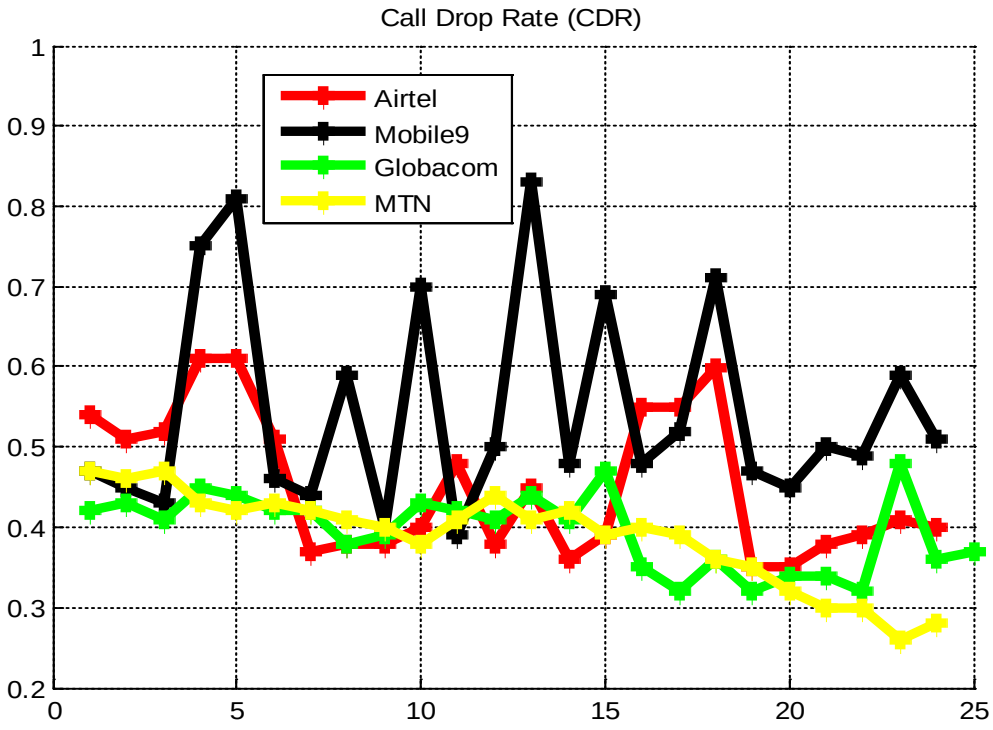

Figure 2: Call Drop Rate (CDR) ≤ 1%

3.3 The results for the Standalone Dedicated Control Channel (SDCCH)

The results for the Standalone Dedicated Control Channel (SDCCH) are given in Figure 3. According to NCC benchmark, SDCCH should be equal to or less than 0.2%. The results show that from June, 2020 to May, 2022, Airtel has lowest SDCCH value of 0.04, followed by MTN with SDCCH value of 0.07, Globacom had SDCCH value of 0.08 and 9mobile SDCCH value of 0.08.

Again, from the results plotted in Figure 3, it can be seen that for a 24 months' analysis only the network of MTN and Airtel show better SDCCH success < 0.2% as mandated by the NCC. However, Globacom had SDCCH success > 0.2% in October and 9mobile had SDCCH success > 0.2% in about 13 months' period which is a drawback for the two networks and it is not good for maintaining subscribers.

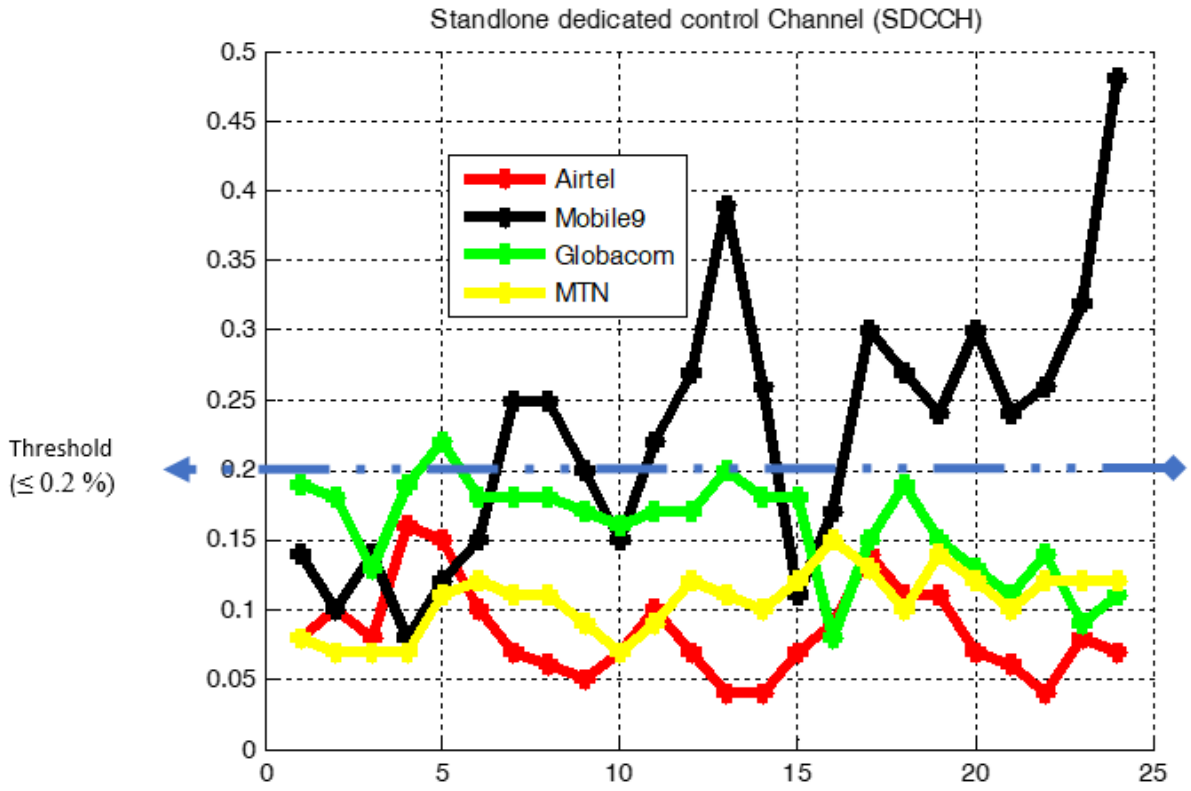

Figure 3: Standalone Dedication Control Channel (SDCCH) ≤ 0.2 %

3.4 The results for the Traffic Control Channel (TCCH)

The results for the Traffic Control Channel (TCCH) are given in Figure 4. According to NCC benchmark, TCCH should be equal to or less than 2%. The results show that from June, 2020 to May, 2022, Airtel has lowest TCCH value of 0.03, followed by 9mobile with TCCH value of 0.09, MTN had TCCH value of 0.13 and Globacom had TCCH value of 0.43.

Again, the monthly plots (in Figure 4) show that for all the communication networks of Airtel, 9mobile, Globacom and MTN all have an appreciable level (TCCH) below the threshold mark of ≤ 2%. Also, it clearly shows that Airtel, 9mobile, Globacom and MTN have satisfied the NCC requirement of TCCH ≤ 2%.

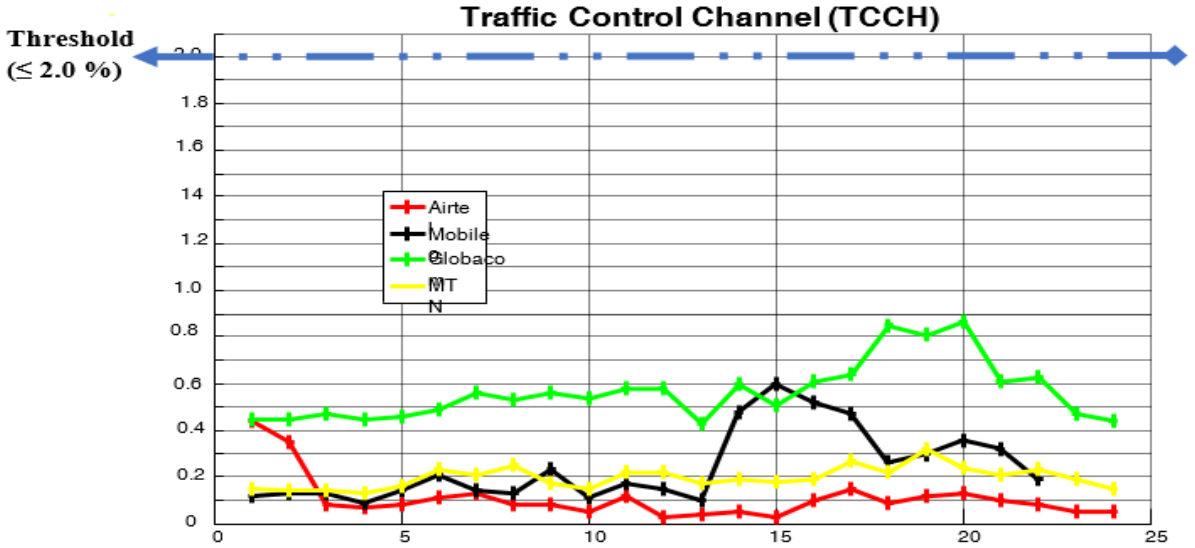

Figure 4: Traffic Control Channel (TCCH) ≤ 0.2 %

3.5 The results for the Call Block Rate (CBR)

The results for the Call Block Rate (CBR) are given in Figure 5. According to NCC benchmark, CBR should be equal to or less than 2%. The results show that from June, 2020 to May, 2022, MTN has lowest CBR value of 0.27, followed by Airtel with CBR value of 0.59, 9mobile had CBR value of 0.81 and Globacom had CBR value of 1.39.

Again, the monthly plots (in Figure 5) show that only Airtel and MTN from Jun'20 through May'22 have an appreciable level of call blocked rate (CBR), falling below the threshold mark of ≤ 2.0% while Globacom exceeded 2% in October 2021 and 9mobile exceeded 2% in about 6months.

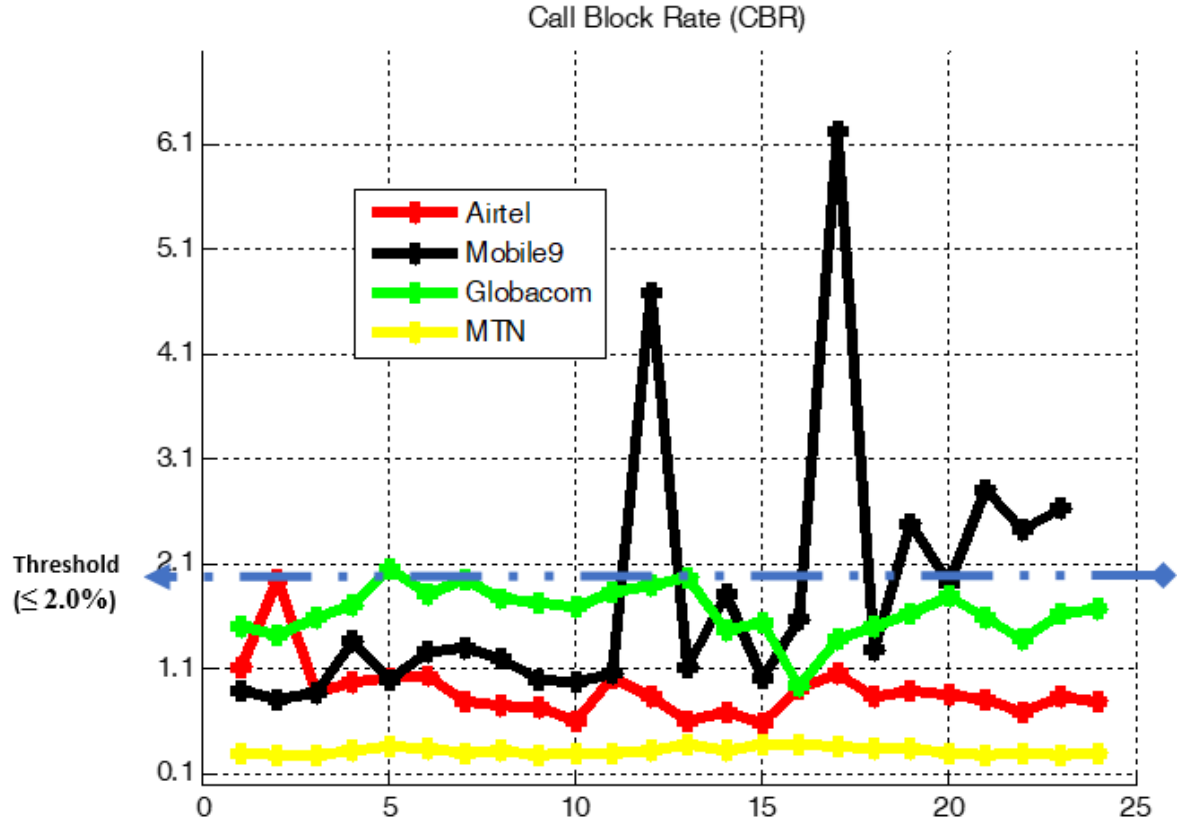

Figure 5: Call Block Rate (CBR) ≤ 2.0 %

3.6 The results for the Handover Success Rate (HOSR)

The results for the Handover Success Rate (HOSR) are given in Figure 6. According to NCC benchmark, HOSR should be equal to or greater than 98%. The results show that from June, 2020 to May, 2022, MTN has highest HOSR value of 99.46%, followed by Airtel with HOSR value of 98.82%, 9mobile had HOSR value of 98.38% and Globacom had HOSR value of 98.12%.

Again, the monthly plots (in Figure 6) show that for the period of the analysis which is Jun'20 through May'22 only MTN network was able to meet the HOSR requirements having a Handover Success Rate (HOSR) of ≥ 98 % in all the months. While the other networks fall below the

threshold mark of 98 % , Airtel had HOSR < 98% for about 5 months, Globacom had HOSR < 98% for all the months and 9mobile had HOSR < 98% for about 17 months.

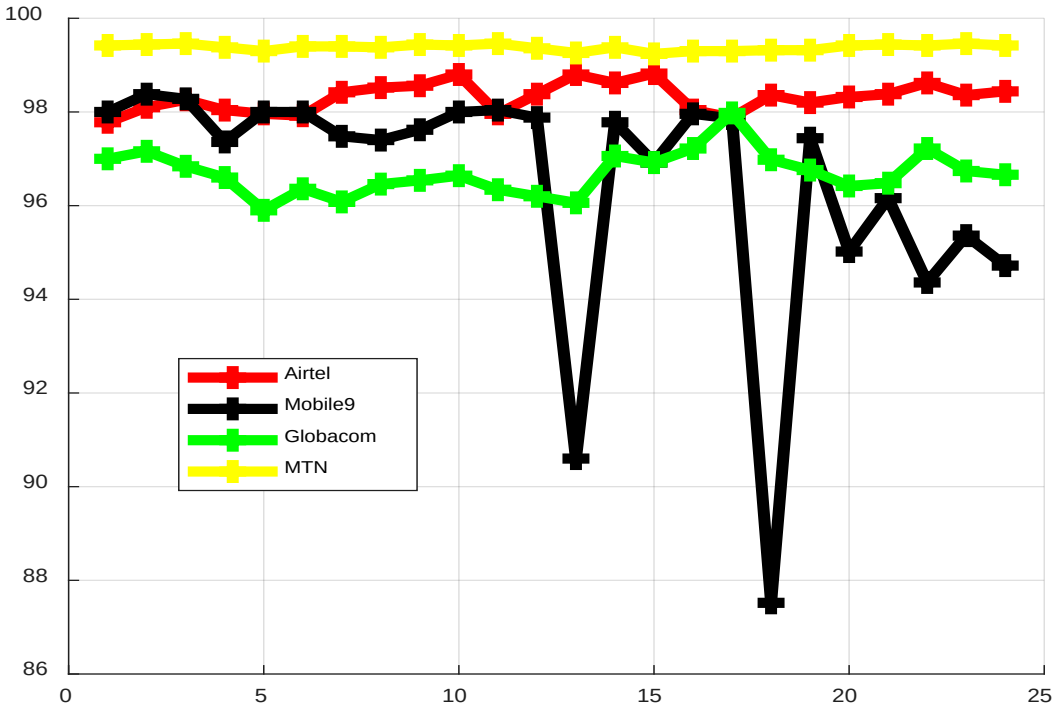

Figure 6: Handover Success Rate (HOSR) ≥ 98.0 %

3.7 The results for the Handover Failure Rate (HOFR)

The results for the Handover Failure Rate (HOFR) are given in Figure 7. According to NCC benchmark, HOFR should be equal to or less than 2%. The results show that from June, 2020 to May, 2022, MTN has lowest HOFR value of 0.54, followed by Airtel with HOFR value of 1.18, 9mobile had HOFR value of 1.62 and Globacom had HOFR value of 1.88.

Again, the monthly plots (in Figure 7) show that for the period of the analysis which is Jun'20 through May'22 only MTN network was able to meet the HOSR requirements having HOFR ≤ 2.0 % in all the months. While the other networks fall below the threshold mark of 98 % , Airtel had HOFR > 2% for about 5 months, Globacom had HOFR > 2% for 23 months and 9mobile had HOFR > 2% for about 17 months.

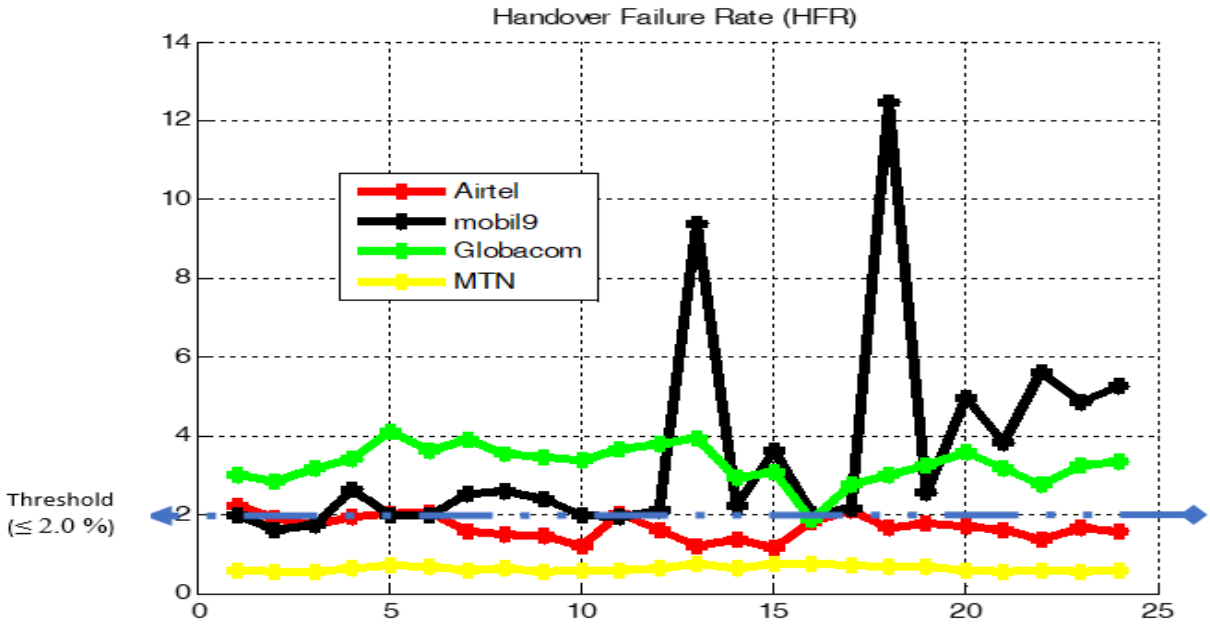

Figure 7: Handover Failure Rate (HOFR) ≤ 2 %

3. CONCLUSION

The performance evaluation of four GSM networks are presented based on the key performance indicators (KPI) and the network datasets acquired for the study. The mathematical expression for computing seven different KPIs are presented and the data is used to perform the numerical computations. Among the four GSM networks considered in the study, namely, Airtel, 9mobile, Globacom and MTN, the best performance in six out of the seven KPI was recorded of the MTN network.

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