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Research Article

Congestion Analysis of a GSM Network in Kaduna State Nigeria

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Abstract – Since the introduction of the Global System for Mobile Communication (GSM), the telecommunication industry has experienced an exponential rise in the number of subscribers. However, all these subscribers, which are in their billions are served by limited resources that need proper management. To ensure that these resources properly serve subscribers through Mobile Network Operators, regulatory bodies, such as the Nigerian Communications Commission (NCC) established a technical Quality of Service (QoS) benchmark that needs to be adhered to by the MNOs. On this premise,this work analyzes the performance of an MNO. From this analysis, it was observed that the Traffic Channel Congestion (TCHC) showed that 6% of the dataset were outside the technical benchmark set by the NCC. The Stand-alone Dedicated Control Channel (SDCCH) congestion showed that 4.2% of the dataset were not within NCC's benchmark. Within each Key Performance Indicator (KPI), it was observed that a couple of BTSs were pointed out for closer observation as they possessed a highprobability of falling outside the set threshold. The Traffic Channel Congestion (TCHC) and Standalone Dedicated Control Channel Congestion (SDCCHC) were compared with the Call Setup Success Rate (CSSR) and Call Completion Rate (CCR), it was observed that an increase in the value of either the TCHC or the SDCCHC showed a decrease proportional to that of the selected KPIs.

Keywords – Congestion analysis, SDCCHC, TCHC, KPI, QoS.

I. Introduction

The role of mobile phones has risen with thewide range of services offered to the end-user. As aresult, subscribers possess multiple lines on the same or various network operator all of which has contributed to the challenge of congestion [1]. The exponential increase in the number of user devices proportionally require fast, reliable and available infrastructure [2]. However, there are many technical challenges to be solved to make the components of this infrastructure work as intended. Although, the goal for Mobile Network Operators (MNOs) is to satisfy the subscribers as outlined by [3], the telephone system is not dimensioned such that all subscribers can be connected at the same time. Providing sufficient resources to carry all traffic that could be offered in a telecommunications system would be very uneconomical [4]. Subscribers have to share resources because equipment at the exchanges isexpensive. As a result of this, telecommunications systems are likely to experience problems at times. In the telephone system, several subscribers share this expensive equipment at the exchanges.

The concentration takes place from the subscriberend toward the exchange. Because the number of equipment is limited for economic reasons, there would be times that a subscriber cannot establish acall, but would have to wait or be blocked, which can be inconvenient to the subscriber [5].

A. *Congestion in a GSM Network*

Congestion in telecommunications is a situation where exchanges or circuit groups are overwhelmed with calls and are unable to serve repeated attempts lead to increase in congestion, thus greatly increasing the load on the common control switching equipment and adds to the overall traffic volume [6]. As itemized by [7], four elements related to congestion are Traffic Channel Congestion (TCHC), Standalone Dedicated Control Channel Congestion (SDCCHC), CommonControl Channel Congestion (CCCHC) and Pulse Code Modulation Congestion (PCMC). Although this work focuses on the first two, which are the SDCCHC and TCHC.

In a cellular network, the TCH and SDCCH are vital resources because the system relies on these two channels to accommodate the user's need. A new call cannot be initiated if SDCCH channels are not available and the same happens when SDCCHs are available but all TCHs are unavailable. Thusfor an operational GSM network, congestion in either TCH or the SDCCH can lead to a severe bottleneck if the phenomenon persists. Therefore, the impact of the TCH congestion, as well as the SDCCH congestion on a network needs to be monitored. Since the information gathered from this can be used to better optimize the network.

II. Materials and Method

The primary tools used in obtaining the data for this research and the tool used for the simulations in this work are delineated hereunder:

(i) File Transfer Protocol (I Manager M2000): This tool was used at the Network Management Switching (NMS) center to extract the data needed for this work.

(ii) MATLAB: This tool was used to plot the behaviour of the necessary KPIs extracted in (i). The graphs generated are evaluated to access the performance of the KPIs. This simulation is executed on a hp Intel ® Core ™ i5-2520M CPU equipped with an 8GB RAM and runs on Windows 10 Pro 2019.

M2000 is collected in a Microsoft Excel file. These KPIs are used to compute or represent the KPIs of interest in this work. The KPIs of interest They are Call Setup Success Rate (CSSR), the Call Completion Ratio (CCR), Stand-alone Dedicated Control Channel Congestion (SDCCHC) and Traffic Channel Congestion (TCHC). The mathematical representations are given as:

(i) Call Setup Success Rate

This KPI measures the ease in which calls are established or setup. It serves as a parameter for evaluating the networks reliability and retainability [4]. Utilizing the KPIs extracted from the NMS center, this can be computed using equation (1):

$$\text{CSSR} = \frac{\text{No. of successful seizure of SDCCH}}{\text{Total No. of request seizures for seizure of SDCCH channel}} \times 100\% \quad (1)$$

(ii) Call Completion Ratio:

This KPI takes into account the number of calls completed to the number of call attempts. It serves as a parameter for evaluating the network's accessibility and retainability. This is given [4] as:

$$\text{CCR} = 1 - \text{Call Drop Rate} \quad (2)$$

Using the KPIs extracted from the NMS center, the CDR can be calculated using equation (3), which is given as:

Where the CDR is given [4] as:

$$\text{CDR} = \frac{\text{No. of TCH drop rate after assignment}}{\text{Total No of TCH assignment}} \times 100\% \quad (3)$$

(iii) Traffic Channel Congestion

This is congestion by the users and it measures the relative ease by which the user seizes a traffic channel to set up a call after a signaling seizure has been successful. This is a critical parameter for resource allocation in a channel, the higher thisvalue the more difficult it is to make a call. This KPI is measured at the busy hour of the day.

SDCCH is used for providing signaling service required by the user. It carries signaling data following the connection of the mobile with base station and just before a TCH assignment is issued by the base station. The SDCCH maintains connection between MSC and BSC. It is really an intermediate and temporary channel that accepts newly completed call from BSC and holds the traffic while waiting for the Base station to allocate a TCH channel. SDCCH is used to send authentication, user validation and alert messages as the mobile synchronizes itself with the frame structure and waits for TCH. Failure to allocateSDCCH to provide authentication to mobile station, location updating and assignments to TCHs during idle periods leads to congestion, which frustrates subscribers and can cost the network.

Table 1 highlights the technical QoS benchmark set by the regulatory body, which is the Nigerian Communications commission. These target values are used to assess the QoS provided to end users by the MNOs.

Table 1. Technical Quality of Service (QoS) Benchmark for GSM [8]

S/No.	Parameter	Target Value (%)
1	Call Completion Rate	96
2	Call Setup Success Rate	98
3	Traffic Channel Congestion	2
4	Standalone Dedicated Control Channel Congestion	0.2

III. RESULTS

In this section, the average of the selected KPIs is calculated in order to assess its performance against the technical QoS benchmark set by the NCC. The values obtained are used to determinethe BTSs that need to be optimized.

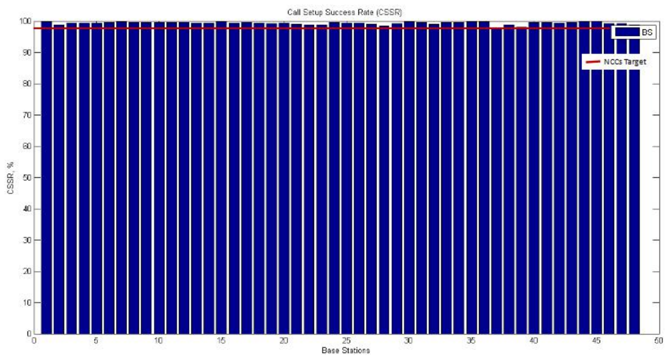

Fig. 1 Bar chart of Mean CSSR with NCC Target

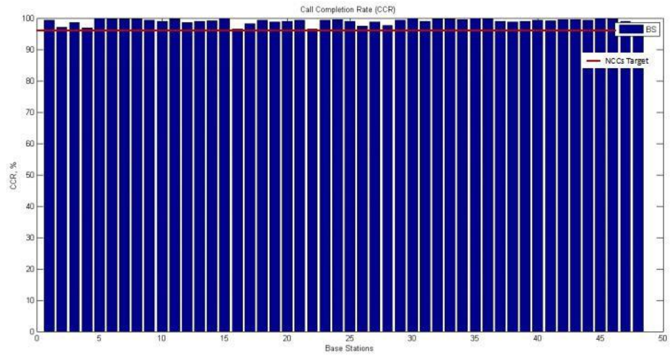

Fig. 2 Bar chart of Mean CCR with NCC Target

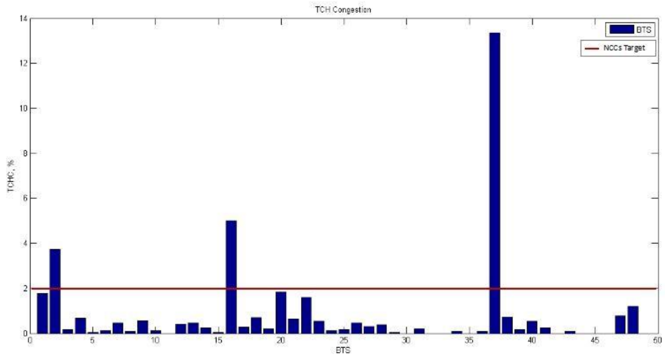

Fig. 3 Bar chart of Mean TCHC with NCC Target

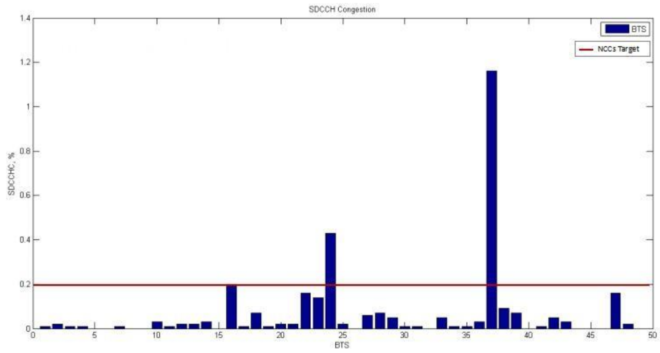

Fig. 4 Bar chart of Mean SDCCHC with NCC Target

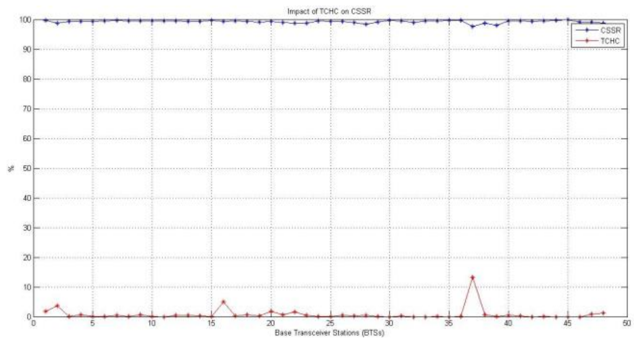

Fig. 5 Impact of TCHC on CSSR

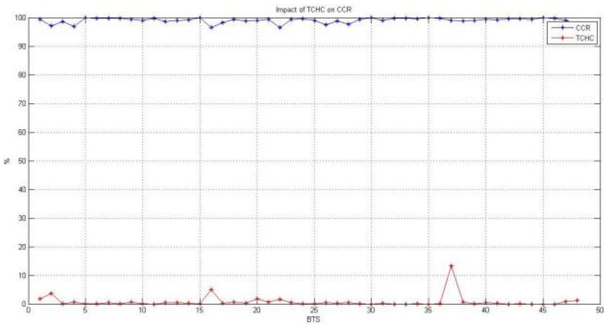

Fig. 6 Impact of TCHC on CCR

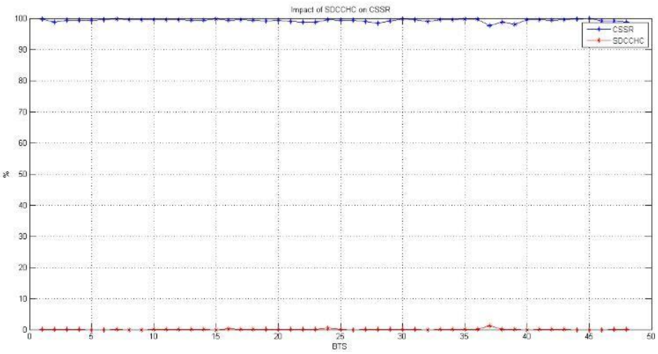

Fig. 7 Impact of SDCCHC on CSSR

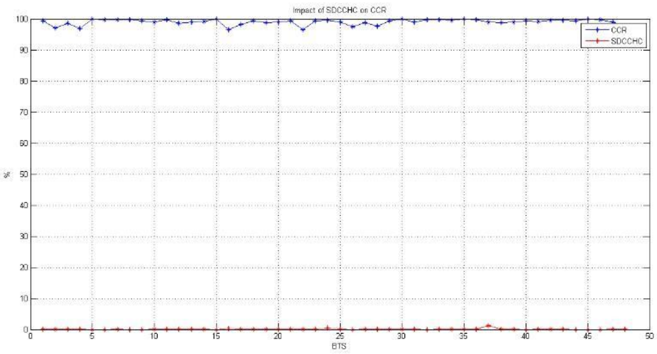

Fig. 8 Impact of SDCCHC on CCR

IV. DISCUSSION

The following subsections discuss the results in Fig. 1 to Fig. 6.

A. *Call Setup Success Rate*

Fig. 1 showed the performance of the CSSR values for 48 BTSs under BSC KDBH14. The results showed that in comparing the performance of the CSSR against the technical benchmark setby the NCC, 98% of the CSSR under BSC KDBH14 were within NCCs benchmark with the 45th BTS having the highest performance, with a percentage of about 99.84%. Conversely, thevalues of the 37th BTS, which made up about 2% of the BTSs, deviated from NCCs benchmark, having its KPI as low as 97.72% which was below the expected threshold. Although, the KPI values of the 39th BTS was within the expected threshold, its increase above the target value was not substantial as the rest, which indicates that close attention needs to be given to the cells of this BTS.

B. *Call Completion Rate*

Fig. 2 illustrates the performance of the CSSR values for 48 BTSs under BSC KDBH14. The chart showed that the performance of all the BTSs were within the expected threshold of the NCC(≥96%). The highest within the expected threshold was the 5th BTS with a value of 99.9% CCR. On the other hand, the BTS within the expected threshold with the lowest performance was the 16th BTS with 96.45%, this result indicates that close attention needs to be given to the cells of this BTS.

C. *Traffic Channel Congestion*

Fig. 3 shows the percentage of TCHC. The results shows that 6.25% of the BTS (that is, the 2nd, 16th and the 37th) were not within the threshold set by NCC (≤2%). This is disturbing as it shows that the increase in the non-availability of channels eventually leads to congestion, in general, communication dynamics will significantly suffer due to the unavailability of channels. This can cause the MNO to lose subscribers and can also cause the MNO to lose a lot in terms of their Operation Expenditure (OPEX). On the other hand,93.75% of the dataset generated from other BTSs were within NCCs benchmark. Although, it was observed that the 1st, 20th and the 22nd BTSs have KPIs above 1.6% which indicates that closeattention needs to be given to their cells.

D. *Standalone Dedicated Control Channel Congestion*

In Fig. 4, this KPI like the TCH Congestion analyzed above is a crucial parameter used for resource allocation in a channel, the higher the value the more difficult it is to make a call. From the results generated from BSC KDBH14, it showsthat the 24th and the 37th which make up about 4.2% of the data generated were not within the expected threshold (≤0.2). This congestion eventually leads to non-availability of traffic channels which in turn causes communication to suffer due to the fact that there is an unavailability of channels which leads to call blocking and congestion with these BTSs. On the other hand, about 95.8% of the dataset from the BSC KDBH14are within the threshold set up by NCC. From the dataset, it is observed that the 16th, 22nd, and the

47th BTSs have KPIs ≥0.16% which indicates that close attention needs to be given to their cells.

In a cellular network, the TCH and SDCCH are important resources; of course there exists other channels, but the system relies on these two to accommodate the user's need. A new call cannot be initiated if SDCCH channels are not available and the same happens when SDCCHs are available but all TCHs are unavailable. Thus for an operational GSM network, congestion in either TCH or the SDCCH can lead to a severe bottleneck if the phenomenon persists. Therefore, following discuss the impact of TCHC and the SDCCH congestion on the CSSR and the CCR.

E. *Impact of the TCHC on the CSSR*

The comparison between the dataset generatedfor both the TCH Congestion and CSSR can be used to predict congestion in neighbouring cells, aswell as CSFR or the possibility of it in a BS.

Shown in Fig. 5 are certain observable drops in the CSSR, a close look at the drops indicate adirect proportional increase in the TCH congestion.Shown in Fig. 5, there are certain observable drops in the CSSR as well as an increase in some of the KPI obtained from the TCH congestion in certain BTSs. Possible reasons for low call setup block as well as the anomalies observed from the results could be as a result of the following: increasing Traffic demand, Hardware fault and installation fault, High Mean Holding Time (MHT), low handover activity, etc. The CSSR was chosen in order to appreciate the impact of congestion in the two most important procedures during a call attempt, directly affecting the QoS offered to the subscriber.

F. *Impact of TCHC on CCR*

In Fig. 6, the TCH Congestion dataset is compared with the dataset generated for the CCR to predict congestion in neighbouring cells, as well as CDR or the possibility of it. As shown in Fig. 6, there are certain observable drops in the CCR as well as an increase in some of the dataset obtained from the TCHC in certain BTSs. Though someBTSs show some anomalies in the dataset generated. Possible reasons for these could be the following: low signal strength on Downlink or Uplink, lack of best server, battery flaw, antenna problems, low BTS output power, missing neighbouring cell definitions, unsuccessful outgoing handover, unsuccessful incoming handover.

G. *Impact of SDCCHC on CSSR*

In Fig. 7, the SDCCH Congestion compared with the CSSR, both of which are obtained from the dataset from BSC (KDBH14), shows that some BTSs that experienced SDCCH Congestion inversely had an effect on the CSSR. From this analysis, it was observed that about 94% of the data compared indicated that an increase in SDCCH Congestion inversely showed a decreasein the CSSR. Though it was observed that the dataset from 3 BTSs (that is, the 16th, 24th, and 47thBTSs), which constituted about 6% of the dataset used for the analysis showed some fluctuations

H. *Impact of SDCCHC on CCR*

The SDCCH Congestion compared with the CCR both of which were obtained from the dataset from BSC (KDBH14), shows that the BTSs that experienced SDCCH Congestion inversely had an effect on the CCR. From this analysis which was done using Matlab R2013b, it was observed that about 90% of the data compared indicated that an increase in SDCCH Congestion inversely showed a decrease in the CCR. Though it was observed that the dataset from 5 BTSs (KAD6050, KAD 6051, KAD 6053, KAD6104 and KAD6536) which constituted about 10% of the dataset used for the analysis showed some anomalies, though notclearly observable from the graph but can be clearly seen from the dataset in table 4.1, these following reasons could have caused the unusual occurrences: low signal strength on Down or Uplink, Poor quality on Down or uplink, too high timing advance and congestion on TCH. The analysis is necessary as it is intended to give an indication on how good the cell/system is at preserving calls.

V. CONCLUSION

The research analyzed congestion in the network in order to measure the network performance. From the analysis, it was shown that 2% of the CSSR failed to be within NCCs benchmark (≥98%). The CCR had all the datasets within NCCs benchmark (≥96%). The TCHC showed thatabout 6% of the dataset were outside the NCCs threshold (≤2%). The SDCCHC showed that about 4.2% of the dataset were not within NCCs benchmark (≤0.2). Within each KPI it was observed that a couple of BTSs where pointed out for closer observation as they possessed a highprobability of falling outside the set threshold.

For the TCHC and SDCCHC comparisons with the selected KPIs which are CSSR and CCR, it was observed that an increase in the value of either the TCHC or the SDCCHC showed a proportional decrease to that of the selected KPIs. In addition, certain fluctuations were outlined as well aspossible reasons that might have caused such occurrence in the processes of evaluation.

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