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Analysis of standalone dedicated control channel congestion for 4g networks in Yenagoa - Southern Nigeria

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ABSTRACT

This work attempts to effectively compare standalone dedicated control channel congestion against industry benchmarks and competitor networks to identify areas for improvement and sets performance targets. Four mobile telecommunication networks operational in Yenagoa – Southern Nigeria were considered. Results obtained shows that 9mobile, Airtel and MTN performed within the regulator's benchmark of 0.2% in most cases, while Globacom had many instances where her performance fell beyond the benchmark. The maximum values obtained within the period in view was 3.09% and it was gotten from 9mobile while the minimum value obtained was 0.00% and it was also from 9mobile. In the year 2020 all the networks had their values within the NCC's benchmark, this affirms that it is possible for the networks to perform optimally if adequate measures are put in place for improved QoS.

***Keywords*:** Call Setup Failure Rate, Data, Erlang Formula, Handover Failure Rate, Key Performance Indicator, Mobile Network, Signaling, Standalone dedicated control channel, Yenagoa

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1. INTRODUCTION

Standalone Dedicated Control Channel (SDCCH) congestion is a critical issue in mobile telecommunication networks, particularly in Long-Term Evolution (LTE) networks. SDCCH serves as a dedicated control channel for signaling purposes, facilitating various essential functions such as call setup, location updates, SMS delivery, and authentication [1]. The Standalone Dedicated Control Channel (SDCCH) is a dedicated signaling channel used primarily for the exchange of control messages between mobile devices (MS) and the Base Transceiver Station (BTS) in Telecommunication networks. It is "standalone" because it is not combined with a traffic channel, allowing it to handle signaling traffic independently [2]. When this channel experiences congestion, it directly impacts the network's ability to handle signaling traffic efficiently, leading to service degradation, call drops, and poor user experience [3].

To calculate Standalone Dedicated Control Channel (SDCCH) congestion in mobile telecommunication networks one must understand the utilization of SDCCH channels and determine when the system is overloaded [4]. The simplest approach to calculate congestion is by examining the ratio of the number of busy SDCCH channels to the total number of available SDCCH channels [5]. The total number of SDCCH channels available in the system is a fixed parameter determined by the network configuration and design. Let's denote this as *N*. The SDCCH channels in use at a given time includes channels being used for call setups, location updates, SMS delivery, etc. Here we denote this as *B*. The congestion ratio represents the utilization of SDCCH channels relative to the total available channels. It is calculated as the ratio of busy channels to total channels:

$$CR = \frac{B}{N} \times 100 \tag{1}$$

where:

B = Number of busy SDCCH channels
N = Total number of SDCCH channels
CR = SDCCH Congestion Ratio (expressed as a percentage)

If the *CR* value is close to 100%, it indicates that a high proportion of SDCCH channels are in use which suggests a potential congestion issues. On the other hand, If the *CR* value consistently exceeds a predefined threshold (e.g., 80-90%), it suggests that the system is overloaded, and measures should be taken to alleviate congestion [6].

SDCCH congestion can be caused by a variety of problems, including:

a) High signaling traffic: SDCCH congestion may result from an increase in signaling load brought on by a large number of call setups, location updates, or SMS traffic.
b) Cell reselection: Mobile devices look for nearby cells with stronger signals on a regular basis. Frequent handovers are a part of this process, which may exacerbate SDCCH congestion.
c) Network failures: Software bugs, hardware malfunctions, or incorrect configuration of network components can impair SDCCH operation and increase congestion.
d) Radio interference: The performance of SDCCH can be hampered by interference from outside sources or nearby cells, which can cause congestion.

e) Overlapping coverage areas: Due to frequent device switching between cells, which exacerbates congestion, areas with overlapping coverage from multiple cells may see higher signaling traffic.

2. PREVIOUS RELATED STUDIES

Due to the extensive array of services available to consumers, mobile phones have become increasingly important. Because of this, users have multiple lines with one or more network providers, which has added to the congestion problem [4]. Fast, dependable, and readily available infrastructure is correspondingly needed given the exponential growth in the number of user devices [7]. Still, there are a lot of technical issues that need to be resolved before the various parts of this infrastructure function as intended. While satisfying subscribers is the primary objective of Mobile Network Operators (MNOs), as stated by [8], the telephone system is not designed to support simultaneous connections from all subscribers. It would be extremely costly to provide enough resources in a telecommunications system to handle all of the traffic that could be offered [9]. The exchanges' expensive equipment forces subscribers to share resources. This means that there may occasionally be issues with telecommunications systems.

According to [10] increased Handover Failure Rate (HOFR) and inadequate network availability both within the communities and even when relocating were the main causes of the poor QoS. [11] in their studies stated that the Call Setup Success Rate, Call Setup Failure Rate (CSFR), Handover Failure Rate and Standalone Dedicated Control Channel (SDCCH) congestion were the most important Key Performance Indicators (KPIs) used in ascertaining the efficiency of GSM network in terms of the quality of services rendered. One of the most significant KPIs used by all mobile operators is Standalone Dedicated Control Channel (SDCCH) congestion rate; however, since there is no standard way to measure this parameter, different operators may use different approaches. The real challenge lies in successfully optimizing the BTS coverage area in addition to providing better service [12,13]. According to [14] most networks issues arise from growing subscriber numbers and changing environmental conditions because of subscriber mobility and the intricacy of radio wave propagation. With the evolution of the network, RF optimization is an ongoing process that is necessary. Using the resources that are currently available, RF optimization is done to increase network performance. SDCCH channels can experience congestion, just like any other resource in a network, when demand for them surpasses capacity [15].

SDCCH congestion is determined by keeping an eye on and examining a number of technical network parameters. To maximize resource use and reduce congestion, dynamic SDCCH channel allocation based on traffic demand is necessary. Based on current traffic conditions, network components like Base Station Controllers (BSCs) and Mobile Switching Centers (MSCs) dynamically modify the number of SDCCH channels allotted to various cells [16]. The purpose of load balancing techniques is to reduce congestion on certain SDCCH channels by redistributing traffic among nearby cells or sectors [17]. To more evenly distribute signaling load throughout the network, this may entail modifying traffic routing policies, handover thresholds, or cell parameters [18]. Expanding capacity might be required in situations where congestion occurs as a result of an increase in signal traffic. To boost signaling capacity, this can entail expanding the number of SDCCHs, improving network hardware, or improving cell configurations. Based on traffic patterns and service demands, sophisticated optimization algorithms like Erlang-B and Erlang-C are used to forecast SDCCH requirements [18]. These algorithms assist in figuring out the ideal number of SDCCH required to minimize congestion and meet service quality goals.

3. IMPACTS OF STANDALONE DEDICATED CONTROL CHANNEL (SDCCH) CONGESTION IN MOBILE NETWORKS

Congestion of Standalone Dedicated Control Channels (SDCCH) in mobile networks can significantly affect user experience, network performance, and overall service quality. Congestion of SDCCH has a direct impact on the network's capacity to manage signaling traffic effectively, which can have a number of detrimental effects. The following are some effects of SDCCH congestion on mobile telecommunication networks' quality of service:

1) Call Setup Failures: An increased risk of call setup failures is one of the most immediate effects of SDCCH congestion. Mobile devices may find it difficult to connect to the network when SDCCH channels are crowded, which could lead to dropped calls or unsuccessful call attempts [19]. When users are unable to make calls successfully, it annoys and frustrates them, which makes them unhappy with the network service.
2) Call Drops and Poor Call Quality: Signaling failures brought on by SDCCH congestion may cause ongoing calls to be interrupted or dropped. Signaling disruptions can cause poor call quality, including delays, voice distortion, and sporadic audio problems for users [20]. Poor call quality and call drops hurt the user experience as a whole and have an adverse effect on customer satisfaction.
3) Increased Network Signaling Load: The network infrastructure's overall signaling load is heightened by SDCCH congestion. Retransmissions and extra signaling overhead may result from signaling messages being lost or delayed on crowded SDCCHs [21]. The performance of other crucial signaling channels and services may be impacted by the increased signaling load, which may also put stress on network resources.
4) Service Degradation: A network-wide deterioration in service quality may arise from persistent SDCCH congestion. Customers may suffer from lower data throughput rates, longer call setup times, and more call drops, all of which would lower quality of service (QoS). Degradation of service erodes customer trust and loyalty by undermining the network's performance and dependability.
5) Revenue Loss and Churn: Mobile operators may incur financial costs as a result of SDCCH congestion, which can result in both revenue loss and subscriber churn. Customers who are dissatisfied may migrate to rival networks that provide higher levels of dependability and service quality, which would reduce the operator's revenue. SDCCH congestion can have a negative financial impact on an operator's long-term growth and profitability due to revenue loss and subscriber churn.
6) Operational Difficulties: Network operators encounter difficulties in effectively managing and mitigating SDCCH congestion. It takes time, effort, and resources to determine the underlying causes of congestion, put corrective measures in place, and optimize network resources. Service interruptions can be prolonged and have a worse effect on users and the company due to operational inefficiencies and delays in fixing congestion problems.

4. MATHEMATICAL TECHNIQUES USED IN RESOLVING STANDALONE DEDICATED CONTROL CHANNEL (SDCCH) CONGESTION

Many mathematical ideas and methods are used to resolve standalone dedicated control channel (SDCCH) congestion in mobile telecommunications networks. These methods are divided into five sections, which are as follows:

1) Traffic Modeling: This plays a crucial role in resolving standalone dedicated control channel (SDCCH) congestion in mobile telecommunications networks. By accurately modeling the traffic behavior, network operators can anticipate demand, dimension the network appropriately, and implement effective congestion management strategies [22]. Traffic modeling involves the use of

a) Erlang B Formula: The formula is commonly used to calculate the probability of blocking in a system with a fixed number of channels and a Poisson arrival process. It can be expressed mathematically as:

$$P_b = \frac{\frac{A^N}{N!}}{\sum_{n=0}^{N} \frac{A^n}{n!}} \tag{2}$$

where P_b is the probability of blocking
A is the offered traffic (measured in Erlangs)
N is the number of channels

b) Erlang C Formula: The formula is used to calculate the probability of delay (queueing) in a system where blocked calls are queued and wait for service. It's particularly useful for modeling situations where blocked calls may retry after a certain period. The formula is more complex than Erlang B but takes into account queuing delay, it is expressed mathematically as:

$$P_w = \frac{\frac{A^N}{N!}\frac{N}{N-A}}{\left(\sum_{i=0}^{N-1}\frac{A^i}{i!}\right)+\frac{A^N}{N!}\frac{N}{N-A}} \tag{3}$$

where P_w is probability of delay when the customer waits to connect with a support agent, P>0
A is total traffic (traffic intensity)of the call center in Erlangs
N is the number of available call center resources/agents.

According to [23], Several assumptions are made by the Erlang C formula, including: A Poisson arrival process (number of events over a specified period of time) is followed by the customer requests. There are a lot of clients, The performance of the system as a whole is hardly affected by the actions of a single customer. Every client uses the system on their own, apart from one another. There is an exponential distribution in service times. Clients never give up on a support request while it's being handled by an agent, All missed calls are just postponed rather than abandoned. A support representative works solely with one client for the allotted time. There are fewer support resources overall than there are clients. Customers exceeds the number of agents by at least ten times.

Customer requests that are not independent or that are prompted by a common event—such as phoning a help line after a natural disaster—do not function with the Erlang C formula [24]. Furthermore, the formula typically yields satisfactory outcomes only when the customer base exceeds the agent count by a factor of ten.

2) Dimensioning and Capacity Planning: These are critical techniques in resolving standalone dedicated control channel (SDCCH) congestion in mobile telecommunications networks. These processes involve determining the appropriate number of resources needed to handle the expected traffic load efficiently while meeting quality of service (QoS) requirements [25]. Basically two methods used which are:

a) Erlang Capacity Tables: These tables enable quick estimation of needed resources based on anticipated traffic loads by providing pre-calculated values for various combinations of offered traffic and number of channels.
b) Traffic Engineering Algorithms: Different algorithms, like the aforementioned Erlang-B or Erlang-C formulas, or more advanced optimization methods, can be employed to dimension the network.

3) Call Admission Control (CAC): This is the technique or procedure used to control voice traffic, particularly in Voice over Internet Protocol (VoIP) and wireless mobile networks. In voice communications networks, call admission control can also be used to guarantee or maintain a specific level of audio quality, or to maintain a specific level of performance in Internet nodes and servers that handle VoIP traffic. The majority of CAC algorithms regulate the total amount of bandwidth that is used, the total number of calls, or the total number of packets or data bits that pass a given point in a given amount of time [26]. A new call may be prevented from joining the network until at least one existing call ends if a predetermined limit is reached or exceeded. Another approach is to control calls based on predetermined parameters, like priority descriptors. This technique blocks new calls from joining the network only when they would overwhelm the Central Processing Unit's (CPU) capabilities on a specific computer or server [27].

4) Load Balancing: The process of dividing network traffic evenly among a pool of resources to support an application is known as load balancing. Millions of users must be processed concurrently by modern applications, and each user must receive accurate text, videos, images, and other data quickly and reliably [28]. It is basically divided into two segments:

a) Traffic Distribution Algorithms: In order to balance the load on SDCCH channels, mathematical algorithms can analyze traffic patterns across various cells or sectors and dynamically redistribute traffic.
b) Cell Breathing: This is a technique that dynamically expands or contracts a cell's coverage area in response to traffic load. This effectively reroutes traffic among nearby cells to relieve congestion.

5) Optimization Techniques: These are techniques or algorithms that are used to find the solution to specific problem. The procedure consists of finding the combination of design variable values that results in the best objective function value, while satisfying all the equality, inequality and side constraints. Here it is basically of two segments:

a) Integer Linear Programming (ILP): This models can be formulated to optimize the allocation of SDCCHs while satisfying constraints such as capacity limits and QoS requirements
b) Gradient Descent Algorithms: These algorithms can iteratively adjust parameters such as channel allocation or admission thresholds to minimize congestion based on feedback from network performance metrics [29].

5. MATERIALS AND METHOD

This study examines the Standalone Dedicated Control Channel congestion of four mobile network providers in Yenagoa, Bayelsa State -Nigeria and conducts comparative assessments to determine which network has the best Standalone Dedicated Control Channel (SDCCH) congestion rate. Cellular networks analyzed include MTN, Airtel, Globacom, and 9mobile. Materials used are

1) Manager M2000 File Transfer Protocol (FTP): This distributed network file system standardizes file access and management through the use of an OSI application Layer 7 protocol. It defines and unifies, into a single protocol, standards for both file transfer and remote file access. It served as a tool for network data collection.
2) Microsoft (MS) Excel tool box: This was employed to plot the data values to make the investigation's findings easier to comprehend and interpret.

This study employs a methodology that entails a systematic approach to gather data from the Management Centers of the four operational mobile networks. The steps are as follows:

a) Data Analysis: Primary data from all the Base Station Controllers (BSCs) in the State served as the basis for the analysis. Following that, a data set analysis was done to look into the QoS performance for every place under study. The Manager M2000 File Transfer Protocol was deployed at the Network Management Switching (NMS) to pull data from the network.
b) Determination of Average Standalone Dedicated Control Channel Congestion Rate: The average variable used in this study was previously assessed using the unprocessed data set that was acquired from the NMS. Using the MS-Excel toolbox, the monthly total average of SDCCH congestion was determined on a daily basis for a month.
c) Evaluation of Data Values: The QoS results from this paper's study were evaluated through performance analysis, with Standalone Dedicated Control Channel (SDCCH) congestion serving as an index. For every one of the four network operators under examination, the performance index values were plotted on graphs for the months of January through December in the following years: 2016, 2017, 2018, 2019, 2020, and 2021. The benchmark set by the Nigerian Communication Commission (NCC) was used to compare these measured values. The NCC has the authority to set minimum QoS requirements for the telecom sector's service delivery. Because all operators must meet these fundamental minimum quality standards in order to continue operating, these QoS standards guarantee that customers will always have access to high-quality telecommunications services (NCC technical standard, 2016). Table 1 shows the KPI benchmarks in Nigeria in accordance with NCC´s regulation

Table 1. KPI Benchmarks in Nigeria

KPI	Benchmark Value
CSSR	≥ 98%
DCR	≤ 1%
SDCCH	≤ 0.2%
TCCH	≤ 2%

6. RESULT ANALYSIS

Yenagoa`s Standalone Dedicated Control Channels (SDCCH) congestion rate has been Calculated for the four network operators under review (MTN, Airtel, Globacom, and 9mobile), the values obtained are as shown in Table 2 for the year 2015. Figure 1 compares the values obtained for the four network operators in the years 2015.

Table 2. 2015 SDCCH Congestion Rate

MONTH	Airtel	9mobile	Globacom	MTN
Jan'15	0.03	0.98	0.08	0.04
Feb'15	0.04	0	0.07	0.1
Mar'15	0.1	0.01	0.17	0.13
Apr'15	0.06	0.02	0.15	0.12
May'15	0.03	0.98	0.05	0.1
Jun'15	0.03	0.07	0.01	0.11
Jul'15	0.04	0.05	0.02	0.14
Aug'15	0.02	0.04	0.01	0.07
Sep'15	0.03	0.01	0.01	0.04
Oct'15	0.04	0	0.58	0.07
Nov'15	0.04	0.03	0.79	0.15
Dec'15	0.15	0.07	1.19	0.16

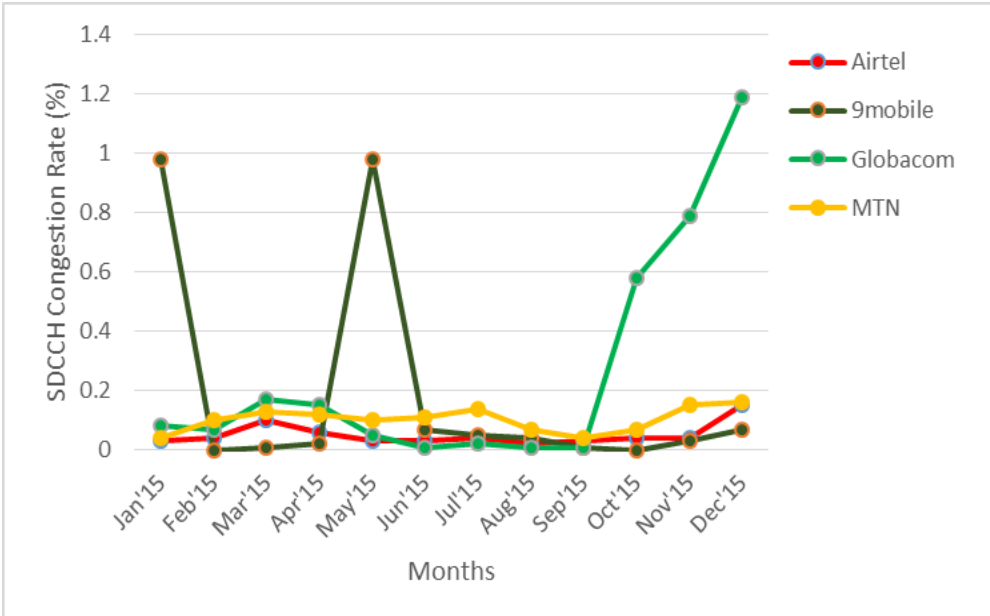

Fig. 1. SDCCH Congestion Rate against Months for year 2015

In the year 2015, 9mobile had the most erratic SDCCH congestion rate with its average values exceeding NCC's benchmark of 0.2% in most of the first six months. Airtel and MTN had their average values well within the NCC's benchmark through the year though Airtel had the best average values. Globacom operated within the NCC's benchmark in the first nine months, the last three months experienced a progressive increase in the SDCCH congestion rate values outside the regulatory benchmark. Table 3 below shows the average values obtained in the year 2016 while Fig. 2 below is a plot of SDCCH congestion rate against months in the year 2016.

Table 3. 2016 SDCCH Congestion Rate

MONTH	Airtel	9mobile	Globacom	MTN
Jan'16	0.04	0.04	1.8	0.16
Feb'16	0.03	0.12	1.71	0.26
Mar'16	0.07	0	0.07	0.23
Apr'16	0.07	0.02	0.53	0.29
May'16	0.05	0.02	0.52	0.1
Jun'16	0.07	0	0.19	0.1
Jul'16	0.08	0.01	0.1	0.13

Aug'16	0.3	0.01	0.08	0.06
Sep'16	0.06	0.01	0.03	0.12
Oct'16	0.05	0.01	0.12	0.13
Nov'16	0.02	0.01	0.04	0.05
Dec'16	0.04	0.02	0.07	0.09

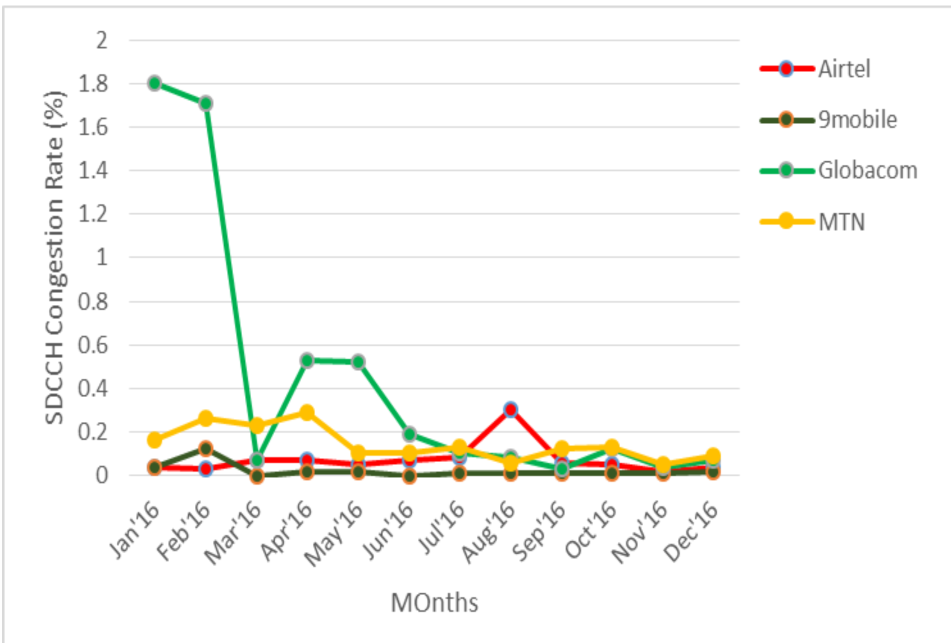

Fig. 2. SDCCH Congestion Rate against Months for year 2016

In 2016, Globacom's average SDCCH Congestion Rate values were well above the regulatory benchmark in the first half of the year but it operated within the benchmark in the second half of the year. 9mobile had the best values in throughout the year while Airtels's values were within the benchmark value except for the month of August where it shot overboard. MTN maintained an average performance even though there were instances where it operated outside the regulatory benchmark. Table 4 below shows the average values obtained in the year 2017 while Fig. 3 below is a plot of SDCCH Congestion Rate against months in the same year.

Table 4. 2017 SDCCH Congestion Rate

MONTH	Airtel	9mobile	Globacom	MTN
Jan'17	0.03	0.01	0.09	0.1

Feb'17	0.04	0.03	0.14	0.13
Mar'17	0.04	0.02	0.1	0.13
Apr'17	0.03	0.01	0.14	0.14
May'17	0.03	0.04	0.15	0.23
Jun'17	0.05	0.02	0.05	0.12
Jul'17	0.04	0.01	0.02	0.12
Aug'17	0.05	0	0.04	0.11
Sep'17	0.09	0.01	0.02	0.04
Oct'17	0.04	0.01	0.07	0.08
Nov'17	0.06	0.02	0.1	0.14
Dec'17	0.09	0.03	0.1	0.11

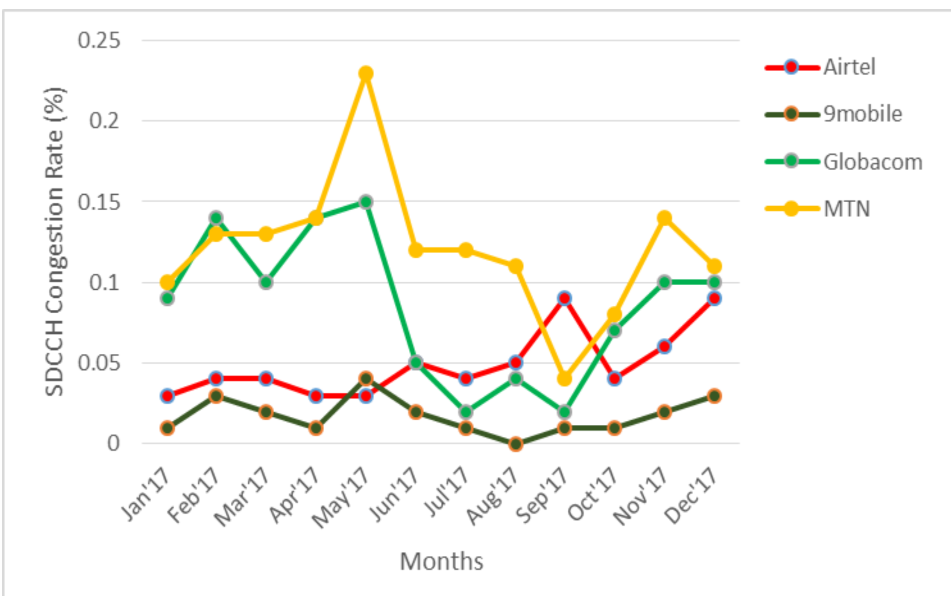

Fig. 3. SDCCH Congestion Rate against Months for year 2017

The four networks under consideration had their values within the NCC's benchmark in the year 2017 except for MTN whose value in May shot above the benchmark. Globacom showed an impressive improvement as compared with the previous years though her values still remained very erratic. 9mobile maintained the best values across board. Table 5 below shows the average values obtained in the year 2018 while Fig. 4 below is a plot of SDCCH Congestion Rate against months in the year 2018.

Table 5. 2018 SDCCH Congestion Rate

MONTH	Airtel	9mobile	Globacom	MTN
Jan'18	0.16	0.02	0.25	0.12
Feb'18	0.03	0.02	0.48	0.07
Mar'18	0.04	0.02	1.02	0.21
Apr'18	0.05	0.01	0.1	0.21
May'18	0.03	0.03	0.13	0.12
Jun'18	0.02	0.04	0.13	0.2
Jul'18	0.09	0.02	0.09	0.1
Aug'18	0.1	0.01	0.06	0.24
Sep'18	0.1	0	0.21	0.13
Oct'18	0.04	0.02	0.14	0.16
Nov'18	0.05	0.01	0.32	0.09
Dec'18	0.08	0.08	0.52	0.16

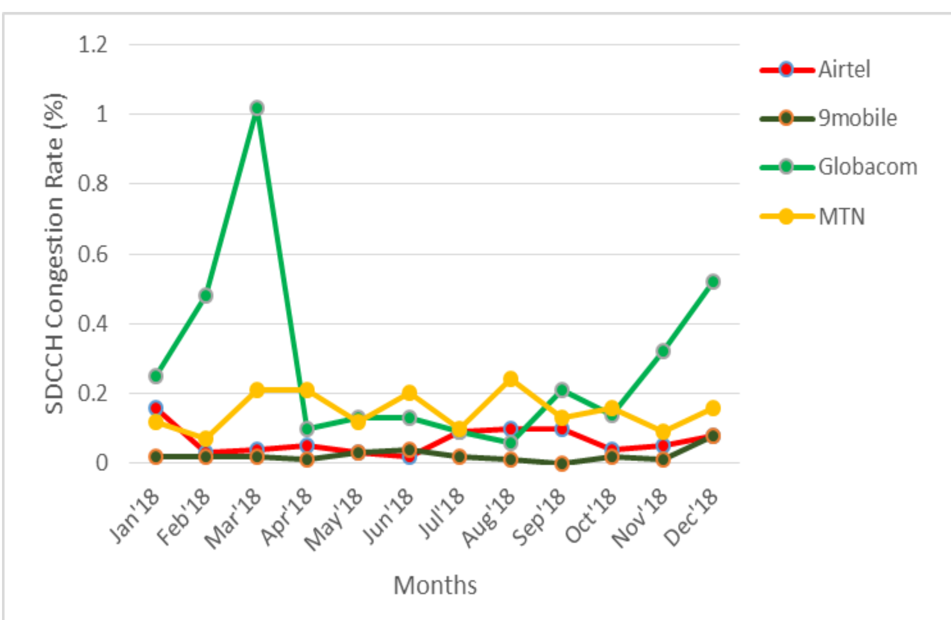

Fig. 4. SDCCH Congestion Rate against Months for year 2018

In the year 2018, the SDCCH Congestion Rate average values for 9mobile was excellent with minimal variation, Globacom had many instances where her values where above NCC's benchmark. Airtel continues to maintain an average and stable values. Table 6 below shows the average values obtained in the year 2019 while Fig. 5 below is a plot of SDCCH Congestion Rate against months in the year 2019.

Table 6. 2019 SDCCH Congestion Rate

MONTH	Airtel	9mobile	Globacom	MTN
Jan'19	0.09	0.05	0.4	0.12
Feb'19	0.04	0.06	0.18	0.05
Mar'19	0.08	0.02	0.06	0.03
Apr'19	0.14	0	0.03	0.05
May'19	0.41	0.01	0.12	0.09
Jun'19	0.27	0.01	0.12	0.02
Jul'19	0.15	0.01	0.03	0.04
Aug'19	0.04	0.01	0.05	0.04
Sep'19	0.06	0.02	0.2	0.02
Oct'19	0.04	0.01	0.09	0.02
Nov'19	0.04	0.04	0.12	0.03
Dec'19	0.03	0.05	0.12	0.02

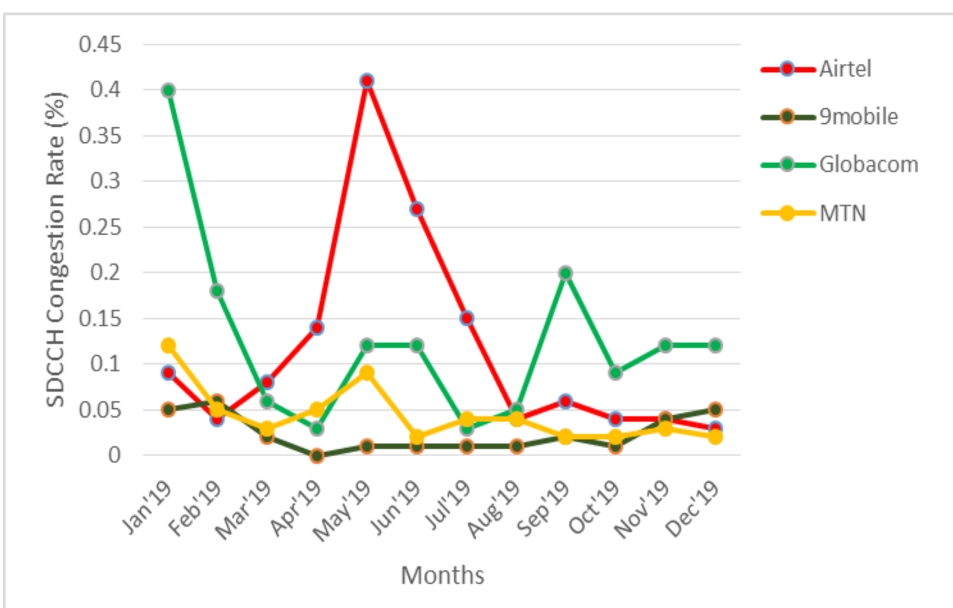

Fig. 5. SDCCH Congestion Rate against Months for year 2019

In the year 2019, MTN and 9mobile had excellent SDCCH Congestion Rate values which remained within the NCC's benchmark at every point in time. 9mobile had superior average values below 0.05% in most cases throughout the year while Globacom recoded only one instance where the value exceeded the benchmark value of ≤0.2% in the month of January. Airtel showed a wide margin of data variation and had many instances where her values exceeded the benchmark. Table 7 below shows the average values obtained in the year 2020 while Fig. 6 below is a plot of SDCCH Congestion Rate against months in the same year.

Table 7. 2020 SDCCH Congestion Rate

MONTH	Airtel	9mobile	Globacom	MTN
Jan'20	0.11	0.15	0.18	0.12
Feb'20	0.09	0.16	0.18	0.11
Mar'20	0.1	0.13	0.18	0.12
Apr'20	0.09	0.12	0.17	0.11
May'20	0.09	0.13	0.18	0.09
Jun'20	0.01	0.01	0.06	0.02
Jul'20	0.02	0.02	0.02	0.01
Aug'20	0.01	0.02	0.01	0.02
Sep'20	0.04	0.05	0.01	0.01
Oct'20	0.08	0.03	0.01	0.03
Nov'20	0.09	0	0.02	0.03
Dec'20	0.06	0.05	0.05	0.02

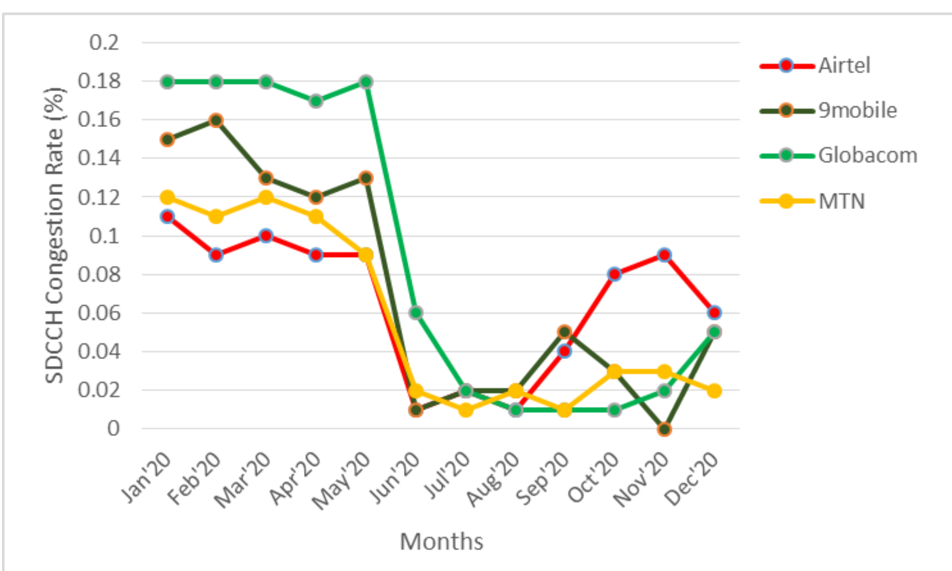

Fig. 6. SDCCH Congestion Rate against Months for year 2020

In the year 2020, the four networks performed very well with average values well below the NCC's benchmark, however a wide margin of data variation was notice as compared to other years. Here, 9mobile had the least values of 0.00% in the month of November while Globacom had the maximum value of 0.18% occurring in the months of January, February, March and May. Table 8 below shows the average values obtained in the year 2021 while Fig. 7 below is a plot of SDCCH Congestion Rate against months in the same year.

Table 8. 2021 SDCCH Congestion Rate

MONTH	Airtel	9mobile	Globacom	MTN
Jan'21	0.04	0.03	0.03	0.04
Feb'21	0.06	0.07	0.09	0.02
Mar'21	0.01	0.4	0.03	0.04
Apr'21	0.02	0.14	0.03	0.05
May'21	0.02	0.14	0.03	0.05
Jun'21	0.05	0.19	0.05	0.02
Jul'21	0.01	0.16	0.01	0.01
Aug'21	0.01	0.07	0.05	0.02
Sep'21	0.15	3.09	0.03	0.02
Oct'21	0.02	0.44	0.1	0.02
Nov'21	0.02	0.27	0.14	0.03
Dec'21	0.01	1.16	0.14	0.1

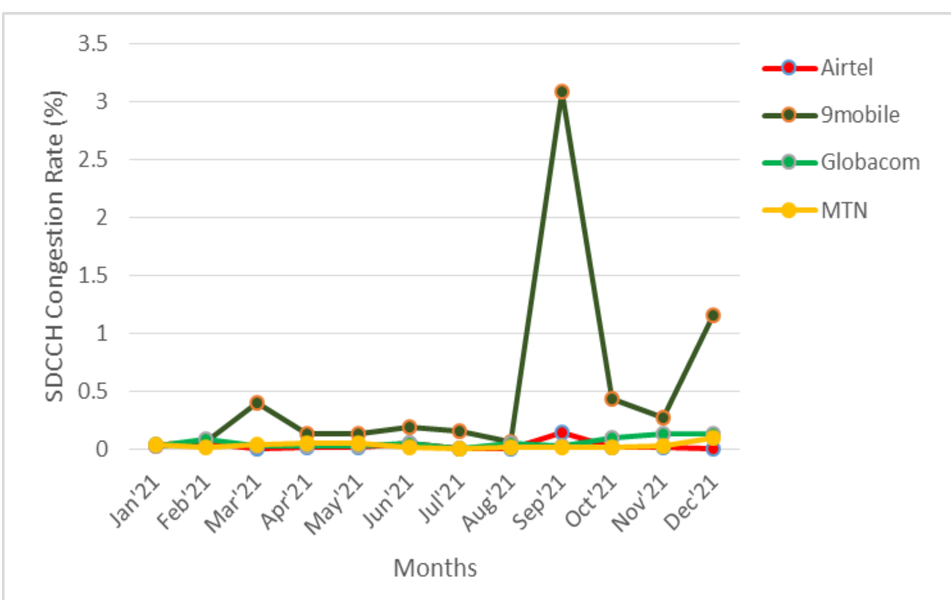

Fig. 7. SDCCH Congestion Rate against Months for year 2021

In 2021, 9mobile despite having the maximum average value of 3.09% also was the most erratic of the four networks under consideration. MTN, Airtel and Globacom showed a high level of stability and performed within the regulator's benchmark value through the year.

7. CONCLUSION

This study deals with Comparing SDCCH Congestion Rate against industry benchmarks and competitor networks for the purpose of identifying areas for improvement and sets performance targets. Four mobile networks operational in Yenagoa the Capital City of Bayelsa State Nigeria were investigated. From the data obtained, the four networks performed well within the benchmark value set by the regulating body Nigeria Communication Commission, however there is room for improvement as some of the networks had instances where their performance fell outside the benchmark. Data from 9mobile was superior among the four networks within the period of investigation (2015 – 2021). MTN and Airtel's data were well within the benchmark most of the time through the period under review and their variations was relatively small. The data from Globacom had wide ranges of variations and had instances where it fell outside the benchmark, which call for improvement in order to maintain good Quality of Service and customer satisfaction. The maximum value of SDCCH Congestion Rate recorded in the 7 years period under review is 3.09% and it was in September 2021 for 9mobile while the least value recorded is 0.00% and it occurred seven times in February and October 2015, July 2016, August 2017, September 2018, April 2019 and November 2020 within the period under review for 9mobile. In the year 2020 all the networks had values within the NCC's benchmark all through. This affirms that it is possible for the networks to perform optimally if adequate measures are put in place for improved QoS.

Recommendation

To address the challenges posed by growing demand and changing network technologies, research on standalone dedicated control channel (SDCCH) congestion in mobile telecommunication networks is essential. The following recommendations, which address various aspects of network performance, must be put into practice:

1) Performance Evaluation and Analysis: Under various traffic scenarios, network configurations, and technological standards (e.g., GSM, UMTS, LTE), conduct a thorough performance evaluation and analysis of SDCCH congestion. Examine the effects of variables on SDCCH congestion, including subscriber density, geographic location, and service usage patterns.

2) Traffic Modeling and Prediction: Create sophisticated traffic models and prediction methods to precisely project SDCCH traffic demand and pinpoint possible hotspots for congestion. Examine data-driven and machine learning methods to forecast SDCCH congestion using past traffic information and network characteristics.

3) Congestion Management Strategies: Assess how well-performing current strategies for reducing SDCCH congestion, such as load balancing, call admission control, and dynamic resource allocation, work Provide new techniques and algorithms for managing congestion that are adapted to the special properties of SDCCH channels and signaling traffic.

4) Network Optimization and Resource Allocation: Examine optimization methods for effective resource allocation and utilization in SDCCH channels, taking into account variables like channel sharing, channel borrowing, and dynamic channel assignment. To maximize SDCCH resource allocation and scalability, investigate the possibilities of virtualization and cloud-based solutions.

5) QoS Improvement: Research how SDCCH congestion affects QoS measures like signaling delay, call setup time, and call completion rate. Provide methods, such as resource allocation schemes with adaptive capabilities and prioritization mechanisms, for enhancing quality of service in crowded SDCCH environments.

6) Network Design and Dimensioning: Examine the best possible approaches for cell layout, sectorization, and capacity provisioning when designing and dimensioning networks to avoid SDCCH congestion during the planning stage. Provide network planners with tools and simulation models to assess various deployment approaches and scenario sizes.

7) Future Trends and Technologies: Examine how SDCCH congestion may be affected by newer technologies like edge computing, 5G, and the Internet of Things. Then, suggest flexible ways to address these changes. Examine how software-defined networking (SDN), network slicing, and network function virtualization (NFV) architectures can be combined with SDCCH congestion management.

8) Security and Privacy Considerations: Examine how SDCCH congestion management techniques may affect security and privacy, particularly in light of possible attacks and signaling flaws. Provide methods for improving signaling traffic security and privacy without sacrificing network performance.

9) Real-World Deployment and Validation: Work with mobile network operators to conduct field tests and real-world deployments to validate suggested algorithms and solutions. Assess the practical feasibility, scalability, and dependability of research findings in live mobile networks. Scholars and practitioners can help develop creative solutions to mitigate SDCCH congestion and improve the dependability and performance of mobile telecommunication networks by addressing these research recommendations.

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