Comparative Performance Analysis Of Traffic Congestion In Six South-South States' Capitals Of A Developed Mobile Communication Network On Christmas Day Celebration Against Muslim Muhammad Birthdays' Celebration

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Abstract:
***Background**: This study evaluates traffic congestion in a developed mobile communication network in the six south-south states' capitals in Nigeria using Percentage Congestion (PCONG) as the primary Key Performance Indicator and Pearson Product-moment correlation coefficient for measuring how strongly the celebrations are associated. Real traffic data collected from72 sectors (12 sectors per state capital) over December 2024 (Christmas day) celebration and June 2025 (Muslim Muhammed birthday celebration) were analyzed to determine congestion levels and identify performance bottlenecks. Results show that different sectors per state recorded congestion values significantly above the 5% KPI threshold, indicating insufficient capacity during peak periods. This finding show that both celebrations have strong relationship agreement and further highlight the need for sector-specific optimization to improve Quality of Service (QoS), reduce call drops, and enhance user experience.*

***Key Word**: Telecom Network Analytics, Congestion Threshold Assessment, Quality of Service (QoS), Mobile Communication Network, Traffic Congestion Analysis, Percentage Congestion (PCONG)*

1.0 Introduction

Mobile communication networks continue to face congestion challenges due to increasing user demand, real-time applications, and limited spectrum resources. Even in developed networks equipped with LTE-Advanced and 5G NR, congestion persists during peak periods. In Nigeria, with over 220 million active mobile subscriptions, congestion remains a major Quality of Service (QoS) concern. This study analyses traffic congestion in the six capitals of the South-South states in Nigeria to determine whether the mobile communication network meets acceptable performance standards, especially during Christmas and Muslim celebrations peak periods; measure their relationship; and to propose targeted improvements.

1.1 Statement Of The Problem

Nigeria has experienced a dramatic increase in mobile communication usage, driven by a growing population, digital transformation and the proliferation of smart phones. As of 2023, the Nigerian Communication Commission (NCC) reported over 220 million active mobile subscriptions making Nigeria one of the largest telecommunications markets in Africa (NCC, 2023). Despite the rollout of advanced technologies such as 3G, 4G LTE and more recently 5G, traffic congestion remains a persisted challenge even in well developed mobile communication networks.

Users across major cities and semi-urban areas continue to experience frequent call drops, poor voice quality, slow internet access and high latency which were all indicators of network congestion (Adebayo & Salihu 2022, Onuoha & Eze 2021). These issues are often most severe during peak usage periods when the demand for network resources exceeds available capacity. While mobile network operators have made efforts to expand coverage and increase bandwidth, the performance efficiency of developed mobile networks under high traffic load has not been adequately studied or optimized.

Without a comprehensive analysis of traffic congestion and its effect on Key Performance Indicators (KPI) which include through call setup success rate and packet loss, network optimization efforts remain reactive and insufficient. This study therefore aims to address this gap by conducting a detailed comparative performance analysis of traffic congestion in a developed mobile communication network in the capital cities of the six South-

South states of Nigeria, with a view to measuring relationship association and proposing data driven recommendations for enhanced network efficiency and user satisfaction.

1.2 Relevance Of The Study

The research is significant as it addresses traffic congestion, a major factor affecting both the Quality of Service (QoS) and the user experience in mobile communication networks and as well as cost and maintenance requirements for the network operators. In Nigeria, one of Africa's largest and fast-growing telecommunication markets, millions rely on mobile network daily for communication, business, education and digital services.

Using real data from Asaba (Delta Sate), Benin City (Edo State), Calabar (Cross River State), Yenegoa (Bayelsa State), Uyo (Akwa Ibom State), Port Harcourt (Rivers State), the study demonstrate that even developed mobile communication networks still face serious congestion issues especially during peak periods. By identifying critical congestion hotspots, the work underscores the importance of sector specific optimization, which is more effective and cost effective than general network wide upgrades.

The study further contributes to telecommunication engineering and policy development by showing how metrics such as Percentage Congestion (PCONG) and Pearson Correlation Coefficient can be applied to monitor network efficiency and guide improvements. It findings are therefore useful not only for network operators but also for regulators like Nigerian Communications Commission (NCC), policy makers and researchers. Finally, the study supports the objectives of the Sustainable Development Goal 9 (Industry, Innovation and Infrastructure) by promoting stronger, more reliable mobile infrastructure that can boost digital inclusion, Innovation and economic growth.

1.3 Objectives Of The Study

The objective of this study is to analyze and measure how strongly the performance of mobile traffic congestion during Christmas celebration can track the performance of mobile traffic congestion during Muhammed birthday celebration in the six South-South States of Nigeria, with the aim of identifying Key Performance challenges, measuring association and proposing strategies to optimize network efficiency.

2.0 Methodology

In this work, real data was collected using a software called Network Management System (NMS) for two months from one of the leading telecommunication companies in Nigeria. NMS is a program for providing detection and configuration for systems to automatically connect to a network. It is a set of co-operative tools that make networking simple and straight forward. The data collected were based on two GSM traffic cells with three sectors each, totaling six sectors for one month i.e twelve sectors for two months per state. About 10,000 calls were monitored per month, ie 20,0000 calls for two months per state. Thus, a total of 120,000 calls were monitored in the six South-South States of Nigeria. In order to obtain numerically significant data, the six sectors for each state monthly were considered. In particular, those sectors were chosen as representative of the whole network taking into account cell extension, number of served subscribers in the area, and traffic load. We were interested in the percentage traffic congestion whereby in any given situation we expected that some calls may be rejected for one reason or another. In our first computation, we need what is known as the percentage traffic congestion; this is the ratio of the number of calls rejected to the number of incoming calls multiplied by one hundred (100).

$$PCONG = \frac{No\ of\ Rejected\ Calls}{Total\ No\ of\ incoming\ Calls}\ X\ 100$$

The percentage traffic congestion is then compared with what is called the Key Performance Indicator (KPI). The KPI is given as five percent (5%) for congestion, ie the percentage traffic congestion should be less than this Key Performance Index, otherwise the cell or sector as the case may be is said to have a traffic congestion problem.

Table 1: ***Statistical estimation of traffic congestion in six sectors (two cells) in the month of December 2024 in Asaba (Delta State)***

CELL(S)	SECTOR NO	NO OF CALL SETUP CONGESTION	NO OF HANDOVER CONGESTION	TCONGS	TOTAL INCOMING CALLS	PCONG (%)
1	1	160	277	437	1855	24
	2	5	56	61	1534	4
	3	3	66	69	1325	5
2	4	50	230	280	2334	13
	5	25	12	37	685	5
	6	172	237	409	2168	19

Table 2: Statistical estimation of traffic congestion in six sectors (two cells) in the month of June 2025 in Asaba (Delta State)

CELL(S)	SECTOR NO	NO OF CALL SETUP CONGESTION	NO OF HANDOVER CONGESTION	TCONGS	TOTAL INCOMING CALLS	PCONG (%)
1	1	165	230	395	2114	19
	2	52	228	280	1198	23
	3	5	56	61	1328	5
2	4	157	275	432	1640	26
	5	25	12	37	675	5
	6	3	66	69	1589	4

Table 3: Statistical estimation of traffic congestion in six sectors (two cells) in the month of December 2024 in Benin City (Edo State)

CELL(S)	SECTOR NO	NO OF CALL SETUP CONGESTION	NO OF HANDOVER CONGESTION	TCONGS	TOTAL INCOMING CALLS	PCONG (%)
1	1	128	214	342	2018	17
	2	65	103	168	1743	10
	3	21	32	53	1544	3
2	4	28	42	70	1682	4
	5	25	33	58	1610	4
	6	21	41	62	1388	4

Table 4: Statistical estimation of traffic congestion in six sectors (two cells) in the month of June 2025 in Benin City (Edo State)

CELL(S)	SECTOR NO	No Of Call Setup Congestion	No of Handover Congestion	TCONGS	Total Incoming Calls	PCONG (%)
1	1	114	194	308	2004	15
	2	38	66	104	1682	6
	3	17	34	51	1601	3
2	4	15	23	38	1612	2
	5	12	28	40	1643	2
	6	28	38	66	1420	5

Table 5: Statistical estimation of traffic congestion in six sectors (two cells) in the month of December 2024 in Calabar (Cross River State)

CELL(S)	SECTOR NO	No Of Call Setup Congestion	No of Handover Congestion	TCONGS	Total Incoming Calls	PCONG (%)
1	1	180	242	A422	1734	24
	2	23	92	115	1486	8
	3	16	48	64	1621	4
2	4	62	164	226	2499	9
	5	14	26	40	692	6
	6	93	124	217	1960	11

Table 6: Statistical estimation of traffic congestion in six sectors (two cells) in the month of June 2025 in Calabar (Cross River State)

CELL(S)	SECTOR NO	NO OF CALL SETUP CONGESTION	NO OF HANDOVER CONGESTION	TCONGS	TOTAL INCOMING CALLS	PCONG (%)
1	1	62	241	303	1948	16
	2	12	33	45	1610	3
	3	24	43	67	1445	5
2	4	61	112	173	2012	9
	5	13	12	25	723	3
	6	79	82	161	2248	7

Table 7: Statistical estimation of traffic congestion in six sectors (two cells) in the month of December 2024 in Yenegoa (Bayelsa State)

CELL(S)	SECTOR NO	NO OF CALL SETUP CONGESTION	NO OF HANDOVER CONGESTION	TCONGS	TOTAL INCOMING CALLS	PCONG (%)
1	1	60	245	305	1898	16
	2	20	53	73	1640	4
	3	14	51	65	1408	5
2	4	24	72	96	681	14
	5	64	142	206	2101	10
	6	81	71	152	2204	7

Table 8: Statistical estimation of traffic congestion in six sectors (two cells) in the month of June 2025 in Yenegoa (Bayelsa State)

CELL(S)	SECTOR NO	NO OF CALL SETUP CONGESTION	NO OF HANDOVER CONGESTION	TCONGS	TOTAL INCOMING CALLS	PCONG (%)
1	1	38	71	109	1642	7
	2	23	46	69	1938	4
	3	29	54	83	1914	4
2	4	20	41	61	841	7
	5	12	51	63	1634	4
	6	58	68	126	2023	6

Table 9: Statistical estimation of traffic congestion in six sectors (two cells) in the month of December 2024 in Uyo (Akwa-Ibom State)

CELL(S)	SECTOR NO	NO OF CALL SETUP CONGESTION	NO OF HANDOVER CONGESTION	TCONGS	TOTAL INCOMING CALLS	PCONG (%)
1	1	53	192	254	1778	14
	2	16	38	54	1802	3
	3	21	52	73	1910	4
2	4	60	101	161	1804	9
	5	15	16	31	762	4
	6	55	71	126	1940	6

Table 10: Statistical estimation of traffic congestion in six sectors (two cells) in the month of June 2025 in Uyo (Akwa-Ibom State)

CELL(S)	SECTOR NO	NO OF CALL SETUP CONGESTION	NO OF HANDOVER CONGESTION	TCONGS	TOTAL INCOMING CALLS	PCONG (%)
1	1	68	114	`182	1810	10
	2	21	37	58	1853	3
	3	28	44	72	1966	4
2	4	38	106	144	1841	8
	5	9	19	28	604	5
	6	27	74	101	1872	5

Table 11: Statistical estimation of traffic congestion in six sectors (two cells) in the month of December 2024 in Port Harcourt (Rivers State)

CELL(S)	SECTOR NO	NO OF CALL SETUP CONGESTION	NO OF HANDOVER CONGESTION	TCONGS	TOTAL INCOMING CALLS	PCONG (%)
1	1	163	230	393	1742	23
	2	48	72	120	1550	8
	3	161	183	344	1848	19
2	4	143	225	368	1922	19
	5	38	69	107	1668	6
	6	26	42	68	1249	5

Table 12: Statistical estimation of traffic congestion in six sectors (two cells) in the month of June 2025 in Port Harcourt (Rivers State)

CELL(S)	SECTOR NO	NO OF CALL SETUP CONGESTION	NO OF HANDOVER CONGESTION	TCONGS	TOTAL INCOMING CALLS	PCONG (%)
1	1	82	192	274	1760	16
	2	23	45	68	1524	4
	3	48	162	210	1710	12
2	4	82	112	194	1929	10
	5	22	41	63	1720	4
	6	15	23	38	1347	3

Now, summing up the figures under PCONG and putting all the December figures (ie Christmas figures) under X variable and those in June (as Muhammed birthday celebration) under Y variable, we have:

X	70	42	62	56	40	80
Y	82	33	43	32	35	49

Expanding this table now using Pearson's Correlation Co-efficient, we have:

X	**Y**	**X^2**	**Y^2**	**XY**
70	82	4900	6724	5740
42	33	1764	1089	1386
62	43	3844	1849	2666
56	32	3136	1024	1792
40	35	1600	1225	1400
80	49	6400	2401	3920
350	274	21644	14312	16904

So,

***Formula*:**

$$r = \frac{N\sum xy - (\sum x)(\sum y)}{\sqrt{[N\sum x2 - (\sum x)2][N\sum y2 - (\sum y)2]}}$$

Substitution:

$$r = \frac{6(16904) - 350(274)}{\sqrt{[6(21644) - 3502][6(14312) - 2742]}}$$

Simplification:

$$r = \frac{101424 - 95900}{\sqrt{[129864 - 122500][85872 - 75076]}}$$

$$= \frac{5524}{\sqrt{(7364)(10796)}}$$

$$= \frac{5524}{\sqrt{79,501,744}}$$

$$= \frac{5524}{8916.375}$$

Final Result: **r=0.6195≈+0.62**

The calculated r of +0.62 indicates that there is a strong positive relationship between Christmas celebration **(X)** and Muhammed birthday celebration **(Y)**.

3.0 Analysis

Cell 1: Sector No.1: All the six capitals recorded **PCONG** values well above the acceptable limit

Sector No.2: **Asaba** has PCONG of **23%** in June **2025**

Benin City has PCONG of **10%** and **6%** in **December 2024** & **June 2-25** respectively.

Calabar has PCONG of **8%** in **December 2024**.

Port Harcourt has PCONG of **8%** in **December 2024** while others have PCONG of **5%** and less.

Sector No.3: All other 5 capitals have PCONG of **5%** and less except **Port Harcourt** that have PCONG of **19%** & **12%** for December **2024** and **June 2025** respectively.

Cell 2: Sector No.4: All other 5 capitals have PCONG well above the acceptable limit except **Benin** City that has PCONG of **4%** and **2%** in December **2024** and June **2025** respectively.

Sector No.5: Most capitals have PCONG of **5%** and less except for **Calabar's 6%** in December **2024**, **Yenegoa's 10%** in December **2024** and **Port Harcout's 6%** in December **2024**.

Sector No.6: **Asaba** has PCONG of **19%** in December **2024**, **Calabar** has PCONG of **11%** and **7%** in December **2024** and June **2025** respectively, **Yenogoa** has PCONG of **7%** and **6%** in December **2024** and June **2025** respectively and **Uyo** that has PCONG of **6%** in December **2024**.

4.0 Conclusion

The results of the study show that sectors/cells cannot perform optionally when the amount of traffic unusually increases. Thus, the advert end to end reconfigurability will influence the structure of the network communication industry, creating new markets and new employment opportunities notably in the mobile wireless information technology administration. The network communication industry end-users and standards will benefit through these ends:

4.1 Efficient, Advanced and Flexible End User Service Provision.

The reconfigurability management of the network communication systems will serve the optimal provision of the end user services and applications, taking into consideration the network/ terminal capabilities, configuration and profile, as well as service/ charging/ security profiles and related context.

4.2 Efficient Spectrum, Radio and Equipment Resources.

Utilization in collaboration with the regulatory authorities and local regulators, the effective use of spectrum resources and associated security issues can easily be met, since such an approach will simplify the process of optimizing resources usage.

Therefore, it is advisable for the network operator to carry out further optimization on all the sectors cells. This will ultimately improve the quality of service (QoS) of the network provider, increase customer satisfaction and thereby generate more revenue for the network operator.

Consequently, we have seen that congestion is as a result of handover and set up. Also, from the analysis more of traffic congestion related problems are as a result of cell being dropped due to handover.

Finally, from the result analysis, we have seen that there is a strong relationship association between the mobile traffic congestion during Muslim Muhammed birthday celebration.

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