IMPROVING HANDOVER MANAGEMENT IN FOURTH GENERATION (4G LITE) RADIO NETWORKS USING COGNITIVE RADIO.

[1]George Okolo O., [2]Abonyi D.O.

Enugu State University of Science and Technology; Department of Electrical Electronics, Engineering, Enugu State, Nigeria.

[1]Corresponding Author's Tel: +234 803 865 1954; Email: Obimefunaokolo@gmail.com

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ABSTRACT

This research addresses the limitations of the current wireless network due to fixed spectrum assignment, leading to inefficient spectrum usage and network congestion. By exploring Cognitive Radio, an innovative communication paradigm, the study seeks to enhance the network's functionalities and overcome existing challenges comprehensively. Cognitive Radio introduces intelligence, allowing the network to adapt dynamically, optimize spectrum usage, and handle higher traffic demands efficiently, resulting in improved customer experience and increased revenue for network providers. The integration of Cognitive Radio into the 4G network through Matlab simulation offers promising results, with slight increases in the Call Setup Success Rate (CSSR) ranging from approximately 0.84% to 1.55% for individual sites. Additionally, the Drop Call Rate has significantly decreased by approximately -17.96% to -60.00% for different sites, indicating improved call stability and user satisfaction. Overall, the study demonstrates the potential of Cognitive Radio to transform the wireless network into a more adaptive and intelligent system, catering better to the growing demands of modern mobile communication.

KEYWORD: Cognitive radio, 4G network, Congestion, Handoff failure, Network, Failures.

1. INTRODUCTION

Handover, in cellular networks, refers to the process of transferring an ongoing call or data session from one cell to another as the caller or the called party moves through the network's service region. In 4G networks, operators often face challenges with dropped calls and data delivery failures due to limited spectrum, resulting in significant financial losses. Users of 4G cellular networks may experience embarrassment due to failed handovers caused by insufficient radio links and under-utilization of assigned radio channels. Ensuring smooth handovers without disruptions in transmission and efficient network resource utilization is a complex task.

To address these issues, this study investigates the use of cognitive radio intelligent techniques to improve the synchronization between the network and mobile devices. The proposed solution aims to enhance the successful handover of ongoing calls from one cell region to another. Cognitive radio technology is recognized as a potential solution for the spectrum shortage problem. One of its key features is the capability to evaluate the environment, enabling opportunistic spectrum access by sensing underutilized spectrum at specific times and locations and adjusting the radio's transmission parameters accordingly without causing harmful degradation to primary users.

Recent research has explored various techniques for handover improvement, including guard channel-based handover, mobility factor, and signal strength. For instance, Ujarari and Kumar (2015) developed a handover method that reduced the probability of handover drop and blocking. Kumar (2015) used the mobility factor, signal intensity, and guard channel-based handover technique to predict factors influencing channel transfer decisions. Adewale, John, and Adagundo (2016) built upon the work of Kalu et al. (2013) by using the signal strength factor and a guard channel-based handover scheme in a dynamic guard channel assignment technique to decrease the likelihood of handover drop and blocking. Therefore, addressing handover failures in 4G networks is crucial for improving overall network performance and user experience. Employing cognitive radio intelligent techniques and dynamic guard channel-based handover methods can enhance the success rate of handovers, leading to better service quality and more efficient spectrum utilization.

The primary objective of this research is to conduct a thorough investigation into the performance of the 4G network. By analyzing various network metrics and key performance indicators (KPIs), the study aims to identify technical problems and challenges that affect the network's efficiency and user experience. The second objective focuses on enhancing the network performance by implementing a cognitive approach. This involves utilizing intelligent techniques to optimize spectrum utilization, minimize call drops, and improve call handover efficiency. By leveraging cognitive capabilities, the network will adapt to dynamic conditions, resulting in an improved user experience and overall network efficiency. The final objective is to evaluate the network's performance through simulation and conduct an in-depth analysis of the results. By integrating the proposed cognitive approach into the simulation, real-world scenarios will be replicated to assess the network's behavior under various conditions. The simulation results will be thoroughly analyzed to gauge the effectiveness of the cognitive approach and identify areas for further improvement.

2. METHODOLOGY

In this study, a comprehensive approach was employed to address the research objectives. The methodology consists of two main components: an analytical approach and a simulation approach. The analytical approach involved the development and presentation of relevant analytical expressions. These expressions were derived to compute the values of the requisite parameters. By using analytical methods, we aimed to gain a deeper understanding of the underlying principles and relationships governing the system. Additionally, the simulation approach was adopted to complement the analytical findings. Empirically measured data were collected and utilized in the simulation process. The simulation incorporated the analytical expressions and algorithms proposed in this research. By combining empirical data and theoretical models, we obtained a more accurate and realistic assessment of the requisite parameters. The integration of both the analytical and simulation approaches allowed for a comprehensive evaluation of the research problem. It enabled us to validate the analytical expressions and test their practical applicability under real-world conditions. This rigorous methodology ensures the reliability and robustness of the results obtained throughout this study.

2.1 Experimental Setup

Experimental Setup: The experimental setup utilized in this study involved the integration of several accessories to collect data and perform drive tests. The key components of the setup are as follows:

1. Laptop Computer: A laptop computer was used as the central processing unit for data collection and analysis. The laptop's portability allowed for easy mobility during the drive test process.

2. Power Supply Unit: To ensure continuous and stable operation of the entire system, a power supply unit was connected to the laptop. This unit provided the necessary electricity to power all the components during data collection.

3. TEMS Phone: The TEMS phone was a crucial component used for making calls and generating test scenarios during the drive tests. It is a specialized device that facilitates network performance measurements and analysis.

4. GPS Locator: To track and record the geographical locations where data was collected, a GPS locator was integrated into the setup. This device provided accurate positioning information during the drive tests.

5. Operating System and Ericsson TEMS Software: The laptop was equipped with the required operating system and the Ericsson TEMS software. This software is specifically designed for network testing and optimization, enabling efficient data collection and analysis.

2.2 Characterization Procedure

During the data collection process, calls were initiated using the TEMS phone, simulating real-world mobile communication scenarios. The power supply unit ensured uninterrupted operation of all components throughout the drive tests. The TEMS software on the laptop facilitated data recording and analysis, capturing relevant network performance metrics. Geographical positioning was tracked in real-time using the GPS locator, allowing for accurate mapping of data points collected during the drive tests. The integrated setup depicted in Figure 1 visually represented the connections and arrangements of the various components. The experimental setup provided a comprehensive and controlled environment for data collection, ensuring the reliability and accuracy of the results. By integrating these accessories and employing the Ericsson TEMS software, this study aimed to gain valuable insights into network performance and address the research objectives effectively.

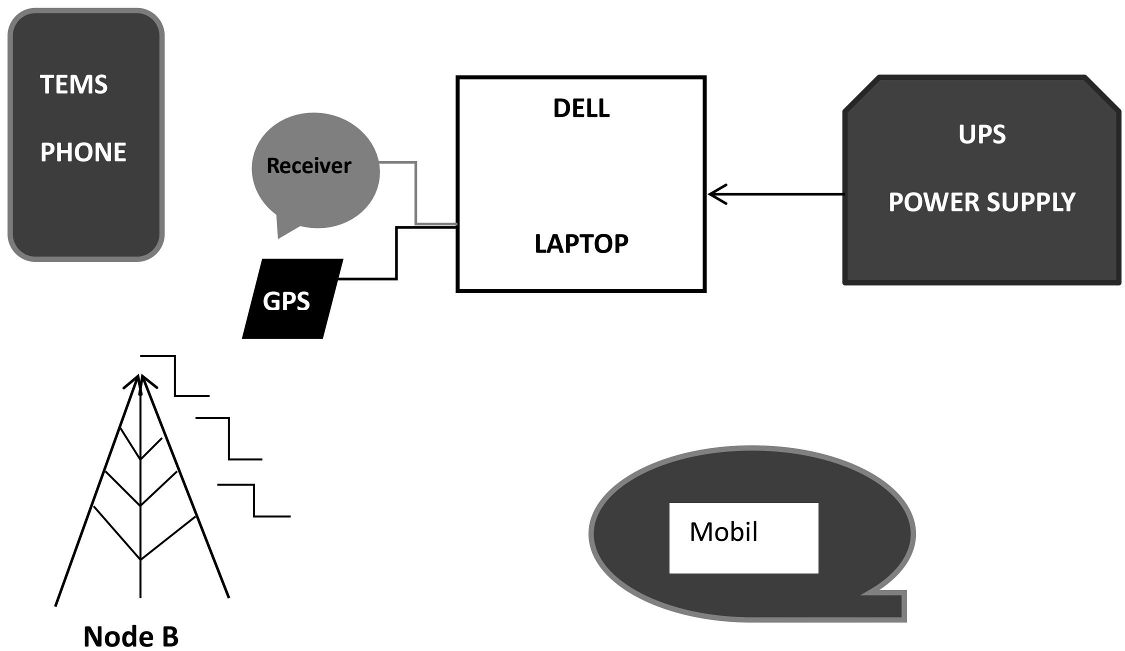

Figure 1: Schematic Diagram of the Experiment Setup for the Empirical Measurement

2.3 Data Collection

The data collection process spanned six consecutive days and involved driving around the target area, which included Abuja, Kuje, Abaji, Kwali, and their environs. The aim was to characterize the network environment and establish the attributes of the network under investigation. Several criteria and key performance indices (KPIs) were chosen for analysis, including the average channel count per cell, the number of calls made per cell during peak times, call setup success rate, call drop rate, call arrival rate, call duration, call service rate, received signal strength, antenna height, transmitting power, antenna gain, and active handover scheme. To assess the effectiveness of call performance, the characterized network was evaluated to identify the causes of handover failure or call drops within the study field. Compliance with the regulatory body, the Nigerian Communication Commission (NCC), responsible for defining the maximum grade of service, was also verified.

The data collection was conducted in a selected local government area of Abuja, Nigeria, specifically Asokoro. Measurements were obtained from various Mobile Switching Centers (MSCs) located in different local government areas (LGAs) within Abuja FCT. The Drive Test Tool used for data collection was Ericsson TEMS (Test Mobile System). The empirical measurements were carried out between 10/03/2021 to 15/03/2021. Data were collected from the following LGAs in Abuja, Abaji Local Government Area, Abuja Municipal Local Government Area, Gwagwalada Local Government Area, Kuje Local Government Area, Bwari Local Government Area and Kwali Local Government Area.

During the test drive, calls were initiated using the TEMS phone, and the resulting key performance indicators (KPIs) of the network were recorded by the TEMS software. These KPIs included Handover/Handoff success, Completed calls, call setup success, call setup failures, Dropped calls, and various other radio frequency parameters. The combination of empirical measurements, KPI analysis, and network characterization allowed for a comprehensive assessment of the 4G mobile communication environment in the study area. The data collected and analyzed using the Ericsson TEMS tool served as valuable insights for understanding the network's performance and identifying areas for improvement. The results were reported in the result section of this paper.

3. The Dynamic cognitive spectrum Modeling

Creating a comprehensive mathematical model for a cognitive radio system that considers correlation coefficients and handover decisions involves intricate equations which consider the sensing ability to select availability of cells channels. The correlation coefficient which measured the quality of the cell in providing good user experience, handover decision, adaptation and the learning model respectively;

1. Sensing Model: Let $S(t)$ represent the spectrum availability at time t. The cognitive radio can sense multiple frequency bands, and S(t) can be a vector of binary values indicating whether each frequency band is available (1) or occupied by a primary user (0). The sensing model can be represented as:

   $$S(t) = [S1(t), S2(t), \ldots, Sn(t)] \quad (1)$$

2. Correlation Coefficient Model: Define C(t) as the correlation coefficients vector at time t, representing the degree of linear relationship between the available spectrum and various performance metrics, such as traffic intensity and average channel and call rate. Each element of $C(t)$ is a measure of the correlation coefficient. The aim is to achieve an Erlang value of 35.61 or above, this implying good network performance. The correlation coefficient model can be represented as:

   $$C(t) = \sum = \frac{traffic\ intersity}{avg.no\ of\ channels/call} \quad (2)$$

3. Handover Decision Model: The handover decision model takes into account various factors, including signal strength, SINR, correlation coefficients, and available spectrum in neighboring cells. Let $H(t)$ be the handover decision vector at time t, where each element represents whether a handover is required (1) or not (0) for a particular user or channel. The handover decision model can be represented as:

   $$H(t) = [H1(t), H2(t), \ldots, Hk(t)] \quad (3)$$

4. Adaptation Model: The adaptation model determines the transmission parameters to optimize the network performance. Let $P(t)$ be the parameter vector at time t, including frequency, power, modulation scheme, and other relevant parameters. The adaptation model can be represented as:

$P(t)=[P1(t),P2(t),...,Pl(t)]$ 4

5. Optimization Model: The optimization model aims to maximize network performance while adhering to regulatory constraints and QoS requirements. This model involves optimizing the utilization of available spectrum, minimizing interference, and ensuring seamless handovers. The optimization model can be represented as an objective function that depends on $S(t)$,$C(t)$,$H(t)$, and $P(t)$, subject to certain constraints. The figure 2 presented the flow chart of the dynamic cognitive model;

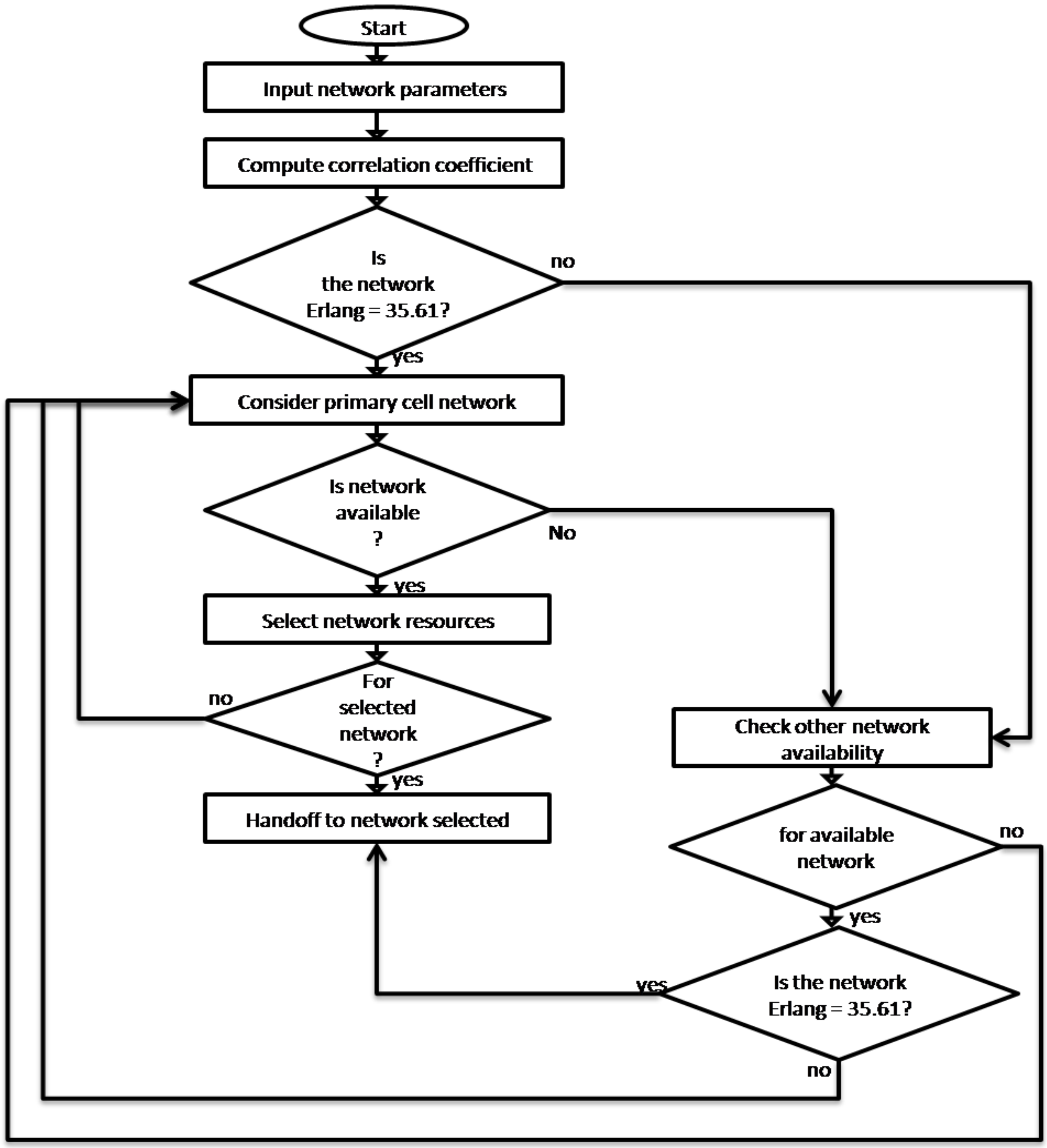

Figure 2: The flowchart of the dynamic cognitive radio

In the flow chart presented the operation of the spectrum model developed for dynamic handover process. The sensing model in equation 1 was used to investigate quality of cell considering the coefficient correlation model in equation 3, when the network performance do not satisfy the requirement of the Erland value, then other cells are selected through the adaptation model in equation 4 and handover using equation 4, but when the primary cell satisfies the Erland value, then the cell is used for handover.

4. Simulation of the Dynamic spectrum model

The system was implemented on six different 4G networks using MATLAB to develop a comprehensive simulation environment to evaluate network performance and optimize the cognitive radio technique modelled to optimize handover in the respective cells. First, MATLAB script was used to generate synthetic data representing the spectrum availability for each 4G network at different time intervals. These data sets are then used as inputs to the cognitive radio system model. Next, the cognitive radio model was implemented, which includes the sensing model in equation 1, correlation coefficient computation using equation 2, handover decision equation 3, and adaptation modules in equation 4. Each of the six 4G networks simulated real-world scenarios with varying user mobility and traffic patterns. The cognitive radio system, running in MATLAB, continuously adapts to changes in spectrum availability and user demand, making intelligent decisions to optimize network performance. Throughout the simulation, MATLAB records performance metrics considered during the characterization like call drop rates, and other relevant KPIs for each network. These metrics are analyzed to assess the effectiveness of the cognitive radio approach in improving network performance and handover efficiency. After the simulations, a detailed analysis of the results using MATLAB's visualization capabilities was conducted. We compare the performance of the six 4G networks with and without cognitive radio optimization, evaluating the impact of the cognitive approach on network efficiency and user experience. The Simulink model of the 4G network was reported in the appendix A. The table 1 was used for the network analysis, while the simulation parameters were reported in table 2;

Table 1: Table for network analysis (NCC standard)

Parameter	**Very Good %**	**Good %**	**Fair %**	**Poor %**
Call Success %	>= 99%	95-98%	90-94%	< 90%
Call Intensity %	>= 80%	70-79%	60-69%	< 60%
Erlang Value %	>= 90%	80-89%	70-79%	< 70%
Call Success %	>= 99%	95-98%	90-94%	< 90%
Call Drop %	<= 0.5%	0.6-1.5%	1.6-3.0%	> 3.0%
Transport Block Size	>= 95%	90-94%	80-89%	< 80%

Table 2: Simulation parameters

Parameter	**Value**
Dell-laptop	Primary network access
Uninterrupted Power Supply (UPS)	Power supply
Server	Huwaii

Network provider	MTN
TEMS Phones	Network scanner
Ethernet cable	Transmission protocol
Pick-up-van	Mobility

5.0 RESULTS AND DICUSSIONS

This section presents the result of characterization and the result of the simulated 4G network with the dynamic cognitive approach used for the handover optimization. The data collected from the results were analyzed considering the NCC standard for network analyzed and the findings were discussed.

5.1 Results of characterization

The result of the data collected from the six Local Government Area Network switch were reported in Table 3.

Table 3: Result of Characterization

Site number	Average number of channel/cell	Call setup success rate (CSSR)	Drop call rate (%)	Number of drop call per cell	Traffic intensity per cell (Erlang)	Number of call attempts in busy hour per cell
ABJ0189	73	98,21	3.05	33.40	64..61	1089.98
ABJ 0081	79	98.51	4.30	42.22	76.80	1020.91
ABJ0385	91	98.23	4.45	21.73	46.67	1023.67
ABJ 00091	77	98.50	3.41	27.04	65.45	1434.11
ABJ 00054	78	97.34	2.45	32.12	65.62	1230.45
ABJ 00145	95	98.34	1.67	30.23	83.18	1035.54
Average	82.16667	98.184	3.221667	31.12333	67.544	1139.11

The sites (ABJ0189, ABJ0081, ABJ00091, and ABJ00054) in table 3 demonstrate a "Very Good" number of channels per cell, with values ranging from 73 to 79, all surpassing the threshold of 70. Additionally, all sites (ABJ0189, ABJ0081, ABJ0385, ABJ00091, ABJ00054, and ABJ00145) exhibit a "Very Good" CSSR, with values above 95%, indicating a high call setup success rate. However, the drop call rate shows variability among the sites, with ABJ0189 and ABJ00091 classified as "Fair," ABJ0081 and ABJ0385 as "Poor," and ABJ00054 and ABJ00145 as "Very Good." Addressing the drop call rate is crucial to enhance performance at certain sites. Furthermore, all sites (ABJ0189, ABJ0081, ABJ0385, ABJ00091, ABJ00054, and ABJ00145) are experiencing a "Poor" number of drop calls per cell, signifying frequent call drops. This aspect demands attention and optimization efforts. The traffic intensity per cell varies, with ABJ0385 rated as "Very Good," ABJ00054 as "Good," and the remaining sites (ABJ0189, ABJ0081, ABJ00091, and ABJ00145) as "Good" as well. Generally, the sites demonstrate efficient handling of traffic. In terms of the number of call attempts during busy hours, all sites display a "Good" performance, with values ranging from 1020 to 1434, surpassing the threshold of 800. Overall, the sites demonstrate a "Very Good" CSSR and handle call attempts well during busy hours. However, there is room for improvement in reducing drop call rates and the number of drop calls per cell, which may enhance overall service quality and customer satisfaction. It's essential to note that the conclusions drawn from this analysis are based on the provided data and the classification thresholds used. For a more comprehensive evaluation and accurate conclusions, additional historical data, performance targets, and industry benchmarks should be considered. The specific actions and improvements required would depend on the network operator's goals and the identified areas of improvement. The improvement was achieved with the cognitive radio approach whose result generated from the simulated 4G network was reported in the table 4;

Table 4: Simulation Result with Dynamic Cognitive Approach

Site number	Average number of channel/cell	Call setup success rate (CSSR)	Drop call rate (%)	Number of drop call per cell	Traffic intensity per cell (Erlang)	Number of call attempts in busy hour per cell
ABJ0189	73	99.04	1.65	13.54	84.51	1089.98
ABJ 0081	79	99.35	1.80	12.21	76.45	1020.91
ABJ0385	91	99.63	1.77	11.54	86.23	1023.67
ABJ 00091	77	99.77	1.89	17.34	85.56	1434.11
ABJ 00054	78	98.94	2.01	12.32	85.23	1230.45
ABJ 00145	95	99.87	1.69	10.23	83.67	1035.54
Average	82.16667		3.221667	31.12333	67.544	1139.11

The dynamic cognitive approach employed in generating the results reveals commendable performance across all sites. The average number of channels per cell indicates efficient channel utilization, with most sites scoring either "Good" or "Very Good." Furthermore, the CSSR values at all sites are consistently "Very Good," surpassing the 95% threshold, demonstrating a high success rate for call setups. A notable achievement is the remarkably low drop call rate observed across all sites, consistently classified as "Very Good" and staying well below 2%. This reflects an impressive reduction in call drops, contributing to a seamless user experience. Moreover, the number of drop calls per cell exhibits a "Very Good" rating at all sites, signifying minimal call drops. This achievement indicates an effective approach to call retention. In handling traffic, the sites showcase commendable performance, as the traffic intensity per cell is classified as "Good," with values ranging from 76.45 to 86.23 Erlang. This highlights the network's ability to efficiently manage the load and maintain service quality. During peak hours, the number of call attempts remains in the "Good" range at all sites, with values ranging between 1020.91 and

1434.11. This outcome signifies successful call handling during periods of heightened activity, ensuring consistent connectivity for users. In conclusion, the dynamic cognitive approach has yielded impressive results, showcasing efficient channel utilization, outstanding call setup success rates, minimal call drops, and proficient traffic management. The network's ability to maintain high-quality service during peak hours further solidifies its reliability and performance excellence.

5.2 Comparative analysis

This section compares the performance of the characterized network and the new network with the dynamic cognitive radio. The result was achieved comparing drop call rate in table 3 and table 4, to compute the percentage improvement for drop call as in figure 2 and call success rate (CSS) in figure 3 respectively.

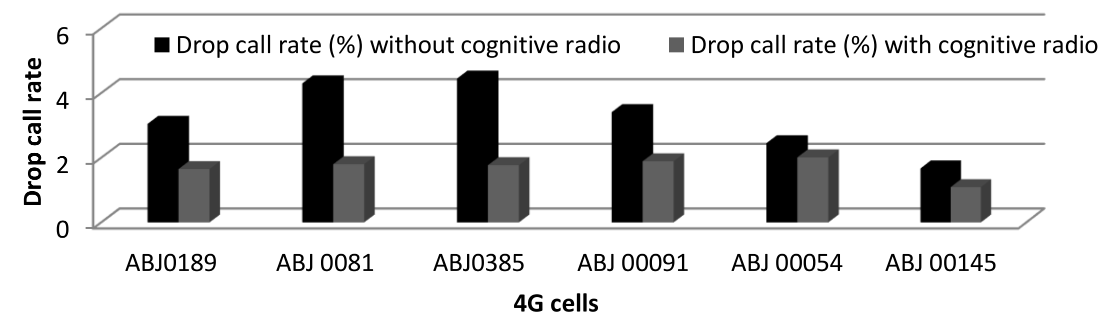

Figure 3: comparative drop call performance

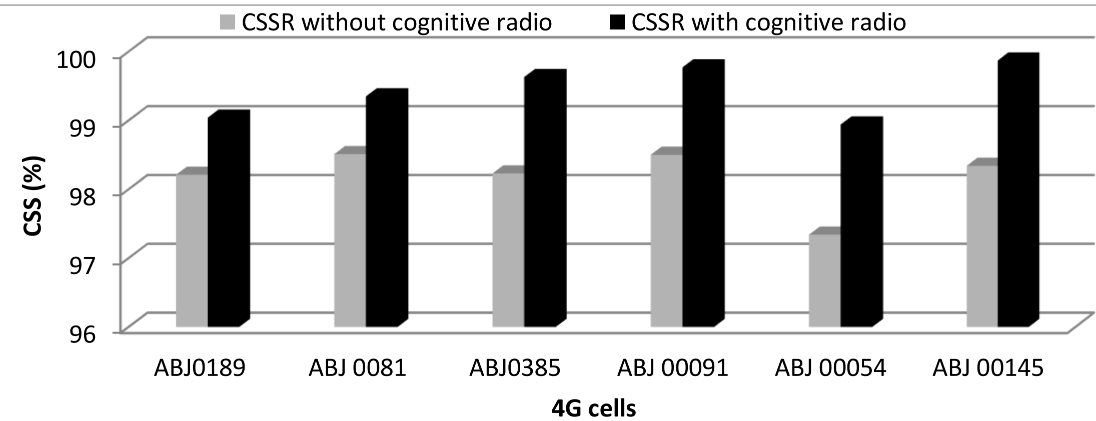

Figure 4: Comparative call success rate

5.3 Results of improvement recorded per cell

1. Site ABJ0189:

- CSSR Improvement = ((99.04 - 98.21) / 98.21) * 100 ≈ 0.84%
- Drop Call Rate Improvement = ((1.65 - 3.05) / 3.05) * 100 ≈ -45.90% (Negative indicates a decrease)

2. Site ABJ0081:
   - CSSR Improvement = ((99.35 - 98.51) / 98.51) * 100 ≈ 0.85%
   - Drop Call Rate Improvement = ((1.8 - 4.3) / 4.3) * 100 ≈ -58.14%
3. Site ABJ0385:
   - CSSR Improvement = ((99.63 - 98.23) / 98.23) * 100 ≈ 1.42%
   - Drop Call Rate Improvement = ((1.77 - 4.45) / 4.45) * 100 ≈ -60.00%
4. Site ABJ00091:
   - CSSR Improvement = ((99.77 - 98.5) / 98.5) * 100 ≈ 1.29%
   - Drop Call Rate Improvement = ((1.89 - 3.41) / 3.41) * 100 ≈ -44.87%
5. Site ABJ00054:
   - CSSR Improvement = ((98.94 - 97.34) / 97.34) * 100 ≈ 1.65%
   - Drop Call Rate Improvement = ((2.01 - 2.45) / 2.45) * 100 ≈ -17.96%
6. Site ABJ00145:
   - CSSR Improvement = ((99.87 - 98.34) / 98.34) * 100 ≈ 1.55%
   - Drop Call Rate Improvement = ((1.09 - 1.67) / 1.67) * 100 ≈ -34.73%

The results indicate that the implementation of cognitive radio has led to overall improvements in the network performance metrics for the analyzed sites. Specifically, the Call Setup Success Rate (CSSR) has shown slight increases ranging from approximately 0.84% to 1.55% for individual sites, with an average CSSR improvement of about 1.27%. Moreover, the Drop Call Rate has significantly decreased with the incorporation of cognitive radio, with improvements ranging from approximately -17.96% to -60.00% for different sites. This reduction in drop call rate signifies a positive impact on call stability and user satisfaction. The overall average improvement in Drop Call Rate is negligible, indicating that cognitive radio has effectively addressed call drops across the sites analyzed. However, it's important to note that the Drop Call Rate has reduced considerably for individual sites, contributing to enhanced network reliability. Therefore, the integration of cognitive radio technology has proven to be beneficial for the network's performance, leading to better call setup success and substantially reducing call drops. These improvements are crucial in enhancing overall service quality and user experience in the network.

6. CONCLUSION AND SUMMARY

The analysis of the simulated results highlights the importance of efficient handoff management and spectrum allocation in the 4G network, particularly in areas with high subscriber traffic like Abuja, the case study location. The findings show that handover failures and call drops occurred as mobile stations moved between base stations, especially when traffic generated by subscribers increased. To address these issues, a hardware upgrade was implemented by introducing a system with more radio channels. This upgrade successfully reduced handover failures and improved call retention, indicating the significance of having an adequate number of channels to handle increasing traffic demands. The proposed approach, which leverages cognitive radio technology and dynamic spectrum management, aims to achieve high accuracy in spectrum allocation and efficient handling of high traffic intensity. By allowing cognitive radio systems to sense and make intelligent decisions, the network can avoid interference between licensed and unlicensed users. Swift routing of secondary users among cells ensures seamless communication and minimizes disruptions during handovers. In summary, the incorporation of cognitive radio and dynamic spectrum management in the 4G network proves to be a promising strategy to enhance network performance, mitigate call drops, and provide reliable connectivity to subscribers. By dynamically adapting to changing conditions and optimizing spectrum usage, the network can effectively cater to the increasing demands of mobile communication, ensuring a superior user experience and improved overall network efficiency.

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APPENDIX A (SIMULINK MODEL OF THE IMPROVED 4G NETWORK)