



# A USER MOBILITY BROADBAND SPECTRUM AGGREGATION APPLICATIONS IN LTE-ADVANCE HETEROGENEOUS WIRELESS NETWORK SYSTEMS USING REAL-TIME SPECTRUM SELECTION FRAMEWORK

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## ARTICLE INFORMATION

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## ABSTRACT

Mobile user equipment can benefit from increased bandwidth and radio coverage of various access technologies through carrier aggregation and integration of heterogeneous networks. However, because of the mobility of user equipment, these technologies have increased the frequency of handoff scenarios, which results in low throughput and a high outage probability. In order to enable users to move between cells without losing connections, handover is an essential part of mobility management. However, no lone access mechanism can provide seamless and delay-free seamless interaction. As a result, the development of a suitable handover decision algorithm is necessary to ensure excellent service continuity and dependable user equipment access to the network at any location and at any moment. To confirm if various handover choice algorithms are effective in preventing communication failures and enhancing system performance. This research produced a mathematical model for the Real-Time Spectrum Selection Framework and Handover Decision Algorithm (RSSF-HDA). Additionally, mathematical models were extracted for comparison between the Multi-influenced Handover Decision Algorithm (MIF-HDA) and the Conventional Handover Decision Algorithm (Conv-HDA). A statistical comparative study was carried out using data from MTN drive-test readings at the Low-Cost housing estate located in Abesan, Ipaja, Lagos. According to statistical analysis results, the Real-Time Spectrum Selection Framework and Handover Decision Algorithm enhance system performance in terms of Cell edge Spectral Efficiency, and user throughput when compared with multi-influenced handover Algorithm and MTN field readings. For cell edge Spectral Efficiency at an average speed of 80km/s, RSSF-HDA gave a value of 1.52 bits/Hertz compared to MIF-HDA and MTN field readings with values of 1.37bits/Hertz and 1.33bits/Hertz respectively. For user throughput, inferred that there is no significant difference in readings of system throughput from the MTN field readings, MIF-HDA, and simulated RSSF-HDA which were 31%, 33%, and 34% respectively.

## 1.0 Introduction

Recent years have seen a rise in research and development aimed at enhancing coverage and capacity to deliver high data rates to user equipment (UEs) at an affordable rate. As a result, cellular networks have seen significant evolutionary improvement as well as new inventions and research initiatives (Hachemi et al., 2022, Sudhamani et al., 2023). The physical layer advancements of contemporary networks are moving in the direction of network efficiency.

Therefore, previous study suggest that systems based on the architecture of dense heterogeneous networks (Het-Nets) and increased utilization of radio spectrum through carrier aggregation techniques be used as solutions (Wahidin et al., 2022, Hashemi, and Farrokhi, 2020). Thus, these two technological advances serve as the cornerstone for network densification, with the inclusion of CA as a crucial functionality in the 3rd Generation Partnership Project (3GPP) Release 10 marking a major step towards the development of Long Term Evolution Advanced (LTE-A)(Satapathy and Mahapatro, 2022). It is anticipated that the addition of CA technology in LTE-A's Release 10 (Rel.10) and later releases will enable high data rates and increase system capacity.(Goyal and Kumar, 2020). This implies that a much-anticipated aspect of LTE-A is the expansion of transmission bandwidth.

LTE-Advanced (Long Term Evolution) has Carrier Aggregation (CA) as one of its primary background characteristics. A maximum bandwidth of 100MHz would be available to customers with CA. There are three possible system bandwidth configurations: contiguous, non-contiguous, and inter-band noncontiguous (Lin et al., 2014). For Long Time Evolution (LTE) carriers, the bandwidth of these Component Carriers (CCs) can vary greatly, from 1.4MHz to 20MHz. Additionally, propagation properties vary throughout different CCs. For instance, CCs in the 800MHz spectrum have different propagation characteristics than component carriers in the 2.4GHz band (Ohmann et al., 2014).

However, a new Handover situation brought about by the introduction of CA technology allows CCs operating in the same sector and eNodeB to undertake handovers, potentially redefining Primary Component Carriers (PCCs). Throughput degradation increases as a result of the higher handover chance. As long as the serving PCC provides the UEs with an adequate amount of RSS, the handover situation here translates into a successful Handover Decision (HoD). In essence, handover is evaluated when a voice call is in progress and heading toward the current eNodeB (i.e., from a source to a target eNodeB). This instance involves a UE reporting signal measurements to the serving eNodeB from the neighboring eNodeB. The measurement report from the UE at the source eNodeB is used to make the handover decision. On the other hand, in a CA-based system, the source and the target eNodeBs may be CCs of the same or separate eNodeBs because of numerous CCs. Making decisions with such a signal Measurement Report (MR) is not completed quickly. Consequently, it increases the likelihood of throughput deterioration, user outage probability, and handover failure, particularly for high-velocity user equipment (Alhammadi, et al., 2023, Bastidas-Puga et al., 2019).

The primary goal of handover is to keep the connection active as the subcarrier passes through the source eNodeB's coverage region and approaches the target eNodeB. Providing services that meet consumer needs is one of the main objectives of communication in cellular networks (Khan and Han, 2015). However, an effective handover decision algorithm improves continuous connectivity, but the network's performance is still insufficiently enhanced. As such, investigating the HoD algorithm is innovative as it may effectively manage the main responsibilities in cellular networks by raising the quality of services and concurrently managing the network's resources, in addition to offering encouragement for conducting this kind of research.

Conventional handover algorithms are applicable in heterogeneous networks and exhibit simple moderate handover with an inaccurate high percentage of unwanted handovers. Multi-

Influenced Factor handover algorithms are applied in Coordinated Carrier Aggregation, the decision-making process integrates RSS, bandwidth, speed, handover situation, and SINR to accomplish seamless mobility and apply to indoor scenarios. Finally, the RSSF-HDA utilizes Coordinated Carrier Aggregation. System performance is improved by using spectrum sensing, which lowers the likelihood of outages, call dropouts, and handover ping-pong. Only two (2) Carrier Component was Considered

The statement of problem thus implies that there are increased in the frequency of handoff which led to low throughput and high outage probability. In order to make sensitive decisions about handover when implementing heterogeneous networks (HetNet) and CA in LTE-A systems, The objective of this study is to utilize a user mobility broadband spectrum aggregation in LTE- advance heterogeneous to mitigate these quality-of-service indices

## 2.0 Materials and Method

The serving eNodeB made handover decision based on the measurement report (MR) received from the served UE. A list of the signal levels of nearby cells is contained in MR, and depending on the HoD algorithm in use, it can also provide additional information. An algorithm for a handover decision can be implemented in multiple ways. It can generally be divided into the following categories:

- i. Conventional Handover Decision Algorithms (Conv HDA)
- ii. Multi-influenced Handover Decision Algorithms (MIF-HDA)
- iii. Real-Time Spectrum Selection Framework and Handover Decision Algorithm (RSSF-HDA)

The conventional handover choice algorithm, known as the RSS-based strategy, used RSS as the primary criterion to initiate handover (Abdullah & Zukarnain, 2017). Here, the handover is enabled as a result of comparing the signal intensities of nearby eNodeBs. The RSS-based approach was improved by using the RSS threshold (hysteresis) (Kunarak & Suleesathira, 2020) and by combining it with the user's distance (Mahardhika et al., 2015), SINR (Khattab et al, 2023), and IINR (Choi et al., 2021). A threshold is established and implemented in relation to signal strength in order to reduce the Ping-Pong effects. If the new eNodeB RSS is more than the threshold and the current eNodeB RSS is less than the threshold, the handover is initiated. However, the RSS-based approach for assessing the attributes and quality of services is straightforward in theory and straightforward to apply. However, route loss in the wireless medium caused the RSS signal to vary, which lead to ping pong, throughput degradation, and needless handovers. Additionally, threshold RSS had disadvantages such as high call drop and handover delay.

However, recent research has shown that incorporating CA and HetNets technologies maked handover decisions more difficult. The RSS-based criterion is insufficient for a decision-making process in HetNet using the CA approach.

Concurrently, in a coordinated carrier aggregation deployment scenario, MIF decision-making criteria was examined (Capez et al, 2022). Several factors that affected the decision-making process were employed by MIF. Even if the simulation's result indicated that ping pong had decreased, the outcome is not ideal when HetNet is taken into account in CA.

The handoff delay and service disruption time are decreased by the multi-criteria algorithm. Consequently, during handover, this reduced packet loss and increased throughput (Alhabo & Zhang, 2020). As a result, in future MIF-HDA research, the selected criteria guaranteed that the level of decision-making accuracy is maintained. RSS, mobility, application, and bandwidth are some of the primary factors that are either user- or network-related. Although every previous work in HetNets and CA was built on a separate set of criteria, it is still uncertain which set of characteristics results in the best handover procedure. Therefore, a new method known as the multi-criteria handover decision algorithm was presented for effective handover decision-making when CA and HetNet are taken into consideration in an LTE-A system to determine the appropriate parameters for a successful handover process (Abdulazeez-Ahmed et al., 2020a).

A novel handover decision algorithm called Real-Time Spectrum Selection Framework And Handover Decision Algorithm (RSSF-HDA) was proposed, and its proposed handover performance for an LTE-A system was compared with two other HODA (MIF-HDA and Conv-HDA) (Nkeleme et al., 2023). According to the results of the simulation analysis, RSSF-HDA was more effective than the current HDA deployment in enabling wider bandwidth and greater SE. The metrics of RSSF-HDA Spectral Efficiency (SE) are higher than those of the other HDA considered in the research, rising from 1.35 bps/Hz/cell at mobile speeds of 20 kmph to 1.87 bps/Hz/cell at 120 kmph.

## **2.1 Simulation of MIF-HDA and RSSF-HDA Carrier Aggregation Based Handover Technique in Heterogenous Network.**

Abdulazeez-Ahmed et al., (2020) provided an effective multi-influence handover decision method that took into account the mobile parameter (load and UE distance) as well as the network parameter (radio resources and network architecture) while making decisions.

To construct LTE-A heterogeneous network topologies, the algorithm was implemented as a multicell system using a system-level simulator from the MATLAB toolbox. Many built-in libraries and capabilities in MATLAB enabled the conversion of C and C++ code into MATLAB programs. Additionally, it raised the likelihood of new technology, allowed the required data manipulation, and fortifies the security of emerging technologies (Nkeleme et al., 2023). PCC is often used for data transfer between the UE and the eNodeB as well as information sharing for control signals. PCC was utilized for the random-access mechanism and SCC allocation in addition it served as a conduit for data transfer.

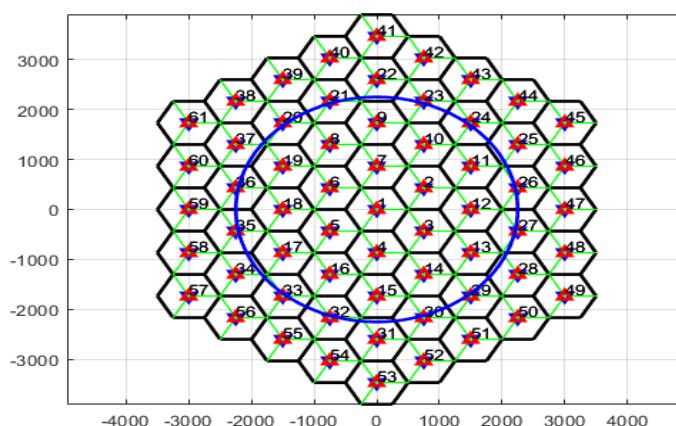
Numerous handover decision algorithms have been developed in response to the CA concept's handover decision issues in LTE-A and next-generation systems, but none of them have produced the desired results, especially for HetNet's Carrier Aggregation Deployment Scenario (CADS). Consequently, Abdulazeez-Ahmed et al., (2020) developed an effective multi-influenced handover decision algorithm that used mobile parameters like load and UE distance as well as network parameters like radio resources and network architecture as input for decision-making. The Third Generation Partnership Project (3GPP)-standardized Cell Range Expansion (CRE) power regulation mechanism (Wu, et al., 2020) was used in this study as a virtual bias applied to the real UE received power (Abdulazeez-Ahmed et al., 2020). the handover choices were conducted adaptively based on the following criteria.

In an LTE-Advanced uplink and downlink system level simulator, Nkeleme et al., (2023) presented a workable CA strategy that made use of two CCs in the same bands (Het-Nets CADS) utilizing the Multi-Taper OFDMA Sensing of Reference Signal Received Power Estimator (MTO-RSRPE) technique. A global rendition algorithm was created to achieve the real-time spectrum selection framework's goal. This algorithm served as the foundation for the implementation of the new RSSF-HDA program flowchart, the Resource allocation, Parameters, and Threshold Values are given in Nkeleme et al., (2023).

## 2.2 System Model and Simulation Configuration for MIF-HDA and RSSF-HDA

The standard (Nkeleme et al., 2023) was utilized in the creation of the radio frequency system model scenario. 30 mobile user devices (UEs) were uniformly distributed at random to serving and target cell sites during each Transmission Time Interval (TTI). The UEs' directional motions was determined at random with a set speed during the design process, which comprises a variety of mobile speed scenarios (5, 25, 40, 70, 100, and 130 Km/h). All users' mobility movements were taken into consideration within the first 32 cells, which are close to the center cell. An illustration of the deployed scenario's clustered eNodeBs is shown in Figure I. During the simulation, each user will suffer interference from six separate eNodeBs, which are regarded as the stations that generate these signals. The Frequency Reuse Factor (FRF) was set to one.

The performance findings for the RSSF-HDA, MIF-HDA, and the starting point Conventional Handover Decision Algorithm (Conv-HDA) were displayed. Results for Cell edge Spectral Efficiency, Average successful Handover, and User throughput was analyzed based on the utilization of hard handover at different mobile speeds. As a result, Figure I displays the Het-Nets CADS architecture. Carrier aggregation enables the deployment of more UEs in macro and micro cells, as the topological architecture illustrates. Six (6) neighbors surrounded each of the sixty-one (61) eNodeB that were taken into consideration.



**Figure I:** An illustration of the deployed scenario's clustered eNodeBs (Nkeleme et al., 2023)

Subsequently, as seen in Figure I, seven (7) eNodeBs create a single cluster. Furthermore, every eNodeB was segmented into three sectors and encompasses an approximate radial distance (R) of 500 meters. Ultimately, a radius of about 5R was established for the mobility area of the mobile stations, also known as User Equipment (UEs) (shown as a blue circle).

### 2.3 Curve Fitting Process and Decomposing of Simulations

In order to extract significant patterns and relationships from datasets, curve fitting is a key procedure in data analysis. This study highlights the capabilities and versatility of the RSSF HDA System by breaking down the stages involved in the curve fitting process. The generated data is saved in an a.mat file, where the independent and dependent variables (observations) were represented by corresponding variables.

To ensure a smooth integration of the data into the Curve Fitting Tool, MATLAB's 'read' function was utilized to import the data into an appropriate format. The Curve Fitting Tool was accessed via the MATLAB Apps tab or programmatically via the 'cftool' command. Its dynamic and user-friendly interface made effective curve fitting possible. The tool allowed to select multiple curve fitting models, alter parameters, and view the fitting process in real-time.

### 2.4 Mathematical Models of performance Indicators

#### 2.4.1 Spectral efficiency

The average bits per second per Hz (bps/Hz) that may be transferred over a radio link channel and accurately received at the receiver side is referred to as spectral efficiency. Mathematically, the user's spectral efficiency are expressed by adding up the entire throughput that is successfully received by the user at a given moment and dividing it by the whole user's channel bandwidth. The equation used in this thesis is expressed as follows:

$$SE = \frac{N_{symbolpersubcarrier} * \log(AMC) * CR}{subframe\ duration * BW} \quad (1)$$

SE is the cell edge spectral efficiency in bps/Hz

$N_{symbolpersubcarrier}$  is the Number of symbols per Subcarrier in bps

AMC is Adaptive Modulation and coding

CR is Cognitive Radio value

BW is Bandwidth in Hertz

The decomposed models for the spectral efficiency variance with reference to the reviewed literature are expressed as follows:

#### Conv-HDA

$$SE_{cdf} = \frac{125.7(SE)^2 - 266SE + 124.3}{(SE)^3 - 127.8(SE)^2 + 179.8SE + 31.38} \quad (2)$$

Where  $SE_{cdf}$  is the cumulative distribution function cell edge spectral efficiency

SE is the cell edge spectral efficiency in bps/Hz

$$SE_{cdf} = \frac{403.3(SE_{Av})^2 - 1140SE_{Av} + 806.1}{(SE_{Av})^3 + 1253(SE_{Av})^2 - 4066SE_{Av} + 3319} \quad (3)$$

Where  $SE_{cdf}$  is the cumulative distribution function cell edge spectral efficiency

$SE_{Av}$  is the Average cell edge spectral efficiency in bps/Hz

$$SE_{Av} = -0.00004048(S)^2 + 0.009475S + 1.237 \quad (4)$$

Where  $SE_{Av}$  is the Average cell edge spectral efficiency.

S is Mobile Speed in Km/hour

#### MIF-HDA

$$SE_{cdf} = \frac{42.45(SE)^2 - 37.88SE - 25.29}{(SE)^3 - 30.39(SE)^2 - 49.39SE + 154.3} \quad (5)$$

Where  $SE_{cdf}$  is the cumulative distribution function cell edge spectral efficiency

SE is the cell edge spectral efficiency in bps/Hz

$$SE_{cdf} = \frac{0.04822(SE_{Av})^2 - 0.1279SE_{Av} + 0.08481}{(SE_{Av})^3 - 4.738(SE_{Av})^2 + 7.448SE_{Av} - 3.876} \quad (6)$$

Where  $SE_{cdf}$  is the cumulative distribution function cell edge spectral efficiency  
 $SE_{Av}$  is the Average cell edge spectral efficiency in bps/Hz

$$SE_{Av} = -0.00004424(S)^2 + 0.01022S + 1.224 \quad (7)$$

Where  $SE_{Av}$  is the Average cell edge spectral efficiency.  
 S is Mobile Speed in Km/hour

### RSSF-HDA

$$SE_{cdf} = \frac{283.8(SE)^2 - 573.1SE + 234.6}{x^3 - 312.1(SE)^2 + 576.8SE - 73.28} \quad (8)$$

Where  $SE_{cdf}$  is the cumulative distribution function cell edge spectral efficiency  
 SE is the cell edge spectral efficiency in bps/Hz

$$SE_{cdf} = \frac{143.6(SE_{Av})^2 - 356.9SE_{Av} + 219.8}{(SE_{Av})^3 + 2219(SE_{Av})^2 - 8020SE_{Av} + 7286} \quad (9)$$

Where  $SE_{cdf}$  is the cumulative distribution function cell edge spectral efficiency  
 $SE_{Av}$  is the Average cell edge spectral efficiency in bps/Hz

$$SE_{Av} = -0.00004322(S)^2 + 0.009998S + 1.335 \quad (10)$$

Where  $SE_{Av}$  is the Average cell edge spectral efficiency.  
 S is Mobile Speed in Km/hour

### 2.4.2 Throughput

The Third Generation Partnership Project (3GPP) group has established five categories of service performance metrics, comprising network availability, accessibility, retainability, mobility, and integrity. In all radio access technologies, user throughput is a crucial measure for assessing the integrity of data services (Buenestado et al., 2014). The throughput with respect to the bite rate adopted in this thesis is expressed mathematically as follows:

$$Bit\ Rate = \frac{N_{RB} * N_{subcarrierperRB} * N_{slotpersubframe} * N_{symbolpersubcarrier} * \log(AMC) * CR}{subframe\ duration} \quad (11)$$

Where:

$AMC$  = selected adaptive modulation scheme,

$CR$  = selected code rate

The decomposed model for Conv-HDA (Khan, and Han, 2015) and the Multi-Influence HDA (Abdullah, and Zukarnain, 2017) with respect to the user throughput is expressed as follows:

### Conv-HDA

$$TH_{cdf} = \frac{8487TH^2 - 4046TH + 484}{TH^3 + 12900TH^2 - 7480TH + 1159} \quad (12)$$

## MIF-HDA

$$TH_{cdf} = \frac{9811TH^2 - 4623TH + 545.4}{TH^3 + 12090TH^2 - 6694TH + 1018} \quad (13)$$

The result obtained from the simulation is expressed as follows:

## RSSF-HDA

$$TH_{cdf} = \frac{6748TH^2 - 3183TH + 376.6}{TH^3 + 9803TH^2 - 5831TH + 953.7} \quad (14)$$

Where  $TH_{cdf}$  is the cumulative distribution function of user Throughput

TH is the User Throughput in Mbps

## 2.5 Field Measurements For LTE-A

In order to offer service to user units, the LTE-A network used advanced base stations (eNodeBs and eNBs) to cover the whole cell. It also utilized the same transmit power level, modulation mechanism, and antenna layouts ( Zhang et al., 2020). Wireless channel parameters in LTE-A systems control the downlink quality between the eNodeB and the user equipment (UE). The channel quality indicator (CQI) used in the LTE-A network expresses the wireless channel's condition. Typically, the SINR value based on reference signal received power (RSRP) and reference signal received quality (RSRQ) represented the CQI established by the user unit (RSRQ). The modulation technique, transfer block size (TBS), and coding rate of the data transmission are chosen in accordance with the user unit's CQI value that is transmitted to the eNodeB, Because of this, throughput and CQI value were directly related. To determine the impact of SINR, RSRP, and RSRQ channel characteristics on the throughput value in the LTE-Advance network, this study employed TEMS software to collect field data from LSDPC low-Cost Housing Estate, Abesan, Ipaja Lagos locations. The drive test was conducted for 15 months (September 2022 to Nov 2023) as shown in Table I.

## 2.6 Method of Field Data computation Using Regression Analysis

The data obtained from the drive test was analyzed using various statistical tools such as Regression Analysis, which is a mathematical equation, that shows the connection between a few independent factors and a dependent variable. The dependent variable Y and the independent variable X in the basic linear regression model are specified as follows.

$$Y_i = \beta_0 + \beta_1 X_i + \epsilon_i \quad i = 1, 2, \dots, n \quad (15)$$

Where:

$\beta$  is the regression coefficient

n is the size of the data,

$\epsilon_i$  represents the error term

Two or more independent variables are used to express the dependent variable (k).

$$Y_i = \beta_0 + \beta_1 X_{i1} + \beta_{12} X_{i2} + \dots + \beta_k X_{ik} + \epsilon_i \quad i = 1, 2, \dots, n \quad (16)$$

According to information obtained from MTN Lagos, the algorithms used are similar to multi-influenced handover decision algorithms. This provides a strong foundation for the comparison, as seen in Table 3.

## 3.0 Results and Discussion

A drive test was conducted in Abesan Estate Ipaja Lagos from the month of September 2022 to November 2023, a summary of the readings obtained are shown in Table I.

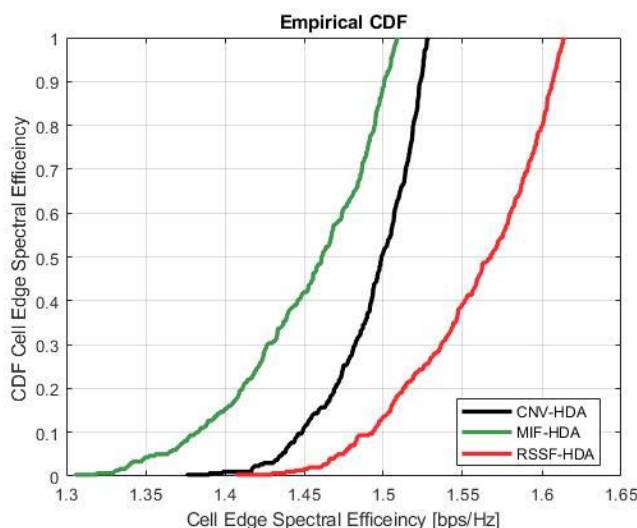


**Table 1: Monthly Average Field Drive-Test Values In Abesan Estate Ipaja Lagos State (Sept 2022 To Nov 2023)**

S/N	Date	Total PDCP DL Throughput	Serving Cell RS SINR (dB)	Serving Cell RSRP (dBm)	Serving Cell RSRQ (dB)
1	Sept 2022	60528.76	11.97	-64.00	-16.79
2	Oct 2022	73187.50	20.83	-87.45	-14.12
3	Nov 2022	36445.00	17.16	-84.42	-12.46
4	Dec 2022	19778.75	14.24	-93.97	-13.78
5	Jan 2023	33452.65	10.13	-91.01	-15.73
6	Feb 2023	31344.65	11.10	-78.09	-16.5
7	March 2023	39708.55	11.80	-70.00	-14.89
8	April 2023	30896.15	19.79	-75.19	-13.19
9	May 2023	36348.25	17.22	-78.80	-17.89
10	June 2023	50672.00	13.89	-78.50	-15.60
11	July 2023	33364.25	15.39	-78.09	-15.80
12	Aug 2023	22520.20	21.29	-88.90	-15.60
13	Sep 2023	32464.15	21.89	-66.00	-13.65
14	Oct 2023	36324.35	14.30	-77.80	-12.93
15	Nov 2023	33160.15	20.70	-90.80	-13.65

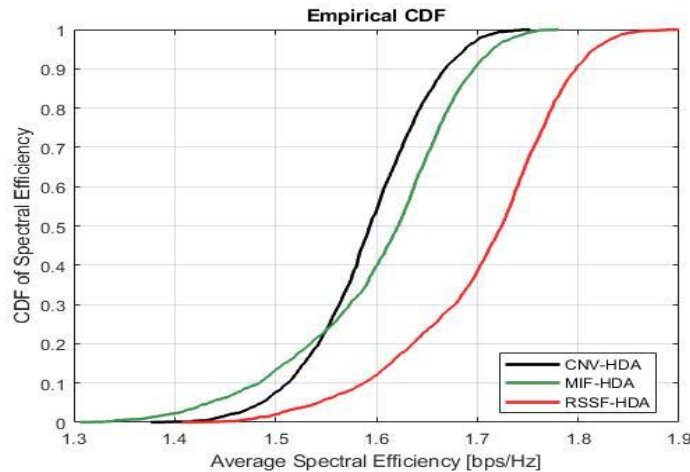
The cumulative density function cell edge spectral efficiency was plotted against the cell edge spectral efficiency for the Three HDA as shown in Figure 2. This is to determine its degree of positive variation. Figure 2 shows that RSSF-HDA has the best cell edge spectral efficiency, meaning greater data rates near the cell's edge. MIF-HDA follows closely behind, providing competitive performance, but Conv-HDA lags, indicating data rate limits at the cell edge. At 1.4bps/Hz, values of 0.12, 0.32, and -0.08 was calculated for Conv-HDA, MIF-HDA, and RSSF-HDA, respectively. At 1.5bps/Hz, the values for Conv-HDA, MIF-HDA, and RSSF-HDA was 0.50, 0.90, and 0.16, respectively.

The high performance of RSSF-HDA at the cell edge as shown in Figure 2 may be helpful in circumstances requiring high-quality connections on the edges of network coverage



**Figure 2: CDF Cell Edge Spectral Efficiency Over Cell Edge Spectral Efficiency**

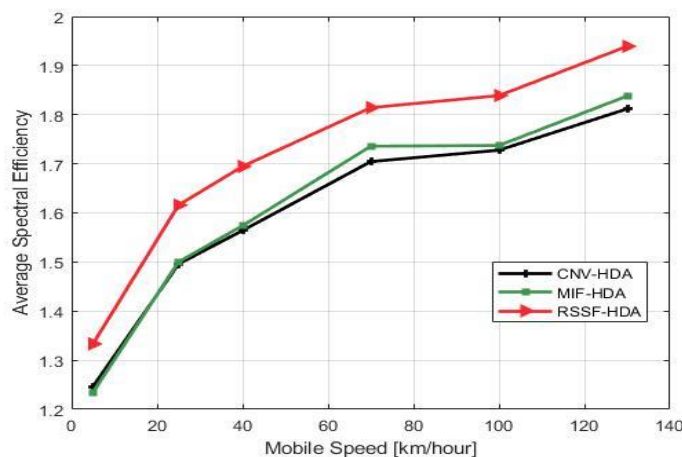
The simulated data plot of the Cumulative Density Function of Spectral Efficiency Over Average Spectral Efficiency is shown in Figure 3. This further shows that the RSSF-HDA has a consistent spectrum efficiency and performance. In comparison, MIF-HDA is somewhat sensitive to network conditions, whereas RSSF-HDA marginally exceeds MIF-HDA in terms of responding to changing conditions. This shows that RSSF-HDA may provide better performance in dynamic situations. Figure 3 further illustrates the comparable values of 1.5bps/Hz cell Edge Spectral Efficiency, to produce values of 0.85, 0.50 and 0.15 for Conv-HDA, MIF-HDA, and RSSF-HAD, respectively



**Figure 3:** CDF Spectral Efficiency Over Average Spectral Efficiency

This further demonstrates that the RSSF-HDA has a consistent spectrum efficiency and performance. In comparison, MIF-HDA is somewhat sensitive to network conditions, whereas RSSF-HDA marginally exceeds MIF-HDA in terms of responding to changing conditions, showing that RSSF-HDA provides better performance in dynamic situations.

The Plot of the Average UE Spectral Efficiency over All Mobile Speeds for Each Handover Decision Algorithm is presented in Figure 4 in relation to the obtained simulation data. Figure 4 compares the average SE of the UE at various mobile speeds using the deployed RSSF-HDA. Generally, it appears from the results (Figure 4) that the average SE rises as UE speed rises. The outcomes shows that the proposed RSSF-HDA surpasses its counterparts for the speeds under consideration. RSSF-HDA significantly outperforms the other HODAs in improving the average SE. Conv-HDA, MIF-HDA, and RSSF-HDA algorithms produced values of 1.72, 1.75, and 1.86, respectively, at 80 km/hr.

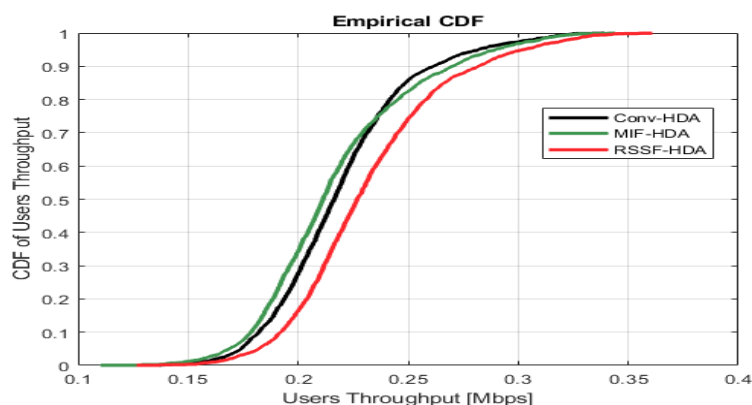


**Figure 4:** UE's Average spectral efficiency over all the mobile speeds

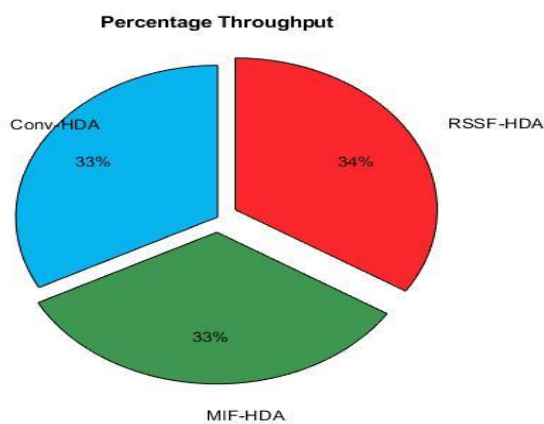
It further indicates that the RSSF-HDA has the best average spectral efficiency, demonstrating efficient data transmission resource utilization. MIF-HDA follows closely but falls just short of RSSF-HDA's performance. Conv-HDA performs similarly to MIF-HDA, meaning that it is a solid overall performer but not the greatest.

Figure 5(a) displays the model plots of User CDF throughput over User Throughput in relation to the acquired simulation data. From Figure 5(a) it is shown that at 0.34Mbps, the Conv-HDA, MIF-HDA, and RSSF-HDA algorithms generated corresponding values of 0.83, 0.77, and 0.70, respectively. RSSF-HDA achieves the highest user throughput, showcasing efficient data transfer capabilities. MIF-HDA closely follows, offering competitive performance. Conv-HDA aligns with MIF-HDA, indicating reliable data transfer efficiency. The decision between these models may depend on specific network requirements and priorities. RSSF-HDA excels in data transfer efficiency, but MIF-HDA and Conv-HDA remain strong contenders for a balance of performance and adaptability.

The User Throughput of RSSF-HDA and the other two handover algorithms is shown in Figure 5 for all UE speeds. In comparison to Conv-HDA and MIF-HDA, RSSF-HDA outperforms both in terms of throughput for the user. In comparison to Conv-HDA and MIF-HDA, RSSF-HDA generally achieves a throughput of 34% while other algorithms have 33% as shown in Figure 5 (b).



(a)



(b)

**Figure 5:** Throughput; (a) User throughput (b) Percentage throughput

The Comparative Assessment of MIF-HDA, and RSSF-HDA Algorithms from MTN LTE-A Network Drive Test Readings is illustrated in Table 2. The Spectral Efficiency and System Throughput are the Key performance indices consider.

**TABLE 2:** Comparative Assessment of MIF-HDA, and RSSF-HDA Algorithms from MTN LTE-A Network Drive Test Readings

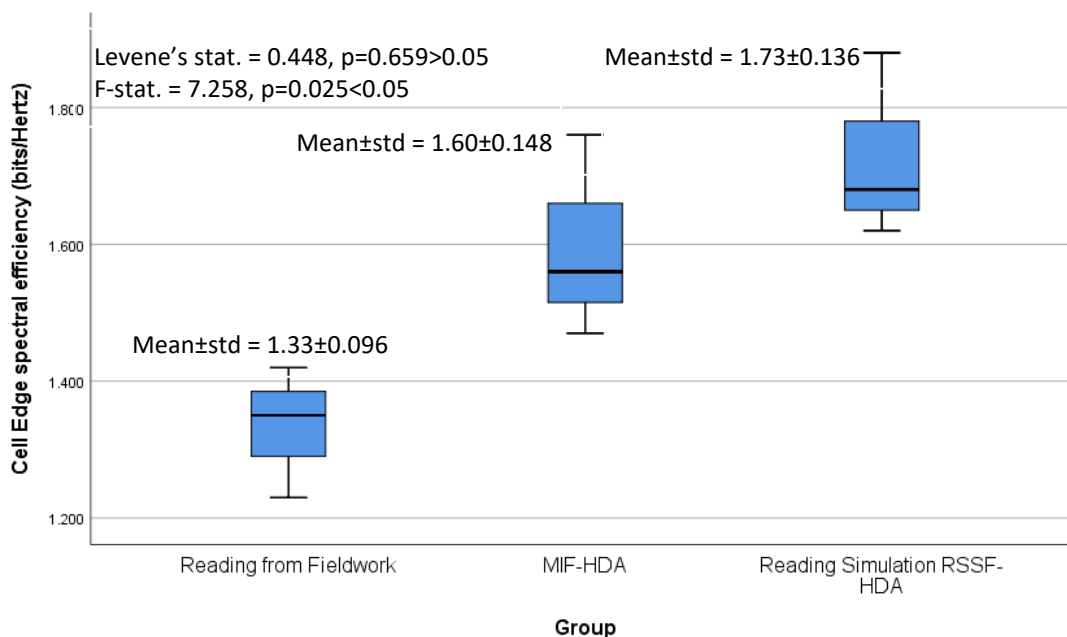
S/N	KPI for seamless Transmission	Graduation (Point of Measurements	Reading from fieldwork	MIF-HDA	Reading Simulation RSSF_HDA
1	Cell Edge spectral efficiency taken @40km/h, 80km/hr, and 120km/hr presented as a, b, and c respectively)	a)	1.23 bits/Hertz	1.47	1.62
		b)	1.35	1.56	1.68
		c)	1.42	1.76	1.88
		Average cell edge Spectral efficiency (bps/Hz)	1.33	1.37	1.52
2	System throughput (taken @ 0.2Mbps, 0.25Mbps, and 0.3Mbps presented as a, b, and c respectively)	a)	0.32	0.35	0.70
		b)	0.65	0.88	0.75
		c)	0.85	0.96	0.92
		Average Percentage throughput	31%	33%	34%

**Note**

- i. All readings taken on the assumption of a Zeros take off (time series reading)
- ii. The average readings are based on several readings from the simulation with the exception of the field measurement which is the average of the three points of measurement

The graphical ANOVA expression for Table 2 when considering Cell Edge Spectral Efficiency at 40km/hr 80km/hr. and 120km/hr is shown in figure 6

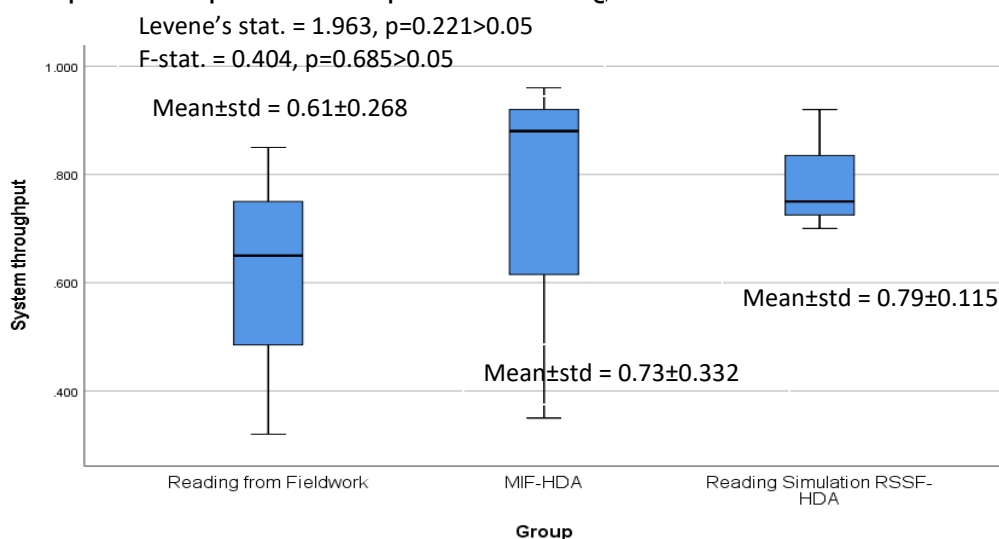
The ANOVA test result (Figure 6) submits that the readings from fieldwork, MIF-HDA, and RSSF-HDA vary substantially ( $F= 7.258, p=0.025<0.05$ ) from each other. The mean±std result shows that the reading from Simulated RSSF-HDA ( $1.73\pm0.136$ bits) is higher in comparison with the readings from MIF-HDA ( $1.60\pm0.148$ bits) and those from fieldwork ( $1.33\pm0.096$ bits). The homogeneity of variance test of the compared groups (Levene (L-Stat.) = 0.448,  $p=0.659>0.05$ ) ascertained that the variances are homogeneous (i.e., equal); therefore, the data series is fit for the application of parametric statistical tools. In the case of Figure 6, the Variance in mean varies substantially from each other. The readings from simulations are higher than those from MIF-HDA and those from fieldwork.



**Figure. 6:** Comparative result of readings from fieldwork, MIF-HDA, and Reading from Simulated RSSF-HDA of Cell Edge spectral efficiency taken @40km/h, 80km/hr, and 120km/hr respectively

The result (Figure. 6) shows that readings from fieldwork lie between  $0.61 \pm 0.268$ ; readings from MIF-HDA lie between  $0.73 \pm 0.332$ , while readings from simulated RSSF-HDA lie between  $0.79 \pm 0.115$ . The Fisher's estimate with an F-statistic value of 0.404 and associated probability value of  $0.685 > 0.05$  indicates that the variations were not significantly high. However, it was inferred that there is no significant difference in readings of system throughput from the fieldwork, MIF-HDA, and simulated RSSF-HDA. The ANOVA test result was confirmed meaningful and accurate by Levene's test (Levene's stat. = 1.963,  $p=0.221 > 0.05$ ); thereby, confirming the homogeneity of the variances in the data series which is one of the key assumptions of a data series for ANOVA test.

The graphical ANOVA expression for Table 2 when considering System throughput at 0.2Mbps, 0.25Mbps, and 0.3Mbps is shown in figure 7



**Figure. 7:** Comparative result of readings from fieldwork, MIF-HAD, and Reading from Simulated RSSF-HDA of System throughput taken 0.2Mbps, 0.25Mbps, and 0.3Mbps respectively

The result (figure. 7) shows that readings from fieldwork lie between  $0.61 \pm 0.268$ ; readings from MIF-HDA lie between  $0.73 \pm 0.332$ , while readings from simulated RSSF-HDA lie between  $0.79 \pm 0.115$ . The Fisher's estimate with an F-statistic value of 0.404 and associated probability value of  $0.685 > 0.05$  indicates that the variations were not significantly high. However, it was inferred that there is no significant difference in readings of system throughput from the fieldwork, MIF-HDA, and simulated RSSF-HDA. The ANOVA test result was confirmed meaningful and accurate by Levene's test (Levene's stat. = 1.963,  $p=0.221 > 0.05$ ); thereby, confirming the homogeneity of the variances in the data series which is one of the key assumptions of a data series for ANOVA test.

#### **4.0 Conclusion**

Voice and multimedia services are in extremely high demand on cellular networks. Due to its limited capacity, the current macro cellular network is unable to fully satisfy this demand. Additionally, adding several macro-base stations to increase capacity and expand coverage is quite expensive. Along with this, there are problems with urban space restrictions. To improve the coverage, capacity, and data rate in LTE-A, numerous strategies have been proposed. The deployment of heterogeneous networks is one of the most economical techniques. LTE-A HetNet significantly boosts wireless cellular networks' capacity and performance. With HetNets, you may employ a variety of cell sizes, including femtocells, macrocells, picocells, microcells, and relays, to enhance capacity and improve coverage. HetNet is the most effective, affordable, and scalable method for increasing the capacity of current and future wireless networks. The UEs receive a solid network connection and an improved user experience as a result. However, if HetNet deployment is poorly managed, it frequently results in increased handover for UEs. In this research, the RSSF-HDA, a novel handover decision algorithm, was proposed as a better option when compared with MIF-HDA and the field data obtained from the drive test. The research further presents a statical comparison of the field drive test readings, the MIF-HDA, and the RSSF-HDA reading to establish the existing relationship between the various cell edge spectral efficiency readings and to further establish the best algorithm under consideration for seamless handover. The outcome of this comparison suggests that RSSF-HDA has better quality of service (QoS) parameters when compared with the MTN real-time drive-test values and the MIF-HDA Algorithm. Therefore, it is recommended that the RSSF-HDA should be adopted by MTN Nigeria for better quality of service.

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