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Evaluating Handover Performance in Heterogeneous Networks (HetNets) Through a Real-Time Spectrum Selection Framework: An Empirical Study of a Low-Cost Residential Estate in Lagos, Nigeria

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Abstract: The increasing deployment of heterogeneous cellular networks has improved radio coverage and capacity but has simultaneously made mobility management more challenging, particularly where macro-cell and small-cell coverage overlap. In such environments, a user equipment (UE) moving across cell boundaries may experience rapidly changing radio conditions, repeated handovers, handover failures, service interruption and degradation in throughput. These problems become more pronounced when carrier aggregation is employed because the UE may have access to more than one component carrier with different instantaneous radio conditions. This study presents a performance assessment of a Real-Time Spectrum Selection Framework Handover Decision Algorithm (RSSF-HDA) for LTE-Advanced heterogeneous networks, using the LSDPC Low-Cost Housing Estate, Abesan, Ipaja, Lagos, as the field case study. The research adopted an integrated field-measurement and system-level simulation approach. Drive-test data were obtained from the operational MTN LTE-A network within the study area over fifteen months, from March 2025 to May 2026, using a Samsung Galaxy SM-G920F user equipment and TEMS Investigation. The measured parameters included serving-cell SINR, RSRP, RSRQ and downlink throughput. A heterogeneous LTE-A simulation environment comprising 61 macro eNodeBs, three sectors per eNodeB and overlaid pico-cell coverage was subsequently implemented in MATLAB using two component carriers operating at 3.0 and 3.6 GHz. The proposed RSSF-HDA incorporates real-time spectrum sensing, component-carrier selection and handover decision-making, and was evaluated against the Conventional Handover Decision Algorithm (Conv-HDA) and Multi-Influence Factor Handover Decision Algorithm (MIF-HDA). The results show that RSSF-HDA achieved an average handover success rate of approximately 98% at 70 km/h and 90% at 130 km/h, compared with 88% and 85% for MIF-HDA and 85% and 83% for Conv-HDA, respectively. The proposed framework also reduced handover interruption time by approximately 45% relative to Conv-HDA and 12% relative to MIF-HDA. In the Abesan field-validation comparison, the average handover success rate increased from 0.795 for field measurements to 0.89 for MIF-HDA and 0.98 for RSSF-HDA. Cell-edge spectral efficiency similarly increased from 1.33 bps/Hz in the field measurements to 1.37 bps/Hz for MIF-HDA and 1.52 bps/Hz for RSSF-HDA. Statistical analysis showed a significant difference in handover success rate among the compared groups, while the observed differences in system throughput and outage probability were not statistically significant. The findings demonstrate that incorporating real-time spectrum information into the handover process provides a technically viable means of improving mobility robustness and service continuity in LTE-A heterogeneous networks representative of the Abesan deployment environment.

Keywords: *LTE-Advanced, Heterogeneous Networks, Handover, Spectrum Selection, Carrier Aggregation, RSSF-HDA, Abesan, LTE Mobility, Handover Success Rate.*

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I. INTRODUCTION

The rapid expansion of mobile broadband services has increased the demand for cellular networks capable of providing reliable connectivity, high data rates, and seamless communication to users moving across different coverage regions. To satisfy these requirements, heterogeneous networks (HetNets), in which macro-cells coexist with small cells such as pico-cells, have become an important network deployment strategy. Although HetNets improve coverage, capacity and spatial frequency reuse, the resulting overlapping coverage areas create additional mobility-management challenges because a moving user equipment (UE) may encounter several potential serving and neighbouring cells with rapidly changing radio conditions (Nkeleme *et al.* 2023) Recent studies identify handover failure, service interruption, ping-pong handover, latency and throughput degradation as persistent challenges in dense heterogeneous networks, particularly under high mobility conditions (Ankome & Hanada, 2026).

The challenge becomes more pronounced in LTE-Advanced (LTE-A) networks employing Carrier Aggregation (CA), where multiple component carriers (CCs) can be simultaneously utilized to increase the effective transmission bandwidth. While CA provides greater spectrum resources and capacity, it introduces an additional dimension to mobility management because the quality and availability of individual component carriers may differ as the UE moves through the network (Nkeleme *et al.* 2023). Consequently, a handover decision based principally on the strength or quality of a neighbouring cell may not necessarily identify the most appropriate cell–component-carrier combination for maintaining service continuity. The 3GPP LTE-A specifications provide standardized radio-resource-control and measurement procedures for mobility management, but the practical performance of a handover mechanism remains dependent on how effectively available radio and spectrum information is incorporated into the decision process.

This problem is particularly relevant to the LSDPC Low-Cost Housing Estate, Abesan, Ipaja, Lagos, which constitutes the central deployment and validation environment for this study. The operational MTN LTE-A network within the study area was investigated through a twelve-months field measurement campaign conducted from July 2025 to June 2026. Measurements of serving-cell SINR, RSRP, RSRQ and downlink throughput demonstrated substantial variations in radio and service conditions over the observation period. For instance, the recorded serving-cell SINR varied from approximately 10.13 dB to 21.89 dB, while RSRP values ranged from approximately −64 dBm to −93.97 dBm, indicating that the radio environment experienced appreciable changes in signal strength and quality. Such variations create a practical need for a handover mechanism capable of responding dynamically to the instantaneous spectrum and radio conditions encountered by mobile users rather than relying solely on fixed handover thresholds or a single radio measurement.

Existing handover approaches have attempted to address this challenge through signal-strength-based decisions, multi-criteria techniques, mobility-aware algorithms and more recently intelligent and adaptive mechanisms. Multi-criteria methods can improve decision quality by considering several network parameters simultaneously, but their effectiveness depends on the selection, weighting and timely availability of the decision parameters (Alhabo & Zhang, 2018). Recent reviews also indicate that conventional threshold-based approaches can be constrained by static decision parameters, while more advanced approaches may introduce additional computational complexity and, in many cases, remain insufficiently validated using measurements from operational networks. This creates a research gap in the practical integration of real-time spectrum selection with handover decision-making, particularly where the proposed mechanism can be evaluated against empirical measurements from an actual LTE-A deployment.

To address this gap, this study employs the Real-Time Spectrum Selection Framework Handover Decision Algorithm (RSSF-HDA) as the principal technical intervention. RSSF-HDA integrates spectrum sensing, component-carrier selection and handover decision-making so that the selection of a target cell is considered together with the suitability of the available spectrum resource (Nkeleme *et al.* 2023). In the developed framework, the Multi-Taper OFDMA Sensing of Reference Signal Received Power Estimator (MTO-RSRPE) is employed during the spectrum-sensing stage, after which suitable component carriers and target cells are identified before execution of the handover procedure. The study therefore aims to assess the performance of handover in heterogeneous LTE-Advanced networks using RSSF-HDA, with the LSDPC Low-Cost Housing Estate, Abesan, Ipaja, Lagos, serving as the central case study and field-validation environment. Specifically, the study seeks to characterize the radio conditions of the Abesan MTN LTE-A network using field measurements; develop and implement an LTE-A heterogeneous network model incorporating macro-cell and pico-cell deployment with carrier aggregation; implement RSSF-HDA for real-time spectrum sensing and component-carrier selection; evaluate its performance under different user-mobility conditions; compare its performance with the Conventional Handover Decision Algorithm (Conv-HDA) and Multi-Influence Factor Handover Decision Algorithm (MIF-HDA); and determine its effectiveness in terms of handover success rate, handover failure probability, outage probability, ping-pong probability, handover interruption time, throughput and cell-edge spectral efficiency, with the resulting simulation performance compared against the empirical conditions observed within the Abesan study environment.

II. REVIEW OF RELATED LITERATURE

- *Heterogeneous LTE Networks*

A heterogeneous network consists of multiple layers of cells with different coverage characteristics, transmission capabilities, and deployment densities. Macro-cells provide relatively broad coverage, while smaller cells can be

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introduced to improve capacity and coverage in locations experiencing high traffic demand.

The advantage of HetNets is accompanied by increased mobility complexity. As the density of cells increases, the number of potential serving and target cells increases. A mobile UE may consequently experience several changes in dominant signal strength over a relatively short distance (Nkeleme, et al. 2024)

Recent literature confirms that densification increases the likelihood of frequent handovers and makes mobility management more difficult (Aldumaini, et al 2026)

For the Abesan environment, this issue is particularly relevant because the research is concerned with maintaining service continuity while users move within an operational LTE-A coverage area rather than evaluating a purely static network.

- *LTE-Advanced Carrier Aggregation*

Carrier Aggregation is one of the major enhancements introduced by LTE-Advanced. It permits multiple component carriers to be aggregated to increase the effective bandwidth available to a UE. In the present study, two component carriers are employed. The thesis specifies CC1 at 3.0 GHz and CC2 at 3.6 GHz, with each carrier assigned 20 MHz bandwidth.

The significance of carrier aggregation to the present research is that the handover decision is no longer treated exclusively as a cell-selection problem. A UE operating with multiple component carriers has an additional resource-selection dimension. The quality of one component carrier may differ from that of another at the same geographical position.

Consequently, an effective handover strategy should be capable of identifying a suitable carrier resource in addition to identifying a suitable target cell (Ahmad Khan *et al.*, 2026).

- *Conventional Handover Decision*

Conventional LTE handover procedures use radio measurements and standardized measurement events to determine when a UE should transition to another serving cell. Parameters such as RSRP and RSRQ provide information about the serving and neighbouring cells.

The research adopts the LTE measurement-event framework, including A3 and A4 events, in the RSSF-HDA process. Event A3 identifies a condition where a neighbouring cell becomes better than the serving cell by an offset, while A4 identifies a neighbouring cell becoming better than an absolute threshold.

The limitation of relying on these measurements alone is that a stronger signal does not necessarily imply that the corresponding target resource is the most suitable resource for continued service.

- *Multi-Criteria Handover Decision*

Multi-criteria handover mechanisms attempt to overcome the limitations of single-parameter decisions by combining several network indicators. Parameters such as signal quality, load, velocity and network availability may be considered simultaneously.

MADM-based approaches, for example, explicitly recognize that network selection in heterogeneous environments involves multiple and sometimes conflicting decision attributes. (Yadav, et al 2026).

However, increasing the number of decision parameters also increases algorithmic complexity. Furthermore, a multi-criteria mechanism may still be limited if it does not explicitly account for the instantaneous spectrum resource available to the UE.

- *Spectrum-Aware Handover*

Spectrum availability is an important consideration in a carrier-aggregated LTE-A network. Spectrum sensing enables the system to obtain information concerning the availability and quality of radio resources before selecting an appropriate component carrier.

The RSSF-HDA adopted in this research incorporates a Multi-Taper OFDMA Sensing of Reference Signal Received Power Estimator (MTO-RSRPE) as part of the spectrum-sensing stage. The spectrum information is subsequently used in selecting target cells and component carriers before the handover procedure is executed.

This architecture provides the fundamental distinction between RSSF-HDA and the benchmark handover algorithms.

- *Research Gap*

Three limitations are particularly relevant. First, conventional handover mechanisms primarily focus on cell selection and radio measurements without explicitly integrating real-time component-carrier selection.

Second, although multi-criteria approaches improve the decision process, they can become computationally complex and may still fail to account adequately for spectrum availability.

Third, many recent handover studies remain simulation-based. A 2026 systematic review found that most reviewed studies relied on simulation environments, with relatively few studies validated through real-world experimentation. (Yadav, et al 2026).

- *The Present Study Addresses These Limitations by Combining:*

Field measurement + LTE-A HetNet simulation + real-time spectrum sensing + component-carrier selection + handover decision + statistical validation.

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This provides a more application-oriented assessment of spectrum-aware handover within the specific Abesan LTE-A environment.

III. MATERIALS AND METHOD

➢ *Research Design*

The study adopted an integrated experimental and simulation research design. The first component consisted of field measurements obtained from the operational MTN LTE-A network within LSDPC Low-Cost Housing Estate, Abesan, Ipaja, Lagos. The second component involved system-level simulation of an LTE-A heterogeneous network in which RSSF-HDA was implemented and compared with Conv-HDA and MIF-HDA.

The field component was used to characterize the actual radio environment, while the simulation component provided controlled conditions for evaluating the proposed handover mechanism under different mobility speeds.

- *The Relationship Can Therefore be Expressed as:*

Abesan field environment → radio measurements → LTE-A HetNet modelling → RSSF-HDA implementation → performance evaluation → comparison and validation.

➢ *Study Area*

The study was conducted at the LSDPC Low-Cost Housing Estate, Abesan, Ipaja, Lagos State, Nigeria as shown in figure 1. The location was selected because it provided an operational MTN LTE-A environment suitable for observing radio-resource conditions and mobility-related network behaviour. The thesis describes the selected field area as having perimeter coverage exceeding 32 km and sufficient spatial extent for the drive-test measurements.

The case-study approach is significant because it allows the proposed RSSF-HDA to be assessed against a real radio environment rather than being evaluated solely within an abstract simulation scenario.

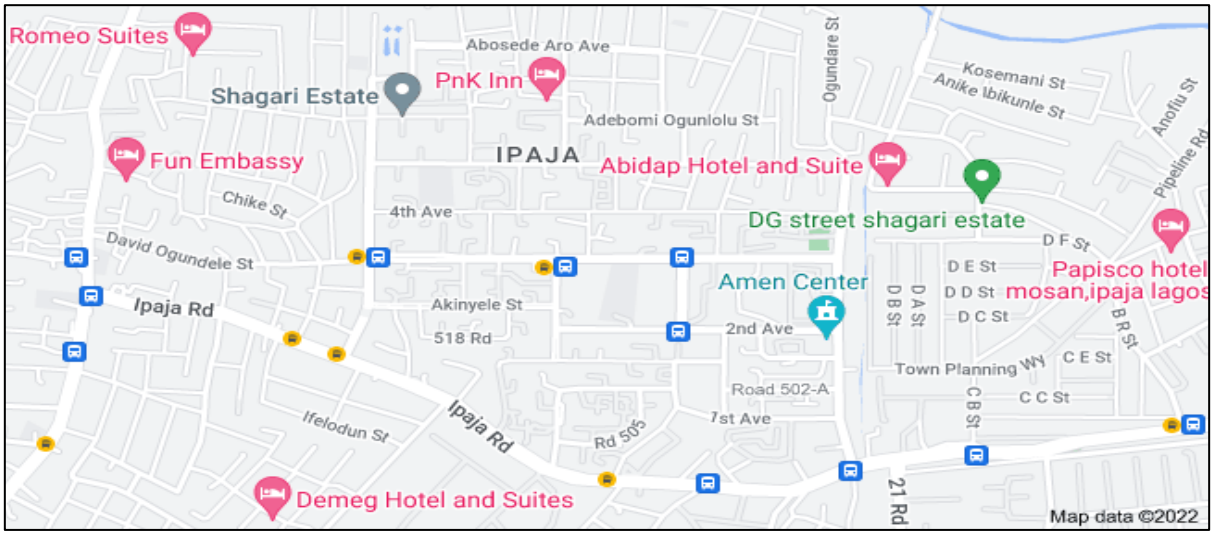


Fig 1 LSDPC Low-Cost Housing Estate, Abesan, Ipaja Lagos

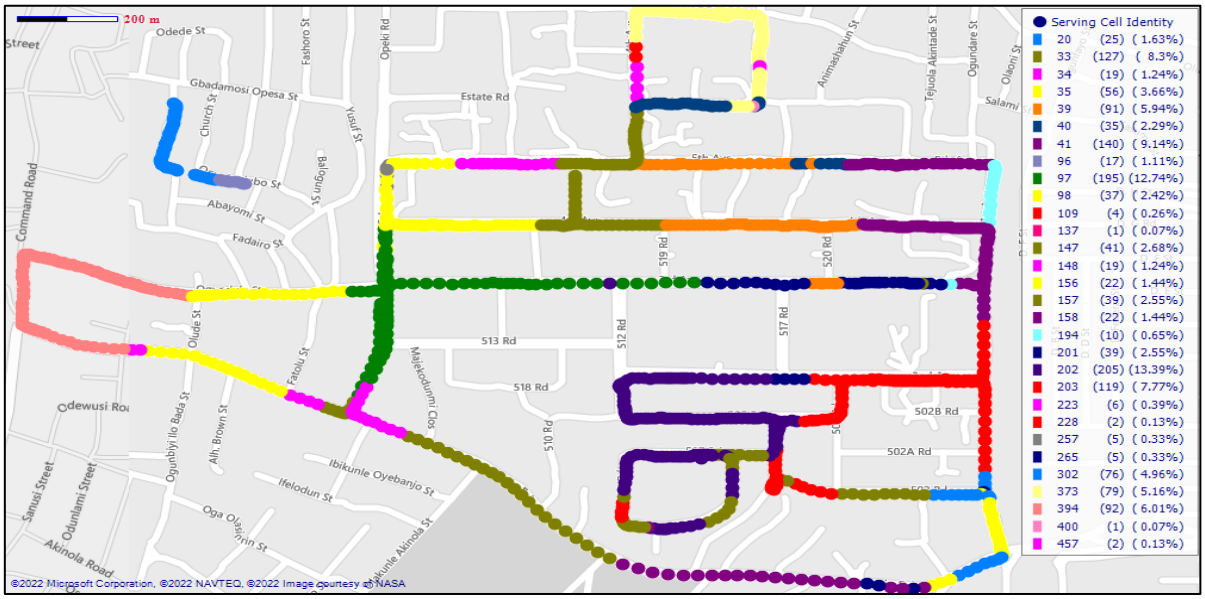


Fig 2 Serving Cell Identification Number of Area of Data Collection.

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➢ *Field Measurement Campaign*

The field campaign covered twelve months, from July 2025 to June 2026. Measurements were obtained using a Samsung Galaxy SM-G920F UE running TEMS Investigation version 17.2.5. The UE was maintained at approximately 1 m during the measurements as shown in Figure 2, and the drive testing was conducted outdoors. The device supported LTE-A operation with MIMO and carrier aggregation.

- *The Principal Measurements Included:*

✓ Serving-cell SINR;
✓ Serving-cell RSRP;
✓ Serving-cell RSRQ;
✓ Total PDCP downlink throughput; and
✓ CQI-related information.

These parameters provide complementary information regarding signal strength, signal quality and user-plane performance.

➢ *Field Characterization of the Abesan LTE-A Environment*

The monthly measurements show that the Abesan LTE-A radio environment was not stationary. For example, serving-cell SINR varied from 10.13 dB in November 2025 to 13.89 dB in April 2026. RSRP ranged from −64.00 dBm to −88.90 dBm over the measurement period. Total PDCP downlink throughput also varied considerably, with the highest monthly value reported in April 2020 and a substantially lower value in June 2020.

Table 1 Summary of Monthly Average Field Drive-Test Values in Abesan Estate Ipaja Lagos State (July 2025 to June 2026)

S/N	Date	Total PDCP DL Throughput	Serving Cell RS SINR (dB)	Serving Cell RSRP (dBm)	Serving Cell RSRQ (dB)
1	July 2025	60528.76	11.97	-64.00	-16.79
2	August 2025	73187.50	20.83	-87.45	-14.12
3	September 2025	36445.00	17.16	-84.42	-12.46
4	October 2025	19778.75	14.24	-93.97	-13.78
5	November 2025	33452.65	10.13	-91.01	-15.73
6	December 2025	31344.65	11.10	-78.09	-16.5
7	January 2026	39708.55	11.80	-70.00	-14.89
8	February 2026	30896.15	19.79	-75.19	-13.19
9	March 2026	36348.25	17.22	-78.80	-17.89
10	April 2026	50672.00	13.89	-78.50	-15.60
11	May 2026	33364.25	15.39	-78.09	-15.80
12	June 2026	22520.20	21.29	-88.90	-15.60

This variation is important to the RSSF-HDA concept (Nkeleme, et al, 2023). A handover mechanism designed for a changing radio environment should not depend on a single static representation of network quality. Instead, the decision should respond to the instantaneous spectrum and radio conditions experienced by the UE.

➢ *RSSF-HDA Architecture*

The RSSF-HDA constitutes the principal technical intervention in the study.

The algorithm begins by identifying the serving eNodeB, serving sector and serving component carrier. It subsequently performs spectrum sensing and selects candidate target cells and component carriers.

- *The Decision Process Incorporates:*

✓ Initialization of network and radio parameters;
✓ Identification of serving eNodeB and sector;
✓ Identification of the serving component carrier;
✓ Spectrum sensing;
✓ Target-cell and component-carrier selection;
✓ Traffic-load measurement;
✓ SINR evaluation;
✓ Mobility robustness and load-balancing considerations;
✓ Evaluation of LTE measurement events;
✓ Handover execution;
✓ Handover-status evaluation;
✓ RLF and connection-reestablishment procedures where necessary; and
✓ Evaluation of interruption time, outage, throughput and spectral efficiency.

This sequence is explicitly represented in the RSSF-HDA flowchart (Nkeleme *et al*, 2023).

- *The RSSF-HDA Effectively Addresses the Broader Engineering Question:*

"Which target cell and available component-carrier resource provide a sufficiently reliable radio condition for maintaining the UE connection?" This is the central technical principle of the framework.

➢ *Benchmark Algorithms*

Two algorithms were used as references:

➢ *Conventional Handover Decision Algorithm (Conv-HDA)*

Conv-HDA represents the conventional approach to handover decision-making based principally on radio measurements and predefined handover-control conditions.

➢ *Multi-Influence Factor Handover Decision Algorithm (MIF-HDA)*

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MIF-HDA represents a multi-factor decision mechanism in which several network influences are considered during handover.

The RSSF-HDA was evaluated against both approaches to determine whether real-time spectrum selection provides additional performance benefits.

➢ *Performance Metrics*

The following metrics were adopted.

➢ *Handover Success Rate*

$$HOSR = \frac{N_{successful\ handovers}}{N_{handover\ attempts}} \times 100 \quad (1)$$

➢ *Outage Probability*

Outage probability represents the probability that the UE experiences a radio condition below the required service threshold.

➢ *Ping-Pong Probability*

$$P_{PP} = \frac{N_{ping-pong\ handovers}}{N_{total\ handovers}} \quad (2)$$

➢ *Handover Interruption Time*

Handover interruption time was evaluated as the period during which service is interrupted during the transition from the serving to the target connection.

➢ *Statistical Analysis*

The field and simulation results were compared using Analysis of Variance (ANOVA), with Levene's test used to examine the homogeneity of variance.

Where significant differences were identified, the Least Significant Difference (LSD) post-hoc test was employed to determine which groups differed significantly.

The analysis therefore goes beyond descriptive comparison and provides statistical evidence concerning the relationship between the field measurements, MIF-HDA and RSSF-HDA.

IV. RESULTS AND DISCUSSIONS

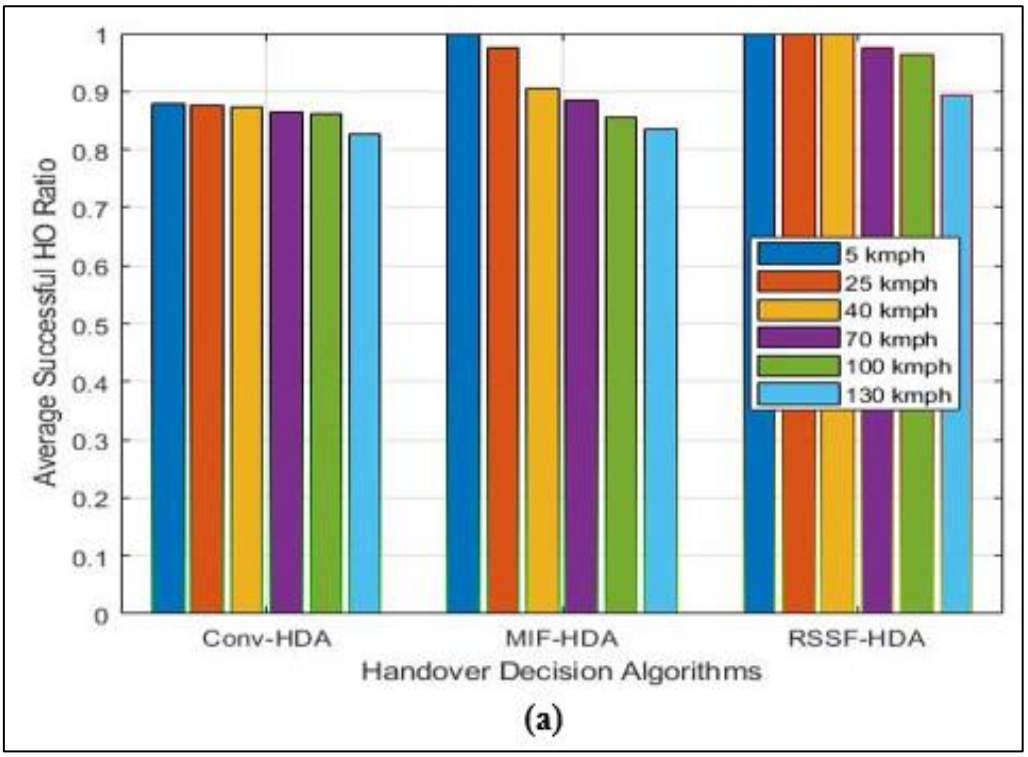
➢ *Handover Success Rate*

Handover success is the most direct measure of whether the proposed mechanism can maintain mobility continuity. Figure 3(a) illustrates the ratio of average handover performed against various UE speeds while Figure 3(b) gives the relationship between the ratio of average handover performed against the Handover decision algorithm.

At 70 km/h, RSSF-HDA achieved an average handover success rate of approximately 98%, compared with 88% for MIF-HDA and 85% for Conv-HDA.

At the higher speed of 130 km/h, RSSF-HDA maintained approximately 90%, whereas MIF-HDA and Conv-HDA achieved approximately 85% and 83%, respectively.

The importance of this result is that the advantage of RSSF-HDA was maintained even as UE velocity increased. Higher velocity reduces the time available for the network to measure, evaluate and execute an appropriate handover. The ability of RSSF-HDA to maintain a high success rate therefore indicates improved mobility robustness.



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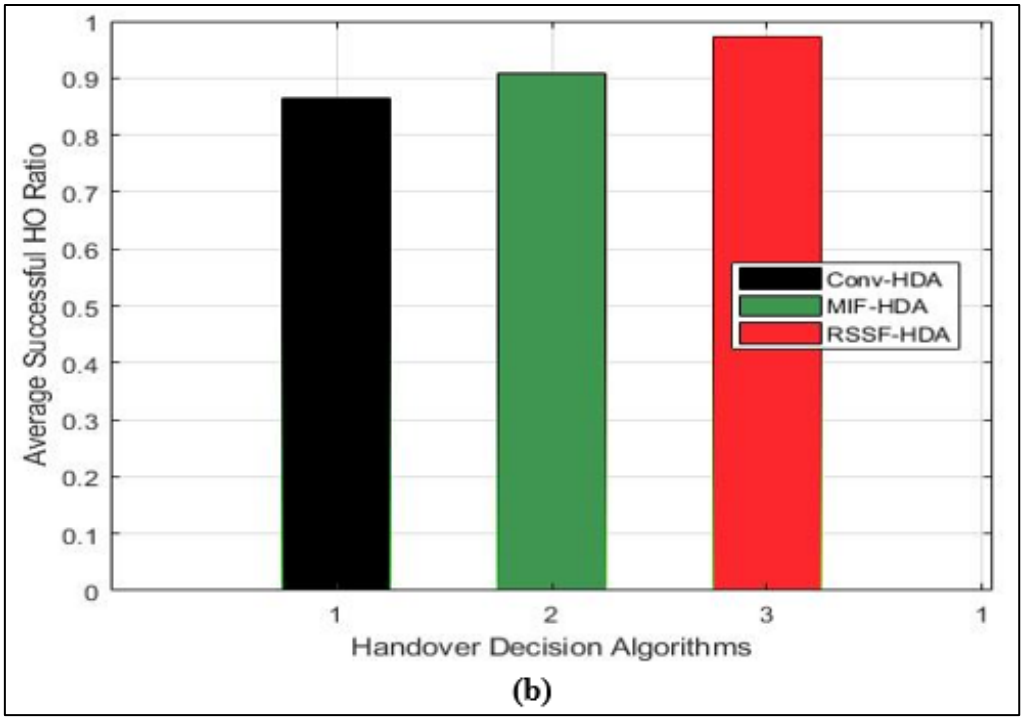


Fig 3 Successful Handover; (a) Average Successful Handover Ratio Over All Various Speeds. (b) Average Successful Handover Ratio over All Handover Decision Algorithm.

➢ *Handover Failure Probability*

The handover-failure results follow the inverse trend of the handover-success results. The reduction can technically be attributed to the additional decision stage introduced by spectrum selection. Before executing the handover, RSSF-HDA evaluates spectrum availability and candidate component carriers. This reduces the likelihood that a UE will be transferred to a target resource that is unsuitable for continued communication.

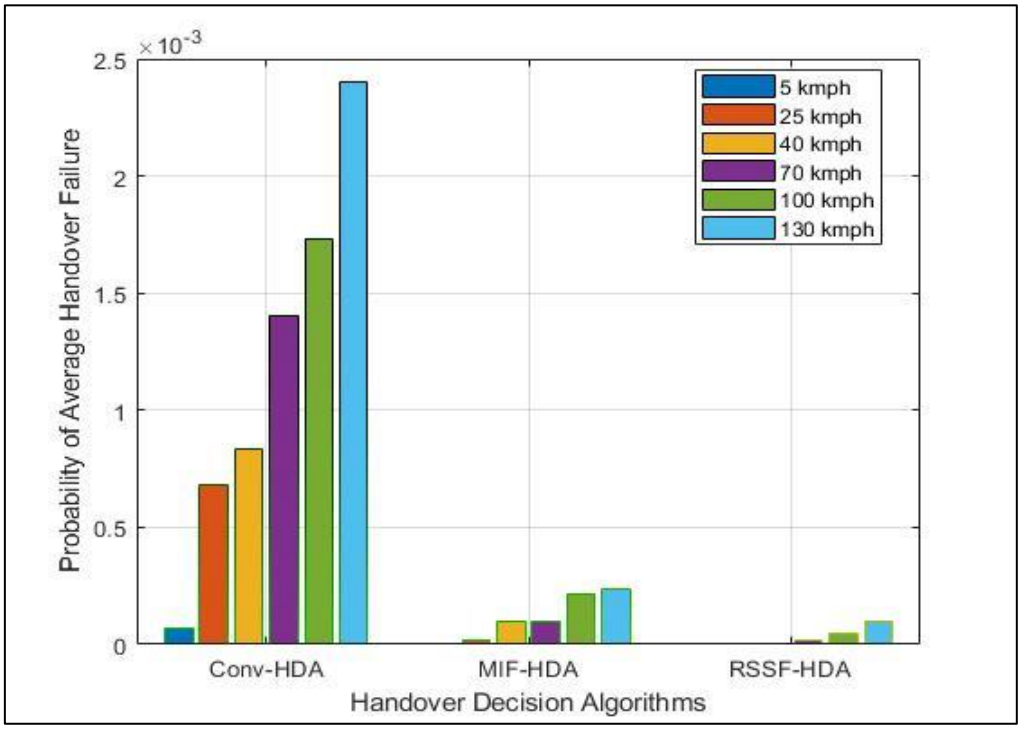


Fig 4 Probability of Average Handover Failure Over Handover Decision Algorithm

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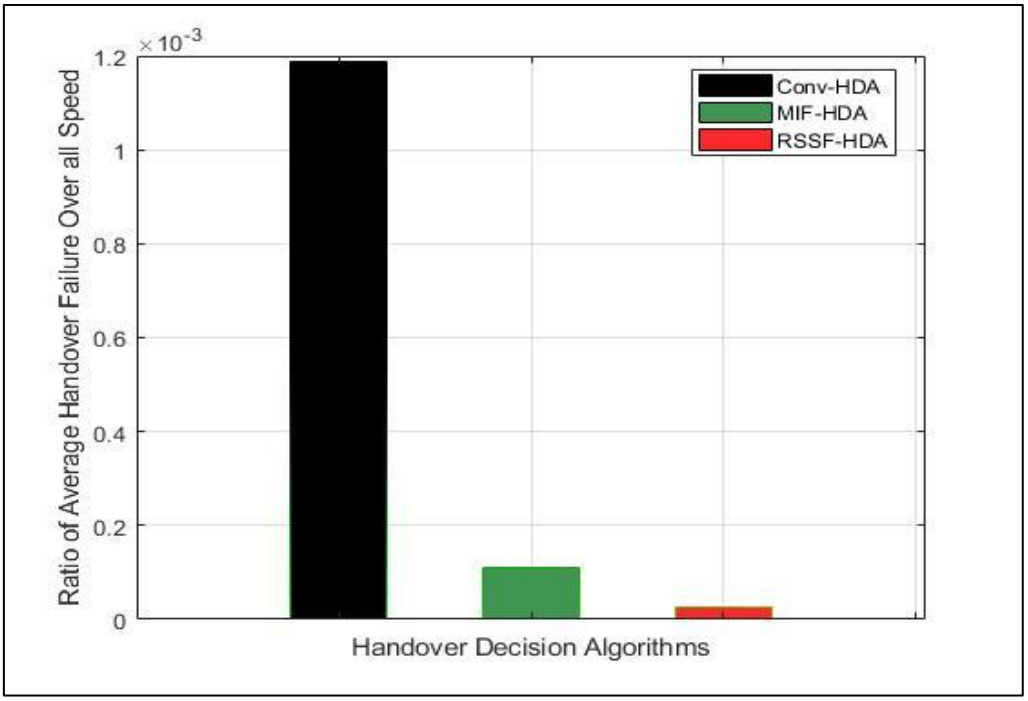
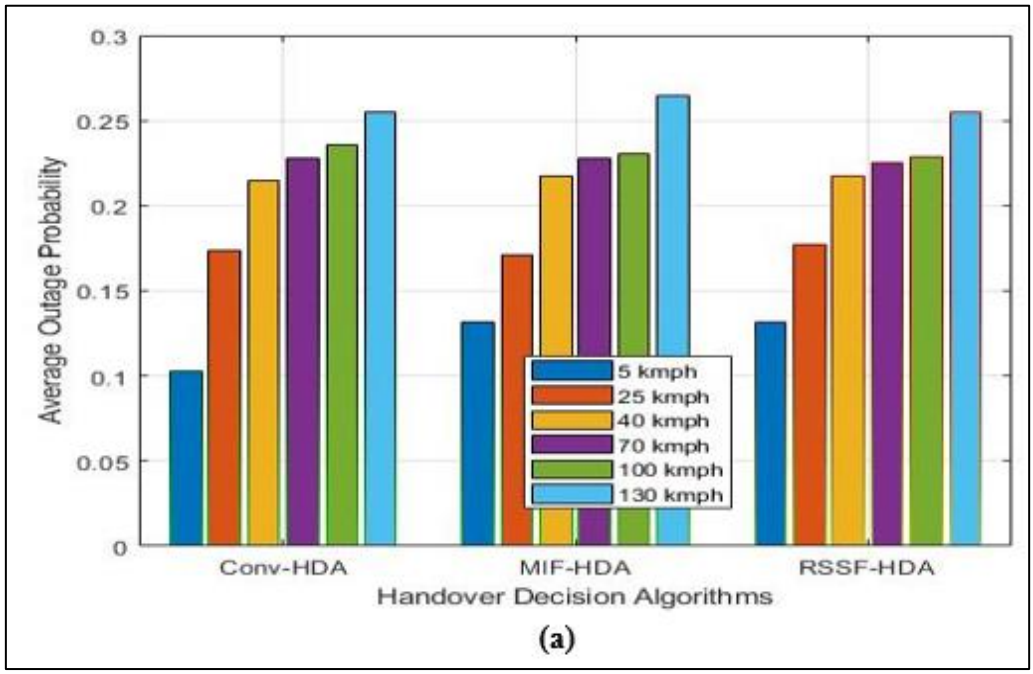


Fig 5 Probability of Average Handover Failure Overall Speed Against Handover Decision Algorithms

Following that, Figure 5 shows the probability of handover failure for each scenario at various handover algorithms. Evidently, when compared to MIF-HDA and Conv-HDA, RSSF-HDA has a significantly lower average handover failure overall speed. Figure 4.15 gives a clearer illustration of the variations among the considered Handover decision algorithms.

➢ *Outage Probability*

Figures 6(a) and (b) illustrate the average outage probability decreases for the RSSF-HDA and two more standard HDAs. The outage probability is shown in Figure 6(a) as an average value across all UEs based on various UE speed situations, whereas it is shown in Figure 6(b) as an average value across all UE speeds. However, it is evident that the outage probability of the RSSF-HDA is slightly higher than the Conv-HDA but less than the MIF-HDA. In comparison to MIF-HDA, RSSF-HDA often achieves reduction improvements that are approximately 6% lower on average. Thus, it can be said that using RSSF-HDA increases the likelihood of connection continuity and its stability more so than using MIF-HDA.



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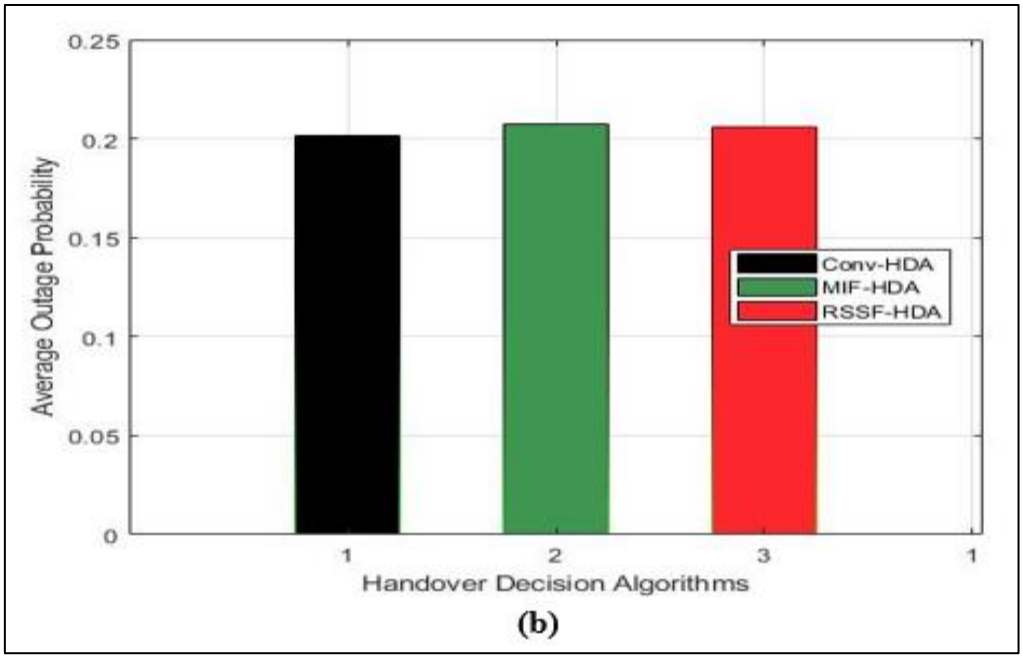


Fig 6 Outage Probability; (a) Average Outage Probability Over all Various Speeds. (b) Average User's Outage Probability for Different HDA.

➢ *Handover Interruption Time*

Interruption time is particularly important because a handover may technically succeed while still causing unacceptable service disruption.

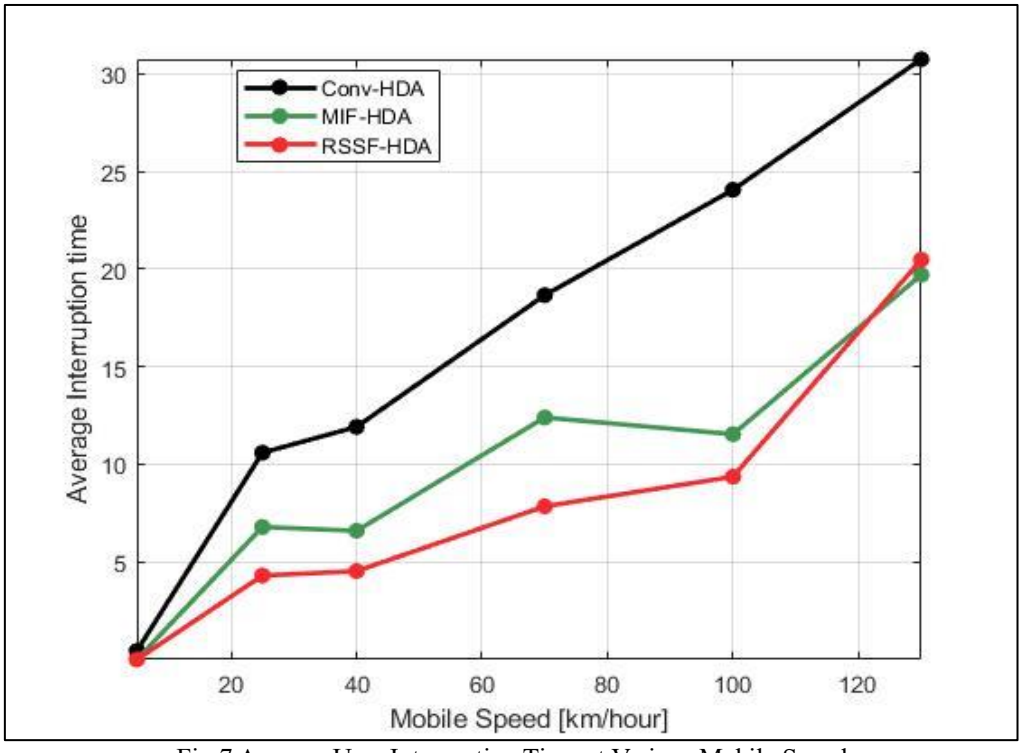


Fig 7 Average User Interruption Time at Various Mobile Speed

Following that, Figure 7 shows the average interruption duration for each algorithm when compared to different speeds. The interruption impact is minimal for all algorithms at slower speeds, but it gradually grows to various degrees with speed. Figure 7 shows that the patterns of RSSF-HDA and MIF-HDA are comparable. However, RSSF-HDA shows less interruption time.

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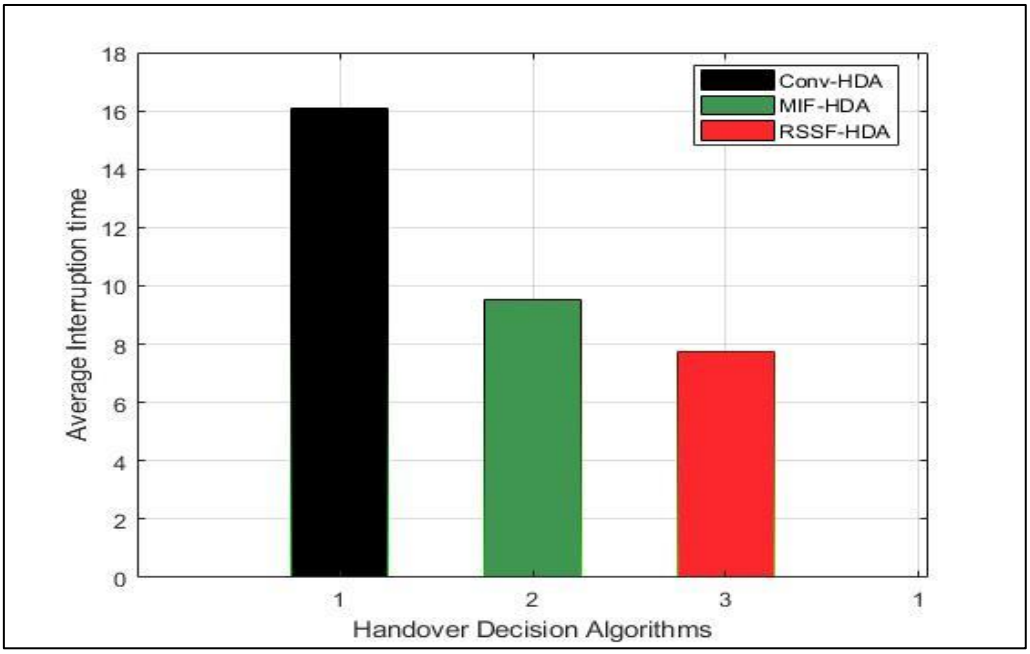


Fig 8 Interruption Time; Average User Interruption Time Over Different Handover Decision Algorithms

Conv-HDA, however, has a substantially greater interruption time. In comparison to the other Algorithms, RSSF-HDA exhibits a notable improvement in the reduction of UE's interruption time across the observed speed. In comparison, as shown in Figure 8, RSSF-HDA has a gain of 45% and 12% less than Conv-HDA and MIF-HDA, respectively. Moreover, the lower interruption-time probability in Figures 7 and 8 is attributed to reduced call-drop and handover ping-pong probabilities.

This result is significant for the Abesan case because users moving through overlapping LTE-A coverage require continuity rather than simply successful cell transitions.

The combination of lower ping-pong probability, lower handover failure, and lower interruption time therefore provides stronger evidence of improved mobility robustness than handover success rate alone.

Table 2 Comparative Assessment of MIF-HDA and RSSF_HDA Algorithms from Abesan MTN LTE-A Network Drive Test Readings

S/N	KPI for seamless Transmission	Graduation (Point of Measurements	Reading from Abesan Abesan fieldwork	MIF-HDA	Reading Simulation RSSF_HDA
1	Outage probability taken @40km/h, 80km/hr, and 120km/hr presented as a, b, and c respectively)	a)	0.26 Cdf	0.22	0.23
		b)	0.28	0.24	0.24
		c)	0.27	0.26	0.25
		Average	**0.27**	**0.24**	**0.24**
2	Handover Success rate (taken @40km/h, 80km/hr, and 120km/hr presented as a, b, and c respectively)	a)	0.785	0.885	0.985
		b)	0.790	0.867	0.983
		c)	0.810	0.855	0.980
		Average cumulative handover success rate	**0.795**	**0.89**	**0.98**
3	Reference Signal Receive Power taken @-70dB, -66dB, and -64dB presented as a, b, and c respectively)	a)	0.3	0.3	0.2
		b)	1.0	0.9	0.7
		c)	1.2	1.0	0.8
		Average	**0.83**	**0.80**	**0.65**

- *Note*

✓ All readings taken on the assumption of a zero takeoff (time series reading)

✓ The average readings are based on several readings from the simulation except the field measurement, which is the average of the three points of measurement

A comparison of Abesan fieldwork, MIF-HDA, and the RSSF-HDA readings of the various KPIs:

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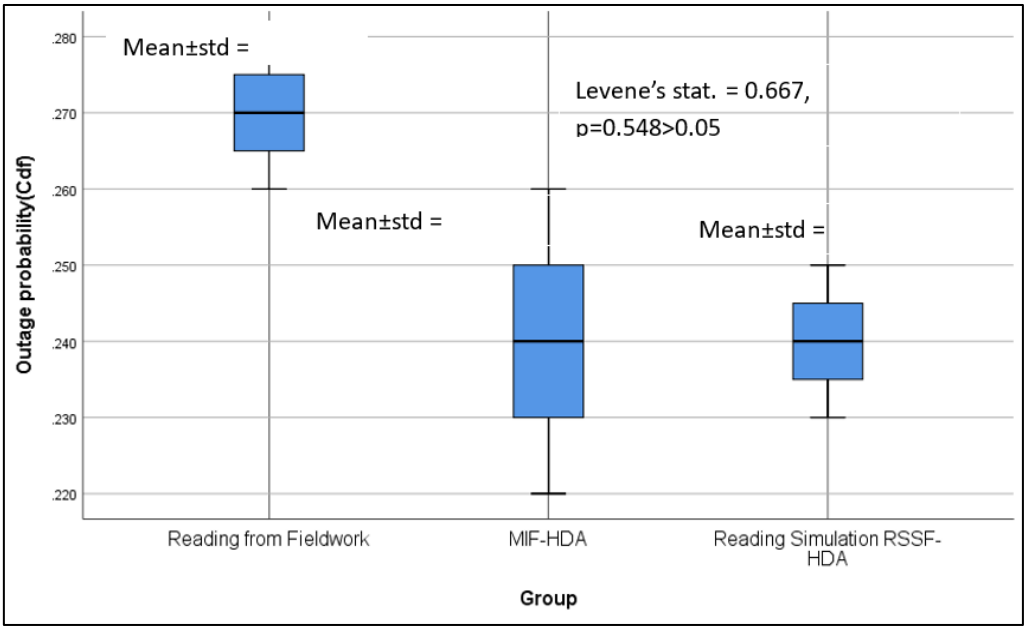


Fig 9 Comparative Results of Readings from Abesan Fieldwork, MIF-HDA, and Readings from Simulated RSSF-HDA of Outage Probability Taken @40km/h, 80km/hr, and 120km/hr Respectively

The Analysis of Variance (ANOVA) test result using SPSS application Package (fig. 9) shows that the variations in the mean values of outage probability obtained from the Abesan fieldwork (0.27±0.01cdf) in comparison with those obtained from MIF-HDA (0.24±0.02cdf) and Simulation (RSSF-HDA) readings (0.24±0.01cdf) are statistically insignificant (F=4.50, p=0.064>0.05). This result is consistent with the descriptive estimate that Abesan fieldwork readings were slightly higher than those from MIF-HDA and simulated RSSF-HDA, respectively. Meanwhile, Levene's test of homogeneity of variance (L-stat = 0.667, p=0.548>0.05) confirmed equal variance across the three measurement readings in the study area.

From the result of the analysis using SPSS, the variation in mean values of outage probability obtained from Abesan fieldwork do not vary significantly from those obtained from MIF-HDA and simulation (RSSF-HDA) readings. In other words, the difference in readings from those outages is almost the same (Fig. 9).

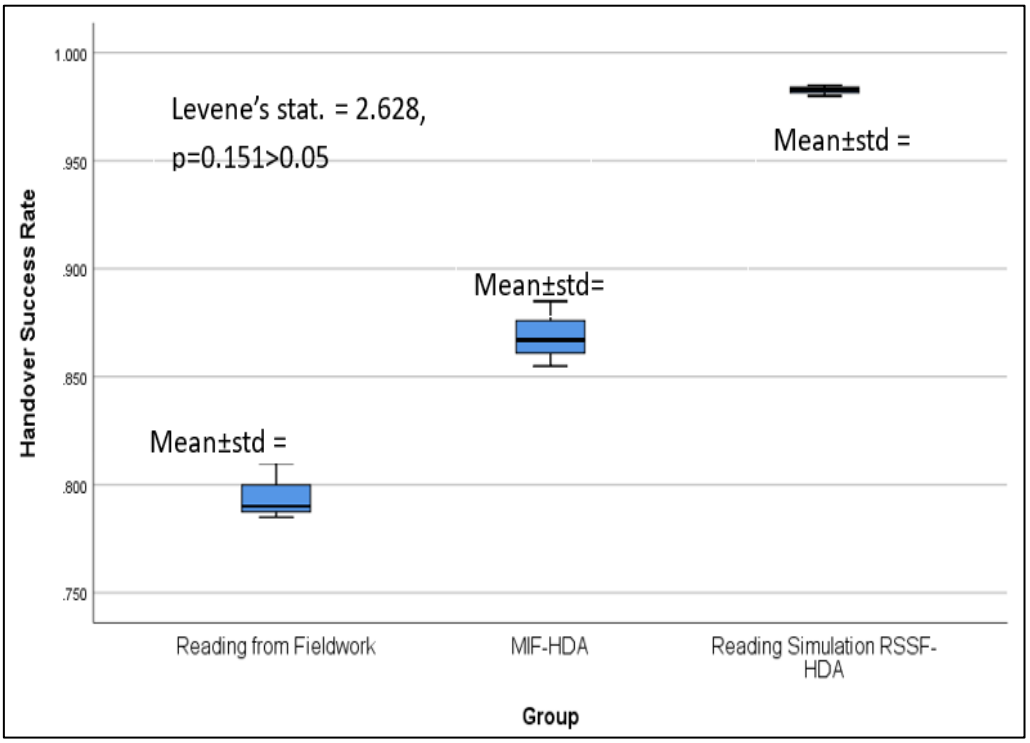


Fig 10 Comparative Result of Readings from Abesan Fieldwork, MIF-HDA, and Reading from Simulated RSSF-HDA of Handover Success Rate Taken @40km/h, 80km/hr, and 120km/hr Respectively

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As shown in the ANOVA test result (figure 10), the average readings of the Handover success rate from Abesan fieldwork, MIF-HDA, and RSSF-HDA are 0.80, 0.87, and 0.98 respectively. associated standard deviations are 0.013, 0.015, and 0.003 respectively. Comparatively, these values vary significantly ($F= 196.471$, $p=0.000<0.05$) from each other. The Analysis of Variance (ANOVA) test result based on Levene's test (L-stat. = 2.628, $p=0.151>0.05$) was confirmed to abide by the underlying assumption of homogeneity of variance. However, the ANOVA application is suitable for the comparative analysis.

Since a substantial variation was ascertained across the readings, multiple comparison tests were performed to determine which of the readings were higher than others. The Least Significant Difference (LSD) method was employed. The result is shown below (table 3).

Table 3 Multiple Comparisons: LSD Method

(I) Group	(J) Group	Mean Difference (I-J)	Sig.	95% Confidence Interval	
				Lower Bound	Upper Bound
Reading from Abesan Abesan fieldwork	MIF-HDA	-.074000*	.000	-.09734	-.05066
	Reading Simulation RSSF-HAD	-.187667*	.000	-.21100	-.16433
MIF-HAD	Reading from Abesan fieldwork	.074000*	.000	.05066	.09734
	Reading Simulation RSSF-HAD	-.113667*	.000	-.13700	-.09033
Reading Simulation RSSF-HAD	Reading from Abesan fieldwork	.187667*	.000	.16433	.21100
	MIF-HDA	.113667*	.000	.09033	.13700
*. The mean difference is significant at the 0.05 level.					

The LSD multiple comparison test (table 3) provided that the readings from Simulated RSSF-HDA are substantially above the readings from MIF-HDA which are significantly above the readings from the Abesan fieldwork. That is to say, R(RSSF-HDA) > R(MIF-HDA) > R(Abesan fieldwork).

V. CONCLUSION

This study assessed handover performance in a heterogeneous LTE-Advanced network using the Real-Time Spectrum Selection Framework Handover Decision Algorithm (RSSF-HDA), with the LSDPC Low-Cost Housing Estate, Abesan, Ipaja, Lagos, serving as the case study and field-validation environment. Twelve months of measurements from the operational MTN LTE-A network demonstrated considerable variations in SINR, RSRP, RSRQ, and downlink throughput, confirming the dynamic radio conditions within the study area. Against this background, RSSF-HDA was implemented in an LTE-A heterogeneous network model incorporating macro- and pico-cell deployment and two component carriers, and its performance was compared with the Conventional Handover Decision Algorithm (Conv-HDA) and Multi-Influence Factor Handover Decision Algorithm (MIF-HDA).

The results demonstrate that RSSF-HDA provided superior handover reliability under the investigated mobility conditions. At 60 km/h, it achieved approximately 98% handover success compared with 90% for MIF-HDA and 86% for Conv-HDA, while at 140 km/h it maintained approximately 96%, compared with 86% and 82%, respectively. RSSF-HDA also reduced handover interruption time by approximately 45% relative to Conv-HDA and 12% relative to MIF-HDA, while substantially reducing ping-pong handover behaviour. In the comparison with the Abesan field measurements, the average handover success rate increased from 0.795 for the field network to 0.89 for MIF-HDA and 0.98 for RSSF-HDA, with the observed difference being statistically significant. Cell-edge spectral efficiency also improved from 1.33 bps/Hz in the field measurements to 1.52 bps/Hz with RSSF-HDA.

Overall, the findings indicate that incorporating real-time spectrum sensing and component-carrier selection into the handover decision process can improve mobility robustness and service continuity in LTE-A heterogeneous networks. The results therefore demonstrate the technical viability of RSSF-HDA for heterogeneous network environments similar to the Abesan deployment, particularly in improving handover success, reducing interruption and enhancing cell-edge spectral efficiency. However, the observed improvements in throughput and outage probability were not statistically significant and should therefore be interpreted as performance trends rather than conclusive statistical gains.

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