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Development of an Enhanced Fuzzy-Logic Based Algorithm for Improved Handoffs in Long Term Evolution (Lte) Systems

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ABSTRACT: High data speed rate and improvement in user mobility is a vital parameter for the Long Term Evolution (LTE) systems since it is meant to support high data rates at various mobile. With increasing speed, the handover procedure are increasingly becoming fast; consequently, improvement in handover performance is becoming essential for real time services. Conventionally, there are default conditions for triggering the handover procedure in LTE systems, which is aimed at decreasing the total number of handovers and ping pong effect, and also having a fast and seamless handover. To maintain a seamless and unbroken link between the Mobile Station and the base station in a cellular network, improved handoff algorithms are essential to keep QoS as high as possible. In this thesis, a fuzzy logic based handoff algorithm was developed to account for integral metrics such as speed, angle of motion, distance and Reference Signal Received Power (RSRP) which are not usually fully considered by most algorithms. Simulation result showed that for 1 UE/cell with a UE speed of 3Km/hr, 30Km/hr and 120Km/hr respectively, the developed fuzzy logic based algorithm reduced the total number of handoff event triggered by 50%, 46.7% and 43.8% respectively when compared to the conventional method. The developed algorithm achieved up to 17.2% reduction in the cost associated with false handoff initiation with the smallest delay in all the speed levels considered. Simulation results show that the developed algorithm is effective as it is able to take handoff decision only when it is necessary and alleviates the ping pong effect. The algorithm is innovative because of its simplicity and low computational cost.

KEYWORDS: Handoff, Fuzzy logic, LTE.

I. INTRODUCTION

Currently, the world is witnessing a proliferating increase in mobile communication traffic given the rapid growth of mobile devices. Service providers are constantly innovating and improving their services to help meet the future requirements of data speed, coverage and capacity. The Third Generation Partnership Program (3GPP) defined Long Term Evolution (LTE) as a radio access technology that enables high-speed data communications of up to 150 Mbps, and also supports the ever-increasing demand for mobile broadband services. Mobility enhancement is an important aspect for the Long Term Evolution technology since it is meant to support mobility for various mobile speeds up to 350km/h or even up to 500km/h. With the moving speed even higher, the handover procedure will be more frequent and fast; therefore, the handover performance becomes more crucial especially for real time services [1].

One key aspect of LTE or any wireless system is to provide fast and seamless handover from the source cell to the target cell. It is expected that the communication link is maintained during the handover procedure, and the data transfer process should not be delayed or lost. Failure to do this would degrade the system performance. This is applicable to LTE systems which are distributed in nature and consists of just one type of node (or base station), known as the eNodeB (eNB) [1].

In mobile cellular networks, the movement of users from one point to another remains a constant, and with the desire to ensure a continuous and optimal access to services, hence, the initiation of the handoff process. The handover takes place only when the UE almost loses its signal strength from the serving cell. It is worthy to note that though the movement of the mobile user away from the coverage area of base station may warrant a drop in the RSRP value, it is not the only factor that could lead to this, as there are many other factors even within a coverage area which could lead to this, hence, the reliance on this metric leads to indiscriminate handoffs which in themselves have inherent consequences such as wastage of bandwidth, increase in system load, call blocking and call termination, packet loss, etc.

It is also important to note that even though the conventional handover method tries to solve the problem of high number of unnecessary handoffs by introducing a delay, yet, it is important that consideration is made of other critical metrics such as the distance between the User Equipment (UE) and the Evolved Node B (eNB), Angle of motion, and the speed of the UE in the handoff decision making so as to improve the performance of the existing system. New and better handoff algorithms are needed to keep QoS as high as possible. Handoff algorithms, based on soft computing techniques such as Fuzzy Logic, Artificial Neural Networks, genetic algorithms, probability theory, etc can be used for the same purpose [2]. Fuzzy logic is a computational approach that is based on ‘degrees of truth’ rather than on Boolean logic (i.e “true or false”, 1 or 0, high or low, etc) which the modern computer is based upon. The fuzzifier transforms real-time measurements into fuzzy sets. For instance, if the received signal strength of a mobile is considered in crisp set, it can be said to be either weak or strong. However, in fuzzy logic, the signal can be referred to as slightly weak, very weak, very strong or strong. The membership values for these are obtained by mapping the values obtained for particular parameter into a membership function [3]. The aim of this work is to develop an enhanced fuzzy logic based algorithm for improved handoff in LTE systems..

II. HANDOFF IN MOBILE COMMUNICATION NETWORKS

Handoff (or Handover) is the process of transferring the point of attachment of a Mobile Station (MS) to the network from a Base Station (BS) to another BS as the MS moves from the region of coverage of the initial serving BS to the coverage region of the target BS. This is usually required to be seamless and continuous, so that the on-going communication is not dropped, and the user does not experience a poor QoS [4]. In cellular telecommunications, handoff is the process of transferring an ongoing call or data session from one channel connected to the core network to another channel. Handoff schemes that are poorly designed usually generate very heavy signalling traffic and, thus decrease the system QoS. Since neighbouring cells are always using a disjoint subset of frequency bands, handoff are necessary to carryout negotiations between the mobile station, the current serving base station, and the next potential base station.

In the work by [5], an ANN based pattern recognition handover algorithm for micro-cellular systems was developed. The received signal strength was used for making handover decision. The handover protocol in Long Term Evolution was modified in the work by [6]. This was achieved by implementing a tabular temporal difference Learning concept. This is a reinforcement learning algorithm which guides network in selecting the next eNodeB to which the User Equipment will get connected to when signal strength of current eNB reduces and when there are more than one option available for handover by first calculating the reward R and then taking decision as per signal strength and recommendations of tabular Temporal Distancing based reinforcement algorithm. [7] developed a delay sensitive protocol for LTE-A systems based on the neuro-fuzzy optimization process and tracking area partitioning into no handover region, low probability handover region and high probability handover region that facilitated advance buffering of the figures of merit. [8] worked on the minimization of number of handoffs using GA in heterogeneous wireless networks. [9] developed a fuzzy logic based decision making algorithm to optimize the handover performance in heterogeneous networks. [10] developed an intelligent handover decision based on fuzzy logic for heterogeneous wireless networks. [11] presented an enhanced handover mechanism using mobility prediction (eHMP) to assist mobile devices in the handover process so that users can experience seamless connectivity.

Handoffs are classified into two categories namely hard and soft handoffs. Hard handoff is divided into two groups namely: Intra- and Inter cell handoffs. Also, soft handoff is also classified into two categories, which are multiway soft handoffs and softer handoffs.

a. Hard Handoff

Hard handoff can be described as a “break before make” connection. Under the control of the Mobile Switching Centre (MSC), the BS hands off the MS’s call to another cell, then drops the call. In this scheme, the link to the prior BS is usually severed before the user is transferred to the new cell’s BS. In hard handoff, the MS cannot be linked to more than one BS at a time.

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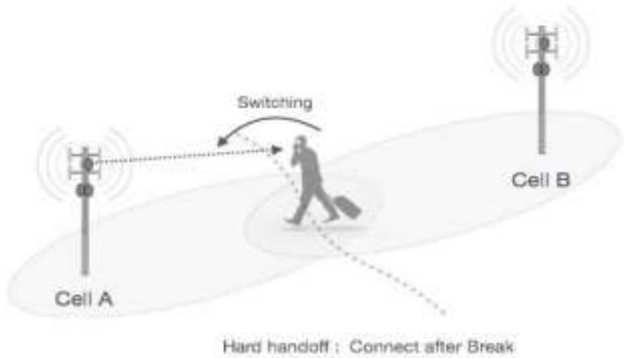

Fig. 1Hard Handoff Scenarios [12]

b. **Soft Handoff**

A soft handoff is essentially a "make before break" connection. The MSC makes a conditional decision to handoff a call from one base station to another, but it only executes the handoff after is has ascertained the signal strengths of the available base stations; the MS is linked to more than one BS at any given time, then it hands off to the base station with the best signal strength amongst other service criteria before it drops the call on the other base station, hence it 'connects before breaking'.

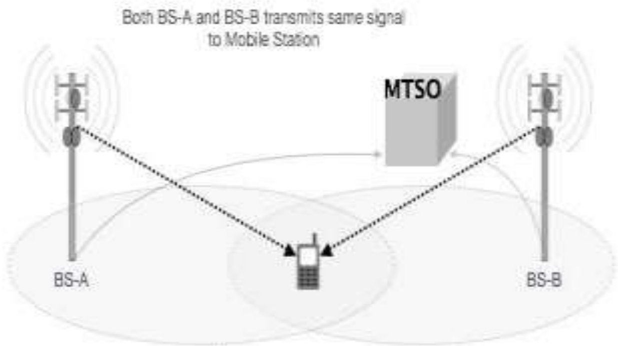

Fig. 2 Soft Handoff Scenarios [12]

III. HANDOVERS IN LTE NETWORK

The handover procedure and mechanism as specified by 3GPP LTE consists of the following steps:

i. UE measures signal strength in downlink
ii. Measurement reports are prepared at the UE
iii. UE sends these reports to the serving cell
iv. Handover decision is made at serving cell using measurement reports of the UE.

The handover process takes place in 3 phases namely:

1. **Handover preparation phase:** This phase consists of the source eNB and target eNB preparing themselves before the handover takes place. The main message and process are as follows:
   i. Measurement control: The source eNB configures the UE measurement procedures.
   ii. Measurement report - The UE periodically sends measurement report message to serving eNB.
   iii. Handover decision - The serving eNB makes the handover decision based on the UE measurement reports.
   iv. Handover request - Once a decision is made to handover then this message is sent to the target eNB asking it to prepare itself for the soon arrival of UE.
   v. Admission control - The target eNB checks if it can admit the handover request based on the QoS requirements.
   vi. Handover Request Acknowledge - If admission control is successful, then the target eNB notifies the serving eNB with this message. It will contain certain parameters required for the UE to attach to the target eNB.
   vii. Handover command - This message is sent to the UE by the serving eNB to trigger the handover.

2. **Handover execution**: This phase consists of the actual handover process. The process is as follows:
   i. SN Status Transfer - This is used to convey the uplink Packet Data Convergence Protocol Sequence Number (PDCP SN) receiver status and the downlink PDCP SN transmitter status of E-UTRAN Radio Access Bearer (E-RABs).
   ii. Synchronization - This involves the UE attaching itself with the target eNB.
   iii. Uplink (UL) Allocation + TA - The target eNB sends the timing advance (TA) to the UE and allocates it uplink resources.

3. **Handover completion:** This phase involves notifying the nodes in Evolved Packet Core (EPC) about the handover and cleanup of resources which will no longer be used. The process is as follows:
   i. Handover confirm - The UE indicates the confirmation of the handover.
   ii. Path switch request – The Mobility Management Entity (MME) is notified of UE's change of cell.
   iii. User plane update request - The MME informs the Serving gateway (S-GW) about the change of cell by the UE.
   iv. Switch downlink path - The S-GW notes this change.
   v. User plane update reply - The S-GW then responds to the MME after the change is incorporated.
   vi. Path switch response - The MME responds to the target eNB once the path has been switched in the S-GW.
   vii. Release resource - This is sent to inform the source eNB to release resources reserved for the UE.
   viii. Release resources - The serving eNB releases related radio and control resources.

IV. FUZZY LOGIC SYSTEM

Fuzzy logic systems mimic human knowledge to give the fuzzy or linguistic descriptions a definite structure. The popular Fuzzy Logic System (FLS) configurations that are commonly used include - pure FLS, Takagi and Sugeno's fuzzy system, and Mamdani's fuzzy system. The FLS proposed by Mamdani has the following components - fuzzifier, fuzzy rule base, fuzzy inference engine, and defuzzifier. This is shown in Figure 3.

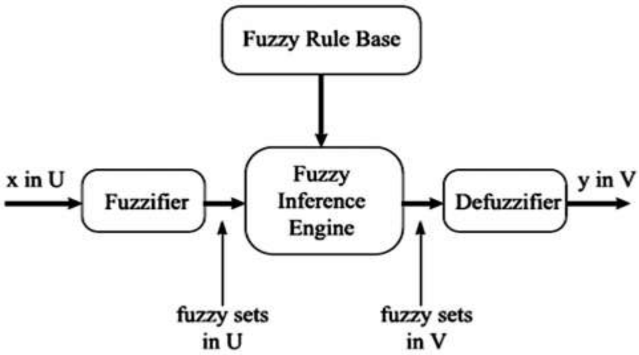

Fig.3 A Generalized Example of Fuzzy Logic System [13].

The fuzzy logic rule base is developed based on the known sensitivity of the handoff algorithm parameters. The Mamdani fuzzy inference method was used. The components of the Fuzzy Inference System (FIS) are the fuzzifier, fuzzy rule base, fuzzy inference engine, and defuzzifier. The task of the fuzzifier is to map crisp value of angle of motion, distance and speed of UE to the fuzzy variables.

For a microcellular system, membership functions for the input variables are shown in Figure 4 to 7

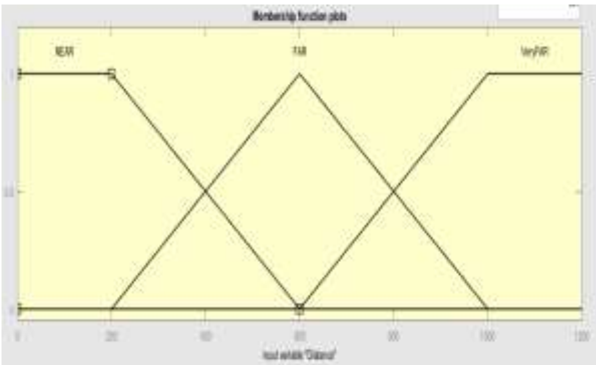

Fig. 4 Distance membership function

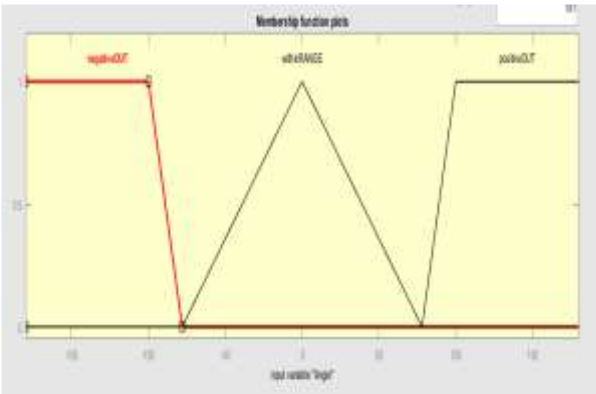

Fig.5 Angle of motion membership function

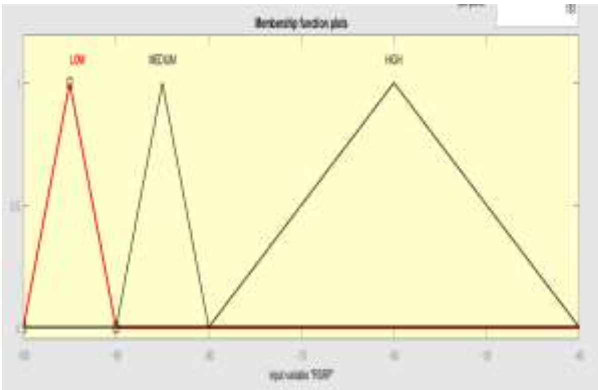

Fig.6 RSRP membership function

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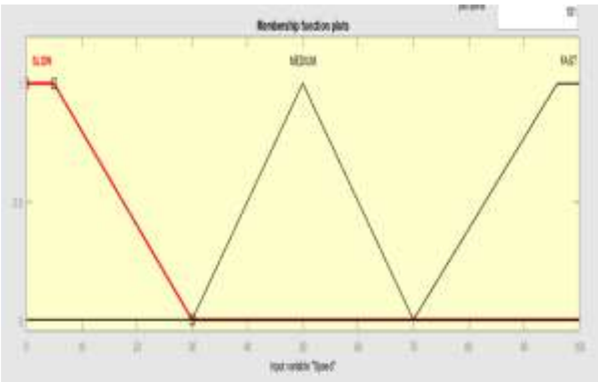

Fig.7 Speed of UE membership function

The input fuzzy variable speed is assigned to one of the three fuzzy sets, “Slow”, “Medium”, and “Fast”. The input fuzzy variable angle of motion is assigned to one of the three fuzzy sets, “negativeOUToff”, “withinRange”, and “positiveOUToff”. The input fuzzy variable RSRP is assigned to one of the three fuzzy sets, “LOW”, “Medium”, and “HIGH”. The input fuzzy variable distance is assigned to one of the three fuzzy sets, “Near”, “Far”, and “veryFast”. Triangular and trapezoidal membership functions were used and 50% overlap of assigned fuzzy sets was considered. The nonsingleton fuzzifier and the center of area (COA) defuzzification method was used. The output variable is the handover decision which is either “YES” or “NO” as shown in figure 8.

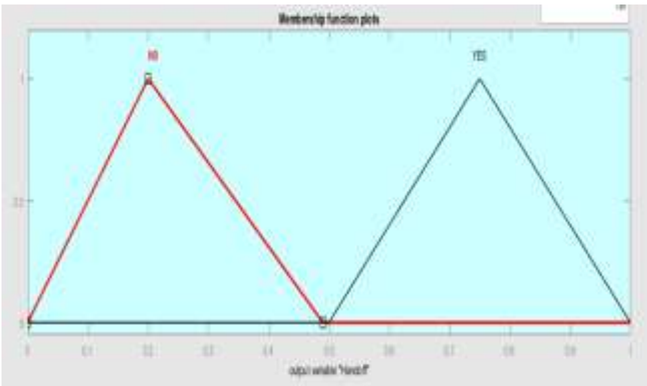

Fig.8 Membership function of Handover output

V. DEVELOPMENT OF THE PROPOSED FUZZY BASED HANDOVER ALGORITHM

The architecture of the proposed fuzzy algorithm is shown in figure 4. The FLS uses the information from the various input blocks to decide time of handoff.

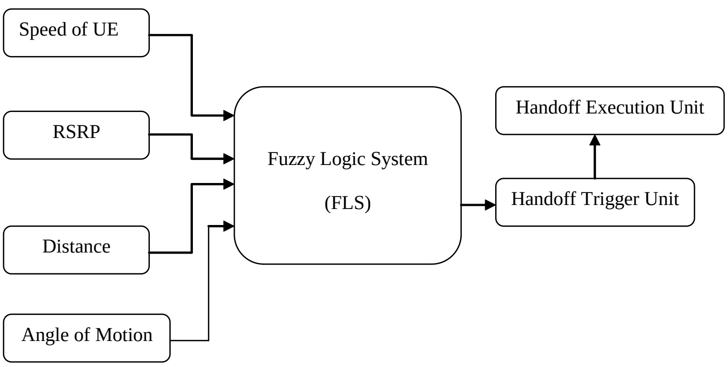

Fig.9 Architecture of FLS

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The various blocks are explained in this section.

1. **Speed of UE:** The most significant feature of mobile cellular system is that the users are moving. The speed block of figure 3.4 estimates the speed of the UE using the Doppler frequency (f_m). The Doppler frequency is related to the speed (V) of the UE, speed of light in free space (c), and carrier frequency of the received signal (f_c) by [14]:

$$V = \left(\frac{c}{f_c}\right) f_m \quad (1)$$

The system estimates f_m using the slope of power spectral density (PSD) of the received signal envelope. A velocity range of 0 to +120Km/h was used for macro cellular system.

2. **Angle of motion:** During the course of movement of the UE, when it gets to the point where the signal strength from the source eNB is below the RSRP threshold (at a distance 'd' from the cell boundary), the need for handoff to the target eNB2 arises only if the direction of motion of the UE from P is in the range $[\theta \, \varepsilon \, (-\theta 1, \theta 1)]$, otherwise, the handoff initiation is a false one. Where[14],

$$\theta_1 = \text{arc Tan}\left(\frac{a}{2d}\right) \quad (2)$$

Where 'a' is the cell radius and for macro cellular system, a = 1000m and d = 100m. The acceptable range of the angle of motion for handoff was calculated to fall within -78° to $+78^{\circ}$. Considering the cell radius, the total parameter range is from -180° to $+180^{\circ}$ [14].

3. **Distance:** This module is responsible for monitoring the distance between the UE and the eNB in the monitored set. The fuzzifier helps in making critical decisions based on certain distance conditions as would be specified in the membership function. This helps to increase the difficulty of radio link replacement.

4. **RSRP:** In LTE network, the UE measures two parameters on reference signal, which are: Reference Signal Received Power (RSRP) and Reference Signal Received Quality (RSRQ). The RSRP indicates the power of the LTE reference signals spread over the full bandwidth and narrow bandwidth. The RSRQ indicates the quality of the received reference signal. RSRP levels for usable signal typically ranges from about -75dBm close in to a cell site to -120dBm at the edge of the cell.

i. The handoff trigger unit collects information from the FLS and determines the appropriate time to start handoff procedures.

ii. The handoff execution unit starts the hierarchical Mobile Internet Protocol (HMIP) registration process at the handoff initiation time calculated by the handoff trigger unit.

For the conventional handover algorithm, the serving cell sends a handover request message to the target cell that has the highest RSRP of neighbor cells, for which equation (3.14) is achieved as long as the UE has stayed for at least 1s in the serving cell [14].

$$R_n > R_s + O_{s,n} + H \quad (3)$$

Where R_n is the RSRP of the neighbor cell, R_s is the RSRP of the serving cell, $O_{s,n}$ is the individual offset of the neighboring cell, and H is the hysteresis or handover margin parameter of the serving cell. The hysteresis parameter is given as [14]:

$$H = S_{th} - S_{min} \quad (4)$$

Where, S_{min} is the minimum Received signal strength (RSS) for acceptable QoS between the UE and the serving cell. S_{th} is the threshold value of RSS to initiate handoff. Therefore, when RSS of the serving cell drops below S_{th}, the UE starts initiating handoff to the monitored cell.

This margin is usually not very large (for unnecessary handoff) or too small (leading to call drop due to weak signal before handoff is completed). When the UE is located at any point in the cell, the need for handoff to the nearest eNB arises only if the UE's direction of motion from the origin is in the range [14]:

$$\theta \in [(-\theta_1, \theta_2] \quad (5)$$

Where, $\theta_1 = \arctan\left(\frac{a}{2d}\right)$ a = cell radius, d = distance.

Otherwise, the handoff initiation is a false one. Therefore, using (3.16), the probability of false handoff initiation is given as [14]:

$$P_a = 1 - \frac{1}{\pi}\arctan\left(\frac{a}{2d}\right) \quad (6)$$

The proposed algorithm in this work improves on this model by also checking for other metrics such as the angle of motion, distance and speed of UE using fuzzy logic.

VI. SIMULATION TEST BED

The system is modeled and simulated in the Fuzzy logic toolbox in Matlab. A radio network of 15 MHz bandwidth with 75 resource blocks was built. Each resource block is consisted of 12 subcarriers of size 15 kHz each. A time slot is 0.5 ms. in duration and the transmission time interval (TTI) is 1 ms. A fixed number of users are uniformly distributed over the area with random initialized positions and they are moving at a fixed speed in random directions. The traffic model is defined as infinite-buffer, an ideal greedy source that always has packets to send.

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TABLE 1
SIMULATION PARAMETERS

S/N	Parameter	Value
1.	eNB Tx Power	1W
2.	Cellular layout	7 cells
3.	Data rate (Uplink/downlink)	50Mbit/s / 100Mbit/s
4.	Cell radius	1000m
5.	System Bandwidth	15Mhz
6.	Transmitting antenna gain, G_{tx}	11dBi
7.	Resource block	180Khz
8.	maximum MS speed	120Km/Hr
9.	Adding and dropping thresholds	1dB
10.	Update time of UE position	1ms
11.	Antenna type	omni-directional antennas
12.	Radio link measurement period	2sec
13.	Subcarrier spacing	15Khz
14.	Simulation time	60s
15.	Maximum Handover delay	30ms
16.	Hysteresis/Time-to-Trigger	0dB/0ms, 3dB/960ms, 6dB/120ms, 9dB/0ms

The FIS Editor Graphical User Interface (GUI) tool shown in figure 10, enables the modification of the attributes of the fuzzy inference system, such as the number of input and output variables, the defuzzification method used, etc. The FIS Editor opens and displays a diagram of the fuzzy inference system with the names of each input variable on the left, and those of each output variable on the right. Based on the descriptions of the input and output variables defined with the FIS Editor, the Rule Editor allows one to construct the rule statements automatically from the GUI.

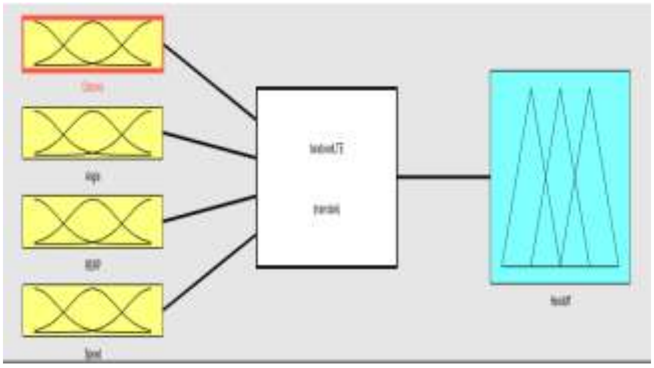

Fig.10 Image of FIS model

The variation of handoff frequency and decisions with reference to speed, distance, angle of motion and RSRP are plotted. Performances in form of probability of false handoff initiation, number of handoff events triggered, and system delay are considered.

To validate the results, the simulation results are compared with those obtained from a conventional distance and RSRP system, and also for a system that limits its performance metrics to distance, direction and RSRP. The FIS model for a conventional distance and RSRP system is shown in figure 11. The FIS model for a system that limits its performance metrics to distance, direction and RSRP is shown in figure 12.

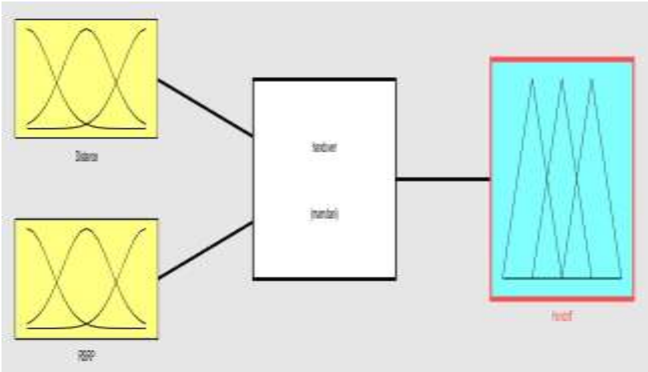

Fig.11 The FIS model for a conventional distance and RSRP system

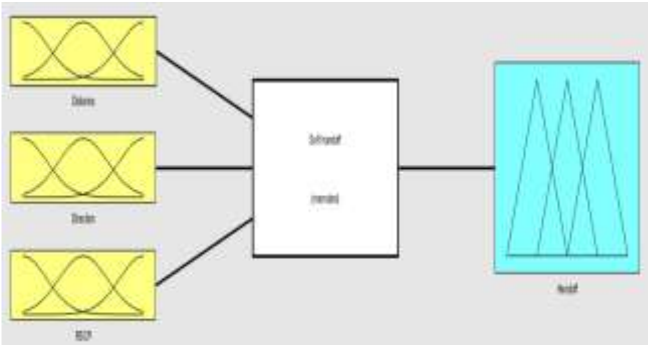

Fig.12 The FIS model for a system that limits its performance metrics to distance, direction and RSRP

VII. SIMULATION RESULTS OF THE DEVELOPED ALGORITHM

The results from the developed algorithm are presented in this section under different scenarios. In this section we provide a numerical evaluation of the handover procedure under different conditions of UE speed and distance. The performance metrics is based on Number of triggered Handover, Number of failed handover, and system delay. Simulation results from the developed system is compared with that of a conventional LTE handover system and a system that improves the conventional system by including direction metric (For the case of this work, it is called modified system). From these analyses, deductions are made to validate the claims made in the objectives of this work. Two scenarios are considered and a snapshot procedure is used to capture the entire simulation scenarios.

I. Scenario 1: Performance analysis for 1 UE/cell at 3, 30, 120 Km/h with Cell Radius 1000m

The case with 1 UE/cell is studied. In this scenario, the UE moves from the first eNB to the neighbouring eNB at varying speeds and distance as well as different angle of motion. The evaluation methodology stated before is applied to evaluate the performances of the handover algorithms under varying factors. Figure 4.4 to 4.9 presents the fuzzy logic simulation outputs for the various systems. For these simulations, instances from the rule viewer and surface viewer are used to present simulation results. This is because the Rule Viewer allows one to interpret the entire fuzzy inference process at once, and also shows how the shape of certain membership functions influences the overall result.

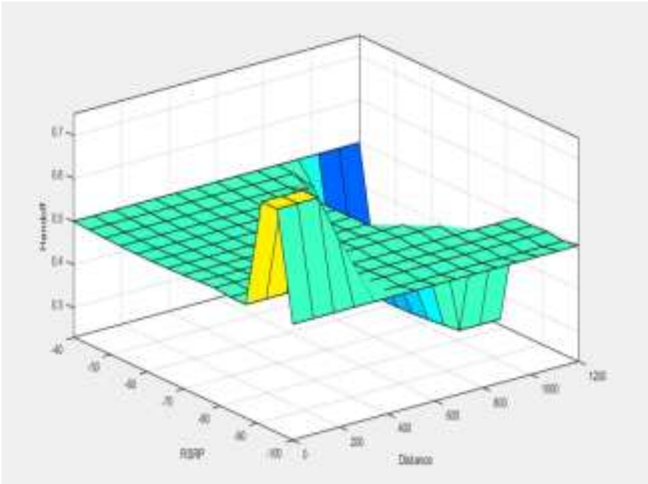

Fig.13 Rule viewer image for a conventional system

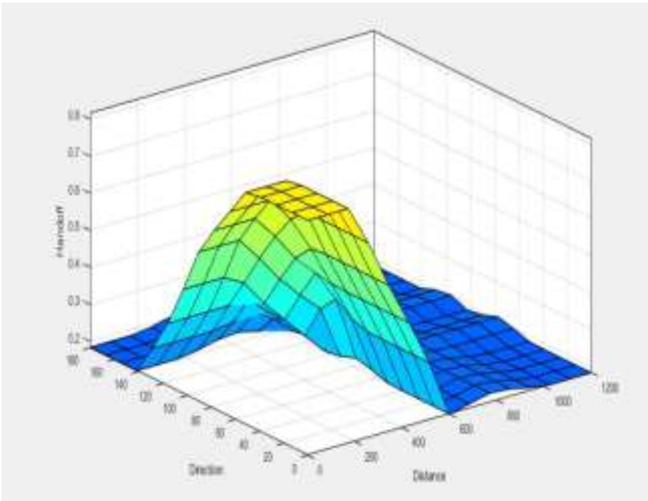

Fig.14 Surface viewer image of the modified system

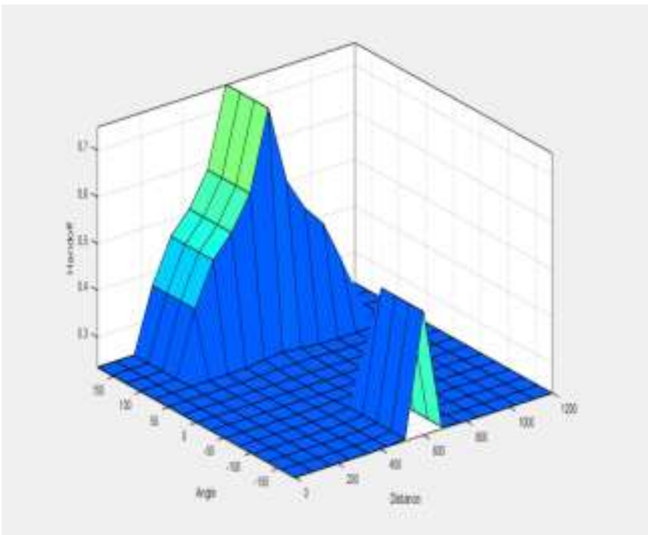

Fig.15 Surface viewer image of the developed system for scenario 1

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From the simulatiuon, as the UE moves across the different eNB's, a number of handover events are triggered and are captured from figure 16 to 18. The total number of triggered handover, false handover and system delay is shown in figure 19 to 21.

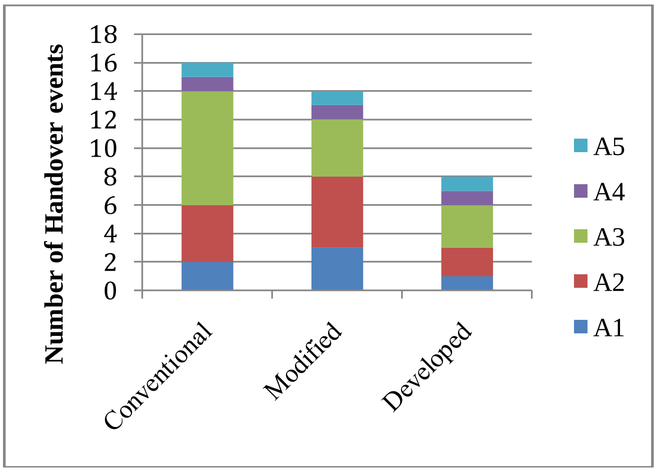

Fig.16 Handover events for 3km/hr scenario 1

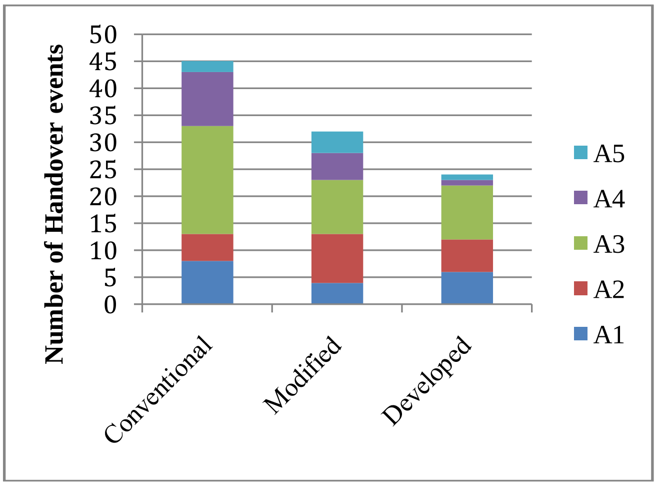

Fig.17 Handover events for 30km/hr scenario 1

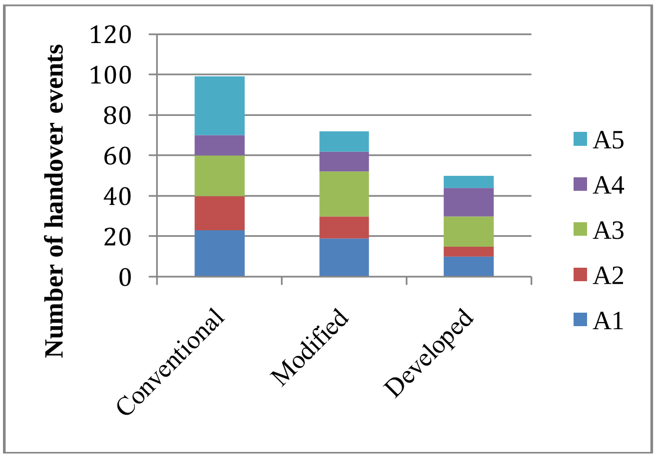

Fig.18 Handover events for 120km/hr scenario 1

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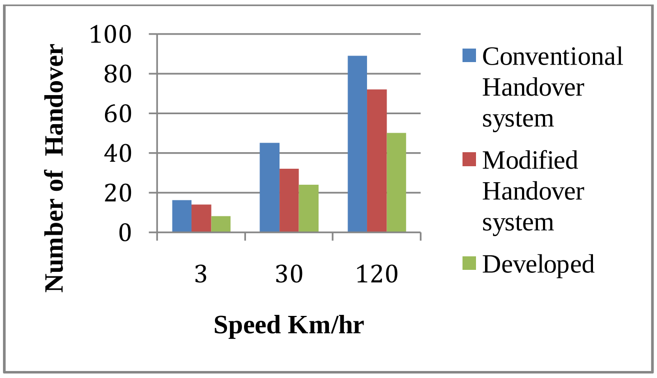

Fig.19 Total number of Handover for scenario 1

TABLE 2
TOTAL NUMBER OF HANDOVER FOR SCENARIO 1

Speed (Km/hr)	Total number of handover event for Conventional Handover system	Total number of handover event for Modified Handover system	Total number of handover event for Developed Handover system
3	16	14	8
30	45	32	24
120	89	72	50

For scenario 1, the results show that when the speed of the UE was 3Km/hr the developed fuzzy logic based algorithm reduces the total number of handoff event triggered by 50% when compared to the conventional method, and by 42.9% when compared to the modified method. When the speed was 30Km/hr the number of handover events triggered was reduced by 46.7% when compared to the conventional method and 25% when compared to the modified system. When the speed was 120Km/hr the number of handover events triggered was reduced by 43.8% when compared to the conventional method and 30.6% when compared to the modified system.

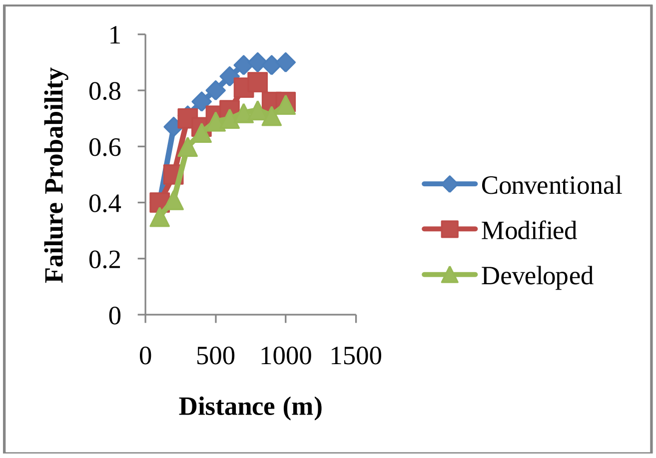

Fig.20: Probability of false handoff initiation for the various algorithms

From figure 20 the probability of false handoff initiation increases as the UE moves farther away from the eNB. This results in the wastage of limited wireless system resources and also increases the load on the network which arises because of the handoff initiation. The distance margin incorporated in the developed algorithm and the modified algorithm helps to check for false handoff initiation as the maximum trigger range is within 250m for each variable of the membership function. This helps to limit the false handoff probability to about 0.75 and 0.76 for the developed and modified algorithm respectively for a cell radius of 1000m. Correspondingly, if the distance margin is not considered as in the conventional case, the false handoff initiation probability gets up to 0.9.

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Consequently, the developed algorithm achieves up to 16.7% reduction in the cost associated with false handoff initiation. The system delay for the 3 systems is as shown in figure 21.

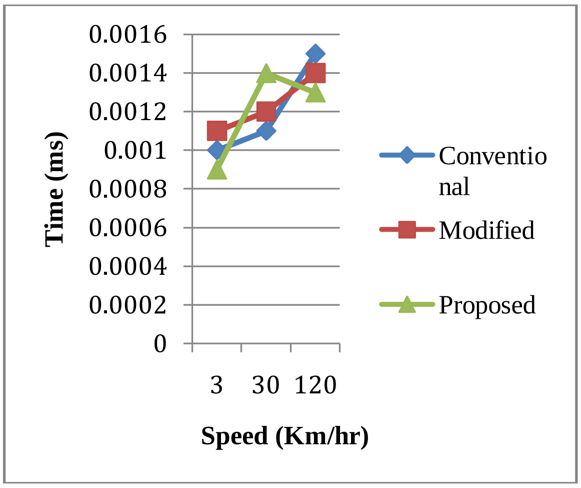

Fig.21 The system delay for the 3 systems under scenario 1

From figure 21, since the handover is more likely to occur frequently as the speed increases, this results in an increasing system delay under all the handover algorithms being evaluated. When compared to the other handover algorithms, the developed algorithm has the smallest delay except for when the speed was 30km/hr.

II. Scenario 2: Performance analysis for 10 UE/cell at 3, 30, 120 Km/h with Cell Radius 1000m

The case with 10 UE/cell was also studied. In this scenario, each cell contains 10 UE and the test UE moves from the first eNB to the neighbouring eNB's at varying speeds and distance as well as different angle of motion. This condition helps to study adn analyse the impact of the algorithms when the channels are loaded. The evaluation methodology stated before is applied to evaluate the performances of the handover algorithms under varying factors. From the simulation, as the test UE moves across the different eNB's, a number of handover events are triggered and are captured from figure 22 to 24. The total number of triggered handover, false handover and system delay is shown in figure 25 to 27.

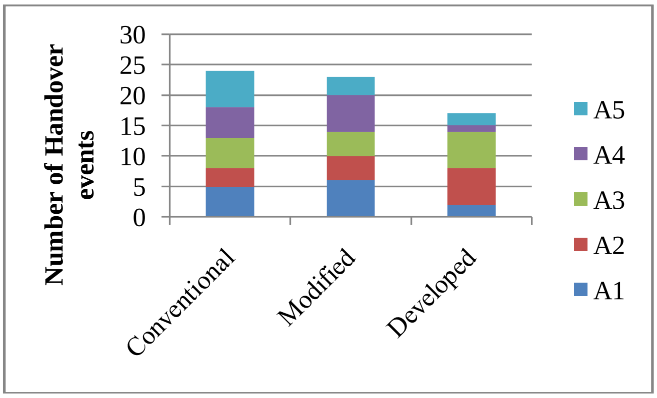

Fig. 22 Handover events for 3km/hr scenario 2

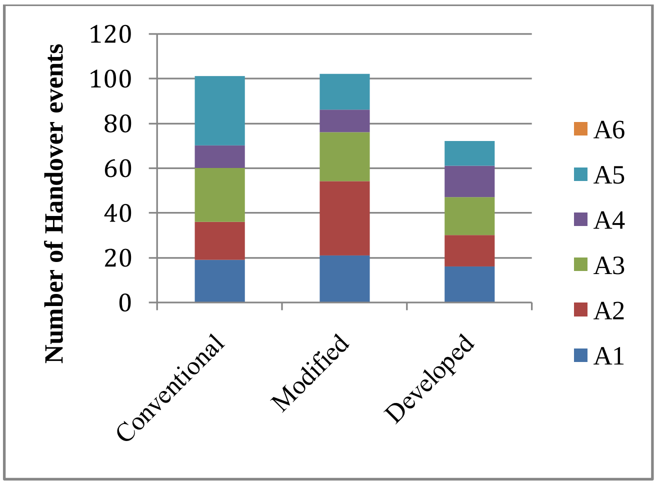

Fig. 23 Handover events for 30km/hr scenario 2

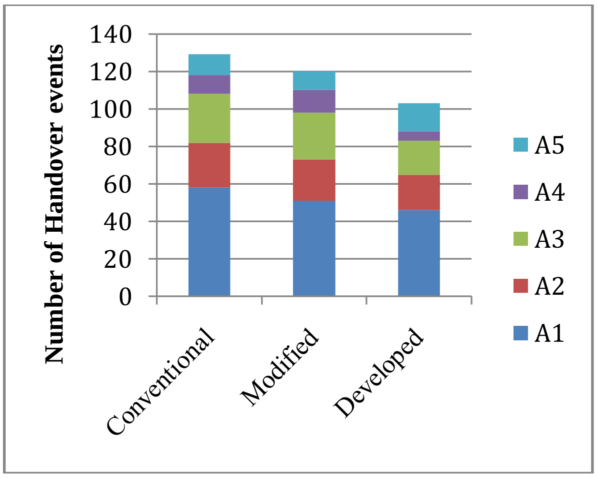

Fig.24 Handover events for 120km/hr scenario 2

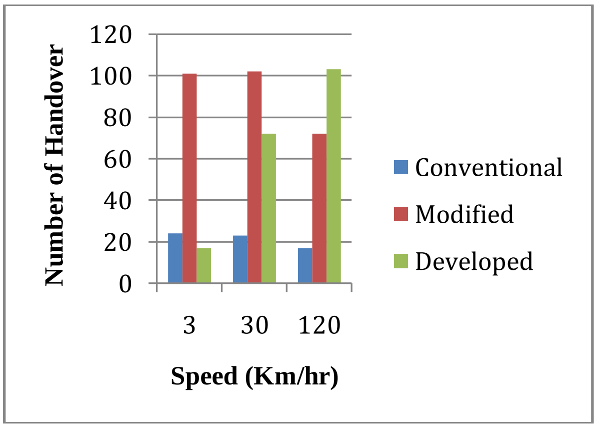

Fig.25 Total number of Handover for scenario 2

TABLE 3
TOTAL NUMBER OF HANDOVER FOR SCENARIO 2

Speed (Km/hr)	Total number of handover event for Conventional Handover system	Total number of handover event for Modified Handover system	Total number of handover event for Developed Handover system
3	24	23	17
30	101	102	72
120	129	120	103

For scenario 2, the results show that when the speed of the UE was 3Km/hr the developed fuzzy logic based algorithm reduces the total number of handoff event triggered by 29.2% when compared to the conventional method, and by 26.1% when compared to the modified method. When the speed was 30Km/hr the number of handover events triggered was reduced by 28.7% when compared to the conventional method and 29.4% when compared to the modified system. When the speed was 120Km/hr the number of handover events triggered was reduced by 20.2% when compared to the conventional method and 14.2% when compared to the modified system.

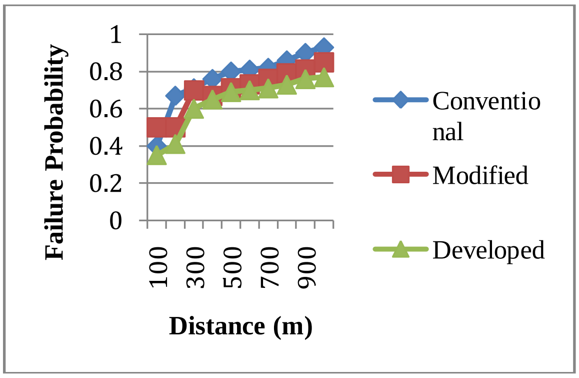

Fig.26: Probability of false handoff initiation for the various algorithms in scenario 2

From figure 26 the false handoff probability is about 0.77 and 0.85 for the developed and modified algorithm respectively for a cell radius of 1000m. Correspondingly, if the distance margin is not considered as in the conventional case, the false handoff initiation probability gets up to 0.93. Consequently, the developed algorithm achieves up to 17.2% reduction in the cost associated with false handoff initiation. The system delay for the 3 systems for scenario 2 is as shown in figure 27.

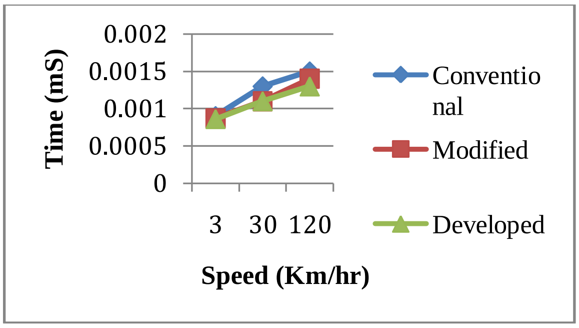

Figure 27 System delay for the 3 systems under scenario 2

From figure 4.27, when compared to the other handover algorithms, the developed algorithm has the smallest delay in all the speed levels when the system has active UE's.

VIII. CONCLUSION

Efficient handover procedure management is critical in wireless networks to maintain QoS for

UE applications through supporting seamless handover decisions. In this thesis, handover performance evaluation under the developed fuzzy logic system has been carried out. Numerical evaluations of the handover procedure has been carried out under different conditions of UE speed and distance. The performance metrics was based on Number of triggered Handover, Number of failed handover, and system delay. The Simulation results from the developed system was compared with that of a conventional LTE handover system and a system that improves the conventional system by including direction metric (For the case of this work, it is called modified system). Two scenarios were considered and a snapshot procedure was used to capture the entire simulation scenarios. The first scenario showed that for 1 UE/cell with a UE speed of 3Km/hr, the developed fuzzy logic based algorithm reduced the total number of handoff event triggered by 50% and 42.9% when compared to the conventional method and modified method respectively. When the speed was 30Km/hr the number of handover events triggered was reduced by 46.7% and 25% when compared to the conventional method and modified method respectively. When the speed was 120Km/hr the number of handover events triggered was reduced by 43.8% and 30.6% when compared to the conventional and modified system respectively. The developed algorithm also achieves up to 16.7% reduction in the cost associated with false handoff initiation. In the second scenario, the results showed that even in a congested environment, the developed algorithm reduced the total number of handoff event triggered by 29% and 26.1% when compared to the conventional and modified method respectively. When the speed was 30Km/hr the number of handover events triggered was reduced by 28.7% when compared to the conventional method and 29.4% when compared to the modified system. When the speed was 120Km/hr the number of handover events triggered was reduced by 20.2% when compared to the conventional method and 14.2% when compared to the modified system. The developed algorithm achieved up to 17.2% reduction in the cost associated with false handoff initiation with the smallest delay in all the speed levels considered. Simulation results show that the developed algorithm is effective as it is able to take handoff decision only when it is necessary and alleviates the ping pong effect. The algorithm is innovative because of its simplicity and low computational cost.

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