Mobility and Signal Strength- Aware Handover Decision in Mobile IPv6 based Wireless LAN

Ali Safa Sadiq, Kamalrulnizam Abu Bakar, Kayhan Zrar Ghafoor, and Alberto J. Gonzalez

***Abstract*—: Existing wireless networks aim to provide information communication services between mobile nodes. As a mobile node move between different radio networks, a handover process is needed to change its point of attachment to the predicted radio network. Since traditional (based on one metric Received Signal Strength Indicator) predictions of handover decisions do not perform well, it is a pressing need to develop an intelligent approach to predict the handover decision process, thus yielding seamless handovers. To this end, in this paper, we propose a Mobility and Signal Strength-Aware Hand-off Decision (MSSHD) approach to predict the handover decision in wireless networks. The Received Signal Strength Indicator and the direction of Mobile Node parameters are considered as inputs to the fuzzy inference system to predict the handover decision, and hence switching to the best preferable access point. To achieve a fair comparison with a standard handover performance, we have implemented a MSSHD approach in Omnet++. The results of the simulation study show that the proposed approach can reduce the handover latency as well as the wireless access media delay (link-layer switching time).**

***Index Terms*— Fuzzy Logic, Handover Decision, Hanover Signalling, and Wireless LAN.**

I. Introduction

THE rapid development in wireless technologies has increased the deployment of mobile networks. The mobile Internet Protocol (IP) provides mobile users with mobility while they alter their point of attachment during the handover process, which occurs between the current wireless access network and the new access network. This mobility is handled by a network layer (Layer 3) via Mobile IP extensions, hence mobile connectivity can be live while a Mobile Node (MN) is roaming between different access networks. However, this process still has many technical weaknesses for wireless networks, including high handover latency and packet loss. These kinds of limitations influence the wireless networks' functionality, and particularly degrade the performance of the applications that are processed over these networks, like real-time applications, such as Voice over IP (VoIP) or video streaming.

Therefore, there are many protocols, which have been designed to achieve uninterrupted linkage. Mobile IPv6 is one of the latest versions, which has been introduced by the Internet Engineering Task Force (IETF) to maintain mobility in wireless networks [1]. This protocol is responsible for processing the network layer (L3) handover between a MN and Access Routers (AR).

Throughout this protocol, a MN provides internet connectivity while its Access Point (AP) changes from one AR to another. During this handover process, time is taken while a data-link switching process take place between the current AP and the new AP. This switching process is called the Layer 2 (L2) handover procedure, which is executed after the handover decision has been taken. The MN in this handover time will not be able to send or receive any packets. Therefore, time is required to complete this process, which can trigger some drawbacks, such as an increase in handover latency and packet loss. To this end, there is an imperative need to develop a method to achieve good mobility management.

Generally, a mobility management system includes two essential elements: a handover-decision management phase and a handover execution phase. These two phases are supposed to be executed in a short time to allow the MN to be reached on any AP to which it wants to move [2]. Therefore, the IEIF has developed another mobility protocol extension to manage the handover process, which is called Fast Mobile IPv6 [3]. FMIPv6 is one of the IPv6 extensions, which tackles mobility management in wireless networks. Unfortunately, this protocol also has some weaknesses in the handover process [4]. FMIPv6 has two modes of operation to perform during the handover: the proactive and reactive modes [4]. In the proactive mode, the fast handover would be able to perform several signals (triggers) during the L2 (link-layer) handover prior to L3 between the current and potential router while it is still connecting with the current AP. Under this proactive mode, two variations occur: hard proactive (HP) and soft proactive (SP) [4], [5]. A MN can execute the SP mode in case there is one or more AP, which has a better signal from the current point of attachment. However, usually, a MN cannot know what the potential handover will be during its roaming period without having a good quality intelligence system. There are some parameters that can provide a timely and correct handover decision while the MN is still connected to the current AP. The horizontal handover process (within this paper's scope) starts when the link quality parameters decrease, for example, the Received Signal Strength Indicator (RSSI), Signal-to-noise ratio (SNR), Data rate ratio, and so on. Based on the range of these variables, a MN will build its own handover decision, which identifies when an AP must be activated. For this handover decision to take place, a MN normally depends on one parameter, which is generated

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from the network environment. For example, in IEEE 802.11/b networks, the link quality is measured by the value of the RSSI.

In this paper, we propose a Mobility and Signal Strength-Aware Hand-off Decision (MSSHD) approach to achieve the correct handover decision in wireless networks. The RSSI and Relative Direction of the MN toward the AP are considered as input parameters to the fuzzy logic system. The output of this fuzzy system is the quality cost of each AP in the range. Using this technique, a MN can predict the correct handover decision in advance before reaching the link-down time, which causes high handover latency which requires building new data-link connection.

II. Related Works

There are many studies, which have examined handover latency in Wireless Local Area Networks (WLAN). In the IEEE 802.11/b standard mode with WiFi, there are several signals that the MN must perform with the AP to obtain association in order to be able to send and receive forwarded traffic. This process contains sequence phases, like probe requests and probe responses, authentication requests and authentication responses, and finally, reassociation requests and reassociation responses. These sequences are distributed as three Layer2 phases: potential phase, probe or scanning phase, and authentication phase. In the potential phase, a MN senses if the current link quality is weakening when some frames fail to be transferred via the network. At the same time, a MN receives other signals, which belong to other, better quality APs in the range. While in the probe or scanning phase, a MN starts to collect the RSSI values for the APs that are available in the range and then makes decisions about the handover. The handover decision depends on the RSSI value, which determines the quality of the current link and the desirable link. Afterwards, the authentication phase is applied between the MN and the new AP; this happens when the authentication is enabled in the APs. In each active scan executed by the MN, the worst possible delay is 300-400 ms [6]. This delay period is taken every time the MN needs to obtain a list of APs in the range in order to make the handover decision.

When the MN decides to make the handover on one unqualified AP, soon afterwards it will need to perform another handover process, which will cause high handover latency. Thus, many researchers have tried to decrease this latency and identify a more effective way to increase the overall latency so as not to degrade the quality of service (QoS), especially with real-time applications. In [7], the authors proposed using the neighbourhood graph (NG) method to help define the APs in the range, which would then support the handover process by selecting an appropriate AP. Other authors [8] used calculating optimals, like MaxChannelTime, MinChannelTime and beacon internal.

Fixing the search operation to a number of APs on a given channel has also been proposed by another study [9] , which aimed to reduce scanning time then decrease the handover latency by using an intelligent channel scan in IEEE 802.11 WLANs. In [10] and [11], respectively, the scanning phase was bypassed to reduce the Media Access Control MAC layer handover, and a location-base technique was used to minimize the handover latency.

In general, the handover process starts when the MN begins to lose a connection with the current associated AP. At the same time, it stops receiving the traffic of packets, which are forwarded by the Corresponded Node (CN) over several seconds. During this disconnected period, the MN is processing the handover procedure. The handover procedure in IEEE 802.11 has two stages: discovery of the available APs by using passive or active scanning, and the re-authentication stage. These two stages, which are handled by L2, then depend on this process the L3 (network-layer) process in order to start the handover procedure. For the duration of the L2 handover process, time is taken, which is known as the access media delay. In [12], they are mansion that main delay in L2 is caused by the scanning phase, while the authentication has a constant delay.

Therefore, the scanning decreases when the MN achieves the most appropriate AP during the handover process. This will depend on the handover decision after the scanning phase. The RSSI quality is discussed in [13], but the maintainability of predicting the future RSSI is not covered by this study. In [13], an analysis study was done to show the effectiveness of the Layer 2 (link-layer) and Layer 3 (network-layer) parameters, in terms of performance of mobility management, which then aim to reduce handover latency. However, the idea of using L2 triggering to help the handover decision is not covered in our analysis. Our aim is to use the L2 parameters, which are RSSI and relative direction of the MN towards the AP to support the MN to make the correct handover decision. The idea of using the relative direction between the MN and each AP is the novel idea will help to obtain accurate handover decisions in collaboration with the RSSI. The two parameters used in our MSSHD approach (in a similar way to the two inputs for the fuzzy-logic system) will be fuzzified then defuzzified; the output will be the quality cost for each AP in the range of the MN.

III. Proposed Algorithm

The proposed MSSHD in this paper used a fuzzy logic system to obtain the quality cost for each AP. A fuzzy logic system helps to decide which AP is chosen as the next new link of attachment for the MN during its roaming. There are two crisp input values for the fuzzy logic system (the RSSI's and the MN's relative direction toward each AP). These crisp values will change to fuzzy values by selecting the membership function for each. In the two sections below, we will discuss the two values, which have been selected in our fuzzy logic system.

A. RSSI measurement

The Received Signal Strength Indicator (RSSI) is one of the most common L2 parameters used in handover decision making [14]. Through RSSI monitoring, which is handled by the MN, we can analyses, the quality and the distance for each AP in the range from collected RSSI values. Therefore, in this study we used "inSSIDer" software in order to measure the RSSI for APs in the range while MN's movement.

The real-test measurement has been done through using one laptop as MN roaming across three APs. The range of the RSSI in IEEE 802.11 WLANs (maximum to minimum value), threshold, and the impact of MN's movement on RSSI value for each AP in the range are tested during this real-test bed. These values will help the designing of membership functions for RSSI values in our fuzzy-logic system.

Moreover, some of real-time applications have been carried out science MN's movement. These kinds of applications have been used in order to determine the most suitable RSSI threshold using for handover decision between the current link of attachment and the potential one.

The ranges from -10dbm maximum value to -255 dbm minimum value within -75dbm threshold of RSSI have been collected from RSSI measurement. From these values we can design clearly the RSSI membership functions to support our fuzzy-logic system.

B. Tracking Direction

In order to achieve more accurate handover decision we designed the fuzzy-logic system in this study depend on relative direction of MN towards APs as well. Direction is the second metric, which was used in our proposed fuzzy logic system.

Generally, when the MN starts roaming across different APs it might identify more than one AP with a good quality RSSI. However, one of these APs may not be situated in the same direction as the MN, so the MN may not move towards this particular AP. This demonstrates that the MN can obtain the wrong handover decision if the AP is not in the same trajectory. This can occur when MN uses the RSSI value only to obtain the handover decision.

During this process, the MN might start the handover process with one AP with a high RSSI even though it is not in a relative direction. However, if the MN obtains an AP in the same direction, the handover decision will be more appropriate.

Formula (1) was used to calculate the angle of direction for each AP from the MN's current position during its movement. Suppose that the direction of the MN is (MdX1, MdY1), the position of AP is (PaX2, PaY2); Mdx and Mdy represent the direction of the MN, with the X-axis and Y-axis, Pax and Pay Position of each AP, also with the X-axis and Y-axis. Formula (1) describes how we can compute the angle.

$$a = \arccos \frac{MdX1.PaX2 + MdY1.PaY2}{\sqrt{Mdx1^2 + MdY1^2}.\sqrt{PaX2^2 + PaY2^2}} \quad (1)$$

If the MN wants to make a handover decision for any AP in the range, it must initiate the handover process. Formula (1) can be used to calculate the angle between the MN and the desirable AP. This calculation is based on the X-axis and Y-axis for the MN and the AP on the geographical map, using Global Positioning System (GPS) technology. The MN is equipped with the GPS to obtain the updated X- and Y- axis with every movement. The AP's location is defined in advance, and is a fixed position. Once all positions for the APs are collected, then these positions can be entered into the GPS. Throughout this process, the MN knows its own position and all APs in the range as well, which enables to calculate the direction angle between MN's current position and each AP.

Frequently, the MN calculates and checks the angle between itself and the desired AP. If this angle is less than 37.7 degree, it means the MN in the same direction as that particular AP.

The two input values (RSSI and Direction) were used in our fuzzy logic system in order to get a robust decision-making process to support the handover procedure.

IV. FUZZY LOGIC SYSTEM

Fuzzy logic is a process of decision making based on input membership functions and a group of fuzzy rules, like the human brain, which simulates the interpretation of uncertain sensory information. Here, fuzzy logic is applied in order to select the most appropriate AP from the list of APs that are available from the scanning phase, which is handled by the MN. Normally, the MN does not know which AP will be a good partner to perform a handover, and it can just depend on the quality of the current and available link. In addition, sometimes, the MN will perform unneeded handovers during its roaming. In other words, the handover obtained by incorrect decision-making will cause overhead signalling and increase the handover latency time. Therefore, fuzzy logic is the answer to this uncertain type of problem.

Therefore, in this study, the handover process has been done using a fuzzy logic system, which will help to identify the correct AP to handle handover decisions. The specified RSSI for IEEE 802.11/b standard and the MN direction are the inputs for the fuzzy-logic system. The adaptive fuzzy system will aid the handover algorithm to obtain the best AP in the range, in terms of its signal strength, ensuring it is directed more towards the best AP; this is called AP-Quality-Cost (AP-Q-Cost).

A. Design of Fuzzy Inference based Mobility and RSSI

The fuzzy inference system consists of fuzzification, knowledge rule base, and defuzzification. The first step of designing a fuzzy inference system is to determine membership functions for the input and output fuzzy variables, based on the defined range. This is followed by designing rules for the fuzzy inference system. Furthermore, a group of rules is used to represent a knowledge base for articulating the control action in a linguistic form. The overall process involved in estimating the best qualified AP (in the range of a WiFi service) is elaborated in the following sections. Figure 2 shows the overall fuzzy-logic system in our article.

B. Fuzzification of Inputs and Outputs

The two input metrics need to be fuzzified; they are the RSSI value, and the Direction between the MN and the AP. The membership functions: "Weak", "Average" and "Strong" were used to describe the RSSI status value for each AP which shown in Figure 3. The initial selection of RSSI membership functions (meaning the range in WiFi networks) was selected using the software "inSSIDer" as mentioned earlier. After using this software and after the real scanning process took place, we observed that the range, within which the AP could work with WiFi IEEE 802.11/b standard with 2.4 Ghz, was from -10 dbm (the best

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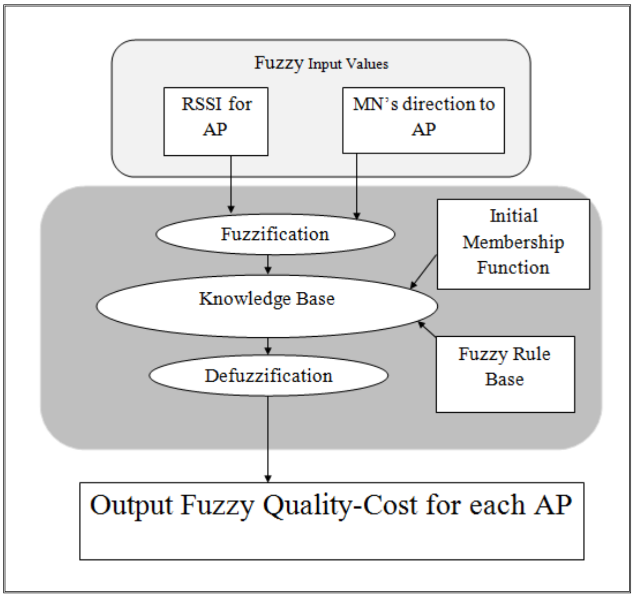

Figure 2. Computation of Fuzzy Quality-Cost for AP

signal strength) to the worst case, -256 dbm, which means the signal is zero. Thus, the membership functions were divided depending on this range considering the threshold value (-75 dbm).

The threshold value was tested using real-time applications, and we observed that the minimum RSSI value should be provided to continue the connection with these kinds of applications. By considering the range and the threshold for the RSSI value in IEEE 802.11 standard, the membership functions can be designed. These designed membership functions for RSSI were used in our MSSHD as one of inputs to the fuzzy-logic system.

The second input value for the fuzzy-logic system is the relative direction of the MN toward an AP. The range for this input value was selected by calculating the direction angle between the MN and the APs in a geographical area as described in the previous section. When we applied Formula (1), we found the range for the Direction value was between 1 to -1. Figure 4 shows the range and the membership functions' distribution. Depending on this range, the membership functions for Direction input were distributed as (Less_Directed), (Medium_Directed), and (High_Directed). The reason for obtaining the relative direction of the MN toward the APs was to predict the next potential AP toward which the MN can move.

While the MN is moving, the fuzzy system can calculate the fuzzy-cost for each RSSI and Direction input values. This process applies to each AP that the MN obtained through the scanning phase. Depending on this fuzzy-logic system, we constructed our MSSHD in this study. When the MN performs the MSSHD approach, we will be able to collect the Cost-Quality for each AP in the range. GPS technology was attached to the MN, which was used to gather its own and the APs' positions in the geographical area. Figures 3, 4, and 5 show the membership function for the input and output variables.

The triangular functions are used as the membership function because they have been used extensively in real-time applications due to their simple formulas and computational efficiency. This wise design of membership functions has a positive impact on the fuzzy decision-making performance.

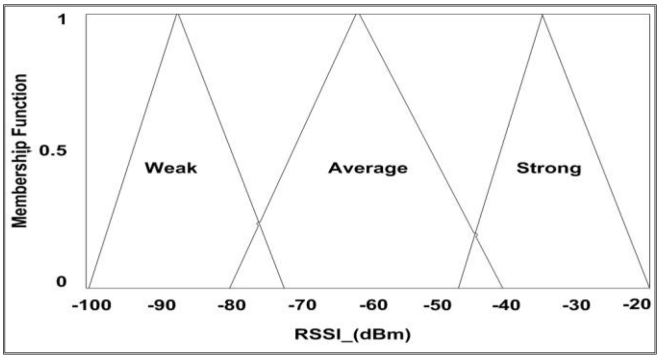

Figure 3. Membership Functions for RSSI Input Value

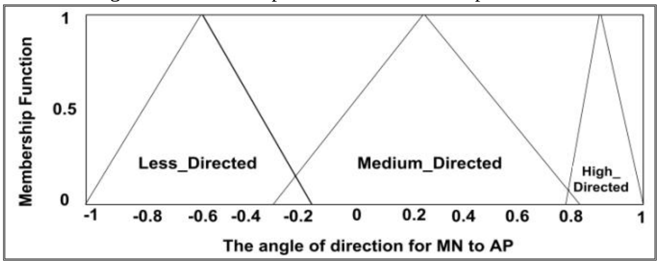

Figure 4. Membership Functions for Direction Input Value

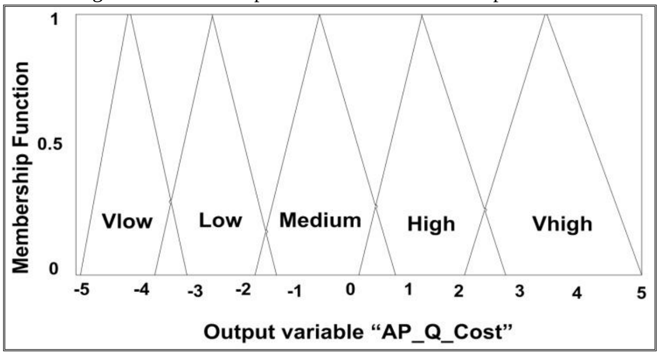

Figure 5. Membership Functions for AP_Quality Cost Output Value

C. *Fuzzy Inference Engine*

The fuzzy inference engine is a group of rules developed using expert knowledge. We have designed the knowledge-based rules that connect the inputs and the outputs based on a careful understanding of the philosophy behind the handover behaviours in wireless networks. The fuzzy inference system is designed based on nine rules, which are presented in Figure 6.

In order to demonstrate the designed fuzzy inference system, one rule is used to show how the inference engine works and the outputs of each rule are combined to generate the fuzzy decision [15]. If we consider a rule: "If RSSI is Strong and Direction is High_Directed, then the AP_Q_Cost is Very high"; this is an example of how to calculate the output of the specified rule. In our fuzzy inference system, consider a case where RSSI is -21.5 dbm and the Direction of the MN to the AP is 0.973. The output is 3.57, which means that the fuzzy cost for that particular AP is very high.

R1: If RSSI is Weak and Direction is Less_Directed THEN AP_Q_Cost is Vlow
R2: If RSSI is Weak and Direction is Medium_Directed THEN AP_Q_Cost is Low
R3: If RSSI is Weak and Direction is High_Directed THEN AP_Q_Cost is Medium
R4: If RSSI is Average and Direction is Less_Directed THEN AP_Q_Cost is VLow
R5: If RSSI is Average and Direction is Medium_Directed THEN AP_Q_Cost is Medium
R6: If RSSI is Average and Direction is High_Directed THEN AP_Q_Cost is High
R7: If RSSI is Strong and Direction is Less_Directed THEN AP_Q_Cost is Low
R8: If RSSI is Strong and Direction is Medium_Directed THEN AP_Q_Cost is High
R9: If RSSI is Strong and Direction is High_Directed THEN AP_Q_Cost is Vhigh

Figure 6. Knowledge Structure Based on Fuzzy Rules

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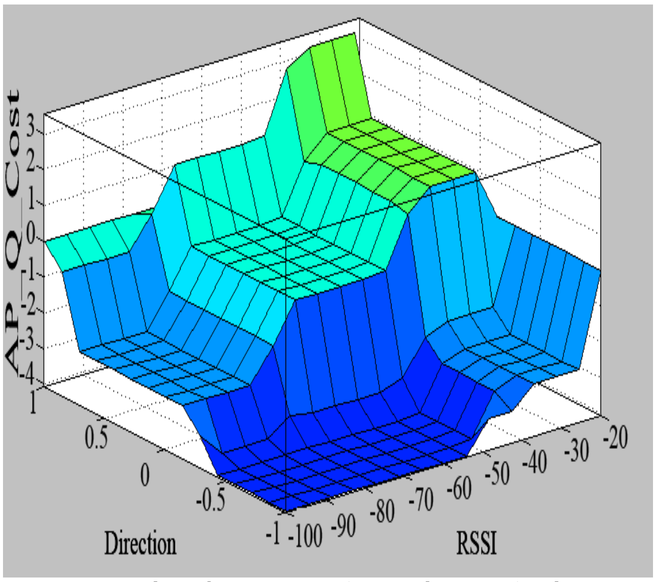

Figure 7. Correlation between Inputs (RSSI and Direction) and Output Fuzzy Variables

This fuzzy cost for the AP became very high because the high value of the RSSI and the MN was directed more towards this particular AP. In other words, the MN was moving in a relative track with this AP, so the angle between the MN and the AP's position reduced. It means our fuzzy inference system uses a compromised decision based on our study's metrics (RSSI and Direction) to select the best quality cost for APs in the scanning area. This output is achieved by using Mamdani's fuzzy inference method [15]. Figure 7 depicts the correlation behaviour between the input and output variables. In Figure 7, the trend shows that the value of the output FuzzyCost increased as the RSSI increased; at the same time, the angle of direction between the MN and the APs decreased. This is because the strongest RSSI and more directed AP leads to a higher probability of fuzzy path selection (light green area).

V. Defuzzification

Defuzzification refers to the way a crisp value is extracted from a fuzzy set as a representation value. In our fuzzy decision making, we take the centroid of area strategy for defuzzification. This defuzzifier method is based on Formula (2).

$$Fuzzy\_Cost = [\sum_{All\ Rules} xi \ * \ \mu(xi)]/[\sum_{All\ Rules} \ \mu(xi) \quad (2)$$

Where Fuzzy_Cost is used to specify the degree of decision making, xi is the fuzzy *AllRules*, and variable and μ(xi) is its membership function. Based on this defuzzification method, the output of the fuzzy cost function is changed to the crisp value.

VI. Performance Evaluation

In this section, by using OMNET++ simulator, we will show how the mobility and RSSI awareness help in terms of handover decision making. This evaluation has been done based on testing the effectiveness of the MSSHD approach in a wireless LAN Media Access Delay, which reflects the handover latency occurring in L2 during the handover processing in the simulated scenario.

A. Simulation Setup

We illustrate here the simulation settings that have been used to evaluate and investigate the latency occurring in the link layer (Wireless Access Media Delay). The simulator OMNET++ 2008 was used along with the xMIPv6 [16], to establish the scenario and generate the mobility. The mobility scenario has one MN moving across three APs. One of them represents the Home Agent for this MN and the others belong to other Foreign Agents. Each one of them has a coverage area of 100 m. In table 1 we have shown the simulator's sittings that we configured for mobility and wireless communication.

B. Simulation Results

After we constructed and configured the simulation scenario, the required results were collected. We designed two simulation test scenarios. The first, which was the represented MN with undirected trajectory (random movement) which depends on MSSHD approach, we will call scenario A. The second, within same settings whereas the default handover procedure is applied, we will call scenario B. The results for both scenarios were collected and are shown in order to achieve the comparison between them.

In Figure 10, scenario A shows that the MN started its movement from it's HA to the other two APs belonging to the FA. Initially, the handover latency in Layer 2 (wireless access media delay) was zero at the beginning of movement; then it rose acutely after the third metre of movement away from the HA. The delay continued to increase until it reached 2.19 seconds. At that time, the MN started to move away from the first AP (HA) and enter the AP1 range, which belonged to FA1.

From this scenario, we can observe the effectiveness of the MSSHD approach in terms of handover decision making. When the MN was working with AP_Home after 2 m, the MSSHD calculated the Quality-Cost for AP2 belonging to FA2, which was higher than the AP1 belonging to FA1. Therefore, the handover decision was taken to perform the handover procedure with this AP2.

We then monitored the curve after the first meter had risen sharply because the L2 handover started with AP2. Figure 10 also illustrates that the delay curve declines consistently after the fifth meter of movement, which means the MN was working with AP2 during all the remaining meters of simulation.

In order to investigate the handover (L2 handover latency) process of the default (and our) approach, we show, in Figure 11, the wireless access media delay, which

TABLE I
Mobility and Wireless Communication Related Parameters

Parameter	Settings
Simulation area	500 × 500 m
Speed for MN	1m/sec
Simulation time	9.5 sec
Power transmit (w)	0.1 dB
Packet reception power threshold	-75 dbm
Buffer size (bits)	1024000
CPU resource parameters/ number of resources(for APR)	3
Processing speed multiplier (for APR)	5.0
Channels of transmission	1,6,11 Fixed
Direction of mobility	Non-Linear movement

m = meter, S= Second, w= Watt, APR= Access Point Router.

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occurred when we ran the simulation within scenario B (the default handover procedure).

In Figure 11, the L2 handover latency trend rose acutely at 4 m. This is no surprise, since the default approach was used without predicting the handover decision. Next, the MN entered the AP1 and the latency reached 10 seconds. This was due to the L2 handover signaling with AP1. When the MN started to move in another direction (away from AP1) after roughly one meter, it decided to undertake the second handover process with AP2. Then the latency decreased consistently until it reached 2.8 seconds at 18 m, which means the MN, started working with AP2 after the handover process was settled.

From our results and an analysis of Figure 11, it is fair to suggest that the handover decision based on a single parameter (RSSI) offers higher handover latency. This is evidenced by the fact that although the MN was not directed towards AP1, the handover still occurred, which caused wrong handover decision then the QoS has been decreased.

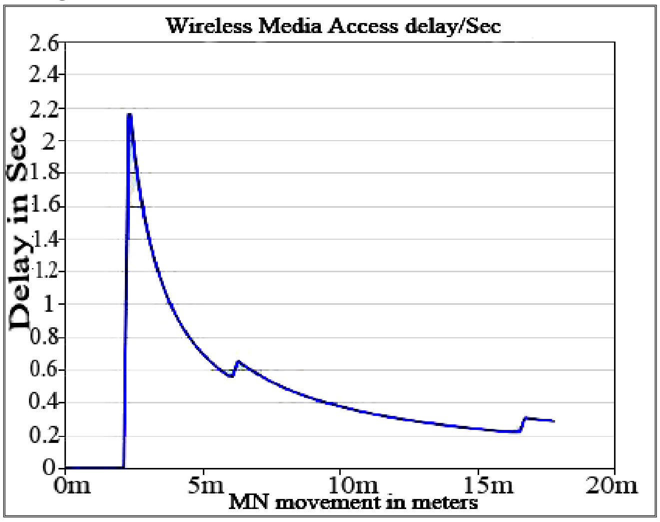

Figure 10. Wireless Access Media Delay (L2 Delay) in MN Moving in an Undirected way to APR2

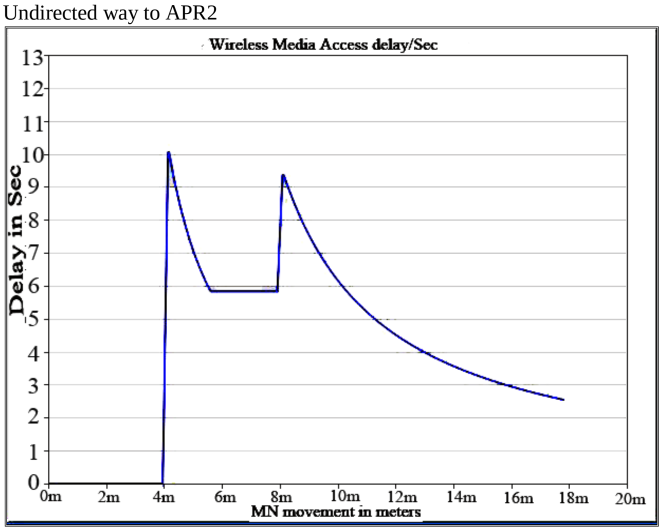

Figure 11. Wireless Access Media Delay (L2 Delay) in MN, Scenario A with Proof of Default Handover

VII. Conclusion and Future Work

In this article, we proposed a unique a Mobility and Signal Strength-Aware Hand-off Decision (MSSHD) approach to predict the most qualified AP within its coverage. The Received Signal Strength Indicator of AP and relative direction of the MN toward the APs were considered as inputs to the fuzzy logic system. We showed that using our proposed approach and through simulation Omnet++, that latency in L2 decreased to achieve the adaptive handover decision. Moreover, a fair comparison was undertaken with a default handover procedure to justify the efficiency of our MSSHD approach. In future work, we will consider other important parameters, like interference, so that the MSSHD will reflect more accurate handover decision making. Moreover, the proposed MSSHD approach can be applied on different scenarios of mobility with various mobile densities to evaluate the efficiency of the proposed schema.

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