Intelligent Handover across Ubiquitous Network

Joanne Mun-Yee Lim, Chee-Onn Chow, and Hiroshi Ishii

***Abstract*—In the upcoming future, continuous coverage of internet connection is necessary to meet the demand for continuous internet connectivity. With an intelligent handover decision, performance of networks can be improved drastically. In this context, a fuzzy logic algorithm has been implemented and tested in our simulation. Mobile node's speed and received signal strength indications are used as the main parameters for handover decision. This simulation is run across twelve access points. Our proposed algorithm is compared with the conventional algorithm. It has been proven based on our observations that performance of networks has been improved. The main contribution of this paper mainly focuses on developing a handover algorithm that has the ability to reduce the number of handovers across a handful of access points and increase networks performance by making a smart decision to handover only when necessary.**

***Index Terms*—Horizontal handover, RSSI, mobile node's speed, wireless LANs, fuzzy logic, mobile IPv6.**

I. Introduction

Due to its low cost and ease of installation, WLANs based on IEEE802.11 has started to develop. WLANs that are independently managed by different organizations are starting to complementarily cover not only one spot but a wide area. These WLANs manage to cover the coverage of a city by using multiple access points (APs) [1]. Various cities worldwide have started to implement city-wide 802.11 coverage, such as Taipei, Philadelphia and London. The main purpose is to achieve seamless connectivity while roaming. This will eventually provide a ubiquitous network across the nation which permits humans to stay connected wherever they are. To achieve this, plenty of access points are needed. As a user move across these access points, an intelligent handover decision algorithm must be able to choose the accurate time to handover in order to reduce number of handovers yet increase its performance. In this context, users can remain connected even when they are travelling on a highway or running in the park without much hassle.

With larger numbers of IP address usage, IPv6 is definitely a great asset to accommodate its growing demand. As humans are constantly on the move, mobile IPv6 is essential to ensure network remains always connected. A fixed IPv6 methodology cuts off connection from the previously connected link when the address changes. However, the situation is different with mobile IPv6. Mobile IPv6 maintains its connectivity with its link even when the address and location of the user changes. This is done by maintaining the address which is assigned to a particular mobile node. This inevitably helps mobile node to remain reachable at all times.

Received Signal Strength Indication (RSSI) has been vastly used as the main decision criteria to handover in WLANs. However, merely based on RSSI to decide when to handover is insufficient. RSSI might lead to wrong decision, thus resulting in drop of performance. As more portable devices have been invented, the need to remain connected to the internet while on the move is also increasing. Therefore, speed is more vital to be considered during handover decision as movement of fast or slow induces a great impact on the handover performance. In a ubiquitous network, a mobile node finds multiple of networks at a time. Solely based on RSSI to decide to handover will eventually result in numerous number of handovers. Thus, this greatly affects its network performance. With this in mind, this paper takes into consideration both, speed and received signal strength indication (RSSI) before making a decision to handover.

The rest of this paper is organized as follows. Section II discusses on the related approaches proposed previously. Section III highlights the new proposed design and implementation of decision to handover algorithm in detail. Section IV briefly outlines the simulation scenario. Section V discusses on the results and performance on both algorithms. A brief summary is presented in Section VI. This paper is concluded in Section VII.

II. Related Work

Many solutions had been proposed to make handover decision more effectively. One of the papers described in [2] proposed to use a pre-active scan phase which worked during normal connectivity to scan and find information about neighbouring APs in range. This pre-active scan phase is active every 2 seconds when the signal strength fell below -80dBm. During the pre-active scan phase, STA checked on signal strength and traffic load of the current AP. At the same time, it scanned for the neighbouring in range APs for their signal strength and traffic load. Using this information, STA performed a brief calculation and obtained handover factor for the APs to decide whether or not a handover should had taken place. Merely considering the use of traffic load and signal strength might not be sufficient as speed might give a great impact to the final results as well.

Mamdani Fuzzy Logic theory was proposed to perform handoff algorithm in [3]. The fuzzy logic rule base is divided

Manuscript received April 5, 2012; revised March 21, 2013. This work was supported in part by the by UMRG (RG003/09ICT) and eScience (01-01-03-SF0566) funds.

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DOI: 10.7763/IJIMT.2013.V4.418

into intrasystem and intersystem. Intersystem handoff occurred between two base stations that belong to two different systems. Intrasystem handoff occurred between neighbouring base station that belongs to a different foreign agent but under the same serving system. Two inputs for their fuzzy logic system were used; velocity and distance. With velocity and distance, they produced RSS threshold as their fuzzy logic output to decide whether or not a handover should had taken place. However using distance as one of the inputs of fuzzy logic might not be able to illustrate the exact quality of the AP. Thus, this fuzzy logic scheme might not seem completely efficient.

Research papers on [4] outlined the use of frame retransmission as the new handover decision criteria. Kazuya Tsukamoto, Suguru Yamaguchi and Yuji Oie showed that the frame retransmission occurred at a distance around 8 metres between the access point (AP) and the mobile node (MN). Having said this, number of frame retransmission had the potential to be one of the criteria considered for handover to start taking place. Nevertheless, paper [4] actually examined the effectiveness of signal strength and frame retransmission as the handover criteria. Based on the results obtained, they had proven that signal strength was unable to detect performance degradation that was caused by radio interference. However, by using frame retransmission as one of the criteria to handover, the output turned out to be much more reliable. This was because frame retransmission was said to be able to detect the performance degradation that was caused by radio interference. However, the information of frame retransmission could only be obtained after a handover had taken place. It could only be verified when sending and receiving had already occurred between two nodes. By then, performance degradation would have already occurred.

This problem however could be solved by sending dummy packets to the selected AP as suggested in [5]. Once mobile node (MN) had associated with a new AP with the strongest RSSI, dummy packets were transmitted to check the quality of the connection. If number of frame retransmission was higher than certain threshold, the connection was terminated. Then, mobile node (MN) started executing access points (APs) search process. However, if the total value of frame retransmission was lower than certain threshold, the algorithm was terminated and connection was maintained with the current access point. This method was actually quite reliable and effective but it caused unnecessary traffic in the network.

A good handover decision should result in minimal service of disruption. Thus, as discussed in [6], they proposed to track received signal strength of neighbouring APs continuously and monitor the quality of the links of all APs operating on the client’s current and overlapping channels. Viviek Mhatre and Konstantine Papagiannaki presented the comparative performance of five triggering algorithms. The five different algorithms were based on the following criterion; lost beacons, received signal strength value, received signal strength difference, received signal strength trend and received signal strength prediction. They concluded that beacon-based and threshold-based were reactive by nature because they triggered a handoff when RSSI of the associated AP degraded. However, received signal strength difference, received signal strength trend and received signal strength prediction were proactive in nature because they were constantly on the look for a better AP. All the methods above were either solely based on received strength signal alone to trigger a handover or triggers handover only when performance degradation had been detected. This was clearly not efficient enough to be implemented in mobile IPv6.

In paper [7], the authors suggested using adapted transmission rate and received signal strength indication as the trigger to start handoff process. Adapted transmission rate was a metric that represents the quality of both uplink and downlink. They suggested that when mobile node was at the edge of the coverage range, the changes of received signal strength became very insignificant. Thus it was not wise to use received signal strength (RSSI) as handoff trigger. Instead, when mobile node was at the edge of coverage region, transmission rate changed drastically. Therefore, the smoothed transmission rate value of transmission rate could be used as a trigger to handoff. When certain conditions were met, transmission rate was used as handoff trigger. However, when there were not enough traffic, then received signal strength (RSSI) was used as trigger. Probability of less traffic occurring could be high at times. Thus, using this scheme might result in handover depending on received signal strength solely at all the times. Thus, this might cause inefficiency in the network system.

III. Design and Implementation of Decision to Handover Algorithm

An intelligent fuzzy logic algorithm is proposed in this section. The overall idea is to design a fuzzy logic algorithm that operates to trigger handover based on mobile node’s speed and received signal strength indication. It is necessary to have an intelligent handover decision system in order to improve the performance of network.

In this section, we look into the implementation of fuzzy logic in our algorithm by using a fuzzy logic control system as shown in Fig. 1 and by using Table I. Next, we explore on the intelligent handoff trigger algorithm with a flowchart in Fig. 2. Then we proceed to describe further on the implementation of our algorithm.

A. Details of Implementation of Fuzzy Logic in Our New Proposed Handover Algorithm

In essence, the fuzzy logic control system employs received signal strength indication (RSSI) and mobile node’s (MN’s) speed as the inputs of this fuzzy logic system. With these two information obtained, the fuzzy logic outputs the decision to handover at the exact right time. Figure 1 below illustrates the fuzzy logic control system.

The decision to handover is made based on nine sets of fuzzy rule matrix. If the speed and the RSSI are below certain thresholds, the system decides not to handover. However, if the RSSI and speed are within certain range, the output decides to either wait for a certain period of time before handover or to execute handover process immediately. This applies to the situation where RSSI and speed are above certain threshold. Table I shows the rule matrix of fuzzy logic implementation into the algorithm in detail.

TABLE I: THE RULE MATRIX OF FUZZY LOGIC IMPLEMENTATION IN THE ALGORITHM

Rule	Input of Fuzzy Logic		Output of Fuzzy Logic
	Received Signal Strength Indication (RSSI)	**Mobile Node's Speed (m/s)**	
1	>47	< 10	Not Handover
2	>47	10 to 19	Not Handover
3	>47	>20	Not Handover
4	43 to 47	<10	Wait 7 seconds before Handover
5	43 to 47	10 to 19	Wait 7 seconds before Handover
6	43 to 47	>20	Not Handover
7	<43	<10	Handover
8	<43	10 to 19	Handover
9	<43	>20	Wait 7 seconds before Handover

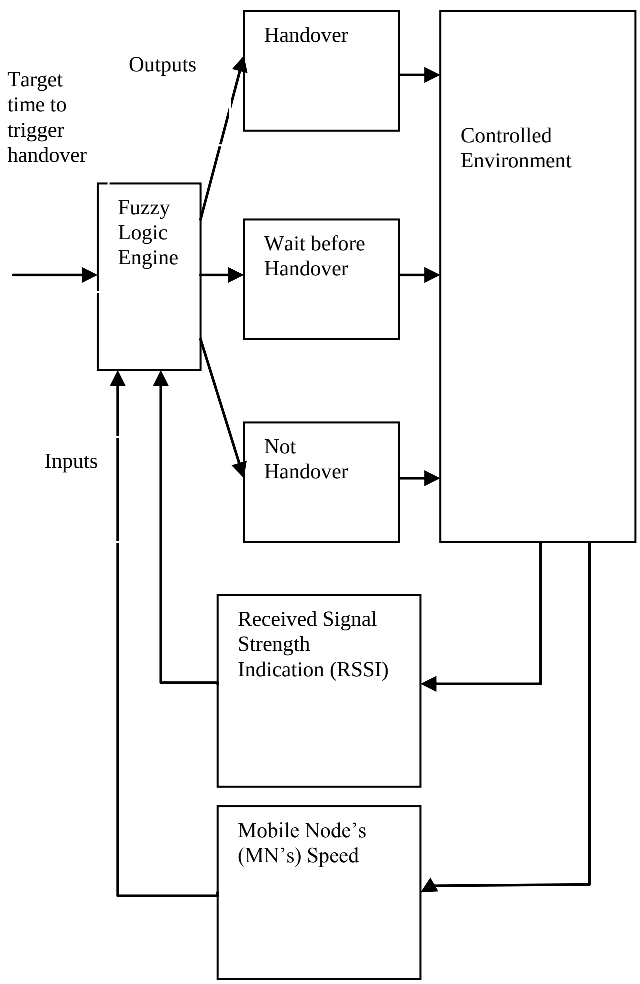

Fig. 1. Fuzzy logic control system.

With every interval of 0.3 seconds, the algorithm is executed. Once the algorithm has been executed, the algorithm starts searching for the current mobile node's speed. Once the mobile node's speed has been tabulated, the algorithm proceeds to calculate the received signal strength (RSSI) of its current associated node. Based on the input membership functions of fuzzy logic scheme, scores are tabulated. Table I provides a guide towards obtaining relevant scores for the decision to handover.

If the score obtained is less than 50%, handover is triggered and mobile node starts searching for the access point with the highest received signal strength indication to associate with. However if the score obtained is between 50% and 70%, the algorithm decides to trigger a delay of 7 seconds before executing the handover process. If the score is more than 70%, the algorithm decides not to handover. Instead, it proceeds to delay for an interval of 0.3 seconds before executing the algorithm again.

B. Details on Intelligent Handover Trigger Algorithm

In this section we analyse thoroughly into the fuzzy logic algorithm based on Fig. 2.

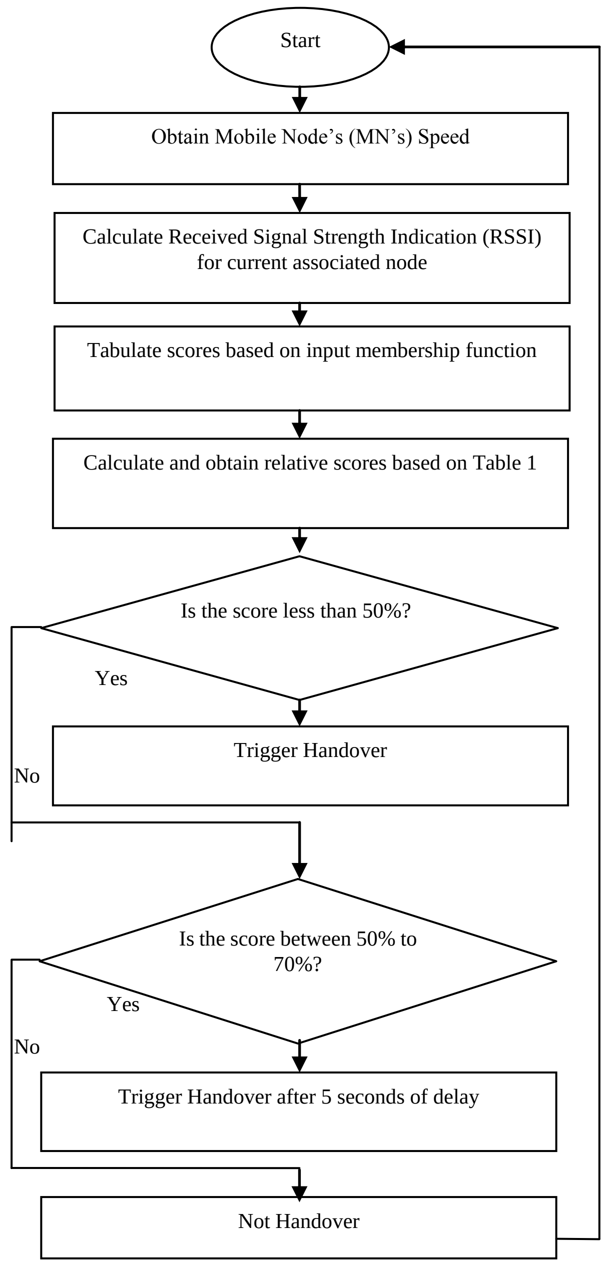

Fig. 2. Flowchart of fuzzy logic implementation on handover decision algorithm.

IV. Simulation

Our algorithm was implemented on Omnet++ software on mobile IPv6 module [8]. Simulation was done across twelve wireless LAN access points. As the mobile node moved across this twelve access points in a rectangular manner as shown in the orange line below, we tabulated the performance based on number of handovers, ratio of packet received to packet sent in percentage, throughput and total number of frame retransmission. We compared our algorithm with the most commonly used algorithm to trigger handover which was based on received signal strength indication (RSSI) threshold. Simulations were run based on different mobile node's speeds (9m/s to 28m/s). Fig. 3 illustrate the simulation environment of our research.

In our simulation, we sent packets with size 1000 bytes every interval of time from the mobile node (MN) to the correspondent node (CN). Radio transmission rate is set at 6Mbps. Based on [8], we tested our simulation with router advertisement set at minimum 0.05s and maximum 1.5s.

The transmission power was set at 30mW with carrier frequency about 2.4 GHz. The distance between each access point was approximately 140 metres apart. As the mobile node (MN) moved across a distance of 2000 metres encountering all these twelve access points on its way, the simulation was tested and run for both algorithms and performance was compared.

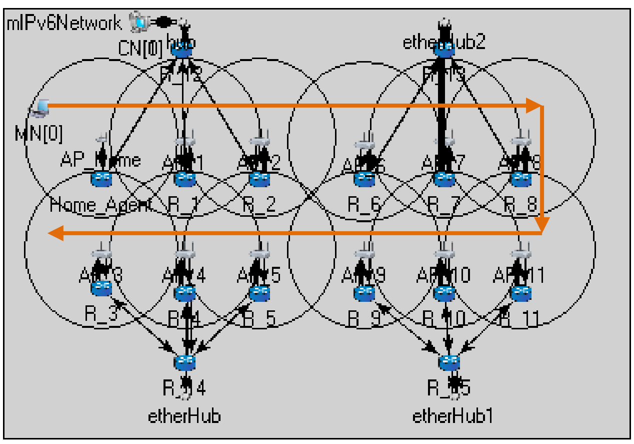

Fig. 3. Simulation scenario.

V. Discussion

The simulation results obtained are shown in Fig. 4-Fig. 7. Fig. 4 clearly shows that our algorithm has managed to reduce the number of handovers as the speed increases. Even though the numbers of handovers has been reduced, the ratio of packet received to packet sent is still higher for fuzzy logic algorithm as compared to RSSI threshold algorithm as shown in Fig. 5.

This is because when the handover process is taking place, network interruptions occur. Thus, during this handover process, packets are lost. Therefore, more handover process results in tendency for more packet loss. However, when there are less handovers, there would be a certain amount of time where mobile node is not connected to any network. This causes packets to be lost as well. However, when the two effects are compared, it turned out that it is better not to connect to any networks rather than keep executing handover process. This is because the total number of handover process causes bigger delay as compared to the delay where mobile node is not connected to any network at all. This certainly applies when mobile node is moving at a higher speed.

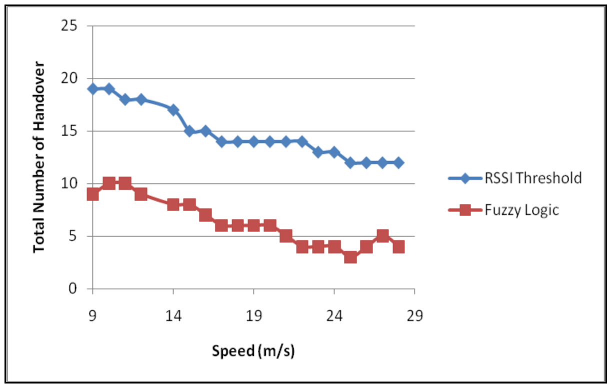

Fig. 4. Graph of number of handovers versus speed for two different algorithms.

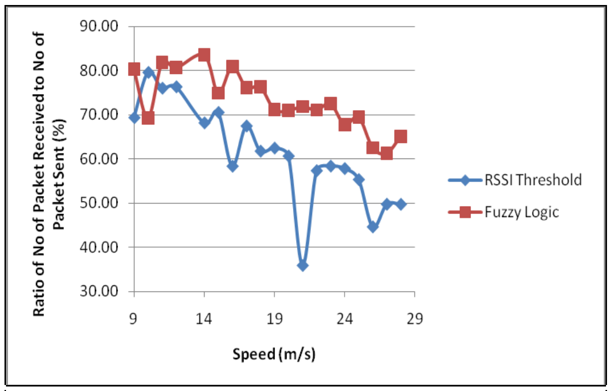

Fig. 5. Graph of ratio of number of packet received to number of packet sent (%) versus speed (m/s) for two different algorithms.

Fig. 4 and Fig. 5 show that the number of handovers has been reduced by using fuzzy logic algorithm. With the number of handovers reduced, the throughput for both algorithms still remained almost the same for both algorithms as shown in Figure 6. Thus, this shows that our new proposed algorithm is manage to reduce number of handovers, reduced packet loss and yet maintained its throughput.

The throughputs for both algorithms are almost similar. However, packet loss is much higher in RSSI threshold algorithm. This is because our new proposed algorithm has higher overall number of frame retransmission as compared to RSSI threshold algorithm as shown in Fig. 7. The packets that could not get through are managed to be sent again when the network is reconnected. Thus, the packet loss is less for our fuzzy logic algorithm.

VI. Summary

This paper outlines an efficient handover scheme based on fuzzy logic. The fuzzy logic algorithm triggers handover based on RSSI and MN's speed in mobile IPv6 across numerous wireless LANs access points. The comparison between our new proposed algorithm and RSSI threshold algorithm shows that our new proposed algorithm is more efficient in reducing the number of handovers and reducing packet loss yet maintaining its throughput. The improvement of our algorithm is inevitably vital in the new and improved mobile IPv6 development.

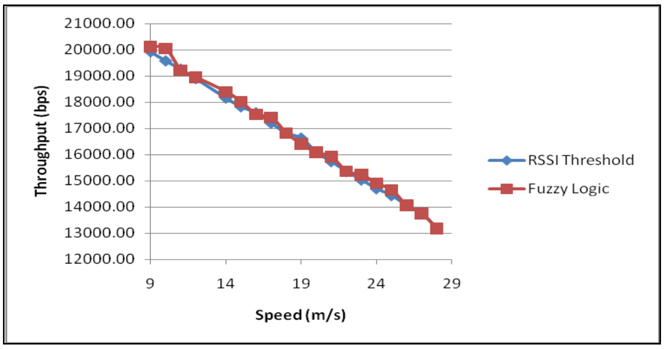

Fig. 6. Graph of throughput (bps) versus speed (m/s) for two different algorithms.

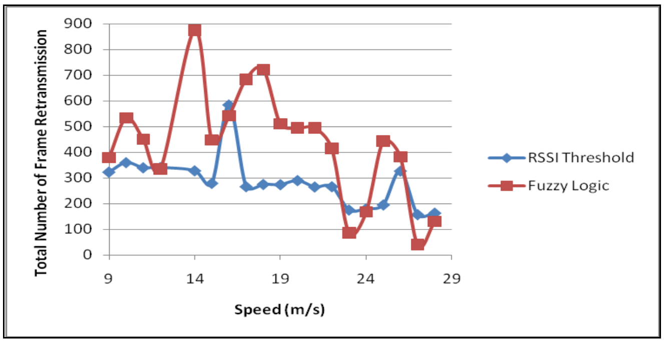

Fig. 7. Graph of total number of frame retransmission versus speed (m/s) for two different algorithms.

VII. Conclusion

In future ubiquitous networks, wireless LAN will definitely experience an unprecedented growth. We strongly believe that an intelligent and smart algorithm will definitely be necessary to accommodate the ever growing population that is constantly on mobile networking. Nevertheless, mobile IPv6 is moving forward to an era of high technology. Thus, an intelligent handover algorithm like ours is necessary to ease humans in networking.

Acknowledgment

This project is partially supported by UMRG (RG003/09ICT) and eScience (01-01-03-SF0566) funds.

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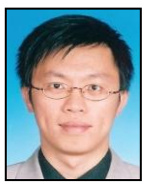

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