Fuzzy Logic based Handoff Latency Reduction Mechanism in Layer 2 of Heterogeneous Mobile IPv6 Networks

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Abstract. Mobile IPv6 (MIPv6) is one of the pioneer standards that support mobility in IPv6 environment. It has been designed to support different types of technologies for providing seamless communications in next generation network. However, MIPv6 and subsequent standards have some limitations due to its handoff latency. In this paper, a fuzzy logic based mechanism is proposed to reduce the handoff latency of MIPv6 for Layer 2 (L2) by scanning the Access Points (APs) while the Mobile Node (MN) is moving among different APs. Handoff latency occurs when the MN switches from one AP to another in L2. Heterogeneous network is considered in this research in order to reduce the delays in L2. Received Signal Strength Indicator (RSSI) and velocity of the MN are considered as the input of fuzzy logic technique. This technique helps the MN to measure optimum signal quality from APs for the speedy mobile node based on fuzzy logic input rules and makes a list of interfaces. A suitable interface from the list of available interfaces can be selected like WiFi, WiMAX or GSM. Simulation results show 55% handoff latency reduction and 50% packet loss improvement in L2 compared to standard to MIPv6.

1. Introduction
The next generation wireless communication system is envisioned to be fully Internet Protocol version 6 (IPv6) based in order to support increasing mobile users. Mobility in IPv6 (MIPv6) [1] was introduced by the Internet Engineering Task Force (IETF) so that a Mobile Node (MN) could have mobility from one Access Point (AP) to another AP seamlessly. However, seamless and ubiquitous connection is a great challenge in mobile environments where heterogeneous technologies are collaborating with each other. In such scenario, mobile users need to be connected with different types of technologies while they are roaming. The continuous growth of wireless communication systems poses problems for seamless connectivity like handoff delays, packet loss and jitter rise when the MN is moving. Two types of delay could happen during this transition, namely; Layer 2 (L2) and Layer 3 (L3).

Fuzzy logic technique is one of the effective techniques that has been employed in the field of network particularly L2 of MIPv6 to minimize its existing limitations, namely; delay and packet loss. The Received Signal Strength Indicator (RSSI) is used to take decision for switching from one AP to another when the MN switches from one AP to another in L2. Heterogeneous network is considered in this research in order to reduce the delays in L2.
another AP in a particular technology like WiFi, WiMAX or GSM. However, in heterogeneous environment, the reliance on only RSSI is not sufficient for taking handoff decision due to diverse parameters of the network. Therefore, to reduce the most time consuming scanning delay, many researchers have proposed many alternative solutions in the form of incorporating fuzzy logic into the decision making process. Fuzzy logic has been used successfully in control system design and prediction based applications. It is a language based approach that allows less dependence on precise quantitative analysis. It is most suitable for uncertain events [2]. One of the main features of fuzzy logic is the ability to take many performances metrics into account and yielding the best possible solution for handoff decision. This approach is more appropriate for heterogeneous environments where many metrics need to be considered such as BER, SNR, velocity, bandwidth, network loads, monetary cost etc. The Fuzzy logic consists of three basic components, namely; fuzzifier, inference engine and defuzzifier as shown in figure 1.

The fuzzy algorithm needs the establishment of fuzzy sets and rules over the N number of inputs. The objective of the fuzzifier in the fuzzy system is to convert the crispy input into non-crispy of a fuzzy set that is ready to be processed in the inference engine with combination of fuzzy rules. Fuzzy rules are based on if-then conditions.

![Fuzzy Reference Model](image)

Figure 1: Fuzzy Reference Model

The defuzzifier converts the non-crispy data into the crispy output as a scalar value which is the output of the handoff factor. Applying fuzzy logic technique, the delay of L2 in MIPv6 can be reduced.

The rest of the paper is organized in the following fashion. Section two discusses about MIPv6 in brief. Related works addressed in section three. Section four proposes proposed mechanism to reduce L2 delays. Simulation model and proposed enhancement have been elaborated in section five and six respectively. Finally, conclusion has been drawn in section seven.

2. Mobile IPv6 (MIPv6)

It has been observed that recent developments in wireless technologies motivated users and vendors to alter their preference from wired Internet connection to wireless Internet connection. This shift in technology provides better communication services in return, such as, the ability to communicate while an MN is moving from one network to another. However, Internet was initially designed for fixed networks. Consequently, there is no provisioning for IP to support mobility. Mobile IP (MIP) (RFC 2002) is the first standard protocol designed by IETF to address the aforementioned issues [3]. The development of MIP has enabled users to maintain continuous connection even while on the move.

MIPv6 is one of the mobility management solutions that has been widely accepted in the academic and industrial community. MIPv6 [1] has been proposed to accommodate the increasing demands of mobility in the Internet by IETF. It has many facilities compared to existing MIPv4 including more address space, enhanced security mechanism, route optimization and other features. Based on the
proposal, an MN should generate a permanent and temporary IP address for further communication [4].
The permanent address is assigned by home network (HN) to the MN as a global identifier that is fixed. A temporary address also known as care-of address (CoA) is obtained from the visiting network which indicates the host’s actual location that changes with time as MN moves to foreign networks. While an MN is attached to its HA, it is able to receive packets destined to its HA by existing routing mechanism. However, whenever it visits any foreign networks, the home address will be invalid. In that case, after obtaining CoA, the MN sends a binding update (BU) to its HA and HA maps the current CoA in its binding cache. To keep this cache updated, each MN sends a BU message containing current CoA information to its HA. The MN sends this BU periodically or whenever it changes its current location [5]. In the meantime, the corresponding nodes (CN) that needs to communicate with the MN also maintains a binding cache. If the CN does not have an active map address for a mobile node in its binding cache, it will send the packets to MN’s home address for the first time. The HA then encapsulates the packets and forwards them to the MN’s CoA through a tunnel. Thus, CN can communicate with MN directly and avoid a triangular path. There are two types of delay are occurred during this transition, namely; Layer 2 (L2), and Layer 3 (L3). The delay associated with L2 is addressed in this paper while L3 related delays are discussed in our previous work [6,7,8].

3. Related Works on Layer 2 (L2)
The term handoff (also known as handover) refers to the process of transferring an ongoing call or data session from one channel connected to the core network to another [1]. Handoff latency is the time duration between the last connection of the old point of attachment and the next data transmission to the new point of attachment. L2 handoff process is related to the link layer communication. This step is the initial part of the total handoff procedures that depends on multiple phases. L2 delays in IEEE 802.11b can be categorized into three components, namely; scanning, authentication and re-association phases.

3.1. Scanning Delay
In the scanning phase, the MN can sense if the current signal strength is weakening and fails to receive some frames from the existing network while it receives probe request from other neighboring networks with a better signal strength. Hence, the MN collects the Received Signal Strength Indicator (RSSI) value from all APs available in the range. The existing IEEE 802.11b uses these RSSI values to take handoff decisions. Additionally, the MN scans not only one AP but also all APs in the coverage area. To scan all these APs, the MN needs long time to scan and process the handoff decision as it is mentioned that scanning phase is the most time consuming phase that accounts for 90% of total L2 handoff procedures [9, 10]. If the MN knows which AP to switch to, there will be no need for further scanning which saves time. Therefore, a fast handoff scheme has been proposed where channels are scanned prior to the time of handoff [11]. This approach is comprised of pre-scanning with selective channel mask and dynamic caching mechanisms. However, this approach has not been benchmarked with any standard mechanism. To minimize the scanning delay from all number of APs, [9] proposed a Global Positioning System (GPS) based model that calculates angel between MN and the APs. Based on the RSSI and calculated angel between MN and AP which is closed to each other, the MN takes the final handoff decision. However, the authors did not consider the velocity of the MN as angular value changes according to the movement of the MN and velocity of MN.

Three performance metrics, namely; RSSI, MN velocity and network loading are taken into consideration for analyzing the handoff delay in heterogeneous scenarios [12]. The author proposes FUzzy Normalization - HandOver Decision Strategy algorithm (FUN-HODS) in a heterogeneous network where 3G, WiMAX and WiFi are converging. This algorithm is suitable for low speed
movement of MN but for high speed movements it shows 15%-50% probability of handoff failure which is not acceptable for real time applications. Moreover, a new Modular Fuzzy Rule Based (MFRB) handover decision algorithm has been proposed [13], which aims to address the issues of multiple QoS parameters and at the same time, reducing the computational complexity significantly by reducing the total number of fuzzy rules. This approach shows better performances over monolithic fuzzy and Adaptive Neuro Fuzzy Inference System (ANFIS) approaches in terms of handoff, average usage of cost and throughput. However, this approach did not consider the velocity of the MN which is one of the performance metrics of an MN in wireless network. A predictive RSSI and fuzzy logic based network selection for vertical handoff in heterogeneous wireless networks has also been suggested [14]. In addition to the RSS metric, the residence time in the target network is predicted which is taken into account for handoff trigger. The simulation results show that the proposed Fuzzy logic theory based Quantitative Decision Algorithm (FQDA) performs better in vertical handoff scenarios and reduced call dropping probability. Furthermore, to reduce L2 delay a Fuzzy logic-based Hand-off Decision (FHD) approach is proposed to reduce L2 delay [15]. This approach combines two parameters RSSI and the direction of an MN towards the APs. However, the direction might change over time since the velocity and the distance between MN and APs are not considered. Some additional metrics for L2 handoff analysis are added, namely; RSSI values, network load and available bandwidth in a heterogeneous wireless networks [16]. However, as velocity and distance are not considered, the aforementioned parameters could be changed due to movement of an MN in a wireless network.

The aim of this research is to use some basic parameters to reduce the handoff delay of L2. The parameters employed in this research for this evaluation is the most important RSSI values, the velocity and distance between MN and APs. The evaluation is considered in the heterogeneous environment where WiFi, 3G and WiMAX technologies are converging with each other. Moreover, to measure the RSSI value of an AP, a software, inSSIDer 2.0 is installed to the MN.

3.2. Authentication Delay
Authentication must be completed followed by scanning phase and prior to the association phase. In pre-authentication schemes, the MN authenticates with the new AP immediately after the scan cycle finishes.

3.3. Re-association Delay
Re-association is a process for transferring associated signal from one AP to another AP after the MN has completed the authentication. Authentication and re-association phase have less delays compared to scanning delay.

4. Proposed Mechanism for L2
In order to address the issue of scanning delay in pertinent to L2, a fuzzy logic based technique is employed to make handoff decisions. The RSSI value and the speed of an MN are considered as the input of the fuzzy logic inference engine. The fuzzy rules and membership functions are designed and set according to certain conditions. The fuzzy logic inference engine processes the input values and perform the defuzzification task to select the available interfaces, namely; WiFi, WiMAX and GSM/3G.

4.1 RSSI Measurement
Only RSSI is being used for conventional WiFi handoff process. This process yields satisfactory performance when the node is stationary. However, when the nodes are mobile in a heterogeneous environment utilizing RSSI value alone is not sufficient to make handoff decisions. Therefore, another parameter like velocity is proposed together with the RSSI value because these parameters dynamically change with time. Theoretically, the measurement process of RSSI is shown in equation 1 [17]. It has formulated the RSSI in dB at a distance d from the AP to be:
\begin{equation}
10 \log_{10} P_r = 10 \log_{10} P_o - 10 \alpha z \log_{10} d + X
\end{equation}

where
\begin{equation}
10 \log_{10} P_o = 10 \log_{10} P_t + 10 \log_{10} G_t + 10 \log_{10} G_r + 20 \log_{10} \left( \frac{\lambda}{4\pi} \right)
\end{equation}

is the received power at a distance of one meter, \(\lambda\) is the wavelength, \(P_t\) is the transmission power and \(G_t = G_r = 1\) are the transmitter and receiver antenna gains respectively. \(\alpha\) is the path-loss gradient and \(\alpha = 3\). \(X\) is a zero mean Gaussian random variable that corresponds to log-normal shadow fading. Practically, the RSSI value can be measured using software. This research utilizes inSSIDer 2.0 to configure the MN’s signal strength. This software is capable to receive RSSI value of all APs in a coverage area. In this research, the MN movement speed is classified into three categories. The velocity, \(v_0\) is in m/s

(i) \(0 < v_0 \leq 10\) in the first category for walking, running or cycling velocity scenario,
(ii) \(10 < v_0 \leq 20\) for city road velocity scenario and
(iii) \(20 < v_0 \leq 30\) for highway velocity scenario.

Based on the velocity range and different values of the RSSI, the fuzzy logic based network identification technique is initiated. The RSSI value changes from time to time. A higher RSSI value means the MN is closer to the AP.

4.2. The MN’s Distance and Velocity Measurement
The MN sends Router Solicitation (RS) message to the APs and the APs reply with Router Acknowledgement (RA) messages whenever the MN changes its previous point of attachments. The MN can track this RS and RA messages transmission and reception time, denoted as \(T_{RS}\) and \(T_{RA}\). The difference between these two signals is known as \(T_{travel}\) time. It is considered that the travelling speed of these messages is at the speed of light \(c\). Therefore, it is easy to calculate the distance between the MN and the APs using the expression in equation 2.

\begin{equation}
d = c \times T_{travel}
\end{equation}

4.3. Fuzzy Logic Based Scanning (L2 Phase)
To reduce the scanning delays, fuzzy logic technique based scanning mechanism is proposed. The MN scans for new APs after detecting the weak signal from previous AP. As shown in Figure 2, the MN scans for new RSSI signals from the new APs and receives it. After receiving the RSSI from the new AP, the MN compares the current RSSI (RSSI_c) with the new RSSI (RSSI_n) and also compares this information with the threshold value of the RSSI. The distance between an MN and AP can be estimated with the help of GPS. The velocity of an MN also can be measured from GPS. Using this measured velocity with the RSSI value, the MN decides to trigger L2 handoff.
The RSSI measurements are calculated based on a fuzzy logic technique. It is assumed that in a heterogeneous coverage area three different technologies, namely; WiFi, WiMAX and GSM/3G are overlapping with each other. RSSI and speed are the two input parameters to the fuzzy input to yield the optimum AP. The fuzzy inference engine processes the given parameters and generate the output as a handoff factor. Three scenarios related to the implementation of this fuzzy logic based technique are discussed below.

4.4. Design Considerations

RSSI values and speed are considered as input parameters for WiFi, WiMAX, and GSM technologies. In this design scenario, only WiFi RSSI values have been discussed where WiMAX and 3G follow the almost similar pattern and skipped in this paper. The RSSI values are set in the range -100dBm (weak) to -15dBm (strong). The classification is as follows, (1) If the RSSI value is in between -100dBm and -70dBm, it indicates the signal is weak, (2) if it is from -70dBm to -50dBm, the signal is termed as average and (3) if it is from -50dBm to -15dBm, the signal is identified to be strong. The speed of an MN can be categorized into three types, namely; (1) walking velocity which ranges from 0 m/s to 10 m/s, (2) city velocity which ranges from 10 m/s to 20 m/s and (3) highway velocity which ranges from 20 m/s to 30 m/s.

On the other hand, (1) if the distance is too far the RSSI is indicated as weak, (2) if the distance is medium, the signal is considered as average and (3) if the distance is very near, the signal is classified as close to AP. Based on these input parameters, the fuzzy rules set the conditions to be processed by
the fuzzy logic inference engine for the interface selections as shown in Figure 3. The output range is set between 0 and 1. If the output range is in between 0 and 0.33, 0.33 and 0.67, 0.67 and 1.0 then WiFi, 3G and WiMAX interface will be selected respectively. Based on these criteria it is designed in this model considering a heterogeneous environment where WiFi, WiMAX and GSM are overlapping.

The fuzzy logic membership rules are set according to certain conditions as shown in Figure 4. The rules are based on if and then conditions. Fuzzy engine compares some set of parameters then takes the decision for the interface selection.

The RSSI value of GSM/3G and velocity of MN to the AP are the input for the fuzzy inference engine to process 3G technology’s handoff process. Similarly, the RSSI value of WiMAX and the velocity of the MN are considered as the input for WiMAX handoff process. These two design models are almost same to the WiFi scenario except the RSSI values of GSM/3G and WiMAX that has larger coverage area and its RSSI value differs from WiFi. It is noted that the RSSI values of GSM differs from WiFi that is -125 dBm to -80 dBm [8].

5. Simulation Model
A Fuzzy Logic controller is employed to simulate the fuzzy logic expert system once it has been verified with the rule viewer using MATLAB SIMULINK. The Fuzzy logic controller block in SIMULINK has two inputs and one output. Using MATLAB SIMULINK, the Fuzzy logic controller shows the output result of the interface selection based on two inputs which are MN velocity and RSSI. These inputs can be observed from MN as crisps inputs. The crisp input is then evaluated using rule base. The composed and aggregated output of rules evaluation is defuzzified and the crisp output is obtained. Figure 5 shows the simulation overview for selecting three wireless technologies, namely; WiFi, WiMAX and GSM/3G.

Figure 4: Fuzzy logic rules

Figure 5: Simulation overview
In this scenario, there are two fuzzy input variables and one output. Each of the fuzzy variables has three subsets. These sets are mapped to the corresponding Gaussian membership functions. The fuzzy rules are set based on the combinations of these two input variables with three subsets that are at least 8 rules. These rules have been previously discussed in section four. The output interface has been selected based on these rules. MATLAB Fuzzy Toolbox platform is used for making decisions provided as input variables while OMNeT++ is used to carry out the networking management tasks.

6. Performance Analysis
In order to evaluate the performance of the proposed mechanisms, two main performance criteria have been considered in this research for the proposed solution. These performance metrics are defined in the context of wireless networks elaborated below:

- **Handoff Latency**: Handoff latency is defined as the interval between the last data packet received from the old access router and the first data packet received at the new access router by the MN. Specifically, it is the amount of time required in order to be granted access to get connected into the new network. Handoff latency is a critical issue for real time applications with mobile MN that needs to meet a required QoS. This paper addresses the issues of handoff latency by proposing the fuzzy logic technique.

- **Packet Loss**: Packet loss is defined as the number of packets lost during the handoff. It is the amount of packets that are lost or corrupt and finally cannot reach the desired destinations. Packet loss is measured in relation to the MN speed ranging from 5 m/s to 30 m/s for proposed mechanisms.

6.1. Handoff Latency in L2
The handoff latency in Layer 2 consists of scanning, authentication and re-association phases. Fuzzy logic technique is applied to scan the alternatively available interfaces while the MN is moving from one coverage area to another.

![Figure 6: Handoff latency in L2](image)

Figure 6 shows the handoff latency in millisecond (ms) with respect to speed of the MN. The standard MIPv6 takes around 400ms to scan an interface based on only RSSI values where this proposed fuzzy enabled MIPv6 scanning takes about less than 200ms. In average, the proposed mechanism shows about 55% improvement over the existing mechanism while the MN is moving. However, for fast movement the scanning time increases a little bit closed to 200ms. On the other hand, two other phases, authentication and re-association need 20ms and 10ms respectively.

6.2. Packet loss in L2
Packet loss results for handoff latency. Long handoff latency implies more packet loss and this degrades the QoS. Packet loss occurs when the MN is switching from one interface to another interface. The drawback of the standard MIPv6 is having more packet loss in L2.
In L2 of MIPv6, the average packet loss is around 0.05% to 0.35% for different movement while the proposed mechanism reduces this number about 0.01% to 0.26% as shown in Figure 7. Moreover, it can be concluded that the overall packet loss in L2 is reduced in average about 50% of standard MIPv6.

7. Conclusion
This paper proposes fuzzy logic based mechanism to reduce L2 handoff latency of MIPv6. Particularly, it addresses the scanning delay that is the most time consuming in MIPv6. According to the simulation result, the handoff latency reduced about 55% and packet loss rate enhanced around 50% in L2.

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9. References

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