Enhanced Handoff Latency Reduction Mechanism in Layer 2 and Layer 3 of Mobile IPv6 (MIPv6) Network

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Abstract: Next Generation Networks (NGN) both static and mobile are expected to be fully Internet Protocol Version 6 (IPv6) based. Mobility in IPv6 (MIPv6) network was designed to provide Internet services to end users at anytime and anywhere. However, MIPv6 is not widely deployed yet due to handoff latency and other limitations leading to packet loss and Quality of Service (QoS) degradation for real time applications such as audio and video streaming. MIPv6 handoff latency can be categorized into layer 2 (L2) and layer 3 (L3) delays that includes link layer establishment delay, movement detection delay, address configuration delay and binding update or registration delay. Movement detection delay and address configuration including Duplicate Address Detection (DAD) in L2 and L3 respectively consume the highest time of the total delay. In order to reduce these handoff latencies, two solutions are proposed to focus all the delays both in L2 and L3. The first solution is the fuzzy logic technique based network awareness to reduce movement detection delay especially the scanning time in L2 in heterogeneous networks. The second solution is Parallel Duplicate Address Detection (PDAD) to reduce address configuration time in L3. Both solutions benchmarked with OMNeT++ simulator show improvements over standard MIPv6 networks. The handoff latency reduced more than 50% and packet loss improved around 55% in L2. Moreover, in L3 the handoff latency reduction accounts for 70% and packet loss improved approximately 60%. The handoff latency is reduced from 1300 ms to 500 ms applying fuzzy logic technique at L2 and PDAD mechanism in L3 leading to overall delay reduction of 60%.

Key words: L2 and L3 of MIPv6, Seamless communication, Parallel Duplicate Address Detection (PDAD), Movement detection, Fuzzy logic, Handoff latency and Packet loss.

INTRODUCTION

The wireless communication systems including the number of wireless applications, services and devices are growing rapidly. The users’ demand is not only to access the facilities at “anytime and anywhere” but also to be “always best connected”. However, these demands becomes challenging since it requires seamless networks. In a seamless network, mobile nodes (MN) move freely from one network to another network maintaining the connectivity of all applications running on the mobile devices, supporting a continuous end-to-end data service within the same session during the switchover. Seamless communication is important for network-enabled applications to operate continuously at the desired quality of service in a wired or wireless IP network, especially for real time applications such as audio and video streaming. Several strategies have been proffered to improve these situations and among them Mobile Internet Protocol Version 6 or MIPv6 (Johnson et al., 2011) so far provides better solutions for its wide address spaces and additional features. In MIPv6, when mobile users migrate from the coverage of one network access point to another, handoff latency is introduced which is one of the major causes of performance degradation. Whenever a mobile node (MN) moves from its registered home agent (HA) to another foreign network (FN) then it needs to be registered with that network in temporary basis by getting a care-of-address (CoA). With this CoA, the MN maintains communication with its HA and other corresponding nodes (CN) who intends to communicate with the MN. To acquire this CoA from the visited network, the MN has to accomplish some operations introducing delays and these includes movement detection – (on average 1.5 sec), new CoA configuration including Duplicate Address Detection (DAD) – (1 sec), and registration or binding update (BU) – (300ms) (Gaogang et al., 2007) as depicted in Fig. 1, (Son et al., 2007; Shanthy 2010; Mishra et al., 2003).
The total duration of handoff latency as given in Fig. 1 is not acceptable for many applications especially for audio and video conferencing. It is clear that, movement detection and address configuration with DAD take the maximum time of total handoff latency that is around 2500ms. Therefore, to minimize the total latency in an acceptable level two solutions have been proposed to achieve seamless communication. The first solution is the combination of fuzzy logic based network awareness to reduce movement detection delay especially the scanning time in L2 and parallel DAD (PDAD) to reduce address configuration time in L3.

The rest of this paper is organized as follows. Section II provides an overview of handoff latency of MIPv6 both in L2 and L3 while section III highlights related works involving MIPv6 handoff latency reduction schemes. Two mechanisms that have been proposed to reduce handoff latency are discussed in details in section IV. Simulation and results are analyzed in section V. Finally, conclusion is drawn in section VI.

Handoff Delay Analysis Of MIPv6:

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 (Johnson et al., 2011). 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. If the MN moves within the same technological Access Point (AP) coverage area, it is known as horizontal handoff latency, for example, the movement of WiFi to WiFi or WiMAX to WiMAX. On the other hand, if the MN moves between AP’s using different technologies it is referred to as vertical handoff latency such as WiFi to WiMAX or UMTS to WiFi. Both horizontal handoff and vertical handoff procedures consist of three phases; (i) Handoff information gathering, (ii) Handoff decision, and (iii) Handoff execution (Johann et al., 2010).

Fig. 1: Delays of MIPv6

Fig. 2: Phases of handoff procedures

Each of these phases is interdependent of each other for their specific tasks as depicted in Fig. 2. The delay incurred due to handoff procedures can be represented by (1) where total delay consists of delay of gathering - $D_{Gathering}$, delay of decision - $D_{Decision}$ and delay of execution - $D_{Execution}$.

$$Total\ Delay = D_{Gathering} + D_{Decision} + D_{Execution}$$

The handoff information gathering phase collects the basic information of the networks including throughput, cost, packet loss ratio, handoff rate, Received Signal Strength (RSS), Signal to Noise Ratio (SNR), Carrier to Interference Ratio (CIR), Signal to Interference Ratio (SIR), Bit Error Ratio (BER), distance, location, and QoS parameters (Johann et al., 2010). It also collects the network properties, user preferences, battery status, resources, speed and service class. Handoff decision phase is another crucial process during handoff. This phase is responsible for taking decision for triggering the handoff “when” and “where” based on the gathered information. The “when” decision refers to the instant in time to make an optimal handoff decision for homogeneous network that depends on the RSSI values. The “where” decision is needed to choose the best network interface for switching in order to meet users requirements in a heterogeneous network. In a
heterogeneous network environment, the handoff decision is quite complex and there is need to consider many parameters obtained from different sources like network, mobile devices and user preferences for smooth handoff (Johann et al., 2010). Handoff execution phase takes final decision based on the previous two decisions and decides for ultimate handoff to the new interface.

These three decision phases of handoff delays are included in L2 handoff delay (the interface association time) and L3 handoff delay (the IP configuration and registration period with DAD time). In L2, the total delays are, namely; scanning, authentication and association. In L3, the total delays are, movement detection delay, address configuration including DAD delay and Registration delay or binding update delay.

**L2 Phase:**

L2 handoff process is related to the link layer communication. This step is the initial part of total handoff procedures that depends on some phases. Scanning phase is the most time consuming part that accounts for 90% of total L2 handoff procedures (Johann et al., 2010; Debabrata et al. 2010). During scanning time MN scans all APs one by one as available in the coverage area. The total scanning latency can be represented by (2) (Cheng, 2004).

\[
\text{Total Scanning Time} = \text{number of channel scanned} \times \text{MaxTime for each channel} + \text{Processing time} \tag{2}
\]

It can be noted from (2) that if the number of channel scanning is reduced, more scanning time can be saved. If the MN knows which AP to switch to, there will be no need for further scanning which saves time (Mustafa et al., 2005). Therefore, a fast handoff scheme has been proposed where channels are scanned prior to the time of handoff (Mustafa et al., 2005). This approach is comprised of pre-scanning with selective channel mask and dynamic caching mechanisms.

There are two types of scanning phase including active and passive phase. During an active scan, the MN broadcasts a probe request packet asking all APs in those respective channels to inform their survival and capability with a probe response packet as shown in Fig. 3.

**L2**

- L2 handoff process is related to the link layer communication.
- Scanning phase is the most time-consuming part.
- Total L2 delays include scanning, authentication, and association.

**Fig. 3:** L2 delays in MIPv6

For example, the MN sends probe request to the new AP1 and new AP2 and receives prove response from the requested APs. In case of a passive scan, the MN listens passively for the beacons bearing all necessary information like beacon interval, capability information, supported rate etc. about an AP. Active scan is normally speedy as it aims to bypass the most time-consuming phases in the layer (L2) handoff procedure, but is unreliable, since probe packets may get lost or greatly delayed in wireless traffic jams. It is estimated in [4] that active scan takes around 100 ms to 500 ms. On the other hand, Passive scan, though reliable, has a long waiting time for beacons which is prohibitive to many services as it takes around 1 sec [4]. Therefore, an appropriate channel
probing should be used wisely. Authentication must be completed followed by scanning phase and prior to association phase. In pre-authentication schemes, the MN authenticates with the new AP immediately after the scan cycle finishes. Association is a process for transferring associated signal from one AP to another AP after the MN has completed the authentication. Authentication and association phase have less delays compared to scanning delay.

**L3 Phase:**

L3 handoff starts after finishing the L2 procedures. L3 causes longest handoff delay of MIPv6. There are three types of delays are discussed in the following sections and the signalling transmission/flow of MIPv6 is shown in Fig. 4.

**Movement Detection Delay:**

An MN detects its detachment when it receives Router Advertisement (RA) messages from the new APs after L2 triggered. It uses movement detection to recognize the changes in the IP connectivity either receiving RA or sending Router Solicitation (RS) messages. This RA messages are sent to the MN at a random time of interval in between 3 and 4 seconds at least and between 1350 and 1800 seconds at most according to IPv6 network Neighbor Discovery (ND) (RFC 2461) for a stationary host (Narten et al., 1998). However, this time is too long for a mobile node to get connected with the new routers. Therefore, the MN can accelerate this process to receive this RA sending a Router Solicitation (RS). Therefore, the MIPv6 RFC 6275 (Johnson et al., 2011) decreases the interval time to send a beacon frame every 30 to 70 milliseconds (Vogt, 2006) whenever it enters to the new AP’s coverage area. The movement detection consists of router solicitation message (RS) and router advertisement (RA). Thus, movement detection delay - DMD can be represented by (3) where delay of RS and RA can be denoted as DRS and DRA respectively.

\[ D_{MD} = D_{RS} + D_{RA} \]  

Fig. 4: Signal transmission in MIPv6 network

When the MN detects any new prefixes in its RA messages, it assumes it has moved to a new network. However, reception of a single RA does not give a guarantee that the MN has moved to a different subnet as it might have been switches between APs within the same subnet. Therefore, missing of three RA from the old router indicates more reliable movement towards the new subnets. Moreover, advertisements from multiple routers are more accurate to determine the movement of the MN.
Address Configuration Delay:

After detecting the MN has moved to a new subnet area, it needs to configure a temporary Care of Address (CoA) from the new router prefixes according to the standard MIPv6 RFC (6275). In this phase, the MN uses stateless auto configuration (Thomson and Narten, 1998) process for CoA address configurations. Then the MN chooses an interface identifier, either randomly or based on the interface’s MAC address and combines the network prefix obtained from the router with a suffix generated from its 64-bit interface identifier. This untested address is called Tentative Address (TA). The uniqueness of this newly generated CoA must needs to be checked by sending a Neighbor Soliciting (NS) message to all nodes and routers in the same subnet that is known as Duplicate Address Detection (DAD) process. The MN waits for one second for Neighbor Acknowledgement (NA) as a reply message. If no responses are received within a period of one second from the neighbors indicating the generated CoA is unique. The MN assigns the TA to the interface otherwise the MN starts the address configuration process again (Kempf et al., 2005). The most time consuming part is DAD delay identified as $D_{DAD}$. This happens when MN sends a Neighbor Solicitation (NS) message to ask the surrounding MN/routers uniqueness of the newly generated address and gets reply. Thus, DAD delay $D_{DAD}$ can be represented by (4) where NS and NA delay are denoted as $D_{NS}$ and $D_{NA}$ respectively.

$$D_{DAD} = D_{NS} + D_{NA}$$ (4)

The MN sends newly generated CoA information through Binding Update (BU) message to the HA denoted as $D_{BU_{HA}}$ and gets registered to the corresponding HA by a confirmation Binding Acknowledgement (BA) message to the MN represented as $D_{BA_{MN}}$ and respective delays are given in (5).

$$D_{CoA} = D_{BU_{HA}} + D_{BA_{MN}}$$ (5)

The MN is ready to receive any data destined to it by using its previous address that forwarded to the HA. Prior to this, the MN has to check the authentication of the CN that wish to communicate with the MN and the process is known as Route Optimization (RO). The MN sends Home Test Init (HoTi) and CoA Test Init (CoTi) messages to the HA and CN respectively and receives Home Test (HoT) and CoA Test (CoT) messages. The delay incurred due to this RO procedures are denoted as $D_{HoTi}$, $D_{CoTi}$, $D_{HoT}$ and $D_{CoT}$ as shown in (6). This RO process confirms the security concern that is a new feature of MIPv6 networks.

$$D_{RO} = D_{HoTi} + D_{HoT} + D_{CoTi} + D_{CoT}$$ (6)

Registration Delay:

The MN sends BU message to the HA and CN and receives only BA message from HA. The delay occurred for this registration denoted as $D_{BU_{HA}}$, $D_{BA_{HA}}$ and $D_{BU_{CN}}$ respectively. In MIPv6 networks, the acknowledgement from CN is not included. Thus registration delay can be given by (7).

$$D_{BU} = BU_{HA} + BA_{HA} + BU_{CN}$$ (7)

The time between the sending of the BU from the MN to the HA and the arrival/transmission of the first packet through the new access router is referred as registration delay. By completing this procedure, the MN is fully ready to transmit data to its CN.

Related Works:

MIPv6 is developed to support global mobility management [1]. In MIPv6 every MN has two IP addresses: permanent home address (HoA) and temporary care of address (CoA). When an MN enters to a foreign domain it will create a CoA by the combination of address prefix from visited router and the MAC address of the MN. Prior to register with the HA and CN, the MN has to perform DAD on the network to check the uniqueness on that network. This address configuration and uniqueness checking take the longest time of the total delay. Using this CoA, the MN registers with HA and CN through binding update (BU) messages. To reduce the handoff latency many enhancements have been proposed.

Hierarchical HMIPv6 (Castelluccia, 2000) reduces the signalling overhead by introducing a mobility anchor point (MAP) that separates mobility management into intra-domain mobility and inter-domain mobility. However, any single MAP failure makes the whole communication disconnected. Service and performance is not considered while designing HMIPv6. In Fast MIPv6 (FMIPv6) (Jang et al., 2006), partial handover of Layer 3 is performed in advance by anticipating the movement of the MN to a new subnet. A tunnel is established between a currently attached access router and an anticipated router in order not to lose any packets during the handover process. FMIPv6 allows the MN to quickly detect the movement of an MN for configuring a CoA by using new access point’s information. However, this protocol is developed based on anticipation that does not
guarantee reliable packet transmission. The exact time of MN’s movement is uncertain and unpredictable which may lead to packet loss. Recently, a network based mobility management protocol Proxy MIPv6 (PMIPv6) (Gundavelli et al., 2008) has been developed to enhance the signalling overhead of MIPv6 by introducing two new entities, mobility access gateway (MAG) and local mobility anchor (LMA). The MAG is a software function located at the access router (AR) that determines the movement of the MN and updates to the LMA as it acts as a home agent. However, single failure of a MAG may worsen its performance than standard MIPv6. The optimistic DAD (Moore, 2006) method is developed based on the assumption that the probability of a 64 bit address conflict is very small because the address is randomly generated and duplication case is infrequent. But after configuring an address, if the duplicate address is detected by other node, the MN must immediately reconfigure that address. Normally, the duplication of address depends on the capacity and size of the network. Large networks with many users may experience address collision. This means collision is not negligible. If collision occurs, the recovery time of optimistic DAD could be even longer than standard DAD. Advance DAD (ADAD) (Han et al., 2003) allows the access routers (AR) to store unique address in its pool after generating a random address and performing DAD. The AR listens to other nodes by using neighbor discovery messages in the network. If another node is using the same address in its pool, it must remove that address from its cache, generate and test a new address. However, it puts additional burden to the routers and new address can not be processed when the cache is full. The total handover latency MIPv6 is found to be 5 seconds (Kwon et al., 2005). Based on the author’s assumptions, if the Layer 2 handover takes about 1 second, then the remaining 4 seconds are used for the L3 handover. However, in a consequent paper (Kim et al., 2005) the same authors consider that the router advertisement (RA) message is sent to wireless link in every 1-3 seconds. In (Cabellos-Aparicio et al., 2005) the authors examined different IEEE802.11-based network cards and proposed the reduction of the MaxChannelTime to 100ms in order to reduce the effect of the probing procedure. In (Vivaldi et al., 2003), the authors work specifically on the registration delay component. They make the assumption that the link layer delay can be considered equal to zero for link layer technologies supporting soft handover. The authors of (Ali et al., 2010) use new parameters to measure the received signal strength indicator (RSSI) of the Access Point (AP) by using fuzzy logic to reduce the layer 2 delay. However, they do not consider the MN’s velocity that change every time while the MN is moving. Hence an optimum solution is needed to address the delays of both in L2 and L3.

Proposed Solutions:

To reduce above handoff problems, two solutions are proposed here. In the first solution, to solve the L2 problems especially the scanning problem, a fuzzy logic based intelligent RSSI measuring technique is proposed that calculates optimum value to take wise decision for the MN in conjunction with its velocity. Also to minimize the L3 delays, especially to reduce DAD delay a parallel DAD (PDAD) (Masud et al., 2011) mechanism has been proposed as a second solution.

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 as shown in Fig. 5. The fuzzy rules and membership functions are designed and set according to certain conditions (Mosharraf, 2012). 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.

![Fig. 5: Fuzzy Reference Model](image-url)
First Solution: 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 depicted in Fig. 6, the MN scans for new RSSI values from the new APs. After receiving the RSSI from the new AP, the MN compares the current RSSI (RSSIₙ) with the new RSSI (RSSIₙ₊₁) and also compares this information with the threshold value of the RSSI. It is assumed that the average threshold value of RSSI of the MN is -60dBm in WiFi networks.

It is assumed that both MN and AP are equipped with Global Positioning System (GPS). The MN can retrieve the information like velocity of the MN, locations identification etc. with the help of GPS while it is moving. The location can be identified with Lᵢ and changes of location can be measured by comparing previous location Lᵢ₋₁ where i is a timer initiated from 0. Changes of location indicate that the MN is moving and its velocity can be measured. Using this measured velocity together with the RSSI value, the MN decides to trigger L2 handoff.

Fig. 6: flow chart of fuzzy logic based scanning RSSI

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 Tₚ and Tᵣ. The difference between these is known as \( t_{\text{travel}} \). It is assumed 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 (8)

\[
d = c \times t_{\text{travel}}
\]  

(8)

The velocity of the MN can be calculated according to the (9) where the distance \( d \) is already calculated by (8) and the time is known from RS and RA signal transmission.

\[
v = \frac{d}{t_{\text{travel}}}
\]  

(9)

The RSSI measurements are calculated based on a fuzzy logic technique. It is assumed that in a heterogeneous coverage area there are 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
Received Signal Strength Indicator (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 performance metric velocity is proposed together with the RSSI value because these metrics dynamically change with time. Theoretically, the measurement process of RSSI is shown in (10) [4] that has formulated the RSSI in dB at a distance \( d \) from the AP to be:

\[
10 \log_{10} P_r = 10 \log_{10} P_o - 10 \alpha \log_{10} d + X \quad (10)
\]

where

\[
10 \log_{10} P_o = 10 \log_{10} P_t + 10 \log_{10} G_t + 10 \log_{10} G_r + 20 \log_{10} \left( \frac{\lambda}{4\pi} \right)
\]

\( \lambda \) 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 experiment, the MN movement speed is classified into three categories. The velocity, \( v_0 \) is in m/s (1) \( 0 < v_0 \leq 10 \) in the first category for walking, running or cycling velocity scenario, (2) \( 10 < v_0 \leq 20 \) for city road velocity scenario and (3) \( 20 < v_0 \leq 30 \) 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 MN scans all the APs and gets connected to the AP with the highest RSSI value. The RSSI value changes from time to time. A higher RSSI value means the MN is closer to the AP.

Second Solution: Parallel Duplicate Address Detection (Pdad) (L3 Phase):

Duplicate address detection (DAD) time is the longer phase of handoff transition from current access router (AR) to visiting AR. The goal of this mechanism is to configure a CoA in advance in a parallel fashion by accessing neighbor routers. The new CoA is generated by multiple ARs using a combination of MN’s L2 address and subnet prefix information of the router and then DAD is performed. This mechanism is applicable to common MIPv6 networks and reactive model of FMIPv6 networks. The simple mechanism is after noticing the RSSI value is decreasing and the MN moves to a new subnet, it sends router solicitation (RS) message to the new routers containing MN’s L2 address to all neighbor routers as described in Fig. 7. Here the MN needs to solicit to all neighbor routers. The neighbor routers will form a CoA address by combination of MN’s L2 address and router’s subnet information and stores this address in its cache for the requested MN. The individual router checks the duplication of the newly generated CoA in the same network sending neighbor solicitation (NS) message and conforms with the neighbor acknowledgement (NA). If any other node or router replies NA, the respected router realizes this address is being used by another user and needs to generate another address and follow the same procedure again. Whenever an MN moves to a new subnet, it configures the stored address without performing DAD since it is checked earlier.

Each router keeps this CoA for a specific time in its cache as MN may move to any other neighboring routers so that the MN can easily configure previously generated CoA. If an address collision occurs (generation of a CoA which is already being used by another MN), the router needs to generate another address and perform DAD on that address. Whenever an MN moves further to a neighboring router, it can be configured by a reply message to the MN.

After a specific time the routers release the stored address from its cache assuming that the MN might have changed its location. If the MN proceeds to a fully new routers area then it needs to follow the same procedures as stated above.

Simulation And Result Analysis

Fuzzy Logic Based Scanning (L2 Phase):

RSSI values and speed are considered as input parameters for WiFi, WiMAX, and GSM technologies. The RSSI values are set in the range -100dBm (weak) to -20dBm (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 -75dBm to -40dBm, the signal is termed as average and (3) if it is from -45dBm 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.

MATLAB Fuzzy Toolbox platform is used for making decisions provided as input variables while OMNeT++ is used to carry out the networking management tasks. 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 Fig. 8. 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. These fuzzy rule set has been designed to select in a heterogeneous environment where WiFi, WiMAX and GSM are overlapping.

![Flow chart of PDAD model](image)

**Fig. 7:** Flow chart of PDAD model

**Handoff Latency (L2):**

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. The simulation results of handoff latency in L2 and L3 are discussed in the following sections.

![Fuzzy inputs and outputs for layer 2](image)

**Fig. 8:** Fuzzy inputs and outputs for layer 2

The handoff latency in L2 consists of scanning, authentication and re-association phases. Fuzzy logic technique is applied to scan the alternatives in available interfaces while the MN is moving from one coverage
area to another. Fig. 9 shows the handoff latency in millisecond (ms) with respect to speed of the MN. The standard MIPv6 takes around 400 ms to scan an interface based on only RSSI values where this proposed fuzzy enabled MIPv6 scanning takes about less than 200 ms. The proposed mechanism shows better performance while the MN is slowly moving. Moreover, the handoff latency increases slowly with respect to speed that is not more than 200 ms. On the other hand, two other phases, authentication and re-association consume few milliseconds which are 20 ms and 10 ms respectively.

![Handoff latency in L2](image)

**Fig. 9: Handoff latency in L2**

**Packet Loss (L2):**

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 both proposed mechanisms.

Packet loss results due to 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.

![Packet loss in Layer 2](image)

**Fig. 10: Packet loss in Layer 2**

The drawback of the standard MIPv6 is having more packet loss either in L2 and L3. In L2 of MIPv6, the average packet loss is around 0.06% to 0.36% for different movements while the proposed mechanism reduces this number about 0.26% at 30 m/s as shown in Fig. 10 that is around 28% improvement over standard MIPv6.

**Parallel Duplicate Address Detection (PDAD) (L3 Phase):**

The simulation is implemented on OMNeT++ to evaluate the address configuration delay of standard MIPv6 and proposed PDAD mechanism. The performance of PDAD is evaluated according to the simulation parameters given in table 1.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area</td>
<td>1000m x 1000m</td>
</tr>
<tr>
<td>Number of MN</td>
<td>1</td>
</tr>
<tr>
<td>Number of foreign network</td>
<td>5</td>
</tr>
<tr>
<td>Beacon interval</td>
<td>50 msec</td>
</tr>
<tr>
<td>L2 delay</td>
<td>50 msec</td>
</tr>
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<td>Bandwidth</td>
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<td>Traffic</td>
<td>UDP</td>
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<tr>
<td>Packet Size</td>
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</tr>
<tr>
<td>Mobility</td>
<td>10 m/s</td>
</tr>
<tr>
<td>PDAD delay</td>
<td>500 m/s</td>
</tr>
<tr>
<td>Transmission range</td>
<td>70 m</td>
</tr>
<tr>
<td>Radio</td>
<td>802.11b</td>
</tr>
<tr>
<td>Simulation Time</td>
<td>200ms</td>
</tr>
</tbody>
</table>
The simulation architecture shown in Fig. 11 with 1 MN resides in the home agent, 2 CNs and 5 foreign networks. In this simulation it is assumed that the MN moves to 5 foreign networks in a circular way around the home network. The MN is connected with different networks wirelessly with 2Mbps bandwidth. To transmit a packet continuously from CN to MN UDP traffic is being used without waiting any acknowledgement.

Handoff Latency (L3):

This paper addresses the issues of handoff latency considering the movement among different ARs and with respect to the velocity of the MN. The MN moves among five ARs and handoff latency has measured from each movement of AR. Fig. 12 shows the handoff latency differences between standard MIPv6 and proposed PDAD enabled MIPv6 model for each movement. The proposed model takes the same time of MIPv6 for first movement and takes lower time for subsequent transitions. Moreover, it also maintains almost the same time for each movement which is around 350ms.

Fig. 12: MN’s movement among different ARs versus handoff latency

Fig. 13 shows the comparison of the handoff latency of DAD time of standard MIPv6 and proposed PDAD mechanism for L3. Checking the duplication of the newly generated CoA is mandatory according to RFC 6275 that takes at least 1000 ms. In some worst cases, it will take longer time if address duplication occurs which might be 2000 ms or more than that. The standard MIPv6 model checks DAD every movement from one AR to another AR.
However, in proposed parallel DAD (PDAD) mechanism, the MN checks the DAD in parallel to all neighboring routers and confirms the uniqueness of the CoA. Therefore, the handoff latency varies within 300ms to 400ms while the MN is moving with different speeds.

**Packet Loss (L3):**
Packet loss occurs due to long handoff latency. The packet loss is measured in percentage for each movement while the MN moves among the ARs as depicted in Fig. 14.

In standard MIPv6 protocol, initially the packet loss is little bit higher and for consequent movement it maintains an average rate that is around 0.3% to 0.4%. The proposed mechanism shows that packet loss is reduced about 48% at first movement and remained same for the subsequent movements.

Fig. 15 depicts that the packet loss in L3 with respect to speed of the MN. The number of packet loss varies according to the changes in MN speed. Moreover, the packet loss not only depends on the handoff latency but also on some other constraints like jitter, noise, etc.

The packet loss rate of MIPv6 is from 0.5% to more than 1% while the proposed PDAD mechanism reduces the number of packet loss from 0.15% to about 0.5% which is 50% improvement over standard MIPv6.

**Conclusion:**
Two solutions are proposed to improve handoff latency and reduce the number of packet loss of MIPv6 in L2 and L3. The first solution is suitable for L2 especially to reduce scanning related latency and second solution that deals with DAD latency, the most time consuming phases of handoff latency. In the first solution, the handoff latency
reduced about 55% and packet loss rate enhanced around 50% in L2. The second solution that is related to L3 reduced the latencies from 1000ms to around 300ms that is about 70% and the packet loss rate reduced approximately 60%.

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