Vertical Handoff Reduction Mechanism Using IEEE 802.21 Standard in Mobile IPv6 (MIPv6) Network

Mosharrof H. Masud, Farhat Anwar, S. M. Sadakatul Bari, Omer M. Mohamed
Department of Electrical and Computer Engineering
International Islamic University Malaysia
Kuala Lumpur, Malaysia
masuduia@yahoo.com, farhat@iium.edu.my, sms_bari@yahoo.com,
omer_one@yahoo.com

Abstract— **Low handoff latency and minimum packet loss are envisioned important factors for the next generation Mobile IPv6 (MIPv6) based heterogeneous networks. To meet these constraints IEEE 802.21-Media Independent Handover (MIH) was introduced to enhance the Quality of Service (QoS) of the networks. The MIH provides link layer information to the network layer to reduce handoff latency while the mobile node (MN) changes its active interface to another interface. In this paper an additional entity "Smooth Handoff Controller" (SHC) and an algorithm are proposed to select alternative interfaces in advance while MN is using an active interface. This mechanism helps the MN to configure additional interfaces that reduces handoff latency and packet loss. The simulation result shows better performance over the standard MIPv6. The proposed mechanism is simulated using OMNeT++. The simulation results show 70% reduction of handoff latency and 40% to 45% reduction of packet loss thus indicating a large improvement towards achieving better QoS.**

Keywords- Handoff latency, MIPv6, IEEE 802.21- MIH, packet loss.

I. INTRODUCTION

The next generation wireless communication system is expected to fully Internet Protocol Version 6 (IPv6) based to support different technologies. Mobile IPv6 (MIPv6) [1] has been developed later by Internet Engineering Task Force (IETF) so that a Mobile Node (MN) might move from one Access Point (AP) to another. Nowadays, different network technologies for example, IEEE 802.11a/b/g or Wireless Fidelity (WiFi), IEEE 802.16 or World Interoperability for Microwave Access (WiMAX), General Packet Radio Service (GPRS), Universal Mobile Telecommunication System (UMTS) are converging their infrastructure with the core IPv6 network. The users are not concerned about different types of technologies however they demand seamless connectivity while they are moving. When an MN is moving and attaching itself from one AP to another AP it is known as handoff. The time required to perform this handoff is referred to handoff latency. There are two types of handoff latency in MIPv6 network, horizontal and vertical. If the MN moves within the same technological AP coverage area it is known as horizontal handoff for example, WiFi to WiFi or WiMAX to WiMAX. On the other hand, if the MN moves from one technological AP to another technological AP, it is referred to as vertical handoff such as WiFi to WiMAX or UMTS to WiFi. The horizontal handoff is quite simple and does not take a long time to process. However, vertical handoff is a complicated process and takes a longer time to maintain seamless connectivity. Seamless communication is important for network-enabled applications to operate continuously at the desired quality of service (QoS) in a wired or wireless IP network, especially for real time applications such as audio and video streaming. Several enhancements have been proffered to improve the limitations of MIPv6. This paper proposes a new mechanism to reduce handoff latency by using recently standardized Media Independent Handoff (MIH) or IEEE 802.21 [2].

In this paper, a smooth handoff controller (SHC) is proposed that lies in between MIH and network layer to process handoff procedures in advance when the MN is using an active session. This SHC collects all necessary information from lower layer and upper layer and take decision for handoff to another interface. Therefore, an algorithm is proposed to choose, in advance, an alternative interface as a second interface of the MN. Hence, the handoff latency as well as packet loss is reduced significantly.

The rest of the paper is organized as follows. A brief description of MIPv6 is discussed in section II. Details of handoff delay is analyzed in section III. Section IV discusses IEEE 802.21- media independent handover (MIH) in short. Related works highlighted in section V. Section VI proposes a mechanism and an algorithm to reduce handoff latency using MIH. Performance evaluation is conducted in section VII. The simulation scenario and result analysis is presented in section VIII. Finally, a conclusion is drawn in section IX.

II. Mobile IPv6 (MIPv6)

MIPv6 is one of the mobility management solutions that have been widely accepted in the academia and industry. According to MIPv6, an MN is registered to its home agent (HA). Whenever an MN moves from its registered HA to a foreign network (FN) it needs to be registered with that network at a temporary basis by getting a care-of-address (CoA). With this CoA, the MN maintains communication with its HA and other corresponding nodes (CN) that intend to communicate with the MN. To acquire this CoA from the visited network, the MN has to accomplish some operations introducing delays. These include movement detection – (on average 1.5 sec), new CoA configuration including Duplicate Address Detection (DAD) – (1 sec), and registration or binding update (BU) – (300ms) [3, 4, 5, 6]. The total duration of handoff latency is not acceptable for many applications especially for audio and video conferencing. It is known 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 to an acceptable level a solution has been proposed to achieve seamless communication.

III. Handoff delay analysis of MIPv6

The overall handoff latency in MIPv6 can be categorized into layer 2 (L2) and layer 3 (L3) phases. In L2 (the interface association time) the total delays are: scanning, authentication and association. In L3 (the IP configuration and registration period with DAD time) the total delays are: movement detection delay, address configuration including DAD delay and Registration delay or binding update delay

A. 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 following phases. Scanning phase is the most time consuming part that accounts for 90% of total L2 handoff procedures [8, 9]. There are two types of scanning phases including active and passive phase. During an active scan, the MN broadcasts a probe request packet asking all APs in respective channels to inform their existance and capability with a probe response packet. 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. However it 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 are prohibitive to many services as it takes around 1 sec [5]. 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 phases have less delay compared to scanning delay.

B. L3 Phase

L3 handoff starts after finishing the L2 phase. L3 causes the longest handoff delay of MIPv6. There are 2 types of delays that are discussed here.

1) Address Configuration with Duplicate Address Detection (DAD) Delay

After moving the MN from its previous network to the new network, it acquires the temporary CoA from the new network. To do so, the MN generates the CoA by combining the network prefix and MAC address of the MN. After generating the CoA, the MN runs duplicate address detection (DAD) on the network to check the uniqueness of that address. DAD is a mandatory procedure of MIPv6. The time required to recognize the uniqueness of an IPv6 address is known as address configuration, that takes around 1000 ms. It is one of the important delays in continuous communication.

2) BU/Registration Delay

This represents the time needed between the sending of the binding update (BU) from the MN to the HA and the arrival/transmission of the first packet through the new access router. Prior to completing this procedure, the MN completes the security testing with the MN and CN by sending home test init (HoTi), care of test init (CoTi) etc. after that the MN sends its unique CoA to its HA as well as to CN by sending BU and gets a binding acknowledgement (BA) from the other sides. By completing this procedure, the MN is fully ready to transmit the data to its CN.

IV. IEEE 802.21-MIH

The IEEE 802.21 protocol works as intermediary by service access point (SAP) between L2 and L3 as described in Fig. 1. MIH function has to be deployed in the MN as well as in the network. It allows its peer MIH entities to interact with each other by defined message frame format. It offers multiple radio access technologies to its users. Moreover, it accelerates the handoff procedures between different interfaces like 802.2, 802.3, 802.11, 802.16 and 4G etc. and facilitates handoff management policy mechanisms by user preferences. It takes the link layer (L2) information and passes it to the upper layer (L3) to initiate handoff process. The MIH function consists of three different services: Media Independent Event Service (MIES), Media Independent Command Service (MICS), and Media Independent Information Service (MIIS). The MIES informs the upper layer about the condition of the current network and transmission performance of the L2 data link for example, MAC status, radio resource management etc. It provides event classification, event filtering and event reporting towards handoff preparation. It gathers the link layer movement information and delivers the link status messages to the MIH users such as, link is up, down, going down and link detected etc.

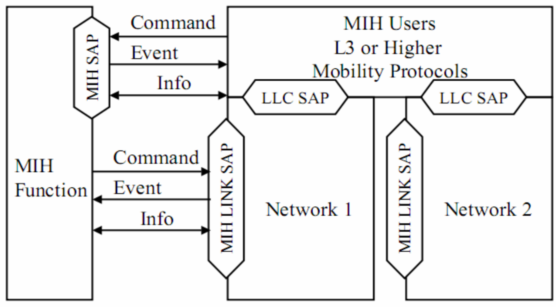

Figure 1. IEEE 802.21-MIH architecture

The MIIS provides a framework and a corresponding mechanism that helps to accumulate the information of a network that exists in a geographical area. It allows a query/response type of service to retrieve the information that is stored in the MIH layer or in a server which is easily accessible. It also supports to find out static information of a network such as neighbor maps and network neighbor discovery. It may incorporate link layer parameters such as channel information, MAC addresses, and security. The MICS is responsible for forwarding commands from upper layer to lower layer to finalize the handoff. This offers generic service primitives for controlling the handoff for instance: connect, disconnect, switch, etc. Events and commands services can be local or remote.

V. RELATED WORKS

The heterogeneous wireless networks are being populated widely for roaming facilities among different technologies with existing infrastructure. Users do expect seamless connection while they are moving around the glove. The efficient and lossless handoff mechanism is required to support real time applications. To reduce handoff latency and packet loss some research works have been conducted.

In [10], the authors evaluate the performance of mobility support mechanism in heterogeneous environment between UMTS and IEEE 802.11 network under IEEE 802.21 standard. They introduce MIH link going down (LGD) event that supports soft handoff from IEEE 802.11 to UMTS to measure handoff latency in soft and hard scenarios. In [11], the authors include an added entity (AE) to the MIH inter layer to accelerate the handoff progress in heterogeneous networks. The authors of [12] evaluate the performance of IEEE 802.21 in integrated IEEE 802.11 and IEEE 802.16e networks. Moreover, they propose connection manager (CM) parameter to utilize MIH services properly. According to their proposed mechanism, the MN starts handoff operation before the disconnection of the previously attached link and therefore handoff latency and packet loss both are reduced. In [13], the paper proposes cross layer address resolution (CAR) mechanism as an infrastructure of seamless handoff for MIPv6 (S-MIPv6). This CAR gathers necessary information for arranging address configuration in advance.

However, most of the research works focus on either theoretical or analytical approach to reduce handoff latency. The measurement of handoff latency and packet loss with respect to MN speed is not clearly analyzed in heterogeneous MIPv6 environment supporting of IEEE 802.21. Therefore, a simulation based analysis for transmitting audio and video streaming in WiMAX and WiFi scenario are considered in this paper.

VI. PROPOSED HANDOFF MECHANISM

1) *Smooth Handoff Controller (SHC)*

A smooth handoff controller (SHC) entity has been proposed in this paper that is incorporated with MIH to smoothen handoff latency both in L2 and L3. This entity lies between MIH and upper layer especially under network layer on the MN. The purpose is to reduce the handoff latency in heterogeneous wireless networks between IEEE 802.16 (WiMAX) and IEEE 802.11x (WiFi).

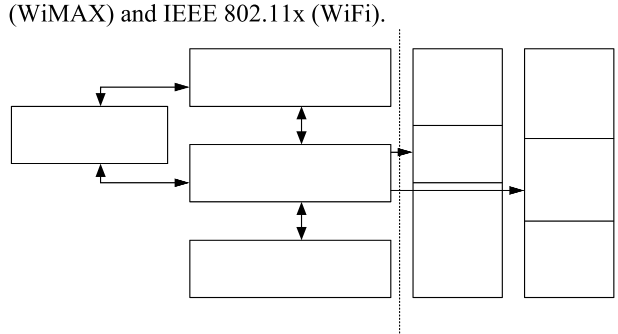

Figure 2. Proposed smooth handoff controller (SHC)

The SHC gathers necessary information of L2 through MIH and forwards to the upper layer to take final decision of vertical handoff as shown in Fig. 2. It is assumed that each MN is enabled with a minimum of two Network Interface Cards (NICs), the first NIC used for transmission the ongoing session and the second NIC put as an idle mode for power saving unless it detects any available interfaces on the network. It is also assumed that the MN is associated with the IEEE 802.16 networks using first interface and moves to IEEE 802.11x by the help of the second interface.

The SHC congregates the movement information of MN and quality of service (QoS) parameters form the upper layer especially form the application layer and run appropriate algorithm for selecting the appropriate interface. The SHC deals all the signals on behalf of MIH and the upper layer and selects the network interfaces.

2) *Alternative Interface Selection Procedure*

The proposed mechanism has been developed using IEEE 802.21 standard with a path selection algorithm. As Next Generation Networks (NGN) will be supported multiple interfaces in a heterogeneous environment, an algorithm is proposed in this paper to select an alternative interface while the MN is connected to an active interface. It is assumed that each MN has at least two interfaces capabilities. The MN identifies the available interfaces through the help of MIH function that is integrated in the MN and in the core router. The procedure of interface selection algorithm is shown in Fig. 3. After detecting all available interfaces, the MN measures the strength of each interface and compares the signal value with the threshold value. If the interface strength value is smaller than the given threshold value, it will again identify the available interfaces. However, if the interface strength is more than the threshold value, the MN will make a list of interfaces and perform PDAD [14] on all the interfaces in advance while the MN is using an ongoing session. After the successful completion of the PDAD procedure, the MN will select that interface, otherwise the MN will start PDAD for another interface. The MN performs the handoff to the selected interface. If the handoff is successfully completed, the MN will switch all the traffic to the selected interface and start to communicate with its corresponding node.

In the mean time, the other interfaces will also follow the same procedure and check the uniqueness of newly generated CoA by performing PDAD algorithm that reduces address configuration time. Whenever the MN detects in cooperation of MIH that it is crossing interface 1 and moving to interface 2, the MN will use CoA generated by interface 2.

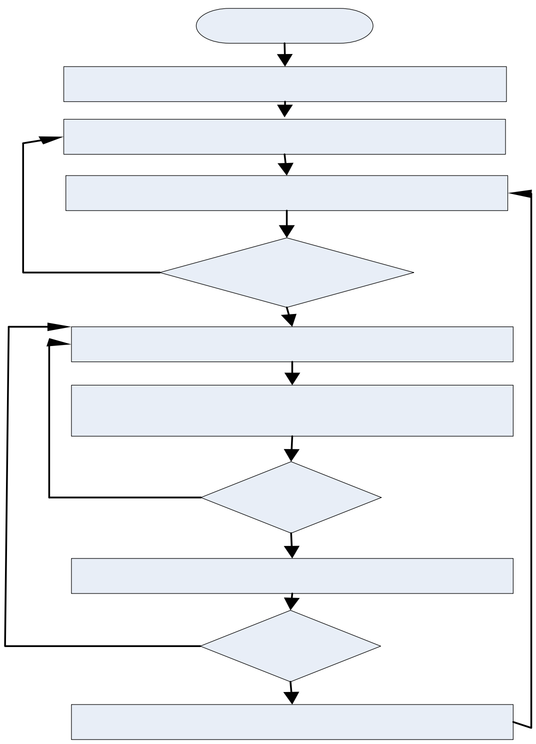

Figure 3. Multiple interface selection algorithm

VII. Performance Evaluation

1) MIPv6

Handoff latencies of MIPv6 are classified into two categories, L2 and L3 as shown in (1).

$$D_{MIPv6} = L2 + L3 \quad (1)$$

L2 consists of three phases, namely; scanning, authentication and association shown in (2).

$$L2 = D_{scanning} + D_{authentication} + D_{association} \quad (2)$$

L3 consists of movement detection (MD), duplicate address detection (DAD), care-of address (CoA), route optimization (RO) and finally registration or binding update (BU) indicated in (3).

$$L3 = D_{MD} + D_{CoA} + D_{DAD} + D_{RO} + D_{BU} \quad (3)$$

Movement detection (MD) consists of router solicitation (RS) and router acknowledgement (RA) as stated in (4).

$$MD = RS + RA \quad (4)$$

After configuring a temporary CoA, the uniqueness of the CoA must be checked by sending neighbor soliciting (NS) and neighbor acknowledgement (NA) message to the serving network that is shown in (5).

$$D_{CoA} = BU\_HA + BA\_MN \quad (5)$$

$$D_{DAD} = NS + NA \quad (6)$$

Route optimization (RO) is a security feature in IPv6 that includes home test init (HoTi) and home test (HoT) and CoA test init (CoTi) and CoA test (CoT).

$$D_{RO} = HoTi + HoT + CoTi + CoT \quad (7)$$

This RO confirms the valid CN that has authority to contact with MN. The overall signaling flow of MIPv6 shown in Fig. 4.

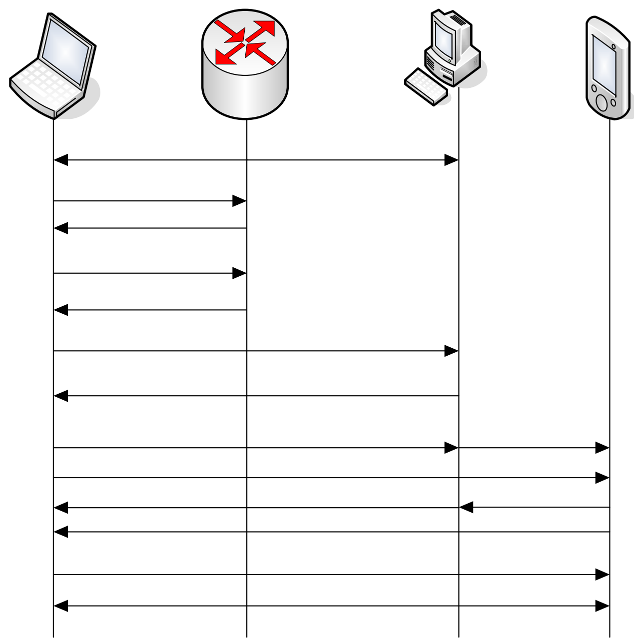

Figure 4. Standard MIPv6 signaling diagram

2) IEEE 802.21 Assisted MIPv6

In Fig. 5, it is depicted that the ongoing data transmission session from CN is connected with the home network of the MN IEEE 802.16. Whenever the current link detects "link going down", it informs to MIH the status of the link and the MIH updates to SHC by sending a "weak signal detected" signal. In the mean time the MIH receives another "new link

Start

detected" signal form IEEE 80.11 and SHC is updated with "link detected" message. After transferring these signaling messages, the SHC starts sending router solicitation (RS) message to the IEEE 802.11 and IEEE 802.16 networks in parallel to configure CoA for the MN.

Subsequently, the MN needs to check the uniqueness of the configured CoA by sending neighbor solicitation (NS) message to other MNs and routers in the same network. Following the completion of these procedures, the SHC compares the parameters with MIH to MIPv6 for final handoff. The MN disconnects its ongoing interface and switch to the newly detected interface. Finally, the MN and CN are connected with IEEE 802.11 network to transmit data.

The noted point here is that the alternative interface processes all the handoff procedures and therefore handoff latency and packet loss is reduced significantly and therefore improves the QoS. IEEE 802.21 assisted MIPv6 delay also can be classified into L2 and L3 as shown in (8).

$$D_{IEEE\ 802.21\ Assisted\ MIPv6} = L2 + L3 \quad (8)$$

Only authentication and association delays are included in L2 that has been stated in (9).

$$L2 = D_{authentication} + D_{association} \quad (9)$$

L3 consists of movement detection (MD), route optimization (RO) and binding update (BU) delays as shown in (10).

$$L3 = D_{MD} + D_{RO} + D_{BU} \quad (10)$$

Applying SHC entity in the MIH module helps the MN to complete scanning procedure in advance while staying in its home network. This mechanism also facilitates to configure CoA and check its uniqueness prior to move to any foreign networks.

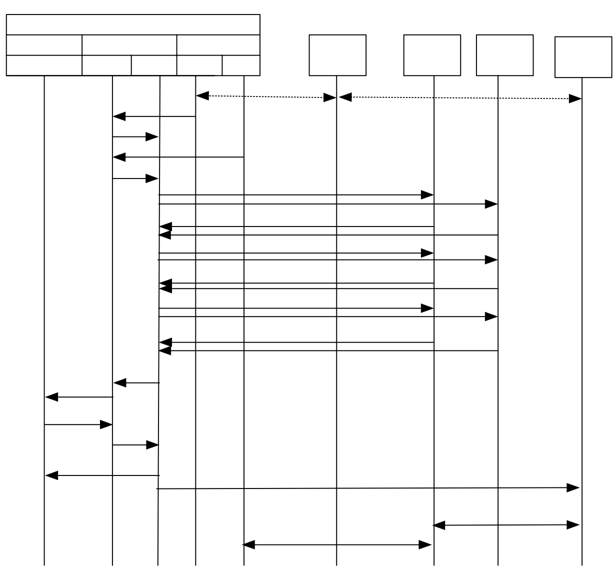

Figure 5. Proposed IEEE 802.21 assisted MIPv6 signaling diagram

Therefore, the most time consuming scanning phase in L2 and CoA configuration and DAD procedure in L3 are not necessarily needed. As long as the active interface is not executing CoA and DAD algorithm on the MN, it saves overall configuration time that reduces handoff latency and packet loss.

VIII. SIMULATION SCENARIO AND RESULT ANALYSIS

The simulations were conducted on OMNeT++ to evaluate the proposed mechanism within an area of 2000m x 2000m.

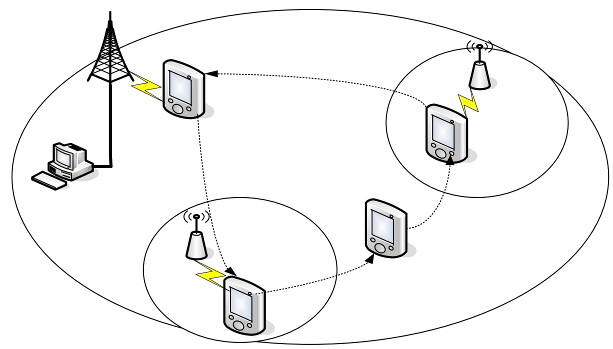

Figure 6. Simulation scenario

In this simulation, it is considered that WiMAX and WiFi are overlapped in a geographical area where WiMAX has 1000m cell radius and 50m for WLAN namely IEEE 802.11x. Two WiFi APs are inside the WiMAX coverage as shown in Fig. 6. The MN is registered to its HA- WiMAX and moves to the WiFi above mentioned area at the speed from 5m/s to 20m/s. During the circular movement of the MN, it enters to WiMAX to WiFi, WiFi to WiMAX, WiMAX to WiFi and finally WiFi to WiMAX. Handoff latency occurs for every change of attachment of the AP. A CN is connected to the core network through 100 Mbps Ethernet with its HA WiMAX network. The overall simulation setup is given in table 1.

Table I. Simulation Setup

Parameters		Value
Area		2000m x 2000m
Number of MN		1
Number of Networks		2
Cell Radius	WiMAX	1000 m
	WiFi	50 m
Bandwidth		2 Mbps
Traffic		UDP
Packet Size	Video	512 Bytes
	Audio	160 Bytes
Mobility		5 m/s
Radio	WiMAX	802.16e
	WiFi	802.11b
Transmission Rate	WiMAX	50 packets/sec
	WiFi	100 packets/sec
Simulation Time	WiMAX	200 seconds
	WiFi	100 seconds

It is also assumed that MN has minimum two NICs. One interface is actively used to communicate with CN and another interface will complete the handoff procedure with the help of IEEE 802.21 standard as discussed above. The purpose is to measure handoff latency of an MN that moves from WiMAX to WiFi and vice versa. The simulations have been conducted 20 times to get the average value and the handoff lataency for video and audio has been calculated separately. Here, the handoff from WiMAX to WiFi and vice versa have been calculated as illustrated in Fig. 7 and Fig. 8 respectively.

The delay of L2 and L3 are added togrther to show the simulation resuts. The simulation results in Fig. 7 shows the handoff latency from WiMAX to WiFi that depicts the SHC enabled MIPv6 performs better than the standard MIPv6 both for video and audio transmission and increases the latency very slowly though MN speed increases.

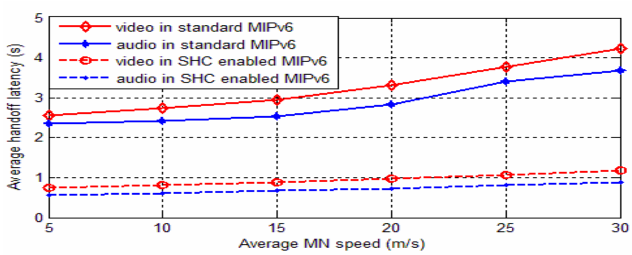

Figure 7. handoff latency from WiMAX to WiFi

It is also observed that handoff latency of video transmission takes a longer time when compared to audio in case of standard MIPv6 and SHC enabled MIPv6. Similarly, the fashion of handoff latency from WiFi to WiMAX is almost same as WiMAX to WiFi both for video and audio. However, it takes shorter time of delay that starts from around 1.5 second for video and audio streaming and increases linearly with speed as depicted in Fig. 8.

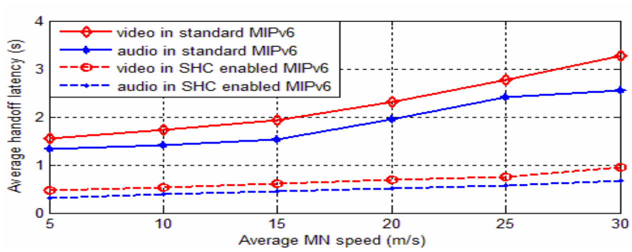

Figure 8. handoff latency from WiFi to WiMAX

SHC enabled MIPv6 reduces the latency significantly and it remains almost the same. According to the simulation results, the handoff latency reduced about 70% in both cases which indicate a great improvement towards achieving QoS.

Fig. 9 and Fig. 10 shows packet loss results of the simulation. Video packet loss is more than audio packet in either case, WiMAX to WiFi and WiFi to WiMAX. Another important point is video transmission takes a longer time in standard MIPv6 and SHC enabled MIPv6.

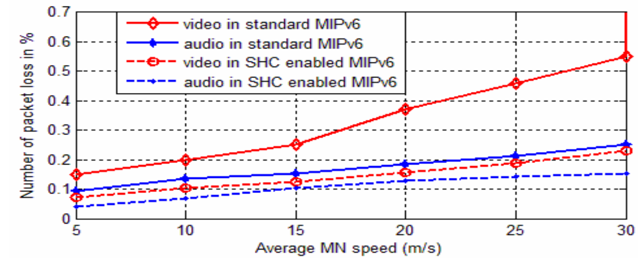

Figure 9. packet loss from WiMAX to WiFi

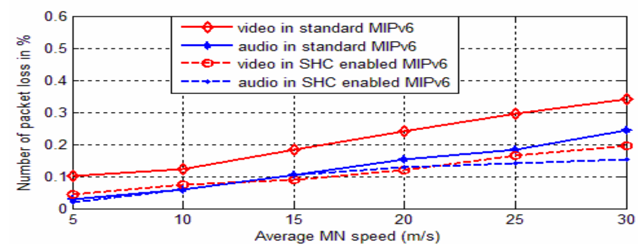

Figure 10. packet loss from WiFi to WiMAX

Moreover, SHC enabled MIPv6 mechanism shows that reduced packet loss for video and audio transmission from CN to MN and the packet loss changes very much in both cases. According to the simulation result, about 40% to 45% packet loss has been observed in both scenarios.

IX. CONCLUSION

In this paper a new entity Smooth Handoff Controller (SHC) is added in between MIH functions and MIPv6 module to accelerate vertical handoff. Another algorithm is proposed to select alternative interface while the MN is using its current session. The simulation results demonstrate that the overall handoff latency and packet loss of standard MIPv6 decreases when the proposed SHC is applied in MIH and MIPv6 modules. Based on the simulation results, handoff latency reduced about 70% and packet loss around 40%.

X. ACKNOWLEDGEMENT

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