Mobility Management across Heterogeneous Access Networks

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ABSTRACT
To satisfy customer demand for a high mobility services in heterogeneous network; Mobile protocol is needed to make intelligent and optimized handover. This paper is a comparative study between mobility management solutions such as (MIPv6 , NEMO , FHMIP and MIPv6 integrated with IEEE802.21) in heterogeneous networks to find out which of them performs better when it comes to send datagram from the correspondent node to the mobile node. Different scenarios were carried out to measure delay and throughput metrics of mobile node while roaming using NS2 (Network Simulator 2). The results showed that mobility protocols integrated with IEEE802.21 performed better in all the tests done and the overall expected handover (both L2 and L3) latency can be reduced even in vehicular environment.

Keywords
MIPv6, FHMIPv6, Handover, Mobility, MIH, NEMO

1. INTRODUCTION
Mobility management is the process of changing the attachment of the mobile terminals while crossing from one wireless technology to another such as IEEE 802.11 and IEEE 802.16. Factors that affect handover decision are (load, coverage, signal strength, speed and session's priority). MIPv6, NEMO, FHMIP and MIPv6 integrated with IEEE802.21 are mobility management solutions that improve the existing Mobile IP standard to comply with the rapid movement of mobile nodes in heterogeneous networks. As applications do not need to be aware of mobility and used as if it is running in a fixed environment, suitable mobility management module should be used to deliver packets to the user's current location. FHMIPv6 addresses the deficiency of MIPv6 and NEMO protocols. The IEEE802.21 has defined a new logical entity within the protocol stack of the network elements to minimize handover latency and loss of performance experienced by mobility protocols. This paper focus on host based mobility management mechanisms and identifies the strengths and shortcomings of them.

1.1 Handover
The process of changing point of attachment from one access router to another occurs with some delay and some packet loss [1]. The overall handover delay consists of Layer 2 (L2) delay and Layer 3 (L3) delay. The L2 handover delay is the period when the MN/MR is disconnected from the current Access Router (AR) till the time it connects with the new AR. The L3 handover delay comprised of the latencies incurred during the IP layer movement detection, network re-authentication, CoA configuration and BU. When a MN/MR moves between the same access-technologies, it is known as Intra-technology handover. Inter-technology handover occurs when a MN moves between different access-technologies (e.g. 802.11g to 802.16e) and causes a change in the L2 Identifier used by the MN.

2. IEEE802.21 MIH
The IEEE802.21, named the "Media Independent Handover (MIH) is a standard that provides information about layer 2 (L2) triggers to the upper layers to facilitate the integration of heterogeneous networks, such as IEEE 802.11 a/b/g/n and IEEE 802.16, etc. IEEE 802.21 module uses the make-before-break (MBB) algorithm for the seamless handover using both interfaces in MN/MR. Figure 1 shows the basic IEEE 802.21 architecture. The MN/MR detects the changes on the lower layers (physical and data link layer) as it is continuously sensing the interfaces. After Link_Parameters_Change event received by MIHF, it reports it to the upper layer to help in link selection. MIH_MN_HO_Candidate_Query-request will be sent to the neighboring BSs by MIH user to discover its status. The MIHF defines three main asynchronous and synchronous services: the Media Independent Event Services (MIES), the Media Independent Command Services (MICS), and the Media Independent Information Services (MIIS).

Dynamic changes in link characteristics and link quality are reported by MIES to upper layers .The status of the connected links was determined by MICS commands to facilitate the handover process .The transfer of information was executed by MIIS and it is classified into three groups: general network information, PoA information, and vendor information.

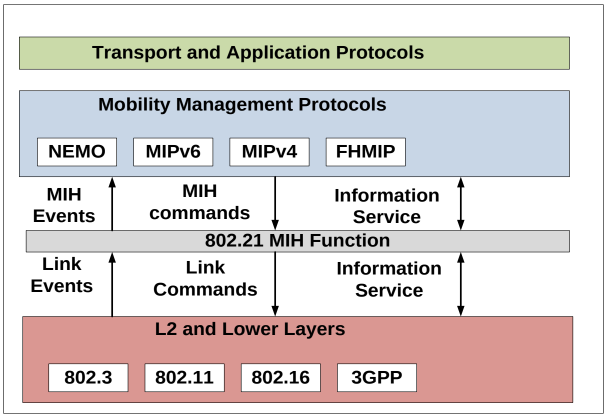


Fig 1: IEEE 802.21 general architecture

3. IP/NETWORK LAYER MOBILITY MANAGEMENT PROTOCOLS

Network layer mobility management solutions such as MIP, NEMO, and FHMIP provide mobility and handover management services and use Break-Before-Make handoff which causes latency, packet loss and signaling overhead. These protocols allow a MN/MR to change its location in the internet without any interruption in session continuity with CN [2]. During such mobility, the MN will perform the handover procedures that involve several stages such as RS, RA, CoA, BU, and BA. Figure 2 illustrates the message flow for the mobility protocols and MAP will be used with FHMIP protocol only.

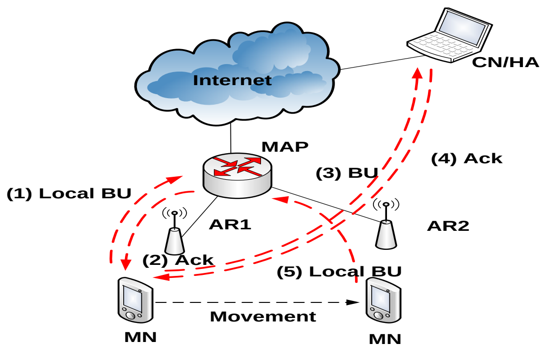


Fig 2: HMIPv6 signaling

Mobile IP (MIP)

MIP improves the existing internet protocol (IP) to comply with the rapid movement of mobile nodes [3], [4]. The mobility challenge is that the host will keep its address while moving as it holds two addresses simultaneously. The permanent address is used by the applications as MN moves away from home, the HA will tunnel packets for the MN temporary address. When the mobile node back home, it must contact the home agent to stop intercepting the packets.

3.1 Nemo

NEMO is an extension to MIP that uses a Mobile Router (MR) which provides a mobility service to IP nodes that do not implement Mobile IP. The Mobile Router (MR) is the only device that needs to support NEMO protocol. The handover procedure of NEMO is very similar to that of MIPv6 [5]. When a mobile network moves away from its home network, the MR acquires a CoA and sends a BU message to all the MNs, which associates its Care of Address (CoA) with the network prefix.

3.2 FHMIP

The mobile node can move inside a specific domain with no need to inform the Home Agent, as long as it moves inside that domain. It is then the responsibility of the domain access router to route data packets destined for the mobile node to the right network. The advantage of these models is that they reduce the signaling load between mobile node and home agent and that the care-of addresses only needs to be registered with the domain access router [6]. HI-HACK conversation is constructed between PAR and NAR. The MN receives the PrRtAdv message from the PAR and sends a request to register with the NAR. The MAP receives a request from the NAR and the MAP begins sending packets to NAR.

4. ENHANCED VERTICAL HANDOVER USING MIH INTEGRATED WITH MIP

MIP is integrated with the IEEE 802.21 to provide seamless mobility and reduce the handover delay during the handover process in homogeneous and heterogeneous networks. Figure 3 is MIH signaling in heterogeneous networks. MN is connected to one access network using one of its network interfaces and listen to the other access networks by the other interface. MIH and MIHF were deployed in MN and it will report a (Link Detect event) to the MIHF as it moves to another access network. The MN configures the NCoA using Interface 2 to keep the current session through Interface 1 until there is Link Going Down event [7].

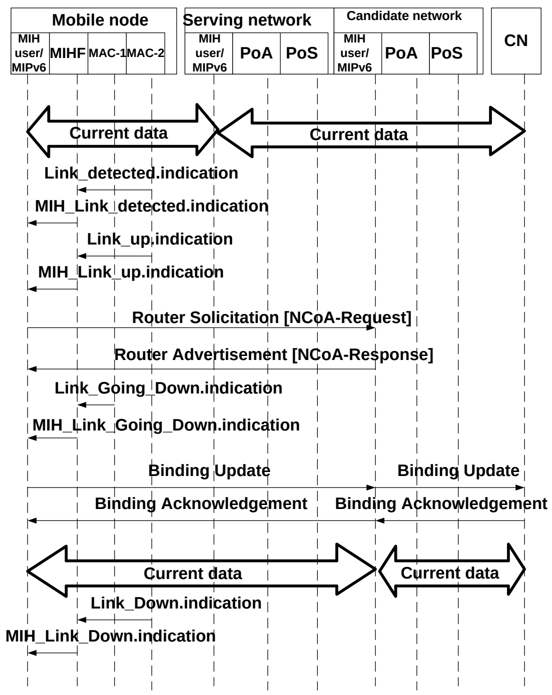


Fig 3: MIH signaling in heterogeneous networks

5. HANDOVER DELAY ENHANCEMENT FOR INTEGRATED PROTOCOLS

Network discovery and re-authentication causes L2 handover delay as shown in equations (1), (2). The MN/MR then starts to scan for available neighboring APs as the signal strength reduced. During movement detection, the MR sends Router Solicitation to NAR. After receiving the RA, the MN will know that it has moved. A delay includes the time caused by RS and RA. Also, it includes the time the MN takes to form a new CoA and test it for address duplication. The MN/MR must perform the BU operation to inform it's HA and CN of its new location. The equations below illustrate the total handover delay.

$$D_{HO\text{-}NEMO} = D_{L2} + D_{RS} + D_{RA} + D_{CoA} + D_{DAD} + D_{BU\ (MN\text{-}HA)} \quad (1)$$

$$D_{L2} = D_{discovery} + D_{Re\text{-}authentication} \quad (2)$$

$$D_{HO\text{-}FMIPv6} = D_{L2} + D_{MN\text{-}NAR} \quad (3)$$

$$T_{HI} = D_{PrRD} + D_{FMIPv6} = D_{RtSolPr} + D_{PrRtAdv} + D_{FBU} + D_{FBack} \quad (4)$$

$$D_{HO\text{-}FMIPv6} = D_{Re\text{-}authentication} + D_{MN\text{-}NAR} \quad (5)$$

FMIPv6 eliminate delays associated with movement detection, new CoA configuration and DAD. The Handover Initiation (HI) time in equations (3), (4) is equal to the time required to send the RtSolPr and PrRtAdv, FBU and FBack messages. DFMIPv6 is the time for sending FBU and receiving FBack messages. Handover delay is considerably reduced by removing the delays associated with scanning and handover initiation. The overall handover delay is expressed in equation (5). IEEE 802.21 MIH services reduce DAD delays, CoA configuration time and the number of Layer 3 messages exchanged during handover.

6. EXPERIMENTAL DESIGN

A comparison between vertical and horizontal handover delay and throughput using Mobile IP, FHMIP and NEMO protocols is summarized. The first step in the implementation was to extend the NS-2 with the available patches (e.g. Mobiwan patch to support the Mobile IPv6 protocol). This patch is extended to enable the MN to support multiple interfaces for communicating with different access networks that provide different bandwidth services and edited by (Ruoshan Kong) from Wuhan University to support NEMO networks [8] . F-HMIP was implemented using F-HMIP patch developed by Robert Hsieh from the National Institute of Standards and Technology [NIST]. IEEE 802.21 MIH patch by NIST was used to improve performance of handover. The handover procedure of MIPv6 was then extended with the help of the IEEE802.21 MIH services provided by the NIST mobility package.

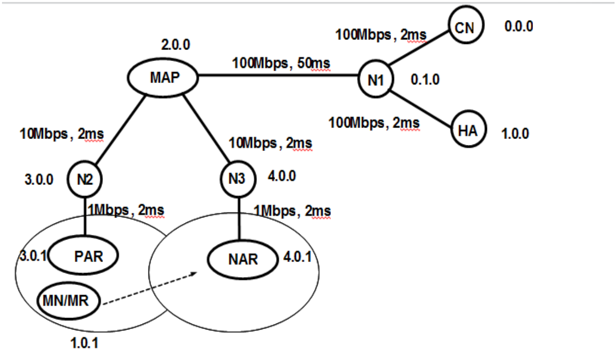


Fig 4: Simulation scenario

Table 1 : Simulation parameters

Coverage Area	Square meters with 6000 meters length	
Communication Range	.11g	250 m
	.16	4000 m
Transmission power	0.005	
Data Rate	.11g	54 Mbps
	.16	20 Mbps
Simulation Time	20 minutes	
Application	Video Conferencing ,etc.	

In Figure 4, there are five domains: the wired node, the correspondent node, the home agent HA, the foreign agent FA and the mobile node. The MR/MN is assumed to be MIH capable devices. In this network topology, the link delay (milliseconds) and bandwidth (megabit/seconds), the coverage area of the two access routers overlapped. MN/MR will move linearly following a linear movement pattern between the access routers from one to another at different speeds. Heterogeneous scenario includes NAR as WiMAX BS, PAR as Wi-Fi AP and MN move from Wi-Fi AP to Wi-MAX BS. The simulation parameters are shown in Table 1.

7. SIMULATION RESULTS

The throughput of a network is defined as the average number of successfully received packets per time slot. Since a wireless network needs more data to be transmitted across the physical medium towards the MNs and this leads to a decrease in throughput. A WiMAX/WLAN dual mode MN/MR is communicating with a CN while moving in the above area [9]. Each time it enters and leaves the WLAN area handover procedures will be initiated. Figure 5 is the throughput achieved by the mobile station and Figure 6 is Packet End-to-End delay for Video conferencing application. The mobile station uses consecutively the Wi-Fi and WiMAX interfaces .The MS is initially in the AP1 coverage and when the throughput estimate in the WiMAX cell overcomes the one in the Wi-Fi, the handover to the WiMAX BS is triggered.

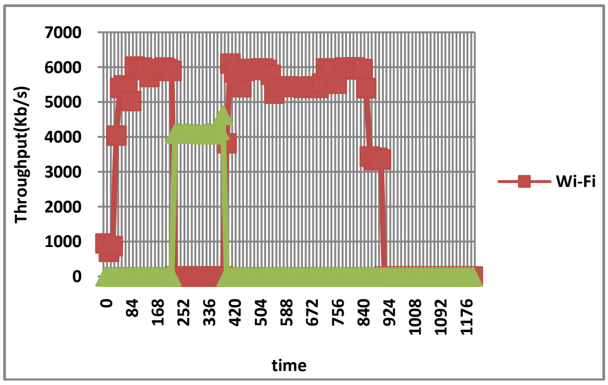


Fig 5: Vertical handover throughput

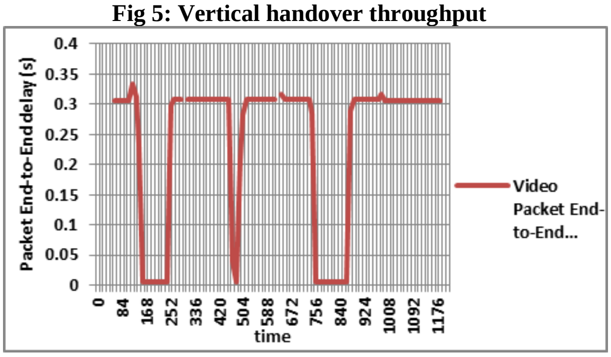


Fig 6: Packet End-to-End delay

The simulation scenarios were repeated with MN/MR moving at different speeds ranging from 5 to 35 Km/hr. From the resulted trace , Table 2 show the results generated with MN moving with speed (15 Km/hr) .In the first column the events that are generated during the process are detailed handoff; the second column shows the instant when each event occurs within the simulation; The third column shows occurrence time of each event . Each table has two parts, the first is the handoff process from the local subnet to the foreign subnet 1 and the second part is the handoff process from the foreign subnet 1 to the foreign subnet 2.

Table 2: Results obtained during the handoff process when the MN moves at a speed of 15 Km/hr

No	Event	Time (s)
1	Starting handoff: HNet -> Net1	46.0
2	Init: BU -> HA	48.0
3	FIN: BU -> HA	48.19
4	Init: BU -> CN	53.0
5	FIN: BU -> CN	53.23
1	Starting handoff: Net1 -> Net2	94.0
2	Init: BU -> HA	96.0
3	FIN: BU -> HA	96.56
4	Init: BU -> CN	110.0
5	FIN: BU -> CN	110.42

Figure 7 is the routing steps during the handover process when the MN moves at a speed of 15 Km/ s. Each event is a handover represented by a color and its time value is displayed with the same color. During the first handover process takes time to run 7 s, whereas in the second handover process takes 16 s. The two values represent the time since the communication is lost (leaving your current network) until the corresponding node is updated with the new address (handover process is completed). During the first handover, it has a dead time (light blue), and during the second handover it have two time (black and blue colors respectively). Equation (6) show the time required for first handover.

$$T_{r\ 15Km/hr1st\ Handoff} = T_{fin:BU<>HA} - T_{init:BU<>HA} \quad (6)$$

$$T_{r\ 15Km/hr1st\ Handoff} = 53s - 48s$$

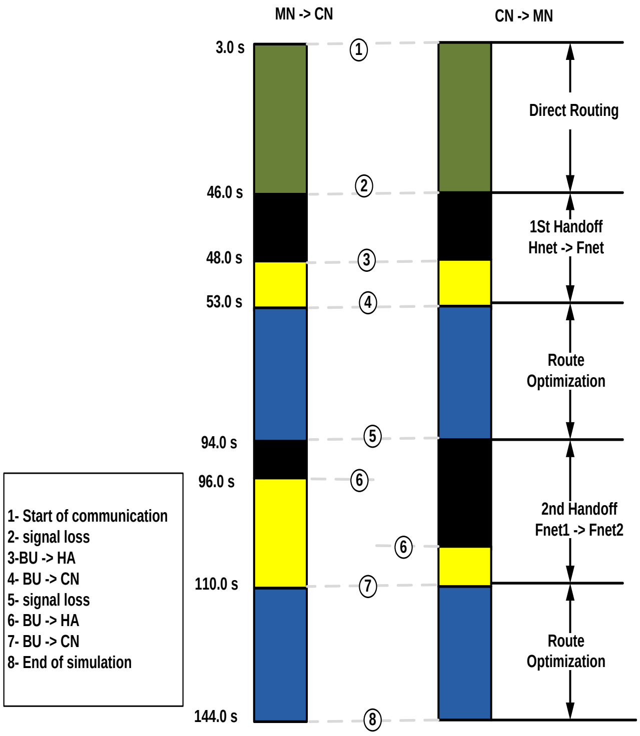


Fig 7: Routing steps during the handover process for a MN that moves with velocity 15km/hr

7.1 Homogeneous WLAN Network

The MN/MR roams across the two WLAN homogeneous ARs (PAR & NAR) [10]. The throughput of received packets by using MIP, FHMIP, NEMO mechanisms in WLAN homogeneous networks is compared. The vertical axis represents the throughput of received packets and the horizontal axis is the simulated time. From the simulation results ,the throughput is larger in FHMIP case as shown in Figure 8 In FHMIP the gap is minimized. MIPv6's throughput shows that as soon as the MN starts moving, throughput begins to go until 190 sec into the simulation and it stabilizes at 6000 kbps. NEMO performance degrades due to the large signaling messages and that MR uses break before make algorithm during handover process. During the handover process, the MN/MR disconnects the association with PAR prior to making the connection with NAR. This results in significant packet loss especially in NEMO case with 15% percentage and high signaling load.

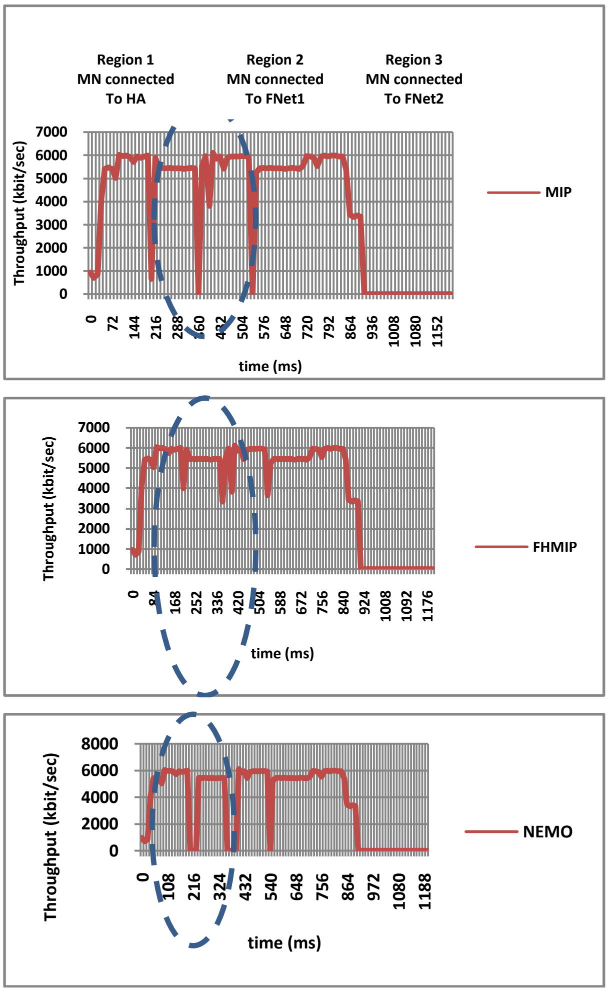


Fig 8: Throughput over MIP & FHMIP & NEMO in homogenous WLAN network

The handover delay is the time interval between the departure of data from the source until its arrival to the destination or the time when the MN/MR loses connectivity with its attached AR till the time it receives a data packet from the newly attached AR [11]. The delay in all scenarios was compared using different mobility protocols and concentrating only on 1st handover region. It can be seen that, the average overall horizontal handover delay for the basic NEMO exceeds 3sec which isn't suitable for handling real-time or multimedia traffic and providing seamless mobility. The simulation is repeated number of times with MN velocity varied from 5 Km/hr to 35 Km/hr and average value is taken. It is obvious that the handover delay is improved by using

FHMIP protocol as shown in Figure 9. This is due to the fact that it needs only the BU registration to the MAP.

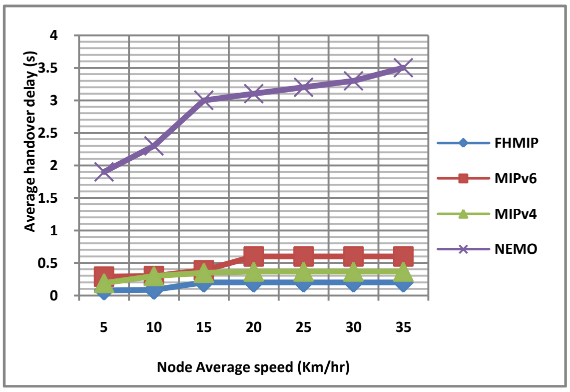


Fig 9: Handover delay Vs speed in homogenous WLAN network

In Figure 10, the overall signaling load for all solutions is shown Vs node speed. The signaling load is the amount of signaling data that is transmitted between the MN and the CN per period of time.

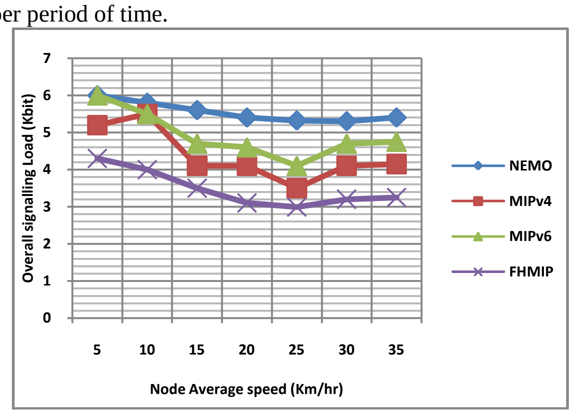
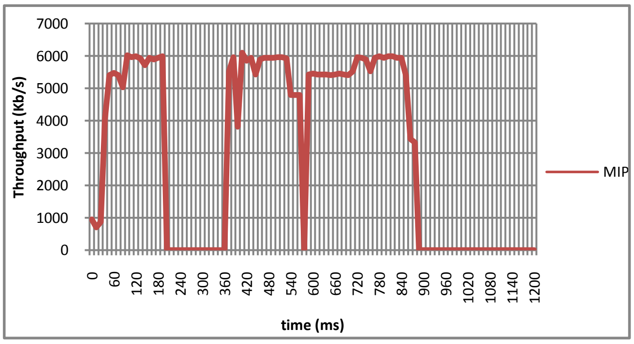
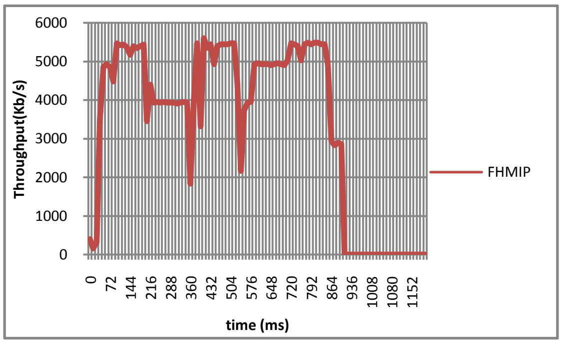


Fig 10: Signaling Load in homogenous WLAN network

7.2 Heterogeneous WLAN and WiMAX Networks

As MN/MR move over WLAN, WiMAX hybrid networks [12]. The MS Initially uses WLAN interface to communicate with the corresponding node (CN) via PAR. Each access network has its own mobility, security and QoS requirements. There is excessive increase in the overall handover delay all of which would lead to decrease in throughput in vertical handover case as shown in Figure 11.





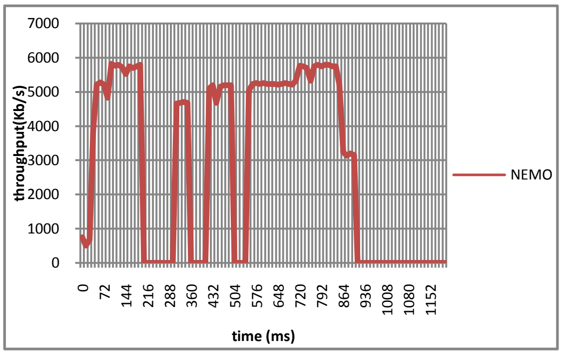


Fig 11: Throughput over MIP & FHMIP & NEMO in heterogeneous network

The handover delay increases in NEMO in Figure 12. It takes the delays associated with L2 scanning time and NCoA configuration time. Additional End-to end delivery delays are introduced by signal strength degradation of MN connection when it moves away from its old AR. Figure 13 is the signaling Load in heterogeneous network.

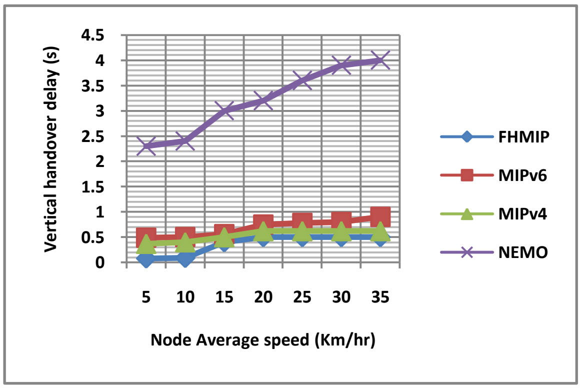


Fig 12: Handover delay Vs speed in heterogeneous network

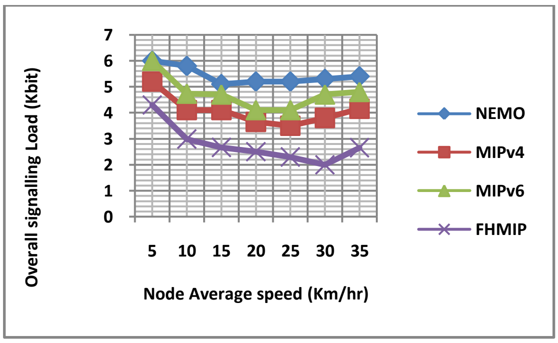


Fig 13: Signaling Load in heterogeneous network

7.3 Handover delay using MIP assisted IEEE 802.21 MIH

7.3.1 Homogeneous WLAN Network

Delay can be significantly improved by using the MIP assisted IEEE 802.21 as shown in Figure 14. The overall handover delay is roughly reduced by 0.45s by using the MIH mechanism. IEEE802.21 assisted MIPv6 does not take into consideration the L2 scanning time. It is shown through analysis that by enabling MIH, MN can be well prepared for handoff and can perform faster movement [13].

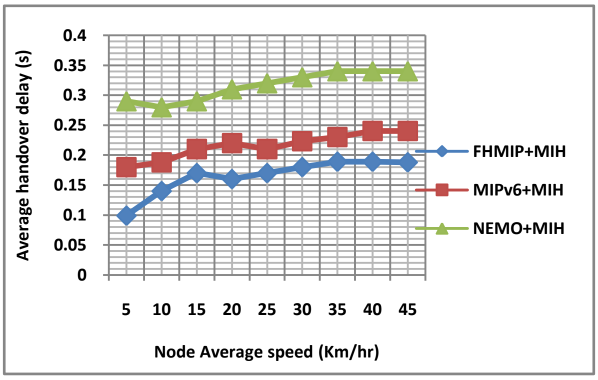


Fig 14: Handover delay Vs speed in WLAN homogeneous network

The overall comparison of throughput performance during handover for MIH and MIPv6 is shown in Figure 15, Figure 16. From the simulation result, we can see that the overall throughput of MIH mechanism has higher performance than the MIPv6 mechanism. Combination of MIH with another protocol in the network layer and above facilitates the change of IP between different technologies. 802.21 assisted MIPv6 and NEMO mechanism optimize handover procedures.

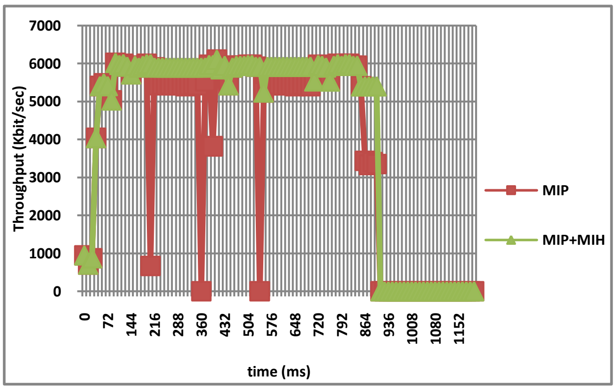


Fig 15: The throughput performance in WLAN homogeneous network

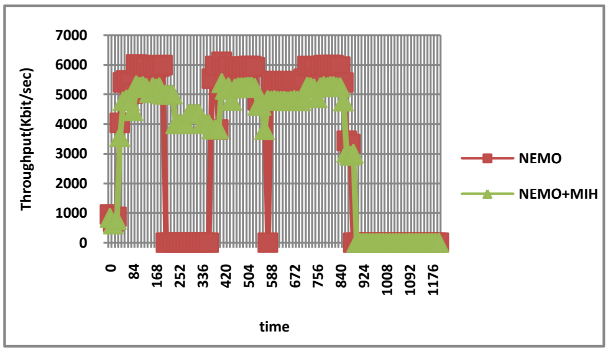


Fig 16: The throughput performance in WLAN homogeneous network

7.3.2 Heterogeneous WLAN and WiMAX Networks

The IEEE 802.21 provides the solution regarding the handover issues across the IEEE 802.11 and IEEE 802.16 heterogeneous networks. This integrated mechanism [14] will solve the handover delay and packet loss issues as shown in Figure 17. The MN can collect and integrate the messages from the MIH via the serving network as it can't receive the neighboring BS's signaling directly [15]. The MIH compares the received neighboring network information such as throughput to make the handover decision. The MIH user selects the WiMAX as the serving network and disables the WLAN interface. The handover delay in MIP integrated with MIH is smaller than the MIP itself.

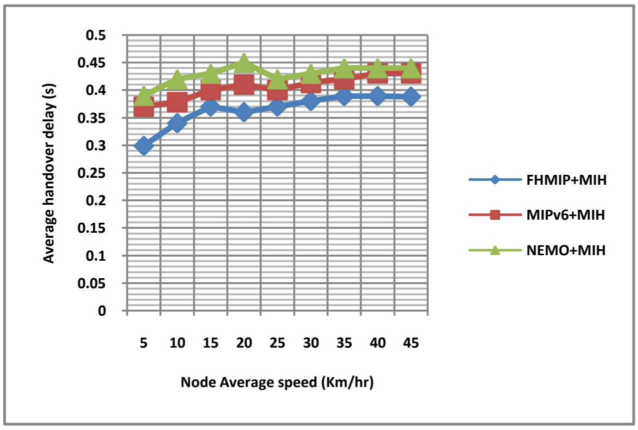


Fig 17: Handover delay Vs speed in heterogeneous network

Figure 18 is the throughput of received packets by using the MIH and the MIPv6 mechanisms in WiMAX homogeneous networks. The MN/MR handovers from Wi-Fi PAR to WiMAX NAR and disconnects the association with PAR to make the connection with NAR.

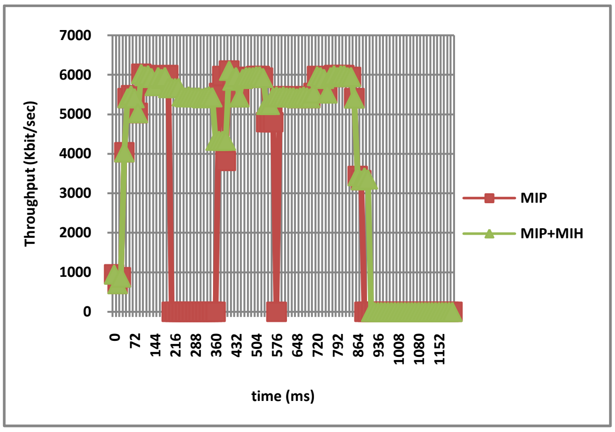


Fig 18: The throughput performance in heterogeneous network

The effect of the number of handovers on performance was examined in Figure 19. While the number of handovers was progressively increased from 1 to 10, it can be observed that FHMIP maintains a higher MOS value. Moreover, the improvement in MOS increases as the number of handovers increase. This is because FHMIP reduces packets being dropped, thereby resulting in a higher MOS value. Table 4 is the percentage of packet loss.

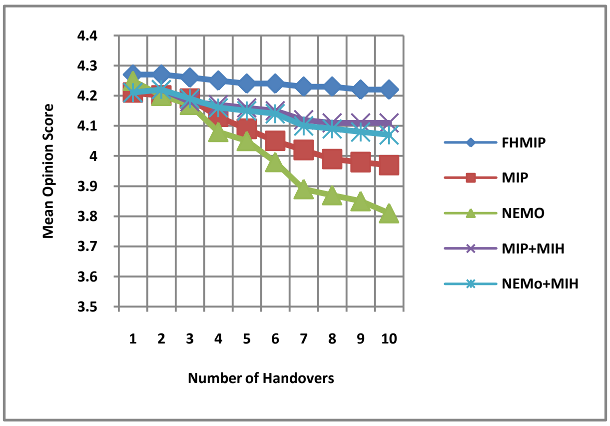


Fig 19: Effect of number of handovers on performance

Table 3: Percentage of packet loss

Protocol	Homogenous Network	Heterogeneous network
	% loss	% loss
MIPv4	12.5	15
MIPv6	10.3	13
FHMIP	3.6	5
NEMO	15	18
MIP+MIH	8	6
NEMO+MIH	10	12

8. CONCLUSION

In conclusion, this paper shows the transport of data between two PoAs using MIH Services. This is achieved using one of the mobility protocols (e.g. MIPv6, NEMO, and FMIPv6) and IEEE802.21 MIH to enable handover between different access technologies. The main challenge in this research is to minimize mobility disruptions when roaming across different layers in the protocol stack.

Through detailed analysis, it is shown that handover performance in FHMIP is improved than the other protocols. The factors that affect delay and throughput are the number of foreign agents along the trajectory path, speed of MN and the number of signaling messages exchanged with the MN. FHMIP integration with IEEE802.21 MIH provide useful information to upper layers to determine the optimized handover moment and path and provides accepted percentage of packet loss for real-time applications .

9. FUTURE WORK

In the future a completion of the implementation aspects:

- Optimizing other handover latency components such as movement detection time, registration time.
- Optimizing DAD procedure
- Study S-MIP and examine the effect of this on the packet arrival time.
- Address the dynamic address problem faced during vertical handoff process.
- Improving the handover performance both at the Network Layer for the Mobile IPv6 and at the Link Layer for IEEE 802.11 networks with a cross-layer proposal.
- Complex scheme is required that takes a wider array of parameters to make intelligent network selection in high speed vehicular environments.
- Enhancing IEEE 802.21 NIST module to support additional access technologies .

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