An Efficient Handover Scheme for PMIPv6 in IEEE 802.16/WiMAX Network

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***Abstract*— In the era of wireless communication, mobility management is an important issue. The world is deploying WiMAX (Worldwide Interoperability for Microwave Access) as the standard for broadband wireless communication because of it's wide application areas, high speed and architecture for seamless handover. Alongside, a network-based mobility management protocol called PMIPv6 (Proxy Mobile Internet Protocol version 6) is being actively standardized and is starting to attract considerable attention among the telecommunication and Internet communities for its less handover latency. In PMIPv6, the functioning network provides control of the mobility management on behalf of the mobile node. Thus the mobile node is relieved from any mobility related signaling. However, the PMIPv6 suffers from handover latency and packet loss during handover. In this paper, an efficient handover scheme is proposed within a PMIPv6 domain in the WiMAX network. The proposed scheme reduces handover latency by eliminating the need of a Policy Server (PS) and by pre-registration of the mobile node for a new access point. Furthermore, a comprehensive analysis has been done by NS-2 (Network Simulator-2) for evaluating the delay of our proposed handover scheme and that of general PMIPv6. The analysis results reveal that the proposed strategy for handover has significantly reduced the handover latency of general PMIPv6.**

***Index Term*— Authentication Latency, Handover Latency, NS-2, PMIPv6, Registration latency, WiMAX, Wireless Link Delay.**

I. Introduction

The IEEE 802.16 protocol for wireless metropolitan area network (WMAN) was standardized to meet the needs of wireless broadband access. The 802.16, also known as WiMAX, aims to develop architecture for fast and efficient handover in an operator's network to maximize the performance of the mobility management as a whole. Recently, a network-based mobility management protocol called proxy mobile IPv6 (PMIPv6) is being actively standardized and is starting to attract considerable attention among the telecommunication and internet communities. Unlike the various existing protocols for IP mobility management such as MIPv6, which are host-based approaches, a network based approach such as PMIPv6 has salient features and is expected to expedite the real deployment of IP mobility management. However, the PMIPv6 still suffers from lengthy handover latency and packet loss during a handover and the detailed handover scheme is not finally specified in the standard. Therefore many research scopes have created on reduction of handover latency of PMIPv6 for IEEE 802.16 WiMAX. This paper addresses a design of efficient handover scheme for PMIPv6 with the objective of minimizing the handover latency of WiMAX network.

In this paper, we consider the problem of packet transfer delay during handover of a mobile node roaming from one access point to other within a PMIPv6 domain in the WiMAX network. Although WiMAX provides seamless handover and the protocol PMIPv6 is one of the best mobility management protocols for its efficient handover it has enough handover latency for a video or audio signal to be distorted during handover. So the problem is that how to reduce the handover latency of PMIPv6 protocol by developing efficient handover scheme. Moreover, reducing the rate of increase of handover latency with the increase of wireless link delay is also a problem to be dealt with. Here we have proposed a new handover procedure for the handover of a mobile node roaming from one access point to another within a PMIPv6 domain in the WiMAX network. To evaluate the performance of the new scheme we have developed a simulator program using NS-2 (Network Simulator-2) and obtained a number of performance graphs which have facilitated us to compare the performance of proposed handover scheme with previous one in the aspect of handover latency.

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II. Overview

Network based mobility protocol has salient features in real deployment of IP mobility support by using only collaborative operations between the network entities without mobile node (MN) being involved. In the NetLMM approach, Proxy Mobile IPv6 (PMIPv6) is one of proposed solutions to support a localized mobility management for a mobile node (MN). PMIPv6 is designed to provide network-based mobility management support to an MN in a topologically localized domain. For the past few years PMIPv6 handover procedure has got significant number of modifications and additions. In this section we will discuss about PMIPv6 in details with the view of [3]. We will also discuss about the handover procedure based on [2].

Basic Terminologies

NETLMM Domain	Network Level Management Protocol.
LMA	Local Mobility Anchor
MAG	Mobile Access Gateway [4]
LMAA	LMA Address
Proxy-CoA	Proxy Care-of Address [4]
PBU	Proxy Binding Update
PBA	Proxy Binding Acknowledgment

A. PMIPv6 Handover Procedure

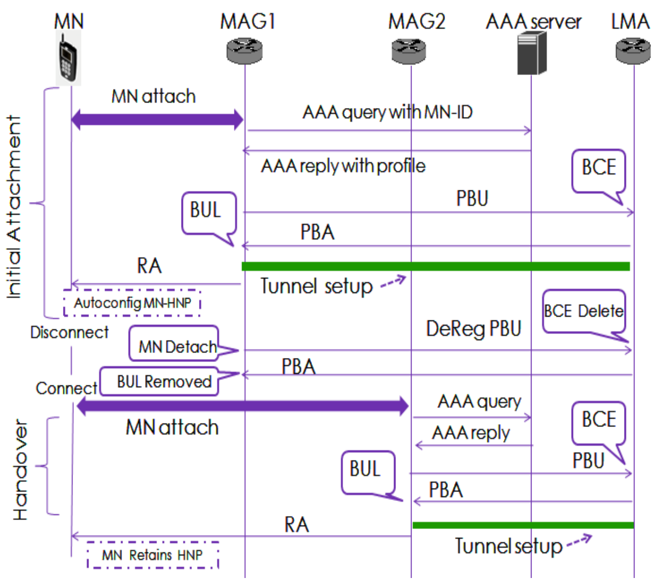

Fig. 1. PMIPv6 signal flow

The whole handover procedure goes as follows [2]:

Step 1, 2 & 3: When an MN enters into a new PMIPv6 domain initially it attaches to MAG-1in the domain. Then the access authentication procedure is performed using an MN-Identifier (MN-ID) via the deployed access security protocols on the access network. After successful access authentication, the MAG-1 obtains the MN's profile, which contains the MN-Identifier, LMA address (LMAA) and supported address configuration mode.

Step 4 & 5: To update the LMA about the current location of the MN, MAG-1 sends a Proxy Binding Update (PBU) message to the LMA on behalf of the MN. Upon receiving the PBU message, the LMA assigns a MN-HNP (Home network Prefix) and creates a BCE that binds the MN-HNP to a Proxy-CoA which is the address of MAG-1. The LMA sends a Proxy Binding Acknowledgement (PBA) message including the MN-HNP.

Step 6: Upon receiving the PBA message, MAG-1 sets up a tunnel to the LMA and adds a default route over the tunnel to the LMA. It also creates a Binding Update List (BUL). The MAG-1 then sends Router Advertisement (RA) messages to the MN on the access link to advertise the MN-HNP as the hosted on-link-prefix. When the MN receives these RA messages, the MN configures the IP address using either a state full or stateless address configuration modes. After successfully completing the address configuration procedure, the MN uses this address for packet delivery.

Step 7 & 8: When the MN moves to the access network of MAG-2, MAG-1 receives a LGD (Link Going Down) trigger and detects that the MN has moved away from its access link. Therefore, MAG-1 sends a DeReg PBU (De-Registration PBU) message to the LMA with the lifetime value set to zero for de-registration. Upon receiving the PBU message with a zero lifetime value, the LMA sends a PBA message to MAG-1 and waits for a Min Delay Before BCE-Delete amount of time, before it deletes the MN's BCE.

Step 9, 10 & 11: When MAG-2 detects the attachment of MN, MAG-2 obtains the MN profile using an MN-ID after successful access authentication. This step is same as step 1, 2 and 3.

B. Handover Steps by Layer Basis

The whole handover procedure can also be divided into two basic steps:

Layer2 Handover: Layer 2 handover can be defined as movement of a MN's point of Layer 2 connection from one wireless access point to another. The layer 2 handoff latency is measured as the time between the first probe request message sent by the mobile node and the arrival of a re-association response message from an access point. Three phases or logical steps can be identified for the layer 2 handoff process: (f1) discovery phase, (f2) re-authentication phase and (f3) re-association phase [1] [5].

Layer3 Handover: Layer3 handover process can be defined as movement of an MN between Foreign Agent (FA) or MAGs (in case of PMIPv6) which involves changing the care of address at layer3. The layer 3 handover is decomposed into creating, verifying and registering a new address. When MN is changing its point of attachment between the MAGs then it requires a new IP address i.e. the new proxy CoA which is the IP address of the new MAG and layer 3 handover is required [6].

C. Limitations of PMIPv6

Although PMIPv6 relieves the MN from mobility related signaling causing less signal overhead, the protocol has some significant drawbacks like the protocol suffers from packet loss during handover, It suffers from handover delay or latency which may cause serious distortions in video or sound signal during handover and it is limited to intra-domain handover.

III. Proposed PMIPv6 Handover Scheme

A network based mobility management protocol like PMIPv6 is better than different host based network mobility management protocols. However, PMIPv6 has always got significant handover latency in its packet transfer procedure. So, many handover procedures have been proposed on reduction of the handover latency of PMIPv6. In this section we discuss our proposed scheme to reduce the handover latency of PMIPv6 which is based on [2] with a significant modification.

Handover latency in PMIPv6 is caused due to following four latencies:

- Link switching latency
- AAA authentication latency
- MN registration latency
- Latency due to Router Solicitation (RS) message and Router Advertisement (RA) messages

In the proposed scheme, the handover latency is reduced due to AAA authentication and MN registration latency.

Reduction Procedure of Authentication Delay- At the advent of handover procedure, MAG-1 sends a neighbor discovery (ND) message containing the MN-profile to neighboring MAGs within the PMIPv6 domain. When neighboring MAGs will receive the MN-profile, they will conceive that as MAG-1 is attached with MN, so the MN is already validated. This will eradicate the need for acquiring MN-profile and checking validation from the AAA server. So, as the authentication is not to be done during handover, the delay due to AAA-authentication will be removed and overall handover latency will be decreased.

Reduction Procedure of MN Registration Delay- In our proposed scheme, the PBA message of new MAG is added with DeReg PBU message and this message packet is sent to the LMA whenever MAG1 is aware of MN's detachment. So, the MN is registered for MAG2 in advance by MAG1. As a result, the tunnel between the LMA and the MAG2 is established in advance.

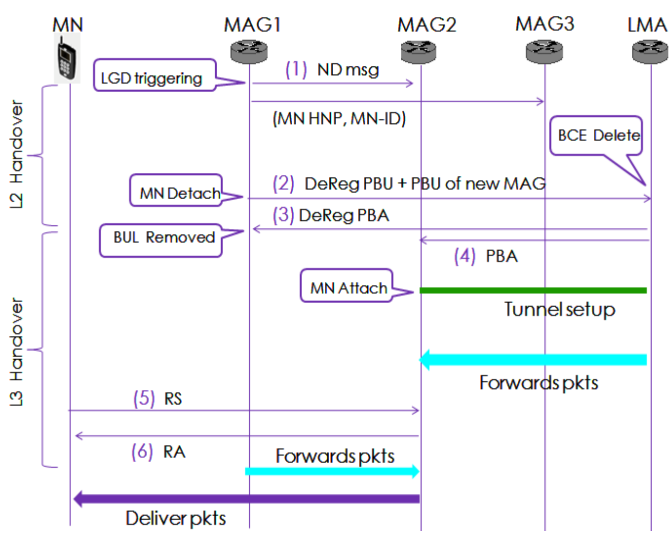

Fig 2. Signal flow of proposed PMIPv6

Our proposed scheme puts forward some advantages over the general PMIPv6 such as:

- As the PBU message of MAG2 is included in DeReg PBU message of MAG1, that is, the MAG1 registers on behalf of the MAG2 which reduces the handover latency to some extent.
- As the MAG2 is registered in advance by MAG1 so the tunnel between the LMA and the MAG2 is established in layer2 handover. This results in packet buffering and transferring in advance.
- This handover scheme reduces the handover latency by sending the MN-profile using a ND message of IPv6 at the beginning of handover. Thereby, it can eliminate the need for the MAGs to acquire the MN-profile from the policy server such as AAA server whenever a MN performs a handover.

But it has a little disadvantage of greater signal overhead than general PIMPv6 procedure. Because during layer2 handover the extra signal overhead of PBA of MAG2 along with that of ND message causes increased signal overhead.

IV. Performance Evaluation

A. System Model

We have chosen the WiMAX network as our Simulation media in lieu of 802.11 wireless media. WiMAX, which stands for Worldwide Interoperability for Microwave Access is a wireless digital communication system. It is also known as 802.16 according to IEEE standard. [8]. It can provide broadband wireless access to a very large area such as 50km for fixed station and 5-15 km for mobile stations. WiMAX is a second generation protocol that allows for more efficient bandwidth use, interference avoidance and most important of all is intended to allow higher data rates as 10Mbs for over longer distances [9]. Because of high performance efficiency of WiMAX, the world of telecommunication is deploying WiMAX as a standard media for wireless communication. Based on these aspects, we have used the WiMAX network for analyzing handover latency of PMIPv6.

The evaluation is done using NS-2software and a system model. In the system model, we evaluate performance of two schemes when an MN moves between MAGs. We assume that a correspondent node (CN) generates data packets destined to the MN and the MN moves between MAGs.

In the simulation, the MN starts from MAG-1 and moves to MAG-2. As any user i.e. CN generates data packets, the packets flow through a router which acts as the internet gateway, then enter PMIPv6 domain through the LMA which is tunneled with MAG1. As the MN moves away from MAG1 and goes near MAG2, layer2 and layer3 handover occurs respectively.

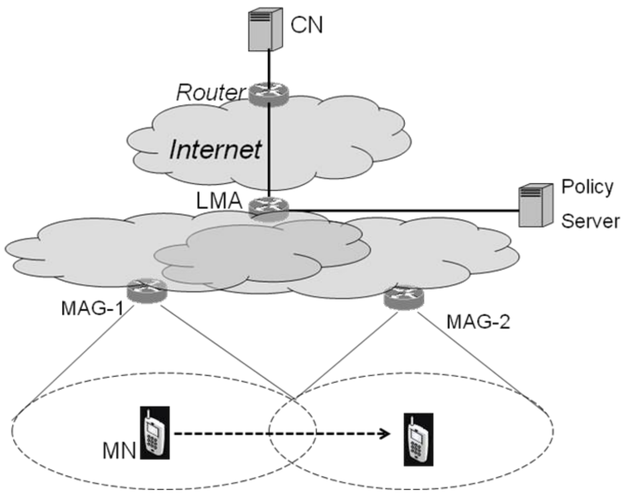

Fig. 3. Network System Model

B. *Practical Simulation Window*

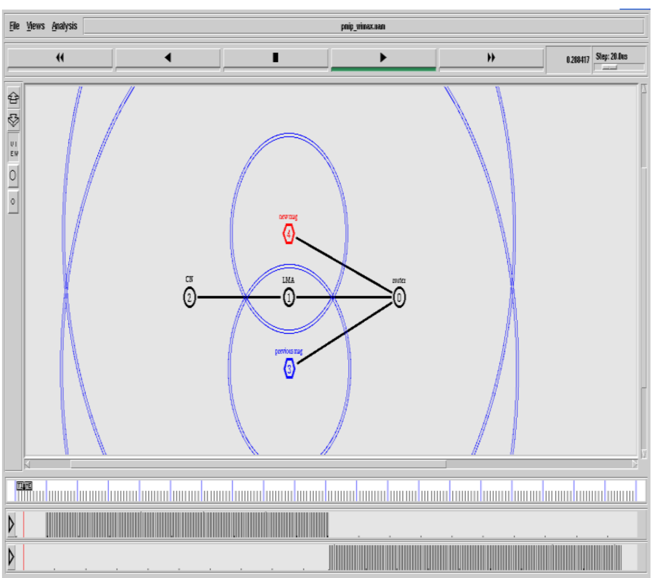

Fig. 4. Practical simulation window of NS-2. The first portion of bar below the window is Bandwidth usage of previous MAG/MAG1 and the remaining part of the bar is the Bandwidth usage of new MAG/MAG2

Table I
Node Assignment of simulation

Node	Assignment
0	Router
1	LMA
2	CN
3	Previous MAG/MAG1 (Blue)
4	New MAG/MAG2 (Red)

At the advent of simulation, the mobile node is not visible in the window. At 2.0 second, when the mobile node enters the radiation zone the packets from the CN passes through LMA and router and reaches the previous MAG. Then the previous MAG sends the packets to mobile node through wireless link.

When the MN communicates with previous MAG the NS-2 simulation window looks like as below:

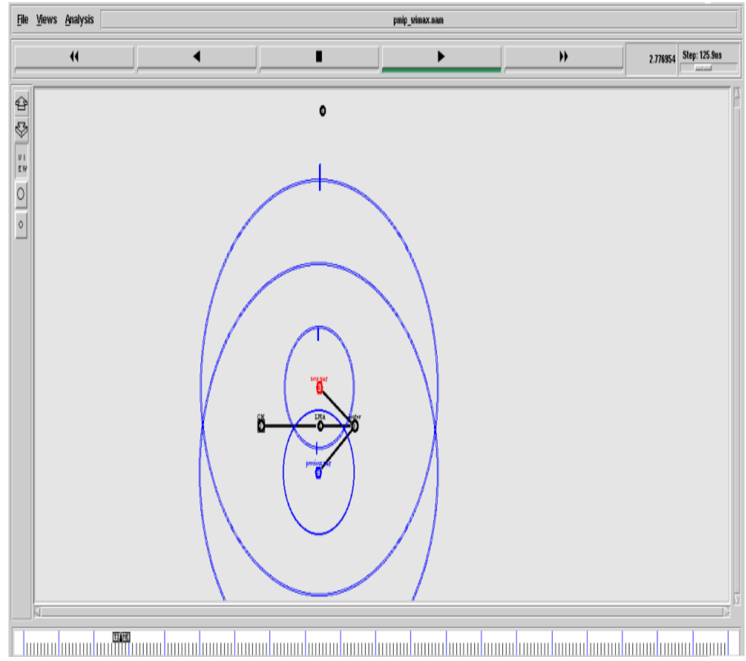

Fig. 5. Practical simulation window of NS-2 before handover

After the handover between previous MAG and new MAG the NS-2 simulation window looks as below:

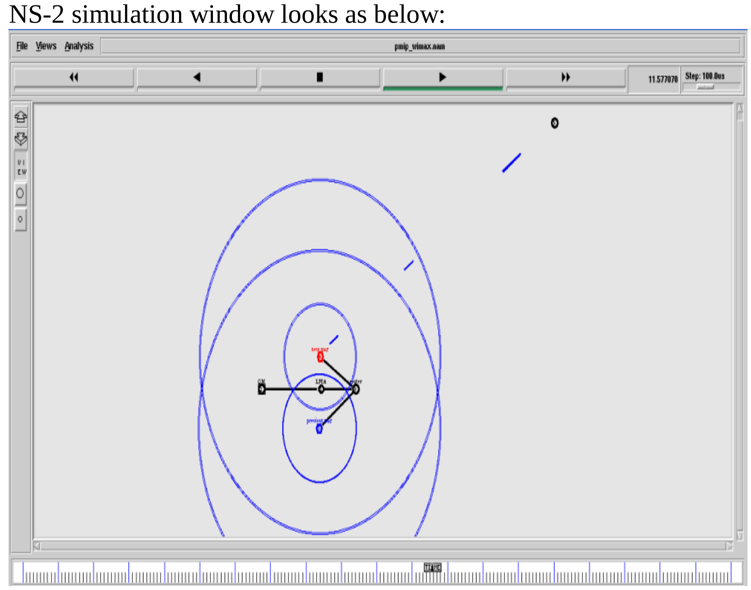

Fig. 6. Practical simulation window of NS-2 after handover

C. *Handover Latency Analysis*

Handover latency measures the maximum time interval in which the MN does not receive any IP packet due to handover. Usually this handover latency is marked by the moment that the MN receives the last IP packet from the previous MAG, and the moment that the MN receives the first IP packet from the new MAG. To analyze handover latency of the two schemes, we define that tMN-MAG, tMAG-LMAandtMAG1-MAG2are transfer delays between an MN and an MAG, an MAG and a LMA, and adjacent two MAGs respectively. Handover latency of PMIPv6 is as follows [3]:

$T_{PMIPv6Latency}$=link switching latency + IP connectivity latency + location update latency

$$= t_{link-switching} + (t_{AAA-Auth} + t_{RS-RA}) + t_{P-Registration}$$

- $t_{link-switching}$=delay during layer 2 handover

- $t_{AAA-Auth} = 2*(t_{MN\text{-}MAG} + t_{MAG\text{-}LMA})$ = delay during authentication of an MN through AAA infrastructure
- $t_{P-Registration} = 2*t_{MAG\text{-}LMA}$ = delay during proxy binding update to a LMA
- $t_{RS-RA} = 2*t_{MN\text{-}MAG}$ =delay during exchanging of a router solicitation (RS) and a router advertisement (RA)messages between the MN and the MAG

Handover latency of our proposed PMIPv6 handover scheme T'PMIPv6Latencycan be defined by the 1st equation. In this case, delay of proxy registration and AAA authentication are reduced, since proxy registration is performed during layer 2 handoff and need of authentication is eliminated by Network discovery message. So, $T'_{PMIPv6Latency} = t_{link-switching} + t_{RS-RA}$

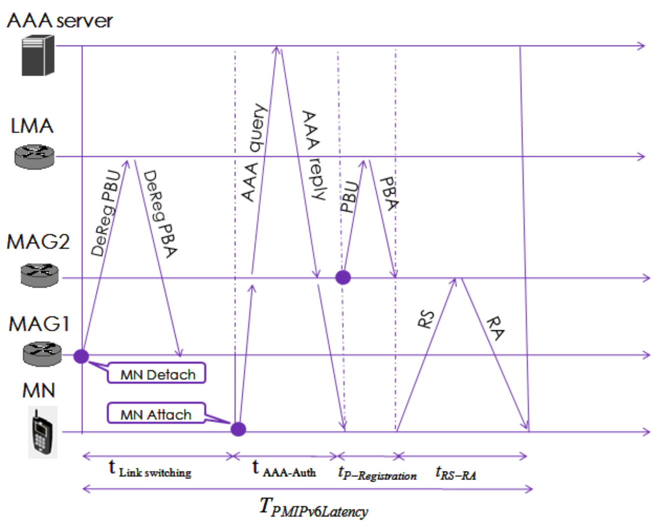

Fig. 7. Handover Latency of PMIPv6

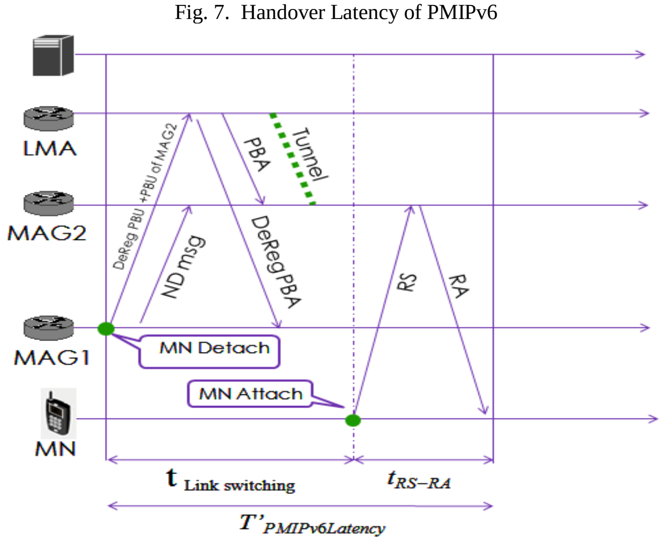

Fig. 8. Handover Latency of proposed PMIPv6 scheme

D. Delay Analysis

In this section, we analyze the delay of packet transfer from corresponding node (CN) to mobile node (MN) both for general PMIPv6 and our proposed PMIPv6 schemes and comparison between the two delays is depicted.

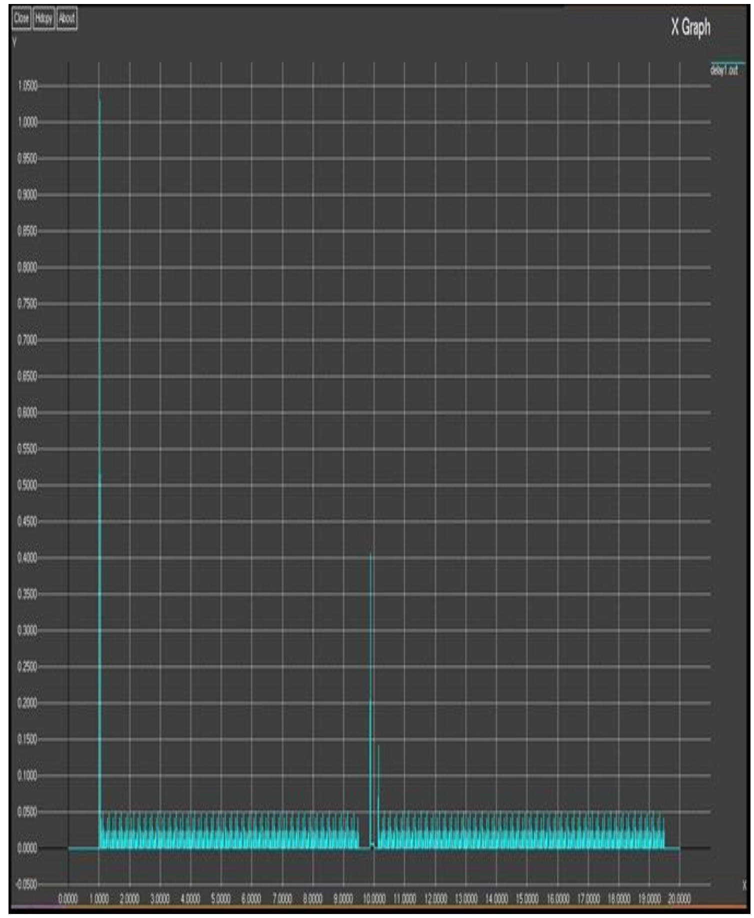

Fig. 9. Delay analysis of general PMIPv6

The above graph is the x-graph version of the general PMIPv6 delay versus time evaluated in NS-2. When an MN enters into a new PMIPv6 domain initially it attaches to a MAG in the domain. Then the access authentication procedure, IP address configuration and at last tunneling is done, so at the beginning of packet transfer i.e. at 1.000ms the delay is about 1.03ms, then as long as the MN remains attached to MAG1, there is an average delay of about 0.0500ms. When a handover is about to begin such as here at 10.0000ms, the packet transfer delay rises to about 0.4000ms. As the handover is finished and MN is attached to new MAG, then the packet transfer delay again drops to the previous average value i.e. 0.0500ms.

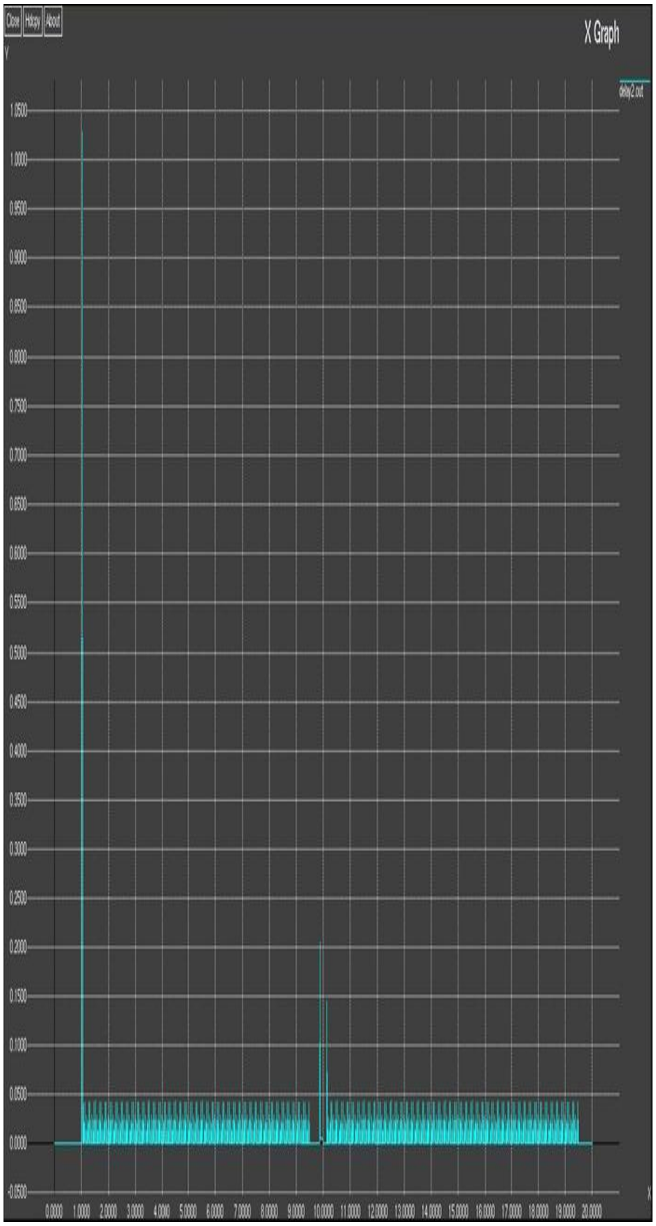

Fig. 10. Delay analysis of proposed PMIPv6

The above graph is the x-graph version of the proposed PMIPv6 delay versus time evaluated in NS-2. Here the average delay i.e. the packet transfer delay when MN is attached to a MAG in a PMIPv6 domain is same as the general PMIPv6 average delay i.e. 0.0500ms. But the whenever is handover is initiated at 10.0000ms the packet transfer delay is 0.2000ms which is much less than the delay at handover of previously described PMIPv6.

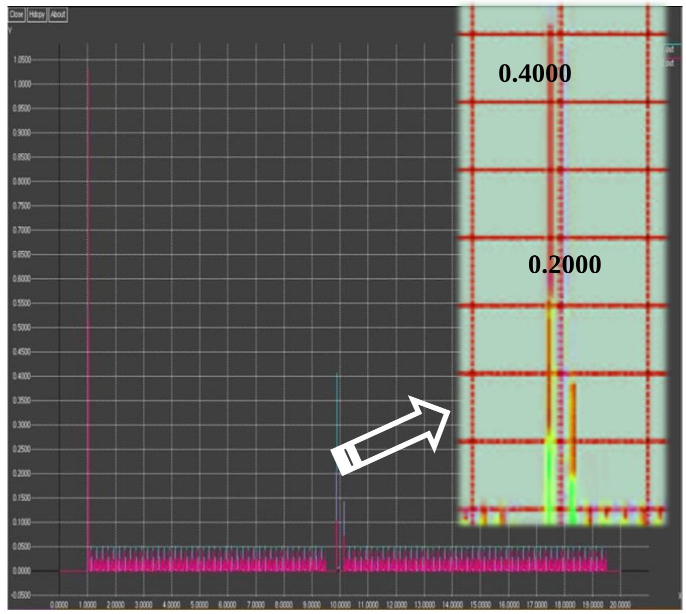

Fig. 11. 5 Delay comparison of general PMIPv6 & Proposed Scheme

The above graph is the x-graph version of general PMIPv6 (Red) & proposed PMIPv6 (Green) delay versus time evaluated in NS-2. For the general PMIPv6, when an MN enters into a new PMIPv6 domain, initially it attaches to a MAG in the domain. Then the access authentication procedure, IP address configuration and at last tunneling is done, so at the beginning of packet transfer i.e. at 1.000ms the delay is about 1.03ms, then as long as the MN remains attached to MAG1, there is an average delay of about 0.0500ms. When a handover is about to begin such as here at 10.0000ms, the packet transfer delay rises to about 0.4000 ms. As the handover is finished and MN is attached to new MAG, then the packet transfer delay again drops to the previous average value i.e. 0.0500 ms. In contrast, for the proposed PMIPv6, the average delay i.e. the packet transfer delay when MN is attached to a MAG in a PMIPv6 domain is same as the general PMIPv6 average delay i.e. 0.0500ms. However, when the handover is initiated at 10.0000ms, the packet transfer delay is 0.2000ms which is much less than that of previously described PMIPv6. The delay at handover of our proposed scheme has been reduced 0.2000ms.

Previous handover latency = 0.4000 ms

Proposed handover latency = 0.2000 ms

Efficiency of proposed scheme = (0.4000/0.2000)*100= 50 %

So the handover latency is decreased by 50% according to our proposal.

E. Handover Latency Analysis based on Wireless Link Delay

For all of the mobility support protocols, it can be observed that handover latencies increase with the wireless link delay even if the slopes of each graph are different from each other. The procedure which uses the wireless link most encounters the highest impact of wireless link delay on its handover latency. MIPv6 is most affected by the change in wireless link delay because it requires the largest number of message exchanges. In contrast, the mobility management procedure which is network based is least affected by the change in wireless link delay. For example, in PMIPv6 which is a network based mobility the mobile node (MN) is not involved in mobility-related signaling. As a result, the wireless link is least used in PMIPv6, so PMIPv6 is least affected by the change of wireless link delay.

V. Simulation Result

In the simulation, we have changed the wireless link delay and measured the handover latency. The increase in handover latency has been measured for the change in wireless link delay for 10ms to 40ms ranges. As the link delay increases, every time the handover latency increases as well. From the simulation of general PMIPv6, we get the following handover latency for corresponding wireless link delay:

Table II
Change of handover latency with wireless link delay for PMIPv6

Wireless Link Delay(ms)	Handover latency (ms)
10	204.0000
15	204.3056
18	405.0000
20	406.0000
30	406.0556
40	406.0556

Table III
Change of handover latency with wireless link delay for proposed PMIPv6

Wireless Link Delay (ms)	Handover latency (ms)
10	203.9745
15	204.0000
18	204.6900
20	205.1500
30	205.1501
40	205.1501

NS-2 generated graph for the values of Fig 10 is depicted below:

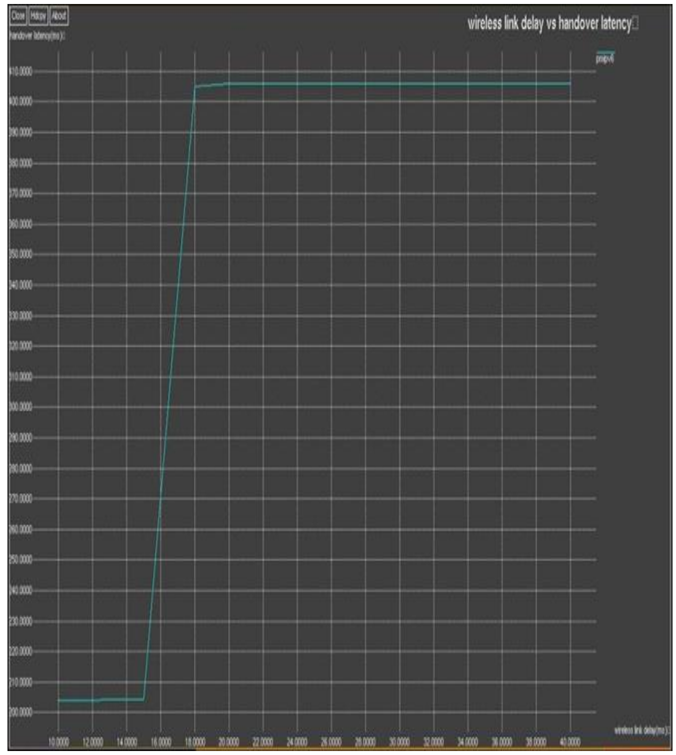

Fig. 12. Graphical representation of Table II

Fig 12 shows the graph of the wireless link delay versus handover latency for general PMIPv6. It is clear from the above figure that as wireless link delay increases, the handover latency changes accordingly. At 10ms-15ms the change in handover latency is less significant. As the wireless link delay crosses 15ms, there is an abrupt increase in handover latency with wireless link delay. After wireless link delay crosses 18ms, the handover latency increases with increase of wireless link delay at a small but linear rate.

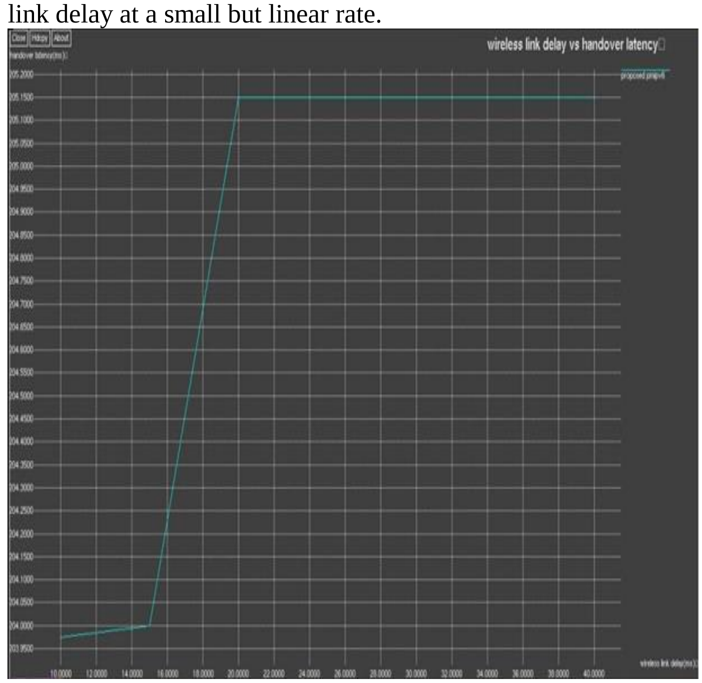

Fig. 13. Graphical representation of Table III

The above figure shows the graph of wireless link delay vs. handover latency for the proposed PMIPv6 scheme. Here also the handover latency is increased with the increase in wireless link delay but with a less abrupt manner than that of the previously described PMIPv6. With a small rate of increase of handover latency with wireless link delay for upto15ms, there is a sharp increase upto 20ms. After that there is an increase of handover latency with a linear and smaller rate than that of the PMIPv6.

Integrating the handover latency values of fig 12 and fig.13 we get the final graph which enables us to graphically compare general PMIPvt6 and proposed PMIPv6 scheme with ease.

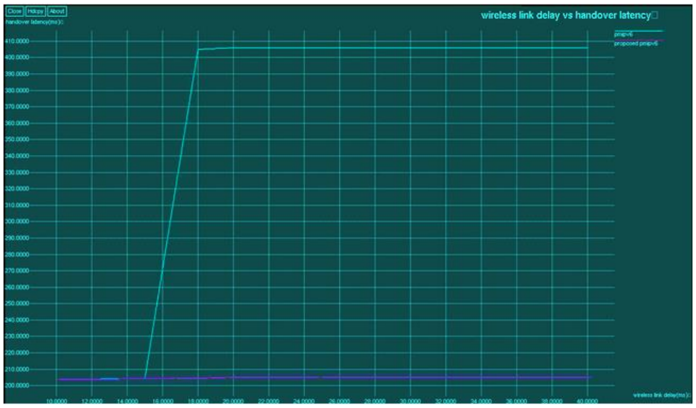

Fig. 14. 3 Comparison of wireless link delay versus handover latency for general PMIPv6 and Proposed PMIPv6

It is clear from the above figure that rate of increase of handover latency of our proposed scheme (Violet) is much smaller than that of the general PMIPv6 (Light Blue). So change of wireless link delay causes much less impact on our proposed PMIPv6 handover scheme. The wireless link delay changes from 10ms-40ms the handover latency increases from 203.9745ms-205.1501ms in the proposed PMIPv6, whereas in the PMIPv6 procedure, the handover latency increases from 204.0000ms-406.0556ms for the same increase in wireless link delay. As a result, it is worth-written that our proposed scheme is a much efficient handover procedure than the PMIPv6 handover procedure.

VI. CONCLUSION

In mobile communication, the handover delay issue is of great importance. So we have focused on reducing the handover latency of mobility management protocol. We have investigated the impacts of various performance parameters among the host-based and network-based mobility management protocols from which we found out that network-based mobility management protocol such as PMIPv6 is of less signal overhead and comparatively less handover latency than the other protocols in most of the circumstances. But PMIPv6 still suffers from handover latency along with packet loss during handover. So, we converged our focus to minimize this problem. We evaluate the performance of both the general PMIPv6 and our proposed handover scheme by NS-2 for a PMIPv6 system model. The simulation results show that our proposed scheme can effectively reduce the handover latency performance of the system than the general one by 50%. The performance was precisely evaluated by the x-graph of the packet transfer delay versus time based on the NS-2 simulation. Moreover, as wireless link delay is a significant parameter for evaluating handover latency, so the handover latency of the both proposed and general PMIPv6 were plotted in a graph with respect to increase in wireless link delay based on the simulation results. The comparison graph shows that the graph of our proposed scheme is less steep than the general one which reveals that the rate of increase of handover latency of our scheme with increase of wireless link delay is small enough to be rated as an efficient handover scheme.

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VIII. SCOPE & LIMITATIONS

In our simulation we consider only handover latency of our proposed scheme. In fact, we have only dealt with reducing the handover latency of PMIPv6. But PMIPv6 also suffers from packet loss during handover and also has a limitation of only intra-domain packet transfer. These are not our concern in our proposed handover procedure. So there is scope to work on developing scheme for handover procedure with a reduced packet loss and facilitating PMIPv6 with inter-domain packet transfer.

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