Proxy Mobile IPv6-Based Handovers for VoIP Services in Wireless Heterogeneous Networks

N. P. Singh and Brahmjit Singh

***Abstract*—The mobile node can experience disruptions of an ongoing real-time session due to handovers in voice over Internet Protocol (VoIP) services. The duration of such interruptions is called disruption time or handover delay and this is very annoying to user. Therefore, this delay needs to be minimized to provide good-quality VoIP services. In this paper, the focus is on the network layer mobility, specifically on mobile Internet Protocols (MIPs), since they are natural candidates for providing mobility at layer 3. Fast MIPv6 (FMIPv6), hierarchical MIPv6 (HMIPv6), Fast-Hierarchical mobile IPv6 (FHMIPv6) and Proxy mobile IPv6 (PMIPv6) have been evaluated analytically and compared their performances in terms of handover delay for VoIP services. Numerical results show that PMIPv6 has lowest handover latency.**

***Index Terms*—Fast mobile IPv6 (FMIPv6), handover delay, hierarchical mobile IPv6 (HMIPv6), internet protocol (IP)-based wireless networks, voice over IP (VoIP), fast-hierarchical mobile IPv6 (FHMIPv6), and proxy mobile IPv6 (PMIPv6).**

I. Introduction

In 4G mobile networks, various wireless access technologies- WLAN, WIMAX, and 2G/2.5G/3G cellular networks will coexist. Under this situation, the mobile node would be able to choose the most suitable network for specific applications. Network selection techniques based on IP in 4G networks will play important role in ensuring quality of service (QOS). In providing the voice over IP (VoIP) service in wireless technologies, the most important concern is the disruption time to process the handover of an ongoing VoIP call. During the handover process of any IP-based protocol, the mobile node (MN) cannot receive IP packets on its new point of attachment until the handover ends. This results in disruption of the ongoing media session and it is very annoying to user. Therefore, it is important to evaluate the disruption time or handover delay of the IP based mobility protocols. Here the disruption time or handover delay is defined as the time interval from when the handover process starts to when the MN can send and receive data packets. The support of VoIP in mobile systems requires low handover latency to achieve seamless handovers.

Mobility management is crucial for providing seamless handoff and service continuity in efficient way. Host based mobility management protocol Mobile IPv6 (MIPv6) was proposed as the main protocol for seamless handover by the Internet Engineering Task Force (IETF).Binding update registration in MIPv6[1] takes more time resulting in high handoff latency and high packet loss rate causing user perceptible deterioration of real-time traffic. Therefore various enhancements of MIPv6 such as hierarchical MIPv6 (HMIPv6) [2], [3], fast MIPv6 (FMIPv6) [4], [5], and fast hierarchical MIPv6 (FHMIPv6) [6], [7], [8] were proposed by IETF. Recently, a network based mobility management protocol called Proxy Mobile IPv6 (PMIPv6) [9] is standardized by the IETF. It handles the mobility management on behalf of the MN .Thus the MN is not required to participate in any mobility related signalling.

Through analytical results in [10], [11], [12], the seamless mobility issue for reducing the disruption time is addressed. Handover latency for MIPv6 and PMIPv6 has been compared in [13].In this paper, we have compared various available protocols including F-HMIPv6 and recently developed PMIPv6 in terms of handoff latency. Results in [11], [13] shows that handover latency in MIPv6 is very high and it is not suitable for VoIP services .Therefore MIPv6 has been not considered in our paper. The rest of the paper is organized as follows: In Section 2, various enhancements of the MIPv6 are described. The performance analysis of the different schemes in terms of handover delay using analytical model is given in Section 3. Then, the results are presented in Section 4, considering various conditions, and the concluding remarks are given in the last Section 5.

II. Overview of Protocols for VoIP Services

A. HMIPv6

Hierarchical MIPv6 is an important improvement for MIPv6 for reducing the amount of signaling and improving handoff delays for mobile connections. HMIPv6 was proposed to handle handoff locally through a special node called Mobility Anchor Point (MAP). An MN entering a MAP domain receives router advertisements containing information on one or more local MAPs. An MN in a MAP's domain is configured with two temporary IP addresses: a regional care-of address (RCoA) on the MAP's subnet and an on-link care-of address (LCoA) that corresponds to the current location of the MN. Hence, the movement of an MN within MAP domain is hidden from home agent (HA)/ (corresponding nodes) CNs. Fig. 1 shows the HMIPv6 handover process.

Manuscript received June 22, 2012; revised July 10, 2012.
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DOI: 10.7763/IJET.2012.V4.425

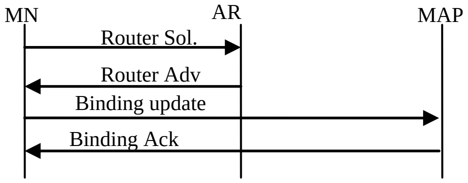

Fig. 1. HMIPv6 handover process.

B. *FMIPv6*

Fast MIPv6 was proposed to reduce handoff delay and minimize service disruption during handovers pertaining to MIPv6. The loss of packets as well as the overhead of sending duplicates of packets should be minimized. The basic idea behind FMIPv6 is that a MN can anticipate the Handover process and inform the new Access Router (new AR) about the Handover. This would shorten the time needed by the MN to detect movement. There are two modes of operations: predictive and reactive. In both modes, the MN sends a router solicitation for proxy advertisement (RtSolPr) to its current access router (AR). The AR replies with a proxy router advertisement (PrRtAdv). This message contains information about the neighbouring AR so that the MN can formulate a prospective new care-of-address (NCoA). The MN can initiate the L3 Handover by sending a fast binding update (FBU) message to inform previous access router (PAR) that packets should be forwarded to next access router (NAR). This message also contains the MN's NCoA. To forward packets, a tunnel is established between PAR and NAR. However, the MN does not know yet if the NCoA is unique on the new link. Therefore, PAR sends a handover initiate (HI) message to NAR for address duplication check on the new link and it sets up the temporary tunnel to redirect packets between PAR and NAR. The NAR responds with handover acknowledgement (Hack) message if the tunnel is set up successfully and there is no address duplication.

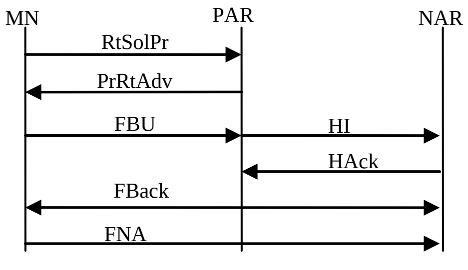

Fig. 2. FMIPv6 predictive handover process.

The MN then receives FBAck message that is used to report status about validation of pre-configured NCoA and tunnel establishment to MN. Moreover, the PAR establishes a binding between PCoA and NCoA and tunnels any packets addressed to PCoA towards NCoA through NAR’s link. The NAR buffers these forwarded packets until the MN attaches to NAR’s link. The MN announces its presence on the new link by sending Router Solicitation (RS) message with the Fast Neighbour Advertisement (FNA) option to NAR. Then, NAR delivers the buffered packets to the MN. The handover process used in FMIPv6 predictive mode is illustrated in Fig. 2. A counterpart to predictive mode of FMIPv6 is reactive mode shown in Fig. 3. This mode refers to the case where the MN does not receive the fast binding acknowledge (FBack) on the previous link since either the MN did not send the FBU or the MN has left the link after sending the FBU (which itself may be lost), but before receiving an FBack. In the latter case, since an MN cannot ascertain whether PAR has successfully processed the FBU, it forwards a FBU, encapsulated in the FNA, as soon as it attaches to NAR.

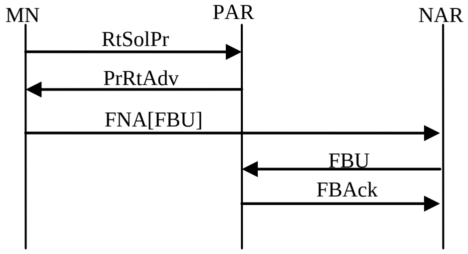

Fig. 3. FMIPv6 reactive handover process.

If NAR detects that NCoA is in use (address collision) when processing the FNA, it must discard the inner FBU packet and send a Router Advertisement (RA) message with the Neighbour Advertisement Acknowledge (NAACK) option in which NAR may include an alternate IP address for the MN to use. Otherwise, NAR forwards FBU to PAR which responds with FBack. At this time, PAR can start tunneling any packets addressed to PCoA towards NCoA through NAR’s link. Then, NAR delivers these packets to the MN.

C. *F-HMIPv6*

FHMIPv6 reduces the handoff latency and packet loss. Bidirectional tunnel is established between MAP and NAR in FHMIPv6. After signalling messages exchange, an MN follows the normal HMIPv6 operations by sending local binding update (LBU) to MAP. When MAP receives LBU with new local care-of-address (NLCoA) from MN, packet forwarding to NAR will be stopped and established tunnel will be cleared. The MAP sends local binding acknowledge (LBack) signal to the MN in response to LBU. The handover process in F-HMIPv6 is shown in Fig. 4.

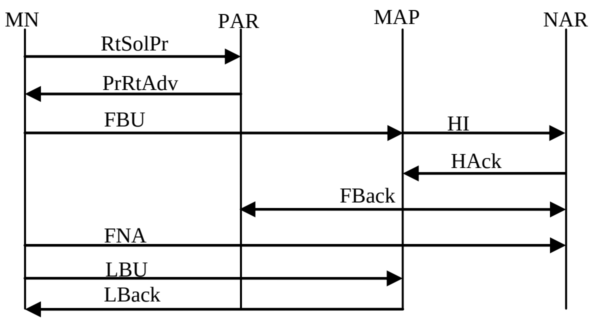

Fig. 4. F-HMIPv6 handover process.

D. *PMIPv6*

PMIPv6 is a network-based mobility management protocol that enables the MN to change its locations without any signal generated by it. The newly introduced mobility service provisioning entities such as mobility access gateway (MAG) and local mobility anchor (LMA) are responsible to manage the movement of the MN in a given PMIPv6 domain. The MAG is located at an access router (AR) as a software function that detects and registers as the MN attaches with the MAG. The LMA, which acts as a home agent (HA), maintains the registration for the MN provided by the MAG. For the MN, registered at the LMA, the LMA assigns and provides the same home network prefix (HNP) to the MN by sending a proxy binding acknowledgement message as a response to a proxy binding update message sent from an MAG. Accordingly, from the viewpoint of the MN changes its location, the MN always obtains the same address, i.e., proxy home address (pHoA), based on the HNP included in the route advertisement (RA) message sent from the MAG. In other words, the entire PMIPv6 domain consisting of at least one LMA and MAGs appears as a single link to the MN. Fig. 5 shows the PMIPv6 handover process.

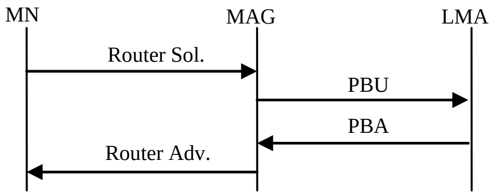

Fig. 5. PMIPv6 handover process.

III. Performance Analysis

In this section handover, delay of the HMIPv6, FMIPv6, FHMIPv6 and PMIPv6 has been evaluated. The analysis is based on a simple model presented in [6] that takes into account the delay between the different entities involved in the handover. Simple network model illustrated in Fig. 6 has been considered for analysis. The notations used are as follows.

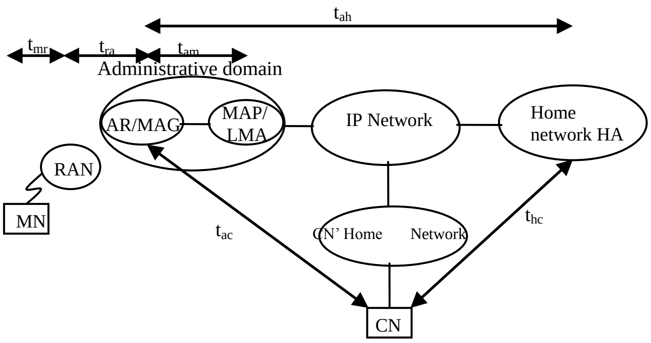

Fig. 6. Model for analysis

- The delay between the MN and the radio access network (RAN) is t_{mr}, which is the time to send a message from MN to RAN through wireless link.
- The delay between the RAN and AR/MAG is t_{ra}, which is the time between the RAN and the AR/MAG connected to the AP.
- The delay between the AR/MAG and MAP/ LMA (i.e., the delay between the AR and MAP in HMIPv6 or between the MAG and LMA in PMIPv6) is $t_{am.}$
- The delay between the AR/MAG and HA is t_{ah}.
- The delay between the AR/MAG and CN is t_{ac}, which is the time required for a packet to be sent between the AR/MAG and the CN, and not via the HA.
- The delay between the MN's home network and CN is t_{hc}.
- The delay between PAR and NAR is t_{pn}.

For simplicity, the following assumptions are considered.

- The delays are considered symmetric.
- Administrative domain is assumed to be foreign network for MIPv6 and FMIPv6 and for HMIPv6 and FHMIPv6 it is assumed as a foreign MAP domain. Similarly for PMIPv6, it is assumed to be home network domain.
- If PMIPv6 is considered, the location of the LMA is assumed to be the same as that of the MAP in HMIPv6 or HA in the case of MIPv6. .
- The delay between the MN and CN is shorter than the sum of the delays between the MN and HA and between the HA and CN.
- The processing and queuing delays are negligible.
- Time needed by DAD process has not been considered.

A. HMIPv6 Handoff

For HMIP, the MN detects the IP subnet by exchanging with AR router solicitation and router advertisement messages, which takes $2(t_{mr} + t_{ra})$. Then, the MN sends to the MAP a BU and gets a BA, which takes $2(t_{mr} + t_{ra}+ t_{am})$. So, the HMIP handoff delay is $4(t_{mr}+ t_{ra}) +2t_{am}$.

B. FMIPv6 Handoff

For FMIPv6, two handover cases have to be distinguished: the predictive handoff and the reactive handoff. In the predictive handoff, the MN obtains a new CoA after exchanging RtSolPr and PrRtAdv with the previous AR, which takes $2(t_{mr}+t_{ra})$. The MN sends an FBU to the previous AR, which takes $(t_{mr}+t_{ra})$. The ARs then exchange HI and Hack, which takes $2t_{pn}$. The previous AR sends an FBAck to the new AR and to the MN, which takes at most $(t_{mr}+t_{ra})$. Finally, the MN sends an FNA to the new AR, which takes $(t_{mr}+t_{ra})$. The predictive FMIPv6 handoff takes $5(t_{mr}+t_{ra}) + 2t_{pn}$. In the reactive handoff, the MN obtains a new CoA after exchanging RtSolPr and PrRtAdv with the previous AR, which takes $2(t_{mr}+t_{ra})$.The MN sends an FBU encapsulated in an FNA to the previous AR, which takes $t_{mr}+t_{ra} + t_{pn}$. The ARs then exchange FBU and FBAck, which takes $2t_{pn}$. The reactive FMIPv6 handoff takes $3(t_{mr}+t_{ra}+t_{pn})$.

C. F-HMIPv6 Handoff

The MN takes $2(t_{mr}+t_{ra})$ for obtaining a new CoA after exchanging RtSolPr and PrRtAdv with the previous AR. The MN sends an FBU to the MAP, which takes $(t_{mr}+t_{ra}+t_{am})$. The MAP then exchange HI and Hack, which takes $2t_{am}$. The MAP sends an FBAck to the new AR and to the new AR, which takes at most t_{am}. The MN sends an FNA to the new AR, which takes $t_{mr}+t_{ra}$. Then, the MN sends to the MAP a LBU and gets a LBA, which takes $2(t_{mr}+t_{ra}+t_{am})$. So, the F-HMIP handoff delay is $6(t_{mr}+t_{ra}+t_{am})$.

D. PMIPv6 Handoff

The total handover delay in PMIPv6 is composed of sum of the proxy binding update delay 2tam between the MAG and the LMA and the delay $2(t_{mr}+t_{ra})$ due to exchange of Router Sol. and Router Adv. between MN and MAG. So, the PMIPv6 handoff delay can be expressed as $2(t_{mr}+t_{ra}+t_{am})$.

IV. Numerical Results

For evaluation of handover delay, we have taken t_{mr}=10ms considering the relatively low bandwidth in the wireless link, and other parameters are as follows t_{ra}=1ms, t_{pn}=5ms, t_{am}=1ms, t_{ah}=101ms, t_{ac} =113ms, and t_{hc}=114ms.

A. Impact of the Wireless Link Delay

Fig. 7 shows the effect of wireless link delay on handover delay. For all protocols, handover delay increases with wireless link delay. PMIPv6 shows lowest handover delay. Reason for lowest delay is that PMIPv6 is network based protocol and therefore MN is not involved in mobility related signalling. F-HMIPv6 shows maximum delay. This is due to more number of signalling with MN. In this situation, PMIPv6 outperforms other protocols and hence it is the best choice for VoIP services.

B. Impact of the Delay between MN and CN

Fig. 8 shows the effect of delay between MN and CN. All protocols are independent of the delay increase between MN and CN. This plot also shows that PMIPv6 has lowest handover delay and it is the most suitable handover protocol for VoIP services.

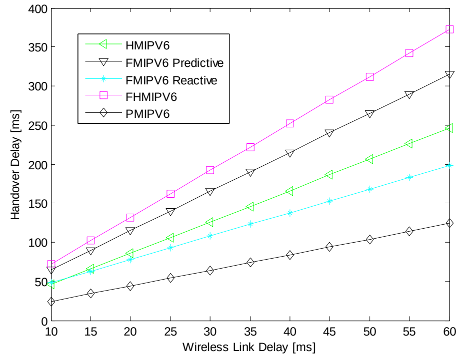

Fig. 7. Impact of wireless link delay

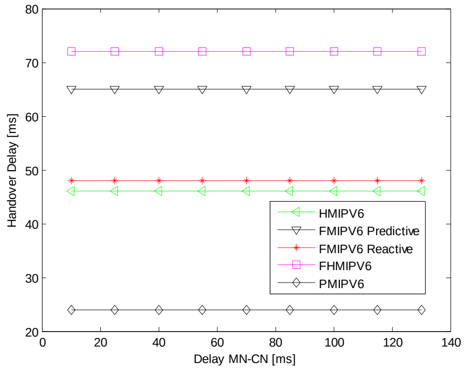

Fig. 8. Impact of delay between MN and CN

C. Impact of Delay between MN and FA/MAP/LMA

Fig. 9 shows that handover delay in FMIPv6 remains constant because it is independent of FA/MAP/LMA. But in PMIPv6, HMIPv6 and F-HMIPv6 handover delay increases with the increase of delay between MN and FA/MAP/LMA. PMIPv6 performs better with smaller values of delay between MN and FA/MAP/LMA but for larger value, FMIP performs better.

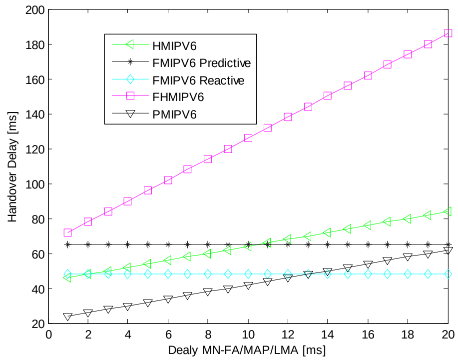

Fig. 9. Impact of delay between MN and FA/MAP/LMA

D. Impact of Delay between MN and Home Network

Fig. 10 shows that handover delay in F-HMIPv6, FMIPv6, HMIPv6 and PMIPv6 are independent of delay between MN and Home network. This plot also shows that handover delay in PMIPv6 is lowest.

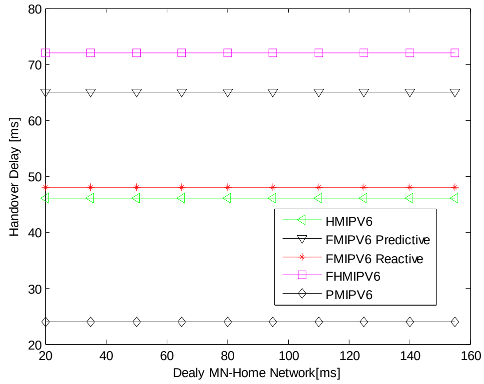

Fig. 10. Impact of delay between MN and Home network

V. Conclusion

As wireless/mobile communications technologies become widespread, providing Internet access to mobile nodes (e.g., laptop, PDA) is of crucial importance. In addition, the recent advent of VoIP services and their fast growth is likely to play a key role in successful deployment of IP-based convergence of mobile/wireless networks. In this article, effect of wireless link delay, delay between MN and Home network, delay between MN and CN and delay between MN and FA/MAP/LMA on handover latency have been shown. Numerical result shows that PMIPv6 shows the minimum handover latency. Hence, PMIPv6 is the best option for VoIP services.

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