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Performance analysis of fast handover for proxy Mobile IPv6

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ABSTRACT

In Proxy Mobile IPv6 (PMIPv6), any involvement by the Mobile Node (MN) is not required, so that any tunneling overhead can be removed from over-the-air. However, during the PMIPv6 handover process, there still exists a period when the MN is unable to send or receive packets because of PMIPv6 protocol operations, suffering from handover latency and data loss. Thus, to reduce the handover latency and data loss in PMIPv6, Fast Handover for PMIPv6 (PFMIPv6) is being standardized in the IETF. Nevertheless, PFMIPv6 has a few weaknesses: (1) handover initiation can be false, resulting in the PFMIPv6 handover process done so far becoming unnecessary. (2) Extra signaling is introduced in setting up an IP-in-IP tunnel between the serving and the new Mobile Access Gateways (MAGs). Therefore, in this paper, we present our study on the protocol overhead and performance aspects of PFMIPv6 in comparison with PMIPv6. We quantify the signaling overhead and the enhanced handover latency and data loss by conducting a thorough analysis of the performance aspects. The analysis is very meaningful to obtain important insights on how PFMIPv6 improves the handover performance over PMIPv6, especially in a highway vehicular traffic scenario where Base Stations (BSs)/Access Points (APs) can be placed in one dimensional space and MN's movements are quasi one-dimensional, so that the degree of certainty for an anticipated handover is increased. Further, our analytical study is verified by simulation results.

1. Introduction

Mobile IPv6 (MIPv6) is a commonly accepted standard to address global mobility of Mobile Nodes (MNs) [8] and solves many problems addressed in MIPv4 [18]. It requires the MNs to register with the Home Agents (HAs) whenever the MNs change their Point of Attachment (PoA) in different subnets. However, such registrations may cause excessive signaling traffic and long service delays, especially for managing localized mobility. These problems call for a protocol that is able to effectively manage regional movements between access routers. Various extensions to MIPv6 such as Fast-Handovers for Mobile IPv6 (FMIPv6) [12] and Hierarchical MIPv6 (HMIPv6) [22] have been proposed to more effectively support the localized mobility management. On the other hand, the extended protocols may not be compatible with some other global mobility protocols other than MIPv6 and require modifications to the existing mobiles since they rely on host-based solutions that require host involvement at the IP layer. Therefore, the recent networking trend has focused mostly on a network-based localized mobility protocol without requiring software support on the host for managing the localized mobility.

Recently, a network-based mobility management protocol called Proxy MIPv6 (PMIPv6) has been standardized by the IETF NETLMM working group as a local mobility management protocol [6]. In particular, PMIPv6 does not require any involvement by an MN so that tunneling overhead can be removed from over-the-air. Most recently, the Third Generation

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Partnership Project (3GPP), 3GPP2, and WiMAX forum have decided to employ PMIPv6 for interworking with heterogeneous wireless access networks [27,1].

PMIPv6 introduces a new entity called a Mobile Access Gateway (MAG) that acts as a relay node between an MN and a Local Mobility Agent (LMA) that plays a similar role to the HA in MIPv6. The MAG conceals the roaming information from the MN by emulating the MN's home link properties. To achieve this, the MAG performs the mobility-related signaling with the LMA on behalf of the MN and hence, a tunnel is established between the LMA and the MAG. Although the signaling between the MN and the network can be saved, PMIPv6 still has a similar drawback to MIPv6. That is, during PMIPv6 handover execution, there is a period when the MN is unable to send or receive packets because of PMIPv6 protocol operations, suffering from handover latency and data loss. Thus, to reduce such handover latency and data loss in PMIPv6, the FMIPv6 solution specified in [12] is suggested to be applied to PMIPv6 which is the basis of Yokota et al. [25].

Fast Handover for PMIPv6 (PFMIPv6) suffers, though, from a few well-known weaknesses. The main weakness is the problem of false handover initiation since in fast handovers of predictive mode, the serving MAG predicts which MAG the MN will move to, with the help of Layer 2 (L2) triggers. More specifically, PFMIPv6 initiates its handover process as soon as the Received Signal Strength (RSS) of the serving Base Station/Access Point (BS/AP) drops below a predefined threshold value and the MN detects a new BS. Then, if the MN changes its direction abruptly and moves to another BS different from the target BS, or returns to the previous BS, the PFMIPv6 handover process done so far becomes unnecessary, being far from reducing handover latency and packet loss. Another weakness is extra signaling introduced in setting up an IP-in-IP tunnel between the serving and new MAGs. Therefore, in this paper, we provide a thorough analysis of signaling overhead, handover latency, and data loss caused by PFMIPv6 and PMIPv6 handovers.

There are previous attempts to analyze the performance of host-based IP mobility management protocols [2,9,15,20,23]. Most recently, the authors of Kong et al. [10,11] analyze and compare the handover latency of PMIPv6 with those of the various existing host-based IP mobility management protocols. However, none of them has performed a thorough analysis of PFMIPv6 and a comparison between PMIPv6 and PFMIPv6. We believe that our analysis is very meaningful to obtain important insights on how PFMIPv6 improves the handover performance over PMIPv6, especially in a highway vehicular traffic scenario where BSs/APs can be placed in one dimensional space and an MN's movements are quasi one-dimensional, so that the degree of certainty for anticipated handovers is increased. In the analysis, we also investigate to what degree the enhancements offered by PFMIPv6 operation toward seamless handover support, are dependent on user's speed and distance from the boundary of the coverage of the serving BS. Further, our analytical study is verified by simulation results.

The remainder of this paper is organized as follows: In Section 2, the PMIPv6 handover procedure and its performance analysis are presented. Section 3 gives a brief explanation of the PFMIPv6 handover operation. The details of the PFMIPv6 performance analysis are presented in Section 5. Section 6 discusses the numerical and simulation results and obtains important observations for cases where the performance improvement of PFMIPv6 is optimized. Finally, Section 7 concludes this paper.

2. Handover in PMIPv6

In this section, we briefly describe the PMIPv6 operation when an MN moves from the previous MAG (pMAG) to a next MAG (nMAG) and analyze the performance of PMIPv6 handover.

As presented in [6], the nMAG obtains the MN's policy profile containing the MN Identifier (ID), the LMA address, and so on, as part of a context transfer procedure. Then the nMAG sends a Proxy Binding Update (PBU) message including the MN ID to the MN's LMA on behalf of the MN. When the LMA receives the PBU message, it sends a Proxy Binding Acknowledgement (PBA) message including the MN's Home Network Prefix (HNP) option, and sets up a route for the MN's HNP over the tunnel to the MAG. The timing diagram for the handover process in a PMIPv6 network is illustrated in Fig. 1 and the related parameters are explained in Table 1.

For the performance analysis, the following notations are used.

- L_P (L_{PT}): Data packet length (including the tunneling header, 40 bytes).
- L_X: X signaling message length.
- d_{A-B}: Hop distance between A and B.
- BW (BW_w): Wired (Wireless) Link bandwidth.
- l (l_w): Wired (Wireless) link delay

In both PMIPv6 and PFMIPv6, the handoff latency is defined as the time duration from when the L2 handover begins to when the MN can receive the first packet from nMAG. Based on the timing diagram in Fig. 1, the handover latency for PMIPv6, D_{pmip} is given by

$$D_{pmip} = \delta + \varepsilon + t_R + \eta + t_{RA} \tag{1}$$

where t_R denotes the proxy registration latency which is given by $t_R = \gamma + d_{nMAG-LMA} \cdot \left(\frac{L_{PBU}+L_{PBA}}{BW} + 2l\right)$ and $t_{RA} = (d_{MN-nMAG} - 1) \cdot \left(\frac{L_{RA}}{BW} + l\right) + \left(\frac{L_{RA}}{BW_w} + l_w\right)$. To perform a PMIPv6 handover, PBU and PBA messages are exchanged between the nMAG and LMA and hence, the handover signaling cost for PMIPv6, C_{pmip} is expressed as