A Scheme to Reduce Packet Loss during PMIPv6 Handover considering Authentication

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Abstract

Mobile IPv6 (MIPv6) is a presentative protocol which supports global IP mobility. MIPv6 causes a long handover latency that a mobile node (MN) doesn’t send or receive packets. This latency can be reduced by using Proxy Mobile IPv6 (PMIPv6). PMIPv6 is a protocol which network supports IP mobility without participation of the MN, and is studied in Network-based Localized Mobility Management (NETLMM) working group of IETF. There is much packet loss during handover in PMIPv6, although PMIPv6 reduces handover latency. In this paper, to reduce packet loss in PMIPv6 we propose Packet Lossless PMIPv6 (PL-PMIPv6) with authentication. In PL-PMIPv6 a previous mobile access gateway (pMAG) registers to a Local Mobility Anchor (LMA) on behalf of a new MAG (nMAG) during layer 2 handoff. Then, the nMAG buffers packets during handover after registration. Therefore, PL-PMIPv6 can reduce packet loss than them in MIPv6 and PMIPv6. Also, we use Authentication, Authorization and Accounting (AAA) infrastructure to authenticate the MN and to receive MN’s profiles securely. We shows performance of PL-PMIPv6 through comparison of packet loss during handover of MIPv6, PMIPv6 and PL-PMIPv6.

1. Introduction

In wireless/mobile networks, mobile nodes (MN) can change their attachment points while they communicate with correspondent nodes (CN). Hence, mobility management is essential for tracking the MNs current locations so that their data can be delivered correctly. IP-based mobility management is critical, since the next-generation wireless/mobile networks are anticipated to be unified networks based on IP technology. Mobile IPv6 (MIPv6) [1] from the Internet Engineering Task Force (IETF) is standardized for mobility management in IPv6 wireless/mobile networks. Mobile IPv6 requires client functionality in the IPv6 stack of a mobile node. Exchange of signaling messages between the MN and a home agent (HA) enables the creation and maintenance of binding between the MN’s home address and its care-of address. Mobility as specified in MIPv6 requires the MN host to send IP mobility management signaling messages to the HA, which is located in the network. MIPv6 is a approach of host-based mobility to solve the IP mobility challenge. However, it takes a long time to process handover and there is much packet loss during handover, since there are many signaling messages via wireless link which occurs long delay during handover.

Network-based mobility is another approach to solving the IP mobility challenge. It is possible to support mobility for IPv6 nodes without host involvement by extending MIPv6 signaling messages and reusing the HA. This approach to supporting mobility does not require the MN to be involved in the exchange of signaling messages between itself and the HA. A Mobile Access Gateway (MAG) in the network performs the signaling with the HA and does the mobility management on behalf of the MN attached to the network. This protocol is called as Proxy Mobile IPv6 (PMIPv6) [2] in Network-based Localized Mobility Management (NETLMM) working group of IETF. PMIPv6 can reduce handover latency, since the proxy mobility agent on behalf of the MN performs handover process. That is, there are a little signaling message via wireless link.

There is much packet loss during handover in PMIPv6, although PMIPv6 reduces handover latency. In this paper, to reduce packet loss in PMIPv6 we propose Packet Lossless PMIPv6 (PL-PMIPv6) with authentication. The similar scheme was studied to reduce packet loss and handover latency in MIPv6, such as fast handovers for MIPv6 (FMIPv6) [3]. In PL-PMIPv6, a previous MAG (pMAG) registers to a Local Mobility Anchor (LMA) on behalf of a new MAG (nMAG) during layer 2 handoff. Then, the
nMAG buffers packets during handover after registration. Therefore, PL-PMIPv6 can reduce packet loss than them in MIPv6 and PMIPv6. Also, we use Authentication, Authorization and Accounting (AAA) infrastructure to authenticate the MN and to receive MN’s profiles securely. We shows performance of PL-PMIPv6 through comparison of packet loss during handover of MIPv6, PMIPv6 and PL-PMIPv6.

The rest of the paper is organized as follows. Section 2 specifies PMIPv6 protocol as related works. Packet-lossless PMIPv6 (PL-PMIPv6) is proposed in Section 3. Section 4 presents analytical model and the numerical results. In Section 5, we conclude this paper.

2. Related Works

PMIPv6 is intended for providing network-based IP mobility management support to a mobile node, without requiring the participation of the MN in any IP mobility related signaling. The mobility entities in the network will track the MN’s movements and will initiate the mobility signaling and setup the required routing state.

The core functional entities in the NETLMM infrastructure are the Local Mobility Anchor (LMA) and the Mobile Access Gateway (MAG). The LMA is responsible for maintaining the MN’s reachability state and is the topological anchor point for the MN’s home network prefix. The MAG is the entity that performs the mobility management on behalf of an MN and it resides on the access link where the MN is anchored. The MAG is responsible for detecting the MN’s movements to and from the access link and for initiating binding registrations to the MN’s LMA.

Once a MN enters PMIPv6 domain and attaches to an access link, the MAG on that access link, after identifying the MN and acquiring its identity, will determine if the MN is authorized for the network-based mobility management service. For updating the LMA about the current location of the MN, the MAG sends a Proxy Binding Update (PBU) message to the MN’s LMA. Upon accepting this PBU message, the LMA sends a Proxy Binding Acknowledgement (PBA) message including the MN’s home network prefix. It also creates the Binding Cache entry and establishes a bi-directional tunnel to the MAG. The MAG on receiving the PBA message sets up a bi-directional tunnel to the LMA and sets up the data path for the MN’s traffic. At this point the MAG will have all the required information for emulating the MN’s home link. It sends Router Advertisement (RA) messages to the MN on the access link advertising the MN’s home network prefix as the hosted on-link-prefix. Figure 1 shows the signaling call flow for the MN’s handover from previously attached MAG (pMAG) to the newly attached MAG (nMAG). After obtaining the initial address configuration in the PMIPv6 domain, if the MN changes its point of attachment, the MAG on the previous link will detect the MN’s detachment from the link and will signal the LMA and will remove the binding and routing state for that MN. However, the LMA upon accepting the request will wait for certain amount of time before it deletes the binding, allowing a smooth handover. The MAG on the new access link upon detecting the MN on its access link will signal the LMA for updating the binding state. Once that signaling is complete, the MN will continue to receive the RAs containing its home network prefix, making it believe it is still on the same link and it will use the same address configuration on the new access link.

3. Proposed Scheme (PL-PMIPv6)

In PMIPv6, there are schemes to reduce handover latency and packet loss [4] [5]. Fast handovers for PMIPv6 is
a scheme that only LMA exchange signaling with MAGs to set up the fast handover [4]. However, this scheme does not follow the order of signaling flow in PMIPv6. The scheme in [5] is the Extended PMA (EPMA) and LPMA functionalities to reduce signaling cost for intra domain handover and to optimize packet delivery [5]. However, this scheme does not prevent packet loss during handover.

In this paper, we propose Packet-Lossless PMIPv6 (PL-PMIPv6) with authentication, to reduce packet loss in PMIPv6. PL-PMIPv6 follows the order of signaling flow in PMIPv6 and reduces packet loss. Figure 2 shows signaling flow of PL-PMIPv6 during handover. After the pMAG is aware of the MN’s detachment, it sends the DeReg PBU message to the LMA in PMIPv6. In PL-PMIPv6 when pMAG sends the DeReg PBU message, the PBU message of nMAG is included in DeReg PBU message. That is, the pMAG registers on behalf of the nMAG in advance to reduce handover latency. As a result, the tunnel between the LMA and the nMAG is established in advance. Also, when the nMAG receives the PBA message, it begins to buffer packets to the MN. After layer 2 handoff, the MN sends the RS message and receives the RA message including the MN’s home network prefix.

In PMIPv6, we use AAA infrastructure to authenticate the MN like in [5]. Then, the nMAG can receive the MN’s profile securely using AAA infrastructure.

4. Performance Evaluations

We make a comparison of MIPv6, PMIPv6 and PL-MIPv6 handover in terms of handover latency, costs and total cost ratio. For those comparisons, we use a system model in Fig. 3. In the system model, we evaluate performance of three schemes when an MN moves between MAGs. We assume that a correspondent node generates data packets destined to the MN at a mean rate \( \lambda \), and the MN moves between MAGs at a mean rate \( \mu \). We define packet to mobility ratio (PMR, \( \rho \)) as the mean number of packets received by the MN from the correspondent per movement. When the movement and packet generation processes are independent and stationary, the PMR is given by \( \rho = \lambda / \mu \). We assume that a cost for transmitting a packet is dependent on the distance between the sender and receiver. We define that \( l_d \) is the average length of a data packet and \( l_c \) is the average length of a control packet [7].

4.1. Handover Latency

In this section, we analyze handover latency of MIPv6, PMIPv6 and PL-PMIPv6. To analyze handover latency of three schemes, we define that \( t_{MN,MAG} \), \( t_{MAG,HN} \) and \( t_{MAG,MAG} \) are transfer delays between an MN and an MAG, an MAG and a LMA, and adjacent two MAGs, respectively.

Handover latency consists of three latencies such as a link switching latency, an IP connectivity latency and a location update latency. The link switching latency is due to a layer 2 handoff. The IP connectivity latency is due to movement detection and new IP address configuration after the layer 2 handoff. An MN can send or receive packets in nMAG after the IP connectivity. We define handover latency of MIPv6 like as,

\[
T_{Latency}^{MIPv6} = t_{link-switching} + t_{AAA-Auth} + t_{Addr-Autoconf} + t_{Registration}.
\]

In Fig. 4, we define handover latency of PMIPv6. Handover latency of PMIPv6 is following,
Handover latency is seriously affected by accesses of wireless link during handover. Hence, handover latencies of PMIPv6 and PL-PMIPv6 is lower than that of MIPv6. Also, PL-PMIPv6 reduces more handover latency than PMIPv6, since the registration of nMAG is performed during layer 2 handoff.

4.2. Total Cost during Handover

In this section we analyze three scheme in terms of total cost. Total cost consists of signaling cost and packet delivery cost during handover. Signaling cost is cost of messages for signaling, and packet delivery cost is cost of packet transferred from a HA.

We assume that signaling and delivery cost are influenced by transmission delay. That is, signaling cost and delivery cost of a packet consist of an average length of signal and data packet and transmission delay, respectively.

Followings are signaling cost of three scheme.

\[
C_{\text{PMIPv6}}^{\text{Registration}} = S_{\text{AAA-Auth}} + S_{\text{Addr-Autoconf}} + S_{\text{Registration}},
\]

\[
C_{\text{PMIPv6}}^{\text{Signal}} = S_{\text{P-Deregistration}} + S_{\text{AAA-Auth}} + S_{\text{P-Registration}} + S_{\text{RS-RA}}.
\]

\[
C_{\text{PL-PMIPv6}}^{\text{Signal}} = S_{\text{P-Deregistration}} + S_{\text{AAA-Auth}} + S_{\text{P-Registration}}/2 + S_{\text{RS-RA}}.
\]

\(S_{\text{AAA-Auth}}\) is cost for process of AAA authentication \((l_c \cdot t_{\text{AAA-Auth}})\), \(S_{\text{Addr-Autoconf}}\) is cost for stateless address autoconfiguration \((l_c \cdot t_{\text{Addr-Autoconf}})\). \(S_{\text{Registration}}\) is cost for binding update to a HA \((l_c \cdot t_{\text{Registration}})\). \(S_{\text{P-Registration}}\) is cost for proxy binding update to a LMA \((l_c \cdot t_{\text{P-Registration}})\). \(S_{\text{RS-RA}}\) is cost for exchanging a RS and a RA messages \((l_c \cdot t_{\text{RS-RA}})\). We have known that signaling costs of three scheme differ little.
We assume that delivery cost consists of packet transmission cost and packet lost during handover. Packet delivery costs of three scheme are followings,

\[ C_{\text{MIPv6}}^{\text{Delivery}} = \lambda \cdot d_{HN,MN} \cdot T_{\text{Latency}} \cdot \eta, \]  
(7)

\[ C_{\text{PMIPv6}}^{\text{Delivery}} = \lambda \cdot d_{HN,pMAG} \cdot T_{\text{PMIPv6}}^{\text{Delivery}} \cdot \eta, \]  
(8)

\[ C_{\text{PL-PMIPv6}}^{\text{Delivery}} = \lambda \cdot d_{HN,MN} \cdot t_{MAG,HN} \cdot \eta + + \lambda \cdot d_{HN,nMAG} \cdot t_{\text{buffering}}. \]  
(9)

\( d_{HN,MN} \) is delivery cost from home network to a MN, \( d_{HN,pMAG} \) is delivery cost from home network to a pMAG. \( d_{HN,nMAG} \) is delivery cost from home network to a new MAG through the pMAG. In MIPv6 and PMIP, all packets sent from the CN are lost during handover. However, in PL-PMIPv6 most packets are tunneled to nMAG and are buffered. Figure 7 shows delivery costs of three schemes. In Fig. 7 costs of PMIPv6 and PL-PMIPv6 are much lower than MIPv6, since handover latencies are short in PMIPv6 and PL-PMIPv6. In addition, cost of PMIPv6 is the lowest in three schemes because packets from the CN are tunneled and buffered in PMIPv6.

We calculate total costs of three schemes using above formulas. Then we calculate cost ratio following formulas to compare performance of three schemes.

\[ \text{CostRatio}_{\text{PL-PMIPv6}/\text{MIPv6}} = \frac{\text{TotalCost}_{\text{PL-PMIPv6}}}{\text{TotalCost}_{\text{MIPv6}}} \]  
(10)

\[ \text{CostRatio}_{\text{PL-PMIPv6}/\text{PMIPv6}} = \frac{\text{TotalCost}_{\text{PL-PMIPv6}}}{\text{TotalCost}_{\text{PMIPv6}}} \]  
(11)

Figure 8 shows total cost ratios of MIPv6 and PMIPv6 about PL-PMIPv6. Through this figures we show that PL-PMIPv6 reduces total cost during handover. That is, PL-PMIPv6 enhances handover performance of 66% compared with MIPv6 and 26% compared with PMIPv6.

5. Conclusions

In PMIPv6 all packets from CNs are lost during handover. To solve this problem, we have proposed PL-PMIPv6. PL-PMIPv6 can prevent packet loss during handover, since process of proxy registration is performed in advance and then packets from CNs are tunneled and buffered to nMAG. Also, we used AAA infrastructure to authenticate a MN and to receive MN’s profiles securely. Hence, security of PMIPv6 is enhanced.

We showed performance of PL-PMIPv6 through performance evaluations. PL-PMIPv6 reduced 26% of total cost compared with PMIPv6. This shows that PL-PMIPv6 can enhance PMIPv6 through tunneling and buffering.

Recently, PMIPv6 is in process of last call in IETF and will be a standard document. Then, if PL-PMIPv6 is used in addition to PMIPv6, PMIPv6 will be a more robust protocol in NETLMM working group of IETF.

References


