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Proxy Mobile IPv6를 위한 개선된 신속한 핸드오버 방안

(An Enhanced Fast Handover Scheme for Proxy Mobile IPv6)

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요 약

망 기반의 이동성 관리 기법인 Proxy Mobile IPv6 (PMIPv6) 는 이동단말 대신 네트워크 측면에서 이동성을 지원하기 때문에, 이동단말은 어떠한 이동성 지원 관련 시그널링에도 관여하지 않는다. 비록, PMIPv6가 IETF NetLMM WG에서 표준화가 진행되고 있으나, PMIPv6는 핸드오버 동안에 긴 지연시간과 on-the-fly packet 손실 문제를 여전히 가지고 있다. 따라서, 본 논문은 PMIPv6를 위한 개선된 신속한 핸드오버 방안을 제안한다. 제안한 방안은 핸드오버 지연시간을 줄이기 위해 수정한 IPv6의 Neighbor Discovery 메시지를 사용하고, 핸드오버 동안에 on-the-fly packet 손실을 줄이기 위해 Mobile Access Gateway (MAG)에 패킷 버퍼링을 사용한다. 또한, Local Mobility Access (LMA)에 추가적인 패킷 버퍼링을 사용해 패킷 순서 문제를 해결한다. 제안한 방안의 성능을 분석적 모델과 시뮬레이션를 통해 비교 분석한다. 수치적 분석을 통해 제안방안이 기존 방안에 비해 짧은 핸드오버 지연시간을 가질 수 있음을 확인할 수 있었으며, 시뮬레이션 결과를 통해 제안방안이 on-the-fly packet 손실을 피하고 패킷 순서를 보장할 수 있음을 확인할 수 있었다.

Abstract

In a network-based approach such as Proxy Mobile IPv6 (PMIPv6), the serving network controls the mobility management on behalf of a Mobile Node (MN), thereby eliminating a MN from any mobility-related signaling. Although PMIPv6 is being standardized by the IETF NetLMM WG, PMIPv6 still suffers from a lengthy handover latency and the on-the-fly packet loss during a handover. Therefore, this paper presents an enhanced fast handover scheme for PMIPv6. The proposed handover scheme uses the Neighbor Discovery message of IPv6 to reduce the handover latency and packet buffering at the Mobile Access Gateway (MAG) to avoid the on-the-fly packet loss during a handover. In addition, it uses an additional packet buffering at the Local Mobility Anchor (LMA) to solve the packet ordering problem. We evaluate the performance of the proposed handover scheme using both analytical model and simulation. The numerical analysis shows that the proposed scheme has a relatively shorter handover latency. Simulation results demonstrate that the proposed scheme could avoid the on-the-fly packet loss and ensure the packet sequence.

Keywords : network-based mobility management, proxy mobile IPv6, fast handover

Ⅰ. Introduction

With the rapid evolution of broadband wireless networks into all-IP networks and explosive growth in numbers of Internet users in wireless environment, the issue of IP mobility management technology is on the rise.

Mobile IPv6 (MIPv6)[1], which is a host-based mobility management protocol, has been standardized by the IETF as the main protocol for mobility management at the IP layer. However, despite its status as a recognized standard for IPv6 mobility, MIPv6 still has some well-known problems, such as handover latency, packet loss, and signaling overhead. Also, the MIPv6 requires protocol stack modification of the Mobile Node (MN) to support IP mobility[2~3].

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Meanwhile, a network-based mobility management protocol, called Proxy Mobile IPv6 (PMIPv6), has recently been standardized by the IETF NetLMM WG[4~5]. Unlike the MIPv6, PMIPv6 allows the serving network to control the mobility management on behalf of an MN, thereby eliminating the MN from any mobility-related signaling.

PMIPv6 is essentially based on MIPv6 in the sense that it extends the MIPv6 signaling and reuses many concepts, such as the functionality of the Home Agent (HA). However, PMIPv6 is also designed to provide network-based mobility management support to an MN in a topologically localized domain. Therefore, an MN is exempt from participating in any mobility-related signaling, and a proxy mobility agent in the serving network performs the mobility-related signaling on behalf of the MN. However, network-based mobility management protocols, such as PMIPv6, still suffer from handover latency and packet loss during a handover, like MIPv6.

Although several fast handover schemes based on PMIPv6 have already been introduced to reduce the handover latency and packet loss[6~8], these schemes still experience some packet loss and packet ordering problem during a handover.

Accordingly, this paper presents an enhanced fast handover scheme for PMIPv6. We use a Neighbor Discovery (ND) message of IPv6[9] to reduce the handover latency. The ND message is modified to support multi-hop communication for neighbor discovery. Since this scheme sends the MN-profile to the neighbor MAGs through the ND message before a handover, it can eliminate the need for the Mobile Access Gateways (MAGs) to acquire the MN-profile from the Policy Server (PS) whenever a MN performs a handover. Also, to avoid the packet loss of "on-the-fly packet", which is routed between the Local Mobility Anchor (LMA) and previous MAG (pMAG), the proposed handover scheme uses a packet buffering at the pMAG. In addition, this scheme uses an additional packet buffering at the LMA to ensure the packet sequence between the on-the-fly packet buffered from pMAG and the packet from the LMA after a handover.

The performance of the proposed handover scheme is evaluated using both an analytical model and a simulation. The numerical results based on the analytical model revealed that the proposed scheme experienced a relatively shorter handover latency. Simulation results demonstrated that the proposed scheme could avoid the packet loss during a handover. The proposed scheme was also able to ensure the packet sequence through the use of additional packet buffering at the LMA.

The remainder of this paper is organized as follows. In Section Ⅱ, we describe the PMIPv6 protocol and related fast handover schemes for PMIPv6. In Section Ⅲ, we illustrate the procedure of the proposed handover scheme. Numerical results and simulation results are presented in Section Ⅳ and in Section Ⅴ. Finally, we make conclusions in Section Ⅵ.

Ⅱ. Related Works

A. PMIPv6

PMIPv6 is designed to provide network-based IP mobility management support to an MN in a topologically localized domain, without requiring the MN to participate in any IP-mobility-related signaling. The core functional components used to support mobility in PMIPv6 are the PS, LMA, and MAG. The PS is the entity that manages an MN's authentication and maintains the MN's profile which is a set of parameters configured for a given MN. Meanwhile, the LMA is similar to the HA in MIPv6, however, it has additional capabilities required to support PMIPv6. The main role of the LMA is to maintain reachability to the MN's address while the MN moves around within the PMIPv6 domain. The LMA includes a Binding Cache Entry (BCE) for each currently registered MN. Finally, the MAG typically runs on the Access Router (AR) and its main role is to detect the movement of an MN and send mobility-related signaling to the MN's LMA on behalf of the MN. In addition, the MAG establishes a tunnel with the LMA for packet transmission. Plus, the MAG ensures that an MN can obtain an address from its HNP and receive its HNP anywhere within the PMIPv6 domain. As a result, the MN believes it is using the same link obtained with its initial address configuration, even after changing its point of attachment within the network.

Fig. 1 shows the signaling flow of the overall operations in PMIPv6; the steps involved in the initial attachment and handover procedure are described as follows:

Steps 1, 2, and 3: When an MN initially attaches to MAG-1 in the PMIPv6 domain, 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, MAG-1 obtains the MN's profile, which contains the MN-Identifier, LMA address (LMAA), and supported address configuration mode.

Steps 4 and 5: To update the LMA about the current location of the MN, MAG-1 sends a Proxy Binding Update (PBU) message to the MN's LMA on behalf of the MN. Upon receiving the PBU message, the LMA assigns an MN-HNP and creates a BCE that binds the MN-HNP to a Proxy-CoA, which is the address of MAG-1. The LMA also establishes a bi-directional tunnel to MAG-1 and sends MAG-1 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. MAG-1 also creates a Binding Update List (BUL) that binds the MN-HNP to the LMAA, 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 stateful or stateless address configuration mode. After successfully completing the address configuration procedure, the MN uses this address for packet delivery.

Steps 7 and 8: When the MN moves to the access network of MAG-2, MAG-1 detects that the MN has moved away from its access link and sends a DeReg PBU (DeRegistration 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 MinDelayBeforeBCE-Delete amount of time, before it deletes the MN's BCE.

Steps 9-14: When MAG-2 detects the attachment of an MN, MAG-2 obtains the MN-profile using the MN-ID after successful access authentication, as shown in Steps 9, 10 and 11. Steps 12 and 13 are same as Steps 4 and 5. After updating the location of the MN through a PBU/PBA exchange, MAG-2 then sends RA messages to the MN with its MN-HNP. Upon receiving the RA messages, the MN believes it is still on the home link.

Unlike MIPv6, the tunnel in PMIPv6 is established between the LMA and the MAG, and not the MN. Plus, as the tunnel between the LMA and the MAG is typically a shared tunnel, it can be used for

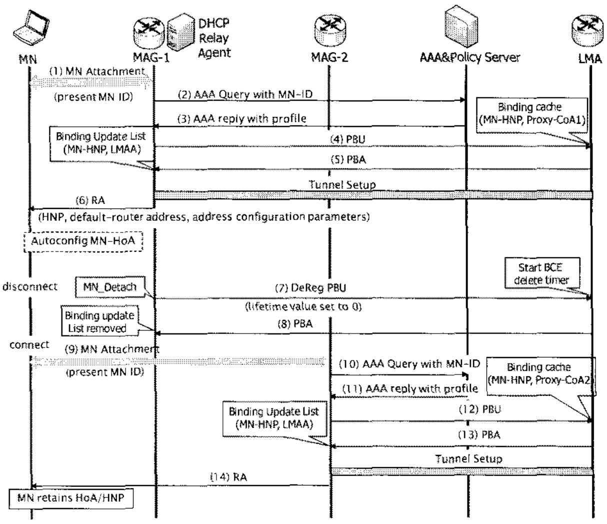

그림 1. PMIPv6의 메시지 절차
Fig. 1. Signaling flow of PMIPv6.

different MNs attached to the same MAG. This shared tunnel also reduces the network and signaling overhead. After bidirectional tunnel is successfully set up, all traffic sent from the MN gets routed to the LMA through this tunnel. The LMA then forwards the packet received from the CN to the MAG through the tunnel. After receiving the packets, the MAG at the other end of the tunnel removes the outer header and forwards the packets to the MN.

B. Fast Handover Schemes for PMIPv6

When an MN moves to a new MAG in a PMIPv6 domain, packet loss and handover latency can occur until the MN receives the MN-HNP advertisement from the newly attached MAG and finishes registration.

Therefore, several fast handover mechanisms have recently been introduced to reduce the handover latency and packet loss with PMIPv6[6~8]. In [6], Lee et al. proposed adapting IAPP (Inter-AP Protocol) to reduce the "access authentication/obtaining MN's profile" time of the total handover delay. Nonetheless, the on-the-fly packets will still be lost during a handover.

In [7], Xia et al. use FMIPv6 signaling to improve the performance of a Layer 3 handover. Before an MN moves from the serving base station to the target base station, the MN provides the target base station information (t-BS ID) through the L2 handover signaling procedure. When the L2 handover decision is made, the pMAG starts buffering to avoid the on-the-fly packet loss. The MN then acquires the IP address of the target MAG from a tuple incorporated in all the MAGs and performs the L3 handover based on this information. However, this scheme also has certain limitations: i) Each MAG needs to have a tuple that contains the BS-IDs and IP addresses for all the MAGs in the PMIPv6 domain. ii) After a handover, a packet ordering problem occurs between the packets buffered at the pMAG and the packets from the LMA after registration. iii) the MN should provide information about the target network to pMAG through L2 signaling.

In [8], Park et al. proposed Fast and Local Proxy MIPv6 (FLPMIPv6) to reduce the handover latency and packet loss. This scheme is based on FMIPv6 and uses the messages defined in IEEE 802.21. The MN provides information on the target MAG using an MIH message before the handover. The current MAG then sends a handover-related message to the new MAG. However, since this scheme is derived from host-based mobility and initiated by mobile nodes, the network access devices need L2 intelligence. In addition, since the current MAG sends a BU message to the LMA before the L2 handover occurs, this means the L3 handover is performed before the L2 handover. Therefore, significant packet loss occurs from the time the L3 handover is completed until the end of the L2 handover.

Ⅲ. The Proposed Enhanced Fast Handover Scheme

Handover latency is mainly caused by the authentication procedure and reconfiguration of the default router when an MN accesses to a new access network, as described in Steps 10, 11, and 14 in Fig. 1. Therefore, the proposed scheme uses a ND message to reduce the handover latency. In addition, a packet buffering is used at the pMAG to reduce the on-the-fly packet loss as in Xia's FMIPv6[7].

Fig. 2 shows the signaling flow of the proposed handover scheme for PMIPv6, and each step is as follows:

Step 1: When MAG-1 receives a Link Going Down (LGD) trigger, it sends the MN-profile to its neighbor MAGs (e.g. MAG-2, MAG-3) using the ND message. This ND message contains the MN-profile with MN-HNP, MN-ID, and LMAA. This eliminates the need for the MAGs to acquire the MN-profile from the policy server whenever an MN performs a handover. In addition, the MN can receive an RA with its home network prefix as soon as it has been attached to the new access link, thereby circumventing authentication and reducing the default router reconfiguration delay. This MAG-1 then starts buffering the packets for the MN in order to avoid the on-the-fly packet loss.

Steps 2 and 3: When MAG-1 detects the detachment of the MN, it sends a DeReg PBU message to the LMA with a lifetime value of zero. Upon receiving the DeReg PBU, the LMA sets the "BCE delete timer" and starts buffering the packets to ensure the packet sequence between the on-the-fly packet buffered from pMAG and the packet from the LMA after a handover. In addition, the number of packet buffered at the pMAG is significantly reduced due to the additional packet buffering at the LMA. So the pMAG can quickly finish forwarding the buffered packets to the MN. The LMA then sends a PBA message to MAG-1.

Steps 4 and 5: When MAG-2 detects the attachment of the MN to its access link, it sends a Handover Notification (HN) message to MAG-1. A new HN message is also proposed to confirm the fact that the MN is attached to the new MAG (e.g. MAG-2). Upon receiving the HN message, MAG-1 forwards the buffered packets to MAG-2, which then forwards these packets to the MN (Step(a) in Fig.2). Therefore, the packet buffering at MAG-1 avoids the on-the-fly packet loss. Upon detecting the attachment of the MN to its access link, MAG-2 sends an RA message with the same MN-HNP to the MN. When the MN receives the RA message, it reconfigures its default router.

Steps 6 and 7: After MAG-2 forwards the packets received from MAG-1 to the MN, it sends a PBU message to the LMA to update the BCE and establishes a tunnel with the LMA. The LMA responds to MAG-2 with a PBA message. The packets buffered at the LMA after the LMA has received the DeReg PBU message from MAG-1 are then forwarded to the MN (Step (b) in Fig.2) through the tunnel between the LMA and MAG-2.

In Xia's FPMIPv6, although the packet buffering at pMAG (e.g. MAG-1) avoids the on-the-fly packet loss like the proposed scheme, the MN can still experience a packet ordering problem. The reason is that the packets from the LMA after new registration can arrive at the MN before the buffered packets forwarded by the pMAG. Thus, to solve the packet ordering problem, we use an additional packet buffering at the LMA.

The advantages of the proposed handover scheme are as follows: i) The proposed handover scheme reduces the handover latency by sending the MN-profile before the handover using the ND message. ii) The proposed scheme avoids on-the-fly packet loss during a handover by using packet buffering at the pMAG. iii) The proposed scheme ensures the packet sequence during a handover by using additional packet buffering at the LMA. iv) In the proposed scheme, the MN is not required to provide any information about the target network to the pMAG, like Xia's FPMIPv6.

However, the proposed handover scheme involves certain overhead. i) Each MAG needs to maintain a database including information on its attached MNs, such as the MN_HNP, MN_IP and LMAA. This information also needs to be advertised to the neighbor MAGs through the ND messages. ii) Also, Sending ND messages to the neighbor MAGs, causes additional traffic. Plus, Modifying the ND message to

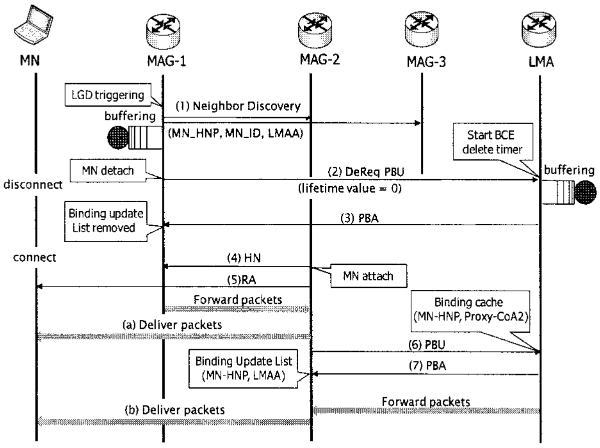

그림 2. 제안방안의 메시지 절차
Fig. 2. Signaling flow of the proposed handover scheme.

support for multihop communication has a implementation overhead. iii) The packet buffering at the MAG and the LMA incurs an overhead. Nonetheless, the proposed scheme can reduce the handover latency and avoid the packet loss.

Ⅳ. Performance Evaluation Using Analytical Model

A. Analysis of Handover Latency

This section presents an analytical model from the viewpoint of two criteria, the handover latency and the handover initiation time[10~12]. The handover latency and handover initiation time for various mobility schemes are shown in Fig. 3, and their parameter notations are illustrated in Table 1.

The handover latency and handover initiation time for each scheme are represented as follows:

The handover delay of PMIPv6 is composed of the L2 handover delay (DL2), AAA access delay (DAAA), registration delay between the MAG and the LMA (DBU), and delay from the MAG to the MN (DMN-nMAG). As a result, the handover latency for the PMIPv6, D_{HO}^{PMIPv6}, can be simply expressed as follows:

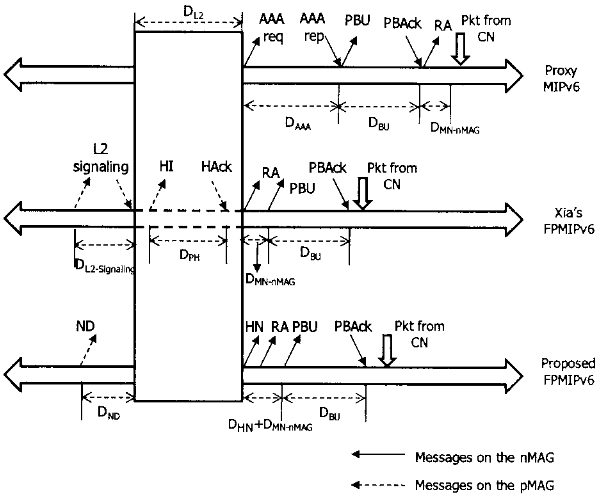

그림 3. PMIPv6, Xia's FPMIPv6, Proposed FPMIPv6에서 지연시간의 구성요소

Fig. 3. Delay components in handover initiation time and handover latency for PMIPv6, Xia's FPMIPv6, and the proposed FPMIPv6.

표 1. 핸드오버 지연시간을 위한 파라미터 정의

Table 1. Definition of parameter notations for the handover latency.

D_{L2}	Layer 2 handover latency
D_{AAA}	Delay between nMAG and policy server
D_{BU}	Delay for proxy binding update procedure
D_{PH}	Delay for HI/HAck message exchange
D_{ND}	Time needed for ND message to reach the neighbor nMAGs
$D_{L2\text{-}Signaling}$	Time needed for negotiation occuring between MN and pMAG through L2 signaling
D_{HN}	Time needed for HN message to reach pMAG
$D_{MN\text{-}nMAG}$	Time needed for RA message to reach MN

$$D_{HO}^{PMIPv6} = D_{L2} + D_{AAA} + D_{BU} + D_{MN-nMAG}. \tag{1}$$

where $D_{AAA} = RTT_{nMAG-AAA}$,

$D_{BU} = RTT_{nMAG-LMA}$

In contrast to PMIPv6, the handover latencies for the Xia's FPMIPv6 and the proposed FPMIPv6 also include the time for the handover initiation at the current access network to reduce the handover latency. The handover initiation procedure for Xia's FPMIPv6 includes the Handover Initiation (HI) and Handover Initiation Acknowledgement (HAck) message exchange, which are used to inform the nMAG of the MN's profile, when the pMAG detects the detachment of the MN. In this scheme, the MN must also provide the pMAG with information about the target network through L2 signaling. Thus, the time taken for handover initiation with Xia's FPMIPv6, D_{HI}^{Xia}, can be derived as follows:

$$D_{HI}^{\text{Xia}} = D_{L2-Signaling} + D_{PH}, \tag{2}$$

where $D_{L2-Signaling} = RTT_{pMAG-MN}$,

$D_{PH} = RTT_{pMAG-nMAG}$

In addition, with Xia's FPMIPv6, when the new MAG detects the attachment of the MN, it sends an RA message with the MN-HNP to the MN and registers the MN with the LMA. Therefore, the handover latency for the Xia's FPMIPv6, D_{HO}^{Xia}, can be given by:

$$D_{HO}^{Xia} = D_{L2} + D_{MN-nMAG} + D_{BU} \tag{3}$$

Meanwhile, with the proposed FPMIPv6, when the pMAG receives the LGD trigger of the MN, it sends an modified ND message to advertise the MN's profile to its neighbor nMAGs. Thus, the time taken for handover initiation with the proposed FPMIPv6, $D_{HI}^{Proposed}$, can be simply expressed by:

$$D_{HI}^{Proposed} = D_{ND} \tag{4}$$

In addition, when the nMAG detects the movement of the MN, it sends an HN message to the pMAG to confirm the MN handover. The nMAG also sends an RA message with the MN-HNP to the MN, and registers the MN with the LMA. Therefore, the handover latency of the proposed FPMIPv6, D_{HO}, can be represented by:

$$D_{HO}^{Proposed} = D_{L2} + D_{HN} + D_{MN-nMAG} + D_{BU} \tag{5}$$

B. Numerical Results

This subsection presents numerical results based on the analysis derived in the previous subsection. For this analysis, the parameter values are given in Table 2[10~12].

표 2. 수치적 결과를 위한 파라미터 값
Table 2. Default values of parameters for numerical results.

Parameters	Values
D_{L2}	50ms
D_{AAA}	6ms
D_{BU}	20ms
D_{PH}	6ms
D_{ND}	3ms
$D_{L2\text{-}Signaling}$	20ms
D_{HN}	3ms
$D_{MN\text{-}nMAG}$	10ms

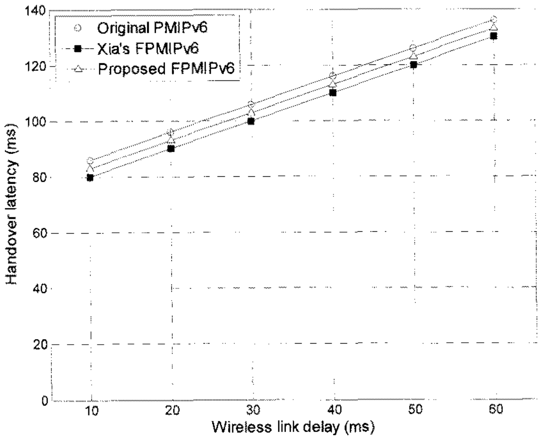

그림 4. 핸드오버 지연시간 비교
Fig. 4. Comparison of handvoer latency.

Fig. 4 compares the handover latencies between the proposed FPMIPv6, the original PMIPv6, and Xia's FPMIPv6 as regards increasing the wireless link delay. While the handover latency of the proposed FPMIPv6 is a little longer than that of Xia's FPMIPv6, it is a little shorter than that of PMIPv6. However, if the HI and HAck message procedure in Xia's FPMIPv6 is not finished during the L2 handover of the MN, the handover latency of Xia's FPMIPv6 will be increased.

Fig. 5 shows that the handover initiation time of the proposed FPMIPv6 is much shorter than that of Xia's FPMIPv6 by increasing the wireless link dely. In the mobility environment, longer handover initiation time would cause the handover preparing failure. In addition, as the wireless link delay increases, the handover initiation time of Xia's

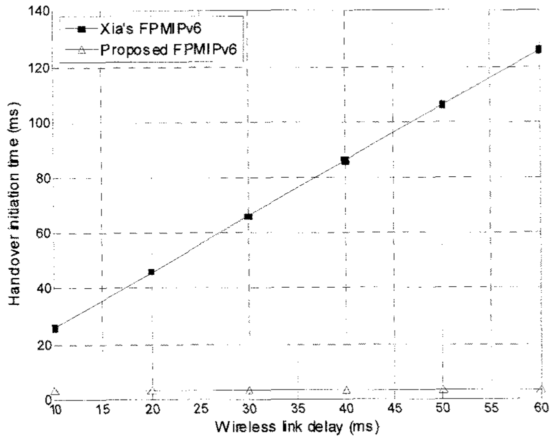

그림 5. 핸드오버 준비시간 비교
Fig. 5. Comparison of handvoer initiation time.

FPMIPv6 significantly increases, because the MN should provide information about the target network through L2 signaling to the pMAG. On the other hand, the handover initiation time of the proposed FPMIPv6 does not change according to the wireless link delay, because the MN is not required to participate in any mobility-related signaling.

As a result, the handover latency of the proposed FPMIPv6 is a little longer than that of Xia's FPMIPv6, but the handover initiation time of the proposed FPMIPv6 is much shorter than that of Xia's FPMIPv6. In addition, the Xia's FPMIPv6 has a packet ordering problem caused by packet buffering at the pMAG, which may cause TCP retransmission due to out-of-order packets. Therefore, we will investigate this problem by simulation in the next section.

Ⅳ. Performance Evaluation Using Simulation

While the previous section compared the handover latencies based on a numerical analysis, this section uses an NS-2 simulator[13] to compare the performance of the proposed FPMIPv6, PMIPv6[5], and Xia's FPMIPv6[7]. The MAC protocol used for the MAGs was the IEEE 802.11b, which has a 250 m transmission range and 2 Mbps link bandwidth, and to create overlapping coverage, the distance between the MAGs was 400m. Plus, a constant bit rate (CBR) application with 0.01-second intervals and FTP application using TCP Reno were considered. In the simulation, the MN started from MAG-1 and moves to MAG-2 and MAG-3 with a velocity of 30m/s. Fig. 6 shows the network topology for the simulation.

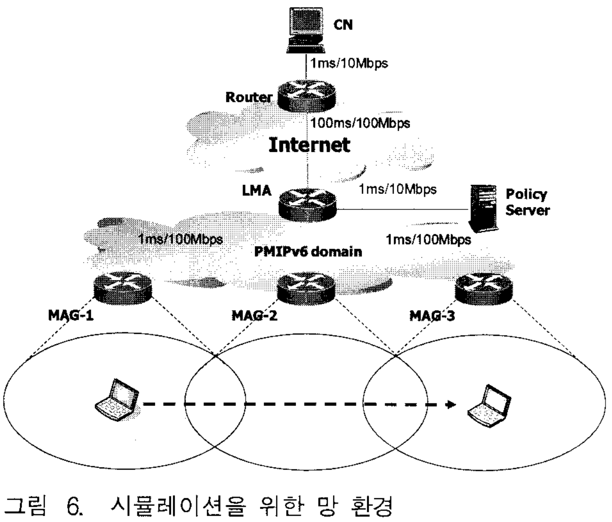

그림 6. 시뮬레이션을 위한 망 환경
Fig. 6. Network topology for simulation.

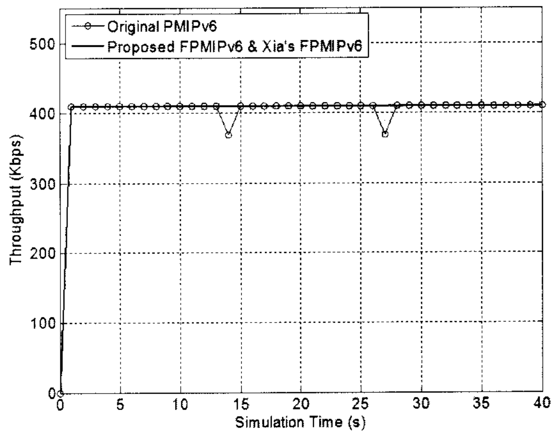

그림 7. UDP 수율 비교
Fig. 7. UDP throughput of MN.

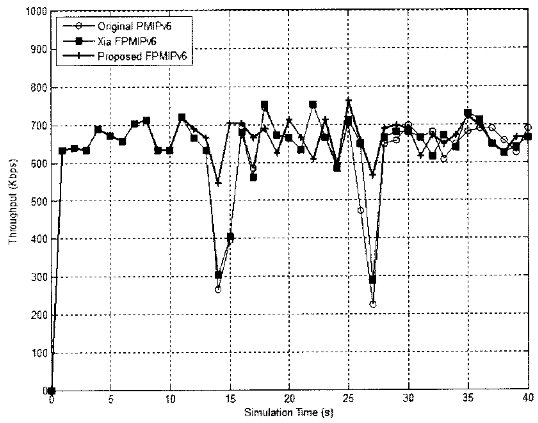

그림 8. TCP 수율 비교
Fig. 8. TCP throughput of MN.

Fig. 7 compares the UDP throughput between the proposed FPMIPv6, original PMIPv6, and Xia's FPMIPv6 when the velocity of the MN was 30m/s. These graphs show that the original PMIPv6 had the on-the-fly packet loss. On the other hand, the proposed FPMIPv6 and the Xia's FPMIPv6 experienced no on-the-fly packet loss during a handover, because they used packet buffering at the pMAG .

Fig. 8 shows a comparison of the TCP throughput between the proposed FPMIPv6, original PMIPv6, and Xia's FPMIPv6 when the velocity of the MN was 30m/s. The throughput of original PMIPv6 is reduced during a handover due to TCP retransmission caused by the on-the-fly packet loss. Furthermore, even through Xia's FPMIPv6 used packet buffering at the pMAG to avoid the on-the-fly packet loss, like the proposed FPMIPv6, it still experienced a throughput decrease during a handover. The reason is that Xia's FPMIPv6 could not ensure the packet sequence between the on-the-fly packets buffered at the pMAG and the packets from the LMA after registration. This packet ordering problem causes the TCP retransmission due to the out-of-order packets.

Unlike the other handover schemes, the proposed FPMIPv6 did not experience serious throughput decrease during a handover, as it used packet buffering at the pMAG to avoid the on-the-fly packet loss. Also, the proposed FPMIPv6 could ensure the packet sequence by using additional packet buffering at the LMA.

Fig. 9 compares the TCP sequence number between the proposed FPMIPv6, original PMIPv6, and Xia's FPMIPv6. Fig. 9 shows that the original PMIPv6 and Xia's FPMIPv6 retransmit the lost packets after the handover due to the same reason as in Fig. 8. In contrast, with the proposed scheme, the sequence number continuously increases, due to avoiding the on-the-fly packet loss while ensuring the packet sequence. Therefore, the TCP throughput of the proposed FPMIPv6 outperforms those of the original PMIPv6 and the Xia's FPMIPv6.

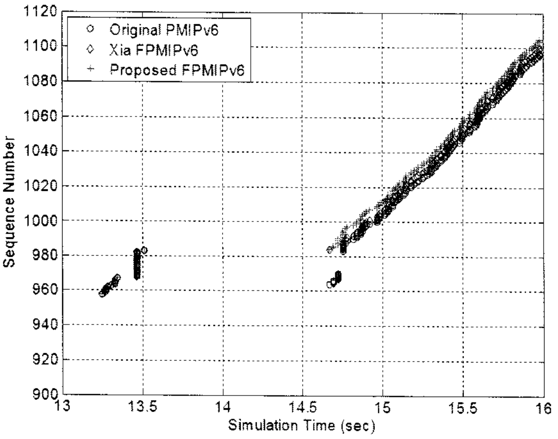

그림 9. MN의 TCP 시퀀스 번호
Fig. 9. TCP sequence number of MN.

V. Conclusion

This paper presented an enhanced fast handover scheme for PMIPv6 to reduce the handover latency and packet loss. The proposed handover scheme uses the ND message of IPv6 to reduce the handover latency, and packet buffering at the pMAG to avoid the on-the-fly packet loss during a handover. Plus, the proposed scheme uses additional packet buffering at the LMA to ensure the packet sequence. When evaluating the performance of the proposed handover scheme, a numerical analysis showed that the proposed scheme had a relatively shorter handover latency. Simulation results demonstrated that the proposed handover scheme could avoid the on-the-fly packet loss when compared with the original PMIPv6. Furthermore, since the proposed scheme ensured the packet sequence through an additional packet buffering at the LMA, it could not experience TCP retransmission due to out-of-order packets during a handover.

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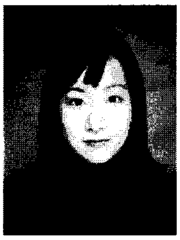
저자소개



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