Efficient Handover Scheme of Proxy Mobile IPv6 in Wireless Local Area Networks

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Abstract

The IEEE 802.11 based WLAN is widely used because of its low cost and high data rate not only in a small office but also in a public hot spot. To support IP mobility of a mobile node in WLAN the mobile node should have a complicated Mobile IP function in its protocol stack if conventional host-based management protocol such as MIPv6 is used. In this paper we propose an efficient hand over scheme of PMIPv6 in WLAN without changing of protocol stack in an IEEE 802.11 based mobile node. The analysis result shows that the proposed scheme reduces handover latency and number of packet lost.

Keywords: *IEEE 802.11, IPv6, Mobile IPv6, Proxy Mobile IPv6, Seamless Handover.*

1. Introduction

While wireless local area network (WLAN) has been designed and utilized for small area application with limited mobility support, WLAN are gaining attention to support high speed wireless service for more wide hotspot area as part of mobile cellular network such as Universal Mobile Telecommunication system (UMTS) and General Packet Radio Service (GPRS) or an independent system.

The series of IEEE 802.11 standard is most widely deployed WLAN technology now days. The popularity of WLAN lies on its low cost and high data rate. The IEEE 802.11 b/g [1][2] uses license-free 2.4 GHz Industrial Scientific and Medical (ISM) ratio band. And the IEEE 802.11g/a [2][3] can support data rate up to 54Mbps.

The mobile Node (MN) can move among Access Points (AP) which is in the same network without losing current connection because the IEEE 802.11 standard provides a link layer roaming. This link layer switch process is called L2 handover and has AP probe, authentication and association phases in IEEE 802.11 based WLAN. However the IEEE 802.11 standard cannot support MN's continuous communication with AP at every time for public user since there are many separate networks which have unique IP address in wider hot spot area. If the MN moves to an AP in different network it has to do reconfigure its IP address again which makes current connection is disabled.

The Mobile Internet Protocol (MIP) supports IP level mobility to provide seamless connectivity to MNs when it moves to another AP which is in a different subnet. The MIP v6 [4]was proposed by the mobile IP working group, the Internet Engineering Task Force (IETF) to manage movement of MNs in wireless IPv6 network. In MIPv6 protocol, IP level mobility is provided by binding Home of Address (HoA) and Care-of Address (CoA) at Home Agent (HA) and Correspondent Node (CN). When a MN moves to a new Access Router (AR) in different subnet it should obtain CoA using Router Advertisement (RA) message from the new AR which is Foreign Agent (FA) in this case and notifies this CoA to HA and CN to bind CoA and HoA.

The proxy Mobile IPv6 (PMIPv6) [7] is a network based localized mobility management (NetLMM) protocol which has been proposed by IETF NetLMM working group. In this PMIPv6 the modification of MN's protocol stack is not necessary and MN is not involved in IP mobility related signalling. In behalf of MN, the network is liable for managing IP mobility. The PMIPv6 guarantees the localized mobility support for MN when MN roams within a local mobility domain region.

In this paper we propose an efficient handover scheme of network based mobile management protocol on wireless LAN without modification of protocol stack of IEEE 802.11 based MN. The L2 and L3 handover is performed at the same time, modified neighbour solicitation message, and neighbour advertisement message are introduced in proposed scheme.

2. Related Works

2.1. Mobile IPv6

Mobile IPv6 (MIPv6) [4] is a host based mobility management protocol that supports global mobility of MN. MN uses a permanent HoA and a temporary CoA in MIPv6 protocol. When MN enters in a foreign domain the MN should obtain the CoA from router advertisement message. After the configuration of new CoA, Duplicate Address Detection (DAD) procedure is performed. Then, MN registers CoA to HA through binding update (BU) message. When MN moves away from the home network, the HA works as a stationary proxy.

The HA intercepts packets destined to the HoA of MN and forwards these packet by tunnelling to the CoA of MN. For efficient transmission of packets the Mobile IPv6 has a route optimization scheme. In this scheme the MN sends its new CoA to CN by BU message. After receiving this BU message the CN sends packets to MN directly. However packets from CN are delivered to MN via HA until the CN receives the new CoA of MN. **Fig. 1** shows handover procedure of mobile IPv6.

The MIPv6 handover procedure consists of movement detection, new CoA configuration, and location update. These procedures will cause long handover latency, which is not acceptable for real time multimedia application. In order to improve the handover latency, the various extensions of MIPv6 such as fast handover for Mobile IPv6 (FMIPv6) [5] and hierarchical MIPv6 (HMIPv6) [6] has been proposed.

Though a lot of enhanced MIPv6 schemes have been reported over the past year the MIPv6 has not deployed widely in practice because of heavy specification which has to be implemented at small mobile node for support MIPv6.

2.2. Movement Detection Procedure in Mobile IPv6

The primary aim of movement detection is to identify L3 handovers. In MIPv6, movement detection generally uses Neighbor Unreachability Detection to determine when the default router is no longer bi-directionally reachable, in which case an MN must discover a new default router on a new link.

However, this detection only occurs when the MN has packets to send, and in the absence of frequent router advertisements or indications from the link-layer, the MN might become unaware of an L3 handover. After a change of link layer connection the MN must detect any change at the IP layer before it can signal the change to the network. MIPv6 uses RS and RA to detect changes of IP network prefix. This is part of the standard router discovery protocol.

The protocol contains built-in timers, these timers prevent a router from sending immediate responses to RS in order to prevent multiple nodes from transmitting at exactly the same time and to avoid long-range periodic transmissions from synchronizing with each other. These are the significant delays since they interfere with the MIPv6 movement detection algorithm thus preventing mobility signaling for up to 1000ms [1] [4].

2.3. Proxy Mobile IPv6

The Proxy Mobile IPv6 (PMIPv6) [7] is a network based mobility management protocol that supports localized mobility of MN in PMIPv6 domain. The Mobile Access Gateway (MAG) and the Local Mobility Anchor (LMA) are main functional constituents of PMIPv6 network.

The MAG performs mobility management on behalf of the MN and it detects the movement of MN and transmits the binding update message to the LMA. The LMA which has function capabilities of HA as defined in MIPv6 protocol is the topological anchor point for the MN’s home network prefix in the PMIPv6 domain. It is responsible for managing the MN’s reachability state.

The PMIPv6 support mobility of the MN which does not have MIP function in its protocol stack. From the help of the MAG and LMA the MN recognizes that it is always in the home network whenever the MN roams in the same PMIPv6 domain. **Fig. 2** shows a PMIPv6 handover process of the MN.

Once the MN enters the region of New MAG (NMAG) the link layer between the MN and the NMAG is established. MN sends MN-identifier to NMAG for authentication. Using this identifier the NMAG obtains the MN’s policy profile from policy store such as an AAA (Authentication, Authorization, and Accounting) sever. This policy profile has essential parameters such as home network prefix and address configuration mode for providing network based mobility services. The NMAG sends AAA request message to the AAA server then, this server performs MN authentication and sends MN’s profile to the MAG.

The NMAG sends Proxy Binding Update (PBU) message to the LMA for updating the location of the MN. Upon receiving the PBU message, LMA establishes a binding between MN’s home network prefix and the address of MAG’s egress interface which is called Proxy care of Address (Proxy–CoA). The LMA sends Proxy Binding Acknowledgement (PBA) message with MN’s home network prefix to the NMAG as a response to PBU message. By exchange of these messages bidirectional tunnel between the NMAG and the LMA is established. Then the NMAG send Router Advertisement (RA) message including MN’s home network prefix. The same with PMIPv6 domain, the MN receives same home network prefix by RA message. So, the MN can recognize it stays at the home network.

3. Proposed Scheme

In this section we propose an efficient network based handover scheme on IEEE 802.11 network without changing mobility stack in IEEE 802.11 based Mobile Node. The MN does not need to transmit or receive any management packet to support IP mobility. The same terminology with PMIPv6 is used and MN's localized mobility is considered.

3.1 Layer 2 Handover Procedure

The IEEE 802.11 link layer handover has typically three distinct phases: discovery, authentication, and reassociation [8]. The MN scans wireless medium to obtain AP information.

From this information the MN selects a candidate AP to establish a new radio link based on the strength of received signal from APs. The MN can broadcast probe request message to get probe reply from AP or wait passively the periodic beacon signal from AP for this purpose.

In our proposed scheme a MAG notifies its address periodically to APs that are connected directly with it. These APs have a distinct buffer that is available only for the address of the MAG. APs stores the received MAG's address periodically in the buffer and puts the address into flexible frame body of periodic beacon message.

3.2 Layer 3 Handover Procedure

In our proposed handover scheme the L3 hand over procedure performed together with L2 handover simultaneously. **Fig. 3** shows proposed handover procedure.

After discover and authentication phase, the MN sends reassociation request message to a New AP (NAP) and the NAP delivers this packet to a New MAG (NMAG) to notify attachment of a new mobile node and its information like a MN-identifier and the PAP address. Then the NMAG requests MN's profile by sending AAA request message to the policy store like AAA server. The MN-Identifier is used for this process. The AAA server returns MN's profile by AAA reply message. This policy profile contains MN's home network prefix. The NMAG informs NAP of MN's home network prefix information by Router Advertisement message.

Based on this information the NMAG notify the PMAG that the MN are moving from the PMAG and inquire to establish a tunnel from the PMAG to the NMAG using Neighbour Discovery procedure defined in IPv6 protocol [9]. Enhanced Neighbour Solicitation message and Enhanced Neighbour Advertisement message are used in ND. The ENS message can be made by adding 2-bits H flag at reserved field and adding the MN's home network prefix and MN-Identifier at option field in neighbour solicitation message frame. By sending the ENS message to the PMAG, the NMAG informs the PMAG of home network prefix and the MN-Identifier of MN which has moved to the NMAG, then requests the PMAG to perform L3 handover procedure.

After finishing tunnel setup the NMAG sends Stored Packet Request (SPR) message to inquire the PMAG to send stored packets heading to the MN in its buffer to the NMAG if the NMAG is ready for receiving packet. MN can receive packet via PMAG and NMAG. However, to support handover optimization the NMAG send LPBU message to LMA. Finally, LMA start to transmit packet to MN via NMAG.

4. Analytical Models

We will explain system and user mobility model used in this paper. A common hexagonal cellular network configuration is used in this paper as shown in **Fig. 4**. We assume each hexagonal cell is an AP area and every cell has same shape and size. A subnet served by AR/MAG is composed of several layers of cell. The innermost cell is called layer "0" which is surrounded by a layer"1". And the layer "1" is surrounded by layer "2" and so on. If an outermost layer of a subnet is layer"n-1" this subnet is called "n" layer subnet. A layer i has 6i cells where i>0 and an "n" layer subnet has $3n^2$-3n+1 cells.

We define AP area radius R_a for hexagonal cell as the distance from centre to the vertex of cell. To calculate mean AP area/subnet residence time the hexagonal AP area is approximated by a circle which has same area [10].

The cell crossing time is just considered as the AP area/subnet residence time for simple analysis. We assume incoming sessions follow the Poisson process. Let t_c be session inter arrival time which is the time interval between two sessions and t_a, t_s be a random variable of the AP area residence time and subnet residence time respectively. Let $f_c(t)$, $f_a(t)$ and $f_s(t)$ be the probability density function of t_c , t_a and t_s respectively. $f_a(t)$ and $f_s(t)$ are the general probability density function. Because incoming session are Poisson process, $f_c(t)$ it is expressed as

$$f_c(t)=\lambda_c e^{-\lambda_c t},$$

$$E[t_c]=\frac{1}{\lambda_c} \quad (1)$$

where λ_c is session arrival rate.

With these parameters we can derive the probabilities $\alpha_a(J)$ and $\alpha_s(k)$ wherein MN crosses J AP areas and K subnets respectively during a session inter arrival time t_c ,as follows [15]:

$$\alpha_a(J) = \begin{cases} 1-\frac{\lambda_a}{\lambda_c}[1-f_a^*(\lambda_c)] & J=0 \\ \frac{\lambda_a}{\lambda_c}[1-f_a^*(\lambda_c)]^2[f_a^*(\lambda_c)]^{J-1} & J>0 \end{cases} \quad (2)$$

$$\alpha_s(K) = \begin{cases} 1-\frac{\lambda_s}{\lambda_c}[1-f_s^*(\lambda_c)] & K=0 \\ \frac{\lambda_s}{\lambda_c}[1-f_s^*(\lambda_c)]^2[f_s^*(\lambda_c)]^{K-1} & K>0 \end{cases} \quad (3)$$

where $f_a^*(s)$ and $f_s^*(s)$ is the Laplace transform of $f_a(t)$ and $f_s(t)$ respectively.

We can easily derived the MN's average number of crossing AP areas ($E(N_a)$) and subnets ($E(N_s)$) as follows:

$$E(N_a) = \sum_{J=0}^{\infty} J\alpha_a(J) = \frac{\lambda_a}{\lambda_c} \quad (4)$$

$$E(N_s) = \sum_{K=0}^{\infty} K\alpha_s(K) = \frac{\lambda_s}{\lambda_c} \quad (5)$$

5. Performance Analysis

The performance of proposed network based mobility management protocol is evaluated analytically in the terms of packet loss and handover latency. For comparison MIP and PMIP protocols are analyzed as well. We do not consider any security scheme in both host and network based MIP protocols. However the procedure of obtaining the MN's profile from the policy store like AAA server is necessary in network based MIP protocol to make the MN feel in the home network. Also, we consider intra domain handover for network based MIP protocol in this analysis.

The handover latency is defined as an interval from the time the MN loose L2 connection with previous AP until the time the MN receives the first packet delivered from CN in this analysis. The handover latency consists of the latency caused by AP area crossing (T_{L2}) and by AR/MAG coverage area crossing (T_{L3}). Therefore the total handover latency (HL) can be expressed as:

$$HL = E(N_a)T_{L2} + E(N_s)T_{L3} \qquad (6)$$

For simplicity of the analysis we assume network is symmetric and all the IEEE 802.11 control packets have same size. Also the size of control packets for IP mobility management is same in this analysis.

The total handover latency of MIP protocol can be expressed as follows:

$$HL(MIP) = E(N_a)[T_{L2}] + E(N_s)[T_{L3}] \qquad (7)$$

where $T_{L2} = T_{scan} + 4T_{MN\text{-}AP}(sl)$ and $T_{L3} = 2T_{MN\text{-}AR}(sp) + T_{add.} + T_{MN\text{-}CN}(sp) + T_{CN\text{-}MN}(sd)$. The sd is the size of data packet.

The total handover latency of PMIPv6 is expressed as:

$$HL(PMIP) = E(N_a)[T_{L2}] + E(N_s)[T_{L3}] \qquad (8)$$

where $T_{L2} = T_{scan} + 4T_{MN\text{-}AP}(sl)$ and $T_{L3} = 2T_{MAG\text{-}AAA}(sp) + T_{MAG\text{-}LMA}(sp) + T_{LMA\text{-}MAG}(sd) + T_{MAG\text{-}MN}(sd)$.

The total handover latency of our proposed PMIP protocol can be expressed as:

$$HL(P\text{-}PMIP) = E(N_L)[T_{L2}] + E(N_s)[T_{L3} - T_{reas}] \qquad (9)$$

6. Comparisons

Wherever Times New Roman is specified, Times Roman, or Times may be used. If neither is available on your word processor, please use the font closest in appearance to Times New Roman that you have access to. Please avoid using bit-mapped fonts if possible. True-Type 1 fonts are preferred.

Fig. 5 illustrates the total handover latency according to subnet layer. Total handover latency is decreased abruptly as subnet layer is increased. In the case of 1 subnet layer, AR/MAG has just one AP. Thus inter AP roaming causes L2 and L3 handover simultaneously. As the number of AP area in subnet is increased the number of L3 hand over is reduced. It means the portion of L2 handover in total handover latency becomes bigger as layer of subnet is larger.

Fig. 6 shows the total handover latency as function of AP area radius. As radius of AP area becomes larger the number of handover is decreased in session duration. Consequently total handover latency is decreased as radius of AP area increases.

7. Conclusions

In this paper, an efficient network based mobility management protocol on IEEE 802.11 standard is proposed. Our scheme does not affect protocol stack in MN. Also an analytical model for evaluating handover performance as function of layer of subnet, radius of AP area and MN's velocity is well described.

8. Acknowledgment

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9. References

[1] IEEE 802.11b, "Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications: Higher-speed Physical Layer Extension in the 2.4 GHz Band," IEEE Standard, Sept. 1999.
[2] IEEE 802.11g, "Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications: Further Higher-Speed Physical Layer Extension in the 2.4 GHz Band," IEEE Standard, June 2003
[3] IEEE 802.11a, "Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications: High-speed Physical Layer in the 5 GHz Band," IEEE Standard, Sept. 1999.
[4] D. B. Johnson, C. E. Perkins and J. Arkko, "Mobility Support in IPv6," *IETF* RFC 3775, 2004.
[5] E. Rajeev Koodli, "Fast Handovers for Mobile IPv6," *IETF* RFC 4068, 2005.
[6] H. Soliman, C. Castelluccia, K. E. Malki, and L. Bellier, "Hierarchical Mobile IPv6 Mobility Management (HMIPv6)," IETF RFC 4140, Aug. 2005
[7] S.Gundavelli, Ed., K. Leung, V. Devarapalli, K. Chowdhury, B. Patil, " Proxy Mobile IPv6", RFC 5213, Aug 2008
[8] Sangheon Pack, Jaeyoung Choi, Taekyung Kwon and Yanghee Choi, " Fast-Handoff Support in IEEE 802.11 Wireless Networks" IEEE Communications Surveys, Vol. 9, No.1 First Quarter 2007, pp.2-12
[9] T. Narten, E. Nordmark, and W. Simpson, "Neighbor Discovery for IP Version 6," IETF RFC 2461, Dec. 1998.
[10] D. Hong and S. **S.** Rappaport, "Traffic model and performance analysis for cellular mobile radio telephone systems with prioritized and nonprioritized handoff procedures," IEEE Trans Veh. Tcchnol., vol. VT-35, no. 3, pp, 77-91, Aug. 1986
[11] C. Makaya and S. Pierre, "An analytical framework for performance evaluation of IPv6-based mobility management protocols," IEEE Trans. Wireless Communication, Volume 7, Issue 3 March 2008, pp:972 – 983
[12] S. Pack and Y. Choi, "A study on performance of hierarchical mobile IPv6 in IP-based cellular networks," IEICE Trans. Commun., vol. E87-B, no. 3, pp. 462-469, March 2004
[13] Shou-Chih Lo; Guanling Lee; Wen-Tsuen Chen; Jen-Chi Liu, Architecture for Mobility and QoS Support in

All-IP Wireless Networks" IEEE journal of selected areas in communications, Vol.22, No.4 ,May 2003, pp.691 - 705

[14]Yeung, K.L.; Nanda, S "Channel Management in Microcell/Macrocell Cellular Radio System" IEEE Transaction on Vehicular Technology, Vol 45, No.4, November 1996, pp. 601 – 612

[15]Yi-Bing Lin, "Reducing Location Update Cost in a PCS Network" IEEE/ACM Transcation on Networking, Vol.5, No.1, Feb.1997,pp.25-33

[16]A.Mishra, M. Shin, W.Arbaugh, "An empirical analysis of the IEEE 802.11 MAC layer handoff process", ACM SIGCOMM Computer Communication Review, Volume 33 , Issue 2, April 2003, pp.93-102

[17]J. McNair, I. F. Akyildiz, and M. D. Bender, "Handoffs for real-time traffic in mobile IP version 6 networks," in Proc. IEEE GLOBECOM, vol. 6, Nov. 2001, pp. 3463-3467.

[18]S. Deering and R. Hinden, "Internet Protocol, version 6 (IPv6) specification," RFC 2460, Dec. 1998.

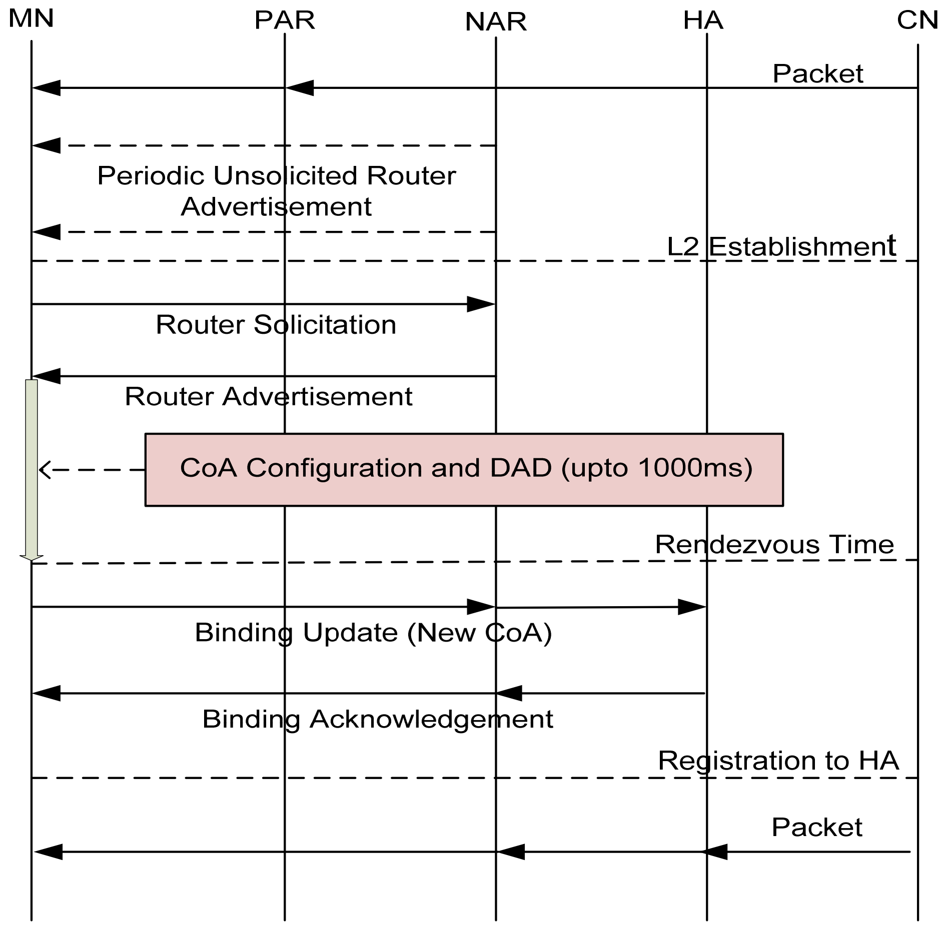

Figure 1. MIPv6 Handover Procedure

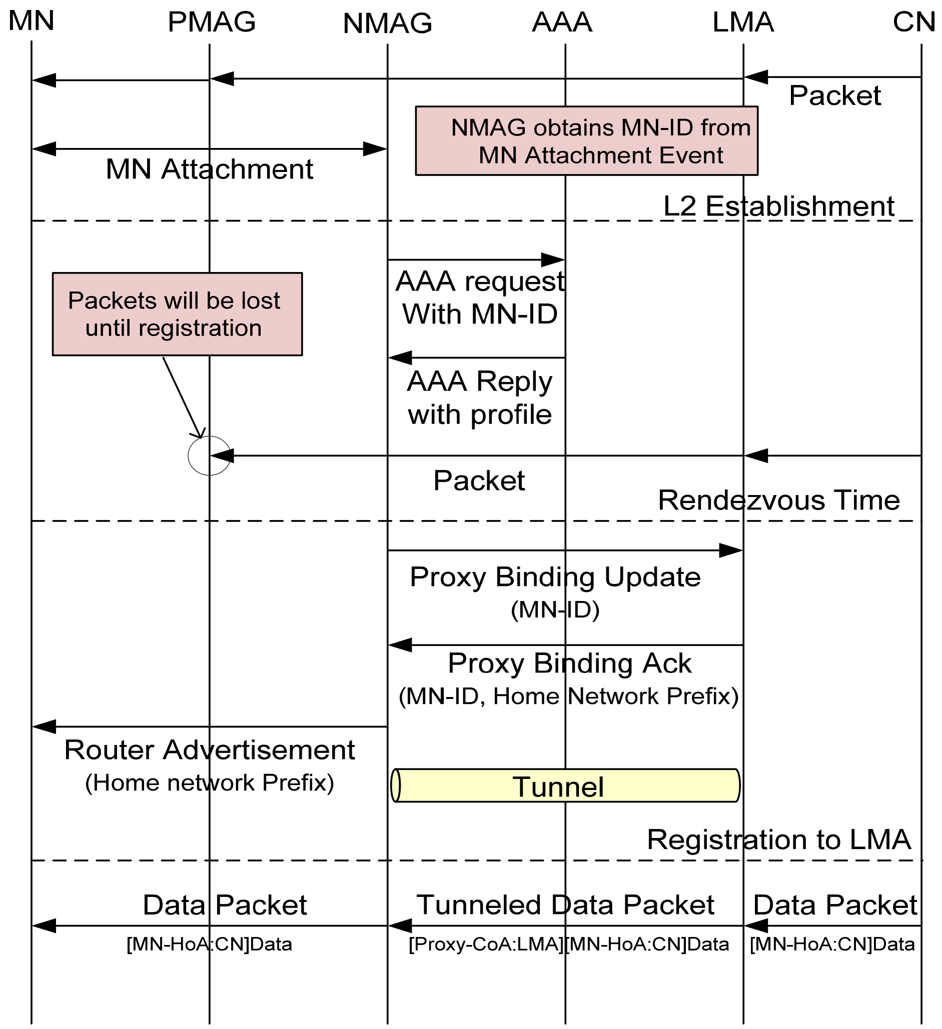

Figure 2. PMIPv6 Handover Procedure

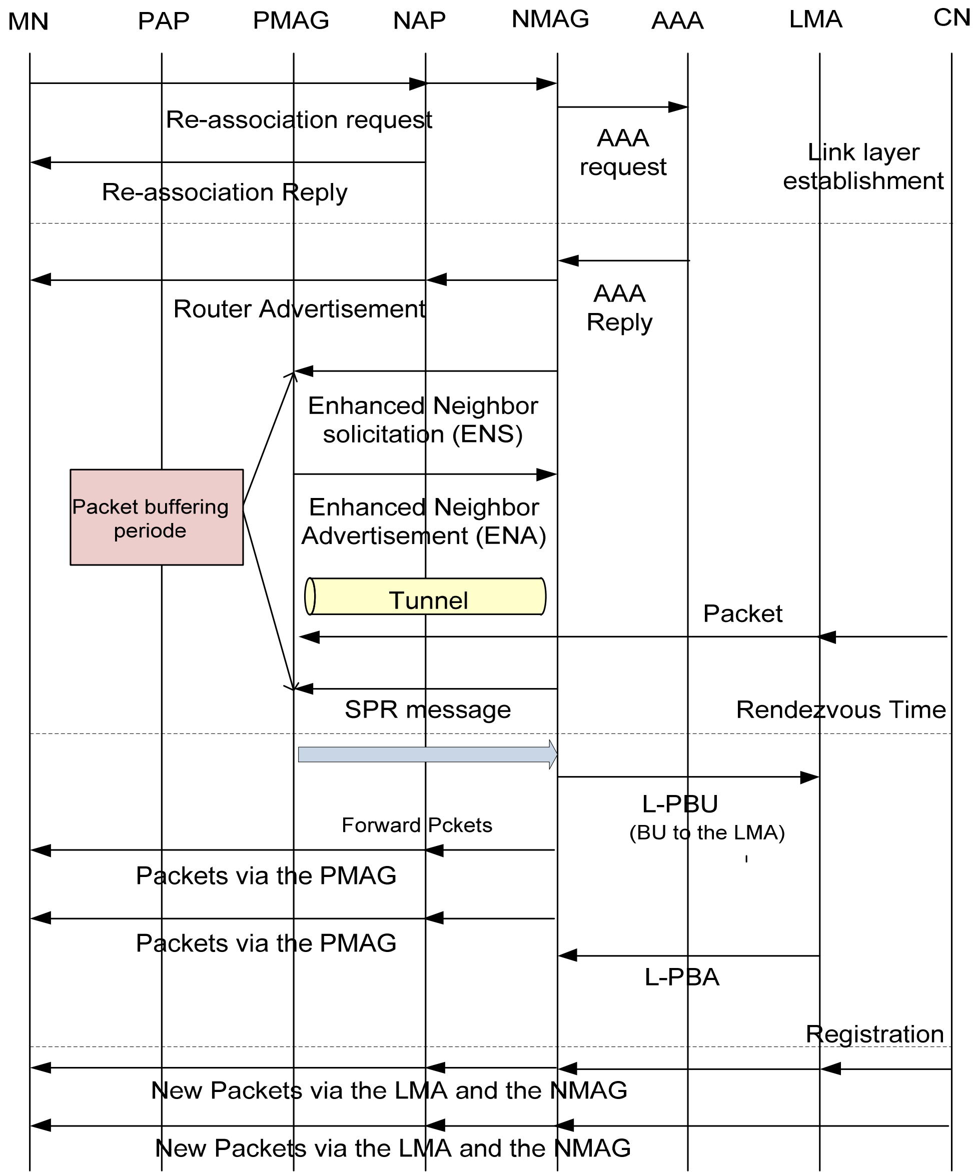

Figure 3. The Proposed Fast Handover Scheme in IEEE 802.11 Network

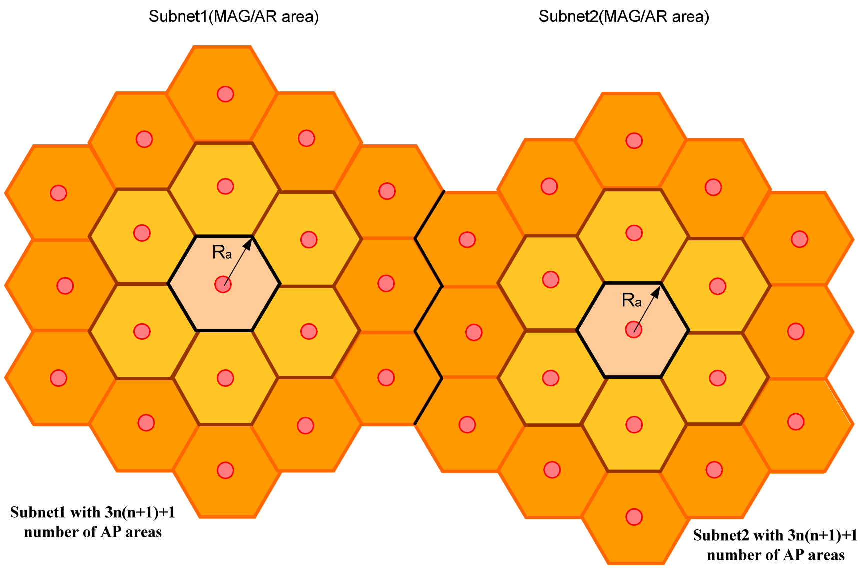

Figure 4. Networks Configuration

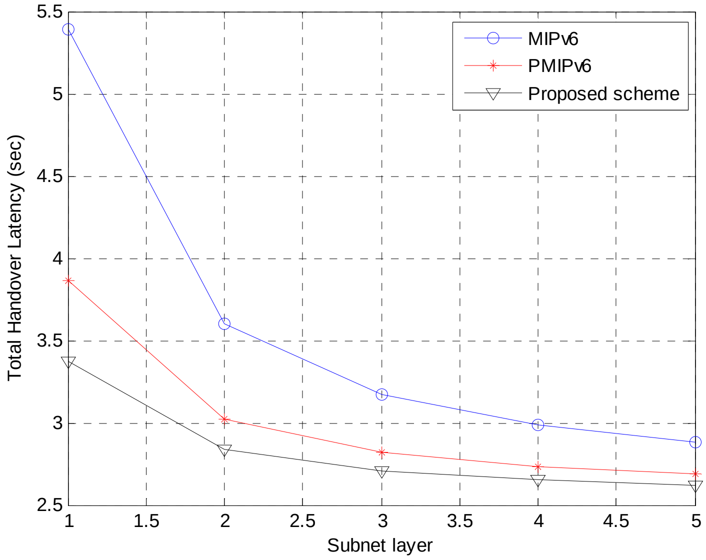

Figure 5. Handover Comparison 1

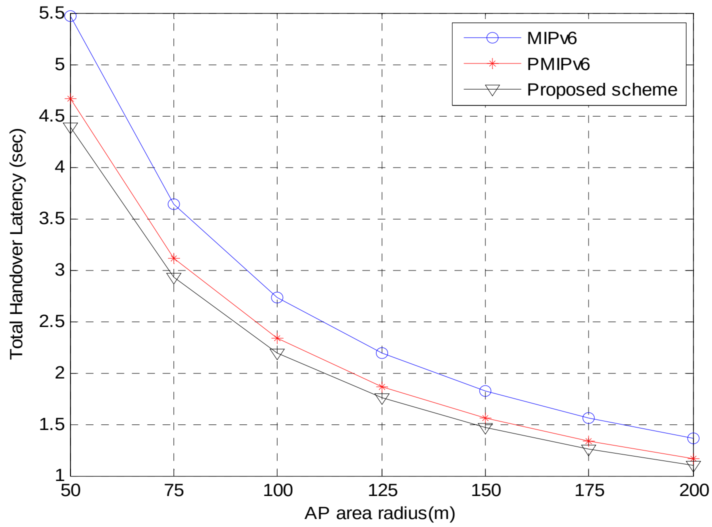

Figure 6. Handover Comparison 2

Table 1. The H Flag of ENS Message

H-flag	Description
00	MN's home network prefix and Identifier are not included
01	Only MN's Identifier is included
10	Only MN's home network prefix is included
11	MN's home network prefix and Identifier are included

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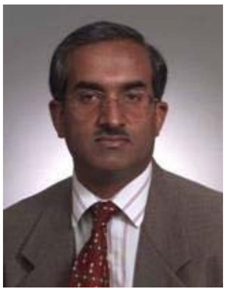

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