International Journal of Future Generation Communication and Networking
Vol. 2, No. 2, June, 2009

ES-FHMIPv6: An Efficient Scheme for Fast Handover over HMIPv6 Networks

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Abstract

The Hierarchical Mobile IPv6 (HMIPv6) has been proposed by IETF to reduce registration control signaling. It separates micro-mobility from macro-mobility with the help of an intermediate mobility agent, called the mobility anchor point (MAP), and exploits a Mobile Node's (MN's) spatial locality. However, in HMIPv6, the handover process reveals numerous problems manifested by the latency in configuring a new care of address and confirmation scheme called duplicate address detection. In this paper, we proposes an Efficient Scheme Fast Handover over HMIPv6 networks. The MIPv6 mobility could be more enhanced by combining FMIPv6 with HMIPv6, in which MIPv6 is benefited from all the advantages of the respective schemes. In previous work an additional benefit by combining FMIPv6 with HMIPv6 is that the overall handover latency in HMIPv6 will be more reduced since in HMIPv6 the MN sends a location update with the with NAP, rather than the HA and CN that are typically further way. An analytical study compares the handover latency of different IP mobility management Schemes, considering the different approaches of HMIPv6 and ES-FHMIPv6. This document describes the enhanced scheme of FHMIPv6 than can reduce the latency handover of message from a certain access router to another router. The ESF-HMIPv6 is designed to be efficient with the data transport feature; we include a dual buffer in Access Point (AP) which stores the received message from Previous Access Router (PAR), the main purpose of the design scheme is to minimize the handover latency time of message transmission.

Keywords: *HMIPv6 Networks, IPv6, HMIPv6, Fast Handover, ES-FHMIPv6*

1. Introduction

Mobile Internet Protocol version 6 (IPv6) allows an IPv6 node to be mobile—to arbitrarily change its location on an IPv6 network—and still maintain reachability. Connection maintenance for mobile nodes is not done by modifying Transport layer protocols, but by handling the change of addresses at the Internet layer using Mobile IPv6 messages, options, and processes that ensure the correct delivery of data regardless of the mobile node's location.

The MIPv6 could be benefited from its two extensional schemes: Hierarchical MIPv6 and Fast Handover for MIPv6. Both the FMIPv6 and HMIPv6 have so far been designed in their own ways so as to enhance the MIPv6 in the signaling and handover aspects.

The Hierarchical MIPv6 (HMIPv6) facilitates to reduce the signaling overhead and delay concerned with the location update, in which an MN sends a local Binding Updates (BU) to the local MAP, rather than the Home Agent (HA) and Correspondent Nodes (CN). On the other hand, the Fast Handover for MIPv6 (FMIPv6) uses bi-directional tunnels between ARs and exploits various L2 triggers for supporting fast handover and further minimizing service disruption during handover.

For improving the handover performance of mobile IPv6 (MIPv6), two typical extensional schemes, hierarchical MIPv6 (HMIPv6) and fast handover for MIPv6 (FMIPv6) are being standardized in the Internet Engineering Task Force [1]. Both FMIPv6 and HMIPv6 have so far been designed in their own ways so as to enhance MIPv6 in the signaling and handover aspects. HMIPv6 facilitates to reduce the signaling overhead and delay concerned with the binding update using a hierarchical architecture, and a new entity, a mobility anchor point (MAP), is introduced for it. On the other hand, FMIPv6 exploits various L2 triggers to prepare for a new care-ofaddress (CoA) at the new router in advance, and a bidirectional tunnel is established between access routers to minimize any service disruption during the handover. It is noted that HMIPv6 does not touch the fast handover support described in FMIPv6. This means that we still need a certain fast handover scheme in HMIPv6-based networks. At a glance, a scheme that simply integrating the FMIPv6 with HMIPv6 may look straightforward However, FHMIPv6 may induce unnecessary processing overhead for re-tunneling at the previous access router (AR), as well as inefficient usage of network bandwidth if we don’t assume a direct secure link between them. The main reason for this is that the data transport of HMIPv6 is based on the tunneling from the MAP to mobile nodes (MNs), not ARs, while FMIPv6 uses the tunneling between the previous AR (PAR) and new AR (NAR) for fast handover. In this paper we proposed a scheme for ES-FHMIPv6 to overcome such ineffectiveness of the simple combination of FMIPv6 and HMIPv6. This paper briefly describes the operation of ES-FHMIPv6 and analyzes its handover performance.

2. Problem Definitions

2.1. Hierarchical Mobile IPv6

A MN may vary its point of attachment to different networks so frequently that significant network overhead and increased signaling messages introduced by the basic Mobile IP. HMIPv6, is an extension of basic Mobile IPv6, provides a localized mobility management protocol (micro-mobility and macro-mobility support) for MN. This scheme introduces a new conceptual entity, called as the Mobility Anchor Point (MAP) to handle mobility management. MAP is a router or a set of routers. This MAP maintains uniquely authoritative administration of a particular domain. MAP connects the domain, and serves to the Internet with its publicly routable IP address (Figure 1) [2]. In HMIPv6 a MN has two types of addresses - a regional care-of address (RCoA) and an on link care-of address (LCoA). The RCoA specifies a particular domain of the

Internet and is known as global address. LCoA is known as locally unique address within the domain.

When the MN moves between local networks inside a MAP domain (micro/intra-domain handoff), it transforms its LCoA and simply requires registering the new LCoA to a MAP on the local link. While moving a MN from one MAP domain to a new MAP domain (macro/inter domain handoff), it changes both addresses.

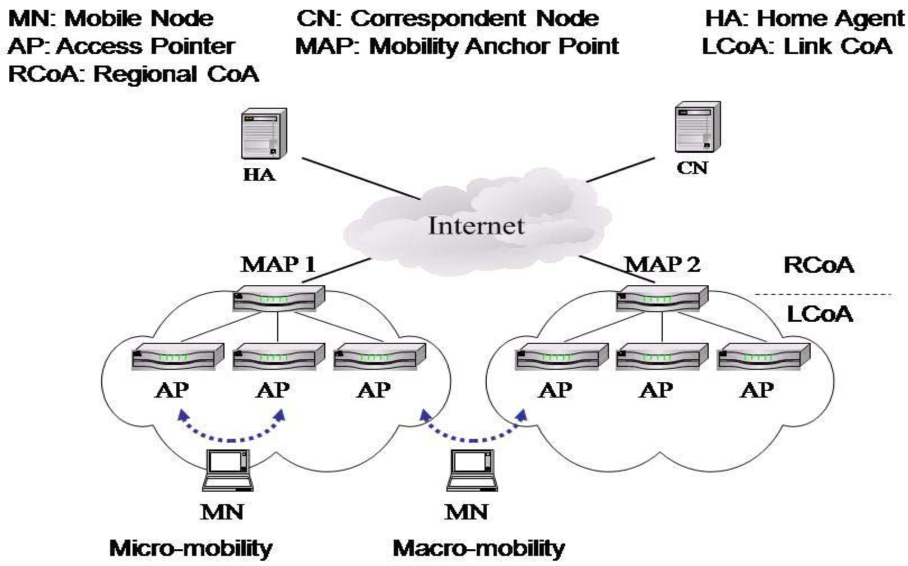

Figure 1. Hierarchical Mobile IPv6

Therefore, this needs registering new local LCoA and new RCoA to the new MAP. At this instant, the new MAP registers global RCoA to the MN's HA. When the MN moves inside a MAP domain, it can be able to prefer between basic mode and extended mode. In basic mode, the MAP acts the same as the local HA to receive packets, which are sent to MN inside the same domain.

The MAP receives all packets intended to the RCoA and subways them to the corresponding LCoA of the MN. In extended mode, the RCoA is the MAP's address. The MAP keeps a binding table with the current LCoA corresponding with the MN home address. When the MAP receives packets intended to a MN, it detunnels and retunnels them to the LCoA.

2.2. Handover in Hierarchical Mobile IPv6

The system for Inter-domain handover is based on the following scenario: the MN has a regional Care-of Address RCoA1 and an on-link Care-of Address LCoA3 (Fig.2). When the CN sends packets to the MN, the packets will be sent through MAP1 to the MN's LCoA3.

When the MN is about to move from the MAP1 domain to the MAP2 domain [2]:

- The MN sends a request control message to MAP1 to construct a multicast group for the MN.
- MAP1 forms a multicast group for the MN and sends a multicast group join request to all other neighboring ARs. The neighboring ARs send response messages after receiving these multicast group requests toward MAP1 to show their availability to receive multicast packets from MAP1.
- The packets encapsulated by MAP1 are tunneled from the CN to the multicast group members. These ARs buffer the packets. As a final point, these neighboring ARs forward the packets.

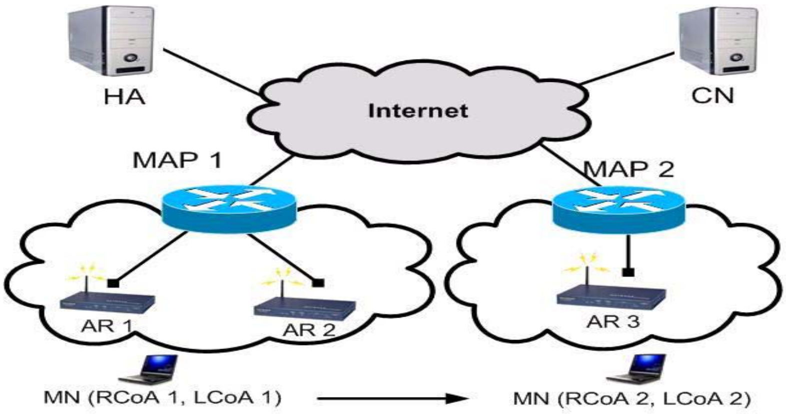

Figure 2. Inter-Domain Handover in HMIPv6

When the MN travels from MAP1 domain to MAP2 domain:

- The MN initially acquires a new address from the MAP2 network (RCoA2, LCoA2).
- The MN sends a Binding Update to MAP2 through AR3 and sends a message requesting AR3 to forward a multicast message. AR4 receives the request message, and subsequently forwards the buffered packets to the MN.
- Whereas AR3 constantly sends multicast packets to MN, MAP2 receives the Binding Update and checks for DAD. MAP2 sends a Binding Update to the MN's Home Agent after receiving the DAD. After that MAP2 waits for a binding acknowledgment from the Home Agent. MAP2 followed by sends a Binding Acknowledgement to the MN.
- The MN receives the Binding Acknowledgement and sends a Binding Update to the CN via MAP2.
- After receiving the Binding Update, CN changes the destination address RCoA1 to new RCoA2 and consequently directs the packets to MN in the new network via MAP2 and AR3.

- AR3 stops sending multicast packets from MAP1 as soon as it receives new packets intended to the MN. MN at this moment receives packets directly from the CN as with Hierarchical Mobile IPv6.

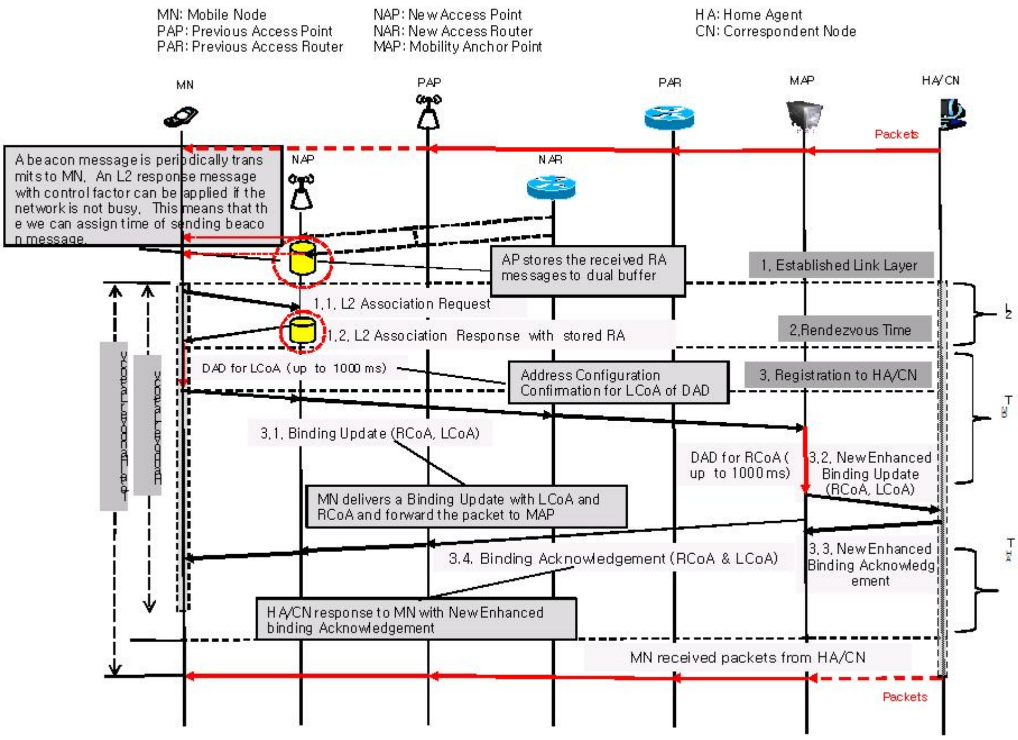

Figure 3. Enhanced Scheme for HMIPv6 Handover Procedure

3. Proposed Enhanced Scheme

In this section we will show and discuss our proposed scheme the Efficient Scheme Fast Handover over HMIPv6 (ES-FHMIPv6). Our scheme is the enhanced handover procedure of Hierarchical MIPv6 handover procedure. We will discuss first the Hierarchical Mobile IPv6 handover procedure and discuss in detailed our proposed scheme the ES-FHMIPv6.

Hierarchical Mobile IPv6 utilizes a new node called the Mobility Anchor Point (MAP). MAP is an entity which assists with MIPv6 handoffs. MAPs are deployed in a treelike structure. Most of the handoffs will occur at the lowest level and so most of the signaling load is handled near the bottom of the hierarchy. The delay of the handoffs will decrease when they are handled closer to the mobile node.

An MN that enters a foreign network first configures its LCoA by the IPv6 address auto-configuration scheme. The MN then sends a local BU message to the MAP. This local BU message includes the MN's RCoA in the Home Address Option field and the LCoA is used as the source address of the BU message. This BU message binds the MN's RCoA to its LCoA. The MAP then performs duplicated address detection (DAD) procedure for the MN's RCoA on its link and returns a Binding Acknowledgement (BAck) message to the MN. In HMIPv6 DAD procedure, it takes at least 1000 ms to detect that there is no duplicate address in the link. So, to reduce total handover latency, a proper address confirmation method has to provide in HMIPv6 networks. The procedure of ES-FHMIPv6 handover is illustrated in Fig. 3. In the figure, it is assumed that an Mobile Node (MN) is trying to move from Previous Access Router (PAR) to New Access Router (NAR) in the Previous Access Point (PAP) region, and the NAR already has the information on the link-layer address (or identifier) and network prefix, also it sends the Router Advertisement (RA) to New Access Point (NAP). NAP is consists of dual Buffer which stores the received RA message that was send by NAR.

Table 1. Parameters for performance analysis

Symbol	**Description**	**Value**
Common Parameters		
T_1	MN <-> NAP	50 ms
T_2	NAP <-> NAR	40 ms
T_3	NAR <-> MAP	80 ms
T_4	MAP <-> HA/CN	100 ms
T_A	MN <-> NAR	
T_B	MN <-> MAP	
Beacon message		100 ms
MIPv6		
T_{L2}	$2T_1$	
T_{MD}	$2(T_1 + T_2)$	
T_{REG_HA}	$2(T_1 + T_2 + T_3)$	
T_{REG_CN}	$2(T_1 + T_2 + T_3 + T_4)$	
T_{CoA_ACC}	2(1000 ms)	
HMIPv6		
T_{L2}	$2T_1$	
T_{MD}	$2(T_1 + T_2)$	
T_{REG_MAP}	$2(T_1 + T_2 + T_3)$	
$T_{REG\_HA/CN}$	$2(T_1 + T_2 + T_3 + T_4)$	
T_{CoA_ACC}	1000 ms	
ES-HMIPv6		
T_{L2}	$2T_1$	
T_{MD_MODI}	T_1	
T_{REG_MODI}	$2(T_1 + T_2 + T_3 + T_4)$	
T_{CoA_ACC}	2(1000 ms)	
αT_{L2}	L2 response message with control factor	

A beacon message is periodically transmitted to MN so that the MN will not wait for the next router solicitation, every 100 ms NAP sends beacon message. MN sends L2 Association request to NAP, NAP send an Association request with Stored Router Advertisement, and after receiving an Address Configuration Confirmation for LCoA of Duplicate Access Detection (DAD) is being process. MN sends a binding update with Link Care of Address and Regional Care of Address to NAR, Address configuration

Conformation for Regional Care of Address with 1000ms time has been established, New Enhanced-Binding Update for LCoA and RCoA, HA/CN response to MN with New Enhanced Binding Acknowledgement.

4. Comparison and Performance Analysis

In this section we will show and explain the Comparison of performance of Hierarchical Mobile IPv6 (HMIPv6) and the Enhanced Scheme Fast Handover MIPv6 (ES-FHMIPv6). We will show the latency handover comparison between HMIPv6 and our proposed scheme. Table 1 shows symbol, description, and value of common parameters, HMIPv6 and ES-HMIPv6.

MIPv6:

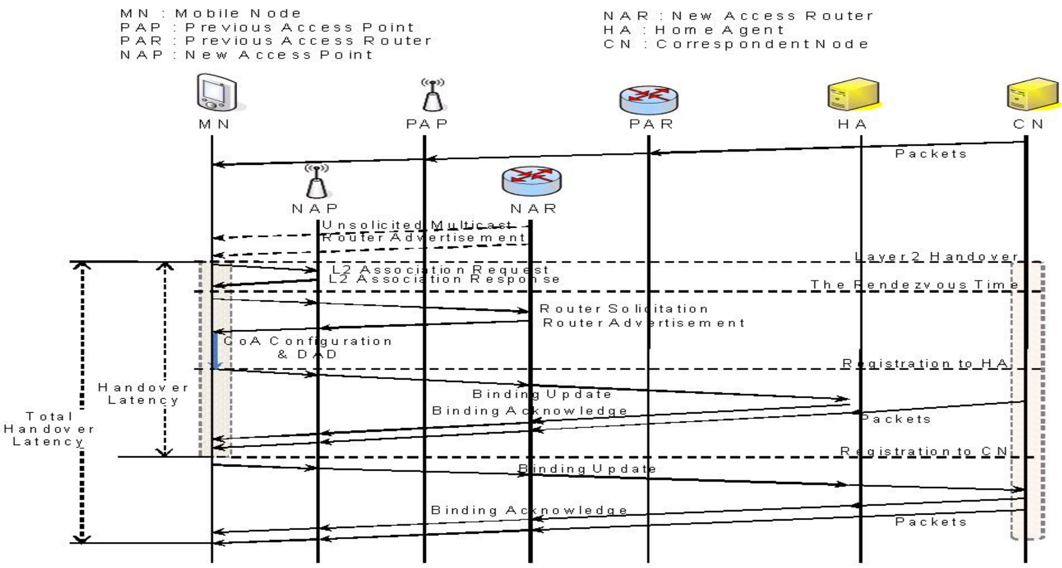

Figure 4. Mobile IPv6 Handover Procedure

$$T_{MIPv6} = T_{L2} + 2T_{CoA\_ACC} + T_{REG\_HA} + T_{REG\_CN}$$
$$= 2T_1 + 2(T_1 + T_2) + 2T_{CoA\_ACC} + 2(T_1 + T_2 + T_3) + 2(T_1 + T_2 + T_3 + T_4)$$
$$= T_{CoA\_ACC} + 2(4T_1 + 3T_2) + 2(2T_3 + T_4)$$

Each simulation used an assumed data in order to get the difference between schemes. We assigned a value for each symbol, T_1=50, T_2=40, T_3=80, T_4=100 and the T_{CoA_ACC} = 1000 ms with their corresponding description. For each scheme, we measured the handover latency as the interval between the last packet in the previous access router and the first packet in the next access router.

As shown in diagrams below, HMIPv6 shows higher handover latency than the ES-HMIPv6 by about 500 ms, even in the case of movement between MAPs. This means that the transmission of message from different Access Router and Access Point may encounter packet lost and also it takes a lot of time for MN to wait for the next router advertisement. This is mainly caused by the ineffective data forwarding and signaling path of HMIPv6. That is, the path is established directly between a MAP and an AR in the proposed scheme.

Below shows the two plotted schemes of HMIPv6 and ES-FHMIPv6 handover procedure. We also show here the corresponding formula of each scheme. After analyzing the scheme and making a formula we come up a result of three graphs that shows the performance analysis between HMIPv6 and ES-FHMIPv6 in terms of handover latency.

HMIPv6:

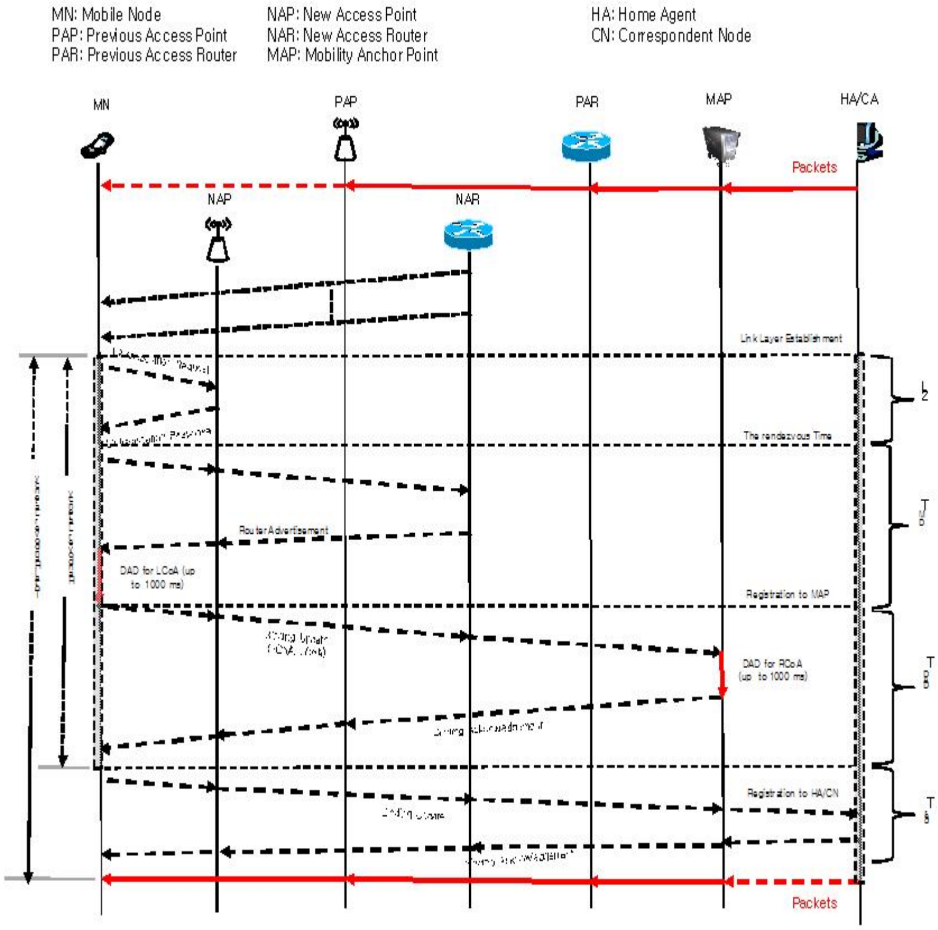

Figure 5. Hierarchical Mobile IPv6 Handover Procedure

$$
\begin{aligned}
T_{HMIPv6} &= T_{L2} + T_{MD} + T_{REG\_MAP} + T_{REG\_HA/CN} + 2T_{CoA\_ACC} \\
&= 2T_1 + 2(T_1 + T_2) + 2(T_1 + T_2 + T_3) + 2(T_1 + T_2 + T_3 + T_4) + 2T_{CoA\_ACC} \\
&= 6T_1 + 6T_2 + 4T_3 + 2T_4 + 2T_{CoA\_ACC} \\
&= 2(3T_1 + 3T_2 + 2T_3 + T_4) + 2T_{CoA\_ACC}
\end{aligned}
$$

ES-FHMIPv6:

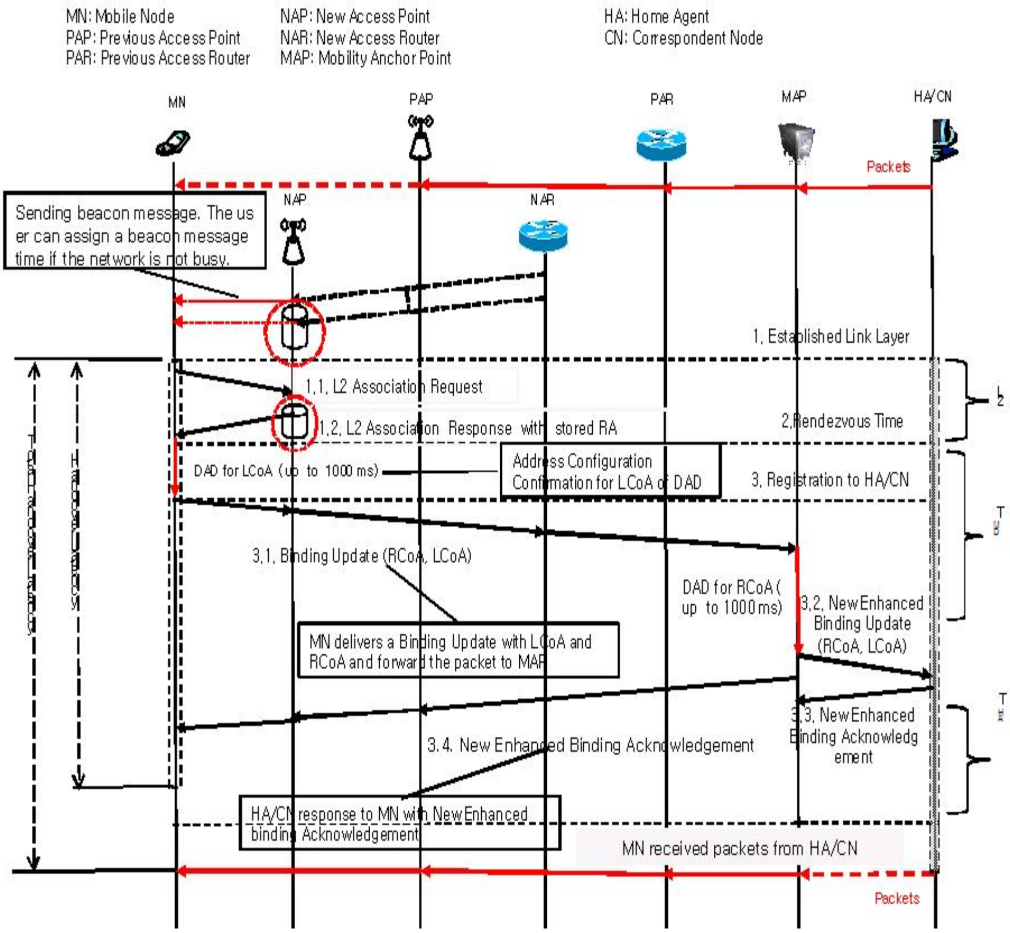

Figure 6. Enhanced Scheme for Hierarchical Mobile IPv6 Handover Procedure

$$
\begin{aligned}
T_{ES-HMIPv6} &= \alpha T_{L2} + T_{MD\_MODI} + T_{REG\_MODI} + 2T_{CoA\_ACC} \\
&= 2T_1 + T_1 + 2(T_1 + T_2 + T_3 + T_4) + 2T_{CoA\_ACC} \\
&= 2T_1 + 3T_1 + 2T_2 + 2T_3 + 2T_4 + 2T_{CoA\_ACC} \\
&= 5T_1 + 2(T_2 + T_3 + T_4) + 2T_{CoA\_ACC}
\end{aligned}
$$

ES-FHMIPv6 with L2 response message with control factor:

$$
\begin{aligned}
T_{ES-HMIPv6} &= \alpha T_{L2} + T_{MD\_MODI} + T_{REG\_MODI} + 2T_{CoA\_ACC} \\
&= 2\alpha T_1 + T_1 + 2(T_1 + T_2 + T_3 + T_4) + 2T_{CoA\_ACC} \\
&= 2\alpha T_1 + 3T_1 + 2T_2 + 2T_3 + 2T_4 + 2T_{CoA\_ACC} \\
&= 2\alpha T_1 + 3T_1 + 2(T_2 + T_3 + T_4) + 2T_{CoA\_ACC}
\end{aligned}
$$

Below are the figures of handover latency comparison between MIPv6, HMIPv6, ES-FHMIPv6, and ES-FHMIPv6 with L2 response message control factor (αT_{L2}). A beacon node periodically transmits a beacon message. The regular beacon message time is 100 ms but if the network is not the busy the beacon message can be control by setting time of seding the message. In this figure the user can control the time of sending a beacon message, we use assigned $\alpha T_{L2} = 0.2$ as a L2 response message. The MN is connected to AP with 50 ms transmission delay. On the other hand, NAP is connected to NAR by the 40 ms, and NAR is connected to the MAP by a 80 ms link.

The three graph shows MIPv6 and HMIPv6 has slower latency handover by around 400 ms which means that it takes a lot of time for the transmission of message because of the sequence of sending and receiving the packets from different AP's and also the time that was spend during the binding of packets and. While the proposed scheme the ES-HMIPv6 shows a fast latency handover because we use dual buffer to store the router solicitation that was send by the NAR to NAP, so there is no need for MN to wait for the next router solicitation because when the MN request an router solicitation to the NAP, the NAP sends a solicitation response with stored Routing Advertisement (RA) and also the user can assign a time of sending beacon message if the network is not busy. As we analyzed the performance of our proposed scheme we proved that ES-FHMIPv6 transmits message faster and efficient than MIPv6 and HMIPv6.

A. MN to AP's distance

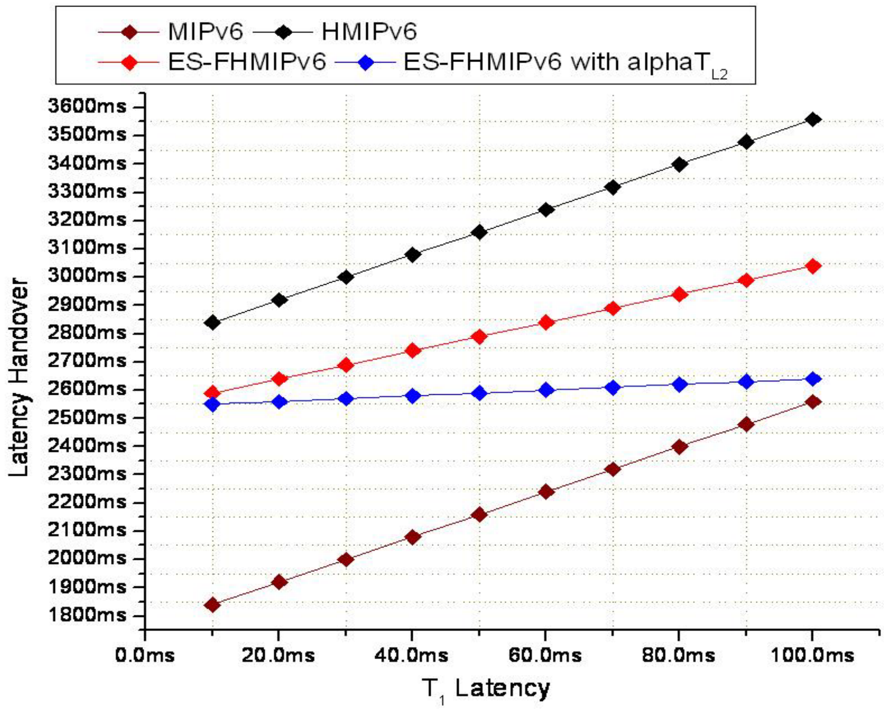

Figure 7. Handover Latency Comparison I

B. AP to AR's distance

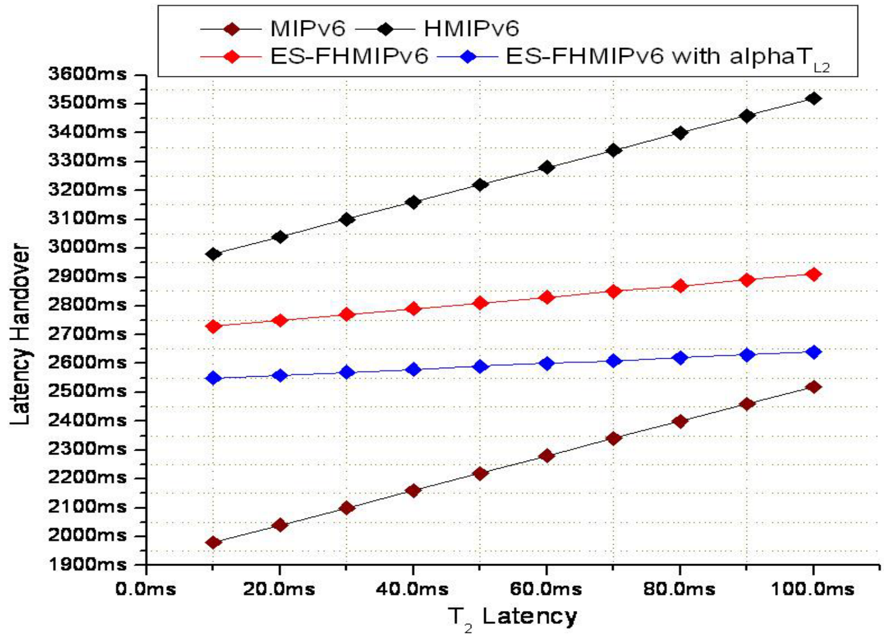

Figure 8. Handover Latency Comparison II

C. AR to MAP's distance change

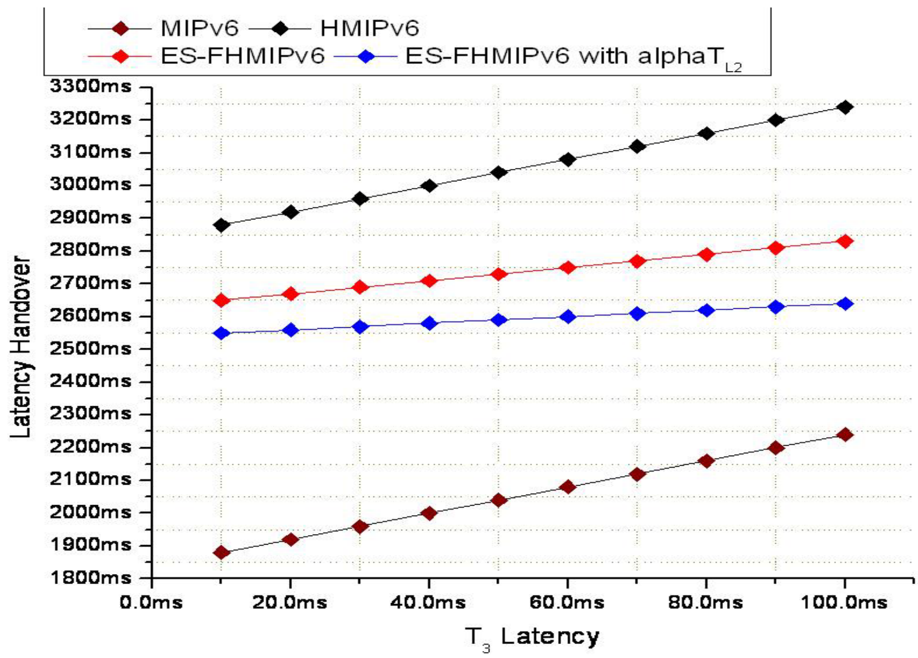

Figure 9. Handover Latency Comparison III

5. Conclusions and Future Works

This paper has described Efficient Scheme Fast Hierarchical Mobile IPv6 (ES-FMHIPv6) as new scheme using dual buffer for storing beacon message and we also used αT_{L2} for L2 message response with control factor for manually assigning a beacon message time to supporting a fast handover effectively. All messages used in ES-FHMIPv6 are just extensions of existing messages already defined in FMIPv6 and HMIPv6. Therefore, ES-FHMIPv6 could be easily introduced in existing systems. For analysis, ES-FHMIPv6 is compared to Mobile Ipv6 (MIPv6) and Hierarchical Mobile IPv6 (HMIPv6) in terms of handover latency and variation of TCP window size. From the analytical results, ES-FHMIPv6 can further reduce the handover latency. Also, note that ES-FHMIP6 additionally can reduce the potential out of sequence possibility of the existing or combined schemes so that it can obtain better TCP traffic performance.

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