EAP: New Fast Handover Scheme based on Enhanced Access Point in Mobile IPv6 Networks

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Summary

Mobile IPv6 has been proposed to support host mobility in the Internet, yet during a handover Mobile IPv6 (MIPv6) suffers from packet disruption and packet loss. However, in MIPv6, the handover process reveals numerous problems manifested by a time-consuming network layer based movement detection. Furthermore, inherent delays associated with movement detection are unavoidable in standard MIPv6. In this paper, we propose to mitigate such effects with a more efficient fast Neighbor Discovery routine which requires each access point to execute movement detection using an enhanced beacon signal with stored Router Advertisement (RA) messages; we also implement a modified access point to handle fast configuration of the care-of address (CoA). Performance analysis indicates the handover latency in the proposed scheme could be reduced compared to standard MIPv6. The proposed scheme is also a strong candidate to support real-time application like VoIP.

Key words:
Mobile IPv6, Handover, Movement Detection.

1. Introduction

In wireless/mobile networks, users freely change their service points while they are connected. In this environment, mobility management is an essential technology for keeping track of the user's current location and for delivering data correctly. In terms of cellular networks used for voice call services, many schemes have been proposed to provide efficient mobility management. However, since next generation wireless networks will be unified heterogeneous networks based on IP technology, they will have different characteristics from existing cellular networks.

MIPv6 is designed to manage the movement of mobile nodes (MNs) between wireless IPv6 networks [1]. The protocol provides seamless connectivity to MNs when they move from one wireless point of attachment to another in a different subnet. MIPv6 notifies the correspondent(s) of an MN about its new location by binding the MN addresses. Even so, the MN cannot receive IP packets on its new point of attachment until the handover finishes.

In Mobile IPv6 network [1], an MN traveling towards a new foreign network needs to properly configure its Network Interface Card to set up and maintain IP layer communications. When the handover is initiated by the MN, it is called mobile station initiated handover. In contrast, when the network can anticipate the handover process based on the prediction information of MN's next location, it is called network initiated handover. The L2 handover happens every time MN changes parameters of the link layer connection, that is, when MN moves from one access point to another access point. The delays caused by the L2 handover affect the magnitude of the overall handover time. In [2] techniques to speed up the L2 handover have been proposed. In general, handover management techniques try to optimize bandwidth reservation and call blocking probability. These techniques attempt to predict the future cell or location of MN and to reduce the cost of location management.

Concerning mobility support in IPv6 (MIPv6) [1], an MN can determine its network layer movement using Router Discovery and Neighbor Unreachability Detection. Unfortunately, delays resulting from network layer-based movement detection and non-optimized time sequencing of handover procedures are inevitable in MIPv6. The delay due to the movement detection procedure causes packet disruption and increases the network load in real-time applications that demand handover latency on the order of hundreds of millisecond. Some studies have been done to estimate the performance of fast handover in different network situations [3] [4] [5].

Choi et al. presented Router Advertisement (RA) Caching in Access Point (AP) for Fast Router Discovery [3]. For seamless handoff, a mobile node must quickly discover its new access router. In their paper, they proposed that AP caches Router Advertisement message and sends it to a mobile node as soon as L2 association is made. They also presented a way for AP to cache necessary RA by using 'RA Caching' and 'AP Notification' functionality on AP.

Costa et al. compared the handover latency of different IP mobility management schemes currently being discussed within the IETF [5]. They include standard MIPv6, FMIPv6 and HMIPv6. FMIPv6 supports a faster handover procedure compared to standard MIPv6, while HMIPv6 provides an approach allowing different hierarchies of mobility agents [4]. In their report, they studied handover latency for each protocol and concluded that the best option, in order to get the better performance, is to implement both HMIPv6 and FMIPv6.

Fikouras et al. studied the performance of Mobile IP handover [5]. According to the results of their study, handover latency is largely dependent on the efficiency of the various movement detection methods such as Lazy cell switching, Eager cell switching and Prefix matching. As stated in their paper, two generic formulae were derived to determine the average handover latencies of the Lazy cell switching and Eager cell switching.

In this paper, we proposes a new scheme that makes the condition of real-time application by using the efficient movement detection procedure which quickly sends stored RA messages without a random delay using an enhanced beacon transmission scheme. The proposed scheme uses enhanced access point (EAP) consisted of EAP system, Route advertisement controller, EAP temporary buffer and sequence checker. The use of enhanced beacon, which does not need waiting random time interval for RA message and DAD procedure, is maintained in EAP.

The remainder of this paper is organized as follows. In Section 2, we provide an overview of related work and problems in existing protocols. In Section 3, we introduce our new fast handover scheme based on enhanced access point (EMIPv6). The performance evaluations and comparisons in standard Mobile IPv6 and proposed EMIPv6 scheme are shown in section 4. Finally, we will conclude this paper in Section 5.

2. Related Works and Problems

2.1 Movement Detection in MIPv6

Mobile IPv6 [1] is a protocol being developed in the Mobile IP WG (Working Group) of the IETF with the advantage of IPv6. Figure 1 shows procedure of agent discovery and registration flow in standard Mobile IPv6. It carries forward the work done by the MIP WG on the original Mobile IPv4 protocol. The intention of Mobile IPv6 is to provide functionality for handling the terminal, node and mobility between IPv6 subnets. 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 the mobile node must discover a new default router on a new link. However, this detection only occurs when the mobile node has packets to send, and in the absence of frequent Router Advertisements or indications from the link-layer, the mobile node 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. In MIPv6 this uses RS and RA to detect changes of IP network prefix. This is part of the standard Router Discovery Protocol [6]. The Router Discovery Protocol of IPv6 Neighbor Discovery contains built-in timers. These timers prevent a router from sending immediate responses to RS so as to stop multiple nodes from transmitting at exactly the same time and to avoid long-range periodic transmissions from synchronizing with each other.

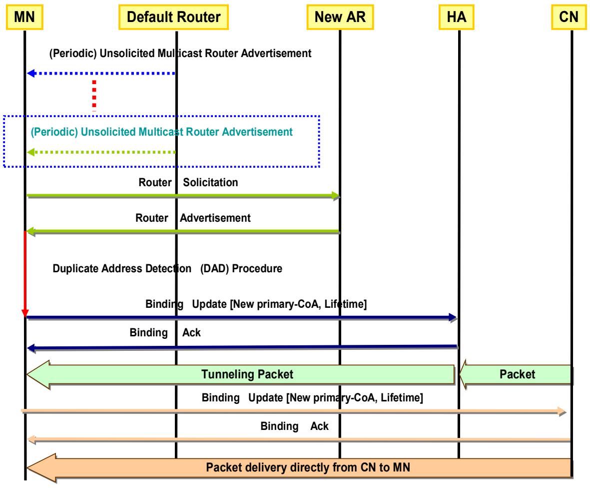


Fig. 1 IETF Standard Mobile IPv6 Handover Procedure.

2.2 Fast Router Discovery

The portion of Router Discovery in Neighbor Discovery of IPv6 contains an inbuilt timer which prevents a router from sending an immediate response in compliance with Router Solicitation message. Therefore, this delay is the second largest delay after DAD in mobile IPv6 handover procedure. The Neighbor Discovery RFC 2461[6] specifies this random time out of between 0 and 500 ms before a router transmits a RS in response to RA. To reduce this unnecessary delay in Neighbor Discovery, Fast Router Discovery was proposed. The Fast router discovery (FastRD) [3] is a scheme that supports seamless handover by discovering MN's new access router. This method can cache the RA in AP manually or can use the following scheme. AR periodically multicasts unsolicited RAs, which go through AP. So AP can scan incoming L2 frames and cache the necessary RA. AP scans L2 frame either continuously or periodically to update stored RA.

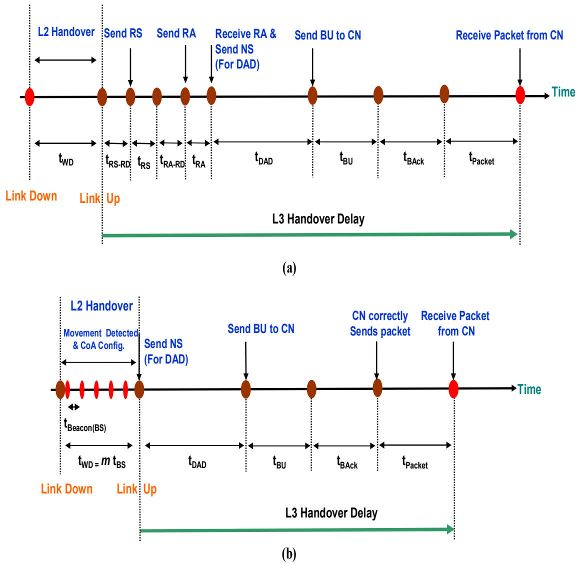


Fig. 2 Handover Timing Diagram of Mobile IPv6 (a) and the proposed EMIPv6 (b).

Moreover, if AR and AP are under the same network administration, they can be configured so that AP caches RA messages efficiently. When a new MN arrives at AP, it sends Association Request Message with its MAC address. Then AP grants association by sending Association Response Message. As soon as association is made, AP sends stored RA to a new MN with MAC address in Association Response message. The MN receives RA just after association is made which is the quickest possible time in current standards.

3. New Fast Handover Scheme Based on Enhanced Access Point (EMIPv6)

Now, instead of receiving RA messages every RtrAdvInterval, an MN can be notified up to 80% faster due to a diminished RtrAdvInterval waiting period. First, a new access point gets RA messages before connecting to an MN. We can buffer the received RA messages in the modified access point. The received RA messages can be broadcasted within the beacon's power range using beacon fame without needing to connect with the new MN. This means that if an MN's current area overlaps two different domains, then every 100ms the MN may recognize the beacon signal containing stored RA messages even while attached to the previous access router. Upon detection of the beacon signal, the MN can configure a new care of address prior to getting a normal RA message from the new access router. Figure 2 shows a comparison of handover timing in standard MIPv6 and our proposed handover scheme (EAP-MIPv6).

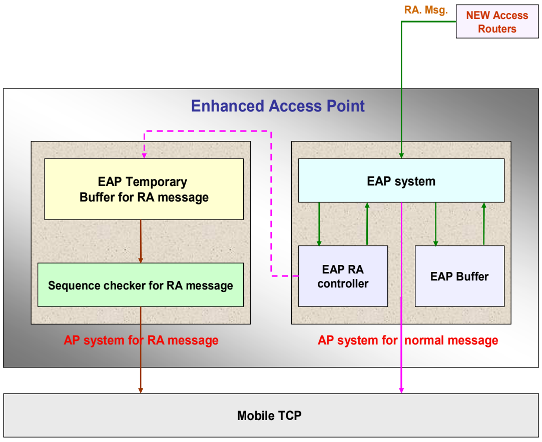


Fig. 3 Enhanced Access Point (EAP) System for RA Message.

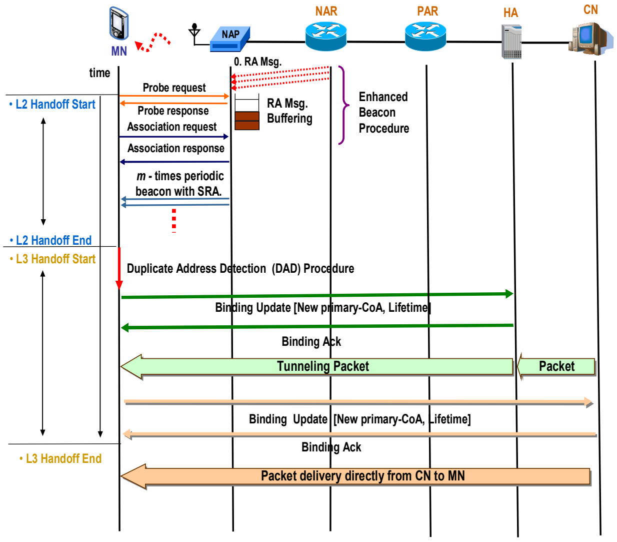


Fig. 4 Proposed EMIPv6 Handover Procedure.

The L2 handover interval is of particular interest here since we can observe the benefit of transmitting a frequent beacon signal.

To quickly process movement detection a beacon signal is transmitted every 100ms and is portrayed in Figure2-(b) by red tick marks (not to scale). To construct the beacon frame quickly, hence speeding movement detection, it is necessary to maintain a buffer in the EAP of RA messages. We assume that the buffer size in the EAP is enough to cache an RA message during an L2 handover.

The beacon period is not yet established by the standard, so each basic service set can transmit a beacon signal over an arbitrary interval. Manufacturers generally set the beacon signal to 100 ms, although the influence of this parameter on network throughput is yet to be determined

[7]. For our purposes we use 100ms for the beacon period which means that the L2 handover interval can be divided 10 times during an entire L2 handover procedure. Depending upon the enhanced access point (EAP) with controller, EAP buffer and sequence checker for RA messages is shown in Figure 3.

During an L2 handover, if an access point (AP) receives an RA message from a router, the AP starts to process the RA message using the EAP controller. That is, the controller compares the received RA message with buffered RA messages, and if the received RA message is new, then the controller stores the message in the EAP's temporary buffer. Finally the controller sends the new RA message to the MN using a beacon message frame. Figure 4 shows the proposed EMIPv6 handover procedure.

4. Performance Analysis

In this section, we will calculate the handover latency per movement for each protocol. Handover latency is defined for a receiving MN as the time that elapses between the disconnection with the previous attachment of point and the arrival of the first packet after the MN moves to NAR.

Our analysis we have assumed that movement detection is accomplished by receiving a beacon message from a new access point with buffered RA messages for which there are two cases.

The first case supposes that the detection of a single beacon advertisement is indicative of movement detection (MD). In this case, the movement detection delay (t_{MD}) is derived by

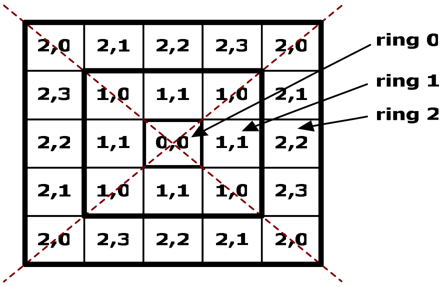
$$0 < t_{MD} < t_{BS} \qquad (1)$$

where t_{BS} is the latency for an L2 handover using an enhanced beacon message frame.

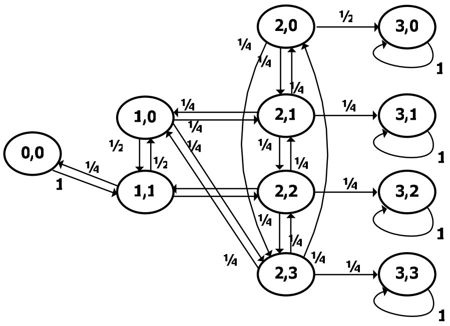
The second case suggests that movement detection can be inferred by the reception of m beacon advertisement messages from an AP. The movement detection delay in this scenario is shown by Eq. 2.

$$(m-1)\cdot t_{BS} < t_{MD} < m\cdot t_{BS} \qquad (2)$$

We use a simple model for the data packet traffic, although the self similar nature of it has been noticed. Our packet traffic model has two layers namely session and packets. During a session, several packets are generated by a CN at an arbitrary rate and they reach an MN at the same rate. We assume that the session duration time has the exponential distribution with mean $E[t_o]=1/\lambda_0$.



(a) 3-layer subnet model



(b) The state diagram of two dimensional random work model

Fig. 5 3-Layer Subnet Area Structure.

4.1 Network System Model

We assume that the homogeneous network of which all wireless AP areas have the same shape and size in a subnet domain. First, we can define some parameters used for performance analysis. Let t_s and t_p be i.i.d. random variables representing the subnet domain residence time and the AP area residence time, respectively. Let $f_s(t)$ and $f_p(t)$ be the density function of t_s and t_p, respectively. In our paper, we suppose that an MN visit k AP areas in a subnet domain for a period t_s^k. During t_s^k, the MN resides at AP area i for a period t_i.

Then, $t_s^k = t_1 + t_2 + t_3 + \cdots + t_{k-1} + t_k$ has the following density function

$$\begin{aligned} f_s^{(k)}(t) = \int_{t_1=0}^{t}\int_{t_2=0}^{t-t_1}\cdots\int_{t_{k-1}=0}^{t-t_1-\cdots-t_{k-2}} & f_p(t_1)f_p(t_2)f_p(t_3) \\ & \cdots f_p(t_{k-1})f_p(t-t_1-\cdots-t_{k-1})dt_{k-1}\cdots dt_2dt_1. \end{aligned} \qquad (3)$$

Using the Laplace transform convolution, we can determine the Laplace transform for $f_s^{(k)}(t)$ as follows:

$$f_s^{(k)*}(s) = [f_p^*(s)]^k \qquad (4)$$

where $f_p^*(s)$ is the Laplace transform of $f_p(t)$.

We describe a two-dimensional random walk model for mesh planes in order to compute the subnet domain residence time density function. Our model is similar to reference [8], however we consider a regular AP area/subnet domain overlay structure. We assume that an MN resides in an access point (AP) area for a period and moves to one of its four neighbors with the same probability, i.e. with probability 1/4. A subnet is referred to as a *n-layer* subnet domain if it overlays with $N = 4n^2 - 4n + 1$ AP areas.

Figure 5 shows the *3-layer* subnet domain in which each of the 25 small squares and the entire square represents each of the AP areas and one subnet domain area, respectively. The AP area at the center of the subnet is called the *layer 0* AP area. The AP areas that surround *layer x-1* AP areas are called *layer x* AP areas.

There are *8x* AP areas in *layer x* and exactly one AP area which is in *layer 0*. An *n-layer* subnet overlays AP areas from *layer 0* to *layer n-1*. Particularly the AP areas that surround the *layer n-1* AP areas are referred to as boundary neighbors, which are outside of the subnet. According to the equal moving probability assumption, we classify the AP areas in a subnet domain into several AP area types. An AP area type is of the form <*x, y*>, where *x* indicates that the AP area is in *layer x}* and *y* represents the *y+1st* type in *layer x*. AP areas of the same type have the same traffic flow pattern because they are at the symmetrical positions on the mesh domain. For example, in Figure 5 (a), the AP type <1, 1>, <2, 1> represent that this AP is in ring 1 and ring 2 and it is the AP of 2nd type in ring 1 and ring 2, respectively.

In the random walk model, a state (*x, y*) represents that the MN is in one of the AP areas of type <*x, y*>. The absorbing state (*n, j*) represents that an MN moves out of the subnet from state (*n-1,j*), where $0 \le j \le 2n-3$. The state diagram of the random walk for *3-layer* subnet is shown in Figure 5 (b). We assume that the AP area residence time of an MN has a Gamma distribution with mean $1/\lambda_p (= E[t_p])$ and variance υ. The Gamma distribution is selected for its flexibility and generality. The Laplace transform of a Gamma distribution is

$$f_p^*(s) = \left(\frac{\gamma\lambda_p}{s + \gamma\lambda_p} \right)^{\gamma}, \ \textit{where}\ \gamma = 1/(\upsilon\lambda_p^2) \tag{5}$$

Also, we can get the Laplace transform $f_s^*(s)$ of $f_s(t)$ and its expected subnet domain residence time $E[t_s]$ from [9]. For an MN, in the end, the probabilities $\prod_p(i)$ and $\prod_s(j)$ that the MN moves across *i* AP areas and *j* subnets during a session duration, can be derived as follows [10]:

$$\prod\nolimits_p(i) = \left\{ \begin{array}{cc} 1 - \frac{E[t_0]}{E[t_p]}(1 - f_p^*(\frac{1}{E[t_0]})) & , i = 0 \\ \frac{E[t_0]}{E[t_p]}(1 - f_p^*(\frac{1}{E[t_0]}))^2 (f_p^*(\frac{1}{E[t_0]})^{i-1}) & , i > 0 \end{array} \right\} \tag{6}$$

$$\prod\nolimits_s(j) = \left\{ \begin{array}{cc} 1 - \frac{E[t_0]}{E[t_s]}(1 - f_s^*(\frac{1}{E[t_0]})) & , j = 0 \\ \frac{E[t_0]}{E[t_s]}(1 - f_s^*(\frac{1}{E[t_0]}))^2 (f_s^*(\frac{1}{E[t_0]})^{j-1}) & , j > 0 \end{array} \right\} \tag{7}$$

4.2 Handover Latency Comparisons

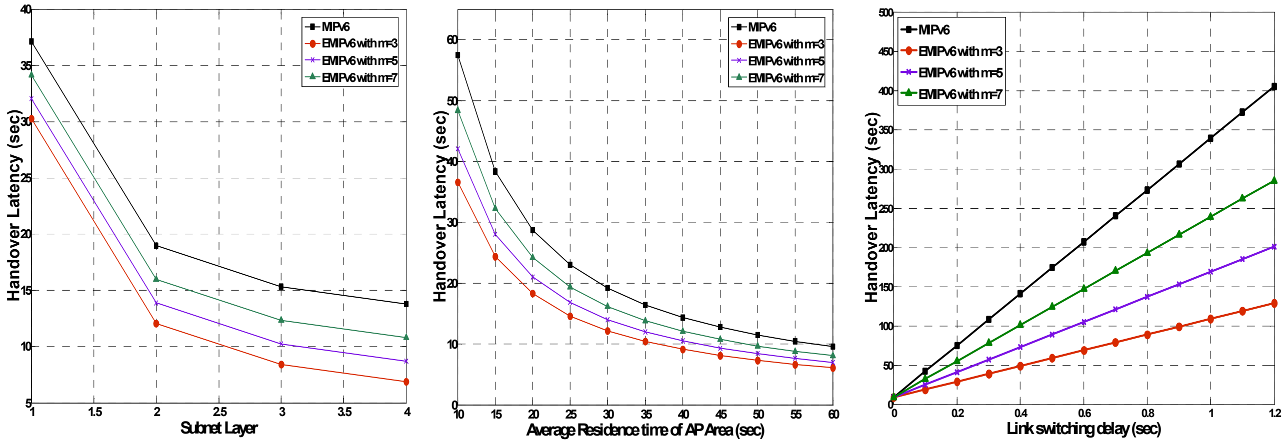
At first, we introduce distance parameters used for handover latency functions. t_{WD} is the wireless component of the delay for a new AP re-association and authentication latency (MN's switching delay between APs). t_{BS} is the latency for an L2 handover using an enhanced beacon message frame. t_{RS} and t_{RA} are the transmission delays for the regular RS, RA messages in standard MIPv6, respectively $(t_{RS} + t_{RA} = 2t_R)$. t_{RD} is the random delay for RS, RA defined as the RFC 3775 $({}^*t_{RD} = t_{RD-RS} + t_{RD-RA})$. t_{BU} and t_{BAck} are the transmission delays for BU/Back messages respectively $(t_{BU} + t_{BAck} = 2t_B)$. t_{packet} is the packet transmission delay from CN to MN. t_{DAD} is the DAD processing delay defined as the RFC 2462. Using such parameters, for the standard MIPv6 and proposed EMIPv6, the average handover latency per session duration is defined as follows:

$$\begin{aligned} HL_{MIPv6} &= \sum\nolimits_{i=0}^{\infty}(i\prod\nolimits_p(i)\cdot t_{WD}) \\ &\quad + \sum\nolimits_{i=0}^{\infty} j\prod\nolimits_p(j)\cdot(2t_R + {}^*t_{RD} + t_{DAD} + 2t_B + t_{packet})) \end{aligned} \tag{8}$$

$$\begin{aligned} HL_{EMIPv6} &= \sum\nolimits_{i=0}^{\infty}(i\prod\nolimits_p(i)\cdot m\cdot t_{BS}) \\ &\quad + \sum\nolimits_{i=0}^{\infty}(j\prod\nolimits_p(j)\cdot(t_{DAD} + 2t_B + t_{packet})) \end{aligned} \tag{9}$$

5. Numerical Results

For examinations, the following fixed parameters are used: $t_{WD} = 1$ sec, $t_{RS/RA} = 0.015$, ${}^*t_{RD} = 1.5$, $t_{DAD} = 1$, $t_{BU/BAck} = 0.065$, $\upsilon = 1.0$, $t_{BS} = 0.1$, $\lambda_0 = 0.0033$ (session duration time is 300sec) and $t_{packet} = 0.065$. As the



(a) (b) (c)

Fig. 6 Handover Latency Comparisons in standard Mobile IPv6 and proposed EMIPv6 with respect to changeable parameter "m" .

target of investigation, we select the following changeable parameters and their default values: $n = 2$ (subnet layer is 2), λ_p (mean of AP area residence time is 30 sec.).

While we select one parameter and change its value, the remaining parameters values are set to their default values during the following investigation. Figure 6 explains the total handover latency per session duration with respect to each changeable parameter. From the figures, we can know that proposed EMIPv6 handover latency are considerably reduced movement detection delay.

Figure 6 (a) shows the total handover latency of each protocol with respect to the subnet layer. It shows that the reduction of latency becomes high when a subnet contains many AP areas.

Figure 6 (b) shows that the handover process occupies much time within the whole session duration when MN moves across AP areas and subnets more frequently. Figure 6 (c) shows the relationship between the handover latency and the delay of link switching in session duration.

Finally, in handover latency comparison, the standard Mobile IPv6 imposes higher handover latency than proposed EMIPv6 scheme. This is due to neighbor discovery procedure in the standard Mobile IPv6 being larger than that in the proposed EMIPv6 scheme.

5. Conclusion

This paper proposed a fast handover mechanism using an enhanced access point with a modified beacon message frame using stored router advertisement messages to support real-time application such as VoIP. The proposed EMIPv6 has advantages including faster movement detection, which obviates the need for using random delays with Router Advertisement messages. By analyzing the total handover delay, we confirmed that the proposed scheme has much lower handover latency than standard MIPv6.

Accordingly, the proposed scheme is a strong candidate to support seamless mobility in MIPv6 based mobile networks.

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