Analytical Approach of An Extended Seamless Proxy-based Handoff Scheme in IP-Based Heterogeneous Mobile Networks

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Abstract

In Next Generation Wireless Networks (NGWN), lots of information, such as voice and video data, will be used in All-IP networks. It is important to note that in such environments, seamless service for users and handoff between heterogeneous networks must be taken into account. Therefore, in this paper, we propose a SePH (Seamless Proxy based Handoff) using PMIPv6-based proxy model, which is able to improve the performance of handoff in NGWN. The SePH can efficiently support seamless and IP-based mobility, by reducing the search process. The performance results show that our proposed scheme outperforms in terms of Quality of Service (QoS), such as throughput, handoff latency, packet loss, and signaling overhead, comparing to the existing schemes.

Keywords: *SePH, Proxy Mobile IPv6, Handoff, NGWN*

1. Introduction

Next Generation Wireless Networks (NGWN) [1] will introduce various services, including many wireless access technologies, personalized services and user-friendly application services. This is of paramount importance to wireless network management that provides these services, as the heterogeneous network is growing rapidly. Users are likely to want seamless roaming service across many different wireless networks, and support for various services and quality of service for multimedia application products in NGWN.

Consequently, the mobility management procedures allow the system to find roaming access points, in order to transfer data packets (location management), and maintain access to existing data packets, when moving to a new subnet (handoff management). When there are different types of wireless access technologies, two types (vertical and horizontal) of handoffs are available in NGWN. Horizontal handoff takes place when Mobile Nodes (MNs) move between Access Points (APs) or Base Station (BS), while vertical handoff happens when APs or BS are in other networks (*e.g.* IEEE 802.11, UMTS). It is commonly known that the nature of NGWN makes performing vertical handoff more difficult, than performing horizontal handoff. This is because constantly maintaining connected sessions is difficult and complex, due to the fact that physical interfaces are evolving. Technological improvements in portable devices have made it possible to support Radio Access Technologies (RAT) of multimode interfaces in the concept of multi-homing. As a result, 3G wireless networks that can offer integrated services of certification, billing and global roaming, and WLAN integration and interworking have caught much attention. Handoff technology is considered as most important in the process of interworking, enabling best assured application service quality, when moving to different networks. However, contention and delays might happen in a wireless IP environment in the process of handoff, and many techniques for providing seamless service are being offered [2, 3].

This paper is an extension of the proxy-based PMIPv6 [4] handoff scheme for SePH (Seamless Proxy-based Handoff) in the heterogeneous network environment. SePH is a proxy-based mobility management protocol for efficient network selection in heterogeneous networks, based on the handoff score function approach. Our proposed SePH, based on performance evaluation, proves more efficient handoff than existing mobility management protocols, by offering guaranteed quality of service, including throughput, handoff, delay, packet loss and signaling, for real-time application in the heterogeneous IPv6-based wireless environment. The SePH protocol suggested in this paper is also effective in regional movement management, context transfer and access network discovery, thanks to its seamless handoffs.

The rest of this paper is organized as follows: Section 2 provides an overview of heterogeneous movement management protocol and PMIPv6. Section 3 presents the operation process of SePH. Section 4 provides an explanation of the performance analysis of the proposed scheme and numerical results. Section 5 summarizes this paper.

2. Related Work

Horizontal handoff has been the object of continuous study, and recent studies on vertical handoff in 4G/NGWN have been drawing wide attention, with results elaborating on the pros and cons of vertical handoff [5]. Relevant papers cover handoff decisions based on the Received Signal Strength (RSS) and bandwidth. Other proposals focus on the architecture design for heterogeneous networks, such as the IPv6 based mobility plan suggested by the Internet Engineering Task Force (IETF). Mobile IPv6 (MIPv6) [6] was proposed in order to manage mobility in IP layers. Each MN can always be located by its home address, regardless of its current point of attachment to the network. MN is connected to Care of Address (CoA), which provides information on the current location, even when it is away from the home network. However, MIPv6 presents problems of signaling traffic overhead, high packet loss rate and handoff registration delays, thus making it hard for users to know real-time traffic. Therefore, people have started studying other solutions to improve the MIPv6 performance. Three extended protocols, H-MIPv6 (Hierarchical MIPv6) [7], F-MIPv6 (Fast MIPv6) [8] and FH-MIPv6 (Fast Hierarchical MIPv6) [9], were suggested by IETF, to solve problems regarding inter-domain mobility. However, each protocol’s drawbacks have also become evident. As for mobility protocol, HMIPv6 is not able to meet the requirements of on-time sensitive real-time traffic, such as Voice over IP (VoIP), due to packet loss and handoff delays [10, 11]. FMIPv6 can’t prevent packet loss, as it does not effectively reduce signaling overhead, and it also needs buffer space. As a result, service interruptions happen in real-time application. Fast handoff design for FHMIPv6 [9] (the combination of FMIPv6 and HMIPv6) is directed to improve network bandwidth usage efficiency. However, FHMIPv6 [9] may collect drawbacks from both FMIPv6 and HMIPv6, such as problems related to synchronization and signaling overhead.

A key difference between PMIPv6 [12] and MIPv6, FMIPv6, HMIPv6 is that PMIPv6 is not a host-based, but rather a network-based mobility management protocol (access routers perform mobility). Mobility management is done by the network, so that it can save limited wireless bandwidth, reduce the size of protocol stack for MN’s mobility signaling, while decreasing frequent signaling with MNs movement along the network, and, to some extent, resolve the energy consumption problem, which is one of the key disadvantages of mobile devices, while reducing the MN’s load. As mentioned earlier in this paper, with the improvement of MIPv6 performance, many enhanced technologies, such as HMIPv6 and FMIPv6, have been introduced, but MN’s protocol stack still has to be modified. Such modifications lead to other complex problems, and additional issues will occur. On the other hand, network-based mobility management technologies like PMIPv6, do not participate in signaling related to the MN's movement, because the network controls the movement management, instead of the MN. The results have a striking effect on the QoS (Quality of Service) side.

3. SePH: Seamless Proxy-based Handoff

The proposed SePH accomplishes the role of a proxy, to avoid the restart of the transmitted-received signaling to the MN, to reduce the interruption of service from the start of the handoff. This needs to be matched to the requirements listed in the request message on the subnet handled by QoS tasks, by the meaning of a seamless continuity of service. QoS consistency remains a very challenging task, and is a crucial factor in real-time applications. In this paper, a consistent process performs network topology for the performance analysis, and it is the value controlled by IHDA (Integrated Handoff Decision Algorithm) that enables mapping in the various networks: the mapping is needed to interpret specifications provided to the session of a heterogeneous network and QoS assurance. As mentioned above, this paper extends the handoff process of PMIPv6. In those process, MN PMIPv6 network powering on first, or after the entry into PMIPv6 network, MAG1 gets the LMA address that MN wants to connect to from the policy store (Policy Storage) in the access network, MN's ID information and the information from the network prefix is assigned to MN. Figure 1 describes SePH process.

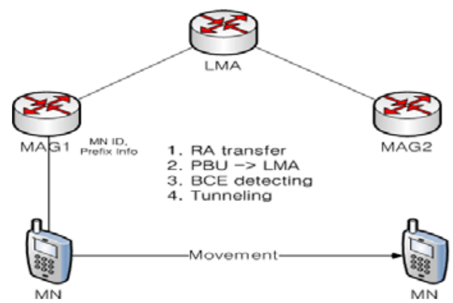

Figure 1. SePH Process

After that, MAG1 sends the RA (Router Advertisement) message to MN, to use the information. MN uses this information to set up their own IP address, and MAG1 creates and sends the PBU (Proxy Binding Update) message to LMA, by using the information received from the server. LMA, receiving the PBU, checks the existence of the corresponded information in its own BCE (Binding Cache Entry). If it is not there, it adds the information about the MN to the storage space. After LMA generates tunnels between LMA and MAG1, by using the address information of the MAG1, and MN moves to MAG2, in the same way as before, MAG2 obtains the information about the MN from the policy store, and lets the information be shared in the same network, by advertising the same network prefix information to MN. If MN receives the same network prefix information, MN assumes itself to be connected to the same network, as before. MAG2 creates a PBU message, and transmits to LMA, by using the MN information received from the server. LMA receives a PBU message, believes that MN moves to the new network through the MN's ID information and the address information of MAG2, and changes the tunnel for MN to LMA-MAG2, from the existing LMA-MAG1. Since the path of MN via LMA and MAG2 is set, the messages that are delivered from the outside of the LMA are handled through the path.

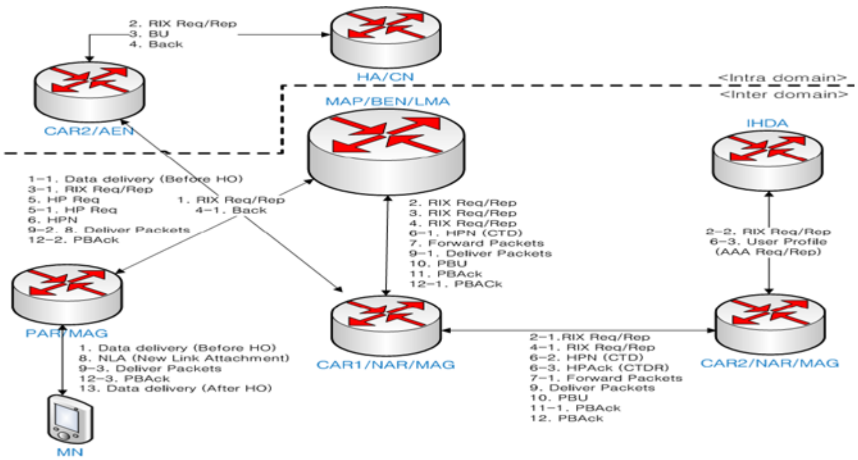

Figure 2. Signaling Process of the Inter/Intra domain

The proposed SePH by All-IP heterogeneous network searches AR and the network based on the messages between IHDA and the mobility of agents, reduces the use of limited radio resources to the minimum, to provide session tunneling through the patterns of the MN and the mobility of the session, and provides rapid mobility and secure transmission. The SePH's main purpose is to avoid the restart of signaling that is transmitted to MN from the start of handoff, to reduce the interruption of service. The MN decides whether to send an HDreq (Handoff Decision Request), depending on the generation of AT (Anticipated Trigger). The elements, such as High bit error rate, link outages (down phenomenon), security risks, financial costs and geographic location, are available as AT. Figure 2 describes the signaling process of the Inter/Intra domain. Figure 3 shows the signaling processing order, in the roaming within the MAP/BEN/LMA domain. Figure 4 shows the flows of the message order in the roaming within the MAP/BEN/LMA domain. On behalf of the MN, NAR/AEN performs BU procedure. The copied information in the AR/AEN cache is updated periodically, according to the original BU list of the MN.

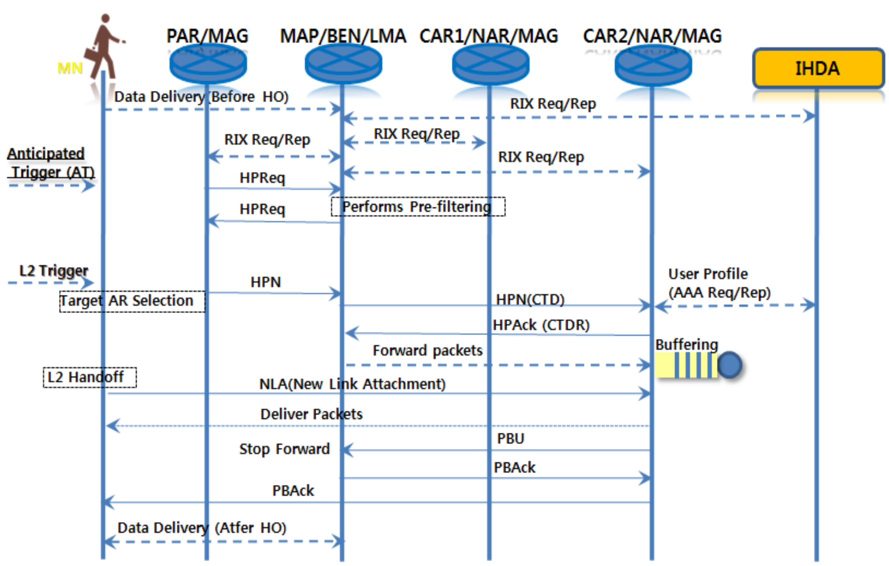

Figure 3. MAP/BEN/LMA Process in the Intra domain

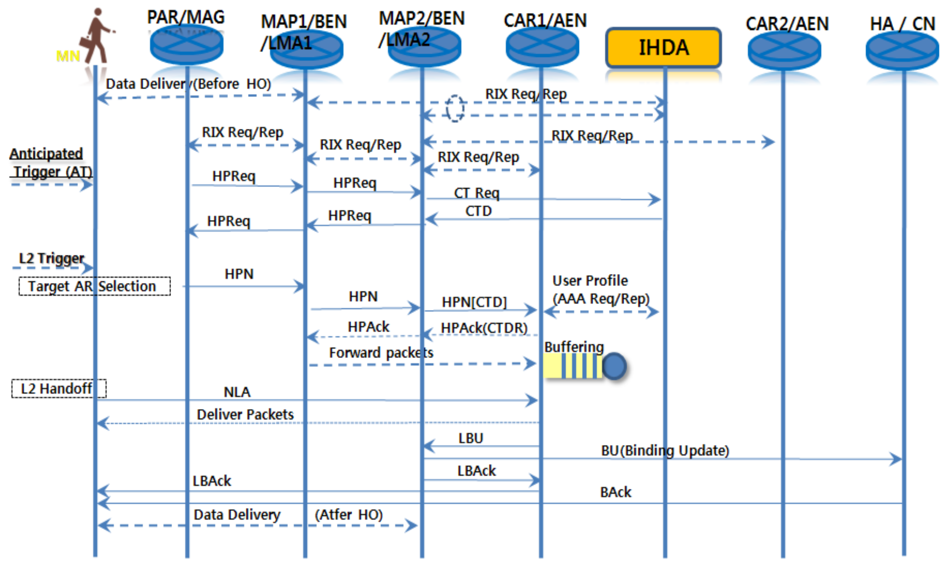

Figure 4. MAP/BEN/LMA Process in the Inter Domain

4. Performance Analysis

4.1. Cost Modeling

QoS in IP-based wireless networks can be defined by packet loss, handoff delay, and signaling overhead. The indicators required for performance analysis in this paper are listed in Table 1.

Table 1. Parameters for Performance Evaluation

Parameter	Description
t_s	Time between 2 consecutive sessions
t_c	Subnet (AR/AEN domain) retention time
t_d	MAP/BEN domain detention
C^g	Global BU cost for HA/CNs
C^l	Local BU cost MAP/BEN
N_{CN}	Number of CNs with BCE for MN
$d_{X,Y}$	Average absorption between node X and Y
$C_{X,Y}$	Control packet transfer cost between node X and Y
PC_X	BU processing cost at node X
P_s	Probability of successful AH signaling
S_s	AH signaling cost by success
S_f	Signaling cost where actual L3 handoff occurs
S_r	Reaction mode signaling cost

User mobility and traffic model are essential for efficient network system design and performance evaluation [13]. The mobility of MN is usually modeled by cell retention time, and various types of variables are randomly used for this purpose. Two mobility models are often used in wireless networks: the random walk model, and the fluid flow model [14, 15].

The performance analysis of wireless networks must consider the total signaling cost resulting from the mobility management method. There are two types of location or BU signaling in NGWN. One is generated when the subnet of MN moves, and the other is generated when the binding expires. There can be two types of BU, that is, global and local types, depending on the mobility type. The global BU occurs when MN moves out of its own MAP/BEN/LMA domains. When this happens, MN registers a new RCoA in HA and CN. On the other hand, if MN changes its current address in the MAP/BEN domain, you only need to register a new LCoA in MAP/BEN. Therefore, the average signaling cost of BU for the session time largely depends on the number of BUs, which is expressed as follows:

$$C_{BU} = E(N_l)C^l + E(N_d)\,nC^g = \frac{1}{SRM\sqrt{M}}\left[C^g + (\sqrt{M}-1)C^l\right]$$

where, SMR is the session-mobility ratio, which is the ratio of the session arrival rate to the user movement rate.

$$SMR = \lambda_s / \mu_c$$

AT and link layer information are used to predict or quickly respond to a (L2 trigger) handoff event. Therefore, the SePH signaling cost depends on the probability of accurate handoff forecasting. If there is no actual handoff after the L2 trigger, all the messages exchanged for handoff forecasting become useless. Therefore, the global/local BU signaling costs at SePH can be expressed as follows:

$$C^g = P_s S_s^g + (1-P_s)\left(S_f^g + S_r^g\right) + C_{ru}\,,\quad C^l = P_s S_s^l + (1-P_s)\left(S_f^l + S_r^l\right) + C_{mu}$$

As the number of lost packets is proportionate to the handoff delay, the value of the handoff delay expression will be determined in this section. The following parameters will be defined, to calculate the handoff delay and packet loss: t_{L2} is the L2 handoff delay, and $t_{x,y}$ is the unidirectional transfer delay for s messages between X and Y. If one of the end points is MN, $t_{x,y}$ can be determined by the following expression:

$$t_{x,y}(s) = \frac{1-q}{1+q}\left(\frac{s}{B_{\omega l}} + L_{\omega l}\right) + \left(d_{x,y}-1\right)\left(\frac{s}{B_{\omega}} + L_{\omega} + \omega_q\right)$$

In this expression, q is the probability of wireless link failure, and *1*-q is the average queueing delay for each router on the Internet. B_{wl} (B_w) is the bandwidth of wireless (wired) link, and L_{wl} (L_w) is the wireless (wired) link delay. The SePH handoff delay is determined by the available information, including the link at which handoff messages are exchanged quickly. The average handoff delay of SePH for MAP/BEN/LMA roaming is given as follows:

$$D^l_{HPAHN} = P_s O^l_{HPAHN} + (1-P_s)\,N^l_{HPAHN}$$

where, $D^l_{HPAHN} = t_{L2} + 2t_{MN,AEN}$ is the handoff delay, when information about NAR/AEN and the impending handoff can be used before the L2 handoff. Otherwise, the handoff delay is $N^{l}_{HPAHN} = t_{L2} + 2t_{MN,AEN} + 2t_{AEN,BEN}$, which is related to the reaction mode of HPAHN. For Inter-MAP/BEN, N^{g}_{HPAHN} is expressed as follows:

$$N^{g}_{HPAHN} = t_{L2} + 2t_{MN,AEN} + 2\left[t_{AEN,BEN} + t_{nBEN,pBEN}\right]$$

and, $O^{g}_{HPAHN} = O^{l}_{HPAHN}$ is true. However, unlike the theory, the handoff process varies only by the Intra-MAP/BEN/LMA communication delay, because the Inter-MAP/BEN/LMA signals are completed before the L2 handoff.

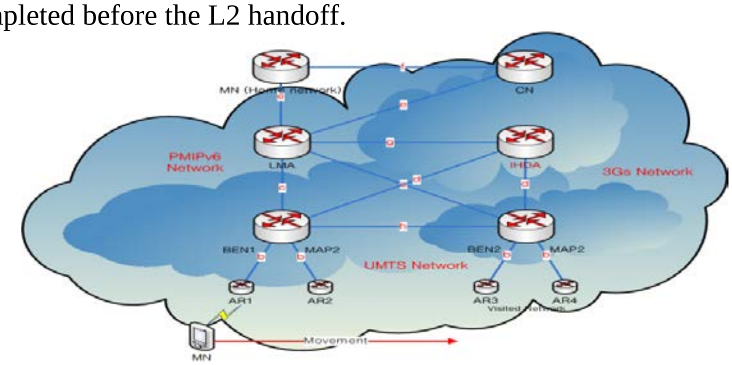

Figure 5. Heterogeneous Network Topology for Performance Evaluation

4.2 Numerical Results

It is assumed that the 3G/UMTS wireless network completely overlaps with the WLAN (*e.g.*, IEEE 802.11) network. For MN, as a higher weight was given to bandwidth and delay requirement, it was established that $\omega^{n}_{s,b} = \omega^{n}_{s,l} = 0.35$, and $\omega^{n}_{s,p} = 0.20$ for power consumption. As a lower weight was given to the use cost, it was established that $\omega^{n}_{s,b} = \omega^{n}_{s,l} = 0.35$ for every n, and $\alpha_i = 0.3$ was applied for every *i*.

The network topology that was considered during the analysis is presented in Figure 5. As it was assumed that the distances between different domain were identical, it was set as $c = e = f = h = 10$, $a = 1$, $b = 2$, and $d = g = 4$. All links must be full-duplex, for capacity and delay. The parameters used for signaling cost calculation were defined as follows:

$$M = 2, \tau = 1, \kappa = 10, PC_{AEN} = 8, PC_{HA} = 24, PC_{CN} = 4, PC_{IHDA} = 15, PC_{BEN} = 12$$

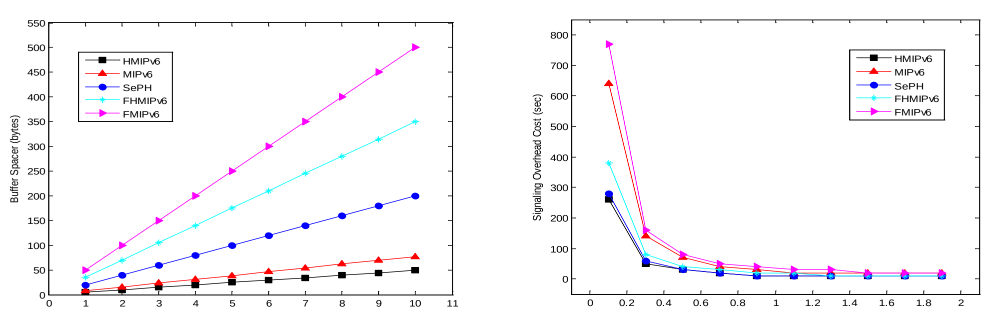

Figure 6. Required Buffer Space by Packet Arrival Rate (left) and BU Signaling Traffic Cost by SMR (right)

Figure 6 (left) shows that as the quick handoff method starts the (FMIPv6 and FHMIPv6) packing buffering and forwarding early, it requires more buffer space than MIPv6 and HMIPv6. This is because the buffer space required for one MN during the handoff process must be considered, and the required buffer space increases in proportion to the number of MN during handoff, as well as to the packet arrival rate. To reduce packet loss, the seamless handoff scheme must support packet buffering and forwarding during handoff [16-18]. This analysis considered the buffer space required for one MN during the handoff process. The required buffer space increases, along with the number of MN, during handoff, and in proportion to the packet arrival rate. Meanwhile, the buffering time may affect the real-time applications [19, 20].

Figure 6 (right) shows the signaling overhead cost during handoff as an SMR function. If SMR is small, the movement rate is greater than the session arrival rate. Then, MN changes the access point frequently due to mobility, and multiple handoffs occur, and signaling overhead increases. However, if the session arrival rate is greater than the movement rate (example: SMR>1) the BU performance count and the signaling overhead decrease. FMIPv6 uses wireless bandwidth more often than MIPv6, due to the additional message for handoff forecasting. To reduce the subnet residence time, the signaling overhead in SePH decreases considerably, compared to FMIPv6. Furthermore, if no notice is received from MN through the previous link, the reaction mode of F-HMIPv6 agrees with HMIPv6, and the exchanged messages in the router search step become unnecessary. However, this message exchange increases signaling overhead for F-HMIPv6, compared to SePH. Unlike SePH, more messages are exchanged in F-HMIPv6, after the generation of L2 trigger. The RIX message exchange calls additional signaling, similarly to the routing information protocol (RIP). However, signaling increases only in the wired section of the network. Compared to the wireless section, the wired section has much greater bandwidth and resources.

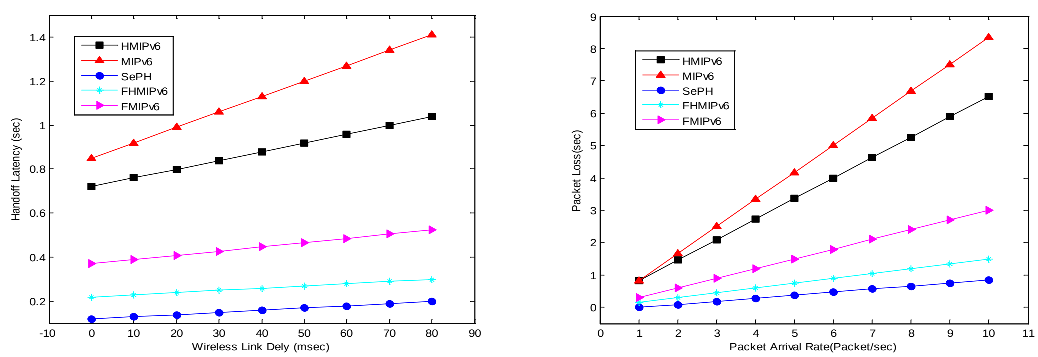

Figure 7. Handoff Delay by Wireless Link Delay (left) and Packet Loss by Packet Arrival Rate (right)

Figure 7 (left) shows that the handoff delay increases in proportion to the wireless link delay. Among all the protocols, the lowest results were obtained from MIPv6 and HMIPv6, followed by FMIPv6 and F-HMIPv6. The delay was the lowest in SePH. F-HMIPv6 has not solved the synchronization problem mentioned above, and causes increased delay and packet loss. SePH solved this problem, and showed a lower delay than F-HMIPv6. It is well known that the maximum allowable delay for bidirectional dialogue is about 200 *ms*. Therefore, if the wireless link delay is set to 50ms or lower, SePH meets this requirement.

As the packet loss is proportionate to the handoff delay, similar results and actions are observed. Figure 7 (right) shows the packet arrival rate for packet loss. The packet loss in much lower in the quick handoff method, than in MIPv6 or HMIPv6. SePH shows lower packet loss than other protocols. If there is no buffering, and handoff is performed in HMPv6 or HMIPv6 due to the forecast handoff method, all packets will be lost. However, in the quick handoff methods (FMIPv6, FHMIPv6 and SePH), packet loss begins from the moment when the L2 handoff is discovered, until the buffering method starts, or from the moment when the buffer overflows. This time gap is shorter in SePH than in FHMIPv6, because it has the ability to solve the synchronization problem. Furthermore, when MN adds a new link in SePH, a packet that has changed direction waits in NAR/AEN.

5. Conclusion

This paper proposes SePH, proxy-based seamless handoff technology, for mobility management protocol in a heterogeneous network, in order to provide better network performance in the PMIPv6-based heterogeneous wireless environment. The proposed SePH protocol uses the IHDA algorithm, based on score functions. The purpose of IHDA is to ensure seamless roaming, service continuity, and reduce service disruption for handoff required in 3G/4G/NGWN. The outcome of the proposed protocol's performance evaluation reveals that SePH has greater performance than existing protocols in terms of handoff delay time, throughput, packet loss rate, and other costs.

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