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Determination of Average Handover Latency in Bi-Directional Tunneling Method in MIPv6 Networks

***Abstract**. Mobile IP allows for a Mobile Node to remain reachable during handover to a new foreign network. When an mobile node moves to a new network, it will be unreachable for a period of time. This period is referred to as handover latency. In general, it is caused by the time used to discover a new network. This period of time for real-time applications, such as video coference and VOIP, which are time sensitive should be very short. IP mobility must be able to support performance in terms of initializing the handover as well as smoothing the process. In this paper, we evaluate handover latency based on highest probability of the latency in mobile Internet protocol verson 6 networks when mobile and correspondence nodes are using bi-directional tunneling over mobile IPv6 networks through simulation.*

***Streszczenie.** W artykule omówiono zagadnienie opóźnienia przejścia sygnału użytkownika między dwoma sieciami komórkowymi, w przypadku wyjścia z zasięgu jednej z nich. W oparciu o symulacje wykonano szacowane obliczenia opóźnienia przekazania sygnału, w oparciu o czynnik największego prawdopodobieństwo opóźnienia w sieci mobilnego internetu o protokole w wersji 6. Badanie przeprowadzono dla przypadku obustronnego tunelowania dwukierunkowego w sieci mobilnej IPv6. (**Wyznaczanie średniego opóźnienia przekazania sygnału w sieci MIPv6 o tunelowaniu dwukierunkowym**).*

Keywords: Mobile IPv6, Handover latency, Bi-directional tunneling, End-to-end delay.
Słowa kluczowe: sieć IPv6, opóźnienie przekazania, tunelowanie dwukierunkowe, opóźnienie end-to-end.

Introduction

Mobile Internet [1] is a standard protocol that allows mobile users to maintain non stop connectivity with their home IP addresses regardless of their physical movement. Mobile node (MN) has two IP addresses in Mobile IP networks. One is the home address, which is indicated as the home network address of the mobile node, and another is the care-of-address (CoA). A home address is a permanent address and each correspondence node (CN) needs this address for communication to the MN, while, CoA is a temporary address. Whenever the MN moves to a new network, it acquires a CoA that indicates the current location of the MN in a foreign network. In mobile IPv4, the foreign agent, which is a router in a foreign network, is responsible to assign a CoA to the MN and also assist the MN to detect whether it has left the foreign network or not. In mobile IPv6, movement detection is done by the IPv6 neighbor discovery protocol [2]. IPv6 neighbor discovery protocol enables an MN to discover its current location in a foreign network. Using IPv6 neighbor discovery protocol [3,4], an IPv6 router broadcasts a router advertisement message to the MN on that network. These messages carry the IPv6 address of the router and network prefix. This message helps the MN to detect whether it has moved out from the current foreign network to another, or whether an IPv6 router is still reachable. The MN combines the network prefix of the router advertisement message with the mobile's own hardware address to configure its CoA. The MN in mobile IPv6 can acquire its CoA by using a stateless address auto-configuration or by stateful protocols, such as DHCPv6 [5]. The MN should register this address in the Home Agent (HA) to maintain its connections to the sender(s). A HA is a router in a home network, which is responsible for sending and receiving packets between MN(s) and CN(s). When the HA receives a new CoA, it updates its binding cache. Therefore, when a CN sends a packet to a home address of an MN, the HA receives it and searches its binding cache [6] to find a record of the indicated home address in the packet and then sends the packet to the current location of the MN. Once the MN decides to undergo handover and move from its home agent, it delivers the packets via a tunnel (in bi-directional tunneling method).

The main problem with handovers is the time-span in which an MN is not able to receive packets for a period of time when roaming to another access router. During this time, the mobile node obtains a new CoA and updates its past communications [5]. This period of time can be higher than the threshold for the support of real-time services [7].

Some proposals on hierarchical management network protocols such as Hierarchical Mobile IPv6 (HMIPv6) [8], and fast handover protocols such as Fast Mobile IPv6 (FMIPv6) [9] also try to reduce handover latency in mobile IPv6 networks. Beside, a fast vertical handover scheme (FVHMIPv6) [10] has been proposed for mobility in heterogeneous wireless networks and to reduce vertical handover latency in heterogeneous networks. The author has analyzed the handover latency of mobile IPv6 over wireless LAN in [11], and compared the layer 2 delays with layer 3 delays. He has proved that handover latency could be considerably reduced by using the anticipation of link layer trigger.

Thus, the focus of our research paper is to conduct an in-depth study on the effect of handover on end-to-end delay when MN and CN use bi-directional tunneling [12,16] method for routing packets over Mobile IPv6. We simulate end-to-end delay, average end-to-end delay, and traffic received when MN moves through a defined trajectory between different foreign networks and evaluates handover latency. The rest of the paper is organized as follows. In the next section, a mathematical model for computing handover latency in mobile IPv6 networks is presented. Then, we describe method used for our approach. This is followed by a discussion and simulation results. A summary concludes the paper.

Mathematical Modelling

The handover latency ($L_{Latency}$) is the period of time in which the MN gets out from the range of current network until it receives a router advertisement message [13] from a new available network. In this section, the calculation of the average value of handover latency ($L_{Latency}$) [14,15] is presented. We assumed that variables C_{time} and R are random and dependent. The joint density function of C_{time}, R expressed as

$$P_{C_{time},R}(C_{time}, r) = P_{C_{time}|R}(C_{time} \mid r).P_R(r) \tag{1}$$

where $P_{C_{time}|R}(C_{time} \mid r)$ is the probability distribution for

C_{time} given R . C_{time} is distributed in the interval $[0,R]$. Also, R is the first router advertisement received after C_{time}. The probability distribution $P_{C_{time}|R}(C_{time}\mid r)$ can be calculated as

$$P_{C_{time}|R}(C_{time}\mid r)=\frac{1}{r}.1_{C_{time}} \tag{2}$$

The density function $P_R(r)$ illustrates the probability of C_{time} occurring in an interval of size $R=r$. The density function $P_R(r)$ is obtained as $f(r)$.

$$P_R(r)=\frac{r}{\int_{R_{\min}}^{R_{\max}}\frac{r}{rdr}}.1_r \qquad r\in[R_{\max},R_{\min}] \tag{3}$$

By solving this integral, we have

$$P_R(r)=\frac{2r}{R_{\max}^2-R_{\min}^2}.1_r \qquad r\in[R_{\max},R_{\min}] \tag{4}$$

By combining (3) in (1), we have

$$P_{C_{time},R}(C_{time},r)=\frac{2}{R_{\max}^2-R_{\min}^2}.1_{C_{time}}.1_r \qquad C_{time}\in[0,r], r\in[R_{\max},R_{\min}] \tag{5}$$

The density function $P_{L_{latency}}(l)$ can be obtained [14] using the following integral:

$$P_{L_{latency}}(l)=\int_{-\infty}^{\infty}P_{C_{time},R}(C_{time},C_{time}+l)dc_{time} \tag{6}$$

Finally, the highest probability of the obtained handover latency is found to be in the range of $[0,R_{\min}]$.

Method

We consider a Mobile IPv6 scenario to study the effect of handover on end-to-end delay (Figure 1). Simulation results are conducted using OPNET IT Guru which consists of one MN, one CN, one HA, three access routers in various foreign networks, and two intermediate routers that interconnect the MN to the server. In this scenario, the MN runs a video-conference application, which is located in its home network at the starting time. This node travels along the defined trajectory from three departments, such as "Physic, Science, and Mathematics" and then come back to its home network, which is the Computer department. The MN's average speed is considered to be10km/h.

Results

Figure 2 shows the results of layer-2 connectivity between the MN and connected routers in the home and foreign networks. The Base Station Subsystem (BSS) ID numbers reflected within the graph identify that the MN is connected to the access routers in the mobile IPv6 network. The value of -1 indicates the MN losing connectivity with an agent. As the MN follows the trajectory, it establishes layer-2 connectivity with all the access routers. When the MN moves out of the home network, it loses connectivity with the home agent (BSS ID=0) at 8 minutes and connects to access router_1, i.e., Physics Department (BSS ID=1). Disconnection occurs again at approximately 17 minutes when the MN leaves the access router_1 and enters access router_2, i.e., Science Department. Connection with access router_2 is lost at approximately 32 minutes when it roams to access router_3. Ultimately, the MN loses agent connectivity upon leaving access router_3, i.e., Mathematics Department at 42 minutes.

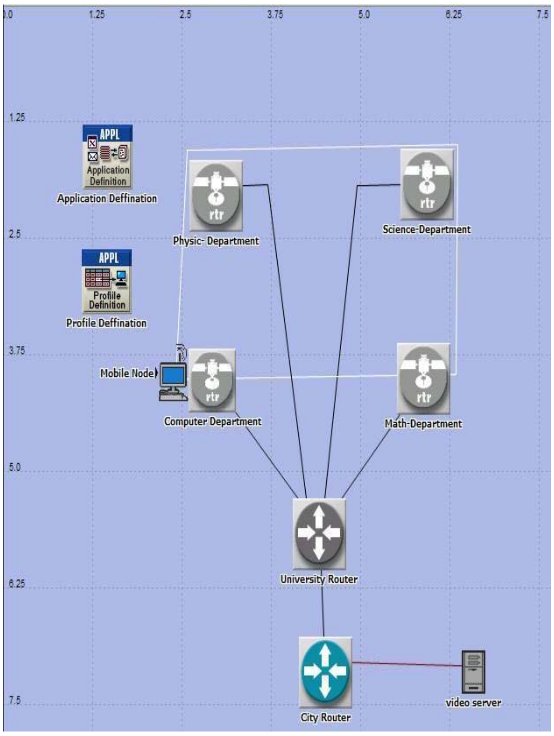

Fig. 1. Simulation Topology

Figures 3 and 4 illustrate the IP traffic sent/received and tunneled traffic sent and received during the periods of 50 minutes (packets / second). When the MN is inside its home network, as it uses the IP protocol for communication, it does not need to receive CN packets via the tunnel. However, when the MN travels through the access router in foreign networks, it sends and receives traffic via the established tunnel. There are gaps between the traffic received, as shown in Figure 3, and tunneled traffic received, as shown in Figure 4. These gaps, called handover latency [17], indicate that MN is roaming between various foreign routers and is not able to receive traffic upon leaving access router_1 and entering access router_2 at 8 minutes.

The end-to-end packet delay is depicted in Figure 5. In the simulation results, packet loss begins at approximately 8 minutes, when the MN moves out of the home network and loses connection with the HA and resumes again at approximately 9 minutes. Packet flow resumes when the MN successfully registers its current location in the access router_1. Figure 5 indicates a gap between 18 and 32 minutes when the MN roams between access routers_1, 2, and 3. Packet loss occurs again at approximately 42 minutes when the MN leaves access router_3 and enters its home network. Packet flow resumes again at approximately 43 minutes.

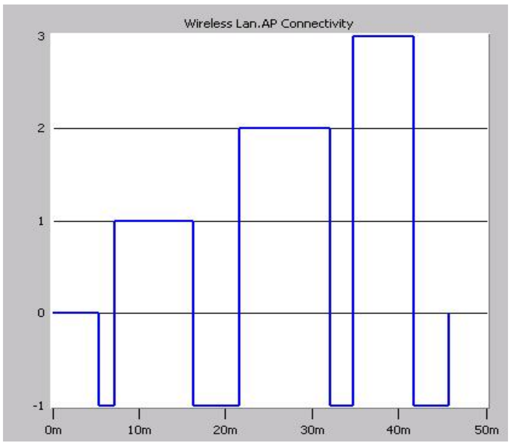

Fig. 2. Access Router Connectivity

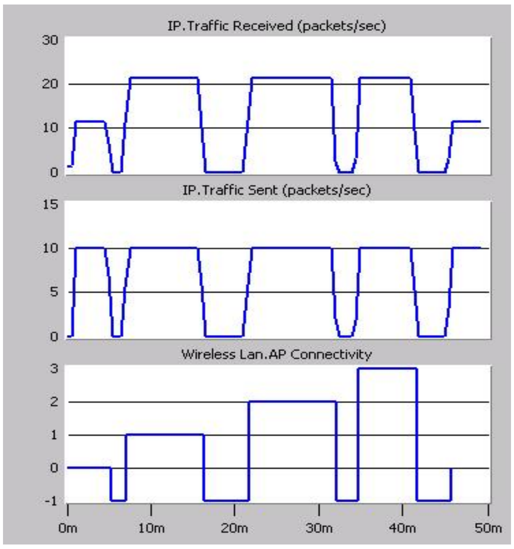

Fig. 3. IP Traffic Received (Bits/Seconds)

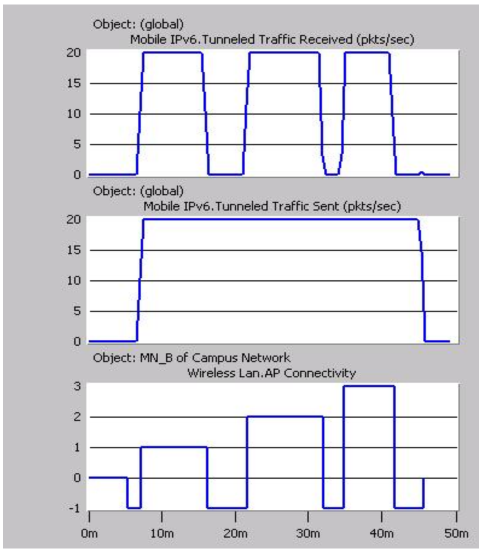

Fig. 4. Mobile IPv6 Tunneled Traffic Sent/Received (packets/seconds)

When the MN is in the home network, the minimum end-to-end delay is much smaller than that in the foreign networks. The main reason for this is that the MN does not use mobile IPv6 protocol when it resides in the home network and it uses the IP protocol [18] to communicate with the CN. When the MN moves to foreign networks, it utilizes the Mobile IPv6 protocol. It thus needs to register its CoA in the HA and send/receive packets via a tunnel, as shown in Figure 6. Figure 6 shows that the end-to-end delay increases along the time according to MN movement to foreign networks, while, at 42 minutes, the end-to-end delay drops mainly because the MN comes back to its home network.

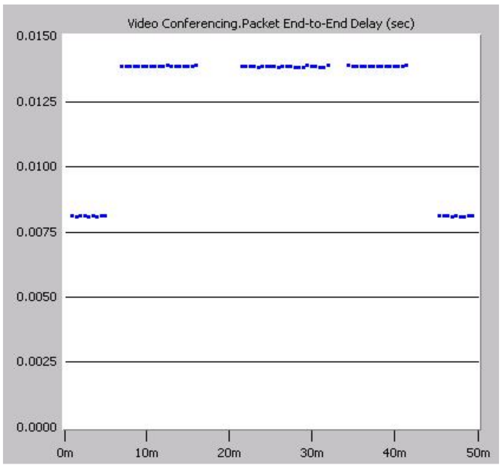

Fig. 5. End-to-End Delay

Conclusion

In this paper, we have evaluated handover based on highest probability of the latency. Through simulation, we have characterized the important metrics that should be considered for examining the handover performance within mobile networks, such as handover counting, handover rate, and handover probability. When several networks are candidates to serve as a target for a handover, the one that provides most bandwidth and the most stable connection would be the first choice. Our contribution in this paper can be summarized as follows: i) The effect of handover on end-to-end delay when MNs and CNs use bi-directional tunneling has been studies. ii) Besides, comparison of the average end-to-end delay and traffic received for an MN during handover to a new foreign network via a defined trajectory has been made.

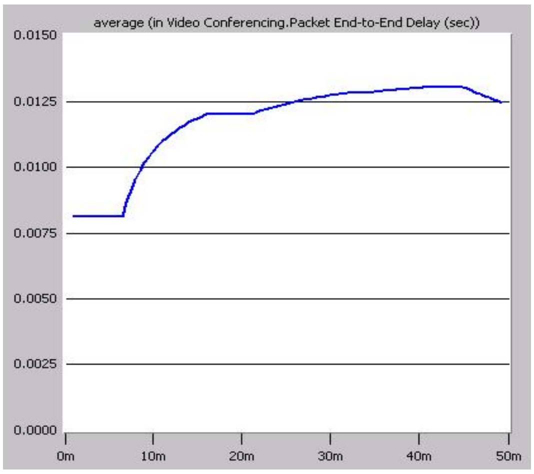

Fig. 6. Average End-to-End Delay

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