A Study of Performance Enhancement in Hierarchical Mobile IPv6 using Fast-Handoff

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Abstract

The combination of Fast-Handoff and Hierarchical Mobile IPv6 (F-HMIPv6) allows the anticipation of the layer3 handoff such that data traffic can be efficiently redirected to the mobile node's new location before it moves there. However, after moving to the new Access Router (NAR), if the mobile node (MN) sends the Local Binding Update (LBU) to the Mobility Anchor Point (MAP) before receiving all of the buffered packet from the NAR, the MN may receive the general packet from the MAP. That is, the MN may simultaneously receive two types of packet which has different sequence number. These cause the confusion in packet order, and the MN sends the dup ack for the packet retransmission to the CN. It results in the degradation of the TCP performance. Therefore, we propose the scheme for minimizing the out-of-sequence packet in F-HMIPv6.

1. Introduction

In Internet environments, when a host moves and attaches itself to another network, it needs to obtain a new IP address. With this change of IP address, all existing connections to the mobile host terminates, as the IP routing mechanisms cannot deliver the data to the correct end-point. Mobile IPv4 [1] overcomes this by introducing a level of indirection at the network (IP) layer. It deploys a home agent that intercepts packets from the correspondent host and redirects these packets by tunneling them to the mobile node. This approach ensures correspondent host transparency and only requires the mobile node to update its location to the home agent when changing in between networks. However, initiating this indirection requires a timely home network registration process and an address resolution procedure. These have been shown to result in long handoff latencies. Handoff latency results in packet losses and severe End-to-End TCP performance degradation as TCP, perceiving these losses as congestion, causes source retransmission.

Two ways of overcoming these problems are to use a hierarchical architecture [3], and to apply a technique known as Fast-Handoff [4]. Hierarchical schemes reduce handoff latency by employing a hierarchical network structure in minimizing the location update signaling with external networks. It separates micro from macro mobility, by receiving packets on behalf of the mobile node that it is serving. Thus, when a host moves within a single domain, only location update to the MAP is necessary. This minimizes latency due to handoff between access routers by enabling the mobile node to perform only one Local Binding Update, i.e., MAP binding update (BU).

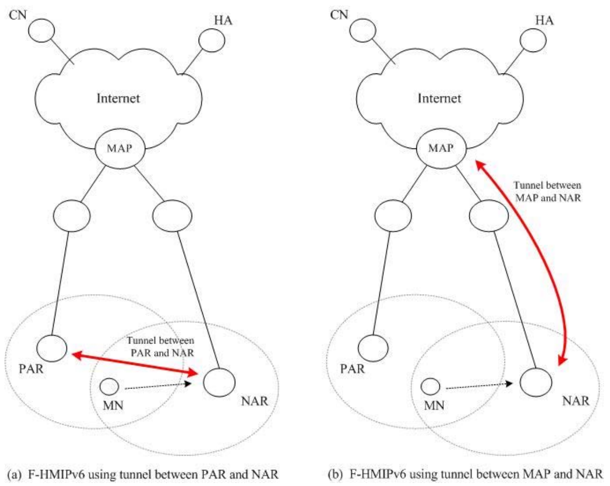
Fast-Handoff schemes reduce the handoff latency by allowing the mobile node to pre-configure a new Care-of-Address (CoA) before it moves to a new access network. IETF draft proposals [3] and [4] have incorporated these concepts of the hierarchical framework and Fast-Handoff mechanism into the IPv6 network.

The contribution of this paper is how to use Fast-Handoff over HMIPv6 (F-HMIPv6) so as to provide better handoff performance. We propose the scheme for minimizing out-of-sequence packets and handoff latency during handover.

2. Hierarchical Mobile IPv6 using Fast-Handoff

2.1 F-HMIPv6 Architecture

There are two kinds of integrating the HMIPv6 and Fast-Handoff mechanism. Figure 1 shows the two scenario of integrating the HMIPv6 and Fast-Handoff.



(Figure 1) F-HMIPv6 Architecture

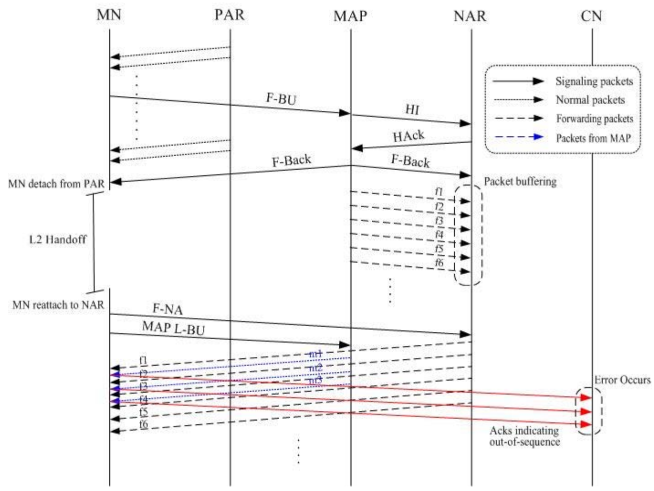
The first scenario involves placing MAPs in place of the ARs which is a natural step (Figure 1a). This specifies forwarding of packets between previous Access Router (PAR) and new Access Router (NAR). However, this could be inefficient in terms of delay, bandwidth efficiency since packets will traverse the MAP-PAR link twice and packets arriving out of order at the mobile node. The second scenario involves placing the MAP in an aggregation router above the ARs (Figure 1b). Using the MAP in the aggregation router would improve the efficiency of fast handoff which could make use of the MAP to redirect traffic, thus saving delay and bandwidth between the aggregation router and the PAR. Therefore, in this paper, we use the F-HMIPv6 architecture in Figure 1b.

2.2 Out-of-Sequence Packet in F-HMIPv6

Before handoff, according to the HMIPv6 operations, the data packets sent by the CN are tunneled by MAP to MN with the following IP fields :

- Inner IP header :
  <Source = CN, Destination : RCoA of MN>
- Outer IP header :
  <Source = MAP, Destination : old LCoA of MN>

When the F-HMIPv6 handoff is triggered, the MAP will establish a bi-directional tunnel with the NAR, and then begin to forward the data packets to the NAR over the tunnel. By the tunnel, each data packet has an additional outer IP header <Source = MAP, Destination = NAR> to the normal HMIPv6 headers.



(Figure 2) Out-of-Sequence Packet in F-HMIPv6

When receiving the tunneled data packets from the MAP, the NAR will decapsulate them and then be caching the decapsulated data packets. When the MN moves into the NAR region, the NAR will deliver the cached data packets to the MN using the Fast Neighbor Advertisement (F-NA) message, as done in FMIPv6. At this time, if the MN sends the Local Binding Update (LBU) message to the MAP before receiving all of the buffered packet from the NAR, the MN may receive the general packet from the MAP, namely outer IP header <Source=MAP, Destination =new LCoA of MN>. That is, as shown in Figure 2, the MN may simultaneously receive two types of packet which has different sequence number. These cause the confusion in packet order, and the MN sends the duplication acknowledgements (dup acks) for the packet retransmission to the CN. These dup acks degrade the TCP performance.

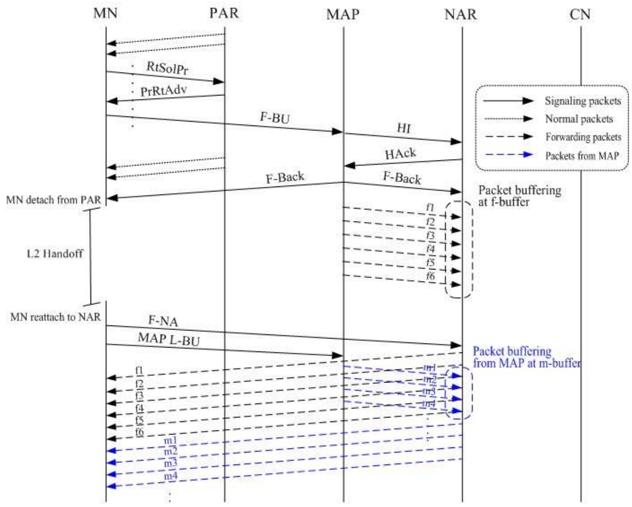
3. Proposed Scheme for F-HMIPv6

As examined in section 2.2, the combination of Fast-Handoff and HMIPv6 causes packet sequence disruption between the new directly delivered packets and rerouted packets. These out-of-sequence packets bring in several unwanted effects. For TCP congestion control, they create dup acks and invoke unnecessary packet retransmissions.

To solve the problems described in section 2.2, we use the dual-buffer at the NAR. The NAR maintains two types of buffer, named f-buffer and m-buffer. The f-buffer will contain packets forwarded through the tunnel which is made by Fast-Handoff procedure. To distinguish with the buffered packet in m-buffer, these forwarded packets will be marked with the flag bit in IP header. The m-buffer will contain general packets delivered from MAP to NAR when the MN sends the Local Binding Update (LBU) message to the MAP after attaching at the NAR region. Therefore, upon reception of the F-NA message from the MN, the NAR will start emptying the m-buffer after completely transmitting the buffered packet in f-buffer.

Figure 3 illustrates the flow of the proposed scheme for F-HMIPv6. Based on L2 handoff anticipation, the MN sends Router Solicitation for Proxy (RtSolPr) to the PAR. In response to the RtSolPr, the PAR sends the Proxy Router Advertisement (PrRtAdv) to the MN, which contains information such as the NAR's network prefix. The MN sends Fast Binding Update (F-BU) to the MAP. After receiving the F-BU from the MN, the MAP will sends Handoff Initiate (HI) to the NAR so as to establish bi-directional tunnel.

The MAP sends Fast Binding Ack (F-BAck) toward the MN over previous LCoA and new LCoA. Then, the MAP will begin to forward the data packets destined to the MN to the NAR by using the established tunnel. The NAR stores these forwarded packets in f-buffer.



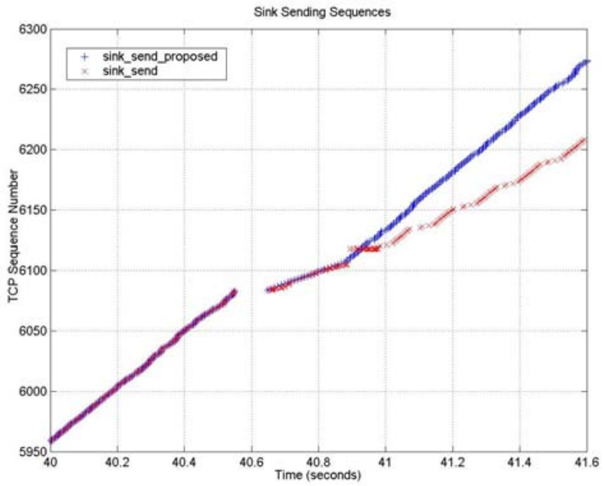
(Figure 3) Proposed Scheme for F-HMIPv6

After attaching to the NAR region, the MN sends a Fast Neighbor Advertisement (F-NA) to the NAR to receive the buffered packet in f-buffer. The MN then follows the normal HMIPv6 operation by sending a LBU to the MAP. By doing so, the MAP delivers the packet to the NAR. As shown in Figure 3, the NAR stores the packets of sequence numbers from m1 to m4 into the m-buffer. To avoid out-of-sequence packet, the NAR starts emptying the m-buffer after completely transmitting the buffered packet in f-buffer.

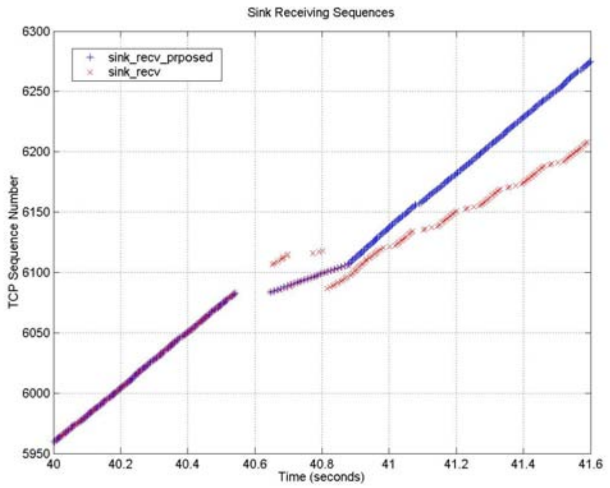
4. Simulation and Performance Evaluation

4.1 Simulation Environment

The Network Simulator, ns-2 was used for the evaluation of the HMIPv6 with Fast-Handoff mechanism. The standard ns distribution was patched with the freely available ns wireless extension module. This was further extended with our implementation of the MAP, the AR entity, the Mobile IPv6 binding mechanism, as well as protocols for the hierarchical management and the Fast-Handoff mechanism. A ns TCP source agent is attached to the Corresponding Node (CN) and a ns TCP sink agent is attached at the Mobile Node (MN).



(Figure 4) sink_send(ack) from MN's perspective



(Figure 5) sink_recv(data) from MN's perspective

The TCP Tahao, which follows a 'go back-n model using accumulative positive acknowledgement with slow start, congestion control avoidance and fast retransmission' model, was chosen as the default TCP.

4.2 Simulation Analysis

Figure 4, 5 shows the detail of handoff from the TCP receiver's(sink) perspective. The receiver's receiving sequences are denoted by the sink_recv(data) curve while the sending sequences are denoted by the sink_send(ack) curve. At t=40.54s to t=40.64s, the L2 handoff occurs as indicated by the sink_recv and sink_send curves.

As shown in Figure 5, the F-HMIPv6 having only one buffer at the NAR receives simultaneously two types of packet at t=40.64s, namely delivered packets from the MAP and buffered packet at the NAR. Therefore, the MN sends the dup acks for packet retransmission. However, in case proposed F-HMIPv6, namely the NAR that has two buffer (f-buffer, m-buffer), the MN receives completely the buffered packets in f-buffer , and then receives the buffered packets in m-buffer. There are no packet retransmission. As can be seen from the sink_send and sink_recv curves in Figure 4, 5, the proposed F-HMIPv6 performs well, considering the overall handoff latency and TCP performance.

5. Conclusion

This paper presented the combination of fast handoff and HMIPv6. The F-HMIPv6 causes packet sequence disruption between the new directly delivered packet and rerouted packets. We proposed in this paper how to use Fast-Handoff over HMIPv6 networks so as to provide better handoff performance. Also, we presented the scheme for minimizing out-of-sequence packets and handoff latency during handover. We have shown through the simulation that proposed scheme for F-HMIPv6 is capable of minimizing out-of-sequence packets and handoff latency.

Reference

[1] C. Perkins, "IP mobility support", RFC2002, IETF, October 1996

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