An Approach to Reliable and Efficient Routing Scheme for TCP Performance Enhancement in Mobile IPv6 Networks

Byungjoo Park[1], Youn-Hee Han[2], and Haniph Latchman[1]

[1] Department of Electrical and Computer Engineering,
University of Florida, Gainesville, USA
{pbj0625, latchman}@ufl.edu
[2] School of Internet-Media, Korea University of Technology and Education,
Cheonan-Si, Chungnam, 330-708, Korea
yhhan@kut.ac.kr

Abstract. In Mobile IPv6, the handover process reveals numerous problems manifested by movement detection, non-optimized time sequencing of handover procedures, latency in configuring a new care of address and binding update to a home agent (HA). These problems may cause packet loss as well as packet disruption. To mitigate such effects, Fast handover for Mobile IPv6 (FMIPv6) has been developed. FMIPv6 can reduce a packet loss using tunnel based handover mechanism which relies on L2 triggers such as transmitting a packet from a previous access router (PAR) to a new access router (NAR). However, this mechanism may result in decreasing the performance of TCP due to the out-of-sequence packets between tunneling packet from the Home Agent, PAR and directly transmitted packet from the correspondent node (CN). In this paper, we propose a new scheme called EF-MIPv6 to prevent packet reordering problem using new snoop mechanism (NS). This new scheme can prevent a sequence reordering of data packet using proposed "MSAD" controlling. Simulation results demonstrate that managing the packet sequence in our proposed scheme greatly increases the overall TCP performance in Mobile IPv6 network.

1 Introduction

Mobile IPv6 is designed to manage the movement of mobile nodes (MNs) between wireless IPv6 networks [1]. This protocol supports transparency above the IP layer, including the maintenance of TCP connections. However, TCP error control is focused on congestion losses and does not distinguish the possibility of temporary time delays due to handovers in wireless, mobile environments. Packet losses during handovers are treated as an indication of network congestion, which causes TCP to take some unnecessary congestion avoiding measures [2].

In MIPv6, to perform packet transmission continuously without disconnection of the layer 3, a mobile node maintains a home IP address (HoA) for identification

F. Stajano et al. (Eds.): ICUCT 2006, LNCS 4412, pp. 160–169, 2007.

and a temporal IP address for routing information. When an MN moves to a new subnet it should disconnect with the current access router and connect with the new access router; in addition, the MN should obtain a new temporal address called care-of address (CoA). Next, the MN should register the binding between its new CoA (NCoA) and HoA with it's home agent (HA) and CNs. We also need to know the handover latency, which is collectively defined as the delay incurred during movement detection, the new CoA configuration time, and the binding update time required to start internet service from the new subnet network. During a handover, the packets transmitted from an HA or CN may be lost. Recent work has been aimed at improving the handover performance of Mobile IPv6 in order to support real time and other delay sensitive traffic. a few trials have been developed to solve this problem such as Smooth handover by Route Optimization in Mobile IP [3], Fast Handover for Mobile IPv6 [4], Design and Analysis of the mobile agent preventing out of sequence packets [5], performance improvement by packet buffering [6], and reducing out-of-sequence packets using priority scheduling [7]. Also, the snoop mechanism [9] is designed to improve the performance of TCP while recovering wireless errors locally. The snoop mechanism introduces a module, called snoop agent, at the base station (BS). The agent monitors every packet that passes through the TCP connection in both directions and maintains a cache of TCP packets sent across the link that have not yet been acknowledged by the receiver. The main problem with TCP performance in networks with both wired and wireless links is that packet losses ,which occur because of bit-errors, are mistaken by the TCP sender as being due to network congestion.

We propose an efficient TCP mechanism in FMIPv6 to prevent the misordering problem of packets during a handover using new snoop (NS) mechanism based enhanced fast binding update (EF-BU) message [8]. This is accomplished by adding a new reordering scheme to the base station connected to the NAR and by adding a modified TCP header format at the source device, such as an HA and CN. These functions are performed by two new proposed main routines: NS mechanism for data called *"MSAD"* and the enhanced fast biding update (EF-BU) message procedure. Some modifications that are explained in Section 3 are required to compare the sequence of data packets in the base station and to indicate the arrival of the final packet from the previous access router. The remainder of this paper is organized as follows. We will describe FMIPv6 protocol in Section 2. Section 3 introduces our proposed reordering algorithm (EF-MIPv6) to increase the performance of TCP. The performance evaluations are shown in Section 4. Finally, we present the conclusions in Section 5.

2 Fast Handover for MIPv6 (FMIPv6)

The basic operation of FMIPv6 [4] is depicted in Fig. 1. While an MN is connected to its PAR and is about to move to an NAR, FMIPv6 requires that the MN obtains a new CoA at the NAR while still connected to the PAR.

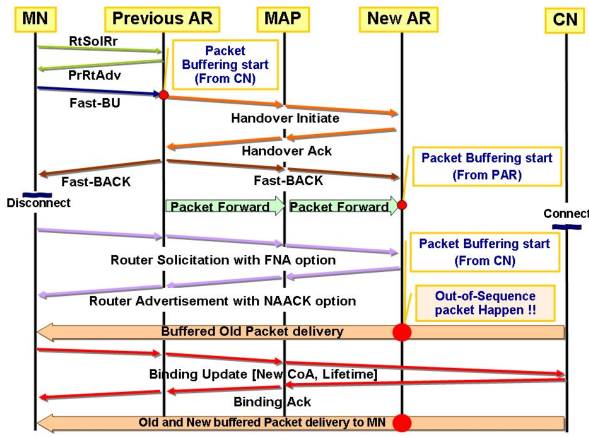

Fig. 1. IETF FMIPv6 Handover Procedure

Furthermore, the MN must send a Binding Update message to its PAR to update its binding cache with the MN's new CoA, and finally the PAR must start forwarding packets, originally destined for the MN, to the NAR.

Either the MN or the PAR may initiate the Fast Handover procedure by using the L2 trigger. The link-layer information indicates that the MN is moving from the current access point (AP) to another; that is, from the PAR to the NAR. If the L2 trigger is received at the MN (Mobile-initiated handover), the MN will initiate an L3 handover by sending a Router Solicitation for Proxy (RtSoPr) message to the PAR. On the other hand, if the L2 trigger is received at the PAR (Network-controlled handover), then the PAR will transmit a Proxy Router Advertisement (PrRtAdv) message to the appropriate MN, without any solicitation message.

The MN obtains a new CoA (NCoA) while still connected to the PAR by means of router advertisements containing network information from the NAR. The PAR validates the MN's new CoA and initiates the process of establishing a bidirectional tunnel between the PAR and the NAR by sending a Handover Initiate (HI) message to the NAR. Then, the NAR verifies that its new CoA can be used on the NAR's link. Also, in response to the HA message, the NAR sets up a host route for the MN's previous CoA (PCoA) and responds with a Handover Acknowledge (HACK) message.

When the MN receives a PrRtAdv message, it should send a Fast Binding Update (F-BU) message, preferably prior to disconnecting its link. When the PAR receives an FBU message, it must verify that the requested handover is accepted by the NAR as indicated in the HACK message status code. Then, the PAR begins forwarding packets intended for the PCoA to the NAR and sends a Fast Binding Acknowledgement (F-BACK) message to the MN. After changing link connectivity with the NAR, the MN and NAR exchange a Router Solicitation (RS)

Message including the Fast neighbor Advertisement (FNA) option and a Router Advertisement message (RA) with the Neighbor Advertisement Acknowledgment (NAACK) option. After the NAR sends a Router Advertisement message with the NAACK option, it starts to deliver buffered packets tunneled from the PAR and buffered packets from the CN directly. Until the CN receives a BU, the packets sent from the CN are tunneled from the PAR to the NAR. After the CN receives a BU, the CN directly delivers the packets to the MN. Consequently, if the distance between the CN and NAR is shorter than the tunneled distance from the CN to the NAR via the PAR, the MN may receive out-of-sequence packets. Fig. 2 shows the out-of-sequence packet problem.

After the PAR receives an F-BU message, packets four through eight are tunneled from the PAR to the NAR and buffered until the NAR receives an RS message with FNA from the MN. When the CN receives a BU from the MN, the CN sends packet nine to ten directly to the NAR. These packets are also buffered in the NAR until the NAR sends an RA with NAACK option to the MN.

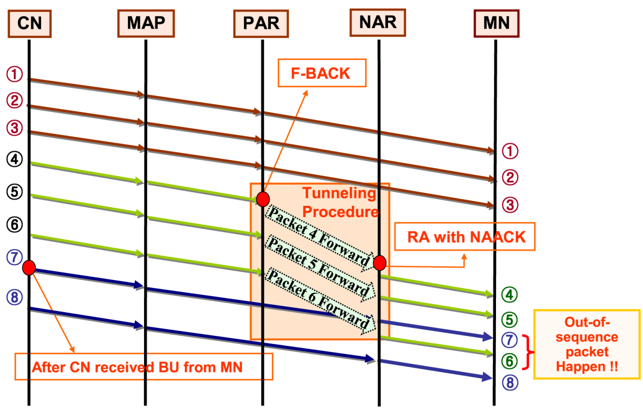

Fig. 2. Out-of-sequence packets in FMIPv6

Consequently, if the distance between the CN and NAR is shorter than the tunneled distance from the CN to the NAR via the PAR, buffered packets in the NAR would be out of sequence due to the packet delay time incurred by tunneling. So when an MN receives mis-ordered packets, the use of TCP in the MN creates a duplicate ACK (DACK) for packets seven and eight in accordance with its congestion control procedure.

3 Reliable and Enhanced Reordering Algorithm (EF-MIPv6)

In this section, we propose a new reordering algorithm to improve TCP performance in Fast Mobile IPv6 networks by eliminating out-of-sequence packets

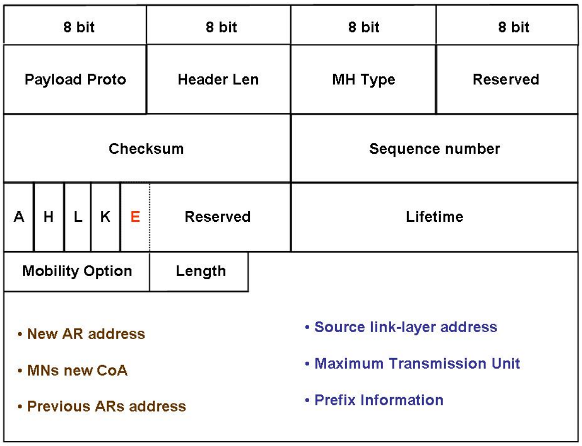

Fig. 3. Enhanced Fast Binding Update (*EF-BU*) Message

during handover. It is based on the NS mechanism which prevents DACK and controls the TCP packet data sequence in new access point (AP). The modified access point (NAP) with NS agent consists of a NAP controller, NAP buffer, and sequence checker. In movement detection, an MN is aware of performing handover to another AP because of channel maintenance or L3 handover. The MN performs a scan to see APs through probes. In proposed scheme, after process of establishing a bidirectional tunnel from the PAR to the NAR is made, the PAR sends new Enhanced Fast Binding Update (EF-BU) [8] message to the CN as soon as an MN start moving so that the number of packets which need to be forwarded from PAR to NAR is decreased.

3.1 New Enhanced Fast Binding Update Message (EF-BU)

In proposed scheme, after process of establishing a bidirectional tunnel from the PAR to the NAR is made, the PAR sends new Enhanced Fast Binding Update (*EF-BU*) message to the CN as soon as an MN start moving so that the number of packets which need to be forwarded from PAR to NAR is decreased. That is, as soon as setting up tunnel between the PAR and the NAR, the PAR send *EF-BU* quickly to the CN. This *EF-BU* message can be modified by adding a 2-bit E-flag to the reserved flag and including the “New AR address” and “MNs New CoA” as options in the option field. Fig.3 show the formats of the *EF-BU* message. Table 1 defines the E-bits. When a CN receives an *EF-BU* message the CN has to be operated by E-bits.

The description for each message exchange in proposed *EF-MIPv6* is as follows:

1) PAR sends EF-BU message after finishing tunneling-path between PAR and NAR.

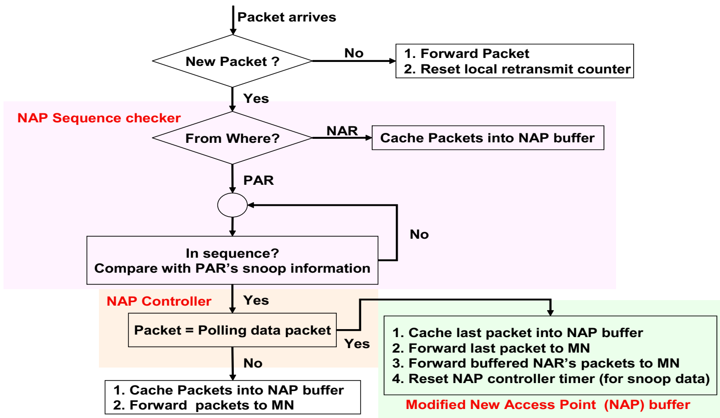

Fig. 4. MSAD Procedure in NAP

2) The CN sends EF-BUACK message to the PAR.
3) The CN send modified TCP data packet after setting MLP flag to "1".
4) The PAR send F-BACK message to the MN and NAR at the same time.
5) The PAR buffer packet addressed to previous CoA and start to forward buffered packets to the NAR.
6) The NAR start to check received TCP data packet MLP flag.
7) The MN sends router solicitation message to the NAR.
8) The NAR sends router advertisement message to the MN.
9) The CN send packets to the MN addressed to new CoA.
10) The NAR buffer packets addressed to new Co until getting the tunneled packet with MLP flag "1"
11) After receiving last tunneled packet with MLP flag "1", the NAR deliver buffered packet which came from the CN directly.

Table 1. The E-Flag of EF-BU message

E-Flag	Mean
00	Can not apply in IEEE-802 case
01	Can send data packet to the MNs new CoA
10	Must send data packet to the MNs old CoA.
10	Must use standard BU message from an MN

3.2 New Enhanced Reordering Algorithm for TCP Data with Polling Scheme

Fig. 4 shows the flowchart of the NS mechanism for data (MSAD) to perform the proposed scheme. Firstly, during a handover in Fast Mobile IPv6, when a PAR receives an F-BU message, the PAR sends an HI message with the PAR's NS information in order to control the TCP packet sequence. As soon as receiving Hack message from NAR, the PAR send EF-BU message to CN. After the PAR sends an F-BACK message to both the NAR and the MN, buffered packets in the PAR are delivered to the NAR. When the CN receives a EF-BU message, it sends the rest of the packets to the NAR directly. Also, the CN sends the last packet with a modified TCP header to the PAR. The modified last packet is called the MLP. In order to distinguish the last packet amongst all the received packets in the NAR, the TCP packet can be modified by adding a 1 bit MLP flag to the reserved field in the TCP header. Fig. 5 shows modified TCP packet format.

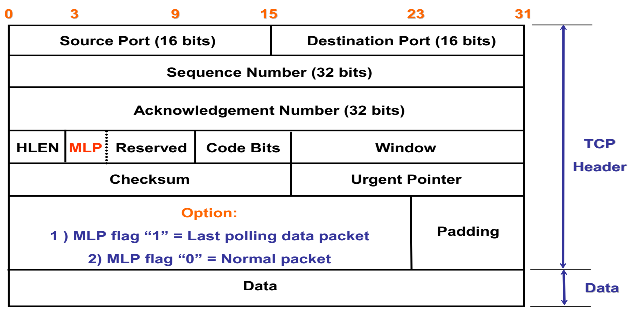

Fig. 5. Modified TCP Packet Header Format

When the MLP flag is "0", the packet acts as a normal packet. However, if the MLP flag is "1", the packet acts as a polling data packet from the PAR. That is, after the CN receives a binding update message from an MN, it simultaneously sends the last data packet and a polling data packet to the MN. The polling data packet is a control message to the MN to signal that no more tunneled packets exist. If the PAR receives this polling message, it can remove the MN's information. After sending a polling data packet, the CN can send a new data packet to the NAR without the tunneling mechanism. First, the NAP sequence checker uses the PAR's NS information, previously sent in a handover initiate (HI) message, to determine if the received packet is from the PAR or the NAR. In other words, when the PAR sends an HI message to the NAR, the HI message includes NS information about the PAR. Then, if the received packet has arrived in sequence, the MNC controller starts checking for the MLP flag.

The MLP flag is important to distinguish between packets delivered by tunneling from the PAR and packets delivered directly from the CN, without tunneling. Until the NAR receives the MLP with the flag bit set to "1", the packets delivered directly from the CN are buffered at the NAP buffer. Fig. 6 shows packet transmission during a handover in EF-MIPv6 networks.

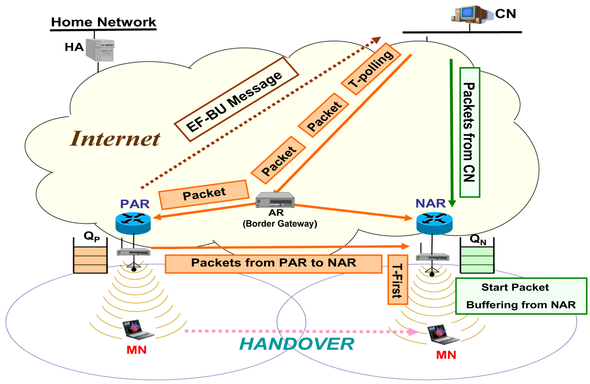

Fig. 6. The packet transmission during handover in EF-MIPv6

As shown in Fig.6, after the CN receives the EF-BU message from the PAR, the packets sent from the CN to NAR directly are cached in the NAP's buffer. Therefore, we define the data packet buffering time (T_{BT}) as the time needed to finish the packet transfer from the PAR to the NAR. T_{BT} is represented by

$$T_{BT} = |T_{First-packet} - T_{Polling-data-packet}| \tag{1}$$

Where $T_{First-packet}$ and $T_{Polling-data-packet}$ are the time when the first packet is delivered and the time when the polling data packet is delivered from the PAR to the NAR via tunneling, respectively; thus, during T_{BT}, only the packet that was received from the PAR by tunneling is forwarded to the MN. At this time, the NAP controller calculates the waiting time, T_{BT}, until the polling data packet arrives. In our paper, we assume the buffer size in the NAP is enough to cache the received packets directly from the CN during T_{BT}. After T_{BT} expires, the NAP buffer starts delivering buffered packets to the MN continuously. Moreover, to prevent packet overflow in the NAP buffer, the NAR sends control messages periodically for notifying buffer states to the CN or HA. Using these message, the CN or MN can control the data traffic. The buffer in the NAR is constructed with non priority First-In-First-Out.

4 Simulation Results

We evaluate the performance of our proposed scheme using Network Simulator (NS-2). Based on the standard NS-2 distribution version ns-allinone2.1b6, the simulation code used for the experiments was designed on top of the INRIA/Motorola MIPv6 code. We have extended the code with two main modules: a reordering algorithm for data and enhanced fast binding update message procedure. Some modifications have been done to the original release in order to extend the code to work with more than one mobile node. In TCP code, we used TCP-NEWRENO. Bulk data transfer (by FTP) is connected between the

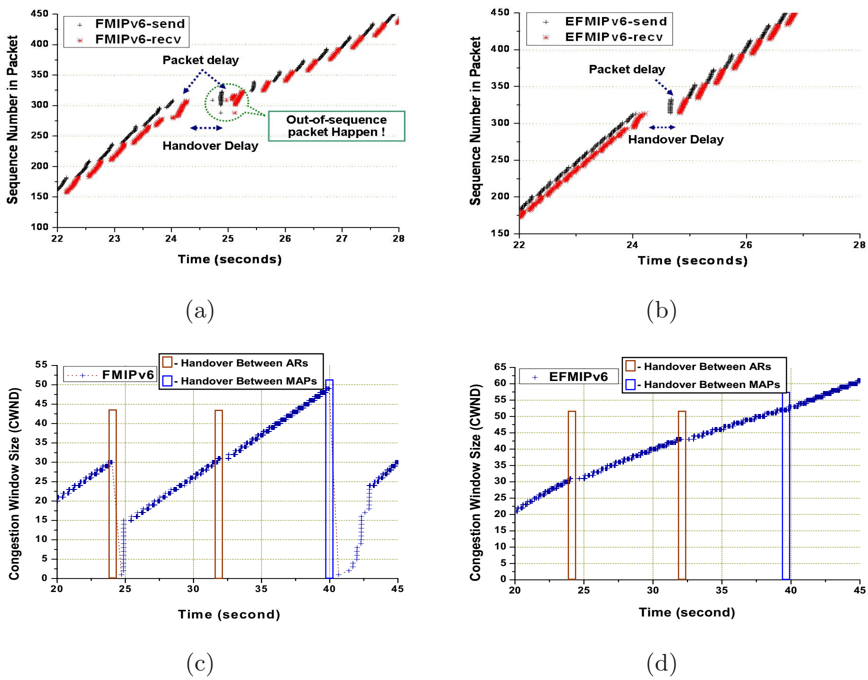

Fig. 7. The effect of handover between ARs: (a) FMIPv6 and (b) EF-MIPv6. TCP congestion window size in packet between ARs after handover: (c) FMIPv6 and (d) EF-MIPv6.

CN and the MN. The throughput of TCP is measured by the sequence number of packets successfully received by the MN. In our simulation, the buffer size is predetermined to be sufficient to cache the received packets directly from the CN to ensure the buffer does not cause packet overflow. Fig. 7 shows the received sequence number (SN) of TCP data with respect to the simulation time in FMIPv6 and Proposed EF-MIPv6, respectively.

Fig. 7 (a) shows the packet transmission associated with buffering in the NAR and PAR during a handover in FMIPv6. Although packet loss does not happen, the received packet sequence is changed in an MN due to the out-of-sequence packet problem caused by the packets received by tunneling and the packets received directly from the CN. Consequently, the out-of-sequence packet problem results in sending a DACK to the CN leading to a drop in TCP performance. Fig. 7 (c) shows the CWND in FMIPv6 between ARs. During a handover between ARs packet loss did not happen. However, after the sender received the same ACK three times from an MN, the sender transmits a delayed packet caused by tunneling between the PAR and NAR. These packet retransmissions reduce the CWND, which causes a large amount of data packets to wait for a larger CWND.

In Fig. 7 (b) and (d), although packet delay occurred, the receiver accepts the packet normally, avoiding packet loss and the out-of-sequence packet problem so retransmission is not required. The EF-MIPv6 scheme can tolerate a slight packet delay and still deliver the packet during fast handover. Therefore, the value of the sender's CWND is maintained and the performance of TCP is improved.

5 Conclusion

This paper has introduced our proposed Fast Mobile IPv6 with reordering algorithm for handovers. We have also analyzed the impact of handovers between ARs for out-of-sequence packets under Mobile IPv6 in a fast handover environment. In this paper, we showed that EF-MIPv6 can improve TCP performance and prevent the out-of-sequence packet problem in existing Mobile IPv6 network.

Acknowledgment

This work was supported in part by the Winitec com. "NGN" Research project and in part by the University of Florida LIST Research Laboratory project of the MIPv6 Technology, 2006.

References

1. D.Johnson, C. Perkins, J. Arkko, "Mobility Support in IPv6", RFC 3775, June 2004.
2. V. Tsaotissidis, "Open Issues on TCP for Mobile Computing", Jouinal of Wireless Communication and Mobile Computing, Vol.01.2, 2002.
3. C.Perkins and D.Johnson, "Route optimization in Mobile IP", Internet Draft, IETF, Sep. 2001.
4. Koodli, R., "Fast Handovers for Mobile IPv6", RFC 4068, July 2005.
5. D. Lee, C. Oh, S. Lee, J. Park, and K. Kim, "Design and analysis of the mobile agent preventing out-of-sequence", Proc. ICOIN, Jan. 1999.
6. D. S. Eom, M. Sugano, M. Murata, and H. Miyahara, "Performance Improvement by packet buffering in mobile IP based networks", IEICE Trans. Communication, vol. E83-B, no. 11, pp.2501-2512, Nov. 2000.
7. D. Lee, G. Hwang, "Performance enhancement of Mobile IP by reducing out-of-sequence packets using priority scheduling", IEICE Trans. Communication, vol. E85-B, no. 8, pp.1442-1446, Aug.2002.
8. Byungjoo Park, H. Latchman, "An Approach to Efficient and Reliable Media Streaming Scheme", in. Proc. of IEEE International Symposium on Broadband Multimedia Systems and Broadcasting (ISBMSB), April 3-6, 2006.
9. H. Balakrishnan, S. Seshan, and R. H. Katz, "Improving reliable transport and handoff performance in cellular wireless networks,", ACM Wireless Networks, vol. 1, no. 4, pp. 469-481, Dec., 1995.