

# Impact of Mobile IPv6 handover on the performance of TCP: an experimental Testbed

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## ABSTRACT

Mobile Internet protocol version 6 (MIPv6) [1] is a proposal for handling routing of IPv6 packets to mobile nodes that have moved away from their home network. We have studied the cost of the mobile IPv6 handover that occurs when a mobile node moves between networks. The experiments carried involve a real internetwork connected to the experimental wide area IPv6 backbone. The mobile IPv6 software provided by "Kame" [2] is used to evaluate the impact of the basic operations of MIPv6 on the performance of TCP bulk data flow. The MIPv6 basic functionalities have got a clear incident on the way TCP recovers from packet loss. The impact of IPv6 fragmentation due to MIPv6 on the performance of TCP has been illustrated.

## 1. INTRODUCTION

Mobile IPv6 (MIPv6) has been proposed to solve the problem of mobility in the new Internet IPv6. In the near future, with the simultaneous growth of the mobile user population and the Internet, users will move more frequently between networks as they stay connected to the Internet and access its resources. Thus, as mobility increases across networks, handovers will significantly impact on the transport and thus on the user application. The focus of this study has been to evaluate by the experiment how mobile IPv6 handover affects the performance of TCP. For our experiment, a file is transferred from a Correspondent Node (CN) to a Mobile IPv6 Mobile node (MN) that is changing its point of attachment in the Internet. This study involves a real experimental internetwork connecting IPv6 hosts and routers over Ethernet. The testing environment allows connecting our internetwork to the global IPv6 backbone (6Bone). Few tests have shown the consequences of communicating with a CN either in the vicinity of the MN or far away from it. The side effects of fragmentation on the TCP throughput have been illustrated when the MN's Home Agent (HA) performs

encapsulation or when the CN appends a routing header and sends the packets directly at the MN's Care of address (CoA).

## 2. THE TESTBED EXPERIMENTS

The network used, consists of a collection of dual stack IPv4/IPv6 hosts and routers running FreeBSD-4.4 or Red-hat Linux 7.2. Ethernet 10 Mb/s interconnects the nodes at the link layer. Our experiment involves two kinds of networks: The small size internetwork and the wide area IPv6 backbone (6Bone). In the small size internetwork the CN and the HA are in the vicinity of the MN. In the wide area experiment, we have connected our internetwork to the wide area IPv6 backbone 6Bone via two portals (BT in U.K and CERNET in China). This was done by configuration of two static IPv4 tunnels to transport IPv6 packets from our site to the 6Bone. The MN is moving by disconnecting it from one link and immediately reconnecting it to a new link. The MN moves either from home or between foreign networks. A File Transfer Protocol (ftp) server for IPv6 is running at the CN. Although the MIPv6 software provided by the kame-2002128-freebsd44-snap is not fully updated with the very recent extensions proposed by the fast evolving IETF draft-18, it implements the basic routing functionalities of MIPv6.

## 3. MOBILE IPv6 HANDOVER LATENCY

The MIPv6 handover duration will affect the performance of an on going TCP connection. The handover latency in MIPv6 is due to: the movement detection, the neighbour un-reachability detection, the selection of a new default router, the selection of the new Care of address, before the Binding Update (BU) message is sent to both the HA and the MN's CN. Performing all these steps introduces a significant delay that causes the MN to be unable to continue the communication with the CN for some time.

## 4. RISK OF FRAGMENTATION DUE TO MOBILE IPv6

The risk of fragmentation of IPv6 packets containing a TCP payload exists after the data packets en route for a MN away from home are encapsulated by the HA ready to be tunnelled to the MN's CoA. When the HA intercepts the resulting 1500 bytes of IPv6 packet, it adds an outer 40 bytes IPv6 header with the source address the HA address and destination address the MN's CoA. As the resulting packet then exceed 1500 bytes, the IPv6 module of the HA performs fragmentation of the packet inserting the HA's IPv6 header and the fragment header before the 1338 bytes

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of TCP data. The other fragmented segment sent after the first one includes the remaining 52 bytes of TCP data.

The risk of fragmentation also occurs when the CN inserts a routing header (24 bytes) to the IPv6 packets destined to the MN's CoA.

The following illustrates some risks of the interaction between MIPv6 and TCP.

## 5. COMMUNICATIONS WITH A NEARBY CN

### 5.1 Issues when Communicating with an IPv6 CN

The IPv6 CN in this experiment is an IPv6 node that is not running MIPv6. It does not support the BU option. In such a scenario, the CN is able to process the home address option (as an IPv6 node compliant with the MIPv6 draft) and the packets sent by the CN are addressed to the MN's Home address. This results in triangular routing with the packets being sent to the MN's home network, intercepted by the HA and tunnelled to the MN's CoA. Sending of an ACK altogether with a BU provides an efficient way to send out an Acknowledgement: It requires minimum bandwidth utilization to send one packet instead of two separately. However, the ACK sent in the IPv6 packet containing the BU option will not be passed to the TCP module. The CN's IPv6 module discards this datagram with the BU option including the ACK and sends out an ICMP parameter problem in return to the MN Home address. This is a side effect of transmitting TCP ACKs in packets containing the BU destination option when the MN's CN does not support MIPv6. This dramatically increases the time for TCP to recover.

### 5.2 Effect of MIPv6 handovers on the average TCP throughput when communicating with an IPv6 CN

When the CN is in the vicinity of the MN, the average file transfer throughput is always higher when the CN is running MIPv6.

## 6. COMMUNICATIONS WITH A DISTANT CN

For the communication with a distant CN, we have configured a static tunnel from the CN to BT's 6Bone router. Thus for this experiment, all packets sent from the MIPv6 CN to the MN travel through the 6Bone before coming back to our network. Our router R1 is simultaneously connected to the 6Bone via CERNET-china. Thus the packets from the MN to the CN (TCP ACKs for example) are tunnelled to China before coming back via the BT tunnel. We think that such a configuration is quite well suited to reflect how TCP packets would be routed from one end to another in the global emerging IPv6 Internet.

### 6.1 Experiment with a MIPv6 CN

In this experiment, packets sent by the CN suffer fragmentation because of the insertion of the routing header. In these conditions, MIPv6 with route optimisation offers a lower throughput than in the case of MIPv6 with triangular routing.

## 6.2 Effect on the average throughput

This example illustrates the adverse effects that fragmentation may have on the throughput of a bulk data transfer. Currently, there is no requirement for any interlayer communication between MIPv6 and TCP to instruct the TCP with the Maximum Segment Size (MSS) that should be used for a connection to avoid possible fragmentation caused by MIPv6 tunnelling or insertion of the routing header.

In general if Path MTU discovery is implemented to track a possibly changing path MTU as the MN moves across networks, it can be used to inform the on going TCP about the biggest MSS possible to avoid return of ICMP packets too big messages to the CN. An appropriate TCP segment size calculation would need to track regularly the result of the path MTU discovery mechanism to the MN and the MIPv6 tunnelling header information. However long delays to complete the path MTU discovery will increase the time taken before a TCP sender can adjust dynamically its segment size to fit in the path MTU.

## 7. CONCLUSION

This study has evaluated the impact of MIPv6 basic operations on the performance of TCP bulk data flow. The File Transfer Protocol has been used to perform a one-way transfer of data from the CN to the MN while the MN is moving across access routers. The study has been conducted using an experimental Testbed. The internetwork used for this experiment has been connected to the wide area IPv6 backbone. The configuration of our small size internetwork and its connection with the global IPv6 backbone makes it possible for testing MIPv6 functionalities in the small size and in the wide area networks. The CN is either close to the MN or far away in the 6Bone. The CN is either a MIPv6 node or an IPv6 node compliant with the Home address destination option header of MIPv6. The latency of various movement detection components involved in the MIPv6 handover processing impacts on the TCP. The experiments illustrate how an IPv6 CN might degrade the TCP performance in the presence of BU destination option sent with TCP ACK. Moreover, the use of IPv6 encapsulation and routing header can cause fragmentation of data packets sent from the CN. Fragmentation in return may have a negative effect on the TCP throughput depending on the network conditions. In the small area network, the effect of fragmentation is almost not perceptible while it became more apparent in the wide area experiment.

## REFERENCES

- [1] David B. Johnson, Charles E. Perkins, Jari Arkko, "Mobility Support in IPv6", IETF draft, June 2002.
- [2] <http://www.kame.net/>

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