

Flow-Based Fast Handover Method for Mobile IPv6 Network

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ABSTRACT

Mobile IPv6 provides comprehensive mobility management for the IPv6 protocol. It provides many benefits compared to Mobile IPv4, such as reroute optimization, protocol extensions and IP Security (IPSec). One problem still remains, the handover time is relatively long. This is a big problem at least in real-time connections. This paper presents a new method for faster handover in IPv6 network, called *Flow based Fast Handover for MIPv6* (FFHMIPv6), which uses the features of IPv6 protocol and benefits from IPv6 traffic control.

I. INTRODUCTION

Mobility in IPv6 networks [1][2] has evolved remarkably compared to Mobile IPv4 protocol [3]. Mobile IPv6 (MIPv6) enables transparent routing of IPv6 packets to Mobile Nodes (MNs) from Correspondent Nodes (CNs). The mobility is made possible by using a Home Agent (HA) and a local Care-of-Address (CoA). Unfortunately it is still unsolved how to minimize the handover time between two logical subnets so that the outtime is as short as possible. As early as in 1996 Perkins and Johnson proposed a Router-Assisted Smooth Handoff to the MIPv6 protocol [2]. In the proposal, MN sends the Binding Update (BU) message to its previous serving router, which then acts as a local HA tunneling the traffic to the MN's new CoA. This idea is developed further in [4]. In [5] and [6] a Hierarchical Mobile IPv6 (HMIPv6) proposal suggests a Mobile Anchor Point (MAP) to act as a local HA to reduce signaling delays in handovers. However, the handover delays still remain unacceptable for some applications.

In the past few years, different proposals have been presented to minimize the handover delay in Mobile-IPv6 networks. Many of the proposed methods require modification of the Access Routers (ARs). Two slightly different handover solutions using multicast routing are presented in [7] and [8]. In [7] the CNs see the MN as a Multicast group. When the MN moves from one subnet to another it joins the Multicast group with its new CoA and if possible, remains connected to the Multicast Group with its previous CoA. In [8] all the CNs, in connection with a particular MN, subscribe to a multicast

group. The handoffs of the MN are informed to the CNs via this multicast group. The maintenance of the multicast groups means additional tasks for the network elements.

The idea of using a "virtual" HA which is located closer to the MN than the actual HA has been proposed in different forms. The use of a Routing Agent to be used between the HA and the Foreign Agent is presented in [9] and [10] to fasten the handoff process. The use of a Local Mobility Agent to act as a local HA is proposed in [11]. In [12] a specialized path setup scheme is proposed, where host-based forwarding entries are installed in specific routers so the MN's network address remains the same within a domain.

While many proposals concentrate on modifying the ARs, another approach to diminish the handover delay is the modification of the MN. A mobile node buffering function is proposed in [13] to mitigate the effects of handover. The MN buffers the TCP ACKs just before the handoff forcing the CN to stop its transmitting. After the handover the buffered TCP ACKs are delivered to the CN and it resumes the transmission. In [14] a new handoff mechanism and an enhancement to the Mobile IP registration is proposed. In the proposal the periodic Router Advertisements (RAs) are modified to be send only when a handoff is necessary. The MN keeps a RA cache to help on the decision where to make the handover. These methods require minor modifications to the network elements, but require additional resources from the MN and detection of the upcoming handover beforehand.

Recently, optimization of routing protocols have also been proposed to decrease the delay in handovers [15][16][17]. An improvement to HMIPv6 [5][6] is presented in [15], in which a mobility profile (an average residence time in the current subnet) is maintained and according to a defined threshold time the MN can use a Local CoA instead of a Regional CoA, in order to accomplish route optimization. Another improvement to HMIPv6 was presented in [17], where the reception of packets from the new AR is possible at the same time with the BU registration process. This requires for the MN to "see" the approaching of the handover, so the old Mobile Anchor Point (MAP) can set up a multicast group to deliver packets destined

to the MN. The possible new ARs are asked to join the multicast group and start buffering the packets destined to the MN. These HMIPv6 improvements require some additional resources from the network elements. In [16] a small part of the overall delay in MIPv6 handover is addressed. The delay of unicast Router Advertisement (RA) in response to Router Solicitation (RS) is removed by assigning one router to provide immediate unicast responses to RSs. This proposal could be used in conjunction with other methods to further decrease the overall handover delay.

In this paper we present a new method (first presented in [18]) for faster handover in Mobile IPv6 network, called *Flow based Fast Handover for MIPv6* (FFHMIPv6). FFHMIPv6 uses the features of IPv6 protocol and benefits from IPv6 traffic control. By using the IPv6 *Flow Label* each traffic flow can be identified and redirected to a new location. This makes possible the reception of packets simultaneously with the BU registration process, thus minimizing the delay experienced in the handover. The proposed method requires only few modifications to the existing MIPv6 protocol and minor computational and memory requirements from the ARs. In our analysis we found the proposed new FFHMIPv6 method to have smaller handover delays than the MIPv6 [1] and the HMIPv6 [5] protocols.

The remainder of the paper is organized as follows. Section II describes the proposed FFHMIPv6 method. The analysis methods and the results are presented in section III. Finally, in section IV we discuss conclusions and future work.

II. FFHMIPv6 METHOD

The proposed FFHMIPv6 method requires that most of the routers in the IPv6 network fill the traffic flow property and maintain the state information of the traffic flows. Traffic flow is determined by the IPv6 *Flow Label*, source and destination addresses. Mobile node (MN), home agent (HA) and corresponding node (CN) use the *Flow Label*, so the connections (MN,HA) and (MN,CN) form identifiable traffic flows. This flow information is used to control the traffic when MN moves between logical networks.

Fig. 1 explains the FFHMIPv6 principle. When the MN moves to a new logical subnet, it receives a new Care-of-Address (CoA) and registers it to the HA (Fig. 1, step 2). This register message includes also a prior *Flow Label* of the mobile connection. Using this *Flow Label* the router at the crossing point (Fig. 1, AR2) redirects the flow to the new location of the MN.

Next we consider more precisely the functions of the mobile node and the router in the FFHMIPv6 method. Also the requirements of the method are discussed.

A. Mobile Node's functions

The FFHMIPv6 method is used only, when the primary CoA changes (Fig. 1, step 1). The *Hop-by-Hop* frame, including the addresses of the HA and the CN(s) and the *Flow Label*, is added to the BU register message (Fig. 1, step 2). The *Hop-by-Hop* frame (Fig. 4) includes a new FFHMIPv6 identifier

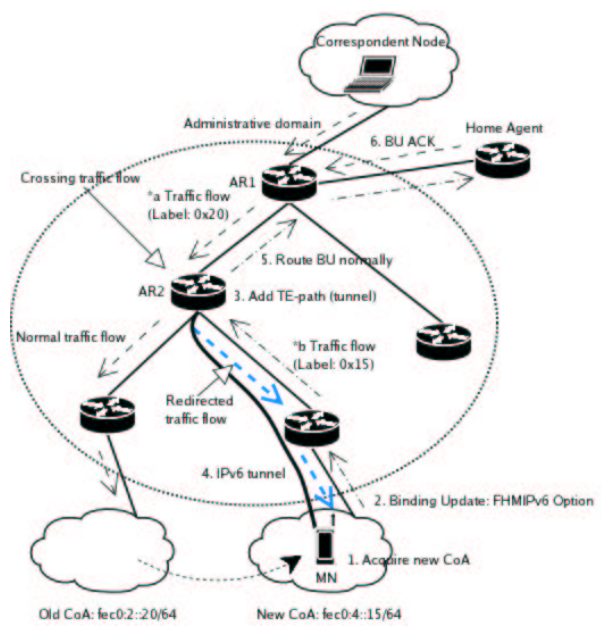


Fig. 1. The FFHMIPv6 principle

type, where the parameters of the FFHMIPv6 method are determined to the routers. On the basis of this information, the traffic flow from the HA and the CN (Fig. 1, *a) is redirected (tunneled) (Fig. 1, step 4) to the new location.

The MN receives and disassembles the capsuled IPv6 in IPv6 packets. The source and the destination addresses of the inner tunnel are verified; the source address must be the HA's or MN's address and the destination address the MN's old CoA. In this way, we can be certain that the packets belong to the FFHMIPv6 method.

The tunneling of the traffic flow is always temporary and durationally constant (some seconds) so that during this redirection the MN has had the time to register the new CoA to the HA and the CN(s). On the other hand, the MN has the possibility to disassemble the created IPv6 tunnel earlier and release the old CoA. When the MN moves back to the home network, FFHMIPv6 method is disabled to avoid possible routing loops.

B. Router's functions

Passive traffic flow has a defined lifetime in the network. After this the state information disappears. [19] defines that traffic flow has at most 120 seconds lifetime after it becomes passive. The state information identifies the traffic flow heading for the old CoA (Fig. 1, *a) and the traffic flow can be redirected to the new CoA.

Identification uses the BU message's *Hop-by-Hop* frame. Every router must go through this frame. If the router identifies the FFHMIPv6 definition, it handles the frame as described in Fig. 2. If *Flow Path* (Fig. 4) is defined (*Flow Path* = 1), FFHMIPv6 has been made in the network. Using the information from the *Hop-by-Hop* frame the traffic flow is searched from the router's flow state information. If the traffic

flow is found, an ICMP message is sent to the MN's new CoA so that it knows the other end of the IPv6 tunnel, which is the crossover router (Fig. 1, AR2). After that, the IPv6 tunnel is formed between the router AR2 and the MN and the traffic flow is redirected to the established tunnel. Next, the Flow Path bit in the Hop-by-Hop frame is set to one so that the FFHMIPv6 process is not performed again. Finally the BU message is forwarded towards HA and the MIPv6 registration process continues.

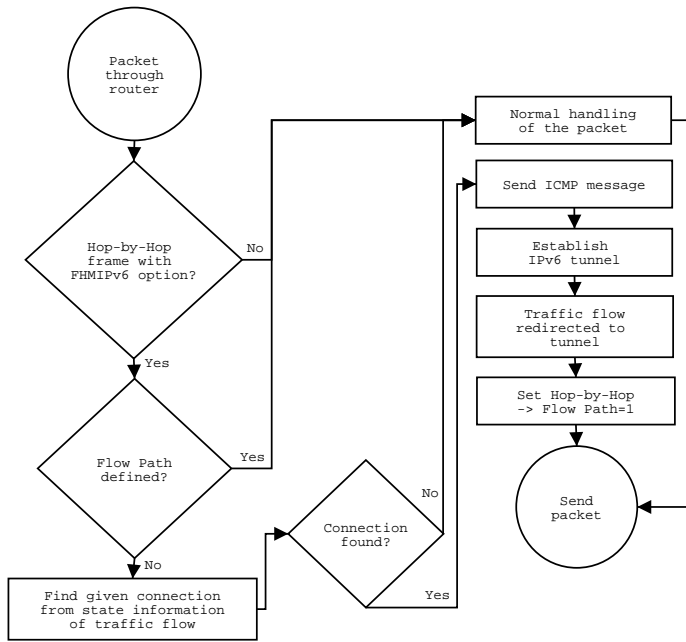


Fig. 2. Handling of the Hop-by-Hop frame

The packets heading for the old CoA are capsuled to a new IPv6 packet heading for the new CoA. In other case the traffic would be redirected to the new location only after the registration process is done to both HA and CN(s). The IPv6 tunnel connection remains for the time it takes to register the primary CoA to the HA and CN(s). After that the traffic flow is directed straight to the new CoA without tunneling.

In Fig. 3 is described the whole chronological process of the FFHMIPv6 method. The BU message is processed in the crossover router AR2 and the IPv6 tunnel is established. Then the BU message proceeds the registration process to the HA. After that the registration is done to the CN(s). As can be observed (Fig. 3), the traffic flow is redirected to the new CoA before the whole registration process is finished.

C. Requirements

The FFHMIPv6 method requires few extensions to the existing MIPv6 protocol. *Hop-by-Hop frame* includes *Option Type* identifier field, which is 8 bits. It identifies the property in question and how the routers must handle the included information. FFHMIPv6 method requires a new *FFHMIPv6 identifier type*, which is used to define the FFHMIPv6 parameters to the routers (Fig. 4). All the bits of the frame function

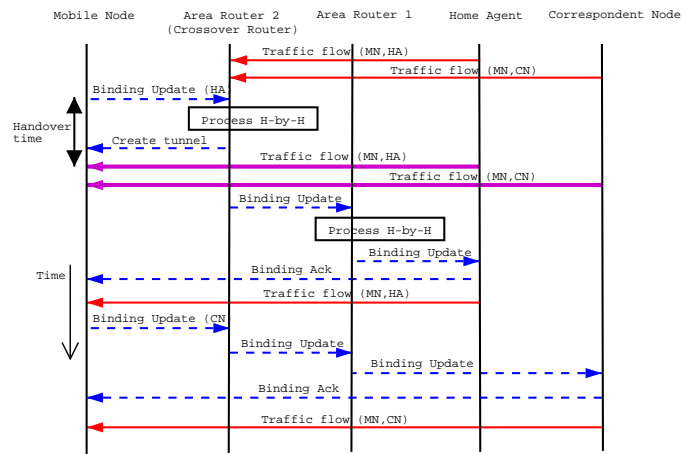


Fig. 3. The FFHMIPv6 process

as the property identifier. The bits are defined in the following way:

- bits 6-7: 00 – if the router doesn't recognize the Hop-by-Hop type, it is proceeded normally
- bit 5: 1 – *Hop-by-Hop Option* field can change en-route
- bit 0-4 – function identification

Hop-by-Hop Option identifier type was chosen to be the next available from the IANA (Internet Assigned Numbers Authority) (01011). *Option Data Length* is determined by the number of the mobile connections and flows of the MN. After the *Data Length* the *FFHMIPv6 options* are defined:

- bit 3: 1 – Flow Path is already established in the IPv6 network
- bit 2: 1 – if an alternative CoA follows *Flow Label*
- bits 0-1: reserved

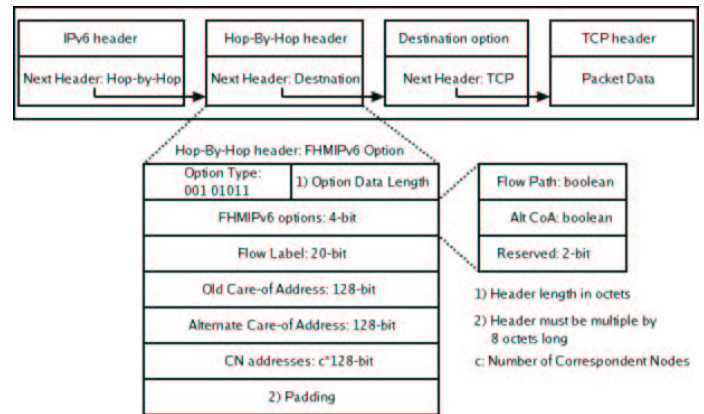


Fig. 4. Hop-by-Hop frame with the FFHMIPv6 Option

The HA, MN and CN must send the IPv6 packets using the same Flow Label so the traffic flow can be identified correctly. MN must maintain the old CoA after the handover, because it is used inside the IPv6 tunnel. The routers must be able to form the IPv6 tunnel and maintain state information of the

Parameter	Description	State	Direction	Component
a^1	Acquire Care-of Address	Static	-	MN
d	Propagation delay (routing)	Variable	Bidirectional	-
b^1	Hop-by-Hop process	Static	-	Router
b^2	Flow State search	Variable	-	Router
b^3	Redirect & tunnel traffic	Static	-	Router
c^1	Binding Update	-	Upstream	MN
c^2	Binding Update ACK	-	Downstream	HA/CN

TABLE I

THE ELEMENTS AFFECTING ON THE HANDOVER TIME.

traffic flows. Also, the traffic flow's direction to the established tunnel must be possible.

III. ANALYSIS METHODS AND RESULTS

We focus on the theoretical analysis of the proposed FFH-MIPv6 method concentrating on functionality and efficiency. Our proposed method is compared to handover methods used in MIPv6 [1] and HMIPv6 [5] protocols. We use two scenarios which represent the handover situation in the best case (the MN remains connected to the same AR) and the worst case (the MN connects to an AR in a different domain) (Fig. 5).

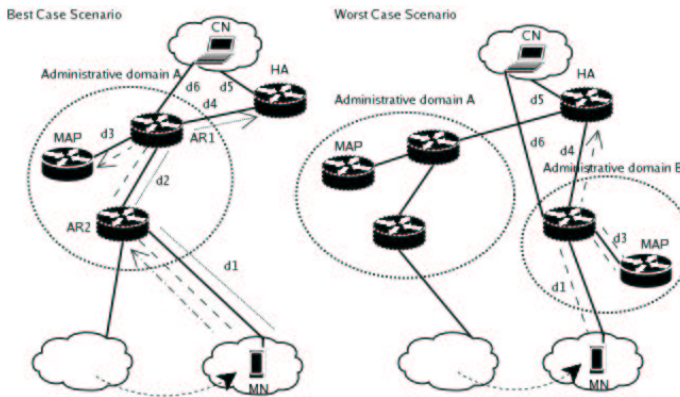


Fig. 5. The best and the worst case scenarios

There exists mainly two factors which affect the MN's handover time – the number of registrations and the time to accomplish one registration. The number of registrations depends on the number of CNs and the time to accomplish one registration depends on the connection delay of the network. The elements which have an effect on the total handover time are listed in Tab. I.

The registration of CoA requires acquiring the connection settings (Tab. I, a^1), sending the BU (c^1) and acknowledgement of the registration (c^2). The network router handles the BU message's *Hop-by-Hop* frame (b^1), searches the traffic flows concerning the FFH-MIPv6 process (b^2) and redirects the flows to MN (b^3). Tab. I also shows the state, direction and components involved with the parameters affecting the handover time.

The comparison of the handoff times in FFH-MIPv6, HMIPv6 and MIPv6 handover methods is presented in Fig.

6. The comparison is made on the basis of Fig. 5. The model takes into consideration the amount of signalling (return routability, RR), the number of registrations and the total time of the handover process required by the methods.

Best Case Scenario		Worst Case Scenario	
Fast Handover	Value	Fast Handover	Value
BU: HA+c*CN	2	HA+c*CN	2
Handover delay: 2*d1	4	6*d1+3*d4+d5+3*d6	152
BU process: BU->AR2		BU->HA + RR->CN + BU->CN	
Hierarchical MIPv6 Handover		Hierarchical MIPv6 Handover	
BU: MAP	1	MAP+HA+c*CN	3
Handover delay: 2*d1+2*d2+2*d3	8	8*d1+8*d3+3*d4+d5+3*d6+e	165
BU process: BU->MAP		BU->MAP + DAD + BU->HA + RR->CN + BU->CN	
MIPv6 Handover		MIPv6 Handover	
BU: HA+c*CN	2	HA+c*CN	2
Handover delay: 6*d1+6*d2+3*d4+d5+3*d6	158	6*d1+3*d4+d5+3*d6	152
BU process: BU->HA + RR->CN + BU->CN		BU->HA + RR->CN + BU->CN	

d1-d6: link delay
c: number of correspondent nodes
e: duplicate address detection (DAD)

d1=2 ms e=1 ms
d(2-3)=1 ms c=2
d(4-6)=20 ms

Fig. 6. The computational comparison of the methods.

If we assume that the links in Fig. 5 have delays ($d1-d6$) presented in Fig. 6 and the Duplicate Address Detection (DAD) time of the HMIPv6 protocol is 1 ms, then we acquire the handover times presented in Fig. 7.

In the best case scenario our proposed FFH-MIPv6 method is clearly the most effective. It takes only one registration message to AR2, which has a constant time of 4 ms. The HMIPv6 method takes also only one registration (to the MAP), but the registration time is longer (8 ms), because the MAP is situated farther than AR2. The MIPv6 was found to be the slowest method requiring a handover time of 158 ms. This includes the registrations to the HA and to the CN. Also RR signalling is included. The number of the registrations in MIPv6 protocol is linear and depends on the number of the CNs. In the FFH-MIPv6 method the number of registrations has not direct effect to the handover time. In the HMIPv6 method it depends on the network topology.

In the worst case scenario the proposed FFH-MIPv6 method is as effective as the MIPv6 method (152 ms). The FFH-MIPv6 method is then in fact functioning as MIPv6. The tunneling is not used, because the router, where the traffic flow crosses does not exist. The HMIPv6 method requires always an additional registration to the MAP making it the slowest of the compared methods.

IV. CONCLUSIONS

In this paper we have presented a new Flow based Fast Handover method for Mobile IPv6 network. The new FFH-MIPv6 proposal was compared with the MIPv6 and the HMIPv6 methods. The analysis was done in the best and the worst case handover scenarios and we found the handover time to be significantly shorter using the proposed FFH-MIPv6 method compared to the MIPv6 and the HMIPv6 methods.

The proposed FFH-MIPv6 method requires only small changes in the present MIPv6 protocol and only minor computational and memory requirements from the ARs participating in the redirection of the traffic flow.



Fig. 7. The handover delays of the compared methods.

The state information of the IPv6 traffic flows must be implemented to almost all routers, if the traffic flow property of the IPv6 protocol is to be used. On the basis of this it is expected that the FFHMIPv6 method can be implemented widely in Mobile IPv6.

We are currently implementing the FFHMIPv6 method for the Network Simulator 2 (NS2) simulation environment. Our purpose is to compare the proposed new FFHMIPv6 method with other handover methods focusing on the handover delay, packet loss and required processing time.

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