AN ANALYSIS OF THE FLOW-BASED FAST HANDOVER METHOD FOR MOBILE IPV6 NETWORK

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Abstract: Mobile IPv6 has been proposed by the IETF (Internet Engineering Task Force) to be the solution to mobility management in IPv6 network. The work is now culminating to a standard status. But, one problem still remaining is the length of the handover time, which might cause packet loss. Thus the handover time should be as short as possible. Especially the real-time traffic suffers from packet loss. Earlier we have introduced a new method for faster handover process in Mobile IPv6 network called the *Flow-based Fast Handover Method for Mobile IPv6* (FFHMIPv6). FFHMIPv6 uses the flow state information stored in the routers for the fast redirection of the flow. In this paper we compare the proposed FFHMIPv6 protocol to other methods using both theoretical analysis and Network Simulator 2 (ns-2) simulations.

1 INTRODUCTION

The evolution of mobility in IPv6 networks (Johnson et al., 2004) has been significant when compared to the Mobile IPv4 protocol (Perkins, 2002). Mobile IPv6 (MIPv6) provides transparent routing of IPv6 packets to Mobile Nodes (MNs) from Correspondent Nodes (CNs). The mobility is achieved by using a Home Agent (HA) and a local Care-of-Address (CoA). Unfortunately, the minimization of the handover time between two logical subnets is still unsolved. Real-time applications, like VoIP, are intolerant to delay and jitter. On the other hand the handover time causes packet loss, which might affect the application in use (e.g. real-time multimedia).

During the past few years, several different proposals have been presented to decrease the handover delay in Mobile IPv6 networks. But, for some applications, the handover delays still remain unacceptable. Also, many of the proposals require substantial and undesirable modifications to the access routers (ARs) or the MN.

The use of a “virtual” HA, located closer to the MN than the actual HA is presented in (Castelluccia, 2000) and it is developed further in (Soliman et al., 2004). The HMIPv6 method has been used as a ground for other proposals (Ramjee et al., 2002)(Thing et al., 2003). Another approach to decrease the handover delays is based on multicast routing (Ernst et al., 2000). Some proposals concentrate on the modification of the MN, instead of the AR(s) (Omae et al., 2002)(Patanapongpibul and Mapp, 2003). Recently, optimization of routing protocols have also been proposed to decrease the delay in handovers, such as improvements to HMIPv6 (Hwang et al., 2003)(Vivaldi et al., 2003), requiring additional resources from the network elements. In (Daley et al., 2003) a method is presented, where a small part of the overall delay in MIPv6 handover is addressed. This method can be used in conjunction with most of the methods.

One way to reduce the packet loss during the handover is to use tunneling and redirection of the flow heading for the old CoA. In (Koodli, 2004) is presented the *Fast Handovers in Mobile IPv6* (FHO) method, in which the flow is tunneled from the previous AR to the new AR during the handover. FHO method also employs L2 triggers to start the handover procedure earlier. In (Sulander et al., 2004) we introduced a new method for faster handover in Mobile IPv6 network called the *Flow based Fast Handover for Mobile IPv6* (FFHMIPv6). By using the traffic flow information each traffic flow can be identified and redirected to a new location. The redirection takes place in the router where the old and the new traffic flow crosses. The method makes possible the recep-

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tion of packets simultaneously with the BU registration process, thus minimizing the delay and packet loss experienced in the handover.

In addition to faster handover proposals several performance studies have been published. In (Montavont and Noel, 2002) the performance of the basic Mobile IPv6 is analyzed. Under evaluation are the L2 and L3 handover latencies up to 4 mobile nodes. The performance analysis of FHO have been performed in (Torrent-Moreno et al., 2003). The number of MNs, the handoff rate, the distance of the CNs and HA, effect on different applications etc. were analyzed using ns-2 simulations. FHO was found to be more effective than MIPv6 to the point where the radio channel is congested because of the number of MNs and the amount of traffic. This analysis was expanded in (Perez-Costa et al., 2003) to include Hierarchical MIPv6 and the combination of the HMIPv6 and FHO. The combination was found to have the shortest handover delay and lowest packet loss.

The remainder of the paper is organized as follows. Section 2 presents the idea of the proposed FFHMIPv6 method. The method is presented more thoroughly in (Sulander et al., 2004). Analysis methods and the achieved results are presented in section 3. Finally, in section 4 we discuss conclusions and future work.

2 FFHMIPv6 METHOD

In (Sulander et al., 2004) a *Flow-based Fast Handover for Mobile IPv6* (FFHMIPv6) method is proposed for MIPv6 networks. It uses the flow state information of the routers to locate the flows heading for the old CoA. These flows are then encapsulated and redirected to the new CoA during the BU process.

When the MN moves to a new logical subnet, it receives a new CoA and registers it to the HA and possibly to the CN(s) via BU process. In FFHMIPv6 method the *Hop-by-Hop* frame, including the the old CoA, is added to the BU register message heading for the HA.

Every router maintain the state information of the flows it receives, sends or routes. A Flow is defined by the source and destination addresses and the *Flow Label*. In every router between the MN and the HA the flow state information and the old flow information from the Hop-by-Hop header is compared. If the traffic flow is found, an IPv6 tunnel is established between the crossover router (CR) and the nCoA of 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 in another router. Finally the BU message is forwarded towards the HA and in the next hop the same procedure is repeated.

During the tunneling MN has had the time to register the new CoA to the HA and CN(s). The FFHMIPv6 enables the receiving of the traffic flow simultaneously with the BU process; thus minimizing *downstream* packet loss. The FFHMIPv6 method functions best as a micro mobility solution. The network topologies are often built hierarchically so that all of the domains ingress and egress traffic pass a same router (border router). Given this assumption the crossover router would probably be found. If the flows are not found from the routers flow state information or the routers do not support FFHMIPv6, the FFHMIPv6 functions just like MIPv6 and its BU process.

3 ANALYSIS METHODS AND RESULTS

We analyzed the FFHMIPv6 method theoretically and with *ns-2* (ns-2, 2004) simulations. The analysis with both analysis methods is meant to be performed identically so that the results could be compared. Theoretically we compare the basic MIPv6, HMIPv6, FHO and FFHMIPv6 methods. The ns-2 simulations are performed with MIPv6 and FFHMIPv6 methods. We are working on the HMIPv6 and FHO implementations to ns-2.

The scenarios shown in Figure 1 are the same in both analysis methods. The route optimization is not used, so all the flows from CNs are routed via HA. The FFHMIPv6 method is therefore used to redirect the flow from the HA to the new CoA. The handover delay is defined to be the time from the first BU register message to the time when the MN is able to receive the flow. Packet loss is defined to be the loss due one specific handover. While MN is in the overlapping area of the BSs, according to IEEE 802.11 WLAN standard (IEEE 802.11, 1999), MN can receive and send data only from one BS at a time.

3.1 Theoretical Analysis

In (Sulander et al., 2004) we compared theoretically the handover delays of the MIPv6, HMIPv6 and FFHMIPv6. In this paper we extend this analysis to include the *Fast Handovers for Mobile IPv6* (FHO) (Koodli, 2004). We concentrate on the situation, where the MN can not anticipate the shortly occurring handover. So it can't receive L2 triggers or predict the next access router. This assumption has an effect on the performance of the FHO method.

We use two sample scenarios which represent the handover situation in the best (scenario 1) and the worst case (scenario 2) for the FFHMIPv6 method

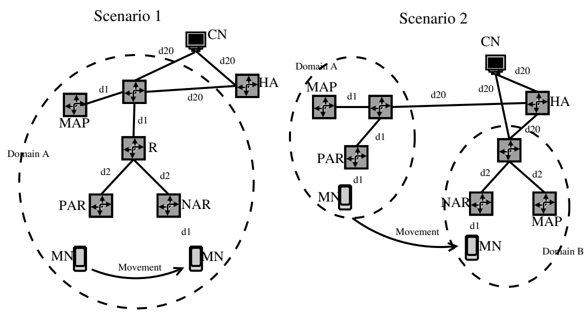

Figure 1: The analysis scenarios

(Figure 1). In scenario 1 the MN changes access router within the same MAP domain (MAP exists only in HMIPv6 network) and the access routers (PAR and NAR) are connected to the same router (the cross-over router in FFHMIPv6). In scenario 2, the MN changes it's MAP domain and there does not exist a cross-over router for FFHMIPv6.

There exists mainly two factors which affect the MN's MIPv6 handover delay – the number of registrations and the time to accomplish one registration. In the case, where the route optimization is not in use, the handover delay consists of the BU process to the HA. There are also other factors like movement detection, acquiring new CoA, the processing delay in the routers inflicted by the Hop-by-Hop header and the flow state information procedures. The processing delays are to be analyzed in future work. Acquiring the new CoA with stateless address autoconfiguration (including duplicate address detection (DAD)) causes a lot of delay, but it has similar effect on every handover method. Because it does not affect the ratios of the handover delays, they were not taken into consideration.

We assume that the links in Figure 1 have delays $d1 = 1ms$, $d2 = 2ms$ and $d20 = 20ms$. The delays have been selected to represent network where access routers are near, but HA and CNs can be located quite far. The values are not selected to improve the performance of the proposed method.

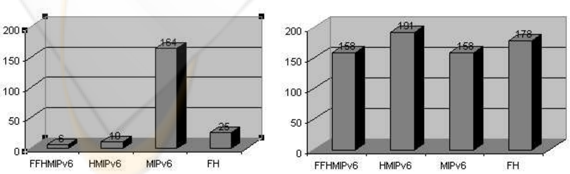

Figure 2: Theoretical analysis results in the good and bad scenarios

MIPv6 requires the handover time of the BU process to the HA. The BU process is similar in both scenarios. In scenario 1 HMIPv6 needs only the BU registration to the MAP because the MN moves within its MAP domain. In scenario 2 the MN must perform the BU process to the new MAP and HA. Because the occurring handover can not be predicted, FHO requires the signaling to the previous AR to establish the tunnel to the new AR. This assumption degrades the performance of the FHO method significantly. FFHMIPv6 requires only the BU message to the crossover router in the scenario 1. In scenario 2 the crossover router is not found, so the FFHMIPv6 method is in practice functioning as MIPv6. Figure 2 presents the results of the theoretical analysis.

Table 1: The simulation results

	Scenario 1		Scenario 2	
	MIPv6	FFHMIPv6	MIPv6	FFHMIPv6
Delay (ms)	58.8	13.8	65.2	65.2
Loss (pkts)	5	1	6	6

3.2 Simulation studies

Mobile IPv6 extensions for Network Simulator 2 (ns-2, 2004) have been developed by Motorola Labs Paris in collaboration with Inria Planete team at Inria Rhône-Alpes. The extension called Mobiwan (Ernst, 2002) works in *ns* version 2.1b6. We implemented the FFHMIPv6 protocol to this environment.

The link bandwidths were chosen so that they do not affect the simulation results. CN sends constant bit rate (CBR) traffic to the MN during the handover. Because route optimization is not used the flow is routed via HA. CBR traffic's packet size is 500 bytes and packet sending interval 0.05 seconds (10kbps). MN originated in the PAR area moves at constant speed of 15 m/s towards the NAR and does the L3 handover with MIPv6 and FFHMIPv6 handover methods. The handover delay and resulting packet loss is calculated in both situations.

Results are presented in Table 1. In scenario 1 the FFHMIPv6 handover time is much shorter than in MIPv6, because the BU register message to the crossover router R1 is enough. R1 tunnels the CBR traffic to the new location of the MN. The packet loss is also very self-explanatory, because the traffic MN receives is constant bit rate sent at the interval of 10 ms. In scenario 2 the FFHMIPv6 is functioning as MIPv6, because the crossover router is not found. The results achieved by the ns-2 simulations are much similar as expected due to theoretical analysis, thus simular results are expected also to the HMIPv6 and FHO handover methods.

4 CONCLUSIONS

In (Sulander et al., 2004) we presented a new Flow-based Fast Handover method for Mobile IPv6 network. In this paper we expanded the performance analysis of the FFHMIPv6 method. The proposal was compared theoretically and with ns-2 simulations to other methods.

Theoretical analysis were made with statical link delays and calculating the required signaling. FFHMIPv6 was implemented to ns-2 and it was compared with simulations to the basic Mobile IPv6. Both the theoretical analysis and simulations were done in the so-called good and bad case handover scenarios and we found the handover delay to be significantly shorter than other handover methods under the given assumptions.

The future work includes the expansion of the FFHMIPv6 performance analysis. We are implementing the HMIPv6 and FHO handover methods to ns-2. In addition the simulations are going to be performed to include the variables of number of MNs and the handover rate. MNs sporadic movement and different applications are also to be considered. These bring us closer to more realistic situation. Also the required processing time or the processing load to the core routers is brought as a new parameter besides the handover delay and the packet loss.

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