Research on Mobile IPV6 Technology and Handover Performance Optimization

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Abstract. The working principle and handover process of MIPv6、FMIPv6 and HMIPv6 are analyzed firstly, some problems existing in handover process and crucial factors impacting on handover performance are pointed out next. Then several optimization programs about mobile handover are proposed. FHMIPv6 combines the advantages of FMIPv6 and HMIPv6, and is more suitable for the multimedia real-time requirement. A handover algorithm of HMIPv6 based on fast DAD can reduce the intra-domain and inter-domain delay effectively. An optimization program based on optimal routing functions can obviously reduce the binding registration delay and packet loss, but it still need to be validated in complex and real-time network environment. Finally, the research outlook of MIPv6 technology is proposed.

Keywords: Handover delay, Care-of-Address, Duplicate address detection, Signaling interactions.

1 Introduction

With the rapid development of Internet and mobile communication technology, the combination of wireless mobile access technology and IPv6 has been a new research focus. The Internet Engineering Task Force (IETF) Mobile IP Working Group standardized RFC3775 for supporting Mobile IPv6 (MIPv6) in 2004[1]. In MIPv6 protocol, when a Mobile Node (MN) moves to new subnet, its communication may be disconnected for a few seconds, which is called handover delay. If the time of handover delay is more, the packets will be lost, network resource will be wasted, which will seriously affected network performance. Therefore, how to enhance the handover performance in MIPv6 is a research focus.

2 MIPv6 Handover Performance Analyses

In MIPv6, when in local subnet, MN communicates normally with other nodes; when moving to a new subnet, MN will disconnect with previous access router(PAR), then connects with a new access router(NAR). This procedure is called mobile handover, which includes link-layer procedure and network-layer procedure. The network-layer handover procedure is initiated only after the link-layer handover procedure comes to

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end. And the network-layer handover process includes Movement Detection, care-of address configuration, Duplicate Address Detection and Binding Update.

DL2 denotes the link-layer delay in this paper, which is different because of using different devices. For example, DL2 is 200ms~1500ms in 802.11b.

Movement Detection (MD) procedure is to determine whether or not it moves to a new subnet, the delay of MD is marked DMD. In MIPv6 the value of DMD is 0.5-1.5s.

After completing MD, MN configures its New Care-of Address (NCoA), and this delay is marked DNCoA. If using stateful address auto-configuration, the value of DNCoA equals to the time of configuring DHCP server. If using stateless address auto-configuration, MN generates a NCoA through adding its interface ID to the router prefix information, and the delay of this way can be ignored.

To verify the uniqueness of the NCoA, MN should run Duplicate Address Detection(DAD) procedure, before assigning the address to its interface. D_{DAD} which denote the delay of DAD procedure in this paper is a higher percentage of the whole delay of MIPv6.

Through the Binding Update (BU) procedure, MN registers its temporary location to its Home Agent (HA) in its home network and Correspondent Node (CN) every time it moves, which brings a lot of signaling messages, and increases network load. $D_{BUHA/CN}$ denotes the delay of BU in this paper.

Fig.1 shows that $D_{MIPv6}= D_{L2}+D_{MD}+ D_{NCoA} + D_{DAD} +D_{BUHA/CN}$, D_{MIPv6} denotes the whole delay of MIPv6, among which D_{MD}, D_{DAD}, and $D_{BUHA/CN}$ can be optimized. Because of long delay of handover in MIPv6, MN can not receive packets when in handover procedure, and the ratio of data loss is high.

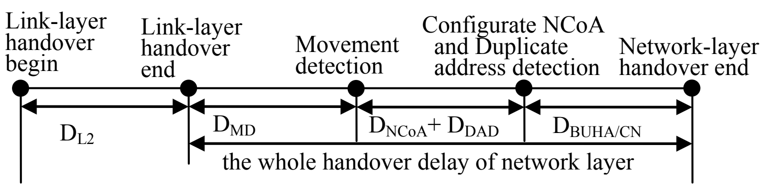

Fig. 1. Handover delay of MIPv6

3 FMIPV6 Handover Performance Analyses

IETF standardized Fast Handover for Mobile IPv6 (FMIPv6) for supporting IPv6 mobility in 2005[2]. In FMIPv6, before moving to a NAR, MN generates its NCoA which can be used in the region of NAR through signaling messages. If MN hasn't generated its NCoA after connecting to the NAR, it should establish a tunnel from the PAR to the NAR to forward packets.

FMIPv6 technology can be divided into predictive handover and reactive handover. When connecting with PAR MN receives FBACK message, which is called predictive handover. When disconnecting with PAR MN hasn't received FBACK message, which is called reactive handover. Fig.2 shows the procedure of predictive handover.

In predictive handover, MN communicates in the region of PAR before handover. When detecting a new network, MN sends a Router Solicitation for Proxy (RtSolPr) to

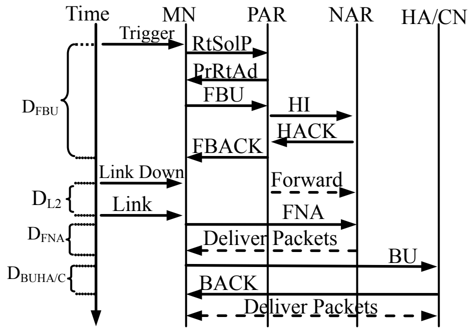

Fig. 2. Predictive handover procedure

the PAR, the PAR will responds to MN a Proxy Router Advertisement (PrRtAdv) message including the information of the NAR's network premix and IP address. Then MN generates an NCoA and sends a Fast Binding Update (FBU) message to the PAR, the PAR immediately sends a Handover Initiate (HI) message with MN's NCoA to the NAR. The NAR verifies that the NCoA can be used on the NAR's link, and responds to PAR a Handover Acknowledge (HACK) message. Then PAR sends a Fast Binding Acknowledgement (FBACK) message to MN, and begins forwarding packets to the NAR by bidirectional tunnel between PAR and NAR. In this paper, D_{FBU} denotes the time from MN's beginning to detect the NAR to this moment. Since then MN disconnects with PAR, and can not receive packets. Link-layer handover begins.

After moving to the region of NAR, MN sends a Fast Neighbor Advertisement (FNA) message to NAR asking for packets. Then NAR starts to forward buffering packets to MN, and then the communication between MN and CN is restored. This paper use D_{FNA} denoting the above time.

Finally, MN sends BU message to HA and CN, then HA and MN responds to MN by Binding Acknowledgement (BACK), the whole handover procedure comes to end. Therefore $D_{FMIPv6}= D_{FBU} + D_{L2} + D_{FNA} + D_{BUHA/CN}$, D_{FMIPv6} denotes the whole delay of FMIPv6.

There are several problems in FMIPv6. Because MN registers its NCoA to HA and CN every time it moves, the registration signaling overhead is still high; when MN moves repeatedly and fast between two adjacent routers, the handover performance of FMIPv6 will be deteriorated, and more data lost; when MN has completed the network-layer handover and does not binding update with HA and CN, MN moves again from current NAR to another NAR, more data lose.

4 HMIPV6 Handover Performance Analyses

In MIPv6 and FMIPv6, when MN far from its HA and moving through more subnets, frequent handover brings more signaling messages, and increases delay. IETF standards Hierarchical Mobile IPv6 (HMIPv6) protocol[3], which using local registration mechanism to update binding update procedure, reduce the number and delay of MN's registration to HA and CN.

HMIPv6 uses a local anchor point called Mobility Anchor Point(MAP). The MAP's function is equal to the local agents of foreign network; it deals with MN's intra-domain movement. The domain managed by MAP can be divided into several subnets. The Fig.3 shows the system architecture of HMIPv6.

In HMIPv6, MN obtains Regional Care-of Address(RCoA) from MAP and uses RCoA to communicate with HA and CN; MN also obtains Link Care-of Address(LCoA) from access router and communicates with MAP using LCoA. When moving in a MAP's intra-domain, MN only registers LCoA to MAP (this paper use D_{LBU} denoting the delay of this registration), and needn't send BU message to HA and CN because of RCoA having no change. This intra-domain handover is very fast, so $D_{IHMIPv6}= D_{FBU} +D_{L2} + D_{FNA} + D_{BUHA/CN}$, $D_{IHMIPv6}$ denotes the whole delay of intra-domain HMIPv6.

When performing inter-domain movement, MN needs to select a new MAP as its regional agents, then sends binding update message to the new MAP to bind LCoA and RCoA. Then MN also sends binding update message to HA and CN to bind HA and RCoA. Let us denote by $D_{OHMIPv6}$ the whole delay of inter-domain movement, it can be concluded that $D_{OHMIPv6}= D_{IHMIPv6}+ D_{BUHA/CN}$.

HMIPv6 protocol reduces effectively the times of MN's registration to HA and CN through local registration mechanism, and has obvious improvement in signaling cost. But the map discovery protocol in HMIPv6 still needs to improve; and the latency of MD and NCoA's configuration is also not been shortened.

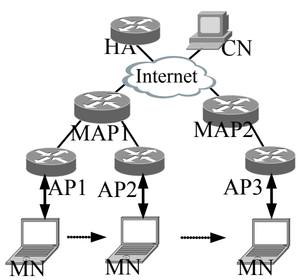

Fig. 3. System architecture of HMIPv6

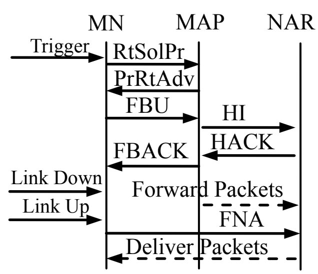

Fig. 4. FHMIPv6 handover process

5 Optimization and Improvement of Mobile Handover Technology

5.1 FHMIPv6 Technology and Handover Performance Analysis

Fast Handover for Hierarchical MIPv6 (FHMIPv6) protocol combines the advantages of HMIPv6 and FMIPv6 [4]. The network architecture of FHMIPv6 is similar to HMIPv6's architecture which shown in Fig.3.

According to the Fig.3, in the simple combination way, HMIPv6 protocol is used to connect the MAP and access router, and FMIPv6 protocol is used to realize handover between the two access routers. The packets CN sending to MN will be delivered to PAR through MAP, and then PAR will use tunnel to follow the packets to NAR. Therefore, it will bring triangle routing problem, and increase handover delay, waste communication bandwidth.

In the optimized combination method, the Fig.4 shows the handover procedure of the figure 3. ①MN sends a RtSolPr message to MAP to ask for the NAR's information. ②The MAP replies a RtSolPr message, including the NAR network prefix and IP address. ③MN generates a New Link Care-of Address (NLCoA) according to the NAR's network prefix and interface address, and sends FBU message to MAP. ④The MAP sends a HI message including MN's NLCoA to the NAR. ⑤ After receiving HI message, the NAR firstly verifies that the NLCoA can be used on the NAR's link, and then responds with a HACK message to MAP. ⑥The MAP responds a FBACK message to MN, and begins forwarding packets to the NAR by bidirectional tunnel between MAP and NAR. ⑦MN begins link-layer handover. After completing link-layer handover, MN sends a FNA message to NAR. Then NAR forwards the buffering packet to MN. The whole handover procedure comes to end.

Based on the above analysis we can see that the FHMIPv6 protocol can shorten the registration delay, and reduce the disruption in the communication process. But it requires higher device preference; MN needs periodically send location information when moving to a coverage area covered by several routers. Thus it will generate more signaling, and increase the processing load of MAP.

5.2 Duplicate Address Detection Optimization

The delay of DAD is a large proportion in the whole MIPv6 delay. The every DAD operation consumes a random time which is 1s in IETF RFC2462. But the delay of multimedia real-time business is less than 600ms. In order to reduce the DAD delay's impact on handover performance, RFC3315 and RFC 4429 optimize the DAD operation.

Through NS2 simulation, a handover algorithm of HMIPv6 based on fast DAD can reduce the intra-domain handover delay to 202ms, and the inter-domain handover delay to 339ms [5]. Therefore it can meet the mobile real-time requirement of multimedia business. But it should be authenticated in more complex experimental environment, and it also brings the load of address pool management to NAR and MAP.

5.3 Binding Registration Optimization

In HMIPv6 protocol, the intra-domain binding registration delay of MN can be reduced effectively, but the inter-domain binding registration delay has no improvement. A new enhanced forwarding mechanism reconstructs FBU message from MN to PAR, it can rapidly establish the tunnel between PAR and NAR, shorten binding delay, and reduce the handover delay [6].

An optimization program based on optimal routing functions has been proposed [7]. In this optimization program, when switching intra-domain, MN just needs to find the optimal functions routing FR* between the two MAP according to optimal routing algorithm, and registers to the FR*. Obviously, the distance between MN and FR* will be less than the distance between MN and HA. The results of experimental simulation show that this new method can reduce greatly the binding delay and packet loss.

6 Summaries

Reducing the handover delay is one of key issues of MIPv6 technology. The FMIPv6 mechanism reduces address configuration delay to speed handover process; the HMIPv6 mechanism uses MAP management to reduce the binding update delay and network signaling load. The FHMIPv6 mechanism is more suitable for the multimedia real-time requirement, but it increases the MAP's load dealing with signaling interactions. This paper also proposes several optimization programs about the delay of DAD and BU, but these programs just past simulation, and still need to be validated and improved in real network environment. With increasing quality requirements of mobile Internet services, the future research should focus on address allocation policy based on FHMIPv6, and reduce or cancel DAD operation. Therefore it is necessary for future research to find a balance point to reduce the handover delay, improve network performance, and reduce the complexity of protocol and network load.

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