QoS Provisioning in an Enhanced FMIPv6 Architecture

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Abstract. Mobility management and QoS provisioning are both key techniques in the future wireless mobile networks. In this paper we propose a framework for supporting QoS under an enhanced "Fast Handovers for Mobile IPv6" (FMIPv6) architecture. By introducing the key entity called "Crossover Router" (CR), we shorten the length of packet forwarding path before the MN completes binding update. For QoS guarantee, we extend the FBU and HI messages to inform the NAR of the MN's QoS requirement and make advance resource reservation along the possible future-forwarding path before the MN attaches to the NAR's link. We keep RSVP states in the intermediate routers along overlapped path unchanged to reduce reservation hops and signaling delays. The Performance analysis shows that the proposed scheme for QoS guarantee has lower signaling cost and latency of reservation re-establishment, as well as less bandwidth requirements in comparison with MRSVP.

1 Introduction

Wireless devices are expected to increase in number and capabilities in the following years. Mobile and wireless access will become more and more popular. Thus Mobile IPv6 (MIPv6) protocol [1] is proposed to manage mobility and maintain network connectivity in the next generation Internet.

However, there are still two problems to be resolved in MIPv6 environment. Firstly, the handover latency and packet loss in basic MIPv6 protocol are not ideal, which raises the need for a fast and smooth handover mechanism. A number of ways of introducing hierarchy into IPv4 as well as IPv6 networks, and realizing the advanced configuration have been proposed in the last few years [2-4]. Secondly, as real-time services grow, the desire for high quality guarantee of these services becomes eager in MIPv6 networks. As we know, two different models are proposed to guarantee QoS in the Internet by IETF: the integrated services (IntServ) [5] and differentiated services (DiffServ) [6] models. However, only IntServ model which uses RSVP protocol [7] to reserve resources can provide end-to-end QoS.

In this paper we propose a scheme for QoS provisioning in an enhanced "*Fast Handovers for Mobile IPv6*" (FMIPv6) architecture [2]. Two enhancements are introduced to improve the performance of basic FMIPv6. To reduce tunnel distance between the *Previous Access Router* (PAR) and the *New Access Router* (NAR), we propose that the *Crossover Router* (CR) intercept packets destined to MN and forward them to the NAR. CR is the first common router of the old path and the new forwarding path. We also use an efficient mechanism to eliminate the long *Duplicate*

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Address Detection (DAD) latency. As for QoS guarantee, we use extended FBU and HI messages to inform the NAR of the MN's QoS requirement. Upon receiving the information, the NAR initiates an advance reservation process along the possible future-forwarding path before the MN arrives the NAR's link. Again the CR is used to reduce the length of reservation path.

The rest of the paper is organized as follows. Section 2 presents some related work. Section 3 presents the overview of proposed scheme. Section 4 describes the detailed handover and resource reservation process. Section 5 gives the performance measurement, and Section 6 concludes the paper and presents some areas for future work.

2 Related Work

2.1 Fast Handover for MIPv6

FMIPv6 aims to decrease packet loss by reducing IP connectivity latency and binding update latency. The MN uses L2 triggers to discover available *access points* (APs) and obtain further information of corresponding *access routers* (ARs) when it is still connected to its current subnet. After that, the MN may pre-configure the *New CoA* (NCoA) and register it to the PAR to bind *previous CoA* (PCoA) and NCoA. Through these operations the movement detection latency and the new CoA configuration latency are reduced. To reduce the binding update latency, a bi-directional tunnel between the PAR and the NAR is used to forward packets until the MN completes binding update. When the MN moves to the new subnet link, it will announce its attachment to launch forwarding of buffered packets from the NAR.

However, there are two disadvantages in basic FMIPv6 protocol. One is that the tunnel between the PAR and the NAR is fairly long. The other is that the DAD procedure for NCoA validation causes large handover latency. We'll discuss the solutions later.

2.2 Techniques of QoS Provisioning

Due to host mobility and characteristics of wireless networks, there are several problems in applying RSVP to mobile wireless networks. In the past several years many RSVP extensions were proposed to solve the problems. Talukdar et al. [9] proposed the MRSVP protocol in which resource reservations are pre-established in the neighboring ARs to reduce the timing delay for QoS re-establishment. However, too many advance reservations may use up network resources.

Chaskar et al. [10] proposed a solution to perform QoS signaling during the binding registration process. This mechanism defines the structure of "*QoS OBJECT*" which contains the QoS requirement of MN's packet stream. One or more QoS OBJECTs are carried in a new IPv6 option called "*QoS OBJECT OPTION*" (QoS-OP), which may be included in the hop-by-hop extension header of binding update and acknowledgement messages. Fu et al. [11] applied QoS-OP in the *Hierarchical Mobile IPv6* (HMIPv6) [3] architecture. Both schemes make use of intrinsic mobility signaling and achieve faster response time for effecting QoS along the new path.

Moon et al. [12] explained the concept of CR, which is the beginning router of the common path. And the common path is the overlapped part of the new path and previous path. Fig. 1 presents an example of the common path and the CR. Shen et al. [13] presented an interoperation framework for RSVP and MIPv6 based on the "Flow Transparency" concept, which made use of common path by determining the "Nearest Common Router" (just like CR) too. In both schemes the CR ensures that reservation will not be re-established in the routers along common path. Thus the QoS signaling overheads and delays as well as data packet delays and losses during handover can be greatly reduced.

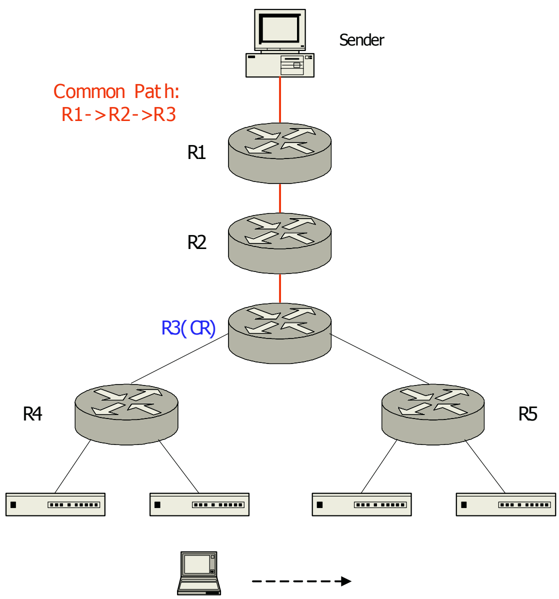


Fig. 1. Common Path and Crossover Router (CR)

3 Overview of Proposed Solution

The proposed solution includes two parts: some improvements to basic FMIPv6 and an efficient framework for end-to-end QoS guarantee in the enhanced FMIPv6 architecture.

Assuming that we have determined the location of CR, data forwarding path using the bi-directional tunnel of FMIPv6 would be CN-CR-PAR-CR-NAR. Obviously we can shorten the path to CN-CR-NAR. The method for CR determination will be introduced later. Though the bi-directional tunnel is eliminated in our scheme, a unidirectional tunnel from PAR to NAR is still included because the CR does not know when to intercept packets that destined to the MN's PCoA. When tunneling process begins, the PAR sends a TUN_BEGIN message which enables the CR to intercept the packets destined to the MN's PCoA and forward them to the NAR. In the opposite direction, the NAR directly sends packets with the CN's address filled in the destination address field. The CR intercepts these packets, sets the source address field to the MN's PCoA and forwards them to the CN.

A further modification to the basic FMIPv6 is the elimination of DAD procedure. We adopt the method of "Address Pool based Stateful NCoA Configuration" [8]. The NCoA pools are established at NAR or PAR. Each NCoA pool maintains a list of NCoAs already confirmed by the corresponding NAR. Thus the NCoA assigned to the MN at each handover event is already confirmed so that the DAD procedure can be ignored.

Now come to the part of QoS guarantee. As we know in FMIPv6 architecture, the NCoA is pre-established. Thus we can set up reservation along several possible future-forwarding paths (one or more NARs may be detected in FMIPv6) in advance when the MN still locates in the PAR's link. Just like MRSVP, *active* and *passive* Path/Resv messages and reservations are defined in our proposal. The NAR, which makes advance reservation and maintains soft state on behalf of the MN, acts as *remote mobile proxy*. To inform the NAR of the MN's QoS requirements, we extend the FBU and HI messages with QoS-OP in the hop-by-hop extension header.

Then we can initiate advance reservation along possible future path. Since there may be more than one NARs detected by the MN, all the possible future-forwarding paths must perform advance reservation. If the MN is a receiver, the CR issues the *passive Path* message to the NAR on behalf of the CN and the NAR in turn sends the *passive Resv* message to the CR. If the MN is a sender, the NAR issues the passive Path message. Upon receiving Path message, the CR immediately replies with a passive Resv message to the NAR. By performing these operations, the passive RSVP messages are restricted within the truly new part of the possible future path, which results in decreased RSVP signaling overheads and delays.

When the MN attaches to certain NAR's link, the packets sent from or destined to it can acquire QoS guarantee without any delay. At the same time advance reservations in other NARs' link must be released immediately. The modified FMIPv6 handover and resource reservation procedures when the MN acts as a receiver are depicted in Fig. 2.

In conclusion, our proposed QoS provisioning scheme has the following advantages:

1. The transmission of QoS requirement makes use of intrinsic mobility signaling of FMIPv6, which results in faster response time for effecting QoS along the new path.
2. The advance reservation along the possible future path decreases the delay of reservation re-establishment and provides QoS guarantee for the MN until it completes binding update.
3. The CR keeps reservation along common path unchanged. Thus the reservation delay and signaling cost can be minimized, which in turn minimizes the handover service degradation.
4. The duration of advance reservations in our proposal is much shorter than MRSVP.

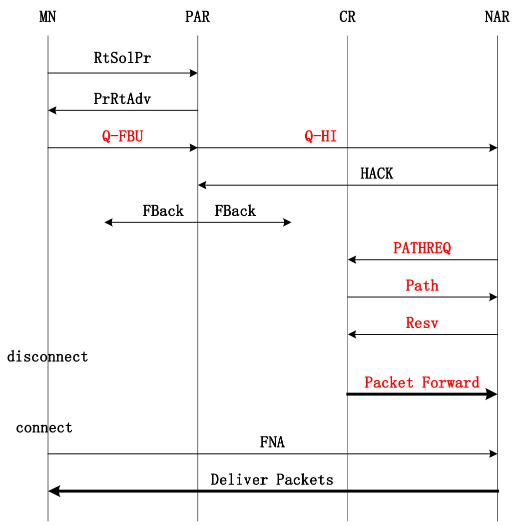


Fig. 2. Handover and Reservation Procedures of a Mobile Receiver

4 Detailed Operations

First of all, we assume that the MN moves into the boundary of the PAR so that the fast handover procedure launches. The procedures of proposed fast handover and resource reservation are as follows:

1) The MN discovers available APs using link-layer specific mechanisms and then sends a *Router Solicitation for Proxy* (RtSolPr) message including the identifiers of the APs to the PAR.
2) After the reception of the RtSolPr message, the PAR resolves the access point identifiers to subnet router(s) (i.e. the [AP-ID, AR-Info] tuples). Though several NARs may be discovered, the following description will just focus on the operations of certain NAR. Using the "*PAR-based stateful NCoA configuration*" proposed in [8], the PAR obtains a confirmed NCoA and responds the NCoA as well as the [AP-ID, AR-Info] tuple (via PrRtAdv) to MN.
3) In response to the PrRtAdv message, the MN sends a *Q-FBU* message to the PAR before its disconnection from the PAR's link. The Q-FBU message includes a QoS-OP (contains one or more QoS OBJECTs) in the hop-by-hop extension header. The QoS OBJECT may contain RSVP objects such as FLOW_SPEC, SENDER_TSPEC and FILTER_SPEC.
4) On reception of the Q-FBU message, the PAR again includes the MN's QoS requirement in the *Q-HI* message and sends it to the NAR. The Q-HI message should also contain the CN address corresponding to each QoS OBJECT, which will be used as the destination address of the *PATHREQ* message when the MN acts as a receiver.

Case 1. When the MN acts as a sender,

5a) The NAR directly issues the passive Path message. A RSVP router decides if it is the CR just by comparing the home address, the CoA and the previous RSVP hop carried in the passive Path message against the same information stored in the Path State. If there is a Path state related to the home address of passive Path message, and for the same home address both the CoA and the previous RSVP hop have been changed, then the router decides it is the CR. The binding of PCoA and NCoA is also included in a hop-by-hop extension header of the passive Path message. The CR will use the binding to prevent packet forwarding between the PAR and NAR.

6a) The CR does not forward the Path message further to the CN, but immediately replies with a passive Resv message to the NAR. By performing these operations, the RSVP states in the routers along the common path will not change. Fig. 3a describes the advance reservation process when the MN acts as the sender.

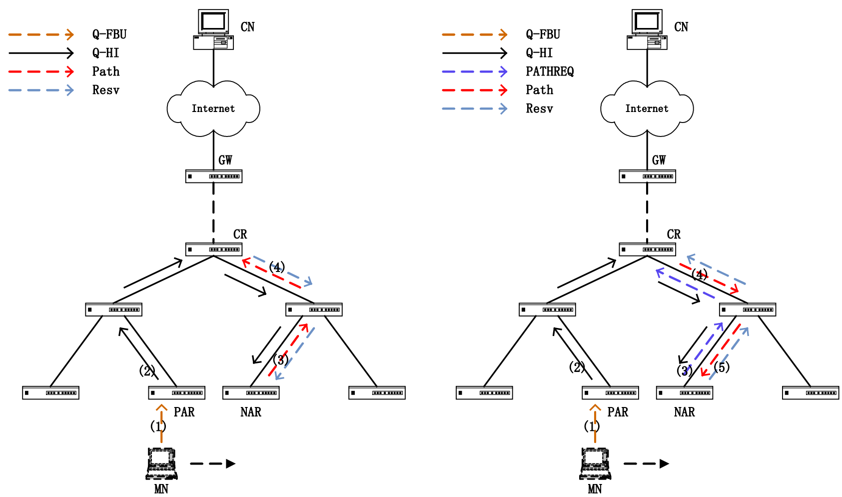
Case 2. Otherwise, the MN acts as a receiver,

5b) The NAR sends a PATHREQ message which has the CN's address as destination address (thus the CR can intercept this message) to request passive Path message. A RSVP router decides if it is the CR by searching the home address in PATHREQ against the same field in PATH state on the downlink direction. If there is a match of the home address in the PATH state in the downlink direction, then the router decides it is the CR. The PATHREQ message, which contains MN's home address and new CoA as introduced in [13], is extended to include the binding of PCoA and NCoA.

6b) The CR then issues the passive Path message to the NAR on behalf of the CN because the path between the CR and the CN is the common path and needn't any change. Finally the NAR will issue the passive Resv message towards the CR. Fig. 3b depicts the advance reservation process when the MN acts as the receiver.

7) At the same time as advance reservation process initiates, the NAR replies with a HACK message to the PAR, which may in turn issue the FBack message. The PAR may ignore sending this message because the NCoA is already confirmed.
8) When packet tunneling launches, the PAR will send a *TUN_BEGIN* message which has the CN's address as destination address. Upon receiving this message the CR begins to intercept packets destined to the PCoA and forward them to the NAR. Reversely, the NAR directly sends packets with the CN's address filled in the destination address field. The CR intercepts these packets, sets the source address field to the MN's PCoA and forwards them to the CN.
9) As soon as the MN attaches to the NAR, it sends the FNA message to the NAR. As a response, the NAR forwards buffered packets to the MN.

Finally, the MN can send a binding update to the HA and the CN. After it completes binding update, the CR stops intercepting packets sent from or destined to the MN. The packets will be forwarded with QoS guarantee along the new RSVP path.



(a) Mobile Sender (b) Mobile Receiver

Fig. 3. Procedures of Advance Resource Reservation

5 Performance Analysis

In this section we study the performance of handover and resource reservation. We consider a network environment with a single domain made up of 16x16 square-shaped subnets and model the MN's mobility as a two-dimensional (2-D) random walk, which is similar to reference [14]. In a 2-D random walk, an MN may move to one of four neighboring subnets with equal probability. Under FMIPv6 architecture, only when the MN moves into the overlapped area of two or more APs, it may achieve information of the possible future NARs. Thus the number of the NARs is less than two. Under other simulated or real environments, the number of possible NARs is always less than the number of neighboring ARs in MRSVP.

Parameters:

N_p	average number of possible NARs in FMIPv6;
N_n	average number of neighboring ARs of current AR in MRSVP;
d_{x_y}	average number of hops between x and y;
B_w	bandwidth of the wired link;
B_{wl}	bandwidth of the wireless link;
L_w	latency of the wired link (propagation delay and link layer delay);
L_{wl}	latency of the wireless link (propagation delay and link layer delay);
P_t	routing table lookup and processing delay;
s_a	average size of a signaling message for resource reservation;
B_r	amount of the actual resource requirement of the handover MN;
t_r	average time the MN will resident in certain AR's link;
t_{pl}	time from completion of reservation to the beginning of L2 switch;
t_{l2}	time to complete L2 switch.

With the above parameters, we define $t(s, d_{x\_y})$ as the transmission delay of a message of size s sent from x (an MN always) to y via the wireless and wired links.

$$t(s, d_{x\_y}) = (\frac{s}{B_{wl}} + L_{wl}) + d_{x\_y} \times (\frac{s}{B_w} + L_w) + (d_{x\_y} + 1) \times P_t \quad (1)$$

5.1 Handover

Our proposed handover scheme affects the handover performance of FMIPv6 in three aspects. Firstly, the elimination of DAD procedure can reduce significant delays in FMIPv6. Secondly, decreased length of packet forwarding path during handover saves packet delivery time. When the MN attaches to the NAR's link, it can receive these packets from the NAR more quickly. This is necessary for real-time applications for that more packets' latency will be less than the threshold so that the application can use them for real-time audio and video playback. However, we should also consider the signaling cost of TUN_BEGIN message and additional overheads of PCoA and NCoA binding notification to the CR.

Finally, our proposed QoS guarantee mechanism also influences the handover performance. The Q-FBU and Q-HI messages size is enlarged to hold QoS requirement. So the signaling cost is larger than the basic FMIPv6 protocol. Since the size of QoS requirement is small in proportion to the total signaling cost, the additional latency introduced by the Q-FBU and Q-HI messages can be ignored.

Further analysis is not presented and we focus the discussion on the performance analysis of resource reservation.

5.2 Resource Reservation

1) *Total signaling cost of resource reservation*: In our proposed scheme, signaling messages for resource reservation include Q-FBU, Q-HI, PATHREQ, Path and Resv messages. s_a is the average size of these messages. Q-FBU message travels from the MN to the PAR; Q-HI message from the PAR to the NAR; PATHREQ, Path and Resv messages from NAR to CR. The total signaling cost of resource reservation is denoted by C and is computed as the following.

$$C_{FMIPv6-R} = s_a \times (d_{MN\_AR} + d_{AR\_AR} + 3 \times d_{AR\_CR}) \times N_p \quad (2)$$

If MN acts as a sender, the PATHREQ message is not used.

$$C_{FMIPv6-S} = s_a \times (d_{MN\_AR} + d_{AR\_AR} + 2 \times d_{AR\_CR}) \times N_p \quad (3)$$

In MRSVP, Spec, MSpec, Path, active Resv and passive Resv message are the signaling messages for resource reservation. We consider the scenario that the sender acts as the *receiver_anchor* node [9].

$$C_{MRSVP} = s_a \times (d_{AR\_AR} \times N_n + d_{AR\_CN}) + 2s_a \times d_{AR\_CN} \times (N_n + 1) \quad (4)$$

2) *Reservation establishment delay*: We compute the total delay since the MN issues Q-FBU to PAR. As the signaling cost, total delay of QoS establishment is affected by the same messages. The total delay of reservation establishment is denoted by D.

$$D_{FMIPv6-R} = t(s_{a,} d_{MN\_AR}) + t(s_a, d_{AR\_AR}) + 3 \times t(s_a, d_{AR\_CR}) \quad (5)$$

$$D_{FMIPv6-S} = t(s_{a,} d_{MN\_AR}) + t(s_a, d_{AR\_AR}) + 2 \times t(s_a, d_{AR\_CR}) \quad (6)$$

$$D_{MRSVP} = t(s_a, d_{AR\_AR}) + 3 \times t(s_a, d_{AR\_CN}) \quad (7)$$

Note that the delays we compute here are reservation establishment delays. Actually, except for switch operation between active and passive reservation, the resource reservation can be used immediately when the MN attaches to the new subnet both in our FMIPv6 based advance reservation mechanism and in MRSVP.

3) *Bandwidth requirements*: The duration of advance reservation along the paths between CR and possible NARs is t_{pl} plus t_{l2}. When the MN arrives certain NAR's link, reservation status on this link changes to active while other passive reservations are released. We use B to denote the total bandwidth requirements including active and passive reservation during the period a MN residents in certain AR's link.

$$\begin{aligned} B_{FMIPv6} &= B_r \times (d_{AR\_CR} + d_{CR\_CN}) \times t_r \\ &+ B_r \times d_{AR\_CR} \times (t_{pl} + t_{l2}) \times N_p \end{aligned} \quad (8)$$

$$B_{MRSVP} = B_r \times d_{AR\_CN} \times t_r \times (N_n + 1) \quad (9)$$

Now we can compare the performance of our proposal and the MRSVP. Let's focus on three pairs of parameters: d_{AR_CR} against d_{AR_CN}, N_p against N_n, and $t_{pl}+t_{l2}$ against t_r. The comparison results are identical: the former is much less than the latter. Thus we can draw the conclusion that the total signaling cost of resource reservation and the reservation establishment delay, as well as bandwidth requirements in our scheme are much less than those in MRSVP.

6 Conclusion

This paper proposes a framework for QoS guarantee based on an enhanced FMIPv6 architecture. We introduce a key entity which called "Crossover Router" (CR) to reduce the length of packet forwarding path before the MN completes binding update. Furthermore we use "Address Pool based Stateful NCoA Configuration" mechanism to eliminate the long DAD latency. The proposed QoS guarantee scheme achieves low signaling cost and reservation re-establishment latency by making use of the FBU and HI signaling messages of FMIPv6 to transmit QoS requirements and adopting the idea of advance reservation and common path. Performance analysis shows that our proposal outperforms MRSVP in terms of signaling cost, reservation re-establishment delay, and bandwidth requirements.

The simulation based on NS2 [15] platform for our scheme will be done soon to achieve the further performance analysis under various environments. When and how to release passive reservations on other NARs' link after the MN attaches to certain NAR's link, should be considered. Furthermore, we are also making efforts to apply the idea of our QoS provisioning scheme to F-HMIPv6 architecture [4].

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