

# QoS-Conditionalized Handoff for Mobile IPv6

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**Abstract.** In this paper we present a scheme that enables a mobile user to perform a "QoS-conditionalized" handoff when moving to an overlapping area in Mobile IPv6. The idea is to use a QoS hop-by-hop option piggybacked in the binding messages for QoS signaling and conditionalize a handoff upon the availability of sufficient resources along the new transmission path. Our scheme builds upon the hierarchical mobile IPv6 protocol and is especially suited for micro-mobility. It also enables the mobile node to flexibly choose among a set of available access points so that the mobile node can transmit packets through a route which offers satisfying QoS.

## 1 Introduction

With the advent of various radio access technologies, the increasing amount of IP services over wireless as well as wired networks, and the cheap availability of IP equipment, all-IP networks will be deployed in mobile environments. As a node moves within such a network, it must be reachable and able to communicate. One solution are the Mobile IP [2] and recently the MobileIPv6 (MIPv6)[4] protocols. MIPv6 ensures correct routing of packets to a mobile node (MN) when the MN changes its point of attachment within the IPv6 network. However, supporting QoS during handoffs is still a challenging problem, e.g. due to changing routes between endpoints or varying (wireless) link characteristics when connecting to different access points.

In future all-IP networks, a multitude of different wireless technologies and service providers is likely to co-exist, and hence connections to different access points can even happen at the same time. For example, in case of a wireless access network made up of different access technologies such as UMTS and Wireless LAN, the coverage areas may overlap. With such heterogeneous access networks, the need and opportunity to select among a number of available access points arises. In particular, when a mobile node has established QoS flows, it would be desirable to perform a handoff only when the QoS of these flows can be guaranteed after the handoff as well. Therefore, a handoff should not be performed if the MN's QoS requirement is not met; yet if the QoS can be met, handoff should be performed as quickly as possible. This indicates that a handoff

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should be conditionalized upon the availability of sufficient QoS resources; also, an appropriate access router (AR) based on the QoS requirements should be selectable among a set of ARs — an example scenario would be an MN moving in an area where several radio access technologies overlap. It is the main goal of this paper to describe a handoff scheme that is in this sense QoS-conditionalized.

Furthermore, many handoffs are local in the sense that the paths from the CN to the old and new ARs only diverge before the ARs; this point of divergence is called a “switching router.” In the context of QoS-conditionalized handoffs, it is desirable to restrict QoS negotiations to the path between switching router and new AR, as the path between CN and switching router remains the same. Supporting such local renegotiations depends on the mobility mechanism. The IETF Hierarchical Mobile IPv6 (HMIPv6) protocol [7] is able to optimize such local mobility, but unable to carry QoS information; hence, handoffs do not take QoS into account.

Therefore, we introduce a QoS-conditionalized handoff scheme taking advantage of HMIPv6. If all nodes along the route between the AR and the switching router are capable of fulfilling the QoS request related to the handoff, the switching router will decide to perform the actual handoff (binding entries will be modified); otherwise, the old route will still be used. The process could be iterated until the QoS requirements are met or no more ARs/routes are available.

In the rest of this paper, we first describe related work in Section 2 and then present our scheme in Section 3. Section 4 discusses some possible extensions, followed by a comparison with other approaches for QoS support in mobile IP in Section 5. Section 6 concludes the paper and outlines our future work.

## 2 Related Work

### 2.1 Mobile IP

The concept of Mobile IPv6 is based on the usage of home agent. Put briefly, a mobile node entering a foreign network obtains a local IP address, the care-of-address. This address is registered with the home agent (HA) in the home network and, when necessary, with the correspondent node. The HA can then intercept all packets destined to the MN to the CoA via IP tunneling; CNs can send packets directly. While Mobile IP ensures reachability and optimizes packet routes, it suffers from signaling load and potentially long handoff latency.

To improve on these two points, Hierarchical Mobile IPv6 (HMIPv6) [7] introduces a new entity, the Mobility Anchor Point (MAP). When a MN moves into a new MAP domain (i.e., its MAP changes), it gets 2 CoAs: a Regional CoA on the MAP’s subnet (RCoA) and an on-link address (LCoA). The MN then sends a BU to the MAP specifying its RCoA in the Home Address field and its source address is LCoA, as well as requests a binding (RCoA, Home Address) from its HA and CNs. If it moves locally, only the LCoA is changed and only a registration to the MAP is needed. The MAP then acts as a proxy between the RCoA and the LCoA. Packets addressed to the RCoA are then intercepted

by the MAP, encapsulated and routed to the MN. While this approach is efficient and scalable for mobility support, it is unable to provide QoS support for mobile users. In practical deployment, the MAP would usually be located in the switching router (possibly a gateway of an administrative domain); such an arrangement will be assumed in the remainder of this paper.

## 2.2 Mobile QoS Support

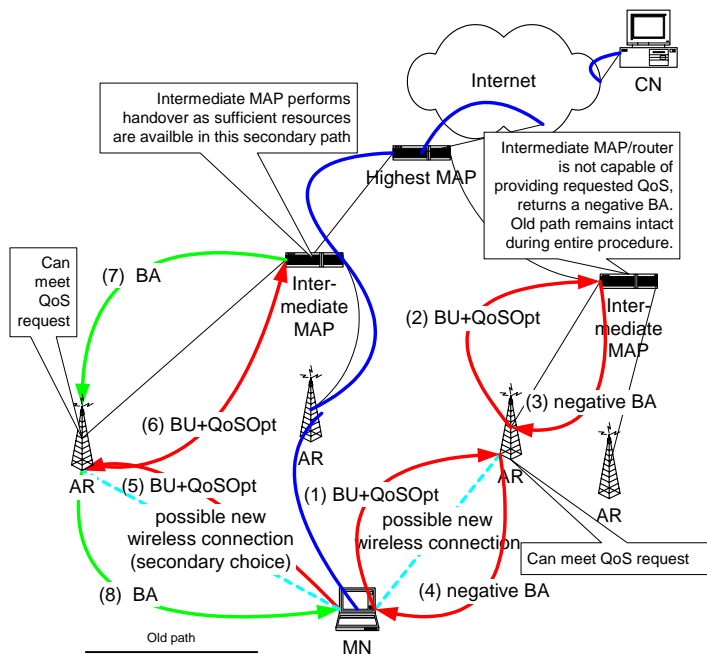
As RSVP is a well established protocol for signaling, much work has been done to address the RSVP-mobile IP interaction. An analysis of the current situation is presented in [8]. Shen et al. [6] extend RSVP to support QoS signaling in mobile IP by introducing a unified flow identifier during handoff for the interworking between RSVP and mobile IP, and taking advantages of RSVP Path/Resv two-pass procedure to setup the reservation in the new path during handoffs. However, these approaches have problems regarding scalability and signaling overhead. To overcome this, Chaskar et al. [1] introduce a new IPv6 hop-by-hop packet header option called "QoS option", composed of one or more QoS objects, to carry the QoS information for the IP flows between a MN and its CN.

This option can be included in MIPv6 registration messages, namely the Binding Update (BU) and Binding Acknowledgement (BA) messages. Since the BU is sent as soon as the data transmission from the new CoA is ready to begin, the included QoS option triggers the necessary actions to set up QoS forwarding treatment along the new path. This approach does not rely on round-trip signaling such as Path/Resv of RSVP, but rather on triggering QoS forwarding treatment along the new network path in one pass; the latency for packets to get proper QoS treatment is therefore decreased. However, it does not allow mobile users to select another AR in case of insufficient resources along the route between MN and CN (the user is not even made aware of the fact). Hence, we extend this approach to allow QoS-conditionalization and specifically base our mechanism on HMIPv6 and more details will be discussed in the forthcoming next version of the internet draft [3].

## 3 QoS-Conditionalized Handoff for Mobile IPv6

### 3.1 Overview

The all-IP network is assumed to consist of routers which may also be responsible for the management of QoS resources, in which case we call them QoS entities. For the purpose of this paper, such a QoS entity acts as a black box to which QoS requests for a certain path (e.g., from the AR to the MAP) can be sent, which checks resource availability (resources would typically include link bandwidth, buffer space in the router, CPU resources, etc.) along the particular part of the route it is responsible for, and either grants the request (and reserves the resources), denies it, or, optionally, grants a reduced version of the request. Typically, QoS entities would be located at least in the ARs and in the MAPs.



**Fig. 1.** Example of the QoS-conditionalized Handoff Procedure

The operation of QoS-conditionalized handoff is as follows. A QoS hop-by-hop option is carried in the message containing the BU option to the MAP — this message is called BU+QoS message. Each QoS entity between the MN and the MAP (including the MAP) will pass the QoS requirement represented by the QoS option to internal QoS mechanisms and check its resource availability. If resources are available locally, they are reserved and the message will be forwarded along its route. If resources are not available, negative feedback will be provided to the MN by means of an extended Binding Acknowledgement (BA+QoS) message. If a BU+QoS message has reached the switching MAP and passed the local QoS test as well, the handoff will take place (the binding cache in the MAP is updated to reflect the new LCoA) and a positive BA+QoS message is returned to the MN. Otherwise, no handoff is performed and a negative BA+QoS message is returned to the MN. When observing a negative BA+QoS message, intermediate QoS entities can release reservations that could not be granted further upstream.

In order to allow both upstream and downstream QoS requirements to be considered, this approach assumes that packets for both directions follow the same route. Extending our approach to asymmetric routes should be feasible but this is beyond the scope of this paper.

Figure 1 shows one example of a QoS-conditionalized handoff procedure.

### 3.2 Message Format

The QoS option [1] is an IPv6 hop-by-hop header option which allows applications to specify their QoS requirements (eg., maximum/minimum bandwidth, delay) in the form of QoS objects, describing these parameters in a type-length-value format. We extend its definition by using two reserved bits in the option header: one to indicate whether only a single QoS object is present in the QoS option or if two objects are included, representing “acceptable” and “desired” level of QoS; another bit to indicate whether enough resources along the route up to the current router are available (if set it indicates failure to provide resources). These bits are called the “A” (acceptable only) and “F” (failed) bit, respectively.

### 3.3 Description of QoS-Conditionalized Handoff

This section describes the QoS-conditionalized handoff scheme in more detail. The main point to note is that a handoff that is local to a single MAP does not involve the CN and hence no modification to the CN is necessary; here the algorithms based on HMIPv6 in basic mode are provided.

**Mobile Nodes.** Algorithm 1 shows pseudo-code for the main event loop of the network-layer code of a mobile terminal. Main events to process are detecting connectivity to a new AR or losing connectivity to an existing router and the arrival of a packet from a lower or higher protocol layer. As a simplification, the code here assumes that whenever a new AR becomes available, a handoff to this AR should be attempted; in reality, other policy-specific handoff schemes could be possible. Note that the treatment of acceptable/desirable QoS is also not shown here; the necessary modifications are reasonably straightforward.

**Intermediate Nodes and MAPs.** The procedure for intermediate nodes and MAPs is shown in Algorithm 2.

Note that in order to correctly process the BA+QoS message, all routers concerned with QoS management, such as MAPs, ARs, and possibly DiffServ and MPLS edge routers (ER), as well as IntServ nodes need to maintain a soft state for each flow. These states will time-out along an unused path. They can further be explicitly released via a message carrying a QoS option with “F” bit set (as illustrated in Algorithm 2) upon a successful handoff.

## 4 Further Discussion

### 4.1 Reducing the Signaling Load over the Wireless Link

As both wireless bandwidth and processing power on mobile terminals are precious resources, it would be desirable to minimize the amount of QoS information

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**Algorithm 1** Pseudocode of the QoS-conditionalized handoff procedure for mobile nodes

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1: loop {Wait for event}
2:   if Event reports connectivity to an additional AR then
3:     MN acquires new local IP address
4:     Compose a BU+QoS message;
5:     Send BU+QoS towards MAP (via new AR);
6:     Increment number of ARs by 1
7:     if Connected = false then
8:       Connected  $\leftarrow$  true
9:       Inform application of reconnection
10:    end if
11:  else if Event reports loss of connectivity to AR then
12:    Decrease number of ARs by 1
13:    if Number of ARs = 0 then
14:      Connected  $\leftarrow$  false
15:      Inform application of loss of connectivity
16:    else if Lost AR is currently used AR then
17:      QoSGuaranteed  $\leftarrow$  false
18:      Inform application of loss of QoS guarantees
19:    end if
20:  else if Event is packet from lower layer then
21:    if Packet is BA+QoS then
22:      if "F" bit not set then {request succeeded}
23:        Use this AR henceforth
24:        if QoSGuaranteed = false then
25:          QoSGuaranteed  $\leftarrow$  true
26:          Inform application of QoS reestablishment
27:        end if
28:      end if{Otherwise, no action is required: either still use old AR, or QoS
        guarantees have already been lost}
29:    else if Packet is normal IP packet then
30:      Deliver to application
31:    end if
32:  else if Event is packet from higher layer then
33:    Forward packet, using current AR
34:  end if
35: end loop

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traversing the wireless link and the processing in the MN. Here, Context Transfer protocol (CT) [5] appears to be particularly useful. In case CT is used, the processing in MNs and ARs must be changed accordingly. An (old) AR needs to store QoS requirement information for each of its MNs. When a MN wishes to associate itself with a new AR, it could simply inform the new AR of the old AR's identity as well as of its own address. The new AR then fetches the QoS requirement description from the old AR and initiates the BU process on behalf of the MN; BAs would still have to be provided eventually to the MN.

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**Algorithm 2** Pseudocode of QoS-enabled handoff procedure for routers and MAPs

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loop {For every packet received from link layer:}
  if Packet is BU+QoS then
    if "F" bit in BU+QoS not set then
      Ask QoS entity for resources
      if Resources are not available then
        Set "F" bit in BU+QoS packet
      end if
    end if
    if This node is a MAP then
      if This node is the switching MAP then
        Compose a BA+QoS packet from the BU+QoS packet {with "F" bit as in
        the BU+QoS packet}
        if "F" bit is not set then
          Update the MN's binding to the new LCoA
          Optionally: Compose a negative BA+QoS message and send it along the
          old path to release reservations
        end if
        Return the BA+QoS message to the MN
      else {This node is an intermediate MAP, but not the switching MAP}
        if "F" bit is not set then
          Determine the next, hierarchically higher MAP
          Compose a new BU+QoS packet for the next MAP
          Forward this new packet to the MAP
        else {Request has failed somewhere along the path}
          Compose a BA+QoS packet (with "F" bit set)
          Return BA+QoS to the MN
        end if
      end if
    else {This node is just a normal router}
      Forward packet towards destination
    end if
  else if Packet is BA+QoS then
    if "F" bit is set in BA+QoS then
      Release any possibly reserved resources for this flow
    end if
    Forward packet towards MN
  else {Normal packet}
    Forward packet with proper QoS treatment
  end if
end loop

```

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## 4.2 Upgrading the Level of QoS

Another concern is which level of QoS requirements is appropriate for a MIPv6 QoS solution. As the MN requests a “(acceptable QoS, desired QoS)” pair in the new path, it can obtain any level above the acceptable QoS provided that there are sufficient resources in the path, depending on the policy of the provider. To reduce the difficulty in authorization/charging (which may be based on previously used QoS), we assume that the route between the switching router and the CN has already been guaranteed with the desired QoS level, hence only the remaining part (mobile part, typically in an access network) will be actually effected.

## 4.3 Macro-Mobility Consideration

Our scheme is mainly designed for intra-MAP mobility cases but it can be extended for macro-mobility scenarios. For handoffs between different domains (i.e., there is no MAP on the joint part of the paths  $CN \leftrightarrow$  old AR and  $CN \leftrightarrow$  new AR), the BU+QoS message could be sent to the CNs directly after an MN moves to a new AR. All the intermediate routers follow the procedure outlined in Algorithm 2 as indicated in Section 3.3 and the CN now takes, in a sense, the responsibility of a MAP. However, the mechanisms to detect an inter-MAP mobility and switch between an intra-MAP mobility and an inter-MAP mobility for both CN and MN require further study.

# 5 Comparison with Other Proposals

This section compares the proposed scheme with two other proposals to support QoS in mobile IP: QoS framework for Mobile IPv6 [1] and RSVP for MIPv6 [6].

First, the latency to re-establish QoS forwarding mechanisms is vital for a QoS solution in mobile IP. As an example, suppose a handoff is local and the transmission delay from a MN to MAP is 10 ms, considerably lower than the end-to-end delay from MN to CN, 100 ms. Then our QoS-enabled handoff scheme needs a period of two passes for signaling from MN to switching router, which is 20 ms, for both downstream and upstream QoS re-establishment, and actual downstream forwarding can take place already after 10 ms (once the MAP has received the BU+QoS, downstream forwarding can already begin). The approach in [1] needs an even lower latency for upstream QoS re-establishment (10 ms), but only if the resources are actually available. For downstream QoS re-establishments, [1] needs two passes for signaling delay from MN to CN (or a local mobility agent if micro-mobility solution is used), 200 ms (or 20 ms). [6] needs two and three passes signaling delay from MN to MAP for upstream and downstream QoS re-establishment, 20 ms and 30 ms, respectively. It shows our scheme performs relatively well in the local mobility case. Choosing another AR when one route is unable to accommodate the QoS request is possible with our approach and [6], yet not possible using [1]. Finally, all three approaches

compared enhance the efficiency of QoS signaling for handoff, but our approach is the only one that can ensure that a handoff is performed only when QoS requirements are met. A summary of the comparison is given in Table 1.

**Table 1.** Comparison with other protocols

		QoS-Conditionalized Handoff	QoS Framework for MIPv6	RSVP for MIPv6
Latency for QoS re-establishment	Downstream	Two passes from MN to switching router	Two passes from MN to CN or local agent	Two passes from MN to switching router
	Upstream	Two passes from MN to switching router	One pass from MN to switching router	Three passes from MN to switching router
Ability to choose another AR		Yes	No	Possible
Ability to perform QoS-conditionalized handoff		Yes	No	No

## 6 Conclusions and Future Work

QoS support in all-IP mobile networks brings about great challenges and requirements. This paper presents a hierarchical, flexible, and scalable solution that makes use of an IPv6 hop-by-hop option. Our scheme reduces the signaling bandwidth on the backbone by hiding local mobility while still providing ability to do QoS signaling. Our work extends the work in [1] by: 1) enabling mobile users to choose a "good" access point when several (or overlapping) ones are available (e.g., WLAN and UMTS in hot spots); 2) having handoffs QoS-conditionalized, i.e., handoffs could be performed only when QoS requirements are met or most satisfied. The latency for QoS re-establishment is reduced compared to RSVP-based approaches during a handoff.

We are extending the work presented in this paper as follows: 1) Prototype implementation of QoS option and measuring the benefits of applying our scheme; 2) the QoS option may be changed or misused by attackers, hence we also study how to appropriately secure the QoS-conditionalized handoff procedure.

Other future research items include incorporating our scheme with other mobility solutions such as fast handoff and experimenting with adaptive applications using our scheme.

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