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A Framework for QoS Support in Mobile IPv6
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Abstract

This draft describes a solution to perform QoS signaling along the new network path, when mobile node using Mobile IPv6 acquires a new care-of address. The solution is based on the definition of new option called QoS OBJECT OPTION. This option is included in the hop-by-hop extension header of certain packets, preferably the ones carrying binding messages, propagating between mobile node and correspondent node or between mobile node and regional mobility agent(s). Such an approach takes advantage of mobility signaling inherent in Mobile IPv6 to program QoS forwarding treatment as well, along the new network path. It naturally blends in with micro-mobility techniques. Further, compared to using RSVP, our solution has much smaller latency until QoS forwarding treatment is programmed over the new network path after handover.

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1.0 Introduction

While Mobile IP [1] ensures correct and efficient routing of mobile node's (MN) packets as the MN changes its point of attachment with the Internet, the issue of Quality of Service (QoS) for MN's packet streams is not addressed yet. This document describes the problem statement, outlines a solution and provides comparison with existing (mobility-unaware) approaches such as RSVP [2] to QoS signaling.

1.1 Problem statement

As an MN moves from one access router (AR) to another, the paths traversed by MN's packet streams with its correspondent nodes (CNs), may change. This is always true for the path in the access network to which MN is attached. In addition, handover between ARs in different access networks may cause the path traversed by MN's packet streams in the core network to change as well. If the MN's packet streams are QoS-sensitive, a mechanism is needed to signal desired QoS forwarding treatment along the new paths in the network. It is important to note that while the routing aspect of mobility has been addressed in Mobile IPv6, the problem of maintaining desired QoS forwarding treatment in the light of mobility has not been addressed.

Subsequent to handover, the new end-to-end path between CN(s) and MN may span a number of networks (access and core) employing a variety of QoS schemes, notably IntServ [3] in access and MPLS [4] and DiffServ [5] in core. There may as well be best effort networks in the end-to-end path. Thus, as a basic requirement, mobility-aware QoS signaling mechanism must be capable of providing QoS forwarding information for MN's packet streams to relevant routers in different networks in the end-to-end path. The QoS signaling mechanism must have fast response time so that the latency between the time packets using the new care-of address (CoA) are released into the network and the time QoS forwarding information is signaled along the new path should be minimized. In other words, the mechanism must be able to make use of intrinsic handover signaling to minimize "QoS alignment" latency for MN's packet streams. Furthermore, any mobility-aware QoS signaling mechanism should be able to exploit micro-mobility [6,7] and fast handover [8] solutions in order to localize the extent of signaling to affected branches of the network only. Finally, such a mechanism should impose minimal requirements on the end terminals with limited processing power, memory and battery resources.

1.2 Solution overview

Our solution is based on the use of new option called QoS OBJECT OPTION. It may contain a number of QoS OBJECTs, each of which corresponds to one unidirectional QoS-sensitive packet stream of

MN. The basic idea is to include QoS OBJECT OPTION in IPv6 hop-by-hop extension header along with packets propagating in the same direction as the QoS-sensitive packet streams of MN. Since binding update (BU) is sent as soon as the data transmission from the new CoA is ready to begin, the QoS OBJECT OPTION sent along with it in hop-by-hop extension header, promptly triggers the necessary actions to set up QoS forwarding treatment along the new path. Same is true regarding binding acknowledgment (BA) when the packet streams in the direction from CN(s) to MN are considered. With basic Mobile IPv6, the binding messages travel end-to-end. Thus, the QoS object processing also spans end-to-end network path. With micro-mobility solutions, these messages travel only as far as the nearest mobility agent that needs to update its route table entry. Note that the QoS OBJECT OPTION also needs to travel only as far as the nearest node requiring an update to its route entry. Thus, by combining the transmission of QoS OBJECT OPTION with binding messages, a natural optimization is achieved with micro-mobility solutions. However, note that QoS object option may be included in hop-by-hop extension header of any other packet propagating in the same direction as QoS-sensitive packet stream.

The actions taken by intermediate routers upon examining the QoS OBJECT OPTION in hop-by-hop extension header depend on the QoS scheme employed by their network domains. Generally, in access networks, QoS OBJECTs in QoS OBJECT OPTION will be used by all routers to program QoS forwarding treatment for MN's packets. In the core network, typically edge routers process the QoS OBJECT OPTION, while internal routers ignore it.

Note that our approach does not relay on round-trip signaling such as PATH/RESV of RSVP, but rather performs programing of QoS forwarding treatment along the new network path in one pass. Also, this is done ahead of the time the packets using new CoA arrive at intermediate routers along the new end-to-end path. This minimizes the number of packets that would get default forwarding treatment at intermediate nodes due to lack of QoS forwarding information in those nodes after handover.

2.0 Terminology and Abbreviations

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in RFC 2119.

MN: Mobile node
CN: Correspondent node
QoS: Quality of service

CoA: Care-of-address
HoA: Home address
AR: Access router

BU/BA: Binding update/Binding acknowledgment
ER: Edge router of network domain
IR: Interior router of network domain
MPLS: Multi-protocol label switching
FEC: Forwarding equivalence class
DiffServ: Differentiated services
IntServ: Integrated services
Uplink/Downlink direction: From MN/Towards MN

3.0 **Composition of QoS OBJECT OPTION**

The QoS signaling solution described here uses a new IPv6 extension header option called QoS OBJECT OPTION. The composition of QoS OBJECT OPTION is shown in Figure 1. It contains zero or more QoS OBJECTs in TLV format.

```
     0                   1                   2                   3
     0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
                                    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
1                                   |0|0|1| Opt Type| Opt Data Len  |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
2   |     Reserved  |        One or more QoS OBJECTs in TLV format
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 1: Composition of QoS OBJECT OPTION

The composition of a QoS OBJECT is shown in Figure 2. A QoS OBJECT is an extension of RSVP QoS and FILTER_SPEC objects.

```
     0                   1                   2                   3
     0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
                    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
1                   |     Reserved    | Object Length |QoS Requirement|
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
2   | Max Delay (16-bit integer) ms |Delay Jitter (16-bit integer)ms|
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
3   |     Average Data Rate (32-bit IEEE floating point number)     |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
4   |Burstiness:Token Bucket Size(32-bit IEEE floating point number)|
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
5   |      Peak Data Rate  (32-bit IEEE floating point number)      |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
6   |            Minimum Policed Unit  (32-bit integer)             |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
7   |           Maximum Packet Size  (32-bit integer)               |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
8   |                                                               |
    |                                                               |
    |            Values of Packet Classification Parameters         |
```

```
   |                                                               |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 2: Composition of a QoS OBJECT

- QoS Requirement: This field describes the QoS requirement of the MN's packet stream in terms of traffic class. An example is the QoS specification in terms of delay sensitivity, such as interactive-delay sensitive, non-interactive delay sensitive or delay insensitive, as in UMTS QoS specification [9]. Another example is specification in terms of DiffServ PHB classes such as EF or AF. Yet another alternative is QoS specification in terms of IntServ classes such as guaranteed service or controlled load service. Some examples are,

  00000xxx: DiffServ EF PHB
  00001xxx: DiffServ AF PHB

  00010xxx: IntServ guaranteed service
  00011xxx: IntServ controlled load service

  00100xxx: UMTS traffic class

- Delay specification: The fields "Max Delay" and "Delay Jitter" specify the end-to-end values of respective quantities in milliseconds that the packet stream can tolerate.

- Traffic Volume: The fields Average Data Rate, Burstiness, Peak Data Rate, Minimum Policed Unit and Maximum Packet Size describe the volume and nature of traffic that the corresponding packet stream is expected to generate.

- Packet Classification Parameters: This field provides values for parameters in packet headers that can be used for packet classification. In particular, it specifies a subset of TCP/UDP port numbers, IPv6 flow label and SPI corresponding to particular packet stream. Typically, source and destination IP addresses to be used for packet classification can be inferred from header of packet carrying QoS OBJECT OPTION.

4.0 Inclusion of QoS OBJECT OPTION in hop-by-hop extension header

The basic idea here is to include QoS OBJECT OPTION containing QoS OBJECTs corresponding to MN's packet stream(s), in the hop-by-hop extension header along with the packet that propagates in the same direction as the corresponding packet stream(s). QoS OBJECTs in this option can then inform the routers at the intermediate network domains about the QoS forwarding requirement of the relevant packet streams. Routers make use of this information, in a manner that is consistent with the QoS scheme employed by their network domains (see Section 6), to immediately program proper QoS forwarding treatment for those packet stream(s).

4.1 Basic Mobile IPv6

In basic Mobile IPv6, MN sends BU to CN as soon as it is ready to use new CoA. QoS OBJECT OPTION containing QoS OBJECT(s) corresponding to uplink packet stream(s) SHOULD be included in hop-by-hop extension header with this BU. QoS OBJECT OPTION promptly triggers necessary processing at the intermediate routers so as to offer proper QoS forwarding treatment to MN's uplink packet streams along the new end-to-end path.

By the same reasoning, QoS OBJECT OPTION containing QoS OBJECT(s) corresponding to downlink packet stream(s), SHOULD be included in hop-by-hop extension header along with BA that is sent from CN to MN.

Note however that QoS OBJECT OPTION can be included in the hop-by-hop extension header of any packet that propagates in the same direction as the corresponding packet stream(s).

4.2 Micro-mobility scenarios

Micro-mobility solutions introduce local mobility agents, such as a Gateway Mobility Agent (GMA) in Regional Registration or Mobility Anchor Point (MAP) in Hierarchical Mobile IPv6 approach for proxying a regional CoA. Regional CoA remains constant while the MN moves inside the visited domain. This approach alleviates the need for sending BUs to all the CNs for every handover. This conserves wireless bandwidth as well as reduces the signaling load caused by binding messages outside the visited domain. It decreases the latency associated with binding messages as they are sent only up to the local mobility agent.

The proposed solution readily makes use of micro-mobility mechanisms, facilitating QoS modification along only those segments of end-to-end forwarding path that are affected by the MNÆs movement. The QoS OBJECT OPTION would be carried in the BU to the regional mobility agent, and the routers in the path traversed by BU process this hop-by-hop option, making modifications to their QoS forwarding engines as necessary. The BA from the regional mobility agent would trigger similar adjustments for QoS forwarding treatment for packets destined to the MN.

We observe some significant performance benefits in combining QoS signaling with micro-mobility. First, the QoS signal itself would travel only as far as what is deemed necessary by the particular micro-mobility mechanism. This reduces the round-trip signaling latency. Incidentally, we note that with Regional Registrations for Mobile IPv6, this distance is up to the cross-over router, where as with HMIPv6, it is the number of hops up to MAP. Second, QoS object option with micro-mobility greatly enhances existing state re-usage. That is, the existing

QoS state beyond the GMA or the MAP need not be modified at all when the mobile nodeÆs movement is limited to the visited domain (implying that the Regional CoA does not change). Regional Registrations further extends this state re-use to the nodes within the visited domain itself. For example, when the mobility limits route changes to a node below the GMA in hierarchy, such as a cross-over router, the existing state above the cross-over state can be re-used, since those nodes do not perceive a change in the source address in the packets.

5.0 Performance Considerations (Comparison with RSVP)

In this section, we compare the performance of QoS signaling approach proposed in this document to that of using RSVP for QoS signaling upon handover. The performance metric used is the latency between the time nodes (MN or CN) are ready to use new CoA and the time QoS forwarding requirement is signaled over the new forwarding path.

We observe that RSVP introduces latency of about one round-trip time (between the MN and the CN) from the time packets using new CoA are released into the network until the time QoS forwarding treatment is programmed over the new path. Note that one end-to-end round-trip may involve, in the worst case, four traversals of wireless links. The worst case happens when both MN and CN are attached via low bandwidth wireless links. In that case, the packets released into the network during this time period would get default forwarding treatment at intermediate network domains. On the contrary, in our approach, programming of QoS forwarding treatment along the new end-to-end path is immediate. This is shown by the following illustration.

Suppose MN is currently at CoA1. Consider data traffic from the CN towards the MN (downlink direction). The following events occur:

o MN moves to CoA2 and sends BU from CoA2 to CN. BU reaches CN. CN sends BA to MN at CoA2.

RSVP	HOP-by-HOP QoS OBJECT OPTION
CN initiates RSVP signaling to program QoS forwarding treatment for downlink traffic over the new network path. For this, CN sends RSVP PATH to MN at CoA2.	QoS OBJECT OPTION for downlink packet stream(s) is included in HOP-by-HOP OPTIONS EXTENSION HEADER along with the BA.

o CN may start sending MN's packets to CoA2. These packets contain CoA2 as destination address.

```
              RSVP                    |   HOP-by-HOP QoS OBJECT OPTION

   Note that QoS forwarding        | QoS OBJECT OPTION precedes these
   treatment for these packets is  | these packets and programs QoS
   not yet programmed along the    | forwarding treatment along the
   new network path. This is       | new network path. The processing
   certainly true for the segment  | time of QoS OBJECT OPTION along
   of end-to-end path that was     | the new network path would
   not present in the old          | determine how quickly proper QoS
   end-to-end path. Even over      |forwarding treatment is offered.
   that segment of the end-to-end  |In RSVP, this latency is at least
   path which remains unchanged    |one round-trip time plus the
   after handover, these packets   |processing time of PATH and RESV
   would get default forwarding    |messages along the new end-to-end
   treatment. This is because,     |network path.
   RSVP session is primarily       |
   identified by destination       |
   address which now has changed   |
   from CoA1 to CoA2.              |

   ----[One way end-to-end delay ellapses, then]----

   o BA reaches MN at CoA2.

   RSVP PATH reaches MN at CoA2. |
   MN sends RSVP RESV to CN.     |

   ----[One way end-to-end delay ellapses, then]----

             RSVP                |

   o RSVP RESV reaches CN.       |
                                 |
   It is at this time that the   |
   proper QoS forwarding         |
   treatment is programmed at the|
   intermediate nodes for packets|
   destined to CoA2.             |
```

It is worth noting that the above drawback of RSVP's OPWA (One Pass with Advertisement) method is also observed in [10].It is shown in [10] that under certain assumptions, the severity of this drawback can be reduced. However, validity of those assumptions is not obvious.

6.0 Processing of QoS OBJECT OPTION at Intermediate Networks

When QoS OBJECT OPTION is included in the HOP-by-HOP OPTIONS EXTENSION HEADER in IPv6 packet, intermediate routers MUST examine this option. The purpose of this is to obtain information about QoS forwarding requirement about MN's packet streams.

Typically, there are multiple and possibly heterogeneous (in terms of QoS mechanism employed) network domains in the end-to-end path. Here, a network domain is defined as a collection of network nodes (routers) that implements a particular QoS mechanism independently and under the same control

framework. There are edge routers (ER) at the edge of these domains and internal routers (IR) inside the domains. Each of these domains may be a best-effort domain or may employ QoS mechanisms such as MPLS, DiffServ or IntServ. Typically, access networks would employ flow-based QoS mechanisms such as IntServ, while core network will use aggregate-based schemes such as MPLS and DiffServ. Note that QoS OBJECT contains enough information so that any of these QoS schemes can extract the information relevant to them from the QoS OBJECT. The actual mapping between QoS object parameters to the parameters used by different QoS schemes is implementation specific, and thus beyond the scope of this document. In the following, we outline the semantics of processing QoS OBJECT OPTION at ERs and IRs of these network domains.

6.1 IntServ domain

In IntServ domain, there are two ways to process the QoS OBJECT OPTION. According to one method which fully complies with One Pass with Advertisement (OPWA) model of RSVP, ingress ER examines the QoS OBJECT OPTION in hop-by-hop extension header to determine QoS forwarding requirement of MN's packet streams. It also determines the egress ER of that network domain where MN's packets will be forwarded. Ingress ER sends RSVP PATH message to egress ER. Ingress ER MAY include (a version of) QoS OBJECT OPTION in _destination_ extension header of the packet carrying RSVP PATH message. This will provide egress ER with the information necessary to determine the actual resources that are required to be reserved. Egress ER sends RSVP RESV to ingress ER. Once ingress ER receives RESV from egress ER, it forwards the packet containing QoS OBJECT OPTION through the network domain. IRs in the network domain simply ignore the QoS OBJECT OPTION.

The above method has the following drawback that is intrinsic to OPWA model of resource reservation of RSVP, when it is used in mobile environment. It takes one round trip time in the network domain before QoS forwarding treatment is programmed at the routers in the network domain. In other words, MN's packets that arrive at the ingress ER get default forwarding treatment until the time RESV reaches ingress ER. This drawback is eliminated if the following method of resource reservation is used instead.

Ingress ER of IntServ network domain examines the QoS OBJECT OPTION and immediately performs reservation of resources such as buffer, bandwidth, priority etc. at that router. Ingress ER then forwards the packet containing QoS OBJECT OPTION to next IR in the network domain. IR examines the QoS OBJECT OPTION and immediately performs resource reservation at that router. IR then forwards the packet to next IR in the network domain. This continues until the packet reaches egress ER which performs resource reservation at that router, and forwards the packet to next network domain.

6.2 MPLS domain

Ingress ER at MPLS domain (often called edge label switching

router (edge LSR)) determines the forwarding equivalence class (FEC) to which the packets of MN's packet stream(s) should belong to in that domain. This decision is based on the destination IP address of the packet and QoS forwarding requirement of packet stream(s). FEC translates to label switching path (LSP) over which the packets should be forwarded through that domain. Ingress ER may also use traffic volume parameters in QoS OBJECT(s) to perform admission control over those LSPs. Ingress ER creates FEC mapping context that would map subsequent packets of MN's packet stream(s) onto appropriate LSPs. Packet classification parameters in the QoS OBJECT(s) are used to set up FEC mapping context.

Ingress ER then forwards the packet containing QoS OBJECT OPTION through the network domain using label based forwarding paradigm. As a result of this, IRs do not even see the IP header, and hence, do not process any hop-by-hop options.

6.3 DiffServ domain

Ingress ER at DiffServ domain uses QoS OBJECT(s) in QoS OBJECT OPTION to program packet classification context for the packets of MN's packet stream(s). This context would assign appropriate differentiated services code point (DSCP) to subsequent packets of these packet stream(s). ER may also perform admission control to ensure that service level agreement (SLA) is not violated by the volume of traffic generated by these packet stream(s).

IRs in DiffServ domain simply ignore the QoS OBJECT OPTION.

7.0 Security considerations

To be discussed.

8.0 Acknowledgment

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