QoS Support in Mobile IP version 6

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***Abstract*- This paper proposes a solution to perform QoS signaling along the new path in the network, when a mobile node using Mobile IP version 6 acquires a new care-of address. The solution is based on the definition of a new IPv6 option called the "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 a mobile node and its correspondent node or between a mobile node and the regional mobility agent(s). Such an approach takes advantage of the mobility signaling inherent in Mobile IPv6 to quickly program the QoS forwarding treatment along the new network path. It naturally blends in with micro-mobility techniques. Further, compared to using conventional QoS signaling protocol such as RSVP, our approach has significantly smaller latency until the QoS forwarding treatment is programmed over the new network path subsequent to handover.**

I. INTRODUCTION

The design of Mobile IP version 6 (MIPv6) has addressed correct and efficient routing of packets to a Mobile Node (MN) as the MN changes its point of attachment to the Internet [1, 2]. However, the issue of quickly establishing the desired Quality of Service (QoS) forwarding treatment for the MN's packets along the *new* end-to-end path has not been addressed yet. As the MN moves from one Access Router (AR) to another, the path(s) of packets between the MN and the Correspondent Node(s) (CN) changes. This is always true for the path in the access network to which MN is attached. In addition, handovers between ARs in different access networks may cause the path traversed by MN's packet stream(s) in the core network to change as well. An example of such situation is the handover between an outdoor cellular network and an indoor LAN. If the MN's packet streams are QoS-sensitive, a mechanism is needed to signal desired QoS forwarding treatment along the new path in the network.

Such a mechanism should have the following desirable features. Since the end-to-end path may contain network domains employing different QoS schemes [3, 4], notably Integrated Services (IntServ) [5] in the access and Differentiated Services (DiffServ) [6] or Multi-Protocol Label Switching (MPLS) [7, 8] in the core, the signaling mechanism must be able to provide sufficient information to relevant routers in these different network domains to program their QoS engines. 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 is programmed along the new path should be minimized. This is particularly important for applications such as VoIP which would not tolerate perceivable QoS degradation upon every handover. In other words, the mechanism must be able to make use of intrinsic handover signaling in MIPv6 to minimize the "QoS alignment" latency for MN's packet stream(s). Any such scheme should also naturally integrate with the micro-mobility solutions such as Regional Registrations [9] or Hierarchical Mobile IPv6 [10]. Finally, it should impose minimal requirements on the end terminals with limited processing power, memory and battery resources.

Our solution makes use of the mobility signaling messages, such as the binding messages that are intrinsic in MIPv6, to achieve fast response time. It is based on the use of new IPv6 option called QoS OBJECT OPTION (QoS-OP). This option is included in the hop-by-hop extension header in packets propagating in the same direction as the QoS-sensitive packet stream(s). Since binding update (BU) is sent as soon as the MN is ready to use a new CoA, if the QoS-OP is sent along with BU in the hop-by-hop extension header, it promptly triggers the necessary actions to set up QoS forwarding treatment for the uplink packet stream(s) along the new path. Note that uplink direction refers to the direction away from the MN. The same is true regarding binding acknowledgment (B-ACK), when the packet stream(s) in the downlink direction is considered. With basic MIPv6, binding messages travel end-to-end. Hence, the processing of QoS-OP also spans the new end-to-end packet path. With micro-mobility solutions, binding messages travel only as far as the nearest mobility agent that needs to update its route table entry. Note that the QoS-OP 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-OP with the binding messages, a natural optimization is achieved with the micro-mobility solutions. However, note that QoS-OP may be included in the hop-by-hop extension header of any other packet propagating in the same direction as the QoS-sensitive packet stream(s) of the MN.

The rest of the paper is organized as follows. Section II describes the composition of QoS-OP. Inclusion of QoS-OP in hop-by-hop extension header is described in Section III for basic MIPv6 as well as for the micro-mobility solutions. Section IV describes the processing that the QoS-OP triggers at different routers in the end-to-end path. Performance comparison of our approach with RSVP [11], which is the conventional end-to-end QoS signaling protocol, is given in Section V. Section VI contains the conclusion.

II. COMPOSITION OF QOS-OP

A QoS-OP primarily contains one or more QoS OBJECTs, each of which corresponds to one unidirectional QoS-sensitive packet stream of a MN. In other words, a QoS-OP is a placeholder for one or more QoS OBJECTs each of which represents a unidirectional packet stream. A QoS OBJECT includes three important pieces of information about the MN's packet stream. First, it describes the QoS requirement in terms of traffic class such as UMTS traffic class (conversational, streaming, interactive or background), IntServ service class (guaranteed or controlled load service) or DiffServ Per-Hop Behavior (PHB). It may also contain end-to-end tolerable delay in quantitative form. Second, it describes the volume of traffic expected from the corresponding packet stream. Finally, the QoS OBJECT provides packet classification parameter information. Such parameters include a subset of TCP or UDP port numbers, IPv6 flow label and security parameter index. The source and destination IP addresses to be used in the packet classification process can be inferred from the corresponding fields in the IP header of the packet carrying QoS-OP itself, and hence, need not be included in the QoS-OP. The qualitative composition of a QoS OBJECT is shown in Figure 1. For the bit-level details about the composition of a QoS OBJECT, the reader is referred to [12]. It can be seen that a QoS OBJECT is essentially an extension of RSVP's QoS and packet classification objects such as FLOW_SPEC, SENDER_TSPEC and FILTER_SPEC. A QoS OBJECT is designed to contain sufficient information to feed into the QoS module of relevant routers at the network domains employing different QoS mechanims such as IntServ, DiffServ or MPLS.

1. Traffic class, end-to-end tolerable delay
2. Traffic volume: Mean rate, peak rate, burstiness, minimum policed unit, maximum data unit
3. Packet classification parameters

Figure 1: Composition of a QoS OBJECT

III. INCLUSION OF QOS-OP IN HOP-BY-HOP EXTENSION HEADER

The basic idea here is to include QoS-OP, containing QoS OBJECTs corresponding to the MN's QoS-sensitive packet streams, in the hop-by-hop extension header of some packet propagating along the same path as the corresponding packet streams. QoS-OP will then be examined by the routers along the path of the corresponding packet streams. These routers make use of the information in QoS-OP to program QoS forwarding treatment for the MN's packet streams. The exact manner in which the information in the QoS-OP is used by a router, depends upon the QoS mechanism deployed by its network domain (see Section IV for more details).

A. Basic MIPv6

In basic MIPv6, a MN sends BU to its CN, as soon as it is ready to use the new CoA. If QoS-OP corresponding to the uplink packet streams is included in the hop-by-hop extension header along with this BU, it promptly triggers the programming of QoS forwarding treatment at the routers in the new path of uplink packet streams. By the same reasoning, the QoS-OP corresponding to the downlink packet streams should be included in the hop-by-hop extension header along with the Binding Ack sent from the CN to the MN. However, note that QoS-OP can be included in any packet such as simple data packet, that propagates along the same path as the QoS-sensitive packet streams of the MN. This is useful in scenarios where the new QoS-sensitive application is started on the MN independent of handovers.

B. Micro-mobility solutions

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 (HMIPv6) 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 the bandwidth on the wireless link where MN is attached (since now only one BU is required), 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 MN's movement. The QoS-OP 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 B-ACK 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 by combining QoS signaling with micro-mobility solutions. 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, whereas with HMIPv6, it is the number of hops up to MAP. Second, QoS-OP 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 node's 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.

IV. PROCESSING AT THE INTERMEDIATE ROUTERS

When a QoS-OP is included in the hop-by-hop extension header of an IPv6 packet, the intermediate routers examine this option. The purpose is to obtain information about the QoS forwarding requirement of the MN's packet streams. Typically, there are multiple and possibly heterogeneous (in terms of the 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 a QoS mechanism such as MPLS, DiffServ or IntServ. Typically, access networks would employ flow-based QoS mechanisms such as IntServ, while the core network uses aggregate-based schemes such as MPLS and DiffServ. In the following, we outline the semantics of the processing of a QoS-OP at the ERs and the IRs of these network domains.

A. *IntServ domain*

In the IntServ domain, there are two ways to process a QoS-OP. In the approach fully compliant with the One Pass with Advertisement (OPWA) model of RSVP, the ingress ER examines the QoS-OP in the hop-by-hop extension header to determine the QoS forwarding requirement of the MN's packet streams. It also determines the egress ER of that network domain where MN's packets will be forwarded. The ingress ER sends RSVP PATH message to egress ER. The ingress ER may include (a version of) QoS-OP in the 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 the ingress ER receives RESV from the egress ER, it forwards the packet containing QoS-OP through the network domain. The IRs in the network domain simply ignore the QoS-OP.

The above method has the following drawback that is intrinsic to the OPWA model of resource reservation of RSVP (see also Section V), when it is used in the 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 arrives at the ingress ER. This drawback is eliminated if the following method of resource reservation is used instead.

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

B. *MPLS domain*

In the MPLS network domain, packets are forwarded using the label swapping paradigm. The packet tunnels (also called label switched paths or LSPs) of desired capacities and QoS characteristics are established between different ingress-egress router pairs of the MPLS domain, during the traffic engineering phase. Well-known protocols such as RSVP or CR-LDP are used for LSP creation and label distribution. The establishment of such LSP results in the creation of an appropriate entry in the label information base (LIB) of every router in the path of that LSP. LIB points to the QoS forwarding requirement and the output interface for the incoming packet, based on its label. LIB also shows the label to be attached to this packet so that similar information is conveyed to downstream router.

Note that the ingress ER knows how much capacity and what kind of QoS an LSP originating from itself and terminating at some egress ER has. The ingress ER is responsible for classifying the incoming packets and attaching appropriate labels to them, so that those packets are forwarded over the desired LSPs. It can also exercise admission control based on the knowledge of the traffic volume of a packet stream. Thus, a packet stream must be able to provide information such as QoS requirement, traffic volume and packet classification parameters to the ingress ER of the MPLS network domain. In our approach, such an information is provided by the QoS-OP.

Ingress ER at the MPLS domain (often called edge label switching router (edge LSR)) examines the QoS-OP. Based on the destination address of the packet carrying the QoS-OP, edge LSR first determines the egress ER through which the corresponding packet stream would be forwarded. It uses the QoS requirement information in the QoS-OP to fix one of the LSPs between itself and the egress ER for the packet stream. The traffic volume information is used to perform admission control on the said LSP. Using the packet classification parameters in the QoS-OP, edge LSR programs a classifier context that would directly map the subsequent packets of the corresponding stream to thus determined LSP. It then forwards the packet carrying the QoS-OP over the same LSP. Note that due to the label-based forwarding of this packet as well, the IRs in the MPLS domain do not even see the IP header of this packet. Thus, they do not incur any burden of processing the QoS-OP.

C. *DiffServ domain*

The ingress ER of the DiffServ network domain is responsible for marking appropriate Differentiated Services Code Points (DSCP) in the IP headers of the incoming packets. The IRs offer forwarding treatment to the packets based on the DSCP marked in them by the ingress ER. The ingress ER thus needs to create "packet classifier context" that would classify the incoming packets, based on the parameters in their headers such as IP addresses, port numbers etc., into different per-hop behaviors (PHB). A PHB translates to DSCP. The ingress ER of the DiffServ domain may also perform admission control based on the existing service level agreement (SLA) with the neighboring network domains.

The QoS-OP provides the necessary information about the MN's packet streams to the ingress ER of the DiffServ network domain for it to perform the above mentioned functions. First, the QoS requirement information directly translates to the PHB that the packets should be mapped to at that network domain. Traffic volume information in the QoS-OP enables ingress ER to verify the conformance with SLA. Finally, packet classification parameters in the QoS-OP are used to create classifier context that would directly map the subsequent packets of the corresponding packet streams to the appropriate PHB. IRs in the DiffServ domain simply ignore the QoS-OP.

A concept that is often used in conjunction with DiffServ is "Bandwidth Broker". At this point, it is important to note that the QoS signaling in our approach, or for that matter any flow-based QoS signaling, does not directly interact with the bandwidth broker. It is the (edge) routers in the DiffServ network domain that would interact with the bandwidth broker based on the aggregate information about the flows traversing those routers.

Figure 3 illustrates the processing of the QoS-OP at the intermediate routers, when the end-to-end path contains network domains using diverse QoS mechanisms.

V. PERFORMANCE ANALYSIS: COMPARISON WITH RSVP

In this section, we compare the performance of the QoS signaling approach proposed in this paper to that of using RSVP for QoS signaling upon handover. For this, we first consider the latency between the time nodes (MN or CN) are ready to use a new CoA and the time the QoS forwarding treatment is programmed signaled over the new forwarding path. Note that this latency is indicative of the number of packets using the new CoA that will get default forwarding treatment at the intermediate nodes due to the lack of QoS forwarding information in those nodes. Hence, this latency should be minimal. We now compare RSVP with the QoS signaling approach proposed in this paper in view of the performance criterion of latency in QoS programming along the new path.

This is best done with the help of an illustration. Suppose that there are three nodes in the new end-to-end path that are concerned with the programming of QoS forwarding treatment. Let P denote the generic processing time of a QoS signal (RSVP PATH, RSVP RESV or QoS-OP in hop-by-hop extension header) at an intermediate node. Also, let T denote the generic transfer delay between the two nodes. This could be the transfer delay on a wireless link (for example where the MN is attached to the AR), or the link transfer delay between the two physically successive routers, or the transfer delay between the ingress and egress ERs of a network domain (as shown in Figure 2). Suppose that the CN receives BU from the MN. It is then ready to send packets to the MN at a new CoA. If RSVP were used for end-to-end QoS signaling along the new path, it is at this time that the CN issues PATH message towards the MN at the new CoA. If our approach is used instead, the CN includes QoS-OP corresponding to the downlink packet streams in hop-by-hop extension header of the B-ACK. The following table shows the latency in QoS programming at each of the intermediate nodes, starting from the time instant of potential arrival of the first packet destined to the new CoA at that node.

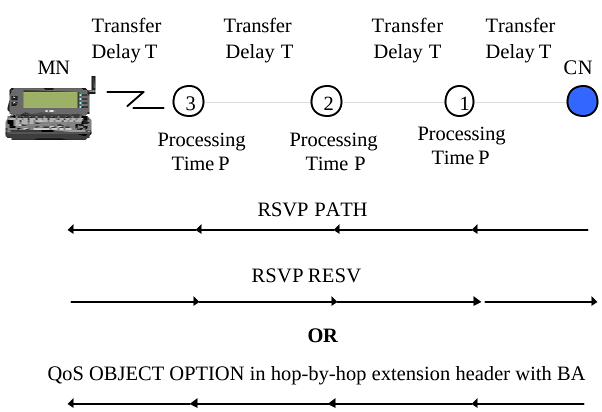

Figure 3: End-to-end QoS signaling after handover (for the packet streams from the CN to the MN)

	RSVP	QoS signaling with binding messages
Node 1	6 T + 6 P	P
Node 2	4 T + 5 P	2 P
Node 3	2 T + 4 P	3 P

Table 1: Latencies involved in the QoS programming at the intermediate nodes along the new path after handover

It can be easily seen that our approach of combining QoS signaling with mobility signaling incurs much smaller latency in programming proper QoS forwarding treatment along the new end-to-end path after handover. This also means less number of packets getting default forwarding treatment, and hence, minimal interruptions in the QoS at handover instants. Minimizing such QoS interruption will be particularly important for the applications such as VoIP.

We observed that RSVP's OPWA model of reservation introduces large latencies in programming the QoS forwarding treatment along the new path after handover. OPWA however has been designed to work efficiently with IP multicast. It is worth noting that if the MN wishes to receive certain multicast group, it does not need to use any binding messages. When the MN moves from one access router to another, it simply needs to subscribe to that multicast group using IGMP messaging with the new access router. Since there are no binding messages in the multicast scenario, any optimization based on the binding messages is not feasible.

VI. CONCLUSION

In this paper, we have presented a novel mechanism to support QoS in Mobile IPv6 protocol, in the light of handovers. Our approach is based on using an IPv6 option that carries required QoS information to allow the routers along the new path to program their forwarding engines. We have shown that this option, typically used with the Mobile IPv6 binding messages, has several advantages. First, it makes use of intrinsic mobility signaling to achieve faster response times for effecting QoS along the new path subsequent to handover. Second, it readily makes use of micro-mobility mechanisms to restrict the extent of signaling to the visited domain, thus reducing signaling latency and facilitating existing state re-usage. Finally, it presents a significant performance benefit compared to the traditional RSVP model of resource reservation. This type of in-band signaling, coupled with terminal mobility, provides a viable solution to the important problem of supporting QoS in the mobile environments.

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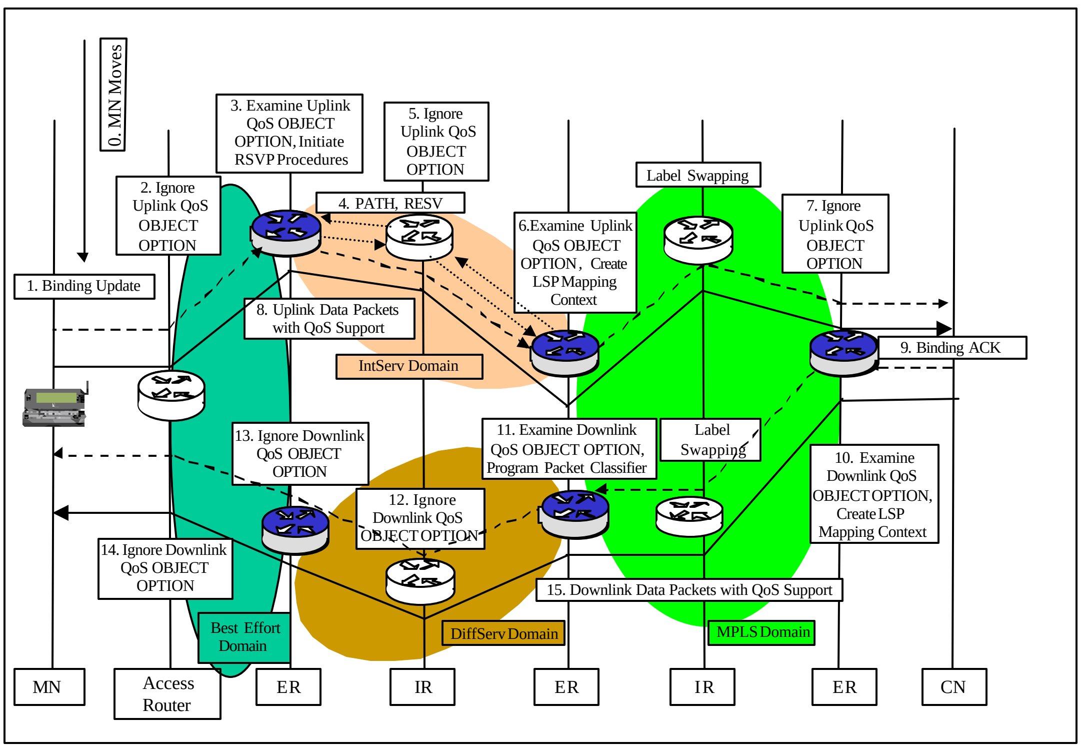

Figure 2: Processing of QoS OBJECT OPTION in the end-to-end path

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