A QoS Provision Architecture for Mobile IPv6 over MPLS Using HMAT

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Abstract. The Resource Reservation Protocol (RSVP) provides a signaling mechanism for end-to-end QoS in Integrated Services Internet. Multi-Protocol Label Switching (MPLS) is a fast label-based switching technique that can offer new QoS capabilities for large scale IP networks. In this paper, in order to obtain more efficient use of scarce wireless bandwidth, increase data rate and reduce QoS signaling delay and data packet delay during handoff in Mobile IPv6, we propose a novel scheme that improves the efficiency using a Hierarchical Mobile Agents Tree (HMAT) based on the definition of new option called QoS Object Option (QOO) over MPLS. The HMAT can be chosen and configured in any way as the network administrator thinks appropriate. The QOO is included in the hop-by-hop extension header of certain packets that carry Binding messages. Mobile agents are required to manage QOO, resource reservation and other mobility related tasks on behalf of mobile hosts. The root mobile agent of the HMAT is also an edge Label Switch Router (LSR) in the MPLS Core Network. This paper defines the efficient signaling and control mechanisms to support QoS in Access and Core Network for Mobile IPv6.

1 Introduction

The Internet Engineering Task Force (IETF) has introduced the Mobile IPv4 [1] and Mobile IPv6 [2] to interoperate seamlessly with protocols that provide real-time services in the Internet. Multi-Protocol Label Switching (MPLS) is a fast label-based switching technology that integrates the label-swapping paradigm with network-layer routing [3]. Resource Reservation Protocol (RSVP) [4] [5] is a resource reservation setup protocol designed for a wired network. Provision of end-to-end QoS in wireless networks is more complex [6] than in wired networks because of the user mobility.

In this paper, we will propose a novel scheme that defines the signaling and control mechanisms to support QoS using the Hierarchical Mobile Agents Tree (HMAT) based on the definition of new option called QoS Object Option (QOO) [12] over MPLS to improve the efficiency during handoff in Mobile IPv6.

In section 2, we provide related works, and in section 3, we describe our scheme to

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provide a new QoS mobility support. In section 4, we present simulation results to prove the efficiency of our scheme. Finally, we give our conclusions in section 5.

2 Related Works

Recently there have been some works [7-14] that focus on the handoff management problem. In [7], the drawback of this architecture proposed by Talukdar is that a mobile knows the addresses of all the subnets it is going to move into and which is not always possible. In [8], the proposal proposed by Mahadevan is based on the assumption that a base station knows the addresses of the base stations in all the neighboring cells. In [9], the protocol proposed by Zhang may result in triangle routing problem, and the pre-provisioned RSVP tunnels are not flexible and efficient. In [10], Chen describes another signaling protocol based on IP Multicast Tree. Figure 1 shows an example for reservations. When the handoff occurs, the Multicast Tree will be modified dynamically. After the new Multicast Tree is formed, the Predictive Reservation from Merge Point to current mobile proxy is switched into Conventional Reservation. The original Conventional Reservation from the Merge Point to the original mobile proxy is switched to Predictive Reservation, and some new Predictive Reservations along the new Multicast Tree from the source to the neighboring cells surrounding the current cell of mobile host should be set up. Then the flow of data packets can be transmitted over that new Conventional Reservation link. In this protocol, there are 8 additional messages presented to complete the functions of Multicast Tree modifying

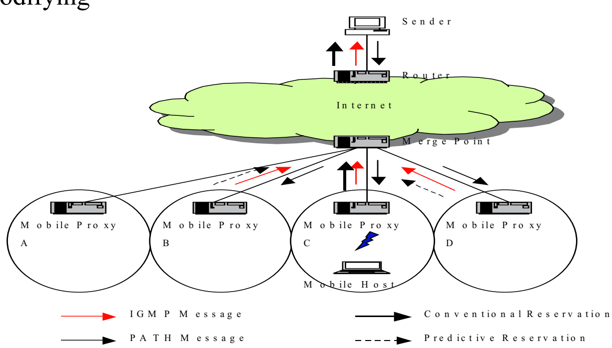

Fig. 1. RSVP Mobility Based on Multicast Tree

and RSVP setting up. Talukdar [7], Mahadevan [8] and Chen [10] have a problem that is how to predict the Mobile node's movement behavior so that pre-reservations can be done only in necessary cells to reduce the QoS signaling delay, the data packet delay. In [11], it is difficult to choose a proper router as the Nearest Common Router, and this scheme is not feasible. In [12], when the MN is receiver in Access Network, the Binding Acknowledgment has to be used so that the proposal is not efficient, and has more data packet delay. In [13], the handoff message has to be used only for Access Network, thus the flexibility is not better. In [14], the QoS provision Architecture has been considered only in the Access Network for the Mobile IPv6. In [17], Zhong considered the supporting MPLS only in Mobile IPv4, and the QoS guarantee has not been considered. In [18], Choi does not show details of the data delivery procedure and QoS guaranteed LSP setup procedure.

3 Proposed Scheme

In this section we propose a framework using a Hierarchical Mobile Agents Tree (HMAT) based on the definition of new option called QoS Object Option (QOO) [12] to get more efficient use of scarce wireless bandwidth, minimize the QoS signaling delay, the data packet delay and losses and get higher data rate during handoff in mobile IPv6 environment.

3.1 QoS Object Option (QOO)

Table 1. Composition of a QoS Object

	0	0	1	Option Type 5bit	Option Data Len 8bit
Reserved	Object Length 8bit				QoS Requirement 8bit
Max Delay (ms) 16bit				Delay Jitter (ms) 16bit	
Average Data Rate 32bit					
Burstiness : Token Bucket Size 32bit					
Peak Data Rate 32bit					
Minimum Policed Unit 32 bit					
Maximum Packet Size 32 bit					
Values of Packet Classification Parameters					

This option is included in the hop-by-hop extension header of certain packets carrying Binding Update message in Mobile IPv6. The composition of a QOO [12] is shown in Table 1 by using TLV format. A QoS Object is not only an extension of RSVP QoS that can be used in Access Network, but also used in Core Network to get a better QoS support. In QOO, the QoS Requirement describes the QoS requirement of the MN's packet stream, the fields Max Delay and Delay Jitter specify the delay that packet stream can tolerate, 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, the field Packet Classification Parameters provide values for parameters in packet headers that can be used for packet classification.

3.2 Hierarchical Mobile Agents Tree (HMAT)

Our hierarchical mobile agents tree is aimed at solving the problem that the QoS signaling delay, the data packet delay will increase and the data rate will decrease and the packet losses, possible service degradation may occur due to frequent handoff. The HMAT means Hierarchical Mobile Agents Tree that contains mobile agents of several levels, and can be chosen and configured in any way as the network administrator thinks appropriate.

A mobile agent is an entity that manages QOO, resource reservations and other mobility related works. Mobile agents in a HMAT can be divided into two kinds. First type is the mobile agent in a domain and the first level of the HMAT, similar to home agents in Mobile IPv6, manages QOO for QoS support, processes the mobile related RSVP messages and maintains the mobile soft state for mobile hosts, is organized into a hierarchy to handle local movements of Mobile hosts within the domain. And the second type is the mobile agent in higher levels of the HMAT can manage QOO for QoS support, merge path message and reservation message. The first type mobile agent's function includes the second type mobile agent's function. Specially the root of the HMAT, as a second type mobile agent, is also a Label Switch Router (LSR) in the MPLS Core Network.

3. 3 Mobile IPv6 Support in MPLS Core Network

In our scheme, we integrate Mobile IPv6 with MPLS, and the QOO [12] is used to interoperate with RSVP-TE [15][16] to make the performance of QoS-sensitive applications running on the MN maintained at a desired level. We also use the HMAT in the Access Network where the Mobile Node can roam freely and the root of the HMAT is as an edge LSR in the Core MPLS network. Thus the LSP is established only between the root mobile agent of the HMAT and CN's edge LSR. And the design principle is that only active data is supposed to traverse over QoS guaranteed LSP. This would be efficient to save the bandwidth on network and to reduce end-to-end delay. Our scheme considers the smooth handoff support in Mobile IPv6 over MPLS to reduce the signaling load and the latency or interruption due to handoff. There are no additional messages on legacy MPLS signaling to setup QoS guaranteed LSP. There are no obligation of MPLS signaling on the Mobile Node because of the use of the HMAT so that MN does not need to install RSVP-TE at all, this can reduce memory cost and complexity of a MN device

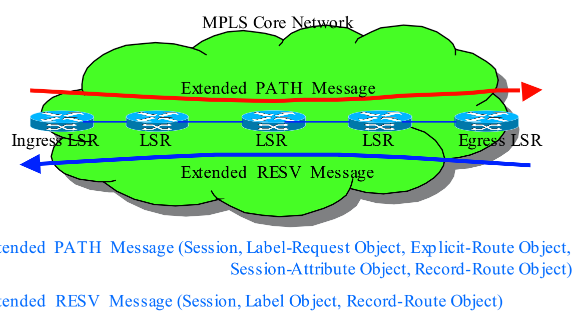

Fig. 2. LSP Setup Using RSVP-TE

3. 3. 1 LSP Setup Using RSVP-TE

We use RSVP-TE to extend the RSVP, allow the establishment of the explicitly routed Label Switched Path (LSP) Tunnel which can be automatically routed away from network failures, congestion and bottlenecks, and distribute label-binding information using the RSVP-TE as a signaling protocol. We extend the RSVP to setup the LSP because of already existing RSVP implementations in our HMAT and it would provide a unified signaling system within the whole network. Figure 2 shows this procedure of LSP setup using RSVP_TE

3. 3. 2 Smooth Handoff

When handoff occurs, the MN sends the Binding Update with QOO along the HMAT to the root of the HMAT. The root of HMAT, as an edge LSR in MPLS Core Network, receives the Binding Update with QOO from the MN, examines the QOO, then sends the PATH message of RSVP-TE to the CN's edge LSR. The CN's edge LSR receives the PATH of RSVP-TE and Binding Update with QOO, sends the RESV message of RSVP-TE back to the root of the HMAT to setup the QoS guaranteed LSP, also sends the Binding Update with QOO to the CN. The CN receives the Binding Update with QOO, sends back the Binding Acknowledgement to the MN. The root of the HMAT receives the RESV of RSVP-TE, then the new QoS guaranteed LSP has been established between the root of the HMAT and the edge LSR of the CN before the MN receives the Binding Acknowledgment. Figure 3 shows this smooth handoff support in MPLS Core Network

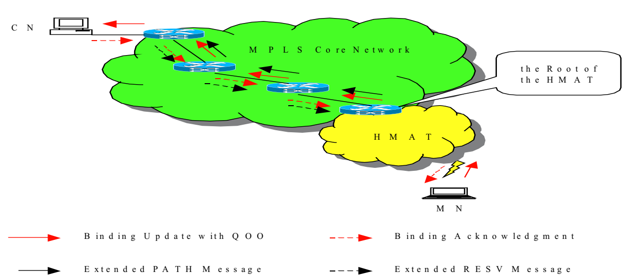

Fig. 3. Smooth Handoff Support in MPLS Core Network

3. 3. 3 Data Delivery Procedure

The packets from the CN to the MN are forwarded to the edge LSR of CN. Then the edge LSR of CN receives the packet from CN, searches the IP routing table, sends the packet to the MPLS layer, then looks up its label table to find the out label and out port, inserts the label to the packet and sends the packet along the LSP that has been setup to the root of the HMAT. The root of the HMAT receives the packet, and then looks up its label table. The out label and out port are empty, therefore the root of the

HMAT striped off the label and sends the packet to the IP layer, finally looks up its routing table and forwards the packet to the MN along the HMAT.

The data delivery procedure from the MN to the CN is the same with the data delivery procedure from the CN to the MN.

3. 4 QoS Support Using HMAT

There are two scenarios in QoS support based on our HMAT scheme.

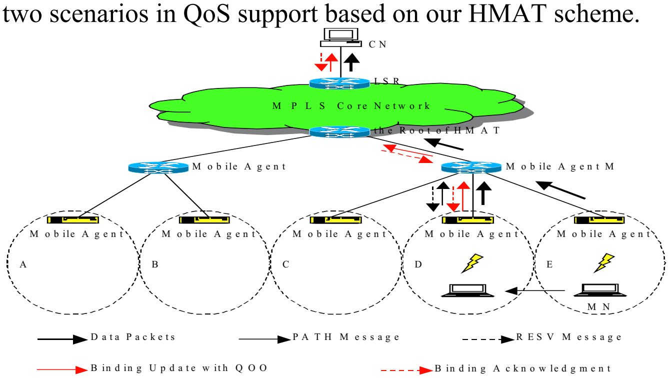

Fig. 4. MN as Sender in HMAT Model

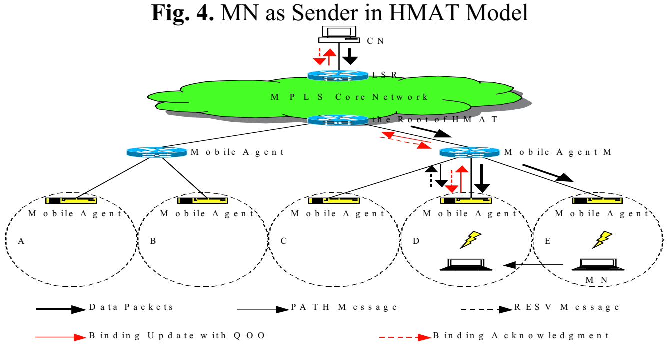

Fig. 5. MN as Receiver in HMAT Model

When the MN is sender, the CN is receiver, after a handoff, the MN sends a Binding Update with QOO to CN along HMAT, in the first level mobile agent, this agent examines QOO and immediately performs the resource reservation, sends the new PATH message to CN with the same source flow identity as the one before handoff, and also sends the Binding Update with QOO to the CN. Then the PATH message can be merged at the merging mobile agent M that has already a path state in HMAT for that flow which is created before. This will make RSVP to have a Local Repair for sender route. Therefore the mobile agent sends a RESV message associated with the flow along the new path in HMAT to the MN upstream at once, also sends the Binding Update with QOO to the CN downstream. The flow path reserved resources previously from the mobile agent to the CN can be reused. After the CN receives the Binding Update with QOO, the CN will send the Binding Acknowledgment to the MN's current location through the HMAT. Then the data packets will be sent from the MN's new location to the CN. Figure 4 shows this scenario.

When the MN is receiver and the CN is sender, the difference with previous scenario is that when the Binding Update with QOO gets to the merging mobile agent M, the M examines QOO and immediately sends the new PATH message to the MN downstream and at the same time sends the Binding Update with QOO upstream to the CN. When the MN receives the new PATH, it sends RESV to the M. And after the CN receives the Binding Update with QOO, the CN sends the Binding Acknowledgment to the MN's current location. Figure 5 shows this scenario.

We use Rational Rose 2000 to show the Sequence Diagram of the Multicast Tree scheme in Figure 6, the Sequence Diagram of our HMAT scheme in Figure 7 and Figure 8

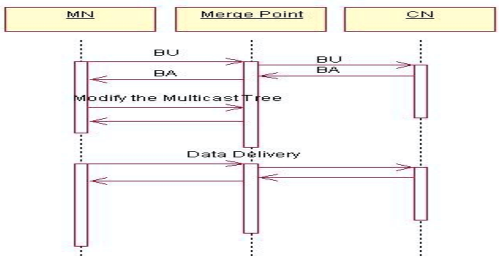

Fig. 6. Sequence Diagram of the Multicast Tree Scheme (MN as Sender)

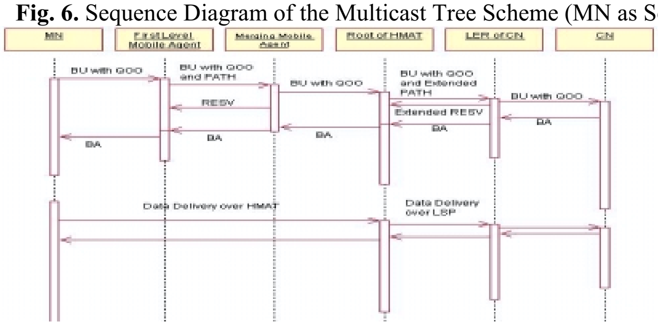

Fig. 7. Sequence Diagram of the HMAT Scheme (MN as Sender)

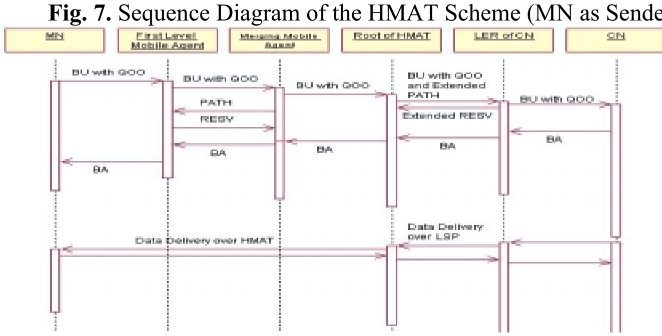

Fig. 8. Sequence Diagram of the HMAT Scheme (MN as Receiver)

4 Simulation Results

We use the OPNET Modeler v8.0 to simulate our scheme and compare our scheme with RSVP Mobility Based on Multicast Tree [10]. For simplicity our simulation is based on an assumption that the capacity of the links between the mobile agents is not limited. And we only considered the unicast data flows from a single mobile sender roaming freely at a rate of 5km/hr in wireless domain to a fixed static receiver for simplicity. Figure 9 shows the network topology used for our simulation. There are two cells in this network, we set the radius of each cell 1km, and each cell has a mobile agent as the first type mobile agent in HMAT that has two levels.

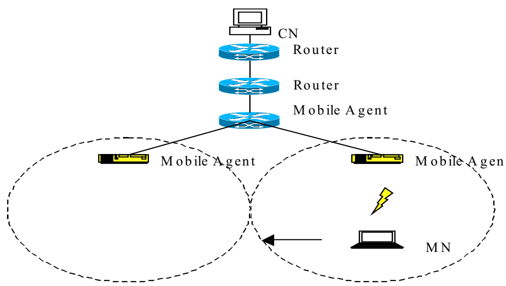

Fig. 9. Network Configuration for Simulation

The goal of our simulation work is for evaluating the QoS, such as data rate, packet loss ratio and packet delay, by using our scheme and comparing with RSVP Mobility Based on Multicast Tree [10] when the handoff occurs. We use a real time traffic source at a peak rate of 1Mbps to get the variations of data rate, packet loss ratio and packet delay received by the fixed static receiver CN due to the handoff.

Figure 10 shows the simulation results of the data rate using our HMAT scheme and Multicast Tree scheme over simulation time. In the figure, the X-axis represents the simulation time (minute) and the Y-axis represents the relative data rate (kbps). We can see that the data rate of Multicast Tree scheme is obviously decreased, especially at the moment a handoff takes place, and our HMAT scheme has a real smooth handoff. Figure 11 shows the packet loss ratio of the Multicast Tree scheme is more than that of the HMAT scheme especially when handoff takes place. Figure 12 shows the Multicast Tree scheme has more packet delay than our HMAT scheme especially when handoff takes place.

These simulation results have the following reasons. First, in the Multicast Tree scheme, when the handoff occurs, the Binding Update is sent to the CN and the MN receives the Binding Acknowledgment, then the Multicast Tree should be modified dynamically and some QoS signaling messages should be used, the new Conventional Reservation and all of the Predictive Reservations should be made again, then the data packets is be sent continually. Second, in our HMAT scheme, there are no any extra QoS setting up delay not only in the Access Network but also in the Core Network due to handoff and all the packets will be offered QoS as desired. Therefore the Multicast Tree scheme has more QoS signaling delay, packet loss ratio, data packet delay and lower data rate than our HMAT scheme whenever a handoff occurs.

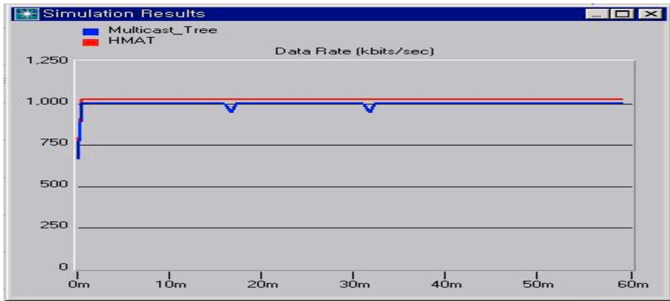

Fig. 10. Simulation Results (Data Rate)

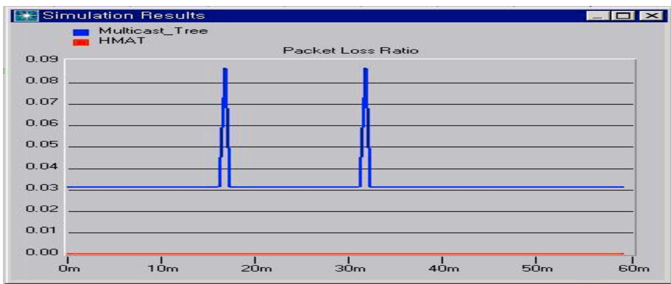

Fig. 11. Simulation Results (Packet Loss Ratio**)**

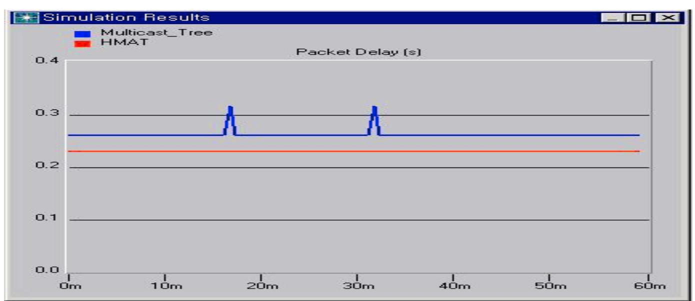

Fig. 12. Simulation Results (Packet Delay)

5 Conclusions

In this paper, a novel framework for QoS support in Mobile IPv6 using the HMAT based on QoS Object Option (QOO) [12] over MPLS has been proposed. When a handoff occurs, the RSVP can be made a Local Repair in the HMAT based on the QOO and the LSP can be setup using RSVP-TE and QOO during the time when the Binding Update with QOO and Binding Acknowledgement message are transmitted between the MN and the CN through the HMAT Access Network and the MPLS

Core Network. There are no any extra QoS setting up delay not only in the Access Network but also in the Core Network due to handoff and all the packets will be offered QoS as desired. The RSVP and RSVP-TE have been used because there is a unified signaling system applied in the whole network.

Moreover, we use OPNET Modeler to simulate our scheme and compare with RSVP Mobility Based on Multicast Tree [10]. The simulation results prove that our scheme can provide higher data rate, lower packet delay and packet loss ratio, and improve the efficiency by using HMAT based on QOO over MPLS when handoff takes place in Mobile IPv6.

Acknowledgement

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