Evaluation of End-to-end QoS Support for Mobile Hosts in IPv6 with IEEE802.11e

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Abstract— **This paper proposes and evaluates a simple, yet effective, end-to-end QoS architecture for mobile hosts that combines IntServ/DiffServ and MIPv6 with IEEE802.11e. IntServ and DiffServ are two architectures developed by the IETF to support Internet QoS. Designed for wired non-mobile networks, IntServ provides per-flow QoS and is deemed to be only suitable for edge networks while DiffServ provides aggregate QoS and is suitable for use in core networks. For mobile hosts, IPv6 has built-in capability to support IP level mobility, which we refer to as Mobile IPv6 (MIPv6), and IEEE802.11e provides QoS support at the MAC layer of IEEE802.11-based WLANs. In this paper, we use IntServ at edge networks, DiffServ at core networks, and IEEE802.11e at the wireless last hop to provide end-to-end QoS for mobile hosts. Moreover, it is found that the loss of Router Advertisement (RAD) messages of MIPv6 adversely affects the handoff performance. Therefore, minimizing or totally eliminating the loss of RADs is a key aspect of our approach. We achieve this by assigning RADs a higher priority and compare the handoff performance with the case of no priority for RADs.**

I. INTRODUCTION

Work on providing quality of service (QoS) in the Internet has led to two distinct approaches: Integrated Services (IntServ)[1] and Differentiated Service (DiffServ)[2]. IntServ provides QoS to individual connections while DiffServ provides QoS to aggregates. IntServ's scalability problem makes it only suitable for access networks while DiffServ, which has been designed to eliminate the scalability problem, is suitable for the core networks. It has been reported and supported by simulation results[3] that integrating IntServ and DiffServ can guarantee end-to-end QoS in a wired network. However, both IntServ and DiffServ are designed for wired non-mobile networks and become ineffective under host mobility.

With the increasing deployment of the wireless networks, proliferation of mobile computing devices, and emergence of new multimedia applications, there is an increasing need to provide QoS to mobile devices. Mobility management in the Internet is handled by Mobile IP[4]. The next generation IPv6 protocol has built-in capability to support IP level mobility, which we refer to as Mobile IPv6 (MIPv6)[5]. While some work has been done to extend RSVP/IntServ or DiffServ to wireless mobile networks, all these studies have been carried out on the network or higher layer and have not considered the QoS guarantee in lower layers. QoS assurance is as good as the weakest link in the QoS "chain" and this "chain" is not only end-to-end between sender and receiver but also top-to-bottom in hierarchical architecture[6]. To guarantee end-to-end QoS, every segment of the route must have QoS support but this is not true for the existing IEEE802.11-based wireless access networks. This led to the development of the IEEE802.11e wireless LAN standard[7] to provide QoS support in the medium access control (MAC) layer.

In this paper, we use the QoS support in MAC layer provided by 802.11e to guarantee QoS on the wireless last hop, and combine it with IntServ/DiffServ and MIPv6 to provide end-to-end QoS for mobile hosts. Moreover, it is found that the loss of Router Advertisement (RAD) messages of MIPv6 adversely affects the handoff performance. Therefore, minimizing or totally eliminating the loss of RADs is a key aspect of our approach. We achieve this by assigning RADs a higher priority and compare the handoff performance with the case of no priority for RADs.

The remainder of this paper is organized as follows. Section 2 discusses service mapping in the architecture that combines IntServ/DiffServ, MIPv6 and IEEE802.11e. Section 3 describes the improvement on handoff performance by assigning RADs higher priority. Section 4 presents the simulation study and shows corresponding simulation results. Finally, section 5 provides some concluding remarks.

II. SERVICE MAPPING

The primary issue in integrating IntServ, DiffServ and IEEE802.11e is service mapping not only between IntServ and DiffServ but also between IntServ/DiffServ and IEEE802.11e. Besides best effort (BE) service, IntServ provides Guarantee service (GS) and Controlled-load (CL) service, while DiffServ provides Expedited Forwarding (EF) and Assured Forwarding (AF) service. IEEE802.11e protocol does not provide explicit QoS services. It provides QoS guarantee by assigning different transmission priority to different traffic classes.

IntServ service types are specified by a set of parameters known as Tspec (Traffic Specification) while DiffServ service types are specified by the DiffServ Code Points (DSCPs). When combining IntServ with DiffServ, IntServ services must be mapped into the corresponding DiffServ services. The mapping procedures include[8]:

- Selecting the appropriate PHBs in the DiffServ domain for requested service in the IntServ domain (when the PHB has been selected for a particular IntServ flow, it is necessary to assign an appropriate DSCP to packets from this flow);
- Performing appropriate policing, shaping and marking at the edge router of the DiffServ domain;
- Taking into account the resource availability in the DiffServ domain, perform admission control for traffic coming from the IntServ domain.

When a PHB is selected for a particular IntServ flow specified by Tspec, it is necessary to assign an appropriate DSCP code to packets from this flow. To ensure QoS can be achieved for IntServ flows when running over a DiffServ domain, appropriate service mapping should be selected.

Both IntServ and DiffServ define different services that can be used by different types of applications. EF service in DiffServ provides a low loss, low latency, low jitter and assured bandwidth end-to-end service, which is nearly equivalent to GS service in IntServ that offers strict assurance of both throughput and delay. These two kinds of services are suitable for real time non-adaptive applications such as Voice over IP (VoIP). On the other hand, the AF service in DiffServ is a means to offer different levels of forwarding assurances for IP packets. It could implement the function of CL service in IntServ that requires services close to BE service under unloaded network conditions. AF service and CL service can support adaptive applications such as one way voice or video, which require for their operation soft QoS guarantees, i.e. they may be tolerant in terms of delay bounds and jitter. Both Best Effort services in IntServ and DiffServ do not guarantee any bandwidth and only get the available bandwidth. They are associated with applications requiring no QoS like file transfers or e-mail. Therefore, GS service is mapped to EF service, CL service is mapped to AF service and BE service in IntServ is still BE service in DiffServ.

The service classes in IntServ and DiffServ are not supported in wireless mobile environments. Therefore, in order to guarantee end-to-end QoS for mobile hosts, these services have to be mapped to the QoS mechanisms in the MAC layer. In the IEEE802.11e MAC protocol, there are eight traffic categories (TCs) with different priority. MAC Service Data Units (MSDUs) are delivered through multiple backoff timers that are determined by TC-specific parameters. In order to satisfy different QoS requirements, the IntServ GS class is mapped to TCs of highest priority, CL class is mapped corresponding to TCs of secondary priority and the BE class is mapped to TCs of the lowest priority.

III. IMPROVEMENT ON HANDOFF PERFORMANCE BY ASSIGNING RADS HIGHER PRIORITY

When a mobile node enters into the coverage area of one base station, it will receive RADs that the base station broadcasts. The mobile nodes maintain a BS list that records the base stations from which they receive RADs. The BS list needs to be updated when the mobile node receives RADs. When a mobile node receives a RAD from a base station, it will check its BS list. If this base station is not in the BS list, the mobile node will begin to handoff to attach itself to the new base station and add a entry for this new base station. If this base station is already in the BS list, the mobile node refreshes the lifetime entry of this base station. This avoids the problem of excessive handoffs due to router advertisement received from different base stations while a mobile node moves within an overlapping coverage area.

A problem arises when some *RADs* are dropped due to congestion in the wireless channel. The loss of RADs will cause the problem that the mobile node cannot detect its movement to a new link instantly. What is more, when the mobile node is in the overlap area of two base stations, the loss of some *RADs* could lead to the situation of unnecessary handoffs due to the lack of refreshment of the base station list. The mobile node may switch between two base stations repetitively, which is usually called *ping-pong* handoff. This ping-pong handoff between two base stations may lead to large handoff latency and affects the handoff performance seriously.

IEEE802.11e MAC protocol can transmit different traffics with different priority. In order to eliminate the loss of RADs, we use this QoS feature of IEEE802.11e to assign RADs a higher priority to transmit. We could minimize or totally eliminate the loss of RADs by this way and improve the handoff performance. We will prove this through simulation in the next chapter.

IV. SIMULATION STUDIES

The simulation is based on the network simulation tool Network Simulator (NS2). The purposes of the simulation are:

1) Study and compare the end-to-end QoS achievable by mobile nodes using a combination of IntServ/ DiffServ, MIPv6 with IEEE802.11 and with IEEE802.11e;
2) Study and compare the end-to-end QoS achievable by mobile nodes after intra- and inter-domain handoff;
3) Study and compare the handoff performance of MIPv6 with no priority for RADs and with high priority for RADs provided by the IEEE802.11e MAC.

A. Simulation Configuration and Parameters

In the simulation, we use goodput, end-to-end delay, delay jitter, and packet drop ratio as QoS performance criteria, and handoff latency to evaluate the handoff performance of MIPv6 in IEEE802.11e. The performance of flows that require GS, CL and BE services respectively (we call them GS flow, CL flow and BE flow respectively) will be compared and evaluated using these criteria.

We define a network topology comprising five domains, as shown in Figure 1. Access Network1 is an IntServ domain and Access Network2 is a best-effort domain. Core network is a DiffServ domain. There are two wireless domains. Sources S1 and S2 are in Access Network1, which use RSVP to reserve resources for every flow. Source S3 is in Access Network2. S1 generates GS flows, S2 generates CL flows and S3 generates BE flow. All three flows are CBR (Constant Bit Rate) traffic.

During simulation, we assume sources are fixed nodes, and mobile nodes are destinations. We list the common parameters and traffic management algorithms used in simulation, in Table1 and Table 2 respectively.

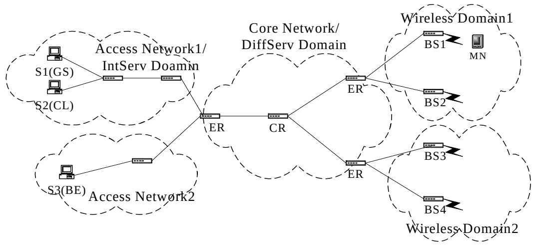

Figure 1. Simulation configuration

TABLE 1. THE COMMON SIMULATION PARAMTERS

Packet size	1000bytes
Bandwidth (in wired and wireless network)	1M
Link delay (in core network)	25ms
Link delay (in access network)	1ms

TABLE 2. TRAFFIC MANAGEMENT

	IntServ/RSVP domain	**DiffServ domain**
Admission control	Simple Threshold	Token Bucket
Buffer management	DropTail	RED
Scheduler	WFQ	Priority

B. *Simulation Results*

This section discusses the simulation results for end-to-end QoS and handoff performance of our proposed QoS architecture.

The simulation includes three scenarios:

i. *Scenario 1: End-to-end QoS achieved by a combination of IntServ/DiffServ, MIPv6 with IEEE802.11 vs with IEEE802.11e*

In this scenario, the mobile node is connected to its home agent and does not move. Firstly, wireless networks in Figure 1 are set to IEEE802.11 wireless LAN, then to IEEE802.11e. We compare the end-to-end QoS obtained by the GS, CL and BE flows in these two cases.

In the simulation, we let the three source rates increase from 100kbps to 400kbps concurrently. The bandwidth in the wireless subnet is 1Mbps, hence the saturation throughput of wireless channel is about 0.8M[10]. When every source rate is more than 250kbps, the wireless network will be congested. When every source rate gets to 330kbps, the core network will face congestion.

We use goodput, average flow delay, packet drop rate and delay jitter as QoS performance criteria (see Figures 2-5). From these figures, it can be observed that with IEEE802.11, the performance of GS and CL flows in terms of goodput, delay, packet drop rate and delay jitter deteriorates when the network is under heavy load. On the contrary, with the IEEE802.11e, the goodput of GS flow can be guaranteed and the packet drop rate of GS is zero. The delay and delay jitter of GS flow is kept quite low. Although we do not set a delay bound for GS flow, the delay remains almost unchanged when the network load varies from light load to heavy congestion. Therefore, it can be said that the strict requirement of GS on maximum delay can be achieved. The goodput, packet drop

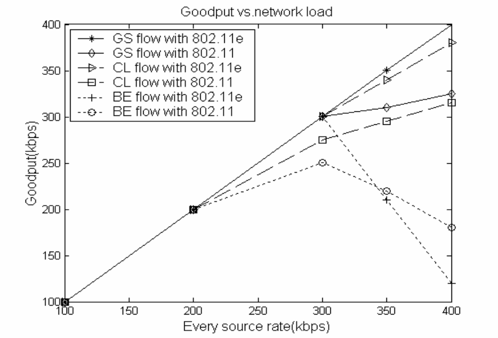

Figure 2. Goodput of GS, CL and BE flow vs. network with IEEE802.11 and with IEEE802.11e

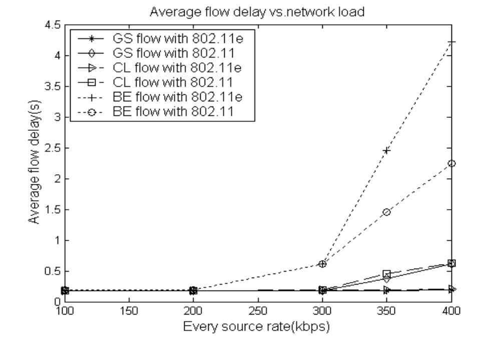

Figure 3. Average flow delay of GS, CL and BE flow vs. network load with IEEE802.11 and with IEEE802.11e

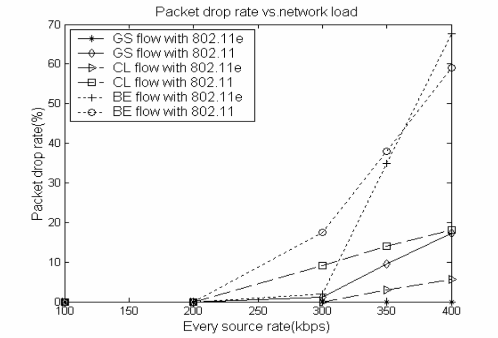

Figure 4. Packet drop rate of GS, CL and BE flow vs. network load with IEEE802.11 and with IEEE802.11e

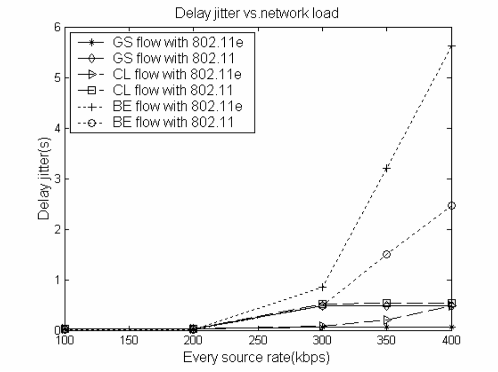

Figure 5. Delay jitter of GS, CL and BE flow vs. network load with IEEE802.11 and with IEEE802.11e

rate, delay and delay jitter of CL flow with IEEE802.11e change slightly when the network is in heavy congestion. The performance of CL flow under heavy network load is equivalent to the one under light network load. Therefore, it can be concluded that the end-to-end QoS obtained by GS and CL flow in the architecture that combines IntServ/DiffServ, MIPv6 and IEEE802.11e can be guaranteed. On the other hand, the performance of BE flow worsened with IEEE802.11e than with IEEE802.11.

ii. Scenario 2: End-to-end QoS after intra-domain and inter-domain handoff

In this scenario, the mobile node first moves from home agent BS1 to adjacent base station BS2 within the same subnet, and then to BS3 in other subnet.

Here, we compare the end-to-end QoS obtained by a mobile node after intra-domain and inter-domain handoff. The wireless networks use the IEEE802.11e MAC and since every source is sending at 400kbps giving a total of 1200kbps, the wireless link is heavily congested.

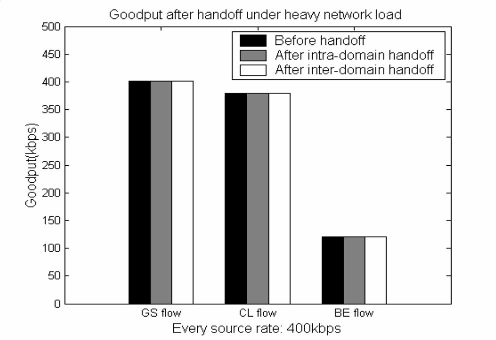

Figure 6. Goodput of GS, CL and BE flow after handoff under heavy network load

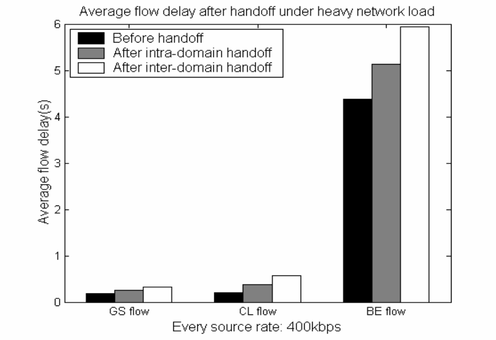

Figure 7. Average flow delay of GS, CL and BE flow after handoff under heavy network load

Figure 6 to Figure 9 show the end-to-end QoS obtained by the mobile node under heavy network load. The goodput of GS, CL and BE flows increase very slightly after intra-domain handoff and inter-domain handoff. Similarly, the average flow delay and delay jitter increase after intra-domain handoff and inter-domain handoff. The reason is that when the old binding update in CN has expired and a new binding update has not reached CN, some packets are sent to HA by CN, and HA then tunnels these packets to the mobile node. The packets tunneled from HA result in the slight increase of goodput and increase of delay and delay jitter. The packet drop rate also remains unchanged.

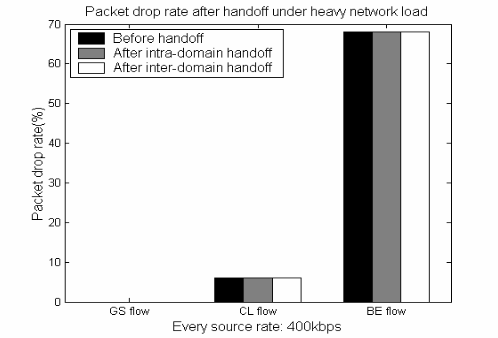

Figure 8. Packet drop rate of GS, CL and BE flow after handoff under heavy network load

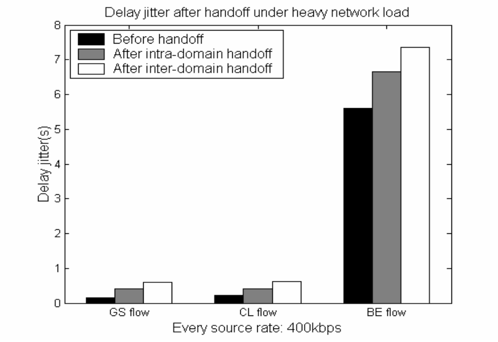

Figure 9. Delay jitter of GS, CL and BE flow after handoff under heavy network load

iii. Scenario 3: Handoff performance with no priority for RADs and with higher priority for RADs supported by the IEEE802.11e MAC

In this scenario, the mobile node is originally connected to its home agent BS1, and then moves from BS1 to BS2. Firstly, we investigate the probability of dropping *RADs* with no priority for *RADs* and with higher priority for *RADs*.

It can be seen in Figure10 that if we do not assign the *RADs* priority and when the network is under medium load (less than 0.6M), the probability of dropping *RADs* is about 3%, i.e. the *RADs* are dropped slightly. However, when the network load is more than 0.6M, the probability of dropping *RADs* becomes larger. When the network load is larger than the saturated bandwidth of the wireless channel, the probability of dropping *RADs* is more than 30%, which will worsen the handoff performance. If we assign *RADs* a higher priority to transmit, *RADs* are not dropped even if the network is congested.

Now, we compare the handoff performance in terms of handoff latency with no priority for RADs and with higher priority for RADs. We study two cases: handoff latency varies with network load and varies with last wired link delay. The last wired link delay represents the “distance” between the base stations and between the CNs and MNs[10]. Figure 11 shows how handoff latency varies with network load. It can be seen that the handoff latency increases noticeably from when the network load passes 600kbps if no priority is assigned for

RADs. When assigning higher priority for RADs, the handoff latency increases marginally with the increase of the network load.

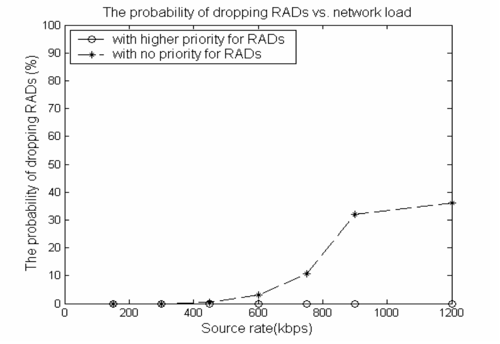

Figure 10. The probability of dropping RADs in IFQ vs. network load

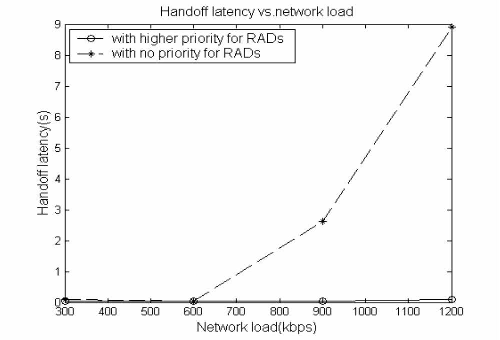

Figure 11. Handoff latency varying with network load

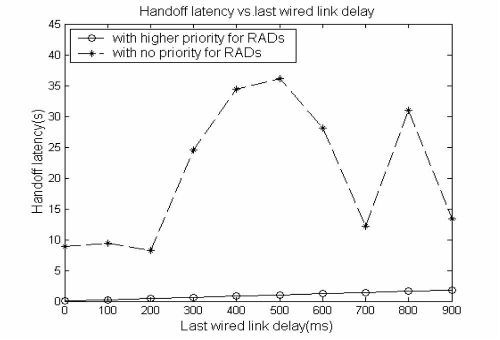

Figure 12. Handoff latency varying with last wired link delay

When we study the handoff latency varying with the last wired link delay, the total source rate is set to 1200kbps to achieve network congestion. From Figure 12, we can see that with higher priority for *RADs*, the handoff latency increases proportionately with the last wired link delay. The handoff latency with no priority for *RADs* is substantially larger than the case of higher priority for *RADs* in every instance. Moreover, the handoff latency when no priority is given *RADs* is unpredictable. The handoff latency becomes very long when large number of *RADs* are dropped at some points in time.

C. Findings from simulation results

From above simulation results, we conclude that:

1) End-to-end QoS in terms of goodput, average flow delay, delay jitter and packet drop ratio cannot be guaranteed just from the use of IntServ over a DiffServ backbone with MIPv6 and IEEE802.11 at the wireless last hop, because IEEE802.11 does not provide QoS support. The QoS achieved at the wired part is void at the wireless last hop. When IEEE802.11e is deployed at the last hop, the packet drop ratio is almost zero and end-to-end delay is very low for GS flow, packet drop ratio and delay are also small for CL flow, but the performance of BE flow becomes worse as more resources are channeled to satisfy the QoS of the other two classes. Therefore, the end-to-end QoS for GS and CL flows are guaranteed.

2) End-to-end QoS could also be guaranteed after intra-domain and inter-domain handoff for the GS and CL flows with the QoS support from IEEE802.11e.

3) Handoff performance in terms of handoff latency and handoff packet drop is improved after RADs are given high priority to transmit under heavy network load conditions.

V. CONCLUSION

In this paper, we presented a study on the performance of integrated IntServ/DiffServ and IPv6 mobility support with IEEE802.11e. We show that the QoS improved significantly when the IEEE802.11-based MAC is replaced by the QoS-enabled IEEE802.11e MAC. Simulation results quantitatively demonstrated that the QoS guarantee could be obtained by integrating IntServ, DiffServ and IPv6 mobility functions with IEEE802.11e. This paper also studied the performance of MIPv6 in IEEE802.11e and showed that the handoff performance can be improved largely when RADs are given higher priority to transmit under heavy network load.

VI. ACKNOWLEDGEMENT

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