Selective Establishment of Pseudo Reservations for QoS Guarantees in Mobile Internet

Kyounghee Lee[†], Myungchul Kim[†], Sungwon Kang[†] and Jonghyun Lee[††]
[†]*School of Engineering, Information and Communications University, Taejon, Korea*
[††]*Service Development Laboratory, Korea Telecom, Seoul, Korea*
[†]*{leekhe, mckim, kangsw}@icu.ac.kr ,*[††]*jhyun@kt.co.kr*

Abstract

In this paper, we propose a new mechanism for supporting seamless QoS guarantees in mobile Internet, called Selective Establishment of Pseudo Reservations (SEP). SEP addresses the issues of the conventional approaches such as excessive reservation requirements due to establishment of multiple advance reservations. It significantly reduces the number of required advance reservations by employing a movement detection scheme using link-layer functionalities. SEP requires fewer functional and structural changes in the current Internet components and protocols since all enhanced features are integrated into leaf base stations (BSs). Experimental results show that SEP outperforms the conventional approaches such as HMRSVP in reservation session loss and completion rates as the offered load in the network becomes high and the average number of handoffs increases during a reservation session.

1. Introduction

Multimedia streaming services became one of the fascinating applications in mobile Internet since mobile devices are getting powerful and wireless links provide higher bandwidth. However, there remain some limitations in mobile Internet that make such services difficult to deploy. The limitations include handover latency and traffic path redirection overhead due to host mobility as well as poor communication characteristics in wireless networks. One of the ultimate challenges for mobile multimedia streaming service is to provide continuous QoS guarantees while a host is moving across the multiple wireless cells.

Several useful mechanisms including Resource Reservation Protocol (RSVP) [1] and Differentiated Service (DiffServ) [23] have been proposed for QoS guarantees in wired Internet. RSVP is a signaling protocol that enables QoS guarantee by reserving resources along the fixed traffic path in which the RSVP signaling messages are delivered. Even though it guarantees the desirable QoS in the wired Internet, there are two major reasons that make RSVP inapplicable to Mobile IP [2] networks: First, RSVP messages are invisible to the intermediate routers within an IP tunnel due to the IP-in-IP encapsulation scheme of Mobile IP. Second, the previously reserved resources become no longer valid after a host moves to a new cell. This incurs the overhead and latency for a new resource reservation path establishment.

There have been approaches [3-11] to address the problems above. RSVP tunnel [3] was proposed to solve the RSVP signal message invisibility problem but it did not address the reservation path invalidation problem. Mobile RSVP (MRSVP) [4, 5] introduced an advance resource reservation, called *passive reservation*, to adapt RSVP to mobile Internet. A drawback in MRSVP is that the excessive passive reservations may waste a lot of network resources. Later approaches [6-11] mainly focus on reducing the overhead and delay caused by the advance resource reservation scheme with RSVP. However, most existing approaches did not address the important issue that all adjacent neighbor cells should be involved in the advance reservation process while a mobile host (MH) actually will visit only one of them. Only Hierarchical MRSVP (HMRSVP) [9] proposed a solution for the issue but the scheme requires considerable modifications in the existing Internet protocols and components such as the intermediate routers and the mobility agents (MAs).

In this paper, we propose a new mechanism, Selective Establishment of Pseudo Reservations (SEP), which significantly reduces the number of the required advance reservations, called Pseudo Reservation Paths (PRPs). SEP employs a link-layer movement detection scheme to predict a MH's next location. It requires a facility from underlying wireless networks that a MH can receive beacon signals from multiple attach points

(APs) simultaneously. SEP provides some architectural advantages over the existing approaches such as HMRSVP. First, SEP requires fewer functional and structural changes in the current Internet components. In addition, it requires no change on the existing RSVP and Mobile IP protocol. It integrates all enhanced features, such as pseudo reservation and path extension, into leaf BSs. Second, SEP guarantees that the establishment of PRP always finishes before completion of the Mobile IP handoff. Finally, SEP manages network resources more efficiently than HMRSVP does since a MH can choose its next BS depending on not only the strength of link-layer beacon signals but also available resources in the reachable BS.

The rest of the paper is organized as follows: In Section 2, we introduce some existing approaches related to RSVP with mobility support and link-layer movement detection scheme. The proposed mechanism, SEP, is introduced in Section 3. In Section 4, we describe the architecture of our experimental testbed and simulation model used to show the SEP performance. Some noteworthy experimental results obtained from our implementation and simulations are presented in Section 5. Finally, Section 6 concludes the paper.

2. Related work

Talukdar proposed the Mobile RSVP (MRSVP) [4, 5], which introduces a *passive reservation* that is one of the advance reservations to prepare for a MH's possible movement. It requires special hosts, *proxy agents*, to make active or passive reservations on behalf of the MH. Since the passive reservations are established along a multicast tree consisting of a correspondent host (CH) and all proxy agents in the neighboring cells, the routers within the multicast tree must manage all state information in the passive reservation. This overhead and resource consumption for the excessive passive reservation can be several times higher than that for an active reservation. Moreover, the passive reservation functions should be added to all routers in the network, and a MH is required to have prior knowledge of its mobility.

Mahadevan [8] proposed a scheme that requires fewer passive reservation-capable routers than MRSVP does. In this scheme, all the passive reservations are established between two neighboring BSs. If a MH moves to one of the current cell's neighbors, the corresponding passive reservation is activated and attached to the original RSVP path. Thereafter, traffic is delivered along the extended reservation path. Only when a neighboring cell resides in a different QoS domain, which is defined as a set of administratively grouped cells, a passive reservation is established between a gateway router and the neighboring BS instead. Thus the extended reservation path is adjusted along a normal routing path when a MH moves to another QoS domain. This prevents the infinite extension of a reservation path. However, this approach requires a significant number of network components to be equipped with passive reservation capabilities since most routers in the real networks act as gateways for their own subnets.

Chen [7] described a method similar to MRSVP, which employs a *predictive reservation* and *temporary reservation* scheme. Predictive reservations are made at all the locations where a MH may visit. These locations become the leaves of a multicast tree and the mobility of a host is modeled as transitions in the multicast group membership. To make more efficient use of wireless resources, temporary reservations can temporarily use the inactive bandwidth reserved by the other predictive reservations.

Tseng proposed the Hierarchical MRSVP (HMRSVP) [9] to reduce the overhead and resource consumption due to excessive passive reservations. It requires RSVP tunneling [3] and Mobile IP regional registration scheme [12]. HMRSVP saves resources by establishing the advanced reservations only when a MH moves between two different regions, possibly between two routing domains. However, it requires considerable modifications in the current Internet protocols and components to support RSVP tunneling, Mobile IP regional registration, and passive reservations. When an inter-region handoff arises, the number of RSVP tunnels in a reservation path may increase. Moreover, the QoS disruption time for an inter-region handoff can be longer than the Mobile IP handoff time since the establishment of passive reservations starts with the Mobile IP registration with home agent (HA).

Pasklis [6] introduced a mobility adaptation scheme with RSVP where a RSVP mobility proxy (RSVP-MP) in the access network dynamically updates its own binding between a MH's Local Care-of Address (LCoA) and Domain Care-of Address (DCoA). Since a RSVP-MP performs dynamic address translation of RSVP messages and data packets, a MH's IP address can be always represented by a single IP address (i.e., DCoA) while it is moving within an access network. This approach requires the existence of a mechanism to maintain a single contact IP address inside a domain. Also the approach requires another QoS technology such as DiffServ to support wider mobility between different access networks.

Some approaches [13, 14] have been proposed to reduce the Mobile IP handoff latency by tightly coupling the layer-3 handoff process with the layer-2 functionality. Movement anticipation can be performed by detecting link-layer beacon signals from the multiple mobile agents. Thus a MH (or a mobile agent) can initiate the handoff procedure immediately after the MH moves into the overlapped area of the two adjacent wireless cells. This reduces the handoff latency time by enabling to perform the layer-2 and layer-3 handoff processes simultaneously.

Concatenation and Optimization for Resource Reservation Path (CORP) [10, 11] requires only minimal changes in the existing Internet protocols and components though it supports seamless QoS guarantees for inter-routing domain handoffs as well as intra-routing domain handoffs. It extends a reservation path by activating and concatenating an advance reservation, called a pseudo reservation, to support a MH's movement. Pseudo reservations are established between neighboring BSs and recognized by a normal RSVP session by the intermediate routers. CORP also dynamically reduces the extended reservation path to avoid the infinite path extension problem.

Unfortunately, most existing approaches do not address the excessive requirement for advance reservations at all the neighboring cells. Though HMRSVP [9] gives a solution to this issue, it requires significant modifications in the current Internet environments as mentioned before. In this paper, we propose a new mobile QoS guarantee mechanism that addresses the excessive advance reservation requirements while it demands minimal changes in the current Internet protocols and components. In the next section, we shall give the detailed description of the proposed mechanism.

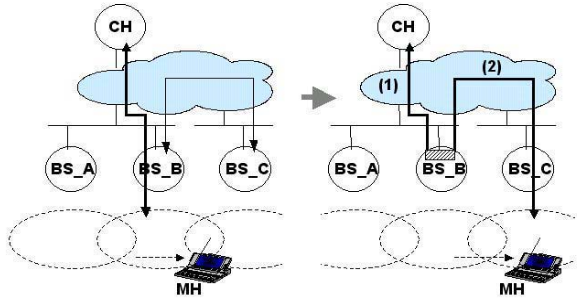
3. SEP

In this section, we shall present an overview of the SEP mechanism and the detailed descriptions of the two key procedures in SEP: *Concatenation of Reservation Path* (CRP) and *Optimization for Reservation Path* (ORP).

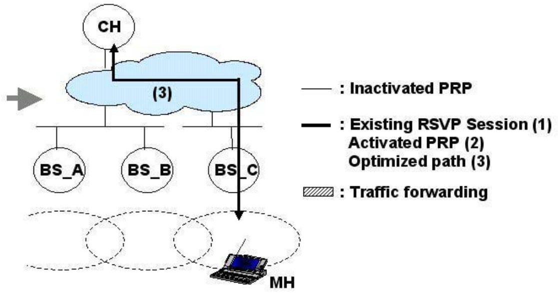
3.1. Overview

In SEP, each BS takes charge of the RSVP process and supports mobility of MHs. An advance reservation, called *pseudo reservation*, is used in place of the passive reservation in MRSVP. A pseudo reservation session is established in the same way as a normal RSVP session but no traffic is delivered over the session until it is activated. With the movement detection scheme described in the following sections, a BS pre-establishes Pseudo Reservation Paths (PRPs) only at the neighboring BSs to which a MH is likely to visit. If a MH moves to one of the neighboring cells, the corresponding PRP (a PRP between the current cell and the previous cell) is activated and traffic is delivered through the activated PRP. The previous BS concatenates the original RSVP path with the activated PRP and forwards traffic on it. To reduce the overhead for advance reservations, the resources allocated to a PRP can be temporarily used to deliver best-effort traffic until the PRP is activated.

Each BS performs all the process including establishment, maintaining and release of a PRP. A PRP can be established and released using RSVP *path*, *resv*, and *path teardown* messages [1]. A SEP BS dynamically terminates useless PRPs after a MH leaves the current wireless cell. An advantage of a pseudo reservation is that the networks do not need to know whether a RSVP session is a pseudo or active reservation. SEP integrates all its enhanced features, such as pseudo reservation and path extension, into the leaf BSs. While traffic on the passive reservations should be blocked by the intermediate routers until they are activated, SEP enables only leaf BSs to know about the existence of PRPs and handle them in a manner different from active reservations. Since a PRP is always established between two leaf BSs, traffic blocking and forwarding over the PRP are performed by one of those two BSs without any additional features such as RSVP tunneling.



(a) Pseudo reservation establishment (b) CRP process



(c) ORP process

Figure 1. Overall SEP process

The SEP process consists of three steps: (a) establishment of PRPs, (b) CRP process, and (c) ORP process as shown in Figure 1. In the first step, a SEP

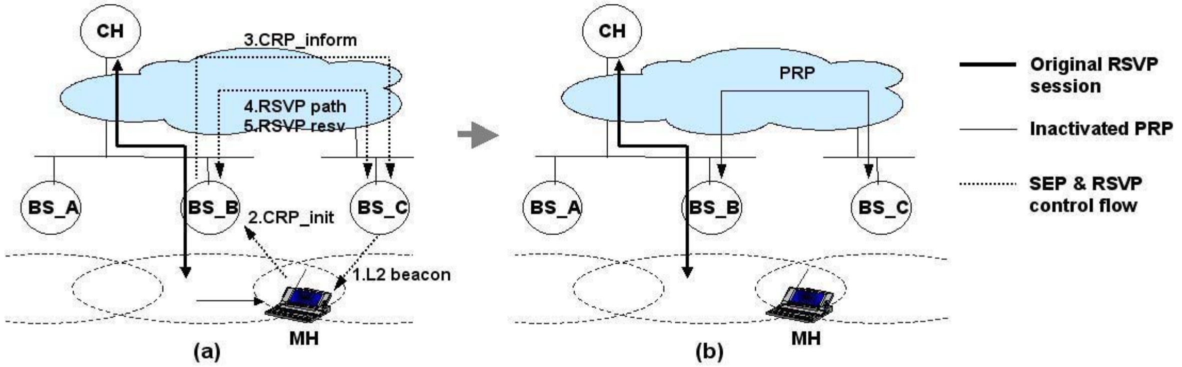


Figure 2. CRP process before a handoff

BS establishes the required PRPs from (to) its neighbors to prepare a movement of the MH that participates in a RSVP session. In Figure 1(a), the MH just enters into the overlapped area of BS_B and BS_C. Thus, an inter-routing-domain PRP is established between the two BSs. When the MH finishes the Mobile IP handoff from cell B to C, the CRP process begins. In this step, as shown in Figure 1(b), a corresponding PRP is activated and then the previous BS (BS_B) concatenates the activated PRP to the original RSVP session by forwarding traffic between those two reservation paths. As the final step, the extended reservation path by CRP process is optimized to make efficient use of network resources. Thus, the reservation path is adjusted along a normal routing path between the CH and MH as shown in Figure 1(c).

3.2. Movement detection in SEP

The main idea of SEP is to use the link-layer (layer-2, L2) functionality to detect a host's movement. Mobile IP was originally designed without any assumptions in the underlying link levels so that it could achieve the widest applicability. However, in the proposed mechanism, we assume that a MH can detect L2 beacons from multiple wireless attach points simultaneously. Since Mobile IP registration with a new FA begins after a L2 roaming has completed, detecting L2 beacons is a useful way to recognize a MH's movement without suffering from a Mobile IP handoff delay. Such underlying networks can be built with the IEEE 802.11 Wireless LAN.

We define a message, *CRP_initiate*, which is used to notify the current BS that a MH has come into the overlapped area to which L2 beacon signals from multiple BSs are delivered. A *CRP_initiate* message contains the new BS's MAC address obtained from the beacon signal. When a MH enters into the overlapped area between the current BS and a new BS, it sends a *CRP_initiate* message to the current BS to notify the possible handoff. Each SEP BS has a *neighbor-mapping table* that binds IP and MAC addresses of all its neighbor BSs. Thus the current BS can send a *CRP_inform* message to the new BS to prepare a PRP between them. This *CRP_inform* message triggers the establishment process of a PRP.

SEP establishes PRPs for all the movements predicted while a MH resides in a cell. However, a noteworthy enhanced feature in this mechanism is that a movement prediction is performed only when a MH enters into the overlapped area by neighboring cells.

3.3. CRP process: before a handoff

Figure 2 shows the CRP process in SEP before a handoff arises. To show that SEP supports the movements of MHs between two different routing domains, the example in Figure 2 describes a case that an inter-routing-domain PRP is established.

- In Figure 2(a), the MH originally resides in the BS_B's cell and participates in a RSVP session. When the MH enters in the area which is overlapped by both BS_B's cell and BS_C's cell, it becomes to be able to receive a beacon periodically delivered from the BS_C. Then the MH sends a *CRP_initiate* message to its current BS, BS_B, to notify the MAC address of BS_C. BS_B looks into its neighbor mapping table to get the BS_C's IP address, and passes a *CRP_inform* message to BS_C for informing the possibility of future entrance of the MH into the BS_C's cell. When the MH is a sender in the original RSVP session, a *CRP_inform* message should include *Tspec*, which defines the traffic characteristics of the data flow that the MH will generate. These traffic characteristics are used to reserve resources between BS_B and BS_C by the RSVP signaling messages. When BS_C receives a *CRP_inform* message, it sends a RSVP *path* message to BS_B in order to establish a PRP from

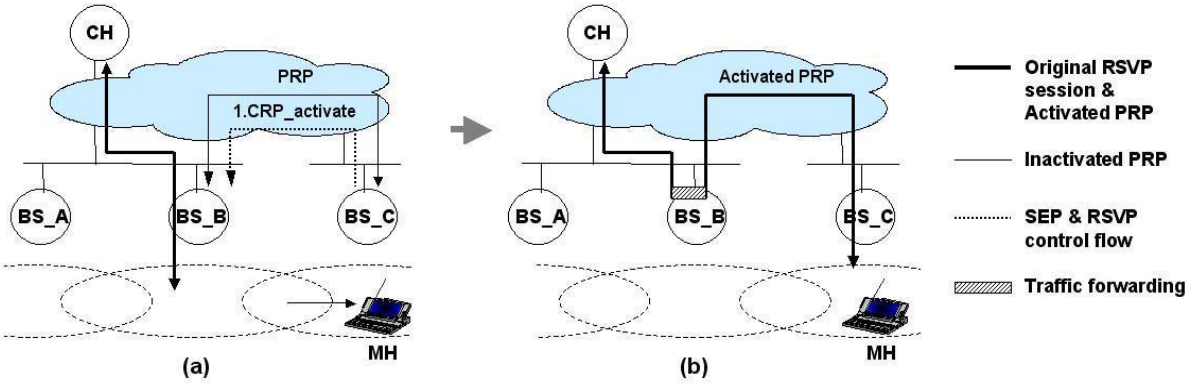


Figure 3. CRP process after a handoff

itself to BS_B. This RSVP *path* message should include *Tspec* and BS_B replies to the message with a RSVP *resv* message. Then a PRP between BS_B and BS_C is established as shown in Figure 2(b).

- When a MH is a receiver in the original RSVP session, CRP process before a handoff is similar to the procedure when a MH is a sender. However, there are some minor differences in establishing PRPs because RSVP is a *receiver-initiated* setup protocol. Since RSVP *path* messages including *Tspec* should be delivered from the current BS to one of the its neighbors, a *CRP_inform* message does not have to include *Tspec*. Thus, in Figure 2(a), the *CRP_inform* message delivered from BS_B to BS_C only needs to notify the possibility of future entrance of the MH into the BS_C's cell. Subsequently, BS_B and BS_C perform the PRP establishment process by exchanging RSVP *path* and *resv* messages in the reverse direction to the case that the MH is a sender. Finally, a PRP is successfully established to prepare the MH's movement from the cell B to the cell C as shown in Figure 2(b).

3.4. CRP process: after a handoff

After a MH's handoff, there is little difference in the SEP process depending on whether the MH is a sender or a receiver in the original RSVP session. The difference is only in the direction of the traffic delivered between the MH and CH. Figure 3 shows the CRP process in SEP after a handoff.

PRP activation can be performed by one of the current BS and the previous BS, depending on which BS currently acts as the sender of the PRP. When a MH enters into a new wireless cell, it tries to perform a Mobile IP registration process with its home agent (HA)[2]. By relaying a Mobile IP *registration request* packet from the MH to the HA, the current BS knows that a corresponding PRP between the previous BS and itself should be activated. Then the current BS sends a *CRP_activate* message to the previous BS to inform the need of PRP activation. Finally, one of the two end BSs of the PRP, whichever is the current sender, activates the PRP by beginning to send traffic along the PRP.

- In Figure 3(a), when the MH moves into the cell in which BS_C resides, the new current BS, BS_C sends a *CRP_activate* message to BS_B to notify this movement and the PRP between BS_B and BS_C is activated by a sender of the PRP. Then, by concatenating the activated PRP to the original RSVP session, the reservation path is extended to guarantee seamless QoS to the MH. To do that, BS_B forwards the traffic between the activated PRP and the original RSVP session as shown in Figure 3(b).

3.5. ORP process

SEP performs the ORP process after a reservation path is extended by the CRP process. Since CRP has been built on the "path extension" technique, a reservation path can be extended too long if a MH continuously moves across the wireless cells. Thus, when necessary, the ORP process should replace the extended reservation path with the optimized one laid along the shortest routing path between a sender and a receiver.

The ORP process can be performed either by using multicast IP address or by using unicast IP address. The ORP process using unicast IP address starts with establishing a new RSVP session between the current BS and CH. The newly established RSVP session is laid along the shortest routing path between the current BS and CH. Thus the extended reservation path is replaced by the newly established RSVP session. Even

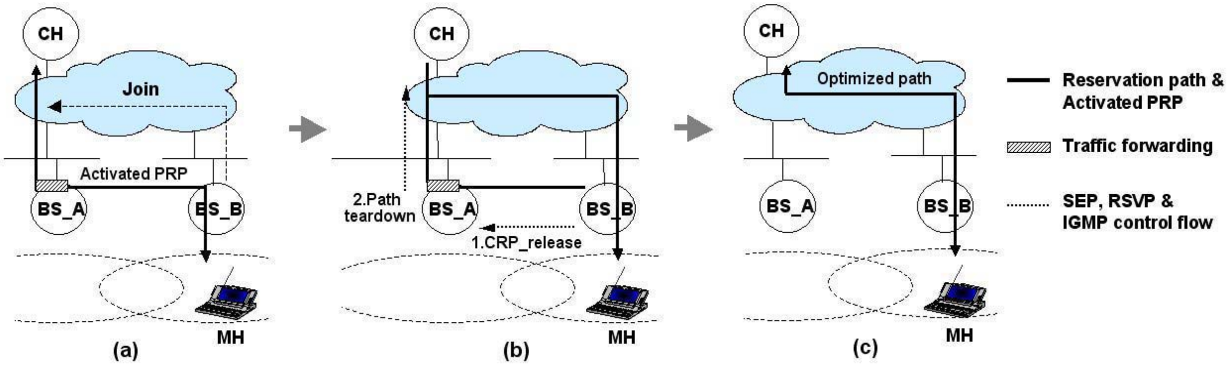


Figure 4. ORP process (using multicast address)

though the ORP process using multicast IP address is a more efficient way to optimize an extended reservation path, the ORP process using unicast address is still necessary for some reasons. When the underlying networks do not support IP multicasting or a newly entering MH already participates in a unicast RSVP session, SEP should perform the ORP process using unicast IP address.

Figure 4 describes the ORP process using multicast IP address. In the figure, we assume that a RSVP session with multicast address had been established between BS_A and the CH, and that a CRP process has been performed as described in Section 3.3 and Section 3.4. As shown in Figure 4(a), BS_B first joins into the existing multicast RSVP session to get a direct reservation path along the shortest path between a CH and itself. In this procedure, there are some differences according to whether the MH is a sender or a receiver in the existing RSVP session.

- When the MH is a sender, BS_B first sends a RSVP *path* message destined to a multicast address of the existing RSVP session to join in the session. This message is delivered to the receiver (CH) and BS_A. BS_A discards the message because it knows that BS_B is on the extended path. However, the CH is not aware of this, so it replies with a RSVP *resv* message. This allows BS_B to join in the existing RSVP session as a sender.
- When the MH is a receiver, BS_B joins in the IP multicast group using the Internet Group Management Protocol (IGMP) *report* message [15]. Then it waits for a RSVP *path* message which the sender (CH) periodically sends through the IP multicast session to identify a flow for a new destination [1]. In this situation, BS_B can directly receive traffic from the router because it is a member of the IP multicast group, but the quality of service cannot be guaranteed. To support seamless QoS to the MH, BS_B should deliver traffic from the activated PRP to the MH and, at the same time, it should wait for a RSVP *path* message delivered directly from the sender. When BS_B receives the *path* message, it replies with a RSVP *resv* message. This enables BS_B to join in the multicast RSVP session.

Consequently, BS_B is now able to send (receive) traffic from (toward) the MH through the new RSVP path as shown in Figure 4(b). Then it terminates the activated PRP between BS_A and itself using a *CRP_release* message. After receiving the *CRP_release* message, BS_A leaves the multicast group by sending a RSVP *path teardown* message to terminate the existing reservation path from (to) the CH. Finally, only an optimized path between BS_B and the CH is left as shown in Figure 4(c).

We have described the features and procedures of the SEP mechanism. In the following sections, we will present the performance evaluation of the proposed mechanism.

4. Experimental testbed and simulation model

The testbed architecture for SEP is shown in Figure 5. Each BS is composed of *SEP module*, *Mobile IP Foreign Agent (FA) module*, *RSVP signaling module* and *routing/traffic-scheduling module*. *SEP module* handles all SEP control messages for CRP/ORP processes. It also directs *RSVP signaling module* to execute all the RSVP activities on behalf of a MH. *Routing/traffic-scheduling module* delivers traffic between wired and wireless networks and deals with incoming/outgoing packets according to its scheduling policy.

The testbed consists of a RSVP-capable gateway router, two SEP BSs, a MH with SEP capability. To communicate over wireless link, each BS and MH equips a WaveLAN card that provides a bandwidth of

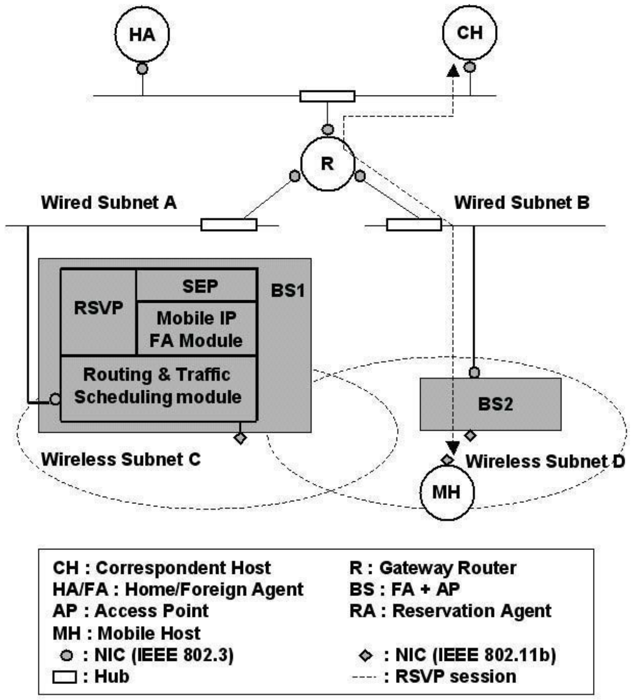


Figure 5. The experimental testbed architecture

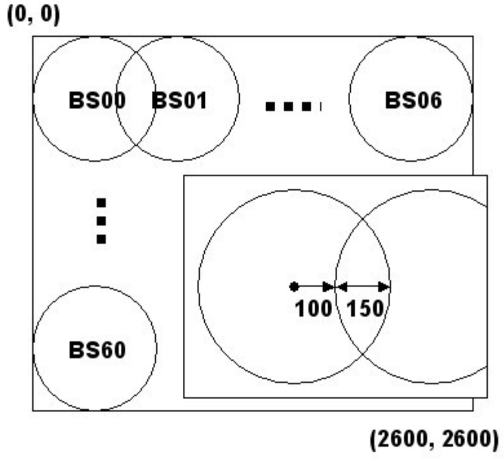


Figure 6. 7×7 mesh simulation model

11 Mbps [16]. A gateway router runs Alternate Queueing Package (ALTQ) [17] for traffic control. To support mobility, Dynamics Mobile IP software [18] is deployed. RSVP package from Southern California University [19] is modified to perform RSVP signaling required by the SEP process.

To show the performance of the SEP mechanism in various aspects, the NS-2 network simulator [22] was used. We used 7×7 mesh topology, in which all wireless cells have overlapped areas with their neighbors. Figure 6 shows the network topology for our simulation. As shown in the figure, all BSs are uniformly distributed over the whole test area, and each cell has the communication range of 250 m. The overlapped area size between two cells is 150 m and the L2 beacon interval in each BS is configured with 100 ms. For simplicity, we designed that all BSs are 1 hop away from the gateway router. Figure 7 shows an example of a MH's movement history for our simulation. It follows *Random Direction* Mobility Model [21]. The initial location and direction of a MH is randomly chosen over the whole test area. Also the direction of the movement is randomly selected again whenever the MH arrives at the border of the test area.

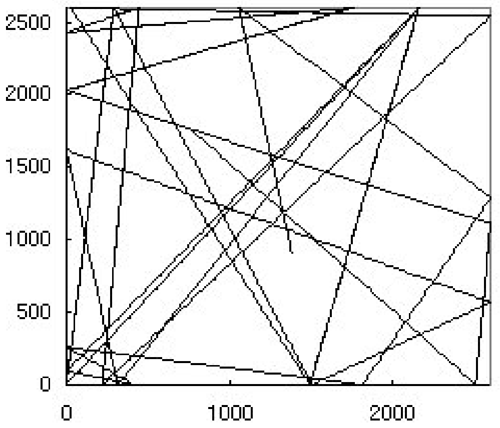


Figure 7. Random direction mobility model

5. Experimental results

In this section, we present some experimental results to evaluate the performance of the proposed mechanism. The results are measured with SEP implementation on the testbed described in Figure 5. We also present simulation results to show the performance improvement of SEP by comparing some QoS factors with those of the existing approaches. We evaluate the SEP performance in terms of advance reservation establishing time, service disruption time after a handoff, data transmission rate, reservation blocking rate, reservation session loss rate, reservation session completion rate [9], and so on.

Figure 8 shows the general procedure and each step's latency to support a MH's handoff. First, using layer-2 (L2) beacon signals delivered from the current attach/access point (AP) and its neighbors, a MH knows when it should associate with a new AP. The average latency that a MH performs L2 roaming can be estimated to be higher than a half of the L2 beacon interval. The L2 beacon interval typically appears

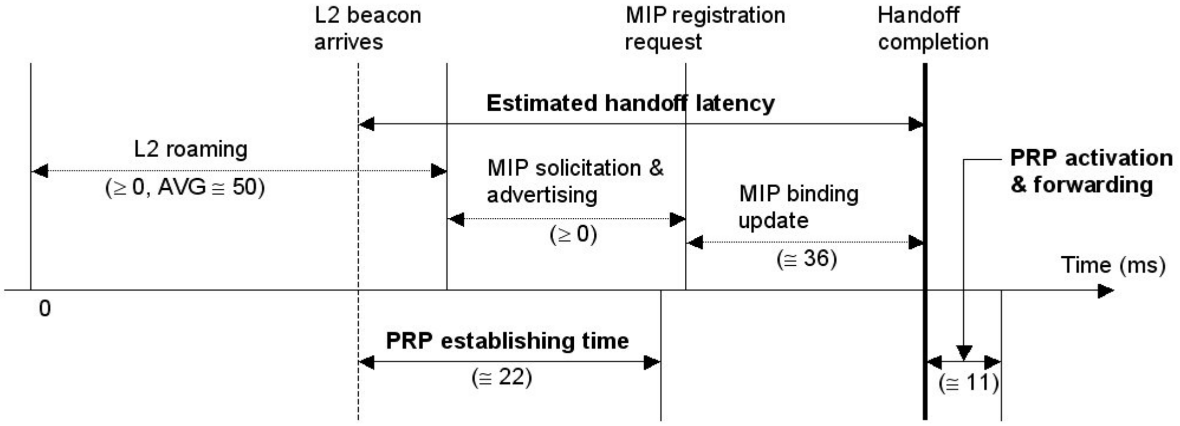


Figure 8. Analysis of handoff latency in Mobile IP and SEP

about 100 ms. Second, after completion of L2 roaming process, a MH waits for an *agent advertisement* message to be delivered from a new mobile agent or broadcasts an *agent solicitation* message in order to perform the Mobile IP (L3) handoff procedure [2]. This latency is also dependent on the pre-configuration in Mobile IP agent. Third, after receiving an agent advertisement message, a MH starts the Mobile IP registration procedure by sending a *registration request* message to its home agent (HA). We measured the MIP binding update time representing a period from the time of sending a registration request message to the time of receiving *registration reply* message from HA. The binding update time appears about 36 ms in our testbed as shown in Figure 8.

On the other hand, the PRP establishing procedure in SEP takes about 22 ms on the average in our implementation, where the neighboring 2 BSs are 2 hops away from each other as illustrated in Figure 5. Note that an actual delay for the Mobile IP handoff is greater than or equal to the MIP binding update time, which is represented as 36 ms in Figure 8. This guarantees that the PRP establishing procedure in SEP always finishes before completion of the Mobile IP handoff in our implementation. It means that the establishment of PRP incurs no further service disruption except the original Mobile IP handoff latency. Only service disruption time caused by SEP is the PRP activation time, about 11 ms in Figure 8, which is required for activating a PRP and forwarding traffic on it.

Figure 9 shows the average data rate variations measured from our experimental testbed when RSVP and SEP are applied. As shown in Figure 5, the MH is initially located in BS2's wireless cell. 250 kilobytes of bandwidth (2000 kbps) have been reserved between a sender (CH) and a receiver (MH), and a sender transmits 250 data packets per second with each packet size fixed at 1024 bytes. According to our measurements, the maximum capacity of the wired/wireless link in our testbed is about 9,300/4,700 kbps respectively. Thus, we generated background traffic by 9,000 kbps between the gateway router and BS1 so that the MH faces the congestion after moving from BS2 to BS1. The Multi-Generator tool (MGEN) [20] was used to generate the fixed-rate data traffic. In Figure 9, we can observe that the stable data transmission rate is maintained after the MH moves into a congested cell when SEP is applied. The momentary degradation of the data rate just after a handoff is caused by PRP activation and traffic forwarding delay in the SEP mechanism. However, the RSVP protocol cannot guarantee the service quality after the MH moves into the congested network since RSVP does not reserve resources in advance at the neighboring BSs.

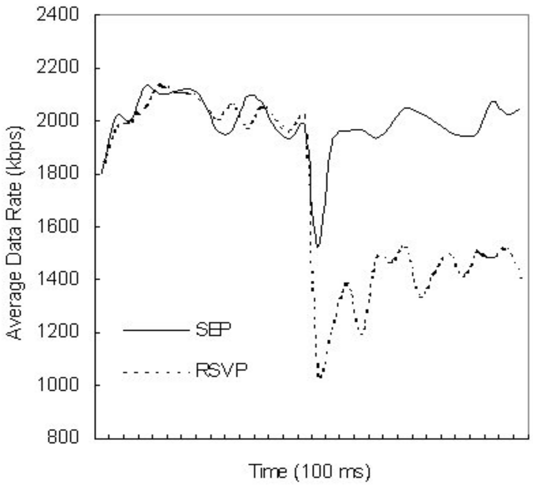


Figure 9. Average data transmission rates

With our simulation model, we evaluated the number of the reachable BSs in each second when a MH moves around the test area for 300 seconds according to the mobility pattern described in Figure 7. The average number of the reachable BSs appears about 1.49. This value represents the total sum of reservation requirements in SEP, including active and pseudo reservations. SEP makes a PRP only when a MH finds a new reachable BS, namely, when a beacon signal from a new BS except the current one arrives at the MH. When a MH is served by SEP, it necessarily requires only one active reservation path. It means that a MH requires about 0.49 PRPs on the average during a SEP session. The corresponding values in MRSVP [4, 5] and CORP [10, 11] appear about 4 in our simulation since a wireless cell is surrounded by 4 neighboring cells. To simulate the inter-region handoffs with HMRSVP, we configured that a passive reservation is established whenever a MH arrives at the border of the simulation network. The overhead in SEP due to PRPs is scarcely affected by the size of region (i.e., routing domain) and the network configuration. However, the resource consumption in HMRSVP due to passive reservations seems to vary with the percentage of border cells (*P*) in a region since a MH may establish a passive reservation only when it resides in one of those border cells. *P* is calculated to be about 0.489 in 7×7 mesh network, and about 0.438 in 8×8 mesh network.

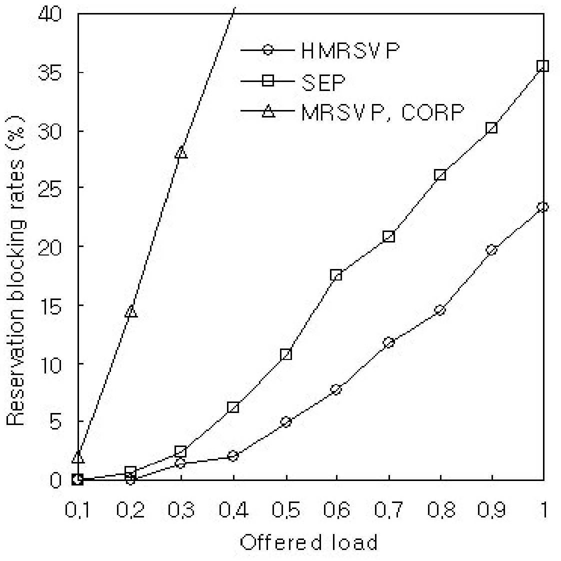


Figure 10. Reservation blocking rates

Figure 10 shows the reservation blocking rates for the four schemes related to RSVP mobility support under discussion. A parameter for this simulation is the system offered load for a wireless cell. The offered load (ρ) is modeled by four factors, reservation inter-arrival time, reservation duration, total capacity of a wireless cell (C), and average number of MHs per cell (N). We assume that the reservation inter-arrival time and the reservation duration are exponential distributions with mean 1/λ and 1/μ respectively. Thus the offered load is equivalent to Nλ/Cμ [9]. We varied the offered load from 0.1 to 1, and measured how many active reservation creations were blocked due to lack of network resources. As we impose more offered load to the network, the blocking rates increase in all the schemes under discussion. However, we can see that the reservation blocking rates of MRSVP and CORP are significantly higher than those of SEP and HMRSVP. It is caused by the excessive reservation requirements at the neighboring cells in MRSVP and CORP. In our simulation, HMRSVP makes a passive reservation only when the MH passes the border of the test area while SEP makes a PRP when the MH finds a new neighbor BS that it can reach. This is the cause that the reservation blocking rate of SEP is higher than that of HMRSVP.

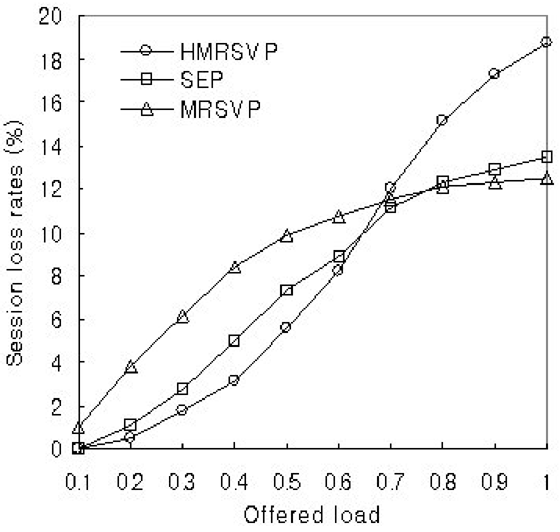


Figure 11. Reservation session loss rates

Figure 11 shows the session loss rates for MRSVP, HMRSVP and SEP. The session loss rate represents what is the probability for a MH to lose its reservation path after it handoffs to a new cell [9]. Without advance reservations, a MH may lose its reservation path after it moves into the cell that has been already congested. Though advanced reservations are applied, a MH also may lose its reservation path when it moves into one of the cells that the previous advance reservation request has been rejected. In general, more advance reservations give the higher QoS guarantees. However, the session loss rate of MRSVP appears higher than that of SEP or HMRSVP when the offered load in the network is not much. This is because SEP and HMRSVP, which do not make advance reservations at all the neighboring cells, can retain more available resources than MRSVP does. When the offered load is higher than 0.7, HMRSVP has the highest session loss rate in all the schemes under discussion. In Figure 11, we can observe that SEP provides the similar session loss rate with that of HMRSVP when the offered load is low while it provides the similar rate with that of MRSVP when the offered load becomes high. This illustrates that SEP suffers from excessive advance reservations less than MRSVP when the offered load is not high. It also argues that SEP sufficiently establishes PRPs for providing remarkably better session loss rate than that of HMRSVP when the offered load is high.

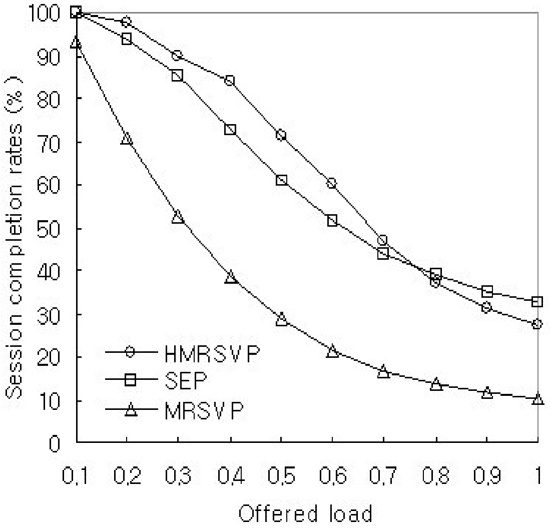


Figure 12. Reservation session completion rates

Figure 12 describes the reservation session completion rates for the three schemes under discussion. The reservation session completion rate represents the probability that a MH can maintain a reservation path without suffering from any reservation blocking and session loss until it finishes the reservation session successfully. The session completion rate is the most important evaluation aspect since it is a combinational effect of the reservation blocking rate and reservation session loss rate [9]. In Figure 12, the session completion rates for the three schemes are presented where a reservation session is completed after 5 handoffs from establishment of the reservation session. The session completion rate (C) can be calculated with an equation, $C = (1 - B)(1 - L)^N$, where B is the reservation blocking rate, L is the session loss rate, and N represents how many handoffs have been occurred before the reservation session finishes. Figure 12 shows that MRSVP has the lowest session completion rates. We can observe that SEP shows better session completion rate than HMRSVP especially when the offered load is higher than about 0.75, i.e., the network is more congested. The reason is that the session loss rate of HMRSVP increases rapidly as the offered load increases as shown in Figure 11. It also results in that the session completion rate of SEP is getting better than that of HMRSVP as the number of handoffs increases during a reservation session.

6. Conclusions and future work

In this paper, we proposed a new mechanism, SEP, which guarantees seamless QoS support for a MH while it is moving around in the mobile Internet. To support a QoS-guaranteed handoff, SEP extends a reservation path by activating an advance reservation, Pseudo Reservation Path (PRP), between two neighboring BSs and by concatenating it to the original reservation path. It also dynamically optimizes the extended reservation path to avoid the infinite path extension problem. SEP addresses the excessive reservation requirements due to establishment of multiple advance reservations by significantly reducing the number of required PRPs with the movement detection scheme using layer-2 (link layer) functionalities.

In addition, there are some architectural advantages of SEP over the existing approaches such as HMRSVP. First, SEP requires fewer functional and structural changes in the existing network components. It requires no modification or enhancement on the existing RSVP and Mobile IP protocol and integrates all additional/enhanced features, such as pseudo reservation and path extension, only into leaf BSs. Second, SEP guarantees that the establishment of PRP always finishes before completion of the Mobile IP handoff. Finally, SEP enables to manage resources in the network more efficiently than the conventional approaches do, because a MH can choose its next BS according to not only the strength of layer-2 beacon signals but also available resources in the reachable BS.

Our experimental results demonstrate that SEP considerably saves resources required for the establishment of PRPs while it does not degrade the QoS guarantees. SEP outperforms the conventional approaches such as MRSVP and HMRSVP in reservation session loss and reservation session completion rates as the offered load in the network becomes high and as the average number of handoffs increases during a reservation session. It means that SEP is a better approach than conventional ones in completing a reservation session successfully in the congested mobile networks. As the future work, the performance improvement in SEP due to reservation balancing in the network will be studied.

7. Acknowledgements

This research is supported by Korea Science and Engineering Foundation (KOSEF) under project no. 2000-1-303-004-3.

8. References

[1] R. Branden, L. Zhang, S. Berson, S. Herzog, S. Jamin, "Resource ReSerVation Protocol (RSVP) – Version 1 Functional Specification", RFC 2205, IETF, Sep. 1997.

[2] C. E. Perkins, "IP Mobility Support", RFC 2002 on IETF, Oct. 1996.

[3] A. Terzis, M. Srivastava, L. Zhang, "A Simple QoS Signaling Protocol for Mobile Hosts in the Integrated Service Internet", IEEE Proceedings, INFOCOM 99, Vol. 3, Mar. 1999.

[4] A. K. Talukdar, B. R. Badrinath, A. Acharya, **"**MRSVP: a resource reservation protocol for an integrated service networks with mobile hosts**",** ACM Wireless Networks, Vol.7 Issue 1, Jan. 2001.

[5] A. K. Talukdar, B. R. Badrinath, A. Acharya, "On Accommodating Mobile Hosts in an Integrated Services Packet Network", in proc. IEEE INFOCOM 97, Apr. 1997.

[6] S. Paskalis, A. Kaloxylos, and E. Zervas, "An efficient QoS Scheme for Mobile Hosts", 26th Annual IEEE Conference on Local Computer Network (LCN 2001), pp. 630-637, 2001.

[7] W. Chen and L. Huang, "RSVP Mobility Support: A Signaling Protocol for Integrated Services Internet with Mobile Hosts", in proc. IEEE INFOCOM 2000, Part vol. 3, pp. 1283-1292 Vol. 3, 2000.

[8] I. Mahadevan and K. M. Sivalingam, "Architecture and Experimental Results for Quality of Service in Mobile Networks using RSVP and CBQ", ACM Wireless Networks 6, pp. 221-234, Jul. 2000.

[9] C. Tseng, G. Lee, and R. Liu, "HMRSVP: A Hierarchical Mobile RSVP Protocol", ACM Wireless Networks, Vol.9 Issue 2, Mar. 2003.

[10] K. Lee, M. Kim, S. T. Chanson, C. Yu, J. Lee, "CORP- A Method of Concatenation and Optimization for Resource Reservation Path in Mobile Internet", IEICE Transactions on Communications, pp. 479 – 489, Vol. E86-B, No. 2, Feb. 2003.

[11] M. Lee, K. Lee, T. C. Thang, N. N. Thanh, M. Kim, Y. Ro, J. Lee, "MPEG Streaming over Mobile Internet", IS&T/SPIE's 14th Annual Symposium, Electronic Imaging 2002, Jan. 2002.

[12] E. Gustafsson, A. Jonson, C. E. Perkins, "Mobile IP Regional Registration", Internet Draft on IETF, Oct. 2002.

[13] K. E. Malki, P. R. Calhoun, T. Hiller, J. Kempf, P. J. McCann, A. Singh, H. Soliman, S. Thalanany, "Low Latency Handoffs in Mobile IPv4", Internet Draft on IETF, Jun. 2002.

[14] P. Calhoun, "FA Assisted Hand-off", Internet Draft on IETF, Mar. 2000.

[15] W. Fenner, "Internet Group Management Protocol, Version 2", RFC 2236 on IETF, Nov. 1997.

[16] "WaveLAN", http://www.agere.com/client/wlan.html

[17] K. Cho, "The Alternate Queueing (ALTQ) homepage", http://www.csl.sony.co.jp/person/kjc/kjc/software.html

[18] "Dynamics – HUT Mobile IP", http://www.cs.hut.fi/Research/Dynamics/

[19] "RSVP Code rel4.2a3", ftp://ftp.isi.edu/rsvp/release/

[20] "MGEN - The Multi-Generator Tool", http://manimac.itd.nrl.navy.mil/MGEN/

[21] T. Camp, J. Boleng, V. Davies, "A Survey of Mobility Models for Ad Hoc Network Research", Wireless Communication & Mobile Computing (WCMC): Special issue on Mobile Ad Hoc Networking: Research, Trends and Applications, vol. 2, no.5, 2002.

[22] "The Network simulator – NS-2", http://www.isi.edu/nsnam/ns/

[23] S. Blake, D. Black, M. Carlson, E. Davies, Z. Wang, W. Weiss, "An Architecture for Differentiated Services", RFC 2475 on IETF, Dec. 1998.