

# A Seamless Resource Reservation Mechanism for Wireless Mobile Networks

Moonjeong Chang, Meejeong Lee  
Dept. of Computer Science and Engineering  
Ewha Womans University  
Seoul, Korea  
[mjchang@ewhain.net](mailto:mjchang@ewhain.net), [lmj@ewha.ac.kr](mailto:lmj@ewha.ac.kr)

Hyunjeong Lee  
Dept. of Electrical Engineering,  
University of Nevada  
Reno, USA  
[hyunlee@unr.edu](mailto:hyunlee@unr.edu)

**Abstract**—In this paper, we propose a wireless network domain structure which deploys a special cell, called a *gray cell*. The boundaries of wireless network regions are surrounded by the gray cells, and the gray cells are supposed to belong to all of its neighboring regions. Based on this wireless domain structure, we propose a mechanism which completely removes the waste of redundant resource reservation in the wireless network domain while greatly reducing the risk of reservation disruption caused by inter-region handovers. Using simulation, it is shown that the proposed mechanism can deal with inter-region handover as effectively as it does with intra-region handover. It is also presented that the proposed mechanism outperforms existing mechanisms with respect to reservation disruption time and packet losses caused by handovers.

**Keywords**—Handover, QoS, Resource reservation, Mobility

## I. INTRODUCTION

A drastically growing demand for real-time multimedia applications in wireless networks has driven active research on provision of Quality of Service (QoS). Prior work mostly focused on wireless network characteristics such as low bandwidth, high loss rate, terminal constraints, etc. However, QoS provisioning mechanisms need to consider not only network characteristics but also the terminal mobility. Therefore, recent research work proposed several approaches to apply Differentiated Services (DiffServ) [1, 2, 3, 4] and Integrated Services (IntServ) models [5, 6, 7, 8, 9, 10] to wireless mobile networks. While IntServ provides per-flow guarantees through explicit resource reservation, DiffServ follows the philosophy of mapping multiple flows into a few service levels. In this paper, we focus on the IntServ approach using Resource Reservation Protocol (RSVP) [11] as the target QoS provisioning mechanism.

In [10], Hierarchical Mobile RSVP (HMRSVP) integrates RSVP with the Mobile IP regional registration protocol [12] and makes advance resource reservations only when a MN moves into the overlapped area of the boundary cells of two different regions<sup>1</sup>. Since the regional registration protocol localizes the registration process within a wireless network

region, the path set-up latency is normally short. Therefore, a MN in HMRSVP does not reserve any resource in advance for the intra-region movement. It makes a passive resource reservation only when visiting the overlapped area of the boundary cells between two regions (i.e., the MN is expected to perform an inter-region movement). Later, the passive reservation path will be changed to the active one as the MN changes its point of attachment to the new region. This scheme can thus reduce the waste of resource compared to MRSVP. However, depending on the size of an overlapped cell area, the mobile speed, and the reservation latency, the resource disruption may occur. When a MN moves to a new region, the reservation latency may be considerable because the resource reservation over the Internet is required. Thus, the MN may suffer temporary disruption if the resource reservation latency exceeds the time duration for the MN to pass through the overlapped area. Note that a seamless handover can be retained only if the reservation process is completed during the time the MN resides in the overlapped area. Therefore, in practice, in order to provide QoS guarantee, a systematic strategy to ensure sufficient time for MNs to stay in the overlapped area is called for.

In this paper, we propose a novel Gray Cell Approach (GCA) that overcomes a drawback of HMRSVP when an inter-region handover happens. In GCA, a wireless network domain consists of multiple regions is considered. GCA deploys a new wireless network domain structure with special cells named as *gray cells*. As shown in Fig. 1, neighboring regions are entirely bordered by the gray cells, which belong to all of the neighboring regions. A MN has to cross one or more gray cell(s) in order to handover to a new region, and advance resource reservations for inter-region handovers are processed while a MN resides in the gray cell. As a result, the GCA greatly reduces the risk of a reservation disruption caused by inter-region handover. Note that the overlapped area between neighboring regions becomes multiple time of the one considered in the existing research where it takes only a part of a cell. We also propose a mechanism to remove the waste of redundant resource reservation in the wireless network domain.

The rest of the paper is organized as follows. Section 2 proposes the details of GCA scheme based on wireless network domain structure with gray cells. Then, Section 3 evaluates and compares the performance of our solution to other existing

<sup>1</sup> Region is defined as the wireless network area governed by a single Gateway Foreign Agent (GFA) in the regional registration protocol. While a MN moves around within a region, registration request is dealt with by the local GFA of the wireless network region.

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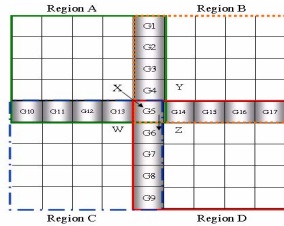


Figure 1. An architecture of wireless network with gray cells

techniques through simulation study. Finally, we conclude our work in Section 4.

## II. A GRAY CELL APPROACH

In order to resolve the resource disruption problem of HMRSVP operations associated with inter-region handovers, we present a novel GCA that provides a structured method to ensure the sufficient time period within which an advance resource reservation over the Internet can be completed. Like HMRSVP, GCA is also based on RSVP with MIP regional registration protocol, and thus, for intra-region handovers, it operates in the same way as HMRSVP does.

Without loss of generality, a MN is assumed to be equipped with MIP and RSVP modules. We also assume that a HA is capable of maintaining multiple Care of Addresses (CoA) for each MN so that it can register with multiple regions when staying in gray cells. Unlike HMRSVP, in order to ensure a seamless inter-region handover as well as an intra-region handover, GCA accounts for the critical timing issue related to the size of an overlapped area among neighboring regions and the latency to complete a registration process. To this end, it is necessary to configure a wireless network in such a way that the entire area of the cells located in the geographical border of two or more adjacent regions belongs to all of those regions. Hence, as shown in Fig. 1, a MN has to pass more than one gray cell whenever it handovers to a new region.

Once a MN enters a gray cell, GCA reserves resources for every region to which the gray cell belongs. However, only one RSVP session is activated to send and receive actual data packets. All other RSVP sessions are to remain passive just to reserve resources for the Internet part of the path, that is, from a CN to the Gateway Foreign Agents (GFAs). GCA does not make redundant resource reservations within a wireless network region in order to minimize the waste of resource within the wireless network. GCA can achieve the same level of QoS guaranteed data transmissions for inter-region handovers as it can for intra-region handovers since the necessary resource is already reserved in the Internet part (i.e., from the CN to the GFA) whenever a MN moves into a new cell. Only the resource reservation within a wireless network region would be necessary in inter-region handover cases as well as in the intra-region cases due to a special gray cell region structure.

In the case that a MN moves from one gray cell to another, there must be more than one RSVP sessions already reserved between the GFA and the CN.

In general, when a MN changes its attachment to a new cell, it performs the following processes:

1. If the active RSVP session in the previous cell is still available in the new cell, it remains as active one. If not, it selects a new RSVP session from available passive RSVP sessions and changes it to the active one. The previous active session is torn down.
2. Establish new RSVP sessions between the CN and GFAs for the regions that are newly available in the cell.

### A. GCA control messages

In GCA, a FA announces available GFAs by broadcasting an advertisement message periodically. A FA uses the G-Agent Advertisement Message (G-AAM) illustrated in Fig. 2. There are two changes to the MIP Agent Advertisement Message Extension: 1) the *C flag* is added and must be set to indicate that the region supports GCA, 2) the Care-of-Address field is used as the GFA list field to record the GFAs of every available region. The G-Registration Request Message (G-RRM) shown in Fig. 3 is used by a MN to register with the current available GFAs encoded in the G-Agent Advertisement Message. In this request message, the only change from the original Regional Registration Message is the *A flag* to indicate the active RSVP session. In the sequel, we shall name the GFA as the active GFA if it is responsible for an active RSVP session and as the passive GFA if it is for a passive RSVP session.

### B. GCA operations

#### 1) MN and FA operations

When a MN moves to a new cell, it receives the G-AAM from the FA serving the cell. The MN maintains the list of all available GFAs and selects the one to be active in the new cell. For this selection, the MN first looks up the list announced by the new FA. If the list includes the current active GFA, it is again selected. Otherwise, the MN selects a new one from the list. After the selection, the MN creates a request message only destined to the chosen active GFA. Specifically, it sets the *A flag* and records this active GFA IP address in the G-RRM. Only when the MN receives the registration reply from the GFA or the HA and finds any change to its GFA list, it informs the CN of the change (i.e., a new passive or active GFA) through the Mspec message.

As the FA receives the G-RRM, it makes the copy of the message for every available GFA with necessary modifications. Specifically, in the copy for the passive GFA, it records the corresponding GFA IP address as a destination and sets the *A flag* to zero. In the example shown in Fig. 4, the FA receives the registration request from the MN, and makes three copies for available GFAs (i.e., GFA<sub>0</sub>, GFA<sub>1</sub>, and GFA<sub>2</sub>). The GFA address field is changed to GFA<sub>0</sub>, GFA<sub>1</sub>, and GFA<sub>2</sub> in each copy. The *A flag* field in the copy destined to GFA<sub>0</sub> only has

Type	Length	Sequence Number											
Lifetime		R	B	H	F	M	G	√	T	S	I	C	resv
GFA List													

Figure 2. G-Agent Advertisement Message

Type	S	B	D	M	G	r	T	A	Lifetime
Home address									
GFA IP address									
Care-of address									
Identification									
Extensions ...									

Figure 3. G-Registration Request Message

value 1 to encode that it is the active GFA for the requesting MN.

Since a MN needs to send one request to the active GFA instead of sending multiple requests to all available GFAs, GCA strives to minimize the registration overheads.

### 2) GFA operations

A GFA receives a G-RRM and first reads the A flag field. If the A flag field is on, the request is for an active RSVP session. Otherwise, the request is for a passive one. Accordingly, the GFA performs as follows:

1. If A flag is on: the requesting MN has been already registered with the corresponding GFA for either a passive or an active RSVP session. Hence, the GFA does not need to forward the registration request to the HA. The GFA sends the registration reply to the MN and checks whether the requesting MN has performed an intra-region handover. This can be readily achieved by reading the CoA field of the G-Registration Request Message. If the FA encoded in the message conforms to its own information, (i.e., the FA recorded in the GFA to serve the requesting MN), this request is to periodically refresh the registration. If not, the MN performed an intra-region movement. Thus, the GFA sets up a new RSVP session with the new FA for the requesting MN by sending a Path message to the new FA while it sends a PathTear message to the previous FA to tear down the existing RSVP session.
2. If A flag is off: The GFA does not need to check whether the MN performed intra-region handover or not because the passive RSVP session does not involve a wireless region resource reservation. Instead, the GFA checks if the requesting MN is new to its region. If the GFA does not possess any information on the requesting MN in its own list, the MN is new to the GFA. Therefore, the GFA forwards the request to the HA. If the MN has been already registered with the GFA, the GFA directly sends the registration reply without involving the HA. In the meantime, when a GFA receives a Path message from a CN, it sends a Resv message to set up a new RSVP session with the CN on behalf of the MN.

### 3) CN operations

Upon receiving an Mspec message from a MN, the CN forwards its data packets to a new active GFA, and triggers a Path message to the new passive GFAs.

### 4) An example GCA Processes

Fig. 5 illustrates an example of GCA processes. Suppose that Cell<sub>0</sub> with FA<sub>0</sub> and Cell<sub>2</sub> with FA<sub>2</sub> belong to Region<sub>0</sub> and

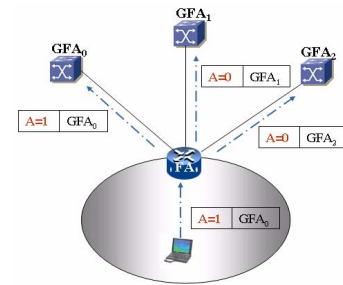


Figure 4. Forwarding method of G-registration request message

Region<sub>1</sub>, respectively. Cell<sub>1</sub> with FA<sub>1</sub> belongs to both regions as a gray cell. When a MN moves towards Cell<sub>1</sub>, and enters the overlapped area of Cell<sub>0</sub> and Cell<sub>1</sub>, it starts to receive a G-AAM from FA<sub>1</sub>. Upon receiving it, the MN sends a G-RRM to inform FA<sub>1</sub> of the selected active GFA (i.e., GFA<sub>0</sub>) as shown in Fig. 5-□. FA<sub>1</sub> receives the request and makes two copies of it for GFA<sub>0</sub> and GFA<sub>1</sub>. Note that the A flag should be *on* in the copy destined to active GFA<sub>0</sub> (See Fig. 5-□') and be *off* in the copy destined to passive GFA<sub>1</sub> (See Fig. 5-□''). In GFA<sub>0</sub>, since this is the intra-region handover, the request has been processed as it would be in the original regional registration protocol: GFA<sub>0</sub> sends the reply to FA<sub>1</sub> (See Fig. 5-□') and builds a new RSVP session by exchanging a Path and a Resv messages (See Fig. 5-□' and □'). Finally, a new end-to-end active RSVP session is established as shown in Fig. 5-⑥'.

Meanwhile, the G-RRM is also delivered to GFA<sub>1</sub> in Region<sub>1</sub> as shown in Fig. 5-□''. Because the MN is new to Region<sub>1</sub>, the request is forwarded to the HA (See Fig. 5-□''') and thus the HA sends the reply as shown in Fig. 5-□'''. As the MN receives the reply and adds GFA<sub>1</sub> to its available GFA list, it informs the CN of the two available GFAs through the Mspec message as shown in Fig. 5-□''. Then, the CN and the GFA<sub>1</sub> exchange the Path and Resv messages (See Fig. 5-□'' and □'') to build a new passive RSVP tunnel (See Fig. 5-□''). The MN keeps moving towards to Region<sub>1</sub> and enters Cell<sub>2</sub> of which region is only Region<sub>1</sub>. The MN now receives a G-AAM from FA<sub>2</sub>, selects GFA<sub>1</sub> to be active and sends a G-RRM to FA<sub>2</sub>. Then, FA<sub>2</sub> forwards the request to its GFA<sub>1</sub>. In GCA, GFA<sub>1</sub> is able to process this request as for an intra-region handover because the passive RSVP session with the CN over the Internet has already been established when the MN stayed in the gray cell Cell<sub>1</sub>. GFA<sub>1</sub> sends a registration reply message to the MN (See Fig. 5-□), and exchanges a Path and a Resv messages with FA<sub>2</sub> to establish a new RSVP tunnel (See Fig. 5-□ and □). As the MN receives the registration reply from GFA<sub>1</sub>, it sends an Mspec message to inform the CN of the new active GFA so that the CN sends its data packets over the RSVP session to GFA<sub>1</sub>.

## III. PERFORMANCE EVALUATION

We have constructed a simulation model using the RSVP module of ns-2 [13]. The main objective of the simulation study is to evaluate and to compare the performance of the proposed GCA to HMRSVP. Fig. 6(a) and (b) show GCA and HMRSVP network models used in the simulation. Both models are configured in the same way but a gray cell is included in the GCA network model. The propagation delay passing

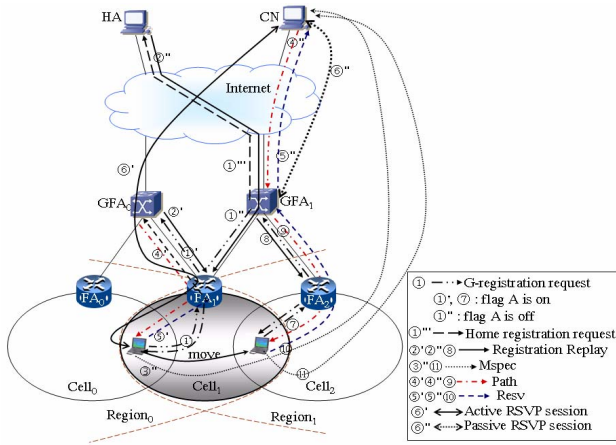


Figure 5. GCA processes

through the Internet has been set to 50ms. The propagation delays on the links from a CN, HA, or GFA to an Internet gateway were set to 2ms and the propagation delays between FAs and GFAs were set to 1ms. A 10 Mbps and a 2 Mbps data rates were used for a wired connection and for a wireless connection, respectively. The distance to pass through a gray cell has been set to 300m while the distance to pass through the overlapped area between two adjacent cells has been set to 50m. A CN generates data packets every 10ms. A packet size was set to 1000 bytes and each packet was transmitted to the MN using UDP. In each simulation, we varied the velocity of the MN and the number of intermediate routers within the Internet.

We examined the reservation disruption time caused by handovers as illustrated in Fig. 7. The reservation disruption time is the difference between the time when a MN leaves the current cell and the time when a resource reservation is completed in the new cell. During 1000 seconds of simulation time, all of the reservation disruption times were measured and averaged. A resource disruption may occur due either to an intra-region or an inter-region handover. As the MN moves faster, the resource disruption possibility increases because the time duration that the MN passes through an overlapped area or a gray cell decreases. For instance, when the MN moves in 15m/sec, the time durations that a MN passes through an overlapped area and a gray cell are approximately 3.33 seconds and 20 seconds, respectively.

With HMRSVP, both inter- and intra-region handovers generate resource disruptions and the average resource disruption time increases rapidly when the velocity is above 12m/sec. On the other hand, with GCA, no resource disruption due to inter-region handovers occurs. Only a few resource disruptions due to intra-region handovers are appeared when the velocity is above 15m/sec. Since resource disruptions in GCA are not from inter-region handovers, GCA yields the shorter disruption time than the one of HMRSVP.

We then looked at the packet loss rate in the same experimental environments (See Fig. 8). The packet loss rate is the ratio of lost packets to total generated packets. The results have been averaged over ten experiments. In GCA, since there

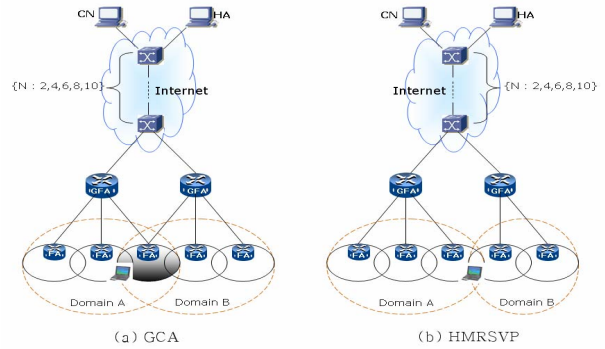


Figure 6. A simulation network model

is no packet loss stemmed from resource disruptions with inter-region handovers, the loss rate gradually increases as the mobility increases. Two additional main reasons for the packet loss besides the resource disruption caused by inter-region handovers are: 1) intra-region handovers and 2) data packets transmitted over the previous path after a MN leaves the overlapped area. In fact, in the second case, packets can get lost without involving any resource disruption. In HMRSVP, the loss rate increases rapidly when the velocity is above 12m/sec. Moderate packet losses are observed when the velocity is between 6m/sec and 9m/sec at which there is no resource disruption appeared. HMRSVP still yields the higher packet loss rate than the one associated with GCA even when no resource disruption is involved. This is because a MN with GCA can send an Mspec message to CN as soon as the regional registration is completed while a MN with HMRSVP must wait until it completely leaves the overlapped area. As a result, the CN with HMRSVP may transmit data packets over an obsolete path for a longer time than the CN with GCA does. Thus, more packets are lost in HMRSVP.

A ping-pong phenomenon refers to the event that a MN keeps changing its point of attachment alternately between two regions when it stays in the border of two. In fact, if a MN with HMRSVP stays in an overlapped area of a cell in the boundary of two regions, it may be difficult to decide to which cell the MN finally will move in. Therefore, in order to prevent the ping-pong phenomenon, HMRSVP must not allow a MN to change an active GFA when it stays in the overlapped area. On the other hand, due to our special gray cell feature, even though a MN changes its active GFA to a new one in the overlapped area of a gray cell and its neighboring cell, and then comes back to the original gray cell, the gray cell still belongs to the new active GFA. Thus, it is not necessary for the MN to change back its active GFA to the previous one. Therefore, GCA allows a MN to change its active GFA while it stays in



Figure 7. Mobile speed versus reservation disruption time

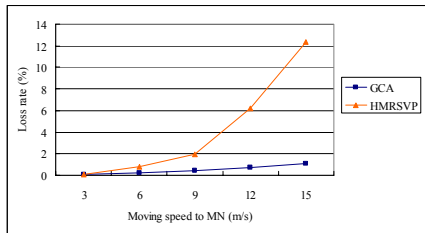


Figure 8. Mobile speed versus packet loss rate

the overlapped area, without concerning on ping-pong phenomenon.

Fig. 9 shows the sequence numbers of data packets versus the simulation time when the velocity of a MN is set to 15m/sec. For this simulation experiment, we labeled the IP packets with the sequence numbers in order to check the transient behavior of the packet losses. A solid circle indicates the instance of an inter-region handover and a dotted circle for an intra-region handover. With HMRSVP as shown in Fig. 9 (a), the sequence number gap due to an inter-region handover is larger than the one due to an intra-region handover. Unlike this, with GCA, the sequence number gaps due to both inter- and intra-region handovers are similar. This confirms our reasoning that GCA provides the same level of QoS guarantees for both intra- and inter-region handovers.

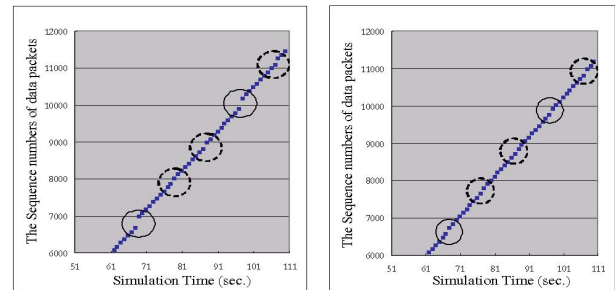
We then measured the packet loss rate while varying the number of intermediate routers from 2 to 10. We note that the RSVP protocol overhead may increase as the number of intermediate routers over the Internet increases. As shown in Fig. 10, GCA does not display an increase in the packet loss rate as the number of intermediate routers increases since no resource disruption occurs. However, the packet loss rate associated with HMRSVP proportionally increases as the number of router increases because the resource disruption time increases.

Overall, our GCA outperforms HMRSVP with the expense of additional resource reservations over the wired Internet. However, no additional resource reservation is required over the wireless network domain where resource is scarce.

#### IV. CONCLUSION

We have presented the Gray Cell Approach (GCA) with an efficient wireless resource management strategy. In order to provide a consistent QoS level, GCA locates gray cells in the boundary of two or more of adjacent regions in a wireless network. GCA provides the same level of QoS guarantees for both inter- and intra-region handovers.

Our simulation results prove this and show that GCA outperforms HMRSVP with regards to the reservation disruption time and the packet loss rate caused by handovers. While the protocol details within GCA in this paper are designed based on MIPv4 with regional registration, the proposed GCA domain structure can facilitate Hierarchical Mobile IPv6 (HMIPv6) [14] that is the enhancement of MIPv6 for local mobility handling as the regional registration protocol in MIPv4.



(a) HMRSVP

(b) GCA

Figure 9. Data packet sequence numbers related to inter- and intra-region handovers

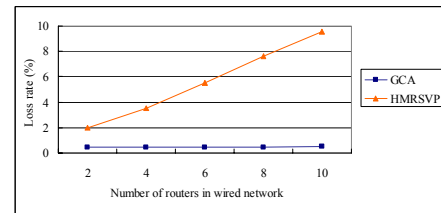


Figure 10. Loss rate versus number of intermediate routers

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