

An Efficient Handover Mechanism Using the General Switch Management Protocol on a Multi-Protocol Label Switching Network

Seong Gon Choi, Hyun Joo Kang, and Jun Kyun Choi

Using the general switch management protocol on a multi-protocol label switching network, we present an efficient method for handling handovers. The proposed method directly changes an established path into a new path for supporting a handover. Our investigation reveals the effects of the proposed scheme and demonstrates that this method significantly reduces signaling costs and delays.

Keywords: Handover, GSMP, MPLS.

I. Introduction

Due to the increased popularity of portable computers and wireless communications devices, mobile networking applications have become more and more popular. In the mobile environment, the demand to provide wireless Internet access is growing rapidly. Since mobile users change their locations, several requirements, such as lossless data transmission, simple signaling, short latency time, efficient handover handling, and clear location management, must be fulfilled to achieve efficient mobility. To meet these challenges, the Internet Engineering Task Force (IETF) has created a working group to study the mobile IP [1], and specifically, researchers have proposed several multi-protocol label switching (MPLS)-based mobility schemes to support mobility on IP networks. In addition, there is a general switch management protocol (GSMP), which can control MPLS-based IP switches.

The IETF has currently standardized mobile IP [1], and several ideas including micro-mobility schemes have been proposed [2]-[6]. Although many of those proposals try to provide global mobility, seamless handover, fast handover, and reduction of signaling traffic, they still lack sufficient mobility support, especially in handover latency time.

Recently, various researchers have proposed MPLS-based mobility schemes [7]-[10]. Other studies have aimed at improving network reliability [11], [12]. However, these schemes have not proved sufficient for use in the mobile environment because a new MPLS path must be established whenever a mobile host (MH) changes its location, or multi-

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MPLS paths need to be reserved for handovers. The former condition can cause a long latency time, and the latter can result in a waste of resources.

GSMP plays the role of connection management for the general switching system [13]. GSMP is a master/slave protocol, where an MPLS-based router can be the slave, and it allows the master (or controller) to establish and release connections and to manage a port. In addition, the protocol allows the slave to inform the controller if something interesting, such as a link attachment, happens on the slave. In this way, if a handover occurs, the GSMP slave (an MPLS-based router) can inform the GSMP controller of an attachment or detachment of an MH. Thus, if the GSMP is used for mobility support, the mobility can be efficiently handled, and the handover latency time can be reduced.

In this paper, we propose a method to reduce handover latency time by using the GSMP on an MPLS network. The general method of our proposal is that if an MH moves from one cell to another, the GSMP controller receives event messages corresponding to the attachment message from the new GSMP slave and the detachment message from the old GSMP slave. The controller then directly changes the MPLS path at the crossover label switched router (LSR) by using the routing table in the GSMP controller. This results in the advantage of a low handover latency time.

This paper is organized as follows. Section II describes related work. In section III, we introduce a GSMP-based mobility management procedure on the MPLS network for supporting mobility. Performance analysis and its results are presented in section IV. Section V consists of the conclusion and proposed further study.

II. Related Work

In this section, we look into several existing related studies. These consist of overviews of the basic Mobile IP architectures followed by their extensions. In addition, we also simply introduce the GSMP.

1. Mobile IP

Mobile IP [1] is a well known approach for mobility support in IP networks and an accepted standard in the IETF community.

The objective of mobile IP is to support mobility in a pure network layer. Especially, it aims at maintaining connections even when handovers cause IP address changes.

The fundamental assumption in mobile IP is that an MH has an IP home address and gets a temporary care-of-address (CoA) in a foreign network. A correspondent node (CN)

addresses the MH via its IP home address. Mobile IP has two instances, a home agent (HA) and a foreign agent (FA). Routing is performed by address translation and tunneling. When the CN tries to send packets to the mobile host, it sends them to its HA first. In turn, the HA intercepts and tunnels the packets to the CoA of the MH. To tunnel a packet, the packets are encapsulated by the HA. The FA decapsulates the packets and forwards them via local mechanisms to the mobile host. For the reverse direction from the MH to the CN, the MH is allowed to send packets directly. This is referred to as triangular routing.

The mobile IP standard [1] specifies a general handover protocol for the Internet. It requires that the home network of the MH be notified of every change of location. These location updates incur a latency in traveling to distant home networks and communicating hosts. They also add traffic to the wide area portion of the internetwork. As currently defined, therefore, mobile IP does not extend well to large numbers of portable devices moving frequently between small cells.

2. Micro-Mobility

Existing proposals for micro-mobility can be broadly classified into two types: tunnel-based and routing-based schemes, and they are summarized well in [10].

Tunnel-based micro-mobility schemes include mobile IP regional registration. It uses the idea of a gateway foreign agent (GFA). The MH registers the GFA as the FA. In this way, mobility within the subnet of the GFA does not require a re-registration with the remote HA and is achieved by a local registration with the GFA, thus resulting in decreased signaling overhead and latency. A forwarding entry for the mobile host is necessary at the GFA(s), and the rest of the nodes in the network are oblivious to the mobility management.

HAWAII [5] and cellular IP (CIP) [6], which are routing-based schemes, maintain regular IP forwarding processes to provide robustness within a domain and also eliminate the tunnel overhead. A domain has one root node providing the routable address and acting as an FA for all MHs in its scope. In this case, changing routing table entries in all corresponding nodes can support the mobility between two access routers. The limitation of these schemes is that a large number of nodes in the domain need to maintain forwarding entries for all MHs. This means that all nodes need to maintain a flat address lookup table that contains entries for all MHs in the domain, so every node in the domain has to implement the protocol, preventing gradual deployment.

3. MPLS-Based Schemes

Several studies have presented MPLS-based mobility schemes [7]-[10]. In one form or another, MPLS-based

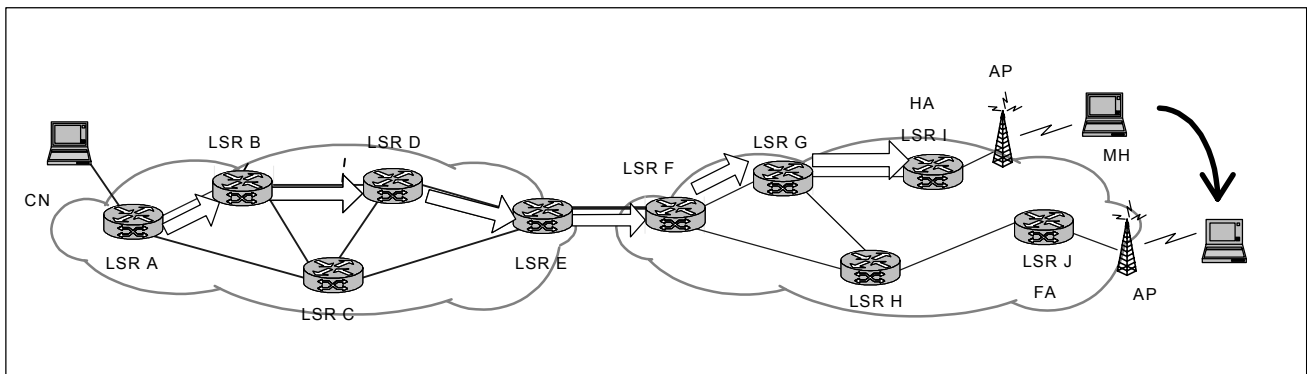


Fig. 1. MPLS-based mobile network.

schemes use the idea of a label switched path (LSP). Guo et al. [7] presented an IP transport scheme for third generation radio access networks based on an MPLS. Its basic idea was to establish and manage LSP(s) for interconnecting APs and radio network controllers. This proposal also explained transport bears to support bandwidth provisioning and a variety of quality of service (QoS) requirements in the radio access network well. However, their study failed to explain mobility, such as handovers.

The integration scheme of mobile IP and MPLS [8] uses a typical mobile IP concept for mobility. As Fig. 1 shows, if an MH changes its LSR by a handover, then the FA (LSR J) and the HA (LSR I) of the MH must give and take the registration request and registration reply messages as shown in Fig. 2. The HA will then send a label request using the label distribution protocol (LDP) to the FA with a CoA as a forwarding equivalent class (FEC). The FA replies with an LDP label mapping message to the HA. When this label mapping message arrives at the HA, the LSP is established. After that, the HA updates its label table and sends a registration reply message to the FA along the LSP from the HA to the FA. Consequently, the registration process by handover may require a long latency time at the registration process by a handover. If the HA is in a different network, which is connected to the FA with more hops, it takes a longer handover latency time.

Kim et al. proposed a mobility-aware MPLS scheme [9] to improve the deficiencies in the mobile IP. This proposal provided an efficient micro-mobility with continuous QoS support by combining the advantages of the MPLS, such as IP QoS support, with the advantages of host-based micro-mobility schemes, such as low-latency handovers. For those capabilities, this scheme used a domain-based approach to address micro-mobility management. Each access MPLS domain has one gateway node. Within a wireless access MPLS domain, multiple LSPs are formed between each AP and a gateway to

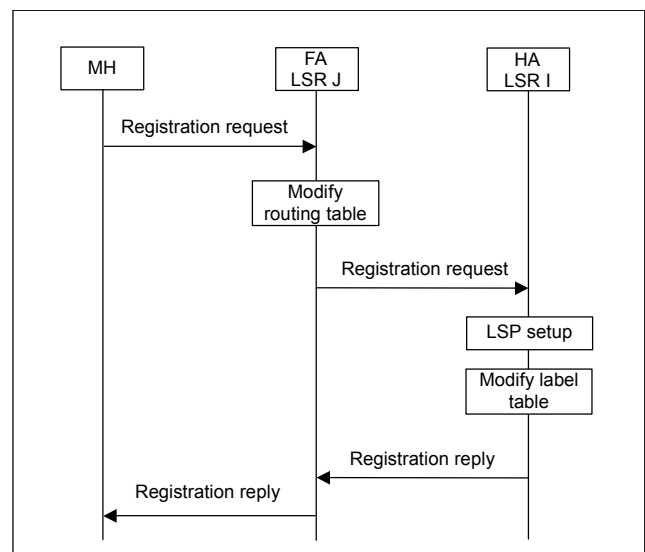


Fig. 2. Registration procedure in a foreign network.

support multiple FECs, and the gateway maintains the packet forwarding table. This scheme can result in waste of resources.

The label edge mobility agent (LEMA)-based MPLS proposal [10] had some advantages, such as a distributed and scalable nature, the ability to provide for QoS through traffic engineering, ease of gradual deployment, and efficient design and handover performance. One of the key differentiating factors of this scheme is that the mobile has the flexibility to create its own hierarchy of agents based on its mobility pattern, the bandwidth availability in the network, and other factors. Although this scheme has more advantages than other hierarchical mobility schemes, it also has more signaling traffic for supporting handovers by using the LEMA concept. This means that even though an MH changes its LEMA within the same administrative domain by handover, several signaling messages, such as redirect request, redirect confirm, and binding update toward the HA, occur if it is an upper level LEMA.

4. GSMP

Here we provide an introduction to the GSMP. It is important to realize that IP switching is essentially independent of the GSMP, and vice versa. The GSMP is used solely to control a switch (e.g., an MPLS-based router) [14]. The GSMP consists of a controller and a slave. The controller could be any general-purpose computer. The protocol allows the controller to

- Establish and release connections,
- Add and delete leaves,
- Perform port management,
- Request data (configuration information, statistics).

In addition, the protocol allows the slave to inform the controller if something interesting happens on the switch. The GSMP contains some messages for statistics gathering, e.g., general port and switch management. There are six classes of GSMP request/response messages: connection management, port management, state and statistics, configuration, reservation management, and QoS.

The GSMP slave can inform the GSMP controller of an attachment or detachment of an MH by using the messages if a handover occurs, so when the GSMP is used for mobility support, we can efficiently handle the mobility, and the handover latency time can be reduced. In addition, if an MH changes its AP within the same administrative domain, it does not need to inform its HA of the handover. In this way, the GSMP controller can change the MPLS path by directly modifying the label information at the crossover LSR on the MPLS network.

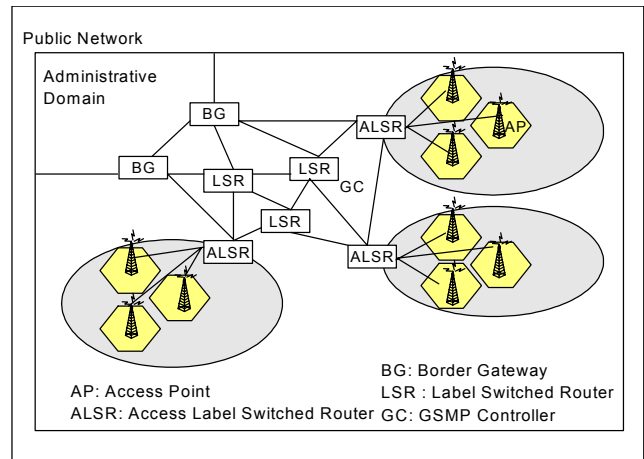


Fig. 3. Mobile network model in an MPLS domain.

III. GSMP-Based Mobility Management Procedure for Supporting Mobility

We approach mobility management on an MPLS network using the GSMP and mainly deal with the handover process. We consider the network architecture of Fig. 3, where the administrative domain under consideration uses MPLS and the GSMP. Each access MPLS domain has one GSMP controller node. The GSMP controller is connected with all routers, which are logically GSMP slaves. An MH communicates with one or more access points (APs) that are connected to access LSRs (ALSRs).

We apply our scheme in an MPLS domain for a micro-mobility solution. Within an MPLS domain, LSPs are formed between each AP and a border gateway (BG). Multiple LSPs

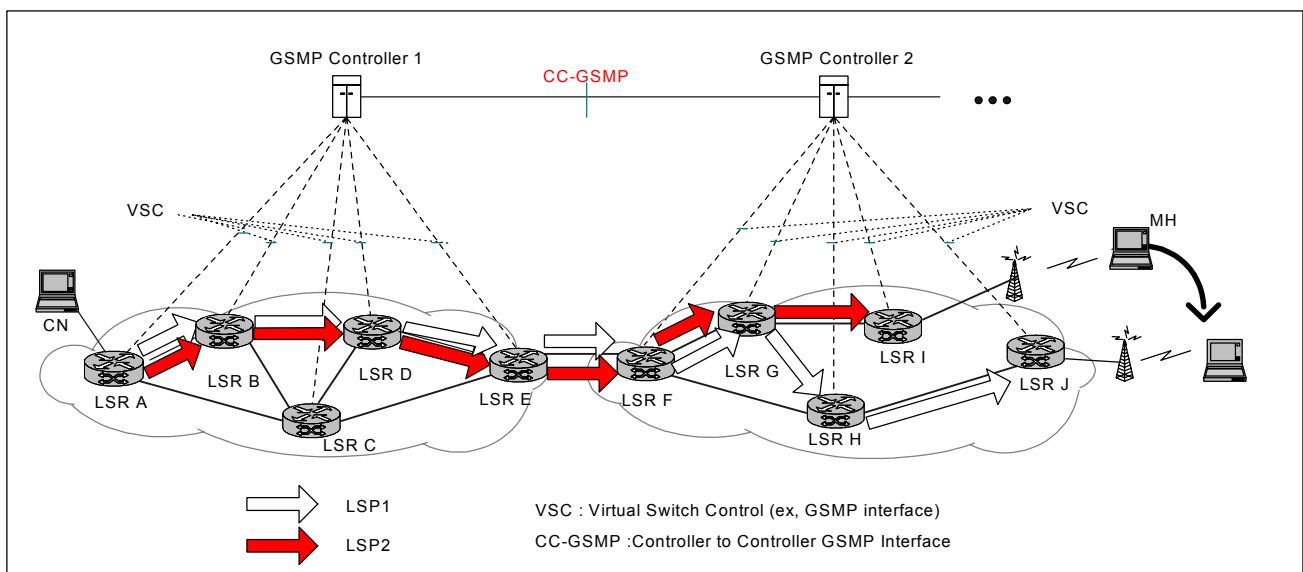


Fig. 4. An architecture using GSMP on an MPLS network.

are created between an AP and a BG to support multiple FECs that can be mapped to signaling traffic and different classes, and LSPs are newly established between the BGs and the APs. If the public network is an MPLS network, the BGs are edge LSRs.

From now, we assume that a public network is also an MPLS network. The GSMP controller is connected to each slave (Fig. 4), so all information about the LSPs can be sent to the GSMP controller. Several key differentiating factors of this scheme, as opposed to other hierarchical and MPLS-based mobility schemes, are as follows: all information about LSPs can be sent to the GSMP controller and stored using the GSMP. An MH's handover can be detected at the GSMP controller via a GSMP slave. If a handover occurs, controller 2 can easily announce the LSP release to the old LSR I and also establish a new path toward LSR J at the crossover router (LSR G) using stored LSPs information in the GSMP controller (Fig. 4). Thus, no update message within the same domain is sent to the HA at a handover process.

For the situation in Fig. 4, in order to maintain other domains, we should define the controller-to-controller GSMP interface. A controller in a different domain reports events through this interface. The events may be similar to typical GSMP messages, but we leave this as a further study.

1. LSP Configuration

At first, multiple LSPs between each AP and a BG are provisioned statically. A network operator creates them based on network provisioning policies. We refer to this LSP setup scheme as a static LSP configuration scheme. The static LSP configuration is good for use with differentiated service models for supporting IP QoS services, and has been proposed by the IETF [9].

When one LSR in an ongoing MPLS path has a problem and cannot be used, the GSMP controller detects an alternative path using its resource table. After that, the GSMP controller makes the corresponding LSRs update each label table. We call this a dynamic LSP configuration scheme. The dynamic LSP configuration scheme is used to support the integrated service model and to improve network reliability.

In this paper, we consider that the static LSP configuration is used first, and the dynamic LSP configuration can be used when a handover occurs.

2. Registration Procedure

- 1) An MH sends a registration message after it receives agent advertisement messages broadcasted by an AP.
- 2) The AP forwards the registration message using the pre-

established signaling LSP between itself and a BG.

3) When the BG receives the registration message, it updates its forwarding table by associating the MN's IP address with the interface from which the registration message was received. If the wireless access MPLS domain is not the MN's home domain, the BG sends a registration message to the MN's HA so that packets destined for the MN can be tunneled from the HA to the FA.

4) At the same time, each LSR corresponding to the LSP informs the GSMP controller of its state with regard to the LSP.

3. Handover Procedure

Figure 5 shows the handover management procedure in which LSR G is the crossover router, and LSR I and LSR J are the old FA and the new FA, respectively.

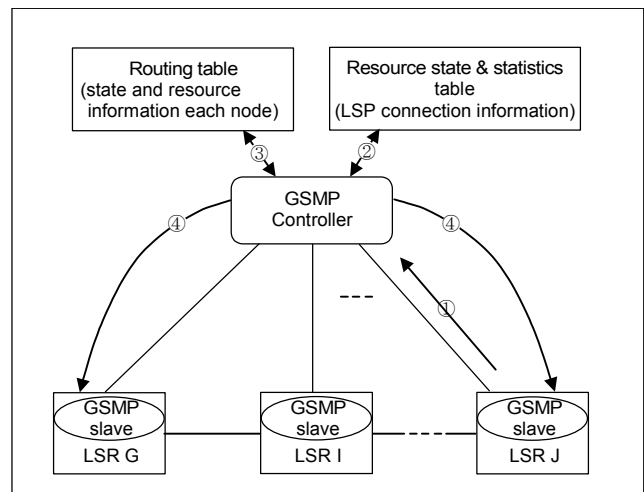


Fig. 5. The path re-establishing procedure.

If an MH moves into the LSR J, and it sends a registration request message, then the LSR J informs the GSMP controller of the attachment of the MH (step 1). Immediately on receiving the message, the GSMP controller examines the resource table about the LSP (step 2). After this process, it can detect an alternative path from the routing table (step 3). After choosing the alternative path with the link and node state, the GSMP controller orders slave LSR G to modify the label table (step 4).

Figure 6 shows an update procedure of the LSP configuration reference table in the GSMP controller at handover time, where it is assumed that LSR G is connected to LSR I with port number 4, and LSR H is connected with port number 5. LSR G is also connected to LSR I with out label value 36 at port number 4, and it is connected to LSR H with out label value 48 at port number 5.

Resv ID in Fig. 6 indicates the resource state of the system. If the Resv ID of LSR F in LSP 1 of the configuration reference table is 1, LSR F is being used for LSP 1. If the Resv ID is 2 or any other number, then the port of the system may be reserved as one for the LSP.

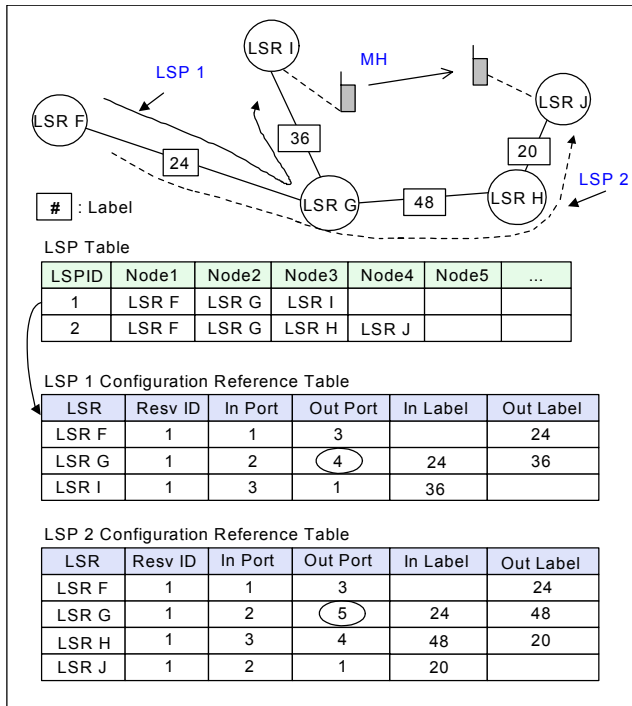


Fig. 6. Forwarding table in the GSMP controller.

Figure 6 shows that an MH is in the LSR I region at first and uses LSP 1. If the MH moves into LSR J from LSR I, the MH is served by LSP 2, so the GSMP controller orders LSR G to change its out label value to 48 and its out port number to 5 for in label value 24. It also makes LSR H establish out label value 20 at the out port number 4 for in label value 48.

On the other hand, packet loss during handover should be taken into consideration. In general, there are some ideas, such as buffering and forwarding concepts, for solving it in a packet network using signaling. The buffering concept is that the crossover LSR starts to buffer data packets if it detects a handover using the GSMP or any other method. After an MH finishes the handover process, the crossover LSR sends the buffered packets to the MH in good order. However, it is difficult to determine the optimized buffer size. Especially in realtime service, a delay problem may result from the queuing delay according to the buffering.

The forwarding concept is that an old LSR first receives data packets and then forwards them toward the new LSR. For this scheme, the GSMP controller needs to establish a new LSP between the old LSR and the new LSR. This scheme can also

cause transmission delay because the data packets go to the new LSR via the old LSR.

Therefore, in this paper, we consider a direct path change at a crossover LSR without buffering data packets. Since all adjacent wireless cells by APs may be overlapped for a smooth handover and the GSMP controller easily finds a crossover LSR over the data path, a handover can be performed at the crossover LSR without packet loss if the overlapped region is well deployed. In other words, while an MH resides in the overlapped region, a proper LSP can be selected, and the handover can be performed in time. For this, several factors, such as packet transmission delay, the MH's moving speed, and the processing time of each device, should be considered. We will continue to study this concept as a further study.

IV. Analysis and Numerical Results

In this section, we look into some characteristics of our proposal, compare our scheme with other ones, and investigate the overall performance in terms of signaling cost and latency time. We refer to [15] for the analysis method here.

Our scheme addresses a fast handover with a short latency time. This scheme eliminates the signaling toward the remote HA of an MH as long as the MH resides within the same administrative domain. An attachment of an MH toward a new LSR in the same administrative domain creates a registration message only locally.

We consider cost and delay for signaling and packet delivery. In evaluating the latency time, transmission delay and system time in databases are considered. The signaling procedure of registration and packet forwarding by handover involves the exchange of registration messages among the network elements. The costs for location management are associated with the traffic of messages between the entities and the accessing cost of the database.

In order to present and evaluate the performance of the signaling procedure, we define the following parameters for the rest of the paper:

- c_1 is the transmission cost of messages between an LSR and a controller.
- c_2 is the transmission cost of messages between an LSR and another LSR.
- c_3 is the transmission cost of messages between a controller and another controller.
- α is the weighting factor of the transmission cost including layers 1 and 2.
- β is the weighting factor of the access cost including layer 3.
- h is the number of total hops associated with the signaling or packet transmission.
- a_R is the router access cost including layer 3.

- a_H is the database access cost of an HA.
- a_C is database access cost of a controller

We also assume that the controller and LSR are modeled as a single exponential server with an infinite buffer. A designated LSP is established for signaling between the controller and each LSR.

The average system time consists of the service time and the waiting time in the queue. It is represented by s_C , s_L , and s_R . The s_C is the service time for the processing database in the controller, the s_L is the service time for the layer 2 process in the LSR according to the MPLS, and the s_R is the service time for the layer 3 process in a router in using a pure mobile IP. Each average service time is $1/\mu_C$, $1/\mu_R$, and $1/\mu_L$ for the controller, router, and LSR, respectively. The waiting times are denoted by w_C , w_R , and w_L .

The message transmission delay is ignored because the message length of signaling is very short, and the transmission rate between the network elements is very high.

Lastly, it is assumed that the cost for update and deletion in the database is the same, and for simplicity, we deal with the performance only with the average values without delay jitter.

Now we investigate the location registration cost for two different cases. One is for when the MH performs a handover in the same domain, and the other is for when the MH performs a handover between different domains.

When the MH performs the handover in the same domain, we know that the signaling cost for transmission is $2\alpha hc_2$ using the mobile IP from Fig. 5. Using the GSMP, the cost is $2\alpha hc_1$.

On the other hand, we consider the access cost that involves the controller and the LSR. The cost is $\beta [(h-1) a_R + a_H]$ and $2\beta \cdot a_C$ for using the mobile IP and for using the GSMP, respectively, where $2 \cdot a_C$ indicates that the controller refers to two databases, a routing table and a resource state table, as shown in Fig. 5. The database access cost in using the GSMP is not dependent on a_R , because the signaling traffic is transmitted at layer 2 using the designated LSP.

The transmission cost and access cost for the handover between different domains in a mobile IP are equal to the cost for the handover in the same domain.

In using the GSMP, the transmission cost is $2\alpha hc_1 + 2\alpha hc_3$. If we assume that the c_1 is equal to the c_3 , then the cost can be $2\alpha hc_1$. The access cost is $4\beta a_C$ for controller 1 and controller 2.

Consequently, the average location registration cost, $C^r(\text{MIP})$ and $C^r(\text{GSMP})$, can be calculated as:

$$\begin{aligned} C_0^r(\text{MIP}) &= C_1^r = 2\alpha hc_2 + \beta[(h-1)a_R + a_H] \\ C_0^r(\text{GSMP}) &= 2\alpha hc_1 + 2\beta \cdot a_C \\ C_1^r(\text{GSMP}) &= 2\alpha hc_1 + 4\beta \cdot a_C, \end{aligned} \quad (1)$$

where C_0 and C_1 indicate the cost for handovers inside the

same domain and between the different domains, respectively.

Next, we investigate the cost for signaling packet delivery. The packet delivery cost for a mobile IP is obtained by

$$\begin{aligned} C_d(\text{MIP}) &= 2\alpha hc_2 + \beta[(h-1)a_R + a_H] \\ C_d(\text{GSMP}) &= 2\alpha hc_2 + 2\beta a_C, \end{aligned} \quad (2)$$

where the packet delivery cost in using the GSMP is not dependent on a_R , because the packet is transmitted via layer 2, and the cost for layer 2 is considered with the transmission cost.

The delay of accessing each database, $s(\cdot)$, is

$$s(\cdot) = 1/\mu(\cdot) + w(\cdot), \quad (3)$$

where $1/\mu(\cdot)$ represents the average processing time for a database and $w(\cdot)$ denotes the waiting time for the database. For example, if the average arrival rate of location registration at the controller is η_C , then the waiting time is obtained as in [15], [16].

$$w_C = \frac{\eta_C \mu_C^2 + \eta_C \sigma_C^2}{2(1 - \frac{\eta_C}{\mu_C})}, \quad (4)$$

where $\sigma^2(\cdot)$ is the variance of the processing time in each database.

Accordingly, the delay of the location registration for a handover in the same domain with the GSMP is a combination of the delay of accessing the LSR and the controller.

$$\begin{aligned} \text{delay}(\text{GSMP}) &= (h-1)s_L + 2s_C \\ &= (h-1) \left[\frac{1}{\mu_L} + \eta_L \frac{\mu_L^2 + \sigma_L^2}{2 \cdot \left(1 - \frac{\eta_L}{\mu_L}\right)} \right] \\ &\quad + 2 \left[\frac{1}{\mu_C} + \eta_C \frac{\mu_C^2 + \sigma_C^2}{2 \cdot \left(1 - \frac{\eta_C}{\mu_C}\right)} \right] \end{aligned} \quad (5)$$

where the first item is the service time of the LSR, and $2s_C$ indicates that the controller accesses two databases within itself, the routing table and the resource state table.

For MH handovers inside the same domain, the delay of location registration is

$$\text{delay}(\text{MIP}) = (h-1)s_R + s_H$$

When the MH performs a handover between different domains, the delay is

$$\begin{aligned} \text{delay(MIP)} &= (h-2)s_R + s_H \\ \text{delay(GSMP)} &= (h-2)s_L + 2(s_{C1} + s_{C2}), \end{aligned}$$

where $h-2$ indicates that there are at least 2 LSRs or routers, because an MH moves into a different domain. In addition, the s_{C1} and s_{C2} are for the system times for controller 1 and controller 2, respectively. Therefore, the average delay for location registrations $D^r(\text{MIP})$ and $D^r(\text{GSMP})$ is

$$\begin{aligned} D_0^r(\text{MIP}) &= (h-1)s_R + s_H \\ D_1^r(\text{MIP}) &= (h-2)s_R + s_H, \quad (h \geq 2) \\ D_0^r(\text{GSMP}) &= (h-1)s_L + 2s_C \\ D_1^r(\text{GSMP}) &= (h-2)s_L + 4s_C, \quad (s_C = s_{C1} = s_{C2}, h \geq 2), \end{aligned} \quad (6)$$

where D_0 and D_1 indicate handovers inside the same domain and between different domains, respectively, and $h \geq 2$ indicates that there are at least 2 LSRs or routers, because the MH moves into a different domain.

For signaling packet delivery, delay is similar to the case of (2).

$$\begin{aligned} D_d(\text{MIP}) &= 2(h-1)s_R + s_H \\ D_d(\text{GSMP}) &= 2(h-1)s_L + 2s_C. \end{aligned} \quad (7)$$

Figure 7 shows the average location registration cost as a function of the number of hops passed by a signaling message, where Case 0 indicates that the handover occurs inside the same domain, and Case 1 indicates that the handover occurs between different domains. The Case 1 (GSMP) line starts at number 2 of the x axis because we assumed that an MH moves into a different domain. Table 1 gives all the parameters used in our performance analysis. Studying this table, we can see that the average location registration cost of using a typical mobile IP increases significantly. However, using the proposed method increases the cost slightly with an increase in the number of hops. The initial cost of using the proposed method is larger than that of the typical mobile IP, because a controller refers to two databases within itself, the routing table and the resource state table. However, the larger the number of hops, the more effective the proposed method.

Figure 8 shows the average packet delivery cost for signaling. In this figure, we can observe that the average packet delivery cost of using the typical mobile IP is always equal to or larger than that of using the GSMP, except for the initial point. At the initial point up to 3 hops, the value for using the GSMP is larger than that of using the Mobile IP, because a controller refers to two databases within itself.

Therefore, as shown in Figs. 7 and 8, using the proposed method is more profitable than using the mobile IP if the

Table 1. Performance analysis parameter.

Signaling transmission cost				Access cost			Variance of DB processing time(ms)	
c_1	c_2	c_3		a_c	a_H	a_R	σ	
1	1	1		8	8	6	0.01	
Average processing time (ms)				Avg. arrival rate for DB reg. (ms^{-1})			Weighting factor	
$1/\mu_C$	$1/\mu_H$	$1/\mu_L$	$1/\mu_U$	η			α	β
0.5	0.5	0.1	0.4	0.001			0.4	0.6

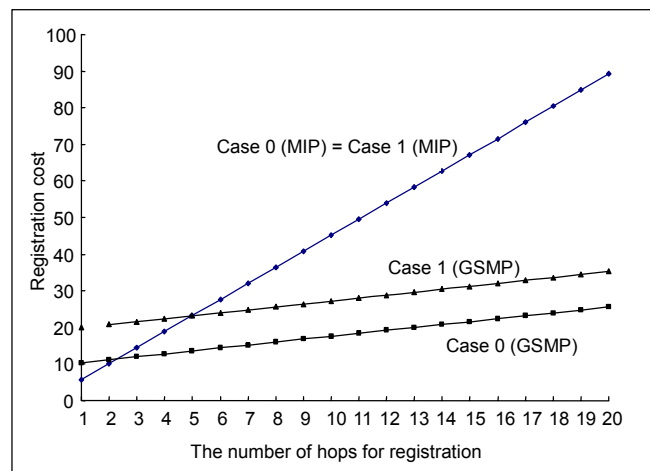


Fig. 7. Average location registration cost.

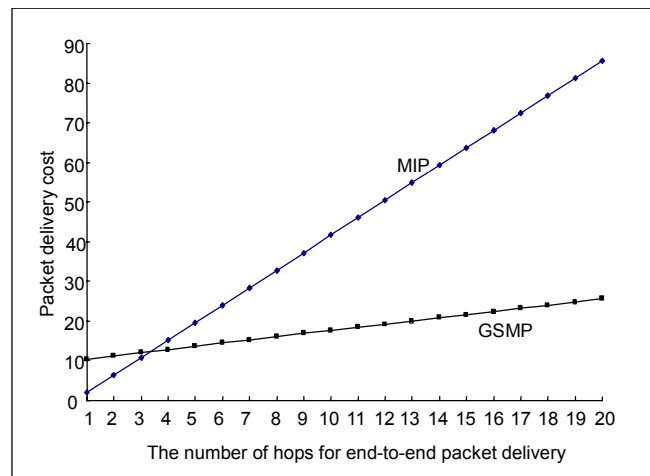


Fig. 8. Average packet delivery cost.

number of hops for registration of the HA is larger than 3 when the MH resides in the same domain.

Figure 9 shows the average location registration delay as a function of the number of hops passed by a signaling message,

where the Case 1 (GSMP) line starts at number 2 of the x axis because we assumed that an MH moves into a different domain. In this figure, although the average location registration delay using the proposed method increases slightly with the number of hops, the delay of using the typical mobile IP increases significantly. While the initial value of the delay for the proposed method is larger than that for a mobile IP, it becomes lower than that of the mobile IP when the number of hops increases.

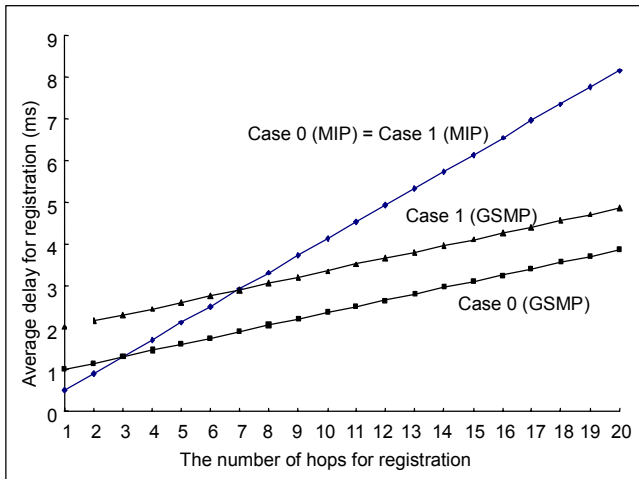


Fig. 9. Average location registration delay.

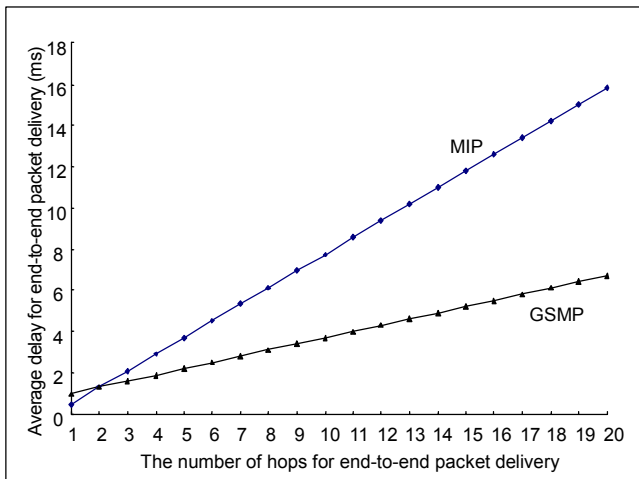


Fig. 10. Average packet delivery delay.

Figure 10 shows the average packet delivery delay for signaling. In this figure, we can see that the average delay of using the typical mobile IP is always equal to or larger than that of using the GSMP, except for the initial point. At an initial point up to 2 hops, the value for using the GSMP is larger than that of using a mobile IP, because a controller refers to two databases within itself.

Therefore, as shown in Figs. 9 and 10, using the proposed

method is more profitable than using the mobile IP if the number of hops for registration of the HA is larger than 2 when the MH resides in the same domain.

V. Conclusion and Further Study

In this paper, we introduced a hierarchical architecture for supporting mobility by using the GSMP on an MPLS network. Since a GSMP controller can manage its own domain as a centralized server, the proposed method can directly change the routing path at a crossover router when a handover occurs. Therefore, in the proposed method, the farther the distance between an FA and an HA, the more efficient the latency time and the registration cost at the handover time.

For using the proposed method efficiently, first, the controller-to-controller GSMP should be studied more. It can be efficient for inter-domain handovers. Second, it would be advantageous to arrange relations between the notification messages that are sent to the controller from a salve (a new FA) and other messages when an MH performs a handover. Third, the proposed network configuration still has the single point of failure although the proposed configuration can be more reliable than previous configurations using the gateway concept in a hierarchical mobile structure. Thus, since the single point of failure is a very important issue, we should consider the problem as one of the most important for further studies.

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