# Paging-Aided Connection Setup for Real-time Communication in Mobile Internet

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*Abstract*— **Mobile IP is a solution for mobility on the global Internet. However, the basic Mobile IP does not support paging. The main benefit of providing paging services is to save the battery power consumption at mobile terminals. Next generation Internet is expected to support multimedia communications. For real-time data traffic, Quality of Service (QoS) provision must be guaranteed. The Resource Reservation Protocol (RSVP) was proposed to support the signaling of end-to-end IP QoS. When both IP paging and RSVP are supported in the network, the signaling delay for connection setup is the sum of the paging delay and the time for RSVP path setup. This paper introduces a new scheme for fast connection setup of real-time communication. The connection is set up with the help of Mobile IP location registration and paging. Performance analysis shows that the proposed scheme reduces the overall signaling delay and the total number of signaling messages.**

## I. Introduction

Mobile IP is a solution for mobility on the global Internet [1] [2]. It has been standardized by Internet Engineering Task Force (IETF) to provide continual Internet connectivity to mobile users. Mobile IP introduces three new functional entities: home agent (HA), foreign agent (FA), and mobile node (MN). When an MN moves out of its home network, it obtains a temporary address: care-of address (CoA). This address is used to identify the MN in the local network. When the MN moves from one foreign network to another, it registers its new location, i.e., its new CoA, to its HA. Packets for an MN are sent to its permanent address, i.e., its home address first. The HA intercepts all the IP packets destined to the MN and tunnels them to the serving FA of the MN. The FA decapsulates and forwards these packets to the MN.

A major problem of mobile terminals is their limited battery capacity. Mobile IP requires that an MN registers its new location to its HA whenever it enters a new subnet. Statistics indicate that the power of actively communicating MNs spent in location updating is an order of magnitude greater than the power spent in standby mode, where MNs perform location updates less frequently [3]. In order to save the battery power consumption at mobile terminals, IP paging is proposed as an extension for Mobile IP [4]-[10].

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Under Mobile IP paging, an MN is allowed to enter a power saving idle mode when it is inactive for a period of time. During the idle mode, the system knows the location of the MN with coarse accuracy defined by a paging area which is composed of several subnets [4]. The MN may also deactivate some of its components for energy-saving purpose. An MN in idle mode does not need to register its location when moving within a paging area. It performs location update only when it changes paging areas. When packets are destined to an MN in idle mode, they are terminated at a paging initiator. The paging initiator buffers the packets and locates the MN by sending out paging requests within the paging area. After known the exact location of the MN, i.e., the subnet where the MN is residing, the paging initiator forwards the data packets to the serving FA of the subnet and further to the MN. When an MN is in active transmission mode, it operates in the same manner as in Mobile IP and the system keeps the exact updated location information of the MN. The state transition diagram of MNs with paging support is shown in Fig. 1.

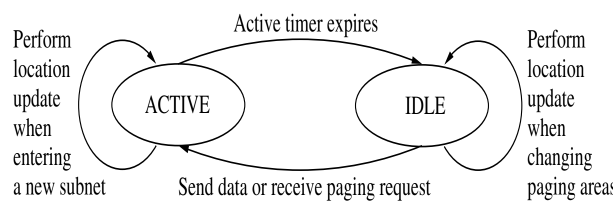


Fig. 1. State transition diagram of Mobile IP paging.

Next generation Internet is expected to support multimedia communications. For real-time data traffic such as Internet telephony, video conferencing, audio library, and news-on-demand, Quality of Service (QoS) provision must be guaranteed so that the real-time traffic may get predictable service [11]. There has been a lot of research on the provision of QoS guarantees in the environment of wireless and mobile Internet [12]-[15]. The Resource Reservation Protocol (RSVP) was developed by IETF to support the signaling of end-to-end IP QoS [16]. It allows a host on behalf of a real-time application to request a given QoS from the network. Mobile RSVP (MRSVP) was later proposed to resolve the impact of mobility on RSVP in mobile computing environments [17].

Under RSVP, signaling messages exchange along the path between the source and the destination to reserve the requested resource for the real-time traffic. After resource reservations are established in each router along the path, the application makes use of these reservations to send real-time traffic.

When there is a real-time communication request from a correspondent node (CN) to an MN in idle mode, a connection between the CN and the MN along which the requested resources are reserved should be set up for the real-time data traffic. RSVP signaling messages are first sent from the CN to the HA of the MN. When both Mobile IP paging and RSVP are supported in the network, the HA operates in two phases sequentially before the real-time communication. During the first phase, the HA pages the MN to find its exact location. Then, the HA sets up a RSVP path and reserves the requested resources along the path between the HA and the corresponding FA of the MN. Therefore, the signaling delay before the data communication is the sum of the paging delay and the connection setup time of the RSVP path.

In this paper, we introduce a new scheme for fast connection setup of real-time communication. Under the proposed scheme, the total signaling delay is reduced compared with the traditional scheme. We make the following assumptions in the rest of this paper:

- The receivers of the real-time traffic are mobile users roaming across the network.
- Both Mobile IP paging and RSVP are supported in the network.

The focus of this paper is the connection setup phase before the real-time communication. How to maintain the real-time communication during the handoff procedure when an MN moves from one subnet to another is beyond the scope of this paper.

This paper is organized as follows. In Section II, the related work on Mobile IP paging and RSVP is reviewed in detail. In Section III, the proposed paging-aided connection setup scheme is presented. The protocols for unicast and multicast communications are described. After that, in Section IV, the performance of the proposed scheme is evaluated, followed by the conclusions in Section V.

## II. Background

In this section, we introduce the related work on Mobile IP paging. We also explain the details of RSVP.

### A. Mobile IP Paging

Currently, there are three major paging protocols proposed for Mobile IP. In *home agent paging* [5], the HA acts as the paging initiator and buffers the data packets to MNs before paging. When an MN registers with its HA, it also sends a multicast address of all the FAs in its current paging area to the HA. This multicast address is used for HA to send paging requests. After receiving paging requests, all the FAs in a paging area broadcast paging messages to MNs in their subnets through wireless links. The paged MN sends a paging reply to the paging initiator through its serving FA. The HA updates the current location of the MN and forwards all the buffered packets to the MN. In *foreign agent paging* [6] [7], the paging initiator is the registered FA, which is the FA that an MN registers with when entering a new paging area. Note that the registered FA of an MN is not necessarily to be the current serving FA of the subnet the MN is residing. The registered FA buffers data packets destined to an MN in idle mode and sends paging requests to all other FAs in the paging area. *Domain paging* is a distributed paging architecture, where the paging initiator is dynamically selected from the routers along the path from the domain root router to the last serving FA of the MN [5] [8]. The decision of the paging initiator depends on the paging load of each router.

### B. RSVP Signaling

RSVP signaling messages are carried directly within IP packets following the same paths between the source and the destination as the associated application data packets. The two primary messages are PATH (path establishment) and RESV (reservation). In order to determine and record the path through which the application data will traverse, the sender transmit periodic PATH messages to the receiver which contains: the IP address of the node sending the message; the QoS being requested; and a *flow* that defines which packets are to receive the specified QoS. The flow is specified as a set of protocol header fields that can be used by a node to distinguish the application data packets from all others. Routers along the path modify the PATH messages by swapping its own IP address with that in the sender field, and forwards the message to the next hop. In order to actually reserve resources along the path from the sender to the receiver, the receiver responds to PATH messages with RESV messages. Routers along the path correlate RESV messages with previously seen PATH messages, examining the QoS on a hop-by-hop basis to determine whether there are sufficient resources to fulfill the request. If so, a router reserves the necessary resources and sends the RESV message to the node from which it received a PATH message. Once resources have been reserved along the entire path, i.e., the connection between the source and the destination is set up, the sender begins to transmit real-time data packets.

Some additional features of RSVP are:

- An RSVP reservation is unidirectional. Bidirectional real-time flows require two reservations.
- Reservations are initiated by the receiver. This allows RSVP to accommodate multicast groups with large and changing group membership.
- RSVP does not perform its own routing. It uses information provided by underlying routing protocols to determine the paths along which to request the QoS.
- RSVP makes reservations at each router for a limited lifetime. Each data session's PATH and RESV messages must be retransmitted periodically to refresh the state information held by routers along the path. This *soft-state signaling* ensures that reserved resources along any

given path will be automatically released if routes change during the lifetime of a data session.
- RSVP may merge resource reservation requests from different branches of a multicast tree to a single reservation request. The outgoing reservation request must satisfy all the requirements of the incoming requests.

## III. Paging-Aided Connection Setup for Real-time Communication

In this section, we propose a new scheme for fast connection setup of real-time communication in mobile Internet. Since the signaling messages of location registration and paging are not avoidable for MNs roaming across Internet, it is desirable to utilize these messages to achieve connection setup concurrently. Thus, the total signaling delay before the data communication is reduced. We explain the detailed operations in the following.

### A. Unicast Case

First, we assume the communication is unicast in which one sender and one receiver are involved.

The proposed scheme employs home agent paging architecture [5]. When an MN in idle mode moves from one paging area to another, it performs idle mode location registration to its HA. During the location registration procedure, besides the home address and the newly obtained CoA of the MN, the FA of the subnet where the MN is currently visiting inserts a multicast address of all the FAs within the current paging area into the location registration message. This multicast address is used to identify the paging area. The extended location registration message is sent to the HA of the MN, as shown in Fig. 2.

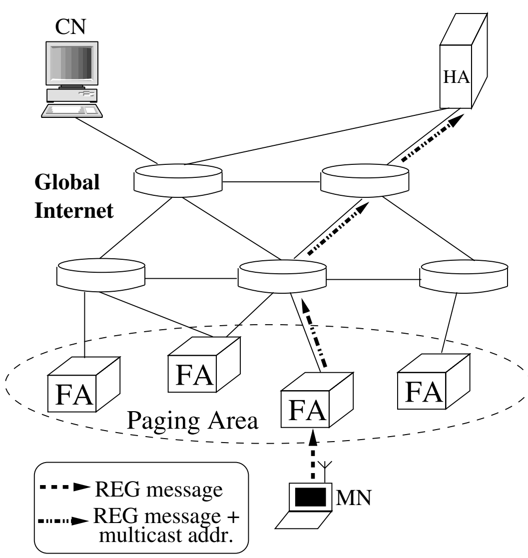


Fig. 2. Procedure of location registration.

If a CN wants to have a real-time communication with an MN in idle mode, the CN sends out RSVP PATH messages to set up a connection. These RSVP signaling messages are sent to the HA of the MN first. The HA needs to find the exact location of the MN. It checks its record of the MN and sends out combined messages of paging request and RSVP PATH to the identity of the paging area, i.e., the multicast address. In other words, the combined messages are sent to all the FAs within the paging area, as illustrated in Fig. 3. These messages have the information for paging: the multicast address of the paging area and the home address of the paged MN. They also contain the information to support RSVP PATH function. The combined paging and PATH messages follow the *shortest-path* IP route toward the destinations, installing path and QoS states in each router as they go.

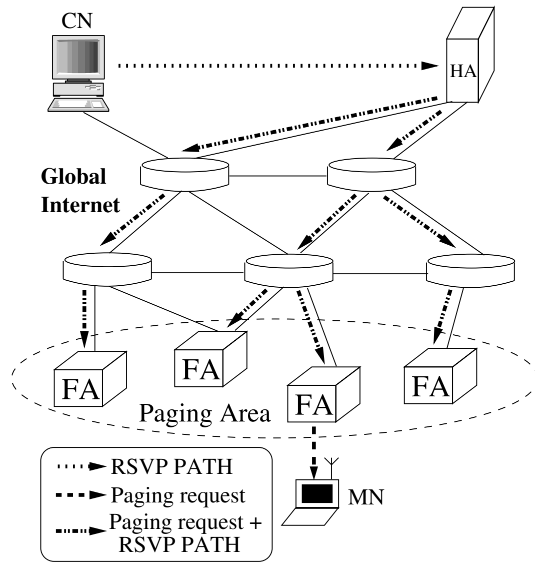


Fig. 3. Procedure of sending paging request and RSVP PATH messages.

After receiving the combined messages, the FAs extract the paging information from the signaling messages and page the MN in their subnets over the air. The paged MN sends paging reply message to its serving FA after receiving the paging request. The corresponding FA of the MN sends the combined message of paging reply and RSVP RESV to the HA. This message retraces the steps of the matching PATH messages, establishing resource reservation in each router along the path, as shown in Fig. 4. Note that other FAs do not reply to the paging requests. The soft states in the routers along the paths between the HA and other FAs will be expired after a certain period. Finally, if the combined message reaches the HA, resources are established along the entire path and the HA obtains the location information of the paged MN at the same time. The HA updates the record of the MN and sends the RSVP RESV message back to the CN to finish the real-time connection setup.

Note that by employing home agent paging architecture, the established connection from the HA to the serving FA of the MN follows the shortest IP routing path. If other paging architectures are employed, the shortest-path property cannot be guaranteed. For example, if foreign agent paging architecture [6] [7] is employed, i.e., the registered FA functions

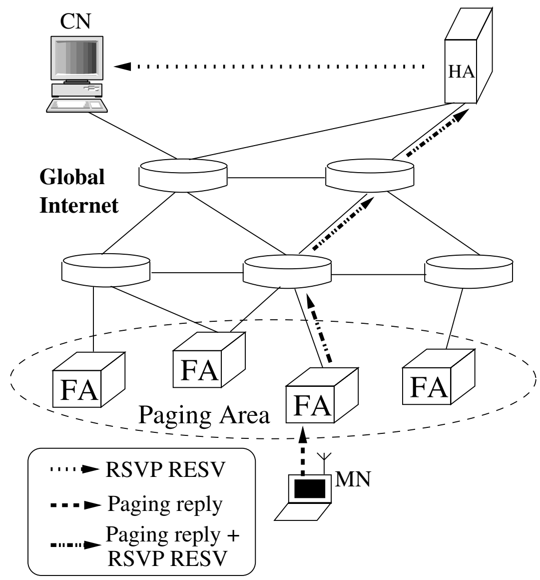


Fig. 4. Procedure of sending paging reply and RSVP RESV messages.

as the paging initiator to send out paging requests. Under the proposed scheme, the path along which the resources are reserved will be from the HA to the registered FA and further to the corresponding FA of the paged MN, which is not necessarily to be the shortest path.

### B. Multicast Case

RSVP may scale to very large multicast groups because it uses receiver-oriented reservation requests that merge as they travel up the multicast tree. The proposed scheme is also applicable to multicast communication by using paging request aggregation [7] and RSVP reservation request aggregation [16]. The flow chart of the operation on multicast communication is shown in Fig. 5. In the figure, we assume there are two real-time traffic receivers. If the receivers of the real-time traffic do not belong to the same home network, the operations are similar to the case of the unicast communication. Each connection between the CN and one of the receivers is setup separately. If the receivers belong to the same network but are not located in the same paging area, one aggregated RSVP PATH message is sent from the CN to the HA of all the receivers. The HA operates the same as for unicast communication to each receiver. If the receivers are located in the same paging area, the HA sends an aggregated message with paging request and RSVP PATH function to the multicast address of the FAs within the paging area. This aggregated message lists the home addresses of all the paged MNs. The message aggregation helps to reduce the signaling overhead as the number of receivers increases.

## IV. Performance Evaluation

In this section, we evaluate the proposed scheme in terms of connection setup time, signaling overhead, and processing overhead. We compare the proposed scheme with the traditional scheme: connection setup without the help of location registration and paging. Table I lists the performance analysis of the two schemes for unicast communication. We assume there are $N$ FAs within a paging area. When comparing the connection setup time of the two schemes, we compare the time to set up a real-time connection between the HA and the serving FA of the receiver. When comparing the number of signaling messages, we do not take the periodic updates of the PATH and RESV messages to refresh their soft states in each router into account.

From the table, we may see that the proposed paging-aided connection setup scheme has advantages over the traditional scheme in terms of fast connection setup and less signaling messages. But it requires more processing resources in routers. Note that sending and processing RSVP messages usually require more time than paging messages, since each router along the communication path needs to modify the PATH messages, setup QoS states, and reserve the requested resources. The time of sending and processing combined paging and RSVP messages is approximately equal to that of sending and processing pure RSVP messages. Therefore, under the proposed scheme, the time for paging can be saved. The total signaling delay for connection setup is approximately equal to the time for RSVP path setup under the traditional scheme. The total number of signaling messages are also reduced under the proposed scheme. But note that there is additional overhead of each combined signaling message due to the increase of packet size. Under the proposed scheme, more path and QoS states are installed in the routers as the RSVP PATH messages travel. But these states are soft states and will be expired later. In addition, no resources are actually reserved if no further RESV messages are sent by the receiver. These temporarily soft states also do not influence the resource reservation by other data sessions.

## V. Conclusion

In this paper, we introduced a new paging-aided connection setup scheme for real-time communication in Mobile Internet. The proposed scheme employs home agent paging architecture in order to keep the property of shortest IP routing path. Instead of performing paging and RSVP path setup sequentially, we proposed to perform the two procedures concurrently. We explained the operation details for both unicast and multicast communications under the proposed scheme. Performance analysis demonstrated that the new paging-aided connection setup scheme outperforms the traditional scheme in terms of reducing the overall connection setup time and the total number of signaling messages.

## References


[1] C. E. Perkins, "IP mobility support for IPv4," Request for Comments (RFC) 3220, January 2002.

[2] C. E. Perkins, "Mobile IP," *IEEE Communication Magazine*, pp. 84-99, May 1997.

[3] T. Simunic, L. Benini, P. Glynn, and G. De Micheli, "Dynamic power management for portable systems," *Proc. ACM Mobicom'2000*, pp. 11-19, 2000.

[4] H. Haverinen and J. Malinen, "Mobile IP regional paging (work in progress)," Internet Draft, Internet Engineering Task Force, draft-haverinen-mobileip-reg-paging-00.txt, June 2000.

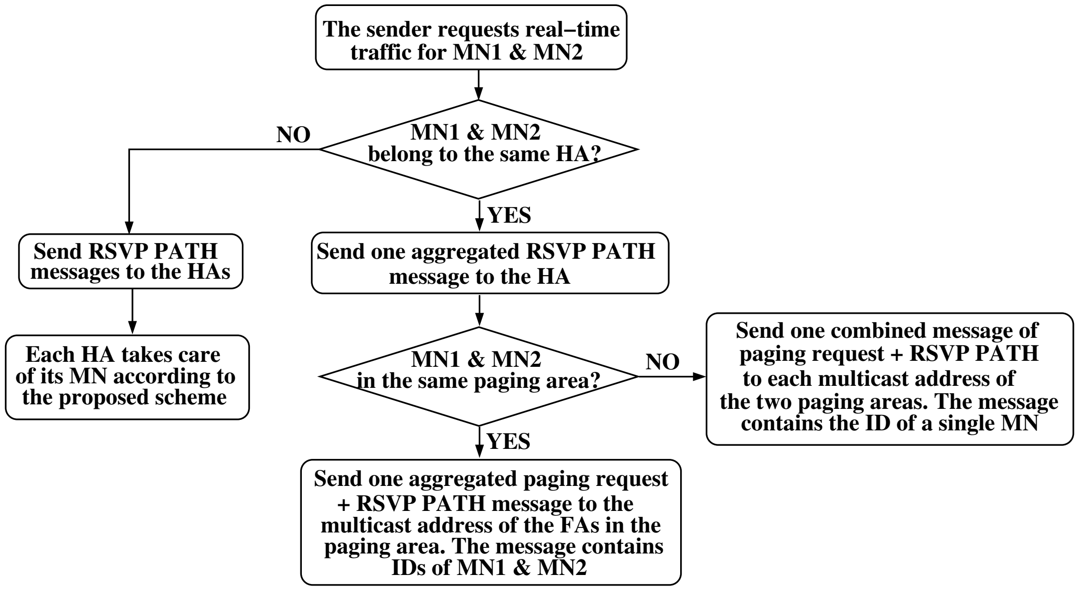


Fig. 5. Flow chart for multicast case.

TABLE I
PERFORMANCE ANALYSIS

| | Connection setup without the help of paging | Paging-aided connection setup |
|---|---|---|
| Connection Setup Time (from HA to the serving FA) | Time for sending and processing (paging request + paging reply + PATH message + RESV message) | Time for sending and processing (combined message of paging request & PATH + combined message of paging reply & RESV) |
| Number of Signaling Messages | $N$ paging requests (flooding) + 1 paging reply (unicast) + 1 PATH message (unicast) + 1 RESV message (unicast) | $N$ combined messages of paging request & PATH (flooding) + 1 combined message of paging reply & RESV (unicast) |
| Processing Overhead | 1 path is setup "softly" + 1 path is setup "hardly" | $N$ paths are setup "softly" + 1 path is setup "hardly" |


[5] R. Ramjee, L. Li, T. La Porta, and S. Kasera, "IP paging service for mobile hosts," *ACM Wireless Networks (WINET)*, vol. 8, no. 5, pp. 427-441, September 2002.

[6] X. Zhang, J. G. Castellanos, A. T. Campbell, K. Sawada, and M. Barry, "P-MIP minimal paging extensions for Mobile IP (work in progress)," Internet Draft, Internet Engineering Task Force, draft-zhang-pmip-00.txt, July 2000.

[7] X. Zhang, J. G. Castellanos, and A. T. Campbell, "P-MIP: paging extensions for Mobile IP," *ACM Mobile Networks and Applications (MONET)*, vol. 7, no. 2, pp. 127-141, April 2002.

[8] R. Ramjee, T. La Porta, and L. Li, "Paging support for IP mobility (work in progress)," Internet Draft, Internet Engineering Task Force, draft-ietf-mobileip-paging-hawaii-01.txt, January 2001.

[9] A. Misra *et al.*, "IDMP: An intra-domain mobility management protocol using mobility agents (work in progress)," Internet Draft, Internet Engineering Task Force, draft-mobileip-misra-idmp-00.txt, July 2000.

[10] B. Sarikaya *et al.*, "Mobile IPv6 hierarchical paging (work in progress)," Internet Draft, Internet Engineering Task Force, draft-sarikaya-seamoby-mipv6hp-00.txt, September 2001.

[11] S-U Yoon, J-H Lee, K-S Lee, and C-H Kang, "QoS support in mobile/wireless IP networks using differentiated services and fast handoff method," *Proc. IEEE Wireless Communications and Networking Conference (WCNC 2000)*, vol. 1, pp. 266-270, 2000.

[12] A. Terzis, M. Srivastava, and L. Zhang, "A simple QoS signaling protocol for mobile hosts in the integrated services Internet," *Proc. IEEE INFOCOM'99*, vol. 3, pp. 1011-1018, 1999.

[13] G. Le Grand, J. Ben-Othman, and E. Horlait, "Providing quality of service in mobile environments with MIR (Mobile IP Reservation Protocol)," *Proc. IEEE International Conference on Networks (ICON 2000)*, pp. 24-29, 2000.

[14] C-C Tseng, G-C Lee, and R-S Liu, "HMRSVP: A hierarchical mobile RSVP protocol," *Proc. 2001 International Conference on Distributed Computing Systems Workshop*, pp. 467-472, 2001.

[15] K-I Kim and S-H Kim, "Domain based approach for QoS provisioning in Mobile IP," *Proc. IEEE GLOBECOM'2001*, vol. 4, pp. 2230-2234, 2001.

[16] R. Braden, L. Zhang, S. Berson, S. Herzog, and S. Jamin, "Resource ReSerVation Protocol (RSVP), Version 1 Functional Specification," Request for Comments (RFC) 2205, September 1997.

[17] A. K. Talukdar, B. R. Badrinath, and A. Acharya, "Integrated services packet networks with mobile hosts: architecture and performance," *ACM Wireless Networks (WINET)*, vol. 5, no. 2, pp. 111-124, March 1999.