Scalable Mobility and QoS Support Mechanism for IPv6-based Real-time Wireless Internet Traffic

Seisho Yasukawa, Jun Nishikido and Komura Hisashi
NTT Network Service Systems Laboratories
3-9-11 Midori-cho, Musashino-shi, Tokyo 180-8585, Japan

Abstract- **Advances in wireless broadband communications have continued steadily over the last few years. Both cellular operators and ISPs, together with the relevant standardization bodies (e.g., 3GPP, IETF), are eagerly looking at the possibility of employing IP and its mobility and security extensions within their wireless networks. Mobile IPv6 is the most promising technology for developing such an all-IP mobile architecture.**

There are still several performance defects in this protocol for supporting QoS of real-time wireless traffic, however, because only simple route optimization methods and handoff mechanisms have been proposed. Therefore, innovative route optimization and handoff mechanisms that can handle the quality of service (QoS) of real-time wireless traffic must be developed.

A scalable mobility and QoS support mechanism is proposed in this paper. This method optimizes the routing path between a corresponding node and a mobile node by checking the Home Address' binding cache entry prior to data transmission using RSVP signaling messages. Thus, prior bandwidth reservations at intermediate nodes along the optimal routing path can be achieved. This method also creates a scalable and flexible routing path that can adapt its routing topology dynamically to account for both changing membership and changing routes. This routing path is constructed by using RSVP's resource reservation capability. Therefore, a fast and smooth handoff for the mobile node can be achieved, while guaranteeing the QoS of real-time traffic.

Our proposed schemes are scalable and can be applied to future large-scale mobile IP networks.

I. INTRODUCTION

Real-time applications running on mobile nodes (MNs) impose certain additional quality of service (QoS) requirements originating from network mobility. To guarantee QoS for real-time wireless applications, it is very important to control both macro- and micro-mobility simultaneously in a mobile IP network.

Two major conditions must be met to guarantee the QoS. The first condition is that a route-optimized path must be set and made as stable (fixed) as possible during a session flow. This means that a major part of the routing path must be pinned to a fixed route during the session ON period. The second condition is that changes in routing paths should be as few as possible and restricted to within the area near the MN. This means that a major part of the routing path must not be changed during the MN's handoff process. To meet this condition, an anchor point must be set near the MN. Then, only the path between the anchor point and MN is permitted to change its routing path according to the movement of the MN.

In a conventional Mobile IPv6 process, the corresponding node (CN) doesn't know the MN's current care-of address (CoA) when starting a flow. Therefore, data packets are transmitted to the Home Address (HA) and triangle routing is performed for the beginning of the flow. Only after receiving a Binding Update (BU) message from the MN can the CN directly transmit data packets to the MN along the optimal routing path. In this scenario, the routing path dramatically changes from a triangular route to the optimal route during the flow session. This results in severe QoS degradation. Moreover, the degradation becomes more worse when handoff processes take place more frequently. In the conventional Mobile IPv6 protocol, a change in the MN's CoA must be sent directly to the CN by using BU messages. This means that the CN cannot optimize routing paths so quickly, because the signaling delay becomes very large when the MN is far away from the CN. Resetting the QoS path is much more difficult because all the nodes along the path must be set again using QoS signaling (e.g., RSVP).

In this paper, we propose a scalable mobility and QoS support mechanism for IPv6-based real-time wireless Internet traffic. This method optimizes the routing path between a corresponding node and a mobile node by checking the HA's binding cache entry prior to data transmission using RSVP signaling messages. Thus, prior bandwidth reservations at intermediate nodes along the optimal routing path can be achieved. This method also creates a scalable and flexible routing path that can adapt its routing topology dynamically to account for both changing membership and changing routes. We also introduce a Transit Agent (TA), which operates as an anchor point when an MN moves its subnet and a handoff takes place. By using this TA and RSVP signaling, a fast and smooth handoff guaranteeing QoS constraints can be achieved. Our proposed schemes are scalable and can be applied to future large-scale mobile IP networks.

The rest of this paper is organized as follows. Section II describes the detail architecture of our proposal, including the architectures of the route optimization and fast handoff methods. The architecture of a hierarchical TA arrangement is also proposed. Finally, section III summarizes our proposal.

II. Scalable MOBILITY AND QOS SUPPORT MECHANISM FOR IPV6-BASED REAL-TIME WIRELESS INTERNET TRAFFIC

A. Route optimization method

1) *Architecture overview*: To achieve route optimization prior to data transmission, we integrate RSVP with Mobile IPv6. Fig. 1 shows an overview of the proposed architecture. As a conventional Mobile IPv6 process, an MN located in another network (away from the home network) sends its current CoA to the HA by using a BU message (P1). The CN that wants to establish a QoS-capable session transmits a Path message to the Home Address (HAddr, P2). When the HA receives the Path message and notices that the MN is now away from its home subnet by checking its binding cache entry, the HA replies to the CN with a PathErr message (P3). The PathErr message includes an Alternate Care-of Address sub-option in the Binding Update option and a Home Address option in the destination option header of the IPv6 header. Upon receiving this PathErr message, the CN detects the MN's current CoA and redirects the Path message directly to the MN (P4). The MN then

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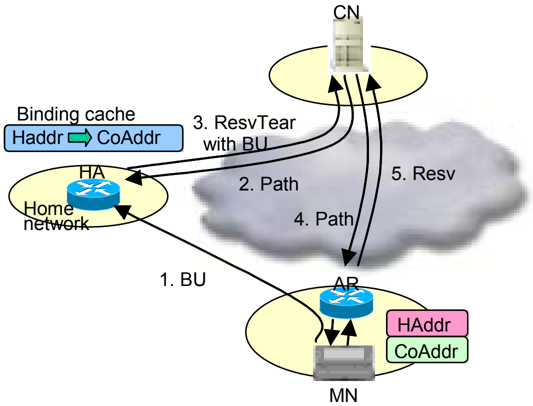

Fig. 1. Route optimization method using RSVP signaling

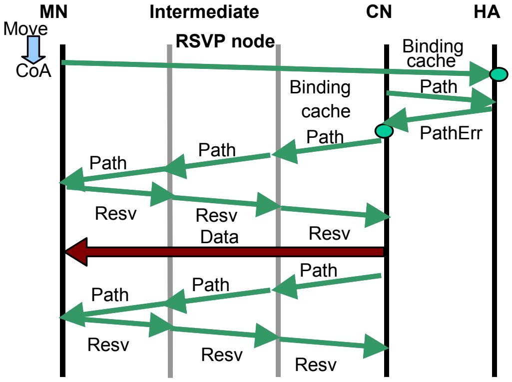

Fig.2. Message sequence of proposed route optimization method

replies to this Path message with a Resv message (P5). In this way, an RSVP session with the optimal routing path is established.

Fig. 2 shows the message sequence of the proposed architecture. We should note that the proposed scheme exploits the extension header facilities provided by IPv6, and hence no extra fields are introduced into the basic RSVP messages.

2) *Corresponding Node (CN) operation*: The CN must have the capability to handle a PathErr message with Binding Update and Home Address options. When the CN receives this type of message, it must redirect the Path message directly to the MN's CoA.

3) *Home Agent operation*: The HA must have the capability to handle a Path message addressed to an MN located in a foreign network. The HA must reply to the CN with a PathErr message including an Alternate Care-of Address sub-option.

4) Mobile *Node operation*: The support for this proposal is completely transparent to the conventional RSVP and Mobile IPv6 protocol.

B. *Fast and smooth handoff method*

1) Architecture *overview*: As mentioned earlier, we introduce an anchor point to achieve fast, smooth handoff. Fig. 3 shows an overview of the proposed architecture. We introduce a new agent called the Transit Agent (TA). The TA acts as an anchor point when an MN moves and a handoff take place.

First, we explain the registration process to make the TA act as an anchor point. The CN transmits a path message to the MN's CoA (P1,P2,P3). In this architecture, the TA is dynamically selected according to the routing path between CN and MN. In other words, a router located at the edge of the TA domain and on the optimal routing path acts as a TA for the MN. Upon receiving a Path message, the TA sets its address in this message and relays it to the MN. This message informs the MN of the address of the TA now serving as the anchor point for the RSVP session. AFter receiving the Path message, the MN checks the TA's address. It then replies to the TA with a Resv message, including Binding Update and Home Address options to relate the MN's HAddr and current CoA (P4,P5). When the Resv message reaches the TA, the TA checks its Destination option header and create a binding cache entry for the MN (HAddr->CoAddr(AR1), P6). The TA also replaces the CoAddr in the Binding update option (CoAddr(AR1)-> CoAddr(TA)), then relays the Resv message to the upstream router along the distribution tree in the reverse direction (P7). In this scenario, the CoA included in this BU message acts as a regional

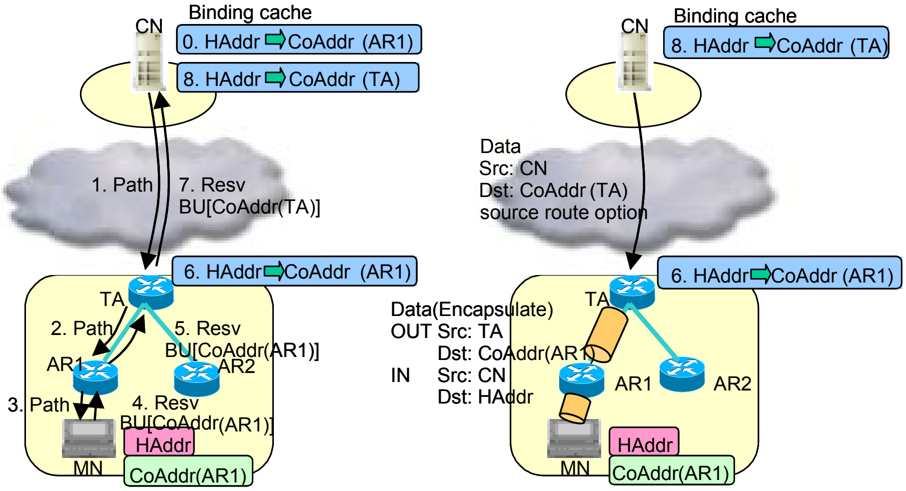

Fig. 3. Registration process for Transit Agent and packet transmission mechanism

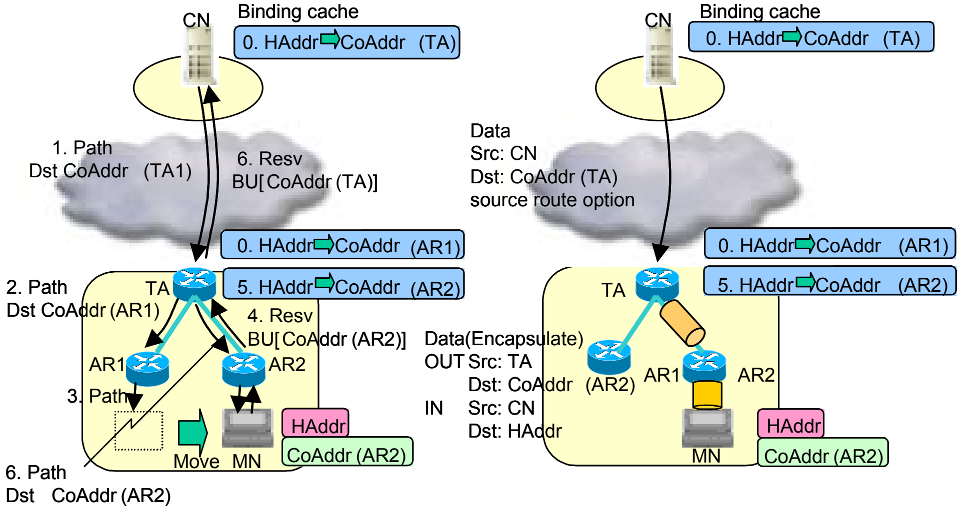

Fig. 4. Fast handoff mechanism using Transit Agent

CoA for the MN. Finally, the BU message is relayed to the CN. After receiving the message and checking its destination option header, the CN renews a binding cache entry for the MN (HAddr->(CoAddr(AR1)->CoAddr(TA)).

In this way, an RSVP session between the CN and the MN is established. After establishing the RSVP session, data packets addressed to the MN are transmitted first to the TA, which then encapsulates the packets and transmits them to the MN using tunnel transmission. Finally, the MN decapsulates the packets. In this scenario, the TA acts as a regional HA and is responsible for routing packets locally within the TA domain.

2) *Fast handoff*: Fig. 4 illustrates the handoff mechanism of this architecture. Consider the situation in which an MN is first located in AR1's subnet. In this case, an RSVP session is established along the path CN->TA->AR1->MN (P1,P2,P3). Then consider the situation in which the MN moves to AR2's subnet and a handoff takes place. Creating a new CoA by address auto-configuration, the MN sends a Resv message to the TA, containing a BU option with a new CoA (CoAddr(AR2), P4). The TA receives this Resv message and creates a new binding cache entry for the MN (HAddr->CoAddr(AR2), P5). The TA then merges the Resv message into the previous session message (P6). In this way, the RSVP session is modified to operate along the path CN->TA->AR2->MN. An RSVP session can adapt dynamically to changing membership, as well as to changing routes, because the receiver rather than the sender can make resource reservations. Due to these characteristics, only a minor path modification between the TA and AR is necessary to transmit packets to the MN during the handoff process. Thus, a fast handoff process is attained. Fig. 5 shows the message sequence of the proposed handoff architecture.

3) *Smooth handoff*: It is easy to construct a duplicate RSVP reservation path between the TA and the ARs (Fig. 4, TA-AR1, TA->AR2). By using RSVP multicast capability, we can construct a multicast routing tree during the handoff process. Therefore, we can transmit data to the MN in a lossless manner. The TA can initiate its path to AR1 by using a PathTear message after the MN moves AR2's subnet completely. In this way, we can construct a dynamic multicast routing-tree that changes its routing topology dynamically according to an MN's movement. By using this technique, smooth

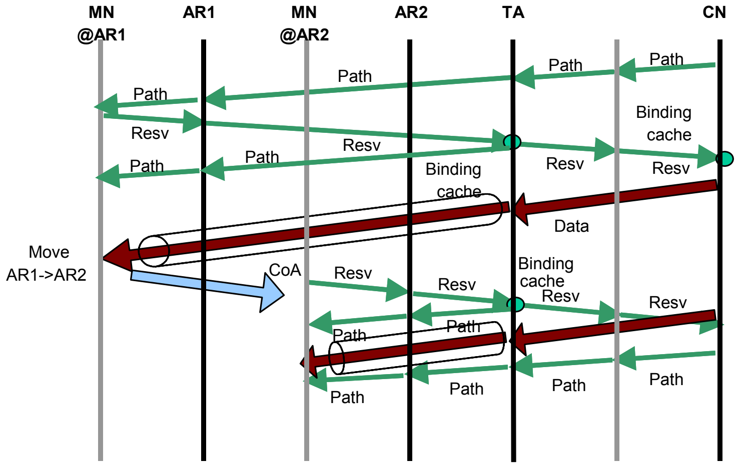

Fig. 5. TA registration message and Handoff message sequence

handoff is achieved.

4) *Transit Agent operation*: As mentioned above, the TA acts as a regional HA. It intercepts all the packets addressed to the mobile node and tunnels them to the corresponding CoA.

C. *Hierarchical handoff method*

In implementing a carrier-scale network, scalability performance is also important. We can expand the size of the proposed network by combining TAs in a hierarchical manner without degrading handoff performance. Fig. 6 shows an example of a proposed network using the hierarchical TA method.

As mention earlier, a TA is selected within an optimal routing path. In this case, several TAs are selected to construct multiple anchor points. For example, TA2(n) and TA21(n-1) are selected and operate as anchor points for the MN. Each selected TA works as an HA for the MN. Registration to a TA is processed in a hierarchical manner, as mentioned earlier, by using Resv messages with BU options. In this example, the MN first registers its CoA to TA21(n-1), then TA21(n-1) registers its CoA to TA2(n), and finally TA2(n) registers its CoA to the CN. Therefore, TA21(n-1) has a binding cache entry of CoAddr(AR2), TA2(n) has CoAddr(TA21(n-1)), and CN has CoAddr(TA2(n)). By combining these CoA's in a hierarchical manner, one can construct a care-of address tree to the MN (HAddr->CoAddr(TA2(n))->CoAddr(TA21(n-1))->CoAddr(AR2)). Data packets addressed to the MN are transmitted by relaying via these TAs' care-of address tree. In this scenario, all the TAs act as HAs for the MN.

Note that the MN can select any TA according to the direction of the CN. The TA is selected only according to the routing path topology. This means that an MN's TA can be changed flexibly based on the CN's location (e.g., TA1 or TA2 or TA3). Due to this characteristic, we can construct a hierarchical TA network according to real traffic patterns, and a scalable and highly reliable mobile IP network can be implemented.

III. CONCLUSION

In this paper, we have proposed a scalable mobility and QoS support mechanism for IPv6-based real-time wireless Internet traffic that can be applied to large-scale mobile IP networks. In our proposal, we introduce a simple RSVP signaling extension to achieve prior route optimization. We also introduce a Transit Agent, which act as an anchor point for the handoff. Based on this architecture, a route optimized path for an RSVP session can be established initially, and fast handoff can be achieved even if an MN frequently moves its subnets.

We have concluded that the proposed architecture is scalable enough to be applied to a large-scale mobile IP network, and that it can be a key technology for future mobile IP networks.

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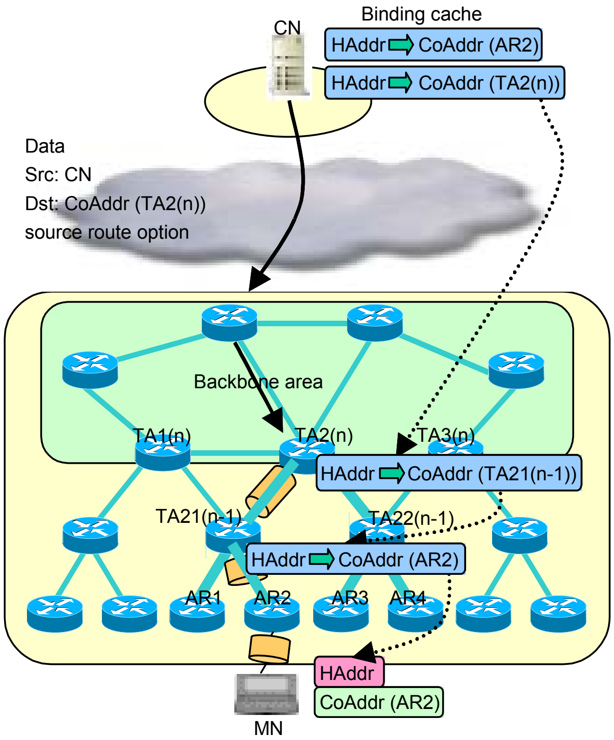

Fig. 6. Hierarchical TA network architecture and hierarchical handoff Mechanism