A Dynamic Resource Reservation Scheme Designed for Improving Multicast Protocols in HMIPv6-Based Networks

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Abstract— **This paper aims at proposing a dynamic resource reservation scheme to enhance wireless multicasting protocols run in the hierarchical mobile IP version 6 (HMIPv6) based networks. The novelty of this scheme relies on techniques of dynamic resource reservation, priority, pre-registration, and path prediction, which are used to improve wireless multicasting and guarantee service continuity. Through numerical examples, we demonstrate that the proposed scheme performs well in terms of robustness, adaptiveness, and quality of service (QoS) guarantee.**

I. Introduction

We have witnessed that many research efforts in the last decade have been devoted to extending existing Internet applications from wired to wireless networks, e.g., mobile IPv4 (MIPv4) [12], [13]. Since several major drawbacks have been reported for MIPv4, mobile IPv6 (MIPv6) [8] based on IP version 6 (IPv6) [6] is then developed to further circumvent shortcomings of MIPv4 so that mobile users can stay connected to the Internet as they move by using an extensible packet header, including home and care of addresses (CoAs) etc. Under MIPv6, an mobile host (MH) (after moving into a visited network) informs its correspondent node (CN) of the CoA so that the MH and CN can exchange packets directly without having to communicate via the home network. To further enhance the capability of MIPv6, HMIPv6 shown in Fig. 1 is proposed to reduce unnecessary signaling and accelerate the handoff process by separating micro-mobility (handoff between access routers (ARs) of the same mobility anchor point (MAP)) from macro-mobility (handoff between ARs which belong to two different MAPs) through employing two CoAs, i.e., regional CoA (RCoA) for macro-mobility and on-link CoA (LCoA) for micro-mobility [2], [15].

Due to diverse services in contemporary networks, multimedia services, such as voice, video, and data, gradually become important. Thus, how to efficiently handle multimedia services has been a critical issue. To fulfill this goal, multicast techniques are frequently utilized. Currently, two main approaches have been specified in the field of Mobile IP [12] by the Internet engineering task force (IETF) to support the multicast service, i.e., *bi-directional tunnelling*, e.g., mobile multicast (MoM) [5] which is a well-known multicast protocol for MIPv4 networks and *remote subscription* which is the default multicast technique for MIPv6 [14]. To further improve wireless multicasting in HMIPv6-based networks, we focus on the corresponding resource reservation by extending the resource reservation protocol (RSVP) [1]. We propose a new dynamic resource reservation scheme to improve system performance, e.g., connectivity. This scheme incorporates pre-reservation employed by [10] to provide seamless handoff and path prediction which makes pre-reservation efficient into consideration. Although how to extend RSVP for unicast communication to HMIPv6 has been previously discussed in [7], our proposed scheme focuses on multicast services. Moreover, source mobility is taken into account in this paper by setting the highest priority to the source node in bandwidth reservation due to the fact that handoff failure of the source node would be more detrimental than handoff failure of other members. Hence, a prioritized resource allocation mechanism is applied to four kinds of service requests, i.e., request by the source/receiving node when the intra-/inter-MAP handoff occurs.

The rest of this paper is organized as follows. Section II gives a brief overview of RSVP and relevant protocols in Mobile IP. Section III presents the proposed scheme composed of path prediction, dynamic resource reservation tailored for HMIPv6 environments, and prioritized resource allocation for the source node. Section IV demonstrates merits of the proposed scheme using the simulation approach. Finally, Section V concludes the paper.

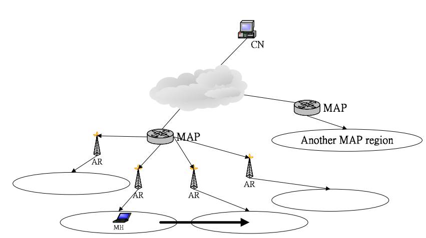

Fig. 1. The system architecture of HMIPv6.

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II. A Brief Overview of RSVP and Relevant Protocols in Mobile IP

How to guarantee QoS requirements for real-time services should be well taken care for multimedia dissemination, in particular, those utilizing the multicast technique. As one knows, RSVP [1] is one of commonly used techniques to achieve different QoS requirements in the literature. It is designed for reserving bandwidth along the packet delivery path by exchanging PATH and RESV messages between senders and receivers. Once the requested resources are available on all links, soft-state reservation [1] is then established along the path. To maintain the reservation, periodical exchanges of PATH and RESV messages are required.

However, RSVP is initially designed for wired networks but not for wireless networks. Some problems may be raised when directly applying RSVP to provide QoS for MHs in MIPv4. Note that a problem is raised during handoff. When a CN wants to send packets to an MH, these packets must be sent to the home agent (HA) first; however, the MH responds directly to the CN. Thus, inappropriate paths may be reserved by RSVP due to the triangle routing [8]. In addition, a new RSVP reservation may not be immediately available during the handoff, causing an interruption for real-time services. To overcome this problem, pre-reservation [10] is proposed with extra wasted resources. To further improve the bandwidth efficiency, MRSVP [16] introduces two types of reservations: active reservation and passive reservation. That is, it allows other mobile users to consume pre-reserved bandwidth, but the bandwidth must become available once the MH with a higher priority requests it. In [7], how to enhance RSVP to HMIPv6 for unicast services has been studied. A QoS agent is introduced to handle the RSVP QoS update messages during the intra-MAP handoff and adjacent QoS agents are invited to make pre-reservations by using the IP multicast [3] during the inter-MAP handoff. In the following section, we specifically design dynamic resource reservation for wireless multicast rather than unicast in HMIPv6-based networks.

III. Description of the Proposed Scheme

Let us describe in detail the dynamic resource reservation scheme designed for providing QoS guarantee and improving system performance of multicasting in HMIPv6-based networks. The scheme is mainly composed of three techniques, i.e., path prediction, dynamic resource reservation, and prioritized resource allocation. Now, they are depicted as follows.

A. Path Prediction

Path prediction can be employed in mobile communication environments to improve system performance, for examples, [9], [11]. In this paper, path prediction is also utilized to avoid unnecessary pre-reservations for a mobile host so as to make bandwidth usage efficient. To simply illustrate how path prediction works, we use relative distances between the mobile host and its neighboring ARs as the metric in the prediction. Of course, one can choose signal strength/power for the same purpose. Using relative distances, path prediction is described as follows. When a mobile host continues moving, the relative distances to the surrounding ARs change as well. If the distance between the mobile host and a specific AR is less than a pre-defined threshold, we may consider that the mobile host is intending to move toward the cell covered by that AR. Thus, resources of this cell can be *passively* reserved accordingly. Of course, it is not necessary to reserve resources in cells with distances larger than the threshold, avoiding unnecessary bandwidth wastage. The path prediction can be performed in a periodical manner. That is to say, a fixed time period, say T_{pp}, can be set in advance and the path prediction is triggered at every time instant of multiples of T_{pp}.

B. Dynamic Resource Reservation (DRR)

Like resource reservation, e.g., RSVP or MRSVP commonly used to provide QoS guarantee for real-time services and to prevent performance degradation during handoff, a dynamic resource reservation scheme in this paper is tailored for HMIPv6 multicast. In the proposed scheme, mobile hosts register to the multicast group through the MAP. When the source wants to send packets to its group members, packets are first delivered to the MAP and then multicasted by the MAP to all group members within its service area. Furthermore, when a mobile host moves but stays within the same MAP, it only needs to update its information (LCoA) to the MAP without re-registration, thus effectively reducing the network overhead. In the following, the proposed dynamic resource reservation is further detailed for the intra-MAP handoff and the inter-MAP handoff in HMIPv6 multicast environments.

DRR when the intra-MAP handoff occurs: Only resource between the approaching AR(s) and the MAP is reserved to avoid service interruption so as to provide better QoS guarantee.

DRR when the inter-MAP handoff occurs: The resource reservation is made between two MAPs, between the approaching MAP and AR(s), and between the AR and the mobile host as well. *If there is no member belonging to the same multicast group under the approaching MAP, a multicast join process and resource reservation between the source and the MAP have to be performed. On the contrary, no multicast join process is required and the mobile host needs only to register to the approaching MAP its LCoA*. Note that the above procedure is not taken for the unicast service. This is a main difference between multicast and unicast.

The proposed scheme thus takes advantage of the hierarchical structure in HMIPv6 by letting the MAP register to the multicast source node its RCoA on behalf of mobile hosts within its coverage similar to [2] and [7]. This would help reduce system overhead because most handoffs are actually local and can be handled locally within an MAP.

C. Prioritized Resource Allocation when Considering Source Mobility

In the literature, a fixed source node of a multicast group is frequently assumed for simplicity. Thus, few papers discussed it before except [4]. In this paper, source mobility is touched.

To guarantee service continuity and QoS, a prioritized resource allocation mechanism is used when dealing with different kinds of service requests. Before presenting the prioritized resource allocation, three system states are classified first when both source handoff and member handoff occur simultaneously. Afterwards, the necessary procedures required for different states are described.

- Intra-MAP handoff vs. intra-MAP handoff: When both the source and a member hand off simultaneously within their own MAP, all nodes involved merely need to update necessary information (e.g., LCoA) to the corresponding MAPs. Thus, no extra signaling exchange is required. Hence, the source (member) handoff would be transparent to the member (source).
- Intra-MAP handoff vs. inter-MAP handoff: Only one of the source and the member is moving between two different MAPs. The one performing the intra-MAP handoff only updates necessary information (LCoA) to its MAP, while the other one which performs the inter-MAP handoff has to build a *temporary tunnel* between two MAPs so that the end-to-end communication can still be maintained through the tunnel. After the new end-to-end path is established and the multicast information is registered between the associated two MAPs, the communication is switched from the tunnel to the newly established path. After that, the tunnel is released subsequently. Note that we employ a mixture of *tunnelling* and *remote subscription* to guarantee service continuity and QoS but avoid longer delay coming from *tunnelling*.
- Inter-MAP handoff vs. inter-MAP handoff: When both the source and the member perform the inter-MAP handoff. The system first checks whether there are members in the approaching MAP. If so, just update information (LCoA) to the MAP; otherwise, the old MAP still has to communicate with the mobile host through the temporary MAP-to-MAP tunnel. Of course, the newly established end-to-end path will take over the MAP-to-MAP tunnel once it is established.

The above proposed procedures are able to effectively avoid overhead of unnecessary information across the Internet. Together with pre-reservation and MAP-to-MAP tunnelling, our scheme can reduce the delay incurred when performing multicast registration and information update during the inter-MAP handoff but maintain the continuity of services.

Let us get back to the prioritized resource allocation. In general, source handoff is more important than member handoff because the overall QoS would degrade more caused by the failure of the source handoff than a member handoff failure. Thus, the source handoff is given a higher priority in resource allocation to ensure that the source can perform the smooth handoff. Besides, we also let inter-MAP handoffs have higher priorities than intra-MAP handoffs under the consideration of less recovery time.

The collaboration of the above mentioned techniques then forms the dynamic resource reservation scheme of this paper, which is shown in Fig. 2.

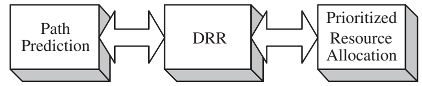


Fig. 2. The functional view of the proposed scheme.

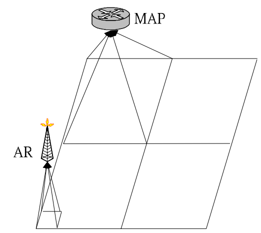


Fig. 3. System topology employed in the simulation.

IV. Simulation Results and Discussions

By observing *connectivity* which is defined as the ratio of the current number of connected members and the initial number of connected members for a same multicast group, *AR load*, *routing efficiency* which is defined as the ratio of the optimal length of multicast routing paths and the length of the resultant multicast routing paths, and *source blocking probability* etc. in the following experiments, we illustrate merits of our scheme over other schemes previously proposed in the literature. Let us first elaborate on experiment arrangements.

A. Models and Assumptions

An 8×8 wrapped around mesh cell structure is assumed in the following simulations. In each cell, there is an AR. For every 16 cells, there is an MAP governing these 16 ARs. Fig. 3 gives a simple and diagrammatical view for the system topology. As for the user moving model, it is based on the random-way-point model proposed by [18]. The initial position of a mobile host in a cell is randomly distributed. Its moving speed and moving direction are changed every fixed time period Δt. The new moving speed v_{new} is determined by

$$v_{new} = \begin{cases} \min\{\max[v_{old} + \Delta v, 0], V_{max}\}, & \text{if } p \leq p_s, \\ 0, & \text{otherwise,} \end{cases} \tag{1}$$

where v_{old} means the old speed, Δv is the step size of speed, V_{max} is a pre-specified maximum of speed, p represents a probability, and p_s is a pre-specified probability threshold. As for the moving direction, it is uniformly distributed. Thus, the moving direction is determined by

$$\phi_{new} = \phi_{old} + \Delta\phi, \tag{2}$$

where ϕ_{new} (ϕ_{old}) represents the new (old) direction and $\Delta\phi$ denotes the step size of direction. Table I gives the default parameters for the moving model. In our experiments, we assume reliable data transmission since this paper mainly focuses on the effect of users moving rather than errors coming from bad channel conditions. In the following, one multicast group is assumed for simplicity.

TABLE I
DEFAULT PARAMETER SETTING OF USER MOBILITY

parameter	value
V_{max}	40 km/hr
Δv	uniformly distributed on $[-5, 5]$ in km/hr
$\Delta \phi$	uniformly distributed on $[-\frac{\pi}{8}, \frac{\pi}{8}]$
p	uniformly distributed on $[0, 1]$
p_s	0.7

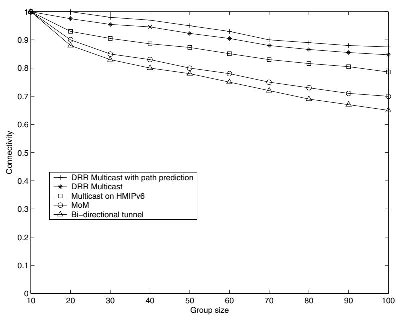


Fig. 4. The connectivity of a multicast group for different schemes.

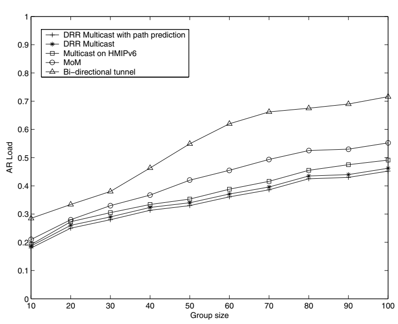


Fig. 5. AR Load of multicast data transmission for different schemes.

B. Numerical Results

In our numerical results, results of MIPv4-based schemes, i.e., MoM and bi-directional tunnelling, and HMIPv6-based schemes are included for the comparison purpose. For HMIPv6-based schemes, the following three schemes are considered: basic scheme based on the HMIPv6 hierarchy denoted by Scheme RHB which serves as a reference HMIPv6-based scheme, scheme with DRR (and priority setting) denoted by Scheme I, and scheme with DRR, path prediction (and priority setting) denoted by Scheme II. Now, we discuss the simulation results using the above-mentioned metrics as follows.

1) *Connectivity*: Let us first observe the *connectivity* of different schemes in Fig. 4. Compared to MoM, bi-directional tunnelling, and Scheme RHB, we note that about (21%, 31%, 9%) and (25%, 35%, 12%) improvements are gained respectively by Scheme I and Scheme II when the group size is fixed at 100. Obviously, our schemes (Schemes I and II) perform well than MoM, bi-directional tunnelling, and the basic HMIPv6-based scheme, in particular, Scheme II.

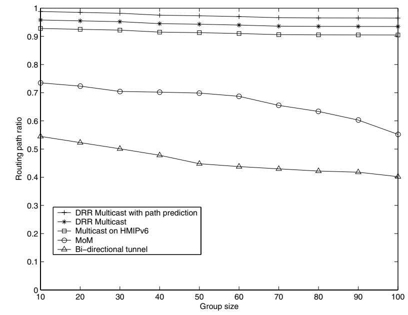


Fig. 6. Routing efficiencies for different schemes.

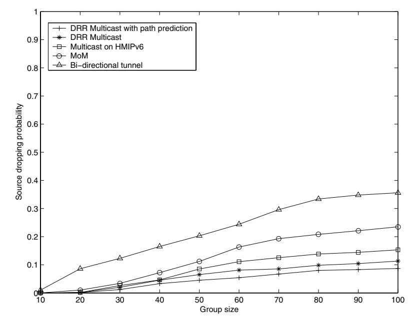


Fig. 7. Source dropping probabilities for different schemes.

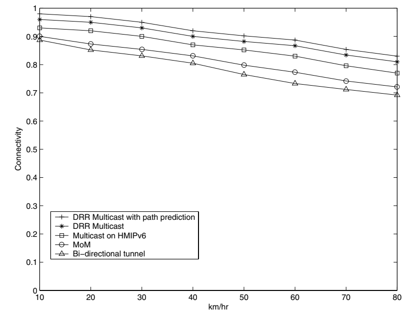
2) *AR load*: Shown in Fig. 5 is the *AR load* of different schemes. Except forwarding data to members, receiving data from the MAP, ARs in bi-directional tunnelling still send data to other ARs through tunnels. Hence, the *AR load* for bi-direction tunnelling is the largest. However, Scheme II poses the least load to ARs. Again Scheme II performs best. Scheme II can alleviate about 16%, 36%, and 7% of ARs' load when the group size is set to 100 as compared to MoM, bi-directional tunnelling, and Scheme RHB. Therefore, we emphasize the results of Scheme II in the following discussions.

3) *Routing efficiency*: We now show the routing efficiency of different schemes in Fig. 6. The *triangle routing* problem causes MoM and bi-directional tunnelling to posses worse routing efficiency. For MoM (bi-directional tunnelling), the routing efficiency is lower than 72% (54%). As the group size increases, the routing efficiencies for these two schemes decrease noticeably. As for routing efficiencies of Schemes RHB, I, and II, they fall within the range of $[0.9, 0.92]$, $[0.935, 0.95]$, and $[0.97, 0.985]$, respectively and decrease less as the group size increases since the intra handoff uses the reserved path between the AR to be visited and the MAP and the inter handoff temporarily uses a tunnel first and then switch to the better path once it is established. Note that the routing efficiency for Scheme II is very high (greater than 0.97). Compared to MoM, bi-directional tunnel, and Scheme RHB, about 74%, 140%, and 7% improvements are gained by

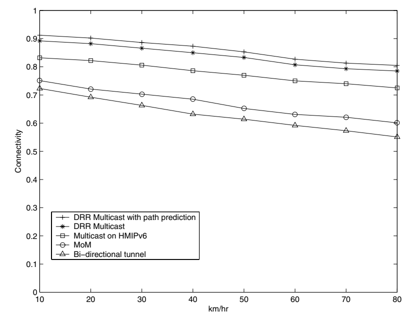
Scheme II when the group size is 100.

4) *Source dropping probability*: Since the source node of a multicast group is allowed to move in the simulation environment, we now demonstrate the technique of prioritized bandwidth allocation for the source node can reduce the source dropping probability in Fig. 7 which says that about 62%, 75%, and 46% improvements are got by Scheme II as compared to MoM, bi-directional tunnelling, and Scheme RHB when the group size is 100. Note that the source dropping probability is lower than 9% when the group size varies from 10 to 100 for Scheme II.

5) *Effect of moving speed*: At last, let us observe the effect of moving speed of users. The parameter set employed is $\{(V_{max}, \Delta v, \Delta\phi, p_s)\}$=$\{(10, 2, \pi/4, 0.5), (20, 3, \pi/4, 0.5), (30, 3, \pi/4, 0.6), (40, 5, \pi/8, 0.7), (50, 6, \pi/8, 0.7), (60, 7, \pi/8, 0.8), (70, 7, \pi/12, 0.8), (80, 8, \pi/12, 0.8)\}$. Shown in Fig. 8 is the connectivity vs. maximum speed for two different group sizes. Obviously, fast moving speed causes the connectivity to fall down. We note that Scheme II can maintain connectivity more than 80% even though the group size and the maximum speed reach to 100 and 80 km/hr, respectively. This demonstrates that Scheme II can perform robustly to guarantee QoS requirements.



(a) Group size of 50.



(b) Group size of 100.

Fig. 8. The effect of moving speed for two different group sizes.

V. Conclusions

Dynamic resource reservation along with path prediction and prioritized bandwidth allocation for the source node, which jointly form our dynamic resource reservation scheme, are proposed in this paper to improve wireless multicast protocols in the HMIPv6-based network. Our numerical results show that the best improvement gained by our proposed scheme, i.e., Scheme II, can achieve 40% (70%) more as compared to the basic HMIPv6-based scheme (bi-directional tunnelling, an MIPv4-based scheme). Besides, the proposed scheme can maintain better connectivity for various moving speeds. Thus, better robustness is achieved by the proposed scheme. Hence, better robustness and QoS guarantee as well as service continuity can be achieved by the proposed scheme.

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