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Improving Handover Performance in HMIPv6 Using Area Border Routers in Wireless Mobile Networks

Md. Khaliluzzaman, Deepak Kumar Chy. And Madina Akter

Abstract-Hierarchical Mobile IPv6 (HMIPv6) introduces a mobility anchor point (MAP) that localizes the signaling traffic and hence reduces the handoff latency. To support inter-area handovers, several methods have been proposed in the literature to address the challenging problems of minimizing the handoff signaling delay and call blocking probability for Hierarchical Mobile IP version 6 (HMIPv6). In this paper, we propose a new concept for inter-area handovers to solve signaling delay and call blocking probability. In this concept, the border zone is made between two different neighboring cells. Each neighboring cells is assigned as MAP region. Since the border zone is an overlapping MAP region, MHs can maintain the same MAP as long as they remain inside the border zone.

Index Terms - HMIPv6, MAP, Border Zone, Quality of Service, Multicast Group.

I. Introduction

Future wireless networks beyond 3G evolve following an IP based infrastructure, which enables the support of applications in a cost-effective and scalable way. 3G network architecture is based on Internet technology for simultaneous real and non-real time services. Predominant mobile real-time services in the 3G Internet architecture such as wireless mobile Internet telephony require both Quality of Service (QoS) and mobility support. Resource Reservation Protocol (RSVP) is a network-control protocol that enables Internet applications and designed for providing Integrated Services over Internet. It does not support mobility. So, it needs to be modified to support both mobility and to provide sufficient QoS in wireless mobile networks. For this purpose, there are many approaches are proposed by many researchers.

Mobile IPv6 (MIPv6) [1] is the de facto mobility protocol in IPv6 wireless/mobile networks designed by Internet Engineering Task Force (IETF) to overcome intrinsic shortcomings in IPv4 such as limited IP addresses, poor accommodation for QoS and mobility. Hierarchical Mobile IPv6 (HMIPv6) [2] was proposed by IETF to mitigate the high signaling overhead that is incurred in mobile IPv6

networks when mobile nodes (MNs) perform frequent handoffs. In HMIPv6, the mobility is classified into *Intra-site* mobility and *Inter-site* mobility. The resources are pre-reserved to the newly added path instead of whole path between sender and destination. Hence, HMIPv6 efficiently reduces the number of signaling messages that delivered in the Internet. To ensure minimum disruption during inter-MAP handovers, HMIPv6 is combined with the fast handover options of F-HMIPv6 [3], where link layer information is used to either predict or rapidly respond to handover events. MHs either send a BU to their previous MAPs specifying their new LCoAs, or the AR identifies MH movement and informs the corresponding MAP. Consequently, the current MAP can still forward all incoming traffic until the handover update takes place. Although F-HMIPv6 minimizes the disruption during inter-MAP handovers, it does not restrict the mobility signaling, which raises scalability concerns in case of frequent fluctuations between neighboring MAPs.

The provision of QoS is considered challenging due to mobility, especially within a heterogeneous environment. To address wireless QoS, several architectures and mechanisms have been proposed in literature as summarized in [4, 5], with the potential to incorporate traffic engineering as well as QoS routing (QoS) [6] capabilities. A selection of hierarchical QoS proposals is summarized in [7], while one of the most common implementations, based on Open Shortest Path First (OSPF), is adopted as the hierarchical paradigm in our work.

In this paper first presents a method to automatically limit the handoff RSVP renegotiation process within the newly added portion of the path between CN and MN; second presents a wireless hierarchical formation considering Hierarchical Mobile IPv6 (HMIPv6) as the local mobility protocol; third, it proposes an inter-area handover policy for establishing smooth and scalable handovers. Thus, handoff resource reservation delays and signaling

- **Md. Khaliluzzaman** is with the Department of Computer Science & Engineering, University of Information Technology & Sciences, Chittagong, 4225, Bangladesh.
- **Deepak Kumar Chy.** is with the Department of Electrical & Electronics Engineering, University of Information Technology & Sciences, Chittagong, 4225, Bangladesh.
- **Madina Akter** is with the Department of Computer Science & Engineering, University of Information Technology & Sciences,

overheads can be minimized which in turn minimizes the handoff service degradation.

The remainder of this paper is organized as follows. The next section presents the related work, while the following one exhibits Flow Transparent Multicast Pre-Reservation Model in RSVP. The configuration of hierarchical QoS (HQoS) in wireless access networks is then described; while the inter-area handover policy is introduced.

II. Related Work

In HMIPv6 [8] MAPs act as local home agents (HAs) receiving all packets on behalf of serving MHs and tunneling them toward their corresponding address. To ensure minimum disruption during inter-MAP handovers, HMIPv6 is combined with the fast handover options of F-HMIPv6 [3]. Although F-HMIPv6 minimizes the disruption during inter-MAP handovers, it doesn't restrict the mobility signaling. In [9] proposed a scheme, called Mobile IP with Location Registers for 3G cellular systems. It is efficient, but requires more delay for location update to MAP when the MN performs location update. Recently proposed an RSVP and Mobile IPv6 integration model [10]. It has problems like long resource reservation delays and signaling overheads during handoff. Each time an RSVP renegotiation has to be performed end-to-end, no matter how significant the handoff affects the path between CN and MN. In [11] proposed a modification of RSVP to support real-time services in Hierarchical Mobile IPv6 (HMIPv6). In [12] a comparison of four MAP selection schemes based on distance, mobility, and session to mobility ratio is performed where dynamic schemes were shown to outperform the equivalent static ones in terms of scalability and load balancing. Nevertheless, false selections or rapid changes on the selection information might still cause frequent inter-MAP handovers among specific MAPs. To avoid such incidents and reduce the inter-MAP handover signaling [13] introduces the concept of *virtual domains* in the presence of a multilevel MAP arrangement. The virtual domain defines a geographic region containing ARs between neighboring MAP domains, where MHs have a high inter-MAP handover probability. MHs inside the virtual domain hand over to a higher-level MAP, which is in charge of such area. The current HMIPv6 specification, including the proposed MAP selection processes, considers a flat routing arrangement. In [14] a mechanism to perform fast inter-area handovers is proposed based on multicasting. MHs migrating to ARs located by the boundary of different areas trigger the multicasting of incoming traffic toward the candidate ARs. This improves the performance of multimedia applications at the expense of bandwidth utilization, assuming infrequent inter-area handovers. A similar approach is also proposed in [5] considering an inter-MAP handover even among heterogeneous access technologies. Specifically, the gateway that connects multiple MAPs performs the required resource negotiations along new paths and multicasts incoming data until the handover is completed. An alternative prediction-based approach with emphasis on cellular systems, which employs preliminary activities like bearer

reservation and rerouting, is analyzed in [15]. The proposed scheme is shown to ensure faster intercluster handovers, reducing the call dropping probability. Specifying a hierarchical configuration considering mobility and including a high inter-area handover probability zone between neighboring areas, in which MHs maintain the same MAP independent of the migrating area, is critical for the performance of wireless networks. First, it significantly reduces the amount of inter-MAP handovers affecting the mobility signaling overhead, maximizing the scalability benefits of the hierarchical arrangement. Second, it introduces a minimal path update producing less routing overhead, while decreasing the MH blocking and dropping rates.

III. Flow Transparent Multicast Pre-reservation Model in RSVP

In this method each MNs location is denoted by M_{vc} , where M is the MN number, v is the Mobile Anchor Point (MAP) number and c is the cell number that the mobile M resides. If V is the total number of MAP in the networks, then v is in the range of 1 to V . Similarly, if C is the total number of cells in the MAP, then c is in the range of 1 to C . If cells are numbered according to Fig.1, there are seven MAP in this figure and the BC and Center Cell (CC) for a MAP v of MN number M is computed as follows.

$$M_{vc} = \begin{cases} \text{Boundary Cell,} & \text{if } c \neq 1 \\ \text{Center Cell,} & \text{if } c = 1 \end{cases} \quad (1)$$

For each BC, the corresponding MAP maintains a MG (Multicast Group) of adjacent cells just around that BC except that are in the same MAP. Mathematically, if A is the set of all adjacent neighbor cells around the BC, B and G is the MG of B , then G is the subset of A containing the cells such that $\text{MAP}[B] \neq \text{MAP}[A]$. For example, if 17 is the BC, then 63, 75, and 74 are the MG of 17. The objective of the selection of the MG is to select appropriate reservation mechanism.

The movement of a MN towards the MG is determined by measuring the change in signal strength of that MN in BC. If the MN is in the BC continuing exchanging data, the signal strength is measured in regular interval. If the signal strength is decreased, then the resources are pre-reserved in the MG. But, this actually does not mean that the MN moving towards the MG. In this case, the MN may also move towards the cells in the same MAP. From Fig. 1, it is observed that when MN is in BC 15 and moving towards the indicated directions, the signal strength is decreased and cell 47, 53 and 52 are in the MG but cell 14, 11 and 16 are in the same MAP. When the MN leaves the system, the corresponding cells ends the *leave message* to the NCR for that MN, but when the MN performs a handoff to another cell, the previous cell sends the *leave message* and the current cell sends the *join message* almost at the same time to the NCR for that MN. So, only one delay is the result for the notification of handoff (*join message* delay or *leave message*

delay). These messages are used to differentiate between handoff and leaving of MN from the system. These messages are also used for releasing the resources of MN's previous location and the unused prereserved resources of the remaining MG after the handoff of the MN from BC to MG. The decision of whether the MN performing a handoff or leaving from a system and relaxation of resources from the MNs previous cells can be determined by the following procedure:

1. If NCR receives only a *leave message* but not *join message* from a cell for a MN almost at the same time, then the MN leaves the system.
2. If NCR receives both a *leave message* and a *join message* from two cells for a MN almost at the same time, the MN performs the handoff. This *join* and *leave messages* are comparable to *Path Req* or *Binding Update* message of [8].
3. For inter-subnet handoff, the resources of the MNs previous location from which NCR receives *leave message* and that of all the remaining cells of the MG except the cell from which the NCR receive *join message* are released.

Table1: Comparison of No. Of Cells in the MG of Different Methods

Method	Is MG formed?	No. of cells in the MG
FT	No	N/A
HMIPv6	Yes	6
Multicast Pre-Reservation	Yes	3

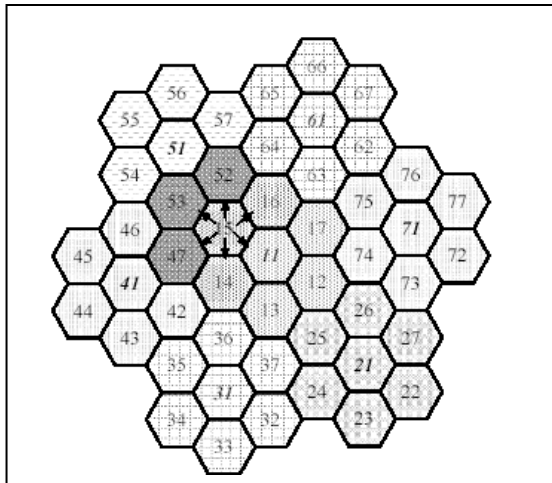


Fig.1. Configuration of Center and Boundary cells

Table 1 compares the No. Of Cells in the MG among FT, HMIPv6 and Multicast Pre-Reservation. It shows that only HMIPv6 and Multicast Pre-Reservation use MG and the Multicast Pre-Reservation reduces 50% cells in the MG compared to HMIPv6.

IV. HQOSR Configuration

The adopted hierarchical arrangement based on OSPF divides the network topology into smaller autonomous areas. Four types of OSPF routers are defined based on the area membership. *AS boundary routers* or *gateways* connect different autonomous systems (ASs) or regions. Their main responsibility is to summarize the AS internal routing information to exchange with boundary routers belonging to other ASs. All routers inside the AS learn about paths toward external networks through AS boundary routers. *Backbone routers* are nonarea- border routers located in the backbone area. Area border routers (ABRs) belong to more than one area and usually provide backbone connectivity to non-backbone areas; they are responsible for inter-area routing. Finally, *internal routers* are members of non-backbone areas without ABR functionality.

V. Inter-Area Routing and ABR

In wireless access networks every OSPF area forms a cluster of ARs, which is geographically continuous, and reflects estimated handover and traffic patterns. Each AR cluster needs to be equipped with one or more MAPs to provide local mobility. HMIPv6 specification does not restrict the location of MAPs and provides flexibility in protocol deployment. Assuming the intra-area handover rates are much higher than the inter-area ones, it improves the handover performance to place MAPs either inside each area or at the border with the backbone. Usually, a multilevel MAP arrangement is desired for scalability purposes.

Non-backbone areas are usually not directly connected, and routing between them is performed through the backbone. However, from the perspective of handover performance and network scalability, connectedness between neighboring areas is essential. It contributes to introducing minor path changes upon an inter area handover, minimizing the QoS update as well as the risk of session disruption and dropping probability. It also enables easier use of fast handovers [3] while ensuring that packet forwarded from the previous MAP to the new AR located in a different area travel through the shortest distance. Besides ensuring smooth inter area handovers, the direct connectivity contributes to utilizing a dynamic hierarchical configuration as introduced in to efficiently handle traffic and topology variations.

Direct connectivity between OSPF non-backbone areas is provided through the use of ABRs. The OSPF specification defines ABRs as routers attached to multiple areas but not necessarily to the backbone. Without backbone connectivity the ABRs get summarized routing information about distant areas through the attached neighboring. This follows a distant vector paradigm with all the performance degradation consequences explained in [16]; therefore, such ABR deployment is prohibited.

As an alternative implementation, [16] introduces ABRs that only maintain a separate routing table for each area they belong to, without including summarized information. Such ABRs are not members of the backbone, but act like

internal routers for all associated areas. Specifically, they do not advertise neighboring area connectivity to any other routers, but forward all bypass traffic designated to their neighboring area directly. The operations of “alternative” ABRs exploit the direct area connectivity mainly for performing inter-area handovers while other sessions between two neighboring areas are usually established through the backbone. Since the use of such ABRs serves the purpose of direct area connectivity and at the same time reduces the routing overhead related to advertising summarized information, they are selected for the proposed wireless hierarchical configuration.

V. Inter Area Handover Policy

Inter-area handovers are ideally desired to be transparent for migrating MHs with the same performance as intra-area ones. Since individual areas are equipped with different sets of MAPs, an inter-area handover is also associated with a MAP handover if each MAP domain is defined within the limits of its corresponding area. Under such an arrangement, the conventional HMIPv6 route update upon an inter-area handover traverses the new MAP as illustrated in Fig. 1, while the direct connectedness between neighboring areas is only used for fast handover purposes. Although such relation of routing and mobility functionality produces adequate handover performance, it is not scalable and reduces the signaling delay, especially under frequent MH fluctuations by the border of neighboring areas due to handover and routing overhead. To overcome such signaling delay issues, an alternative solution is proposed that defines a high inter-area handover probability region, referred to as the *border zone*, between neighboring areas, as shown in Fig. 2. The border zone contains ARs associated with every MAP domain located by the edge of each hierarchical area, constituting an overlapping MAP region.

MHs migrating between neighboring areas initially enter the border zone. Since the border zone is an overlapping MAP region, MHs can maintain the same MAP as long as they remain inside the border zone despite being in a different area for the duration of the ongoing session. Keeping the same MAP inside a region of frequent inter-area handovers reduces the mobility signaling, while in combination with the direct area connectedness it causes route updates with minor path adjustments toward new ARs. Fig. 2 illustrates a path update example after an inter-area handover is performed, pointing out the difference between the conventional and proposed route update processes as well as the contribution of the border zone. Since path updates are minor, there is a reduction of the routing overhead, while at the same time the blocking and dropping rates go down.

MHs that traverse the border zone into a neighboring area perform a change MAP operation following the conventional path update procedure. Since MHs need to traverse the border zone, keeping the current MAP before changing MAP regardless of the direction of movement, such a procedure eliminates frequent MAP handovers especially when users fluctuate by the border of neighboring areas. The border zone is assumed to be estimated in advance based on collected handover data and is assigned by the network administrator. Although the border zone varies depending also on the network topology, its size is required to be as small as possible. Otherwise, as MHs advance into neighboring areas, their distance from the associated MAP increases, causing higher handover delays.

VII. Conclusions

In this paper, we have conducted a comparative study of border zone approach with the alternative where non-overlapping MAP domains are formed within the limit of the hierarchical area. HMIPv6 pre-reservation exhibits high call blocking probabilities, and end-to-end RSVP signaling delays. Multicast pre-reservation methods minimize the call blocking probability and RSVP signaling delays by reducing 50% cells in the MG compare with HMIPv6 shown in Table 1. By ensuring minimum signaling delay and call blocking in inter-area handovers, the introduction of the border zone is shown to outperform conventional approaches, which define detached MAP domains associated with each non-blocked hierarchical area. In this case the border zone approach study demonstrates its impact on producing significantly lower inter-MAP handover rates in the presence of high inter-area migrations, reducing the associated mobility signaling and routing overhead as well as the bandwidth blocking and dropping rates.

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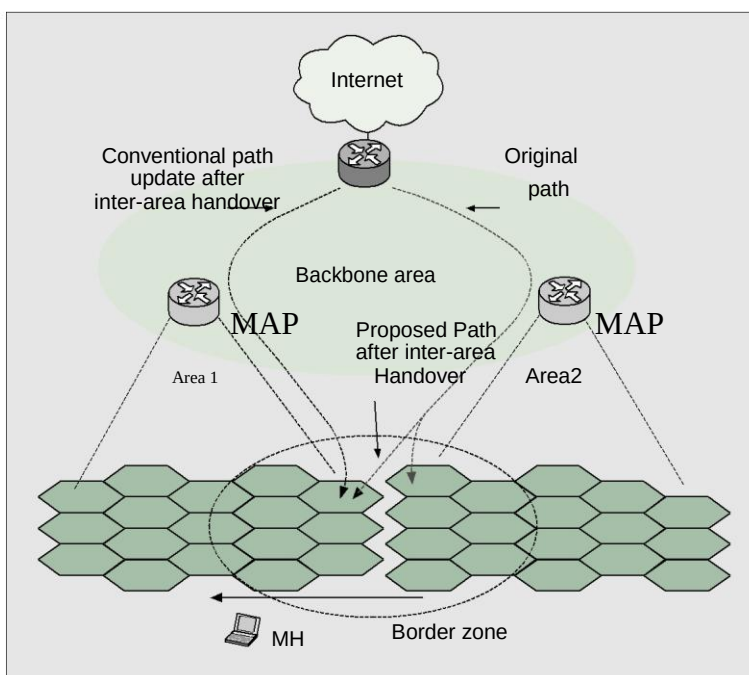


Fig. 2. Inter-MAP handovers and the impact of a border zone.

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Madina Akter continuing her graduation in Computer Science & Engineering Department at University of Information Technology & Sciences (UITS), Chittagong, Bangladesh. Her current research interests are in the area of Wireless Communication, Networking.

Md. Khaliluzzaman received the B.Sc (Engg) degree in Computer Science & Engineering from Khulna University of Engineering & Technology (KUET) in 2007. Now he is continuing his Post graduation in Chittagong University of Engineering & Technology (CUET). He is now working as a faculty member in Computer Science & Engineering Department at University of Information Technology & Sciences (UITS), Chittagong, Bangladesh. His current research interests are in the area of image processing, Wireless Communication, Networking, Data Mining and Wireless network Security. The e-mail of the author is khalil_021@yahoo.co.in.

Deepak Kumar Chy. received the B.Sc (Engg) degree in Electrical & Electronics Engineering from Chittagong University of Engineering & Technology (CUET) in 1998 and received his MSc in CSCE from University of Duisburg-Essen, Germany. He is now working as a faculty member in Electrical & Electronics Engineering Department at University of Information Technology & Sciences (UITS), Chittagong, Bangladesh. His current research interests are in the area of signal processing, Wireless Communication, Networking, Data Mining and Wireless network Security.