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A Proxy Mobile IPv6 Based Global Mobility Management Architecture and Protocol

Huachun Zhou · Hongke Zhang · Yajuan Qin · Hwang-Cheng Wang · Han-Chieh Chao

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Abstract This paper specifies a global mobility management architecture and protocol procedure called GPMIP, which is based on Proxy Mobile IPv6. In GPMIP, mobility management is performed by the network entity rather than individual mobile nodes. The benefit is the elimination of the wireless link data delivery tunnel overhead between a mobile node and the access router. To compare with the well known Hierarchical Mobile IPv6 mobility management protocol, the location update, packet delivery, and total cost functions generated by a mobile node during its average domain residence time are formulated for each protocol based on fluid flow mobility model. Then, the impacts of various system parameters on the cost functions are analyzed. The analytical results indicate that the proposed global mobility management protocol can guarantee lower total costs. Furthermore, a qualitative comparison between GPMIP and some other global management protocols is also investigated.

Keywords global mobility management · proxy mobile IPv6 · hierarchical mobile IPv6 · fluid flow mobility model · cost function

1 Introduction

Mobile IPv6 (MIPv6) [1] enables a mobile node (MN) to maintain its connectivity to the Internet during handover. In order to reduce the amount of signaling between the mobile node, its correspondent nodes and its home agent, the Hierarchical Mobile IPv6 Mobility Management (HMIPv6) [2] protocol was established. HMIPv6 is an extension of Mobile IPv6 and IPv6 neighbor discovery to allow for local mobility handling. However, mobile IP protocols are mobile node-centric in that the handover related decision making is mostly performed by the mobile node.

Recently, IETF proposed the Network-based Localized Mobility Management (NETLMM) [3, 4] protocol, which requires no localized mobility management support on the mobile node. Instead, the network is responsible for managing IP mobility on behalf of the mobile node. In previous NETLMM discussions, HMIPv6 was presented as a candidate solution but was ruled out because of host involvement. Proxy Mobile IPv6 (PMIPv6) [5] enables IP mobility for mobile nodes without inducing any mobility-related signaling. The PMIPv6 protocol was finally adopted by NETLMM since standards development organizations have identified requirements needed to support PMIPv6 solution. Note that although PMIPv6 was derived from MIPv6, it is different from HMIPv6.

One limitation of PMIPv6 is that it is restricted to providing IP connectivity and reachability for mobile nodes within an access network. On the other hand, mobile nodes require global mobility management protocols in order to

H. Zhou · H. Zhang · Y. Qin · H.-C. Chao
School of Electronic and Information Engineering,
Beijing Jiaotong University,
Beijing 100044, China

H. Zhou
e-mail: hchzhou@bjtu.edu.cn

H. Zhang
e-mail: hkzhang@bjtu.edu.cn

Y. Qin
e-mail: yjqin@bjtu.edu.cn

H. Zhou · H. Zhang · Y. Qin · H.-C. Wang · H.-C. Chao (✉)
Department of Electronic Engineering, National Ilan University,
I-Lan, Taiwan
e-mail: hcc@niu.edu.tw

H.-C. Wang
e-mail: hcwang@niu.edu.tw

support global mobility across different NETLMM access networks [6]. To the best of our knowledge, no study has been conducted in the area of PMIPv6-based global mobility management schemes.

In this paper, PMIPv6 is extended and the design of a PMIPv6-based global mobility management architecture and protocol support is described. The resulting scheme is called GPMIP. One distinguishing feature of GPMIP is that the mobility management is actually performed by the network entity instead of mobile nodes. Another feature is the separation of network address and identity of the mobile node. To assess the efficiency of the proposed scheme, the location update and packet delivery costs are compared against the well-known HMIPv6.

The remainder of the paper is organized as follows. Section 2 gives the design motivations and provides an overview of related work. Section 3 describes the GPMIP, including the mobility management architecture and protocol. HMIPv6-based global mobility management architecture and protocol are described in section 4. In section 5, the analytical network and user mobility models are described, followed by the derivation of location update, packet delivery and total cost functions for GPMIP and HMIPv6-based method. Subsequently, the numeric results of cost comparison are analyzed in section 6. Section 7 gives a qualitative comparison between GPMIP and other global management protocols. Finally, in section 8, conclusion is drawn.

2 Design motivations and related work

2.1 Design motivations

This paper specifies a PMIPv6-based global mobility management architecture and protocol. There are two design considerations. The first is that future mobile network requires network-based mobility management, shifting the mobility management function from mobile nodes to access network by using existing mobile IP protocols [7]. Recent developments in network architectures in standards development organizations, such as WiMAX Forum [8] and 3GPP [9] have identified a need to support proxy mobile solution. The WiMAX network architecture [8] currently supports proxy mobile IPv4 for enabling mobility for mobile nodes that may not have a mobile IPv4 client. PMIPv6 is a solution that is aligned with the architectural direction of WiMAX. In 3GPP, there has been some degree of interest in PMIPv6 as well, primarily in the SAE (System Architecture Evolution) [9] work item. The possible solution is the use of a hierarchical mobility concept including a global mobility protocol and a local mobility protocol. This paper extends PMIPv6 to support global mobility management.

The second consideration is that future mobile network will introduce the separation between network address and identity of a mobile node entity. Ambient Networks have developed a framework of naming, addressing and identity mechanisms that enable dynamic bindings for supporting connectivity across heterogeneous network domains [10]. Furthermore, node-identity-based internetworking architecture is proposed in paper [11]. The Mobility Management framework [12] describes an IP-based Mobility Management framework. Some design considerations include separation of user identifier and location identifier, and location and handover management information flows. Recently, many architectural discussions show that the split of address and identity of a mobile node entity may help issues such as routing scalability, mobility, and identity authentication in the Internet architecture [13, 14]. In a PMIPv6 access network, the mobile node has a stable identifier. After the mobility management entities in a PMIPv6 access network identify the mobile node and acquire the mobile node's identity, the mobile node can be authorized for the network-based mobility management service, i.e., permitted by the network to obtain an access address. The proposed PMIPv6-based global mobility management architecture and protocol exploit this feature.

2.2 Related work

There are two classes of mobility management methods. The first is tunnel based approach, as exemplified by Mobile IPv6, in which mobility agents establish tunnels to forward packets whose destination address does not belong to the network. As long as the tunnel endpoints can support the protocol, intermediate nodes need not be aware of the protocol and their routing tables are not affected. The second is host-routing based approach, such as Cellular IP and HAWAII [15], in which mobility agents maintain the next hop for the mobile node and packets destined for the mobile node are relayed by these agents. Although there is no tunnel overhead, all the nodes need to be aware of the protocol and their routing tables are influenced. A detailed description of these mobility support protocols is provided in [15]. It should be noted Mobile IPv6, Cellular IP and HAWAII are host-based solution. In contrast, GPMIP is a network-based solution, i.e., a network entity, the Mobile Access Gateway, sends Proxy Binding Update messages for location registration. The Local Mobility Anchor advertises the mobile node's home network prefix or an aggregated prefix with a larger scope to the Routing Infrastructure.

Mobile IPv6 is a host-based solution for handling the global mobility of hosts in IPv6 networks. This means that a host is involved in mobility-related signaling and a modification of the host protocol stack is required for operating Mobile IPv6 [16]. In contrast, GPMIP provides a network-based solution for handling the mobility of IPv6 hosts. Therefore, no requirement on the hosts is needed.

3GPP General Packet Radio Service (GPRS) has devised its own protocol, the GPRS Tunneling Protocol (GTP) as documented in 3GPP TS 23.060, to handle mobility. In the GTP protocol, a tunnel is established from Serving GPRS Support Node (SGSN) to Gateway GPRS Support Node (GGSN) for the User Equipment's data packets. GTP provides a kind of IP localized mobility management that requires minimal host involvement. From the IP perspective of the mobile node, the mobile node is attached to a single subnet while it moves around a particular GPRS domain. When the MN roams outside its home network, GPRS Roaming eXchange (GRX) as prescribed in GSM Operators' Association Permanent Reference Document IR.33 is used as a global mobility management protocol. GRX is a network-based protocol that enables the serving network GGSN to manage an address in the home network in a way similar to Mobile IP. To support the mechanism, Mobile Switching Center/Visitor Location Register (MSC/VLR) and Home Location Register (HLR) in the existing GSM network are also modified [17].

Recently, 3GPP is working on the new SAE Evolved Packet System (EPS) for Release 8. The target is a low-latency, higher data-rate, all-IP core network capable of supporting real-time packet services over multiple access technologies. Two network architecture solutions are GTP-based solution described in 3GPP TS 23.401 and PMIP-based solution outlined in 3GPP TS 23.402. 3GPP does not require PMIP for different technology handover (that is done by LTE, WIMAX or UMTS specific L2 mobility), but wants to deploy PMIP for the integration of these technologies in an SAE architecture.

In contrast, GPMIP has some resemblance to GPRS in that they are both network-based mobility management protocols and have similar functionalities. The bi-directional tunnel in GPMIP is established between the Local Mobility Anchor and Mobile Access Gateway and is typically a shared tunnel, and can be employed to route traffic streams for different mobile nodes attached to the same Mobile Access Gateway. From the perspective of the mobile node, the PMIPv6 access network appears as its home link or a single link. Furthermore, there exist a location database server for maintaining global and visitor locations and an Authentication, Authorization, and Accounting server for global AAA and AAA in the GPMIP core and access network, respectively.

GPMIP is an Internet protocol which is not dependent on any access-technology-specific protocol. Therefore, it can be used in any IP-based network. On the other hand, GPRS is an access-technology-specific protocol closely coupled with the signaling protocols used in legacy cellular systems.

The roaming mechanisms between PMIPv6 domains have been discussed in NETLMM working group. In [18], Local Mobility Anchors and Mobile Access Gateways in two domains perform exchange of mobility signaling messages on behalf of mobile nodes. All scenarios that require direct interaction between MIPv6 and PMIPv6 are analyzed in [19]. One of the scenarios uses MIPv6 to manage mobility among different access networks and uses PMIPv6 to implement mobility within an access network. This interaction is very similar to the HMIPv6-MIPv6 interaction. However, based on the design considerations mentioned in subsection 2.1, the proposed GPMIP is a centralized architecture. It introduces a global location database server and a global AAA server. In this paper, the proposed GPMIP is compared with the distributed HMIPv6-MIPv6 protocol.

3 GPMIP global mobility management architecture and protocol

This section describes the proposed PMIPv6-based global mobility management architecture and the protocol procedure.

3.1 PMIPv6 overview

PMIPv6 [5] is a network-based mobility management protocol reusing MIPv6 entities and concepts as much as possible. PMIPv6 Domain is a localized mobility management domain where the mobility management of a mobile

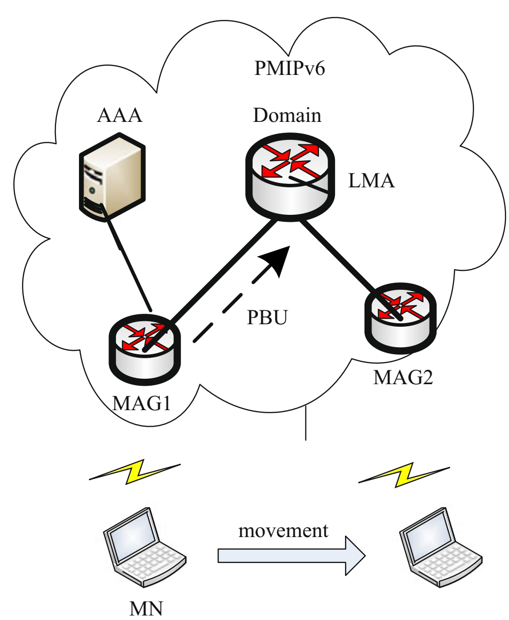

Fig. 1 PMIPv6 domain architecture