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Performance analysis of Virtual Mobility Domain scheme vs. IPv6 mobility protocols

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ABSTRACT

The population of mobile users seeking connectivity to the Internet has been growing over the years, spurred by the capabilities of handsets and the increasing rich Internet content and services. Mobility management to enable efficient Internet access for users on the move is thus gaining significance. IETF has standardized several protocols such as Mobile IPv6, Hierarchical Mobile IPv6, and Proxy Mobile IPv6 to provide mobility management on the IP network. With future Internet design initiatives gaining momentum, it is important that these initiatives consider mobility management as an integral part of the design. In this article, we introduce the concept of Virtual Mobility Domain and describe the main features and key strengths of Virtual Mobility Domain that are designed to provide mobility management in a newly proposed tiered Internet architecture. Instead of IP addressing, the proposed Virtual Mobility Domain uses a tiered-addressing scheme to identify a mobile node with a single address regardless of its location. The tiered addressing provides a dynamic address length which brings less signaling overhead and scalable management. We also propose a collaborative network-based mobility management mechanism to provide low-latency handoffs and less processing-overhead on the mobile node compared to the IPv6-based protocols. The proposed mobility scheme unifies inter and intra-domain mobility management by introducing common anchor cloud concept which provides a distributed management and seamless mobility experience. We present comparative qualitative and quantitative performance analysis of Virtual Mobility Domain and aforementioned IPv6-based mobility protocols for Intra-AS roaming support. We examine handoff latency and signaling overhead performance of each protocol based on numerical results retrieved from analytical models and OPNET modeler based simulations. The results from a comparative performance study show the potential for more efficient mobility management under the proposed Internet architecture.

1. Introduction

Significant advances in hardware and wireless technologies have made mobile communication devices affordable to a vast user community. With the advent of rich multimedia and social networking content, and influx of myriads of applications, there is an increasing user demand for Internet connectivity anywhere and anytime. Robust Internet protocols and evolutionary research efforts have enabled the Internet to withstand the demands of the users and the emerging technologies.

Research programs worldwide such as the National Science Foundation's Future Internet Design Initiative [1] and Future Internet Architecture Project [2] in the United States, the European Union's sixth and seventh framework programs [3], the Asia consortium [4], and New Generation

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Networks [5] in Japan have started funding clean slate future Internet research to efficiently harness the related advanced technologies and to better address user demands. Mobility management is an integral feature in many of these future Internet designs [6]. Mobility management includes *seamless roaming of mobile users* requiring fast handoff with low latency and low packets loss to allow continuation of active sessions transparently as users change network connections [7].

The authors of this work proposed a tiered Internet architecture[1] derived from the tiered structure existing today among Internet Service Providers (ISPs) to define their business and peering relationships [8,9]. The topological connections between ISPs exhibit *a hybrid structure* that leverages the attributes of hierarchical and distributed structures. In a tiered structure, there can be several entities in one tier such as an ISP, an Autonomous System (AS) or an access network that operate in a distributed and autonomous manner. However, entities at a lower tier are customers of entities at a higher tier, exhibiting a hierarchical relationship. The tiered structure enables defining Virtual Mobility Domains (VMDs) of varying scopes by deploying to any tier. VMD defines a virtual roaming boundary which is not geographically or physically constrained to a locality for a mobile user. A user is tracked with a single short-length tiered-address in the VMD. Seamless user movement within the domain is collaboratively managed by nodes in the network. Collaborative management scheme provides a distributed and scalable management of the mobility.

In this article, extensive analytical and simulation based performance study of intra-AS roaming support of VMD [10] in a tiered Internet architecture in comparison with Mobile IPv6 (MIPv6) [11], Hierarchical Mobile IPv6 (HMIPv6) [12], and Proxy Mobile IPv6 (PMIPv6) [13] is presented. These protocols are chosen specifically because they present fundamentally different ways of handling a handoff and we aim to investigate the contributions due to locations and functions of the different mobility agents on the network. It is not possible to compare the VMD based mobility protocol with other recent future Internet solutions because most are in the research phase. However, a comparison with MIPv6, HMIPv6, and PMIPv6 will show the relative performance improvements achieved with VMD and also serve as benchmark for future mobility related studies. Our study in this paper reveal that VMD outperforms MIPv6, HMIPv6, and PMIPv6 significantly in terms of handoff latency, packet loss, and signaling overhead – the three important performance metrics to assess seamless user mobility.

The rest of the paper is organized as follows. Section 2 covers a summary of previous and ongoing research on mobility management. Section 3 presents the tiered Internet architecture and the VMD concept, followed by VMD intra-AS roaming support in Section 4. The analytical models for VMD, MIPv6, HMIPv6, and PMIPv6 are provided in Section 5. Performance comparison of VMD against MIPv6, HMIPv6, and PMIPv6 based on both analytical and simulation models are presented in Section 6. Concluding remarks are given in Section 7.

2. Related work

Fundamental to any internetwork design is an understanding of the current mobility solutions, the rationale behind their design, and their performance in the context of the current Internet architecture. This section is thus directed to mobility solutions developed under the current Internet architecture, followed by mobility solutions proposed by few future Internet efforts.

Mobility protocols can be categorized broadly as *network-based* or *host-based* [14]. They can also be categorized based on the scope (intra-domain vs. inter-domain) such as *micro-mobility* or *macro-mobility* protocols [15]. Each type of mobility protocols operationally views mobile devices and networks differently depending on the underlying mobility management principles.

Few of the major mobility protocols that were developed under the Internet Engineering Task Force (IETF) initiatives are MIPv6 [11], HMIPv6 [12], and PMIPv6 [13]. These protocols were developed to work with the current Internet architecture and protocols. They use IP addresses to identify a mobile node (MN) and to route packets to them [16]. Hence, when an MN moves across access routers (ARs) or domains, new IP address has to be acquired at the newly connected network. The MN next updates the previous network with the acquired address through a process called address binding. This will aid in forwarding packets to the new location of the MN. The operations of these protocols are described in Section 5. Improvements and enhancements to MIPv6, HMIPv6 and PMIPv6 are proposed and studied in [17–19] respectively.

Another approach to enhance mobility management is to separate the locator and the ID of an MN. Host Identity Protocol (HIP) [20] uses an IP address only as a location identifier and introduces Host Identity name space as an endpoint identifier. Locator Identifier Separation Protocol (LISP) [21] uses an MN endpoint identifier and routing locator address. If an MN roams, its routing locator changes and the mapping between the endpoint identifier and the routing locator is handled by a network-based map-and-encapsulate scheme [22]. Routing on Flat Labels (ROFL) [23] proposes a naming and routing architecture based on flat identifiers that do not have location semantics. Therefore, the MN name does not change and mobility support is provided by distributed hash tables maintained at each node. Mobility and Multihoming Supporting Identifier Locator Split Architecture (MILSA) [24] proposes a hybrid design combining locator/ID split and core–edge separation to provide renumbering and mobility support among others. MobilityFirst [25] and eXpressive Internet Architecture [26] identify the Internet content, mobile devices or users with human-readable strings, and use naming and location services to map string identifiers to actual network addresses.

Another mobility management approach provides an overlay structure to route data packets to an MN when it roams. General Packet Radio Service (GPRS) provides overlay routing in the local topology so that identity and

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