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# Comprehensive performance evaluation of distributed and dynamic mobility routing strategy

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ABSTRACT

In this paper, we conduct a comprehensive performance study of distributed and dynamic mobility management (DDMM). DDMM presents a new architectural paradigm for a sustainable mobile networking against an ever-increasing amount of Internet data traffic, providing IP mobility management with distributed deployment of mobility anchors and dynamic activation when mobility is needed. Such a distributed mobility management concept is generally and intuitively accepted in terms of effective distribution of mobile traffic when compared with centralized mobility management (CMM) approaches. Nevertheless, the routing strategy of DDMM has not yet been properly examined through performance studies, and especially the impact of potential mobility routing strategies on the user plane is an open question. We perform a mathematical analysis of DDMM and present numerical results aiming to identify in which conditions, by which factors, and how much, DDMM improves mobility performance. For comparison, Mobile IPv6, Proxy Mobile IPv6 (PMIPv6), and PMIPv6 localized routing (PMIPv6-LR) were considered as representative IP mobility protocols following CMM approaches. Analytical results demonstrate that DDMM generally achieves higher performance when compared with CMM-based protocols in terms of packet delivery cost, tunneling overhead, and throughput, but specific performance varies in function of multiple input parameters.



## 1. Introduction

The enormous proliferation of mobile devices and the exploding use of high-volume multimedia services using wireless interfaces (i.e. Wi-Fi, 3G, and LTE) have introduced serious scalability and reliability issues on mobile networks. To cope with these traffic issues, various optimization techniques like LIPA/SIPTO [1], IP Flow Mobility [2], and LIPA Mobility and SIPTO at the Local Network (LIMONET) [3] have been proposed, aiming at data offloading in all communication layers.

Current mobile architectures are deployed in a hierarchical and centralized manner, in what is called centralized mobility management (CMM), which enables mobility access routers to be connected through a mobility anchor, e.g. Home Agent (HA) in Mobile IP [4] and Local Mobility Anchor (LMA) in Proxy Mobile IPv6 (PMIPv6) [5]. Such centralized mobility anchoring approaches introduce a single point of failure due to excessive data packets and corresponding processing burden. Furthermore it brings non-optimal routing and unnecessary resource reservation for IP tunnel management, even while no mobility is in place [18]. This CMM approach can be enhanced with load

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balancing [6] or HA switching [7], but these approaches still do not seem scalable with current Internet traffic trends, increasingly entailing heavy-size multimedia streaming services with QoE demands.

One idea to address the problem is the flattening of the current mobile architecture, decreasing the traffic burden and contributing to reliable mobility management for users and networks. Such an intuitive idea has been progressed with two technological directions [8]. One direction is exploring intra-domain IP routing protocols, e.g. BGP [9], which updates a routing path by advertising the IP address newly assigned to an attached mobile node (MN). The reachability for the MN is kept inside the domain, without the use of any mobility anchor. However, the handover performance is associated with the routing protocol operation; handover latency is affected by intra-domain routing convergence time and frequent routing updates introduce broadcast storms within the domain [8]. The second direction tries to redesign IP mobility protocols, locating and deploying multiple mobility anchor functions that provide a role of mobility manager for the anchored sessions associated with IP addresses or IP prefixes at the edges. Throughout this paper, we name such a mobility routing strategy – only focused on the data plane – as distributed and dynamic mobility management (DDMM)[1] which commits to a very specific routing strategy, one that can be classified in the DMM category. This strategy will be running in mobility routers, known as DDMM routers (DMRs), which can be classified in two types: the anchor DMR (A-DMR) and the serving DMR (S-DMR). DDMM is based on the following operation: when an MN initiates a new session through the connected DMR, the DMR acts as an S-DMR with no need of mobility management; but if the MN moves to another DMR while the session is active, the previous S-DMR acts as the MN's A-DMR only for that IP flow session.

Many proposals have been made on this second direction. The proposed solutions can be divided into host-based and network-based approaches, in function of the MN's involvement in mobility process [10–12]. Furthermore, individual approaches can be classified as partially-distributed or fully-distributed [13], depending whether the control plane is distributed to get the MN's mobility profile or not. In general, these proposed mobility solutions have similar mobility routing strategies in the data plane, providing regular IP routing for the established session when the MN is attached to a new DMR and a new session is initiated, and anchoring the session while the MN is becoming mobile (see the routing operations at Fig. 1 in Section 2). The DDMM routing strategy is generally expected to be employed to effectively cope with the explosive data problem for future mobile architecture, facilitating shorter routing paths between the A-DMR and S-DMR of the MN's IP flow, and reducing workload on mobility anchors, ultimately leading to throughput improvements. Notwithstanding the existence of general ideas on DMMM protocols, a comprehensive performance study addressing various network environments and conditions the users are facing (i.e. the size of mobile network, cell crossing rate, the use of supported routing optimization, session duration time, and so on) is missing.

It is worth identifying which factors and which conditions enable DDMM routing to provide better performance (and by how much this DDMM performance will be improved), compared to more traditional mobility routing techniques. For this purpose, we conduct a comprehensive performance study to assess the DDMM routing strategy focused on the data plane. Signaling impact is highly associated with control plane design, such as how and where the mapping information between the MN's ID and its current network location is obtained from, and which signaling protocol is used. Since it has not yet been fully specified as a standardized solution, and it seems to be a minor factor, we do not consider the control plane into our comparison with the several target protocols. MIPv6 is here compared with DDMM, representing a reference of a host-based IP mobility protocol following the CMM approach. PMIPv6 – providing improved handover performance and having been adopted in standardization bodies [14,15] – and localized routing-enabled PMIPv6 (PMIPv6-LR) [16], based on CMM approaches, are also compared. Particularly, the selected target protocols have routing optimization schemes, thus their impact could be compared with DDMM.

The remainder of this paper is structured as follows. Section 2 briefly describes how MIPv6 and PMIPv6 work for mobility routing, and highlights drawbacks of the protocols based on CMM approach. In Section 3, we describe the concept of DDMM-based mobility routing. Section 4 presents a mathematical analysis for MIPv6, PMIPv6, PMIPv6-LR, and DDMM. Section 5 provides numerical results, comparing the performance of these protocols. In Section 6, we summarize the related work on DDMM and its performance studies. We conclude this paper in Section 7.

## 2. Preliminaries: mobility routing in MIPv6 and PMIPv6

### 2.1. MIPv6 and PMIPv6

MIPv6 consists of a HA and Access Routers (ARs), coupled with mobility functions and protocol stacks. After an MN registers to the assigned HA, it configures its home address based on the received HA's network prefix, and then all data packets are routed with standard IP routing. The HA is responsible for managing the MN's reachability from its home network. Once the MN moves to an AR under a foreign network, it maintains the home address but is additionally required to configure a care-of-address (CoA) to be used in the foreign network. The MN then sends the Binding Update (BU) message to the HA. The HA updates a binding cache entry for the MN and sends back the Binding Acknowledgment (BA) message to the MN. The MN updates its Binding Update List (BUL) by

[1] DMM and DDMM may share similar aspects for providing IP mobility management. However, DMM could be used as a symbolic term with a broad meaning mostly representing the concept of flat mobile networks (against the concept of hierarchical mobile networks), not explicitly defining specific strategies that could be enabled by DMM, while DDMM specifically denotes the mobility routing shape or strategy, illustrated in Fig. 2, made by the distributed deployment of mobility anchors and dynamic mobility.