

Network Working Group
Internet-Draft
Intended status: Informational
Expires: August 7, 2014

H. Chan (Ed.)
Huawei Technologies
D. Liu
China Mobile
P. Seite
Orange
H. Yokota
KDDI Lab
J. Korhonen
Broadcom Communications
February 3, 2014

Requirements for Distributed Mobility Management
draft-ietf-dmm-requirements-14

Abstract

This document defines the requirements for Distributed Mobility Management (DMM) at the network layer. The hierarchical structure in traditional wireless networks has led primarily to centralized deployment models. As some wireless networks are evolving away from the hierarchical structure, a distributed model for mobility management can be useful to them.

Requirements Language

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in RFC 2119 RFC 2119 [RFC2119].

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Table of Contents

1. Introduction	3
2. Conventions used in this document	4
2.1. Terminology	4
3. Centralized versus distributed mobility management	5
3.1. Centralized mobility management	6
3.2. Distributed mobility management	7
4. Problem Statement	8
5. Requirements	10
6. Security Considerations	13
7. IANA Considerations	13
8. Contributors	13
9. References	15
9.1. Normative References	15
9.2. Informative References	15
Authors' Addresses	18

1. Introduction

In the past decade a fair number of network-layer mobility protocols have been standardized [RFC6275] [RFC5944] [RFC5380] [RFC6301] [RFC5213]. Although the protocols differ in terms of functions and associated message formats, they all employ a mobility anchor to allow a mobile node to remain reachable after it has moved to a different network. The anchor point, among other tasks, ensures connectivity by forwarding packets destined to, or sent from, the mobile node. It is a centrally deployed mobility anchor in the sense that the deployed architectures today have a small number of these anchors and the traffic of millions of mobile nodes in an operator network are typically managed by the same anchor.

Distributed mobility management (DMM) is an alternative to the above centralized deployment. The background behind the interests to study DMM are primarily in the following.

- (1) Mobile users are, more than ever, consuming Internet content including that of local Content Delivery Networks (CDNs) which had not taken mobility service into account before. Such traffic imposes new requirements on mobile core networks for data traffic delivery. To prevent exceeding the available core network capacity, service providers need to implement new strategies such as selective IPv4 traffic offload (e.g. [RFC6909], 3GPP work items Local IP Access (LIPA) and Selected IP Traffic Offload (SIPTO) [TS.23.401]) through alternative access networks (e.g. WLAN) [Paper-Mobile.Data.Offloading]. In addition, a gateway selection mechanism takes the user proximity into account within EPC [TS.29303]. Yet these mechanisms were not pursued in the past owing to charging and billing which require solutions beyond the mobility protocol. Consequently, assigning a gateway anchor node from a visited network in roaming scenario has until recently been done and are limited to voice services only.

Both traffic offloading and CDN mechanisms could benefit from the development of mobile architectures with fewer levels of routing hierarchy introduced into the data path by the mobility management system. This trend towards so-called "flat networks" works best for direct communications among peers in the same geographical area. Distributed mobility management in a truly flat mobile architecture would anchor the traffic closer to the point of attachment of the user.

(2) Today's mobile networks present service providers with new challenges. Mobility patterns indicate that mobile nodes often remain attached to the same point of attachment for considerable periods of time [Paper-Locating.User]. Specific IP mobility management support is not required for applications that launch and complete their sessions while the mobile node is connected to the same point of attachment. However, currently, IP mobility support is designed for always-on operation, maintaining all parameters of the context for each mobile subscriber for as long as they are connected to the network. This can result in a waste of resources and unnecessary costs for the service provider. Infrequent node mobility coupled with application intelligence suggest that mobility support could be provided selectively such as in [I-D.bhandari-dhc-class-based-prefix] and [I-D.korhonen-6man-prefix-properties], thus reducing the amount of context maintained in the network.

DMM may distribute the mobility anchors in the data-plane towards a more flat network such that the mobility anchors are positioned closer to the user; ideally, mobility agents could be collocated with the first-hop router. Facilitated by the distribution of mobility anchors, it may be possible to selectively use or not use mobility protocol support depending on whether such support is needed or not. It can thus reduce the amount of state information that must be maintained in various mobility agents of the mobile network. It can then avoid the unnecessary establishment of mechanisms to forward traffic from an old to a new mobility anchor.

This document compares distributed mobility management with centralized mobility management in Section 3. The problems that can be addressed with DMM are summarized in Section 4. The mandatory requirements as well as the optional requirements for network-layer distributed mobility management are given in Section 5. Finally, security considerations are discussed in Section 6.

The problem statement and the use cases [I-D.yokota-dmm-scenario] can be found in [Paper-Distributed.Mobility.Review].

2. Conventions used in this document

2.1. Terminology

All the general mobility-related terms and their acronyms used in this document are to be interpreted as defined in the Mobile IPv6 base specification [RFC6275], in the Proxy mobile IPv6 specification [RFC5213], and in Mobility Related Terminology [RFC3753]. These terms include the following: mobile node (MN), correspondent node

(CN), and home agent (HA) as per [RFC6275]; local mobility anchor (LMA) and mobile access gateway (MAG) as per [RFC5213], and context as per [RFC3753].

In addition, this draft introduces the following terms.

Centrally deployed mobility anchors

refer to the mobility management deployments in which there are very few mobility anchors and the traffic of millions of mobile nodes in an operator network are managed by the same anchor.

Centralized mobility management

makes use of centrally deployed mobility anchors.

Distributed mobility management

is not centralized so that traffic does not need to traverse centrally deployed mobility anchors far from the optimal route.

Flat mobile network

has few levels of routing hierarchy introduced into the data path by the mobility management system.

Mobility context

is the collection of information required to provide mobility management support for a given mobile node.

3. Centralized versus distributed mobility management

Mobility management is needed because the IP address of a mobile node may change as the node moves. Mobility management functions may be implemented at different layers of the protocol stack. At the IP (network) layer, mobility management can be client-based or network-based.

An IP-layer mobility management protocol is typically based on the principle of distinguishing between a session identifier and a routing address and maintaining a mapping between the two. In Mobile IP, the new IP address of the mobile node after the node has moved is the routing address, whereas the original IP address before the mobile node moves serves as the session identifier. The location management (LM) information is kept by associating the routing address with the session identifier. Packets addressed to the

session identifier will first route to the original network which re-directs them using the routing address to deliver to the session. Re-directing packets this way can result in long routes. An existing optimization routes directly using the routing address of the host, and such is a host-based solution.

The next two subsections explain centralized and distributed mobility management functions in the network.

3.1. Centralized mobility management

In centralized mobility management, the location information in terms of a mapping between the session identifier and the routing address is kept at a single mobility anchor, and packets destined to the session identifier are routed via this anchor. In other words, such mobility management systems are centralized in both the control plane and the data plane (mobile node IP traffic).

Many existing mobility management deployments make use of centralized mobility anchoring in a hierarchical network architecture, as shown in Figure 1. Examples are the home agent (HA) and local mobility anchor (LMA) serving as the anchors for the mobile node (MN) and Mobile Access Gateway (MAG) in Mobile IPv6 [RFC6275] and in Proxy Mobile IPv6 [RFC5213] respectively. Cellular networks such as the Third Generation Partnership Project (3GPP) General Packet Radio System (GPRS) networks and 3GPP Evolved Packet System (EPS) networks employ centralized mobility management too. In the 3GPP GPRS network, the Gateway GPRS Support Node (GGSN), Serving GPRS Support Node (SGSN) and Radio Network Controller (RNC) constitute a hierarchy of anchors. In the 3GPP EPS network, the Packet Data Network Gateway (P-GW) and Serving Gateway (S-GW) constitute another hierarchy of anchors.

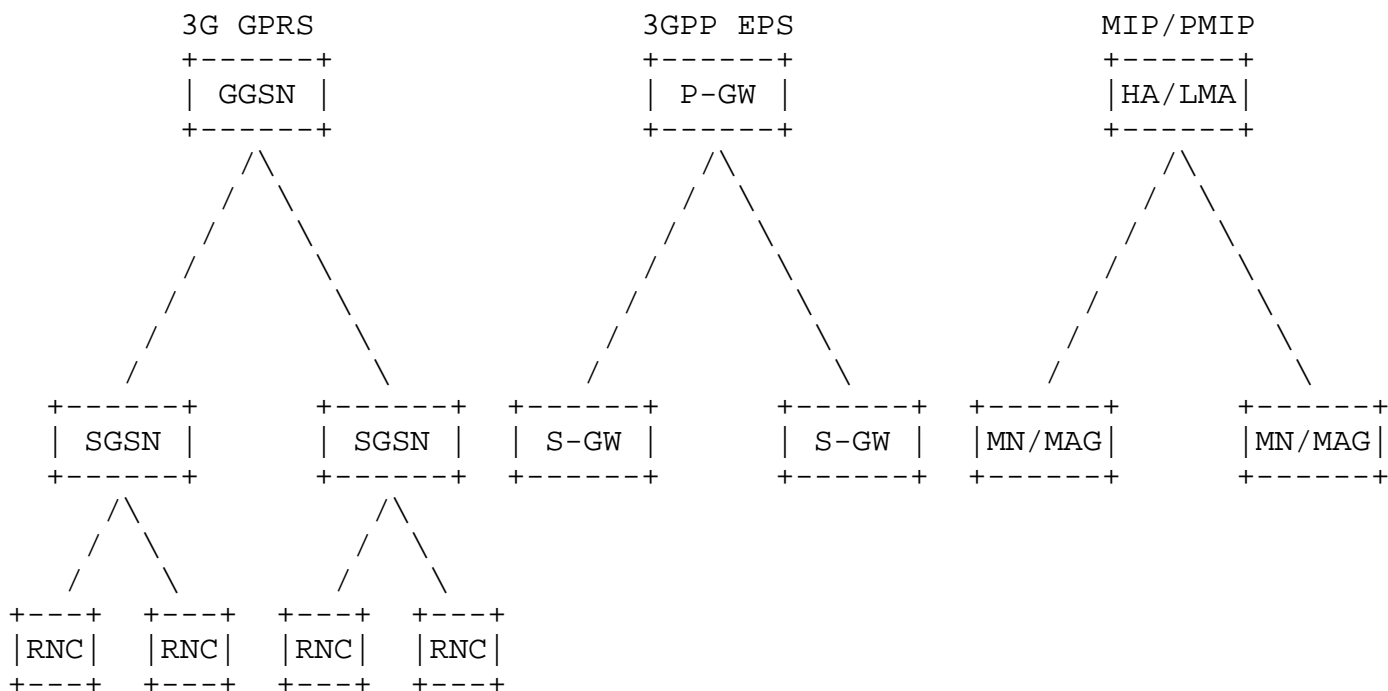


Figure 1. Centralized mobility management.

3.2. Distributed mobility management

Mobility management functions may also be distributed to multiple networks as shown in Figure 2, so that a mobile node in any of these networks may be served by a nearby function with appropriate mobility/routing management (RM) capability.

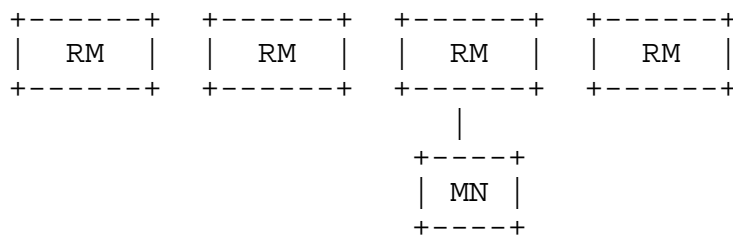


Figure 2. Distributed mobility management.

Mobility management may be partially or fully distributed [I-D.yokota-dmm-scenario]. In the former case only the data plane is distributed, implicitly assuming separation of data and control planes as described in [I-D.wakikawa-netext-pmip-cp-up-separation]. Fully distributed mobility management implies that both the data plane and the control plane are distributed. While mobility management can be distributed, it is not necessary for other

functions such as subscription management, subscription database, and network access authentication to be similarly distributed.

A distributed mobility management scheme for a flat mobile network of access nodes is proposed in [Paper-Distributed.Dynamic.Mobility]. Its benefits over centralized mobility management have been shown through simulations [Paper-Distributed.Centralized.Mobility]. Moreover, the (re)use and extension of existing protocols in the design of both fully distributed mobility management [Paper-Migrating.Home.Agents] [Paper-Distributed.Mobility.SAE] and partially distributed mobility management [Paper-Distributed.Mobility.PMIP] [Paper-Distributed.Mobility.MIP] have been reported in the literature. Therefore, before designing new mobility management protocols for a future distributed architecture, it is recommended to first consider whether existing mobility management protocols can be extended.

4. Problem Statement

The problems that can be addressed with DMM are summarized in the following:

PS1: Non-optimal routes

Routing via a centralized anchor often results in non-optimal routes, thereby increasing the end-to-end delay. The problem is manifested, for example, when accessing a nearby server or servers of a Content Delivery Network (CDN), or when receiving locally available IP multicast or sending IP multicast packets. (Existing route optimization is only a host-based solution. On the other hand, localized routing with PMIPv6 [RFC6705] addresses only a part of the problem where both the MN and the correspondent node (CN) are attached to the same MAG, and it is not applicable when the CN does not behave like an MN.)

PS2: Divergence from other evolutionary trends in network architectures such as distribution of content delivery.

Mobile networks have generally been evolving towards a flat network. Centralized mobility management, which is non-optimal with a flat network architecture, does not support this evolution.

PS3: Lack of scalability of centralized tunnel management and mobility context maintenance

Setting up tunnels through a central anchor and maintaining

mobility context for each MN usually requires more concentrated resources in a centralized design, thus reducing scalability. Distributing the tunnel maintenance function and the mobility context maintenance function among different network entities with proper signaling protocol design can avoid increasing the concentrated resources with an increasing number of MNs.

PS4: Single point of failure and attack

Centralized anchoring designs may be more vulnerable to single points of failures and attacks than a distributed system. The impact of a successful attack on a system with centralized mobility management can be far greater as well.

PS5: Unnecessary mobility support to clients that do not need it

IP mobility support is usually provided to all MNs. Yet it is not always required, and not every parameter of mobility context is always used. For example, some applications or nodes do not need a stable IP address during a handover to maintain session continuity. Sometimes, the entire application session runs while the MN does not change the point of attachment. Besides, some sessions, e.g. SIP-based sessions, can handle mobility at the application layer and hence do not need IP mobility support; it is then unnecessary to provide IP mobility support for such sessions.

PS6: Mobility signaling overhead with peer-to-peer communication

Wasting resources when mobility signaling (e.g., maintenance of the tunnel, keep alive signaling, etc.) is not turned off for peer-to-peer communication.

PS7: Deployment with multiple mobility solutions

There are already many variants and extensions of MIP as well mobility solutions at other layers. Deployment of new mobility management solutions can be challenging, and debugging difficult, when they co-exist with solutions already deployed in the field.

PS8: Duplicate multicast traffic

IP multicast distribution over architectures using IP mobility solutions (e.g., [RFC6224]) may lead to convergence of duplicated multicast subscriptions towards the downstream tunnel entity (e.g. MAG in PMIPv6). Concretely, when multicast subscription for individual mobile nodes is coupled

with mobility tunnels (e.g. PMIPv6 tunnel), duplicate multicast subscription(s) is prone to be received through different upstream paths. This problem may also exist or be more severe in a distributed mobility environment.

5. Requirements

After comparing distributed mobility management against centralized deployment in Section 3 and describing the problems in Section 4, this section identifies the following requirements:

REQ1: Distributed processing

IP mobility, network access and routing solutions provided by DMM MUST enable distributed processing for mobility management so that traffic can avoid traversing single mobility anchor far from the optimal route.

Motivation: This requirement is motivated by current trends in network evolution: (a) it is cost- and resource-effective to cache contents, and the caching (e.g., CDN) servers are distributed so that each user in any location can be close to one of the servers; (b) the significantly larger number of mobile nodes and flows call for improved scalability; (c) single points of failure are avoided in a distributed system; (d) threats against centrally deployed anchors, e.g., home agent and local mobility anchor, are mitigated in a distributed system.

This requirement addresses the problems PS1, PS2, PS3, and PS4 described in Section 4.

REQ2: Bypassable network-layer mobility support

DMM solutions MUST enable network-layer mobility but it MUST be possible to not use it. Mobility support is needed, for example, when a mobile host moves and an application cannot cope with a change in the IP address. Mobility support is also needed, for example, when a mobile router moves together with a host and an application in the host is interrupted by a change of IP address of the mobile router. However mobility support at the network-layer is not always needed; a mobile node can often be stationary, and mobility support can also be provided at other layers. It is then not always necessary to maintain a stable IP address or prefix.

Motivation: The motivation of this requirement is to enable

more efficient routing and more efficient use of network resources by selecting an IP address or prefix according to whether mobility support is needed and by not maintaining context at the mobility anchor when there is no such need.

This requirement addresses the problems PS5 and PS6 described in Section 4.

REQ3: IPv6 deployment

DMM solutions SHOULD target IPv6 as the primary deployment environment and SHOULD NOT be tailored specifically to support IPv4, in particular in situations where private IPv4 addresses and/or NATs are used.

Motivation: This requirement conforms to the general orientation of IETF work. DMM deployment is foreseen in mid- to long-term horizon, when IPv6 is expected to be far more common than today.

This requirement avoids the unnecessarily complexity in solving the problems in Section 4 for IPv4, which will not be able to use some of the IPv6-specific features.

REQ4: Existing mobility protocols

A DMM solution MUST first consider reusing and extending IETF-standardized protocols before specifying new protocols.

Motivation: Reuse of existing IETF work is more efficient and less error-prone.

This requirement attempts to avoid the need of new protocols development and therefore their potential problems of being time-consuming and error-prone.

REQ5: Coexistence with deployed networks and hosts

The DMM solution may require loose, tight or no integration into existing mobility protocols and host IP stack. Regardless of the integration level, the DMM solution MUST be able to coexist with existing network deployments, end hosts and routers that may or may not implement existing mobility protocols. Furthermore, a DMM solution SHOULD work across different networks, possibly operated as separate administrative domains, when allowed by the trust relationship between them.

Motivation: (a) to preserve backwards compatibility so that existing networks and hosts are not affected and continue to function as usual, and (b) enable inter-domain operation if desired.

This requirement addresses the problem PS7 described in Section 4.

REQ6: Security considerations

A DMM solution MUST NOT introduce new security risks, or amplify existing security risks, that cannot be mitigated by existing security mechanisms or protocols.

Motivation: Various attacks such as impersonation, denial of service, man-in-the-middle attacks, and so on, may be launched in a DMM deployment. For instance, an illegitimate node may attempt to access a network providing DMM. Another example is that a malicious node can forge a number of signaling messages thus redirecting traffic from its legitimate path. Consequently, the specific node is under a denial of service attack, whereas other nodes do not receive their traffic. Accordingly, security mechanisms/protocols providing access control, integrity, authentication, authorization, confidentiality, etc. can be used to protect the DMM entities as they are already used to protect against existing networks and existing mobility protocols defined in IETF.

This requirement prevents a DMM solution from introducing uncontrollable problems of potentially insecure mobility management protocols which make deployment infeasible because platforms conforming to the protocols are at risk for data loss and numerous other dangers, including financial harm to the users.

REQ7: Multicast considerations

DMM SHOULD enable multicast solutions to be developed to avoid network inefficiency in multicast traffic delivery.

Motivation: Existing multicast deployment have been introduced after completing the design of the reference mobility protocol, often leading to network inefficiency and non-optimal routing for the multicast traffic. Instead DMM should consider multicast early so that the multicast solutions can better consider efficiency nature in the multicast traffic delivery (such as duplicate multicast subscriptions towards the downstream tunnel entities). The multicast solutions should then avoid restricting the management of all IP multicast traffic to a single host through a dedicated

(tunnel) interface on multicast-capable access routers.

This requirement addresses the problems PS1 and PS8 described in Section 4.

6. Security Considerations

Please refer to the discussion under Security requirement in Section 5.6.

7. IANA Considerations

None

8. Contributors

This requirements document is a joint effort among numerous participants working in a team. In addition to the authors, each of the following has made very significant and important contributions to this work:

Charles E. Perkins
Huawei Technologies
Email: charliep@computer.org

Melia Telemaco
Alcatel-Lucent Bell Labs
Email: telemaco.melia@googlemail.com

Elena Demaria
Telecom Italia
via G. Reiss Romoli, 274, TORINO, 10148, Italy
Email: elena.demaria@telecomitalia.it

Jong-Hyouk Lee
Sangmyung University, Korea
Email: jonghyouk@smu.ac.kr

Kostas Pentikousis
EICT GmbH
Email: k.pentikousis@eict.de

Tricci So
ZTE
Email: tso@zteusa.com

Carlos J. Bernardos
Universidad Carlos III de Madrid
Av. Universidad, 30, Leganes, Madrid 28911, Spain
Email: cjbc@it.uc3m.es

Peter McCann
Huawei Technologies
Email: Peter.McCann@huawei.com

Seok Joo Koh
Kyungpook National University, Korea
Email: sjkoh@knu.ac.kr

Wen Luo
ZTE
No.68, Zijinhua RD, Yuhuatai District, Nanjing, Jiangsu 210012, China
Email: luo.wen@zte.com.cn

Sri Gundavelli
Cisco
sgundave@cisco.com

Marco Liebsch
NEC Laboratories Europe
Email: liebsch@neclab.eu

Carl Williams
MCSR Labs
Email: carlw@mcsr-labs.org

Seil Jeon
Instituto de Telecomunicacoes, Aveiro
Email: seiljeon@av.it.pt

Sergio Figueiredo
Universidade de Aveiro
Email: sfigueiredo@av.it.pt

Stig Venaas
Email: stig@venaas.com

Luis Miguel Contreras Murillo
Telefonica I+D
Email: lmcm@tid.es

Juan Carlos Zuniga
InterDigital
Email: JuanCarlos.Zuniga@InterDigital.com

Alexandru Petrescu
Email: alexandru.petrescu@gmail.com

Georgios Karagiannis
University of Twente
Email: g.karagiannis@utwente.nl

Julien Laganier
Juniper
Email: julien.ietf@gmail.com

Wassim Michel Haddad
Ericsson
Email: Wassim.Haddad@ericsson.com

Dirk von Hugo
Deutsche Telekom Laboratories
Email: Dirk.von-Hugo@telekom.de

Ahmad Muhanna
Award Solutions
Email: asmuhanna@yahoo.com

Byoung-Jo Kim
ATT Labs
Email: macsbug@research.att.com

Hassan Ali-Ahmad
Orange
Email: hassan.aliahmad@orange.com

Alper Yegin
Samsung
Email: alper.yegin@partner.samsung.com

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Authors' Addresses

H Anthony Chan (editor)
Huawei Technologies
5340 Legacy Dr. Building 3, Plano, TX 75024, USA
Email: h.a.chan@ieee.org

Dapeng Liu
China Mobile
Unit2, 28 Xuanwumenxi Ave, Xuanwu District, Beijing 100053, China
Email: liudapeng@chinamobile.com

Pierrick Seite
Orange
4, rue du Clos Courtel, BP 91226, Cesson-Sevigne 35512, France
Email: pierrick.seite@orange.com

Hidetoshi Yokota
KDDI Lab
2-1-15 Ohara, Fujimino, Saitama, 356-8502 Japan
Email: yokota@kddilabs.jp

Jouni Korhonen
Broadcom Communications
Porkkalankatu 24, FIN-00180 Helsinki, Finland
Email: jouni.nospam@gmail.com