         A unified mobility management protocol framework and DMM gap analysis
                draft-chan-dmm-framework-gap-analysis-02

Abstract

   This draft proposes a unified framework of mobility management in
   terms of abstracted logical functions. It is shown that mip, pmip,
   and several of their extensions can be expressed in terms of
   different configurations of these logical functions. Such a unified
   framework provides a convenient view on gap analysis of existing
   protocols, and also on the needed re-configurations of the logical
   functions as well as the needed extensions towards distributed
   mobility management.

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   This Internet-Draft will expire on January 14, 2013.

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1. Introduction

   While there are research on new protocols for distributed mobility
   management it has also been proposed, e.g., in [Paper-
   Distributed.Mobility.PMIP] and in many other publications, that
   distributed mobility management can be designed using primarily the
   existing mobility management protocols with extensions. A
   requirement in distributed mobility management is to first use
   existing protocols and their extensions before considering new
   protocol design.

   Mobile IP [RFC6275] , which has primarily been deployed in a
   centralized manner for the hierarchical mobile networks, has numerous
   variants and extensions including PMIP [RFC5213] , hierarchical MIP
   (HMIP) [RFC5380] , Fast MIP (FMIP) [RFC4068] [RFC4988] , Proxy-based
   FMIP (PFMIP) [RFC5949] and more. These different modifications or
   extensions of MIP have been developed over the years owing to the
   different needs that are found afterwards.

   It is convenient to abstract the functions of existing mobility
   management protocols in terms of logical functions. Different
   variants of existing mobility management protocols are then different
   design variations of how the logical functions are configured. The
   result is a convenient framework to perform gap analysis of the
   existing protocols, and to reconfigure these logical functions
   towards various distributed mobility management designs.

1.1. Overview

   Section 3 proposes to abstract the existing mobility management
   protocols functions into the logical functions of home address
   allocation, mobility routing, location management, and proxy. Such
   decoupling enables separation between the data plane and the control
   plane, and enables flexibility for the implementation to place the
   logical functions at their most appropriate locations.

   Section 4 shows that the logical functions can indeed perform the
   same functions as the major existing mobility protocols. These
   functions therefore enables a unified framework upon which different
   designs of distributed mobility may be constructed.

   Section 5 presents the gap analysis of the existing protocols by
   comparing them against the DMM requirements of first taking advantage
   of existing protocols, compatibility, distributed deployment,
   dynamically providing mobility support, route optimization, IPv6
   deployment, and security considerations.

   Extensions to overcome the gaps are illustrated in Sections 6-8.

With the unified framework, extensions to dynamically provide
mobility support is described in Section 6 where the home IP address
of an MN is generalized to that of an application session. A
distributed database architecture is described in Section 7. Using
this distributed architecture, various route optimization can be
achieved as is described in Section 8.

2. Conventions and Terminology

2.1. Conventions used in this document

   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 [RFC2119].

2.2. 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] and in the Proxy mobile IPv6
   specification [RFC5213]. These terms include mobile node (MN),
   correspondent node (CN), home agent (HA), local mobility anchor
   (LMA), and mobile access gateway (MAG).

   In addition, this draft introduces the following terms.

   Mobility routing (MR) is the logical function to intercept packets
      to/from the HoA of a mobile node and to forward the packets, based
      on the internetwork location information, either to the
      destination or to some other network element that knows how to
      forward to the destination.

   Home address allocation is the logical function to allocate the home
      network prefix or home address to a mobile node.

   Location management (LM) is the logical function to manage and keep
      track of the internetwork location information of a mobile node,
      which include a mapping of the HoA of the MN to the routing
      address of the MN or another network element that knows how to
      forward packets towards the MN.

      Optionally, one (or more) proxy may exist between LM and MN so
      that the LM function is maintained in the hierarchy LM-proxy-MN.
      Then to the LM, the proxy behaves like the MN; to the MN, the
      proxy behaves like the LM.

Home network of an application session (or an HoA IP address) (LM)
is the network that has allocated the IP address used as the
session identifier (HoA) by the application being run in an MN.
Because a MN may run multiple applications each using a different
HoA, the notion of the home network may be generalized to that of
an application session rather than that of a MN.

3. Logical functions of mobility management

The existing mobility management functions of MIP, PMIP, and HMIP may
be abstracted into the following logical functions to provide a
unified framework of existing mobility management and to allow a more
flexible design to achieve DMM. These logical functions are as
follows:

1. allocation of home network prefix or HoA to a MN that registers
    with the network;

2. mobility routing (MR) function: intercepting packets to/from the
    HoA of the MN and forwarding the packets, based on the
    internetwork location information, either to the destination or
    to some other network element that knows how to forward to the
    destination. and

3. internetwork location management (LM) function: managing and
    keeping track of the internetwork location of a MN, which include
    a mapping of the HoA to the mobility anchoring point that the MN
    is anchored to;

    (Optionally, one (or more) proxy may exist between LM and MN so
    that the LM function is maintained in the hierarchy LM-proxy-MN.
    Then to the LM, the proxy behaves like the MN; to the MN, the
    proxy behaves like the LM.)

4. Functional represenation of existing mobility protocols

This section shows that the existing mobility management protocols
can be expressed as different configurations of the above logical
functions in a unified framework.

4.1. Mobile IP

Figure 1 shows Mobile IPv6 [RFC6275] in the functional
representation. A mobile node MN11 was originally attached to the

first network (Network1) and was allocated the IP prefix for HoA11.
Now, MN11 has moved to Network3, from which it is allocated a new IP
address IP32. LM1 keeps the binding HoA11: IP32 so that packets from
CN21 in Network2 destined to HoA11 will be intercepted by MR1, which
will then tunnel the packet to IP32.


```
  Network1        Network3        Network2
   +-----+
   | LM1 |
   +-----+
 HoA1 alc        IP3 alc         IP2 alc
     |
     |
   +-----+
   | MR1 |
   +-----+
     .
     .        +----+ +----+      +----+
     .        |MN31| |MN11|      |CN21|
     .        +----+ +----+      +----+
   HoA11       IP31   IP32,
                      HoA11
```
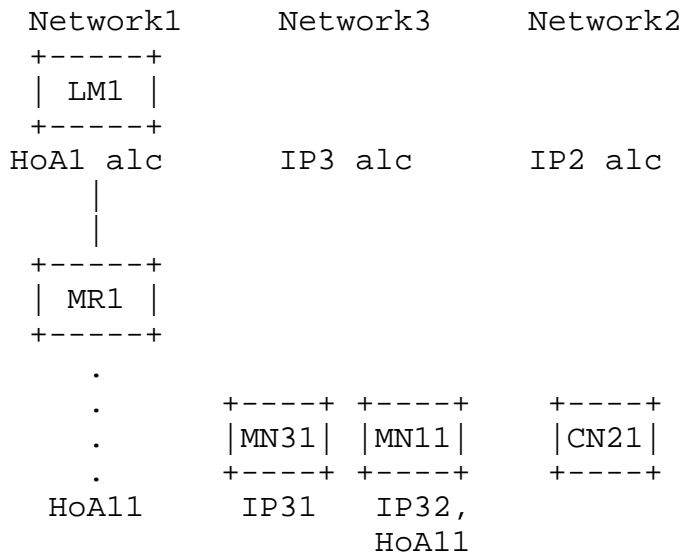
Figure 1. Functional representation of Mobile IP.

4.2. MIP versus PMIP

MIP and PMIP both employ the same concept of separating session
identifier and routing address into the HoA and CoA respectively.
Figure 2 compares (a) MIP and (b) PMIP by showing the destination IP
address in the network-layer header as a packet traverses from a CN
to an MN.

```
(a) MIP:
+---+        +---+---+        +---+
|HoA|  -->   |HoA|HoA|        |HoA|
|   |        |   |---|        |---|
|   |        |   |CoA| ==>    |CoA|
+---+        +---+---+        +---+
 CN           anchor           MN


(b) PMIP:
+---+        +---+---+        +---+---+       +---+
|HoA|  -->   |HoA|HoA|        |HoA|HoA|  -->  |HoA|
|   |        |   |---|        |---|   |       |   |
|   |        |   |C0A| ==>    |CoA|   |       |   |
+---+        +---+---+        +---+---+       +---+
 CN           anchor            MAG            MN
```
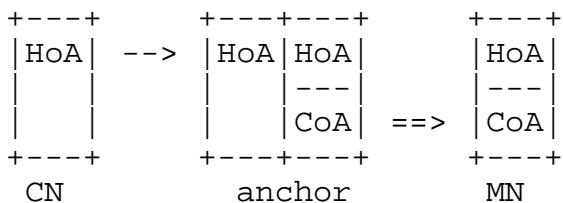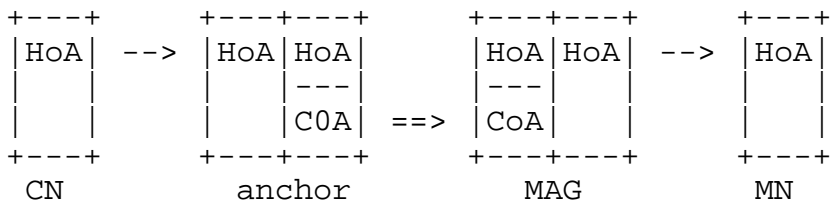
Figure 2. Network layer in the protocol stack of packets sent from
the CN and tunneled (a) to the MN in MIP; and (b) to the MAG in PMIP
showing the destination IP address as the packet traverses from the
CN to the MN.

The comparison shows that, as far as the data-plane traffic is
concerned, the route from CN to MN in MIP is similar to the route
from CN to MAG in PMIP. The difference is only in replacing the MN
in MIP with the MAG-MN combination in PMIP. Therefore, the
architecture using MIP can be adapted to the architecture using PMIP
by replacing the MN with the MAG-MN combination.

Mobile IP and Proxy mobile IP bundle all the three mobility
management logical functions: LM1, IP1 prefix allocation, and MR1
into the home agent and local mobility anchor respectively.

The functional representation of Proxy mobile IPv6 [RFC5213] is shown
in Figure 3. Here MN11 is attached to the access router AR31 which
has the IP address IP31 in Network3. LM1 keeps the binding HoA11:
IP31. The access router AR31 also behaves like a home link to MN11
so that MN11 can use its original IP address HoA11.

```
     Network1       Network3        Network2
     +-----+
     | LM1 |
     +-----+
   HoA1 alc      IP3 alc        IP2 alc
       |
       |
   +-----+
   | MR1 |
   +-----+
      .
      .          +----+ +----+     +----+
      .          |AR31| |MN32|     |CN21|
      .          +----+ +----+     +----+
   HoA11          IP31   IP32
                    |
                    |
                 +----+
                 |MN11|
                 +----+
                  HoA11
```

   Figure 3. Functional representation of PMIP.

4.3. Hierarchical Mobile IP

   The functional representation of Hierarchical Mobile IPv6 [RFC5380]
   is shown in Figure 4.

```
   Network1        Network3        Network2
    +-----+
    | LM1 |
    +-----+
  HoA1 alc        IP3 alc        IP2 alc
      |
      |
    +-----+         +-----+
    | MR1 |         | MR3 |
    +-----+         +-----+
      .            / \
      .           /   \
      .          /     \
      .     +----+ +----+      +----+
      .     |AR31| |MN11|      |CN21|
      .     +----+ +----+      +----+
   HoA11     IP31    IP32,
      |           HoA11
      |
            +----+
            |MN31|
            +----+
```
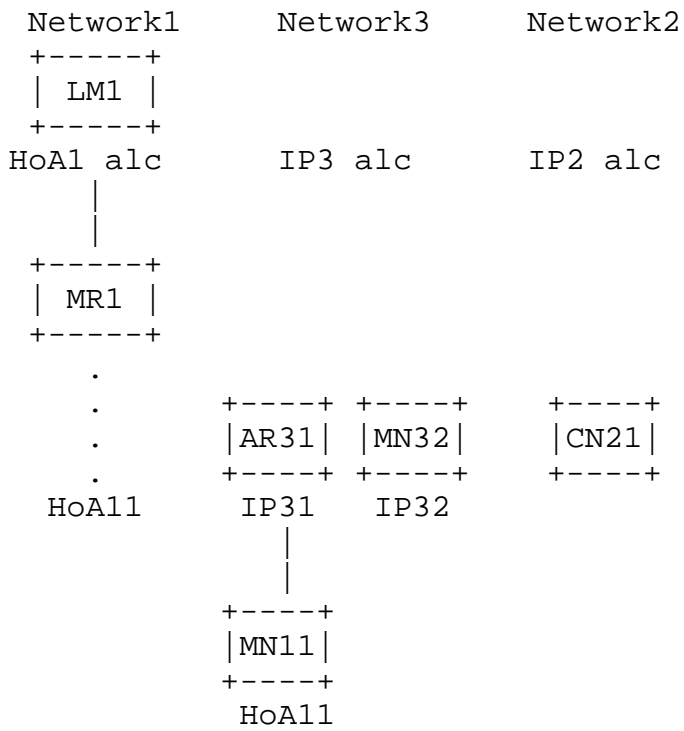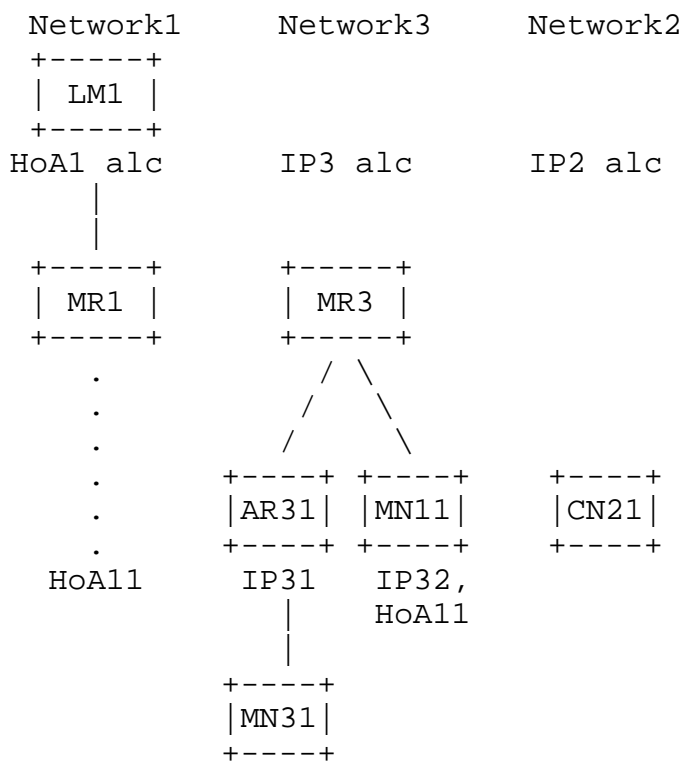
Figure 4. Functional representation of Hierarchical Mobile IP.

   Besides the logical functions: LM1, MR1, and HoA1 prefix allocation
   in Network1 as MIP in Figure 2 and PMIP in Figure 3, there is an MR
   function (MR3) in the visited network (Network3). The MR3 is also a
   proxy between LM1 and MN11 in the hierchical LM function LM1--MR3--
   MN11. That is, LM1 keeps the LM binding HoA11:MR3 and MR3 keeps the
   LM binding HoA11:IP32.

   In Figure 4, if MN11 takes the place of MN31 which is attached to
   AR31, the resulting mobility management becomes network-based.

4.4. Migrating home agents

   When all these logical functions are bundled into one single entity
   known as the home agent in Mobile IP and as the local mobility anchor
   in Proxy Mobile IP, having this anchor in only one network results in
   triangle routing when the MN and the CN are in networks close to each
   other but are far from the anchor points.

   A method to solve the triangle routing problem is to duplicate the
   anchor points in many networks in different geographic locations as
   in [Paper-Migrating.Home.Agents]. A functional representation of
   Migrating Home Agents is shown in Figure 5.

```
  Network1        Network3        Network2
  +-----+         +-----+         +-----+
  | LM0 |------| LM0 |------| LM0 |
  +-----+         +-----+         +-----+
 HoA1 alc        HoA3 alc        HoA2 alc
    |               |               |
    |               |               |
  +-----+         +-----+         +-----+
  | MR1 |         | MR3 |         | MR2 |
  +-----+         +-----+         +-----+
    .              / \
    .             /   \
    .            /     \
    .          +----+ +----+      +----+
    .          |AR31| |MN11|      |CN21|
    .          +----+ +----+      +----+
 HoA11          IP31   IP32,
    |                  HoA11
                    |
                 +----+
                 |MN31|
                 +----+
```
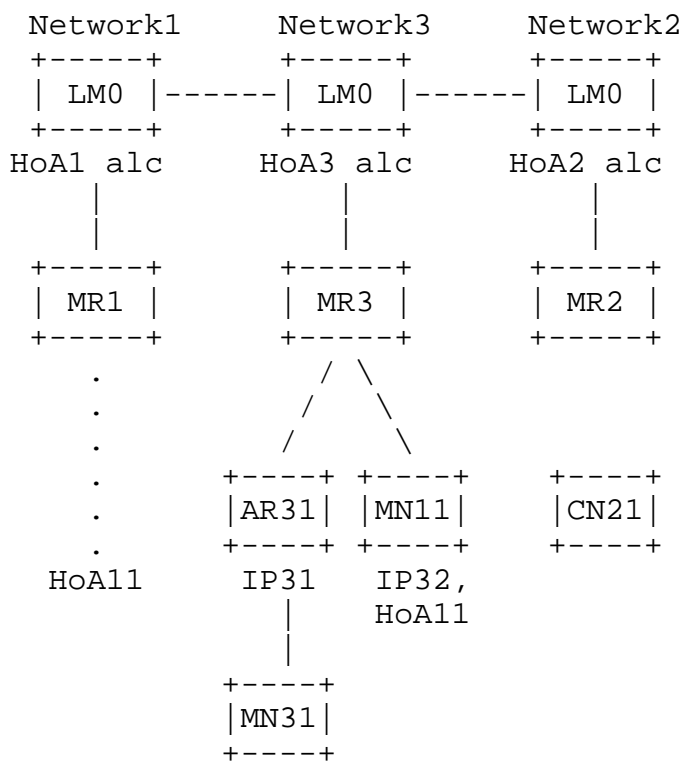
Figure 5. Functional representation of Migrating Home Agents.

Here, the MR function is available in each of the three networks
Network1, Network2, and Network3? the LM function in each network
(LM0) contains the LM information of all the networks. Each MR in
each network advertises the HoA IP prefixes of all these networks
using anycast. Traffic from CN21 in Network2 destined to HoA11 will
therefore be intercepted by the MR nearest to CN, which is MR2.
Using the LM information in LM0 MR2 will using the binding HoA11:IP32
to tunnel the packet to MN11.

Similarly, traffic originating from MN11 will be served by its
nearest MR (MR3). Trianle routing is therefore avoided. Yet the
synchronization of all the home agents will then be a challenge
[Paper-SMGI]. In addition, the amount of signaling traffic needed in
synchronizing the home agents may become excessive when the number of
mobile nodes and the number of home agents both increase.

As before, if MN11 in Figure 5 takes the place of MN31 which is
attached to AR31, the resulting mobility management becomes network-
based.

5. Gap analysis

5.1. Considering existing protocols first

   The fifth DMM requirement is on existing mobility protocols.

   REQ5: A DMM solution SHOULD first consider reusing and extending the
   existing mobility protocols before specifying new protocols.

   Abstracting the existing protocol functions into logical functions in
   this draft is a way to see how one can maximize the use of existing
   protocols. It remains to be seen whether all the DMM requirements
   can be met. One needs to check the rest of the requirements to check
   for gaps.

5.2. Compatibility

   The second part of the fourth DMM requirement is on compatibility:

   REQ4: The DMM solution SHOULD be able to work between trusted
   administrative domains when allowed by the security measures deployed
   between these domains. Furthermore, the DMM solution MUST be able to
   co-exist with existing network deployment and end hosts so that the
   existing deployment can continue to be supported. For example,
   depending on the environment in which dmm is deployed, the dmm
   solutions may need to be compatible with other existing mobility
   protocols that are deployed in that environment or may need to be
   interoperable with the network or the mobile hosts/routers that do
   not support the dmm enabling protocol.

5.3. Distributed deployment

   The first DMM requirement is on Distributed deployment IP mobility.

   REQ1:network access and routing solutions provided by DMM MUST enable
   a distributed deployment of mobility management of IP sessions so
   that the traffic can be routed in an optimal manner without
   traversing centrally deployed mobility anchors.

   Multiple MRs are allowed in MIP by simply having an HA for each home
   network. It is illustrated in terms of the logical functions as in
   Figure 6.

   The figure shows, as an example, three networks. Each network has
   its own IP prefix allocation function. The mobility routing function
   is distributed to multiple locations at the MRs so that routing can
   be optimized. Again, the resulting mobility management becomes
   network-based if MN takes the position of MN31.

```
   +-----+        +-----+        +-----+
   | LM1 |        | LM2 |        | LM3 |
   +-----+        +-----+        +-----+
  HoA1 alc       HoA3 alc       HoA2 alc
     |              |              |
     |              |              |
   +-----+        +-----+        +-----+
   | MR1 |        | MR3 |        | MR2 |
   +-----+        +-----+        +-----+
     .            / \
     .           /   \
     .          /     \
     .      +----+ +----+       +----+
     .      |AR31| |MN11|       |CN21|
     .      +----+ +----+       +----+
   HoA11     IP31   IP32,
     |               HoA11
     |
          +----+
          |MN31|
          +----+
```
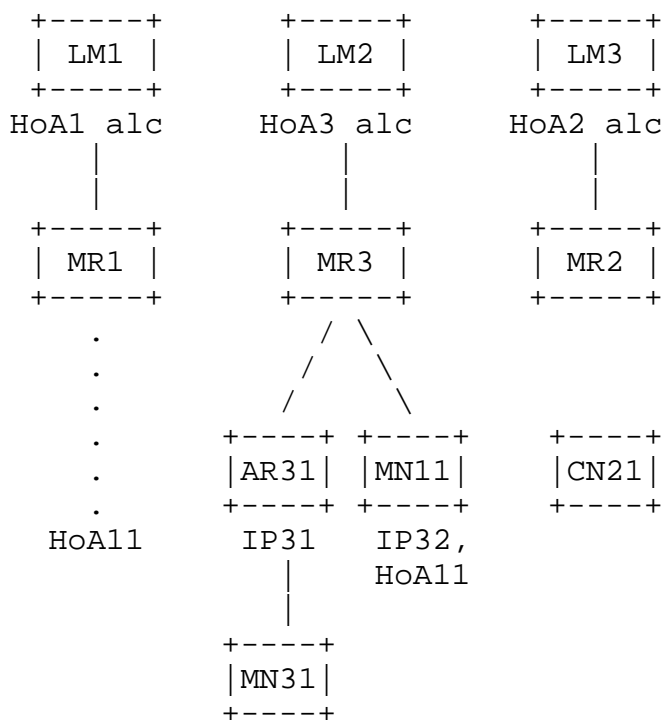
   Figure 6. A distributed architecture of mobility management.

5.4. Dynamically providing mobility support

   To see how to avoid traversing centralized deployed mobility anchors,
   let us look at the second requirement on non-optimal routes.

   REQ2: The DMM solutions MUST provide transparency above the IP layer
   when needed. Such transparency is needed, when the mobile hosts or
   entire mobile networks [RFC3963] change their point of attachment to
   the Internet, for the application flows that cannot cope with a
   change of IP address. Otherwise the support to maintain a stable
   home IP address or prefix during handover may be declined.

   In order to avoid traversing long routes after the MN has moved to a
   new network, the new network can simply be used as the home network
   for new sessions. The sessions that had already started in the
   previous network would still need to use the original network in
   which the session had started as the home network. There may then be
   different IP sessions using different IP prefixes/addresses in the
   same MN.

   The capability to use different IP addresses for different IP
   sessions are therefore needed.

   The assoication with the HoA of a MN is not sufficient to support the

above use of IP for an application. This gap can be overcome by
generalizing the concept of the HoA of the MN to the HoA of an
application running on the MN as will be discussed in Section 7.1
below.

Using the dynamic mobility management scheme has avoided routing back
to the home network when the application does not have such need.
There are however application sessions that had originated from a
prior network and that also requires mobility support. Longer routes
than the natural IP route can be encountered. Route optimization
schemes already exist, but one needs to deal with multiple HA's when
using multiple HA's.

5.5. Route optimization

One generalization in terms of the unified framework is that the LM
functions can be considered as a distributed database as will be
shown in the next section. There, the MN and the LM has a client-
server relationship, with optionally a proxy in between and the proxy
which can co-locate with an MR. A distributed database may have
different servers to store different data. The data in each server
need not be pushed to all the other servers but the database system
only needs to know which data resides in which server. In addition,
each client needs to be able to query the database.

The existing functions such as BU and BA can be considered as the
database function to update a record. Completing the design of
messages of the database functions will enable the distributed
database design.

In the unified scheme complete with database function and mobility
routing function, numerous route optimizations can be designed as
described in Section 8.

5.6. IPv6 deployment

The third DMM requirement on IPv6 deployment

REQ3: The DMM solutions SHOULD target IPv6 as primary deployment and
SHOULD NOT be tailored specifically to support IPv4, in particular in
situations where private IPv4 addresses and/or NATs are used.

is not an issue with the MIPv6, PMIPv6 and their extensions. Using
the unified scheme here based on abstracting these existing protocol
functions will meet the DMM requirements.

5.7. Security

   The first part of the fourth requirement as well as the sixth DMM
   requirement are on security considerations.

   REQ6: The protocol solutions for DMM MUST consider security, for
   example authentication and authorization mechanisms that allow a
   legitimate mobile host/router to access to the DMM service,
   protection of signaling messages of the protocol solutions in terms
   of authentication, data integrity, and data confidentiality, opti-in
   or opt-out data confidentiality to signaling messages depending on
   network environments or user requirements.

   are on security. It is preferred that these security requirements be
   considered as an integral part of the DMM design.

6. Dynamic mobility management

   The above distributed architecture, which has an MR and an HoA
   allocation function in each network, enables dynamic mobility
   management.

   When new applications are started after moving to a new network, the
   device can simply use a new IP address allocated by the new network.
   Dynamic mobility management, i.e., invoking mobility management only
   when needed, has been proposed in [Paper-
   Distributed.Dynamic.Mobility].

   The architecture with multiple mobility routing functions compared
   with a centralized approach is more convenient to achieve dynamic
   mobility management. In Figure 6 above, the LM function and the IP
   address allocation function may co-locate. The device MN11
   originally attached to the first network (Network1) may simply be
   using a dynamic IP address HoA11 which is leased from Network1 with a
   finite lifetime of say 24 hours. As MN11 leaves the first network
   and attaches to the third network (Network3), it acquires a new IP
   address IP33 from Network3. MN11 may or may not have ongoing
   sessions requiring session continuity. If it does not, there is no
   need for LM1 to keep a binding for the home address HoA11 of MN11.
   If it does, it may use the existing MIP signaling mechanism so that
   the LM1 will keep the binding HoA11:MR3. MR3 in turn will keep the
   binding HoA11:IP33. Such a hierchy of binding with MR3 acting as the
   proxy location maintenance function between LM1 and MN11 will also
   cause MR3 to act as a proxy mobility routing function between MR1 and
   MN11 so that packets destined to MR1 will be redirected to MR3.

   When all the ongoing sessions requiring session continuity have

terminated, it is possible for MN11 to deregister with LM1. Yet one
may not assume the device will always perform the de-registration.
Alternatively the lease of the dynamic IP address HoA11 will expire
upon which LM1 will remove the binding.

In the event that the ongoing session outlives the lease of the
HoA11, MN11 will need to renew the lease with the IP address
allocation function in the first network.

More details on dynamically providing mobility support are found in
[ID.seite-dmm-dma], [ID.liu-dmm-dynamic-anchor-discussion],
[ID.bernardos-dmm-pmip], [I-D.ma-dmm-armip], and [ID.sarikaya-dmm-
dmipv6].

[I-D.seite-dmm-dma] describes the dynamic mobility management using
PMIP. There the MR, LM, and the HoA allocation functions are co-
located at the access router in a flattened network.

[Paper-Net.based.DMM], or equivalently the draft [I-D.seite-dmm-dma],
also describes dynamic mobility management in which the MR and the
HoA allocation function are both co-located at the access router
whereas the LM information in each of these access routers are linked
together under the hierarchy of a centralized LM server.

[ID.sarikaya-dmm-dmipv6] also described dynamic mobility management
for a flattened network, with separate data plane and control plane.
The needed authentication is also described.

[ID.bernardos-dmm-pmip] co-locates the home prefix allocation
function and the mobility routing function at the access router,
which is then named Mobility Anchor and Access Router (MAAR) in that
draft. The LM function is centralized and is named Central Mobility
Database (CMD).

[I-D.ma-dmm-armip] again describes dynamic mobility management in
which the MR and the HoA allocation function are both co-located at
the access router.

[ID.liu-dmm-dynamic-anchor-discussion] describes the gaps and
extensions needed to accomplish dynamic mobility management.

6.1. Home network of an application session

Because a MN may run multiple applications each using a different IP
address, there can be multiple HoAs belong to different networks.
Therefore the notion of home network may be generalized to that of an
application session or the IP address used by that session as an HoA.
Then the home network of an application session is simply the network

that has allocated the IP address used as the session identifier
(HoA) by the application run in an MN.

7. Multiple MRs and distributed LM database

   The different use case scenarios of distributed mobility management
   are described in [I-D.dmm-scenario] as well as in [Paper-
   Distributed.Mobility.Review]. The architecture described in this
   draft is mainly on separating the data plane and the control plane.

   Figure 7 shows an architecture of DMM with an example of the same
   three networks in Figure 6. As is in Figure 6, each network in
   Figure 7 has its own IP prefix allocation function. In the data
   plane, the mobility routing function is distributed to multiple
   locations at the MRs so that routing can be optimized. In the
   control plane, the MRs may signal with each other. In addition to
   these features in Figure 6, the LM function in Figure 7 is a
   distributed database, with multiple servers, of the mapping of HoA to
   CoA.

```
    Network1         Network3         Network2
    +-----+          +-----+          +-----+
    | LM1 |          | LM3 |          | LM2 |
    +-----+          +-----+          +-----+
   HoA1 alc         HoA3 alc         HoA2 alc
     | \ \         / | \         / / |
     |  \  \      /  |  \      /  /   |
     |   \   \   /   |   \/   /   /   |
     |    \   \/ \   |   /\  /   /    |
     |     \  /\  \| /    \/   /      |
     |      \/  \  /|\     /\ /       |
     |      /\   \/ | \   /  \/       |
     |     /  \  /\ |  \ /   /\       |
     |    /   / \  \|   /   /  \ \    |
     |   /   /   \  | /   /    \ \    |
     |  / /       \ | /        \ \ |
    +-----+          +-----+          +-----+
    | MR1 |------| MR3 |------| MR2 |
    +-----+          +-----+          +-----+
       .              / \
       .             /   \
       .            /     \
       .           /       \
       .       +----+ +----+      +----+
       .       |AR31| |MN11|      |CN21|
       .       +----+ +----+      +----+
    HoA11        IP31   IP32,
                 |      HoA11
                 |
               +----+
               |MN31|
               +----+
```
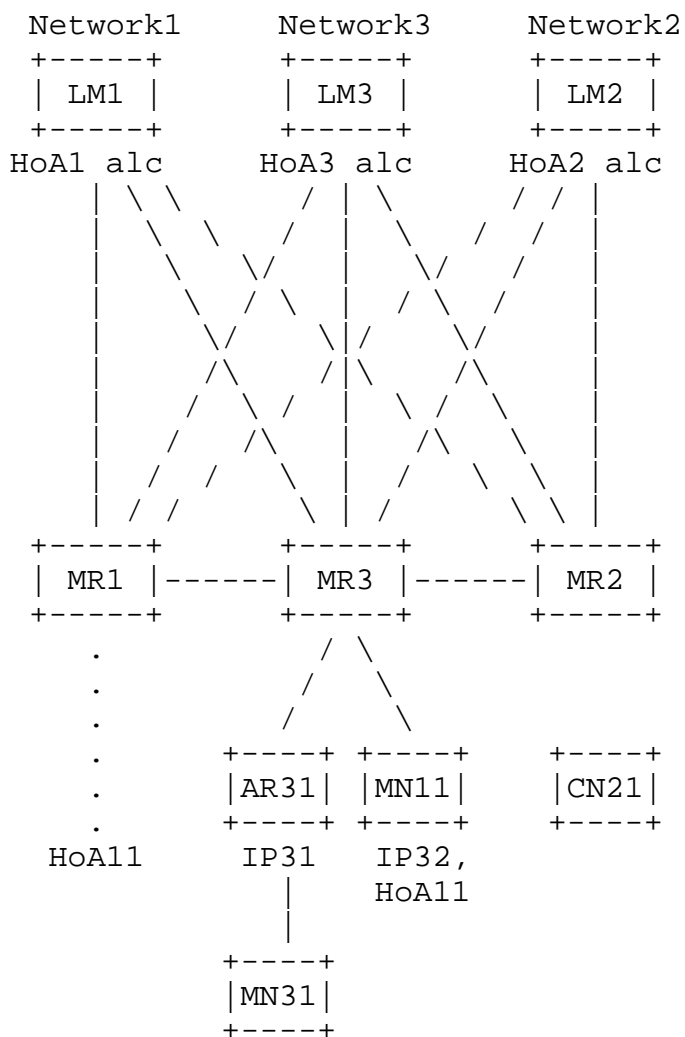
Figure 7. A distributed architecture of mobility management.

To perform mobility routing, the MRs need the location information
which is maintained at the LMs. The MRs are therefore the clients of
the LM servers and may also send location updates to the LM as the
MNs perform handover. The location information may either be pulled
from the LM servers by the MR or pushed to the MR by the LM servers.
In addition, the MR may also cache a limited amount of location
information.

This figure shows three MRs (MR1, MR2, and MR3) in three networks.
MN11 has moved from the first network supported by MR1 and LM1 to the
third network supported by MR3 and LM3. It may use an HoA (HoA11)
allocated to it when it was in the first network for those
application sessions that had already started when MN11 was attached
there and that require session continuity after handover to the third
network. When MN11 was in the first network, no location management

is needed so that LM1 will not keep an entry of HoA11. After MN11
has performed handover to the third network, the database server LM1
keeps a mapping of HoA11 to MR3. That is, it points to the third
network and it is the third network that will keep track of how to
reach MN11. Such an hierarchical of mapping can avoid frequent
update signaling to LM1 as MN11 performs intra-network handover
within the third network. In other words, the concept of
hierarchical mobile IP [RFC5380] is applied here but only in location
management and not in routing in the data plane.

8. Route optimization mechanisms

   The distributed architecture has already enabled dynamic mobility
   management, as is described in [I-D.seite-dmm-dma], even when the
   routes are not optimized. Route optimization mechanism can be
   achieved in addition to dynamic mobility.

   With the above architecture, there are a number of ways to enable
   reachability of an MN by packets sent from a CN using the mobility
   routing function.

   The target to avoid unnecessarily long route is the direct route
   instead of a triangular route. In general, when a packet is sent
   from a CN in one network to a MN in another network, the direct route
   consists of the following 3 routing segments (RS):

   RS1.CN-MR(CN): the route segment from the CN to the nearest MR;

   RS2.MR(CN)-MR(MN): the route segment from the MR serving (and
      therefore being closest to) the CN to the MR serving the MN; and

   RS3.MR(MN)-MN: the route segment from the MR serving the MN to the
      MN.

   One may therefore examine the route optimization mechanism in terms
   of these 3 routing segments. In the first segment RS1:CN-MR(CN), the
   alternatives are:

   RS1.CN-MR(CN).anycast: Use anycast to route the packet to the
      nearest MR function. Here, each MR includes all the HoAs in its
      route announcement as if each of them is the destination for the
      HoA. Such route announcements will affect the routing table such
      that the packet destined to an HoA will be routed to the nearest
      MR. The use of anycast to reach the nearest HA has been used in
      [Paper-Migrating.Home.Agents] but with a different distributed
      architecture of duplicating many HAs. It is again proposed in
      [Paper-Distributed.Mobility.PMIP].

   RS1.CN-MR(CN).gw/ar: Co-locate the MR function at a convenient
      location to which the packet will always pass. Such locations may
      be the gateway router or the access router. This approach will be
      described later.
      It is noted here that in PMIP design in a hierchical network,
      generally, the MAG is at the access router but LMA can be in the
      gateway router of a network. Whether a distributed mobility
      design enhances the MAG or the LMA may involve quite different
      mechanisms. Yet when looking at the logical function, it is
      basically the same MR function whether this function co-locates
      with the access router or the gateway router. This draft
      therefore put both approaches together. There is however a
      difference that the access router needs to perform proxying
      function when using PMIP. Yet the logical MR functions are the
      same.
      It is again noted that in flattened network, the access router and
      the gatway router may merge together. With they are merged, the
      needed function is again the same logical MR function.

   In the second segment RS2.MR(CN)-MR(MN), the alternatives are:

   RS2.MR(CN)-MR(MN).query: The MR query the LM database and use the
      result to tunnel the packet to the MR serving the MN. In order
      words, the MR pulls the needed internetwork location information
      from the LM server. There will be a delay owing to the time taken
      to send this query and to receive the reply. Optionally, before
      receiving the reply, the first packet or the first few packets may
      be forwarded using mip or pmip. Then the first packet may incur a
      triangle route rather than to wait for the query reply. After
      receiving the reply, the packet will be tunneled to the MR(MN).
      The result may be cached for forwarding subsequent packets.

   RS2.MR(CN)-MR(MN).push: The MR routes the first packet to the home
      network using the existing MIP or PMIP mechanism. It will then be
      intercepted by the MR of the MN which, with the help of LM, knows
      whether the MN has moved to a different network and use the
      mapping in LM to tunnel the packet to the MR of the MN. Then the
      MR of the MN will inform MR of the CN to tunnel the packet
      directly to the MR of the MN in future. In order words, after
      MR(CN) has forwarded the first packet to MR(MN), the MR(MN) is
      triggered to push the location information to MR(CN). The MR of
      the CN may keep this information in its cache memory for
      forwarding subsequent packets.

   In the final segment RS3.MR(MN)-MN, the MR may keep track of the
   location of MN and route to it using its intra-network mobility
   management mechanism.

Different designs using the above architecture can be made by taking different combinations of the different designs in the different route segments. For example, the overall design of DMM may be:

1. RS1.CN-MR(CN).anycast followed by RS2.MR(CN)-MR(MN).query:

2. RS1.CN-MR(CN).anycast followed by RS2.MR(CN)-MR(MN).push:

    An example is [Paper-Distributed.Mobility.PMIP] which is explained for network-based mobile IP but is also applicable to host-based mobile IP.

3. RS1.CN-MR(CN).gw/ar followed by RS2.MR(CN)-MR(MN).query:

    An example is in [I-D.luo-dmm-pmip-based-dmm-approach] or [I-D.liu-dmm-pmip-based-dmm-approach] in which the MR function is co-located at the MAG which is usually at the access router. Here, when CN is also a MN using PMIP, the packet sent from it naturally goes to the access router which takes the logical function of MR so that it will query the LM, which resides in the LMA. It then uses the query result to tunnel the packet to the MR(MN), which resides in the AR/MAG of the destination MN. The signaling flow and other details are described in the referenced draft.

    Another example is in [I-D.jikim-dmm-pmip]. In the signal driven approach, the MR is co-located the access router, which is considered as an extension of MAG. The MR, i.e., the extended MAG, serving the CN queries the LM and cache the result so that it can tunnel packets to the MR serving the destination MN.

    [I-D.dmm-nat-phl] also colocates the MR at the gateways. The gateway which serves the network of transmitting node and where the MR is colocated is called the Ingress router, whereas that at the network of the MN at the receiving side is called egress router. Instead of tunneling between these 2 gateways, header rewrite using NAT is used to forward the packet through the internetwork route segment.

4. RS1.CN-MR(CN).gw/ar followed by RS2.MR(CN)-MR(MN).push:

    Another example is described in [Paper-Distributed.Mobility.Management].

9. Security Considerations

    TBD

10. IANA Considerations

   None

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