DMM
Internet-Draft
Intended status: Informational
Expires: May 4, 2020

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November 1, 2019

Distributed Mobility Anchoring
draft-ietf-dmm-distributed-mobility-anchoring-14

Abstract

This document defines distributed mobility anchoring in terms of the different configurations and functions to provide IP mobility support. A network may be configured with distributed mobility anchoring functions for both network-based or host-based mobility support according to the needs of mobility support. In a distributed mobility anchoring environment, multiple anchors are available for mid-session switching of an IP prefix anchor. To start a new flow or to handle a flow not requiring IP session continuity as a mobile node moves to a new network, the flow can be started or re-started using an IP address configured from the new IP prefix anchored to the new network. If the flow needs to survive the change of network, there are solutions that can be used to enable IP address mobility. This document describes different anchoring approaches, depending on the IP mobility needs, and how this IP address mobility is handled by the network.

Status of This Memo

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1. Introduction

A key requirement in distributed mobility management [RFC7333] is to enable traffic to avoid traversing a single mobility anchor far from

an optimal route. This document defines different configurations, functional operations and parameters for distributed mobility anchoring and explains how to use them to avoid unnecessarily long routes when a mobile node moves.

Companion distributed mobility management documents are already addressing the architecture and deployment [I-D.ietf-dmm-deployment-models], source address selection [RFC8653], and control-plane data-plane signaling [I-D.ietf-dmm-fpc-cpdp]. A number of distributed mobility solutions have also been proposed, for example, in [I-D.seite-dmm-dma], [I-D.ietf-dmm-pmipv6-dlif], [I-D.sarikaya-dmm-for-wifi], [I-D.yhkim-dmm-enhanced-anchoring], and [I-D.matsushima-stateless-uplane-vepc].

Distributed mobility anchoring employs multiple anchors in the data plane. In general, control plane functions may be separated from data plane functions and be centralized but may also be co-located with the data plane functions at the distributed anchors. Different configurations of distributed mobility anchoring are described in Section 3.1.

As a Mobile Node (MN) attaches to an access router and establishes a link between them, a /64 IPv6 prefix anchored to the router may be assigned to the link for exclusive use by the MN [RFC6459]. The MN may then configure a global IPv6 address from this prefix and use it as the source IP address in a flow to communicate with its correspondent node (CN). When there are multiple mobility anchors assigned to the same MN, an address selection for a given flow is first required before the flow is initiated. Using an anchor in a MN's network of attachment has the advantage that the packets can simply be forwarded according to the forwarding table. However, after the flow has been initiated, the MN may later move to another network which assigns a new mobility anchor to the MN. Since the new anchor is located in a different network, the MN's assigned prefix does not belong to the network where the MN is currently attached.

When the MN wants to continue using its assigned prefix to complete ongoing data sessions after it has moved to a new network, the network needs to provide support for the MN's IP address -- and session continuity, since routing packets to the MN through the new network deviates from applying default routes. The IP session

continuity needs of a flow (application) determines how the IP address used by this flow has to be anchored. If the ongoing IP flow can cope with an IP prefix/address change, the flow can be reinitiated with a new IP address anchored in the new network. On the other hand, if the ongoing IP flow cannot cope with such change, mobility support is needed. A network supporting a mix of flows both requiring and not requiring IP mobility support will need to distinguish these flows.

2. Conventions and Terminology

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "NOT RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in BCP 14 [RFC2119] [RFC8174] when, and only when, they appear in all capitals, as shown here.

All general mobility-related terms and their acronyms used in this document are to be interpreted as defined in the Mobile IPv6 (MIPv6) base specification [RFC6275], the Proxy Mobile IPv6 (PMIPv6) specification [RFC5213], the "Mobility Related Terminologies" [RFC3753], and the DMM current practices and gap analysis [RFC7429]. These include terms such as mobile node (MN), correspondent node (CN), home agent (HA), home address (HoA), care-of-address (CoA), local mobility anchor (LMA), and mobile access gateway (MAG).

In addition, this document uses the following terms:

Home network of a home address: the network that has assigned the HoA used as the session identifier by the application running in an MN. The MN may be running multiple application sessions, and each of these sessions can have a different home network.

Anchoring (of an IP prefix/address): An IP prefix, i.e., Home Network Prefix (HNP), or address, i.e., HoA, assigned for use by an MN is topologically anchored to an anchor node when the anchor node is able to advertise a connected route into the routing

infrastructure for the assigned IP prefix. The traffic using the assigned IP address/prefix must traverse the anchor node. We can refer to the function performed by IP anchor node as anchoring, which is a data plane function.

Location Management (LM) function: control plane function that keeps and manages the network location information of an MN. The location information may be a binding of the advertised IP address/prefix, e.g., HoA or HNP, to the IP routing address of the MN or of a node that can forward packets destined to the MN.

When the MN is a mobile router (MR), the location information will also include the mobile network prefix (MNP), which is the aggregate IP prefix delegated to the MR to assign IP prefixes for use by the mobile network nodes (MNNs) in the mobile network.

In a client-server protocol model, location query and update messages may be exchanged between a Location Management client

(LMc) and a Location Management server (LMs), where the location information can be updated to or queried from the LMc. Optionally, there may be a Location Management proxy (LMp) between LMc and LMs.

With separation of control plane and data plane, the LM function is in the control plane. It may be a logical function at the control plane node, control plane anchor, or mobility controller.

It may be distributed or centralized.

Forwarding Management (FM) function: packet interception and forwarding to/from the IP address/prefix assigned for use by the MN, based on the internetwork location information, either to the destination or to some other network element that knows how to forward the packets to their destination.

This function may be used to achieve traffic indirection. With separation of control plane and data plane, the FM function may split into a FM function in the data plane (FM-DP) and a FM function in the control plane (FM-CP).

FM-DP may be distributed with distributed mobility management. It may be a function in a data plane anchor or data plane node.

FM-CP may be distributed or centralized. It may be a function in a control plane node, control plane anchor or mobility controller.

3. Distributed Mobility Anchoring

3.1. Configurations for Different Networks

We next describe some configurations with multiple distributed anchors. To cover the widest possible spectrum of scenarios, we consider architectures in which the control and data planes are separated, as described in [I-D.ietf-dmm-deployment-models].

3.1.1. Network-based DMM

Figure 1 shows a general scenario for network-based distributed mobility management.

The main characteristics of a network-based DMM solution are:

- o There are multiple data plane anchors, each with a FM-DP function.

- o The control plane may either be distributed (not shown in the figure) or centralized (as shown in the figure).
- o The control plane and the data plane (Control Plane Anchor -- CPA -- and Data Plane Anchor -- DPA) may be co-located or not. If the CPA is co-located with the distributed DPAs, then there are multiple co-located CPA-DPA instances (not shown in the figure).
- o An IP prefix/address IP1 (anchored to the DPA with IP address IPa1) is assigned for use to a MN. The MN uses this IP1 address to communicate with CNs (not shown in the figure).
- o The location management (LM) function may be co-located or split (as shown in the figure) into a separate server (LMs) and a client (LMc). In this case, the LMs may be centralized whereas the LMc may be distributed or centralized.

```
           ____________  Network
```

```
          ___/            \___________
         /      +-----+                \___
        (       |LMs  |    Control         \
       /        +-.---+    plane            \
      /  +--------.---+    functions         \
     (   |CPA:    .   |    in the             )
     (   |FM-CP, LMc  |    network            )
     (   +------------+                        \
    /          . .                              \
   (           .     .                           )
   (           .         .                       )
   (           .             .                   \
    \    +------------+ +------------+Distributed )
     (   |DPA(IPa1):  | |DPA(IPa2):  |DPAs        )
     (   |anchors IP1 | |anchors IP2 |          _/
      \  |FM-DP       | |FM-DP       | etc.    /
       \ +------------+ +------------+        /
        \___                Data plane  _____/
            \______         functions  /
                   \__________________/

         +------------+
         |MN(IP1)     | Mobile node attached
         |flow(IP1,..)| to the network
         +------------+
```

Figure 1: Network-based DMM configuration

3.1.2. Client-based DMM

Figure 2 shows a general scenario for client-based distributed mobility management. In this configuration, the mobile node performs Control Plane Node (CPN) and Data Plane Node (DPN) mobility

functions, namely the forwarding management and location management (client) roles.

```
          +-----+
          |LMs  |
          +-.---+
   +--------.---+
   |CPA:    .   |
```

```
|FM-CP, LMp  |
+------------+
      . .
      .     .
      .         .
      .             .
+------------+ +------------+ Distributed
|DPA(IPa1):  | |DPA(IPa2):  | DPAs
|anchors IP1 | |anchors IP2 |
|FM-DP       | |FM-DP       |  etc.
+------------+ +------------+

+------------+
|MN(IP1)     |Mobile node
|flow(IP1,..)|using IP1
|FM,    LMc  |anchored to
+------------+DPA(IPa1)
```

Figure 2: Client-based DMM configuration

4. IP Mobility Handling in Distributed Anchoring Environments - Mobility Support Only When Needed

IP mobility support may be provided only when needed instead of being provided by default. Three cases can be considered:

- o Nomadic case: no address continuity is required. The IP address used by the MN changes after a movement and traffic using the old address is disrupted. If session continuity is required, then it needs to be provided by a solution running at L4 or above.
- o Mobility case, traffic redirection: address continuity is required. When the MN moves, the previous anchor still anchors the traffic using the old IP address, and forwards it to the new MN's location. The MN obtains a new IP address anchored to the new location, and preferably uses it for new communications, established while connected at the new location.
- o Mobility case, anchor relocation: address continuity is required. In this case the route followed by the traffic is optimized, by using some means for traffic indirection to deviate from default routes.

A straightforward choice of mobility anchoring is the following: the

MN's chooses as source IP address for packets belonging to an IP flow, an address allocated by the network the MN is attached to when the flow was initiated. As such, traffic belonging to this flow traverses the MN's mobility anchor [I-D.seite-dmm-dma] [I-D.ietf-dmm-pmipv6-dlif].

The IP prefix/address at the MN's side of a flow may be anchored to the access router to which the MN is attached. For example, when a MN attaches to a network (Net1) or moves to a new network (Net2), an IP prefix from the attached network is assigned to the MN's interface. In addition to configuring new link-local addresses, the MN configures from this prefix an IP address which is typically a dynamic IP address. It then uses this IP address when a flow is initiated. Packets from this flow addressed to the MN are simply forwarded according to the forwarding table.

There may be multiple IP prefixes/addresses that an MN can select when initiating a flow. They may be from the same access network or different access networks. The network may advertise these prefixes with cost options [I-D.mccann-dmm-prefixcost] so that the mobile node may choose the one with the least cost. In addition, these IP prefixes/addresses may be of different types regarding whether mobility support is needed [RFC8653]. A MN will need to choose which IP prefix/address to use for each flow according to whether it needs IP mobility support or not, using for example the mechanisms described in [RFC8653].

4.1. Nomadic case (no need of IP mobility): Changing to new IP prefix/address

When IP mobility support is not needed for a flow, the LM and FM functions are not utilized so that the configurations in Section 3.1 are simplified as shown in Figure 3.

```
   Net1                                                 Net2

   +---------------+                                    +---------------+
   |AR1            |            AR is changed           |AR2            |
   +---------------+              ------->              +---------------+
   |CPA:           |                                    |CPA:           |
   |---------------|                                    |---------------|
   |DPA(IPa1):     |                                    |DPA(IPa2):     |
   |anchors IP1    |                                    |anchors IP2    |
   +---------------+                                    +---------------+

   +...............+                                    +---------------+
   .MN(IP1)        .              MN moves              |MN(IP2)        |
   .flow(IP1,...)  .              =======>              |flow(IP2,...)  |
   +...............+                                    +---------------+
```

Figure 3: Changing to a new IP address/prefix

When there is no need to provide IP mobility to a flow, the flow may use a new IP address acquired from a new network as the MN moves to the new network.

Regardless of whether IP mobility is needed, if the flow has not terminated before the MN moves to a new network, the flow may subsequently restart using the new IP address assigned from the new network.

When IP session continuity is needed, even if a flow is ongoing as the MN moves, it may still be desirable for the flow to change to using the new IP prefix configured in the new network. The flow may then close and then restart using a new IP address configured in the new network. Such a change in the IP address of the flow may be enabled using a higher layer mobility support which is not in the scope of this document.

In Figure 3, a flow initiated while the MN was using the IP prefix IP1 -- anchored to a previous access router AR1 in network Net1 -- has terminated before the MN moves to a new network Net2. After moving to Net2, the MN uses the new IP prefix IP2 -- anchored to a new access router AR2 in network Net2 -- to start a new flow. Packets may then be forwarded without requiring IP layer mobility support.

An example call flow is outlined in Figure 4. A MN attaches to AR1, which sends a router advertisement (RA) including information about the prefix assigned to MN, from which MN configures an IP address

(IP1). This address is used for new communications, for example with a correspondent node (CN). If the MN moves to a new network and

attaches to AR2, the process is repeated (MN obtains a new IP address, IP2, from AR2). Since the IP address (IP1) configured at the previously visited network is not valid at the current attachment point, and any existing flows have to be reestablished using IP2.

Note that in this scenarios, if there is no mobility support provided by L4 or above, an application might be able to stop before changing point of attachement, and therefore the traffic would stop.

```
    MN                    AR1           AR2                           CN
     |MN attaches to AR1:  |             |                             |
     |acquires MN-ID and profile          |                             |
     |--RS---------------->|             |                             |
     |                     |             |                             |
     |<----------RA(IP1)---|             |                             |
     |                     |             |                             |
   Assigned prefix IP1     |             |                             |
   IP1 address configuration           |                             |
     |                     |             |                             |
     |<-Flow(IP1,IPcn,...)-+------------------------------------------>|
     |                     |             |                             |
     |MN detaches from AR1 |             |                             |
     |MN attaches to AR2   |             |                             |
     |                     |             |                             |
     |--RS------------------------------>|                             |
     |                     |             |                             |
     |<--------------RA(IP2)-------------|                             |
     |                     |             |                             |
   Assigned prefix IP2     |             |                             |
   IP2 address configuration           |                             |
     |                     |             |                             |
     |<-new Flow(IP2,IPcn,...)-----------+---------------------------->|
     |                     |             |                             |
```

Figure 4: Re-starting a flow with new IP prefix/address

4.2. Mobility case, traffic redirection

When IP mobility is needed for a flow, the LM and FM functions in

Section 3.1 are utilized. There are two possible cases: (i) the mobility anchor remains playing that role and forwards traffic to a new locator in the new network, and (ii) the mobility anchor (data plane function) is changed but binds the MN's transferred IP address/prefix. The latter enables optimized routes but requires some data plane node that enforces rules for traffic indirection. Next, we focus on the first case. The second one is addressed in Section 4.3.

Mobility support can be provided by using mobility management methods, such as the several approaches surveyed in the academic papers ([Paper-Distributed.Mobility], [Paper-Distributed.Mobility.PMIP] and [Paper-Distributed.Mobility.Review]). After moving, a certain MN's traffic flow may continue using the IP prefix from the prior network of attachment. Yet, some time later, the application generating this traffic flow may be closed. If the application is started again, the new flow may not need to use the prior network's IP address to avoid having to invoke IP mobility support. This may be the case where a dynamic IP prefix/address, rather than a permanent one, is used. Packets belonging to this flow may then use the new IP prefix (the one allocated in the network where the flow is being initiated). Routing is again kept simpler without employing IP mobility and will remain so as long as the MN which is now in the new network does not move again to another network.

```
    MN                    AR1           AR2                           CN
     |MN attaches to AR1:  |             |                             |
     |acquires MN-ID and profile         |                             |
     |--RS---------------->|             |                             |
     |                     |             |                             |
     |<----------RA(IP1)---|             |                             |
     |                     |             |                             |
   Assigned prefix IP1     |             |                             |
   IP1 address configuration             |                             |
     |                     |             |                             |
     |<-Flow(IP1,IPcn,...)-+------------------------------------------>|
     |                     |             |                             |
     |MN detaches from AR1 |             |                             |
     |MN attaches to AR2   |             |                             |
     |                     |             |                             |
     |--RS------------------------------>|                             |
      (some IP mobility support solution)
     |<--------------RA(IP2,IP1)---------|                             |
     |                     |             |                             |
     |                     +<-Flow(IP1,IPcn,...)---------------------->|
     |                     +<===========>+                             |
     |<-Flow(IP1,IPcn,...)-------------->+                             |
     |                     |             |                             |
   Assigned prefix IP2     |             |                             |
   IP2 address configuration             |                             |
```

```
  |                      |             |                           |
Flow(IP1,IPcn) terminates              |                           |
  |                      |             |                           |
  |<-new Flow(IP2,IPcn,...)------------+-------------------------->|
  |                      |             |                           |
```

Figure 5: A flow continues to use the IP prefix from its home network after MN has moved to a new network

An example call flow in this case is outlined in Figure 5. In this example, the AR1 plays the role of FM-DP entity and redirects the traffic (e.g., using an IP tunnel) to AR2. Another solution could be to place an FM-DP entity closer to the CN network to perform traffic steering to deviate from default routes (which will bring the packet to AR1 per default routing). The LM and FM functions are implemented as shown in Figure 6.


```
Net1                                                 Net2

+---------------+                                    +---------------+
|AR1            |                                    |AR2            |
+---------------+                                    +---------------+
|CPA:           |                                    |CPA:           |
|               |                                    |LM:IP1 at IPa1 |
|---------------|      IP1 (anchored to Net1)        |---------------|
|DPA(IPa1):     |      is redirected to Net2         |DPA(IPa2):     |
|anchors IP1    |             =======>               |anchors IP2    |
+---------------+                                    +---------------+

+...............+                                    +---------------+
.MN(IP1)        .             MN moves               |MN(IP2,IP1)    |
.flow(IP1,...)  .             =======>               |flow(IP1,...)  |
.               .                                    |flow(IP2,...)  |
+...............+                                    +---------------+
```

Figure 6: Anchor redirection

Multiple instances of DPAs (at access routers), which are providing IP prefixes to the MNs, are needed to provide distributed mobility anchoring in an appropriate configuration such as those described in Figure 1 (Section 3.1.1) for network-based distributed mobility or in Figure 2 (Section 3.1.2) for client-based distributed mobility.

4.3. Mobility case, anchor relocation

We focus next on the case where the mobility anchor (data plane function) is changed but binds the MN's transferred IP address/ prefix. This enables optimized routes but requires some data plane node that enforces rules for traffic indirection.

IP mobility is invoked to enable IP session continuity for an ongoing flow as the MN moves to a new network. Here the anchoring of the IP address of the flow is in the home network of the flow (i.e., different from the current network of attachment). A centralized mobility management mechanism may employ indirection from the anchor in the home network to the current network of attachment. Yet it may be difficult to avoid using an unnecessarily long route (when the route between the MN and the CN via the anchor in the home network is significantly longer than the direct route between them). An alternative is to move the IP prefix/address anchoring to the new network.

The IP prefix/address anchoring may move without changing the IP prefix/address of the flow. Here the LM and FM functions in Figure 1 in Section 3.1 are implemented as shown in Figure 7.


```
Net1                                            Net2

+---------------+                               +---------------+
|AR1            |                               |AR2            |
+---------------+                               +---------------+
|CPA:           |                               |CPA:           |
|LM:IP1 at IPa1 |                               |LM:IP1 at IPa2 |
|   changes to  |                               |               |
|   IP1 at IPa2 |                               |               |
|---------------|                               |---------------|
|DPA(IPa1):     | IP1 anchoring effectively moved |DPA(IPa2):     |
```

```
|anchored IP1   |            =======>            |anchors IP2,IP1|
+---------------+                                +---------------+

+...............+                                +---------------+
.MN(IP1)        .            MN moves            |MN(IP2,IP1)    |
.flow(IP1,...)  .            =======>            |flow(IP1,...)  |
+...............+                                +---------------+
```

Figure 7: Anchor mobility

As an MN with an ongoing session moves to a new network, the flow may preserve IP session continuity by moving the anchoring of the original IP prefix/address of the flow to the new network.

One way to accomplish such a move is to use a centralized routing protocol, but such a solution may present some scalability concerns and its applicability is typically limited to small networks. One example of this type of solution is described in [I-D.ietf-rtgwg-atn-bgp]. When a mobile associates with an anchor the anchor injects the mobile's prefix into the global routing system. If the mobile moves to a new anchor, the old anchor withdraws the /64 and the new anchor injects it instead.

5. Security Considerations

As stated in [RFC7333], "a DMM solution MUST supportany security protocols and mechanisms needed to secure the network and to make continuous security improvements". It "MUST NOT introduce new security risks".

As described in [I-D.ietf-dmm-deployment-models], there are different potential deployment models of a DMM solution. The present document has presented 3 different scenarios for distributed anchoring: (i) nomadic case, (ii) mobility case with traffic redirection, and (iii) mobility case with anchor relocation. Each of them has different security requirements, and the actual security mechanisms would depend on the specifics of each solution/scenario.

As general rules, for the first distributed anchoring scenario (nomadic case), no additional security consideration is needed, as this does not involve any additional mechanism at L3. If session connectivity is required, the L4 or above solution used to provide it

MUST also provide the required authentication and security.

The second and third distributed anchoring scenarios (mobility case) involve mobility signalling among the mobile node and the control and data plane anchors. The control-plane messages exchanged between these entitites MUST be protected using end-to-end security associations with data-integrity and data-origination capabilities. IPsec ESP in transport mode with mandatory integrity protection SHOULD be used for protecting the signaling messages. IKEv2 should be used to set up security associations between the data and control plane anchors.

6. IANA Considerations

This document presents no IANA considerations.

7. Contributors

Alexandre Petrescu and Fred Templin had contributed to earlier versions of this document regarding distributed anchoring for hierarchical network and for network mobility, although these extensions were removed to keep the document within reasonable length.

This document has benefited from other work on mobility support in SDN network, on providing mobility support only when needed, and on mobility support in enterprise network. These works have been referenced. While some of these authors have taken the work to jointly write this document, others have contributed at least indirectly by writing these drafts. The latter include Philippe Bertin, Dapeng Liu, Satoru Matushima, Pierrick Seite, Jouni Korhonen, and Sri Gundavelli.

Valuable comments have been received from John Kaippallimalil, ChunShan Xiong, Dapeng Liu, Fred Templin, Paul Kyzivat, Joseph Salowey and Yoshifumi Nishida. Dirk von Hugo, Byju Pularikkal, Pierrick Seite have generously provided careful review with helpful corrections and suggestions. Marco Liebsch and Lyle Bertz also performed very detailed and helpful reviews of this document.

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