Mobility-aware Floating Anchor (MFA)
draft-gundavelli-dmm-mfa-01.txt

Abstract

   IP mobility protocols are designed to allow a mobile node to remain
   reachable while moving around in the network. The currently deployed
   mobility management protocols are anchor-based approaches, where a
   mobile node's IP sessions are anchored on a central node. The mobile
   node's IP traffic enters and exits from this anchor node and it
   remains as the control point for all subscriber services. This
   architecture based on fixed IP anchors comes with some complexity and
   there is some interest from the mobile operators to eliminate the use
   of fixed anchors, and other residual elements such as the overlay
   tunneling that come with it.

   This document describes a new approach for realizing a mobile user-
   plane that does not require fixed IP anchors. The architectural-
   basis for this approach is the separation of control and user plane,
   and the use of programmability constructs of the user-plane for
   traffic steering. This approach is referred to as, Mobility-aware
   Floating Anchor (MFA).

Status of this Memo

Copyright Notice

Table of Contents

1. Introduction

   IP mobility protocols are designed to allow a mobile node to remain
   reachable while moving around in the network. The currently deployed
   mobility management protocols are anchor-based approaches, where a
   mobile node's IP sessions are anchored on a central node. The mobile
   node's IP traffic enters and exits from this anchor node and it
   remains as the control point for all subscriber services. This
   architecture based on fixed IP anchors comes with some complexity and
   there is some interest from the mobile operators to eliminate the use
   of fixed anchors, and other residual elements such as the overlay
   tunneling that come with it. Some of the key objectives for this
   effort are listed below.

   o Access-agnostic, shared user-plane that can be used for multiple
      access technologies

   o Optimized Routing for the mobile node's IP flows with topology
      awareness and leveraging the transport QoS

   o Elimination of overlay tunnels from the user-plane network for
      avoiding packet fragmentation, and reducing encapsulation related
      packet-size overhead

   o Elimination of centralized mobility anchors and shift towards a
      distributed mobility architecture, leveraging the edge compute at
      radio-access network for offloading some of the subscriber
      management services

   o Co-existence with control-plane and user-plane separated
      architecture; a stateless user-plane with no tunnels, and a
      control plane with the business/service logic

   o Support for services including accounting, charging, lawful-
      interception and other user plane services

   Currently, there is a study item in 3GPP to explore options for
   simplifying the mobile user-plane. There are few proposals in IETF,
   which are presented as candidate solutions for user-plane
   simplification. However, each of these proposals come with certain
   complexity and do not leverage the 3GPP control plane, or the
   programmability aspects of the user-plane. For example, ILA defines
   a translation scheme without the need for overlay tunnels, but it
   also introduces significant amount of translation related state in
   the user-plane, and additionally introduces a new control-plane
   protocol for managing the mapping tables and the cache states.
   Therefore, we believe that none of the currently known approaches can
   adequately meet the stated goals for user-plane simplification.

This document describes a new approach for realizing a mobile user-plane that does not require any fixed IP anchors. The first-hop router on the link where the mobile node is attached remains as the IP anchor and thereby eliminating the need for IP tunneling to some central anchor node. Even when the mobile node moves in the network and changes its point of attachment, the IP anchor is always the first-hop router on that new link. The MFA entities will track the mobile node's movements in the network and will ensure the mobile node's IP flows always take the most optimal routing path. This is achieved by MFA entities programming the needed traffic steering rules for moving mobile node's IP packets directly between the correspondent node and the mobile node's edge anchor, which can be relocated to a new edge, e.g. in case of mobility. Furthermore, this approach does not require a new control-plane protocol, but instead leverages the SDN interfaces of the user-plane, and the mobility events in the control-plane for managing IP mobility. The architectural basis for this approach is the separation of control and user plane, and the use of programmability constructs of the user-plane for traffic steering. This approach is referred to as, Mobility-aware Floating Anchor (MFA). The rest of the document explains the operational details of the MFA approach.

2. Conventions and Terminology

2.1. Conventions

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 [RFC2119].

2.2. Terminology

All mobility related terms used in this document are to be interpreted as defined in the IETF mobility specifications, including [RFC5213] and [RFC6275]. Additionally, this document uses the following terms:

MFA Domain

   MFA domain refers to the network where the mobility management of a mobile node is handled by the MFA entities. The MFA domain includes MFA mobile node anchors, MFA corresponding node anchors, and MFA node controller, between which security associations can be set up for authorizing the configuration of traffic steering policies and other mobility management functions.

MFA Mobile Node Anchor (MFA-MNA)

Its an MFA function located in the user-plane network very close
to the layer-2 access-point to where the mobile node is attached.
It is typically on the first-hop router for the mobile node's IP
traffic. The node hosting this function is required to support
the standard IPv6 packet forwarding function, FPC or a similar
interface for policy configuration, and packet steering functions
such as based on SRv6 or alternative means that can support per-
flow or per-flow-aggregate traffic steering. Typically, the MFA-
MNA function will be collocated with the User Plane Function (UPF)
in the 3GPP 5G system architecture.

MFA Corresponding Node Anchor (MFA-CNA)

Its an MFA function located in the user-plane node in the path
between the mobile node and the correspondent node. If the
correspondent node is another mobile node in the MFA domain, then
the MFA-CNA is on the first hop router on the link shared with the
correspondent node. The node hosting this function is required to
support the standard IPv6 packet forwarding function, FPC or a
similar interface for policy configuration, and packet steering
functions such as based on SRv6 or alternative means that can
support per-flow or per-flow-aggregate traffic steering.
Typically, the MFA-CNA function will be collocated with the IP
forwarding nodes on the N6 interface of the 3GPP 5G system
architecture.

MFA Node

A generic term used for referring to MFA-MNA, or the MFA-CNA.

MFA Node-Controller (MFA-NC)

The is the function that controls the forwarding policies on the
MFA-MNA and MFA-CNA nodes. This entity interfaces with the MFA
node using the FPC interface [I-D.ietf-dmm-fpc-cpdp], or a similar
interface that support user-plane policy configuration. This is
typically co-located with the SMF, or the AMF functions in the
3GPP 5G system architecture, and on WLAN controller in the case of
Wi-Fi access architectures.

Node Location Database (NLDB)

A database that contains the location information of every mobile
node that is part of the MFA domain and is currently attached to
the network.

Network Topology Database (NTDB)

A database that contains the MFA node information along with the
link state and directly connected neighbor information.

Home Network Prefix (HNP)

An IPv6 prefix assigned to the mobile node. This prefix is hosted
by the MFA-MNA on the access link shared with the mobile node.
The network will provide mobility support for the HNP prefixes. A
meta-data tag indicating the mobility property
[I-D.ietf-dmm-ondemand-mobility] is included in router
advertisements and in address assignment related protocol
messages.

Local Network Prefix (LNP)

An IPv6 prefix assigned to the mobile node. This prefix is hosted
by the MFA-MNA on the access link shared with the mobile node.
The network will not provide mobility support for the LNP
prefixes. A meta-data tag indicating that there is no mobility
support [I-D.ietf-dmm-ondemand-mobility] is included in router
advertisements and in address assignment related protocol
messages.

3. Overview

This specification describes the MFA protocol. The MFA protocol is
designed for providing mobility management support to a mobile node
without the need for a fixed IP anchor. In this approach the mobile
node's IP session is always anchored on the first-hop router sharing
the link with the mobile node. The entities in the MFA domain track
the mobile node's movements in the MFA domain and will provision the
forwarding states in the user-plane nodes for optimal routing and for
ensuring the anchor is always the first-hop router. Any time the
mobile node moves within the MFA domain and resulting in the mobile
node's IP flows going through the previous anchor, the mobility
entities detect this event and a corrective action is taken by
provisioning the forwarding nodes with the path stitching rules. The
result of this approach is an user-plane with no fixed anchors, and
dynamically programmed user-plane for mobility and optimal packet
routing.

The following are the key functional entities in the MFA domain:

o MFA Node Controller (MFA-NC)

o MFA Mobile Node Anchor (MFA-MNA)

   o MFA Correspondent Node anchor (MFA-CNA)

   The MFA-NC is typically collocated with the access network specific
   control-plane functions. It interfaces with the radio network/
   authentication functions for detecting the mobile node's movements in
   the MFA domain for managing the forwarding states in the user-plane
   entities, MFA-MNA and MFA-CNA. The MFA node controller requires
   access to node location database and network topology database.
   These are the conceptual entities that can be realized using existing
   elements that are already present in different access architectures.

   The MFA-MNA and the MFA-CNA are the functions in the user-plane
   network and they are collocated with the elements in the network that
   perform IP packet forwarding functions. The MFA-MNA is typically
   located on the first-hop router and whereas the MFA-CNA can be
   collocated with the access-gateways and transit routers. These
   entities interface with the MNA-NC using FPC
   ([I-D.ietf-dmm-fpc-cpdp]), or an alternative interface), for managing
   the IP forwarding policies.
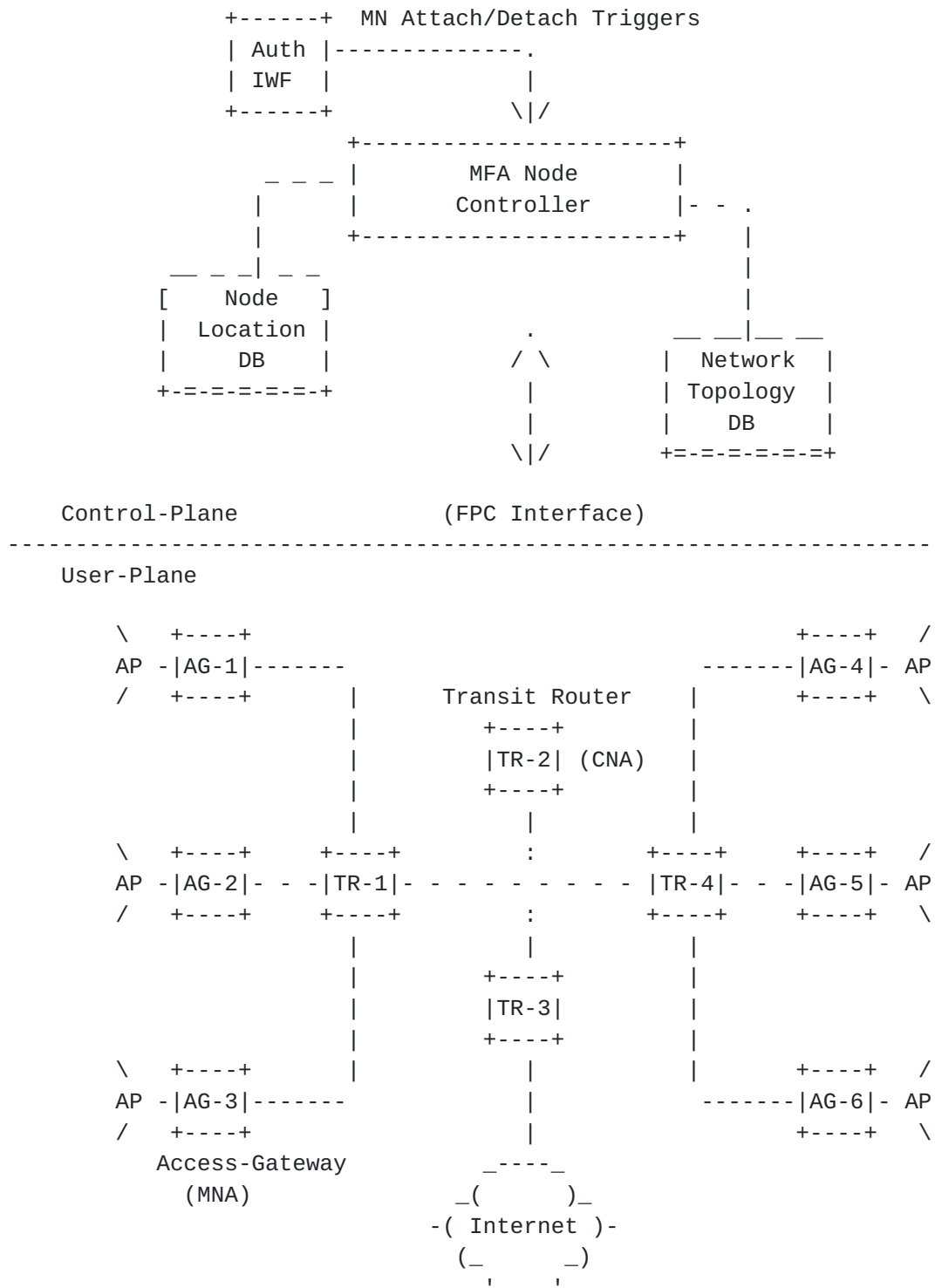
```
                  +------+  MN Attach/Detach Triggers
                  | Auth |--------------.
                  | IWF  |              |
                  +------+             \|/
                        +----------------------+
                _ _ _ |        MFA Node       |
                |     |       Controller      |- - .
                |     +----------------------+    |
          __ _ _| _ _                              |
          [     Node   ]                           |
          | Location |            .                |
          |    DB    |           / \        __ __|__ __
          +-=-=-=-=-=-+           |         | Network  |
                                  |         | Topology |
                                 \|/        |    DB    |
                                            +=-=-=-=-=-=+


     Control-Plane                 (FPC Interface)
 ---------------------------------------------------------------------
     User-Plane


      \   +----+                                  +----+   /
      AP -|AG-1|-------                     -------|AG-4|- AP
      /   +----+        |    Transit Router  |     +----+   \
                        |          +----+          |
                        |          |TR-2| (CNA)    |
                        |          +----+          |
                        |            |             |
      \   +----+    +----+     :          +----+    +----+   /
      AP -|AG-2|- - -|TR-1|- - - - - - - - - |TR-4|- - -|AG-5|- AP
      /   +----+    +----+     :          +----+    +----+   \
                        |          |             |
                        |        +----+          |
                        |        |TR-3|          |
                        |        +----+          |
      \   +----+    |        |          |    +----+   /
      AP -|AG-3|-------      |          -------|AG-6|- AP
      /   +----+             |                 +----+   \
          Access-Gateway       _----_
            (MNA)            _(      )_
                            -( Internet )-
                             (_      _)
                               '----'


      * MFA-MNA is collocated with the access gateways
      ** MFA-CNA is collocated with the access gateways and transit routers



                  Figure 1: Example of a MFA Domain
```

3.1. The Network Topology Database

   The network topology database contains the complete and the current
   information about all the MFA nodes in the network. The information
   includes the capabilities of each node, supported functions,
   supported interfaces with the interface-type, connected neighbors,
   hosted prefixes on each link, security configuration and other
   related configuration elements. The topology database can be used to
   determine the route between two nodes within the MFA domain, or the
   best exit gateway for reaching a correspondent node outside the MFA
   domain.

3.2. The Node Location Database

   The node location database consists of location information of each
   mobile node that is currently attached to the MFA domain. It also
   includes the type of attachment, previous anchor, and other
   information elements, such as the mobile node's connection status and
   detailed or approximate location (e.g. tracking area) in case of
   device dormancy. Typically, the MFA entities obtain this information
   from the control-plane functions in the access network. For example,
   a WLAN controller and the authentication functions will be able to
   provide this information in IEEE 802.11 based networks. In 5G system
   architecture this information can be obtained from AMF/SMF functions.

   Below diagram is an example NLDB database.

```
+===============+===========+===========+============+
|      MN       | Current   | Previous  | Handover   |
|   Identifier  | Anchor    | Anchor    |   Type     |
+===============+===========+=======================+
|  MN1@ietf.org |   AG1     |    -      | NEW_ATTACH |
+---------------+-----------+-----------+------------+
|  MN2@ietf.org |   AG6     |   AG2     | HANDOVER   |
+---------------+-----------+-----------+------------+
|  MN3@ietf.org |    -      |   AG4     | UNKNOWN    |
+---------------+-----------+-----------+------------+
```

                    Figure 2: Example NLDB Table

3.3. **Determination of the Correspondent Node Anchor**

   The anchor for a correspondent node is a MFA node that is closest to
   the correspondent node and is in path for all the MN-CN IP traffic
   flows. The MFA node controller leverages the topology database for
   the CN-anchor determination.

   If the correspondent node is another mobile node in the MFA domain,
   then the CN-Anchor for that correspondent node is the access gateway
   to which it is currently attached.

   If the correspondent node is outside the MFA domain, then the CN-
   anchor is typically the exit gateway, or any MFA node that is always
   in path for reaching the CN's network. This is typically the PE
   router of the data center that hosts the correspondent node service,
   or a programmable data plane node inside the data center.

   The below illustration is an example topology of a MFA domain. The
   domain consists of MFA nodes, mobile and correspondent nodes. A
   query for CN2's anchor should result in finding AG4, as that is the
   MFA node in the traffic path and closest to CN2. Similarly, the
   query for CN3's anchor which is outside the MFA domain should result
   in finding TR3 as that is the last exit gateway in the MFA domain and
   closest to the CN3.

```
        AG1                      AG4 - - CN2
         |           TR2          |
   MN1- - -AG2-----TR1--|--TR4----AG5
         |           TR3          |
        AG3            |          AG6
              {internet}
                  |
                CN3
```
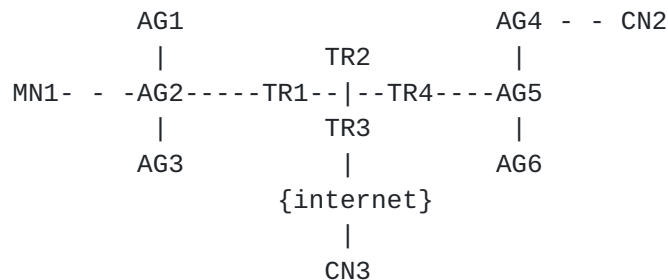
                Figure 3: CN Anchor Determination - Example Topology

3.4. **Traffic Steering Approaches**

   The MFA nodes support traffic steering approaches for moving the
   mobile node's IP traffic between the MFA nodes over the most optimal
   routing path. Segment Routing for IPv6 (SRv6) is one approach that
   this specification focuses on for steering the traffic between two
   points in the network, whereas the MFA-NC can utilize the available
   information from Network Topology- and Node Location Database to
   enforce policies in the MFA nodes in support of alternative data

plane protocols to enable traffic steering. Future versions of the
document may include information about additional mechanisms.

When using SRv6 for traffic steering, the approaches specified in
[I-D.ietf-dmm-srv6-mobile-uplane] and
[I-D.filsfils-spring-srv6-network-programming] will be leveraged for
moving the mobile node's IP traffic between the MFA-MNA and the MFA-
CNA nodes. The SRv6 policy including the SID information and the
associated functions are pushed from the MFA Node controller to the
MFA nodes. This document mostly leverages the functions specified in
those documents, but may require some changes to the SRv6 functions
for reporting the flow meta-data of the non-optimal traffic flows to
the MFA node controller. The definitions of those SRv6 functions
will be specified in either in the future revisions of this document,
or in other IETF documents.

The following table captures the possible SRv6 function activation
when IP traffic steering approach is in use. This is only an
example.

FLOW DIRECTION	MN-Anchor	CN-Anchor
MN to CN	Variant of T.Insert (Transit with insertion of SRv6 policy and may require trigger to MFA-NC such as activation of Flow.Report)	Variant of End.X (Or, End.B6, instantiation of a binding SID); Or, End.T for internet traffic
CN to MN	Variant of End.X (Layer-3 cross connect (Or, End.B6, instantiation of a binding SID	Variant of T.Insert (Transit with insertion of SRv6 policy and may require trigger to MFA-NC such as activation of Flow.Report.

                Figure 4: Using SRv6 for Traffic Steering - Example

3.5. Mobile Node Attachment Triggers

   The MFA domain relies on the access network for certain key events
   related to the mobile node's movements in the network. These events
   include:

   o INITIAL_ATTACH - Initial Attachment of the mobile node to the MFA
      domain

   o HANDOVER - Layer-2/Layer-3 Handover of the mobile node within the
      MFA Domain

   o DETACH - Detachment of the mobile node from the MFA domain

   o UNKNOWN - State of the mobile node is Unknown; TBD

   The MFA node controller interfaces with the radio network and the
   authentication infrastructure for these events. These events drive
   the policy configuration on the MFA nodes.

3.6. Programming the User-plane

   The MFA-NC leverages suitable southbound semantics and operation to
   enforce traffic steering rules in the selected access gateways (AG)
   and/or transient routers (TR). One suitable data model and operation
   is being specified in [I-D.ietf-dmm-fpc-cpdp] for Forwarding Policy
   Configuration (FPC). The model and operation applies in between a
   FPC Client function and an FPC Agent function.

   A deployment of FPC with the specification per this document about
   MFA, the FPC Client is co-located with the MFA-NC, whereas the FPC
   Agent function is co-located with functions that enforce user plane
   configuration per the rules received from the FPC Client. The FPC
   Agent can either reside on an transport network- or SDN controller
   and be in charge of the configuration of multiple user plane nodes
   (MFA-TR, MFA-MA, MFA-CA), or an FPC Agent resides on each MFA node.

   The following figure schematically draws an example how FPC can
   integrate with the functional MFA architecture per this
   specification. The example assumes that MFA nodes can be
   programmatically configured by an SDN Controller. Details about
   whether a single or multiple distributed SDN Controllers are deployed
   are left out.

   The FPC data model includes the following components:

Data Plane Nodes (DPN) Model:

   Representation of nodes in the data plane which can be selected
   and enforce rules per the control plane's directives. DPNs take a
   particular role, which is identified in the model. In the context
   of this document, the role of a DPN can be, for example, an anchor
   node or a transit router.

Topology Model:

   Representation of DPNs in the network and associate in between
   DPNs. The FPC Client and Agent use the Topology to select most
   appropriate data plane node resources for a communication. In the
   context of this document, Topology has can be leveraged to
   implement the NTDB for the selection of steering paths and
   associated DPNs which function as MFA-MNA, MFA-CNA, or MFA-TR.

Policy Model:

   Defines and identifies rules for enforcement at DPNs.

Mobility-Context:

   Holds information associated with a mobile node and its mobility
   sessions. In the context of this document, Mobility-Context can
   be enriched with traffic steering related rules.

Monitor:

   Provides mechanisms to register monitors (traffic, events) in the
   data plane and define status reporting schedules, which can be
   periodic or event-based. In the context of this document,
   Monitors may be used to detect traffic from a CN to an MN on an
   MFA node, which could result in a notification to the MFA-NC for
   path optimization and associated steering of traffic to the MN's
   current MFA-MNA.

Please refer to [I-D.ietf-dmm-fpc-cpdp] for model and operational
details.

```
                       +----------------------+
           +----+      |       MFA Node       |     +----+
           |NLDB+----+      Controller     +----+NTDB|
           +----+    +-----+ -  -  -  - +----+    +----+
                     | FPC Client |
                     +------------+
                          |
                          | FPC models and operation
                          |
                     +------------+
                     | FPC Agent  |
                    +-+ -  -  -  - +-+
                     | SDN Controller |
                     +----------------+
                            ^
           +---------+----------+-----------+----------+
           |         |       +---+          |          |
           v         v       |TR2|          v          v
     +-------+---+     +---+    +---+    +---+     +---+-------+
  //-|MFA-NMA/AG2|-----|TR1|----------------|TR4|------|AG4/MFA-CAN|-//
     +-------+---+     +---+              +---+     +---+-------+
```
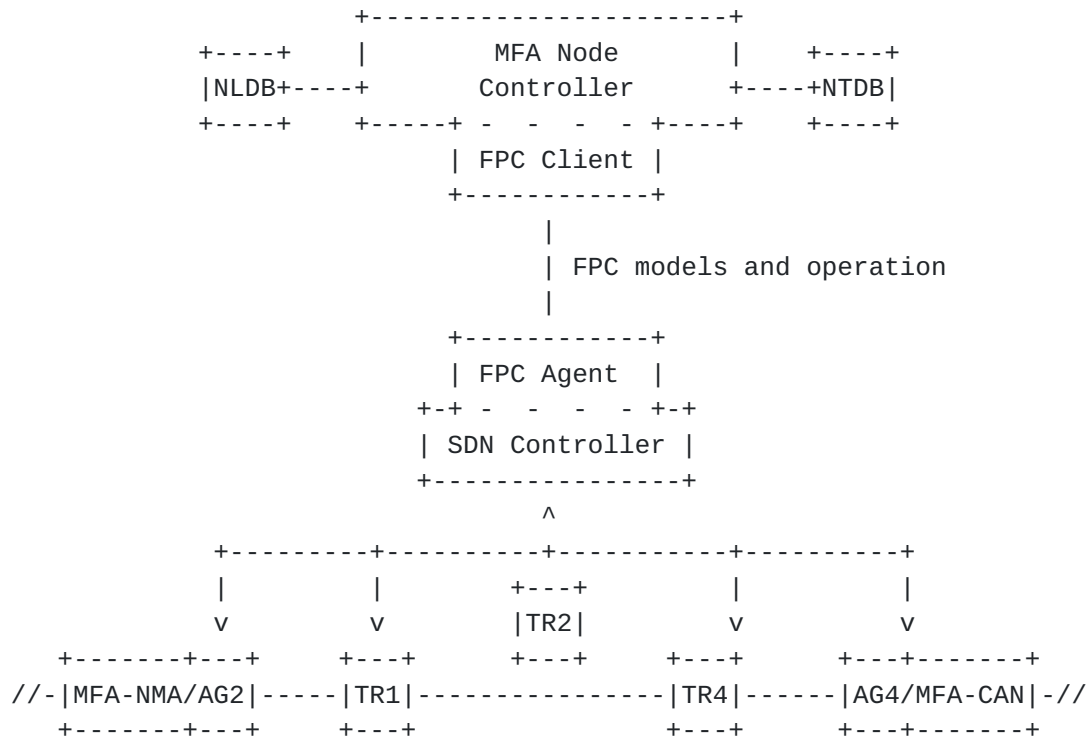
        Figure 5: Deployment of the FPC models and operation in between the
                MFA-NC and MFA nodes on the user plane

4. **Life of a Mobile Node in a MFA Domain**

    Reference Topology

```
                      +-----------------------+
                      |       MFA Node        |
                      |      Controller       |
                      +-----------------------+

        \   +----+                              +----+    /
        AP -|AG-1|-----                     -----|AG-4|- AP  CN1
        /   +----+      |    MFA Transit Router  |    +----+    \
                        |          +----+        |
                        |          |TR-2|        |
                        |          +----+        |
                        |            |           |
        \   +----+   +----+          :       +----+    +----+    /
   MN   AP -|AG-2|- -|TR-1|- - - - - - - - - |TR-4|- -|AG-5|- AP
        /   +----+   +----+          :       +----+    +----+    \
                        |            |           |
                        |          +----+        |
                        |          |TR-3|        |
                        |          +----+        |
        \   +----+      |            |           |    +----+    /
        AP -|AG-3|-----               |                -----|AG-6|- AP
        /   +----+                    |                +----+    \
         MFA Access-Gateway        _----_
                                 _(      )_
                                -( Internet )---- CN2
                                 (_      _)
                                   '----'
```

                      Figure 6: Reference Topology

4.1. MN's Initial Attachment to a MFA Domain

   A mobile node, MN enters the MFA domain and attaches to the access
   point on the gateway AG-2.

```
 +===+      +--+    +----+      +----+      +--+       +===+      +===+
 |MN1|      |AP|    |AG-2|      |AIWF|      |NC|       |CN1|      |CN2|
 +===+      +--+    +----+      +----+      +--+       +===+      +===+
   |          |        |           |          |          |          |
 1 *-ATTACH-*          |           |          |          |          |
   |          |        |           |          |          |          |
 2 *<-------*-AUTH------------>*              |          |          |
   |          |        |           |          |          |          |
 3 |          |        |        *-NOTIFY-->*             |          |
   |          |        |           |          *          |          |
 4 |          |     *<-PROV---------------*              |          |
   |          |        |           |          |          |          |
 5 *<--IP_CONFIG--->*             |           |          |          |
   |          |        |           |          |          |          |
 6 *< -(OPTIMIZED) -X- USER_PLANE_PACKET (HNP Flow)->*              |
   |          |        |           |          |          |          |
 7 *< -(OPTIMIZED)- X- USER_PLANE_PACKET (LNP Flow) - - - - - >*
   |          |        |           |          |          |          |
```
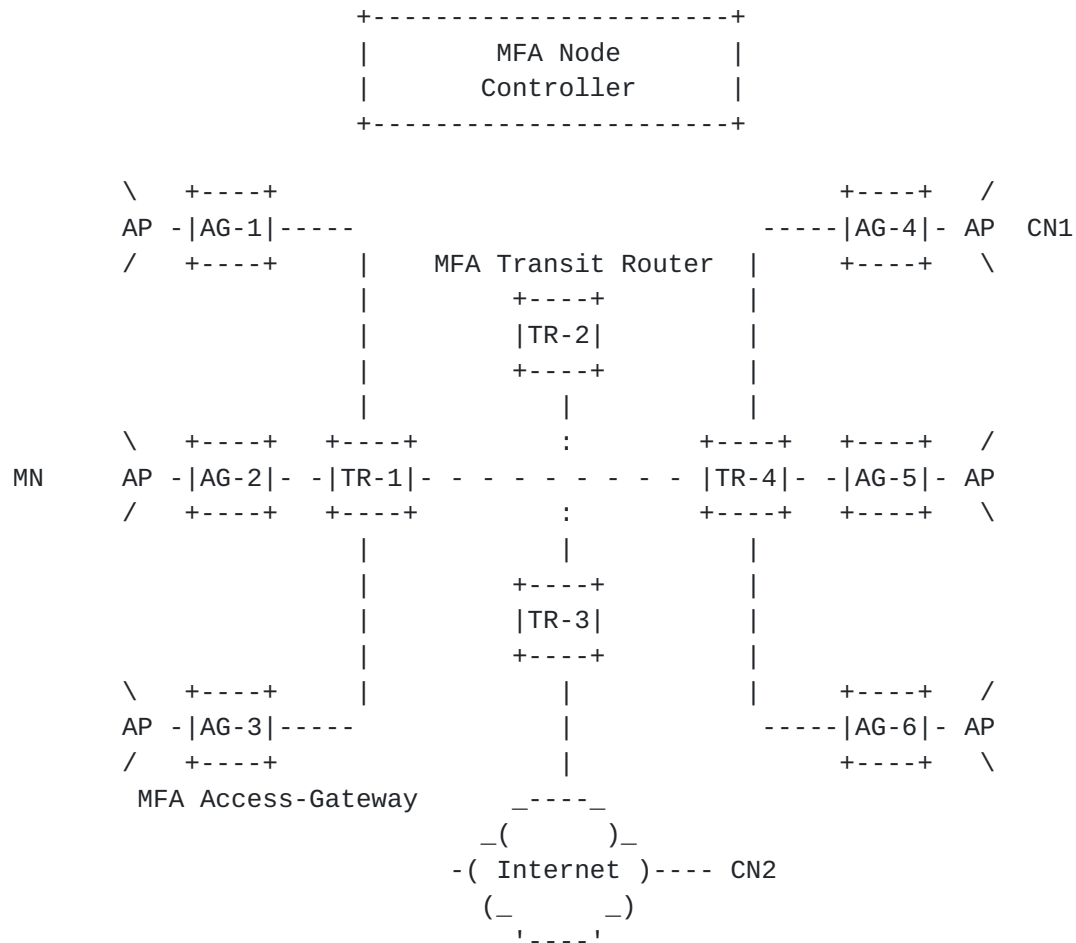
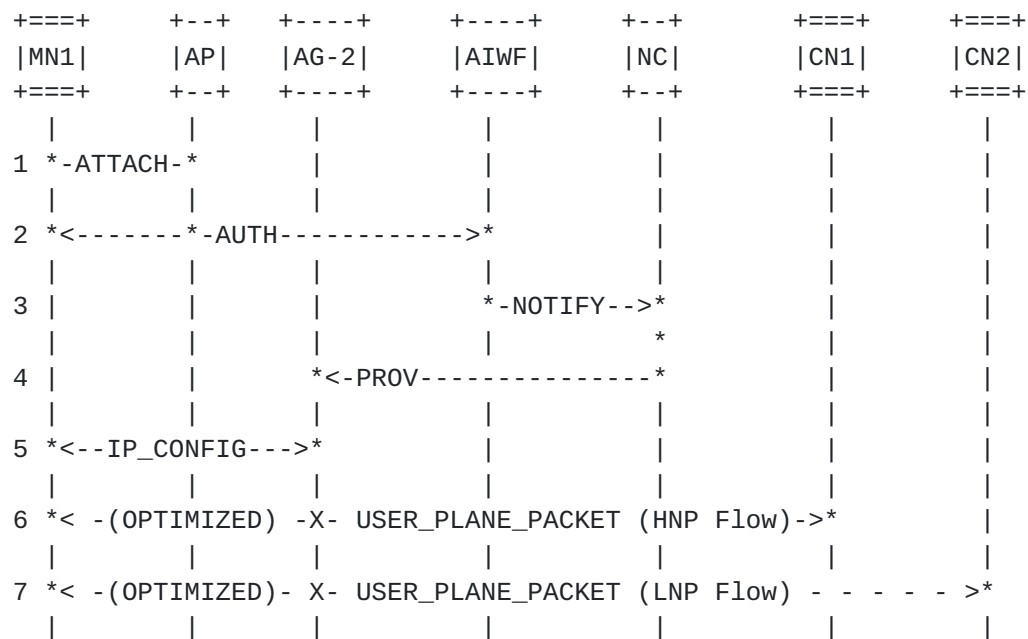   Figure 7: Mobile Node's Initial Attachment to a MFA Domain

   o 1-ATTACH: The mobile node with NAI (MN1@ietf.org) performs a
      layer-2 attach to the access point. This access point is
      connected to the access-gateway, AG-2, over a layer-2 link. The
      mobile node anchor function is supported on AG-2 and is active.

   o 2-AUTH: The mobile node completes the access authentication access
      technology specific access mechanisms. The mobile node's identity
      is established and is authorized for MFA domain access. The
      Authentication interworking (AUTH-IWK) function records the mobile
      node's identity, type of attach as INITIAL_ATTACH, and the current
      location of the mobile node in the access-network, to the node
      location database.

   o 3-NOTIFY: The Auth-IWK function delivers the attach event to the
      MFA node controller. The information elements that are delivered
      include the mobile node identifier (MN-1@ietf.org), type of attach
      as INITIAL_ATTACH, and the identity of the access gateway, which
      is AG-2.

   o 4-PROV: The NC provisions AG-2 for hosting the MN's home-network
      prefix(es). The assigned prefixes are HNP, H1::/64 and LNP,
      L1::/64. These prefixes are from a larger aggregate block (Ex:
      H1:://48; L1::/48) which are topologically anchored on AG-2. The
      policies for hosting the HNP prefixes on the link are provisioned
      using FPC interface. The AG-2 will include meta-data in the IPv6
      RA messages for indicating the properties of the prefixes; H1::/64

      as the prefix with mobility support and L1 as the prefix with no
      mobility support.

   o 5-IP_CONFIG: The mobile node generates one ore more IPv6 addresses
      using the prefixes H1 and L1. The generated addresses are tagged
      with the property meta-data in the host's source address policy
      table. This allows the applications on the mobile node to pick
      the addresses based on the application's mobility requirements.

   o 6-USER_PLANE_PACKET: The mobile node establishes IP flow with CN1.
      The source address is based on the prefix H1. This IP address
      will have mobility support. The packets associated with this flow
      will take the optimized routing path. There are no tunnels, or
      special traffic steering rules in the network.

   o 7-USER_PLANE_PACKET: The mobile node establishes IP flow with CN2.
      The source address is based on the prefix L1. This IP address
      will not have mobility support. There are no tunnels, or special
      traffic steering rules in the network.

4.2. MN's Roaming within the MFA Domain

   The mobile node roams and changes its point of attachment. It was
   initially attached to the access network on AG-2 and now it attaches
   to access network on AG-6. At the time of roaming, the mobile node
   had two active IPv6 prefixes HNP, H1::/64 and LNP, L1::/64 and there
   were two active IP flows, one to CN1 using an IPv6 address from the
   prefix H1::/64 and another flow to CN2 using an IPv6 address from the
   prefix L1:://64. The MFA network will ensure the prefix H1::/64 will
   be routable on the new network and the active flow to CN1 will
   survive, however the prefix L1::/64 will not be routable in the new
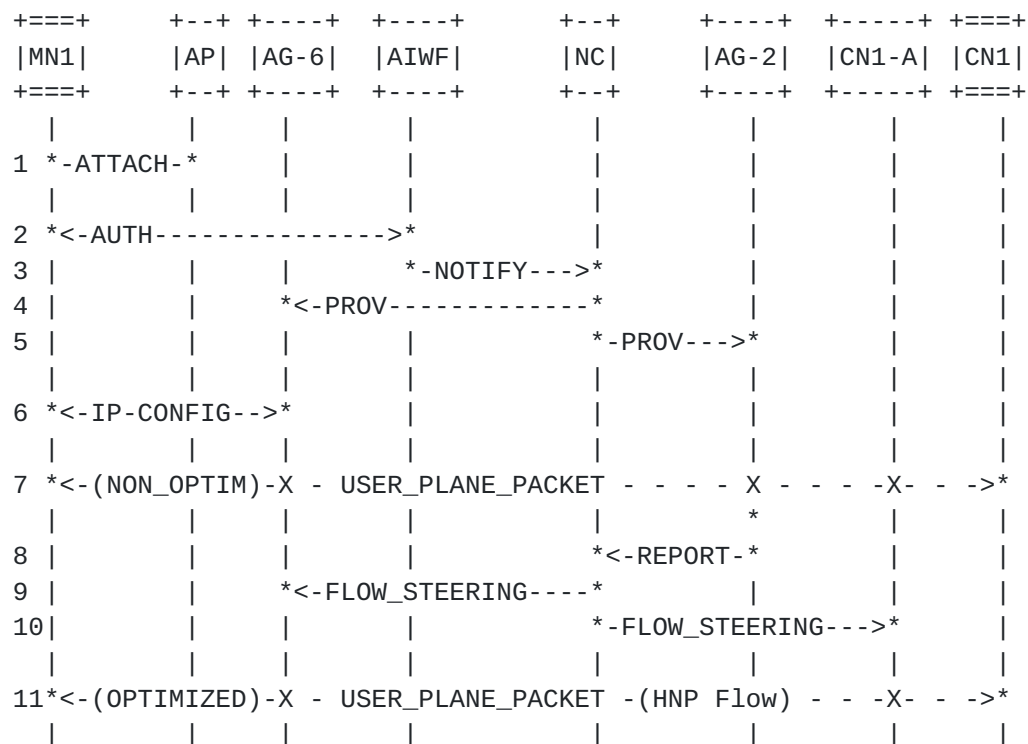   access network and therefore the flow to CN2 will not survive.

```
 +===+      +--+ +----+  +----+        +--+      +----+  +-----+ +===+
 |MN1|      |AP| |AG-6|  |AIWF|        |NC|      |AG-2|  |CN1-A| |CN1|
 +===+      +--+ +----+  +----+        +--+      +----+  +-----+ +===+
   |         |    |        |            |          |        |     |
 1 *-ATTACH-*      |        |            |          |        |     |
   |         |    |        |            |          |        |     |
 2 *<-AUTH--------------->*             |          |        |     |
 3 |         |    |        *-NOTIFY--->*            |        |     |
 4 |         |    *<-PROV-------------*             |        |     |
 5 |         |    |        |           *-PROV--->*            |     |
   |         |    |        |            |          |        |     |
 6 *<-IP-CONFIG-->*        |            |          |        |     |
   |         |    |        |            |          |        |     |
 7 *<-(NON_OPTIM)-X - USER_PLANE_PACKET - - - - X - - - -X- - ->*
   |         |    |        |            |          *        |     |
 8 |         |    |        |           *<-REPORT-*           |     |
 9 |         |    *<-FLOW_STEERING----*            |        |     |
 10|         |    |        |           *-FLOW_STEERING--->*        |
   |         |    |        |            |          |        |     |
 11*<-(OPTIMIZED)-X - USER_PLANE_PACKET -(HNP Flow) - - -X- - ->*
   |         |    |        |            |          |        |     |
```

Figure 8: Mobile Node's Roaming within the MFA Domain

o 1-ATTACH: The mobile node with NAI (MN1@ietf.org) roams in the
   network from AG-2 to AG-6.

o 2-AUTH: The mobile node completes the handover to the new access
   network using access network specific security mechanisms. The
   Auth-IWK function updates the mobile node's location in the node-
   location database. The updated entry in the node location
   database will include the mobile node's NAI, attach type as
   HANDOVER, and the current access-network location as AG-6.

o 3-NOTIFY: The Auth-IWK function function delivers the handover
   event to the MFA node controller. The information elements that
   are delivered include the mobile node identifier (MN-1@ietf.org),
   type of attach as HANDOVER, and the identity of the access gateway
   as AG-6.

o 4-IP_PROV: The NC provisions AG-6 for hosting the MN's home-
   network prefix and local network prefix. The home network prefix,
   H1::/64 is from the previous anchor, AG-2 and is not topologically
   anchored on AG-6. However, for supporting mobility the prefix is
   hosted on the access link while the mobile node is attached to
   that access network and till there are active flows. The NC also

      provisions AG-6 for hosting a new local network prefix, L2::/64.
      This prefix, L2::/64 is from a larger aggregate block that is
      topologically anchored on AG-6. The AG-6 will include meta-data
      in the IPv6 RA messages for indicating the properties of the
      prefixes; H1::/64 as the prefix with mobility support and L2::/64
      as the prefix with no mobility support. The NC also provisions a
      traffic steering rule to steer all uplink IP traffic with source
      address H1::/64 through the previous anchor AG-2.

   o 5-IP_PROV: The NC provisions AG-2 to steer all IP traffic to
      destination addresses matching the prefix, H1::/64 to AG-6, and it
      also provisions a rule to report flow meta-data of those flows
      taking the non-optimal traffic path through AG-2. This
      essentially allows the NC to learn about any mobile node's IP
      flows still going through AG-2, so it can stitch the optimized
      path for those flows and remove AG-2 from the path for those
      flows.

   o 6-IP_CONFIG: The prefix H1::/64, obtained at the new location,
      will continue to be available on the new access link. The new
      local network prefix L2::/64 will also be available on the new
      access link and will be marked as a prefix with no mobility
      property. The mobile node may generate one, or more IPv6
      addresses using the prefix L2::/64. The prefix L1::/64 is no
      longer hosted on the new link and the mobile node will remove it
      from interface configuration.

   o 7-USER_PLANE_PACKET: Any uplink IP link from CN1 will come to
      AG-2, as its the topological anchor for that address/prefix and
      AG-2 will steer the traffic directly to AG-6. On detecting an IP
      flow with the IP address belonging to prefix H1::/64, AG-2 will
      report the CN1-MN1 flow meta-data to NC.

   o 8-Report: The NC on receiving this event will lookup the CN anchor
      for the flow in its node location database. If the CN is another
      MN within the MFA domain, its current anchor information is
      retrieved from the node location database. However, if the CN is
      a node outside the MFA domain, the anchor for this node can be any
      transit router in the MFA domain which is always in path for that
      destination. The CN-anchor determination for nodes outside the
      MFA domain will be based on the network topology database.

   o 9-FLOW_STEERING: The NC inserts a IP traffic steering rule on AG-6
      to steer the MN1-CN1's IP flows using H1::/64 directly to CN1's
      anchor which is CN1-A, and bypassing AG-2.

   o 10-FLOW_STEERING: The NC inserts a IP traffic steering rule on
      CN1-A to steer the MN1-CN1 IP flows using H1::/64 directly to

      MN1's current anchor which is AG-6, and bypassing AG-2.

   o 11-USER_PLANE_PACKET: The MN1-CN1's IP flows using H1::/64 will be
      steered directly from CN1-A to AG-6; AG-2 will not be in the path.

4.3. Traffic Steering State Removal

   The mobile node's IP flows that were established at the previous
   location are no longer active. The steering state that was
   introduced at AG-6 and CN1-A will removed on detecting the inactive
   flows. The network may also optionally choose to withdraw the prefix
   H1::/64 and may assign a new HNP prefix which are topologically
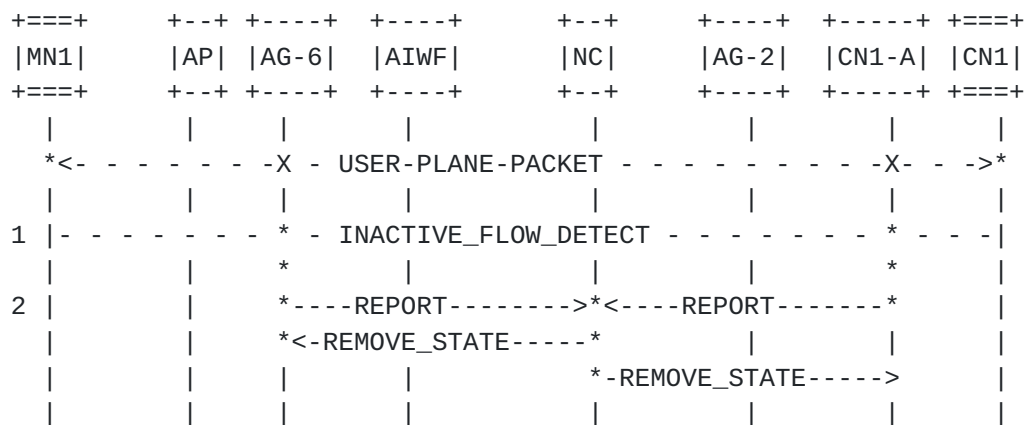   anchored in the new location.

```
   +===+      +--+ +----+  +----+      +--+      +----+  +-----+ +===+
   |MN1|      |AP| |AG-6|  |AIWF|      |NC|      |AG-2|  |CN1-A| |CN1|
   +===+      +--+ +----+  +----+      +--+      +----+  +-----+ +===+
     |         |    |        |          |          |        |      |
    *<- - - - - -X - USER-PLANE-PACKET - - - - - - - -X- - ->*
     |         |    |        |          |          |        |      |
   1 |- - - - - - - * - INACTIVE_FLOW_DETECT - - - - - - - * - - -|
     |         |    *        |          |          |        *      |
   2 |         |    *----REPORT-------->*<----REPORT-------*       |
     |         |    *<-REMOVE_STATE-----*          |        |      |
     |         |    |        |              *-REMOVE_STATE----->   |
     |         |    |        |          |          |        |      |
```

                       Figure 9: State Removal

   o 1-IN_ACTIVE_FLOW_DETECT: At some point the MN1-CN1 flow using the
      prefix H1::/64 is no longer active.

   o 2-REPORT: Both AG-6 and AG-2 will detect the inactive flows and
      may report this event to the NC. The steering state associated
      with MN1-CN1 flow using the prefix H1::/64 may be removed prior to
      reporting to the NC. Optionally, the NC on receiving the
      INACTIVE_FLOW_DETECT event may provision AG-6 and CN1-A to remove
      the steering state.

   o 4-REMOVE_STATE:

4.4. Mobile Node's new IP flows

   The mobile node's IP flows that were established at the previous
   location are no longer active and any created steering state was
   removed. The network may optionally choose to withdraw the prefix
   H1::/64 and may assign a new HNP prefix which is topologically
   anchored in the new location. All new IP flows will use the new
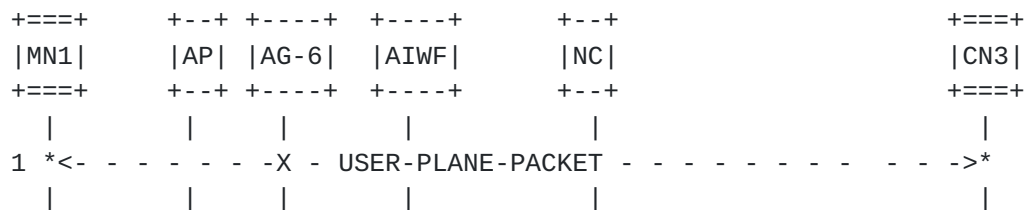   prefix and the flows will take optimal routing path.

```
+===+      +--+ +----+  +----+      +--+                     +===+
|MN1|      |AP| |AG-6|  |AIWF|      |NC|                     |CN3|
+===+      +--+ +----+  +----+      +--+                     +===+
  |         |     |       |          |                        |
1 *<- - - - - - -X - USER-PLANE-PACKET - - - - - - -  - - ->*
  |         |     |       |          |                        |
```

                        Figure 10: New Flows

   o 1-USER_PLANE_PACKET: The mobile node's has established some IP
      flows using the IP address from the new HNP and LNP assigned at
      the new location. These IP flows will take optimal routing path
      and there is no need for any steering state, or the use of tunnels
      in the network for the mobile node's traffic.

5. MFA in 5G System Architecture

   3GPP is specifying the 5G System Architecture, which follows a split
   between control- and data plane. Key control plane functions, which
   have interfaces to the data plane, are the Access Network and
   Mobility Management Function (AMF), and the Session Management
   Function (SMF). AMF and SMF cooperate to set up data plane nodes in
   the (radio) access network ((R)AN) and the core network, which
   comprises one or multiple User Plane Functions (UPF). As soon as a
   mobile node (UE) attaches to the network, as Packet Data Unit (PDU)
   Session is established and the SMF in the control plane selects one
   UPF as PDU Session Anchor, which serves also as IP address anchor.
   The SMF may select one more UPF on the path in between the PDU
   Session Anchor and the (R)AN, which enables routing traffic in
   between the UE and a local packet data network (PDN) with a
   correspondent node or service without the need to traverse the PDU
   Session Anchor.

   In the view of MFA, each UPF can represent a locator for the UE's
   downlink traffic on the N9 as well as on the N6 reference point in

the 5G System Architecture. Since the SMF is in charge of UPF
selection and configuration, the MFA-NC can leverage the SMF to
retrieve node location information per this specification's procedure
to access the NLDB from the MFA-NC. For MFA node selection and
traffic steering, the MFA-NC may need more information about the data
plane in terms of the transport network nodes and topology. Details
about the NTDB are left out of this version of the document, but a
realization may exploit available Topology information per
[I-D.ietf-dmm-fpc-cpdp].

In the figure below, a UE's UPFs can function as MFA nodes, either as
MFA-MNA or as MFA-CNA in case of mobile to mobile communication.
Other transport network nodes, which may function as MFA-CNA for the
UE's communication with a (non-mobile) correspondent node or service,
are not explicitly depicted in the below figure. The MFA function
can be tightly coupled with a UFP (co-located) or loosely coupled
(separated). The MFA-NC utilized the FPC models and operation to
enforce traffic steering policies in the MFA nodes. In case of loose
coupling, the SMF utilizes the N4 protocol per the 3GPP standard to
configure the selected UPF, whereas the MFA-NC uses FPC to enforce
policies in the associated (loosely coupled) MFA node. In case of
tight coupling, the MFA-NC may be co-located with the SMF and a
single reference point and associated protocol may be used in between
the SMF/MFA-NC and a UPF/MFA node.

```
 +----+  +----+  +----+  +----+  +----+  +----+  +----+
 |NSSF|  |NEF |  |NRF |  |AUSF|  |UDM |  |PCF |  | AF |
 +----+  +----+  +----+  +----+  +----+  +----+  +----+
    |       |       |       |       |       |       |
 -----------------------------------------------------------
          |                 |                 |
        +-----+          +-----+          +------+
   +-------| AMF |          | SMF |----+----|MFA-NC|--+
   |       +-----+          +-----+    |    +------+  |
   |         |                N4|        NLDB      |     NTDB
   |         |                  |                  |
   |         |              FPC +---:----------------+
   |         |                  |   |              | FPC
   |N1       | N2             +-|---+------+ +-------+--------+
   |         |                | |   N4    | |                |
 +----+   +-----+          +------+     +------+             |
 | UE |   |(R)AN|-----|  UPF |------|  UPF |-----------(PDN)
 +----+   +-----+ N3 |    +  | N9   |   +  |      N6
                     |  MFA |      |  MFA |
                     +------+      +------+
```
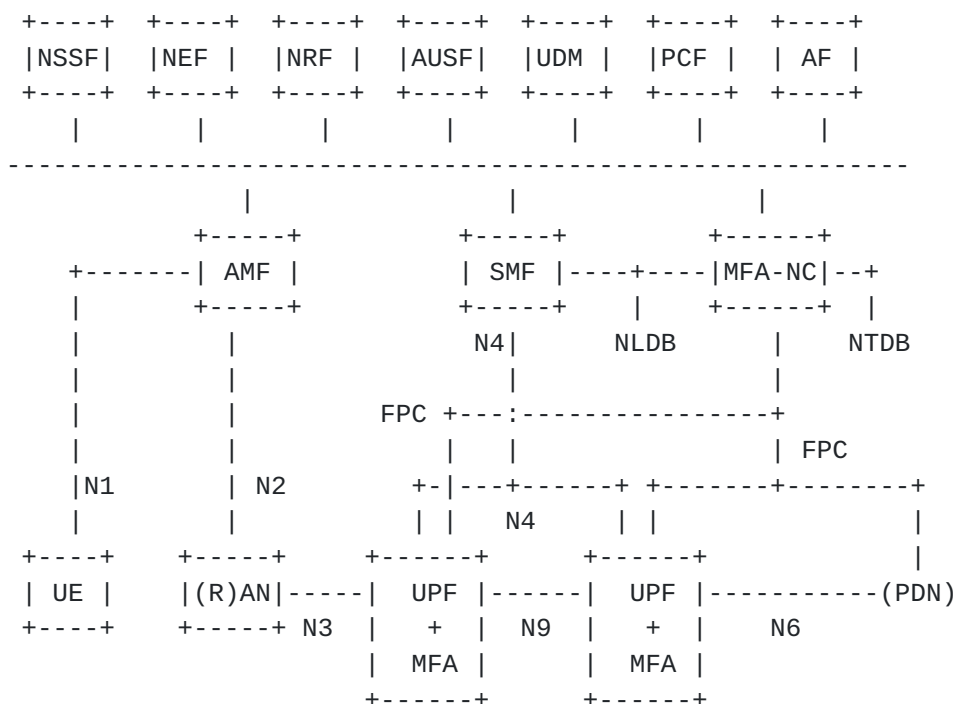
                       Figure 11: New Flows

6. IANA Considerations

   TBD

7. Security Considerations

   This specification allows a mobility node controller to provision IP
   traffic steering policies on the user plane nodes. It essentially
   leverages the FPC interface [I-D.ietf-dmm-fpc-cpdp] for interfacing
   with the user-plane anchor nodes. The security considerations
   specified in the FPC specification are sufficient for securing the
   messages carried on this interface.

   The traffic steering rules that are provisioned on the MFA nodes by
   the MFA node controller are the standard policy rules that the FPC
   interface defines and does not require any new security
   considerations.

8. Acknowledgements

   TBD

9. References

9.1. Normative References

   [RFC2119] Bradner, S., "Key words for use in RFCs to Indicate
              Requirement Levels", BCP 14, RFC 2119, DOI 10.17487/
              RFC2119, March 1997,
              <https://www.rfc-editor.org/info/rfc2119>.

9.2. Informative References

   [I-D.filsfils-spring-srv6-network-programming]
              Filsfils, C., Leddy, J., daniel.voyer@bell.ca, d.,
              daniel.bernier@bell.ca, d., Steinberg, D., Raszuk, R.,
              Matsushima, S., Lebrun, D., Decraene, B., Peirens, B.,
              Salsano, S., Naik, G., Elmalky, H., Jonnalagadda, P.,
              Sharif, M., Ayyangar, A., Mynam, S., Henderickx, W.,
              Bashandy, A., Raza, K., Dukes, D., Clad, F., and P.
              Camarillo, "SRv6 Network Programming",
              draft-filsfils-spring-srv6-network-programming-03 (work in

                    progress), December 2017.

   [I-D.ietf-dmm-fpc-cpdp]
                Matsushima, S., Bertz, L., Liebsch, M., Gundavelli, S.,
                Moses, D., and C. Perkins, "Protocol for Forwarding Policy
                Configuration (FPC) in DMM", draft-ietf-dmm-fpc-cpdp-09
                (work in progress), October 2017.

   [I-D.ietf-dmm-ondemand-mobility]
                Yegin, A., Moses, D., Kweon, K., Lee, J., Park, J., and S.
                Jeon, "On Demand Mobility Management",
                draft-ietf-dmm-ondemand-mobility-13 (work in progress),
                January 2018.

   [I-D.ietf-dmm-srv6-mobile-uplane]
                Matsushima, S., Filsfils, C., Kohno, M.,
                daniel.voyer@bell.ca, d., and C. Perkins, "Segment Routing
                IPv6 for Mobile User-Plane",
                draft-ietf-dmm-srv6-mobile-uplane-00 (work in progress),
                November 2017.

   [RFC5213] Gundavelli, S., Ed., Leung, K., Devarapalli, V.,
                Chowdhury, K., and B. Patil, "Proxy Mobile IPv6",
                RFC 5213, DOI 10.17487/RFC5213, August 2008,
                <https://www.rfc-editor.org/info/rfc5213>.

   [RFC6275] Perkins, C., Ed., Johnson, D., and J. Arkko, "Mobility
                Support in IPv6", RFC 6275, DOI 10.17487/RFC6275,
                July 2011, <https://www.rfc-editor.org/info/rfc6275>.

Authors' Addresses

   Sri Gundavelli
   Cisco
   170 West Tasman Drive
   San Jose, CA 95134
   USA

   Email: sgundave@cisco.com

Marco Liebsch
NEC
Kurfuersten-Anlage 36
D-69115 Heidelberg,
Germany

Email: liebsch@neclab.eu

Satoru Matsushima
SoftBank
Tokyo,
Japan

Email: satoru.matsushima@g.softbank.co.jp