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Network-Hexagons: H3-LISP Dataflow Virtualization for Mobility Edge
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Abstract

Geolocation-Services aggregate raw data uploads from vehicles using mobility edge compute locations and process these uploads to verified ,localized, geospatial detection-channels. Geospatial detection channels are used by mobility clients in vehicles and in the cloud to support aspects of Mobility use-cases: i. Crowd-sourced mapping of lanes, markings, and signage ii. Intelligent Driving heads-up notifications on hazards, blockages, and connivances such as parking or charging on the driving route.

The allocation of Geolocation Services is dynamic and adjusted to road activity and number of active vehicles. This dynamics combined with the dynamics of vehicles mobile-access IP Anchors creates coherency, context-switching, geo-privacy, and service continuity key issues. These issues are resolved by dataflow virtualization, or communication indirection, between mobility clients in vehicles and Geolocation Services. LISP overlay network-virtualization [I-D.ietf-lisp-rfc6830bis] offers a mobility-network solution. Such a LISP mobility-network deployment is described in this document.

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Table of Contents

1. Introduction

Geolocation-Services aggregate raw data uploads from vehicles using mobility edge compute locations and process these uploads to verified ,localized, geospatial detection-channels. Geospatial detection channels are used by mobility clients in vehicles and in the cloud to support aspects of Mobility use-cases: i. Crowd-sourced mapping of lanes, markings, and signage ii. Intelligent Driving heads-up notifications on hazards, blockages, and connivances such as parking or charging on the driving route.

Geolocation services transform inaccurate, duplicated geospatial data captured and uploaded by multiple vehicles points of view, into consolidated information channels. Functional abstraction of a Geolocation Service includes:

- Addressable queues for uploads from mobility clients in vehicles
- Addressable detection channels subscribed to by mobility clients
- State & functions transforming upload data to detection channels

In order to scale in large cities and dense areas Geolocation Services are broken to shards, or geospatial areas, according to formal grid lines. The allocation of Geolocation Services shards is dynamic and adjusted to road activity and number of active vehicles during times of the day. Less shards per compute location and more locations during peak commute hours to absorb the upload and processing load, more shards per location and less compute locations during the night, and the various street load conditions in between. This dynamics combined with the dynamics of mobility clients in vehicles selecting mobile-provider, and consequently switching IP Anchors, creates key-issues:

- Coherency of Geolocation Services IP addresses cached in clients
- Context-switching between Geolocation Service shards while driving
- Geo-privacy of clients while interacting with Geolocation Services
- Service continuity when clients switch providers while driving

These issues are resolved by dataflow virtualization, or communication indirection, between mobility clients and Geolocation Services. Such communication when based on logical addresses of entities and geospatial topics solves these issues. It allows for dynamic and portable allocation of Geolocation Services, algorithmic context-switching between Geolocation Services while driving, service continuity when mobile carriers are switched by vehicle modules while driving for reception, preserving the geo-privacy of mobility clients. LISP overlay network-virtualization can offer such a solution through specific use of Endpoint Identifiers (EID):

- EID addressing of upload queues per geospatial grid identifiers
- EID addressing of detection channels per geospatial topics
- EID addressing of mobility clients assigned and renewed periodically

These EIDs are tracked by the LISP mobility-network offering dynamic portability of queues and channels, where functions are assumed to be available in any compute location. Geolocation current-state used for consolidation is quickly regenerated by Geolocation Services.

EIDs of mobility clients are tracked across the LISP mobility-network enabling service continuity when mobile carriers are switched by the vehicle systems. These EIDs are ephemeral and make it difficult for just any mobility service provider to track mobility clients movement during the day. The use of LISP as the mobility-network for dataflow virtualization between mobility client to Geolocation Services is described in this informational document

Note 1: The breakdown of Geolocations Services to area-shards is done based on formal grid lines known to both mobility clients and Geolocation Services. Geospatial detections, raw uploads and consolidated channels also made using a formal grid known to both clients and services. This document is based on the H3 grid (https://h3geo.org/).H3 resolution 9 (H3.r9) or roughly 0.1 square kilometers is used for the Geolocation Services shards, and H3 resolution 15 (H3.r15), roughly 1 square meter is used for geospatial detections. Each H3 hexagonal tile has unique 64bit identifier (HID).

Note 2: LISP solution for dataflow virtualization is an application network. In order for clients and services to use it there needs to be a formal provisioning step. For the clients this step will require AAA procedure by which clients are assigned and renew EIDs and XTRs to be used to communicate with services. This process may be done in various vendor specific methods, in this document we use a DIAMETER [RFC6733] based AAA service, this is meant as a life-cycle example only.

Note 3: In order to make the notion of geospatial detection concrete, we add to the 64bit HID of "where" is a detection, 64bit of "what" is the detection. These 64bits are detailed in a bit-mask of possible detections based on a taxonomy defined by Berkeley Deep Drive (BDD) consortium (https://bdd-data.berkeley.edu). It is meant as a baseline that can be extended in additional specifications, yet proven minimal sufficient in current implementations.

```
                                           _____
                                          /     \
Off-Peak Allocation        Addresable >>  States >> Addressable
 _  _    _  _             Upload Queues   \_____/     Channels
/ \/ \  / \/ \  ----                ^   f1()..fn()       v
\_/\_/  \_/\_/  ----                ^                    v
/ \/ \  / \/ \  ----       Peak Geolocation Service Allocation
\_/\_/  \_/\_/  ----       _  _    _  _    _  _    _  _
/ \/ \  / \/ \  ----      / \/ \  / \/ \  / \/ \  / \/ \  ----
\_/\_/  \_/\_/  ----      \_/\_/  \_/\_/  \_/\_/  \_/\_/  ----
/ \/ \  / \/ \  ----      / \/ \  / \/ \  / \/ \  / \/ \  ----
\_/\_/  \_/\_/  ----      \_/\_/  \_/\_/  \_/\_/  \_/\_/  ----
 ^  ^    ^  ^   ^  ^       ^ ^     ^  ^    ^  ^    ^  ^   ^  ^
 Site   Site  Standby     Site    Site    Site    Site  Standby
```

Figure 1: Geolocation Service Schematics and Dynamic Allocation

2. Definition of Terms

H3ServiceEID: Is an EID addressable Geolocation Service shard. It is a designated destination for geospatial detections, and an (s,g) source of multicast of themed detection channels. It has a light-weight LISP protocol stack to tunnel packets aka ServerXTR. The EID is an IPv6 EID that contains the HID.

ServerXTR: Is a data-plane only LISP protocol stack implementation, it is co-located with H3ServiceEID process. ServerXTR encapsulates and decapsulates packets to and from EdgeRTRs.

MobilityClient: Is an application that may be a part of a vehicle system, part of a navigation application, part of municipal application, or a street view consumer application. It has a light-weight LISP data-plane stack to packets - ClientXTR.

MobilityClient EID: Is the IPv6 EID used by the Mobility Clients. The destination of such packets are H3ServiceEIDs. The EID format is assigned as part of the MobilityClient mobility-network AAA.

ClientXTR: Is a data-plane only LISP protocol stack implementation co-located with the Mobility Client application. It encapsulates and decapsulates packets to and from EdgeRTRs.

EdgeRTR: Is the core scale and structure of the LISP mobility-network. EdgeRTRs connect H3ServiceEIDs and MobilityClient H3ServiceEID. EdgeRTRs also manage MobilityClients multicast registrations. EdgeRTRs aggregate MobilityClients/H3Services using tunnels to facilitate hosting-providers and mobile-providers for accessing the mobility-network. EdgeRTRs decapsulate packets from ClientXTRs, ServerXTRs and re-encapsulates packets to clients and servers tunnels. EdgeRTRs glean H3ServiceEIDs and MobilityClient EIDs when they decapsulate packets. EdgeRTRs store H3ServiceEIDs and route locations (RLOC) of where the H3ServiceEID is currently using the map-cache. Mappings are registered to the LISP mapping system.These mappings may be provisioned when H3Services are assigned EdgeRTRs. EdgeRTRs do not register MobilityClients' EIDs. Enterprises may provide their own EdgeRTRs to protect geo-privacy.

```
                          ___                                    ___
   H3ServiceEIDs   ___  /     \           H3ServiceEIDs ___  /     \
            ___  /     | H3.r9 |                 ___  /     | H3.r9 |
          /     | H3.r9 \ ___ /                /     | H3.r9 \ ___ /
         | H3.r9 \ ___ /  sXTR                | H3.r9 \ ___ /  sXTR
          \ ___ /  sXTR    |                   \ ___ /  sXTR     |
            sXTR    |      |                     sXTR     |      |
             |      |      |                      |       |      |
             |      |      |                      |       |      |
             + -  - + - - EdgeRTR           EdgeRTR - + - + - -  +
                             ||  (   (   ((  ||
                          (                        )
                        (      Network Hexagons      )
                      (            H3-LISP             )
                        (      mobility-network       )
                          ((                        )
                            ||  ((   (())   ()  ||
                            ||                  ||
                = = = = = = =                     = = = = = = =
               ||                                              ||
            EdgeRTR                                         EdgeRTR
           ..    ..                                       ..      ..
          ..       ..                                   ..          ..
  ((((|))))   ((((|))))                        ((((|))))   ((((|))))
     /|\    RAN   /|\                               /|\    RAN   /|\
      ..                                                           ..
      ..                                                           ..
      ..          Road tiled by 1 sqm H3.r15 ID-Ed Geo-States    ..
      ..                                                           ..
      ..                  ___    ___    ___                        ..
      ..  ............. /     \/     \/     \ << cXTR::MobilityClientB
      .. - - - - - - -  H3.r15  H3.r15 H3.r15 - - - - - - - - - - - -
      MobilityClientA::cXTR >> \ ___ /\ ___ / ......................
```

Figure 2: H3.r15 state representation, H3.r9 state aggregation

Figure 2 above describes the following entities:

- MobilityClientA detections used by MobilityClientB, and, vice versa
- Clients: share information via Geolocation Services routed by LISP
- ClientXTR (cXTR): tunnels packets over access networks to EdgeRTR
- ServerXTR (sXTR): tunnels packets over cloud networks to EdgeRTR
- H3-LISP Mobility Network: overlay which spans cXTRs to sXTRs
- Uploads: routed to appropriate Geolocation Service by LISP
- EdgeRTRs: perform multicast replication to EdgeRTRs and to cXTRs
- Clients: receive geospatial detection updates via multicast channels

3. Deployment Assumptions

The specification described in this document makes the following deployment assumptions:

(1) Unique 64bit HID is associated with each H3 geo-spatial tile
(2) MobilityClients and H3ServiceEIDs share grid based indexing
(3) 64bit BDD state value is associated with each H3-indexed tile
(4) Tile state is compiled 16 fields of 4-bits, or max 16 enums

```
0       1       2       3       4       5       6       7
+-------+-------+-------+-------+-------+-------+-------+-------+
|-0-|-1-|-2-|-3-|-4-|-5-|-6-|-7-|-8-|-9-|-A-|-B-|-C-|-D-|-E-|-F-|
|0123012301230123012301230123012301230123012301230123012301230123
+---------------------------------------------------------------+
```

Figure 3: Nibble based representation, 16 fields x 16 enumerations

We name the nibbles using hexadecimal index according to the position where the most significant nibble has index 0. Values are defined in section 8.

Subscription of MobilityClients to mobility-network is renewed while driving. It is not intended as the basic connectivity. MobilityClients use DNS/AAA to obtain temporary EIDs/EdgeRTRs and use (LISP) data-plane tunnels to communicate using their temporary EIDs with the dynamically assigned EdgeRTRs. MobilityClient are otherwise unaware of the LISP network control plane and regard the data-plane tunnels as mobility network.

In order to get access to the mobility-network, MobilityClients first authenticate with the Mobility AAA. DIAMETER [RFC6733] based AAA can be used as a solution for the many types of mobility clients: vehicle systems, driving applications, city and consumer applications.

ClientXTRs perform the following steps to use the mobility-network:
1) obtain the address of the mobility-network AAA server using DNS
2) obtain MobilityClientEIDs and EdgeRTRs from AAA DIAMETER server
3) renew authorization from AAA while using the mobility-network

```
MobilityClient DomainNameServer  DIAMETER-AAA  MobilityEdgeRTR
|                    |                   |                   |
| nslookup nexagon   |                   |                   |
|------------------->|                   |                   |
|<-------------------|                   |                   |
|  Mobility AAA IP   |                   |                   |
|                    |                   |                   |
|  AAR(AVP:IMSI/User/Password/Toyota)    |                   |
|--------------------------------------->|                   |
|                    |                   | ACR(AVP ClientEID)|
|                    |                   |------------------>|
|                    |                   |<------------------|
|                    |                   | ACA(AVP ClientEID)|
|    AAA (Client::EID,EdgeRTR::RLOC)     |                   |
|<---------------------------------------|                   |
|                    |                   |                   |
.                                                            .
. Upload to IPv6 H3ServiceEID, Subscribe MLDv2 H3ServiceEID  .
.                                                            .
|                                                            |
|----------------------------------------------------------->|
.                                                            .
.                                                            .
|<-----------------------------------------------------------|
|                                                            |
.                                                            .
.   Signal freeing multicast Updates from H3ServiceEID       .
.                                                            .
|                    |                   |                   |
|               AAR(Interim)             |                   |
|--------------------------------------->|   ACR (Interim)   |
|                    |                   |------------------>|
|                    |                   |<------------------|
|                    |                   |   ACA (Interim)   |
|<---------------------------------------|                   |
|               AAA (Interim)            |                   |
```

Figure 4: DNS and AAA Exchange for lisp mobility-network login

Using such an AAA procedure we can ensure that:

- MobilityClientEIDs serve as credentials with the EdgeRTRs
- EdgeRTRs are provisioned to whitelist MobilityClient EIDs
- EdgeRTRs are not tightly coupled to H3.r9 areas (privacy/balance)
- MobilityClients do not need to update EdgeRTRs while driving

4. Mobility Clients Network Services

The mobility-network functions as a standard LISP overlay.
The overlay delivers unicast and multicast packets across:

- multiple access-networks and radio-access specifications
- multiple cloud edge providers, public, private, and hybrid

We use data-plane XTRs in the stack of each mobility client/server. ClientXTRs and ServerXTRs are homed to one or more EdgeRTRs. This structure allows for MobilityClients to "show up" at any location behind any network provider in a given mobility-network admin/NAT domain, and for any H3ServiceEID to be instantiated, moved, or failed-over to any cluster in any cloud-provider. LISP overlay enables these roaming mobility-network elements to communicate uninterrupted. This quality is insured by the LISP RFCs. The determination of identities for MobilityClients to always refer to the correct H3ServiceEID is insured by H3 geo-spatial HIDs.

In this specification we assume semi-random association between ClientXTRs and EdgeRTRs applied by the AAA procedure. We assume that in a given metro edge a pool of EdgeRTRs can distribute the Mobility Clients load randomly between them and that EdgeRTRs are topologically equivalent. Each RTR uses LISP to tunnel traffic to and from other EdgeRTRs forMobilityClient and H3Service exchanges.

To summarize the H3LISP mobility-network layout:

(1) Mobility-Clients traffic is tunneled via data-plane ClientXTRs
    ClientXTRs are homed to EdgeRTR(s)
(2) H3ServiceEID traffic is tunneled via data-plane ServerXTR
    ServerXTRs are homed to EdgeRTR(s)
(3) EdgeRTRs use mapping service to resolve unicast EIDs to RTR RLOCs
    EdgeRTRs also register to (Source, Group) H3ServiceEID multicasts

```
MobilityClients <> ClientXTR <Access Provider > EdgeRTR  v
                                                         v
v < < < <      LISP Mobility-Network Overlay  < < < <    v
v
> > > > EdgeRTR <Cloud Provider> ServerXTR <> H3ServiceEID
```

Figure 5: The Data Flow Between MobilityClients and H3ServiceEIDs

5. Mobility Unicast and Multicast

Regardless of the way a given ClientXTR was associated with EdgeRTR, an authenticated MobilityClient EID can send: [64bitH3.15ID :: 64bitState] detection to the H3.r9 H3ServiceEID. The H3.r9 EID can be calculated by clients algorithmically from the H3.15 localization.

The ClientXTR encapsulates MobilityClient EID and H3ServiceEID from the ClientXTR with the destination of the EdgeRTR RLOC LISP port. EdgeRTRs then re-encapsulate annotation packets to remote EdgeRTR. The remote EdgeRTR aggregating H3ServiceEIDs re-encapsulates MobilityClient EID to the ServerXTR of the H3ServiceEID.

The headers consist of the following fields:

Outer headers size = 40 (IPv6) + 8 (UDP) + 8 (LISP) = 56
Inner headers size = 40 (IPv6) + 8 (UDP) + 4 (Nexagon Header) = 52
1500 (MTU) - 56 - 52 = 1392 bytes of effective payload size

Nexagon Header Type allows for kv tupples or vkkk flooding using the same key and the same formats of key and value
Type 0:reserved
Type 1:key-value, key-value.. 1392 / (8 + 8) = 87 pairs
Type 2:value, key,key,key.. (1392 - 8) / 8 = 173 H3-R15 IDs
Type 3-255: unassigned
Nexagon Header GZIP field: 0x000 no compression, or GZIP version.
The compression refers to entire kv or vkkk payload.
Nexagon Header Reserved bits
Nexagon Header key and value count (in any format)

```
  0                   1                   2                   3
  0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+ \
 |Version| Traffic Class |           Flow Label                  |  |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+  |
 |         Payload Length        |  Next Header  |   Hop Limit   |  |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+  |
 |                                                               |  |
 +                                                               +  |
 |                                                               |  |
 +                    Source MobilityClientEID                   +  |
 |                                                               | IPv6
 +                                                               +  |
 |                                                               |  |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+  |
 |                                                               |  |
 +                                                               +  |
 |                                                               |  |
 +                       Dest H3ServiceEID                       +  |
 |                                                               |  |
 +                                                               +  |
 |                                                               | /
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |       Source Port = xxxx      |       Dest Port = xxxx        | \
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+ UDP
 |           UDP Length          |        UDP Checksum           | /
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+ \
 |  Type         |gzip |        Reserved         | Pair Count = X| Nexgon
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+ /
 |                                                               |
 +                       64bit H3-R15 ID                        +
 |                                                               |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |                                                               |
 +                       64bit State                            +
 |                                                               |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |                                                               |
 +                       64bit H3-R15 ID                        +
 |                                                               |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |                                                               |
 +                       64bit State                            +
 |                                                               |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 6: Uploaded detections packet format

To Summarize Unicast Uploads:

(1) MobilityClients can send detections localized to H3.r15 tile.
These detections are sent to H3.r9 mobility H3ServiceEIDs
(2) MobilityClient EID and H3ServiceEID HID are encapsulated:
XTR <> RTR <> RTR <> XTR
(3) RTRs re-encapsulate original source-dest to ServerXTRs
ServerXTRs decapsulate packets to H3ServiceEID

Each H3Service is also an IP Multicast Source used to update subscribers on the aggregate state of the H3.r15 tiles in the H3.r9 area. We use [RFC8378] signal-free multicast to implement channels in the overlay. The mobility-network has many channels, with thousands subscribers per channel. MobilityClients driving through/subscribing to an H3.r9 area can explicitly issue an [RFC4604] MLDv2 in order to subscribe, or, may be subscribed implicitly by the EdgeRTR.

The advantage of explicit client MLDv2 registration as [RFC8378] trigger is that clients manage their own mobility multicast per driving-direction vectors, and that it allows for otherwise silent non uploading clients. The advantage of EdgeRTR implicit registration is that less signaling required.

MLDv2 signaling messages are encapsulated between the ClientXTR and EdgeRTR, therefore there is no requirement for the underlying network to support native multicast. If native access multicast is supported then MobilityClient registration to H3ServiceEID safety channels may be integrated with it, in which case mobile packet-core element supporting it will use this standard to register with the appropriate Geolocation Service channels in its area.

Multicast update packets are of the following structure:

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+ \
|Version| Traffic Class |           Flow Label                  |  |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+  |
|         Payload Length        |  Next Header  |   Hop Limit   |  |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+  |
|                                                               |  |
+                                                               +  |
|                                                               |  |
+                        Source H3-R9 EID Address               +  |
|                                                               | IPv6
+                                                               +  |
|                                                               |  |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+  |
|                                                               |  |
+                                                               +  |
|                                                               |  |
+                           Group Address                       +  |
|                                                               |  |
+                                                               +  |
|                                                               | /
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|       Source Port = xxxx      |       Dest Port = xxxx        | \
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+ UDP
|           UDP Length          |        UDP Checksum           | /
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+ \
|                                                               |Nexagon
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+ /
~                            Nexagons Payload                   ~
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 7: multicast update packet header

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+ \
|  Type =   1   |gzip |        Reserved         | Pair Count = X|Nexagon
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+ /
|                                                               |
+                       64bit H3-R15 ID                        +
|                                                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                                                               |
+                       64bit State                            +
|                                                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                                                               |
+                       64bit H3-R15 ID                        +
|                                                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                                                               |
+                       64bit State                            +
|                                                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 8: multicast update payload, key-value, key-value..

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+ \
|  Type =   2   |gzip |     Reserved            |H3R15 Count = X|Nexagon
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+ /
|                                                               |
+                        64bit State                            +
|                                                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                                                               |
+                        64bit H3-R15 ID                        +
|                                                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                                                               |
+                        64bit H3-R15 ID                        +
|                                                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                                                               |
+                        64bit H3-R15 ID                        +
|                                                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 9: multicast update payload, value, key, key.. for larger areas

The remote EdgeRTRs homing MobilityClients in turn replicate the packet to the MobilityClients registered with them.

We expect an average of 600 H3.r15 tiles of the full 7^6 (~100K) possible in H3.r9 to be part of any road. The H3.r9 server can transmit the status of all 600 or just those with meaningful states based on updated SLA and policy.

To Summarize:

(1) EIDClients tune to H3.r9 mobility updates using [RFC8378]
    EIDClient issue MLDv2 registration to H3.r9 HIDs
    ClientXTRs encapsulate MLDv2 to EdgeRTRs who register (s,g).

(2) ServerXTRs encapsulate updates to EdgeRTRs who map-resolve (s,g)
    RLOCs EdgeRTRs replicate mobility update and tunnel to registered
    EdgeRTRs Remote EdgeRTRs replicate updates to ClientXTRs.

6. Security Considerations

The nexagon mobility-network is inherently secure and private. All information is conveyed using Geolocation Services. MobilityClients receive information only from geospatial channels originating from a trusted server. MobilityClients have no indication as to the origin of the raw data.

In order to be able to use the nexagon mobility-network for a given period, the mobility clients go through a DNS/AAA stage by which they obtain their clientEID identifiers-credentials and the RLOCs of EdgeRTRs they may use as gateways to the network. This MobilityClient <> EdgeRTR interface is the most sensitive in this network to privacy and security considerations.

The traffic on the MobilityClient<>EdgeRTR interface is tunneled, and its UDP content may be encrypted; still, the EdgeRTR will know based on the LISP headers alone the MobilityClient RLOC and H3-R9 (~0.1sqkm) geo-spatial area to which a given client uploads or subscribes to.

For this reason we envision the ability of enterprise or groups of users to "bring their own" EdgeRTRs. For example a car OEM offering EdgeRTRs on behalf of its vehicles for use with Geolocation Services. BYO-RTR masks individual clients' RLOC to H3.r9 association and is pre-provisioned to be able to use the mapping system and be on a white-list of EdgeRTRs aggregating H3ServiceEIDs. If the EdgeRTR functionality is delivered by 5GCore UPF then the only entity which can correlate underlay IP, User, and Geo-location is the regulated carrier, which can do so anyway.

Beyond this hop, the mapping system does not hold MobilityClientEIDs, and remote EdgeRTRs are only aware of MobilityClient ephemeral EIDs, not actual RLOC or any other mobile-device identifiers. EdgeRTRs register in the mapping (s,g) H3-R9 multicast groups. Which clients use which EdgeRTR is not in the mapping system, only the AAA server is aware of that. The H3ServiceEIDs themselves decrypt and parse actual H3-R15 annotations; they also consider during this MobilityClientEID credentials to avoid "fake-news", but again these are only temporary EIDs allocated to clients in order to be able to use the mobility network and not for their actual IP.

H3Services are provisioned to their EdgeRTRs, in the EdgeRTRs, and optionally also in the mapping system.

In summary of main risk mitigations for the lisp-nexagon interface:

(1) tapping: all communications are through dynamic tunnels therefore may be encrypted using IP-Sec or other supported point to point underlay standards. These are not static tunnels but LISP re-tunneling routers (RTRs) perform all nexagon Overlay aggregation.

(2) spoofing: it is very hard to guess a MobilityClientEID valid for a short period of time. Clients and H3Services EIDs are whitelisted in EdgeRTRs, Clients using the AAA procedure, H3Services via dev-ops.

(3) impersonating: efforts to use MobilityClients and H3Services RLOCs should be caught by the underlying service provider edge and access networks. EID impersonating is caught by EdgeRTR EID RLOC whitelist mismatch.

(4) credibility: the interface crowd-sources geo-state and does not assume to trust single detections. Credit history track to MobilityClientEIDs by as part of normal H3Services fact checking, aggregate scores affect AAA credentials.

(5) privacy: Only EdgeRTRs are aware of both clients' RLOC and geo-location, only AAA is aware of client IDs credentials and credit but not geo-location. Aggregate credit score span all H3Services administratively without source.

7. Acknowledgments

We would like to kindly thank Joel Halperin for helping structure the AAA section and Geo-Privacy provisions, Luigi Lannone for promoting such LISP Compute First Networking (CFN) use-cases, helping structure the IANA section, and shepherding this draft to completion. We would like to thank George Ericson for help clarifying Geolocation Services terminology through work on the AECC specifications and papers.

8. IANA Considerations

This section provides guidance to the Internet Assigned Numbers Authority (IANA) regarding registration of values related to the LISP specification, in accordance with BCP 26 [RFC8126].

IANA is asked to create a registry named NEXAGON Parameters.

Such registry should be populated with the following sub registries.

State Enumeration Field 0x0: Traffic Direction:

Value	Description	Reference
0x0	Null	[This Document]
0x1	Lane North	[This Document]
0x2	Lane North + 30	[This Document]
0x3	Lane North + 60	[This Document]
0x4	Lane North + 90	[This Document]
0x5	Lane North + 120	[This Document]
0x6	Lane North + 150	[This Document]
0x7	Lane North + 180	[This Document]
0x8	Lane North + 210	[This Document]
0x9	Lane North + 240	[This Document]
0xA	Lane North + 270	[This Document]
0xB	Lane North + 300	[This Document]
0xC	Lane North + 330	[This Document]
0xD	Junction	[This Document]
0xE	Shoulder	[This Document]
0xF	Sidewalk	[This Document]

State Enumeration Field 0x1: Persistent Condition:

Value	Description	Reference
0x0	Null	[This Document]
0x1	Pothole Light	[This Document]
0x2	Pothole Deep	[This Document]
0x3	Speed-bump Low	[This Document]
0x4	Speed-bump High	[This Document]
0x5	Icy	[This Document]
0x6	Flooded	[This Document]
0x7	Snow-cover	[This Document]
0x8	Deep Snow	[This Document]
0x9	Cone	[This Document]
0xA	Gravel	[This Document]
0xB	Choppy	[This Document]
0xC	Blind-Curve	[This Document]
0xD	Steep	[This Document]
0xE	Low-bridge	[This Document]
0xF	Other	[This Document]

State Enumeration Field 0x2: Transient Condition:

Value	Description	Reference
0x0	Null	[This Document]
0x1	Jaywalker	[This Document]
0x2	Bike or Scooter	[This Document]
0x3	Stopped Vehicle	[This Document]
0x4	Moving on Shoulder	[This Document]
0x5	First Responder	[This Document]
0x6	Sudden Slowdown	[This Document]
0x7	Oversize Vehicle	[This Document]
0x8	Light/Sign Breach	[This Document]
0x9	Collision Light	[This Document]
0xA	Collision Severe	[This Document]
0xB	Collision Debris	[This Document]
0xC	Collision Course	[This Document]
0xD	Vehicle Hard Brake	[This Document]
0xE	Vehicle Sharp Turn	[This Document]
0xF	Freed-up Parking	[This Document]

State Enumeration Field 0x3: Traffic-light Counter:

Value	Description	Reference
0x0	Null	[This Document]
0x1	1 Second to Green	[This Document]
0x2	2 Second to Green	[This Document]
0x3	3 Second to Green	[This Document]
0x4	4 Second to Green	[This Document]
0x5	5 Second to Green	[This Document]
0x6	6 Second to Green	[This Document]
0x7	7 Second to Green	[This Document]
0x8	8 Second to Green	[This Document]
0x9	9 Second to Green	[This Document]
0xA	10 Second to Green	[This Document]
0xB	20 Second to Green	[This Document]
0xC	30 Second to Green	[This Document]
0xD	60 Second to Green	[This Document]
0xE	Green Now	[This Document]
0xF	Red Now	[This Document]

State Enumeration Field 0x4: Impacted Tile:

Value	Description	Reference
0x0	Null	[This Document]
0x1	Epicenter	[This Document]
0x2	2 Tiles Away	[This Document]
0x3	3 Tiles Away	[This Document]
0x4	4 Tiles Away	[This Document]
0x5	5 Tiles Away	[This Document]
0x6	6 Tiles Away	[This Document]
0x7	7 Tiles Away	[This Document]
0x8	8 Tiles Away	[This Document]
0x9	9 Tiles Away	[This Document]
0xA	10 Tiles Away	[This Document]
0xB	20 Tiles Away	[This Document]
0xC	30 Tiles Away	[This Document]
0xD	60 Tiles Away	[This Document]
0xE	<100 Tiles Away	[This Document]
0xF	<200 Tiles Away	[This Document]

State Enumeration Field 0x5: Expected Duration:

Value	Description	Reference
0x0	Null	[This Document]
0x1	Next 1 Second	[This Document]
0x2	Next 5 Seconds	[This Document]
0x3	Next 10 Seconds	[This Document]
0x4	Next 20 Seconds	[This Document]
0x5	Next 40 Seconds	[This Document]
0x6	Next 60 Seconds	[This Document]
0x7	Next 2 Minutes	[This Document]
0x8	Next 3 Minutes	[This Document]
0x9	Next 4 Minutes	[This Document]
0xA	Next 5 Minutes	[This Document]
0xB	Next 10 Minutes	[This Document]
0xC	Next 15 Minutes	[This Document]
0xD	Next 30 Minutes	[This Document]
0xE	Next 60 Minutes	[This Document]
0xF	Next 24 Hours	[This Document]

State Enumeration Field 0x6: Lane Right Sign:

Value	Description	Reference
0x0	Null	[This Document]
0x1	Yield	[This Document]
0x2	Speed Limit	[This Document]
0x3	Straight Only	[This Document]
0x4	No Straight	[This Document]
0x5	Right Only	[This Document]
0x6	No Right	[This Document]
0x7	Left Only	[This Document]
0x8	No Left	[This Document]
0x9	Right Straight	[This Document]
0xA	Left Straight	[This Document]
0xB	No U Turn	[This Document]
0xC	No Left or U	[This Document]
0xD	Bike Lane	[This Document]
0xE	HOV Lane	[This Document]
0xF	Stop	[This Document]

State Enumeration Field 0x7: Movement Sign:

Value	Description	Reference
0x0	Null	[This Document]
0x1	Keep Right	[This Document]
0x2	Keep Left	[This Document]
0x3	Stay in Lane	[This Document]
0x4	Do Not Enter	[This Document]
0x5	No Trucks	[This Document]
0x6	No Bikes	[This Document]
0x7	No Peds	[This Document]
0x8	One Way	[This Document]
0x9	Parking	[This Document]
0xA	No Parking	[This Document]
0xB	No Standing	[This Document]
0xC	No Passing	[This Document]
0xD	Loading Zone	[This Document]
0xE	Rail Crossing	[This Document]
0xF	School Zone	[This Document]

State Enumeration Field 0x8: Curves & Intersections:

Value	Description	Reference
0x0	Null	[This Document]
0x1	Turns Left	[This Document]
0x2	Turns Right	[This Document]
0x3	Curves Left	[This Document]
0x4	Curves Right	[This Document]
0x5	Reverses Left	[This Document]
0x6	Reverses Right	[This Document]
0x7	Winding Road	[This Document]
0x8	Hair Pin	[This Document]
0x9	Pretzel Turn	[This Document]
0xA	Cross Roads	[This Document]
0xB	Cross T	[This Document]
0xC	Cross Y	[This Document]
0xD	Circle	[This Document]
0xE	Lane Ends	[This Document]
0xF	Road Narrows	[This Document]

State Enumeration Field 0x9: Tile Traffic Speed:

Value	Description	Reference
0x0	Null	[This Document]
0x1	< 1 m/sec	[This Document]
0x2	< 2 m/sec	[This Document]
0x3	< 3 m/sec	[This Document]
0x4	< 4 m/sec	[This Document]
0x5	< 5 m/sec	[This Document]
0x6	< 6 m/sec	[This Document]
0x7	< 7 m/sec	[This Document]
0x8	< 8 m/sec	[This Document]
0x9	< 9 m/sec	[This Document]
0xA	< 10 m/sec	[This Document]
0xB	< 20 m/sec	[This Document]
0xC	< 30 m/sec	[This Document]
0xD	< 40 m/sec	[This Document]
0xE	< 50 m/sec	[This Document]
0xF	> 50 m/sec	[This Document]

State Enumeration Field 0xA: Pedestrian Curb Density:

Value	Description	Reference
0x0	Null	[This Document]
0x1	100%	[This Document]
0x2	95%	[This Document]
0x3	90%	[This Document]
0x4	85%	[This Document]
0x5	80%	[This Document]
0x6	70%	[This Document]
0x7	60%	[This Document]
0x8	50%	[This Document]
0x9	40%	[This Document]
0xA	30%	[This Document]
0xB	20%	[This Document]
0xC	15%	[This Document]
0xD	10%	[This Document]
0xE	5%	[This Document]
0xF	No Peds	[This Document]

State enumeration fields 0xB, 0xC, 0xD, 0xE, 0xF, are unassigned. IANA can assign them on a "First Come First Served" basis according to [RFC8126].

9. Normative References

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