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Network-Hexagons:Geolocation Mobility Edge Network Based On H3 and LISP
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Abstract

This document describes an interoperable system of Geolocation agents that utilizes virtual layer 3 routing and geospatial addressing to form a mobility-edge network. The network uses a hierarchical H3 grid to calculate the high-resolution tile positions of detections made by vehicles equipped with vision AI cameras using their GPS coordinates. When these vehicles detect elements of interest or map road segments, the system uses the tile ID of the detection or road segment as the basis for an IPv6 endpoint identifier (EID). These EIDs are the destination queues and channel sources for network-addressable agents that consolidate detections from all vehicles in a given area.
The mobility network is constructed using the Locator/ID Separation Protocol (LISP).

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1. Introduction

This document describes an interoperable system of Geolocation agents that utilizes virtual layer 3 routing and geospatial addressing to form a mobility-edge network. The network uses a hierarchical H3 grid to calculate the high-resolution tile positions of detections made by vehicles equipped with vision AI cameras using their GPS coordinates. When these vehicles detect elements of interest or map road segments, the system uses the tile ID of the detection or road segment as the basis for an IPv6 endpoint identifier (EID). These EIDs are the destination queues and channel sources for network-addressable agents that consolidate detections from all vehicles in a given area.
The mobility network is constructed using the Locator/ID Separation Protocol (LISP).The system utilizes addressable agents per hexagonal grid areas, referred to as "nexagons," which are dynamically delegated to compute locations to consolidate road activity, vehicle uploads, and client subscriptions. The dynamic location and density of vehicles can cause key issues, which are resolved by the use of LISP. These key issues include the dynamic delegation of agents, resulting in cache incoherency of Geolocation IPs; context-switching of Geolocation IPs by vehicles while driving across geospatial areas; geo-privacy

violations and tracking of vehicles interacting with Geolocation agents; and continuity and scalability of Geolocation subscriptions.

The key issues related to the dynamics of vehicles and clients are resolved using LISP EID addressing. This addressing virtualizes the communication between clients and agents, utilizes algorithmic Geolocation addressing based on geospatial grid identifiers and ephemeral client addressing based on an authorization procedure. Geolocation addressing of agents' queues and channels helps to solve the portability of agents, therefore enables dynamic resource allocation and context-switching. Client EIDs enables subscription continuity, notification scaling, and geo-privacy.

```
                                   ___
                                 /     \
                  Addressable >>  States  >> Addressable
                 Upload Queues   \ ___ /     Channels
                       /\      Functions()      \/
```

Figure 1: Geolocation Agents (nexagons)

```
Off-Peak Nexagon Allocation
Agents packed on less compute
   _  _    _  _
  / \/ \  / \/ \  ----
  \_/\_/  \_/\_/  ----           Peak Nexagon Allocation
  / \/ \  / \/ \  ----      Agents spread on more compute locations
  \_/\_/  \_/\_/  ----       _  _    _  _    _  _    _  _
  / \/ \  / \/ \  ----      / \/ \  / \/ \  / \/ \  / \/ \  ----
  \_/\_/  \_/\_/  ----      \_/\_/  \_/\_/  \_/\_/  \_/\_/  ----
  / \/ \  / \/ \  ----      / \/ \  / \/ \  / \/ \  / \/ \  ----
  \_/\_/  \_/\_/  ----      \_/\_/  \_/\_/  \_/\_/  \_/\_/  ----
   ^  ^    ^  ^   ^  ^       ^ ^     ^  ^    ^  ^    ^  ^   ^  ^
   Site   Site  Standby     Site    Site    Site    Site  Standby
```

Figure 2: Geolocation Agents dynamic allocation per geospatial activity

Note 1: nexagon agents are based on a grid called [H3], which is a hierarchical hexagonal grid with clear tile adjacency properties. Each tile in the H3 grid has a unique 64-bit identifier called an HID, which is algorithmically mapped to EID. The H3 grid is used at two different resolutions: one for the nexagons (called "h3.rB") and one for detections and road segment mapping (called "h3.rS"). Mappings between GPS coordinates, HIDs, and EIDs are all algorithmic. The number of messages needed to convey the state of a nexagon can be calculated based on the size of the nexagon, the density of roads within it, and the maximum transmission unit (MTU) of the system. This calculation involves dividing the size of h3.rB by the size of h3.rS, multiplying by the road density, and then dividing by the MTU.

Note 2: the mobility network requires a formal provisioning step for both clients and agents. For clients, this step involves an authentication, authorization, and accounting (AAA) procedure by which clients request and renew EIDs and tunnel-routers to be used to interact with agents. This process may be implemented using various methods or a formal AAA agent. An example AAA procedure is described later in a life-cycle example.

Note 3: In order to provide a concrete usability of this document for detection and dynamic road discovery, 64 bits of information about "what" the detection is are outlined with the 64-bit HID of "where" the detection is. These 64 bits are detailed in a bit-mask based on a taxonomy defined by Berkeley Deep Drive [BDD] and serve as a baseline that can be extended or overridden as needed.

2. Definition of Terms

Based on [RFC9300][RFC9301]

H3SAgentEID: Is an EID addressable Geolocation agent or nexagon. 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 via ServerXTR. The EID is IPv6 and contains HID in the lower bits.

ServerXTR: Is a data-plane only LISP protocol stack implementation, it is co-located with H3AgentEID 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, gov-muni application etc. It has light-weight LISP data-plane stack to packets via ClientXTR.

MobilityClientEID: Is the IPv6 EID used by the Mobility Clients. The destination of such packets are H3AgentEIDs. 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: The EdgeRTR network connects Mobility Clients to Agents, and manages MobilityClientEIDs multicast registrations [RFC8378]. EdgeRTRs aggregate Mobility Clients and Geolocation Agents using encapsulation to facilitate accessing the mobility network from hosting providers and mobile providers. RTRs re-encapsulate packets from ClientXTRs and ServerXTRs, and remote RTRs. EdgeRTRs glean H3 agent EIDs and MobilityClientEIDs when they decapsulate packets, and store H3AgentEIDs and route locations (RLOCs) using map-caches. These mappings are registered to the LISP mapping system [RFC9301] and provisioned when Geolocation Agents are assigned EdgeRTRs. EdgeRTRs do not register MobilityClientEIDs. Enterprises may provide their own EdgeRTRs to protect geo-privacy.

```
                                nexagons
                          ___                                  ___
   H3AgentEIDs     ___  /     \           H3AgentEIDs   ___  /     \
            ___  /     | h3.rB |                 ___  /     | h3.rB |
          /     | h3.rB \ ___ /                /     | h3.rB \ ___ /
         | h3.rB \ ___ /  sXTR                | h3.rB \ ___ /  sXTR
          \ ___ /  sXTR   ||                   \ ___ /  sXTR    ||
            sXTR   ||     ||                    sXTR     ||     ||
             ||    ||     ||                      ||     ||     ||
             ||    ||     ||                      ||     ||     ||
             = = = = = = EdgeRTR                 EdgeRTR = = = = =
                             ||  ((  ()     ))    ||
                         (    Geolocation LISP      )
                        (      Mobility Network     )
                          ( ||  ((   (  )   ()  || )
                            ||                  ||
                0 = = = = = = =                   = = = = = = =
               ||                                              ||
            EdgeRTR                                          EdgeRTR
           ..    ..                                       ..      ..
          ..      ..                                    ..          ..
  ((((|))))    ((((|))))                         ((((|))))    ((((|))))
     /|\    RAN   /|\                               /|\    RAN   /|\

     ||                                                            ||
   Uploads Upstream                                                ||
   Channels Downstream                                             ||
     ||                   ___    ___    ___                        ||
     ||   << << << <<   /     \/     \/     \<<cXTR::MobilityClientB
     || - - - - - - - - -  h3.rS  h3.rS  h3.rS - - - - - - - - - - - -
      MobilityClientA::cXTR >> \ ___ /\ ___ / >> >> >> >>  >>  >>
```

Figure 3: Geolocation clients and agents communication

Figure 3 above describes:

- MobilityClientA detections used by MobilityClientB, and vice versa
- Clients: share information only via Geolocation agents
- ClientXTR (cXTR):encapsulates packets over access network to EdgeRTR
- ServerXTR (sXTR):encapsulates packets over edge network to EdgeRTR
- Uploads: routed to appropriate Geolocation agent by EdgeRTRs
- Channels: originate from Geolocation agents replicated by EdgeRTRs

3. Deployment Assumptions

I. We assume enumerated detections can be localized to h3.rS tiles

```
0       1       2       3       4       5       6       7
+-------+-------+-------+-------+-------+-------+-------+-------+
|-0-|-1-|-2-|-3-|-4-|-5-|-6-|-7-|-8-|-9-|-A-|-B-|-C-|-D-|-E-|-F-|
|0123012301230123012301230123 Index  0123012301230123012301230123
+---------------------------------------------------------------+
```

Figure 4: Nibble based detection enumeration

Detections are enumerated in 16 fields x 16 enumerations. Nibbles are named using hexadecimal index according to the position where the most significant nibble has index 0. Enumeration based on [BDD] are defined in section 8.

The authorization of Mobility Clients to the mobility network is renewed while driving. The AAA procedure described below can be used as an example for obtaining EIDs and EdgeRTRs, and for enabling the use of the network. Diameter [RFC6733] based AAA can be used to accommodate a wide range of Mobility Clients, including vehicles, driving assists, navigation applications, and smart city applications. An example procedure for clients XTRs to use the mobility network:

1) obtain the address of the mobility-network AAA using DNS
2) obtain MobilityClientEIDs and EdgeRTRs from AAA procedure
3) renewed periodically from AAA while using the network

```
MobilityClient DomainNameServer    AAA Server   MobilityEdgeRTR
|                    |                   |                    |
| lookup AAA Server  |                   |                    |
|------------------->|                   |                    |
|<-------------------|                   |                    |
|   AAA  Server IP   |                   |                    |
|                    |                   |                    |
|  Client identifier and credentials     |                    |
|--------------------------------------->|                    |
|                    |                   |Provision Client EID|
|                    |                   |------------------->|
|                    |                   |<-------------------|
|                    |                   | Ack Provisioed EID |
|  Send ClientEID,EdgeRTR RLOC           |                    |
|<---------------------------------------|                    |
.                                                             .
.       Use The H3-LISP Geolocation Mobility Network          .
.                                                             .
|<----------------------------------------------------------->|
.                                                             .
```

```
   .      Renew AAA ClientEID and EdgeRTR provisioning           .
```

Figure 5: Example AAA procedure for mobility clients

4. Mobility Clients-Agents Networking

The mobility network functions as a standard LISP overlay delivering unicast and multicast packets across data plane XTRs, which are used in the stack of each mobility client and server. ClientXTRs and ServerXTRs are associated with EdgeRTRs, which allows MobilityClients to "show up" at any location within the mobility network, regardless of the network provider or network address translation domain. This structure also enables any H3 agent EID to be instantiated, delegated, or failed over to any compute location.

In this specification, we assume a semi-random association between ClientXTRs and EdgeRTRs assigned by the AAA procedure, with a pool of EdgeRTRs, which can be dynamicaly allocated, distributing the load of MobilityClients within a given metro area. We also assume EdgeRTRs are topologically equivalent and use LISP to encapsulate traffic to and from other EdgeRTRs. It is possible for there to be more than one ClientEID in the same process using the same ClientXTR. The implementation of such vendor-specific multiplexing is unspecified.

```
     MobilityClient == ClientXTR       ClientXTR == MobilityClient
  (Encryption and Decryption) ||       || (Encryption and Decryption)
                              ||       ||
                         EdgeRTR  X    EdgeRTR
                              ||       ||
  (Encryption and Decryption) ||       || (Encryption and Decryption)
       H3AgentEID == ServerXTR       ServerXTR == H3AgentEID
```

Figure 6: LISP network connecting MobilityClients and H3AgentEIDs

The following Lisp Canonical Address Format (LCAF) [RFC8060] is used to encode H3-IDs into IPv6 address:

```
  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
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |           AFI = 16387         |     Rsvd1     |     Flags     |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |Type = 17 HID  |     Rsvd2     |            Length = 8         |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |                             HID (high-order)                  |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |                             HID (low-order)                   |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 7: LCAF for encoding HIDs in H3AgentEIDs

5. Mobility Unicast and Multicast

The day in a life of unicast detection upload:

1. A client detects condition of interest using AI camera
2. The client uses its GPS to establish its h3.rS location
3. It then estimates the h3.rS location of the detection
4. Detection h3.rS center is used to calculate h3.rB => H3ServerEID
5. Client sends (encrypted) location-detection via its ClientXTR

```
Outer Header src/dest: ClientXTR RLOC, EdgeRTR RLOC
Inner Header src/dest: ClientEID, H3AgentEID
```

6. EdgeRTR gleans and caches ClientEID and ClientXTR RLOC
7. EdgeRTR resolves RLOC of remote EdgeRTR, and re-encapsulates:

```
Outer Header src/dest: EdgeRTR RLOC, remote EdgeRTR RLOC
Inner Header src/dest: ClientEID, H3AgentEID
```

8. Remote EdgeRTR lookups H3ServerEID ServerXTR RLOC, re-encapsulates:

```
Outer Header src/dest: EdgeRTR RLOC, ServerXTR RLOC
Inner Header src/dest: ClientEID, H3AgentEID
```

9. ServerXTR delivers ClientEID message to H3AgentEID

The detection message 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 allows for key-value (kv) tuples or value-key,key ..(vkkk) using the same formats of key and value outlined bellow

```
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+\
|  Type          |gzip |         Reserved         | Pair Count = X|Nexagon
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+/
```

Figure 8: Nexagon header format

Nexagon Header 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.rS IDs
 Type 3-255: unassigned
Nexagon Header GZIP field: 0x000 no compression, or (**) GZIP version.
Nexagon Header Reserved bits
Nexagon Header key and value count (in any format kv or vkkk)

(*) Reserved fields are specified as being set to 0 on transmission,

ignored when received.
(**) GZIP refers to entire kv or vkkk payload and major GZIP version, packets with unsupported GZIP version are dropped

```
 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 H3AgentEID                      +  |
|                                                               |  |
+                                                               +  |
|                                                               | /
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|       Source Port = xxxx      |       Dest Port = xxxx        | \
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+ UDP
|           UDP Length          |        UDP Checksum           | /
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+ \
|  Type         |gzip |        Reserved         | Pair Count = X|Nexagon
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+ /
|                                                               |
+                        64bit h3.rS ID                       +
|                                                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                                                               |
+                        64bit State                            +
|                                                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                                                               |
+                        64bit h3.rS ID                       +
|                                                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                                                               |
+                        64bit State                            +
|                                                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 9: Uploaded detections packet format

Each H3Agent is also an IP Multicast Source used to update subscribers on the state of the h3.rS tiles in the h3.rB area. We use [RFC8378] signal-free multicast to implement overlay channels. Mobility-networks have many channels with thousands subscribers each. MobilityClients driving through/subscribing to an h3.rB area issue group address report based on any mechanism supported by [RFC8378]. Example report formats are specified in [RFC4604]. It is advised that clients establish a ring of objects on their areas of interest. Report messages are encapsulated between ClientXTRs and EdgeRTRs.

The day in a life of multicast update:

1. H3AgentEID determines change or timing requiring an update
2. H3AgentEID sends (S,G) update message via its ServerXTR

   Outer Header src/dest: ServerXTR RLOC, EdgeRTR RLOC
   Inner Header (S,G): H3ServerEID, EID chosen for theme

3. EdgeRTR resolves subscribed remote EdgeRTRs, replicates

   Outer Header src/dest: EdgeRTR RLOC, remote EdgeRTR RLOC
   Inner Header (S,G): H3ServerEID, EID chosen for theme

4. EdgeRTRs lookups subscribed ClientEIDs ClientXTRs RLOCs, replicates

   Outer Header src/dest: EdgeRTR RLOC, ClientXTR RLOC
   Inner Header (S,G): H3ServerEID, EID chosen for theme

5. ClientXTR delivers multicast channel update message to clientEID

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 H3AgentEID                  +  |
|                                                               | IPv6
+                                                               +  |
|                                                               |  |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+  |
|                                                               |  |
+                                                               +  |
|                                                               |  |
+                          Group Address                        +  |
|                                                               |  |
+                                                               +  |
|                                                               | /
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|       Source Port = xxxx      |       Dest Port = xxxx        | \
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+ UDP
|           UDP Length          |        UDP Checksum           | /
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+ \
|                                                               |Nexagon
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+ /
~                            Nexagons Payload                   ~
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 10: 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.rS ID                       +
 |                                                               |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |                                                               |
 +                        64bit State                            +
 |                                                               |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |                                                               |
 +                        64bit h3.rS ID                       +
 |                                                               |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |                                                               |
 +                        64bit State                            +
 |                                                               |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 11: 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.rS ID                        +
|                                                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                                                               |
+                       64bit h3.rS ID                        +
|                                                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                                                               |
+                       64bit h3.rS ID                        +
|                                                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 12: multicast update payload, value, key, key.. for larger areas

6. Security Considerations

The LISP mobility-network is inherently secure and private. All information is conveyed to clients using provisioned Geolocation agents. MobilityClients receive information only via geospatial channels originating at provisioned agents, replicated by EdgeRTRs. All traffic is carried over encrypted tunnels.

7. Privacy Considerations

MobilityClients have no indication as to the origin of the raw data. In order to be able to use the mobility-network for a given period, the mobility clients go through a DNS/AAA stage by which they obtain temporary clientEID and RLOCs of EdgeRTRs.

This MobilityClient to EdgeRTR interface is the most sensitive from privacy perspective. The traffic on this interface is tunneled, its detection content may be encrypted between ClientXTR to EdgeRTR. Still, the EdgeRTR will know based on headers the client RLOC, and the h3.rB area a client engages with.

Enterprises such as vehicle OEMs or carriers can "bring their own" EdgeRTRs (BYO_RTR). BYO_RTRs are pre-provisioned to be able to use the mapping system and are put on the approved list of the other EdgeRTRs. A carrier offering EdgeRTR agents on multiaccess edge compute (MEC) is optimal for security and for traffic steering-replication.

Beyond client to EdgeRTR hop, the mapping system does not hold MobilityClientEIDs info. Remote EdgeRTRs are only aware of clients temporary EIDs. When EdgeRTRs register in the mapping for channels, they do not register which clients use which EdgeRTR.

The H3AgentEIDs decrypt and parse actual h3.rS detections. They also consider MobilityClientEID credentials encoded in the client EID and assigned by AAA. This helps avoid poorly made or localized detections.

In summary the privacy risk mitigations are:

(1) tapping: all communications are through tunnels therefore may be encrypted using IP-Sec or other supported point to point underlay standards.

(2) spoofing: it is very hard to guess a MobilityClientEID valid for a short period of time. Clients and H3Agents EIDs are provisioned in EdgeRTRs, Clients using the AAA procedure, H3Agents via dev-ops.

(3) credibility: the interface crowd-sources geo-state and does not assume to trust single detections. Credit history track MobilityClient EIDs as part of normal H3Agents operation. The aggregate scores from all objects are delivered to AAA subsystem for updating credentials.

(4) geo-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. Ongoing client credit score adjustments span all H3Agents administratively to AAA without specific geo-source.

7. Acknowledgments

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8. IANA Considerations

In accordance with BCP 26 [RFC8126].IANA is asked to create a registry named NEXAGON with the following sub registries.

Value	LISP LCAF Type Name	Reference
17	H3 ID	Section 4

Nexagon Header Bits

Spec Name	IANA Name	Bit Position	Description
Type	nexagon-type	0-7	Type of key-value encoding
gzip	nexagon-gzip	8-10	gzip major version used
PairCount	nexagon-paircount	24-31	key-value pair count

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 Field 0xB: Local Zone Speed Limit:

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	15 m/sec	[This Document]
0xC	20 m/sec	[This Document]
0xD	25 m/sec	[This Document]
0xE	30 m/sec	[This Document]
0xF	35 m/sec	[This Document]

State enumeration fields 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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