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Network-Hexagons:Geolocation Mapping Network Based On H3 and LISP

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Abstract

This specification describes functionality of LISP Nexagon networks. The network shares a joint vision of any number of producing sources, fleets, drones, and satellite, with any number of consuming clients, maps, GIS, and path planning copilots.

Specifically it outlines:
- joint-vision tiled enumeration geolocation language channels
- addressing change notifications, overlaps, points of view,
- freshness, privacy, localization, seamless context-switching,
- via stateful driving of stateless models by EID location agents

Safety applications of this network are:
1. **Safety on-road: blockages & hazards beyond line of sight**
2. **Safety off-road: traffic-ability and varying risk degrees**
3. **Safety during disasters: fires, floods, snow, abrupt change**

The use of LISP enables the network to function securely uninterrupted while vision producers and consumers are constantly moving due to the connectivity-anchoring properties of LISP EIDs. Since EIDs are logical being based on mapping-system, it provides semantic-anchoring as well. Semantic joint vision consolidation uses H3 EID unicast and multicast.

Status of This Memo

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1. Introduction

This specification describes real-time machine-to-machine traffic-ability mapping of any terrain based on the Locator/ID Separation protocol (LISP) and the H3 hierarchical hexagonal grid. Distributed geolocation agents are logically addressed using LISP endpoint identifiers (EID), determined by the agent's geospatial jurisdiction according to the H3 hexagonal grid. Geolocation agents consolidate and propagate data and logic to and from in-vehicle and satellite feeds. In-vehicle agents' EIDs are ephemeral to protect vehicle owners geo-privacy while interacting with geolocation agents. The in-vehicle agents' EIDs are obtained and renewed through an authorization, authentication, and accounting procedure (AAA).
Geolocation traffic-ability mapping includes training and notification prompts based on H3 tile traffic-ability key-value enumeration.

The [H3] grid is a hierarchical, spatially-aware system that uses a hexagonal tiling scheme to subdivide the earth's surface into nested hexagons, each with a unique identifier (HID). This grid efficiently represents both fine-grained and coarse-grained spatial data, and its HIDs form the basis for the IPv6 EIDs of the geolocation agents in the network, also known as 'nexagons' in this document. These agents consolidate and process the data uploaded by vehicles within their jurisdiction, and delegate remote procedure calls to them. Agents use their EIDs as destination queues for vehicle uploads and source channels for updates. The agents are dynamically deployed to compute locations based on vehicle density and activity, which poses several key challenges: preserving the geo-privacy of vehicles, maintaining vehicle-agent selection coherency, context-switching between agents as vehicles move, and maintaining scaled-continuity of subscriptions to notifications from agents' channels. To address these challenges, the network employs algorithmic EID-addressing using LISP qualities.

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

Figure 1: Nexagon Agents

The nexagon agents in the system utilize the H3 hierarchical hexagonal grid because of its clear tile adjacency properties. Each tile in the H3 grid has a unique 64-bit identifier called an HID, which is algorithmically mapped to an EID. The H3 grid is used at two resolutions: one for the nexagons ("h3.rB") and one for geo-mapping, detections, and navigation paths ("h3.rS"). Mappings between GPS coordinates, HIDs, and EIDs are all algorithmic.

Unlike traditional mapping associating geospatial attributes with objects, in this document, we associate traffic-ability enumerations to geospatial tiles. 64 bits of information about "what" traffic-ability enumerations are outlined with the 64-bit HID of "where" is the enumeration association, totaling 127 bits or 16 Bytes. Enumeration 64 bits are detailed in a bit-mask based on a taxonomy defined by Berkeley Deep Drive [BDD] and serve as a baseline. This baseline can be extended or overridden

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 through which clients request and renew EIDs and tunnel-routers to interact with agents. This process may be implemented using various methods or formal AAA. An example procedure is provided below.

```
   Off-Peak Nexagon
  Condensed Allocation
   _  _    _  _
  / \/ \  / \/ \  ----
  \_/\_/  \_/\_/  ----     Peak allocation - same Nexagons/EIDs
  / \/ \  / \/ \  ----       Spread on more compute locations
  \_/\_/  \_/\_/  ----       _  _    _  _    _  _    _  _
  / \/ \  / \/ \  ----      / \/ \  / \/ \  / \/ \  / \/ \  ----
  \_/\_/  \_/\_/  ----      \_/\_/  \_/\_/  \_/\_/  \_/\_/  ----
  / \/ \  / \/ \  ----      / \/ \  / \/ \  / \/ \  / \/ \  ----
  \_/\_/  \_/\_/  ----      \_/\_/  \_/\_/  \_/\_/  \_/\_/  ----
   ^  ^    ^  ^   ^  ^       ^ ^     ^  ^    ^  ^    ^  ^   ^  ^
   Site   Site  Standby     Site    Site    Site    Site  Standby
```

Figure 2: Nexagon dynamic allocation per activity

2. Definition of Terms

Based on [RFC9300][RFC9301]

H3AgentEID: H3AgentEID is an EID-addressable Geolocation agent, also known as a nexagon. It serves as a designated destination for Geolocation aggregation and an (S,G) source of multicast themed channels. It has a LISP data-plane stack to encapsulate packets via ServerXTR.

ServerXTR: ServerXTR is a data-plane only LISP protocol stack implementation that is co-located with the H3AgentEID process. It encapsulates and decapsulates packets to and from EdgeRTRs.

MobilityClient: MobilityClient is an application that may be a part of a driving system or mobility application, It has a LISP data-plane stack to encapsulate packets via ClientXTR.

MobilityClientEID: MobilityClientEID is the IPv6 EID used by Mobility Clients. The destination of such packets are H3AgentEIDs. The EID is assigned as part of the MobilityClient network AAA.

ClientXTR: 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 is responsible for connecting Mobility Clients to Agents and managing MobilityClientEIDs multicast registrations [RFC8378]. The network achieves this by using encapsulation to aggregate Mobility Clients and Geolocation Agents, making it easier to access the mobility network from hosting providers and mobile providers.

The RTRs within the EdgeRTR network re-encapsulate packets from ClientXTRs, ServerXTRs, and remote RTRs. During packet decapsulation, EdgeRTRs glean H3 agent EIDs and MobilityClientEIDs and store them along with route locations (RLOCs) in map-caches. These mappings are then registered to the LISP mapping system [RFC9301] and are provisioned when Geolocation Agents are assigned to EdgeRTRs.
It's key to note that EdgeRTRs do not register MobilityClientEIDs.
Enterprises can provide their own EdgeRTRs to protect the 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 = = = = =
                             ||  ((  ()     ))    ||
                         (  Underlays used for the  )
                        (      Mapping Network     )
                          ( ||  ((   (  )   ()  || )
                            ||                  ||
                = = = = = = =                     = = = = = = =
               ||                                              ||
            EdgeRTR                                         EdgeRTR
           ..    ..                                       ..      ..
          ..       ..                                    ..          ..
  ((((|))))    ((((|))))                        ((((|))))   ((((|))))
     /|\    RAN   /|\                              /|\    RAN   /|\

     ||                                                          ||
     ||<--Encapsulations to Agents' Queues & Channels via RTRs-->||
     ||
      <<    <<    <<   <<    <<    <<  cXTR::MobilityClientB   Vehicle
     ||                   ___    ___    ___                    (_) (_)
     ||                 /     \/     \/     \
     || - - - - - - - -  h3.rS  h3.rS  h3.rS - - The Tiled Road  - - -
     ||                 \ ___ /\ ___ / \ __ /

     Vehicle  MobilityClientA::cXTR   >>  >>  >>  >>   >>  >> >>
     (_) (_)
```

Figure 3: Nexagon Network

- MobilityClientA detections used by MobilityClientB and vice versa
- Clients share information only through the Geolocation agents
- ClientXTR (cXTR):encapsulates packets over access to EdgeRTR
- ServerXTR (sXTR):encapsulates packets over metro area to EdgeRTR
- Uploads: routed to appropriate Geolocation agent by EdgeRTRs
- Notifications: from Geolocation agents replicated by EdgeRTRs

3. Deployment Assumptions

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:

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 Provisioned EID|
     |  Send ClientEID,EdgeRTR RLOC            |                    |
     |<----------------------------------------|                    |
     .                                                              .
     .       Use The H3-LISP Geolocation Mobility Network           .
     .                                                              .
     |<------------------------------------------------------------>|
     .    Renew AAA ClientEID and EdgeRT provisioning               .
```

Figure 4: Example AAA procedure for mobility clients

Detections are enumerated in 16 fields x 16 enumerations. Nibbles named using hexadecimal index according to the position where most significant nibble has index 0. Enumerations defined in section 8.

```
   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  01230123012301230123012301230123
   +---------------------------------------------------------------+
```

Figure 5: Nibble based detection enumeration

4. Clients-Agents Networking

The mobility network functions as a standard LISP overlay that delivers 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 dynamically allocated, distributing the load of MobilityClients within a given metro area. We also assume that 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 multiplexing is not specified.

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

Figure 6: LISP network connecting MobilityClients and H3AgentEIDs

Encode HID to EID:

```
 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 2
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |           AFI = 16387         |     Rsvd1     |     Flags     |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |               |               |          Length = 8           |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |                            HID (high-order)                   |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |                            HID (low-order)                    |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 7: Encoding HIDs in H3AgentEIDs

5. Mobility Unicast and Multicast

The day in a life of unicast road-segment mapping 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

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

Figure 8: Nexagon header format

Nexagon Header allows for key-value (kv) tuples or value-key,key ..(vkkk) using the same formats of key and value outlined bellow:

```
 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 =  | NXGN
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+ /
|                                                               |
+                        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 notification 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 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           | /
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+ \
|                                                               |NXGN
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+ /
~                               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|NXGN
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+ /
 |                                                               |
 +                        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|NXGN
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+ /
|                                                               |
+                       64bit State                           +
|                                                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                                                               |
+                       64bit h3.rS ID                        +
|                                                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                                                               |
+                       64bit h3.rS ID                        +
|                                                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                                                               |
+                       64bit h3.rS ID                        +
|                                                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 12: multicast update payload, value, key, key..

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 encapsulation.

7. Privacy Considerations

In the mobility network, MobilityClients obtain temporary clientEIDs and RLOCs of EdgeRTRs through an AAA process in order to access the network for a certain period. The interface between MobilityClients and EdgeRTRs is the most sensitive from a privacy perspective, as the EdgeRTR can determine the client RLOC and the h3.rB area that the client is engaged with based on header information, even though the traffic on this interface is tunneled and the detection content is encrypted between ClientXTR and EdgeRTR. Enterprises such as vehicle OEMs or carriers can use their own EdgeRTRs (BYO_RTRs), which are pre-provisioned to use the mapping system and are approved by other EdgeRTRs. Beyond the client to EdgeRTR hop, the mapping system does not hold MobilityClientEID information and remote EdgeRTRs are only aware of clients' temporary EIDs. H3AgentEIDs decrypt and parse actual h3.rS detections, taking into account MobilityClientEID credentials encoded in the client EID and assigned by AAA to 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 and does not assume to trust single detections. Credit history track MobilityClient aggregate scores from all agents are delivered to AAA subsystem
(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 adjustments span all H3Agents administratively to AAA without specific geo-source.

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9. IANA Considerations

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

Spec	IANA Name	Bit	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].

10. Normative References

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