LISP Working Group
Internet-Draft
Intended status: Informational
Expires: February 28,2023

S. Barkai
B. Fernandez-Ruiz
R. Tamir
Nexar Inc.
A. Rodriguez-Natal
F. Maino
Cisco Systems
A. Cabellos-Aparicio
J. Paillisse Vilanova
Technical University of Catalonia
D. Farinacci
lispers.net
October 1, 2022

Network-Hexagons:Geolocation Mobility Edge Network Based On H3 and LISP
draft-ietf-lisp-nexagon-41

Abstract

This document uses virtual layer3 routing and geospatial addressing based on a hierarchical grid forming a Geolocation mobility-edge network. When vehicles with AI cameras detect objects of interest on the road, they use their GPS to calculate their high-resolution grid-tile position. Then they use this tile to calculate the high-resolution tile of the detection. A low-resolution tile which contains the detection-tile identifies a network-addressable object. The object tile-ID is used as basis for IPv6 endpoint identifier(EID). Geospatial EIDs are queue-destination and channel-source of objects. Geolocation objects consolidate detections form all vehicles in a given area. Geolocation objects based on EID queues and channels are network portable via the Locator/ID Separation Protocol (LISP).

Status of This Memo

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1. Introduction

This document uses virtual layer3 routing and geospatial addressing based on a hierarchical grid forming a Geolocation mobility-edge network. When vehicles with AI cameras detect objects of interest on the road, they use their GPS to calculate their high-resolution grid-tile position. Then they use this tile to calculate the high-resolution tile of the detection. A low-resolution tile which contains the detection-tile identifies a network-addressable object. The object tile-ID is used as basis for IPv6 endpoint identifier(EID). Geospatial EIDs are queue-destination and channel-source of objects. Geolocation objects consolidate detections form all vehicles in a given area. Geolocation objects based on EID queues and channels are network portable via the Locator/ID Separation Protocol (LISP).

Network addressable hexagonal grid objects (nexagons) encapsulate geolocation processing are delegated dynamically to compute locations per road activity: vehicle uploads and client subscriptions. Dynamics of vehicles and clients causes key-issues resolved by LISP:

- Dynamic allocation and coherency of services IPs cached by clients

- Context-switching between Geolocation Services IPs while driving
- Geo-privacy and tracking of clients interacting with services
- Subscription continuity when switching IP Anchors while driving

These key-issues are resolved using LISP mapped EID virtualization:

- Addresses virtualization of the communicating clients and services
- Algorithmic service-addressing based on geospatial grid identifiers
- Algorithmic client-addressing based on an authorization procedure

Geolocation virtual addressing for queues and for channels helps solve services objects portability. Because other than queues and channels, functional stacks are pervasive and objects-states quickly regenerate. Portability solves dynamic allocation and reduces coherency issues. As for client side EIDs, these enable subscription continuity and geo-privacy. The resulting elastic allocation uses EID algorithmic context switching, maintain subscription continuity and IP geo-privacy.

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

Figure 1: Geolocation schematics: queues, channels, states, functions

To summarize Address virtualization based on LISP EIDs:

- EID addressing of Geolocation upload queues by H3 identifiers
- EID addressing of detection channels, H3 ID sources and topics
- EID addressing of mobility clients, assigned and also renewed

Note 1: The breakdown of Geolocations Services to objects is done based on geospatial grid lines known to both mobility clients and Geolocation Services. We use H3 [H3] hierarchical hexagonal grid because of its clear tile adjacency properties. Each grid-tile in each resolution has a unique 64bit identifier (HID). HIDs are mapped to EIDs algorithmically. In addition to objects, the same grid at higher resolution (smaller tiles) is used to localize detections. We refer to h3.rB as the lower resolution object big tile, and h3.rS as the detection location, higher resolution small tile.

Mappings: GPS => h3.rS => H3.rB => EID are therefore algorithmic.
Sizeof (h3.rB) / Sizeof (h3.rS) x density-factor / MTU ~ number of messages needed to convey object state snapshot of small-tiles in it.

```
Off-Peak object Allocation
 Packed on less compute

   _  _    _  _
  / \/ \  / \/ \  ----
  \_/\_/  \_/\_/  ----        Peak object Geolocation Allocation
  / \/ \  / \/ \  ----     Geospatial objects spread on more compute
  \_/\_/  \_/\_/  ----      _  _    _  _    _  _    _  _
  / \/ \  / \/ \  ----     / \/ \  / \/ \  / \/ \  / \/ \  ----
  \_/\_/  \_/\_/  ----     \_/\_/  \_/\_/  \_/\_/  \_/\_/  ----
  / \/ \  / \/ \  ----     / \/ \  / \/ \  / \/ \  / \/ \  ----
  \_/\_/  \_/\_/  ----     \_/\_/  \_/\_/  \_/\_/  \_/\_/  ----
   ^  ^    ^  ^   ^  ^      ^ ^     ^  ^    ^  ^    ^  ^   ^  ^
   Site   Site  Standby    Site    Site    Site    Site  Standby
```

Figure 2: Geolocation dynamic allocation per geospatial activity

Note 2: LISP solution for address virtualization forms 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 Authentication Authorization and Accounting (AAA) procedure by which clients are assigned and renew EIDs and XTRs to be used to interact with services. This process may be done in various vendor specific methods, or multivendor AAA service. AAA procedure is described as a life-cycle example.

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 or situation. These 64 bits are detailed in a bit-mask based on a taxonomy defined by Berkeley Deep Drive [BDD]. It is meant as a baseline that can be extended or overridden depending on need.

2. Definition of Terms

Based on [I-D.ietf-lisp-rfc6830bis][I-D.ietf-lisp-rfc6833bis]

H3ServiceEID: Is an EID addressable Geolocation Service object. 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 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, 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 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: EdgeRTR network connects MobilityClients to H3ServiceEIDs. EdgeRTRs manage MobilityClients multicast registrations [RFC8378]. EdgeRTRs aggregate MobilityClients/H3Services using tunnels to facilitate hosting-providers and mobile-providers in accessing the LISP based Geolocation mobility-network. EdgeRTRs decapsulate packets from ClientXTRs and ServerXTRs, and re-encapsulates packets to clients and servers. EdgeRTRs glean H3ServiceEIDs and MobilityClient EIDs when they decapsulates packets. EdgeRTRs store H3ServiceEIDs and route-locations (RLOC) using map-caches. Mappings are registered to the LISP mapping system [I-D.ietf-lisp-rfc6833bis]. 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.

```
                      h3.rB routed-objects grid tiles
                          ___                                  ___
   H3ServiceEIDs   ___  /     \           H3ServiceEIDs ___  /     \
            ___  /     | h3.rB |                 ___  /     | h3.rB |
          /     | h3.rB \ ___ /                /     | h3.rB \ ___ /
         | h3.rB \ ___ /  sXTR                | h3.rB \ ___ /  sXTR
          \ ___ /  sXTR   ||                   \ ___ /  sXTR    ||
            sXTR   ||     ||                    sXTR     ||     ||
             ||    ||     ||                      ||     ||     ||
             ||    ||     ||                      ||     ||     ||
             = = = = = = EdgeRTR                 EdgeRTR = = = = =
                             ||  ((  ()     ))    ||
                         (      Geolocation      )
                       (       Mobility Network    )
                       (       Based on LISP        )
                        (   ||  ((   (())   ()  || )
                            ||                  ||
                = = = = = = =                     = = = = = = =
               ||                                              ||
            EdgeRTR                                         EdgeRTR
           ..    ..                                      ..      ..
          ..       ..                                  ..          ..
  ((((|))))    ((((|))))                         ((((|))))    ((((|))))
     /|\    RAN   /|\                               /|\    RAN   /|\
     ||                                                          ||
     ||                                                          ||
   Uploads Upstream                                              ||
 Channels Downstream                                             ||
     ||                   ___    ___    ___                      ||
     ||   << movment << /     \/     \/     \<<cXTR::MobilityClientB
     || - - - - - - - -  h3.rS  h3.rS  h3.rS - - - - - - - - - - - -
      MobilityClientA::cXTR >> \ ___ /\ ___ / >> movement >> .......
```

Figure 3: Geolocation clients and services interaction layout

Figure 3 above describes:

- MobilityClientA detections used by MobilityClientB, and vice versa
- Clients: share information only via Geolocation Services

- ClientXTR (cXTR):encapsulates packets over access network to EdgeRTR
- ServerXTR (sXTR):encapsulates packets over edge network to EdgeRTR

- Uploads: routed to appropriate Geolocation Service by EdgeRTRs
- Channels: originate from Geolocation Services replicated by EdgeRTRs

3. Deployment Assumptions

I. We assume detections can be localized to h3.rS tiles and can be enumerated. Compact 64bit detection enumeration format:

```
0       1       2       3       4       5       6       7
+-------+-------+-------+-------+-------+-------+-------+-------+
|-0-|-1-|-2-|-3-|-4-|-5-|-6-|-7-|-8-|-9-|-A-|-B-|-C-|-D-|-E-|-F-|
|012301230123012301230123 Index  0123012301230123012301230123012301230123
+---------------------------------------------------------------+
```

Figure 4: Nibble based compact representation of tile state

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

II. Authorization of MobilityClients to mobility-network is renewed while driving. DNS/AAA procedure described bellow can be used as an example to obtain EIDs/EdgeRTRs and for enabling use of the network. Diameter [RFC6733] based AAA can be used to accommodate many types of mobility clients in a rich eco-system: vehicle systems, driving and navigation applications, smart-city and consumer applications. Example procedure for ClientXTRs 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 exchange for mobility-network usage

4. Mobility Clients-Services Networking

The mobility-network functions as a standard LISP overlay.
The overlay delivers unicast and multicast packets across:
Data-plane XTRs are used in the stack of each mobility client/server.
ClientXTRs and ServerXTRs are associated with EdgeRTRs.

This structure allows for MobilityClients to "show up" at any of mobility-network location behind any network provider or network address translation domain. It allows for any H3ServiceEID to be instantiated, delegated, or failed-over to any compute location.

In this specification we assume semi-random association between ClientXTRs and EdgeRTRs assigned by the AAA procedure. We assume in any given metro area a pool of EdgeRTRs distribute the Mobility Clients load. We assume EdgeRTRs are topologically equivalent. EdgeRTRs use LISP to encapsulate traffic to and from other EdgeRTRs. There may be more than one ClientEID in the same process using the same ClientXTR. For example layers on base-map or heads-up display. Such vendor specific multiplexing implementation is unspecified he

```
     MobilityClient == ClientXTR       ClientXTR == MobilityClient
  (Encryption and Decryption) ||       || (Encryption and Decryption)
                              ||       ||
                         EdgeRTR  X   EdgeRTR
                              ||       ||
  (Encryption and Decryption) ||       || (Encryption and Decryption)
       H3ServiceEID == ServerXTR       ServerXTR == H3ServiceEID
```

Figure 6: LISP network connecting MobilityClients and H3ServiceEIDs

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 H3ServiceEIDs

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, H3ServiceEID

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, H3ServiceEID

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

   Outer Header src/dest: EdgeRTR RLOC, ServerXTR RLOC
   Inner Header src/dest: ClientEID, H3ServiceEID

9. ServerXTR delivers ClientEID message to H3ServiceEID

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 H3ServiceEID                      +  |
|                                                               |  |
+                                                               +  |
|                                                               | /
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|       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 H3Service 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. H3ServiceEID determines change or timing requiring an update
2. H3ServiceEID 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 H3ServiceEID                   +  |
|                                                               | 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 Services. MobilityClients receive information only via geospatial channels originating at provisioned services, 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 services 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 H3ServiceEIDs decrypt and parse actual h3.rS detections. They also consider MobilityClientEID credentials encoded in the client EID and assigned by AAA. This helps avoid "fake-news", e.g. poorly made or poorly 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 H3Services EIDs are provisioned in EdgeRTRs, Clients using the AAA procedure, H3Services 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 H3Services 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 H3Services administratively to AAA without specific geo-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 from Dell, Lei Zhong from Toyota, Mikael Klein from Ericsson, Leifeng Ruan from Intel, Ririn Andarini from NTT, for helping with Geolocation and Dataflow Virtualization terminology and key-issues during joint work at the AECC. We would like to thank Professor Trevor Darrel and Professor Fisher Yu of BDD for reviewing IANA enumerations for detections-consolidations feasible by visionAI and Edge Computing. Finally we would like to thank Isaac Brodsky, Nick Rabinowitz, David Ellis, and AJ Friend of the H3 steering committee for reviewing the use of the H3 grid in the lisp-nexagon network.

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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Authors' Addresses

Sharon Barkai
Nexar
CA
USA

Email: sbarkai@gmail.com

Bruno Fernandez-Ruiz
Nexar
London
UK

Email: b@getnexar.com

Rotem Tamir
Nexar
Israel

rotemtamir@getnexar.com

Alberto Rodriguez-Natal
Cisco Systems
170 Tasman Drive
San Jose, CA
USA

Email: natal@cisco.com

Fabio Maino
Cisco Systems
170 Tasman Drive
San Jose, CA
USA

Email: fmaino@cisco.com

Albert Cabellos-Aparicio
Technical University of Catalonia
Barcelona
Spain

Email: acabello@ac.upc.edu

Jordi Paillisse-Vilanova
Technical University of Catalonia
Barcelona
Spain

Email: jordip@ac.upc.edu

Dino Farinacci
lispers.net
San Jose, CA
USA

Email: farinacci@gmail.com