Network-Hexagons:Geolocation Mobility Edge Network Based On H3 and LISP
draft-ietf-lisp-nexagon-36

Abstract

  This informational document describes the combination of LISP and the
  H3 geospatial 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. They then use this tile to calculate the
  high-resolution tile of the detection. The low-resolution (big)
  grid-tile containing the detection tile identifier is used as basis to
  IPv6 LISP endpoint identifier (EID). This EID is the queue destination
  of Geolocation process consolidating detections form all vehicles in
  that area. Geolocation processes use their EID as source of channels
  consolidating per theme of all ongoing road situations in their area.
  Vehicles driving or navigating to an area subscribe to these channels.

Status of This Memo

Table of Contents

1. Introduction

   This informational document describes the combination of LISP and the
   H3 geospatial 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. They then use this tile to calculate the
   high-resolution tile of the detection. The low-resolution (big)
   grid-tile containing the detection tile identifier is used as basis to
   IPv6 LISP endpoint identifier (EID). This EID is the queue destination
   of Geolocation process consolidating detections form all vehicles in
   that area. Geolocation processes use their EID as source of channels
   consolidating per theme of all ongoing road situations in their area.
   Vehicles driving or navigating to an area subscribe to these channels.

   Geolocation processes are delegated dynamically to compute locations
   according road activity in their area. This services dynamics combined
   with clients' IP Anchor dynamics causes key-issues resolved by LISP:

   - Coherency of Geolocation processes' IPs cached by vehicle clients
   - Context-switching between Geolocation processes per driving client

- Geo-privacy and tracking of clients interacting with geo-processes
   - Client subscription continuity switching IP Anchors while driving

Resolving these key-issues is achievable by address virtualization:

- Addresses virtualization for clients and services communicating
- Algorithmic services addressing based on geospatial grid identifiers
- Algorithmic clients addressing based on an authorization procedure

Virtual addressing based on LISP EIDs is applied to Geolocation:

- Addressable queues for uploads from mobility clients
- Addressable channels for subscribed mobility clients

In addition to queues and channels Geolocations Services include
application state and functions. Functions are available in all
compute locations, geospatial-situation state regenerates.

```
                     ___
                   /     \
     Addressable >>  State  >> Addressable
    Upload Queues   \ ___ /     Channels
          /\      Functions()      \/
```
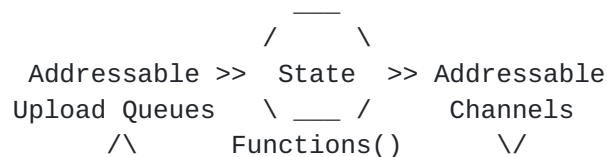
Figure 1: Geolocation schematics: queues, channels, states, functions

Address virtualization based on LISP EIDs includes:

  - EID addressing of Geolocation queues based on H3 identifiers
  - EID addressing of detection channels, H3-ID sources and topics
  - EID addressing of mobility clients, assigned-renewed periodically

Service EIDs enable portability of Geolocation queues and channels.
Client EIDs enable channel-subscription continuity, for when mobile
cellular or wifi carriers are switched for reception or other reasons.
Client EIDs are temporary and make it difficult to track by services.

EIDs, geospatial-service and temporary-clients, allow for dynamic and
portable service allocation, algorithmic context switching between
processes while driving, subscription continuity, and IP geo-privacy.

Note 1: The breakdown of Geolocations Services to processes 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 shards, the same grid
at higher resolution (smaller tiles) is used to localize detections.
We refer to h3.rB as the lower resolution shard 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 big-tile shard a snapshot of small-tiles.

```
  Off-Peak Allocation
 Packed on less compute

   _  _    _  _
  / \/ \  / \/ \  ----
  \_/\_/  \_/\_/  ----            Peak Geolocation Allocation
  / \/ \  / \/ \  ----        Geospatial shards 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 is an application
network. In order for clients and services to use it there needs to be
a formal provisioning step. For the clients this step will require
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 64bits 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 shard.
      It is a designated destination for geospatial detections,
      and an (S,G) source of multicast of themed detection channels.
      It has a light-weight LISP protocol stack to tunnel packets
      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-shards 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 >> .......
```
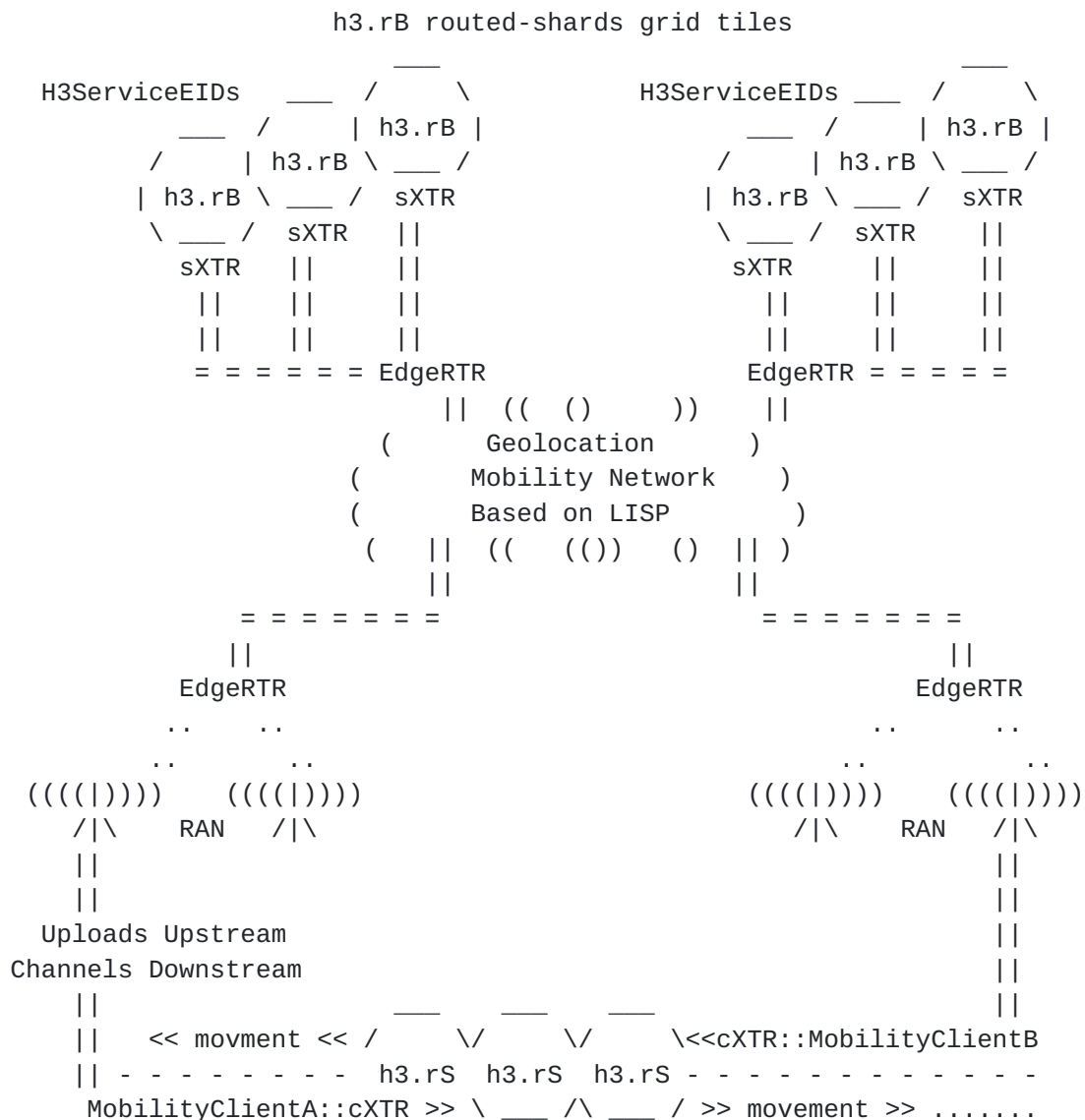
   Figure 3: Geolocation clients and services interaction layout

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 detection enumeration format is described bellow:

```
0       1       2       3       4       5       6       7
+-------+-------+-------+-------+-------+-------+-------+-------+
|-0-|-1-|-2-|-3-|-4-|-5-|-6-|-7-|-8-|-9-|-A-|-B-|-C-|-D-|-E-|-F-|
|01230123012301230123 Index   0123012301230123012301230123
+--------------------------------------------------------------+
```

   Figure 4: Nibble based compact representation of tile detection 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 in AAA procedure. We assume in
   any given metro area a pool of EdgeRTRs to distribute the Mobility
   Clients load. We assume EdgeRTRs are topologically equivalent.
   EdgeRTRs use LISP to encapsulate traffic to and from other EdgeRTRs.

```
     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

Note: there may be more than one ClientEID in the same process using the
same ClientXTR. For example multiple layers of map or heads-up display.
Such vendor specific multiplexing implementation is unspecified here.

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 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-tunnels:

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

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

   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 7: 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                                +
 |                                                               |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```
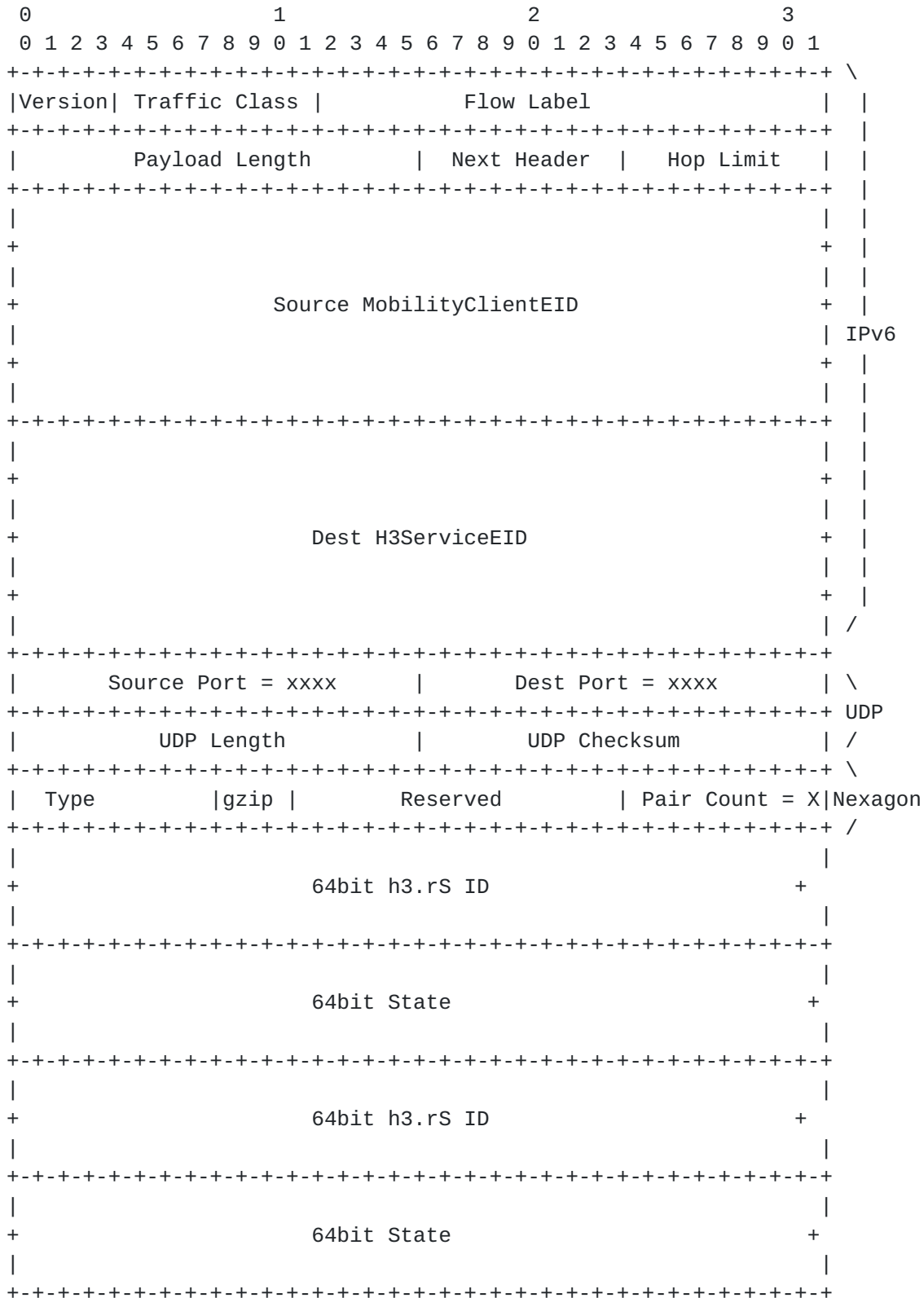
   Figure 8: Uploaded detections packet format

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].
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                          ~
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```
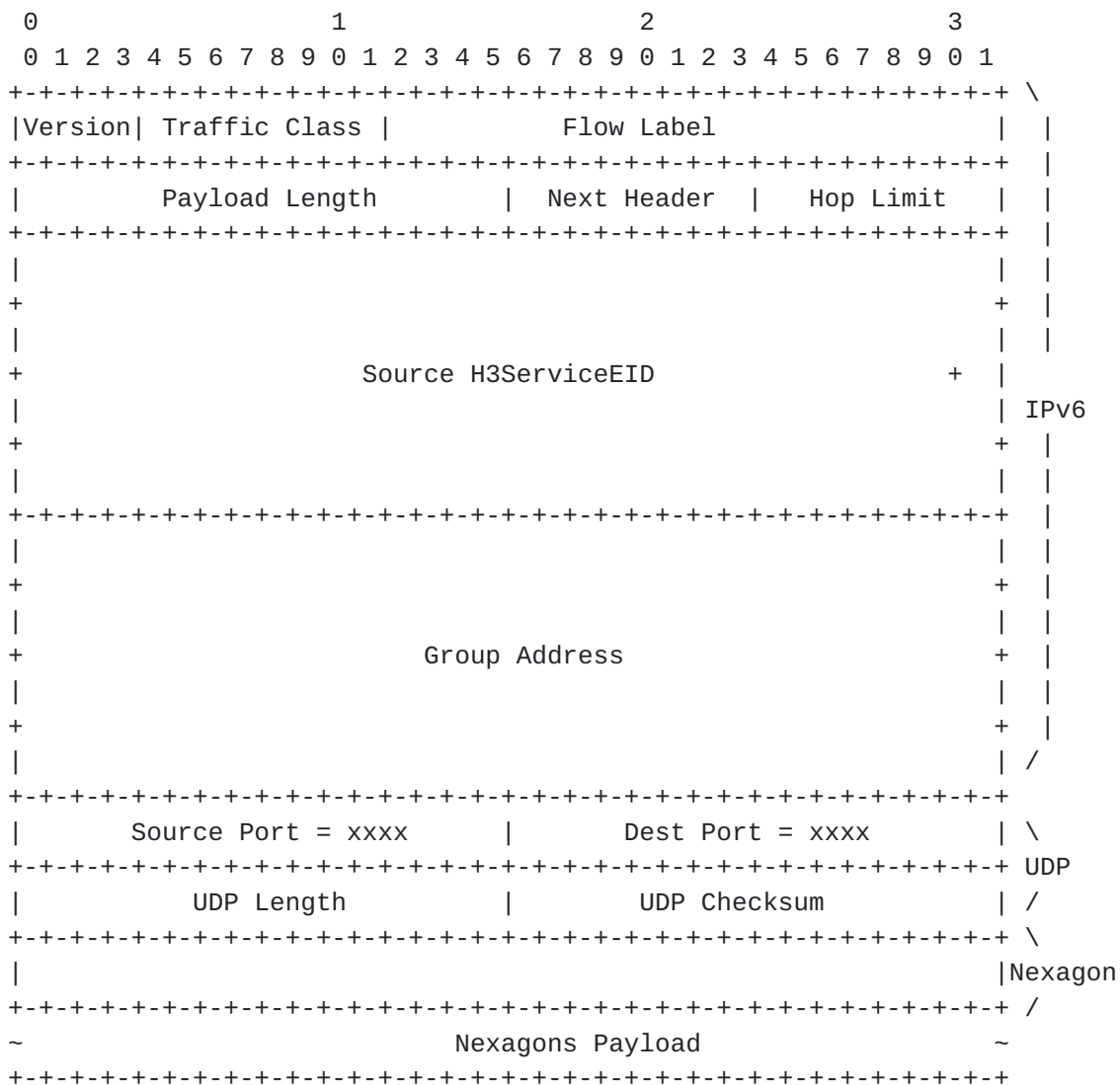
Figure 9: multicast update packet header

```
 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                           +
|                                                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```
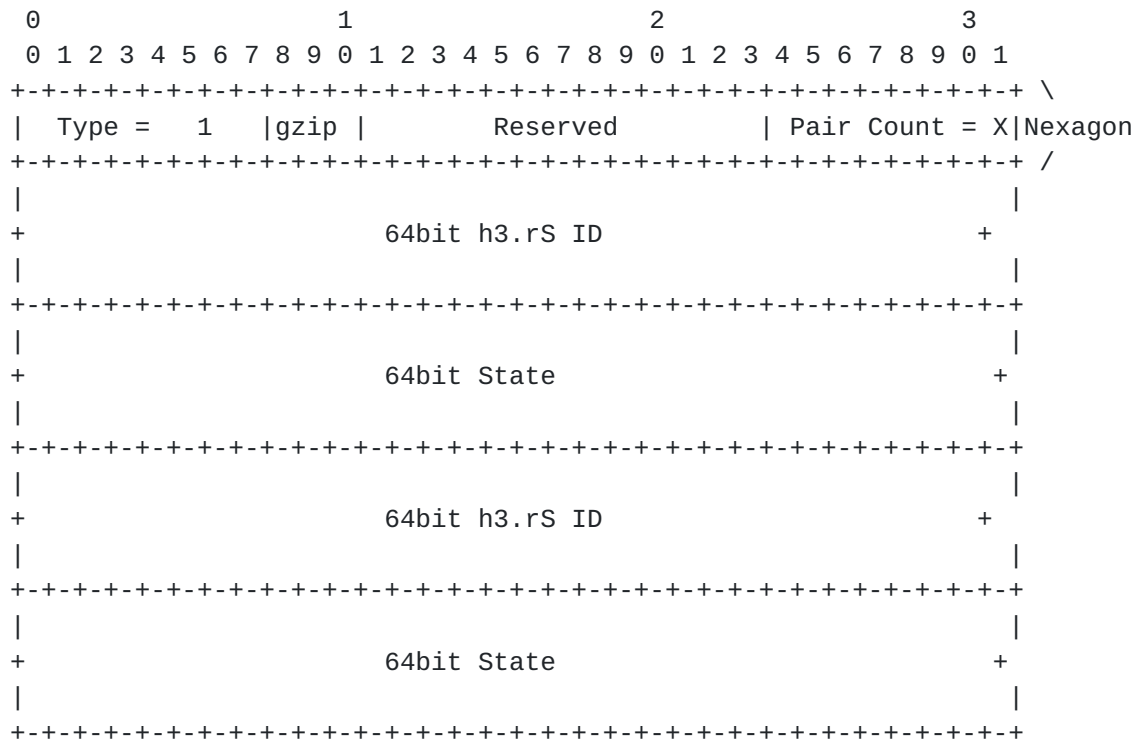
   Figure 10: multicast update payload, key-value, key-value..

```
 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                           +
|                                                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```
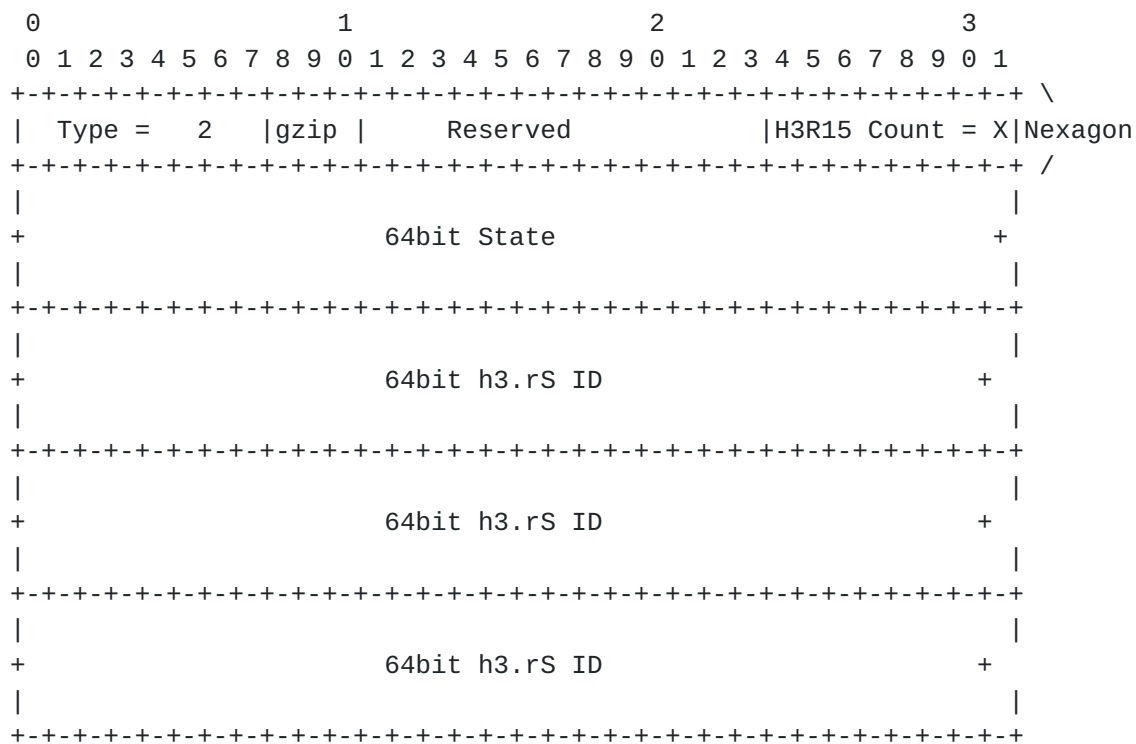
 Figure 11: multicast update payload, value, key, key.. for larger areas

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.

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 to
MobilityClientEIDs by as part of normal H3Services fact checking,
aggregate scores affect AAA 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 can span
all H3Services administratively to AAA without specific geo-source.

7. Acknowledgments

8. IANA Considerations

This section provides guidance to the Internet Assigned Numbers
Authority (IANA) regarding registration of values related to the LISP
specification, in accordance with BCP 26 [RFC8126].
IANA is asked to create a registry named NEXAGON Parameters.
Such registry should be populated with the following sub registries.

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

9. Normative References

[I-D.ietf-lisp-rfc6830bis]
          Farinacci, D., Fuller, V., Meyer, D., Lewis, D., and A.
            Cabellos-Aparicio, "The Locator/ID Separation Protocol
            (LISP)", draft-ietf-lisp-rfc6830bis-38 (work in progress),
            May 2020.

[I-D.ietf-lisp-rfc6833bis]
          Farinacci, D., Maino, F., Fuller, V., and A. Cabellos,
            "Locator/ID Separation Protocol (LISP) Control-Plane",
            draft-ietf-lisp-rfc6833bis-31 (work in progress), May
            2020.

[RFC4604] Holbrook, H., Cain, B., and B. Haberman, "Using Internet
            Group Management Protocol Version 3 (IGMPv3) and Multicast
            Listener Discovery Protocol Version 2 (MLDv2) for Source-
            Specific Multicast", RFC 4604, DOI 10.17487/RFC4604,
            August 2006, <https://www.rfc-editor.org/info/rfc4604>.

[RFC6733] Fajardo, V., Ed., Arkko, J., Loughney, J., and G. Zorn,
            Ed., "Diameter Base Protocol", RFC 6733,
            DOI 10.17487/RFC6733, October 2012,
            <http://www.rfc-editor.org/info/rfc6733>.

[RFC8126] Cotton, M., Leiba, B., Narten, T., "Guidelines for
            Writing an IANA Considerations Section in RFCs", RFC8126,
            DOI 10.17487/RFC8126, June 2017,
            <https://www.rfc-editor.org/info/rfc8126>.

[RFC8378] Farinacci, D., Moreno, V., "Signal-Free Locator/ID
            Separation Protocol (LISP) Multicast", RFC8378,
            DOI 10.17487/RFC8378, May 2018,
            <https://www.rfc-editor.org/info/rfc8378>.

[H3]   Uber Technologies Inc. [n.d.]. H3: Ubers Hexagonal
            Hierarchical Spatial Index, May 2021,
            <https://eng.uber.com/h3>.

[BDD]   Fisher Yu, Wenqi Xian, Yingying Chen, Fangchen Liu, Mike
            Liao, Vashisht Madhavan, and Trevor Darrell. BDD100K: A
            diverse driving video database with scalable annotation
            tooling. arXiv:1805.04687, 2018. 2, 3
            <https://doi.org/10.48550/arXiv.1805.04687>

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