LISP Working Group
Internet-Draft
Intended status: Informational
Expires: January 1, 2022

S. Barkai
B. Fernandez-Ruiz
S. ZionB
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

September 2, 2021

Network-Hexagons: H3-LISP GeoState & Mobility Network
draft-ietf-lisp-nexagon-11

Abstract

This document specifies the use of H3 and LISP for Geolocation services, the utilization of geospatial data for mobility-uses by:
- Predefined IPv6 addressable tiled abstraction of road-segments.
- Interface for detections and annotations of tiled road-segments.
- Sharing hazards, blockages, parking, weather, inventory..
- Brokering the production and consumption of geo-state.
- IP multicast channels of geo-state to subscribed clients.

Status of This Memo

This Internet-Draft is submitted in full conformance with the provisions of BCP 78 and BCP 79.

Internet-Drafts are working documents of the Internet Engineering Task Force (IETF). Note that other groups may also distribute working documents as Internet-Drafts. The list of current Internet-Drafts is at https://datatracker.ietf.org/drafts/current/.

Internet-Drafts are draft documents valid for a maximum of six months and may be updated, replaced, or obsoleted by other documents at any time. It is inappropriate to use Internet-Drafts as reference material or to cite them other than as "work in progress."

This Internet-Draft will expire on January 1, 2022.

Copyright Notice

Copyright (c) 2021 IETF Trust and the persons identified as the document authors. All rights reserved.

This document is subject to BCP 78 and the IETF Trust's Legal Provisions Relating to IETF Documents (https://trustee.ietf.org/license-info) in effect on the date of publication of this document. Please review these documents carefully, as they describe your rights and restrictions with respect to this document. Code Components extracted from this document must include Simplified BSD License text as described in Section 4.e of the Trust Legal Provisions and are provided without warranty as described in the Simplified BSD License.

Table of Contents

1. Introduction 2
2. Requirements Language 3
3. Definition of Terms 3
4. Deployment Assumptions 4
5. Mobility Clients Network Services 4
6. Mobility Unicast-Multicast 5
7. Security Considerations 6
8. Acknowledgments 6
9. IANA Considerations 6
10. Normative References 8
Authors' Addresses 9

1. Introduction

The Locator/ID Separation Protocol (LISP) [I-D.ietf-lisp-rfc6830bis] splits IP addresses in two different namespaces, Endpoint Identifiers (EIDs) and Routing Locators (RLOCs). LISP uses map-and-encap approach (1) a Mapping System (distributed database) that stores and resolves EID-RLOC mappings and on (2) LISP tunnel routers (xTRs) encapsulating and decapsulating data packets based on content of those mappings.

H3 (https://h3geo.org)is a geospatial indexing system using hexagonal grid that can be subdivided into finer and finer hexagonal grids, combining the benefits of a hexagonal grid with hierarchy.
H3 supports sixteen resolutions. Each finer resolution has cells with 1/7 the area of the coarser resolution. Hexagons cannot be perfectly subdivided into seven hexagons, so the finer cells are approximately contained within a parent cell. Each cell is identified by 64bit HID.

The Berkeley Deep Drive (BDD) (https://bdd-data.berkeley.edu) Industry Consortium investigates computer vision technologies for automotive applications and for taxonomy of published automotive classification.

These standards are combined to create an in-network state reflecting condition of each hexagonal tile (~1sqm) in every road. LISP network maps & encapsulates traffic between client endpoint identifiers (EID) and addressable tile-objects (HID=>EID). Objects are aggregated by H3 EID services.

The H3-LISP mobility network bridges timing and location gaps between production and consumption of information by clients of mobility data:
- o vision, sensory, LIADR, AI applications -- information producers
- o driving-apps, map-apps, command & control -- information consumers

This is achieved by putting the physical world on a shared addressable state-grid of road-segments at the edge for low-latency upload. Tiled geo-state sharing is done using a brokered-network of tile representation, an indirection which solves key issues in v2v information sharing. For example multiple perspectives, geo-privacy, cyber security. These challenges arise when clients communicate when they do not really need to. A communication pattern which causes unnecessary complexity and exposures.

In non brokered v2v models, a situation observable by some end-points, it is unclear if the relevant nee-to-know end-points will receive: i. consistent, ii. conflicting, iii. multiple, or iv. no indications. As an example, when a vehicle experiences a sudden highway slow-down, sees brake lights or "feels" an accelerometer slowdown, there is no clear way for it to share this annotation with vehicles 20-30sec away. Or, when a vehicle crosses an intersection, observing opposite-lane obstruction such as: construction, double-park, commercial loading, garbage truck, or stopped school-bus.. there is no clear way for it to alert approachers from another direction as it drives away.

Geo-state indirection helps communicate advanced machine vision and radar annotations. These are evolving technologies, and relaying road enumerations using peer-to-peer poses significant interoperability challenges.

These peer-to-peer limitations are inherent yet unnecessary, in most situations vehicles are not really proper peers. They happen to be in the same place at the same time. H3-LISP mobility network solves these limitations of direct vehicle-to-vehicle communication by broker-tile. Bridging timing, security, privacy, and interoperability gaps. Brokering is achieved by clients communicating through tiles. Addressable tiles are aggregated and maintained by H3 EIDs.

Clients can provide drivers with heads-up alerts on hazards/obstacles beyond the line of sight of the driver and the in-car sensors: over traffic, around blocks, far-side junction, beyond road turns or curvatures. This highlights the importance of networks for road safety and role in Autonomous Vehicle (AV) operation support (AV-OSS).

To summarize the H3-LISP solution outline:

(1) MicroPartition: 64bit indexed geo-spatial H3.r15 of road-tiles
(2) EnumState: 64bit state values of tile condition representation
(3) Aggregation: EID per H3.r9 group of individual H3.r15 road-tiles
(4) Channels: H3.r9 EIDs multicast address for geo-state updates
(5) Scale: EID addressable services distributed for throughput
(6) Overlay: tunneled-network routes the mobility-network traffic
(7) Signal-free: overlay is used to map-register for mcast channels
(8) Aggregation: tunnels used between client EIDs and H3 EIDs
(9) Access: client/server XTRs tunnel traffic to-from the LISP RTRs
(10) Control: RTRs register-resolve H3 EIDs and mcast subscriptions

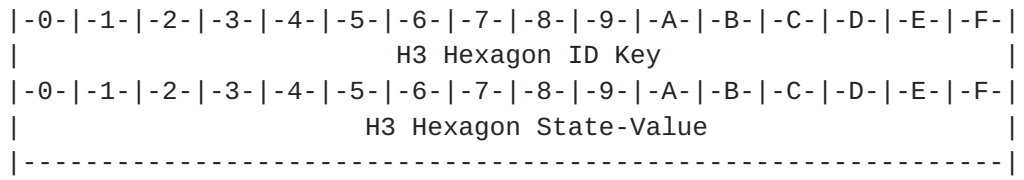


Figure 1: 64 bit H3 ID, 64 bit compiled state value

Each H3.r9 hexagon is an EID Service with corresponding H3 hexagon ID. Bound to that service is a LISP xTR specified to encapsulate packets to and from EID services and LISP Edge. Edge RTRs are used to re -tunnel packets from clients to services. Each service is also a multicast source for updating clients on the state of the H3.r15 tiles aggregated by the EID services.

2. Requirements Language

3. Definition of Terms

H3ServiceEID: Is an addressable aggregation of H3.r15 state-tiles. It is a designated destination for physical world annotations, and an (s,g) source of multicast public-safety update channels. H3ServiceEID is itself an H3 hexagon, large enough to provide geo-spatial conditions context, but not too large as to over-burden subscribers with too much information. For Mobility Network it is H3.r9. It has a light-weight LISP protocol stack to tunnel packets aka ServerXTR. The EID is an IPv6 EID that contains the H3 64-bit address numbering scheme. See IANA consideration for details.

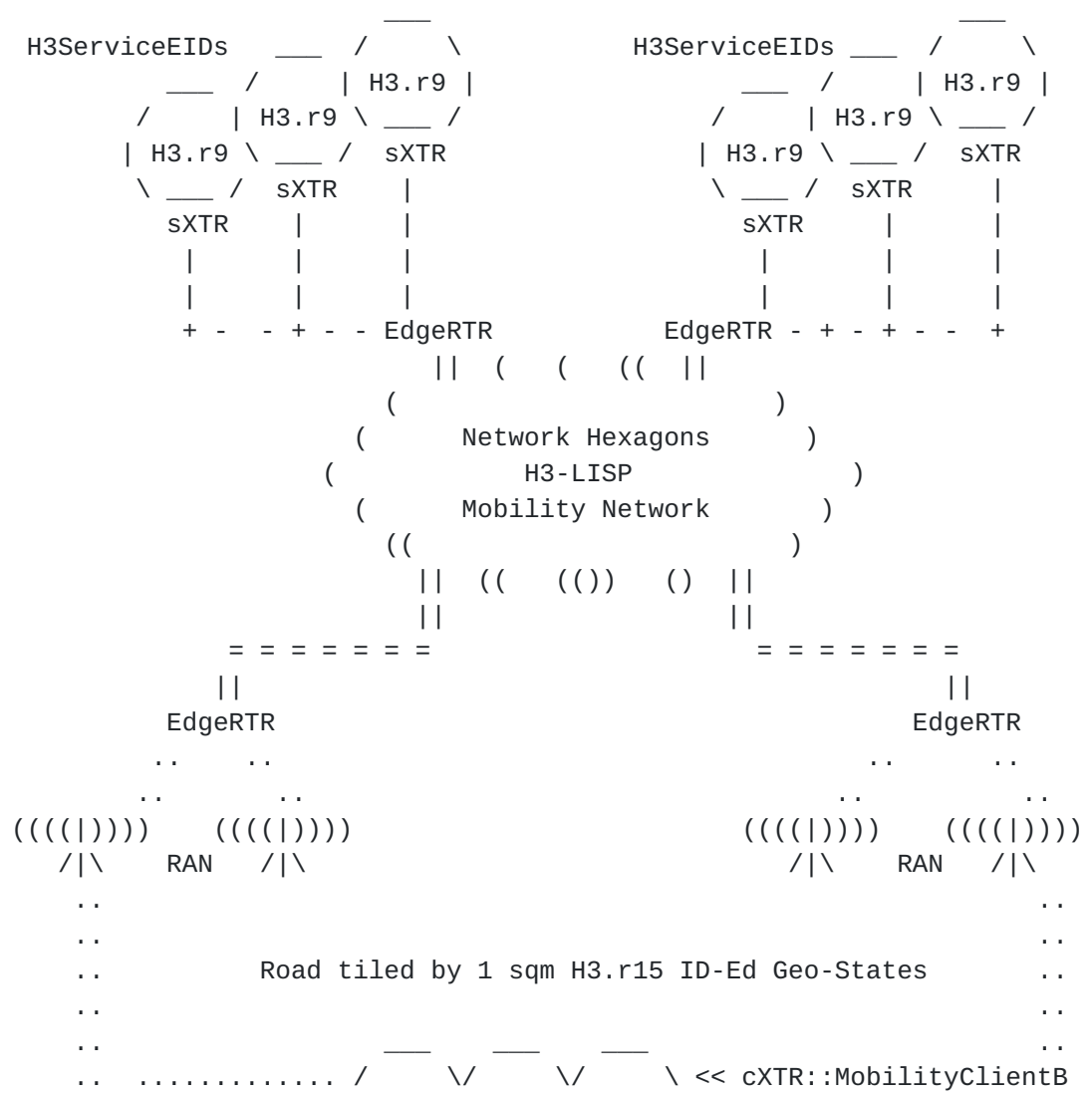
ServerXTR: Is a data-plane only LISP protocol stack implementation, it co-exists with H3ServiceEID process. When the server roams, the xTR is with it. ServerXTR encaps/decaps packets to/from EdgeRTRs.

MobilityClient: Is a roaming application that may be a part of an automobile, part of a navigation application, part of municipal, state or federal government command and control application, or a street view consumer application. It has a light-weight LISP data-plane stack to tunnel packets, aka ClientXTR.

MobilityClient EID: Is the IPv6 EID used by the Mobility Clients to source packets. The destination of such packets are only H3ServiceEIDs. The EID format is opaque and is assigned as part of the MobilityClient mobility-network authorization.

ClientXTR: Is a data-plane only LISP protocol stack implementation co-located with the Mobility Client application. It encaps/ decaps packets from/to applications to/from EdgeRTRs.

EdgeRTR: Is the core scale and structure of the LISP mobility network. EdgeRTRs proxy H3ServiceEIDs and MobilityClient H3ServiceEID mcast registration. EdgeRTRs aggregate MobilityClients/H3Services using tunnels to facilitate hosting-providers and mobile-providers for accessing the mobility network. EdgeRTRs decapsulate packets from ClientXTRs, ServerXTRs and re-encaps packets to the clients and servers tunnels. EdgeRTRs glean H3ServiceEIDs/MobilityClient EIDs when they decapsulates packets. EdgeRTRs store H3ServiceEIDs and RLOCs of where the H3ServiceEID is currently reachable from the map-cache. These mappings are registered to the LISP mapping so other EdgeRTRs know where to encapsulate for such EIDs. These mappings may be provisioned by dev-ops when H3Services are assigned EdgeRTRs. EdgeRTRs do not register MobilityClients' EIDs at the mapping as these are temporary-renewed while using the mobility network. Enterprises may provide their own EdgeRTRs to protect geo-privacy.



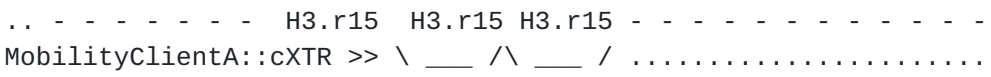


Figure 2: H3.r15 state representation, H3.r9 state aggregation

Figure 2 above describes the following entities:
- MobilityClientA has seen MobilityClientB future, and, vice versa
- Clients share information using addressable state routed by LISP
- ClientXTR (cXTR): tunnel encaps over access network to EdgeRTR
- ServerXTR (sXTR): tunnel encaps over cloud network to EdgeRTR
- H3-LISP Mobility overlay spans cXTRs to sXTRs
- Uploads are routed to appropriate tile by the LISP network
- EdgeRTRs perform multicast replication to edges and then cXTRs
- Clients receive tile-by-tile geo-state updates via the multicast

4. Deployment Assumptions

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

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

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

Figure 3: Nibble based representation- 16 fields x 16 eunms

We name the nibbles using hexadecimal index according to the position where the most significant nibble has index 0.
Values are defined in section 9.

Subscription of MobilityClients to mobility-network is renewed while on the move and is not intended as the basic connectivity. MobilityClients use DNS/AAA to obtain temporary EIDs/EdgeRTRs and use (LISP) data-plane tunnels to communicate using their temporary EIDs with the dynamically assigned EdgeRTRs.

MobilityClient are otherwise unaware of the LISP network control plane and simply regard the data-plane tunnels as a virtual private network (VPN) that supports IPv6 EID to publish (Ucast) and Subscribe-to (Mcast) H3Services.

In order to get access to the MobilityVPN, MobilityClients first authenticate with the MobilityVPN AAA Server. DIAMETER [RFC6733] based AAA is typically done at the provider edge (PE) by gateways. However, the typical case involves several types of CPE connected to a specific service provider. The Mobility VPN, on the other hand, may overlay a number of wireless networks and cloud-edge providers. It also involves dozens of Car-OEM, Driving-Applications, Smart-City vendors. This is why we require clients to first go through AAA in order to get both a MobilityClientEID and EdgeRTR RLOC.

ClientXTR performs the following steps to use the mobility network:
1) obtain the address of the mobility network AAA server using DNS
2) obtain MobilityClientEID and EdgeRTR(s) from AAA DIAMETER server
3) renew authorization from AAA while using the mobility network

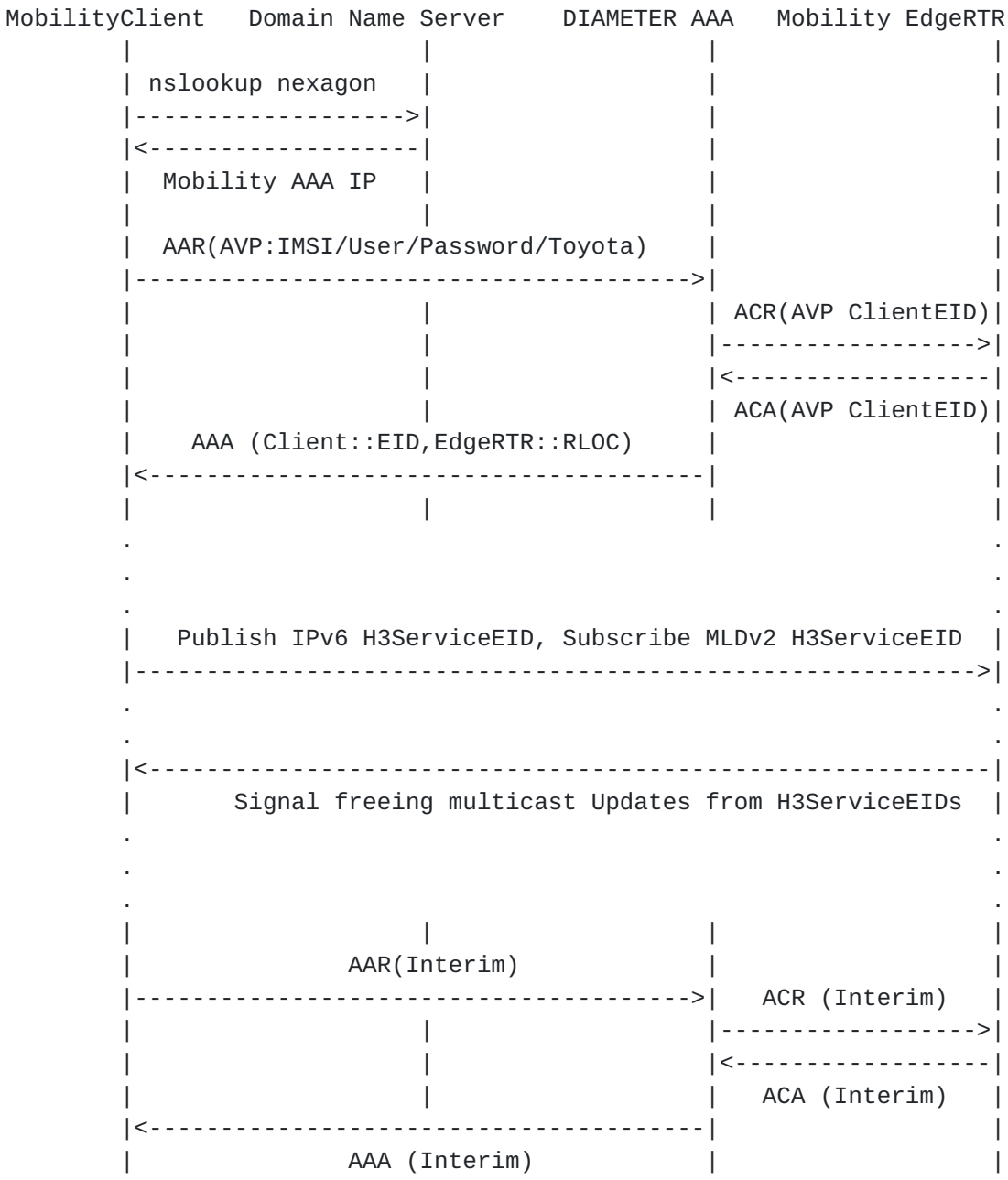


Figure 4: DNS and AAA Exchange for nexagon-network login

Using this network login and re-login method we ensure that:
- the MobilityClientEIDs serve as credentials with the EdgeRTRs
- EdgeRTRs are provisioned to whitelist MobilityClient EIDs
- EdgeRTRs are not tightly coupled to H3.r9 areas (privacy/balance)
- Mobility Clients do not need to update EdgeRTRs while roaming

The same EdgeRTR may serve several H3.r9 areas for ride continuity and several EdgeRTRs may load balance an H3.r9 area with high

density of MobilityClients. When a MobilityClient ClientXTR is homed to EdgeRTR, it is able to communicate with H3ServiceEIDs.

5. Mobility Clients Network Services

The mobility network functions as a standard LISP overlay.
The overlay delivers unicast and multicast packets across:
- multiple access-networks and radio-access specifications
- multiple edge providers, public, private, and hybrid clouds

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

There are two options to associate ClientXTRs with LISP EdgeRTRs:

i. Semi-random load-balancing by DNS/AAA

In this option we assume that in a given metro edge a pool of EdgeRTRs can distribute the Mobility Clients load randomly between them and that EdgeRTRs are topologically equivalent. Each RTR uses LISP to tunnel traffic to and from other EdgeRTRs for MobilityClient with H3Service exchanges. MobilityClients home to EdgeRTRs.

ii. Topological by anycast

In this option we align an EdgeRTR with topological aggregation. Mobility Clients are roaming in an area home to that RTR and so is the H3 Server. There is only one hop across the edge overlay between clients and servers and mcast replication is more focused, but clients need to keep re-homing as they move.

To summarize the H3LISP mobility network layout:

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

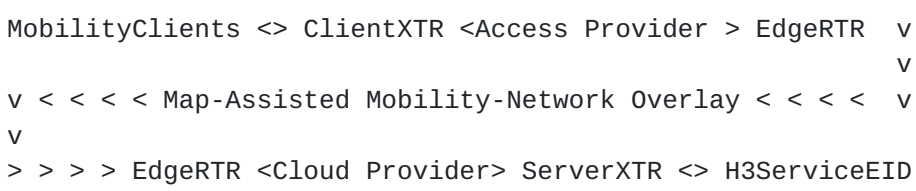


Figure 5: The Data Flow Between MobilityClients and H3ServiceEIDs

6. Mobility Unicast and Multicast

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

The ClientXTR encapsulates MobilityClient EID and H3ServiceEID from the ClientXTR with the destination of the EdgeRTR RLOC LISP port. EdgeRTRs then re-encapsulate annotation packets either to a remote EdgeRTR (option 1) or to homed H3ServiceEID ServerXTR (option 2). The remote EdgeRTR aggregating H3ServiceEIDs re-encapsulates MobilityClient EID to the ServerXTR, to the H3ServiceEID.

The headers consist of the following fields:

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

Nexagon Header Type allows for kv tupples of vkkk flooding
Type 0: reserved
Type 1:key-value, key-value.. 1392 / (8 + 8) = 87 pairs
Type 2:value, key,key,key.. (1392 - 8) / 8 = 173 H3-R15 IDs
Type 3-255: unassigned

Nexagon Header GZIP allows for compression, very effective for H3IDs
At this point we designate 001 value if content was GZIP compressed.
Additional values may be added in the futuer for compression types.

Nexagon Header Reserved bits
Nexagon Header kv count (in any format)

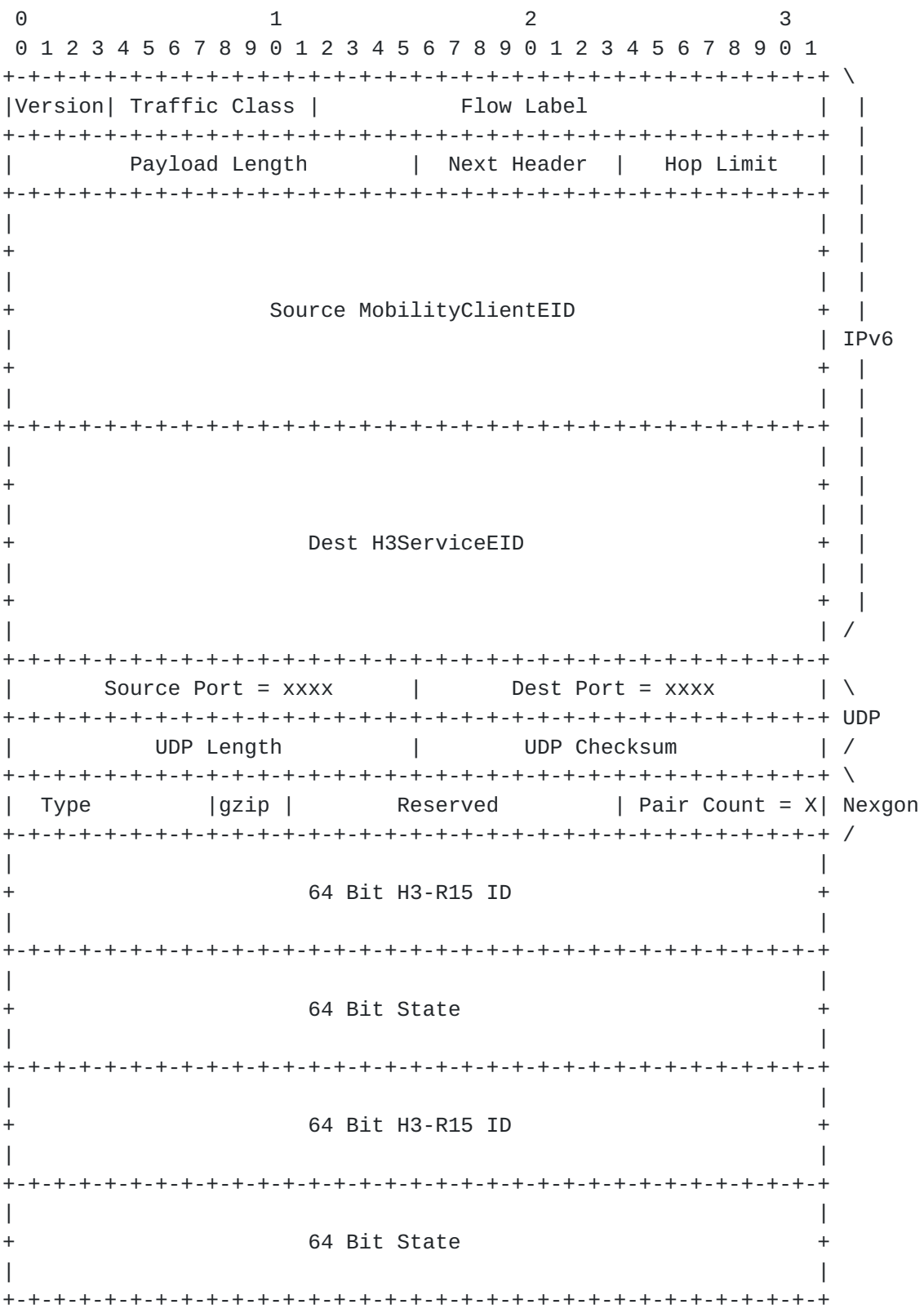


Figure 6: Published detections packet format

To Summarize Unicast:

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

Each H3.r9 Server is also an IP Multicast Source used to update subscribers on the aggregate state of the H3.r15 tiles in the H3.r9 server. This forms a multipoint to multipoint state channel per H3 location, where the aggregation has compute-first propagation.

We use [RFC8378] signal-free multicast to implement mcast channels in the overlay. The mobility network has many channels, with thousands subscribers per channel. MobilityClients driving through/subscribing to an H3.r9 area can explicitly issue an [RFC4604] MLDv2 in order to subscribe, or, may be subscribed implicitly by the EdgeRTR.

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

MLDv2 signaling messages are encapsulated between the ClientXTR and EdgeRTR, therefore there is no requirement for the underlying network to support native multicast. If native access multicast is supported then MobilityClient registration to H3ServiceEID safety channels may be integrated with it, in which case mobile packet-core element supporting it will use this standard to register with the appropriate H3.r9 channels in its area.

Multicast update packets are of the following structure:

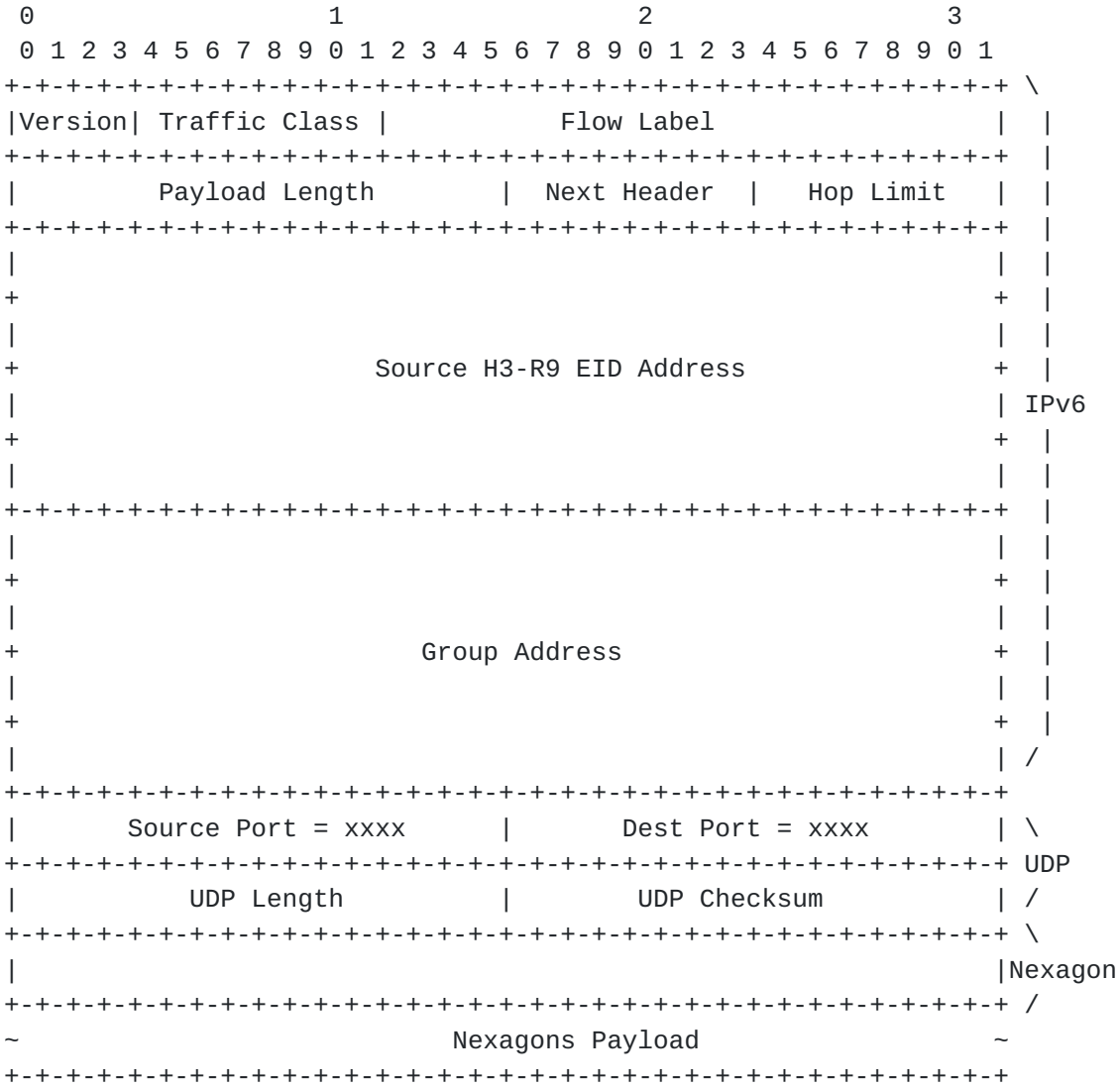


Figure 7: Mcast update packet header

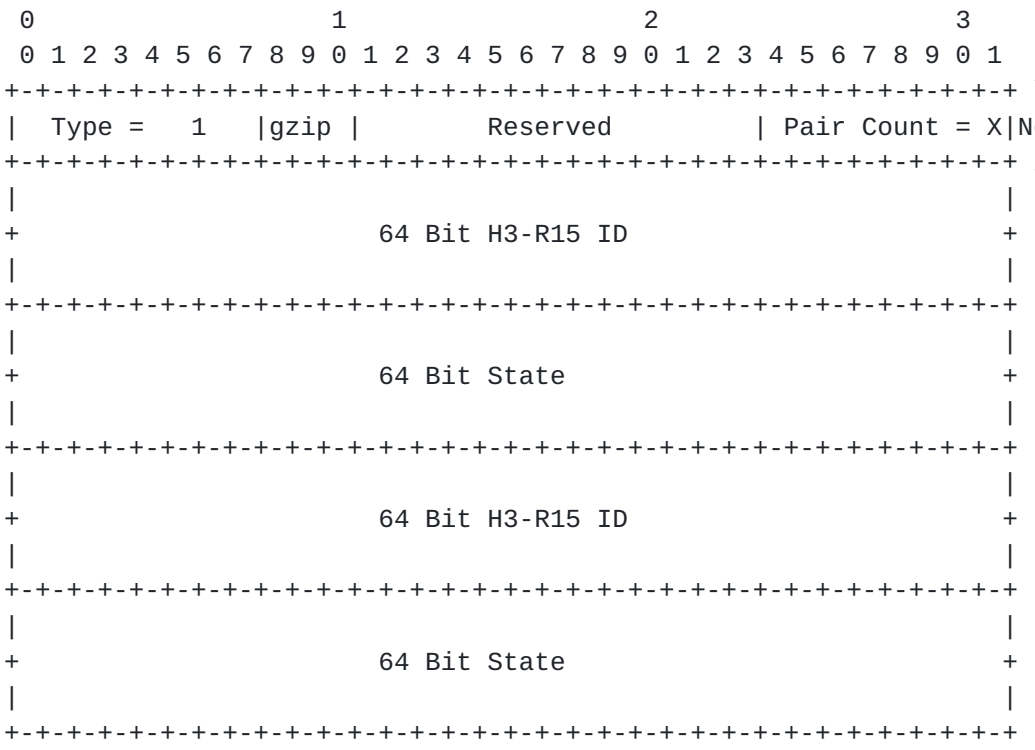


Figure 8: Mcast update payload, key-value, key-value..

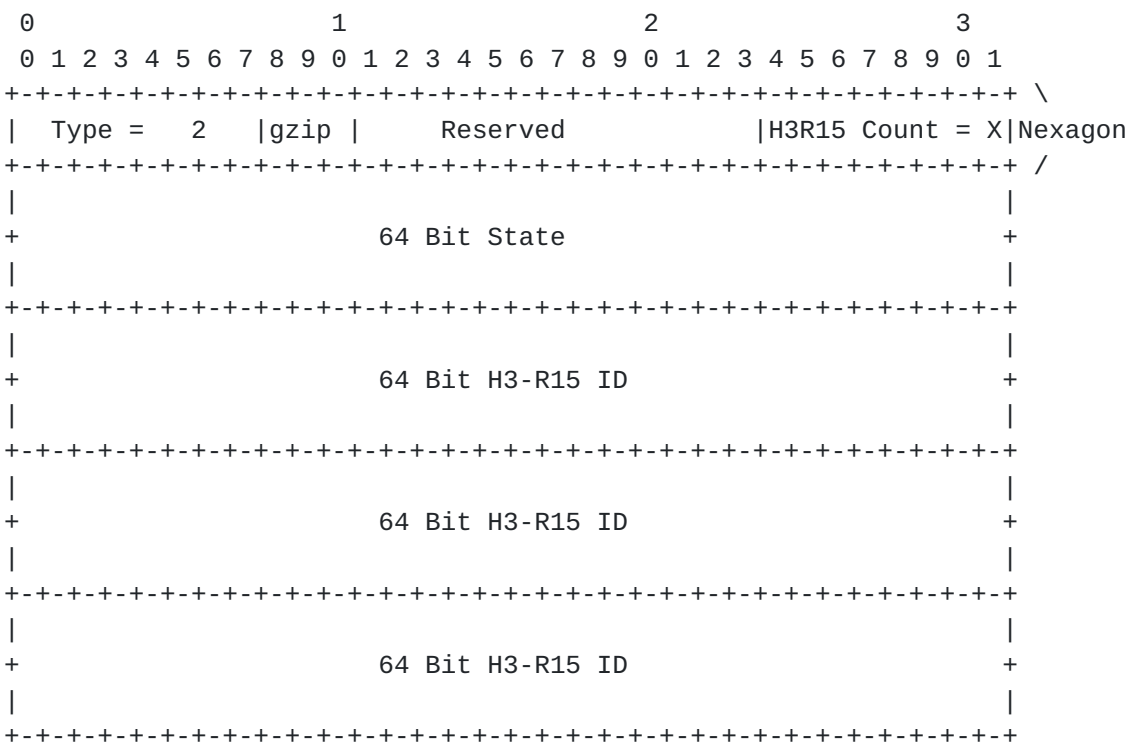


Figure 9: Mcast update payload, value, key, key.. for larger areas

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

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

To Summarize:

(1) H3LISP Clients tune to H3.r9 mobility updates using [RFC8378]
H3LISP Client issue MLDv2 registration to H3.r9 HIDs
ClientXTRs encapsulate MLDv2 to EdgeRTRs who register (s,g).

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

7. Security Considerations

The nexagon layer3 v2n network is inherently more secure and private then peer to peer alternatives because of the indirection. No car or infrastructure element communicates directly with MobilityClients. All information is conveyed using shared addressable geo-state. MobilityClients receive information only from network channels published by a trusted broker. MobilityClients have no indication as to the origin of the information. This is an important step towards better privacy, security, extendability, and interoperability compared with legacy layer2 protocols.

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

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

For this reason we envision the ability of enterprise or groups of users to "bring their own" EdgeRTRs. BYO-RTR masks individual clients' RLOC to H3-R9 association and is pre-provisioned to be able to use the mapping system and be on a white-list of EdgeRTRs aggregating H3ServiceEIDs. If the EdgeRTR functionality is delivered by 5GCore UPF then the only entity which can correlate underlay IP, User, and Geo-location is the regulated carrier, which can do so anyway.

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

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

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

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

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

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

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

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

8. Acknowledgments

9. IANA Considerations

State enum fields of H3 tiles:

Field 0x0: Traffic Direction {
0x0 - null
0x1 - Lane North
0x2 - Lane North + 30
0x3 - Lane North + 60
0x4 - Lane North + 90
0x5 - Lane North + 120
0x6 - Lane North + 150
0x7 - Lane North + 180
0x8 - Lane North + 210
0x9 - Lane North + 240
0xA - Lane North + 270
0xB - Lane North + 300
0xC - Lane North + 330
0xD - junction
0xE - shoulder
0xF - sidewalk
}

field 0x1: Persistent or Structural {
 0x0 - null
 0x1- pothole light
 0x2 - pothole severe
 0x3 - speed-bump low
 0x4 - speed-bump high
 0x5 - icy
 0x6 - flooded
 0x7 - snow-cover
 0x8 - snow-deep
 0x9 - construction cone
 0xA - gravel
 0xB - choppy
 0xC - blind-curve
 0xD - steep-slope
 0xE - low-bridge
 0xF - unassigned
}

```
field 0x2: Transient Condition {
 0x0 - null
 0x1 - pedestrian
 0x2 - bike scooter
 0x3 - stopped car / truck
 0x4 - moving car / truck
 0x5 - first responder vehicle
 0x6 - sudden slowdown
 0x7 - oversized over-height vehicle
 0x8 - red-light-breach
 0x9 - light collision (fender bender)
 Ax - hard collision / casualty
 0xB - collision course
 0xC - collision debris
 0xD - hard brake
 0xE - sharp corner
 0xF - freeing-parking
}

field 0x3: Traffic-light Cycle {
 0x - null
 0x1 - 1 seconds to green
 0x2 - 2 seconds to green
 0x3 - 3 seconds to green
 0x4 - 4 seconds to green
 0x5 - 5 seconds to green
 0x6 - 6 seconds to green
 0x7 - 7 seconds to green
 0x8 - 8 seconds to green
 0x9 - 9 seconds to green
 0xA - 10 seconds or less
 0xB - 20 seconds or less
 0xC - 30 seconds or less
 0xD - 60 seconds or less
 0xE - green now
 0xF - red now
}
```

```
field 0x4: Impacted Tile from Neighboring {
 0x - null
 0x1 - epicenter
 0x2 - light yellow
 0x3 - yellow
 0x4 - light orange
 0x5 - orange
 0x6 - light red
 0x7 - red
 0x8 - light blue
 0x9 - blue
 0xA - green
 0xB - light green
 0xC - unassigned
 0xD - unassigned
 0xE - unassigned
 0xF - unassigned
}
field 0x5: Transient, Cycle, Impacted, Valid for Next{
 0x - null
 0x1 - 1sec
 0x2 - 5sec
 0x3 - 10sec
 0x4 - 20sec
 0x5 - 40sec
 0x6 - 60sec
 0x7 - 2min
 0x8 - 3min
 0x9 - 4min
 0xA - 5min
 0xB - 10min
 0xC - 15min
 0xD - 30min
 0xE - 60min
 0xF - 24hours
}
field 0x6: LaneRightsSigns {
 0x - null
 0x1 - yield
 0x2 - speedLimit
 0x3 - straightOnly
 0x4 - noStraight
 0x5 - rightOnly
 0x6 - noRight
 0x7 - rightStraight
 0x8 - leftOnly
 0x9 - leftStraight
 0xA - noLeft
 0xB - noUTurn
```

```
 0xC - noLeftU
 0xD - bikeLane
 0xE - HOVLane
 0xF - Stop
}
```

```
field 0x7: MovementSigns {
0x - null
0x1 - keepRight
0x2 - keepLeft
0x3 - stayInLane
0x4 - doNotEnter
0x5 - noTrucks
0x6 - noBikes
0x7 - noPeds
0x8 - oneWay
0x9 - parking
0xA - noParking
0xB - noStandaing
0xC - noPassing
0xD - loadingZone
0xE - railCross
0xF - schoolZone
}
field 0x8: CurvesIntersectSigns {
0x - null
0x1 - turnsLeft
0x2 - turnsRight
0x3 - curvesLeft
0x4 - curvesRight
0x5 - reversesLeft
0x6 - reversesRight
0x7 - windingRoad
0x8 - hairPin
0x9 - pretzelTurn
0xA - crossRoads
0xB - crossT
0xC - crossY
0xD - circle
0xE - laneEnds
0xF - roadNarrows
}
```

field 0x9: Current Tile Speed {
0x - null
0x1 - < 5kmh
0x2 - < 10kmh
0x3 - < 15kmh
0x4 - < 20kmh
0x5 - < 30kmh
0x6 - < 40kmh
0x7 - < 50kmh
0x8 - < 60kmh
0x9 - < 80kmh
0xA - < 100kmh
0xB - < 120kmh
0xC - < 140kmh
0xD - < 160kmh
0xE - > 160kmh
0xF - queuedTraffic
}

field 0xA: Vehicle / Pedestrian Traffic {
0x - null
0x1 - probability of ped/vehicle on tile close to 100%
0x2 - 95%
0x3 - 90%
0x4 - 85%
0x5 - 80%
0x6 - 70%
0x7 - 60%
0x8 - 50%
0x9 - 40%
0xA - 30%
0xB - 20%
0xC - 15%
0xD - 10%
0xE - 5%
0xF - probability of ped/vehicle on tile close to 0%, empty
}

filed 0xB - reserved
field 0xC - reserved
field 0xD - reserved
field 0xE - reserved
field 0xF - reserved

Reserved fields and values are for future RFC extensions

10. 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-36 (work in progress), September 2020.

[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>.

[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>.

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

Authors' Addresses

Sharon Barkai
Nexar
CA
USA

Email: sbarkai@gmail.com

Bruno Fernandez-Ruiz
Nexar
London
UK

Email: b@getnexar.com

S ZionB
Nexar
Israel

Email: sharon@fermicloud.io

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