

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

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
September 14, 2021

Network-Hexagons: H3-LISP GeoState & Mobility Network
draft-ietf-lisp-nexagon-19

Abstract

This document specifies the use of H3 and LISP for Geolocation Services. Geolocation Services utilize geospatial data for: Fresh HDMaps, Intelligent Driving, Cruise and Parking assists. Geospatial utilization is delivered using in-network compute for brokered verification, curation, and localization of data, using:

- EID addressable geospatial-tiles abstraction of road-segments.
- EID Interface for detections and uploads to the tile-contexts.
- EID Routing-Sharing hazards, blockages, parking, road-inventory.
- EID themed multicast channels per tile 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.

Internet-Draft

LISP

September 2021

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. | Definition of Terms | 5 |
| 3. | Deployment Assumptions | 7 |
| 4. | Mobility Clients Network Services | 10 |
| 5. | Mobility Unicast and Multicast | 11 |
| 6. | Security Considerations | 17 |
| 7. | Acknowledgments | 18 |
| 8. | IANA Considerations | 19 |
| 9. | Normative References | 30 |
| | Authors' Addresses | 31 |

[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.

Internet-Draft

LISP

September 2021

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. The mobility H3-LISP network maps & encapsulates traffic between client endpoint identifiers (EID) and addressable geospatial contexts (H3-HID=>EID).

The H3-LISP mobility network bridges timing and location gaps between production and consumption of information by clients of mobility data:

- o information producers: vision, sensory, LIADR, AI applications
- o information consumers: driving-apps, map-apps, command & control

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

In non brokered v2v models, for a situation observable by some end points, it is unclear if the need-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 senses an accelerometer slowdown, there is no clear way for it to share this data 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.

Geospatial context indirection helps communicate advanced vision and radar annotations. As these are evolving technologies, relaying road enumerations using peer-to-peer poses 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 the limitations of direct vehicle-to-vehicle communication by brokering exchanges using addressable geospatial context. Bridging timing, security, privacy, and interoperability gaps between endpoints. Brokering is achieved by clients communicating via context, addressable tiles which aggregated and relay data using H3 EIDs.

Clients can provide drivers with heads-up alerts on hazards/obstacles beyond the line of sight of driver and 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 mobility solution principles are:

- (1) Problem Partition: 64bit H3.r15 ID road-tiles for detections
- (2) Enumerated State: 64bit values of tile condition representation
- (3) Grouping: EID per H3.r9 geo-context for its H3.r15 road-tiles
- (4) Group Channels: H3.r9 EIDs mcast address for geo-state updates
- (5) Scale: EID addressable contexts distributed on edge servers
- (6) Overlay: tunneled-network routes the mobility-network traffic
- (7) Signal-free: overlay is used to map-register for mcast channels
- (8) Layering: overlay tunnels used between clients and geo-contexts
- (9) Access: client/server XTRs tunnel traffic to-from the LISP RTRs
- (10) Control: RTRs register-resolve H3 EIDs and mcast subscriptions

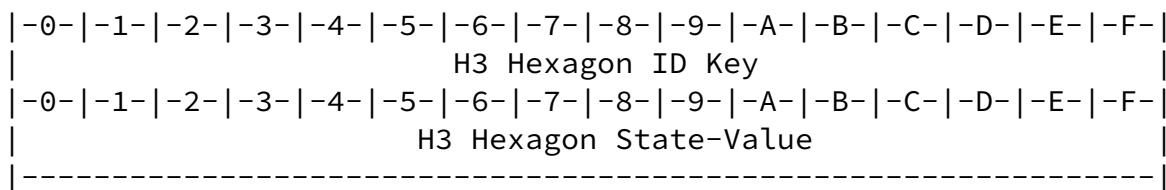


Figure 1: 64 bit H3 ID, 64 bit compiled state value

Each H3.r9 hexagon is an EID context with corresponding H3 hexagon ID. Bound to that context is a LISP xTR specified to encapsulate packets to and from EID context 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 addressable geospatial context.

2. Definition of Terms

H3ServiceEID: Is an addressable aggregation of H3.r15 tiles. It functions as geospatial data association context for filtering, verifying, localizing, and propagating vehicles data uploads. It is a designated destination for physical world annotations, and an (s,g) source of multicast themed update channels. H3ServiceEID is itself an H3 hexagon, large enough to provide geo-spatial compute 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.

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. These 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.

Internet-Draft

LISP

September 2021

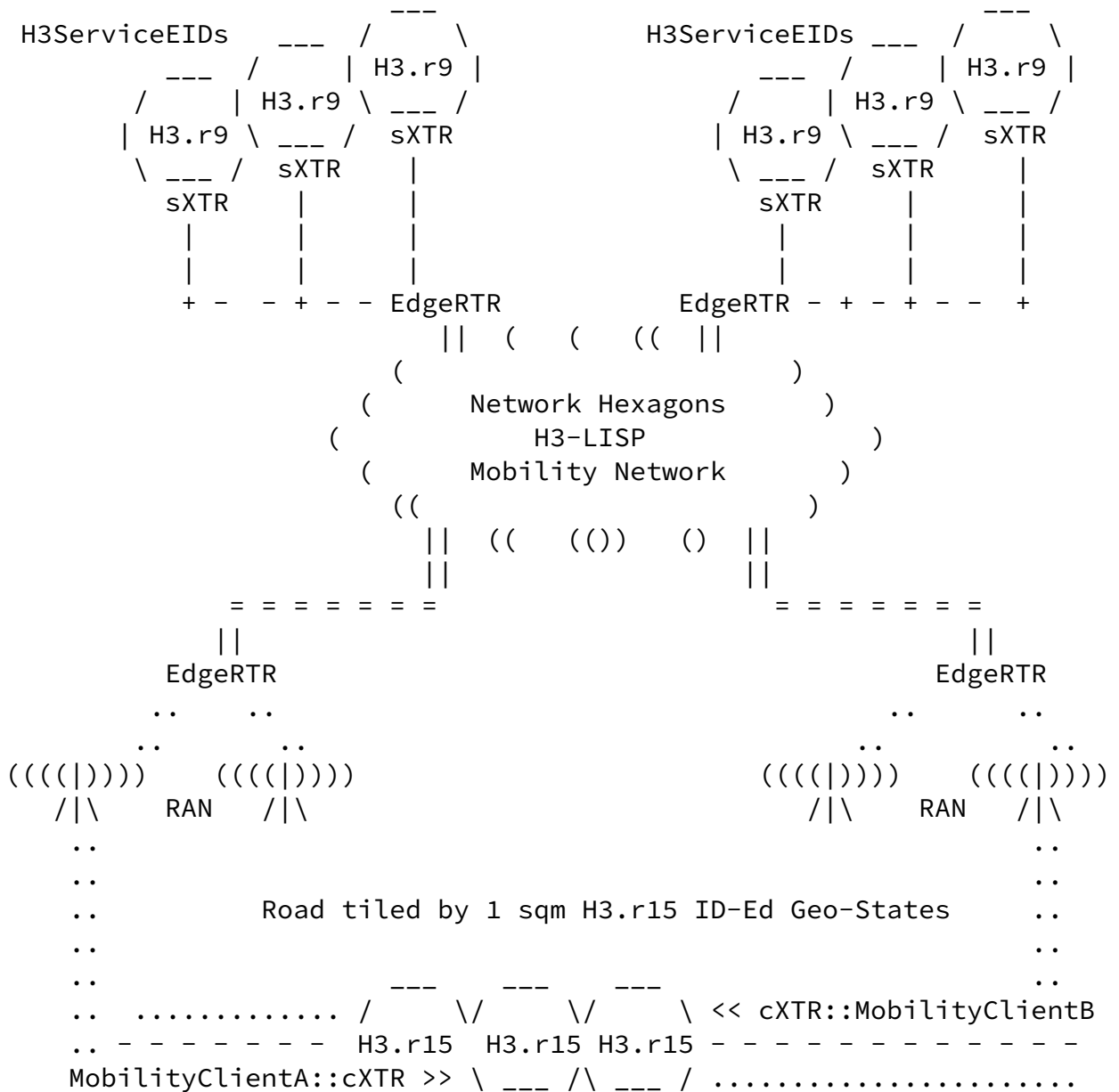


Figure 2: H3.r15 state representation, H3.r9 state aggregation

Figure 2 above describes the following entities:

- MobilityClientA sees MobilityClientB future, and, vice versa
- Clients: share information using addressable state routed by LISP
- ClientXTR (cXTR): encapsulates over access network to EdgeRTR
- ServerXTR (sXTR): encapsulates over cloud network to EdgeRTR
- H3-LISP Mobility: overlay which spans cXTRs to sXTRs
- Uploads: 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

3. 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

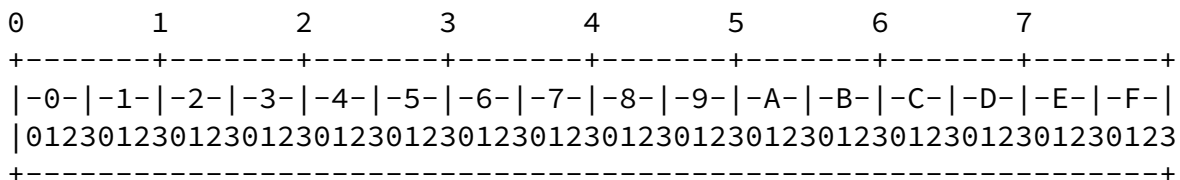


Figure 3: Nibble based representation, 16 fields x 16 enumerations

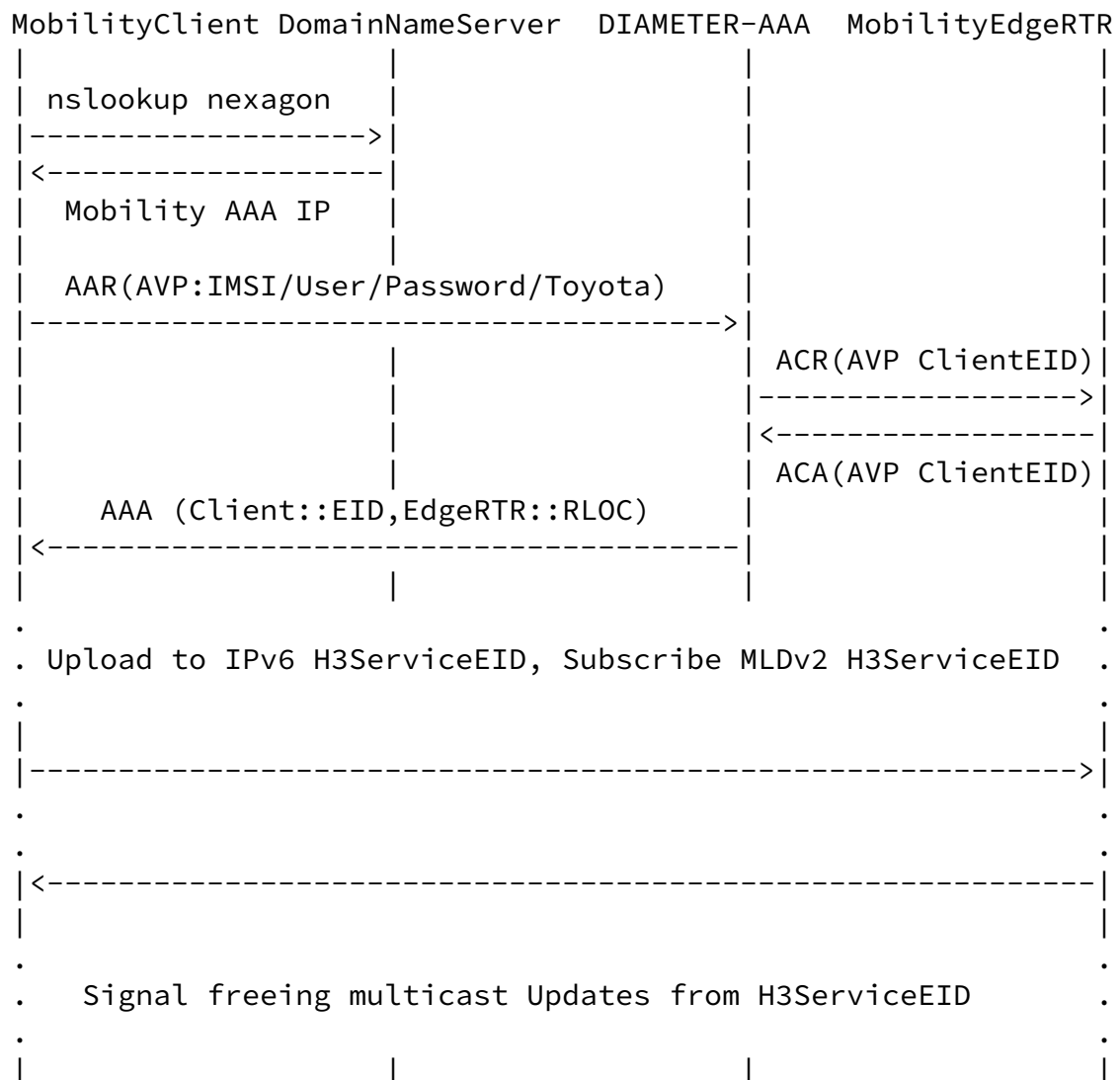
We name the nibbles using hexadecimal index according to the position where the most significant nibble has index 0. Values are defined in [section 8](#).

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 upload (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. On other hand, the Mobility VPN 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



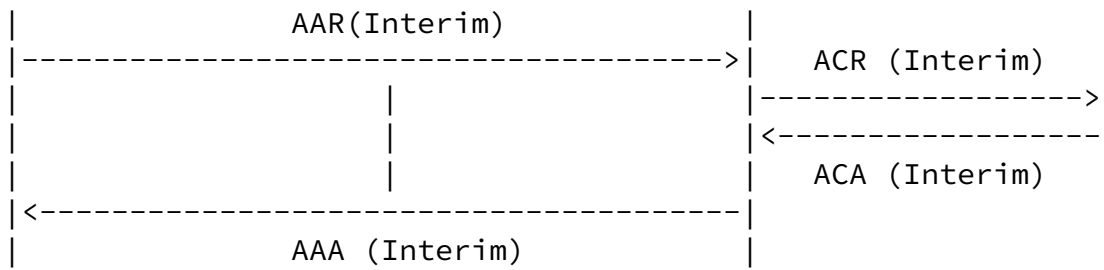


Figure 4: DNS and AAA Exchange for nexagon-network login

Using this network login and re-login method we ensure that:

- 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)
- MobilityClients 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.

[4. 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/NAT 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

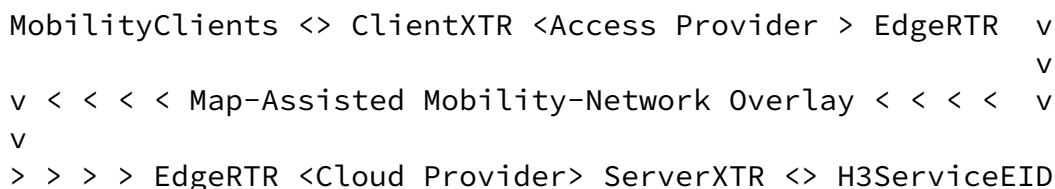


Figure 5: The Data Flow Between MobilityClients and H3ServiceEIDs

5. Mobility Unicast and Multicast

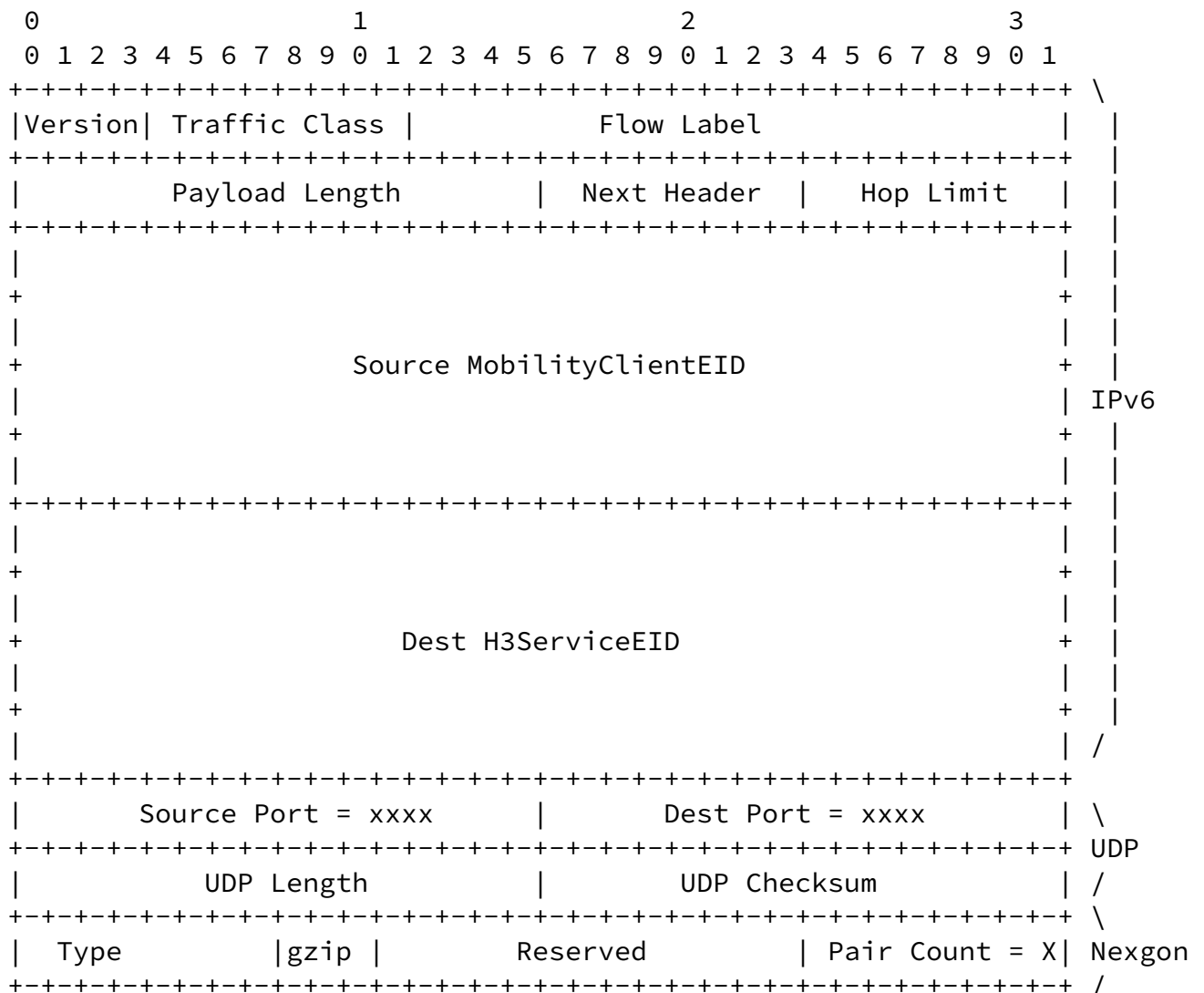
Regardless of the way a given ClientXTR was associated with EdgeRTR, an authenticated MobilityClient EID can send: [64bitH3.15ID :: 64bitState]annotations to the H3.r9 H3ServiceEID. The H3.r9 EID can be calculated by clients algorithmically from the H3.15 localization.

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 to remote EdgeRTR. 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 tuples or 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 field: 0x000 no compression, or GZIP version.
 Nexagon Header Reserved bits
 Nexagon Header kv count (in any format)



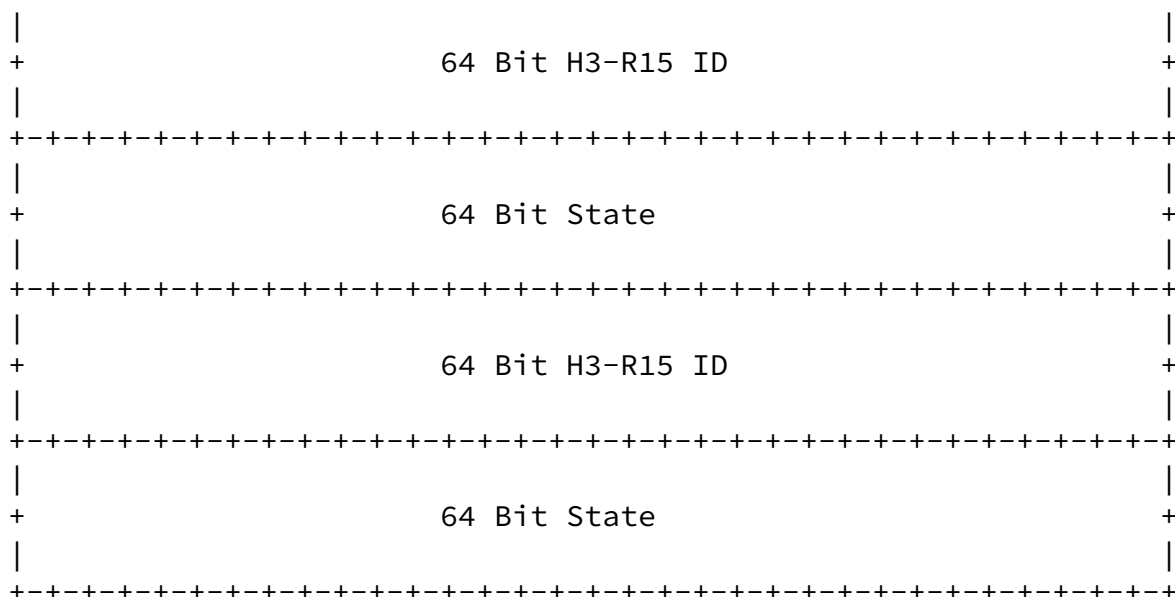


Figure 6: Uploaded detections packet format

To Summarize Unicast Uploads:

- (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.

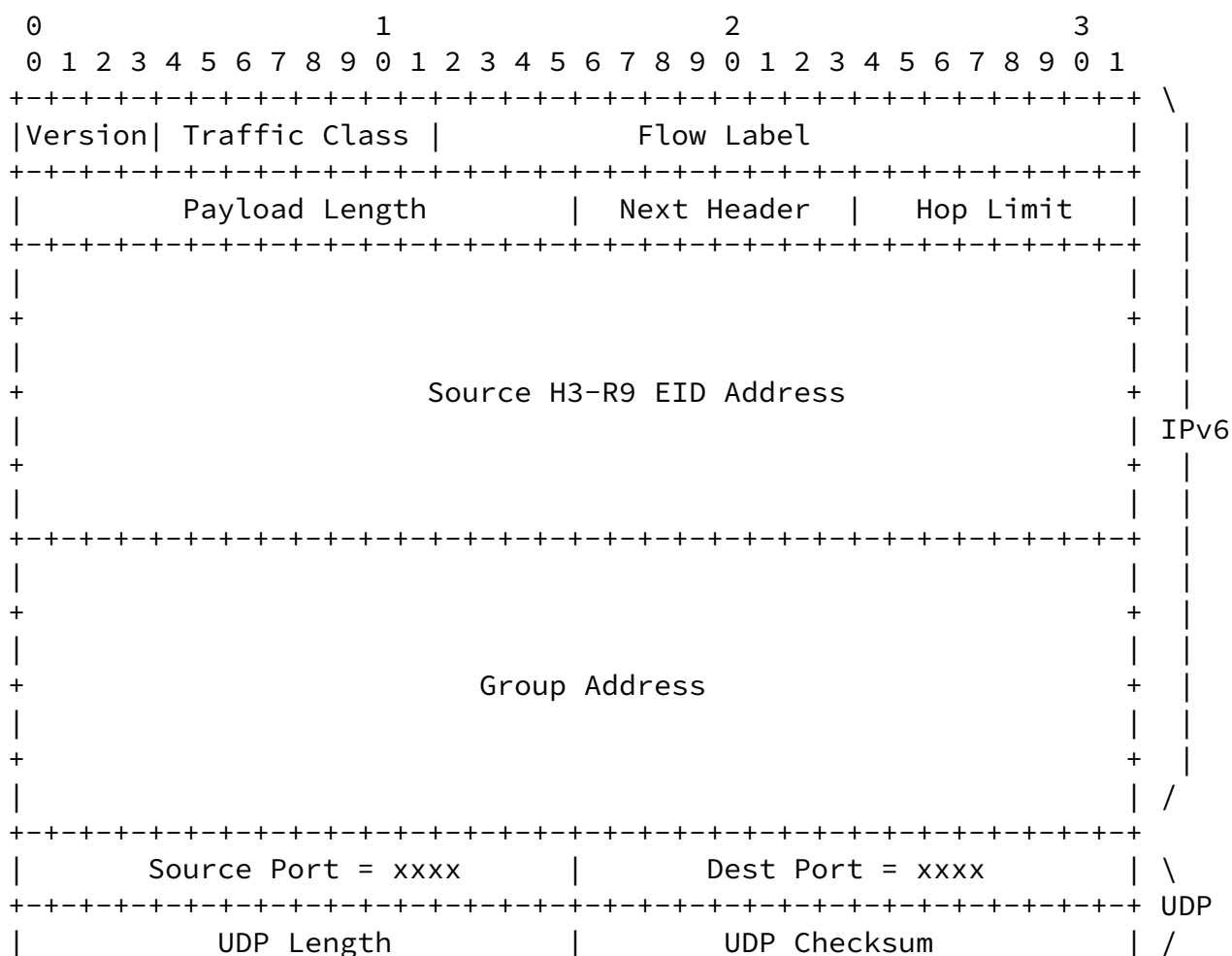
We use [[RFC8378](#)] signal-free multicast to implement mcast channels in the overlay. The mobility network has many channels, with thousands subscribers per channel. MobilityClients driving through/subscribing to an H3.r9 area can explicitly issue an [[RFC4604](#)] MLDv2 in order to subscribe, or,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



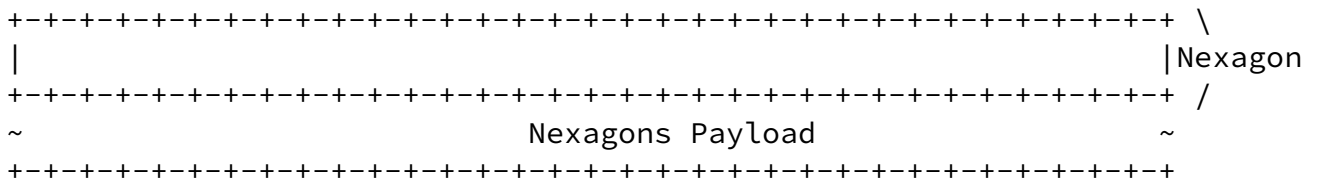


Figure 7: Mcast update packet header

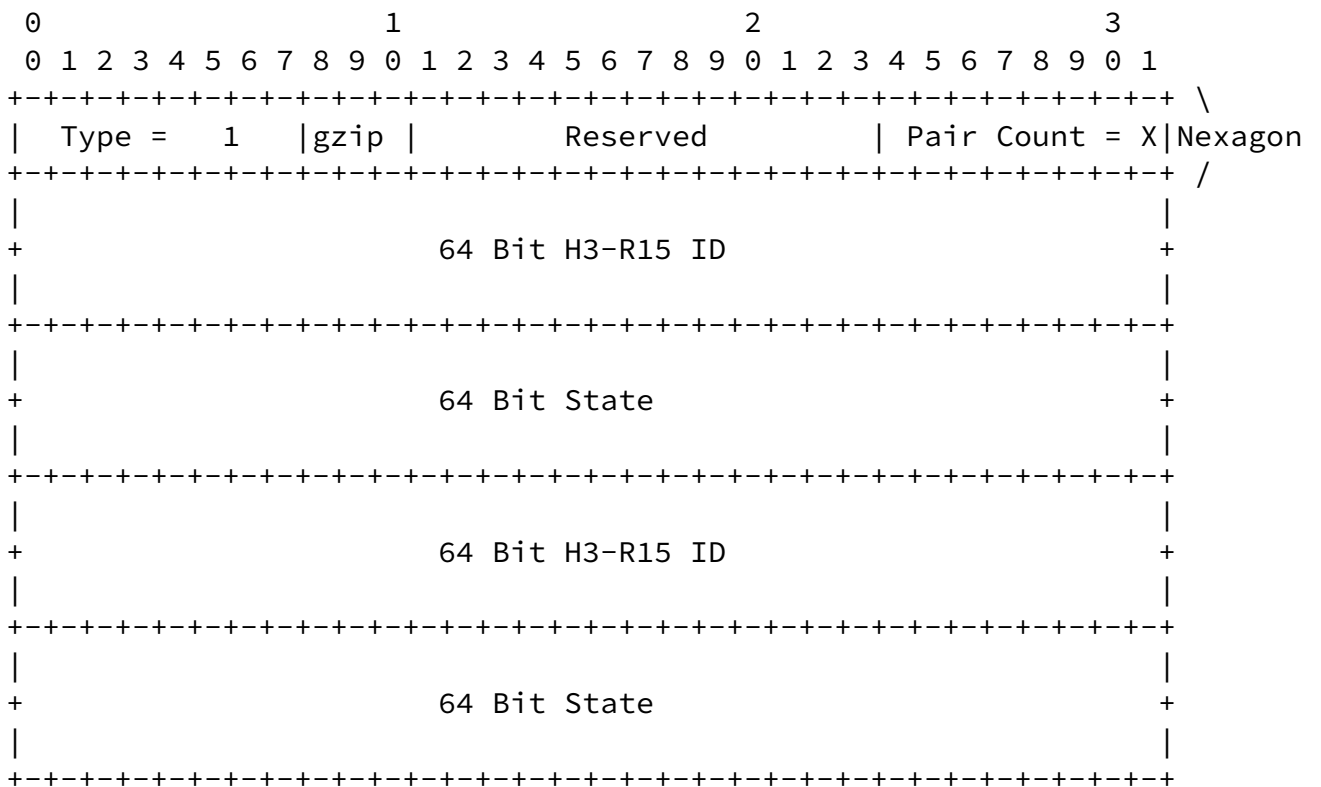
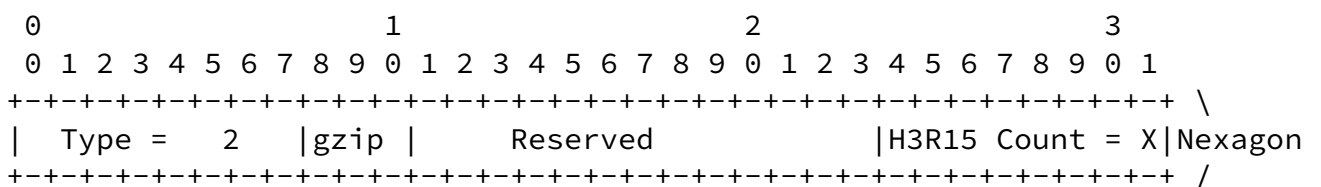


Figure 8: Mcast update payload, key-value, key-value..



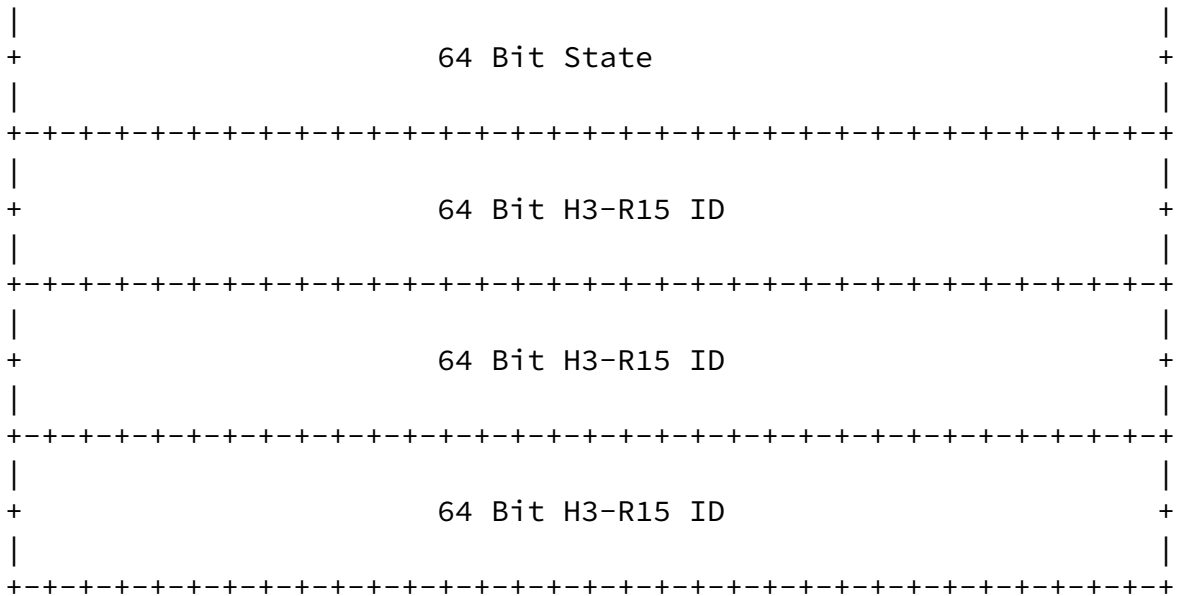


Figure 9: Mcast update payload, value, key, key.. for larger areas

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.

[6.](#) 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 geospatial channels originating from 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 uploads 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.

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.

Barkai, et al.

Expires January 1, 2022

[Page 18]

Internet-Draft

LISP

September 2021

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.

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 |
|-------|-------------|-----------|
|-------|-------------|-----------|

| 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-36](#) (work in progress), September 2020.

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

Barkai, et al.

Expires January 1, 2022

[Page 30]

Internet-Draft

LISP

September 2021

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

Barkai, et al.

Expires January 1, 2022

[Page 31]

Internet-Draft

LISP

September 2021

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

Barkai, et al.

Expires January 1, 2022

[Page 32]