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A Decent LISP Mapping System (LISP-Decent)
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Abstract

This draft describes how the LISP mapping system can be distributed for scale, decentralized for management and maintain trust among data-plane nodes. The intended status for this document is Informational RFC and should be used by LISP-Decent implementations to interoperate with each other.

Requirements Language

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "NOT RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in BCP 14 [RFC2119] [RFC8174] when, and only when, they appear in all capitals, as shown here.

Status of This Memo

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1. Introduction

The LISP architecture and protocols [RFC9300] introduces two new numbering spaces, Endpoint Identifiers (EIDs) and Routing Locators (RLOCs) that are intended to provide overlay network functionality. To map from EID to a set of RLOCs, a control-plane mapping system is used [RFC6836] [RFC8111]. These mapping systems are naturally distributed in their deployment for scalability but are centrally managed by a third-party entity, namely a Mapping System Provider (MSP). The entities that use the mapping system, such as data-plane LISP Tunnel Routers (xTRs), depend on and trust the MSP. They do not participate in the mapping system other than to register and retrieve information [RFC9301].

This document introduces a Decentralized Mapping System (DMS) so the xTRs can participate in the mapping system as well as use it. They can trust each other rather than rely on third-party infrastructure. The xTRs act as Map-Servers to maintain distributed state for scale and reduce the attack surface. The trust relationships between the xTRs are established through authentication and authorization procedures in [RFC9301] and [I-D.ietf-lisp-ecdsa-auth].

This design was first introduced to the LISP WG in January 2018. It was presented in London March 2018 [MAR-WG-PRESO] and in Prague July 2019 [JUL-WG-PRESO]. This informational document is not a standard and did not reach community consensus to make it IETF LISP working group document.

The intended audience for this specification are protocol development engineers who would implement this specification in products as well network engineers who deploy the technology in operational environments.

This design does not conflict with those designs or contradicts any other LISP design principles produced by the working group. This solution makes no fundamental LISP protocol changes and adheres to the specifications documented in [RFC9301].

By the nature of this work, this document uses IP addresses as examples. They should not be copied or used outside of a lab environment. Deployments should use addresses appropriate for their environment.

2. Definition of Terms

Mapping System Provider (MSP): infrastructure service that deploys LISP Map-Resolvers and Map-Servers [RFC9301] and possibly LISP-ALT nodes [RFC6836] or LISP-DDT nodes [RFC8111]. ALT-nodes and DDT-nodes use different algorithms for connecting together Map-Resolvers and Map-Servers. The MSP can be managed by a separate organization other than the one that manages xTRs. This model provides a business separation between who manages and responsible for the control-plane versus who manages the data-plane overlay service.

Decentralized Mapping System (DMS): a mapping system entity that is managed by the xTR nodes that use it and not third-party nodes/operators. The xTRs themselves are part of the mapping system. The state of the mapping system is fully distributed across xTRs, decentralized, and the trust relies on the xTRs that use and participate in their own mapping system.

Decent-Pull Based Mapping System: the mapping system is pull-based meaning that xTRs will lookup and register mappings by algorithmic transformation to locate which Map-Resolvers and Map-Servers are used. It is required that the lookup and registration uses a consistent algorithmic transformation function. Map-Registers are sent to specific Map-Servers. Map-Requests are considered external lookups when sent to Map-Resolvers on xTRs that do not participate in the mapping system and the Map-Requests are considered internal lookups when they are sent to Map-Resolvers on xTRs that do participate in the mapping system.

Modulus Value: this value is used in the Pull-Based Mapping System. It defines the number of map-server sets used for the mapping system. The modulus value is used to produce a Name Index used for a DNS lookup. The Modulus Value is chosen based on the horizontal scale-out width of the map-server cluster the network operator chooses to deploy.

Name Index: this index value <index> is used in the Pull-Based Mapping System. For a mapping system that is configured with a map-server set of DNS names in the form of <name>.example.com, the name index is prepended to <name> to form the lookup name <index>.<name>.example.com. If the Modulus Value is 8, then the name indexes are 0 through 7.

Hash Mask: The Hash Mask is used in the Pull-Based Mapping System. It is a mask value with 1 bits left justified. The mask is used to select what high-order bits of an EID-prefix are used in the hash function.

Decent-Push Based Mapping System: the mapping system is push-based meaning that xTRs will push registrations via IP multicast to a group of Map-Servers and do local lookups acting as their own Map-Resolvers.

Replication List Entry (RLE): an RLOC-record format that contains a list of RLOCs that an Ingress Tunnel Router (ITR) replicates multicast packets on a multicast overlay. The RLE format is specified in [I-D.ietf-lisp-rfc8060bis]. RLEs are used with the Decent-Pushed Based mapping system.

Group Address EID: an EID-record format that contains IPv4 (0.0.0.0/0, G) or IPv6 (0::/0, G) state. This state is encoded as a Multicast Info Type LCAF specified in [I-D.ietf-lisp-rfc8060bis]. Members of a seed-group send Map-Registers for (0.0.0.0/0, G) or (0::/0, G) with an RLOC-record that RLE encodes its RLOC address. Details are specified in [I-D.ietf-lisp-rfc8378bis].

Seed-Group: a set of Map-Servers joined to a multicast group for the Decent-Push Based Mapping system or are mapped by DNS names in a Pull-Based Mapping System. A core seed-group is used to bootstrap a set of LISP-Decent xTRs so they can learn about each other and use each other's mapping system service. A seed-group can be pull-based to bootstrap the Decent-Push based mapping system. That is, a set of DNS mapped map-servers can be used to join the mapping system's IP multicast group.

3. Overview

The clients of the Decentralized Mapping System (DMS) are also the providers of mapping state, see [RFC9301] for formal details. Clients are typically Egress Tunnel Routers (ETRs) that Map-Register EID-to-RLOC mapping state to the mapping database system. ITRs are clients in that they send Map-Requests to the mapping database system to obtain EID-to-RLOC mappings that are cached for data-plane use. When xTRs participate in a DMS, they are also acting as Map-Resolvers and Map-Servers using the protocol machinery defined in LISP control-plane specifications [RFC9301], [RFC9303], and [I-D.ietf-lisp-ecdsa-auth]. The xTRs are not required to run the database mapping transport system protocols specified in [RFC6836] or [RFC8111].

This document will describe two decentralized and distributed mapping system mechanisms. A Decent-Push Based Mapping System uses IP multicast so xTRs can find each other by locally joining an IP multicast group. A Decent-Pull Based Mapping System uses DNS with an algorithmic transformation function so xTRs can find each other.

The document proposes two approaches to provide state/bandwidth, ease of configurability, and robustness/complexity tradeoffs. When the Decent-Push Based approach is used there is less messaging involved. xTRs can multicast a single Map-Register message which goes to all Map-Servers joined to the multicast group. When Map-Servers are added to or removed from the Map-Server cluster group, the mapping system updates quickly with little human intervention. In the push model, all mapping state is stored in all Map-Servers so there is robustness achieved through redundancy. However, this requires a multicast underlay in nodes between all xTRs and Map-Servers. When a multicast underlay is not available, the Decent-Pull Based approach can be used with the help of the DNS system. This approach uses less state overall among the Map-Servers (they each have different mapping system state) and the ITRs know which Map-Server to ask by using the hashing techniques described later in this document.

This document does not describe any compatibility with other mapping systems. The design is intentional all xTRs and Map-Servers support this specification. Moreover, all xTRs and Map-Servers MUST support either the Pull-Based or Push-Based algorithms. They cannot be mixed. When both are used, they are completely discrete mapping systems just like they would be using one of the LISP Working Group mapping system designs. An implementation can decide to implement only the Pull-Based approach or the Push-Based approach and still be compliant with this specification.

4. Decent-Push Based Mapping System

The xTRs are organized in a mapping-system group. The group is identified by an IPv4 or IPv6 multicast group address or using a Decent-Pull based approach described in Section 5. When using multicast, the xTRs join the same multicast group and receive LISP control-plane messages addressed to the group. Messages sent to the multicast group are distributed when the underlay network supports IP multicast [I-D.ietf-lisp-rfc6831bis] or via the overlay multicast mechanism described in [I-D.ietf-lisp-rfc8378bis]. When overlay multicast is used and LISP Map-Register messages are sent to the group, they are LISP data encapsulated with a instance-ID set to 0xffffffff in the LISP header. The inner header of the encapsulated packet has the destination address set to the multicast group address and the outer header that is prepended has the destination address set to the RLOC of mapping system group member. The members of the mapping system group are kept in the LISP data-plane map-cache so packets for the group can be replicated to each member RLOC.

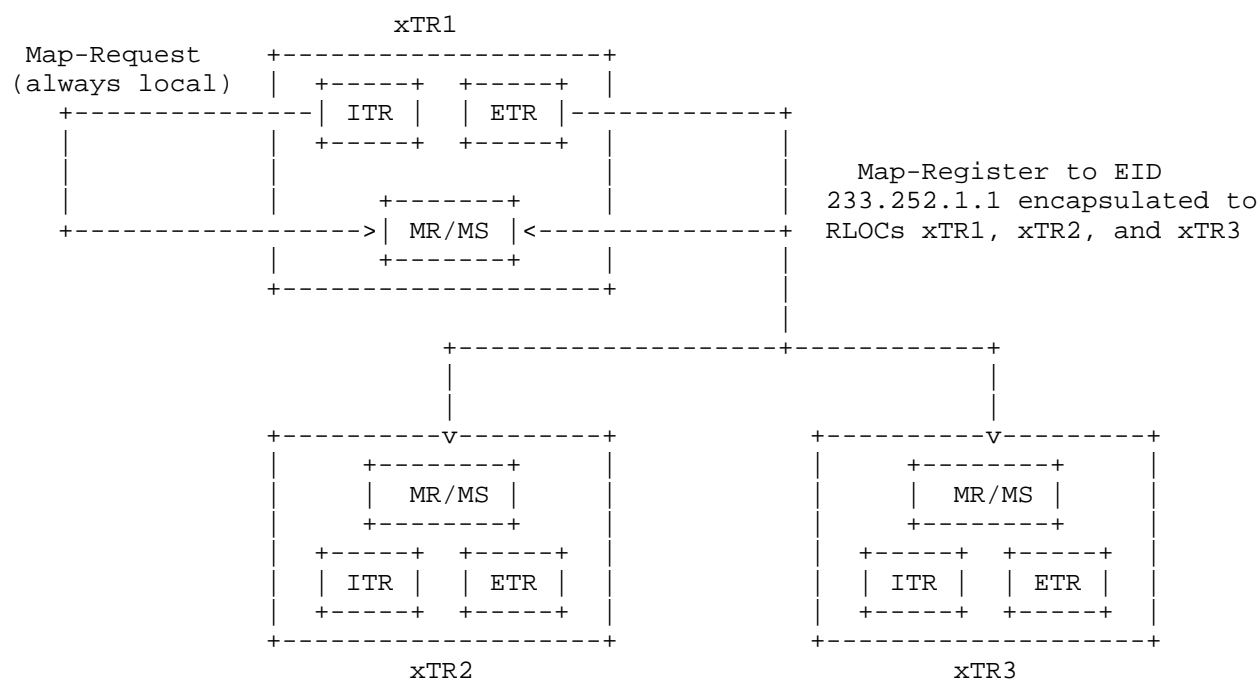
All xTRs in a mapping system group will store the same registered mappings and maintain the state as Map-Servers normally do. The members are not only receivers of the multicast group but also send packets to the group.

4.1. Components of a Decent-Pushed Based LISP-Decent xTR

When an xTR is configured to be a LISP-Decent xTR (or PxTR [RFC6832]), it runs the ITR, ETR, Map-Resolver, and Map-Server LISP network functions.

The following diagram shows 3 LISP-Decent xTRs joined to mapping system group 233.252.1.1. When the ETR function of xTR1 originates a Map-Register, it is sent to all xTRs (including itself) synchronizing all 3 Map-Servers in xTR1, xTR2, and xTR3. The ITR function can populate its map-cache by sending a Map-Request locally to its Map-Resolver so it can replicate packets to each RLOC for EID 233.252.1.1.

In this document, there is no special meaning for the multicast group address 233.252.1.1. It is used for example purposes only.



Note if any external xTR would like to use a Map-Resolver from the mapping system group, it only needs to have one of the LISP-Decent Map-Resolvers configured. By doing a looking to this Map-Resolver for EID 233.252.1.1, the external xTR could get the complete list of members for the mapping system group.

For future study, an external xTR could multicast the Map-Request to 233.252.1.1 and either one of the LISP-Decent Map-Resolvers would return a Map-Reply or the external xTR is prepared to receive multiple Map-Replies.

4.2. Implementation Considerations

There are no LISP protocol changes required to support the Decent-Push based LISP-Decent set of procedures. An implementation that sends Map-Register messages to a multicast group versus a specific Map-Server unicast address MUST change to call the data-plane component so the ITR functionality in the node can encapsulate the Map-Register as a unicast packet to each member of the mapping system group.

An ITR SHOULD lookup its mapping system group address periodically to determine if the membership has changed. The lookup interval is a configuration parameter only needed when when the ITR does not use the PubSub capability documented in [RFC9437] to be notified when a new member joins or leaves the multicast group. When PubSub is not used, there needs to be coordination (via configuration management) among all xTRs so they rendezvous roughly at the same time and to the same group address.

4.3. Configuration and Authentication

When xTRs are joined to a multicast group, they MUST have their site registration configuration consistent. Any policy or authentication key material MUST be configured consistently among all members. When [I-D.ietf-lisp-ecdsa-auth] is used to sign Map-Register messages, public-keys can be registered to the mapping system group using the site authentication key mentioned above or using a different authentication key from the one used for registering EID records. An out-of-band registration controller, like an ETR dedicated for this function, can send Map-Register messages for public-key encoded EIDs.

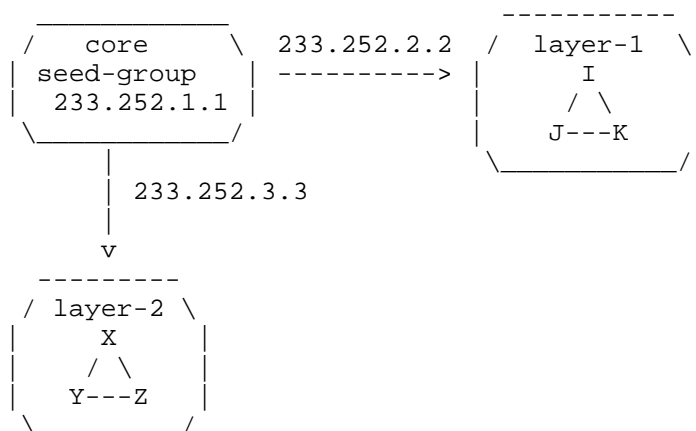
4.4. Core Seed-Group

A core seed-group can be discovered using a multicast group in a Decent-Push based system or a Map-Server set of DNS names in a Decent-Pull based system (see Section 5 for details).

When using multicast for the mapping system group, a core seed-group multicast group address can be preconfigured to bootstrap the decentralized mapping system. The group address (or DNS name that maps to a group address) can be explicitly configured in a few xTRs to start building up the registrations. Then as other xTRs come online, they can add themselves to the core seed-group by joining the seed-group multicast group.

Alternatively or additionally, new xTRs can join a new mapping system multicast group to form another layer of a decentralized mapping system. The group address and members of this new layer seed-group would be registered to the core seed-group address and stored in the core seed-group mapping system. Note each mapping system layer could have a specific function or a specific circle of trust.

This multi-layer mapping system can be illustrated:



Configured in xTRs A, B, and C (they make up the core seed-group):
233.252.1.1 -> RLE: A, B, C

core seed-group DMS, mapping state in A, B, and C:
233.252.2.2 -> RLE: I, J, K
233.252.3.3 -> RLE: X, Y, Z

layer-1 seed-group DMS (inter-continental), mapping state in I, J, K:
EID1 -> RLOCs: i(1), j(2)
...
EIDn -> RLOCs: i(n), j(n)

layer-2 seed-group DMS (intra-continental), mapping sate in X, Y, Z::
EIDa -> RLOCs: x(1), y(2)
...
EIDz -> RLOCs: x(n), y(n)

The core seed-group multicast address 233.252.1.1 is configured in xTRs A, B and C so when each of them send Map-Register messages, they would all be able to maintain synchronized mapping state. Any EID can be registered to this DMS but in this example, seed-group multicast group EIDs are being registered only to find other mapping system groups.

For example, lets say that xTR I boots up and it wants to find its other peers in its mapping system group 233.252.2.2. Group address 233.252.2.2 is configured so xTR I knows what group to join for its mapping system group. But xTR I needs a mapping system to register to, so the core seed-group is used and available to receive Map-Registers. The other xTRs J and K in the mapping system group do the

same so when any of I, J or K needs to register EIDs, they can now send their Map-Register messages to group 233.252.2.2. Examples of EIDs being register are EID1 through EIDn shown above.

When Map-Registers are sent to group 233.252.2.2, they are encapsulated by the LISP data-plane by looking up EID 233.252.2.2 in the core seed-group mapping system. For the map-cache entry to be populated for 233.252.2.2, the data-plane MUST send a Map-Request so the RLOCs I, J, and K are cached for replication. To use the core seed-group mapping system, the data-plane MUST know of at least one of the RLOCs A, B, and/or C.

5. Decent-Pull Based Mapping System

5.1. Components of a Decent-Pulled Based LISP-Decent xTR

When an xTR is configured to be a LISP-Decent xTR (or PxTR [RFC6832]), it runs the ITR, ETR, Map-Resolver, and Map-Server LISP network functions.

Unlike the Decent-Push Based Mapping System, the xTRs do not need to be organized by joining a multicast group. In a Decent-Pull Based Mapping System, a hash function over an EID is used to identify which xTR is used as the Map-Resolver and Map-Server. The Domain Name System (DNS) [RFC1034] [RFC1035] is used as a resource discovery mechanism.

The RLOC addresses of the xTRs will be A and AAAA records for DNS names that map algorithmically from the hash of the EID. A SHA-256 hash function [RFC6234] over the following ASCII formatted EID string is used:

```
[<iid>]<eid>/<ml>
[<iid>]<group>/<gml>-<source>/<sml>
```

In this section, where you see angle brackets, they are replaced with values in ASCII characters. For example, a unicast EID of 1.1.1.1 in instance-id 11 would be encoded as a string "[11]1.1.1.1/32".

Where <iid> is the instance-ID and <eid> is the EID of any EID-type defined in [I-D.ietf-lisp-rfc8060bis]. And then the Modulus Value <mv> is used to produce the Name Index <index> used to build the DNS lookup name:

```
eid = "[<iid>]<eid>/<ml>"
index = hash.sha_256(eid) MOD mv
```

The Hash Mask is used to select what bits are used in the SHA-256 hash function. This is required to support longest match lookups in the mapping system. The same map-server set needs to be selected when looking up a more-specific EID found in the Map-Request message with one that could match a less-specific EID-prefix registered and found in the Map-Register message. For example, if an EID-prefix [0]240.0.1.0/24 is registered to the mapping system and EID [0]240.0.1.1/32 is looked up to match the registered prefix, a Hash Mask of 8 bytes can be used to AND both the /32 or /24 entries to produce the same hash string bits of "[0]240.0".

For (*,G) and (S,G) multicast entries in the mapping system, the hash strings are:

```
sg-eid = "[<iid>]<group>/<gml>-<source>/<sml>"
index = hash.sha_256(sg-eid) MOD mv

starg-eid = "[<iid>]<group>/<gml>-0.0.0.0/0"
index = hash.sha_256(starg-eid) MOD mv
```

The Hash Mask MUST include the string "[<iid>]<group>" and not string <source>. So when looking up [0](2.2.2.2, 233.252.1.1) that will match a (*, 233.252.1.1/32), the hash string produced with a Hash Mask of 12 bytes is "[0]233.252.1.1".

When the <index> is computed from a unicast or multicast EID, the DNS lookup name becomes:

```
<index>.map-server.example.com
```

When an xTR does a DNS lookup on the lookup name, it will send Map-Register messages to all A and AAAA records for EID registrations. For Map-Request messages, xTRs MAY round robin EID lookup requests among the A and AAAA records.

5.2. Deployment Example

Here is an example deployment of a Decent-Pull based model. Let's say 4 map-server sets are provisioned for the mapping system. Therefore 4 distinct DNS names are allocated and a Modulus Value 4 is used. Each DNS name is allocated Name Index 0 through 3:

```
0.map-server.lispers.net
1.map-server.lispers.net
2.map-server.lispers.net
3.map-server.lispers.net
```

The A records for each name can be assigned as:

```
0.map-server.lispers.net:
  A <rloc1-att>
  A <rloc2-verizon>
1.map-server.lispers.net:
  A <rloc1-bt>
  A <rloc2-dt>
2.map-server.lispers.net:
  A <rloc1-cn>
  A <rloc2-kr>
3.map-server.lispers.net:
  A <rloc1-au>
  A <rloc2-nz>
```

When an xTR wants to register "[1000]fd::2222", it hashes the EID string to produce, for example, hash value 0x66. Using the modulus value 4 (0x67 & 0x3) produces index 0x3, so the DNS name 3.map-server.lispers.net is used and a Map-Register is sent to <rloc1-au> and <rloc2-nz>.

Note that the Decent-Pull based method can be used for a core seed-group for bootstrapping a Decent-Push based mapping system where multicast groups are registered.

5.3. Management Considerations

An implementation SHOULD do periodic DNS lookups to determine if A records have changed for a DNS entry. This is a configuration parameter the network operator selects. This specification makes no recommendation for an interval value.

When xTRs derive Map-Resolver and Map-Server names from the DNS, they need to use the same Modulus Value otherwise some xTRs will lookup EIDs to the wrong place they were registered.

The Modulus Value can be configured or pushed to the LISP-Decent xTRs. A future version of this document will describe a push mechanism so all xTRs use a consistent modulus value.

6. Security Considerations

Refer to the Security Considerations section of [RFC9301] for a complete list of security mechanisms as well as pointers to threat analysis drafts.

It is recommended, where DNS is deployed for the Pull-Based Mapping System, DNSSEC [RFC9364] be used to add more security to the DNS lookup system.

Replay attacks, spoofing, and trust relationships are discussed in detail in [RFC9301] and [RFC9303].

7. IANA Considerations

At this time there are no specific requests for IANA.

8. References

8.1. Normative References

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Appendix A. Acknowledgments

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Appendix B. Document Change Log

[RFC Editor: Please delete this section on publication as RFC.]

B.1. Changes to draft-farinacci-lisp-decent-20

- * Posted October 2025.
- * Made editorial changes suggested by Eliot.

B.2. Changes to draft-farinacci-lisp-decent-19

- * Posted October 2025.
- * Victor Moreno completed proof-read and submitted editorial comments.
- * Dino completed final proof-read.
- * Updated references to latest working group drafts and RFCs.

B.3. Changes to draft-farinacci-lisp-decent-18

- * Posted July 2025.
- * Made suggested changes to reflect comments from Joel and Padma per ISE (Eliot) distinguished review request. This should be final review cycle.

B.4. Changes to draft-farinacci-lisp-decent-17

- * Posted April 2025.
- * Made suggested changes to reflect second review from ISE (Eliot Lear).

B.5. Changes to draft-farinacci-lisp-decent-16

- * Posted December 2024.
- * Made suggested changes from ISE review.

B.6. Changes to draft-farinacci-lisp-decent-15

- * Posted June 2024.
- * Making draft an ISE submission as Informational RFC.
- * Update references and document expiry timer.

B.7. Changes to draft-farinacci-lisp-decent-14

- * Posted April 2024.
- * Update references and document expiry timer.

B.8. Changes to draft-farinacci-lisp-decent-13

- * Posted October 2023.
- * Make the general definitions of "pull-based" and "push-based" be more specific to the way LISP-Decent uses them. Call them Decent-Pull and Decent-Push.

B.9. Changes to draft-farinacci-lisp-decent-12

- * Posted August 2023.
- * Update references and document expiry timer.

B.10. Changes to draft-farinacci-lisp-decent-11

- * Posted February 2023.
- * Update references and document expiry timer.

B.11. Changes to draft-farinacci-lisp-decent-10

- * Posted August 2022.
- * Update references and document expiry timer.

B.12. Changes to draft-farinacci-lisp-decent-09

- * Posted February 2022.
- * Update references and document expiry timer.

B.13. Changes to draft-farinacci-lisp-decent-08

- * Posted August 2021.
- * Update references and document expiry timer.

B.14. Changes to draft-farinacci-lisp-decent-07

- * Posted March 2021.
- * Update references and document expiry timer.

B.15. Changes to draft-farinacci-lisp-decent-06

- * Posted September 2020.
- * Update references and document expiry timer.

B.16. Changes to draft-farinacci-lisp-decent-05

- * Posted March 2020.
- * Update references and document expiry timer.

B.17. Changes to draft-farinacci-lisp-decent-04

- * Posted September 2019.
- * Update references and document expiry timer.

B.18. Changes to draft-farinacci-lisp-decent-03

- * Posted March 2019.
- * Introduce the Hash Mask which is used to grab common bits from a registered prefix and a lookup prefix.
- * Spec how multicast lookups are done in the pull-based mapping system.
- * Indicate the hash string includes the unicast EID mask-length and multicast group and source mask-lengths.

B.19. Changes to draft-farinacci-lisp-decent-02

- * Posted November 2018.
- * Changed references from peer-group to seed-group to make the algorithms in this document more like how blockchain networks initialize the peer-to-peer network.
- * Added pull mechanism to complement the push mechanism. The pull mechanism could be used as a seed-group to bootstrap the push mechanism.

B.20. Changes to draft-farinacci-lisp-decent-01

- * Posted July 2018.
- * Document timer and reference update.

B.21. Changes to draft-farinacci-lisp-decent-00

- * Initial draft posted January 2018.

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