LISP Flow Mapping

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Contents

CHAPTER 1

LISP Flow Mapping User Guide

1.1 Overview

1.1.1 Locator/ID Separation Protocol

Locator/ID Separation Protocol (LISP) is a technology that provides a flexible map-and-encap framework that can be used for overlay network applications such as data center network virtualization and Network Function Virtualization (NFV).

LISP provides the following name spaces:

- Endpoint Identifiers (EIDs)
- Routing Locators (RLOCs)

In a virtualization environment EIDs can be viewed as virtual address space and RLOCs can be viewed as physical network address space.

The LISP framework decouples network control plane from the forwarding plane by providing:

- A data plane that specifies how the virtualized network addresses are encapsulated in addresses from the underlying physical network.
- A control plane that stores the mapping of the virtual-to-physical address spaces, the associated forwarding policies and serves this information to the data plane on demand.

Network programmability is achieved by programming forwarding policies such as transparent mobility, service chaining, and traffic engineering in the mapping system; where the data plane elements can fetch these policies on demand as new flows arrive. This chapter describes the LISP Flow Mapping project in OpenDaylight and how it can be used to enable advanced SDN and NFV use cases.

LISP data plane Tunnel Routers are available at OpenOverlayRouter.org in the open source community on the following platforms:

- Linux
- Android

- OpenWRT

For more details and support for LISP data plane software please visit the OOR web site.

1.1.2 LISP Flow Mapping Service

The LISP Flow Mapping service provides LISP Mapping System services. This includes LISP Map-Server and LISP Map-Resolver services to store and serve mapping data to data plane nodes as well as to OpenDaylight applications. Mapping data can include mapping of virtual addresses to physical network address where the virtual nodes are reachable or hosted at. Mapping data can also include a variety of routing policies including traffic engineering and load balancing. To leverage this service, OpenDaylight applications and services can use the northbound REST API to define the mappings and policies in the LISP Mapping Service. Data plane devices capable of LISP control protocol can leverage this service through a southbound LISP plugin. LISP-enabled devices must be configured to use this OpenDaylight service as their Map Server and/or Map Resolver.

The southbound LISP plugin supports the LISP control protocol (Map-Register, Map-Request, Map-Reply messages), and can also be used to register mappings in the OpenDaylight mapping service.

1.2 LISP Flow Mapping Architecture

The following figure shows the various LISP Flow Mapping modules.

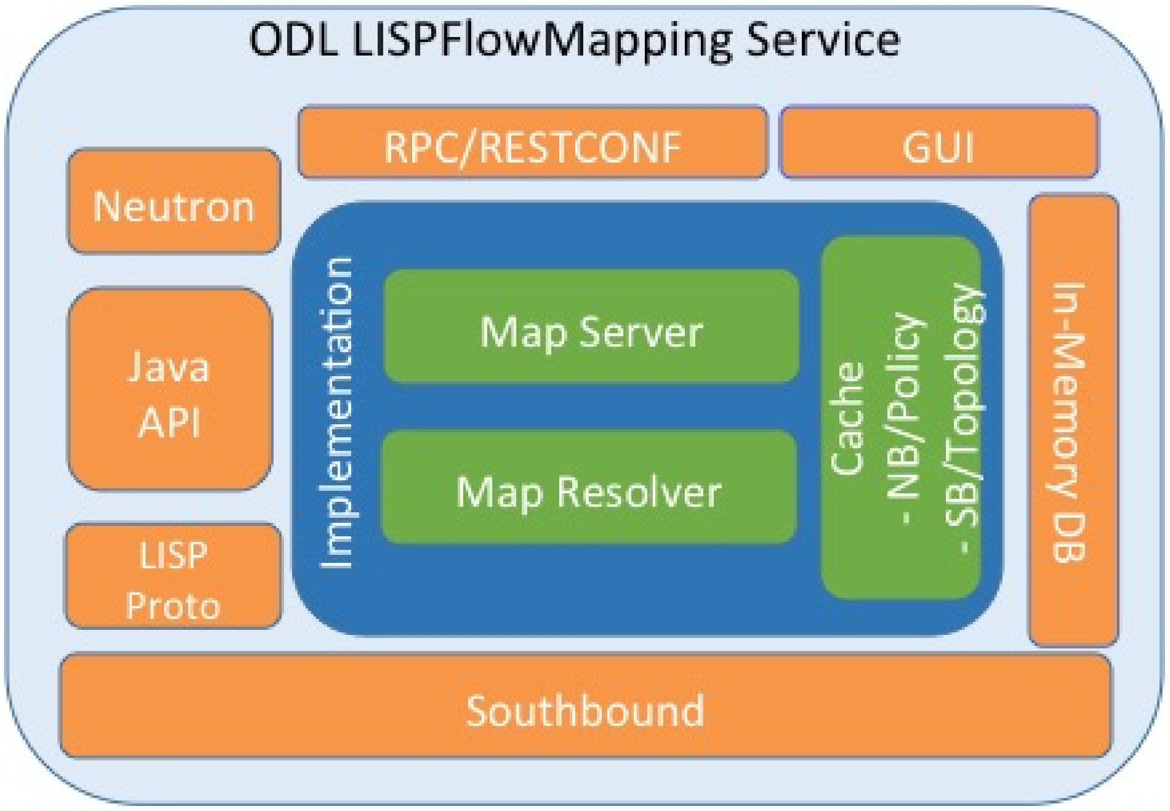


Fig. 1: LISP Mapping Service Internal Architecture

A brief description of each module is as follows:

- **DAO (Data Access Object):** This layer separates the LISP logic from the database, so that we can separate the map server and map resolver from the specific implementation of the mapping database. Currently we have an implementation of this layer with an in-memory HashMap, but it can be switched to any other key/value store and you only need to implement the ILispDAO interface.
- **Map Server:** This module processes the adding or registration of authentication tokens (keys) and mappings. For a detailed specification of LISP Map Server, see LISP.
- **Map Resolver:** This module receives and processes the mapping lookup queries and provides the mappings to requester. For a detailed specification of LISP Map Server, see LISP.
- **RPC/RESTCONF:** This is the auto-generated RESTCONF-based northbound API. This module enables defining key-EID associations as well as adding mapping information through the Map Server. Key-EID associations and mappings can also be queried via this API.
- **Neutron:** This module implements the OpenDaylight Neutron Service APIs. It provides integration between the LISP service and the OpenDaylight Neutron service, and thus OpenStack.
- **Java API:** The API module exposes the Map Server and Map Resolver capabilities via a Java API.
- **LISP Proto:** This module includes LISP protocol dependent data types and associated processing.
- **In Memory DB:** This module includes the in memory database implementation of the mapping service.
- **LISP Southbound Plugin:** This plugin enables data plane devices that support LISP control plane protocol (see LISP) to register and query mappings to the LISP Flow Mapping via the LISP control plane protocol.

1.3 Configuring LISP Flow Mapping

In order to use the LISP mapping service for registering EID to RLOC mappings from northbound or southbound, keys have to be defined for the EID prefixes first. Once a key is defined for an EID prefix, it can be used to add mappings for that EID prefix multiple times. If the service is going to be used to process Map-Register messages from the southbound LISP plugin, the same key must be used by the data plane device to create the authentication data in the Map-Register messages for the associated EID prefix.

The `etc/custom.properties` file in the Karaf distribution allows configuration of several OpenDaylight parameters. The LISP service has the following properties that can be adjusted:

lisp.smr (default: *true*) Enables/disables the Solicit-Map-Request (SMR) functionality. SMR is a method to notify changes in an EID-to-RLOC mapping to "subscribers". The LISP service considers all Map-Request's source RLOC as a subscriber to the requested EID prefix, and will send an SMR control message to that RLOC if the mapping changes.

lisp.elpPolicy (default: *default*) Configures how to build a Map-Reply southbound message from a mapping containing an Explicit Locator Path (ELP) RLOC. It is used for compatibility with dataplane devices that don't understand the ELP LCAF format. The *default* setting doesn't alter the mapping, returning all RLOCs unmodified. The *both* setting adds a new RLOC to the mapping, with a lower priority than the ELP, that is the next hop in the service chain. To determine the next hop, it searches the source RLOC of the Map-Request in the ELP, and chooses the next hop, if it exists, otherwise it chooses the first hop. The *replace* setting adds a new RLOC using the same algorithm as the *both* setting, but using the origin priority of the ELP RLOC, which is removed from the mapping.

lisp.lookupPolicy (default: *northboundFirst*) Configures the mapping lookup algorithm. When set to *northboundFirst* mappings programmed through the northbound API will take precedence. If no northbound programmed mappings exist, then the mapping service will return mappings registered through the southbound plugin, if any exists. When set to *northboundAndSouthbound* the mapping programmed by the northbound is returned, updated by the up/down status of these mappings as reported by the southbound (if existing).

lisp.mappingMerge (default: *false*) Configures the merge policy on the southbound registrations through the LISP SB Plugin. When set to *false*, only the latest mapping registered through the SB plugin is valid in the southbound mapping database, independent of which device it came from. When set to *true*, mappings for the same EID registered by different devices are merged together and a union of the locators is maintained as the valid mapping for that EID.

1.4 Textual Conventions for LISP Address Formats

In addition to the more common IPv4, IPv6 and MAC address data types, the LISP control plane supports arbitrary Address Family Identifiers assigned by IANA, and in addition to those the LISP Canoncal Address Format (LCAF).

The LISP Flow Mapping project in OpenDaylight implements support for many of these different address formats, the full list being summarized in the following table. While some of the address formats have well defined and widely used textual representation, many don't. It became necessary to define a convention to use for text rendering of all implemented address types in logs, URLs, input fields, etc. The below table lists the supported formats, along with their AFI number and LCAF type, including the prefix used for disambiguation of potential overlap, and examples output.

Name	AFI	LCAF	Prefix	Text Rendering
No Address	0	•	no:	No Address Present
IPv4 Prefix	1	•	ipv4:	192.0.2.0/24
IPv6 Prefix	2	•	ipv6:	2001:db8::/32
MAC Address	16389	•	mac:	00:00:5E:00:53:00
Distinguished Name	17	•	dn:	stringAsIs
AS Number	18	•	as:	AS64500
AFI List	16387	1	list:	{192.0.2.1,192.0.2.2,2001:db8::1 }
Instance ID	16387	2	•	[223] 192.0.2.0/24
Application Data	16387	4	appdata:	192.0.2.1!128!17!80-81!6667-7000
Explicit Locator Path	16387	10	elp:	{192.0.2.1→192.0.2.2|lps→192.0.2.3}
Source/Destination Key	16387	12	srcdst:	192.0.2.1/32|192.0.2.2/32
Key/Value Address Pair	16387	15	kv:	192.0.2.1192.0.2.2
Service Path	16387	N/A	sp:	42(3)

Table: LISP Address Formats

Please note that the forward slash character / typically separating IPv4 and IPv6 addresses from the mask length is transformed into `%2f` when used in a URL.

1.5 Karaf commands

In this section we will discuss two types of Karaf commands: built-in, and LISP specific. Some built-in commands are quite useful, and are needed for the tutorial, so they will be discussed here. A reference of all LISP specific commands, added by the LISP Flow Mapping project is also included. They are useful mostly for debugging.

1.5.1 Useful built-in commands

`help` Lists all available command, with a short description of each.

`help <command_name>` Show detailed help about a specific command.

`feature:list [-i]` Show all locally available features in the Karaf container. The `-i` option lists only features that are currently installed. It is possible to use `| grep` to filter the output (for all commands, not just this one).

`feature:install <feature_name>` Install feature `feature_name`.

`log:set <level> <class>` Set the log level for `class` to `level`. The default log level for all classes is INFO. For debugging, or learning about LISP internals it is useful to run `log:set TRACE org.opendaylight.lispflowmapping` right after Karaf starts up.

`log:display` Outputs the log file to the console, and returns control to the user.

`log:tail` Continuously shows log output, requires `Ctrl+C` to return to the console.

1.5.2 LISP specific commands

The available lisp commands can always be obtained by `help mappingservice`. Currently they are:

`mappingservice:addkey` Add the default password `password` for the IPv4 EID prefix 0.0.0.0/0 (all addresses). This is useful when experimenting with southbound devices, and using the REST interface would be combersome for whatever reason.

`mappingservice:mappings` Show the list of all mappings stored in the internal non-persistent data store (the DAO), listing the full data structure. The output is not human friendly, but can be used for debugging.

1.6 LISP Flow Mapping Karaf Features

LISP Flow Mapping has the following Karaf features that can be installed from the Karaf console:

`odl-lispflowmapping-msmr` This includes the core features required to use the LISP Flow Mapping Service such as mapping service and the LISP southbound plugin.

`odl-lispflowmapping-ui` This includes the GUI module for the LISP Mapping Service.

`odl-lispflowmapping-neutron` This is the experimental Neutron provider module for LISP mapping service.

1.7 Tutorials

This section provides a tutorial demonstrating various features in this service. We have included tutorials using two forwarding platforms:

1. Using Open Overlay Router (OOR)
2. Using FD.io

Both have different approaches to create the overlay but ultimately do the same job. Details of both approaches have been explained below.

1.7.1 Creating a LISP overlay with OOR

This section provides instructions to set up a LISP network of three nodes (one "client" node and two "server" nodes) using OOR as data plane LISP nodes and the LISP Flow Mapping project from OpenDaylight as the LISP programmable mapping system for the LISP network.

Overview

The steps shown below will demonstrate setting up a LISP network between a client and two servers, then performing a failover between the two "server" nodes.

Prerequisites

- The OpenDaylight Karaf Distribution
- **The Postman Chrome App**: the most convenient way to follow along this tutorial is to use the Postman App to edit and send the requests. The project git repository hosts a collection of the requests that are used in this tutorial in the `resources/tutorial/OOR/Beryllium_Tutorial.json.postman_collection` file. You can import this file to Postman by clicking *Import* at the top, choosing *Download from link* and then entering the following URL: https://git.opendaylight.org/gerrit/gitweb?p=lispflowmapping.git;a=blob_plain;f=resources/tutorial/OOR/Beryllium_Tutorial.json.postman_collection;hb=refs/heads/stable/fluorine. Alternatively, you can save the file on your machine, or if you have the repository checked out, you can import from there. You will need to create a new Postman Environment and define some variables within: `controllerHost` set to the hostname or IP address of the machine running the OpenDaylight instance, and `restconfPort` to 8181, if you didn't modify the default controller settings.
- **OOR version 1.0 or later** The README.md lists the dependencies needed to build it from source.
- **A virtualization platform**

Target Environment

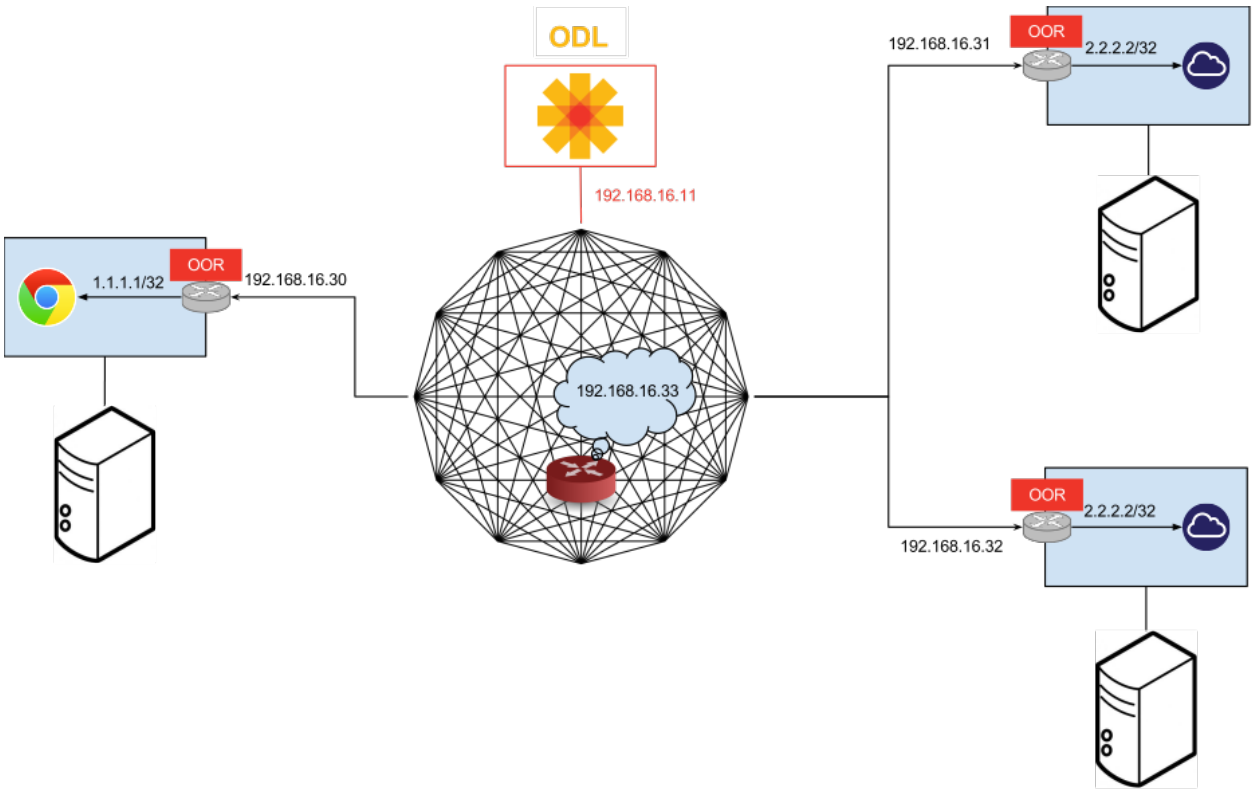
The three LISP data plane nodes and the LISP mapping system are assumed to be running in Linux virtual machines, which have the `eth0` interface in NAT mode to allow outside internet access and `eth1` connected to a host-only network, with the following IP addresses (please adjust configuration files, JSON examples, etc. accordingly if you're using another addressing scheme):

Node	Node Type	IP Address
controller	OpenDaylight	192.168.16.11
client	OOR	192.168.16.30
server1	OOR	192.168.16.31
server2	OOR	192.168.16.32
service-node	OOR	192.168.16.33

Table: Nodes in the tutorial

The figure below gives a sketch of network topology that will be used in the tutorial.

In LISP terminology **client**, **server1** and **server2** are mobile nodes (MN in OOR), **controller** is a MS/MR and **service-node** is a RTR.



Instructions

The below steps use the command line tool cURL to talk to the LISP Flow Mapping RPC REST API. This is so that you can see the actual request URLs and body content on the page.

1. Install and run the OpenDaylight distribution on the controller VM. Please follow the general OpenDaylight Installation Guide for this step. Once the OpenDaylight controller is running install the *odl-lispflowmapping-msmr* feature from the Karaf CLI:

   ```
   feature:install odl-lispflowmapping-msmr
   ```

   It takes quite a while to load and initialize all features and their dependencies. It's worth running the command `log:tail` in the Karaf console to see when the log output is winding down, and continue with the tutorial after that.

2. Install OOR on the **client**, **server1**, **server2**, and **service-node** VMs following the installation instructions from the OOR README file.

3. Configure the OOR installations from the previous step. Take a look at the `oor.conf.example` to get a general idea of the structure of the conf file. First, check if the file `/etc/oor.conf` exists. If the file doesn't exist, create the file `/etc/oor.conf`. Set the EID in `/etc/oor.conf` file from the IP address space selected for your virtual/LISP network. In this tutorial the EID of the **client** is set to 1.1.1.1/32, and that of **server1** and **server2** to 2.2.2.2/32.

4. Set the RLOC interface to `eth1` in each `oor.conf` file. LISP will determine the RLOC (IP address of the corresponding VM) based on this interface.

5. Set the Map-Resolver address to the IP address of the **controller**, and on the **client** the Map-Server too. On **server1** and **server2** remove the Map-Server configuration, so that it doesn't interfere with the mappings on the controller, since we're going to program them manually.

6. Modify the "key" parameter in each `oor.conf` file to a key/password of your choice (*password* in this tutorial).

   Note: The `resources/tutorial/OOR` directory in the project git repository has the files used in the tutorial checked in, so you can just copy the files to `/etc/oor.conf` on the respective VMs. You will also find the JSON files referenced below in the same directory.

7. Define a key and EID prefix association in OpenDaylight using the RPC REST API for the **client** EID (1.1.1.1/32) to allow registration from the southbound. Since the mappings for the server EID will be configured from the REST API, no such association is necessary. Run the below command on the **controller** (or any machine that can reach **controller**, by replacing *localhost* with the IP address of **controller**).

```
curl -u "admin":"admin" -H "Content-type: application/json" -X PUT \
    http://localhost:8181/restconf/config/odl-mappingservice:mapping-database/
↪virtual-network-identifier/0/authentication-key/ipv4:1.1.1.1%2f32/ \
    --data @add-key.json
```

   where the content of the *add-key.json* file is the following:

```
{
    "authentication-key": {
        "eid-uri": "ipv4:1.1.1.1/32",
        "eid": {
            "address-type": "ietf-lisp-address-types:ipv4-prefix-afi",
            "ipv4-prefix": "1.1.1.1/32"
        },
        "mapping-authkey": {
            "key-string": "password",
            "key-type": 1
        }
    }
}
```

8. Verify that the key is added properly by requesting the following URL:

```
curl -u "admin":"admin" -H "Content-type: application/json" -X GET \
    http://localhost:8181/restconf/config/odl-mappingservice:mapping-database/
↪virtual-network-identifier/0/authentication-key/ipv4:1.1.1.1%2f32/
```

   The output the above invocation should look like this:

```
{
    "authentication-key":[
        {
            "eid-uri":"ipv4:1.1.1.1/32",
            "eid":{
                "ipv4-prefix":"1.1.1.1/32",
                "address-type":"ietf-lisp-address-types:ipv4-prefix-afi"
            },
            "mapping-authkey":{
                "key-string":"password"
                ,"key-type":1
            }
        }
    ]
}
```

9. Run the `oor` OOR daemon on all VMs:

```
oor -f /etc/oor.conf
```

For more information on accessing OOR logs, take a look at OOR README

10. The **client** OOR node should now register its EID-to-RLOC mapping in OpenDaylight. To verify you can lookup the corresponding EIDs via the REST API

```
curl -u "admin":"admin" -H "Content-type: application/json" -X GET \
    http://localhost:8181/restconf/operational/odl-mappingservice:mapping-
↪database/virtual-network-identifier/0/mapping/ipv4:1.1.1.1%2f32/southbound/
```

An alternative way for retrieving mappings from OpenDaylight using the southbound interface is using the lig open source tool.

11. Register the EID-to-RLOC mapping of the server EID 2.2.2.2/32 to the controller, pointing to **server1** and **server2** with a higher priority for **server1**

```
curl -u "admin":"admin" -H "Content-type: application/json" -X PUT \
    http://localhost:8181/restconf/config/odl-mappingservice:mapping-database/
↪virtual-network-identifier/0/mapping/ipv4:2.2.2.2%2f32/northbound/ \
    --data @mapping.json
```

where the *mapping.json* file looks like this:

```
{
    "mapping": {
        "eid-uri": "ipv4:2.2.2.2/32",
        "origin": "northbound",
        "mapping-record": {
            "recordTtl": 1440,
            "action": "NoAction",
            "authoritative": true,
            "eid": {
                "address-type": "ietf-lisp-address-types:ipv4-prefix-afi",
                "ipv4-prefix": "2.2.2.2/32"
            },
            "LocatorRecord": [
                {
                    "locator-id": "server1",
                    "priority": 1,
                    "weight": 1,
                    "multicastPriority": 255,
                    "multicastWeight": 0,
                    "localLocator": true,
                    "rlocProbed": false,
                    "routed": true,
                    "rloc": {
                        "address-type": "ietf-lisp-address-types:ipv4-afi",
                        "ipv4": "192.168.16.31"
                    }
                },
                {
                    "locator-id": "server2",
                    "priority": 2,
                    "weight": 1,
                    "multicastPriority": 255,
                    "multicastWeight": 0,
                    "localLocator": true,
```

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```
                    "rlocProbed": false,
                    "routed": true,
                    "rloc": {
                        "address-type": "ietf-lisp-address-types:ipv4-afi",
                        "ipv4": "192.168.16.32"
                    }
                }
            ]
        }
    }
}
```

Here the priority of the second RLOC (192.168.16.32 - **server2**) is 2, a higher numeric value than the priority of 192.168.16.31, which is 1. This policy is saying that **server1** is preferred to **server2** for reaching EID 2.2.2.2/32. Note that lower priority value has higher preference in LISP.

12. Verify the correct registration of the 2.2.2.2/32 EID:

```
curl -u "admin":"admin" -H "Content-type: application/json" -X GET \
    http://localhost:8181/restconf/config/odl-mappingservice:mapping-database/
↪virtual-network-identifier/0/mapping/ipv4:2.2.2.2%2f32/northbound/
```

13. Now the LISP network is up. To verify, log into the **client** VM and ping the server EID:

```
ping 2.2.2.2
```

14. Let's test fail-over now. Suppose you had a service on **server1** which became unavailable, but **server1** itself is still reachable. LISP will not automatically fail over, even if the mapping for 2.2.2.2/32 has two locators, since both locators are still reachable and uses the one with the higher priority (lowest priority value). To force a failover, we need to set the priority of **server2** to a lower value. Using the file mapping.json above, swap the priority values between the two locators (lines 14 and 28 in *mapping.json*) and repeat the request from step 11. You can also repeat step 12 to see if the mapping is correctly registered. If you leave the ping on, and monitor the traffic using wireshark, you can see that the ping traffic to 2.2.2.2 will be diverted from the **server1** RLOC to the **server2** RLOC.

    With the default OpenDaylight configuration the failover should be near instantaneous (we observed 3 lost pings in the worst case), because of the LISP Solicit-Map-Request (SMR) mechanism that can ask a LISP data plane element to update its mapping for a certain EID (enabled by default). It is controlled by the `lisp.smr` variable in `etc/custom.porperties`. When enabled, any mapping change from the RPC interface will trigger an SMR packet to all data plane elements that have requested the mapping in the last 24 hours (this value was chosen because it's the default TTL of Cisco IOS xTR mapping registrations). If disabled, ITRs keep their mappings until the TTL specified in the Map-Reply expires.

15. To add a service chain into the path from the client to the server, we can use an Explicit Locator Path, specifying the **service-node** as the first hop and **server1** (or **server2**) as the second hop. The following will achieve that:

```
curl -u "admin":"admin" -H "Content-type: application/json" -X PUT \
    http://localhost:8181/restconf/config/odl-mappingservice:mapping-database/
↪virtual-network-identifier/0/mapping/ipv4:2.2.2.2%2f32/northbound/ \
    --data @elp.json
```

where the *elp.json* file is as follows:

```
{
    "mapping": {
        "eid-uri": "ipv4:2.2.2.2/32",
```

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```
        "origin": "northbound",
        "mapping-record": {
            "recordTtl": 1440,
            "action": "NoAction",
            "authoritative": true,
            "eid": {
                "address-type": "ietf-lisp-address-types:ipv4-prefix-afi",
                "ipv4-prefix": "2.2.2.2/32"
            },
            "LocatorRecord": [
                {
                    "locator-id": "ELP",
                    "priority": 1,
                    "weight": 1,
                    "multicastPriority": 255,
                    "multicastWeight": 0,
                    "localLocator": true,
                    "rlocProbed": false,
                    "routed": true,
                    "rloc": {
                        "address-type": "ietf-lisp-address-types:explicit-locator-
↪path-lcaf",
                        "explicit-locator-path": {
                            "hop": [
                                {
                                    "hop-id": "service-node",
                                    "address": "192.168.16.33",
                                    "lrs-bits": "strict"
                                },
                                {
                                    "hop-id": "server1",
                                    "address": "192.168.16.31",
                                    "lrs-bits": "strict"
                                }
                            ]
                        }
                    }
                }
            ]
        }
    }
}
```

After the mapping for 2.2.2.2/32 is updated with the above, the ICMP traffic from **client** to **server1** will flow through the **service-node**. You can confirm this in the OOR logs, or by sniffing the traffic on either the **service-node** or **server1**. Note that service chains are unidirectional, so unless another ELP mapping is added for the return traffic, packets will go from **server1** to **client** directly.

16. Suppose the **service-node** is actually a firewall, and traffic is diverted there to support access control lists (ACLs). In this tutorial that can be emulated by using `iptables` firewall rules in the **service-node** VM. To deny traffic on the service chain defined above, the following rule can be added:

```
iptables -A OUTPUT --dst 192.168.16.31 -j DROP
```

The ping from the **client** should now have stopped.

In this case the ACL is done on the destination RLOC. There is an effort underway in the OOR community to allow filtering on EIDs, which is the more logical place to apply ACLs.

17. To delete the rule and restore connectivity on the service chain, delete the ACL by issuing the following command:

```
iptables -D OUTPUT --dst 192.168.16.31 -j DROP
```

which should restore connectivity.

1.7.2 Creating a simple LISP overlay with FD.io

In this section, we use the Overlay Network Engine (ONE) project in FD.io to facilitate fully scripted setup and testing of a LISP/VXLAN-GPE network. Overlay Network Engine (ONE) is a FD.io project that enables programmable dynamic software defined overlays. Details about this project can be found in ONE wiki.

The steps shown below will demonstrate setting up a LISP network between a client and a server using VPP. We demonstrate how to use VPP lite to build a IP4 LISP overlay on an Ubuntu host using namespaces and af_packet interfaces. All configuration files used in the tutorials can be found here.

Prerequisites

- The OpenDaylight Karaf Distribution
- **The Postman Chrome App**: Please follow the *instructions* and import postman collection from the following URL: https://git.opendaylight.org/gerrit/gitweb?p=lispflowmapping.git;a=blob;f=resources/tutorial/FD_io/lfm_vpp.postman_collection.json;hb=refs/heads/stable/fluorine.
- **Vagrant** (optional): Download it from Vagrant website and follow the setup instructions.

Target Environment

Unlike the case with OOR, we use network namespace functionality of Linux to create the overlay in this case. The following table contains ip addresses of nodes in the overlay topology used in the tutorial. Our objective will be to create this topology and be able to ping from client to server through an intermediary hop, **service node**, which is a `rtr node` providing the service of re-encapsulation. So, all the packets from client to server will be through this **service node**.

Node	Node Type	IP Address
controller	OpenDaylight	6.0.3.100
client	VPP	6.0.2.2
server	VPP	6.0.4.4
service node	VPP	6.0.3.3

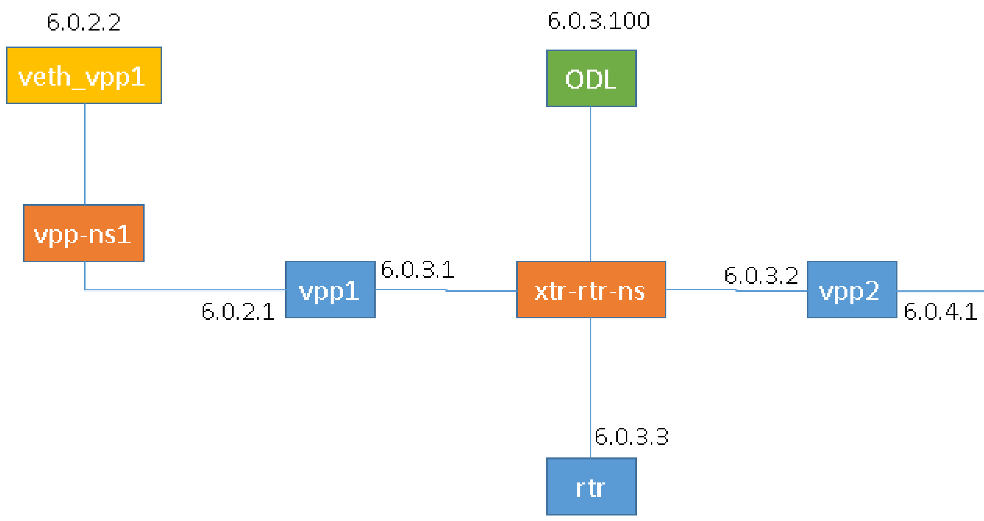
Table: Nodes in the tutorial

The figure below gives a sketch of network topology that will be used in the tutorial.

Instructions

Follow the instructions below sequentially.

1. Pull the VPP code anonymously using:



```
git clone https://gerrit.fd.io/r/vpp
```

2. Then, use the vagrant file from repository to build virtual machine with proper environment.

```
cd vpp/build-root/vagrant/
vagrant up
vagrant ssh
```

3. In case there is any error from `vagrant up`, try `vargant ssh`. if it works, no worries. If it still doesn't work, you can try any Ubuntu virtual machine. Or sometimes there is an issue with the Vagrant properly copying the VPP repo code from the host VM after the first installation. In that case `/vpp` doesn't exist. In both cases, follow the instructions from below.

   1. Clone the code in `/` directory. So, the codes will be in `/vpp`.
   2. **Run the following commands:**

   ```
   cd /vpp/build-root
   make distclean
   ./bootstrap.sh
   make V=0 PLATFORM=vpp TAG=vpp install-deb
   sudo dpkg -i /vpp/build-root/*.deb
   ```

   Alternative and more detailed build instructions can be found in VPP's wiki

4. By now, you should have a Ubuntu VM with VPP repository in `/vpp` with `sudo` access. Now, we need VPP Lite build. The following commands builds VPP Lite.

```
cd /vpp
export PLATFORM=vpp_lite
make build
```

   Successful build create the binary in `/vpp/build-root/install-vpp_lite_debug-native/vpp/bin`

5. Install bridge-utils and ethtool if needed by using following commands:

```
sudo apt-get install bridge-utils ethtool
```

6. Now, install and run OpenDaylight on the VM. Please follow the general OpenDaylight Installation Guide for this step. Before running OpenDaylight, we need to change the configuration for RTR to work. Update `etc/custom.properties` with the `lisp.elpPolicy` to be replace.

   ```
   lisp.elpPolicy = replace
   ```

   Then, run OpenDaylight. For details regarding configuring LISP Flow Mapping, please take a look at *Configuring LISP Flow Mapping*. Once the OpenDaylight controller is running install the *odl-lispflowmapping-msmr* feature from the Karaf CLI:

   ```
   feature:install odl-lispflowmapping-msmr
   ```

   It may take quite a while to load and initialize all features and their dependencies. It's worth running the command `log:tail` in the Karaf console to see when the log output is winding down, and continue with the tutorial after that.

7. For setting up VPP, get the files from `resources/tutorial/FD_io` folder of the lispflowmapping repo. The files can also be found here. Copy the `vpp1.config`, `vpp2.config` and `rtr.config` files in `/etc/vpp/lite/`.

8. In this example, VPP doesn't make any southbound map registers to OpenDaylight. So, we add the mappings directly from northbound. For that, we need to add the mappings to OpenDaylight via RESTCONF API.

   Register EID-to-RLOC mapping of the Client EID 6.0.2.0/24.

   ```
   curl -u "admin":"admin" -H "Content-type: application/json" -X PUT \
       http://localhost:8181/restconf/config/odl-mappingservice:mapping-database/
   ↪virtual-network-identifier/0/mapping/ipv4:6.0.2.0%2f24/northbound/ \
       --data @epl1.json
   ```

   Content of epl1.json:

   ```
   {
       "mapping": {
           "eid-uri": "ipv4:6.0.2.0/24",
           "origin": "northbound",
           "mapping-record": {
               "recordTtl": 1440,
               "action": "NoAction",
               "authoritative": true,
               "eid": {
                       "address-type": "ietf-lisp-address-types:ipv4-prefix-afi",
                       "ipv4-prefix": "6.0.2.0/24"
               },
               "LocatorRecord": [
                   {
                       "locator-id": "ELP",
                       "priority": 1,
                       "weight": 1,
                       "multicastPriority": 255,
                       "multicastWeight": 0,
                       "localLocator": true,
                       "rlocProbed": false,
                       "routed": false,
                       "rloc": {
   ```

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```
                        "address-type": "ietf-lisp-address-types:explicit-locator-
↪path-lcaf",
                        "explicit-locator-path": {
                            "hop": [
                                {
                                    "hop-id": "Hop 1",
                                    "address": "6.0.3.3",
                                    "lrs-bits": "lookup rloc-probe strict"
                                },
                                {
                                    "hop-id": "Hop 2",
                                    "address": "6.0.3.1",
                                    "lrs-bits": "lookup strict"
                                }
                            ]
                        }
                    }
                }
            ]
        }
    }
}
```

Similarly add EID-to-RLOC mapping of the Server EID 6.0.4.0/24.

```
curl -u "admin":"admin" -H "Content-type: application/json" -X PUT \
    http://localhost:8181/restconf/config/odl-mappingservice:mapping-database/
↪virtual-network-identifier/0/mapping/ipv4:6.0.4.0%2f24/northbound/ \
    --data @epl2.json
```

Content of elp2.json:

```
{
    "mapping": {
        "eid-uri": "ipv4:6.0.4.0/24",
        "origin": "northbound",
        "mapping-record": {
            "recordTtl": 1440,
            "action": "NoAction",
            "authoritative": true,
            "eid": {
                    "address-type": "ietf-lisp-address-types:ipv4-prefix-afi",
                    "ipv4-prefix": "6.0.4.0/24"
            },
            "LocatorRecord": [
                {
                    "locator-id": "ELP",
                    "priority": 1,
                    "weight": 1,
                    "multicastPriority": 255,
                    "multicastWeight": 0,
                    "localLocator": true,
                    "rlocProbed": false,
                    "routed": false,
                    "rloc": {
                        "address-type": "ietf-lisp-address-types:explicit-locator-
↪path-lcaf",
```

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```
                                    "explicit-locator-path": {
                                        "hop": [
                                            {
                                                "hop-id": "Hop 1",
                                                "address": "6.0.3.3",
                                                "lrs-bits": "lookup rloc-probe strict"
                                            },
                                            {
                                                "hop-id": "Hop 2",
                                                "address": "6.0.3.2",
                                                "lrs-bits": "lookup strict"
                                            }
                                        ]
                                    }
                                }
                            }
                        ]
                    }
                }
}
```

The JSON files regarding these can be found in here. Even though there is no southbound registration for mapping to OpenDaylight, using northbound policy we can specify mappings, when Client requests for the Server eid, Client gets a reply from OpenDaylight.

9. Assuming all files have been created and OpenDaylight has been configured as explained above, execute the host script you've created or the `topology_setup.sh` script from here.
10. If all goes well, you can now test connectivity between the namespaces with:

```
sudo ip netns exec vpp-ns1 ping 6.0.4.4
```

11. Traffic and control plane message exchanges can be checked with a wireshark listening on the odl interface.
12. **Important:** Delete the topology by running the `topology_setup.sh` with `clean` argument.

```
sudo ./topology_setup.sh clean
```

1.7.3 Creating a LISP overlay with Cisco IOS-XE

This section describes how to create a simple LISP overlay using the Cisco IOS-XE network operating system as the data plane software running on the Cisco CSR 1000v Series Cloud Services Router.

Prerequisites

- The OpenDaylight Karaf Distribution**
- CSR1Kv image with Cisco IOS-XE version 03.13.00.S or later; the instructions have been tested on version 03.15.00.S.
- **A virtualization platform** supported by CSR1Kv images (VMware ESXi, Citrix XenServer, KVM, and Microsoft Hyper-V).

Target Environment

The CSR1Kv images are configured with one management interface (`GigabitEthernet1`), and another interface (`GigabitEthernet2`) connected to a host-only network on the virtualization platform, while the LISP mapping system is assumed to be running in a Linux virtual machine, which has the `eth0` interface in NAT mode to allow outside internet access and `eth1` connected to the host-only network, with the following IP addresses (please adjust configuration files, JSON examples, etc. accordingly if you're using another addressing scheme):

Node	Node Type	IP Address
controller	OpenDaylight	192.168.16.11
client	CSR1Kv	192.168.16.30
server	CSR1Kv	192.168.16.31

Table: Nodes in the tutorial

The scenario and EID allocation is the same as the OOR scenario, except that there is no **server2** and **service-node** (for now).

Before this tutorial can be followed, basic connectivity between the Linux VM and the CSRs should work on the host-only network.

Instructions

The below steps use the command line tool cURL to talk to the LISP Flow Mapping RPC REST API. This is so that you can see the actual request URLs and body content on the page. The easy way is to just use Postman.

1. Install and run the OpenDaylight distribution on the controller VM. Please follow the general OpenDaylight Installation Guide for this step. Once the OpenDaylight controller is running install the *odl-lispflowmapping-msmr* feature from the Karaf CLI:

   ```
   feature:install odl-lispflowmapping-msmr
   ```

   It takes quite a while to load and initialize all features and their dependencies. It's worth running the command `log:tail` in the Karaf console to see when the log output is winding down, and continue with the tutorial after that.

2. Create the **client** and **server** VMs following the installation instructions from the CSR1Kv Configuration Guide.

3. Define a key and EID prefix association in OpenDaylight using the RPC REST API for the **client** and **server** EIDs (1.1.1.1/32 and 2.2.2.2/32 respectively) to allow registration from the southbound. Run the below command on the **controller** (or any machine that can reach **controller**, by replacing *localhost* with the IP address of **controller**).

   ```
   curl -u "admin":"admin" -H "Content-type: application/json" -X PUT \
       http://localhost:8181/restconf/config/odl-mappingservice:mapping-database/
   ↪virtual-network-identifier/0/authentication-key/ipv4:1.1.1.1%2f32/ \
       --data @add-key.json
   ```

   where the content of the *add-key.json* file is the following:

   ```
   {
       "authentication-key": {
           "eid-uri": "ipv4:1.1.1.1/32",
           "eid": {
               "address-type": "ietf-lisp-address-types:ipv4-prefix-afi",
               "ipv4-prefix": "1.1.1.1/32"
   ```

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```
        },
        "mapping-authkey": {
            "key-string": "password",
            "key-type": 1
        }
    }
}
```

The same should be done for 2.2.2.2/32 too.

4. Verify that the key is added properly by requesting the following URL:

```
curl -u "admin":"admin" -H "Content-type: application/json" -X GET \
    http://localhost:8181/restconf/config/odl-mappingservice:mapping-database/
↪virtual-network-identifier/0/authentication-key/ipv4:1.1.1.1%2f32/
```

The output the above invocation should look like this:

```
{
    "authentication-key":[
        {
            "eid-uri":"ipv4:1.1.1.1/32",
            "eid":{
                "ipv4-prefix":"1.1.1.1/32",
                "address-type":"ietf-lisp-address-types:ipv4-prefix-afi"
            },
            "mapping-authkey":{
                "key-string":"password"
                ,"key-type":1
            }
        }
    ]
}
```

5. Configure the CSR installations from the previous step. The EID needs to be configured on a loopback interface (except when the CSR is used as a router not a simple client like in this tutorial and the EID is assigned to a real interface).

```
interface Loopback0
 ip address 1.1.1.1 255.255.255.255
```

6. The LISP specific configuration goes to a `router lisp` section in the configuration. A `locator-set` defines the list of locators with their priorities and weights, either statically, or better yet, as an interface name:

```
locator-set rloc-network
 IPv4-interface GigabitEthernet2 priority 1 weight 1
 exit
```

7. To make sure a Map-Request is using the above defined `rloc-network` locator set, the following configuration is used:

```
map-request itr-rlocs rloc-network
```

8. Each Instance ID needs its own configuration. For the default Instance ID of 0, the following configuration is needed for a besic setup:

```
eid-table default instance-id 0
 database-mapping 1.1.1.1/32 locator-set rloc-network
 map-cache 0.0.0.0/0 map-request
 no ipv4 map-cache-persistent
 ipv4 itr map-resolver 192.168.16.11
 ipv4 itr
 ipv4 etr map-server 192.168.16.11 key password
 ipv4 etr
 exit
```

`database-mapping` defines the EID prefix the router will register in the mapping system and which locator set it will use (`rloc-network` in this case, which was defined in step 6).

The next line creates a static map-cache entry for the whole IPv4 EID space, causing a Map-Request to be triggered for every destination (that is not directly connected on some interface).

LISP routers save their map cache to a fie which is used to restore previous state on reboot. To avoid confusion due to state restored from a previous run, `no ipv4 map-cache-persistent` can be used to disable this behavior for non-production testing environments.

A `map-resolver` is then defined, where Map-Requests will be directed to for mapping lookups, and then a `map-server` association with a shared secret key.

9. Here's the full configuration that needs to be pasted into the configuration of the **client** to follow this tutorial:

```
interface Loopback0
 ip address 1.1.1.1 255.255.255.255
!
router lisp
 locator-set rloc-network
  IPv4-interface GigabitEthernet2 priority 1 weight 1
  exit
 !
 map-request itr-rlocs rloc-network
 eid-table default instance-id 0
  database-mapping 1.1.1.1/32 locator-set rloc-network
  map-cache 0.0.0.0/0 map-request
  no ipv4 map-cache-persistent
  ipv4 itr map-resolver 192.168.16.11
  ipv4 itr
  ipv4 etr map-server 192.168.16.11 key password
  ipv4 etr
  exit
 !
 exit
```

Configuring the **server** is done by replacing `1.1.1.1` with `2.2.2.2` in the above configuration snippet.

10. The CSR nodes should now register their EID-to-RLOC mappings to OpenDaylight. To verify, the corresponding EIDs can be looked up via the REST API:

```
curl -u "admin":"admin" -H "Content-type: application/json" -X GET \
    http://localhost:8181/restconf/operational/odl-mappingservice:mapping-
↪database/virtual-network-identifier/0/mapping/ipv4:1.1.1.1%2f32/southbound/
```

An alternative way for retrieving mappings from OpenDaylight using the southbound interface is using the lig open source tool.

Yet another different way is to use the OpenDaylight mappingservice CLI, and type the following at the Karaf prompt:

```
mappingservice:mappings
```

This needs the *odl-lispflowmapping-mappingservice-shell* feature to be loaded. The output is intended for debugging purposes and shows the full Java objects stored in the map-cache.

11. Now the LISP network is up. It can be verified by pinging the **server** EID from the **client** CSR EID:

```
ping 2.2.2.2 source 1.1.1.1
```

1.8 LISP Flow Mapping Support

For support the lispflowmapping project can be reached by emailing the developer mailing list: lispflowmapping-dev@lists.opendaylight.org or on the #opendaylight-lispflowmapping IRC channel on irc.freenode.net.

Additional information is also available on the Lisp Flow Mapping wiki

1.9 Clustering in LISP Flow Mapping

Documentation regarding setting up a 3-node OpenDaylight cluster is described at following odl wiki page.

To turn on clustering in LISP Flow Mapping it is necessary:

- run script **deploy.py** script. This script is in integration-test project placed at *tools/clustering/cluster-deployer/deploy.py*. A whole deploy.py command can looks like:

{path_to_integration_test_project}/tools/clustering/cluster-deployer/**deploy.py**
–**distribution** {path_to_distribution_in_zip_format}
–**rootdir** {dir_at_remote_host_where_copy_odl_distribution}
–**hosts** {ip1},{ip2},{ip3}
–**clean**
–**template** lispflowmapping
–**rf** 3
–**user** {user_name_of_remote_hosts}
–**password** {password_to_remote_hosts}

Running this script will cause that specified **distribution** to be deployed to remote **hosts** specified through their IP adresses with using credentials (**user** and **password**). The distribution will be copied to specified **rootdir**. As part of the deployment, a **template** which contains a set of controller files which are different from standard ones. In this case it is specified in
{path_to_integration_test_project}/tools/clustering/cluster-deployer/lispflowmapping directory.
Lispflowmapping templates are part of integration-test project. There are 5 template files:

- akka.conf.template
- jolokia.xml.template
- module-shards.conf.template
- modules.conf.template

- org.apache.karaf.features.cfg.template

After copying the distribution, it is unzipped and started on all of specified **hosts** in cluster aware manner.

1.9.1 Remarks

It is necessary to have:

- **unzip** program installed on all of the host
- set all remote hosts /etc/sudoers files to not **requiretty** (should only matter on debian hosts)