Red Hat OpenStack Platform 17.0-Beta

Spine Leaf Networking

Configuring routed spine-leaf networks using Red Hat OpenStack Platform director
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Abstract

This guide provides a basic scenario about how to configure a routed spine-leaf network on the overcloud. This includes configuring the undercloud, writing the main configuration files, and creating roles for your nodes.
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Making Open Source More Inclusive

Red Hat is committed to replacing problematic language in our code, documentation, and web properties. We are beginning with these four terms: master, slave, blacklist, and whitelist. Because of the enormity of this endeavor, these changes will be implemented gradually over several upcoming releases. For more details, see our CTO Chris Wright’s message.
CHAPTER 1. INTRODUCTION TO SPINE-LEAF NETWORKING

The following chapters provide information about constructing a spine-leaf network topology for your Red Hat OpenStack Platform environment. This includes a full end-to-end scenario and example files to help replicate a more extensive network topology within your own environment.

1.1. SPINE-LEAF NETWORKING

Red Hat OpenStack Platform has a composable network architecture that you can use to adapt your networking to the routed spine-leaf data center topology. In a practical application of routed spine-leaf, a leaf is represented as a composable Compute or Storage role usually in a data center rack, as shown in Figure 1.1, “Routed spine-leaf example”. The Leaf 0 rack has an undercloud node, Controller nodes, and Compute nodes. The composable networks are presented to the nodes, which have been assigned to composable roles. The following diagram contains the following configuration:

- The StorageLeaf networks are presented to the Ceph storage and Compute nodes.
- The NetworkLeaf represents an example of any network you might want to compose.

Figure 1.1. Routed spine-leaf example

1.2. SPINE-LEAF NETWORK TOPOLOGY

The spine-leaf scenario takes advantage of OpenStack Networking (neutron) functionality to define multiple subnets within segments of a single network. Each network uses a base network which acts as Leaf 0. Director creates Leaf 1 and Leaf 2 subnets as segments of the main network.

This scenario uses the following networks:
Table 1.1. Leaf 0 Networks (base networks)

<table>
<thead>
<tr>
<th>Network</th>
<th>Roles attached</th>
<th>Subnet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Provisioning / Ctlplane / Leaf0</td>
<td>Controller, ComputeLeaf0, CephStorageLeaf0</td>
<td>192.168.10.0/24</td>
</tr>
<tr>
<td>Storage</td>
<td>Controller, ComputeLeaf0, CephStorageLeaf0</td>
<td>172.16.0.0/24</td>
</tr>
<tr>
<td>StorageMgmt</td>
<td>Controller, CephStorageLeaf0</td>
<td>172.17.0.0/24</td>
</tr>
<tr>
<td>InternalApi</td>
<td>Controller, ComputeLeaf0</td>
<td>172.18.0.0/24</td>
</tr>
<tr>
<td>Tenant [1]</td>
<td>Controller, ComputeLeaf0</td>
<td>172.19.0.0/24</td>
</tr>
<tr>
<td>External</td>
<td>Controller</td>
<td>10.1.1.0/24</td>
</tr>
</tbody>
</table>

[1] Tenant networks are also known as project networks.

Table 1.2. Leaf 1 Networks

<table>
<thead>
<tr>
<th>Network</th>
<th>Roles attached</th>
<th>Subnet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Provisioning / Ctlplane / Leaf1</td>
<td>ComputeLeaf1, CephStorageLeaf1</td>
<td>192.168.11.0/24</td>
</tr>
<tr>
<td>StorageLeaf1</td>
<td>ComputeLeaf1, CephStorageLeaf1</td>
<td>172.16.1.0/24</td>
</tr>
<tr>
<td>StorageMgmtLeaf1</td>
<td>CephStorageLeaf1</td>
<td>172.17.1.0/24</td>
</tr>
<tr>
<td>InternalApiLeaf1</td>
<td>ComputeLeaf1</td>
<td>172.18.1.0/24</td>
</tr>
<tr>
<td>TenantLeaf1 [1]</td>
<td>ComputeLeaf1</td>
<td>172.19.1.0/24</td>
</tr>
</tbody>
</table>

[1] Tenant networks are also known as project networks.

Table 1.3. Leaf 2 Networks

<table>
<thead>
<tr>
<th>Network</th>
<th>Roles attached</th>
<th>Subnet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Provisioning / Ctlplane / Leaf2</td>
<td>ComputeLeaf2, CephStorageLeaf2</td>
<td>192.168.12.0/24</td>
</tr>
<tr>
<td>StorageLeaf2</td>
<td>ComputeLeaf2, CephStorageLeaf2</td>
<td>172.16.2.0/24</td>
</tr>
<tr>
<td>Network</td>
<td>Roles attached</td>
<td>Subnet</td>
</tr>
<tr>
<td>-----------------------</td>
<td>----------------</td>
<td>--------------</td>
</tr>
<tr>
<td>StorageMgmtLeaf2</td>
<td>CephStorageLeaf2</td>
<td>172.17.2.0/24</td>
</tr>
<tr>
<td>InternalApiLeaf2</td>
<td>ComputeLeaf2</td>
<td>172.18.2.0/24</td>
</tr>
<tr>
<td>TenantLeaf2 [1]</td>
<td>ComputeLeaf2</td>
<td>172.19.2.0/24</td>
</tr>
</tbody>
</table>

[1] Tenant networks are also known as project networks.

**Figure 1.2. Spine-leaf network topology**

---

### 1.3. SPINE-LEAF REQUIREMENTS

To deploy the overcloud on a network with a L3 routed architecture, complete the following prerequisite steps:

**Layer-3 routing**

Configure the routing of the network infrastructure to enable traffic between the different L2 segments. You can configure this routing statically or dynamically.

**DHCP-Relay**
Each L2 segment not local to the undercloud must provide \texttt{dhcp-relay}. You must forward DHCP requests to the undercloud on the provisioning network segment where the undercloud is connected.

\textbf{NOTE}

The undercloud uses two DHCP servers. One for baremetal node introspection, and another for deploying overcloud nodes. Ensure that you read DHCP relay configuration to understand the requirements when you configure \texttt{dhcp-relay}.

\section*{1.4. SPINE-LEAF LIMITATIONS}

- Some roles, such as the Controller role, use virtual IP addresses and clustering. The mechanism behind this functionality requires L2 network connectivity between these nodes. You must place these nodes within the same leaf.

- Similar restrictions apply to Networker nodes. The network service implements highly-available default paths in the network with Virtual Router Redundancy Protocol (VRRP). Because VRRP uses a virtual router IP address, you must connect master and backup nodes to the same L2 network segment.

- When you use tenant or provider networks with VLAN segmentation, you must share the particular VLANs between all Networker and Compute nodes.

\textbf{NOTE}

It is possible to configure the network service with multiple sets of Networker nodes. Each set of Networker nodes share routes for their networks, and VRRP provides highly-available default paths within each set of Networker nodes. In this type of configuration, all Networker nodes that share networks must be on the same L2 network segment.
CHAPTER 2. CONFIGURING ROUTED SPINE-LEAF IN THE UNDERCLOUD

WARNING

The content for this feature is available in this release as a Documentation Preview, and therefore is not fully verified by Red Hat. Use it only for testing, and do not use in a production environment.

This section describes a use case about how to configure the undercloud to accommodate routed spine-leaf with composable networks.

2.1. CONFIGURING THE SPINE LEAF PROVISIONING NETWORKS

To configure the provisioning networks for your spine leaf infrastructure, edit the undercloud.conf file and set the relevant parameters included in the following procedure.

Procedure

1. Log in to the undercloud as the stack user.

2. If you do not already have an undercloud.conf file, copy the sample template file:

   ```
   [stack@director ~]$ cp /usr/share/python-tripleoclient/undercloud.conf.sample ~/undercloud.conf
   ```

3. Edit the undercloud.conf file.

4. Set the following values in the [DEFAULT] section:
   a. Set local_ip to the undercloud IP on leaf0:

      ```
      local_ip = 192.168.10.1/24
      ```

   b. Set undercloud_public_host to the externally facing IP address of the undercloud:

      ```
      undercloud_public_host = 10.1.1.1
      ```

   c. Set undercloud_admin_host to the administration IP address of the undercloud. This IP address is usually on leaf0:

      ```
      undercloud_admin_host = 192.168.10.2
      ```

   d. Set local_interface to the interface to bridge for the local network:

      ```
      local_interface = eth1
      ```
e. Set `enable_routed_networks` to `true`:

```
enable_routed_networks = true
```

e. Define your list of subnets using the `subnets` parameter. Define one subnet for each L2 segment in the routed spine and leaf:

```
subnets = leaf0,leaf1,leaf2
```

g. Specify the subnet associated with the physical L2 segment local to the undercloud using the `local_subnet` parameter:

```
local_subnet = leaf0
```

h. Set the value of `undercloud_nameservers`.

```
undercloud_nameservers = 10.11.5.19,10.11.5.20
```

**TIP**

You can find the current IP addresses of the DNS servers that are used for the undercloud nameserver by looking in `/etc/resolv.conf`.

5. Create a new section for each subnet that you define in the `subnets` parameter:

```
[leaf0]
  cidr = 192.168.10.0/24
  dhcp_start = 192.168.10.10
  dhcp_end = 192.168.10.90
  inspection_iprange = 192.168.10.100,192.168.10.190
  gateway = 192.168.10.1
  masquerade = False

[leaf1]
  cidr = 192.168.11.0/24
  dhcp_start = 192.168.11.10
  dhcp_end = 192.168.11.90
  inspection_iprange = 192.168.11.100,192.168.11.190
  gateway = 192.168.11.1
  masquerade = False

[leaf2]
  cidr = 192.168.12.0/24
  dhcp_start = 192.168.12.10
  dhcp_end = 192.168.12.90
  inspection_iprange = 192.168.12.100,192.168.12.190
  gateway = 192.168.12.1
  masquerade = False
```

6. Save the `undercloud.conf` file.

7. Run the undercloud installation command:
This configuration creates three subnets on the provisioning network or control plane. The overcloud uses each network to provision systems within each respective leaf.

To ensure proper relay of DHCP requests to the undercloud, you might need to configure a DHCP relay.

2.2. CONFIGURING A DHCP RELAY

You run the DHCP relay service on a switch, router, or server that is connected to the remote network segment you want to forward the requests from.

NOTE
Do not run the DHCP relay service on the undercloud.

The undercloud uses two DHCP servers on the provisioning network:

- An introspection DHCP server.
- A provisioning DHCP server.

You must configure the DHCP relay to forward DHCP requests to both DHCP servers on the undercloud.

You can use UDP broadcast with devices that support it to relay DHCP requests to the L2 network segment where the undercloud provisioning network is connected. Alternatively, you can use UDP unicast, which relays DHCP requests to specific IP addresses.

NOTE
Configuration of DHCP relay on specific device types is beyond the scope of this document. As a reference, this document provides a DHCP relay configuration example using the implementation in ISC DHCP software. For more information, see manual page dhcrelay(8).

Broadcast DHCP relay

This method relays DHCP requests using UDP broadcast traffic onto the L2 network segment where the DHCP server or servers reside. All devices on the network segment receive the broadcast traffic. When using UDP broadcast, both DHCP servers on the undercloud receive the relayed DHCP request. Depending on the implementation, you can configure this by specifying either the interface or IP network address:

Interface
Specify an interface that is connected to the L2 network segment where the DHCP requests are relayed.

IP network address
Specify the network address of the IP network where the DHCP requests are relayed.

Unicast DHCP relay

This method relays DHCP requests using UDP unicast traffic to specific DHCP servers. When you use UDP unicast, you must configure the device that provides the DHCP relay to relay DHCP requests to
both the IP address that is assigned to the interface used for introspection on the undercloud and the IP address of the network namespace that the OpenStack Networking (neutron) service creates to host the DHCP service for the `ctlplane` network.

The interface used for introspection is the one defined as `inspection_interface` in the `undercloud.conf` file. If you have not set this parameter, the default interface for the undercloud is `br-ctlplane`.

**NOTE**

It is common to use the `br-ctlplane` interface for introspection. The IP address that you define as the `local_ip` in the `undercloud.conf` file is on the `br-ctlplane` interface.

The IP address allocated to the Neutron DHCP namespace is the first address available in the IP range that you configure for the `local_subnet` in the `undercloud.conf` file. The first address in the IP range is the one that you define as `dhcp_start` in the configuration. For example, **192.168.10.10** is the IP address if you use the following configuration:

```
[DEFAULT]
local_subnet = leaf0
subnets = leaf0,leaf1,leaf2

[leaf0]
cidr = 192.168.10.0/24
dhcp_start = 192.168.10.10
dhcp_end = 192.168.10.90
inspection_iprange = 192.168.10.100,192.168.10.190
gateway = 192.168.10.1
masquerade = False
```

**WARNING**

The IP address for the DHCP namespace is automatically allocated. In most cases, this address is the first address in the IP range. To verify that this is the case, run the following commands on the undercloud:

```
$ openstack port list --device-owner network:dhcp -c "Fixed IP Addresses"
+----------------------------------------------------------------------------+
| Fixed IP Addresses                                                         |
+----------------------------------------------------------------------------+
| ip_address='192.168.10.10', subnet_id='7526fbe3-f52a-4b39-a828-ec59f4ed12b2' |
+----------------------------------------------------------------------------+

$ openstack subnet show 7526fbe3-f52a-4b39-a828-ec59f4ed12b2 -c name
```

```
+-------+--------+
| Field | Value  |
+-------+--------+
| name   | leaf0  |
+-------+--------+
```
Example dhcrelay configuration

In the following examples, the `dhcrelay` command in the `dhcp` package uses the following configuration:

- Interfaces to relay incoming DHCP request: `eth1`, `eth2`, and `eth3`.
- Interface the undercloud DHCP servers on the network segment are connected to: `eth0`.
- The DHCP server used for introspection is listening on IP address: `192.168.10.1`.
- The DHCP server used for provisioning is listening on IP address `192.168.10.10`.

This results in the following `dhcrelay` command:

- `dhcrelay` version 4.2.x:

  ```
  $ sudo dhcrelay -d --no-pid 192.168.10.10 192.168.10.1 \
  -i eth0 -i eth1 -i eth2 -i eth3
  ```

- `dhcrelay` version 4.3.x and later:

  ```
  $ sudo dhcrelay -d --no-pid 192.168.10.10 192.168.10.1 \
  -iu eth0 -id eth1 -id eth2 -id eth3
  ```

Example Cisco IOS routing switch configuration

This example uses the following Cisco IOS configuration to perform the following tasks:

- Configure a VLAN to use for the provisioning network.
- Add the IP address of the leaf.
- Forward UDP and BOOTP requests to the introspection DHCP server that listens on IP address: `192.168.10.1`.
- Forward UDP and BOOTP requests to the provisioning DHCP server that listens on IP address `192.168.10.10`.

```
interface vlan 2
  ip address 192.168.24.254 255.255.255.0
  ip helper-address 192.168.10.1
  ip helper-address 192.168.10.10

```

Now that you have configured the provisioning network, you can configure the remaining overcloud leaf networks.

2.3. CREATING FLAVORS AND TAGGING NODES FOR LEAF NETWORKS

Each role in each leaf network requires a flavor and role assignment so that you can tag nodes into their respective leaf. Complete the following steps to create and assign each flavor to a role.

Procedure
1. Source the `stackrc` file:

   [stack@director ~]$ source ~/stackrc

2. Create flavors for each custom role:

   ```bash
   $ ROLES="control compute_leaf0 compute_leaf1 compute_leaf2 ceph-storage_leaf0 ceph-
   storage_leaf1 ceph-storage_leaf2"
   $ for ROLE in $ROLES; do openstack flavor create --id auto --ram <ram_size_mb> --disk
   <disk_size_gb> --vcpus <no_vcpus> $ROLE ; done
   $ for ROLE in $ROLES; do openstack flavor set --property "cpu_arch"="x86_64" --property
   "capabilities:boot_option"="local" --property resources:DISK_GB='0' --property
   resources:MEMORY_MB='0' --property resources:VCPU='0' $ROLE ; done
   ```

   - Replace `<ram_size_mb>` with the RAM of the bare metal node, in MB.
   - Replace `<disk_size_gb>` with the size of the disk on the bare metal node, in GB.
   - Replace `<no_vcpus>` with the number of CPUs on the bare metal node.

3. Retrieve a list of your nodes to identify their UUIDs:

   ```bash
   (undercloud)$ openstack baremetal node list
   ```

4. Tag each bare metal node to its leaf network and role by using a custom resource class:

   ```bash
   (undercloud)$ openstack baremetal node set \
   --resource-class baremetal.LEAF-ROLE <node>
   ```

   Replace `<node>` with the ID of the bare metal node.

   For example, enter the following command to tag a node with UUID `58c3d07e-24f2-48a7-bbb6-
   6843f0e8ee13` to the Compute role on Leaf2:

   ```bash
   (undercloud)$ openstack baremetal node set \
   --resource-class baremetal.COMPUTE-LEAF2 58c3d07e-24f2-48a7-bbb6-6843f0e8ee13
   ```

5. Associate each leaf network role flavor with the custom resource class:

   ```bash
   (undercloud)$ openstack flavor set \
   --property resources:CUSTOM_BAREMETAL_LEAF_ROLE=1 \
   <custom_role>
   ```

   To determine the name of a custom resource class that corresponds to a resource class of a
   Bare Metal Provisioning service node, convert the resource class to uppercase, replace each
   punctuation mark with an underscore, and prefix with `CUSTOM_`.

   **NOTE**

   A flavor can request only one instance of a bare metal resource class.

---

**2.4. MAPPING BARE METAL NODE PORTS TO CONTROL PLANE NETWORK SEGMENTS**
To enable deployment on a L3 routed network, you must configure the `physical_network` field on the bare metal ports. Each bare metal port is associated with a bare metal node in the OpenStack Bare Metal (ironic) service. The physical network names are the names that you include in the `subnets` option in the undercloud configuration.

**NOTE**

The physical network name of the subnet specified as `local_subnet` in the `undercloud.conf` file is always named `ctlplane`.

**Procedure**

1. Source the `stackrc` file:
   ```bash
   $ source ~/stackrc
   ```

2. Check the bare metal nodes:
   ```bash
   $ openstack baremetal node list
   ```

3. Ensure that the bare metal nodes are either in `enroll` or `manageable` state. If the bare metal node is not in one of these states, the command that sets the `physical_network` property on the baremetal port fails. To set all nodes to `manageable` state, run the following command:
   ```bash
   $ for node in $(openstack baremetal node list -f value -c Name); do openstack baremetal node manage $node --wait; done
   ```

4. Check which baremetal ports are associated with which baremetal node:
   ```bash
   $ openstack baremetal port list --node <node-uuid>
   ```

5. Set the `physical-network` parameter for the ports. In the example below, three subnets are defined in the configuration: `leaf0`, `leaf1`, and `leaf2`. The `local_subnet` is `leaf0`. Because the physical network for the `local_subnet` is always `ctlplane`, the baremetal port connected to `leaf0` uses `ctlplane`. The remaining ports use the other leaf names:
   ```bash
   $ openstack baremetal port set --physical-network ctlplane <port-uuid>
   $ openstack baremetal port set --physical-network leaf1 <port-uuid>
   $ openstack baremetal port set --physical-network leaf2 <port-uuid>
   ```

6. Introspect the nodes before you deploy the overcloud. Include the `--all-manageable` and `--provide` options to set the nodes as available for deployment:
   ```bash
   $ openstack overcloud node introspect --all-manageable --provide
   ```

### 2.5. ADDING A NEW LEAF TO A SPINE-LEAF PROVISIONING NETWORK

When increasing network capacity which can include adding new physical sites, you might need to add a new leaf and a corresponding subnet to your Red Hat OpenStack Platform spine-leaf provisioning network. When provisioning a leaf on the overcloud, the corresponding undercloud leaf is used.
Prerequisites

- Your RHOSP deployment uses a spine-leaf network topology.

Procedure

1. Log in to the undercloud host as the stack user.

2. Source the undercloud credentials file:

   ```bash
   $ source ~/stackrc
   ```

3. In the `/home/stack/undercloud.conf` file, do the following:

   a. Locate the `subnets` parameter, and add a new subnet for the leaf that you are adding. A subnet represents an L2 segment in the routed spine and leaf:

   **Example**

   In this example, a new subnet (`leaf3`) is added for the new leaf (`leaf3`):

   ```ini
   subnets = leaf0,leaf1,leaf2,leaf3
   ```

   b. Create a section for the subnet that you added.

   **Example**

   In this example, the section `[leaf3]` is added for the new subnet (`leaf3`):

   ```ini
   [leaf0]
   cidr = 192.168.10.0/24
dhcp_start = 192.168.10.10
dhcp_end = 192.168.10.90
inspection_iprange = 192.168.10.100,192.168.10.190
gateway = 192.168.10.1
masquerade = False

[leaf1]
cidr = 192.168.11.0/24
dhcp_start = 192.168.11.10
dhcp_end = 192.168.11.90
inspection_iprange = 192.168.11.100,192.168.11.190
gateway = 192.168.11.1
masquerade = False

[leaf2]
cidr = 192.168.12.0/24
dhcp_start = 192.168.12.10
dhcp_end = 192.168.12.90
inspection_iprange = 192.168.12.100,192.168.12.190
gateway = 192.168.12.1
masquerade = False

[leaf3]
cidr = 192.168.13.0/24
dhcp_start = 192.168.13.10
```
4. Save the `undercloud.conf` file.

5. Reinstall your undercloud:

   `$ openstack undercloud install`

Additional resources

- Adding a new leaf to a spine-leaf deployment
CHAPTER 3. ALTERNATIVE PROVISIONING NETWORK METHODS

This section contains information about other methods that you can use to configure the provisioning network to accommodate routed spine-leaf with composable networks.

3.1. VLAN PROVISIONING NETWORK

In this example, the director deploys new overcloud nodes through the provisioning network and uses a VLAN tunnel across the L3 topology. For more information, see Figure 3.1, "VLAN provisioning network topology". If you use a VLAN provisioning network, the director DHCP servers can send DHCPOFFER broadcasts to any leaf. To establish this tunnel, trunk a VLAN between the Top-of-Rack (ToR) leaf switches. In the following diagram, the StorageLeaf networks are presented to the Ceph storage and Compute nodes; the NetworkLeaf represents an example of any network that you want to compose.

Figure 3.1. VLAN provisioning network topology

3.2. VXLAN PROVISIONING NETWORK

In this example, the director deploys new overcloud nodes through the provisioning network and uses a VXLAN tunnel to span across the layer 3 topology. For more information, see Figure 3.2, "VXLAN provisioning network topology". If you use a VXLAN provisioning network, the director DHCP servers can send DHCPOFFER broadcasts to any leaf. To establish this tunnel, configure VXLAN endpoints on the Top-of-Rack (ToR) leaf switches.
Figure 3.2. VXLAN provisioning network topology
CHAPTER 4. CONFIGURING THE OVERCLOUD

After you configure the undercloud, you can configure the remaining overcloud leaf networks with a series of configuration files. After you configure the remaining overcloud leaf networks and deploy the overcloud, the resulting deployment has multiple sets of networks with routing available.

4.1. CREATING A NETWORK DATA FILE

To define the leaf networks, create a network data file that contains a YAML formatted list of each composable network and its attributes. Use the `subnets` parameter to define the additional Leaf subnets with a base network.

**Procedure**

1. Create a new `network_data_spine_leaf.yaml` file in the home directory of the `stack` user. Use the default `network_data_subnets_routed.yaml` file as a basis:

   ```bash
   $ cp /usr/share/openstack-tripleo-heat-templates/network_data_subnets_routed.yaml /home/stack/network_data_spine_leaf.yaml
   ```

2. In the `network_data_spine_leaf.yaml` file, edit the YAML list to define each base network and respective leaf subnets as a composable network item. Use the following example syntax to define a base leaf and two leaf subnets:

   ```yaml
   - name: <base_name>
     name_lower: <lowercase_name>
     vip: <true/false>
     vlan: '<vlan_id>'
     ip_subnet: '<network_address>/<prefix>'
     allocation_pools: [{'start': '<start_address>', 'end': '<end_address>'}]
     gateway_ip: '<router_ip_address>'
     subnets:
       <leaf_subnet_name>:
         vlan: '<vlan_id>'
         ip_subnet: '<network_address>/<prefix>'
         allocation_pools: [{'start': '<start_address>', 'end': '<end_address>'}]
         gateway_ip: '<router_ip_address>'
   
   The following example demonstrates how to define the Internal API network and its leaf networks:

   ```yaml
   - name: InternalApi
     name_lower: internal_api
     vip: true
     vlan: 10
     ip_subnet: '172.18.0.0/24'
     allocation_pools: [{'start': '172.18.0.4', 'end': '172.18.0.250'}]
     gateway_ip: '172.18.0.1'
     subnets:
   ```
internal_api_leaf1:
  vlan: 11
  ip_subnet: '172.18.1.0/24'
  allocation_pools: [{'start': '172.18.1.4', 'end': '172.18.1.250'}]
  gateway_ip: '172.18.1.1'

internal_api_leaf2:
  vlan: 12
  ip_subnet: '172.18.2.0/24'
  allocation_pools: [{'start': '172.18.2.4', 'end': '172.18.2.250'}]
  gateway_ip: '172.18.2.1'

NOTE
You do not define the Control Plane networks in the network data file because the undercloud has already created these networks. However, you must set the parameters manually so that the overcloud can configure the NICs accordingly.

NOTE
Define vip: true for the networks that contain the Controller-based services. In this example, InternalApiLeaf0 contains these services.

4.2. CREATING A ROLES DATA FILE

To define each composable role for each leaf and attach the composable networks to each respective role, complete the following steps.

Procedure

1. Create a custom roles directory in the home directory of the stack user:

   $ mkdir ~/roles

2. Copy the default Controller, Compute, and Ceph Storage roles from the director core template collection to the roles directory. Rename the files for Compute and Ceph Storage to suit Leaf 0:

   $ cp /usr/share/openstack-tripleo-heat-templates/roles/Controller.yaml ~/roles/Controller.yaml
   $ cp /usr/share/openstack-tripleo-heat-templates/roles/Compute.yaml ~/roles/Compute0.yaml
   $ cp /usr/share/openstack-tripleo-heat-templates/roles/CephStorage.yaml ~/roles/CephStorage0.yaml

3. Copy the Leaf 0 Compute and Ceph Storage files as a basis for your Leaf 1 and Leaf 2 files:

   $ cp ~/roles/Compute0.yaml ~/roles/Compute1.yaml
   $ cp ~/roles/Compute0.yaml ~/roles/Compute2.yaml
   $ cp ~/roles/CephStorage0.yaml ~/roles/CephStorage1.yaml
   $ cp ~/roles/CephStorage0.yaml ~/roles/CephStorage2.yaml

4. Edit the name, HostnameFormatDefault, and deprecated_nic_config_name parameters in the Leaf 0, Leaf 1, and Leaf 2 files so that they align with the respective Leaf parameters. For example, the parameters in the Leaf 0 Compute file have the following values:
The Leaf 0 Ceph Storage parameters have the following values:

- name: CephStorageLeaf0
  HostnameFormatDefault: '%stackname%-cephstorage-leaf0-%index%'
  deprecated_nic_config_name: 'ceph-storageleaf0.yaml'

5. Edit the network parameter in the Leaf 1 and Leaf 2 files so that they align with the respective Leaf network parameters. For example, the parameters in the Leaf 1 Compute file have the following values:

- name: ComputeLeaf1
  networks:
    InternalApi:
      subnet: internal_api_leaf1
    Tenant:
      subnet: tenant_leaf1
    Storage:
      subnet: storage_leaf1

The Leaf 1 Ceph Storage parameters have the following values:

- name: CephStorageLeaf1
  networks:
    Storage:
      subnet: storage_leaf1
    StorageMgmt:
      subnet: storage_mgmt_leaf1

**NOTE**

This applies only to Leaf 1 and Leaf 2. The network parameter for Leaf 0 retains the base subnet values, which are the lowercase names of each subnet combined with a _subnet suffix. For example, the Internal API for Leaf 0 is internal_api_subnet.

6. When your role configuration is complete, run the following command to generate the full roles data file:

   $ openstack overcloud roles generate --roles-path ~/roles -o roles_data_spine_leaf.yaml
   Controller Compute Compute1 Compute2 CephStorage CephStorage1 CephStorage2

   This creates a full roles_data_spine_leaf.yaml file that includes all of the custom roles for each respective leaf network.

Each role has its own NIC configuration. Before you configure the spine-leaf configuration, you must create a base set of NIC templates to suit your current NIC configuration.

**4.3. CREATING A CUSTOM NIC CONFIGURATION**
Each role requires a unique NIC configuration. Complete the following steps to create a copy of the base set of NIC templates and map the new templates to the respective NIC configuration resources.

**Procedure**

1. Change to the core heat template directory:
   
   ```bash
   $ cd /usr/share/openstack-tripleo-heat-templates
   ```

2. Render the Jinja2 templates with the `tools/process-templates.py` script, your custom `network_data` file, and custom `roles_data` file:
   
   ```bash
   $ tools/process-templates.py \
   -n /home/stack/network_data_spine_leaf.yaml \
   -r /home/stack/roles_data_spine_leaf.yaml \
   -o /home/stack/openstack-tripleo-heat-templates-spine-leaf
   ```

3. Change to the home directory:
   
   ```bash
   $ cd /home/stack
   ```

4. Copy the content from one of the default NIC templates to use as a basis for your spine-leaf templates. For example, copy the `single-nic-vlans` NIC template:
   
   ```bash
   ```

5. Edit each NIC configuration in `/home/stack/templates/spine-leaf-nics/` and change the location of the configuration script to an absolute location. Scroll to the network configuration section, which resembles the following snippet:

   ```yaml
   resources:
   OsNetConfigImpl:
     type: OS::Heat::SoftwareConfig
     properties:
       group: script
       config:
         str_replace:
           template:
             get_file: ../../../scripts/run-os-net-config.sh
       params:
       $network_config:
         network_config:
   ```

   Change the location of the script to the absolute path:

   ```yaml
   resources:
   OsNetConfigImpl:
     type: OS::Heat::SoftwareConfig
     properties:
       group: script
       config:
         str_replace:
           template:
   ```
6. Create a file called `spine-leaf-nics.yaml` and edit the file.

7. Create a `resource_registry` section in the file and add a set of `::Net::SoftwareConfig` resources that map to the respective NIC templates:

   ```yaml
   resource_registry:
   OS::TripleO::Controller::Net::SoftwareConfig: /home/stack/templates/spine-leaf-nics/controller.yaml
   OS::TripleO::ComputeLeaf0::Net::SoftwareConfig: /home/stack/templates/spine-leaf-nics/computeleaf0.yaml
   OS::TripleO::ComputeLeaf1::Net::SoftwareConfig: /home/stack/templates/spine-leaf-nics/computeleaf1.yaml
   OS::TripleO::ComputeLeaf2::Net::SoftwareConfig: /home/stack/templates/spine-leaf-nics/computeleaf2.yaml
   OS::TripleO::CephStorageLeaf0::Net::SoftwareConfig: /home/stack/templates/spine-leaf-nics/ceph-storageleaf0.yaml
   OS::TripleO::CephStorageLeaf1::Net::SoftwareConfig: /home/stack/templates/spine-leaf-nics/ceph-storageleaf1.yaml
   OS::TripleO::CephStorageLeaf2::Net::SoftwareConfig: /home/stack/templates/spine-leaf-nics/ceph-storageleaf2.yaml
   ``

   These resources mappings override the default resource mappings during deployment.

8. Save the `spine-leaf-nics.yaml` file.

9. Remove the rendered template directory:

   ```bash
   $ rm -rf openstack-tripleo-heat-templates-spine-leaf
   ``

   As a result of this procedure, you now have a set of NIC templates and an environment file that maps the required `::Net::SoftwareConfig` resources to them.

10. When you eventually run the `openstack overcloud deploy` command, ensure that you include the environment files in the following order:

   a. `/usr/share/openstack-tripleo-heat-templates/environments/network-isolation.yaml`, which enables network isolation. Note that the director renders this file from the `network-isolation.j2.yaml` Jinja2 template.

   b. `/usr/share/openstack-tripleo-heat-templates/environments/network-environment.yaml`, which is the default network environment file, including default NIC resource mappings. Note that the director renders this file from the `network-environment.j2.yaml` Jinja2 template.

   c. `/home/stack/templates/spine-leaf-nics.yaml`, which contains your custom NIC resource mappings and overrides the default NIC resource mappings.

   The following command snippet demonstrates the ordering:
11. Complete the procedures in the following sections to add details to your network environment file, and define certain aspects of the spine leaf architecture. After you complete this configuration, include this file in the `openstack overcloud deploy` command.

### 4.4. SETTING CONTROL PLANE PARAMETERS

You usually define networking details for isolated spine-leaf networks using a `network_data` file. The exception is the control plane network, which the undercloud creates. However, the overcloud requires access to the control plane for each leaf. To enable this access, you must define additional parameters in your deployment.

In this example, define the IP, subnet, and default route for the respective Control Plane network on Leaf 0.

**Procedure**

1. Create a file called `spine-leaf-ctlplane.yaml` and edit the file.

2. Create a `parameter_defaults` section in the file and add the control plane subnet mapping for each spine-leaf network:

   ```yaml
   parameter_defaults:
   ... 
   ControllerControlPlaneSubnet: leaf0
   Compute0ControlPlaneSubnet: leaf0
   Compute1ControlPlaneSubnet: leaf1
   Compute2ControlPlaneSubnet: leaf2
   CephStorage0ControlPlaneSubnet: leaf0
   CephStorage1ControlPlaneSubnet: leaf1
   CephStorage2ControlPlaneSubnet: leaf2
   ...
   ```

3. Save the `spine-leaf-ctlplane.yaml` file.

### 4.5. SETTING THE SUBNET FOR VIRTUAL IP ADDRESSES

The Controller role typically hosts virtual IP (VIP) addresses for each network. By default, the overcloud takes the VIPs from the base subnet of each network except for the control plane. The control plane uses `ctlplane-subnet`, which is the default subnet name created during a standard undercloud installation.

In this spine leaf scenario, the default base provisioning network is `leaf0` instead of `ctlplane-subnet`. This means that you must add overriding values to the `VipSubnetMap` parameter to change the subnet that the control plane VIP uses.
Additionally, if the VIPs for each network do not use the base subnet of one or more networks, you must add additional overrides to the VipSubnetMap parameter to ensure that the director creates VIPs on the subnet associated with the L2 network segment that connects the Controller nodes.

**Procedure:**

1. Create a file called `spine-leaf-vips.yaml` and edit the file.

2. Create a parameter_defaults section in the file and add the VipSubnetMap parameter based on your requirements:
   - If you use leaf0 for the provisioning / control plane network, set the ctlplane VIP remapping to leaf0:
     ```yaml
     parameter_defaults:
     VipSubnetMap:
     ctlplane: leaf0
     
     - If you use a different Leaf for multiple VIPs, set the VIP remapping to suit these requirements. For example, use the following snippet to configure the VipSubnetMap parameter to use leaf1 for all VIPs:
     ```
     ```
     parameter_defaults:
     VipSubnetMap:
     ctlplane: leaf1
     redis: internal_api_leaf1
     InternalApi: internal_api_leaf1
     Storage: storage_leaf1
     StorageMgmt: storage_mgmt_leaf1
     ```

3. Save the `spine-leaf-vips.yaml` file.

### 4.6. MAPPING SEPARATE NETWORKS

By default, OpenStack Platform uses Open Virtual Network (OVN), which requires that all Controller and Compute nodes connect to a single L2 network for external network access. This means that both Controller and Compute network configurations use a br-ex bridge, which director maps to the datacentre network in the overcloud by default. This mapping is usually either for a flat network mapping or a VLAN network mapping. In a spine leaf architecture, you can change these mappings so that each Leaf routes traffic through the specific bridge or VLAN on that Leaf, which is often the case with edge computing scenarios.

**Procedure**

1. Create a file called `spine-leaf-separate.yaml` and edit the file.

2. Create a parameter_defaults section in the `spine-leaf-separate.yaml` file and include the external network mapping for each spine-leaf network:
   - For flat network mappings, list each Leaf in the NeutronFlatNetworks parameter and set the NeutronBridgeMappings parameter for each Leaf:
     ```yaml
     parameter_defaults:
     NeutronFlatNetworks: leaf0,leaf1,leaf2
     Controller0Parameters:
     ```
NeutronBridgeMappings: "leaf0:br-ex"
Compute0Parameters:
  NeutronBridgeMappings: "leaf0:br-ex"
Compute1Parameters:
  NeutronBridgeMappings: "leaf1:br-ex"
Compute2Parameters:
  NeutronBridgeMappings: "leaf2:br-ex"

- For VLAN network mappings, additionally set the NeutronNetworkVLANRanges to map VLANs for all three Leaf networks:

  NeutronNetworkType: 'geneve,vlan'
  NeutronNetworkVLANRanges: 'leaf0:1:1000,leaf1:1:1000,leaf2:1:1000'

3. Save the spine-leaf-separate.yaml file.

4.7. DEPLOYING A SPINE-LEAF ENABLED OVERCLOUD

When you have completed your spine-leaf overcloud configuration, complete the following steps to review each file and then run the deployment command:

Procedure

1. Review the /home/stack/template/network_data_spine_leaf.yaml file and ensure that it contains each network and subnet for each leaf.

   NOTE

   There is currently no automatic validation for the network subnet and allocation_pools values. Ensure that you define these values consistently and that there is no conflict with existing networks.

2. Review the /home/stack/templates/roles_data_spine_leaf.yaml values and ensure that you define a role for each leaf.

3. Review the NIC templates in the ~/templates/spine-leaf-nics/ directory and ensure that you define the interfaces for each role on each leaf correctly.

4. Review the custom spine-leaf-nics.yaml environment file and ensure that it contains a resource_registry section that references the custom NIC templates for each role.

5. Review the /home/stack/templates/nodes_data.yaml file and ensure that all roles have an assigned flavor and a node count. Also check that you have correctly tagged all nodes for each leaf.

6. Run the openstack overcloud deploy command to apply the spine leaf configuration. For example:

   $ openstack overcloud deploy --templates \
   -n /home/stack/templates/network_data_spine_leaf.yaml \
   -r /home/stack/templates/roles_data_spine_leaf.yaml \
   -e /usr/share/openstack-tripleo-heat-templates/environments/network-isolation.yaml \
   -e /usr/share/openstack-tripleo-heat-templates/environments/network-environment.yaml \
   -e /home/stack/templates/spine-leaf-nics.yaml \\
The `network-isolation.yaml` is the rendered name of the Jinja2 file in the same location (`network-isolation.j2.yaml`). Include this file in the deployment command to ensure that the director isolates each network to the correct leaf. This ensures that the networks are created dynamically during the overcloud creation process.

- Include the `network-environment.yaml` file after the `network-isolation.yaml`. The `network-environment.yaml` file provides the default network configuration for composable network parameters.

- Include the `spine-leaf-nics.yaml` file after the `network-environment.yaml`. The `spine-leaf-nics.yaml` file overrides the default NIC template mappings from the `network-environment.yaml` file.

- If you created any other spine leaf network environment files, include these environment files after the `spine-leaf-nics.yaml` file.

- Add any additional environment files. For example, an environment file with your container image locations or Ceph cluster configuration.

7. Wait until the spine-leaf enabled overcloud deploys.

### 4.8. ADDING A NEW LEAF TO A SPINE-LEAF DEPLOYMENT

When increasing network capacity or adding a new physical site, you might need to a new leaf to your Red Hat OpenStack Platform (RHOSP) spine-leaf network.

**Prerequisites**

- Your RHOSP deployment uses a spine-leaf network topology.

**Procedure**

1. Log in to the undercloud host as the stack user.

2. Source the undercloud credentials file:

   ```bash
   $ source ~/stackrc
   ```

3. In the `/usr/share/openstack-tripleo-heat-templates/network_data_spine_leaf.yaml` file, under the appropriate base network, add a leaf subnet as a composable network item for the new leaf that you are adding.

   **Example**

   In this example, a subnet entry for the new leaf (`leaf3`) has been added:

   ```yaml
   - name: InternalApi
     name_lower: internal_api
     vip: true
   ```
4. Create a roles data file for the new leaf that you are adding.

   a. Copy a leaf Compute and a leaf Ceph Storage file for the new leaf that you are adding.
      
      **Example**

      In this example, `Compute1.yaml` and `CephStorage1.yaml` are copied for the new leaf, `Compute3.yaml` and `CephStorage3.yaml`, respectively:

      ```
      $ cp ~/roles/Compute1.yaml ~/roles/Compute3.yaml
      $ cp ~/roles/CephStorage1.yaml ~/roles/CephStorage3.yaml
      ```

   b. Edit the `name`, `HostnameFormatDefault`, and `deprecated_nic_config_name` parameters in the new leaf files so that they align with the respective Leaf parameters.
      
      **Example**

      For example, the parameters in the Leaf 1 Compute file have the following values:

      ```yaml
      - name: ComputeLeaf1
        HostnameFormatDefault: '%stackname%-compute-leaf1-%index%'
        deprecated_nic_config_name: 'computeleaf1.yaml'
      ```

      **Example**

      The Leaf 1 Ceph Storage parameters have the following values:

      ```yaml
      - name: CephStorageLeaf1
        HostnameFormatDefault: '%stackname%-cephstorage-leaf1-%index%'
        deprecated_nic_config_name: 'ceph-strorageleaf1.yaml'
      ```

   c. Edit the network parameter in the new leaf files so that they align with the respective Leaf network parameters.
      
      **Example**
For example, the parameters in the Leaf 1 Compute file have the following values:

```yaml
- name: ComputeLeaf1
  networks:
    InternalApi:
      subnet: internal_api_leaf1
    Tenant:
      subnet: tenant_leaf1
    Storage:
      subnet: storage_leaf1
```

**Example**

The Leaf 1 Ceph Storage parameters have the following values:

```yaml
- name: CephStorageLeaf1
  networks:
    Storage:
      subnet: storage_leaf1
    StorageMgmt:
      subnet: storage_mgmt_leaf1
```

d. When your role configuration is complete, run the following command to generate the full roles data file. Include all of the leaves in your network and the new leaf that you are adding.

**Example**

In this example, leaf3 is added to leaf0, leaf1, and leaf2:

```
$ openstack overcloud roles generate --roles-path ~/roles -o roles_data_spine_leaf.yaml
Controller Compute Compute1 Compute2 Compute3 CephStorage CephStorage1 CephStorage2 CephStorage3
```

This creates a full `roles_data_spine_leaf.yaml` file that includes all of the custom roles for each respective leaf network.

5. Create a custom NIC configuration for the leaf that you are adding.

a. Copy a leaf Compute and a leaf Ceph Storage NIC configuration file for the new leaf that you are adding.

**Example**

In this example, `computeleaf1.yaml` and `ceph-storageleaf1.yaml` are copied for the new leaf, `computeleaf3.yaml` and `ceph-storageleaf3.yaml`, respectively:

```
$ cp ~/templates/spine-leaf-nics/computeleaf1.yaml ~/templates/spine-leaf-nics/computeleaf3.yaml
$ cp ~/templates/spine-leaf-nics/ceph-storageleaf1.yaml ~/templates/spine-leaf-nics/ceph-storageleaf3.yaml
```

b. In `/usr/share/openstack-tripleo-heat-templates/network_data_spine_leaf.yaml`, under the `resource_registry` section in the file, add a set of `::Net::SoftwareConfig` resources that map to the respective NIC templates:
Example

In this example, the new leaf NIC configuration files (computeleaf3.yaml and ceph-storageleaf3.yaml) have been added:

```
resource_registry:
  OS::TripleO::Controller::Net::SoftwareConfig: /home/stack/templates/spine-leaf-nics/controller.yaml
  OS::TripleO::ComputeLeaf0::Net::SoftwareConfig: /home/stack/templates/spine-leaf-nics/computeleaf0.yaml
  OS::TripleO::ComputeLeaf1::Net::SoftwareConfig: /home/stack/templates/spine-leaf-nics/computeleaf1.yaml
  OS::TripleO::ComputeLeaf2::Net::SoftwareConfig: /home/stack/templates/spine-leaf-nics/computeleaf2.yaml
  OS::TripleO::ComputeLeaf3::Net::SoftwareConfig: /home/stack/templates/spine-leaf-nics/computeleaf3.yaml
  OS::TripleO::CephStorageLeaf0::Net::SoftwareConfig: /home/stack/templates/spine-leaf-nics/ceph-storageleaf0.yaml
  OS::TripleO::CephStorageLeaf1::Net::SoftwareConfig: /home/stack/templates/spine-leaf-nics/ceph-storageleaf1.yaml
  OS::TripleO::CephStorageLeaf2::Net::SoftwareConfig: /home/stack/templates/spine-leaf-nics/ceph-storageleaf2.yaml
  OS::TripleO::CephStorageLeaf3::Net::SoftwareConfig: /home/stack/templates/spine-leaf-nics/ceph-storageleaf3.yaml
```

These resources mappings override the default resource mappings during deployment.

As a result of this procedure, you now have a set of NIC templates and an environment file that maps the required ::Net::SoftwareConfig resources to them. When you eventually run the openstack overcloud deploy command, ensure that you include the environment files in the following order:

c. /usr/share/openstack-tripleo-heat-templates/environments/network-isolation.yaml, which enables network isolation. Note that the director renders this file from the network-isolation.j2.yaml Jinja2 template.

d. /usr/share/openstack-tripleo-heat-templates/environments/network-environment.yaml, which is the default network environment file, including default NIC resource mappings. Note that the director renders this file from the network-environment.j2.yaml Jinja2 template.

e. /home/stack/templates/spine-leaf-nics.yaml, which contains your custom NIC resource mappings and overrides the default NIC resource mappings.

The following command snippet demonstrates the ordering:

```
$ openstack overcloud deploy --templates ...
  -e /usr/share/openstack-tripleo-heat-templates/environments/network-isolation.yaml \
  -e /usr/share/openstack-tripleo-heat-templates/environments/network-environment.yaml \
  -e /home/stack/templates/spine-leaf-nics.yaml \
  ...
```

6. Update the control plane parameters.
In ~/templates/spine-leaf-ctlplane.yaml, under the **parameter_defaults** section, add the control plane subnet mapping for the new leaf network:

**Example**

In this example, the new leaf (**leaf3**) entries are added:

```yaml
parameter_defaults:
  ...
  ControllerControlPlaneSubnet: leaf0
  Compute0ControlPlaneSubnet: leaf0
  Compute1ControlPlaneSubnet: leaf1
  Compute2ControlPlaneSubnet: leaf2
  Compute3ControlPlaneSubnet: leaf3
  CephStorage0ControlPlaneSubnet: leaf0
  CephStorage1ControlPlaneSubnet: leaf1
  CephStorage2ControlPlaneSubnet: leaf2
  CephStorage3ControlPlaneSubnet: leaf3
```

7. Map the new leaf network.
   In ~/templates/spine-leaf-separate.yaml, under the **parameter_defaults** section, include the external network mapping for the new leaf network.

   - For flat network mappings, list the new leaf (**leaf3**) in the **NeutronFlatNetworks** parameter and set the **NeutronBridgeMappings** parameter for the new leaf:

     ```yaml
     parameter_defaults:
       NeutronFlatNetworks: leaf0,leaf1,leaf2,leaf3
       Controller0Parameters:
         NeutronBridgeMappings: "leaf0:br-ex"
       Compute0Parameters:
         NeutronBridgeMappings: "leaf0:br-ex"
       Controller1Parameters:
         NeutronBridgeMappings: "leaf1:br-ex"
       Compute1Parameters:
         NeutronBridgeMappings: "leaf1:br-ex"
       Compute2Parameters:
         NeutronBridgeMappings: "leaf2:br-ex"
       Compute3Parameters:
         NeutronBridgeMappings: "leaf3:br-ex"
     ```

   - For VLAN network mappings, additionally set the **NeutronNetworkVLANRanges** to map VLANs for the new leaf (**leaf3**) network:

     ```yaml
     NeutronNetworkType: 'geneve,vlan'
     ```

8. Redeploy your spine-leaf enabled overcloud, by following the steps in Section 4.7, “Deploying a spine-leaf enabled overcloud”.

   - Adding a new leaf to a spine-leaf provisioning network