Software-Defined Data Center Interconnect

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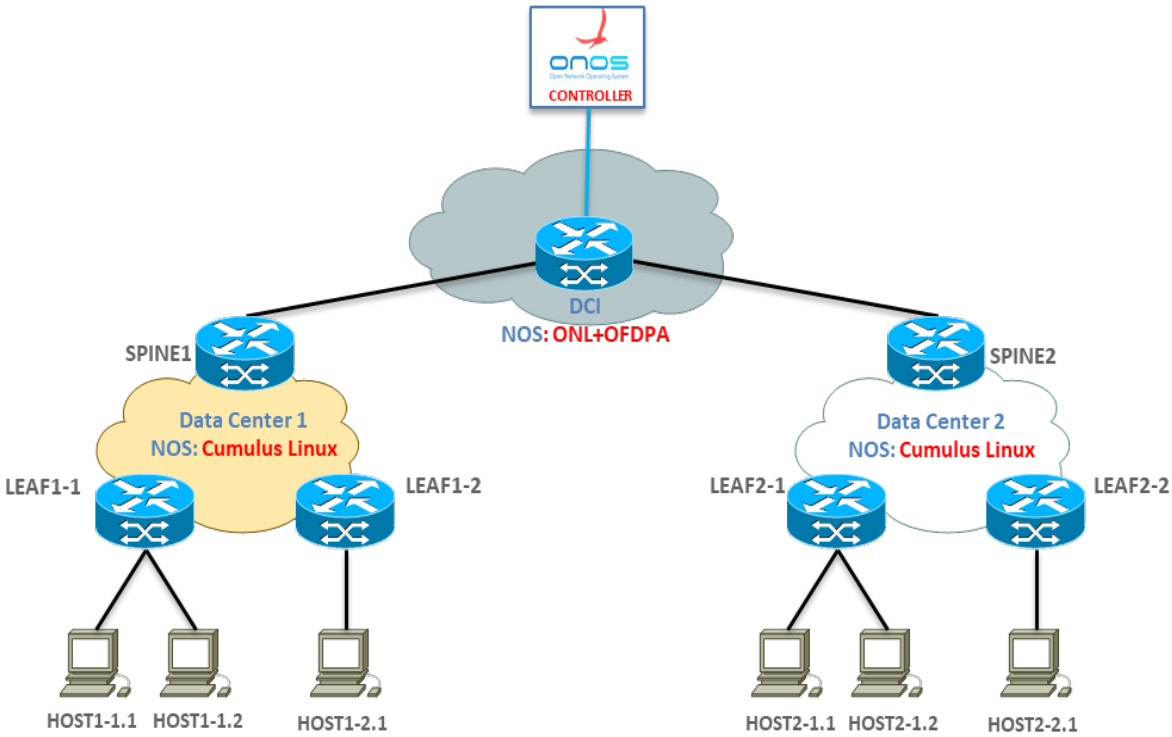
Contents

Background

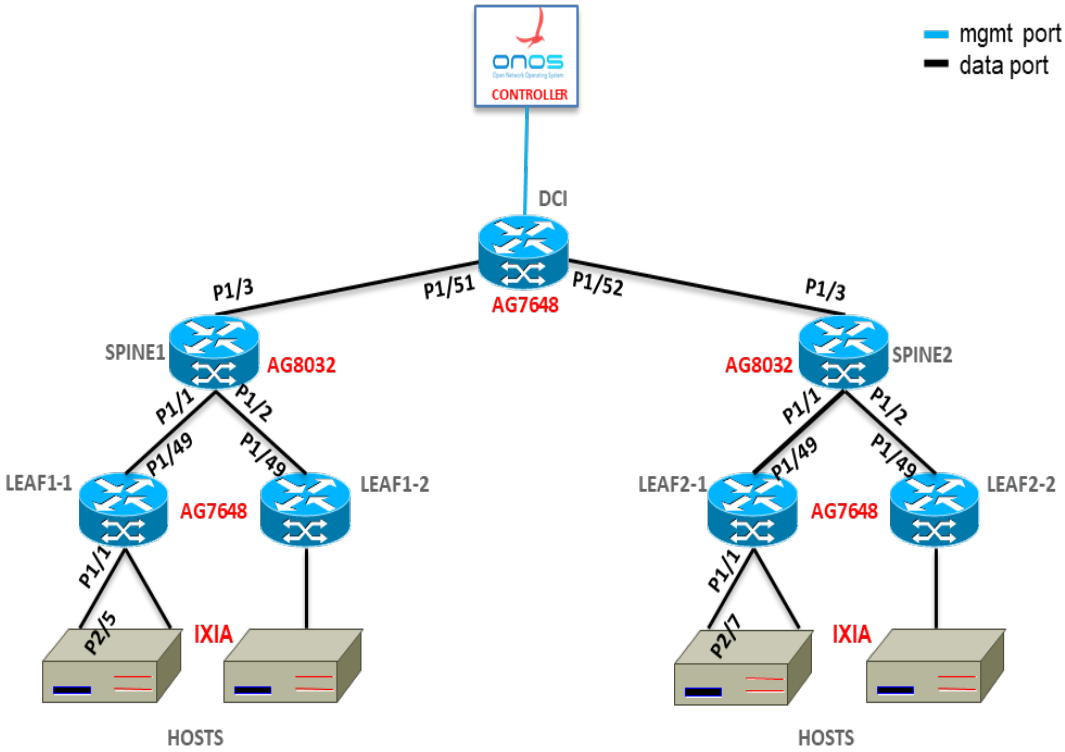
This document covers Software-Defined Data Center Interconnect (SD-DCI). It serves as a guide in setting up, configuring, and validating the use case on Delta Networks white-box switches which are loaded with Open Network Linux (ONL) NOS and enabled with OpenFlow Data Plane Abstraction (OF-DPA) agent. Control Plane is separated out of the switching fabric and moved onto the Open Controller (ONOS Controller) where Segment Routing App is activated. This app enables the controller to program the switches with flows to allow connectivity between the hosts.

Network Topology

SD-DCI Logical Topology



SD-DCI Physical Topology



Topology Notes

- **LEAF1** and **LEAF2** represent the access layer switches on the network.
- **SPINE1** and **SPINE2** represent the aggregation layer switches on the network.
- **HOSTS** represent any number of external network devices connected physically or logically to the access layer switches.
- **Cumulus Linux** version: **3.5.0**

Findings

1. All test cases performed work as expected.
2. Disparate Data Centers can be interconnected thru SDN network with ease and no disruptions on the legacy networks.

Software-Defined Data Center Interconnect (SD-DCI)

Initial Switch Setup

1. Refer to SD-DCI Logical/Physical Topologies.
2. Load Cumulus Linux onto the LEAF and SPINE switches.
3. Log into the **LEAF and SPINE** switches using the default credentials:
   username: ***cumulus***
   password: ***CumulusLinux!***
4. (Optional) Create a new sudo user.
   Example:
   cumulus@cumulus:~$ ***sudo adduser roger***
   Enter new UNIX password: ***cortes***
   Retype new UNIX password: ***cortes***

   Add admin privileges.
   Example:
   cumulus@cumulus:~$ ***sudo adduser roger sudo***

5. Enter **exit** and then login as the new user.
6. Load ONL onto the DCI switch.
7. Copy and install OF-DPA package onto the DCI switch.
   Example:
   root@localhost:~# ***scp <scp_user_name>@<scp_server_ip>:<odfpa_deb_package_path>/ofdpa-ag7648_xxxx_amd64.deb***

root@localhost:~# ***dpkg -i ofdpa-ag7648_xxxx_amd64.deb***

The package is installed in ***/usr/bin/ofdpa*** directory.

Basic SD-DCI Configurations

Here are key LEAF and SPINE configurations. Each of the switches can be configured using the Network Command Line Utility (NCLU), or by editing the **/etc/network/interfaces** and **/etc/frr/frr.conf** files directly as the sudo user.

NCLU is similar to Cisco CLI although it's on Linux. Usage example:
roger@AG7648-38-LEAF1:~$ sudo net add host<tab> # hitting tab will auto-complete ***hostname***

1. Log into the **LEAF1-1** switch:
   username: ***roger***
   password: ***cortes***
2. Setup the proper time zone, configure the management port, and update the hostname.
   sudo dpkg-reconfigure tzdata # Make sure to complete setting the time zone
   sudo net add interface eth0 ip address 10.62.2.38/24
   sudo net add interface eth0 ip gateway 10.62.2.254
   sudo net add hostname AG7648-38-LEAF1-1
   sudo net commit
3. Activate the license.
   sudo cl-license -i
   <copy and paste the license key> then hit "ctl+d"
   sudo reboot or sudo systemctl restart switchd

4. Repeat steps 1 and 3 for **LEAF1-2**, **LEAF2-1**, **LEAF2-2**, **SPINE1,** and **SPINE2** switches.

SD-DCI Network Configurations

LEAF1-1 Configurations

1. Execute the following commands to add the networking configurations on the **LEAF1-1** switch:

```
# Configure the interfaces
sudo net add loopback lo ip address 10.100.1.1/32
sudo net add interface swp1 ip address 10.101.1.1/24
sudo net add interface swp49 link autoneg on

# Configure BGP
sudo net add bgp autonomous-system 65011
sudo net add bgp bestpath as-path multipath-relax
sudo net add bgp neighbor swp49 remote-as external
sudo net add bgp neighbor 10.101.1.2 remote-as internal
sudo net add bgp ipv4 unicast neighbor 10.101.1.2 activate
sudo net add bgp neighbor 10.101.1.2 next-hop-self
sudo net add bgp network 10.100.1.1/32

# Display the configurations for review before committing
sudo net pending

# Commit the configurations
sudo net commit

# Display the configurations
sudo net show configuration
```

The above configurations using NCLU would produce the following in **/etc/network/interfaces** and **/etc/frr/frr.conf** files:

/etc/network/interfaces

```
source /etc/network/interfaces.d/*.intf

# The loopback network interface
auto lo
iface lo inet loopback
        address 10.100.1.1/32

# The primary network interface
auto eth0
iface eth0
        address 10.62.2.38/24
        gateway 10.62.2.254

auto swp1
iface swp1
        address 10.101.1.1/24

auto swp49
iface swp49
        link-autoneg on
```

/etc/frr/frr.conf

```
hostname AG7648-38-LEAF1-1
username cumulus nopassword
!
service integrated-vtysh-config
!
log syslog informational
!
```

```
interface swp1
 ipv6 nd ra-interval 10
 no ipv6 nd suppress-ra
!
interface swp49
 ipv6 nd ra-interval 10
 no ipv6 nd suppress-ra
!
router bgp 65011
 coalesce-time 1150
 bgp bestpath as-path multipath-relax
 neighbor swp49 interface remote-as external
 neighbor 10.101.1.2 remote-as internal
 !
 address-family ipv4 unicast
  network 10.100.1.1/32
  neighbor 10.101.1.2 next-hop-self
 exit-address-family
!
```

2. If the **/etc/network/interfaces** or the **/etc/frr/frr.conf** file was edited, execute the following to activate the configurations:

   sudo systemctl restart switchd

LEAF1-2 Configurations

1. Execute the following commands to add the networking configurations on the **LEAF1-2** switch:

   # Configure the interfaces

   sudo net add loopback lo ip address 10.100.1.2/32

```
sudo net add interface swp49 link autoneg on

# Configure BGP
sudo net add bgp autonomous-system 65012
sudo net add bgp bestpath as-path multipath-relax
sudo net add bgp neighbor swp49 remote-as external
sudo net add bgp network 10.100.1.2/32

# Display the configurations for review before committing
sudo net pending

# Commit the configurations
sudo net commit

# Display the configurations
sudo net show configuration
```

The above configurations using NCLU would produce the following in **/etc/network/interfaces** and **/etc/frr/frr.conf** files:

/etc/network/interfaces

```
source /etc/network/interfaces.d/*.intf

# The loopback network interface
auto lo
iface lo inet loopback
        address 10.100.1.2/32

# The primary network interface
auto eth0
iface eth0
```

```
        address 10.62.2.39/24
        gateway 10.62.2.254

auto swp49
iface swp49
        link-autoneg on
```

/etc/frr/frr.conf

```
hostname AG7648-50-LEAF1-2
username cumulus nopassword
!
service integrated-vtysh-config
!
log syslog informational
!
interface swp49
  ipv6 nd ra-interval 10
  no ipv6 nd suppress-ra
!
router bgp 65012
  coalesce-time 1100
  bgp bestpath as-path multipath-relax
  neighbor swp49 interface remote-as external
!
  address-family ipv4 unicast
    network 10.100.1.2/32
exit-address-family
!
```

2. If the **/etc/network/interfaces** or the **/etc/frr/frr.conf** file was edited, execute the following to activate the configurations:
   sudo systemctl restart switchd

SPINE1 Configurations

1. Execute the following commands to add the networking configurations on the **SPINE1** switch:

```
# Configure the interfaces
sudo net add loopback lo ip address 10.100.1.201/32
sudo net add interface swp1-2 link autoneg on
sudo net add interface swp3 link speed 40000
sudo net add interface swp3 ip address 192.168.1.1/24

# Configure BGP
sudo net add bgp autonomous-system 65111
sudo net add bgp bestpath as-path multipath-relax
sudo net add bgp neighbor swp1 remote-as external
sudo net add bgp neighbor swp2 remote-as external
sudo net add bgp neighbor 192.168.1.2 remote-as external
sudo net add bgp ipv4 unicast neighbor 192.168.1.2 activate
sudo net add bgp neighbor 192.168.1.2 next-hop-self
sudo net add bgp network 10.100.1.201/32

# Display the configurations for review before committing
sudo net pending

# Commit the configurations
sudo net commit

# Display the configurations
```

sudo net show configuration

The above configurations using NCLU would produce the following in **/etc/network/interfaces** and **/etc/frr/frr.conf** files:

/etc/network/interfaces

```
source /etc/network/interfaces.d/*.intf

# The loopback network interface
auto lo
iface lo inet loopback
        address 10.100.1.201/32

# The primary network interface
auto eth0
iface eth0
        address 10.62.2.54/24
        gateway 10.62.2.254

auto swp1
iface swp1
        link-autoneg on

auto swp2
iface swp2
        link-autoneg on

auto swp3
iface swp3
        address 192.168.1.1/24
        link-speed 40000
```

/etc/frr/frr.conf

```
hostname AG9032-54-SPINE1
username cumulus nopassword
!
service integrated-vtysh-config
!
log syslog informational
!
interface swp1
 ipv6 nd ra-interval 10
 no ipv6 nd suppress-ra
!
interface swp2
 ipv6 nd ra-interval 10
 no ipv6 nd suppress-ra
!
interface swp3
 ipv6 nd ra-interval 10
 no ipv6 nd suppress-ra
!
router bgp 65111
 coalesce-time 1200
 bgp bestpath as-path multipath-relax
 neighbor swp1 interface remote-as external
 neighbor swp2 interface remote-as external
 neighbor 192.168.1.2 remote-as external
 !
 address-family ipv4 unicast
  network 10.100.1.201/32
  neighbor 192.168.1.2 next-hop-self
```

```
 exit-address-family
!
```

2. If the **/etc/network/interfaces** or the **/etc/frr/frr.conf** file was edited, execute the following to activate the configurations:

   sudo systemctl restart switchd

LEAF2-1 Configurations

3. Execute the following commands to add the networking configurations on the **LEAF2-1** switch:

```
# Configure the interfaces
sudo net add loopback lo ip address 10.200.1.1/32
sudo net add interface swp1 ip address 10.201.1.1/24
sudo net add interface swp49 link autoneg on

# Configure BGP
sudo net add bgp autonomous-system 65021
sudo net add bgp bestpath as-path multipath-relax
sudo net add bgp neighbor swp49 remote-as external
sudo net add bgp neighbor 10.201.1.2 remote-as internal
sudo net add bgp ipv4 unicast neighbor 10.201.1.2 activate
sudo net add bgp neighbor 10.201.1.2 next-hop-self
sudo net add bgp network 10.200.1.1/32

# Display the configurations for review before committing
sudo net pending

# Commit the configurations
sudo net commit
```

```
# Display the configurations
sudo net show configuration
```

The above configurations using NCLU would produce the following in **/etc/network/interfaces** and **/etc/frr/frr.conf** files:

/etc/network/interfaces

```
source /etc/network/interfaces.d/*.intf

# The loopback network interface
auto lo
iface lo inet loopback
    address 10.200.1.1/32

# The primary network interface
auto eth0
iface eth0
    address 10.62.2.50/24
    gateway 10.62.2.254

auto swp1
iface swp1
    address 10.201.1.1/24

auto swp49
iface swp49
    link-autoneg on
```

/etc/frr/frr.conf

```
hostname AG7648-50-LEAF2-1
```

```
username cumulus nopassword
!
service integrated-vtysh-config
!
log syslog informational
!
interface swp1
 ipv6 nd ra-interval 10
 no ipv6 nd suppress-ra
!
interface swp49
 ipv6 nd ra-interval 10
 no ipv6 nd suppress-ra
!
router bgp 65021
 coalesce-time 1150
 bgp bestpath as-path multipath-relax
 neighbor swp49 interface remote-as external
 neighbor 10.201.1.2 remote-as internal
 !
 address-family ipv4 unicast
  network 10.200.1.1/32
  neighbor 10.201.1.2 next-hop-self
 exit-address-family
!
```

4. If the **/etc/network/interfaces** or the **/etc/frr/frr.conf** file was edited, execute the following to activate the configurations:

   sudo systemctl restart switchd

LEAF2-2 Configurations

3. Execute the following commands to add the networking configurations on the **LEAF2-2** switch:

```
# Configure the interfaces
sudo net add loopback lo ip address 10.200.1.2/32
sudo net add interface swp49 link autoneg on

# Configure BGP
sudo net add bgp autonomous-system 65022
sudo net add bgp bestpath as-path multipath-relax
sudo net add bgp neighbor swp49 remote-as external
sudo net add bgp network 10.200.1.2/32

# Display the configurations for review before committing
sudo net pending

# Commit the configurations
sudo net commit

# Display the configurations
sudo net show configuration
```

The above configurations using NCLU would produce the following in **/etc/network/interfaces** and **/etc/frr/frr.conf** files:

/etc/network/interfaces

```
source /etc/network/interfaces.d/*.intf

# The loopback network interface
```

```
auto lo
iface lo inet loopback
        address 10.200.1.2/32

# The primary network interface
auto eth0
iface eth0
        address 10.62.2.40/24
        gateway 10.62.2.254

auto swp49
iface swp49
        link-autoneg on
```

/etc/frr/frr.conf

```
hostname AG7648-40-LEAF2-2
username cumulus nopassword
!
service integrated-vtysh-config
!
log syslog informational
!
interface swp49
  ipv6 nd ra-interval 10
  no ipv6 nd suppress-ra
!
router bgp 65022
  coalesce-time 1050
  bgp bestpath as-path multipath-relax
  neighbor swp49 interface remote-as external
!
```

```
 address-family ipv4 unicast
  network 10.200.1.2/32
exit-address-family
!
```

4. If the **/etc/network/interfaces** or the **/etc/frr/frr.conf** file was edited, execute the following to activate the configurations:

   sudo systemctl restart switchd

SPINE2 Configurations

1. Execute the following commands to add the networking configurations on the **SPINE2** switch:

```
# Configure the interfaces
sudo net add loopback lo ip address 10.200.1.201/32
sudo net add interface swp1-2 link autoneg on
sudo net add interface swp3 link speed 40000
sudo net add interface swp3 ip address 192.168.1.2/24

# Configure BGP
sudo net add bgp autonomous-system 65221
sudo net add bgp bestpath as-path multipath-relax
sudo net add bgp neighbor swp1 remote-as external
sudo net add bgp neighbor swp2 remote-as external
sudo net add bgp neighbor 192.168.1.1 remote-as external
sudo net add bgp ipv4 unicast neighbor 192.168.1.1 activate
sudo net add bgp neighbor 192.168.1.1 next-hop-self
sudo net add bgp network 10.200.1.201/32

# Display the configurations for review before committing
```

```
sudo net pending

# Commit the configurations
sudo net commit

# Display the configurations
sudo net show configuration
```

The above configurations using NCLU would produce the following in **/etc/network/interfaces** and **/etc/frr/frr.conf** files:

/etc/network/interfaces

```
source /etc/network/interfaces.d/*.intf

# The loopback network interface
auto lo
iface lo inet loopback
        address 10.200.1.201/32

# The primary network interface
auto eth0
iface eth0
        address 10.62.2.36/24
        gateway 10.62.2.254

auto swp1
iface swp1
        link-autoneg on

auto swp2
iface swp2
```

```
        link-autoneg on

auto swp3
iface swp3
        address 192.168.1.2/24
        link-speed 40000
```

/etc/frr/frr.conf

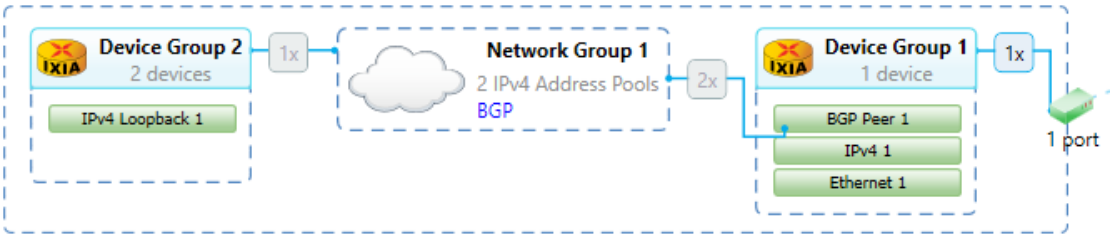
```
hostname AG9032-36-SPINE2
username cumulus nopassword
!
service integrated-vtysh-config
!
log syslog informational
!
interface swp1
  ipv6 nd ra-interval 10
  no ipv6 nd suppress-ra
!
interface swp2
  ipv6 nd ra-interval 10
  no ipv6 nd suppress-ra
!
interface swp3
  ipv6 nd ra-interval 10
  no ipv6 nd suppress-ra
!
router bgp 65221
  coalesce-time 1200
  bgp bestpath as-path multipath-relax
```

```
 neighbor swp1 interface remote-as external
 neighbor swp2 interface remote-as external
 neighbor 192.168.1.1 remote-as external
!
 address-family ipv4 unicast
  network 10.200.1.201/32
  neighbor 192.168.1.1 next-hop-self
 exit-address-family
!
```

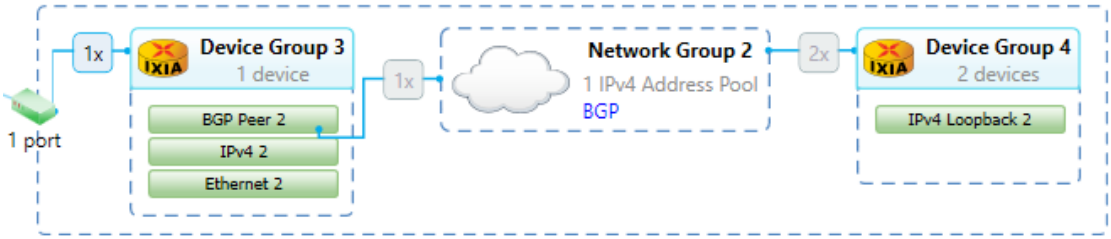
2. If the **/etc/network/interfaces** or the **/etc/frr/frr.conf** file was edited, execute the following to activate the configurations:
   sudo systemctl restart switchd

Ixia Configurations

1. Setup **Ixia port 2/5** to emulate the BGP host network connected to **LEAF1-1** as shown below.



2. Setup **Ixia port 2/7** to emulate the BGP host network connected to **LEAF2-1** as shown below.



3. Start the Ixia.

SD-DCI Network Validation

1. Verify that DC1 and DC2 have no connectivity while the DCI switch isn't programmed with data flows.

   a. BGP routes from hosts (100.0.0.X/32) get propagated onto LEAF1-1, LEAF1-2, and SPINE1 only.

roger@AG7648-38-LEAF1-1:~$ ***sudo net show bgp***

show bgp ipv4 unicast

==========

BGP table version is 185, local router ID is 10.100.1.1

*Status codes: s suppressed, d damped, h history, * valid, > best, = multipath,*

i internal, r RIB-failure, S Stale, R Removed

Origin codes: i - IGP, e - EGP, ? - incomplete

Network	*Next Hop*	*Metric*	*LocPrf*	*Weight*	*Path*
*> 10.100.1.1/32	*0.0.0.0*	*0*		*32768*	*i*
*> 10.100.1.2/32	*swp49*			*0*	*65111 65012 i*
*> 10.100.1.201/32	*swp49*	*0*		*0*	*65111 i*
*>**i100.0.0.1/32**	*10.101.1.2*		*0*	*0*	*i*
*>**i100.0.0.2/32**	*10.101.1.2*		*0*	*0*	*i*

roger@AG7648-39-LEAF1-2:~$ ***sudo net show bgp***

show bgp ipv4 unicast

==========

BGP table version is 189, local router ID is 10.100.1.2

*Status codes: s suppressed, d damped, h history, * valid, > best, = multipath,*

i internal, r RIB-failure, S Stale, R Removed

Origin codes: i - IGP, e - EGP, ? - incomplete

Network	*Next Hop*	*Metric*	*LocPrf*	*Weight*	*Path*
*> 10.100.1.1/32	*swp49*			*0*	*65111 65011 i*
*> 10.100.1.2/32	*0.0.0.0*	*0*		*32768*	*i*
*> 10.100.1.201/32	*swp49*	*0*		*0*	*65111 i*
*> ***100.0.0.1/32***	*swp49*			*0*	*65111 65011 i*
*> ***100.0.0.2/32***	*swp49*			*0*	*65111 65011 i*

roger@AG9032-54-SPINE1:~$ ***sudo net show bgp***

show bgp ipv4 unicast

==========

BGP table version is 181, local router ID is 10.100.1.201

*Status codes: s suppressed, d damped, h history, * valid, > best, = multipath,*

i internal, r RIB-failure, S Stale, R Removed

Origin codes: i - IGP, e - EGP, ? - incomplete

Network	*Next Hop*	*Metric*	*LocPrf*	*Weight*	*Path*
*> 10.100.1.1/32	*swp1*	*0*		*0*	*65011 i*
*> 10.100.1.2/32	*swp2*	*0*		*0*	*65012 i*
*> 10.100.1.201/32	*0.0.0.0*	*0*		*32768*	*i*
*> ***100.0.0.1/32***	*swp1*			*0*	*65011 i*
*> ***100.0.0.2/32***	*swp1*			*0*	*65011 i*

b. a. BGP routes from hosts (200.0.0.X/32) get propagated onto LEAF2-1, LEAF2-2, and SPINE2 only.

roger@AG7648-50-LEAF2-1:~$ ***sudo net show bgp***

show bgp ipv4 unicast

==========

BGP table version is 457, local router ID is 10.200.1.1

*Status codes: s suppressed, d damped, h history, * valid, > best, = multipath,*

i internal, r RIB-failure, S Stale, R Removed

Origin codes: i - IGP, e - EGP, ? - incomplete

Network	*Next Hop*	*Metric*	*LocPrf*	*Weight*	*Path*
*> 10.200.1.1/32	*0.0.0.0*	*0*		*32768*	*i*
*> 10.200.1.2/32	*swp49*			*0*	*65221 65022 i*
*> 10.200.1.201/32	*swp49*	*0*		*0*	*65221 i*
*>**i200.0.0.1/32**	*10.201.1.2*		*0*	*0*	*i*
*>**i200.0.0.2/32**	*10.201.1.2*		*0*	*0*	*i*

roger@AG7648-40-LEAF2-2:~$ ***sudo net show bgp***

show bgp ipv4 unicast

==========

BGP table version is 473, local router ID is 10.200.1.2

*Status codes: s suppressed, d damped, h history, * valid, > best, = multipath,*

i internal, r RIB-failure, S Stale, R Removed

Origin codes: i - IGP, e - EGP, ? - incomplete

Network	*Next Hop*	*Metric*	*LocPrf*	*Weight*	*Path*
*> 10.200.1.1/32	*swp49*			*0*	*65221 65021 i*
*> 10.200.1.2/32	*0.0.0.0*	*0*		*32768*	*i*
*> 10.200.1.201/32	*swp49*	*0*		*0*	*65221 i*
*> ***200.0.0.1/32**	*swp49*			*0*	*65221 65021 i*
*> ***200.0.0.2/32**	*swp49*			*0*	*65221 65021 i*

roger@AG9032-36-SPINE2:~$ ***sudo net show bgp***

show bgp ipv4 unicast

==========

BGP table version is 365, local router ID is 10.200.1.201

*Status codes: s suppressed, d damped, h history, * valid, > best, = multipath,*

i internal, r RIB-failure, S Stale, R Removed

Origin codes: i - IGP, e - EGP, ? - incomplete

Network	*Next Hop*	*Metric*	*LocPrf*	*Weight*	*Path*
> 10.200.1.1/32	*swp1*	*0*		*0*	*65021 i*
> 10.200.1.2/32	*swp2*	*0*		*0*	*65022 i*
> 10.200.1.201/32	*0.0.0.0*	*0*		*32768*	*i*
*> **200.0.0.1/32***	*swp1*			*0*	*65021 i*
*> **200.0.0.2/32***	*swp1*			*0*	*65021 i*

2. Verify that DC1 and DC2 have connectivity once the DCI switch is programmed with data flows.

   a. Start **ofagentapp** on the DCI switch.
   root@localhost:/usr/bin/ofdpa# ***./launcher ofagentapp -t 10.62.2.24:6633&***

   b. Create ***seg-routing-network-cfg.json*** file which contain the following:
   roger@milpitas:~/opt$ ***cat seg-routing-network-cfg.json***

```
{
    "ports" : {
        "of:000000000000da7a/51" : {
            "interfaces" : [
                {
                    "ips" : [ "192.168.1.254/24" ],
                    "vlan-untagged": 10
                }
            ]
```

```
        },
        "of:000000000000da7a/52" : {
            "interfaces" : [
                {
                    "ips" : [ "192.168.1.254/24" ],
                    "vlan-untagged": 10
                }
            ]
        }
    },
    "devices" : {
        "of:000000000000da7a" : {
            "segmentrouting" : {
                "name" : "AG7648-31-DCI",
                "ipv4NodeSid" : 101,
                "ipv4Loopback" : "10.220.1.201",
                "routerMac" : "00:18:23:30:d7:fa",
                "isEdgeRouter" : false,
                "adjacencySids" : []
            },
            "basic" : {
                "driver" : "ofdpa3"
            }
        }
    },
    "hosts" : {
        "00:18:23:30:e6:2f/-1" : {
            "basic": {
              "ips": ["192.168.1.1"],
              "locations": ["of:000000000000da7a/51"]
            }
        },
```

```
        "00:18:23:30:e5:77/-1" : {
            "basic": {
                "ips": ["192.168.1.2"],
                "locations": ["of:000000000000da7a/52"]
            }
        }
    }
}
```

c. Install and then start the ONOS controller.

roger@milpitas:~/opt$ ***ls***
onos-1.12.0.tar.gz
seg-routing-network-cfg.json

roger@milpitas:~/opt$ ***sudo tar -zxf onos-1.12.0.tar.gz***
roger@milpitas:~/opt$ ***sudo mv onos-1.12.0 onos***
roger@milpitas:~/opt$ ***sudo mkdir onos/config***
roger@milpitas:~/opt$ ***sudo cp seg-routing-network-cfg.json onos/config/network-cfg.json***
roger@milpitas:~/opt$ ***cd***
roger@milpitas:~$ ***sudo ./opt/onos/bin/onos-service start***
Welcome to Open Network Operating System (ONOS)!

```
    ____  _  _______  ____
   / __ \/ |/ / __ \/ __/
  / /_/ /    / /_/ /\ \
  \____/_/|_/\____/___/
```

Documentation: wiki.onosproject.org
Tutorials: tutorials.onosproject.org
Mailing lists: lists.onosproject.org

Come help out! Find out how at: contribute.onosproject.org

Hit '<tab>' for a list of available commands
and '[cmd] --help' for help on a specific command.
Hit '<ctrl-d>' or type 'system:shutdown' or 'logout' to shutdown ONOS.

onos>

d. Activate the following applications:
OpenFlow Provider Suite
Network Config Host Provider
Segment Routing

onos> ***app activate org.onosproject.openflow***
Activated org.onosproject.openflow
onos> ***app activate org.onosproject.netcfghostprovider***
Activated org.onosproject.netcfghostprovider
onos> ***app activate org.onosproject.segmentrouting***
Activated org.onosproject.segmentrouting
onos>

e. Display the active applications.

onos> ***apps -s -a***

```
*   6 org.onosproject.route-service          1.12.0    Route Service Server
*  20 org.onosproject.drivers                1.12.0    Default Drivers
*  48 org.onosproject.optical-model          1.12.0    Optical Network Model
*  51 org.onosproject.openflow-base          1.12.0    OpenFlow Base Provider
*  52 org.onosproject.lldpprovider           1.12.0    LLDP Link Provider
*  53 org.onosproject.hostprovider           1.12.0    Host Location Provider
*  61 org.onosproject.netcfghostprovider     1.12.0    Network Config Host Provider
* 127 org.onosproject.segmentrouting         1.12.0    Segment Routing
* 133 org.onosproject.openflow               1.12.0    OpenFlow Provider Suite
onos>
```

f. BGP routes from DC2 are propagated to LEAF1-2.

roger@AG7648-39-LEAF1-2:~$ ***sudo net show bgp***

show bgp ipv4 unicast

==========

BGP table version is 1334, local router ID is 10.100.1.2

*Status codes: s suppressed, d damped, h history, * valid, > best, = multipath,*

i internal, r RIB-failure, S Stale, R Removed

Origin codes: i - IGP, e - EGP, ? - incomplete

Network	*Next Hop*	*Metric*	*LocPrf*	*Weight*	*Path*
*> 10.100.1.1/32	*swp49*			*0*	*65111 65011 i*
*> 10.100.1.2/32	*0.0.0.0*	*0*		*32768*	*i*
*> 10.100.1.201/32	*swp49*	*0*		*0*	*65111 i*
*> ***10.200.1.1/32***	*swp49*			*0*	*65111 65221 65021 i*
*> ***10.200.1.2/32***	*swp49*			*0*	*65111 65221 65022 i*
*> ***10.200.1.201/32***	*swp49*			*0*	*65111 65221 i*
*> 100.0.0.1/32	*swp49*			*0*	*65111 65011 i*
*> 100.0.0.2/32	*swp49*			*0*	*65111 65011 i*
*> ***200.0.0.1/32***	*swp49*			*0*	*65111 65221 65021 i*
*> ***200.0.0.2/32***	*swp49*			*0*	*65111 65221 65021 i*

g. BGP routes from DC1 are propagated to LEAF2-2.

roger@AG7648-40-LEAF2-2:~$ ***sudo net show bgp***

show bgp ipv4 unicast

==========

BGP table version is 1290, local router ID is 10.200.1.2

*Status codes: s suppressed, d damped, h history, * valid, > best, = multipath,*

i internal, r RIB-failure, S Stale, R Removed

Origin codes: i - IGP, e - EGP, ? - incomplete

Network	Next Hop	Metric	LocPrf	Weight	Path
*> **10.100.1.1/32**	swp49			0	65221 65111 65011 i
*> **10.100.1.2/32**	swp49			0	65221 65111 65012 i
*> 10.100.1.201/32	swp49			0	65221 65111 i
*> 10.200.1.1/32	swp49			0	65221 65021 i
*> 10.200.1.2/32	0.0.0.0	0		32768	i
*> 10.200.1.201/32	swp49	0		0	65221 i
*> **100.0.0.1/32**	swp49			0	65221 65111 65011 i
*> **100.0.0.2/32**	swp49			0	65221 65111 65011 i
*> 200.0.0.1/32	swp49			0	65221 65021 i
*> 200.0.0.2/32	swp49			0	65221 65021 i

h. Pings work across DC1 and DC2.

```
roger@AG7648-39-LEAF1-2:~$ ping 200.0.0.1
PING 200.0.0.1 (200.0.0.1) 56(84) bytes of data.
64 bytes from 200.0.0.1: icmp_seq=1 ttl=61 time=0.225 ms
64 bytes from 200.0.0.1: icmp_seq=2 ttl=61 time=0.186 ms
64 bytes from 200.0.0.1: icmp_seq=3 ttl=61 time=0.198 ms
^C
--- 200.0.0.1 ping statistics ---
3 packets transmitted, 3 received, 0% packet loss, time 2000ms
rtt min/avg/max/mdev = 0.186/0.203/0.225/0.016 ms
roger@AG7648-39-LEAF1-2:~$
```