Cisco Evolved Programmable Network Implementation Guide for Small Network with End-to-End Segment Routing, Release 5.0

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CONTENTS

CHAPTER 1

Overview

This chapter contains the following sections:

Cisco Evolved Programmable Network

Cisco Evolved Programmable Network (EPN) is built on the successful Cisco EPN architecture framework, to bring greater programmability and automation. The Cisco EPN system design follows a layered design to simplify the end-to-end transport and service architecture. By decoupling the transport and service infrastructure layers of the network, it allows these two distinct entities to be provisioned and managed independently. The Cisco EPN allows programmatic interaction between the service and transport layers.

This guide explains how a part of the lab network is pertinent to a small network end-to-end segment routing deployment model.

Related Documentation

To explore the transport design, service design, reference Network Service Orchestrator (NSO) user guide and reference system test topology of Cisco EPN, you can refer to the guides given below:

- Transport Design Guide
- Services Design Guide
- Network Service Orchestrator User Guide
- System Test Topology Reference Guide

In addition to the Small Network with End-to-End Segment Routing deployment model, the Cisco EPN can be implemented with one of the following deployment models:

- Large Network - End to End Segment Routing

- Large Network - End to End Programmable Segment Routing
- Large Network - Inter-AS End to End Segment Routing
- Large Network - Segment Routing and LDP Interworking
- Large Network - Layer2 Access to Segment Routing Transport

Small Network with End-to-End Segment Routing

The small network with end-to-end segment routing deployment model is applicable to geographies where core and preaggregation or aggregation domains consist of nodes less than thousand and does not have a distinct physical topology. It is designed such that:

- Segmentation does not become unpractical.
- Single IGP domain is formed by the integration of core, aggregation, and pre-aggregation nodes.

In the Cisco EPN, the integrated domain is represented by a core network with directly connected access domains. Each access domain consists of an independent IGP enabled with SR. The domains are integrated end-to-end through BGP Label unicast, or RFC3107.

Applicable Services

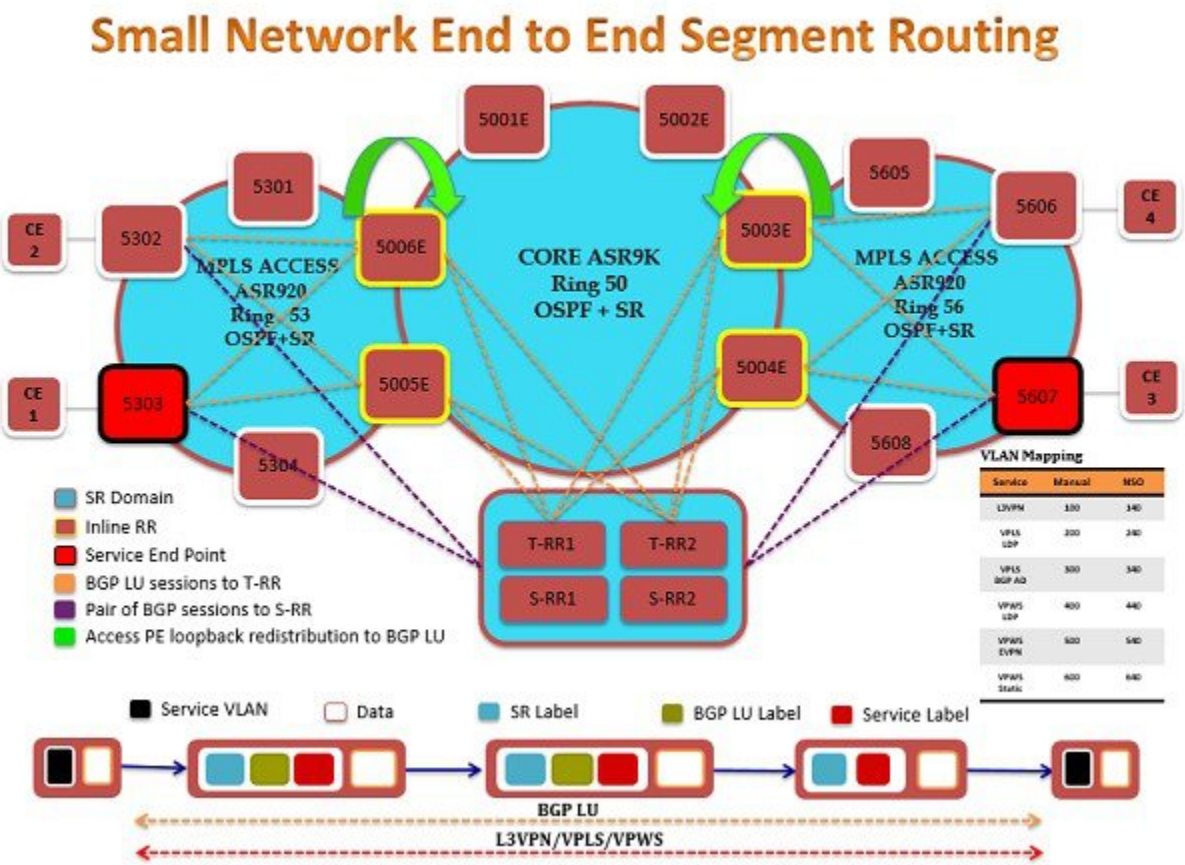
You can deploy the following services through network service orchestrator (NSO) and manual command line interface (CLI) configurations.

- Label Distribution Protocol (LDP) based virtual private wire service (VPWS).
- Ethernet Virtual Private Network (EVPN) based VPWS.
- Static VPWS.
- LDP based virtual private LAN service (VPLS).
- VPLS using BGP auto-discovery (BGP-AD).
- Layer-3 virtual private network (VPN) service.

Network Topology

The figure shown below depicts the network topology used to validate all the services addressed in this deployment model.

Figure 1: Small Network End-to-End Segment Routing



This network consists of two access domains such as Ring 53 and Ring 56, which are connected to a core domain such as Ring 50 in an intra-AS scenario (AS#200). All domains run OSPF with segment routing, to exchange the internal routes and labels. All the domains are integrated through BGP label unicast, to enable the end-to-end distribution of service edge node addresses and their associated labels. To assist in the distribution, two dedicated transport route reflectors (T-RR1 and T-RR2) are implemented in the core, while enabling the inline route reflector functions on the inter-domain aggregation nodes (5005E, 5006E, 5003E, and 5004E). The inline route reflectors are configured to override the next-hop address of the advertised routes with their local address, to allow forwarding towards those destinations within each domain.

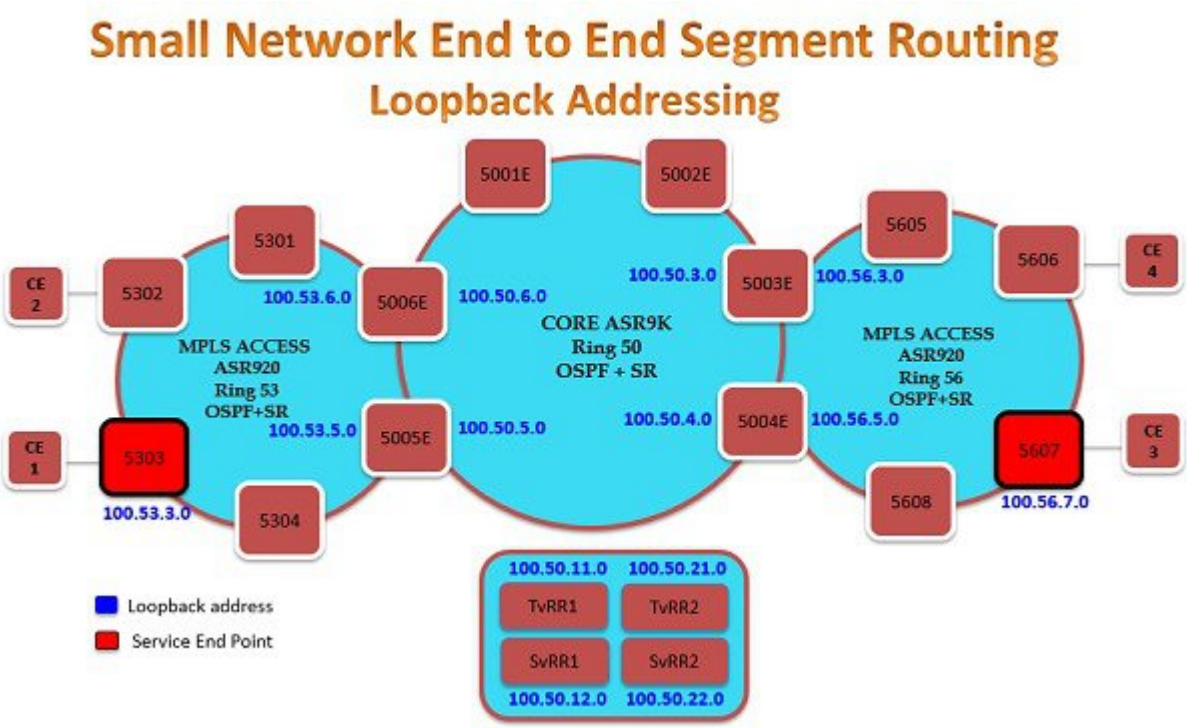
All services are configured between node 5303 on Ring 53 and node 5607 on Ring 56. Both nodes are Cisco ASR920 devices.

For all services, the subscriber UNI is always a 802.1q interface. The customer VLAN (C-VLAN) mapping for various services is provided on the mapping table given in the figure shown above. Different VLANs are used for the services provisioned using CLI and NSO.

For applicable services, the customer routes are distributed site-to-site through two centralized service route reflectors (S-RR1 and S-RR2) that peer directly with the service edge nodes for example, node 5303 and node 5607.

For better understanding of the configuration, see the figure shown below with the loopback addresses of all the nodes in the topology.

Figure 2: Small Network End-to-End Segment Routing—Loopback Addressing



CHAPTER 2

Transport Configuration

This chapter contains the following sections:

Device Roles

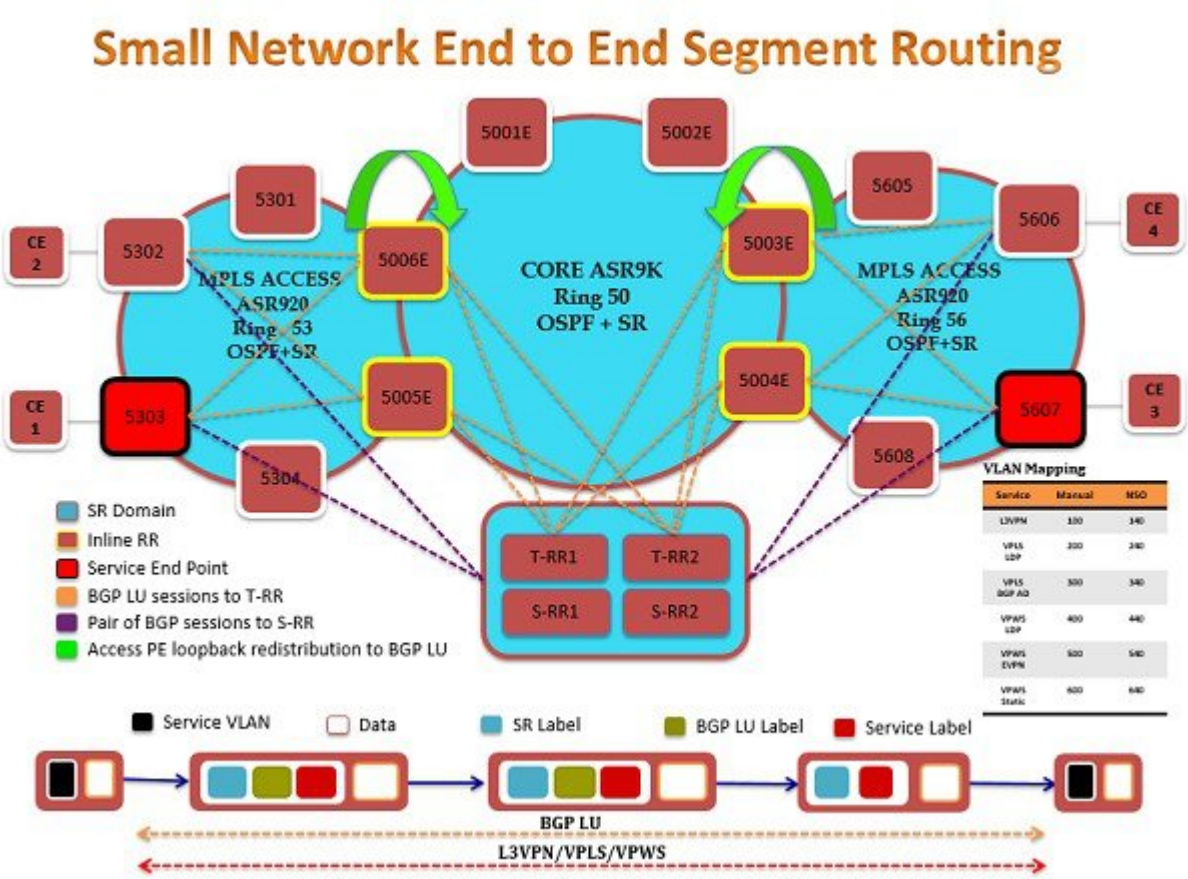
Each deployment model has various device roles such as access provider edge (PE), aggregation PE, core PE, route reflector, and so on. In the following section, the transport configuration pertinent to small network end-to-end segment routing model is captured. Multiple nodes can exist for a particular device role. But as part of this section, the sample transport configuration for a single node is captured.

Core Node Configuration

All core network nodes are either ASR9000 or NCS6000 devices.

In the figure shown below, the core node 5001E is configured for data collection. Similarly, the core node 5002E can be configured for data collection.

Figure 3: Small Network End-to-End Segment Routing



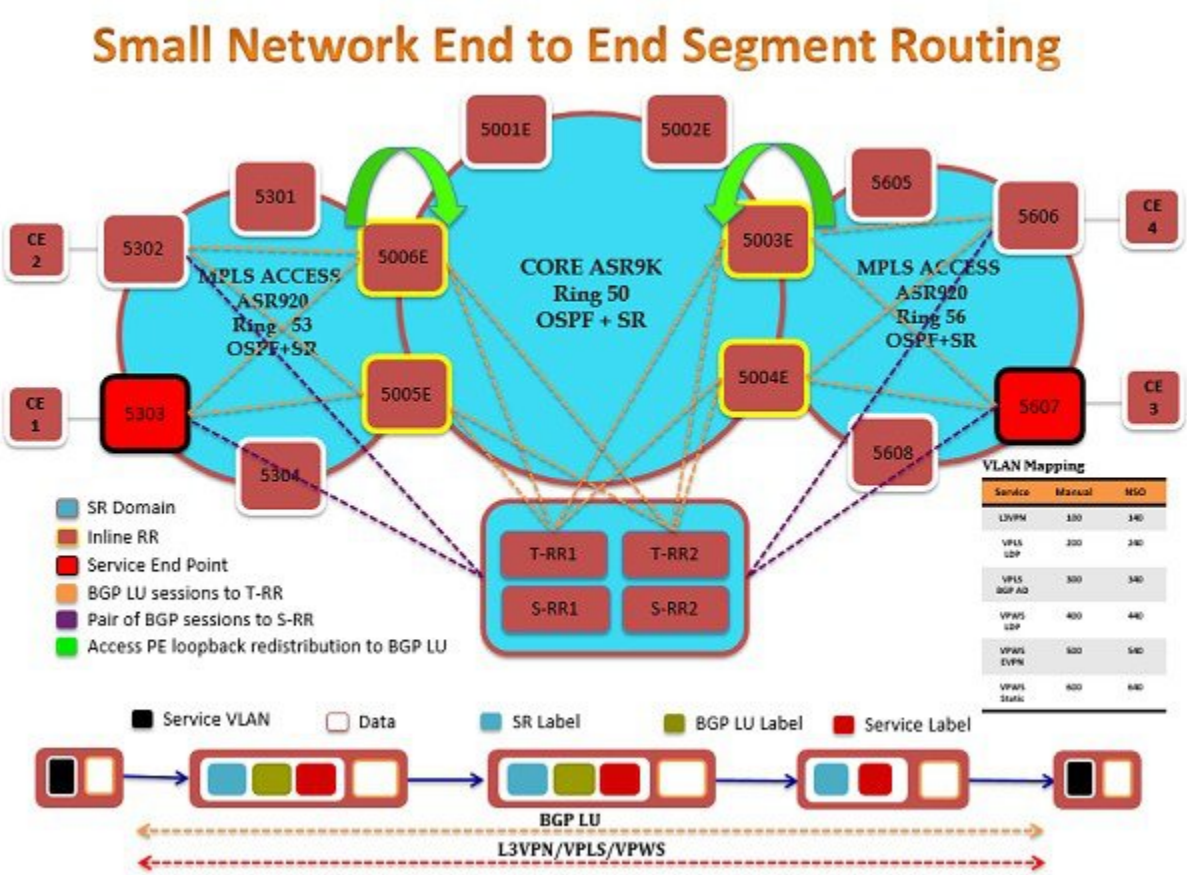
The core nodes are running IGP, for example, OSPF, with segment routing, and topology independent loop-free alternate (TI-LFA) for faster convergence.

```
segment-routing
  global-block 16000 32000

router ospf ring50
 router-id 10.50.1.10
 segment-routing mpls
 segment-routing forwarding mpls
 address-family ipv4 unicast
 area 0
  interface Bundle-Ether21
   bfd minimum-interval 15
   bfd fast-detect
   bfd multiplier 3
   fast re-route per-prefix
   fast-reroute per-prefix ti-lfa enable
  !
  interface Loopback50
   passive enable
   prefix-sid index 5001
 !
```

Inter-domain Aggregation Node Configuration

All inter-domain aggregation nodes are ASR9000 devices. These nodes act as inline route reflectors. In the figure shown below, the inter-domain aggregation node 5005E is configured for data collection. Similarly, the inter-domain aggregation node 5003E, 5004E and 5006E can be configured for data collection.

Figure 4: Small Network End-to-End Segment Routing



The aggregation nodes are running separate IGP, for example, OSPF instances for the core and access domains. The BGP is configured to perform inter-domain routing.

Core IGP Instance Configuration

Two separate IGP instances are configured on the aggregation nodes towards the core and access domains. The segment routing and TI-LFA are enabled for both the instances. The IGP can be OSPF.

```
segment_routing
 global-block 16000 32000

router ospf ring50
 log adjacency changes detail
```

```
 router-id 10.50.5.0
 segment-routing mpls
 segment-routing forwarding mpls
 address-family ipv4 unicast
 area 0
  interface Bundle-Ether43
   bfd minimum-interval 15
   bfd fast-detect
   bfd multiplier 3
   fast-reroute per-prefix
   fast-reroute per-prefix ti-lfa enable
!
  interface Loopback50
   passive enable 50
   prefix-sid index 5005
```

Access Facing IGP Instance Configuration

The access facing IGP instance configured on the aggregation nodes is different from the core IGP instance. The IGP can be OSPF.

```
router ospf ring53
 router-id 10.53.5.0
 segment-routing mpls
 segment-routing forwarding mpls
 address-familiy ipv4 unicast
 area 0
  interface Loopback53
   passive enable
   prefix-sid index 5305
  !
  interface TenGigE0/0/0/19
   bfd minimum-interval 15
   bfd fast-detect
   bfd-multiplier 3
   fast-reroute per-prefix
   fast-reroute per-prefix ti-lfa enable
```

BGP Configuration for Interdomain Routing

BGP labeled unicast neighborship towards transport route reflectors

```
router bgp 200
 bgp router-id 100.50.5.0
 neighbor-group T-RR
  remote-as 200
  update-source Loopback50
 address-family ipv4 labeled-unicast
  next-hop-self
 !
 !
 neighbor 100.50.11.0
  use neighbor-group T-RR
  description Towards T-RR1
 !
 neighbor 100.50.21.0
  use neighbor-group T-RR
 description Towards T-RR2
 !
```

BGP labeled unicast neighborship towards access provider edge nodes

```
router bgp 200
 bgp router-id 100.50.5.0
 neighbor-group Ring53-RRC
```

```
  remote-as 200
 update-source Loopback53
 address-family ipv4 labeled-unicast
  route-reflector-client
 next-hop-self
 !
 neighbor 100.53.2.0
  use neighbor-group Ring53-RRC
  description Ring53 RR-client
 !
 neighbor 100.53.3.0
  use neighbor-group Ring53-RRC
  description Ring53 RR-client
```

BGP Prefix Independent Convergence (PIC) Configuration

BGP PIC configuration provides node redundancy for inter-domain aggregation nodes that act as inline route reflectors.

```
router bgp 200
 bgp router-id 10.50.5.0
 address-family ipv4 unicast
  additional-paths receive
  additional-paths send
  additional-paths selection route-policy ADDPATH

route-policy ADDPATH
  set path-selection backup 1 install multipath-protect advertise
end policy
```

Redistribute access provider edge loopback to BGP

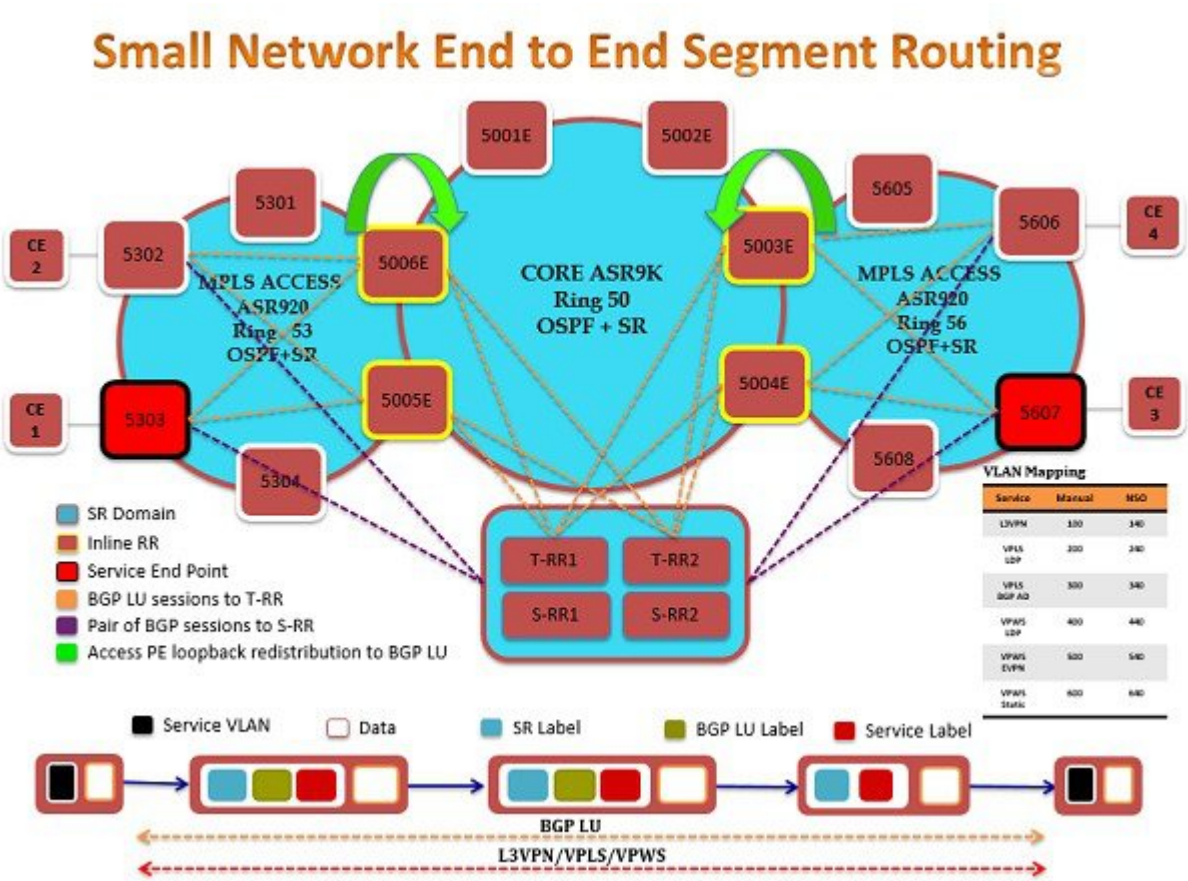
```
router bgp 200
 nsr
 bgp router-id 10.50.5.0
 bgp cluster-id 50
 bgp graceful-restart
 ibgp policy out enforce-modifications
 address-family ipv4 unicast
  redistribute opsf ring53 route-policy ring53-loopbacks
  allocate-label all

route-policy ring53_loopbacks
  if destination in (10.53.3.0/32, 10.53.2.0/32) then
    pass
  end if
end policy
```

Transport Route Reflector Configuration

This network model has a pair of transport route reflectors namely T-RR1 and T-RR2, which are deployed to advertise and learn the loopbacks of the service route reflectors and service provider edge. All transport route reflector nodes are ASR9001 devices. Here, the transport route reflector T-RR1 is configured for data

collection. Similarly, the transport route reflector T-RR2 can be configured for data collection. The figure shown below depicts the network topology.

Figure 5: Small Network End-to-End Segment Routing



Core IGP Configuration for Transport Route Reflector

The core IGP can be OSPF and is configured with segment routing and topology-independent loop-free alternate (TI-LFA).

```
router ospf ring50
 segment-routing mpls
 segment-routing forwarding mpls
 address-family ipv4 unicast
 area 0
  interface loopback50
   passive enable
   prefix-sid index 5011
 !
  interface GigabitEthernet0/0/0/0
   bfd minimum-interval 50
   bfd multiplier 3
   fast re-reoute per prefix
   fast re-reoute per prefix ti-lfa enable
  !
segment-routing
```

```
 global-block 16000 23999
!
```

BGP Configuration for Transport Route Reflector

BGP LU neighborship to S-RRs and Aggregation PEs

The topology shows the BGP LU neighborship to service RRs and all the aggregation routers like 5005E, 5006E, 5003E and 5004E.

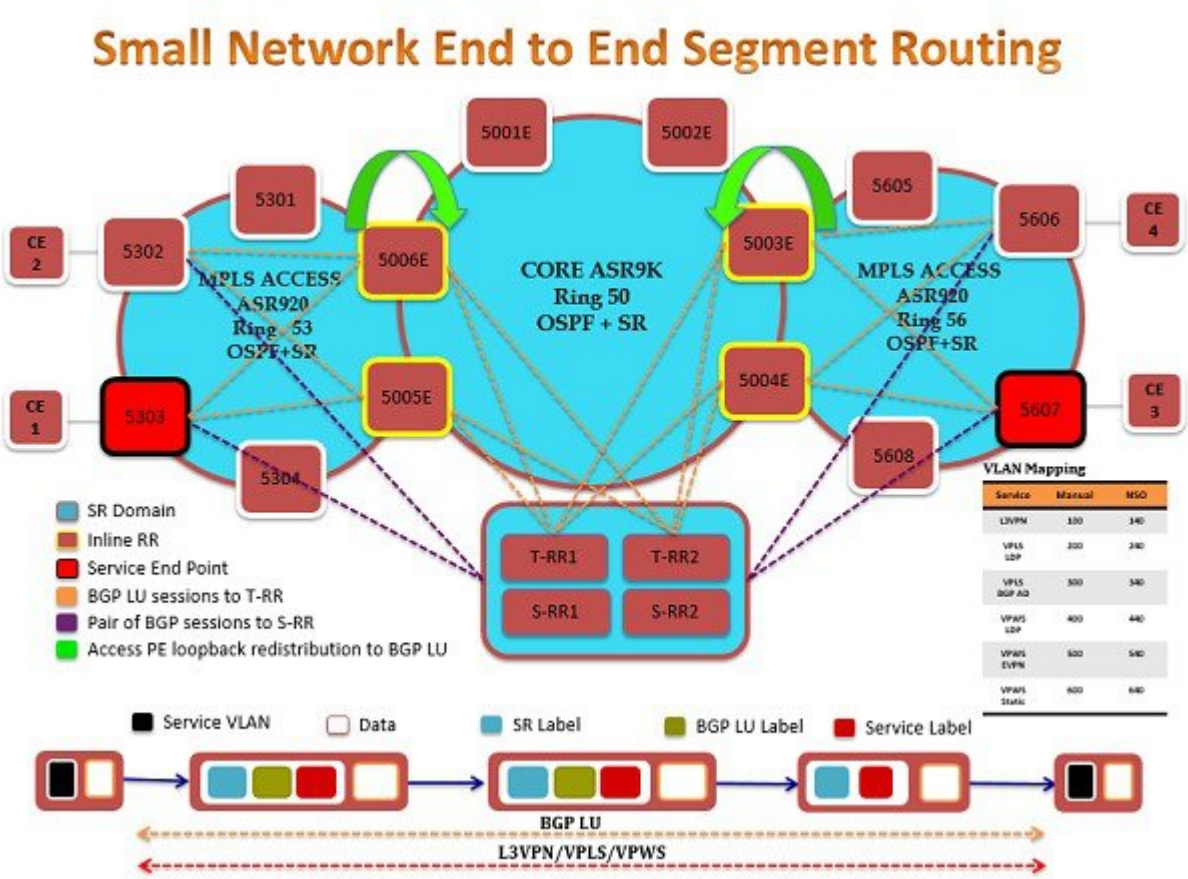
```
 router bgp 200
nsr
 bgp router-id 10.50.11.0
 bgp graceful-restart
 ibgp policy out enforce-modifications
 address-family ipv4 unicast
  additional-paths receive
  additional-paths send
  additional-paths selection route-policy ADDPATH
  allocate-label all
 !
 neighbor-group RR-Client
  remote-as 200
  update-source loopback50
  address-family ipv4 labeled-unicast
   route-reflector-client
 !
 neighbor 10.50.3.0
  use neighbor-group RR-Client
  description 5003E
 !
 neighbor 10.50.4.0
  use neighbor-group RR-Client
  description 5004E
!
 neighbor 10.50.5.0
  use neighbor-group RR-Client
  description 5005E
!
 neighbor 10.50.6.0
 use neighbor-group RR-Client
 description 5006E
!
 neighbor 10.50.12.0
  use neighbor-group RR-Client
  description SvRR1
!
!
neighbor 10.50.22.0
  use neighbor-group RR-Client
  description SvRR2
!
 route-policy ADDPATH
  set path-selection all advertise
end-policy
```

Service Route Reflector Configuration

This network model has a pair of service route reflectors namely S-RR1 and S-RR2, for redundancy purposes. All service route reflector nodes are ASR9001 devices. The service route reflectors are deployed to exchange customer service routes such as vpnv4, vpnv6 and l2vpn among the service end point nodes. In this section,

the node S-RR1 is configured for data collection. Similarly, the node S-RR2 can be configured for data collection. The figure shown below depicts the network topology.

Figure 6: Small Network End-to-End Segment Routing



Core IGP Configuration for Service Route Reflector

The core IGP is configured with segment routing and TI LFA. The IGP can be OSPF.

```
router ospf ring50
 segment-routing mpls
 segment-routing forwarding mpls
 address-family ipv4 unicast
 area 0
 interface loopback50
 passive enable
 prefix-sid index 5012
 !
 interface GigabitEthernet0/0/0/0
   bfd minimum-interval 50
   bfd fast-detect
   bfd multiplier 3
   fast-reroute per-prefix
   fast-reroute per-prefix ti-lfa enable
!
segment-routing
```

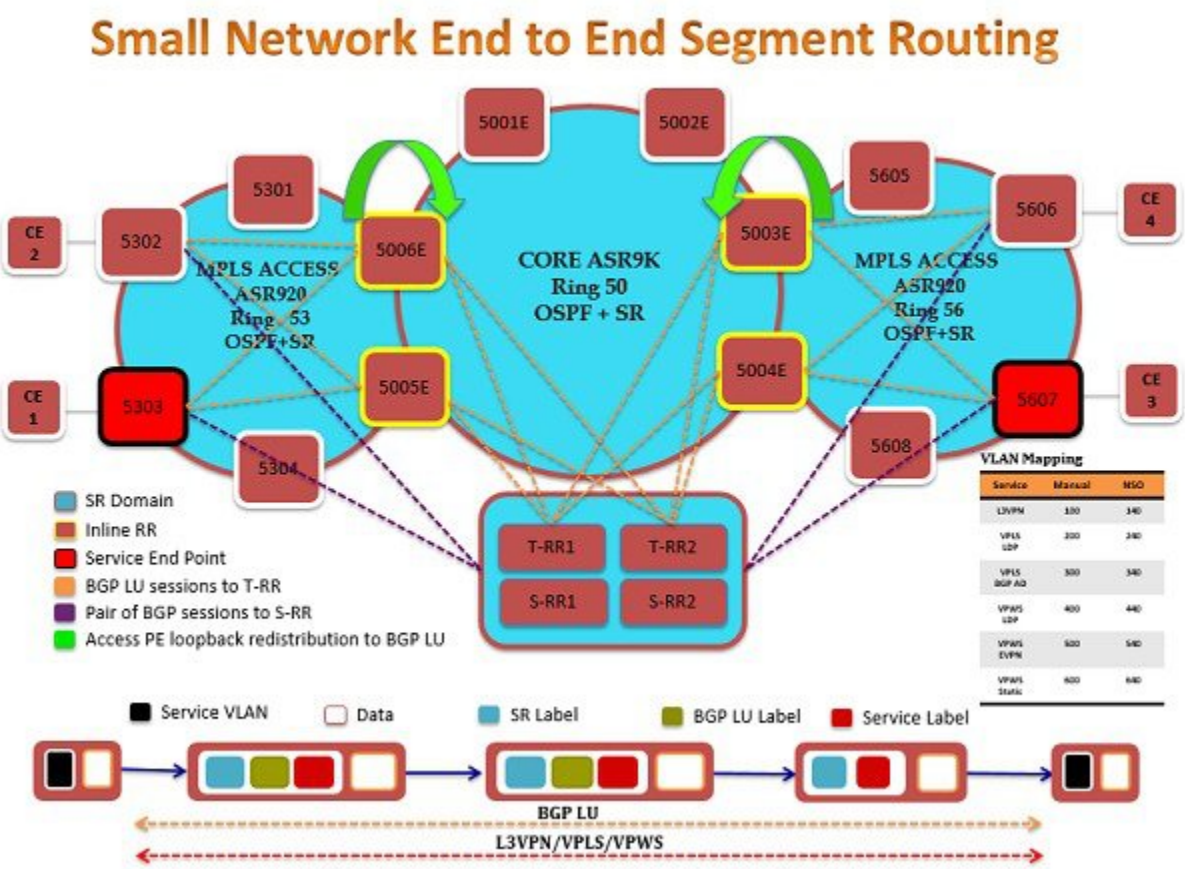
```
global-block 16000 23999
!
```

BGP Configuration for Service Route Reflector

BGP LU neighborship to T-RR

The service route reflector S-RR1 will have a BGP LU neighborship towards transport route reflector RR1, to learn the service end point nodes loopback. For redundancy, the service route reflector S-RR2 will peer with transport route reflector T-RR2 as shown in the below figure.

Figure 7: Small Network End-to-End Segment Routing



Here, the S-RR1 configuration is only listed for reference.

```
router bgp 200
 bgp router-id 100.50.12.0
 address-family ipv4 unicast
  additional-paths receive
  additional-paths send
  additional-paths selection route-policy ADDPATH
  allocate-label all
 !
 neighbor-group T-RR
  remote-as 200
  update-source Loopback50
```

```
  address-family ipv4 labeled-unicast
 !
 neighbor 100.50.11.0
  use neighbor-group T-RR
  description Transport T-RR1
 !
 neighbor 100.50.21.0
  use neighbor-group T-RR
  description Transport T-RR2
```

BGP neighborship to all service end point nodes

```
router bgp 200
 bgp router-id 10.50.12.0
 address-family vpnv4 unicast
  retain route-target all
!
address-family l2vpn vpls-vpws
 retain route-target all
!
address-family l2vpn evpn
 retain route-target all
!
neighbor-group S-RR
 remote-as 200
 update-source Loopback50
 address-family vpnv4 unicast
  route-reflector-client
!
address-family l2vpn vpls-vpws
 route-reflector-client
!
address-family l2vpn vpls-vpws
 route-reflector-client
!
address-family l2vpn evpn
 route-reflector-client
!
neighbor 10.53.2.0
 use neighbor-group S-RR
 description Ring53-Node2
!
neighbor 10.53.3.0
 use neighbor-group S-RR
 description Ring53-Node3
!
neighbor 10.56.6.0
 use neighbor-group S-RR
 description Ring56-Node6
!
neighbor 10.56.7.0
 use neighbor-group S-RR
 description Ring56-Node7
!
```

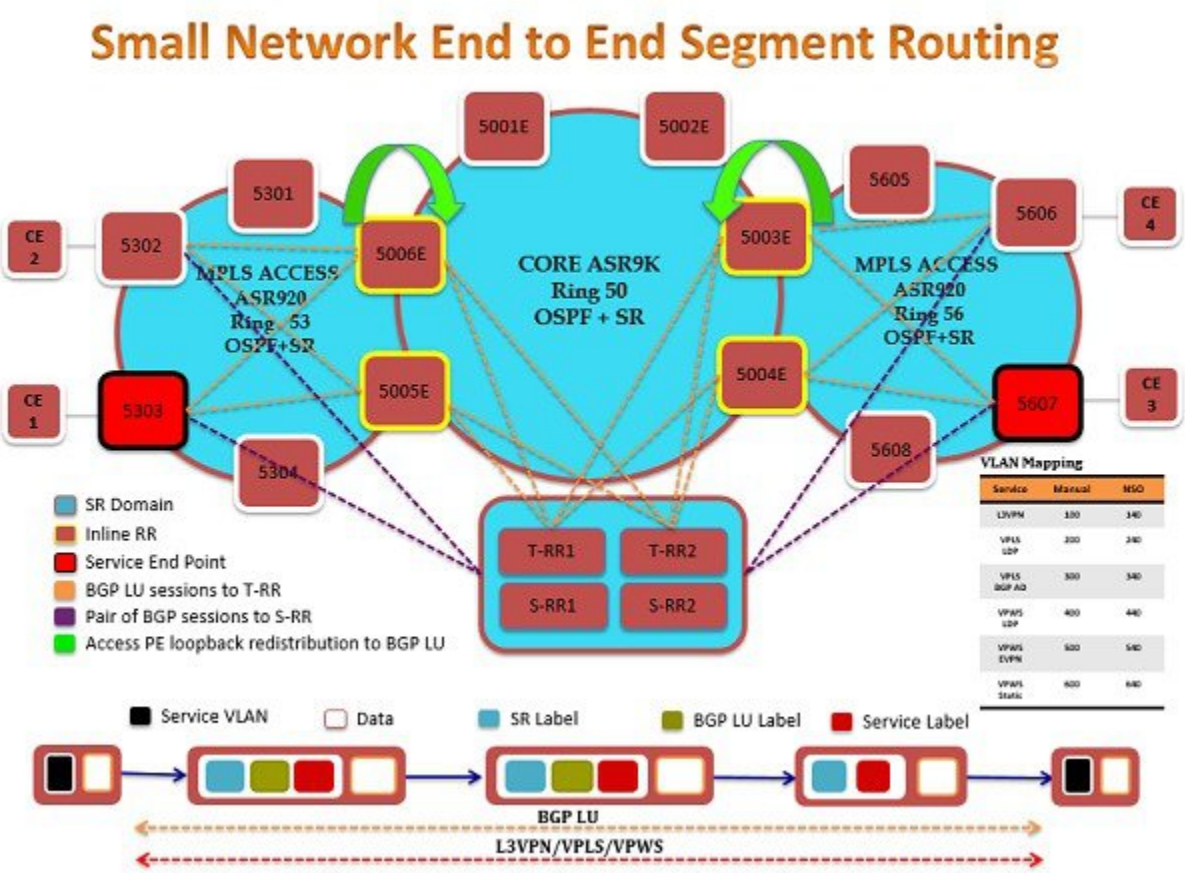
Advertise service RR loopbacks into BGP with prefix SID

```
router bgp 200
address-family ipv4 unicast
  network 10.50.12.0/32 route-policy SET-SID(5012)
  allocate-label all
!
route-policy SET-SID($SID)
  set label-index $SID
end-policy
```

Access Provider Edge Configuration

Multiple nodes act as access provider edge (PE) in Ring 53 and Ring 56 depicted in the network topology diagram as shown below.

Figure 8: Small Network End-to-End Segment Routing



Here, the configuration data is collected from node 5303 of the Ring 53. Similarly, the configuration is available for other access PE nodes.

IGP Configuration for Access Provider Edge

Each ring has its own IGP domain. The IGP can be OSPF and is enabled with segment routing. The IGP configuration for access PE is given below:

```
router ospf 53
 router-id 100.53.3.0
 segment-routing area 0 mpls
 segment-routing mpls
 segment-routing prefix-sid-map advertise-local

segment-routing mpls
```

```
 global-block 16000 32000
 !
 connected-prefix-sid-map
  address-family ipv4
   100.53.3.0/32 index 5303 range 1
  exit-address-family
```

BGP Configuration for Access Provider Edge

The access PE has BGP LU neighborship towards the aggregation nodes which act as inline route reflector with ingress prefix filter. The prefix list is configured to permit only the loopback of the service route reflector's and other service PE's.

As part of the transport configuration, the prefix list is permitted to enable the loopback of both the service route reflectors.

As part of the service configuration, the prefix list is modified by NSO, to permit the loopback of only those access PE's to which the service is being provisioned.

Similarly, if a particular service is unprovisioned, the prefix list is modified by NSO to remove the pertinent access PE's loopback.

```
router bgp 200
 bgp router-id 10.53.3.0
 neighbor Ring53-RR peer-group
 neighbor Ring53-RR remote-as 200
 neighbor Ring53-RR update-source Loopback53
 neighbor 10.53.5.0 peer-group Ring53-RR
 neighbor 10.53.6.0 peer-group Ring53-RR
 !
 address-family ipv4
  neighbor Ring53-RR send-community
  neighbor Ring53-RR prefix-list BGP-Prefix-Filter in
  neighbor Ring53-RR send-label
  neighbor 10.53.5.0 activate
  neighbor 10.53.6.0 activate
 exit-address-family
 !
ip prefix-list BGP-Prefix-Filter seq 1 permit 10.50.12.0/32
ip prefix-list BGP-Prefix-Filter seq 2 permit 10.50.22.0/32
ip prefix-list BGP-Prefix-Filter seq 3 permit 10.56.6.0/32
ip prefix-list BGP-Prefix-Filter seq 4 permit 10.56.7.0/32
```

In access PE, the BGP PIC configuration is also enabled to achieve the aggregation node redundancy.

BGP PIC configuration

```
 router bgp 200
  bgp router-id 10.53.3.0
  address-family ipv4
   bgp additional-paths select backup
   bgp additional-paths install
```

Multiprotocol Label Switching Configuration

The Multiprotocol Label Switching (MPLS) configuration is given below:

This configuration is needed for LDP based L2VPN service.

```
mpls label range 6000 32767 static 100 5999
mpls ldp discovery targeted-hello accept
mpls ldp router-id Loopback53 force
```

CHAPTER 3

Service Configuration

This chapter contains the following sections:

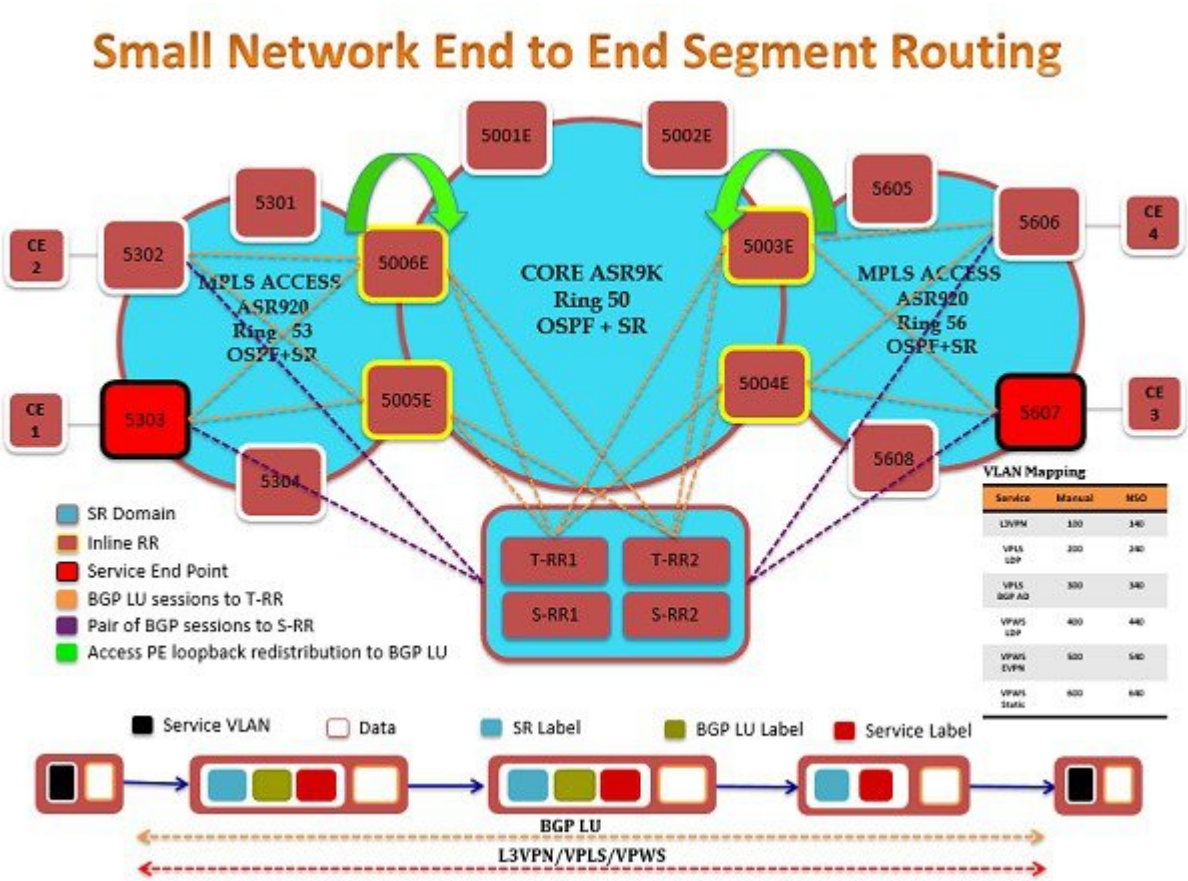
Configuration Settings

In this chapter, the configuration details for all the applicable services of small network end-to-end segment routing deployment model are captured. The configuration can be achieved through traditional CLI method or orchestrated by Cisco NSO with Yet Another Next Generation (YANG) configuration models.

All the access PE's for a particular service have configuration similar to what is captured in this chapter.

Here, only the configuration data from a single access PE 5303 is given. The services are established between access PE 5303 from Ring 53 and access PE 5607 from Ring 56 depicted in the figure below:

Figure 9: Small Network End-to-End Segment Routing



Label Distribution Protocol Based Virtual Private Wire Service

The configuration for LDP—VPWS is given below:

```
interface GigabitEthernet0/0/2
   service instance 400 ethernet MAN_UC1_VPWS_53N3_56N7
      encapsulation dot1q 400
      rewrite ingress tag pop 1 symmetric
   exit
exit
l2vpn xconnect context MAN_UC1_VPWS_53N3_56N3
  interworking ethernet
     member GigabitEthernet0/0/2 service-instance 400
     member 10.56.7.0 400 encapsulation mpls
```

Permit service end point address in BGP LU ingress prefix filter

```
router bgp 200
 address-family ipv4
```

```
  neighbor Ring53-RR prefix-list BGP-Prefix-Filter in
ip prefix-list BGP-Prefix-Filter seq 4 permit 10.56.7.0/32
```

Static Virtual Private Wire Service

The configuration for static VPWS is given below:

```
int gigabitEthernet 0/0/2
  service instance 600 ethernet MAN_UC1_STATIC_VPWS_53N3_56N7
  encapsulation dot1q 600
    xconnect 10.56.7.0 567533101 encapsulation mpls manual
     mpls label 5331 5671
     mpls control-word
```

Permit service end point address in BGP LU ingress prefix filter

```
router bgp 200
 address-family ipv4
  neighbor Ring53-RR prefix-list BGP-Prefix-Filter in
ip prefix-list BGP-Prefix-Filter seq 4 permit 10.56.7.0/32
```

Ethernet VPN based Virtual Private Wire Service

The configuration for Ethernet VPN based VPWS is given below:

```
l2vpn evpn instance 500 point-to-point
!
vpws context MAN_UCI_VPWS_EVPN_R53_3_R56_ 3-1
 service target 500 source 500
 member GigabitEthernet0/0/2 service-instance 500

interface GigabitEthernet0/0/2
 service instance 500 ethernet
  encapsulaton dotlq 500
  rewrite ingress tag 1 symmetric
```

Permit service end point address in BGP LU ingress prefix filter

```
router bgp 200
 address-family igw4
  neighbor Ring53-RR prefix-list BGP-Prefix-Filter in

ip prefix-list BGP-Prefix-FiIter seq 4 permit 10.56.7.0/32
```

LDP based Virtual Private LAN Service

The configuration for LDP based VPLS is given below:

```
interface GigabitEthernet0/0/2
 mtu 1522
 service instance 200 ethernet MAN_UC1_VPLSLDP_R56_Nx_R53_Nx-l
  encapsulaton dotlq 200
  bridge-domain 200
!
pseudowire-class MAN-PW-CLASS-MPLS
 encapsulaton mpls
 control-word
```

```
l2 vfi MAN_UC1_VPLSLDP_R56_Nx_R53_Nx-l
```

Permit service end point addresses in BGP LU in ingress prefix filter

```
ip prefix-list BGP-Prefix-FiIter seq 3 permit 10.56.6.0/32
ip prefix-list BGP-Prefix-FiIter seq 4 permit 10.56.7.0/32

router bgp 200
 address-family igw4
  neighbor Ring53-RR prefix-list 3GP-Prefix-Filter in
```

Virtual Private LAN Service using BGP Active-Discovery

The configuration for VPLS using BGP active-discovery is given below:

```
int gigabitEthernet 0/0/2
 service instance 300 ethernet
  encapsulation dot1q 300
  rewrite ingress tag pop 1 symmetric
  bridge-domain 300
l2 vfi MAN_UC1_VPLSBGP_R53_Nx_R56_Nx-1 autodiscovery
 vpn id 300
 bridge-domain 300
!
```

Permit service end point address in BGP-LU ingress prefix filter

```
ip prefix-list BGP-Prefix-Filter seq 3 permit 10.56.6.0/32
ip prefix-list BGP-Prefix-Filter seq 4 permit 10.56.7.0/32

router bgp 200
 address-family ipv4
  neighbor Ring53-RR prefix-list BGP-Prefix-Filter in
```

Layer-3 VPN

The configuration for L3 VPN is given below:

```
int gigabitEthernet 0/0/2
 service instance 300 ethernet
  encapsulation dot1q 300
  rewrite ingress tag pop 1 symmetric
  bridge-domain 300
l2 vfi MAN_UC1_VPLSBGP_R53_Nx_R56_Nx-1 autodiscovery
  vpn id 300
  bridge-domain 300
!
```

Permit service end point addresses in BGP LU in ingress prefix filter

```
ip prefix-list BGP-Prefix-Filter seq 3 permit 10.56.6.0/32
ip prefix-list BGP-Prefix-Filter seq 4 permit 10.56.7.0/32
router bgp 200
 address-family ipv4
  neighbor Ring53-RR prefix-list BGP-Prefix-Filter in
```