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

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Overview

This chapter contains the following sections:

- Cisco Evolved Programmable Network, page 1
- Related Documentation, page 1
- Small Network with End-to-End Segment Routing, page 2

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
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
Transport Configuration

This chapter contains the following sections:

- Device Roles, page 5
- Core Node Configuration, page 5
- Inter-domain Aggregation Node Configuration, page 7
- Transport Route Reflector Configuration, page 9
- Service Route Reflector Configuration, page 11
- Access Provider Edge Configuration, page 15

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
```
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-family 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 ospf 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-route per prefix
        fast re-route per prefix ti-lfa enable
    !
    segment-routing
```
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
```

Transport Configuration
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

![Small Network End to End Segment Routing Diagram]

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
```

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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
```
Service Configuration

This chapter contains the following sections:

- Configuration Settings, page 17
- Label Distribution Protocol Based Virtual Private Wire Service, page 18
- Static Virtual Private Wire Service, page 19
- Ethernet VPN based Virtual Private Wire Service, page 19
- LDP based Virtual Private LAN Service, page 19
- Virtual Private LAN Service using BGP Active-Discovery, page 20
- Layer-3 VPN, page 20

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
```
Static Virtual Private Wire Service

The configuration for static VPWS is given below:

```plaintext
int gigabitEthernet 0/0/2
  service instance 600 ethernet MAN_UC1_STATIC_VPWS_53N3_56N7
  encapsulation dot1q 600
  xconnect 10.56.7.0 56753101 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:

```plaintext
l2vpn evpn instance 500 point-to-point
  vpws context MAN_UCI_VPN_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
  encapsulation dot1q 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-Filter seq 4 permit 10.56.7.0/32
```

LDP based Virtual Private LAN Service

The configuration for LDP based VPLS is given below:

```plaintext
interface GigabitEthernet0/0/2
  mtu 1522
  service instance 200 ethernet MAN_UCI_VPLSLDP_R56_Nx_R53_Nx-1
  encapsulation dot1q 200
  bridge-domain 200
  !
  pseudowire-class MAN-PW-CLASS-MPLS
  encapsulation mpls
  control-word
```

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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_VPLSBDP_R56_Nx_R53_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 igw4
    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_VPLSBDP_R56_Nx_R53_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
```