Configure Segment Routing for BGP

Border Gateway Protocol (BGP) is an Exterior Gateway Protocol (EGP) that allows you to create loop-free inter-domain routing between autonomous systems. An autonomous system is a set of routers under a single technical administration. Routers in an autonomous system can use multiple Interior Gateway Protocols (IGPs) to exchange routing information inside the autonomous system and an EGP to route packets outside the autonomous system.

This module provides the configuration information used to enable Segment Routing for BGP.

Note For additional information on implementing BGP on your router, see the *BGP Configuration Guide for Cisco NCS 5000 Series Routers*.

- Segment Routing for BGP, on page 1
- Configure BGP Prefix Segment Identifiers, on page 2
- Segment Routing Egress Peer Engineering, on page 3
- Configure BGP Link-State, on page 5
- Example: Configuring SR-EPE and BGP-LS, on page 6

Segment Routing for BGP

In a traditional BGP-based data center (DC) fabric, packets are forwarded hop-by-hop to each node in the autonomous system. Traffic is directed only along the external BGP (eBGP) multipath ECMP. No traffic engineering is possible.

In an MPLS-based DC fabric, the eBGP sessions between the nodes exchange BGP labeled unicast (BGP-LU) network layer reachability information (NLRI). An MPLS-based DC fabric allows any leaf (top-of-rack or border router) in the fabric to communicate with any other leaf using a single label, which results in higher packet forwarding performance and lower encapsulation overhead than traditional BGP-based DC fabric. However, since each label value might be different for each hop, an MPLS-based DC fabric is more difficult to troubleshoot and more complex to configure.

BGP has been extended to carry segment routing prefix-SID index. BGP-LU helps each node learn BGP prefix SIDs of other leaf nodes and can use ECMP between source and destination. Segment routing for BGP simplifies the configuration, operation, and troubleshooting of the fabric. With segment routing for BGP, you can enable traffic steering capabilities in the data center using a BGP prefix SID.

Configure BGP Prefix Segment Identifiers

Segments associated with a BGP prefix are known as BGP prefix SIDs. The BGP prefix SID is global within a segment routing or BGP domain. It identifies an instruction to forward the packet over the ECMP-aware best-path computed by BGP to the related prefix. The BGP prefix SID is manually configured from the segment routing global block (SRGB) range of labels.

Each BGP speaker must be configured with an SRGB using the **segment-routing global-block** command. See the About the Segment Routing Global Block section for information about the SRGB.

Note Because the values assigned from the range have domain-wide significance, we recommend that all routers within the domain be configured with the same range of values.

To assign a BGP prefix SID, first create a routing policy using the **set label-index** *index* attribute, then associate the index to the node.

Note A routing policy with the **set label-index** attribute can be attached to a network configuration or redistribute configuration. Other routing policy language (RPL) configurations are possible. For more information on routing policies, refer to the "Implementing Routing Policy" chapter in the *Routing Configuration Guide for Cisco NCS 5000 Series Routers*.

Example

The following example shows how to configure the SRGB, create a BGP route policy using a $SID parameter and **set label-index** attribute, and then associate the prefix-SID index to the node.

```
RP/0/RSP0/CPU0:router(config)# segment-routing global-block 16000 23999

RP/0/RSP0/CPU0:router(config)# route-policy SID($SID)
RP/0/RSP0/CPU0:router(config-rpl)# set label-index $SID
RP/0/RSP0/CPU0:router(config-rpl)# end policy

RP/0/RSP0/CPU0:router(config)# router bgp 1
RP/0/RSP0/CPU0:router(config-bgp)# bgp router-id 1.1.1.1
RP/0/RSP0/CPU0:router(config-bgp)# address-family ipv4 unicast
RP/0/RSP0/CPU0:router(config-bgp-af)# network 1.1.1.3/32 route-policy SID(3)
RP/0/RSP0/CPU0:router(config-bgp-af)# allocate-label all
RP/0/RSP0/CPU0:router(config-bgp-af)# commit
RP/0/RSP0/CPU0:router(config-bgp-af)# end


RP/0/RSP0/CPU0:router# show bgp 1.1.1.3/32
BGP routing table entry for 1.1.1.3/32
Versions:
  Process           bRIB/RIB  SendTblVer
  Speaker                 74          74
    Local Label: 16003
Last Modified: Sep 29 19:52:18.155 for 00:07:22
Paths: (1 available, best #1)
  Advertised to update-groups (with more than one peer):
    0.2
```

```
Path #1: Received by speaker 0
Advertised to update-groups (with more than one peer):
  0.2
3
  99.3.21.3 from 99.3.21.3 (1.1.1.3)
    Received Label 3
    Origin IGP, metric 0, localpref 100, valid, external, best, group-best
    Received Path ID 0, Local Path ID 1, version 74
    Origin-AS validity: not-found
    Label Index: 3
```

Segment Routing Egress Peer Engineering

Segment routing egress peer engineering (EPE) uses a controller to instruct an ingress provider edge, or a content source (node) within the segment routing domain, to use a specific egress provider edge (node) and a specific external interface to reach a destination. BGP peer SIDs are used to express source-routed inter-domain paths.

Below are the BGP-EPE peering SID types:

- PeerNode SID—To an eBGP peer. Pops the label and forwards the traffic on any interface to the peer.
- PeerAdjacency SID—To an eBGP peer via interface. Pops the label and forwards the traffic on the related interface.

The controller learns the BGP peer SIDs and the external topology of the egress border router through BGP-LS EPE routes. The controller can program an ingress node to steer traffic to a destination through the egress node and peer node using BGP labeled unicast (BGP-LU).

EPE functionality is only required at the EPE egress border router and the EPE controller.

Configure Segment Routing Egress Peer Engineering

This task explains how to configure segment routing EPE on the EPE egress node.

SUMMARY STEPS

1. **router bgp** *as-number*
2. **neighbor** *ip-address*
3. **remote-as** *as-number*
4. **egress-engineering**

DETAILED STEPS

	Command or Action	Purpose
Step 1	**router bgp** *as-number* **Example:** `RP/0/RSP0/CPU0:router(config)# router bgp 1`	Specifies the BGP AS number and enters the BGP configuration mode, allowing you to configure the BGP routing process.

	Command or Action	Purpose
Step 2	**neighbor** *ip-address* **Example:** `RP/0/RSP0/CPU0:router(config-bgp)# neighbor 192.168.1.3`	Places the router in neighbor configuration mode for BGP routing and configures the neighbor IP address as a BGP peer.
Step 3	**remote-as** *as-number* **Example:** `RP/0/RSP0/CPU0:router(config-bgp-nbr)# remote-as 3`	Creates a neighbor and assigns a remote autonomous system number to it.
Step 4	**egress-engineering** **Example:** `RP/0/RSP0/CPU0:router(config-bgp-nbr)# egress-engineering`	Configures the egress node with EPE for the eBGP peer.

Understanding the ECMP Solution for BGP Labeled Unicast

This section explains the drawbacks of using the destination load balancer (DLB) algorithm for BGP labeled unicast (LU) and provides the premise for introducing the ECMP solution.

Drawbacks of Using the Destination Load Balancer Algorithm

A BGP-based data center fabric uses the DLB algorithm to choose the next-hop based on the destination prefix. As an example, consider a scenario with two provider edge routers: Router PE1 and Router PE2. Router PE1 has multiple paths to Router PE2, but only one path is chosen by the DLB algorithm as the best path. Traffic is sent only along the best path between routers PE1 and PE2, and the remaining paths are used for other destination prefixes.

Hence, if Router PE1 receives too much traffic destined for Router PE2, a single path is overloaded. The path overload leads to imbalance and congestion in the network.

ECMP for BGP LU

From Cisco IOS XR Release 6.3.1 onwards, routers using BGP LU can use ECMP to equally distribute the traffic along all available paths to a chosen destination. BGP uses the 5-tuple address hash for ECMP load balancing.

You can enable either the DLB or ECMP method of load balancing by using the **hw-module** command in global configuration mode.

Note Cisco NCS 5000 Series Routers support the configuration of 8 BGP and 8 IGP paths with ECMP. However, even though the system supports the configuration of 64 (8*8) paths, only 32 paths can be processed at a time with ECMP.

Enabling ECMP for BGP LU

This section explains how you can enable ECMP for BGP LU.

Configuration

Use the following configuration to enable ECMP for BGP LU.

Note You must reload the router after enabling ECMP, else the router may not function as expected.

```
RP/0/RP0/CPU0:router(config)# hw-module loadbalancing bgp-3107 ecmp enable
RP/0/RP0/CPU0:router(config)# commit
RP/0/RP0/CPU0:router(config)# end
RP/0/RP0/CPU0:router(config)# reload
```

You have successfully enabled ECMP for BGP LU.

Configure BGP Link-State

BGP Link-State (LS) is an Address Family Identifier (AFI) and Sub-address Family Identifier (SAFI) defined to carry interior gateway protocol (IGP) link-state database through BGP. BGP LS delivers network topology information to topology servers and Application Layer Traffic Optimization (ALTO) servers. BGP LS allows policy-based control to aggregation, information-hiding, and abstraction. BGP LS supports IS-IS and OSPFv2.

Note IGPs do not use BGP LS data from remote peers. BGP does not download the received BGP LS data to any other component on the router.

For segment routing, the following attributes have been added to BGP LS:

- Node—Segment routing capability (including SRGB range) and algorithm
- Link—Adjacency SID and LAN adjacency SID
- Prefix—Prefix SID and segment routing mapping server (SRMS) prefix range

The following example shows how to exchange link-state information with a BGP neighbor:

```
RP/0/RSP0/CPU0:router# configure
RP/0/RSP0/CPU0:router(config)# router bgp 1
RP/0/RSP0/CPU0:router(config-bgp)# neighbor 10.0.0.2
RP/0/RSP0/CPU0:router(config-bgp-nbr)# remote-as 1
```

```
RP/0/RSP0/CPU0:router(config-bgp-nbr)# address-family link-state link-state
RP/0/RSP0/CPU0:router(config-bgp-nbr-af)# exit
```

IGP Link-State Database Distribution

A given BGP node may have connections to multiple, independent routing domains. IGP link-state database distribution into BGP-LS is supported for both OSPF and IS-IS protocols in order to distribute this information on to controllers or applications that desire to build paths spanning or including these multiple domains.

To distribute IS-IS link-state data using BGP LS, use the **distribute link-state** command in router configuration mode.

```
RP/0/RSP0/CPU0:router# configure
RP/0/RSP0/CPU0:router(config)# router isis isp
RP/0/RSP0/CPU0:router(config-isis)# distribute link-state instance-id 32 level 2 throttle
5
```

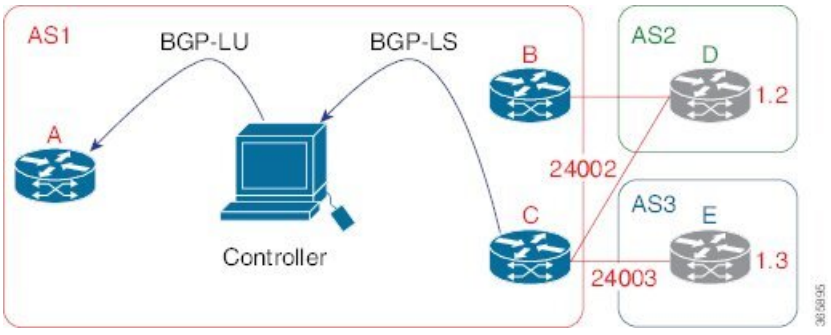
To distribute OSPFv2 link-state data using BGP LS, use the **distribute link-state** command in router configuration mode.

```
RP/0/RSP0/CPU0:router# configure
RP/0/RSP0/CPU0:router(config)# router ospf 100
RP/0/RSP0/CPU0:router(config-ospf)# distribute link-state instance-id 32 throttle 10
```

Example: Configuring SR-EPE and BGP-LS

In the following figure, segment routing is enabled on autonomous system AS1 with ingress node A and egress nodes B and C. In this example, we configure EPE on egress node C.

Figure 1: Topology



Step 1 Configure node C with EPE for eBGP peers D and E.

Example:

```
RP/0/RSP0/CPU0:router_C(config)# router bgp 1
RP/0/RSP0/CPU0:router_C(config-bgp)# neighbor 192.168.1.3
RP/0/RSP0/CPU0:router_C(config-bgp-nbr)# remote-as 3
RP/0/RSP0/CPU0:router_C(config-bgp-nbr)# description to E
```

```
RP/0/RSP0/CPU0:router_C(config-bgp-nbr)# egress-engineering
RP/0/RSP0/CPU0:router_C(config-bgp-nbr)# address-family ipv4 unicast
RP/0/RSP0/CPU0:router_C(config-bgp-nbr-af)# route-policy bgp_in in
RP/0/RSP0/CPU0:router_C(config-bgp-nbr-af)# route-policy bgp_out out
RP/0/RSP0/CPU0:router_C(config-bgp-nbr-af)# exit
RP/0/RSP0/CPU0:router_C(config-bgp-nbr)# exit
RP/0/RSP0/CPU0:router_C(config-bgp)# neighbor 192.168.1.2
RP/0/RSP0/CPU0:router_C(config-bgp-nbr)# remote-as 2
RP/0/RSP0/CPU0:router_C(config-bgp-nbr)# description to D
RP/0/RSP0/CPU0:router_C(config-bgp-nbr)# egress-engineering
RP/0/RSP0/CPU0:router_C(config-bgp-nbr)# address-family ipv4 unicast
RP/0/RSP0/CPU0:router_C(config-bgp-nbr-af)# route-policy bgp_in in
RP/0/RSP0/CPU0:router_C(config-bgp-nbr-af)# route-policy bgp_out out
RP/0/RSP0/CPU0:router_C(config-bgp-nbr-af)# exit
RP/0/RSP0/CPU0:router_C(config-bgp-nbr)# exit
```

Step 2 Configure node C to advertise peer node SIDs to the controller using BGP-LS.

Example:

```
RP/0/RSP0/CPU0:router_C(config-bgp)# neighbor 172.29.50.71
RP/0/RSP0/CPU0:router_C(config-bgp-nbr)# remote-as 1
RP/0/RSP0/CPU0:router_C(config-bgp-nbr)# description to EPE_controller
RP/0/RSP0/CPU0:router_C(config-bgp-nbr)# address-family link-state link-state
RP/0/RSP0/CPU0:router_C(config-bgp-nbr)# exit
RP/0/RSP0/CPU0:router_C(config-bgp)# exit
```

Step 3 Commit the configuration.

Example:

```
RP/0/RSP0/CPU0:router_C(config)# commit
```

Step 4 Verify the configuration.

Example:

```
RP/0/RSP0/CPU0:router_C# show bgp egress-engineering

 Egress Engineering Peer Set: 192.168.1.2/32 (10b87210)
     Nexthop: 192.168.1.2
     Version: 2, rn_version: 2
       Flags: 0x00000002
   Local ASN: 1
  Remote ASN: 2
   Local RID: 1.1.1.3
  Remote RID: 1.1.1.4
   First Hop: 192.168.1.2
        NHID: 3
       Label: 24002, Refcount: 3
     rpc_set: 10b9d408

 Egress Engineering Peer Set: 192.168.1.3/32 (10be61d4)
     Nexthop: 192.168.1.3
     Version: 3, rn_version: 3
       Flags: 0x00000002
   Local ASN: 1
  Remote ASN: 3
   Local RID: 1.1.1.3
  Remote RID: 1.1.1.5
   First Hop: 192.168.1.3
        NHID: 4
```

```
  Label: 24003, Refcount: 3
rpc_set: 10be6250
```

The output shows that node C has allocated peer SIDs for each eBGP peer.

Example:

```
RP/0/RSP0/CPU0:router_C# show mpls forwarding labels 24002 24003
Local  Outgoing    Prefix            Outgoing     Next Hop        Bytes
Label  Label       or ID             Interface                    Switched
------ ----------- ------------------ ------------ --------------- ------------
24002  Unlabelled  No ID             Te0/3/0/0    192.168.1.2     0
24003  Unlabelled  No ID             Te0/1/0/0    192.168.1.3     0
```

The output shows that node C installed peer node SIDs in the Forwarding Information Base (FIB).