



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 *Implementing BGP* module in the *Routing Configuration Guide for Cisco NCS 540 Series Routers*.

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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 540 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/RP0/CPU0:router(config)# segment-routing global-block 16000 23999

RP/0/RP0/CPU0:router(config)# route-policy SID($SID)
RP/0/RP0/CPU0:router(config-rpl)# set label-index $SID
RP/0/RP0/CPU0:router(config-rpl)# end policy

RP/0/RP0/CPU0:router(config)# router bgp 1
RP/0/RP0/CPU0:router(config-bgp)# bgp router-id 10.1.1.1
RP/0/RP0/CPU0:router(config-bgp)# address-family ipv4 unicast
RP/0/RP0/CPU0:router(config-bgp-af)# network 10.1.1.3/32 route-policy SID(3)
RP/0/RP0/CPU0:router(config-bgp-af)# allocate-label all
RP/0/RP0/CPU0:router(config-bgp-af)# commit
RP/0/RP0/CPU0:router(config-bgp-af)# end

RP/0/RP0/CPU0:router# show bgp 10.1.1.3/32
BGP routing table entry for 10.1.1.3/32
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 (10.1.1.3)
    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.

Procedure

	Command or Action	Purpose
Step 1	router bgp <i>as-number</i> Example: RP/0/RP0/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.
Step 2	neighbor <i>ip-address</i> Example: RP/0/RP0/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.

	Command or Action	Purpose
Step 3	remote-as <i>as-number</i> Example: RP/0/RP0/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/RP0/CPU0:router(config-bgp-nbr)# egress-engineering	Configures the egress node with EPE for the eBGP peer.
Step 5	exit Example: RP/0/RP0/CPU0:router(config-bgp-nbr)# exit RP/0/RP0/CPU0:router(config-bgp)# exit RP/0/RP0/CPU0:router(config)#	
Step 6	Use the commit or end command.	commit —Saves the configuration changes and remains within the configuration session. end —Prompts user to take one of these actions: <ul style="list-style-type: none"> • Yes — Saves configuration changes and exits the configuration session. • No —Exits the configuration session without committing the configuration changes. • Cancel —Remains in the configuration session, without committing the configuration changes.

Example

Running Config:

```

router bgp 1
 neighbor 192.168.1.3
   remote-as 3
   egress-engineering
  !
 !
 !

```

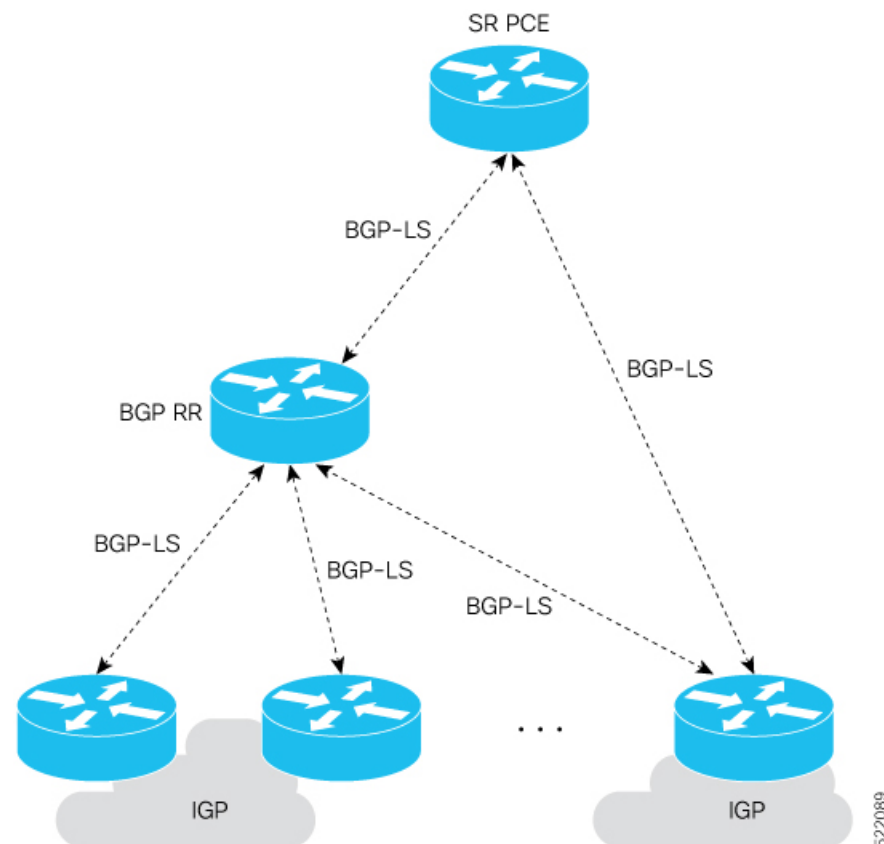
Configure BGP Link-State

BGP Link-State (LS) is an Address Family Identifier (AFI) and Sub-address Family Identifier (SAFI) originally defined to carry interior gateway protocol (IGP) link-state information through BGP. The BGP Network Layer Reachability Information (NLRI) encoding format for BGP-LS and a new BGP Path Attribute called the BGP-LS attribute are defined in [RFC7752](#). The identifying key of each Link-State object, namely a node, link, or prefix, is encoded in the NLRI and the properties of the object are encoded in the BGP-LS attribute.

The BGP-LS Extensions for Segment Routing are documented in [RFC9085](#).

BGP-LS applications like an SR Path Computation Engine (SR-PCE) can learn the SR capabilities of the nodes in the topology and the mapping of SR segments to those nodes. This can enable the SR-PCE to perform path computations based on SR-TE and to steer traffic on paths different from the underlying IGP-based distributed best-path computation.

The following figure shows a typical deployment scenario. In each IGP area, one or more nodes (BGP speakers) are configured with BGP-LS. These BGP speakers form an iBGP mesh by connecting to one or more route-reflectors. This way, all BGP speakers (specifically the route-reflectors) obtain Link-State information from all IGP areas (and from other ASes from eBGP peers).



Usage Guidelines and Limitations

- BGP-LS supports IS-IS and OSPFv2.

- The identifier field of BGP-LS (referred to as the Instance-ID) identifies the IGP routing domain where the NLRI belongs. The NRIs representing link-state objects (nodes, links, or prefixes) from the same IGP routing instance must use the same Instance-ID value.
- When there is only a single protocol instance in the network where BGP-LS is operational, we recommend configuring the Instance-ID value to **0**.
- Assign consistent BGP-LS Instance-ID values on all BGP-LS Producers within a given IGP domain.
- NRIs with different Instance-ID values are considered to be from different IGP routing instances.
- Unique Instance-ID values must be assigned to routing protocol instances operating in different IGP domains. This allows the BGP-LS Consumer (for example, SR-PCE) to build an accurate segregated multi-domain topology based on the Instance-ID values, even when the topology is advertised via BGP-LS by multiple BGP-LS Producers in the network.
- If the BGP-LS Instance-ID configuration guidelines are not followed, a BGP-LS Consumer may see duplicate link-state objects for the same node, link, or prefix when there are multiple BGP-LS Producers deployed. This may also result in the BGP-LS Consumers getting an inaccurate network-wide topology.
- The following table defines the supported extensions to the BGP-LS address family for carrying IGP topology information (including SR information) via BGP. For more information on the BGP-LS TLVs, refer to [Border Gateway Protocol - Link State \(BGP-LS\) Parameters](#).

Table 1: IOS XR Supported BGP-LS Node Descriptor, Link Descriptor, Prefix Descriptor, and Attribute TLVs

TLV Code Point	Description	Produced by IS-IS	Produced by OSPFv2	Produced by BGP
256	Local Node Descriptors	X	X	—
257	Remote Node Descriptors	X	X	—
258	Link Local/Remote Identifiers	X	X	—
259	IPv4 interface address	X	X	—
260	IPv4 neighbor address	X		
261	IPv6 interface address	X	—	—
262	IPv6 neighbor address	X	—	—
263	Multi-Topology ID	X	—	—
264	OSPF Route Type	—	X	—
265	IP Reachability Information	X	X	—
266	Node MSD TLV	X	X	—
267	Link MSD TLV	X	X	—
512	Autonomous System	—	—	X
513	BGP-LS Identifier	—	—	X
514	OSPF Area-ID	—	X	—
515	IGP Router-ID	X	X	—

TLV Code Point	Description	Produced by IS-IS	Produced by OSPFv2	Produced by BGP
516	BGP Router-ID TLV	—	—	X
517	BGP Confederation Member TLV	—	—	X
1024	Node Flag Bits	X	X	—
1026	Node Name	X	X	—
1027	IS-IS Area Identifier	X	—	—
1028	IPv4 Router-ID of Local Node	X	X	—
1029	IPv6 Router-ID of Local Node	X	—	—
1030	IPv4 Router-ID of Remote Node	X	X	—
1031	IPv6 Router-ID of Remote Node	X	—	—
1034	SR Capabilities TLV	X	X	—
1035	SR Algorithm TLV	X	X	—
1036	SR Local Block TLV	X	X	—
1039	Flex Algo Definition (FAD) TLV	X	X	—
1044	Flex Algorithm Prefix Metric (FAPM) TLV	X	X	—
1088	Administrative group (color)	X	X	—
1089	Maximum link bandwidth	X	X	—
1090	Max. reservable link bandwidth	X	X	—
1091	Unreserved bandwidth	X	X	—
1092	TE Default Metric	X	X	—
1093	Link Protection Type	X	X	—
1094	MPLS Protocol Mask	X	X	—
1095	IGP Metric	X	X	—
1096	Shared Risk Link Group	X	X	—
1099	Adjacency SID TLV	X	X	—
1100	LAN Adjacency SID TLV	X	X	—
1101	PeerNode SID TLV	—	—	X
1102	PeerAdj SID TLV	—	—	X
1103	PeerSet SID TLV	—	—	X
1114	Unidirectional Link Delay TLV	X	X	—
1115	Min/Max Unidirectional Link Delay TLV	X	X	—
1116	Unidirectional Delay Variation TLV	X	X	—

TLV Code Point	Description	Produced by IS-IS	Produced by OSPFv2	Produced by BGP
1117	Unidirectional Link Loss	X	X	—
1118	Unidirectional Residual Bandwidth	X	X	—
1119	Unidirectional Available Bandwidth	X	X	—
1120	Unidirectional Utilized Bandwidth	X	X	—
1122	Application-Specific Link Attribute TLV	X	X	—
1152	IGP Flags	X	X	—
1153	IGP Route Tag	X	X	—
1154	IGP Extended Route Tag	X	—	—
1155	Prefix Metric	X	X	—
1156	OSPF Forwarding Address	—	X	—
1158	Prefix-SID	X	X	—
1159	Range	X	X	—
1161	SID/Label TLV	X	X	—
1170	Prefix Attribute Flags	X	X	—
1171	Source Router Identifier	X	—	—
1172	L2 Bundle Member Attributes TLV	X	—	—
1173	Extended Administrative Group	X	X	—

Exchange Link State Information with BGP Neighbor

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

```
Router# configure
Router(config)# router bgp 1
Router(config-bgp)# neighbor 10.0.0.2
Router(config-bgp-nbr)# remote-as 1
Router(config-bgp-nbr)# address-family link-state link-state
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.

```
Router# configure
Router(config)# router isis isp
```



```
Router(config-isis) # distribute link-state instance-id 32
```

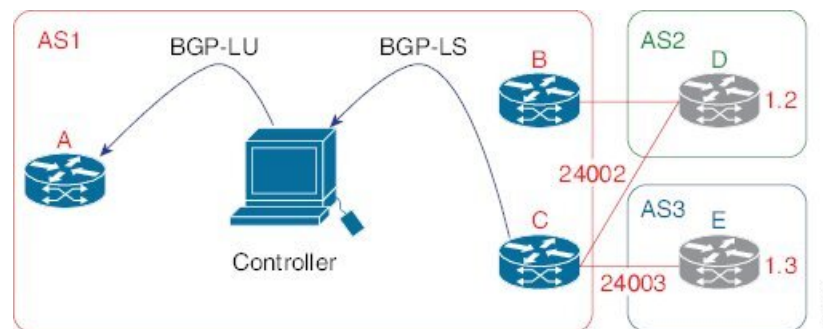
To distribute OSPFv2 link-state data using BGP-LS, use the **distribute link-state** command in router configuration mode.

```
Router# configure
Router(config)# router ospf 100
Router(config-ospf) # distribute link-state instance-id 32
```

Use Case: 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



Procedure

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

Example:

```
RP/0/RP0/CPU0:router_C(config) # router bgp 1
RP/0/RP0/CPU0:router_C(config-bgp) # neighbor 192.168.1.3
RP/0/RP0/CPU0:router_C(config-bgp-nbr) # remote-as 3
RP/0/RP0/CPU0:router_C(config-bgp-nbr) # description to E
RP/0/RP0/CPU0:router_C(config-bgp-nbr) # egress-engineering
RP/0/RP0/CPU0:router_C(config-bgp-nbr-af) # route-policy bgp_in in
RP/0/RP0/CPU0:router_C(config-bgp-nbr-af) # route-policy bgp_out out
RP/0/RP0/CPU0:router_C(config-bgp-nbr-af) # exit
RP/0/RP0/CPU0:router_C(config-bgp-nbr) # exit
RP/0/RP0/CPU0:router_C(config-bgp) # neighbor 192.168.1.2
RP/0/RP0/CPU0:router_C(config-bgp-nbr) # remote-as 2
RP/0/RP0/CPU0:router_C(config-bgp-nbr) # description to D
RP/0/RP0/CPU0:router_C(config-bgp-nbr) # egress-engineering
RP/0/RP0/CPU0:router_C(config-bgp-nbr) # address-family ipv4 unicast
RP/0/RP0/CPU0:router_C(config-bgp-nbr-af) # route-policy bgp_in in
RP/0/RP0/CPU0:router_C(config-bgp-nbr-af) # route-policy bgp_out out
RP/0/RP0/CPU0:router_C(config-bgp-nbr-af) # exit
RP/0/RP0/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/RP0/CPU0:router_C(config-bgp)# neighbor 172.29.50.71
RP/0/RP0/CPU0:router_C(config-bgp-nbr)# remote-as 1
RP/0/RP0/CPU0:router_C(config-bgp-nbr)# description to EPE_controller
RP/0/RP0/CPU0:router_C(config-bgp-nbr)# address-family link-state link-state
RP/0/RP0/CPU0:router_C(config-bgp-nbr)# exit
RP/0/RP0/CPU0:router_C(config-bgp)# exit
```

Step 3 Commit the configuration.

Example:

```
RP/0/RP0/CPU0:router_C(config)# commit
```

Step 4 Verify the configuration.

Example:

```
RP/0/RP0/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: 10.1.1.3
  Remote RID: 10.1.1.4
  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: 10.1.1.3
  Remote RID: 10.1.1.5
  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/RP0/CPU0:router_C# show mpls forwarding labels 24002 24003
```

Local Label	Outgoing Label	Prefix or ID	Outgoing Interface	Next Hop	Bytes Switched
24002	Pop	No ID	Te0/0/0/1	192.168.1.2	0
24003	Pop	No ID	Te0/0/0/2	192.168.1.3	0

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

Configure BGP Proxy Prefix SID

To support segment routing, Border Gateway Protocol (BGP) requires the ability to advertise a segment identifier (SID) for a BGP prefix. A BGP-Prefix-SID is the segment identifier of the BGP prefix segment in a segment routing network. BGP prefix SID attribute is a BGP extension to signal BGP prefix-SIDs. However, there may be routers which do not support BGP extension for segment routing. Hence, those routers also do not support BGP prefix SID attribute and an alternate approach is required.

BGP proxy prefix SID feature allows you to attach BGP prefix SID attributes for remote prefixes learnt from BGP labeled unicast (LU) neighbours which are not SR-capable and propagate them as SR prefixes. This allows an LSP towards non SR endpoints to use segment routing global block in a SR domain. Since BGP proxy prefix SID uses global label values it minimizes the use of limited resources such as ECMP-FEC and provides more scalability for the networks.

BGP proxy prefix SID feature is implemented using the segment routing mapping server (SRMS). SRMS allows the user to configure SID mapping entries to specify the prefix-SIDs for the prefixes. The mapping server advertises the local SID-mapping policy to the mapping clients. BGP acts as a client of the SRMS and uses the mapping policy to calculate the prefix-SIDs.

Configuration Example:

This example shows how to configure the BGP proxy prefix SID feature for the segment routing mapping server.

```
RP/0/RSP0/CPU0:router(config)# segment-routing
RP/0/RSP0/CPU0:router(config-sr)# mapping-server
RP/0/RSP0/CPU0:router(config-sr-ms)# prefix-sid-map
RP/0/RSP0/CPU0:router(config-sr-ms-map)# address-family ipv4
RP/0/RSP0/CPU0:router(config-sr-ms-map-af)# 10.1.1.1/32 10 range 200
RP/0/RSP0/CPU0:router(config-sr-ms-map-af)# 192.168.64.1/32 400 range 300
```

This example shows how to configure the BGP proxy prefix SID feature for the segment-routing mapping client.

```
RP/0/RSP0/CPU0:router(config)# router bgp 1
RP/0/RSP0/CPU0:router(config-bgp)# address-family ip4 unicast
RP/0/RSP0/CPU0:router(config-bgp-af)# segment-routing prefix-sid-map
```

Verification

These examples show how to verify the BGP proxy prefix SID feature.

```
RP/0/RSP0/CPU0:router# show segment-routing mapping-server prefix-sid-map ipv4 detail
Prefix
10.1.1.1/32
  SID Index:      10
  Range:          200
  Last Prefix:    10.1.1.200/32
  Last SID Index: 209
  Flags:
```

Number of mapping entries: 1

RP/0/RSP0/CPU0:router# **show bgp ipv4 labeled-unicast 192.168.64.1/32**

BGP routing table entry for 192.168.64.1/32

Versions:

Process	bRIB/RIB	SendTblVer
Speaker	117	117
Local Label: 16400		

Last Modified: Oct 25 01:02:28.562 for 00:11:45Paths: (2 available, best #1)

Advertised to peers (in unique update groups):

201.1.1.1

Path #1: Received by speaker 0 Advertised to peers (in unique update groups):

201.1.1.1

Local

20.0.101.1 from 20.0.101.1 (20.0.101.1) Received Label 61

Origin IGP, localpref 100, valid, internal, best, group-best, multipath, labeled-unicast

Received Path ID 0, Local Path ID 0, version 117

Prefix SID Attribute Size: 7

Label Index: 1

RP/0/RSP0/CPU0:router# **show route ipv4 unicast 192.68.64.1/32 detail**

Routing entry for 192.168.64.1/32

Known via "bgp 65000", distance 200, metric 0, [ei]-bgp, labeled SR, type internal

Installed Oct 25 01:02:28.583 for 00:20:09

Routing Descriptor Blocks

20.0.101.1, from 20.0.101.1, BGP multi path

Route metric is 0

Label: 0x3d (61)

Tunnel ID: None

Binding Label: None

Extended communities count: 0

NHID:0x0(Ref:0)

Route version is 0x6 (6)

Local Label: 0x3e81 (16400)

IP Precedence: Not Set

QoS Group ID: Not Set

Flow-tag: Not Set

Fwd-class: Not Set

Route Priority: RIB_PRIORITY_RECURSIVE (12) SVD Type RIB_SVD_TYPE_LOCAL

Download Priority 4, Download Version 242

No advertising protos.

RP/0/RSP0/CPU0:router# **show cef ipv4 192.168.64.1/32 detail**

192.168.64.1/32, version 476, labeled SR, drop adjacency, internal 0x5000001 0x80 (ptr 0x71c42b40) [1], 0x0 (0x71c11590), 0x808 (0x722b91e0)

Updated Oct 31 23:23:48.733

Prefix Len 32, traffic index 0, precedence n/a, priority 4

Extensions: context-label:16400

gateway array (0x71ae7e78) reference count 3, flags 0x7a, source rib (7), 0 backups
[2 type 5 flags 0x88401 (0x722eb450) ext 0x0 (0x0)]

LW-LDI[type=5, refc=3, ptr=0x71c11590, sh-ldi=0x722eb450]

gateway array update type-time 3 Oct 31 23:49:11.720

LDI Update time Oct 31 23:23:48.733

LW-LDI-TS Oct 31 23:23:48.733

via 20.0.101.1/32, 0 dependencies, recursive, bgp-ext [flags 0x6020]

path-idx 0 NHID 0x0 [0x7129a294 0x0]

recursion-via-/32

unresolved

local label 16400

```
labels imposed {ExpNullv6}
```

```
RP/0/RSP0/CPU0:router# show bgp labels
BGP router identifier 2.1.1.1, local AS number 65000
BGP generic scan interval 60 secs
Non-stop routing is enabled
BGP table state: Active
Table ID: 0xe0000000 RD version: 245
BGP main routing table version 245
BGP NSR Initial initsync version 16 (Reached)
BGP NSR/ISSU Sync-Group versions 245/0
BGP scan interval 60 secs

Status codes: s suppressed, d damped, h history, * valid, > best
               i - internal, r RIB-failure, S stale, N Nexthop-discard
Origin codes: i - IGP, e - EGP, ? - incomplete
   Network          Next Hop          Rcvd Label      Local Label
*>i10.1.1.1/32      10.1.1.1          3                16010
*> 2.1.1.1/32       0.0.0.0           nolabel          3
*> 192.68.64.1/32  20.0.101.1        2                16400
*> 192.68.64.2/32  20.0.101.1        2                16401
```

