



## Using Segment Routing with OSPF



**Note** Using segment routing with OSPF is similar to using it with IS-IS. Before reading this chapter, see [Using Segment Routing with IS-IS](#).

Segment Routing (SR) is a new paradigm of source routing driven by the IGPs and centered on inserting a list of instructions called segments into each packet. SR forwarding can be instantiated by MPLS or IPv6.

OSPF as an IGP propagates the segment information and may either use it internally (for example, to compute Fast Rerouting repair paths) or hand over the segment information to other clients within the router (for example, TE).

To provide a base SR functionality, OSPF interacts with several components:

- Segment Routing Application—It handles IGP and instance-independent global commands as well as manages global resources used by the SR such as, block of static MPLS labels available for SR Node SID MPLS instantiation).
- MPLS Forwarding Infrastructure (MFI)—Supports MPLS forwarding table.
- RIBv4—Supports the IPv4 routing table
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## Restrictions for Using Segment Routing with OSPF

- Segment routing must be configured at the router level before enabling it at the OSPF instance.
- OSPF instance must successfully register itself with both, Segment Routing Application and MFI and retrieve resources that are necessary for operation, such as SRGB range, dynamically-assigned MPLS labels for Adjacency SIDs, and so on.
- If more than one SR router in the network advertises SID for the same prefix, then the SID values and flags must match. If conflicting attributes are found when calculating the SID for the prefix, then all SIDs for the prefix are ignored.

- Network type point-to-point and Point-to-Multipoint (P2MP) non broadcast are supported.

## Enabling Segment Routing for OSPF

You can enable segment routing for IGP under the router configuration sub mode, through commands. However, IGP segment routing are enabled only after the global SR is configured.

SR functionality configurable globally, that is outside the context of any particular IGP instance, include:

- Global enabling SR on the router.
- Specifying the range of MPLS label values to be used to instantiate SR SIDs into MPLS dataplane (SRGB block)
- Associating SID index with local prefix

## Configuring SR on an OSPF Instance

After SR is enabled globally on the router, it must be enabled in those OSPF instances that need to run SR.

**segment-routing [area *N*] {mpls | disable}**

This command is accepted only if SR is already enabled globally. If the **area** keyword is specified then SR is enabled in that area only, otherwise it is enabled in all areas attached to this OSPF instance. The keyword **disable** can be specified only when the **area** keyword is also present.

Enabling this command causes OSPF to originate RI LSA, Extended Prefix and Extended Link LSAs. It enables MPLS on all interfaces in area(s) enabled for SR and programs SR MPLS labels for forwarding.

## Enabling Advertisement of Mapping Server Prefix Ranges

Global SR configuration may contain prefix-to-SID mapping entries for prefixes that are not local to the router. Each of these entries specify the range of prefixes. Remote mapping entries can be used to find SIDs for prefixes connected to routers that do not supporting SR and hence, are not capable of advertising SIDs themselves. This is part of SR-LDP inter-working functionality.

OSPF learns the ranges configured in the global SR configuration through the SR application and advertises them in the Extended Prefix Range TLVs.

The following command allows an OSPF instance to advertise mapping entries configured in the global SR mode:

**[no] segment-routing prefix-sid-map advertise-local**

This command is configurable in the router mode. Its default state is *disabled*, That is, no mapping ranges are advertised by OSPF even if they are configured in the global SR mode.

## Disabling Mapping Server Functionality

By default, OSPF considers prefix ranges received from mapping servers in the network when computing SIDs for prefixes. This is the core of SR-LDP inter-working label computation. However, if the SR-LDP feature needs to be disabled, use the following command:

**[no] segment-routing prefix-sid-map receive**

Default state of this command is *enabled*. That is, OSPF processes mapping ranges received from mapping servers in the network.

When this command is configured in its non-default form, or the **no** form, it prohibits OSPF from considering prefix-SID mappings from mapping servers.



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**Note** This command does not affect processing of 'native' SIDs, that is, those SIDs that are advertised in the Extended Prefix TLVs by routers to whom the prefix is locally connected.

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## Interface Mode Prefix Attributes Command

Extended Prefix TLV of the Extended Prefix LSA carries flags for the prefix and one of them is N-flag (Node). The N-flag indicates that any traffic sent along to the prefix is destined to the router originating the LSA. This flag typically marks the host routes of the router's loop-back.

By default, OSPF advertises the routes of its loopback with the N-flag. If the IP address of a loopback is not unique (for example, it is part of an anycast address), then OSPF must be configured to *not* advertise the N-flag with the prefix.

Use the following command to cause OSPF to clear N-flag on all prefixes configured on interface in the interface-mode:

```
ip ospf prefix-attributes n-flag-clear
```

## Using OSFP Fast Reroute with Segment Routing

IP Fast Reroute is a set of techniques that allow rerouting IP traffic around a failed link or a failed node in the network within a very short time (< 50ms). One of the techniques to do this is Loop Free Alternates (LFA). Effective with Cisco IOS XE Release 3.18S, OSPF supports per-prefix directly connected LFA and remote LFA (RLFA).

The per-prefix directly connected LFA provides loop-free alternate path for most triangular topologies, but does not provide good coverage for rectangular or circular topologies. However, the RLFA, which uses MPLS forwarding with LDP signaling for tunneling the rerouted traffic to an intermediate node, extends the IPFRR coverage in ring or rectangular topologies. For each link, RLFA defines the P-Space (the set of nodes reachable from the calculating node without crossing the protected link) and Q-Space (the set of nodes that can reach the neighbor on the protected link without crossing the protected link itself). The nodes that belong to both P- and Q-Spaces are called PQ nodes and can be used as the intermediate nodes for the protected traffic. However, for topologies where the P- and Q-Spaces are completely disjoint, there is still no coverage by RLFA.

Topology Independent Fast Reroute (TI-FRR) is a technique that uses Segment Routing to provide link protection in any topology, assuming the metric on the links in the topology is symmetrical. Even TI-LFA does not guarantee a backup in cases where the bandwidth on a single link is asymmetrical. TI-LFA only considers loop-free paths that are on the post-convergence path that helps you to better plan the capacity of the network.

Segment Routing allows creating a full explicit path through the network, but using such a fully specified path is not scalable in larger topologies due to the number of segments along the path. Specifying the whole path is, however, not necessary, and only a subset of the path is needed to carry the traffic to an intermediate

node (release node) which does not loop the traffic back to the protecting node. When the release node is one of the neighbors of S (source or sender node), then we have a directly connected TI-LFA.

Effective with Cisco IOS XE Release 3.18S, an SR Tunnel is constructed to the release node (if remote) and used as the TI-LFA. The tunnel is constructed by explicitly forwarding through a set of one or more repair nodes. The tunnel is created using a SID stack consisting of one SID (Node SID or Adjacency SID) for every repair node and the corresponding label stack is pushed to the protected traffic.

## Per Instance Enablement

- TI-LFA can be enabled on a per interface basis. One interface could be configured for LFA, another interface for LFA and RLFA, yet another interface for LFA and TI-LFA and another interface for LFA, RLFA, and TI-LFA.
- TI-LFA backup path is calculated only if TI-LFA protection is enabled on the output interface of the primary path.
- TI-LFA protection is not available for virtual links, sham links, and TE tunnels.
- Backup paths do not use virtual links, sham links, and TE tunnels.

## Limitations of TI-LFA on OSPF

- TI-LFA is supported only on OSPFv2.
- TI-LFA only computes TI-LFA candidates that have been found based on a post-convergence path excluding the primary link. That is, TI-LFA only provides link protection. Node protection or SRLG protection is not supported.
- TI-LFA is calculated only if D and repair nodes (P, Q, PQ, or other) in the post-convergence path are segment routing capable. S does not need to be SR capable.
- TI-LFA is calculated only if Repair Nodes (P, Q, PQ, or other) in the post-convergence path have node SID. A node SID can be directly connected or one advertised by Mapping Server (SRMS).
- TI-LFA is restricted to a maximum of two or three segment tunnels, which may be lesser than the maximum labels that can be pushed by the router.
- When S is not SR capable, TI-LFA calculates a 0 or 1 segment LFA along the post-convergence path. The 1-segment LFA uses the LDP label to reach the PQ node in the post-convergence path.
- TI-LFA does not compute backup for virtual link, sham link, or TE tunnel path.
- TI-LFA does not use virtual link, sham link or TE tunnel as backup path.
- TI-LFA does not provide adjacency protection. It only protects prefixes. SR TE may provide protection for adjacency segments. Packets arriving with active adjacency segment do not have TI-LFA protection.
- TI-LFA is calculated only for prefixes having SR prefix SID or node SID.
- TI-LFA does not support Multi Topology Routing (MTR). LFA is calculated only for MTID zero.
- Cisco ASR900 routers with RSP3 module, support a maximum of two labels under TI-LFA tunnel.

## Enabling and Disabling TI-FRR

TI-LFA can be enabled on interface, area, and process scopes. By default, TI-LFA is disabled globally.

TI-LFA can be enabled using following commands.

### **fast-reroute per-prefix ti-lfa**

However, when TI-LFA is enabled globally, you have the option to disable it per area level, using following command:.

### **[no] fast-reroute per-prefix ti-lfa [area *area* disable]**

This command is accepted even if Segment-Routing is not enabled on the OSF instance or area. In this case, a TI-LFA backup path is created if the post-convergence path has a PQ node with an LDP label to reach it. That is, RLFA through a post-convergence path.

At the process level:

- **fast-reroute per-prefix ti-lfa [area *area* disable]**
- **fast-reroute per-prefix enable [area *area*] prefix-priority {high | low}**
- **fast-reroute per-prefix remote-lfa [area *area*] maximum-cost *cost***
- **fast-reroute per-prefix remote-lfa [area *area*] tunnel mpls-ldp**
- **fast-reroute per-prefix remote-lfa [area *area*] tunnel mpls-ldp**
- **fast-reroute per-prefix tie-break *attribute* [required] index *index***

At the interface level:

- **ip ospf fast-reroute per-prefix protection disabled**
- **ip ospf fast-reroute per-prefix candidate disable**
- **ip ospf fast-reroute per-prefix protection ti-lfa [disable]**

## Verifying TI-LFA on OSPF

The following show command displays the details about TI-LFA configuration:

### **show ip ospf fast-reroute ti-lfa**

```
OSPF Router with ID (13.13.13.13) (Process ID 100)
Microloop avoidance is enabled for protected prefixes, delay 5000 msec
Loop-free Fast Reroute protected prefixes:
Area Topology name Priority Remote LFA Enabled TI-LFA Enabled
0 Base High Yes Yes
Repair path selection policy tiebreaks (built-in default policy):
0 post-convergence
10 primary-path
20 interface-disjoint
30 lowest-metric
40 linecard-disjoint
50 broadcast-interface-disjoint
256 load-sharing
OSPF/RIB notifications:
Topology Base: Notification Enabled, Callback Registered
Last SPF calculation started 00:02:42 ago and was running for 8 ms.
```

## Verifying the Configuration of SR on OSPF

- The following **show** command displays information about the new LSAs, such as router information, Extended Prefix and Extended Link LSAs:

### **show ip ospf database opaque-area type ext-link**

```

OSPF Router with ID (13.13.13.13) (Process ID 100)
Type-10 Opaque Area Link States (Area 0)
LS age: 1378
Options: (No TOS-capability, DC)
LS Type: Opaque Area Link
Link State ID: 8.0.0.7
Opaque Type: 8 (Extended Link)
Opaque ID: 7
Advertising Router: 4.4.4.4
LS Seq Number: 80000056
Checksum: 0xFEFE8
Length: 76
TLV Type: Extended Link
Length: 52
Link connected to : another Router (point-to-point)
(Link ID) Neighboring Router ID: 12.12.12.12
(Link Data) Interface IP address: 0.0.0.7
Sub-TLV Type: Adj SID
Length : 7
Flags : L-Bit, V-bit
MTID : 0
Weight : 0
Label : 27
Sub-TLV Type: Adj SID
Length : 7
Flags : L-Bit, V-bit, B-bit
MTID : 0
Weight : 0
Label : 34
Sub-TLV Type: Local / Remote Intf ID
Local Interface ID : 7
Remote Interface ID : 0

```

### **show ip ospf database opaque-area type ext-prefix**

```

OSPF Router with ID (13.13.13.13) (Process ID 100)
Type-10 Opaque Area Link States (Area 0)
LS age: 1392
Options: (No TOS-capability, DC)
LS Type: Opaque Area Link
Link State ID: 7.0.0.0
Opaque Type: 7 (Extended Prefix)
Opaque ID: 0
Advertising Router: 4.4.4.4
LS Seq Number: 80000055
Checksum: 0xD156
Length: 44
TLV Type: Extended Prefix
Length: 20
Prefix : 4.4.4.4/32
AF : 0
Route-type: Intra
Flags : N-bit

```

```

Sub-TLV Type: Prefix SID
Length: 8
Flags : None
MTID : 0
Algo : IGP metric based SPT
SID : 4

```

### show ip ospf database opaque-area type router-information

```

OSPF Router with ID (13.13.13.13) (Process ID 100)
Type-10 Opaque Area Link States (Area 0)
LS age: 1402
Options: (No TOS-capability, DC)
LS Type: Opaque Area Link
Link State ID: 4.0.0.0
Opaque Type: 4 (Router Information)
Opaque ID: 0
Advertising Router: 4.4.4.4
LS Seq Number: 80000055
Checksum: 0x7B86
Length: 52
TLV Type: Router Information
Length: 4
Capabilities:
Graceful Restart Helper
Stub Router Support
Traffic Engineering Support
TLV Type: Segment Routing Algorithm
Length: 1
Algorithm: IGP metric based SPT
TLV Type: Segment Routing Range
Length: 12
Range Size: 8000
Sub-TLV Type: SID/Label
Length: 3
Label: 16000

```

- The following show command displays the interface output, but only if segment routing auto-enabled MPLS forwarding on the interface and SIDs were allocated to that interface

### show ip ospf interface

```

Loopback0 is up, line protocol is up
Internet Address 13.13.13.13/32, Interface ID 29, Area 0
Attached via Interface Enable
Process ID 100, Router ID 13.13.13.13, Network Type LOOPBACK, Cost: 1
Topology-MTID Cost Disabled Shutdown Topology Name
0 1 no no Base
Enabled by interface config, including secondary ip addresses
Loopback interface is treated as a stub Host
BDI2104 is up, line protocol is up
Interface is unnumbered, Interface ID 40, Area 0
Using address of Loopback0 (13.13.13.13)
Attached via Interface Enable
Process ID 100, Router ID 13.13.13.13, Network Type POINT_TO_POINT, Cost: 1
Topology-MTID Cost Disabled Shutdown Topology Name
0 1 no no Base
Enabled by interface config, including secondary ip addresses
Transmit Delay is 1 sec, State POINT_TO_POINT, BFD enabled
Timer intervals configured, Hello 10, Dead 40, Wait 40, Retransmit 5
oob-resync timeout 40
Hello due in 00:00:05
Supports Link-local Signaling (LLS)

```

```

Cisco NSF helper support enabled
IETF NSF helper support enabled
Can be protected by per-prefix Loop-Free FastReroute
Can be used for per-prefix Loop-Free FastReroute repair paths
Not Protected by per-prefix TI-LFA
Segment Routing enabled for MPLS forwarding
Index 1/3/3, flood queue length 0
Next 0x0(0)/0x0(0)/0x0(0)
Last flood scan length is 1, maximum is 2
Last flood scan time is 0 msec, maximum is 0 msec
Neighbor Count is 1, Adjacent neighbor count is 1
Adjacent with neighbor 8.8.8.8
Suppress hello for 0 neighbor(s)

```

- The following show command displays the information about segment routing
  - Per-instance state of the feature—whether enabled or disabled, whether operational or not
  - Registration status of OSPF with the SR application and MFI
  - Retrieved SRGB range

### show ip ospf [AS] segment-routing

```

OSPF Router with ID (13.13.13.13) (Process ID 100)
Global segment-routing state: Enabled
Segment Routing enabled:
Area Topology name Forwarding
0 Base MPLS
SR Attributes
Prefer SR Labels
Do not advertise Explicit Null
Local MPLS label block (SRGB):
Range: 16000 - 23999
State: Created
Registered with SR App, client handle: 10
Connected map notifications active (handle 0x18), bitmask 0x1
Active policy map notifications active (handle 0x19), bitmask 0x2
Registered with MPLS, client-id: 100
Bind Retry timer not running
Adj Label Bind Retry timer not running
Adj Protected Label Bind Retry timer not running

```

- The following show command displays information about the SID database for one or for all SIDs. The output displays all prefixes that were advertised with a given SID and highlights which prefixes are local to the router.




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**Note** In the absence of a mis-configuration, there is only one prefix reported for each SID value.

---

### show ip ospf [AS] segment-routing sid-database [SID]

```

OSPF Router with ID (13.13.13.13) (Process ID 100)
OSPF Segment Routing SIDs
Flags: L - local, N - label not programmed,
M - mapping-server
SID Prefix/Mask Adv-Rtr-Id Area-Id
-----
8 8.8.8.8/32 8.8.8.8 0
10 10.10.10.10/32 10.10.10.10 0
13 (L) 13.13.13.13/32 13.13.13.13 0

```

- The following show command displays the database of local prefixes along with their SID values and flags.



**Note** This show command provides information only about locally-configured prefixes. Information about prefixes received from other routers is available either through LSDB (**show ip ospf database opaque-area**) or LRIB (**show ip ospf rib local**) show commands.

#### **show ip ospf [A.S] segment-routing local-prefix**

```
OSPF Router with ID (13.13.13.13) (Process ID 100)
Area 0:
Prefix: Sid: Index: Interface:
13.13.13.13/32 13 0.0.0.0 Loopback0
```

## Troubleshooting Segment Routing on OSPF

Use the following command to debug issues

- **debug ip ospf [A.S] segment-routing**
- **debug ip ospf fast-reroute spf**
- **debug ip ospf fast-reroute spf detail**
- **debug ip ospf fast-reroute rib**
- **debug ip ospf fast-reroute rib [access-list]**

## SR with OSPF Point-to-Multipoint Non Broadcast Mode

*Table 1: Feature History Table*

Feature Name	Release Information	Description
SR with OSPF Point-to-Multipoint Non Broadcast Mode	Cisco IOS XE Cupertino 17.7.1	This feature enables SR on Point-to-Multipoint (P2MP) Non Broadcast (NB) OSPF network type, where you can manually configure neighbor IP address and OSPF sends hello packet using the neighbor unicast address.

The following are the three major network types defined in OSPF:

### 1. Point-to-Point Network

This is the simplest form of the network types. Two routers are connected together with a single link. An example of a point-to-point link is a serial link connecting just two routers (using HDLC or PPP). With point-to-point links, OSPF does not select a Designated Router (DR) or Backup Designated Router (BDR). This network type supports auto neighbor discovery.

### 2. Broadcast Network

In this network type, a broadcast or multicast packet sent by one router on the network can be received by all or some of the other routers. This types of network is also multi-access because more than two routers can be connected to them. Ethernet is an example of a broadcast network. DR and BDR are elected on this network.

### 3. Point-to-Multipoint (P2MP) Non Broadcast (NB) Network

This network type supports multiple routers (multi-access) but do not support the broadcast capability. In this mode, OSPF treats the non-broadcast network like a collection of point-to-point links. There is no DR/BDR election, but neighbors may be automatically discovered, depending on how the interface is configured.

Prior to Cisco IOS XE Cupertino Release 17.7.1, you could only configure SR for point-to-point broadcast network. Starting with Cisco IOS XE Cupertino Release 17.7.1, you can configure SR with P2MP NB mode, where you can manually configure neighbor IP address. In this configuration, OSPF sends hello packet using the neighbor unicast address. Another advantage of running OSPF in this mode is that a common subnet can still be used among the routers, unlike different subnets in the case of point-to-point links.

You must use SDM template, `sr_5_label_push_enable`, for increased number of SR labels. This is applicable to ASR RSP3 module.

## License Requirement

You must use metro aggregation services license to enable this feature:

```
PE1 (config) #license boot level metroaggrservices
```

## Limitation

- Dynamic SRTE, SR micro loop avoidance, and Topology-Independent Loop-Free Alternate (TI-LFA) are not supported on node with P2MP NB OSPF and SR.
- Only native SR is supported.

## Configure SR with OSPF P2MP NB Network

### 1. Configure SR Block

```
segment-routing mpls
  set-attributes
  address-family ipv4
    sr-label-preferred
    explicit-null
  exit-address-family
connected-prefix-sid-map
  address-family ipv4
    Prefix SID/32 index index range 1
  exit-address-family
```

### 2. Configure OSPF

```
router ospf ospf number
  router-id RID
  segment-routing mpls
  segment-routing prefix-sid-map advertise-local
```

```

distribute link-state instance-id unique number
neighbor neighbor interface IP
neighbor neighbor interface IP

```

### 3. Configure on Interface

```

interface interface
ip ospf network point-to-multipoint non-broadcast
ip ospf ospf number area 0

```

## Verification of SR with OSPF P2MP NB Network Configuration

Use `show ip ospf interface br` and `show ip ospf neighbor` commands to verify SR with OSPF P2MP NB mode configuration.

```

PE12#show ip ospf interface br
Interface      PID  Area      IP Address/Mask  Cost  State Nbrs F/C
Lo1            10   0         12.12.12.12/32  1     LOOP  0/0
Fo0/5/1       10   0         192.148.1.2/24  1     P2MP  1/1

PE12#show ip ospf neighbor
Neighbor ID    Pri  State           Dead Time   Address      Interface
13.13.13.13    0    FULL/ -         00:01:36   192.148.1.1 FortyGigabitEthernet0/5/1

```

## Additional References

### Related Documents

Related Topic	Document Title
Cisco IOS commands	<a href="https://www.cisco.com/c/en/us/td/docs/ios-xml/ios/mcl/allreleasemcl/all-book.html">https://www.cisco.com/c/en/us/td/docs/ios-xml/ios/mcl/allreleasemcl/all-book.html</a>

### Standards and RFCs

Standard/RFC	Title
No specific Standards and RFCs are supported by the features in this document.	—

### MIBs

MB	MIBs Link
—	To locate and download MIBs for selected platforms, Cisco IOS releases, and feature sets, use Cisco MIB Locator found at the following URL: <a href="http://www.cisco.com/go/mibs">http://www.cisco.com/go/mibs</a>

**Technical Assistance**

Description	Link
<p>The Cisco Support website provides extensive online resources, including documentation and tools for troubleshooting and resolving technical issues with Cisco products and technologies.</p> <p>To receive security and technical information about your products, you can subscribe to various services, such as the Product Alert Tool (accessed from Field Notices), the Cisco Technical Services Newsletter, and Really Simple Syndication (RSS) Feeds.</p> <p>Access to most tools on the Cisco Support website requires a Cisco.com user ID and password.</p>	<p><a href="http://www.cisco.com/cisco/web/support/index.html">http://www.cisco.com/cisco/web/support/index.html</a></p>