



# Configure Segment Routing for OSPF Protocol

Open Shortest Path First (OSPF) is an Interior Gateway Protocol (IGP) developed by the OSPF working group of the Internet Engineering Task Force (IETF). Designed expressly for IP networks, OSPF supports IP subnetting and tagging of externally derived routing information. OSPF also allows packet authentication and uses IP multicast when sending and receiving packets.

This module provides the configuration information to enable segment routing for OSPF.



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**Note** For additional information on implementing OSPF on your , see the *Implementing OSPF* module in the .

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## Enabling Segment Routing for OSPF Protocol

Segment routing on the OSPF control plane supports the following:

- OSPFv2 control plane
- Multi-area
- IPv4 prefix SIDs for host prefixes on loopback interfaces
- Adjacency SIDs for adjacencies
- MPLS penultimate hop popping (PHP) and explicit-null signaling

This section describes how to enable segment routing MPLS and MPLS forwarding in OSPF. Segment routing can be configured at the instance, area, or interface level.

### Before you begin

Your network must support the MPLS Cisco IOS XR software feature before you enable segment routing for OSPF on your router.



**Note** You must enter the commands in the following task list on every OSPF router in the traffic-engineered portion of your network.

### Procedure

	Command or Action	Purpose
<b>Step 1</b>	<b>configure</b> <b>Example:</b> RP/0/RP0/CPU0:router# <b>configure</b>	Enters mode.
<b>Step 2</b>	<b>router ospf <i>process-name</i></b> <b>Example:</b> RP/0/RP0/CPU0:router (config)# <b>router ospf</b> <b>1</b>	Enables OSPF routing for the specified routing process and places the router in router configuration mode.
<b>Step 3</b>	<b>segment-routing mpls</b> <b>Example:</b> RP/0/RP0/CPU0:router (config-ospf)# <b>segment-routing mpls</b>	<p>Enables segment routing using the MPLS data plane on the routing process and all areas and interfaces in the routing process.</p> <p>Enables segment routing forwarding on all interfaces in the routing process and installs the SIDs received by OSPF in the forwarding table.</p>
<b>Step 4</b>	<b>segment-routing sr-prefer</b> <b>Example:</b> RP/0/RP0/CPU0:router (config-ospf)# <b>segment-routing sr-prefer</b>	Sets the preference of segment routing (SR) labels over label distribution protocol (LDP) labels.
<b>Step 5</b>	<b>area <i>area</i></b> <b>Example:</b> RP/0/RP0/CPU0:router (config-ospf)# <b>area</b> <b>0</b>	Enters area configuration mode.
<b>Step 6</b>	<b>segment-routing mpls</b> <b>Example:</b> RP/0/RP0/CPU0:router (config-ospf-ar)# <b>segment-routing mpls</b>	(Optional) Enables segment routing using the MPLS data plane on the area and all interfaces in the area. Enables segment routing forwarding on all interfaces in the area and installs the SIDs received by OSPF in the forwarding table.
<b>Step 7</b>	<b>exit</b> <b>Example:</b> RP/0/RP0/CPU0:router (config-ospf-ar)# <b>exit</b> RP/0/RP0/CPU0:router (config-ospf)# <b>exit</b>	

	Command or Action	Purpose
<b>Step 8</b>	Use the <b>commit</b> or <b>end</b> command.	<p><b>commit</b> —Saves the configuration changes and remains within the configuration session.</p> <p><b>end</b> —Prompts user to take one of these actions:</p> <ul style="list-style-type: none"> <li>• <b>Yes</b> — Saves configuration changes and exits the configuration session.</li> <li>• <b>No</b> —Exits the configuration session without committing the configuration changes.</li> <li>• <b>Cancel</b> —Remains in the configuration session, without committing the configuration changes.</li> </ul>

**What to do next**

Configure the prefix SID.

## Configuring a Prefix-SID on the OSPF-Enabled Loopback Interface

A prefix segment identifier (SID) is associated with an IP prefix. The prefix SID is manually configured from the segment routing global block (SRGB) range of labels. A prefix SID is configured under the loopback interface with the loopback address of the node as the prefix. The prefix segment steers the traffic along the shortest path to its destination.

A prefix SID can be a node SID or an Anycast SID. A node SID is a type of prefix SID that identifies a specific node. An Anycast SID is a type of prefix SID that identifies a set of nodes, and is configured with n-flag clear. The set of nodes (Anycast group) is configured to advertise a shared prefix address and prefix SID. Anycast routing enables the steering of traffic toward multiple advertising nodes. Packets addressed to an Anycast address are forwarded to the topologically nearest nodes.

The prefix SID is globally unique within the segment routing domain.

This task describes how to configure prefix segment identifier (SID) index or absolute value on the OSPF-enabled Loopback interface.

**Before you begin**

Ensure that segment routing is enabled on an instance, area, or interface.

**Procedure**

	Command or Action	Purpose
<b>Step 1</b>	<b>configure</b> <b>Example:</b>	Enters mode.

	Command or Action	Purpose
	RP/0/RP0/CPU0:router# configure	
<b>Step 2</b>	<b>router ospf</b> <i>process-name</i> <b>Example:</b> RP/0/RP0/CPU0:router(config)# <b>router ospf</b> 1	Enables OSPF routing for the specified routing process, and places the router in router configuration mode.
<b>Step 3</b>	<b>area</b> <i>value</i> <b>Example:</b> RP/0/RP0/CPU0:router(config-ospf)# <b>area</b> 0	Enters area configuration mode.
<b>Step 4</b>	<b>interface</b> <b>Loopback</b> <i>interface-instance</i> <b>Example:</b> RP/0/RP0/CPU0:router(config-ospf-ar)# interface loopback 0	Specifies the loopback interface and instance.
<b>Step 5</b>	<b>prefix-sid</b> { <b>index</b> <i>SID-index</i>   <b>absolute</b> <i>SID-value</i> } [ <b>n-flag-clear</b> ] [ <b>explicit-null</b> ] <b>Example:</b> RP/0/RP0/CPU0:router(config-ospf-ar)# <b>prefix-sid index 1001</b> RP/0/RP0/CPU0:router(config-ospf-ar)# <b>prefix-sid absolute 17001</b>	<p>Configures the prefix-SID index or absolute value for the interface.</p> <p>Specify <b>index</b> <i>SID-index</i> for each node to create a prefix SID based on the lower boundary of the SRGB + the index.</p> <p>Specify <b>absolute</b> <i>SID-value</i> for each node to create a specific prefix SID within the SRGB.</p> <p>By default, the n-flag is set on the prefix-SID, indicating that it is a node SID. For specific prefix-SID (for example, Anycast prefix-SID), enter the <code>n-flag-clear</code> keyword. OSPF does not set the N flag in the prefix-SID sub Type Length Value (TLV).</p> <p>To disable penultimate-hop-popping (PHP) and add an explicit-Null label, enter the <code>explicit-null</code> keyword. OSPF sets the E flag in the prefix-SID sub TLV.</p>
<b>Step 6</b>	Use the <b>commit</b> or <b>end</b> command.	<p><b>commit</b> —Saves the configuration changes and remains within the configuration session.</p> <p><b>end</b> —Prompts user to take one of these actions:</p> <ul style="list-style-type: none"> <li>• <b>Yes</b> — Saves configuration changes and exits the configuration session.</li> <li>• <b>No</b> —Exits the configuration session without committing the configuration changes.</li> </ul>

	Command or Action	Purpose
		<ul style="list-style-type: none"> <li>• <b>Cancel</b> —Remains in the configuration session, without committing the configuration changes.</li> </ul>

Verify the prefix-SID configuration:

```
RP/0/RP0/CPU0:router# show ospf database opaque-area 7.0.0.1 self-originate
OSPF Router with ID (10.0.0.1) (Process ID 1)
Type-10 Opaque Link Area Link States (Area 0)
<...>
Extended Prefix TLV: Length: 20
Route-type: 1
AF      : 0
Flags   : 0x40
Prefix  : 10.0.0.1/32

SID sub-TLV: Length: 8
Flags   : 0x0
MTID    : 0
Algo    : 0
SID Index : 1001
```

## Conditional Prefix Advertisement

In some situations, it's beneficial to make the OSPF prefix advertisement conditional. For example, an Area Border Router (ABR) or Autonomous System Boundary Router (ASBR) that has lost its connection to one of the areas or autonomous systems (AS) might keep advertising a prefix. If an ABR or ASBR advertises the Segment Routing (SR) SID with this prefix, the label stack of the traffic routed toward the disconnected area or AS might use this SID, which would result in dropped traffic at the ABR or ASBR.

ABRs or ASBRs are often deployed in pairs for redundancy and advertise a shared Anycast prefix SID. Conditional Prefix Advertisement allows an ABR or an ASBR to advertise its Anycast SID only when connected to a specific area or domain. If an ABR or ASBR becomes disconnected from the particular area or AS, it stops advertising the address for a specified interface (for example, Loopback).

Configure the conditional prefix advertisement under a specific interface. The prefix advertisement on this interface is associated with the route-policy that tracks the presence of a set of prefixes (prefix-set) in the Routing Information Base (RIB).

For faster convergence, the route-policy used for conditional prefix advertisement uses the new event-based **rib-has-route async** condition to notify OSPF of the following situations:

- When the last prefix from the prefix-set is removed from the RIB.
- When the first prefix from the prefix-set is added to the RIB.

### Configuration

To use the conditional prefix advertisement in OSPF, create a prefix-set to be tracked. Then create a route policy that uses the prefix-set.

```

Router(config)# prefix-set prefix-set-name
Router(config-pfx)# prefix-address-1/length[, prefix-address-2/length,,,
prefix-address-16/length]
Router(config-pfx)# end-set

Router(config)# route-policy rpl-name
Router(config-rpl)# if rib-has-route async prefix-set-name then
Router(config-rpl-if)# pass
Router(config-rpl-if)# endif
Router(config-rpl)# end-policy

```

To advertise the loopback address in OSPF conditionally, use the **advertise prefix route-policy** command under OSPF interface address-family configuration sub-mode.

```

Router(config)# router ospf 1
Router(config-ospf)# area 0
Router(config-ospf-ar)# interface Loopback0
Router(config-ospf-ar-if)# advertise prefix route-policy rpl-name
Router(config-ospf-ar-if)# commit

```

### Example

```

Router(config)# prefix-set domain_2
Router(config-pfx)# 2.3.3.3/32, 2.4.4.4/32
Router(config-pfx)# end-set
Router(config)# route-policy track_domain_2
Router(config-rpl)# if rib-has-route async domain_2 then
Router(config-rpl-if)# pass
Router(config-rpl-if)# endif
Router(config-rpl)# end-policy
Router(config)# router ospf 1
Router(config-ospf)# area 0
Router(config-ospf-ar)# interface Loopback0
Router(config-ospf-ar-if)# advertise prefix route-policy track_domain-2
Router(config-ospf-ar-if)# commit

```

### Running Configuration

```

prefix-set domain_2
  2.3.3.3/32,
  2.4.4.4/32
end-set
!
route-policy track_domain_2
  if rib-has-route async domain_2 then
    pass
  endif
end-policy
!
router ospf 1
  area 0
  interface Loopback0
    advertise prefix route-policy track_domain_2
  !
!
!

```

# Segment Routing ECMP-FEC Optimization

ECMP-FECs are used for any ECMP programming on the system, such as MPLS LSP ECMP, VPN multipath, and EVPN multi-homing.

ECMP-FEC optimization is triggered when all the out\_labels associated with the ECMP paths for a given prefix have the same value. If this rule is not met, then the prefix is programmed with a dedicated ECMP-FEC.

Segment Routing Label Edge Router (LER) ECMP-FEC Optimization enables ECMP-FEC optimization originally developed for Label Switched Router (LSR) nodes (MPLS P) to be enabled on LER (Layer 3 MPLS PE) routers.

## Usage Guidelines and Limitations

- For the labeled prefixes with ECMP across a combination of labeled and unlabeled (PHP) paths, the SR ECMP-FEC Optimization cannot be triggered since the paths associated with the prefix do not have the same outgoing label and/or label action.
- For prefixes with LFA backup paths, the SR ECMP-FEC Optimization is possible since these backup paths do not require an extra label to be pushed; all paths associated with the prefix (primary and backup) have the same outgoing label value.
- For prefixes with TI-LFA backup paths requiring extra labels to be pushed on to the backup, the SR ECMP-FEC Optimization is not possible since all the paths associated with the prefix do not have the same outgoing label value.
- For the duration of time that prefixes are programmed to avoid microloops (when SR MicroLoop Avoidance is triggered), SR ECMP-FEC Optimization is not possible since all the paths associated with the prefix do not have the same outgoing label value. After removal of the microloop-avoidance programming, the SR ECMP-FEC Optimization might be possible again.
- For scenarios with prefixes where the SR ECMP-FEC Optimization is not possible, dedicated ECMP-FEC is allocated per prefix. This could potentially lead to ECMP FEC out-of-resource (OOR) considering the baseline usage of ECMP FEC resources at steady state. During ECMP-FEC OOR, prefixes with multiple paths are programmed with a single path in order to avoid traffic disruption.
- SR ECMP-FEC optimization is applicable in the following instances:
  - Label Switched Router (LSR) nodes (MPLS P)
  - L3VPN Label Edge Router (LER) nodes
- SR ECMP-FEC optimization should not be enabled in the following instances:
  - L2VPN LER nodes
  - L2VPN/L3VPN LER nodes with VPN over BGP-LU over SR
- BGP PIC is not supported.
- For the labeled prefixes, transitioning from TI-LFA to SR ECMP-FEC optimization can cause ECMP-FEC OOR due to different output labels (ECMP label vs backup path's label) at make-before-break. This results in a few second traffic loss depending on route scale

### Enable SR ECMP-FEC Optimization

To enable SR ECMP-FEC optimization, use the **hw-module fib mpls label lsr-optimized** command in global configuration mode. After enabling this feature, reload the line card.

```
Router(config)# hw-module fib mpls label lsr-optimized
Router(config)# commit

LC/0/0/CPU0:Oct 11 20:19:12.540 UTC: fia_driver[185]:
%FABRIC-FIA_DRV-4-MPLS_HW_PROFILE_MISMATCH :
  Mismatch found, reload LC to activate the new mpls profile

Router# reload location 0/0/CPU0

Proceed with reload? [confirm]
Reloading node 0/0/CPU0
```

### Verify the SR ECMP-FEC Optimization

From Cisco IOS XR Release 24.2.1, in addition to IPv4 prefixes, you can view the ECMP-FEC optimization details for IPv6 prefixes using the **show controllers npu resources** command.

The following example shows NPU usage before enabling SR ECMP-FEC optimization for IPv4 and IPv6 prefixes:

```
Router#show controllers npu resources ecmpfec location 0/0/CPU0
Tue May 14 17:17:40.306 UTC
HW Resource Information
  Name                : ecmp_fec
  Asic Type            : JerichoPlus

NPU-0
OOR Summary
  Estimated Max Entries : 4096
  Red Threshold         : 95 %
  Yellow Threshold      : 80 %
  OOR State             : Green
  High Water Mark       : 216
  High Water Mark Time  : 2024.May.14 17:10:46 UTC
  Bank Info            : ECMP

OFA Table Information
(May not match HW usage)
  ipnhgroup           : 111
  ip6nhgroup          : 105

Current Hardware Usage
Name: ecmp_fec
  Estimated Max Entries : 4096
  Total In-Use          : 216      (5 %)
  OOR State             : Green
  High Water Mark       : 216
  High Water Mark Time  : 2024.May.14 17:10:46 UTC
  Bank Info            : ECMP

Name: hier_0
  Estimated Max Entries : 4096
  Total In-Use          : 216
  OOR State             : Green
  High Water Mark       : 216
```



```

High Water Mark Time      : 2024.May.14 17:10:46 UTC
Bank Info                  : ECMP

```

The following example shows NPU usage after enabling SR ECMP-FEC optimization for IPv4 and IPv6 prefixes:

```
Router#show controllers npu resources ecmpfec location 0/0/CPU0
```

```
Tue May 14 17:07:56.266 UTC
```

```
HW Resource Information
```

```

Name                       : ecmp_fec
Asic Type                   : JerichoPlus

```

```
NPU-0
```

```
OOR Summary
```

```

Estimated Max Entries      : 4096
Red Threshold              : 95 %
Yellow Threshold          : 80 %
OOR State                  : Green
High Water Mark           : 16
High Water Mark Time      : 2024.May.14 17:04:47 UTC
Bank Info                  : ECMP

```

```
OFA Table Information
```

```
(May not match HW usage)
```

```

ipnhgroup                : 11
ip6nhgroup              : 5

```

```
Current Hardware Usage
```

```
Name: ecmp_fec
```

```

Estimated Max Entries      : 4096
Total In-Use           : 16      (0 %)
OOR State                  : Green
High Water Mark           : 16
High Water Mark Time      : 2024.May.14 17:04:47 UTC
Bank Info                  : ECMP

```

```
Name: hier_0
```

```

Estimated Max Entries      : 4096
Total In-Use               : 16
OOR State                  : Green
High Water Mark           : 16
High Water Mark Time      : 2024.May.14 17:04:47 UTC
Bank Info                  : ECMP

```

