



# Configure Segment Routing Path Computation Element

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The Segment Routing Path Computation Element (SR-PCE) provides stateful PCE functionality by extending the existing IOS-XR PCEP functionality with more capabilities. SR-PCE is supported on the MPLS data plane and IPv4 control plane.



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**Note** The Cisco IOS XRv 9000 is the recommended platform to act as the SR-PCE. Refer to the [Cisco IOS XRv 9000 Router Installation and Configuration Guide](#) for more information.

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Table 1: Feature History Table

Feature Name	Release Information	Feature Description
Segment Routing Path Computation Element	Release 7.5.2	<p>You can use a recommended platform to act as the Segment Routing Path Computation Element (SR-PCE) to calculate a suitable network path for transmitting data between a source and destination by applying metrics such as IGP, TE, and latency and restrictions such as the affinity of flexible algorithms for delay or IGP, and disjointness for LSPs.</p> <p>SR-PCE supports up to:</p> <ul style="list-style-type: none"> <li>• 50000 nodes</li> <li>• 100000 LSPs</li> <li>• 500000 links</li> <li>• 2000 PCEP sessions</li> </ul> <p>You can use SR-PCE for:</p> <ul style="list-style-type: none"> <li>• <a href="#">Disjoint Policy, on page 6</a></li> <li>• <a href="#">PCE-initiated SR Policies for Traffic Management, on page 7</a></li> <li>• <a href="#">PCC-initiated Policies Delegated to PCE, on page 20</a></li> <li>• <a href="#">SR-PCE IPv4 Unnumbered Interface Support, on page 21</a></li> </ul>

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# About SR-PCE

**Table 2: Feature History Table**

Feature Name	Release Information	Feature Description
TCP Authentication Option	Release 7.3.1	This feature introduces support for TCP Authentication Option (TCP-AO), which replaces the TCP Message Digest 5 (MD5) option, which was used for authenticating PCEP (TCP) sessions by using a clear text or encrypted password.

The path computation element protocol (PCEP) describes a set of procedures by which a path computation client (PCC) can report and delegate control of head-end label switched paths (LSPs) sourced from the PCC to a PCE peer. The PCE can request the PCC to update and modify parameters of LSPs it controls. The stateful model also enables a PCC to allow the PCE to initiate computations allowing the PCE to perform network-wide orchestration.

SR-PCE learns topology information by way of IGP (OSPF or IS-IS) or through BGP Link-State (BGP-LS).

SR-PCE is capable of computing paths using the following methods:

- TE metric—SR-PCE uses the TE metric in its path calculations to optimize cumulative TE metric.
- IGP metric—SR-PCE uses the IGP metric in its path calculations to optimize reachability.
- LSP Disjointness—SR-PCE uses the path computation algorithms to compute a pair of disjoint LSPs. The disjoint paths can originate from the same head-end or different head-ends. Disjoint level refers to the type of resources that should not be shared by the two computed paths.

When the first request is received with a given disjoint-group ID, the first LSP is computed, encoding the shortest path from the first source to the first destination. When the second LSP request is received with the same disjoint-group ID, information received in both requests is used to compute two disjoint paths: one path from the first source to the first destination, and another path from the second source to the second destination. Both paths are computed at the same time.

## TCP Authentication Option

Transmission Control Protocol (TCP) Message Digest 5 (MD5) authentication is used for authenticating PCEP (TCP) sessions by using clear text or encrypted password. This feature introduces support for TCP Authentication Option (TCP-AO), which replaces the TCP MD5 option.

TCP-AO uses Message Authentication Codes (MACs), which provides the following:

- Protection against replays for long-lived TCP connections
- More details on the security association with TCP connections than TCP MD5
- A larger set of MACs with minimal system and operational changes

TCP-AO is compatible with Primary Key Tuple (PKT) configuration. TCP-AO also protects connections when using the same PKT across repeated instances of a connection. TCP-AO protects the connections by using a traffic key that is derived from the PKT, and then coordinates changes between the endpoints.



**Note** TCP-AO and TCP MD5 are never permitted to use simultaneously. TCP-AO supports IPv6, and is fully compatible with the proposed requirements for the replacement of TCP MD5.

## Usage Guidelines and Limitations

To ensure PCEP compatibility, we recommend that the Cisco IOS XR version on the SR-PCE be the same or later than the Cisco IOS XR version on the PCC or head-end.

These are the unsupported configurations for SR-MPLS TE Path Computation for IPv6:

## Configure SR-PCE

This task explains how to configure SR-PCE.

### Before you begin

The Cisco IOS XRv 9000 is the recommended platform to act as the SR-PCE.

### SUMMARY STEPS

1. **configure**
2. **pce**
3. **address ipv4** *address*
4. **state-sync ipv4** *address*
5. **tcp-buffer** *size*
6. **password** {**clear** | **encrypted**} *password*
7. **tcp-ao** *key-chain* [**include-tcp-options**] [**accept-ao-mismatch-connection**]
8. **segment-routing** {**strict-sid-only** | **te-latency**}
9. **timers**
10. **keepalive** *time*
11. **minimum-peer-keepalive** *time*
12. **reoptimization** *time*
13. **exit**

### DETAILED STEPS

	Command or Action	Purpose
<b>Step 1</b>	<b>configure</b> <b>Example:</b> RP/0/RP0/CPU0:router# <code>configure</code>	Enters mode.

	Command or Action	Purpose
Step 2	<p><b>pce</b></p> <p><b>Example:</b></p> <pre>RP/0/RP0/CPU0:router(config)# pce</pre>	Enables PCE and enters PCE configuration mode.
Step 3	<p><b>address ipv4 address</b></p> <p><b>Example:</b></p> <pre>RP/0/RP0/CPU0:router(config-pce)# address ipv4 192.168.0.1</pre>	Configures a PCE IPv4 address.
Step 4	<p><b>state-sync ipv4 address</b></p> <p><b>Example:</b></p> <pre>RP/0/RP0/CPU0:router(config-pce)# state-sync ipv4 192.168.0.3</pre>	Configures the remote peer for state synchronization.
Step 5	<p><b>tcp-buffer size</b></p> <p><b>Example:</b></p> <pre>RP/0/RP0/CPU0:router(config-pce)# tcp-buffer 1024000</pre>	Configures the transmit and receive TCP buffer size for each PCEP session, in bytes. The default buffer size is 256000. The valid range is from 204800 to 1024000.
Step 6	<p><b>password {clear   encrypted} password</b></p> <p><b>Example:</b></p> <pre>RP/0/RP0/CPU0:router(config-pce)# password encrypted pwd1</pre>	<p>Enables TCP authentication for all PCEP peers. Any TCP segment coming from the PCC that does not contain a MAC matching the configured password will be rejected. Specify if the password is encrypted or clear text.</p> <p><b>Note</b> TCP-AO and TCP MD5 are never permitted to be used simultaneously.</p>
Step 7	<p><b>tcp-ao key-chain [include-tcp-options] [accept-ao-mismatch-connection]</b></p> <p><b>Example:</b></p> <pre>RP/0/RP0/CPU0:router(config-pce)# tcp-ao pce_tcp_ao include-tcp-options</pre>	<p>Enables TCP Authentication Option (TCP-AO) authentication for all PCEP peers. Any TCP segment coming from the PCC that does not contain a MAC matching the configured key chain will be rejected.</p> <ul style="list-style-type: none"> <li>• <b>include-tcp-options</b>—Includes other TCP options in the header for MAC calculation.</li> <li>• <b>accept-ao-mismatch-connection</b>—Accepts connection even if there is a mismatch of AO options between peers.</li> </ul> <p><b>Note</b> TCP-AO and TCP MD5 are never permitted to be used simultaneously.</p>

	Command or Action	Purpose
<b>Step 8</b>	<b>segment-routing</b> { <b>strict-sid-only</b>   <b>te-latency</b> } <b>Example:</b> RP/0/RP0/CPU0:router(config-pce)# <b>segment-routing</b> <b>strict-sid-only</b>	Configures the segment routing algorithm to use strict SID or TE latency. <b>Note</b> This setting is global and applies to all LSPs that request a path from this controller.
<b>Step 9</b>	<b>timers</b> <b>Example:</b> RP/0/RP0/CPU0:router(config-pce)# <b>timers</b>	Enters timer configuration mode.
<b>Step 10</b>	<b>keepalive</b> <i>time</i> <b>Example:</b> RP/0/RP0/CPU0:router(config-pce-timers)# <b>keepalive</b> <b>60</b>	Configures the timer value for locally generated keep-alive messages. The default time is 30 seconds.
<b>Step 11</b>	<b>minimum-peer-keepalive</b> <i>time</i> <b>Example:</b> RP/0/RP0/CPU0:router(config-pce-timers)# <b>minimum-peer-keepalive 30</b>	Configures the minimum acceptable keep-alive timer that the remote peer may propose in the PCEP OPEN message during session establishment. The default time is 20 seconds.
<b>Step 12</b>	<b>reoptimization</b> <i>time</i> <b>Example:</b> RP/0/RP0/CPU0:router(config-pce-timers)# <b>reoptimization 30</b>	Configures the re-optimization timer. The default timer is 60 seconds.
<b>Step 13</b>	<b>exit</b> <b>Example:</b> RP/0/RP0/CPU0:router(config-pce-timers)# <b>exit</b>	Exits timer configuration mode and returns to PCE configuration mode.

## Disjoint Policy

SR-PCE configuration compute disjointness for a pair of LSPs signaled by PCCs that do not include the PCEP association group-ID object in their PCEP request. This can be beneficial for deployments where PCCs do not support this PCEP object or when the network operator prefers to manage the LSP disjoint configuration centrally. The disjoint policy configuration is optional.

You can configure the disjoint group ID and the preferred level of disjointness (the type of resources that must not be shared by the two paths). SR-PCE supports the following disjoint path computations:

- `link`—Specifies that links are not shared on the computed paths.
- `node`—Specifies that nodes are not shared on the computed paths.
- `srlg`—Specifies that links with the same SRLG value are not shared on the computed paths.
- `srlg-node`—Specifies that SRLG and nodes are not shared on the computed paths.

If a pair of paths that meet the requested disjointness level cannot be found, then the paths automatically fallback to a lower level in the following way:

- If the requested disjointness level is `SRLG` or `node`, then `link-disjoint` paths will be computed.
- If the requested disjointness level was `link`, or if the first fallback from `SRLG` or `node` disjointness failed, then the lists of segments encoding two shortest paths, without any disjointness constraint, will be computed.

## Configure Disjoint Policy

Perform the following task to configure disjoint policy.

### Configuration Example

```
Router)# configure
Router(config)# pce
Router(config-pce)# disjoint-path
Router(config-pce-disjoint)# group-id 1 type node sub-id 1
Router(config-pce-disjoint)# strict
```

**strict** is an optional parameter. It prevents the automatic fallback behavior of the preferred level of disjointness. If a pair of paths that meet the requested disjointness level cannot be found, the disjoint calculation is stopped and no new path is provided. The existing path is not modified.

```
Router(config-pce-disjoint)# lsp 1 pcc ipv4 192.168.0.1 lsp-name rtrA_t1 shortest-path
```

The above configuration adds LSPs to the disjoint group. The **shortest-path** forces one of the disjoint paths to follow the shortest path from the source to the destination. This option can only be applied to the first LSP specified.

```
Router(config-pce-disjoint)# commit
```

## PCE-initiated SR Policies for Traffic Management

An SR-TE policy can be configured on the path computation element (PCE) to reduce link congestion or to minimize the number of network touch points.



**Note** The PCE-initiated SR-TE policies are entered in PCE configuration mode. For more information on configuring SR-TE policies, see the [SR-TE Policy Overview](#).

The PCE collects network information, such as traffic demand and link utilization. When the PCE determines that a link is congested, it identifies one or more flows that are causing the congestion. The PCE finds a suitable path and deploys an SR-TE policy to divert those flows, without moving the congestion to another part of the network. When there is no more link congestion, the policy is removed.

To minimize the number of network touch points, an application, such as a Network Services Orchestrator (NSO), can request the PCE to create an SR-TE policy. PCE deploys the SR-TE policy using PCC-PCE communication protocol (PCEP).

PCEP defines the communication between PCE and PCC as specified in the following steps:

1. PCE sends a PCInitiate message to the PCC.
2. If the PCInitiate message is valid, the PCC sends a PCRpt message; otherwise, it sends PCErr message.
3. If the PCInitiate message is accepted, the PCE updates the SR-TE policy by sending PCUpd message.

You can achieve high-availability by configuring multiple PCEs with SR-TE policies. If the head-end (PCC) loses connectivity with one PCE, another PCE can assume control of the SR-TE policy.

## Configure PCE-initiated SR Policy

To configure a PCE-initiated SR-TE policy, you must complete the following configurations:

1. Enter PCE configuration mode.
2. Create the segment list.
3. Create the policy.

### Configure PCE-initiated SR Policy with Explicit SID List

Perform the following task to configure PCE-initiated SR policy with explicit SID list.

#### Configuration Example

```
/* Enter PCE configuration mode and create the SR-TE segment lists */
Router# configure
Router(config)# pce

/* Create the SR-TE segment lists */
Router(config-pce)# segment-routing
Router(config-pce-sr)# traffic-eng
Router(config-pce-sr-te)# segment-list name addr2a
Router(config-pce-sr-te-sl)# index 1 address ipv4 192.168.0.1
Router(config-pce-sr-te-sl)# exit

/* Create the SR-TE policy */
Router(config-pce-sr-te)# peer ipv4 10.1.1.1
Router(config-pce-sr-te)# policy P1
Router(config-pce-sr-te-policy)# color 2 end-point ipv4 172.16.0.1
Router(config-pce-sr-te-policy)# candidate-paths
Router(config-pce-sr-te-policy-path)# preference 50
Router(config-pce-sr-te-policy-path-preference)# explicit segment-list addr2a
Router(config-pce-sr-te-pp-info)# end
```



## Running Configuration

```
pce
segment-routing
traffic-eng
segment-list name addr2a
index 1 address ipv4 192.168.0.1
!
peer ipv4 10.1.1.1
policy P1
color 2 end-point ipv4 172.16.0.1
candidate-paths
preference 50
explicit segment-list addr2a
!
!
```

## Configure PCE-initiated SR Policy with Dynamic SID List

Perform the following task to configure PCE-initiated SR policy with dynamic SID list.

### Configuration Example

In this example, the PCE creates the policy and computes the path.

```
/* Enter PCE configuration mode */
Router# configure
Router(config)# pce

/* Create the SR-TE policy */
Router(config-pce)# segment-routing
Router(config-pce-sr)# traffic-eng
Router(config-pce-sr-te)# peer ipv4 10.1.1.1
Router(config-pce-sr-te)# policy P1
Router(config-pce-sr-te-policy)# color 2 end-point ipv4 172.16.0.1
Router(config-pce-sr-te-policy)# binding-sid mpls 10001
Router(config-pce-sr-te-policy)# candidate-paths
Router(config-pce-sr-te-policy-path)# preference 50
Router(config-pce-sr-te-policy-path-preference)# dynamic mpls
Router(config-pce-sr-te-pp-info)# metric type igp
Router(config-pce-sr-te-pp-info)# commit
```

## Running Configuration

```
pce
segment-routing
traffic-eng
peer ipv4 10.1.1.1
policy P1
binding-sid mpls 10001
color 2 end-point ipv4 172.16.0.1
candidate-paths
preference 50
dynamic mpls
metric
type igp
!
!
!
```

!

!

!

!

!

# Exclude Network Resources during Path Computation over SR-TE Policies

*Table 3: Feature History Table*

Feature Name	Release Information	Feature Description
Exclude Network Resources during Path Computation over SR-TE Policies	Release 24.1.1	

Feature Name	Release Information	Feature Description
		<p>You can reduce the risk of attacks due to less secure network resources and IP addresses, improve network performance affected by overloaded or congested paths, and ensure higher levels of network stability and availability that could be impacted by resources experiencing issues and requiring maintenance. These improvements are possible because you can now exclude specific network resources using their IP addresses during path computation for traffic over SR-TE policies.</p> <p>Previously, you could not exclude network resources during path computation.</p> <p>The feature introduces these changes:</p> <p><b>CLI:</b></p> <ul style="list-style-type: none"> <li>• The <b>resources</b> option is introduced in the <a href="#">segment-routing traffic-eng policy</a> and <a href="#">segment-routing traffic-eng on-demand color</a> commands.</li> <li>• The <b>resource-list</b> keyword is introduced in the <a href="#">segment-routing traffic-eng</a> command.</li> </ul> <p><b>YANG Data Models:</b></p> <ul style="list-style-type: none"> <li>• <a href="#">Cisco-IOS-XR-infra-xtc-oper.yang</a></li> <li>• <a href="#">Cisco-IOS-XR-infra-xtc-agent-oper.yang</a></li> <li>• <a href="#">Cisco-IOS-XR-infra-xtc-agent-cfg.yang</a></li> </ul> <p>See (<a href="#">GitHub</a>, <a href="#">Yang Data Models Navigator</a>)</p>

You can configure the SR-TE policies as either single or disjoint candidate paths that do not include certain IP addresses or subnets when traffic is routed through the network.

The key benefits of the feature are:

- **Security** - Excluding certain IP addresses or network resources can help protect sensitive resources from unauthorized access or attacks.
- **Performance** - By excluding certain resources, traffic can be directed away from congested parts of the network.
- **Isolation** - Excluding resources can help isolate different parts of the network, preventing issues in one part of the network from affecting others.

## Configuration to exclude network resources during Path Computation

To exclude network resources during path computation for traffic, you must complete these high-level tasks in order:

1. Configure the network resources or IP addresses that you want to exclude from the network list.
2. Associate the excluded network resources to candidate paths for SR-TE or ODN SR-TE policies.

### Configure the network resources or IP addresses to exclude from the network list

Perform the following task to configure a list of IPv4 addresses that you want to exclude from the network resource list:

```
Router(config)#segment-routing traffic-eng
Router(config-sr-te)#resource-list node_resc_list
Router(config-sr-te-rl)#index 1 ipv4 10.10.10.1
Router(config-sr-te-rl)#index 2 ipv4 10.10.10.8
```

#### Running Configuration

```
!
segment-routing
  traffic-eng
    resource-list node_resc_list
      index 1 ipv4 10.10.10.1
      index 2 ipv4 10.10.10.8
!
!
```

### Associate the excluded network resources to candidate paths for SR-TE policies

Perform the following task to associate the excluded IPv4 addresses to one or more candidate paths for SR-TE policies:

```
Router(config)#segment-routing traffic-eng
Router(config-sr-te)#policy dynamic_pcep_policy
Router(config-sr-te-policy)#candidate-paths
Router(config-sr-te-policy-path)#preference 100
Router(config-sr-te-policy-path-pref)#constraints resources exclude resource-list
node_resc_list
```

#### Running Configuration

```
!
segment-routing
  traffic-eng
    policy dynamic_pcep_policy
      candidate-paths
```

```

    preference 100
    constraints
    resources
    exclude resource-list node_resc_list
    !
    !
    !
    !
    !
    !
    !

```

### Verification

```
Router#show segment-routing traffic-eng policy endpoint ipv4 100.2.1.1 color 8001
```

```

Wed Aug 30 22:21:50.014 UTC
SR-TE policy database
-----
Color: 8001, End-point: 100.2.1.1
Name: srte_c_8001_ep_100.2.1.1
Status:
Admin: up Operational: up for 00:00:50 (since Aug 30 22:20:59.341)
Candidate-paths:
Preference: 100 (configuration) (active)
Name: dynamic_pcep_policy
Requested BSID: 8001
PCC info:
Symbolic name: cfg_dynamic_pcep_policy_discr_100
PLSP-ID: 14042
Constraints:
Protection Type: protected-preferred
Maximum SID Depth: 12
Exclude Resources: node_resc_list
10.10.10.1
10.10.10.8
Dynamic (pce 100.7.1.1) (valid)
Metric Type: TE, Path Accumulated Metric: 440
SID[0]: 41111 [Adjacency-SID, 101.1.5.1 - 101.1.5.2]
SID[1]: 21600 [Prefix-SID, 100.6.1.1]
SID[2]: 41600 [Adjacency-SID, 101.2.6.2 - 101.2.6.1]
Attributes:
Binding SID: 8001
Forward Class: Not Configured
Steering labeled-services disabled: yes
Steering BGP disabled: no
IPv6 caps enable: yes
Invalidation drop enabled: no
Max Install Standby Candidate Paths: 0

```

### Associate the excluded network resources to candidate paths for ODN SR-TE policies

Perform the following task to associate the excluded IPv4 addresses for ODN SR-TE policies:

```

Router(config)#segment-routing
Router(config-sr)#traffic-eng
Router(config-sr-te)#on-demand color 7001
Routerconfig-sr-te-color)#constraints resources exclude resource-list node_resc_list

```

### Running Configuration

```

!
segment-routing
 traffic-eng
  on-demand color 7001

```

```

constraints
resources
exclude resource-list node_resc_list
!
!
!
!
!

```

## Verification

```
Router#show segment-routing traffic-eng policy endpoint ipv4 100.2.1.1 color 7001
```

```
Wed Aug 30 22:53:01.079 UTC
```

```
SR-TE policy database
```

```

-----
Color: 7001, End-point: 100.2.1.1
Name: srte_c_7001_ep_100.2.1.1
Status:
  Admin: up Operational: up for 00:31:56 (since Aug 30 22:21:04.869)
Candidate-paths:
  Preference: 200 (BGP ODN) (inactive) (shutdown)
  Requested BSID: dynamic
  Constraints:
    Protection Type: protected-preferred
    Maximum SID Depth: 12
    Exclude Resources: node_resc_list
    10.10.10.1
    10.10.10.8
  Dynamic (inactive)
    Metric Type: IGP, Path Accumulated Metric: 0
  Preference: 100 (BGP ODN) (active)
  Requested BSID: dynamic
  PCC info:
    Symbolic name: bgp_c_7001_ep_100.2.1.1_discr_100
    PLSP-ID: 14044
  Constraints:
    Protection Type: protected-preferred
    Maximum SID Depth: 12
    Exclude Resources: node_resc_list
    10.10.10.1
    10.10.10.8
  Dynamic (pce 100.7.1.1) (valid)
    Metric Type: IGP, Path Accumulated Metric: 440
    SID[0]: 41111 [Adjacency-SID, 101.1.5.1 - 101.1.5.2]
    SID[1]: 21600 [Prefix-SID, 100.6.1.1]
    SID[2]: 41600 [Adjacency-SID, 101.2.6.2 - 101.2.6.1]
Attributes:
  Binding SID: 51679
  Forward Class: Not Configured
  Steering labeled-services disabled: yes
  Steering BGP disabled: no
  IPv6 caps enable: yes
  Invalidation drop enabled: no
  Max Install Standby Candidate Paths: 0

```

# Enable Strict Disjointness for SR-TE policies in the PCE

Table 4: Feature History Table

Feature Name	Release Information	Feature Description
Enable Strict Disjointness for SR-TE Policies in the PCE	Release 24.1.1	<p>You can now enforce strict disjoint constraints for Label Switched Paths (LSPs) and minimize the risk of a single point of failure that affects multiple LSPs. With this feature, if disjoint paths cannot be found for LSPs, the Path Computation Element (PCE) does not return any path.</p> <p>Previously, enforcing strict disjoint constraints for disjoint paths for LSPs was not possible.</p> <p>The feature introduces these changes:</p> <p><b>CLI:</b></p> <p>The <b>fallback disable</b> keyword is introduced in the <a href="#">segment-routing traffic-eng policy</a> and <a href="#">segment-routing traffic-eng on-demand color</a> commands.</p> <p><b>YANG Data Models:</b></p> <ul style="list-style-type: none"> <li>• <a href="#">Cisco-IOS-XR-infra-xtc-oper.yang</a></li> <li>• <a href="#">Cisco-IOS-XR-infra-xtc-agent-oper.yang</a></li> <li>• <a href="#">Cisco-IOS-XR-infra-xtc-agent-cfg.yang</a></li> </ul> <p>See (<a href="#">GitHub</a>, <a href="#">Yang Data Models Navigator</a>)</p>

When you enable `fallback disable`, the Path Computation Element (PCE) does not return any path for LSPs that are not disjoint if there are no disjoint candidate paths. In other words, when the PCE does not find multiple LSPs that satisfy the disjointness requirement, it returns no path. This indicates that there might be a networking issue that prevents the establishment of the desired redundancy, and you can investigate and address the underlying problem.

Without the option, the PCE can relax disjointness by applying an objective function or use a local policy when no objective function is requested.

Enforcing strict disjointness ensures that LSPs do not share any common links or nodes along their paths, minimizing the risk of a single point of failure affecting multiple LSPs. The feature is critical to maintain network reliability and ensures that traffic is properly routed in the event of a network failure.



## Configure Strict Disjointness in the PCE

### Enable strict disjointness for ODN SR-TE policies

Perform the following steps to enable strict disjointness for ODN SR-TE policies:

```
Router(config)#segment-routing traffic-eng
Router(config-sr-te)#on-demand color 4
Router(config-sr-te-color)#dynamic
Router(config-sr-te-color-dyn)#disjoint-path group-id 1 type node fallback disable
Router(config-sr-te-color-dyn)#commit
```

### Running Configuration

```
segment-routing
 traffic-eng
  on-demand color 4
  dynamic
  disjoint-path group-id 1 type node fallback disable
  !
  !
  !
  !
```

### Enable strict disjointness for SR-TE policies

Perform the following steps to enable strict disjointness for SR-TE policies:

```
Router(config)#segment-routing traffic-eng
Router(config-sr-te)#policy foo
Router(config-sr-te-policy)#color 1 end-point ipv4 10.10.10.1
Router(config-sr-te-policy)#candidate-paths preference 100
Router(config-sr-te-policy-path-pref)#constraints disjoint-path group-id 1 type node fallback
  disable
Router(config-sr-te-policy-path-pref)#commit
```

### Running Configuration

```
segment-routing
 traffic-eng
  policy foo
  color 1 end-point ipv4 10.10.10.1
  candidate-paths
  preference 100
  dynamic
  pcep
  !
  metric
  type latency
  !
  !
  constraints
  disjoint-path group-id 1 type node fallback disable
  !
  !
  !
  !
  !
```

### Verification

```
Router#sh pce association
Wed Mar 13 14:38:27.173 PDT
```

```

PCE's association database:
-----
Association: Type Node-Disjoint, Group 1, Strict
Associated LSPs:
  LSP[0]:
    PCC 10.10.10.1, tunnel name cfg_foo_discr_100, PLSP ID 4, tunnel ID 8, LSP ID 2,
    Configured on PCC
  LSP[1]:
    PCC 10.10.10.1, tunnel name bgp_c_4_ep_10.10.10.2_discr_100, PLSP ID 1, tunnel ID 5,
    LSP ID 3, Configured on PCC
Status: Satisfied

```

## Configure the Shortest Path for Disjoint Candidate Paths

**Table 5: Feature History Table**

Feature Name	Release Information	Feature Description
Configure the Shortest Path for Disjoint Candidate Paths	Release 24.1.1	<p>You can now configure the available disjoint paths for Label Switched Paths (LSPs) to prefer the shortest path between two points in the network. This configuration ensures that traffic is routed along the most efficient route in the network.</p> <p>Previously, you could not configure the shortest path preference for disjoint LSPs.</p> <p>The feature introduces these changes:</p> <p><b>CLI:</b></p> <p>The <b>shortest-path</b> keyword is introduced in the <b>policy candidate-paths constraints disjoint-path</b> command.</p> <p><b>YANG Data Models:</b></p> <ul style="list-style-type: none"> <li>• <a href="#">Cisco-IOS-XR-infra-xtc-oper.yang</a></li> <li>• <a href="#">Cisco-IOS-XR-infra-xtc-agent-oper.yang</a></li> <li>• <a href="#">Cisco-IOS-XR-infra-xtc-agent-cfg.yang</a></li> </ul> <p>See (<a href="#">GitHub</a>, <a href="#">Yang Data Models Navigator</a>)</p>

The configuration enables the available disjoint paths to indicate preference for the shortest path between two points in the network. This way the traffic is contained within specific network planes as per the affinity

constraints while still provisioning Label Switched Paths (LSPs) that are diverse from each other to meet the path disjointness requirement.

In earlier releases, if path disjointness was configured for LSPs, the Path Computation Element (PCE) prioritized finding disjoint paths for the LSPs over adhering to the affinity constraints.

## Configure the shortest path for disjoint candidate paths

Perform the following task to indicate the disjoint path preference for the shortest path in the network:

```
Router(config)#segment-routing traffic-eng
Router(config-sr-te)#policy dynamic pcep_policy_disjoint
Router(config-sr-te-policy)#candidate-paths
Router(config-sr-te-policy-path)#preference 100
Router(config-sr-te-policy-path-pref)#constraints disjoint-path group-id 1 type link
shortest-path
```

### Running Configuration

```
!
segment-routing
  traffic-eng
    policy dynamic_pcep_policy
    candidate-paths
      preference 100
    constraints
      disjoint-path group-id 1 type link shortest-path
!
!
!
!
!
```

### Verification

```
Router#show pce lsp name cfg_dynamic_pcep_policy_disjoint_discr_100 detail
```

Output received:

Wed Aug 30 18:33:57.807 UTC

PCE's tunnel database:

-----

PCC 100.1.1.1:

Tunnel Name: cfg\_dynamic\_pcep\_policy\_disjoint\_discr\_100

Color: 30115

Interface Name: srte\_c\_30115\_ep\_100.2.1.1

LSPs:

LSP[0]:

source 100.1.1.1, destination 100.2.1.1, tunnel ID 9031, LSP ID 24

State: Admin up, Operation active

Setup type: Segment Routing

Binding SID: 30115

Maximum SID Depth: 12

Preference: 100

Bandwidth: requested 0 kbps, applied 0 kbps

Protection type: protected-preferred

Prefix-SID algorithm: 0 (set: 0)

PCEP information:

PLSP-ID 0x36e9, flags: D:1 S:0 R:0 A:1 O:2 C:0

LSP Role: Exclude LSP

State-sync PCE: None

```

PCC: 100.1.1.1
LSP is subdelegated to: None
Reported path:
  Metric type: TE, Accumulated Metric 30
  SID[0]: Node, Label 21200, Address 100.2.1.1
Computed path: (Local PCE)
  Computed Time: Wed Aug 30 18:31:12 UTC 2023 (00:02:45 ago)
  Metric type: TE, Accumulated Metric 30
  SID[0]: Node, Label 21200, Address 100.2.1.1
Reverse path: (Local PCE)
  None
  Computed Time: Wed Aug 30 18:31:12 UTC 2023 (00:02:45 ago)
Recorded path:
  None
Disjoint Group Information:
  Type Link-Disjoint, Group 1 (SP)
SR Policy Association Group:
  Color: 30115, Endpoint: 100.2.1.1
  Policy Name: srte_c_30115_ep_100.2.1.1
  Preference: 100
  CP Name: dynamic_pcep_policy_disjoint

```

## PCC-initiated Policies Delegated to PCE

Policies are created on PCC and a path is requested from PCE. PCEP connection must be up and functional for PCE to perform the path computation.

## Configure PCC-initiated Policies Delegated to PCE

Perform the following task to configure the SR policies at PCC and delegate them to PCE after establishing PCEP connection.

### Configuration Example

```

Router # configure
Router(config)# segment-routing
Router(config-sr)# traffic-eng
Router(config-sr-te)# policy local_dynamic_disj_1
Router(config-sr-te-policy)# binding-sid mpls 19002
Router(config-sr-te-policy)# color 19002 end-point ipv4 192.168.0.1
Router(config-sr-te-policy)# candidate-paths
Router(config-sr-te-policy-path)# preference 100
Router(config-sr-te-policy-path-preference)# dynamic
Router(config-sr-te-pp-info)# pcep
Router(config-sr-te-path-pcep)# exit
Router(config-sr-te-pp-info)# metric
Router(config-sr-te-path-metric)# type te
Router(config-sr-te-path-metric)# exit
Router(config-sr-te-pp-info)# exit
Router(config-sr-te-policy-path-preference)# constraints
Router(config-sr-te-path-pref-const)# affinity
Router(config-sr-te-path-pref-const-aff)# include-any
Router(config-sr-te-path-pref-const-aff-rule)# name blue
Router(config-sr-te-path-pref-const-aff-rule)# name green
Router(config-sr-te-path-pref-const-aff-rule)# commit

```



Adjacency Identifier (NAI) of type 5. This indicates that the segment in the explicit routing object (ERO) is an unnumbered adjacency with an IPv4 ID and an interface index.

- SR-TE process at the head-end router:
  - Compute its own local path over a topology, including unnumbered interfaces.
  - Process PCE-computed paths that contain hops with IPv4 unnumbered interfaces.
  - Report a path that contains hops with IPv4 unnumbered interfaces to the PCE.

## Configure SR-PCE IPv4 Unnumbered Interface

This section provides the commands to configure the SR-PCE IPv4 unnumbered interface.

### Configuration Example

The following example shows how to configure an IPv4 unnumbered interface:

```
Router # configure
Router(config)# interface GigabitEthernet0/0/0/0
Router(config-if)# ipv4 point-to-point
Router(config-if)# ipv4 unnumbered Loopback0
```

To bring up the IPv4 unnumbered adjacency under the IGP, configure the link as point-to-point under the IGP configuration. The following example shows how to configure the link as point-to-point under the IGP configuration:

```
Router # configure
Router(config)# router ospf one
Router(config-ospf)# area 0
Router(config-ospf-ar)# interface GigabitEthernet0/0/0/0
Router(config-ospf-ar-if)# network point-to-point
```

### Verification

Use the **show ipv4 interface** command to display information about the interface:

```
Router # show ipv4 interface GigabitEthernet0/0/0/0 brief
Tue Apr  2 12:59:53.140 EDT
Interface                               IP-Address      Status          Protocol
GigabitEthernet0/0/0/0                 192.168.0.1    Up              Up
```

This interface shows the IPv4 address of Loopback0.

Use the **show snmp interface** command to find the SNMP index for this interface:

```
Router# show snmp interface
Tue Apr  2 13:02:49.190 EDT
ifName : Null0                ifIndex : 3
ifName : Loopback0            ifIndex : 10
ifName : GigabitEthernet0/0/0/0 ifIndex : 6
```

The interface is identified with the pair (IPv4:192.168.0.1, index:6).

Use the **show ospf neighbor** command to display the adjacency:

```
Router# show ospf neighbor gigabitEthernet 0/0/0/0 detail
...
```

```
Neighbor 192.168.0.4, interface address 192.168.0.4
  In the area 0 via interface GigabitEthernet0/0/0/0
  Neighbor priority is 1, State is FULL, 6 state changes
  ...
Adjacency SIDs:
  Label: 24001,      Dynamic, Unprotected
Neighbor Interface ID: 4
```

The output of the **show pce ipv4 topology** command is enhanced to display the interface index instead of the IP address for unnumbered interfaces:

```
Router# show pce ipv4 topology
...
Link[2]: unnumbered local index 6, remote index 4
  Local node:
    OSPF router ID: 192.168.0.1 area ID: 0 ASN: 0
  Remote node:
    TE router ID: 192.168.0.4
    OSPF router ID: 192.168.0.4 area ID: 0 ASN: 0
  Metric: IGP 1, TE 1, Latency 1 microseconds
  Bandwidth: Total 125000000 Bps, Reservable 0 Bps
  Admin-groups: 0x00000000
  Adj SID: 24001 (unprotected)
```

The output of **show pce lsp detail** command includes unnumbered hops:

```
Router# show pce lsp detail
...
Reported path:
  Metric type: TE, Accumulated Metric 3
  SID[0]: Adj unnumbered, Label 24001, local 192.168.0.1(6), remote 192.168.0.4(4)
  SID[1]: Adj unnumbered, Label 24002, local 192.168.0.4(7), remote 192.168.0.3(7)
  SID[2]: Adj unnumbered, Label 24000, local 192.168.0.3(5), remote 192.168.0.2(5)
Computed path: (Local PCE)
  Computed Time: Wed Apr 03 11:01:46 EDT 2019 (00:01:06 ago)
  Metric type: TE, Accumulated Metric 3
  SID[0]: Adj unnumbered, Label 24001, local 192.168.0.1(6), remote 192.168.0.4(4)
  SID[1]: Adj unnumbered, Label 24002, local 192.168.0.4(7), remote 192.168.0.3(7)
  SID[2]: Adj unnumbered, Label 24000, local 192.168.0.3(5), remote 192.168.0.2(5)
```

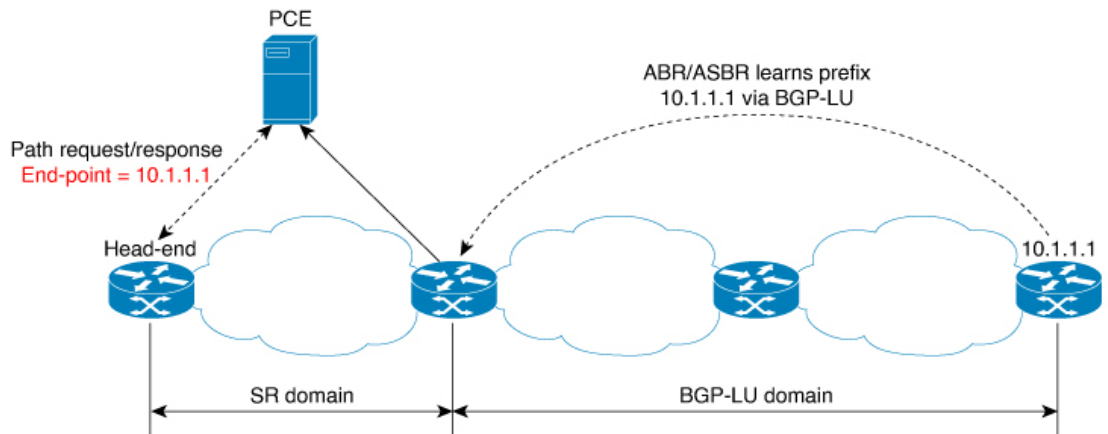
## Inter-Domain Path Computation Using Redistributed SID

A Path Computation Element (PCE) computes SR-TE paths based on SR topology database that stores connectivity, state, and TE attributes of SR network nodes and links. BGP Labeled Unicast (BGP-LU) provides MPLS transport across IGP boundaries by advertising loopbacks and label binding of impact edge and border routers across IGP boundaries.

This feature adds new functionality to the SR-PCE that enables it to compute a path for remote non-SR end-point device distributed by BGP-LU.

The remote end-point device in the BGP-LU domain is unknown to the SR-PCE. For the SR-PCE to know about the end-point device, the gateway ABR/ASBR learns the end-point prefix via BGP-LU. The prefix is then redistributed to SR-PCE topology database from the gateway ABR/ASBR. SR-PCE then can compute the best path from the head-end device to the selected gateway router.

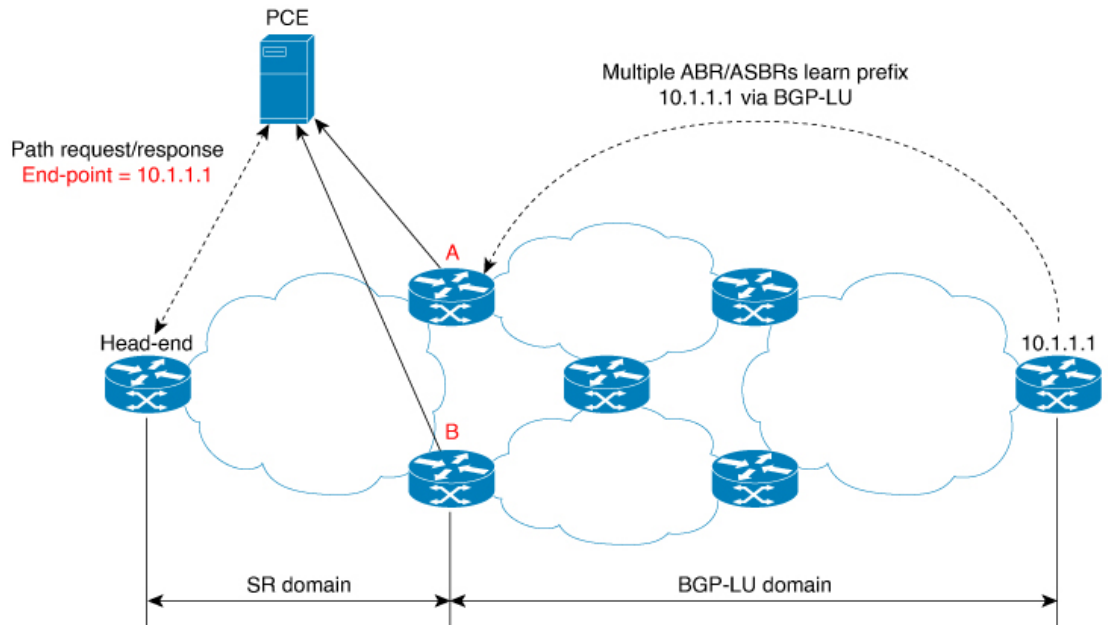
The following topology shows an SR domain and a BGP-LU domain, with a gateway ABR/ASBR between the two domains.



1. The gateway ABR/ASBR is configured with BGP/IGP helper to learn the remote prefix through BGP-LU and redistribute the remote prefix to the IGP helper, then to SR-PCE.
2. The SR-PCE selects the best gateway node to BGP-LU domain and computes the path to reach the remote prefix through the gateway node.
3. The head-end device in the SR domain requests a path to the remote destination and signals the SR profile interworking with the BGP-LU domain.

The BGP-LU prefix advertisement to SR-PCE Traffic Engineer Database (TED) is done by creating an IGP helper on the ABR/ASBR to redistribute BGP-LU prefix information to IGP. IGP then sends the prefix information to the SR-PCE via BGP-LS.

If there are multiple ABR/ASBRs advertising the same remote BGP-LU prefix, the SR-PCE selects the best gateway node to the BGP-LU domain using the accumulative metric from the head-end device to the gateway and the advertised metric from the gateway to the destination.





## Example: Inter-Domain Path Computation Using Redistributed SID

The following examples show the configurations for the IGP helper, BGP-LU, and proxy BGP-SR:

### Configuration on the End-Point Device

Configure the end-point device to allocate a label for the BGP-LU prefix on the end-point device:

```
router bgp 3107
  bgp router-id 1.0.0.8
  address-family ipv4 unicast
    network 1.0.0.8/32 route-policy bgplu-com
    allocate-label all

  route-policy bgplu-com
    set community (65002:999)
  end-policy
```

### Configuration on the Gateway ABR/ASBR

1. Configure the remote prefix set and create the route policy for the BGP-LU domain:

```
prefix-set bgplu
  1.0.0.7/32,
  1.0.0.8/32,
  1.0.0.101/32,
  1.0.0.102/32
end-set
!

route-policy bgp2isis
  if destination in bgplu then
    pass
  else
    drop
  endif
end-policy
!
end
```

2. Configure the helper IGP instance on the Loopback interface:

```
router isis 101
  is-type level-2-only
  net 49.0001.0000.1010.1010.00
  distribute link-state instance-id 9999
  nsf cisco
  nsf lifetime 120
  address-family ipv4 unicast
  metric-style wide
  maximum-paths 64
  router-id Loopback10
  redistribute bgp 3107 metric 200 route-policy bgp2isis
  segment-routing mpls sr-prefer
!
interface Loopback10 >>> this loopback is for gateway SR-TE node-id
  passive
  address-family ipv4 unicast
  prefix-sid index 2001 explicit-null
```

3. Configure the gateway proxy BGP-SR and SR Mapping Server to allocate SR labels:

```
router bgp 3107
  address-family ipv4 unicast
    segment-routing prefix-sid-map
    allocate-label all

segment-routing
global-block 16000 23999
mapping-server
  prefix-sid-map
    address-family ipv4
      1.0.0.7/32 2007
      1.0.0.8/32 2008
      1.0.0.101/32 2101
      1.0.0.102/32 2102
```