Configure Segment Routing Path Computation Element

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

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.

About SR-PCE

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.

Note For more information on PCE, PCC, and PCEP, refer to the Path Computation Element section in the *MPLS Configuration Guide for Cisco ASR 9000 Series Routers*.

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. 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.

  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.

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** *size*
6. **password** {**clear** | **encrypted**} *password*
7. **segment-routing** {**strict-sid-only** | **te-latency**}
8. **timers**
9. **keepalive** *time*
10. **minimum-peer-keepalive** *time*
11. **reoptimization** *time*
12. **exit**

DETAILED STEPS

	Command or Action	Purpose
Step 1	**configure** **Example:** `RP/0/RSP0/CPU0:router# configure`	Enters global configuration mode.

	Command or Action	Purpose
Step 2	**pce** **Example:** `RP/0/RSP0/CPU0:router(config)# pce`	Enables PCE and enters PCE configuration mode.
Step 3	**address ipv4** *address* **Example:** `RP/0/RSP0/CPU0:router(config-pce)# address ipv4 192.168.0.1`	Configures a PCE IPv4 address.
Step 4	**state-sync ipv4** *address* **Example:** `RP/0/RSP0/CPU0:router(config-pce)# state-sync ipv4 192.168.0.3`	Configures the remote peer for state synchronization.
Step 5	**tcp-buffer size** *size* **Example:** `RP/0/RSP0/CPU0:router(config-pce)# tcp-buffer size 1024000`	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	**password** {**clear** | **encrypted**} *password* **Example:** `RP/0/RSP0/CPU0:router(config-pce)# password encrypted pwd1`	Enables TCP MD5 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.
Step 7	**segment-routing** {**strict-sid-only** | **te-latency**} **Example:** `RP/0/RSP0/CPU0:router(config-pce)# segment-routing strict-sid-only`	Configures the segment routing algorithm to use strict SID or TE latency. **Note** This setting is global and applies to all LSPs that request a path from this controller.
Step 8	**timers** **Example:** `RP/0/RSP0/CPU0:router(config-pce)# timers`	Enters timer configuration mode.
Step 9	**keepalive** *time* **Example:**	Configures the timer value for locally generated keep-alive messages. The default time is 30 seconds.

	Command or Action	Purpose
	`RP/0/RSP0/CPU0:router(config-pce-timers)# keepalive 60`	
Step 10	**minimum-peer-keepalive** *time* **Example:** `RP/0/RSP0/CPU0:router(config-pce-timers)# minimum-peer-keepalive 30`	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.
Step 11	**reoptimization** *time* **Example:** `RP/0/RSP0/CPU0:router(config-pce-timers)# reoptimization 600`	Configures the re-optimization timer. The default timer is 1800 seconds.
Step 12	**exit** **Example:** `RP/0/RSP0/CPU0:router(config-pce-timers)# exit`	Exits timer configuration mode and returns to PCE configuration mode.

Configure the Disjoint Policy (Optional)

This task explains how to configure the SR-PCE to 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.

SUMMARY STEPS

1. **disjoint-path**
2. **group-id** *value* **type** {**link** | **node** | **srlg** | **srlg-node**} [**sub-id** *value*]
3. **strict**
4. **lsp** {**1** | **2**} **pcc ipv4** *address* **lsp-name** *lsp_name* [**shortest-path**]

DETAILED STEPS

	Command or Action	Purpose
Step 1	**disjoint-path** **Example:** `RP/0/RSP0/CPU0:router(config-pce)# disjoint-path`	Enters disjoint configuration mode.

	Command or Action	Purpose
Step 2	**group-id** *value* **type** {**link** | **node** | **srlg** | **srlg-node**} [**sub-id** *value*] **Example:** `RP/0/RSP0/CPU0:router(config-pce-disjoint)#` **`group-id 1 type node sub-id 1`**	Configures the disjoint group ID and defines the preferred level of disjointness (the type of resources that should not be shared by the two paths): • **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 will automatically fallback to a lower level: • 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.
Step 3	**strict** **Example:** `RP/0/RSP0/CPU0:router(config-pce-disjoint)#` **`strict`**	(Optional) 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 terminates and no new path is provided. The existing path is not modified.
Step 4	**lsp** {**1** | **2**} **pcc ipv4** *address* **lsp-name** *lsp_name* [**shortest-path**] **Example:** `RP/0/RSP0/CPU0:router(config-pce-disjoint)#` **`lsp 1 pcc ipv4 192.168.0.1 lsp-name rtrA_t1 shortest-path`** `RP/0/RSP0/CPU0:router(config-pce-disjoint)#` **`lsp 2 pcc ipv4 192.168.0.5 lsp-name rtrE_t2`**	Adds LSPs to the disjoint group. The **shortest-path** keyword 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 the first LSP specified.

Global Maximum-delay Constraint

This feature allows a PCE to compare the cumulative latency of a computed path against a global maximum-delay constraint value. If the latency of the computed path exceeds this global constraint, the path is not considered valid. This ensures that all latency-based paths computed by the PCE and signaled to the PCCs in the network do not exceed this maximum-delay constraint.

```
pce
 constraints
   bounds
    cumulative
     type
      latency <1-4294967295> Bound metric value in microseconds
```

Configuration

To configure a PCE for specifying maximum cumulative latency metric, you must complete the following configurations:

```
RP/0/RSP0/CPU0:ios(config)# pce
RP/0/RSP0/CPU0:ios(config-pce)# constraints
RP/0/RSP0/CPU0:ios(config-pce-constr)# bounds
RP/0/RSP0/CPU0:ios(config-pce-constr-bounds)# cumulative
RP/0/RSP0/CPU0:ios(config-pce-constr-bounds-type)# type latency 1000000
RP/0/RSP0/CPU0:ios(config-pce-constr-bounds-type)#
```

Verification

Verify using the **show** command:

```
RP/0/RSP0/CPU0:ios(config-pce-constr-bounds-type)# show
Wed Oct 12 22:18:22.962 UTC
pce
 constraints
  bounds
   cumulative
    type latency 1000000
   !
  !
 !
!
```

PCE-Initiated SR Policies

Use cases based on centralized optimization, such as congestion mitigation solutions, rely on the ability of the PCE to signal and instantiate SR-TE policies in the network. We refer to this as PCE-initiated SR-TE policies.

PCE-initiated SR-TE policies can be triggered via Crossworks Network Controller (recommended approach) or via CLI at the PCE.

For more information on configuring SR-TE policies, see the SR-TE Policy Overview.

The PCE deploys the SR-TE policy using PCC-PCE communication protocol (PCEP).

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.

Configuration Example: PCE-Initiated SR Policy with Explicit SID List

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

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

> **Note** When configuring an explicit path using IP addresses of intermediate links, the SR-TE process prefers the protected Adj-SID of the link, if one is available.

3. Create the policy.

```
/* 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 10 address ipv4 10.1.1.2
Router(config-pce-sr-te-sl)# index 20 address ipv4 10.2.3.2
Router(config-pce-sr-te-sl)# index 30 address ipv4 10.1.1.4
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 2.2.2.2
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)# commit
Router(config-pce-sr-te-pp-info)# end
Router(config)#
```

Running Config

```
pce
 segment-routing
  traffic-eng
   segment-list name addr2a
    index 10 address ipv4 10.1.1.2
    index 20 address ipv4 10.2.3.2
    index 30 address ipv4 10.1.1.4
   !
   peer ipv4 10.1.1.1
    policy P1
     color 2 end-point ipv4 2.2.2.2
     candidate-paths
      preference 50
```

```
  explicit segment-list addr2a
 !
!
```

ACL Support for PCEP Connection

PCE protocol (PCEP) (RFC5440) is a client-server model running over TCP/IP, where the server (PCE) opens a port and the clients (PCC) initiate connections. After the peers establish a TCP connection, they create a PCE session on top of it.

The ACL Support for PCEP Connection feature provides a way to protect a PCE server using an Access Control List (ACL) to restrict IPv4 PCC peers at the time the TCP connection is created based on the source address of a client. When a client initiates the TCP connection, the ACL is referenced, and the client source address is compared. The ACL can either permit or deny the address and the TCP connection will proceed or not.

Refer to the Implementing Access Lists and Prefix Lists chapter in the *IP Addresses and Services Configuration Guide for Cisco ASR 9000 Series Routers* for detailed ACL configuration information.

To apply an ACL to the PCE, use the **pce peer-filter ipv4 access-list** *acl_name* command.

The following example shows how to configure an ACL and apply it to the PCE:

```
pce
 address ipv4 10.1.1.5
 peer-filter ipv4 access-list sample-peer-filter
!
ipv4 access-list sample-peer-filter
 10 permit ipv4 host 10.1.1.6 any
 20 permit ipv4 host 10.1.1.7 any
 30 deny ipv4 any any
!
```

Anycast SID-Aware Path Computation

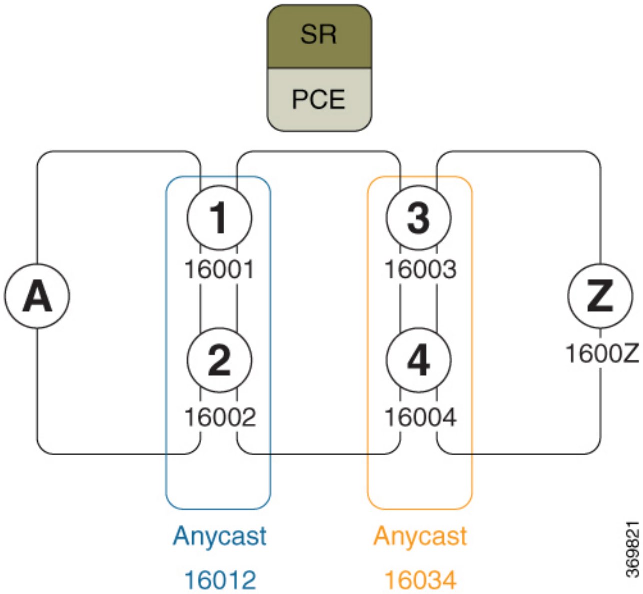
This feature allows the SR-TE head-end or SR-PCE to compute a path that is encoded using Anycast prefix SIDs of nodes along the path.

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, providing load-balancing and redundancy. Packets addressed to an Anycast address are forwarded to the topologically nearest nodes.

Note For information on configuring Anycast SID, see Configuring a Prefix-SID on the IS-IS Enabled Loopback Interface and Configuring a Prefix-SID on the OSPF-Enabled Loopback Interface.

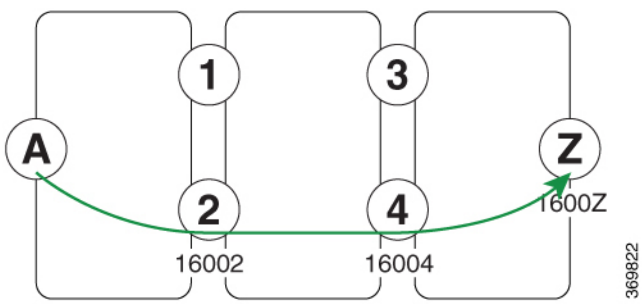
This example shows how Anycast SIDs are inserted into a computed SID list.

The following figure shows 3 isolated IGP domains without redistribution and without BGP 3107. Each Area Border Router (ABR) 1 through 4 is configured with a node SID. ABRs 1 and 2 share Anycast SID 16012 and ABRs 3 and 4 share Anycast SID 16034.



Consider the case where nodes A and Z are provider edge (PE) routers in the same VPN. Node A receives a VPN route with BGP next-hop to node Z. Node A resolves the SR path to node Z based on ODN behaviors with delegation of path computation to SR-PCE.

Before considering Anycast SIDs, the head-end router or SR-PCE computes the SID list.



Assume that the computed path from node A to node Z traverses node 2 and node 4. This translates to SID list {16002, 16004, 1600Z} when node SIDs are leveraged to encode the path.

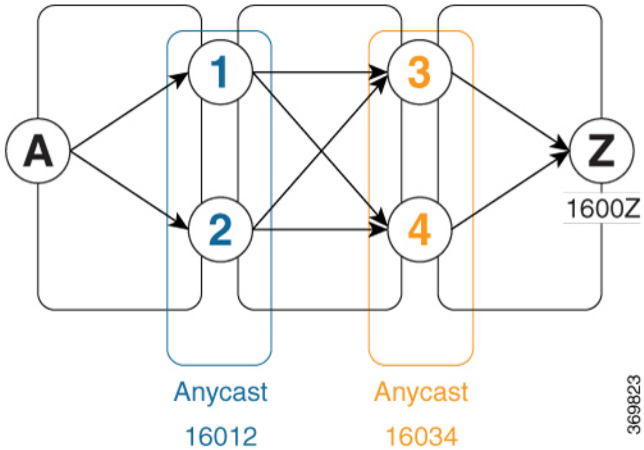
When an Anycast SID-aware path is requested, the path computation algorithm performs the following:

- **Path Computation**—Computes the path according to optimization objectives and constraints
- **Path Encoding**—Encodes the path in a SID list leveraging node-SIDs and adj-SIDs as applicable
- **Anycast SID Replacement**—Reiterates the original SID list by replacing node SIDs with Anycast SIDs present on the nodes along the computed path.
- **Optimality Validation**—The new paths are validated against the original optimization objectives and constraints (maintain same cumulative metric as original SID list and do not violate path constraints).

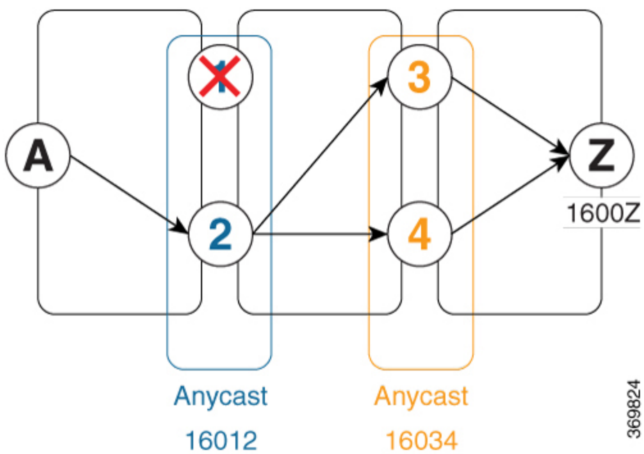
- **Anycast SID Promotion**—If the optimality validation is successful, then the Anycast-encoded SID list is signaled and instantiated in the forwarding.

The following figure depicts cumulative metrics between nodes in the network.

Under these conditions, the optimality check is met, and therefore, the Anycast-encoded SID list from node A to node Z is {16012,16034,1600Z}.



The Anycast SID aware path computation also provides resiliency. For example, if one of the ABRs (in this case, ABR 1) becomes unavailable or unreachable, the path from node A to node Z {16012,16034,1600Z} will still be valid and usable.



Configuration Examples

1. Configure Prefix SIDs on the ABR nodes.
   a. Configure each node with a node SID.
   b. Configure each group of nodes with a shared Anycast SID.

   See Configuring a Prefix-SID on the IS-IS Enabled Loopback Interface and Configuring a Prefix-SID on the OSPF-Enabled Loopback Interface.

2. Configure SR policies to include Anycast SIDs for path computation using the **anycast-sid-inclusion** command.

   This example shows how to configure a local SR policy to include Anycast SIDs for PCC-initiated path computation at the head-end router:

```
Router(config)# segment-routing traffic-eng
Router(config-sr-te)# policy FOO
Router(config-sr-te-policy)# color 10 end-point ipv4 10.1.1.10
Router(config-sr-te-policy)# candidate-paths
Router(config-sr-te-policy-path)# preference 100
Router(config-sr-te-policy-path-pref)# dynamic
Router(config-sr-te-pp-info)# anycast-sid-inclusion
```

Running Configuration

Use the **anycast-sid-inclusion** command to request Anycast SID-aware path computation for the following SR policy types:

- Local SR policy with PCC-initiated path computation at the head-end router:

```
segment-routing
  traffic-eng
    policy FOO
      color 10 end-point ipv4 10.1.1.10
      candidate-paths
        preference 100
          dynamic
            anycast-sid-inclusion
```

- Local SR policy with PCC-initiated/PCE-delegated path computation at the SR-PCE:

```
segment-routing
 traffic-eng
  policy BAR
   color 20 end-point ipv4 10.1.1.20
    candidate-paths
     preference 100
      dynamic
       pcep
       anycast-sid-inclusion
```

- On-demand SR policies with a locally computed dynamic path at the head-end, or centrally computed dynamic path at the SR-PCE:

```
segment-routing
  traffic-eng
   on-demand color 10
    dynamic
     anycast-sid-inclusion
```

- On-demand SR policies with centrally computed dynamic path at the SR-PCE:

```
segment-routing
 traffic-eng
  on-demand color 20
   dynamic
    pcep
    anycast-sid-inclusion
```