Configure SRv6 Traffic Engineering

Table 1: Feature History Table

Feature Name	Release	Description
SRv6 Traffic Engineering	Release 7.3.2	This feature introduces Segment Routing over IPv6 (SRv6) Traffic Engineering. This release supports the following features: • SRv6-TE with SRv6 micro-SIDs (uSIDs) • SRv6 policies • Manual SRv6 policies • Automated steering for Layer 3-based BGP services (IPv4 L3VPN, IPv6 L3VPN, IPv4 BGP global, IPv6 BGP global) • SRv6-aware Path Computation Element (PCE) • PCEPv6 • Path computation optimization objectives (TE, IGP, latency) • Path computation constraints (affinity, disjointness)

This feature introduces Segment Routing over IPv6 (SRv6) Traffic Engineering.

- SRv6-TE Overview, on page 1
- Usage Guidelines and Limitations, on page 2
- Traffic Steering, on page 4
- SRv6-TE Policy Path Types, on page 9
- Protocols, on page 26

SRv6-TE Overview

Traffic engineering over SRv6 can be accomplished in the following ways:

- End-to-End Flexible Algorithm: This is used for traffic engineering intents achieved with Flexible Algorithm, including low latency, multi-plane disjointness, affinity inclusion/exclusion, and SRLG exclusion.
- SRv6-TE Policy: This is used for traffic engineering intents beyond Flex Algo capabilities, such as path disjointness that rely on path computation by a PCE. In addition, this is used for user-configured explicit paths.

End-to-End Flexible Algorithm

SRv6 Flexible Algorithm allows operators to customize IGP shortest path computation according to their own needs. An operator can assign custom SRv6 locators to realize forwarding beyond link-cost-based shortest path. As a result, Flexible Algorithm provides a traffic-engineered path automatically computed by the IGP to any destination reachable by the IGP.

SRv6-TE Policy

SRv6 for traffic engineering (SRv6-TE) uses a “policy” to steer traffic through the network. An SRv6-TE policy path is expressed as a list of micro-segments that specifies the path, called a micro-segment ID (uSID) list. Each segment list is an end-to-end path from the source to the destination, and instructs the routers in the network to follow the specified path instead of following the shortest path calculated by the IGP. If a packet is steered into an SRv6-TE policy, the uSID list is pushed on the packet by the head-end. The rest of the network executes the instructions embedded in the uSID list.

An SRv6-TE policy is identified as an ordered list (head-end, color, end-point):

- Head-end – Where the SRv6-TE policy is instantiated
- Color – A numerical value that distinguishes between two or more policies to the same node pairs (Head-end – End point)
- End-point – The destination of the SRv6-TE policy

Every SRv6-TE policy has a color value. Every policy between the same node pairs requires a unique color value.

An SRv6-TE policy uses one or more candidate paths. A candidate path can be made up of a single SID-list or a set of weighted SID-lists (for weighted equal cost multi-path [WECMP]).

A SID list can be either the result of a dynamic path computation by a PCE or a user-configured explicit path. See SRv6-TE Policy Path Types for more information.

Usage Guidelines and Limitations

Observe the following usage guidelines and limitations for the platform.

This release supports the following SRv6 policy functionality:

- SRv6 policies with SRv6 uSID segments
- SRv6 policies with PCE-delegated dynamic paths
- SRv6 policies with explicit paths
- SRv6 policies with single or multiple candidate paths (CP)

- SRv6 policies with a single SID list per CP
- SRv6 policies with multiple (weighted ECMP) SID lists per CP
- Path delegation and reporting with PCEPv4
- Path delegation and reporting with PCEPv6
- PCEPv4 and PCEPv6 sessions with different PCEs
- PCEP path delegation with the following optimization objective (metric) types:
  - IGP metric
  - TE metric
  - Delay (latency)
  - Hop-count
- PCEP path delegation with the following constraint types:
  - Affinity (include-any, include-all, exclude-any)
  - Path disjointness (link, node, SRLG, SRLG+node)
  - Segment protection-type:
    - Protected-only
    - Protected-preferred
    - Unprotected-only
    - Unprotected-preferred
- SRv6 policy with TI-LFA (protection of the first segment in the segment list at the head-end)
- Steering over SRv6 policies with Automated Steering for the following services:
  - L3 BGP-based services (IPv4 L3VPN, IPv6 L3VPN, IPv4 BGP global, IPv6 BGP global)
  - L2 BGP-based service (EVPN VPWS)

The following functionalities are not supported:

- SRv6 policy counters
- PCE-initiated SRv6 policies via PCEP
- SRv6 policies with head-end computed dynamic paths
- PCE path delegation with segment-type Flex Algo constraint
- PCEPv4 and PCEPv6 sessions with same PCE
- Steering over SRv6 policies based on incoming BSID (remote automated steering)
- PCC with user-configured PCE groups
- SR-PM delay-measurement over SRv6 policies

- SR-PM liveness detection over SRv6 policies
- L3 services with BGP PIC over SRv6 policies
- SRv6 policy ping

SR-PCE and SRv6-TE head-end PCEP compatibility:

- A PCEP session between an SR-PCE running Cisco IOS XR release 7.8.1 and an SRv6-TE head-end running Cisco IOS XR release 7.8.1 is supported.
- A PCEP session between an SR-PCE running Cisco IOS XR release 7.8.1 and an SRv6-TE head-end running an earlier release is supported.
- A PCEP session between an SR-PCE running Cisco IOS XR release earlier than 7.8.1 and an SRv6-TE head-end running Cisco IOS XR release 7.8.1 is not supported.
- A PCEP session between an SR-PCE running Cisco IOS XR release 7.8.1 and another SR-PCE running an earlier Cisco IOS XR release is not supported.
- As a result of the above, prior to upgrading any SRv6-TE headend nodes in the network to Cisco IOS XR release 7.8.1, you must upgrade its SR-PCE to Cisco IOS XR release 7.8.1.

Note When a pair of SR-PCEs part of the same redundancy group run different versions of Cisco IOS XR, they will lose their state-sync PCEP session until both SR-PCEs are upgraded to Cisco IOS XR release 7.8.1.

Traffic Steering

SRv6 Flexible Algorithm

With SRv6 Flexible Algorithm, a PE can advertise BGP service routes (global, VPN) that include the SRv6 locator (Algo 0 or Flex Algo) of the intended transport SLA.

For information about configuring Flexible Algorithm, see Configuring SRv6 IS-IS Flexible Algorithm.

In the example below, the SR domain has 2 network slices. Each slice is assigned a /32 uSID Locator Block.

A slice can be realized with a user-defined Flex-Algo instances (for example, Flex Algo 128 = min-delay)

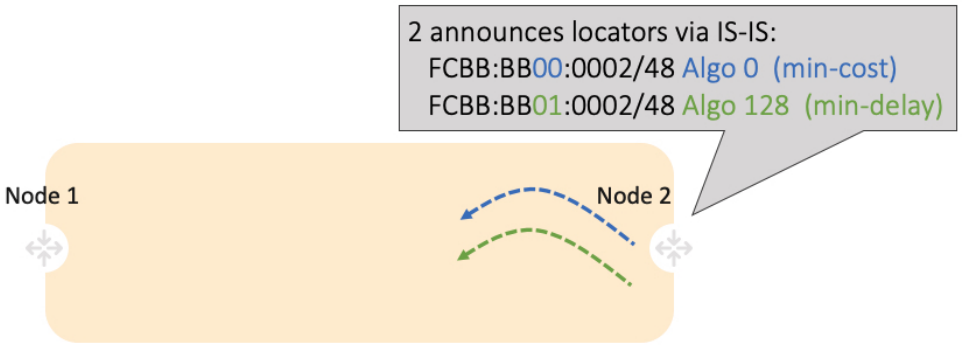
- Min-Cost Slice — FCBB:BB**00**/32
- Min-Delay Slice — FCBB:BB**01**/32

SR node2 gets a Shortest-Path Endpoint uSID (uN) from each slice:

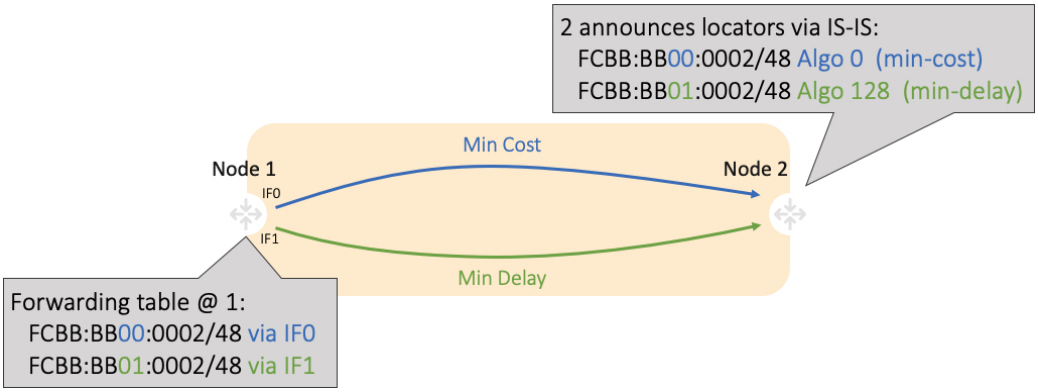
- uN **min-cost** of Node2 — FCBB:BB**00**:0002/48
- uN **min-delay** of Node2 — FCBB:BB**01**:0002/48

Node2 announces locators via IS-IS:

- FCBB:BB**00**:0002/48 Algo **0** (min-cost)
- FCBB:BB**01**:0002/48 Algo **128** (min-delay)



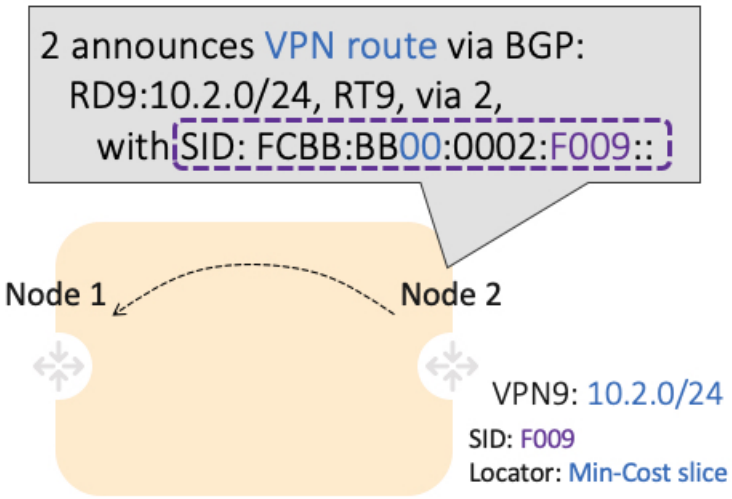
IS-IS in Node1 computes shortest paths for each locator and programs them in the FIB:



Node1 and Node2 are PEs of a common VPN. PEs advertise VPN routes via BGP with different transport SLAs. For example, traffic to a set of prefixes is to be delivered over the min-cost slice, while for another set of prefixes is to be delivered over the min-delay slice. To achieve this, the egress PE's service route advertisement includes the locator of the intended transport SLA type.

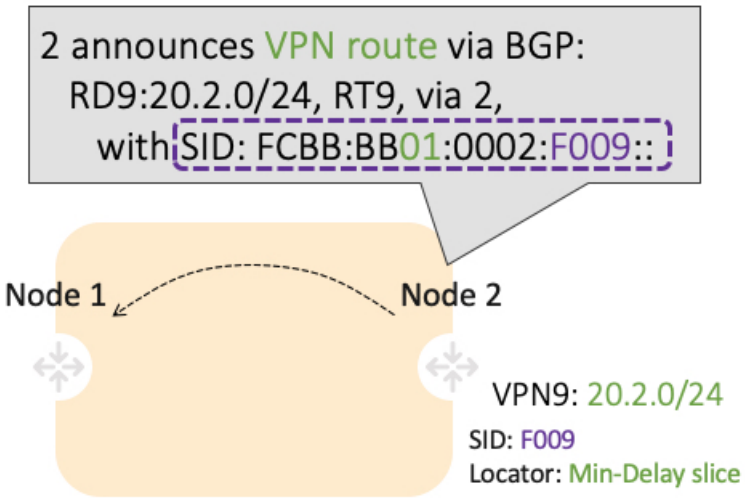
Use-case: VPN over Min-Cost Slice (Control Plane Behavior)

- Intuitive uSID program for routes advertised by Node2:
  - Within the Min-Cost Slice (FCBB:BB**00**)
  - Follow the shortest-path to Node2 (**0002**)
  - Execute VPN9 decapsulation function at Node2 (**F009**)
- Hardware Efficiency
  - Egress PE Node2 processes multiple uSIDs with a single /64 lookup
  - FCBB:BB**00**:**0002**:**F009**/64



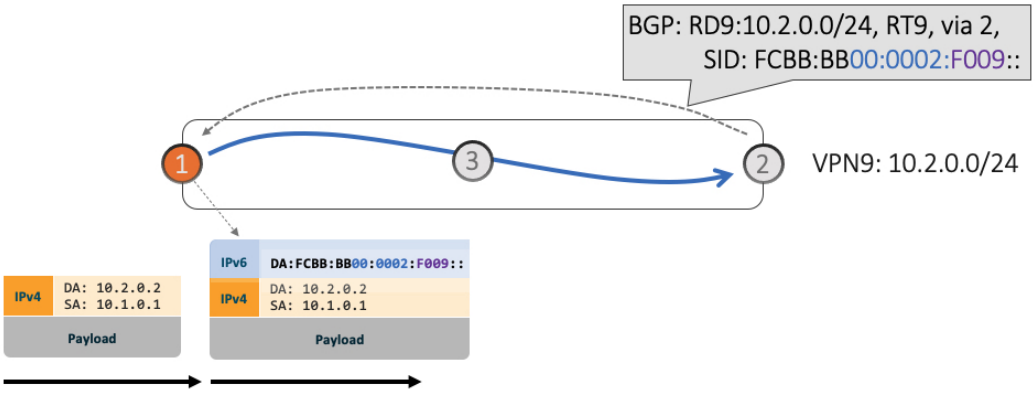
Use-case: VPN over Min-Delay Slice (Control Plane Behavior)

- Intuitive uSID program for routes advertised by Node2:
  - Within the Min-Delay Slice (FCBB:BB**01**)
  - Follow the shortest-path to Node2 (**0002**)
  - Execute VPN9 decapsulation at Node2 (**F009**)
- Hardware Efficiency
  - Egress PE 2 processes multiple uSIDs with a single /64 lookup
  - FCBB:BB**01**:**0002**:**F009**/64



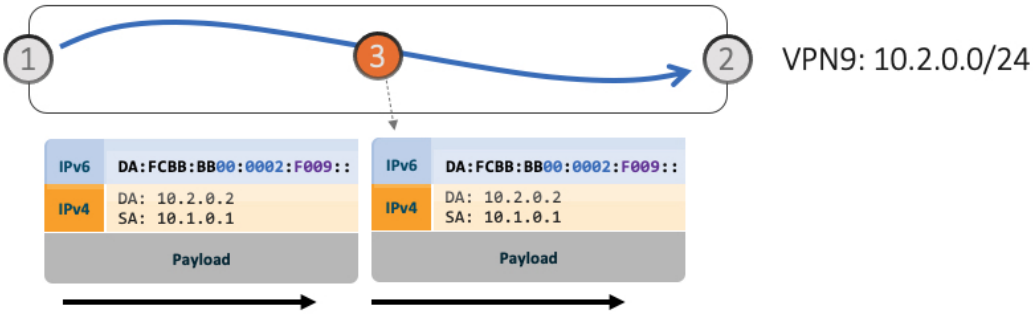
Use-case: VPN over Min-Cost Slice (Data Plane Behavior)

1. Ingress PE (Node 1) learns via BGP that prefix 10.2.0.0/24 in VPN9 is reachable via SID FCBB:BB**00**:**0002**:**F009**
2. Node 1 programs the prefix with "VPN Encaps" behavior
3. When receiving traffic with DA IP matching the prefix 10.2.0.0/24 FIB entry, Node 1 encapsulates the incoming packet into IPv6 with DA of FCBB:BB**00**:**0002**:**F009**

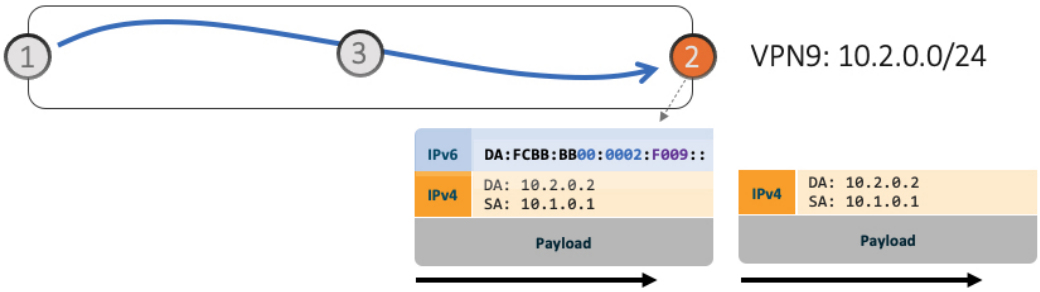


4. SRv6 allows for seamless deployment where any transit node (SRv6-capable or not) simply routes based on a /48 longest prefix match lookup.

   For example, transit node (Node 3) forwards traffic along the Algo 0 (min-cost) shortest path for the remote prefix FCBB:BB00:0002::/48.

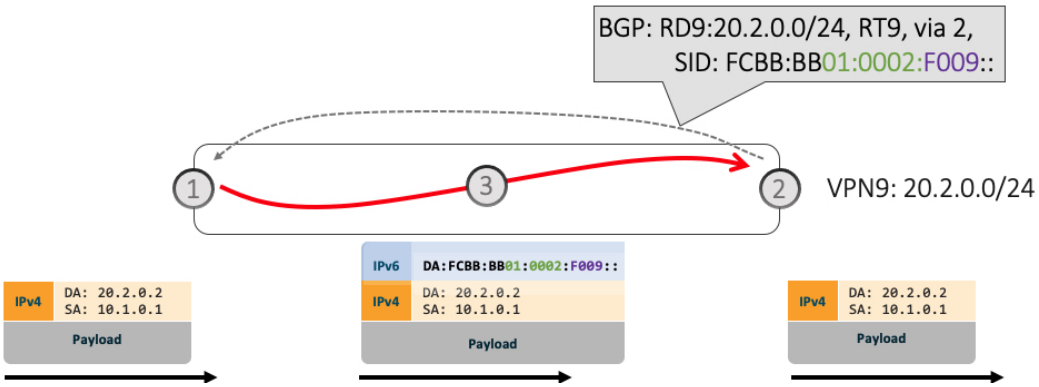


5. Egress PE (Node 2) matches local SID FCBB:BB00:0002:F009/64. Node 2 applies "VPN Decaps" behavior into VRF9 by removing the IPv6 encapsulation and looking up the payload's DA on the corresponding VPN table.



Use-case: VPN over Min-Delay Slice (Data Plane Behavior)

1. Ingress PE (Node 1) learns via BGP that prefix 20.2.0.0/24 in VPN9 is reachable via SID FCBB:BB**01**:**0002**:**F009**
2. Node 1 programs the prefix with "VPN Encaps" behavior
3. When receiving traffic with DA IP matching the prefix 20.2.0.0/24 FIB entry, Node 1 encapsulates the incoming packet into IPv6 with DA of FCBB:BB**01**:**0002**:**F009**
4. Transit node (Node 3) forwards traffic along the Algo 128 (min-delay) shortest path for the remote prefix FCBB:BB01:0002::/48.
5. Egress PE (Node 2) matches local SID FCBB:BB01:0002:F009/64. Node 2 applies "VPN Decaps" behavior into VRF9 by removing the IPv6 encapsulation and looking up the payload's DA on the corresponding VPN table.

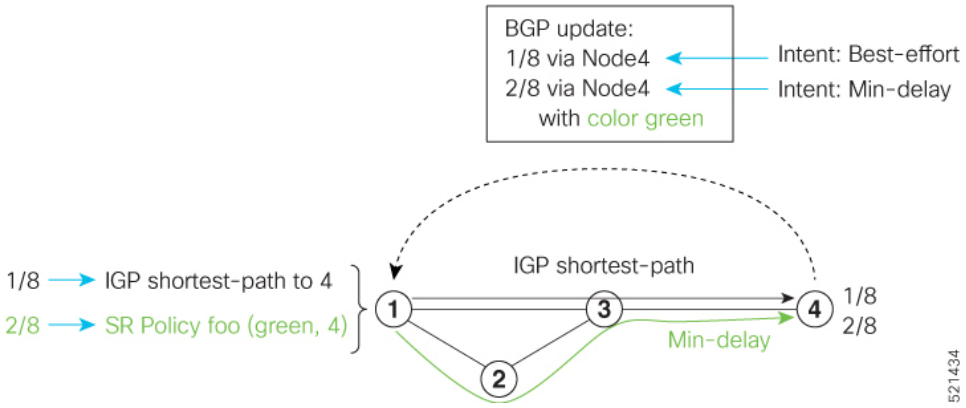


Automated Steering

Automated steering (AS) allows service traffic to be automatically steered onto the required transport SLA path programmed by an SRv6 policy.

With AS, BGP automatically steers traffic onto an SRv6 policy based on the next-hop and color of a BGP service route. The color of a BGP service route is specified by a color extended community attribute. This color is used as a transport SLA indicator, such as min-delay or min-cost.

When the next-hop and color of a BGP service route matches the end-point and color of an SRv6 policy, BGP automatically installs the route resolving onto the BSID of the matching SRv6 policy. Recall that an SRv6 policy on a head-end is uniquely identified by an end-point and color.



When a BGP route has multiple extended-color communities, each with a valid SRv6 policy, the BGP process installs the route on the SRv6 policy giving preference to the color with the highest numerical value.

The granularity of AS behaviors can be applied at multiple levels, for example:

- At a service level—When traffic destined to all prefixes in a given service is associated to the same transport path type. All prefixes share the same color.
- At a destination/prefix level—When traffic destined to a prefix in a given service is associated to a specific transport path type. Each prefix could be assigned a different color.
- At a flow level—When flows destined to the same prefix are associated with different transport path types

SRv6-TE Policy Path Types

An **explicit** path is a specified SID-list or set of SID-lists.

A **dynamic** path is based on an optimization objective and a set of constraints. The head-end computes a solution, resulting in a SID-list or a set of SID-lists. When the topology changes, a new path is computed. If the head-end does not have enough information about the topology, the head-end might delegate the computation to a Segment Routing Path Computation Element (SR-PCE). For information on configuring SR-PCE, see *Configure Segment Routing Path Computation Element* chapter.

An SRv6-TE policy initiates a single (selected) path in RIB/FIB. This is the preferred valid candidate path.

A candidate path has the following characteristics:

- It has a preference – If two policies have same {color, endpoint} but different preferences, the policy with the highest preference is selected.
- It is associated with a single Binding SID (uB6) – A uB6 SID conflict occurs when there are different SRv6 policies with the same uB6 SID. In this case, the policy that is installed first gets the uB6 SID and is selected.
- It is valid if it is usable.

A path is selected when the path is valid and its preference is the best among all candidate paths for that policy.

Note The protocol of the source is not relevant in the path selection logic.

The following SRv6-TE policy path types are supported in this release:

- Explicit Paths
- Dynamic Paths, on page 16

Explicit Paths

Table 2: Feature History Table

Feature Name	Release	Description
Manual SRv6-TE Policies with Explicit Paths	Release 7.8.1	This feature allows you to create an explicit list of segment IDs (SID list) for a candidate path or multiple candidate paths. An explicit path can be a single SID list or set of SID lists.

Usage Guidelines and Limitations

A segment list can use uSIDs or uSID carrier, or a combination of both.

When configuring an explicit path using IP addresses of links along the path, the SRv6-TE process prefers the protected Adj-SID of the link, if one is available. In addition, when manual Adj-SIDs are configured, the SRv6-TE process prefers a manual protected Adj-SID over a dynamic protected Adj-SID.

You can configure the path to prefer the protected or unprotected Adj-SID, or to use only protected or unprotected Adj-SID. See Segment Protection-Type Constraint, on page 20.

You can enable SRv6-TE explicit segment list SID validation to allow the head-end node to validate the SIDs in an explicit SRv6-TE segment list against the SR-TE topology database. See SRv6-TE Explicit Segment List SID Validation, on page 14.

Configure SRv6-TE Policy with Explicit Path

To configure an SRv6-TE policy with an explicit path, complete the following configurations:

1. Create the segment lists with SRv6 segments.
2. Create the SRv6-TE policy.

Behaviors and Limitations

A segment list can use uSIDs or uSID carrier, or a combination of both.

Configure Local SRv6-TE Policy Using Explicit Paths

Create a segment list with SRv6 uSIDs:

```
Router(config)# segment-routing traffic-eng
Router(config-sr-te)# segment-lists
Router(config-sr-te-segment-lists)# srv6
Router(config-sr-te-sl-global-srv6)# sid-format usid-f3216
Router(config-sr-te-sl-global-srv6)# exit
Router(config-sr-te-segment-lists)# segment-list p1_r8_1
Router(config-sr-te-sl)# srv6
Router(config-sr-te-sl-srv6)# index 10 sid FCBB:BB00:10:feff::
Router(config-sr-te-sl-srv6)# index 15 sid FCBB:BB00:100:fe00::
Router(config-sr-te-sl-srv6)# index 20 sid FCBB:BB00:1::
Router(config-sr-te-sl-srv6)# index 30 sid FCBB:BB00:1:fe00::
Router(config-sr-te-sl-srv6)# index 40 sid FCBB:BB00:fe00::
Router(config-sr-te-sl-srv6)# index 50 sid FCBB:BB00:5::
Router(config-sr-te-sl-srv6)# index 60 sid FCBB:BB00:6::
```

Create the SRv6-TE policy:

```
Router(config-sr-te)# policy POLICY1
Router(config-sr-te-policy)# srv6 locator loc1 binding-sid dynamic behavior ub6-insert-reduced
Router(config-sr-te-policy)# color 10 end-point ipv6 FCBB:BB00:2::1
Router(config-sr-te-policy)# candidate-paths
Router(config-sr-te-policy-path)# preference 100
Router(config-sr-te-policy-path-pref)# explicit segment-list p1_r8_1
Router(config-sr-te-pp-info)# exit
Router(config-sr-te-policy-path-pref)# exit
```

Running Configuration

```
Router# show running-config

. . .

segment-routing
 traffic-eng
  segment-lists
   srv6
    sid-format usid-f3216
   !
   segment-list p1_r8_1
    srv6
     index 10 sid FCBB:BB00:10:feff::
     index 15 sid FCBB:BB00:100:fe00::
     index 20 sid FCBB:BB00:1::
     index 30 sid FCBB:BB00:1:fe00::
     index 40 sid FCBB:BB00:fe00::
     index 50 sid FCBB:BB00:5::
     index 60 sid FCBB:BB00:6::
    !
   !
  !
  policy POLICY1
   srv6
    locator loc1 binding-sid dynamic behavior ub6-insert-reduced
   !
   color 10 end-point ipv6 fcbb:bb00:2::1
   candidate-paths
    preference 100
     explicit segment-list p1_r8_1
     !
```

```
    !
   !
  !
 !
!
```

Verification

Verify the SR-TE policy configuration using:

```
Router# show segment-routing traffic-eng policy name srte_c_10_ep_fcbb:bb00:2::1 d

SR-TE policy database
---------------------

Color: 10, End-point: fcbb:bb00:2::1
  Name: srte_c_10_ep_fcbb:bb00:2::1
  Status:
    Admin: up  Operational: down for 00:01:30 (since Oct 31 21:33:24.090)
  Candidate-paths:
    Preference: 100 (configuration) (inactive)
      Name: POLICY1
      Requested BSID: dynamic
      Constraints:
        Protection Type: protected-preferred
        Maximum SID Depth: 13
      Explicit: segment-list p1_r8_1 (inactive)
        Weight: 1, Metric Type: TE
          SID[0]: FCBB:BB00:10:feff::
          SID[1]: FCBB:BB00:100:fe00::
          SID[2]: FCBB:BB00:1::
          SID[3]: FCBB:BB00:1:fe00::
          SID[4]: FCBB:BB00:fe00::
          SID[5]: FCBB:BB00:5::
          SID[6]: FCBB:BB00:6::
      SRv6 Information:
        Locator: loc1
        Binding SID requested: Dynamic
        Binding SID behavior: End.B6.Insert.Red
  Attributes:
    Forward Class: 0
    Steering labeled-services disabled: no
    Steering BGP disabled: no
    IPv6 caps enable: yes
    Invalidation drop enabled: no
    Max Install Standby Candidate Paths: 0
```

Candidate Paths with Weighted SID Lists

If a candidate path is associated with a set of segment lists, each segment list is associated with weight for weighted load balancing. Valid values for weight are from 1 to 4294967295; the default weight is 1.

If a set of segment lists is associated with the active path of the policy, then the steering is per-flow and weighted-ECMP (W-ECMP) based according to the relative weight of each segment list.

The fraction of the flows associated with a given segment list is *w*/*Sw*, where *w* is the weight of the segment list and *Sw* is the sum of the weights of the segment lists of the selected path of the SR policy.

When a composite candidate path is active, the fraction of flows steered into each constituent SR policy is equal to the relative weight of each constituent SR policy. Further load balancing of flows steered into a

constituent SR policy is performed based on the weights of the segment list of the active candidate path of that constituent SR policy.

Configuration Example

```
Router(config)# segment-routing traffic-eng
Router(config-sr-te)# segment-lists
Router(config-sr-te-segment-lists)# srv6
Router(config-sr-te-sl-global-srv6)# sid-format usid-f3216
Router(config-sr-te-sl-global-srv6)# exit
Router(config-sr-te-segment-lists)# segment-list p1_r8_3
Router(config-sr-te-sl)# srv6
Router(config-sr-te-sl-srv6)# index 10 sid FCBB:BB00:10:fe01::
Router(config-sr-te-sl-srv6)# index 20 sid FCBB:BB00:1::
Router(config-sr-te-sl-srv6)# index 30 sid FCBB:BB00:1:fe00::
Router(config-sr-te-sl-srv6)# index 40 sid FCBB:BB00:fe00::
Router(config-sr-te-sl-srv6)# index 50 sid FCBB:BB00:5::
Router(config-sr-te-sl-srv6)# index 60 sid FCBB:BB00:6::
Router(config-sr-te-segment-lists)# segment-list igp_ucmp1
Router(config-sr-te-sl)# srv6
Router(config-sr-te-sl-srv6)# index 10 sid FCBB:BB00:1::
Router(config-sr-te-sl-srv6)# index 20 sid FCBB:BB00:4::
Router(config-sr-te-sl-srv6)# index 30 sid FCBB:BB00:5::
Router(config-sr-te-sl-srv6)# exit
Router(config-sr-te-sl)# exit
Router(config-sr-te-segment-lists)# exit

Router(config-sr-te)# policy po_r8_1001
Router(config-sr-te-policy)# srv6 locator loc1 binding-sid dynamic behavior ub6-insert-reduced
Router(config-sr-te-policy)# color 1001 end-point ipv6 FCBB:BB00:2::1
Router(config-sr-te-policy)# candidate-paths
Router(config-sr-te-policy-path)# preference 1000
Router(config-sr-te-policy-path-pref)# explicit segment-list p1_r8_3
Router(config-sr-te-pp-info)# weight 4
Router(config-sr-te-pp-info)# exit
Router(config-sr-te-policy-path-pref)# explicit segment-list igp_ucmp1
Router(config-sr-te-pp-info)# weight 2
Router(config-sr-te-pp-info)# exit
```

Running Configuration

```
Router# show running-config

. . .

segment-routing
 traffic-eng
  segment-lists
   srv6
    sid-format usid-f3216
   !
   segment-list p1_r8_3
    srv6
     index 10 sid FCBB:BB00:10:fe01::
     index 20 sid FCBB:BB00:1::
     index 30 sid FCBB:BB00:1:fe00::
     index 40 sid FCBB:BB00:fe00::
     index 50 sid FCBB:BB00:5::
     index 60 sid FCBB:BB00:6::
    !
```

```
    !
    segment-list igp_ucmp1
     srv6
      index 10 sid FCBB:BB00:1::
      index 20 sid FCBB:BB00:4::
      index 30 sid FCBB:BB00:5::
     !
    !
   !
   policy po_r8_1001
    srv6
     locator loc1 binding-sid dynamic behavior ub6-insert-reduced
    !
    color 1001 end-point ipv6 fcbb:bb00:2::1
    candidate-paths
     preference 1000
      explicit segment-list p1_r8_3
       weight 4
      !
      explicit segment-list igp_ucmp1
       weight 2
      !
     !
    !
   !
  !
!
```

SRv6-TE Explicit Segment List SID Validation

Table 3: Feature History Table

Feature Name	Release Information	Feature Description
SRv6-TE Explicit Segment List SID Validation	Release 7.8.1	This feature provides a way for the head-end node to validate the SIDs in an explicit SRv6-TE segment list against the SR-TE topology database. If any SID in the segment list is not found on the head-end, the validation fails, and the policy remains down.

SRv6-TE explicit segment list SID validation evaluates whether the explicit segment list of an SR policy's candidate path is valid and therefore usable. The head-end node validates if the hops are in the SR-TE topology database.

When enabled, the segment list SID validation occurs before programming the SR policy and after an IGP topology change.

When the segment list validation fails, then the segment list is declared invalid. An SR policy candidate path is declared invalid when it has no valid segment lists. An SR policy is declared invalid when it has no valid candidate paths.

Usage Guidelines and Limitations

- Segment list SID validation can be enabled globally for all SRv6 explicit segment lists or for a specific SRv6 segment list.

- If SIDs in an explicit segment list are expected to not be found in the headend (for example, a multi-domain case), the topology check can be disabled for that segment list.
- The SR-TE topology should distributed from IGP (for intra-domain paths) or from BGP-LS (for multi-domain paths).
- The SRv6 segment list in an explicit candidate path of an SRv6 policy cannot be empty.
- All segments in a segment list must be of same data plane type: SRv6 or SR-MPLS.
- Top SID validation occurs by performing path resolution using the top SID.
- All SIDs in segment list are validated against local SID block and SID format.
- A segment list is validated against MSD.

Configuration

Prior to enabling SRv6 explicit segment list SID validation, use the **show segment-routing traffic-eng topology** command to verify if the SR-TE topology is available on the headend PCC router.

To enable SID validation globally, use the **segment-routing traffic-eng segment-lists srv6 topology-check** command.

To enable SID validation for a specific explicit SID list, use the **segment-routing traffic-eng segment-lists segment-list** *name* **srv6 topology-check** command.

Configuration Example

The following example shows how to enable SID validation globally for all SRv6 explicit segment lists:

```
Router(config)# segment-routing traffic-eng
Router(config-sr-te)# segment-lists
Router(config-sr-te-segment-lists)# srv6
Router(config-sr-te-sl-global-srv6)# topology-check
```

The following example shows how to enable SID validation for a specific SRv6 explicit segment list:

```
Router(config)# segment-routing traffic-eng
Router(config-sr-te)# segment-lists
Router(config-sr-te-segment-lists)# segment-list p1_r8_1
Router(config-sr-te-sl)# srv6
Router(config-sr-te-sl-srv6)# topology-check
```

The following example shows how to enable SID validation globally and disable SID validation for a specific SRv6 explicit segment list:

```
Router(config)# segment-routing traffic-eng
Router(config-sr-te)# segment-lists
Router(config-sr-te-segment-lists)# srv6
Router(config-sr-te-sl-global-srv6)# topology-check
Router(config-sr-te-sl-global-srv6)# exit
Router(config-sr-te-segment-lists)# segment-list p1_r8_1
Router(config-sr-te-sl)# srv6
Router(config-sr-te-sl-srv6)# no topology-check
```

Running Configuration

```
segment-routing
 traffic-eng
  segment-lists
   srv6
    topology-check
   !
   segment-list p1_r8_1
    srv6
     no topology-check
    !
   !
  !
 !
!
```

Verification

```
Router# show segment-routing traffic-eng policy name srte_c_10_ep_fcbb:bb00:2::1 detail

SR-TE policy database
---------------------

Color: 10, End-point: fcbb:bb00:2::1
  Name: srte_c_10_ep_fcbb:bb00:2::1
  Status:
    Admin: up  Operational: down for 00:04:12 (since Nov  7 19:24:21.396)
  Candidate-paths:
    Preference: 100 (configuration) (inactive)
      Name: POLICY1
      Requested BSID: dynamic
      Constraints:
        Protection Type: protected-preferred
        Maximum SID Depth: 13
      Explicit: segment-list p1_r8_1 (inactive)
        Weight: 1, Metric Type: TE
          SID[0]: fccc:0:10:feff::
          SID[1]: fccc:0:100:fe00::
          SID[2]: fccc:0:1::
          SID[3]: fccc:0:1:fe00::
          SID[4]: fccc:0:fe00::
          SID[5]: fccc:0:5::
          SID[6]: fccc:0:6::
      SRv6 Information:
        Locator: loc1
        Binding SID requested: Dynamic
        Binding SID behavior: End.B6.Insert.Red
  Attributes:
    Forward Class: 0
    Steering labeled-services disabled: no
    Steering BGP disabled: no
    IPv6 caps enable: yes
    Invalidation drop enabled: no
    Max Install Standby Candidate Paths: 0
```

Dynamic Paths

Behaviors and Limitations

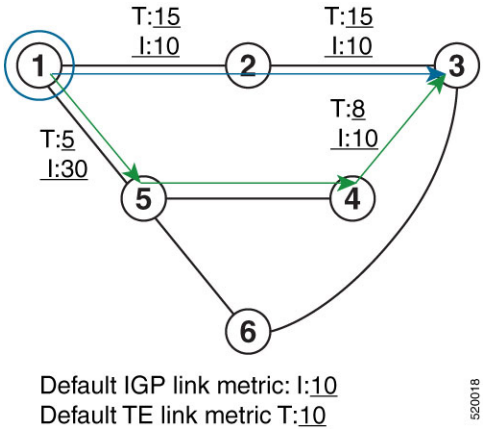
For a dynamic path that traverses a specific interface between nodes (segment), the algorithm may encode this segment using an Adjacency uSID (uA SID).

Optimization Objectives

Optimization objectives allow the head-end router to compute a uSID-list that expresses the shortest dynamic path according to the selected metric type:

- Hopcount — Use the least number of hops for path computation.
- IGP metric — Refer to the "Implementing IS-IS" and "Implementing OSPF" chapters in the *Routing Configuration Guide for Cisco ASR 9000 Series Routers*.
- TE metric — See the Configure Interface TE Metrics section for information about configuring TE metrics.
- Delay (latency) — See the Configure Performance Measurement chapter for information about measuring delay for links or SRv6 policies.

This example shows a dynamic path from head-end router 1 to end-point router 3 that minimizes IGP or TE metric:



- The blue path uses the minimum IGP metric: Min-Metric (1 → 3, IGP) = uSID-list {cafe:0:**3**::}; cumulative IGP metric: 20
- The green path uses the minimum TE metric: Min-Metric (1 → 3, TE) = uSID-list {cafe:0:**5**:**4**:**3**::}; cumulative TE metric: 23

Configure Interface TE Metrics

Use the **metric** *value* command in SR-TE interface submode to configure the TE metric for interfaces. The *value* range is from 0 to 2147483647.

```
Router# configure
Router(config)# segment-routing
Router(config-sr)# traffic-eng
Router(config-sr-te)# interface type interface-path-id
Router(config-sr-te-if)# metric value
```

Configuring TE Metric: Example

The following configuration example shows how to set the TE metric for various interfaces:

```
segment-routing
 traffic-eng
```

```
  interface TenGigE0/0/0/0
   metric 100
  !
  interface TenGigE0/0/0/1
   metric 1000
  !
  interface TenGigE0/0/2/0
   metric 50
  !
 !
end
```

Constraints

Constraints allow the head-end router to compute a dynamic path according to the selected metric type:

Note For path-computation on PCE, configuring both affinity and disjoint-path is not supported.

- Affinity — You can apply a color or name to links or interfaces by assigning affinity bit-maps to them. You can then specify an affinity (or relationship) between an SRv6 policy path and link colors. SRv6-TE computes a path that includes or excludes links that have specific colors,or combinations of colors. See the Named Interface Link Admin Groups and SR-TE Affinity Maps section for information on named interface link admin groups and SRv6-TE Affinity Maps.
- Disjoint — SRv6-TE computes a path that is disjoint from another path in the same disjoint-group. Disjoint paths do not share network resources. Path disjointness may be required for paths between the same pair of nodes, between different pairs of nodes, or a combination (only same head-end or only same end-point).
- Segment protection-type behavior — You can control whether protected or unprotected segments are used when encoding the SID-list of an SRv6 policy candidate path. The types of segments that could be used when building a SID-list include uSIDs and adjacency SIDs (uA SID). See the Segment Protection-Type Constraint, on page 20 for details and usage guidelines.

Named Interface Link Admin Groups and SRv6-TE Affinity Maps

Named Interface Link Admin Groups and SRv6-TE Affinity Maps provide a simplified and more flexible means of configuring link attributes and path affinities to compute paths for SRv6-TE policies.

In the traditional TE scheme, links are configured with attribute-flags that are flooded with TE link-state parameters using Interior Gateway Protocols (IGPs), such as Open Shortest Path First (OSPF).

Named Interface Link Admin Groups and SRv6-TE Affinity Maps let you assign, or map, up to 256 color names for affinity and attribute-flag attributes instead of 32-bit hexadecimal numbers. After mappings are defined, the attributes can be referred to by the corresponding color name in the CLI. Furthermore, you can define constraints using *include-any*, *include-all*, and *exclude-any* arguments, where each statement can contain up to 10 colors.

Note You can configure affinity constraints using attribute flags or the Flexible Name Based Policy Constraints scheme; however, when configurations for both schemes exist, only the configuration pertaining to the new scheme is applied.

Configure Named Interface Link Admin Groups and SRv6-TE Affinity Maps

Use the **segment-routing traffic-eng interface** *interface* **affinity name** *NAME* command to assign affinity to interfaces. Configure this on routers with interfaces that have an associated admin group attribute.

Use the **segment-routing traffic-eng affinity-map name** *NAME* **bit-position** *bit-position* command to define affinity maps. The *bit-position* range is from 0 to 255.

Configure affinity maps on the following routers:

- Routers with interfaces that have an associated admin group attribute.
- Routers that act as SRv6-TE head-ends for SR policies that include affinity constraints.

Configuring Link Admin Group: Example

The following example shows how to assign affinity to interfaces and to define affinity maps. This configuration is applicable to any router (SRv6-TE head-end or transit node) with colored interfaces.

```
Router(config)# segment-routing
Router(config-sr)# traffic-eng
Router(config-sr-te)# interface HundredGigE0/0/0/0
Router(config-sr-if)# affinity
Router(config-sr-if-affinity)# name brown
Router(config-sr-if-affinity)# exit
Router(config-sr-if)# exit

Router(config-sr-te)# affinity-map
Router(config-sr-te-affinity-map)# name brown bit-position 1
```

Running Config

```
segment-routing
 traffic-eng
  interface HundredGigE0/0/0/0
   affinity
    name brown
   !
  !
  affinity-map
   name brown bit-position 1
  !
end
```

Segment Protection-Type Constraint

Table 4: Feature History Table

Feature Name	Release Information	Feature Description
Segment Protection-Type Constraint	Release 7.4.1	This feature introduces the ability to control whether protected or unprotected segments are used when encoding the SID-list of an SR policy candidate path. The types of segments that could be used when building a SID-list include prefix SIDs and adjacency SIDs.

This feature introduces the ability to control whether protected or unprotected segments are used when encoding the SID-list of an SRv6 policy candidate path. The types of segments that could be used when building a SID-list include uSIDs and adjacency SIDs (uA SID).

A prefix SID is a global segment representing a prefix that identifies a specific node. A prefix SID is programmed with a backup path computed by the IGP using TI-LFA.

An adjacency SID is a local segment representing an IGP adjacency. An adjacency SID can be programmed with or without protection. Protected adjacency SIDs are programmed with a link-protectant backup path computed by the IGP (TI-LFA) and are used if the link associated with the IGP adjacency fails.

Prefix SIDs and adjacency SIDs can be leveraged as segments in a SID-list in order to forward a packet along a path traversing specific nodes and/or over specific interfaces between nodes. The type of segment used when encoding the SID-list will determine whether failures along the path would be protected by TI-LFA. Depending on the offering, an operator may want to offer either unprotected or protected services over traffic engineered paths.

The following behaviors are available with the segment protection-type constraint:

- **protected-only** — The SID-list must be encoded using protected segments.
- **protected-preferred** — The SID-list should be encoded using protected segments if available; otherwise, the SID-list may be encoded using unprotected Adj-SIDs. This is the default behavior when no segment protection-type constraint is specified.
- **unprotected-only** — The SID-list must be encoded using unprotected Adj-SID.
- **unprotected-preferred** — The SID-list should be encoded using unprotected Adj-SID if available, otherwise SID-list may be encoded using protected segments.

Usage Guidelines and Limitations

Observe the following guidelines and limitations for the platform:

- This constraint applies to candidate-paths of manual SR policies with dynamically computed paths.
- PCEP has been augmented (vendor-specific object) to allow a PCC to indicate the segment protection-type constraint to the PCE.

- When the segment protection type constraint is protected-only or unprotected-only, the path computation must adhere to the constraint. If the constraint is not satisfied, the SRv6 policy will not come up on such candidate path.
- When the segment protection-type constraint is unprotected-only, the entire SID-list must be encoded with unprotected Adj-SIDs.
- When the segment protection-type constraint is protected-only, the entire SID-list must be encoded with protected Adj-SIDs or Prefix SIDs.

Configuring Segment Protection-Type Constraint

Use the **constraints segments protection** {**protected-only** | **protected-preferred** | **unprotected-only** | **unprotected-preferred**} command to configure the segment protection-type behavior.

The following example shows how to configure the policy with a SID-list that must be encoded using protected segments:

```
Router(config-sr-te)# policy POLICY1
Router(config-sr-te-policy)# color 10 end-point ipv6 2:2::22
Router(config-sr-te-policy)# candidate-paths
Router(config-sr-te-policy-path)# preference 100
Router(config-sr-te-policy-path-pref)# constraints
Router(config-sr-te-path-pref-const)# segments
Router(config-sr-te-path-pref-const-seg)# protection protected-only
```

The following example shows how to configure the SRv6 ODN policy that must be encoded using protected segments:

```
Router(config)# segment-routing traffic-eng
Router(config-sr-te)# on-demand color 20
Router(config-sr-te-color)# constraints
Router(config-sr-te-color-const)# segments
Router(config-sr-te-color-const-seg)# protection protected-only
```

Configure SRv6 Policy with Dynamic Path

To configure a SRv6-TE policy with a dynamic path, optimization objectives, and affinity constraints, complete the following configurations:

1. Define the optimization objectives. See the Optimization Objectives section.
2. Define the constraints. See the Constraints section.
3. Create the policy.

Behaviors and Limitations

For a dynamic path that traverses a specific interface between nodes (segment), the algorithm may encode this segment using an Adjacency micro-SID (uA SID).

Configuration

Create the SRv6-TE Policy

- Use the **segment-routing traffic-eng policy** *policy* **srv6 color** *color* **end-point ipv6** *ipv6-address* command to configure the SRv6-TE policy color and IPv6 end-point address.

```
Node1(config)# segment-routing traffic-eng policy pol_node1_node4_te srv6 color 50
end-point ipv6 cafe:0:4::4
```

Specify Customized Locator and Source Address

- (Optional) Use the **segment-routing traffic-eng policy** *policy* **srv6 locator** *locator* **binding-sid dynamic behavior ub6-insert-reduced** command to specify the customized per-policy locator and BSID behavior. If you do not specify a customized per-policy locator and BSID behavior, the policy will use the global locator and BSID behavior.

```
Node1(config)# segment-routing traffic-eng policy pol_node1_node4_te srv6 locator node1
 binding-sid dynamic behavior ub6-insert-reduced
```

- (Optional) Use the **segment-routing traffic-eng policy** *policy* **source-address ipv6** *ipv6-address* command to specify the customized IPv6 source address for candidate paths. If you do not specify a customized per-policy source address, the policy will use the local IPv6 source address.

```
Node1(config)# segment-routing traffic-eng policy pol_node1_node4_te srv6 source-address
 ipv6 cafe:0:1::1
```

Enable Dynamic Path Computed by the SR-PCE

- Use the **segment-routing traffic-eng policy** *policy* **candidate-paths preference** *preference* **dynamic pcep** command to specify the candidate path preference and enable dynamic path computed by the SR-PCE. The range for *preference* is from 1 to 65535.

```
Node1(config)# segment-routing traffic-eng policy pol_node1_node4_te candidate-paths
preference 100 dynamic pcep
```

Configure Dynamic Path Optimization Objectives

- Use the **segment-routing traffic-eng policy** *policy* **candidate-paths preference** *preference* **dynamic metric type** {**igp** | **te** | **latency**} command to configure the metric for use in path computation.

```
Node1(config)# segment-routing traffic-eng policy pol_node1_node4_te candidate-paths
preference 100 metric type te
```

- Use the **segment-routing traffic-eng policy** *policy* **candidate-paths preference** *preference* **dynamic metric margin** {**absolute** *value*| **relative** *percent*} command to configure the dynamic path metric margin. The range for *value* and *percent* is from 0 to 2147483647.

```
Node1(config)# segment-routing traffic-eng policy pol_node1_node4_te candidate-paths
preference 100 metric margin absolute 5
```

Configure Dynamic Path Constraints

Note Disjoint-path and affinity constraints cannot be configured at the same time.

- Use the **segment-routing traffic-eng policy** *policy* **candidate-paths preference** *preference* **constraints affinity** {**exclude-any** | **include-all** | **include-any**} *name* command to configure the affinity constraints.

```
Node1(config)# segment-routing traffic-eng policy pol_node1_node4_te candidate-paths
preference 100 constraints affinity exclude-any name brown
```

- Use the **segment-routing traffic-eng policy** *policy* **candidate-paths preference** *preference* **constraints disjoint-path group-id** *group-id* **type** {**link** | **node** | **srlg** | **srlg-node**} [**sub-id** *sub-id*] command to configure the disjoint-path constraints. The *group-id* and *sub-id* range is from 1 to 65535

  ```
  Node1(config)# segment-routing traffic-eng policy pol_node1_node4_te candidate-paths
  preference 100 constraints disjoint-path group-id 775 type link
  ```

- Use the **segment-routing traffic-eng policy** *policy* **candidate-paths preference** *preference* **constraints segments protection** {**protected-only** | **protected-preferred** | **unprotected-only** | **unprotected-preferred**} command to configure the segment protection-type behavior.

  See Segment Protection-Type Constraint, on page 20 for details about the segment protection-type constraint.

  The following example shows how to configure the policy with a SID-list that must be encoded using protected segments:

  ```
  Node1(config)# segment-routing traffic-eng policy pol_node1_node4_te candidate-paths
  preference 100 constraints segments protection protected-only
  ```

Examples

The following example shows a configuration of an SRv6 policy at an SRv6-TE head-end router using the global locator and source address. The policy has a dynamic path with optimization objectives and affinity constraints computed by the SR-PCE.

```
Node1(config)# segment-routing
Node1(config-sr)# traffic-eng
Node1(config-sr-te)# srv6
Node1(config-sr-te-srv6)# locator Node1 binding-sid dynamic behavior ub6-insert-reduced
Node1(config-sr-te-srv6)# exit
Node1(config-sr-te)# candidate-paths
Node1(config-sr-te-candidate-path)# all
Node1(config-sr-te-candidate-path-type)# source-address ipv6 cafe:0:1::1
Node1(config-sr-te-candidate-path-type)# exit
Node1(config-sr-te-candidate-path)# exit

Node1(config-sr-te)# policy pol_node1_node4_te
Node1(config-sr-te-policy)# color 20 end-point ipv6 cafe:0:4::4
Node1(config-sr-te-policy)# candidate-paths
Node1(config-sr-te-policy-path)# preference 100
Node1(config-sr-te-policy-path-pref)# dynamic
Node1(config-sr-te-pp-info)# pcep
Node1(config-sr-te-path-pcep)# exit
Node1(config-sr-te-pp-info)# metric type te
Node1(config-sr-te-pp-info)# exit
Node1(config-sr-te-policy-path-pref)# constraints
Node1(config-sr-te-path-pref-const)# affinity
Node1(config-sr-te-path-pref-const-aff)# exclude-any
Node1(config-sr-te-path-pref-const-aff-rule)# name brown
```

Running Config

```
segment-routing
 traffic-eng
  srv6
```

```
   locator Node1 binding-sid dynamic behavior ub6-insert-reduced
  !
  candidate-paths
   all
    source-address ipv6 cafe:0:1::1
   !
  !
  policy pol_node1_node4_te
   color 20 end-point ipv6 cafe:0:4::4
   candidate-paths
    preference 100
     dynamic
      pcep
      !
      metric
       type te
      !
     !
     constraints
      affinity
       exclude-any
        name brown
       !
      !
     !
    !
   !
  !
 !
!
```

The following example shows a configuration of a manual SRv6 policy at an SRv6-TE head-end router with customized locator and source address. The policy has a dynamic path with optimization objectives and affinity constraints computed by the SR-PCE.

```
Node1(config)# segment-routing
Node1(config-sr)# traffic-eng
Node1(config-sr-te)# policy pol_node1_node4_te
Node1(config-sr-te-policy)# source-address ipv6 cafe:0:1::1
Node1(config-sr-te-policy)# srv6
Node1(config-sr-te-policy-srv6)# locator Node1 binding-sid dynamic behavior ub6-insert-reduced
Node1(config-sr-te-policy-srv6)# exit
Node1(config-sr-te-policy)# color 20 end-point ipv6 cafe:0:4::4
Node1(config-sr-te-policy)# candidate-paths
Node1(config-sr-te-policy-path)# preference 100
Node1(config-sr-te-policy-path-pref)# dynamic
Node1(config-sr-te-pp-info)# pcep
Node1(config-sr-te-path-pcep)# exit
Node1(config-sr-te-pp-info)# metric type te
Node1(config-sr-te-pp-info)# exit
Node1(config-sr-te-policy-path-pref)# constraints
Node1(config-sr-te-path-pref-const)# affinity
Node1(config-sr-te-path-pref-const-aff)# exclude-any
Node1(config-sr-te-path-pref-const-aff-rule)# name brown
```

Running Config

```
segment-routing
 traffic-eng
  policy pol_node1_node4_te
   srv6
    locator Node1 binding-sid dynamic behavior ub6-insert-reduced
   !
```

```
   source-address ipv6 cafe:0:1::1
   color 20 end-point ipv6 cafe:0:4::4
   candidate-paths
    preference 100
     dynamic
      pcep
      !
      metric
       type te
      !
     !
     constraints
      affinity
       exclude-any
        name brown
       !
      !
     !
    !
   !
  !
 !
```

Verification

```
Node1# show segment-routing traffic-eng policy color 20

SR-TE policy database
---------------------
Color: 20, End-point: cafe:0:4::4
  Name: srte_c_20_ep_cafe:0:4::4
  Status:
    Admin: up  Operational: down for 00:00:09 (since Nov  5 20:10:26.158)
  Candidate-paths:
    Preference: 100 (configuration)
      Name: pol_node1_node4_te
      Requested BSID: dynamic
      PCC info:
        Symbolic name: cfg_pol_node1_node4_te_discr_100
        PLSP-ID: 1
        Protection Type: unprotected-preferred
        Maximum SID Depth: 13
      Dynamic (pce cafe:0:2::2) (valid)
        Metric Type: NONE,   Path Accumulated Metric: 0
      SRv6 Information:
        Locator: Node1
        Binding SID requested: Dynamic
        Binding SID behavior: End.B6.Insert.Red
  Attributes:
    Forward Class: 0
    Steering labeled-services disabled: no
    Steering BGP disabled: no
    IPv6 caps enable: yes
    Invalidation drop enabled: no
```

Protocols

Path Computation Element Protocol

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.

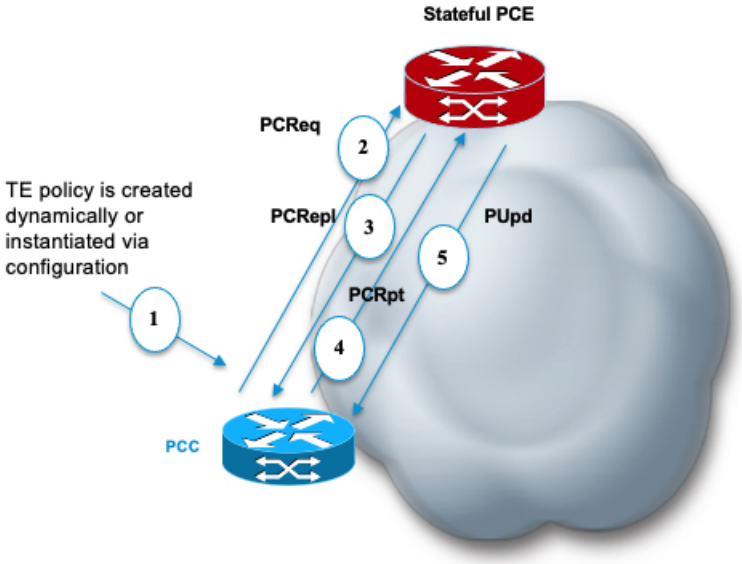
Note Refer to the Usage Guidelines and Limitations, on page 2 section for information about SR-PCE compatibility with different IOS XR releases.

A PCEP channel is established over TCP and has its own light-weight Keep-Alive (KA) mechanism

Upon configuring a PCE peer, a PCC opens a PCEP session to the PCE, and the PCE accepts the PCEP sessions if the following conditions are satisfied:

- The total number of PCEP sessions does not exceed the limit on the total number of PCEP sessions on the PCE.
- The KA interval indicated by PCC is acceptable to the PCE.

Sample Workflow with Stateful PCEP



1. The PCC is configured to instantiate an SRv6-TE policy.
2. The PCC sends a PCEP Path Computation Request (PCReq) to the PCE, requesting a path by specifying path attributes, optimization objectives, and constraints.

3. The PCE stores the request, computes a TE metric shortest-path, and returns the computed SID list in a PCEP Path Computation Reply (PCRepl).
4. The PCC allocates a BSID and activates the SR Policy using the SID list computed by the PCE. The PCC sends a Path Computation Report (PCRpt) to the PCE, delegating the SR Policy to the PCE and including BSID.
5. The PCE updates the paths when required (for example, following a multi-domain topology change that impacts connectivity).

Configure the Head-End Router as PCEP PCC

Configure the head-end router as PCEP Path Computation Client (PCC) to establish a connection to the PCE. The PCC and PCE addresses must be routable so that TCP connection (to exchange PCEP messages) can be established between PCC and PCE.

Configure the PCC to Establish a Connection to the PCE

Use the **segment-routing traffic-eng pcc** command to configure the PCC source address, the SR-PCE address, and SR-PCE options.

A PCE can be given an optional precedence. If a PCC is connected to multiple PCEs, the PCC selects a PCE with the lowest precedence value. If there is a tie, a PCE with the highest IP address is chosen for computing path. The precedence *value* range is from 0 to 255.

```
Router(config)# segment-routing
Router(config-sr)# traffic-eng
Router(config-sr-te)# pcc
Router(config-sr-te-pcc)# source-address ipv6 ipv6-local-source-address
Router(config-sr-te-pcc)# pce address ipv6 ipv6-PCE-address[precedence value]
```

Configure PCEP Authentication

TCP Message Digest 5 (MD5) authentication has been used for authenticating PCEP (TCP) sessions by using a 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 Master Key Tuple (MKT) configuration. TCP-AO also protects connections when using the same MKT across repeated instances of a connection. TCP-AO protects the connections by using traffic key that are derived from the MKT, and then coordinates changes between the endpoints.

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

TCP Message Digest 5 (MD5) Authentication

Use the **password** {**clear** | **encrypted**} *LINE* command to enable 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

```
Router(config-sr-te-pcc)# pce address ipv6 ipv6-PCE-address[password {clear | encrypted}
LINE]
```

TCP Authentication Option (TCP-AO)

Use the **tcp-ao** *key-chain* [**include-tcp-options**] command to enable 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. Use the **include-tcp-options** keyword to include other TCP options in the header for MAC calculation.

```
Router(config-sr-te-pcc)# pce address ipv6 ipv6-PCE-address tcp-ao key-chain
[include-tcp-options]
```

Configure PCEP-Related Timers

Use the **timers keepalive** command to specify how often keepalive messages are sent from PCC to its peers. The range is from 0 to 255 seconds; the default value is 30.

```
Router(config-sr-te-pcc)# timers keepalive seconds
```

Use the **timers deadtimer** command to specify how long the remote peers wait before bringing down the PCEP session if no PCEP messages are received from this PCC. The range is from 1 to 255 seconds; the default value is 120.

```
Router(config-sr-te-pcc)# timers deadtimer seconds
```

Use the **timers delegation-timeout** command to specify how long a delegated SR policy can remain up without an active connection to a PCE. The range is from 0 to 3600 seconds; the default value is 60.

```
Router(config-sr-te-pcc)# timers delegation-timeout seconds
```

PCE-Initiated SR Policy Timers

Use the **timers initiated orphans** command to specify the amount of time that a PCE-initiated SR policy will remain delegated to a PCE peer that is no longer reachable by the PCC. The range is from 10 to 180 seconds; the default value is 180.

```
Router(config-sr-te-pcc)# timers initiated orphans seconds
```

Use the **timers initiated state** command to specify the amount of time that a PCE-initiated SR policy will remain programmed while not being delegated to any PCE. The range is from 15 to 14440 seconds (24 hours); the default value is 600.

```
Router(config-sr-te-pcc)# timers initiated state seconds
```

To better understand how the PCE-initiated SR policy timers operate, consider the following example:

- PCE A instantiates SR policy P at head-end N.
- Head-end N delegates SR policy P to PCE A and programs it in forwarding.

- If head-end N detects that PCE A is no longer reachable, then head-end N starts the PCE-initiated **orphan** and **state** timers for SR policy P.
- If PCE A reconnects before the **orphan** timer expires, then SR policy P is automatically delegated back to its original PCE (PCE A).
- After the **orphan** timer expires, SR policy P will be eligible for delegation to any other surviving PCE(s).
- If SR policy P is not delegated to another PCE before the **state** timer expires, then head-end N will remove SR policy P from its forwarding.

Enable SR-TE SYSLOG Alarms

Use the **logging policy status** command to enable SR-TE related SYSLOG alarms.

```
Router(config-sr-te)# logging policy status
```

Enable PCEP Reports to SR-PCE

Use the **report-all** command to enable the PCC to report all SR policies in its database to the PCE.

```
Router(config-sr-te-pcc)# report-all
```

Customize MSD Value at PCC

Use the **maximum-sid-depth** *value* command to customize the Maximum SID Depth (MSD) signaled by PCC during PCEP session establishment.

The MSD is expressed as a number uSIDs. The number of uSID is expressed as a number of carriers and the number of uSID per carrier.

The default MSD *value* is equal to the maximum MSD supported by the platform (12 — 2 carriers, 6 uSIDs per carrier).

```
Router(config-sr-te-srv6)# maximum-sid-depth value
```

For cases with path computation at PCE, a PCC can signal its MSD to the PCE in the following ways:

- During PCEP session establishment – The signaled MSD is treated as a node-wide property.
  - MSD is configured under **segment-routing traffic-eng maximum-sid-depth** *value* command
- During PCEP LSP path request – The signaled MSD is treated as an LSP property.
  - On-demand (ODN) SR Policy: MSD is configured using the **segment-routing traffic-eng on-demand color** *color* **maximum-sid-depth** *value* command
  - Local SR Policy: MSD is configured using the **segment-routing traffic-eng policy** *WORD* **candidate-paths preference** *preference* **dynamic metric sid-limit** *value* command.

Note If the configured MSD values are different, the per-LSP MSD takes precedence over the per-node MSD.

After path computation, the resulting uSID stack size is verified against the MSD requirement.

- If the uSID stack size is larger than the MSD and path computation is performed by PCE, then the PCE returns a "no path" response to the PCC.
- If the uSID stack size is larger than the MSD and path computation is performed by PCC, then the PCC will not install the path.

Note A sub-optimal path (if one exists) that satisfies the MSD constraint could be computed in the following cases:

- For a dynamic path with TE metric, when the PCE is configured with the **pce segment-routing te-latency** command or the PCC is configured with the **segment-routing traffic-eng te-latency** command.
- For a dynamic path with LATENCY metric
- For a dynamic path with affinity constraints

For example, if the PCC MSD is 4 and the optimal path (with an accumulated metric of 100) requires 5 uSIDs, but a sub-optimal path exists (with accumulated metric of 110) requiring 4 uSIDs, then the sub-optimal path is installed.

Customize the SR-TE Path Calculation

Use the **te-latency** command to enable ECMP-aware path computation for TE metric.

```
Router(config-sr-te)# te-latency
```

Note ECMP-aware path computation is enabled by default for IGP and LATENCY metrics.

Configure PCEP Redundancy Type

Use the **redundancy pcc-centric** command to enable PCC-centric high-availability model. The PCC-centric model changes the default PCC delegation behavior to the following:

- After LSP creation, LSP is automatically delegated to the PCE that computed it.
- If this PCE is disconnected, then the LSP is redelegated to another PCE.
- If the original PCE is reconnected, then the delegation fallback timer is started. When the timer expires, the LSP is redelegated back to the original PCE, even if it has worse preference than the current PCE.

```
Router(config-sr-te-pcc)# redundancy pcc-centric
```

Configuring Head-End Router as PCEP PCC and Customizing SR-TE Related Options: Example

The following example shows how to configure an SR-TE head-end router with the following functionality:

- Enable the SR-TE head-end router as a PCEP client (PCC) with 2 PCEP servers (PCE) with different precedence values. The PCE with IP address cafe:0:2::2 is selected as BEST.
- Enable SR-TE related syslogs.

- Set the Maximum SID Depth (MSD) signaled during PCEP session establishment to 10.
- Enable PCEP reporting for all policies in the node.

```
Node1(config)# segment-routing
Node1(config-sr)# traffic-eng
Node1(config-sr-te)# pcc
Node1(config-sr-te-pcc)# source-address ipv6 cafe:0:1::1
Node1(config-sr-te-pcc)# pce address ipv6 cafe:0:2::2
Node1(config-pcc-pce)# precedence 10
Node1(config-pcc-pce)# exit
Node1(config-sr-te-pcc)# pce address ipv6 cafe:0:3::3
Node1(config-pcc-pce)# precedence 20
Node1(config-pcc-pce)# exit
Node1(config-sr-te-pcc)# report-all
Node1(config-sr-te-pcc)# exit
Node1(config-sr-te)# srv6
Node1(config-sr-te-srv6)# maximum-sid-depth 10
Node1(config-sr-te-srv6)# exit
Node1(config-sr-te)# logging
Node1(config-sr-te-log)# policy status
Node1(config-sr-te-log)# exit
Node1(config-sr-te)#
```

Running Config

```
segment-routing
 traffic-eng
  srv6
   maximum-sid-depth 10
  !
  logging
   policy status
  !
  pcc
   source-address ipv6 cafe:0:1::1
   pce address ipv6 cafe:0:2::2
    precedence 10
   !
   pce address ipv6 cafe:0:3::3
    precedence 20
   !
   report-all
  !
 !
!
```

Verification

```
Node1# show segment-routing traffic-eng pcc ipv6 peer brief

             Address   Precedence        State    Learned From
-------------------- ------------ ------------ ---------------
         cafe:0:2::2           10           up          config
         cafe:0:3::3           20           up          config


Node1# show segment-routing traffic-eng pcc ipv6 peer detail

PCC's peer database:
--------------------
```

```
Peer address: cafe:0:2::2
  Precedence: 10, (best PCE)
  State up
  Capabilities: Stateful, Update, Segment-Routing, Instantiation
  PCEP has been up for: 01:22:23
  Local keepalive timer is 30 seconds
  Remote keepalive timer is 30 seconds
  Local dead timer is 120 seconds
  Remote dead timer is 120 seconds
  Authentication: None
  Statistics:
    Open messages:      rx 1        |  tx 1
    Close messages:     rx 0        |  tx 0
    Keepalive messages: rx 164      |  tx 163
    Error messages:     rx 0        |  tx 0
    Report messages:    rx 0        |  tx 110
    Update messages:    rx 36       |  tx 0

Peer address: cafe:0:3::3
  Precedence: 20
  State up
  Capabilities: Stateful, Update, Segment-Routing, Instantiation
  PCEP has been up for: 01:21:48
  Local keepalive timer is 30 seconds
  Remote keepalive timer is 30 seconds
  Local dead timer is 120 seconds
  Remote dead timer is 120 seconds
  Authentication: None
  Statistics:
    Open messages:      rx 1        |  tx 1
    Close messages:     rx 0        |  tx 0
    Keepalive messages: rx 164      |  tx 162
    Error messages:     rx 0        |  tx 0
    Report messages:    rx 0        |  tx 82
    Update messages:    rx 0        |  tx 0
```