

# Convergence Mechanism of SR-TE Policy based Explicit-Path with TI-LFA Node Protection

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## Introduction

This document describes node protection for the explicit primary path by Topology Independent (TI) - Loop-Free Alternative (LFA) and the solution using Segment Routing (SR) - Traffic Engineering (TE) path with SR-TE metric and Open Shortest Path First (OSPF) flexible algorithm.

## Problem

This section explains the requirements of XYZ Networks, the design constraints and the reason why the TI-LFA backup path fails to protect any intermediate node failure for an explicitly defined primary path.

## Requirements

As per XYZ Networks, these are the requirements of their greenfield network design:

1. The primary traffic path must be explicitly defined and controlled by SR-TE policy (admin) but not by IGP metric.
2. In case of link or node failure, the traffic must converge to a backup path in sub 50 msec of time with a zero-scale network.

If you take a look at Figure 1., an SR-TE policy has been configured end-to-end at the source node PE1 with PE3 being the destination node.

The synopsis of the SR-TE and OSPF configurations are:

<#root>

segment-routing

traffic-eng

!  
!

segment-list PrimaryPath1

index 10 mpls adjacency 10.1.11.0

--> First Hop (P1 node) of the explicit-path

index 20 mpls adjacency 10.1.3.1

-->

Second Hop (P3 node) of the explicit-path

index 30 mpls adjacency 10.3.13.1

--> Third Hop (PE3 node) of the explicit-path

!  
policy POL1

source-address ipv4 11.11.11.11

--> Source Node of the explicit-path

color 10 end-point ipv4 33.33.33.33

--> Destination Node of the explicit-path

candidate-paths

preference 100

--> Secondary Path taken care of dynamically by IGP TI-LFA

dynamic  
metric  
type igp

!  
!  
!

preference 200

explicit segment-list PrimaryPath1

--> Primary Explicit-Path of the SR-TE policy

!  
!

```
router ospf CORE
```

```
nsr
distribute link-state
log adjacency changes
router-id 11.11.11.11
segment-routing mpls
nsf cisco
microloop avoidance segment-routing
max-metric router-lsa on-startup 360
area 0
```

```
interface Bundle-Ether111
```

```
--> Primary Explicit-Path Interface
```

```
authentication null
network point-to-point
fast-reroute per-prefix
fast-reroute per-prefix ti-lfa enable
```

```
--> Enabling TI-LFA on the primary interface
```

```
fast-reroute per-prefix tiebreaker node-protecting index 100
fast-reroute per-prefix tiebreaker srlg-disjoint index 200
prefix-suppression
!
```

```
interface Bundle-Ether211
```

```
--> Secondary Dynamic Path Interface
```

```
authentication null
network point-to-point
fast-reroute per-prefix
fast-reroute per-prefix ti-lfa enable
```

```
--> Enabling TI-LFA on the secondary interface
```

```
fast-reroute per-prefix tiebreaker node-protecting index 100
fast-reroute per-prefix tiebreaker srlg-disjoint index 200
prefix-suppression
!
interface Loopback80
passive enable
prefix-sid index 32130
```

```
--> Enabling Node SID on the loopback interface
```

```
!
!
```

This configuration is a sample method to configure an explicit-path driven SR-TE policy, there are other ways as well. And under OSPF, it is observed that there is TI-LFA enabled.

However, with the SR-TE and OSPF feature combination, it is found in the lab with SR-TE Explicit Path Policy that OSPF TI-LFA is not able to curve out and install a post-convergence, end-to-end (PE1 to PE3) backup path of the SR-TE Explicit Primary Path for intermediate node failure scenarios as shown in Figure 2. As a result, the traffic protection convergence time exceeds well beyond 50 msec in case either the P1 or P3 node goes down.

A simple example has been chosen to explain the issue:

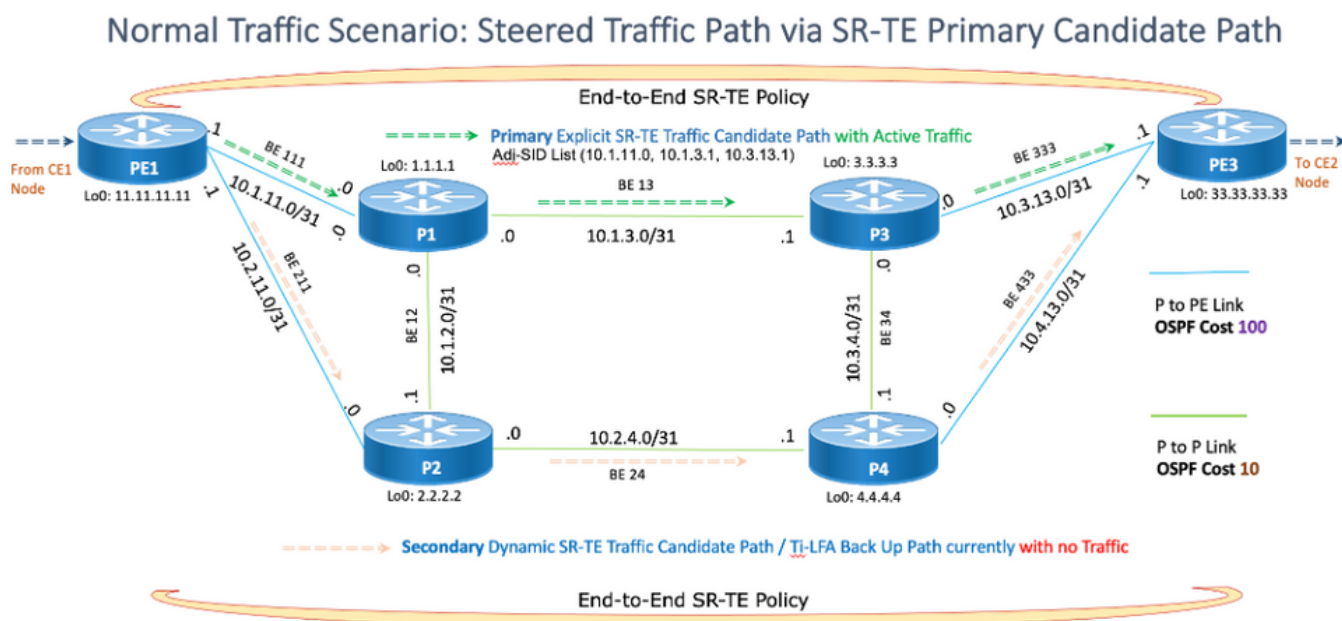


Figure 1: Normal Traffic Scenario

As in Figure 1., the traffic source node is PE1 and the destination node is PE3. Here if we configure an SR-TE explicit path policy where there is an administrative need to send the traffic via explicit primary traffic path **PE1> P1> P3> PE3**.

Under this situation, if we configure an explicit SR-TE path via **PE1> P1 > P3> PE3** then in case of node failure as shown in Figure 2., TI-LFA is not able to protect the node failure scenario but is able to only protect the link failure scenario. The link failure scenario has been covered in detail in the reference document [Convergence of SR-TE Explicit-Path for Link Protection](#).

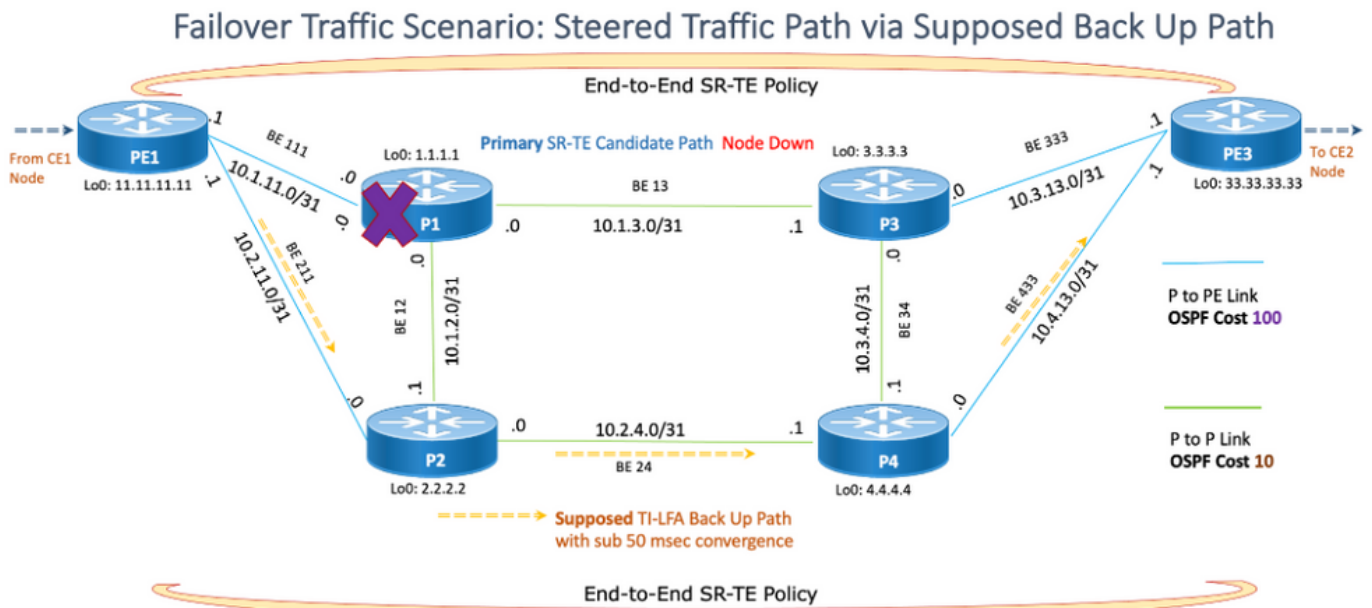


Figure 2: Failover Traffic Scenario

## Why TI-LFA Backup Path Fails to Protect Any Intermediate Node Failure

TI-LFA once configured under OSPF, by default, points to the Node SID of the destination node to compute and install the backup path in the data plane.

But for this scenario and feature set configuration, TI-LFA coverage from the source node to the destination node does not work, or in other words, the TI-LFA backup path fails to protect any intermediate node failure under 50 msec for the explicitly defined primary path.

Analysis shows that the TI-LFA backup path computation algorithm takes the first next-hop/node in the explicit path as the destination endpoint instead of the actual destination node and calculates the backup path trying to protect only the first next-hop/node, for example, node P1 as in Figure 2. As a result, TI-LFA is not able to compute and install a backup path to protect the actual endpoint or destination node, for example, node PE3.

Hence, it is not able to provide end-to-end protection within sub 50 msec of convergence for the actual destination node PE3 for an intermediate node failure in an explicitly defined primary traffic path.

Another way to look at it is in Figure 1., if you configure the node P3 as the next hop in the explicit path then TI-LFA can provide sub-50 msec of protection for node P1 failure and vice versa. But the node protection cannot happen for that particular node which is defined as one of the explicit hops of the end-to-end explicit path.

## Solution

This section focuses on points for explicit primary path-specific scenarios:

### How TI-LFA Backup Path Now Protects Any Intermediate Node Failure under 50 msec Convergence

A proven and tested out solution is to bring in some additional features/modifications to the scenario so as to enable TI-LFA to take care of the sub-50 msec of convergence during the node failure scenario as well

along with the link failure. This solution has been chosen based on the requirements of XYZ Network as mentioned in the Problem section.

## Breaking Down the Solution Steps

1. Explicit-Path is needed but the IGP metric cannot be used as per the requirement.
2. Hence, an alternate metric (SR-TE metric) is used to steer the traffic on a certain path without specifying the explicit hops.
3. OSPF Flex-Algo is used to send traffic to the destination node (using a separate Flex-Algo Node SID reachable via the flex algo) via the topology that uses the SR-TE metric.
3. After OSPF Flex-Algo is added, TI-LFA is able to function normally as it now can protect the actual destination Node SID.

## Understanding Different Components of the Solution

### Explicit Path Characteristic

Since as per one of the requirements IGP metric cannot be used for explicit control of the primary path, the explicit streamlined characteristic of the primary SR-TE path is controlled via the TE metric additionally configured under the SR-TE interfaces (under segment-routing) for all nodes including the headend PE node till the remote destination PE. Their SR-TE metrics are in turn used by OSPF Flex Algo to create an explicit path under the flex-algo paradigm.

SR-TE metric under Segment Routing at PE1:

```
<#root>
```

```
segment-routing
  global-block 100000 299999
  traffic-eng
```

```
interface Bundle-Ether111
```

```
metric 10
```

```
--> SR-TE Metric of BE111 is less than BE211, so it is a more preferred explicit path given that rest of
```

```
!
```

```
interface Bundle-Ether211
```

```
metric 100
```

```
!
```

```
logging
```

```

    policy status
    !

policy er100_to_er102 --> SR-TE policy defined

    source-address ipv4 11.11.11.11.
--> Source Node of the explicit-path

    color 150 end-point ipv4 33.33.33.33
--> Destination Node of the explicit-path

    autoroute
    force-sr-include
    include all
    !

candidate-paths

    preference 200

dynamic --> Here that the primary path is configured as dynamic but it is the SR-TE metric defined ab
make it fixed or explicit

    !
    constraints
    segments

sid-algorithm 128. --> Primary SR-TE path is configured with constraint as Flex-Algo 128 with no explic
the backup path implicitly ensuring sub 50 msec of convergence

    !
    !

```

Show command at node PE1:

```

<#root>
P/0/RP0/CPU0:PE1#
show segment-routing traffic-eng policy

```

Fri Feb 3 10:25:24.716 UTC

```

SR-TE policy database
-----

```

Color: 150, End-point: 33.33.33.33 --> Color and Endpoint Loopback IP address of PE3

Name: srte\_c\_150\_ep\_33.33.33.33

Status:

Admin: up Operational: up for 04:57:30 (since Feb 3 05:27:54.774)

Candidate-paths:

Preference: 200

(configuration) (active)

--> Preference of 200 as configured under SR-TE policy

Name: er100\_to\_er102

Requested BSID: dynamic

Constraints:

Prefix-SID Algorithm: 128 --> Attached to Flex-Algo 128 as configured under SR-TE policy

Protection Type: protected-preferred --> Protected Primary Path

Maximum SID Depth: 12

Dynamic (valid)

Metric Type: TE

, Path Accumulated Metric: 0

--> Metric Type is SR-TE metric

133138

[Prefix-SID: 33.33.33.33, Algorithm: 128].

--> Node SID of destination node PE3 with index 33138

Attributes:

Binding SID: 24010

Forward Class: Not Configured

Steering labeled-services disabled: no

Steering BGP disabled: no

IPv6 caps enable: yes

Invalidation drop enabled: no

## OSPF Flex-Algo

Overview:

Segment Routing Flexible Algorithm allows operators to customize IGP shortest path computation according to their own needs. An operator can assign custom SR prefix-SIDs to realize forwarding beyond



link-cost-based SPF. As a result, Flexible Algorithm provides a traffic-engineered path automatically computed by the IGP to any destination reachable by the IGP.

To provide maximum flexibility, the mapping between the algorithm value and its meaning can be defined by the user. When all the routers in the domain have a common understanding of what the particular algorithm value represents, the computation for such an algorithm is consistent and the traffic is not subject to looping. Here, since the meaning of the algorithm is not defined by any standard, but is defined by the user, it is called a Flexible Algorithm.

Under the OSPF routing paradigm, many possible constraints can be used to compute a path over a network. Some networks are deployed with a single IGP plane and others with multiple IGP planes. For any given network, under each OSPF process, by default, there exists Flex-Algo 0 with a simple form of constraint, for example, OSPF metric.

However, keeping specific requirements in mind, a more sophisticated form of constraint is used here which includes extended parameters like TE-metric (Multiple Flex-Algo numbers range from 128 to 255). In Cisco IOS® XR 7.3.2, this TE metric has to be configured under the SR-TE traffic engineering section but is used by OSPF Flex-Algo for explicit-path computation.

TI-LFA computes the backup path and keeps the data plane ready in case of primary path failure and switches the traffic with a convergence time of sub 50 msec for a zero-scaled network.

Configuration:

OSPF Flex-Algo is configured under Router OSPF and advertised across the network. OSPF flex-algo and TE metric together take care of the explicit path and sub-50 msec of convergence. Configuring Flex-Algo under OSPF builds up a virtual OSPF topology and helps TI-LFA to compute end-to-end backup path in advance for a pair of source-destination endpoints, which in turn ensures less than 50 sec of convergence for primary path failure.

OSPF Configuration at PE1:

<#root>

```
router ospf CORE
  nsr
  distribute link-state
  log adjacency changes
  router-id 11.11.11.11
  segment-routing mpls
  nsf cisco
  microloop avoidance segment-routing
  max-metric router-lsa on-startup 360
  area 0
    interface Bundle-Ether111
      cost 10000
      authentication null
      network point-to-point
      fast-reroute per-prefix
      fast-reroute per-prefix ti-lfa enable
      fast-reroute per-prefix tiebreaker node-protecting index 100
      fast-reroute per-prefix tiebreaker srlg-disjoint index 200
      prefix-suppression
    !
  interface Bundle-Ether211
    cost 10000
    authentication null
```

```
network point-to-point
fast-reroute per-prefix
fast-reroute per-prefix ti-lfa enable
fast-reroute per-prefix tiebreaker node-protecting index 100
fast-reroute per-prefix tiebreaker srlg-disjoint index 200
prefix-suppression
!
interface Loopback80
passive enable
prefix-sid index 32130
```

prefix-sid algorithm 128 index 33130 --> Assigning different Node SIDs to different Flex Algo to keep

prefix-sid algorithm 129 index 34130 --> Assigning different Node SIDs to different Flex Algo to

```
!
!
```

flex-algo 128 --> Defining OSPF Flex Algo which creates a virtual topology and enables TI-LFA to

```
metric-type te-metric
advertise-definition
!
```

flex-algo 129. --> One or more than one Flex Algo can be defined based on the requirement

```
metric-type delay
advertise-definition
!
!
```

## OSPF Config at PE3:

<#root>

```
router ospf CORE
```

```
nsr
distribute link-state
log adjacency changes
router-id 33.33.33.33
segment-routing mpls
nsf cisco
microloop avoidance segment-routing
max-metric router-lsa on-startup 360
area 0
interface Bundle-Ether111
cost 10000
authentication null
network point-to-point
fast-reroute per-prefix
fast-reroute per-prefix ti-lfa enable
fast-reroute per-prefix tiebreaker node-protecting index 100
fast-reroute per-prefix tiebreaker srlg-disjoint index 200
```

```

    prefix-suppression
    !
interface Bundle-Ether211
    cost 10000
    authentication null
    network point-to-point
    fast-reroute per-prefix
    fast-reroute per-prefix ti-lfa enable
    fast-reroute per-prefix tiebreaker node-protecting index 100
    fast-reroute per-prefix tiebreaker srlg-disjoint index 200
    prefix-suppression
    !
interface Loopback80
    passive enable
    prefix-sid index 32138

prefix-sid algorithm 128 index 33138 --> Node SID assigned for OSPF Flex-Algo 128 which is shown above

    prefix-sid algorithm 129 index 34138 --> Assigning different Node SIDs to different Flex Algo to ke

!
!
flex-algo 128. --> Defining OSPF Flex Algo which creates a virtual topology and enables TI-LFA t

metric-type te-metric --> Metric type te-metric

advertise-definition --> To enable the router to advertise the definition for the particular Flexible A
command is used

!
flex-algo 129

--> Additional Flex Algo definition (if needed)

metric-type delay --> Metric type delay

advertise-definition
!
!
```

## Solution Summary

To summarize, the SR-TE metrics help to navigate the traffic through the designated SR-TE explicit-path,

since the IGP metric cannot be used. OSPF Flex-Algo, by adding one layer of the virtual control plane, helps TI-LFA to ensure a sub-50 msec of convergence of the primary explicit-path traffic to the pre-calculated TI-LFA backup path. This happens since only destination Node SID is being advertised to enable TI-LFA to determine the actual destination node and thereby protect both the intermediate nodes (P1 & P3) between a pair of source-destination nodes of the explicit primary path **PE1> P1 > P3> PE3**. The dynamically protected backup path adhering sub 50 msec of convergence with zero-scale, in this case, is **PE1> P2 > P4> PE3**.

## Software Used

The software used to test and validate the solution is Cisco IOS® XR 7.3.2

## Related Information

- Part 1. [Convergence of SR-TE Explicit-Path for Link Protection](#)
- [Cisco Technical Support & Downloads](#)