Implementing Fast Reroute Loop-Free Alternate

Fast Reroute Loop-Free Alternate feature enables you to tunnel a packet around a failed link to a remote loop-free alternate that is more than one hop away.

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Prerequisites for Fast Reroute with Loop-Free Alternate

- Fast Reroute with Loop-Free Alternate functionality can protect paths that are reachable through an interface only if the interface is a point-to-point interface.
- When a LAN interface is physically connected to a single neighbor, you should configure the LAN interface as a point-to-point interface so that it can be protected through Loop-Free Alternate (LFA) FRR.
- For a proper deployment for Fast Reroute with Remote Loop-Free Alternate feature, the protected link should also be configured with BFD

Restrictions for Fast Reroute with Loop-Free Alternate

- Load balance support is available for FRR-protected prefixes, but the 50 ms cutover time is not guaranteed.
- A maximum of eight FRR-protected interfaces can simultaneously undergo a cutover.
- LFA calculations are restricted to interfaces or links belonging to the same level or area. Hence, excluding all neighbors on the same LAN when computing the backup LFA can result in repairs being unavailable in a subset of topologies.
- Only physical and physical port-channel interfaces and subinterfaces are protected. Tunnels and virtual interfaces are not protected.

- The remote LFA backup path for MPLS traffic can be setup only using LDP. Only per-prefix protection is supported.
- Border Gateway Protocol (BGP) Prefix-Independent Convergence (PIC) and FRR can be configured on the same interface as long as they are not used for the same prefix.

IS-IS and FRR

When a local link fails in a network, IS-IS recomputes new primary next-hop routes for all affected prefixes. These prefixes are updated in the RIB and the Forwarding Information Base (FIB). Until the primary prefixes are updated in the forwarding plane, traffic directed towards the affected prefixes are discarded. This process can take hundreds of milliseconds.

In FRR, IS-IS computes LFA next-hop routes for the forwarding plane to use in case of primary path failures. LFA is computed per prefix.

When there are multiple LFAs for a given primary path, IS-IS uses a tiebreaking rule to pick a single LFA for a primary path. In case of a primary path with multiple LFA paths, prefixes are distributed equally among LFA paths.

Repair Paths

Repair paths forward traffic during a routing transition. When a link or a router fails, due to the loss of a physical layer signal, initially, only the neighboring routers are aware of the failure. All other routers in the network are unaware of the nature and location of this failure until information about this failure is propagated through a routing protocol, which may take several hundred milliseconds. It is, therefore, necessary to arrange for packets affected by the network failure to be steered to their destinations.

A router adjacent to the failed link employs a set of repair paths for packets that would have used the failed link. These repair paths are used from the time the router detects the failure until the routing transition is complete. By the time the routing transition is complete, all routers in the network revise their forwarding data and the failed link is eliminated from the routing computation.

Repair paths are precomputed in anticipation of failures so that they can be activated the moment a failure is detected.

The LFA FRR feature uses the following repair paths:

- Equal Cost Multipath (ECMP) uses a link as a member of an equal cost path-split set for a destination. The other members of the set can provide an alternative path when the link fails.
- LFA is a next-hop route that delivers a packet to its destination without looping back. Downstream paths are a subset of LFAs.

LFA Overview

LFA is a node other than the primary neighbor. Traffic is redirected to an LFA after a network failure. An LFA makes the forwarding decision without any knowledge of the failure.

An LFA must neither use a failed element nor use a protecting node to forward traffic. An LFA must not cause loops. By default, LFA is enabled on all supported interfaces as long as the interface can be used as a primary path.

Advantages of using per-prefix LFAs are as follows:

- The repair path forwards traffic during transition when the primary path link is down.
- All destinations having a per-prefix LFA are protected. This leaves only a subset (a node at the far side of the failure) unprotected.

LFA Calculation

The general algorithms to compute per-prefix LFAs can be found in RFC 5286. IS-IS implements RFC 5286 with a small change to reduce memory usage. Instead of performing a Shortest Path First (SPF) calculation for all neighbors before examining prefixes for protection, IS-IS examines prefixes after SPF calculation is performed for each neighbor. Because IS-IS examines prefixes after SPF calculation is performed, IS-IS retains the best repair path after SPF calculation is performed for each neighbor. IS-IS does not have to save SPF results for all neighbors.

Interaction Between RIB and Routing Protocols

A routing protocol computes repair paths for prefixes by implementing tiebreaking algorithms. The end result of the computation is a set of prefixes with primary paths, where some primary paths are associated with repair paths.

A tiebreaking algorithm considers LFAs that satisfy certain conditions or have certain attributes. When there is more than one LFA, configure the **fast-reroute per-prefix** command with the **tie-break** keyword. If a rule eliminates all candidate LFAs, then the rule is skipped.

A primary path can have multiple LFAs. A routing protocol is required to implement default tiebreaking rules and to allow you to modify these rules. The objective of the tiebreaking algorithm is to eliminate multiple candidate LFAs, select one LFA per primary path per prefix, and distribute the traffic over multiple candidate LFAs when the primary path fails.

Tiebreaking rules cannot eliminate all candidates.

The following attributes are used for tiebreaking:

- Downstream—Eliminates candidates whose metric to the protected destination is lower than the metric of the protecting node to the destination.
- Linecard-disjoint—Eliminates candidates sharing the same linecard with the protected path.
- Shared Risk Link Group (SRLG)—Eliminates candidates that belong to one of the protected path SRLGs.
- Load-sharing—Distributes remaining candidates among prefixes sharing the protected path.
- Lowest-repair-path-metric—Eliminates candidates whose metric to the protected prefix is higher.
- Node protecting—Eliminates candidates that are not node protected.
- Primary-path—Eliminates candidates that are not ECMPs.

- Secondary-path—Eliminates candidates that are ECMPs.

Fast Reroute with Remote Loop-Free Alternate

Fast Reroute with Remote Loop-Free Alternate (FRR Remote LFA) feature enables you to tunnel a packet around a failed link to a remote loop-free alternate that is more than one hop away.

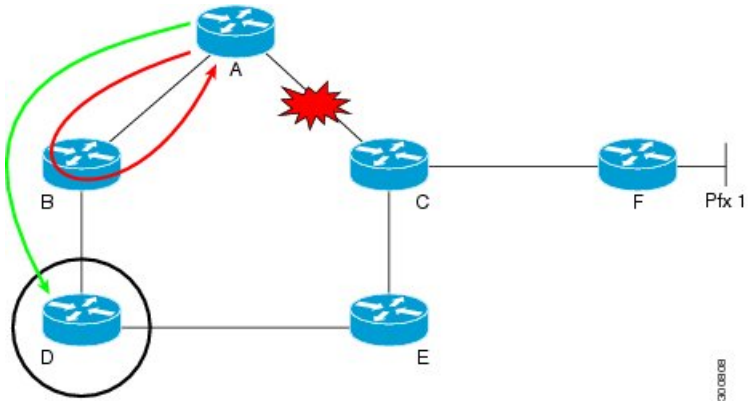
When a link or a router fails, distributed routing algorithms compute new routes that take into account the failure. The time taken for computation is called routing transition. Until the transition is complete and all routers are converged on a common view of the network, the connectivity between the source and destination pairs is interrupted. You can use the IP Loop-Free Alternate (LFA) Fast Reroute (FRR) to reduce the routing transition time to less than 50 milliseconds using a precomputed alternate next hop. When a router is notified of a link failure, the router immediately switches over to the repair path to reduce traffic loss. Note that the routing transition in IGP/BGP convergence can take up to several hundreds of milliseconds.

IP Loop-Free Alternate (LFA) Fast Reroute (FRR) supports the precomputation of repair paths. Intermediate System-to-Intermediate System (IS-IS) routing protocol enables the repair path computation. The resulting repair paths are sent to the Routing Information Base (RIB). Cisco Express Forwarding (formerly known as CEF) and Open Shortest Path First (OSPF) installs the repair path.

With IP local LFA FRR, IGPs only compute directly connected neighbor as an LFA backup path to protect the given prefix's primary path. Label Distribution Protocol (LDP) sets up labeled backup LSP with the next-hop for the protected prefix. Some topologies (for example the commonly used ring-based topology) require protection that is not afforded by LFA FRR. In such cases, use the LDP-based FRR Remote LFA feature where IGPs compute non-directly connected neighbor, which are more than one hop away, as LFA backup path to protect the given prefix's primary path. The LDP sets up labeled backup LSP with the remote next-hop for the protected prefix. LDP also sets up another transport LSP to tunnel traffic to remote next-hop without exposing the LFA backup label as learnt from remote node.

Consider the topology shown in the figure below:

Figure 1: FRR with Remote LFA with Ring Topology



Device A tries to send traffic destined to F to next-hop B. Device B cannot be used as an LFA for prefixes advertised by nodes C and F. The actual LFA is node D. However, node D is not directly connected to the protecting node A. To protect prefixes advertised by C, node A must tunnel the packet around the failed link A-C to node D, provided that the tunnel does not traverse the failing link.

FRR Remote LFA feature enables you to tunnel a packet around a failed link to a remote loop-free alternate that is more than one hop away. In the figure above, the green arrow between A and D shows the tunnel that is automatically created by the remote LFA feature to bypass looping.

Configuration

Perform the following tasks to configure FRR with LFA.

Configure FRR with local LFA

```
/* Configure FRR with local LFA using IS-IS */
Router# configure
Router(config)# router isis ring
Router(config)#  is-type level-1
Router(config-isis)# net 49.0001.0000.0000.0007.00
Router(config-isis)# nsf cisco
Router(config-isis)# address-family ipv4 unicast
Router(config-isis-af)# metric-style wide
Router(config-isis-af)# mpls traffic-eng level-1-2
Router(config-isis-af)# mpls traffic-eng router-id 10.7.7.7
Router(config-isis-af)# exit
Router(config-isis)# interface Loopback 0
Router(config-isis-if)# point-to-point
Router(config-isis-if)# address-family ipv4 unicast
Router(config-isis-if)# exit
Router(config-isis)# interface TenGigabitEthernet 0/0/0/4
Router(config-isis-if)# point-to-point
Router(config-isis-if)# address-family ipv4 unicast
Router(config-isis-af)# fast-reroute per-prefix
Router(config-isis-af)# commit

/* Configure FRR with local LFA using OSPF*/
Router# configure
Router(config)# router ospf 50
Router(config-ospf)# router-id 10.1.1.1
Router(config-ospf)# address-family ipv4 unicast
Router(config-ospf-af)# area 0
Router(config-ospf-af)# mpls traffic-eng
Router(config-ospf-af)# interface Loopback 0
Router(config-ospf-af)# exit
Router(config-ospf)# interface HundredGigE0/9/0/0
Router(config-ospf-if)# fast-reroute per-prefix
Router(config-ospf-if)# exit
Router(config-ospf)# exit
Router(config)# mpls traffic-eng router-id Loopback 0
```

Configure remote FRR with remote LFA.

```
/* Configure FRR with remote LFA using IS-IS */
Router# configure
Router(config)# router isis ring
Router(config)#  is-type level-1
Router(config-isis)# net 49.0001.0000.0000.0007.00
Router(config-isis)# nsf cisco
Router(config-isis)# address-family ipv4 unicast
Router(config-isis-af)# metric-style wide
Router(config-isis-af)# mpls traffic-eng level-1-2
```

```
Router(config-isis-af)# mpls traffic-eng router-id 10.7.7.7
Router(config-isis-af)# exit
Router(config-isis)# interface Loopback 0
Router(config-isis-if)# point-to-point
Router(config-isis-if)# address-family ipv4 unicast
Router(config-isis-if)# exit
Router(config-isis)# interface TenGigabitEthernet 0/0/0/4
Router(config-isis-if)# point-to-point
Router(config-isis-if)# address-family ipv4 unicast
Router(config-isis-af)# fast-reroute per-prefix remote-lfa
Router(config-isis-af)# fast-reroute per-prefix remote-lfa prefix-list /* The prefix-list
option filters PQ node router ID based on prefix list */

Router(config-isis-af)# fast-reroute per-prefix remote-lfa tunnel mpls-ldp
Router(config-isis-af)# commit

/* Configure FRR with remote LFA using OSPF */
Router# configure
Router(config)# router ospf 50
Router(config-ospf)# router-id 10.1.1.1
Router(config-ospf)# address-family ipv4 unicast
Router(config-ospf-af)# area 0
Router(config-ospf-af)# mpls traffic-eng
Router(config-ospf-af)# interface Loopback 0
Router(config-ospf-af)# exit
Router(config-ospf)# interface HundredGigE0/9/0/0
Router(config-ospf-if)# fast-reroute per-prefix
Router(config-ospf-if)# fast-reroute per-prefix remote-lfa tunnel mpls-ldp
Router(config-ospf-if)# exit
Router(config-ospf)# exit
Router(config)# mpls traffic-eng router-id Loopback 0
```

Running Configuration

This section shows the FRR with local LFA configuration.

```
/* FRR with local LFA with ISIS */
router isis ring
 is-type level-1
 net 49.0001.0000.0000.0007.00
 nsf cisco
 address-family ipv4 unicast
  metric-style wide
  mpls traffic-eng level-1-2
  mpls traffic-eng router-id 10.7.7.7
 !
 interface Loopback0
  point-to-point
  address-family ipv4 unicast
  !
 !
 interface HundredGigE0/9/0/0
  point-to-point
  address-family ipv4 unicast
fast-reroute per-prefix

/* FRR with local LFA with OSPF */
router ospf 50
 router-id 10.1.1.1
address-family ipv4 unicast
```

```
 area 0
  mpls traffic-eng
  interface Loopback0
  !
  interface HundredGigE0/9/0/0
 fast-reroute per-prefix
  !
!
 mpls traffic-eng router-id loopback 0
!
```

This section shows the FRR with remote LFA configuration.

```
/* FRR with remote  LFA with ISIS */
ipv4 prefix-list RLFA
 10 deny 3.3.3.3/32
 20 permit 0.0.0.0/0 le 32
router isis ring
 is-type level-1
 net 49.0001.0000.0000.0007.00
 nsf cisco
 address-family ipv4 unicast
 fast-reroute per-prefix remote-lfa prefix-list RLFA
  metric-style wide
  mpls traffic-eng level-1-2
  mpls traffic-eng router-id 10.7.7.7
 !
 interface Loopback0
  point-to-point
  address-family ipv4 unicast
  !
 !
 interface TenGigabitEthernet 0/0/0/4
  point-to-point
  address-family ipv4 unicast
fast-reroute per-prefix
fast-reroute per-prefix remote-lfa tunnel mpls-ldp


/* FRR with remote  LFA with OSPF */
router ospf 50
 router-id 10.1.1.1
address-family ipv4 unicast
 area 0
  mpls traffic-eng
  interface Loopback0
  !
  interface HundredGigE0/9/0/0
 fast-reroute per-prefix
fast-reroute per-prefix remote-lfa tunnel mpls-ldp
  !
!
 mpls traffic-eng router-id loopback 0
!
```

Verification

The show outputs given in the following section display the details of the configuration of the FRR with Remote LFA feature, and the status of their configuration.

```
/* Verify the route summary information about the specified routing table. */

RP/0//CPU0:router# show route 10.3.3.3

Routing entry for 10.3.3.3/32
   Known via "isis 44", distance 115, metric 20, type level-1
   Installed Nov 15 19:43:13.367 for 00:00:34
   Routing Descriptor Blocks
     10.1.1.1, from 10.3.3.3, via TenGigE0/0/0/0, Backup (remote)
       Remote LFA is 10.9.9.9
      Route metric is 0
     10.1.1.2, from 10.3.3.3, via TenGigE0/7/0/3, Protected
       Route metric is 20
   No advertising protos.


/* Verify the MPLS LDP configuration. */

RP/0//CPU0:router# show running mpls ldp
Codes:
   - = GR label recovering, (!) = LFA FRR pure backup path
   {} = Label stack with multi-line output for a routing path
   G = GR, S = Stale, R = Remote LFA FRR backup

 Prefix           Label   Label(s)       Outgoing     Next Hop            Flags
                  In      Out            Interface                        G S R
 ---------------- ------ -------- --------------- ----
 192.0.2.0/24     16019   { 16001        Te0/0/0/0    10.1.1.1        (!)     R
                            28006 }                  (10.9.9.9)
                          ImpNull        Te0/7/0/3    192.0.2.1
 192.0.2.1/32     16013   ImpNull        Te0/0/0/0    10.1.1.1
 192.0.1.0/32     16014   { 16001        Te0/0/0/0    10.1.1.1        (!)     R
                            16002 }                  (10.9.9.9)
                          ImpNull        Te0/7/0/3    192.0.2.2
 10.9.9.9/32      16012   16001          Te0/0/0/0    10.1.1.1
                          28006          Te0/7/0/3    192.0.2.1
 10.23.1.0/24     16018   16004          Te0/0/0/0    10.1.1.1        (!)
                          ImpNull        Te0/7/0/3    192.0.2.1
 10.34.1.0/24     16015   ImpNull        Te0/0/0/0    10.1.1.1
 10.0.0.1/32      16011  { 16001         Te0/0/0/0     10.1.1.1        (!)     R
                            16013 }                  (10.9.9.9)
                          16016          Te0/7/0/3    192.0.2.1
 10.100.0.2/32     16010   { 16001       Te0/0/0/0    10.1.1.1         (!)     R


/* Verify whether RLFA filtering is active */
RP/0/0/CPU0:Router #show isis fast-reroute 1.0.0.2/32 detail

L2 1.0.0.2/32 [20/115] medium priority
     via 1.2.0.2, GigabitEthernet0/0/0/0, R2, Weight: 0
       Backup path: R-LFA, via R3 [1.0.0.3], via 1.4.1.2, GigabitEthernet0/0/0/1 R4, Weight:
 0, Metric: 20 /*3.3.3.3 is filtered out, and another address is picked when RLFA filtering
 is active */
       P: No, TM: 20, LC: No, NP: No, D: No, SRLG: Yes
     src R2.00-00, 1.0.0.2
```