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Remote-LFA Node Protection and Manageability
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Abstract

The loop-free alternates computed following the current Remote-LFA specification guarantees only link-protection. The resulting Remote-LFA nexthops (also called PQ-nodes), may not guarantee node-protection for all destinations being protected by it.

This document describes procedures for determining if a given PQ-node provides node-protection for a specific destination or not. The document also shows how the same procedure can be utilized for collection of complete characteristics for alternate paths. Knowledge about the characteristics of all alternate path is precursory to apply operator defined policy for eliminating paths not fitting constraints.

Requirements Language

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in RFC2119 [RFC2119].

Status of This Memo

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1. Introduction

The Remote-LFA [RFC7490] specification provides loop-free alternates that guarantee only link-protection. The resulting Remote-LFA alternate nexthops (also referred to as the PQ-nodes) may not provide node-protection for all destinations covered by the same Remote-LFA alternate, in case of failure of the primary nexthop node. Neither does the specification provide a means to determine the same.

Also, the LFA Manageability [RFC7916] document requires a computing router to find all possible (including all possible Remote-LFA) alternate nexthops, collect the complete set of path characteristics for each alternate path, run an alternate-selection policy (configured by the operator) and find the best alternate path. This will require the Remote-LFA implementation to gather all the required path characteristics along each link on the entire Remote-LFA alternate path.

With current LFA [RFC5286] and Remote-LFA implementations, the forward SPF (and reverse SPF) is run with the computing router and its immediate 1-hop routers as the roots. While that enables computation of path attributes (e.g. SRLG, Admin-groups) for first alternate path segment from the computing router to the PQ-node, there is no means for the computing router to gather any path attributes for the path segment from the PQ-node to destination. Consequently any policy-based selection of alternate paths will consider only the path attributes from the computing router up until the PQ-node.

This document describes a procedure for determining node-protection with Remote-LFA. The same procedure is also extended for collection of a complete set of path attributes, enabling more accurate policy-based selection for alternate paths obtained with Remote-LFA.

1.1. Abbreviations

This document uses the following list of abbreviations.

LFA - Loop Free Alternates

RLFA or R-LFA - Remote Loop Free Alternates

ECMP - Equal Cost Multiple Path

SPF - Shortest Path First graph computations

NH - Next Hop node

2. Node Protection with Remote-LFA

Node-protection is required to provide protection of traffic on a given forwarding node, against the failure of the first-hop node on the primary forwarding path. Such protection becomes more critical in the absence of mechanisms like non-stop-routing in the network. Certain operators refrain from deploying non-stop-routing in their network, due to the required complex state synchronization between redundant control plane hardwares it requires, and the significant additional performance complexities it hence introduces. In such cases node-protection is essential to guarantee un-interrupted flow of traffic, even in the case of an entire forwarding node going down.

The following sections discuss the node-protection problem in the context of Remote-LFA and propose a solution.

2.1. The Problem

To better illustrate the problem and the solution proposed in this document the following topology diagram from the Remote-LFA [RFC7490] draft is being re-used with slight modification.

```
            D1
           /
     S-x-E
    /     \
   N       R3--D2
    \     /
    R1---R2
```

Figure 1: Topology 1

In the above topology, for all (non-ECMP) destinations reachable via the S-E link there is no standard LFA alternate. As per the Remote-LFA [RFC7490] alternate specifications node R2 being the only PQ-node for the S-E link provides nexthop for all the above destinations. Table 1 below, shows all possible primary and Remote-LFA alternate paths for each destination.

Destination	Primary Path	PQ-node	Remote-LFA Backup Path
R3	S->E->R3	R2	S=>N=>R1=>R2->R3
E	S->E	R2	S=>N=>R1=>R2->R3->E
D1	S->E->D1	R2	S=>N=>R1=>R2->R3->E->D1
D2	S->E->R3->D2	R2	S=>N=>R1=>R2->R3->D2

Table 1: Remote-LFA backup paths via PQ-node R2

A closer look at Table 1 shows that, while the PQ-node R2 provides link-protection for all the destinations, it does not provide node-protection for destinations E and D1. In the event of the node-failure on primary nexthop E, the alternate path from Remote-LFA nexthop R2 to E and D1 also becomes unavailable. So for a Remote-LFA nexthop to provide node-protection for a given destination, it is mandatory that, the shortest path from the given PQ-node to the given destination MUST NOT traverse the primary nexthop.

In another extension of the topology in Figure 1 let us consider an additional link between N and E with the same cost as the other links.

```
                                D1
                               /
                          S-x-E
                         /   / \
                        N---+   R3--D2
                         \     /
                          R1---R2
```

Figure 2: Topology 2

In the above topology, the S-E link is no more on any of the shortest paths from N to R3, E and D1. Hence R3, E and D1 are also included in both the Extended-P space and Q space of E (w.r.t S-E link). Table 2 below, shows all possible primary and R-LFA alternate paths via PQ-node R3, for each destination reachable through the S-E link in the above topology. The R-LFA alternate paths via PQ-node R2 remains same as in Table 1.

Destination	Primary Path	PQ-node	Remote-LFA Backup Path
R3	S->E->R3	R3	S=>N=>E=>R3
E	S->E	R3	S=>N=>E=>R3->E
D1	S->E->D1	R3	S=>N=>E=>R3->E->D1
D2	S->E->R3->D2	R3	S=>N=>E=>R3->D2

Table 2: Remote-LFA backup paths via PQ-node R3

Again a closer look at Table 2 shows that, unlike Table 1, where the single PQ-node R2 provided node-protection for destinations R3 and D2, if we choose R3 as the R-LFA nexthop, it does not provide node-protection for R3 and D2 anymore. If S chooses R3 as the R-LFA nexthop, in the event of the node-failure on primary nexthop E, on the alternate path from S to R-LFA nexthop R3, one of parallel ECMP path between N and R3 also becomes unavailable. So for a Remote-LFA nexthop to provide node-protection for a given destination, it is also mandatory that, the shortest paths from S to the chosen PQ-node MUST NOT traverse the primary nexthop node.

2.2. Additional Definitions

This document adds and enhances the following definitions extending the ones mentioned in Remote-LFA [RFC7490] specification.

2.2.1. Link-Protecting Extended P-Space

The Remote-LFA [RFC7490] specification already defines this. The link-protecting extended P-space for a link S-E being protected is the set of routers that are reachable from one or more direct neighbors of S, except primary node E, without traversing the S-E link on any of the shortest paths from the direct neighbor to the router. This MUST exclude any direct neighbor for which there is at least one ECMP path from the direct neighbor traversing the link(S-E) being protected.

For a cost-based definition for Link-protecting Extended P-Space refer to Section 2.2.6.1.

2.2.2. Node-Protecting Extended P-Space

The node-protecting extended P-space for a primary nexthop node E being protected, is the set of routers that are reachable from one or more direct neighbors of S, except primary node E, without traversing the node E. This MUST exclude any direct neighbors for which there is at least one ECMP path from the direct neighbor traversing the node E being protected.

For a cost-based definition for Node-protecting Extended P-Space refer to Section 2.2.6.2.

2.2.3. Q-Space

The Remote-LFA [RFC7490] draft already defines this. The Q-space for a link S-E being protected is the set of nodes that can reach primary node E, without traversing the S-E link on any of the shortest paths from the node itself to primary nexthop E. This MUST exclude any node for which there is at least one ECMP path from the node to the primary nexthop E traversing the link(S-E) being protected.

For a cost-based definition for Q-Space refer to Section 2.2.6.3.

2.2.4. Link-Protecting PQ Space

A node Y is in link-protecting PQ space w.r.t the link (S-E) being protected, if and only if, Y is present in both link-protecting extended P-space and the Q-space for the link being protected.

2.2.5. Candidate Node-Protecting PQ Space

A node Y is in candidate node-protecting PQ space w.r.t the node (E) being protected, if and only if, Y is present in both node-protecting extended P-space and the Q-space for the link being protected.

Please note, that a node Y being in candidate node-protecting PQ-space, does not guarantee that the R-LFA alternate path via the same, in entirety, is unaffected in the event of a node failure of primary nexthop node E. It only guarantees that the path segment from S to PQ-node Y is unaffected by the same failure event. The PQ-nodes in the candidate node-protecting PQ space may provide node protection for only a subset of destinations that are reachable through the corresponding primary link.

2.2.6. Cost-Based Definitions

This section provides cost-based definitions for some of the terms introduced in Section 2.2 of this document.

2.2.6.1. Link-Protecting Extended P-Space

Please refer to Section 2.2.1 for a formal definition for Link-protecting Extended P-Space.

A node Y is in link-protecting extended P-space w.r.t the link (S-E) being protected, if and only if, there exists at least one direct neighbor of S, Ni, other than primary nexthop E, that satisfies the following condition.

```
D_opt(Ni,Y) < D_opt(Ni,S) + D_opt(S,Y)

Where,
  D_opt(A,B) : Distance on most optimum path from A to B.
         Ni  : A direct neighbor of S other than primary
               nexthop E.
          Y  : The node being evaluated for link-protecting
               extended P-Space.
```

Figure 3: Link-Protecting Ext-P-Space Condition

2.2.6.2. Node-Protecting Extended P-Space

Please refer to Section 2.2.2 for a formal definition for Node-protecting Extended P-Space.

A node Y is in node-protecting extended P-space w.r.t the node E being protected, if and only if, there exists at least one direct neighbor of S, Ni, other than primary nexthop E, that satisfies the following condition.

```
D_opt(Ni,Y) < D_opt(Ni,E) + D_opt(E,Y)

Where,
  D_opt(A,B) : Distance on most optimum path from A to B.
          E  : The primary nexthop on shortest path from S
               to destination.
          Ni : A direct neighbor of S other than primary
               nexthop E.
           Y : The node being evaluated for node-protecting
               extended P-Space.
```

Figure 4: Node-Protecting Ext-P-Space Condition

Please note, that a node Y satisfying the condition in Figure 4 above only guarantees that the R-LFA alternate path segment from S via direct neighbor Ni to the node Y is not affected in the event of a node failure of E. It does not yet guarantee that the path segment from node Y to the destination is also unaffected by the same failure event.

2.2.6.3. Q-Space

Please refer to Section 2.2.3 for a formal definition for Q-Space.

A node Y is in Q-space w.r.t the link (S-E) being protected, if and only if, the following condition is satisfied.

```
D_opt(Y,E) < D_opt(S,E) + D_opt(Y,S)

Where,
  D_opt(A,B) : Distance on most optimum path from A to B.
          E  : The primary nexthop on shortest path from S
               to destination.
          Y  : The node being evaluated for Q-Space.
```

Figure 5: Q-Space Condition

2.3. Computing Node-protecting R-LFA Path

The R-LFA alternate path through a given PQ-node to a given destination is comprised of two path segments as follows.

1. Path segment from the computing router to the PQ-node (Remote-LFA alternate nexthop), and

2. Path segment from the PQ-node to the destination being protected.

So to ensure a R-LFA alternate path for a given destination provides node-protection we need to ensure that none of the above path segments are affected in the event of failure of the primary nexthop node. Sections Section 2.3.1 and Section 2.3.2 show how this can be ensured.

2.3.1. Computing Candidate Node-protecting PQ-Nodes for Primary nexthops

To choose a node-protecting R-LFA nexthop for a destination R3, router S needs to consider a PQ-node from the candidate node-protecting PQ-space for the primary nexthop E on shortest path from S to R3. As mentioned in Section 2.2.2, to consider a PQ-node as candidate node-protecting PQ-node, there must be at least one direct neighbor Ni of S, such that all shortest paths from Ni to the PQ-node does not traverse primary nexthop node E.

Implementations SHOULD run the inequality in Section 2.2.2 Figure 4 for all direct neighbors, other than primary nexthop node E, to determine whether a node Y is a candidate node-protecting PQ-node.

All of the metrics needed by this inequality would have been already collected from the forward SPFs rooted at each of direct neighbor S, computed as part of standard LFA [RFC5286] implementation. With reference to the topology in Figure 2, Table 3 below shows how the above condition can be used to determine the candidate node-protecting PQ-space for S-E link (primary nexthop E).

Candidate PQ-node (Y)	Direct Nbr (Ni)	D_opt (Ni,Y)	D_opt (Ni,E)	D_opt (E,Y)	Condition Met
R2	N	2 (N,R2)	1 (N,E)	2 (E,R2)	Yes
R3	N	2 (N,R3)	1 (N,E)	1 (E,R3)	No

Table 3: Node-protection evaluation for R-LFA repair tunnel to PQ-node

As seen in the above Table 3, R3 does not meet the node-protecting extended-p-space inequality and so, while R2 is in candidate node-protecting PQ space, R3 is not.

Some SPF implementations may also produce a list of links and nodes traversed on the shortest path(s) from a given root to others. In such implementations, router S may have executed a forward SPF with each of its direct neighbors as the SPF root, executed as part of the standard LFA [RFC5286] computations. So S may re-use the list of links and nodes collected from the same SPF computations, to decide whether a node Y is a candidate node-protecting PQ-node or not. A node Y shall be considered as a node-protecting PQ-node, if and only if, there is at least one direct neighbor of S, other than the primary nexthop E, for which, the primary nexthop node E does not exist on the list of nodes traversed on any of the shortest paths from the direct neighbor to the PQ-node. Table 4 below is an illustration of the mechanism with the topology in Figure 2.

Candidate PQ-node	Repair Tunnel Path(Repairing router to PQ-node)	Link-Protection	Node-Protection
R2	S->N->R1->R2	Yes	Yes
R2	S->E->R3->R2	No	No
R3	S->N->E->R3	Yes	No

Table 4: Protection of Remote-LFA tunnel to the PQ-node

As seen in the above Table 4 while R2 is candidate node-protecting Remote-LFA nexthop for R3 and D2, it is not so for E and D1, since the primary nexthop E is in the shortest path from R2 to E and D1.

2.3.2. Computing node-protecting paths from PQ-nodes to destinations

Once a computing router finds all the candidate node-protecting PQ-nodes for a given directly attached primary link, it shall follow the procedure as proposed in this section, to choose one or more node-protecting R-LFA paths, for destinations reachable through the same primary link in the primary SPF graph.

To find a node-protecting R-LFA path for a given destination, the computing router needs to pick a subset of PQ-nodes from the candidate node-protecting PQ-space for the corresponding primary nexthop, such that all the path(s) from the PQ-node(s) to the given destination remain unaffected in the event of a node failure of the primary nexthop node. To determine whether a given PQ-node belongs to such a subset of PQ-nodes, the computing router MUST ensure that none of the primary nexthop node are found on any of the shortest paths from the PQ-node to the given destination.

This document proposes an additional forward SPF computation for each of the PQ-nodes, to discover all shortest paths from the PQ-nodes to the destination. This will help determine, if a given primary nexthop node is on the shortest paths from the PQ-node to the given destination or not. To determine if a given candidate node-protecting PQ-node provides node-protecting alternate for a given destination, or not, all the shortest paths from the PQ-node to the given destination has to be inspected, to check if the primary nexthop node is found on any of these shortest paths. To compute all the shortest paths from a candidate node-protecting PQ-node to one (or more) destination, the computing router MUST run the forward SPF on the candidate node-protecting PQ-node. Soon after running the forward SPF, the computer router SHOULD run the inequality in

Figure 6 below, once for each destination. A PQ-node that does not qualify the condition for a given destination, does not guarantee node-protection for the path segment from the PQ-node to the specific destination.

```
D_opt(Y,D) < D_opt(Y,E) + Distance_opt(E,D)

Where,
  D_opt(A,B) : Distance on most optimum path from A to B.
          D  : The destination node.
          E  : The primary nexthop on shortest path from S
               to destination.
          Y  : The node-protecting PQ-node being evaluated
```

Figure 6: Node-Protecting Condition for PQ-node to Destination

All of the above metric costs except D_opt(Y, D), can be obtained with forward and reverse SPFs with E(the primary nexthop) as the root, run as part of the regular LFA and Remote-LFA implementation. The Distance_opt(Y, D) metric can only be determined by the additional forward SPF run with PQ-node Y as the root. With reference to the topology in Figure 2, Table 5 below shows how the above condition can be used to determine node-protection with node-protecting PQ-node R2.

Destination (D)	Primary-NH (E)	D_opt (Y, D)	D_opt (Y, E)	D_opt (E, D)	Condition Met
R3	E	1 (R2,R3)	2 (R2,E)	1 (E,R3)	Yes
E	E	2 (R2,E)	2 (R2,E)	0 (E,E)	No
D1	E	3 (R2,D1)	2 (R2,E)	1 (E,D1)	No
D2	E	2 (R2,D2)	2 (R2,E)	1 (E,D2)	Yes

Table 5: Node-protection evaluation for R-LFA path segment between PQ-node and destination

As seen in the above example above, R2 does not meet the node-protecting inequality for destination E, and D1. And so, once again, while R2 is a node-protecting Remote-LFA nexthop for R3 and D2, it is not so for E and D1.

In SPF implementations that also produce a list of links and nodes traversed on the shortest path(s) from a given root to others, the inequality in Figure 6 above need not be evaluated. Instead, to determine whether a PQ-node provides node-protection for a given destination or not, the list of nodes computed from forward SPF run on the PQ-node, for the given destination, SHOULD be inspected. In case the list contains the primary nexthop node, the PQ-node does not provide node-protection. Else, the PQ-node guarantees node-protecting alternate for the given destination. Below is an illustration of the mechanism with candidate node-protecting PQ-node R2 in the topology in Figure 2.

Destination	Shortest Path (Repairing router to PQ-node)	Link-Protection	Node-Protection
R3	R2->R3	Yes	Yes
E	R2->R3->E	Yes	No
D1	R2->R3->E->D1	Yes	No
D2	R2->R3->D2	Yes	Yes

Table 6: Protection of Remote-LFA path between PQ-node and destination

As seen in the above example while R2 is candidate node-protecting R-LFA nexthop for R3 and D2, it is not so for E and D1, since the primary nexthop E is in the shortest path from R2 to E and D1.

The procedure described in this document helps no more than to determine whether a given Remote-LFA alternate provides node-protection for a given destination or not. It does not find out any new Remote-LFA alternate nexthops, outside the ones already computed by standard Remote-LFA procedure. However, in case of availability of more than one PQ-node (Remote-LFA alternates) for a destination, and node-protection is required for the given primary nexthop, this procedure will eliminate the PQ-nodes that do not provide node-protection and choose only the ones that does.

2.3.3. Computing Node-Protecting R-LFA Paths for Destinations with ECMP primary nexthop nodes

In certain scenarios, when one or more destinations maybe reachable via multiple ECMP (equal-cost-multi-path) nexthop nodes, and only link-protection is required, there is no need to compute any alternate paths for such destinations. In the event of failure of one of the nexthop links, the remaining primary nexthops shall always provide link-protection. However, if node-protection is required, the rest of the primary nexthops may not guarantee node-protection. Figure 7 below shows one such example topology.

```
                                    D1
                              2    /
                          S---x---E1
                         / \     / \
                        /   x   /   \
                       /     \ /     \
                      N-------E2      R3--D2
                       \  2          /
                        \           /
                         \         /
                         R1-------R2
                              2
```

Primary Nexthops:
  Destination D1 = [{ S-E1, E1}, {S-E2, E2}]
  Destination D2 = [{ S-E1, E1}, {S-E2, E2}]

Figure 7: Topology with multiple ECMP primary nexthops

In the above example topology, costs of all links are 1, except the following links:

Link: S-E1, Cost: 2

Link: N-E2: Cost: 2

Link: R1-R2: Cost: 2

In the above topology, on computing router S, destinations D1 and D2 are reachable via two ECMP nexthop nodes E1 and E2. However the primary paths via nexthop node E2 also traverses via the nexthop node E1. So in the event of node failure of nexthop node E1, both primary paths (via E1 and E2) becomes unavailable. Hence if node-protection is desired for destinations D1 and D2, alternate paths that does not traverse any of the primary nexthop nodes E1 and E2, need to be computed. In the above topology the only alternate neighbor N does not provide such a LFA alternate path. Hence one (or more) R-LFA node-protecting alternate paths for destinations D1 and D2, needs to be computed.

In the above topology, following are the link-protecting PQ-nodes.

Primary Nexthop: E1, Link-Protecting PQ-Node: { R2 }

Primary Nexthop: E2, Link-Protecting PQ-Node: { R2 }

To find one (or more) node-protecting R-LFA paths for destinations D1 and D2, one (or more) node-protecting PQ-node(s) needs to be determined first. Inequalities specified in Section 2.2.6.2 and Section 2.2.6.3 can be evaluated to compute the node-protecting PQ-space for each of the nexthop nodes E1 and E2, as shown in Table 7 below. To select a PQ-node as node-protecting PQ-node for a destination with multiple primary nexthop nodes, the PQ-node MUST satisfy the inequality for all primary nexthop nodes. Any PQ-node which is NOT node-protecting PQ-node for all the primary nexthop nodes, MUST NOT be chosen as the node-protecting PQ-node for destination.

Primary Nexthop (E)	Candidate PQ-node (Y)	Direct Nbr (Ni)	D_opt (Ni,Y)	D_opt (Ni,E)	D_opt (E,Y)	Condition Met
E1	R2	N	3 (N,R2)	3 (N,E1)	2 (E1,R2)	Yes
E2	R2	N	3 (N,R2)	2 (N,E2)	3 (E2,R2)	Yes

Table 7: Computing Node-protected PQ-nodes for nexthop E1 and E2

In SPF implementations that also produce a list of links and nodes traversed on the shortest path(s) from a given root to others, the tunnel-repair paths from the computing router to candidate PQ-node can be examined to ensure that none of the primary nexthop nodes is traversed. PQ-nodes that provide one (or more) Tunnel-repair paths(s) that does not traverse any of the primary nexthop nodes, are to be considered as node-protecting PQ-nodes. Table 8 below shows the possible tunnel-repair paths to PQ-node R2.

Primary-NH (E)	PQ-Node (Y)	Tunnel-Repair Paths	Exclude All Primary-NH
E1, E2	R2	S==>N==>R1==>R2	Yes

Table 8: Tunnel-Repair paths to PQ-node R2

From Table 7 and Table 8, in the above example, R2 being node-protecting PQ-node for both primary nexthops E1 and E2, should be chosen as the node-protecting PQ-node for destinations D1 and D2 that are both reachable via primary nexthop nodes E1 and E2.

Next, to find a node-protecting R-LFA path from node-protecting PQ-node to destinations D1 and D2, inequalities specified in Figure 6 should be evaluated, to ensure if R2 provides a node-protecting R-LFA path for each of these destinations, as shown below in Table 9. For a R-LFA path to qualify as node-protecting R-LFA path for a destination with multiple ECMP primary nexthop nodes, the R-LFA path from the PQ-node to the destination MUST satisfy the inequality for all primary nexthop nodes.

Destination (D)	Primary-NH (E)	PQ-Node (Y)	D_opt (Y, D)	D_opt (Y, E)	D_opt (E, D)	Condition Met
D1	E1	R2	3 (R2, D1)	2 (R2, E1)	1 (E1, D1)	No
D1	E2	R2	3 (R2, D1)	3 (R2, E2)	2 (E2, D1)	Yes
D2	E1	R2	2 (R2, D2)	2 (R2, E1)	2 (E1, D2)	Yes
D2	E2	R2	2 (R2, D2)	2 (R2, E2)	3 (E2, D2)	Yes

Table 9: Finding node-protecting R-LFA path for destinations D1 and D2

In SPF implementations that also produce a list of links and nodes traversed on the shortest path(s) from a given root to others, the R-LFA paths via node-protecting PQ-node to final destination can be examined to ensure that none of the primary nexthop nodes is traversed. R-LFA path(s) that does not traverse any of the primary nexthop nodes, guarantees node-protection in the event of failure of any of the primary nexthop nodes. Table 10 below shows the possible R-LFA-paths for destinations D1 and D2 via the node-protecting PQ-node R2.

Destination (D)	Primary-NH (E)	PQ-Node (Y)	R-LFA Paths	Exclude All Primary-NH
D1	E1, E2	R2	S==>N==>R1==>R2 -->R3-->E1-->D1	No
D2	E1, E2	R2	S==>N==>R1==>R2 -->R3-->D2	Yes

Table 10: R-LFA paths for destinations D1 and D2

From Table 9 and Table 10, in the example above, the R-LFA path from R2 does not meet the node-protecting inequality for destination D1, while it does meet the same inequality for destination D2. And so, while R2 provides node-protecting R-LFA alternate for D2, it fails to provide node-protection for destination D1. Finally, while it is possible to get a node-protecting R-LFA path for D2, no such node-protecting R-LFA path can be found for D1.

2.3.4. Limiting extra computational overhead

In addition to the extra reverse SPF computations suggested by the Remote-LFA [RFC7490] draft (one reverse SPF for each of the directly connected neighbors), this document proposes a forward SPF computations for each PQ-node discovered in the network. Since the average number of PQ-nodes found in any network is considerably more than the number of direct neighbors of the computing router, the proposal of running one forward SPF per PQ-node may add considerably to the overall SPF computation time.

To limit the computational overhead of the approach proposed, this document specifies that implementations MUST choose a subset from the entire set of PQ-nodes computed in the network, with a finite limit on the number of PQ-nodes in the subset. Implementations MUST choose a default value for this limit and may provide user with a configuration knob to override the default limit. This document suggests 16 as a default value for this limit. Implementations MUST also evaluate some default preference criteria while considering a PQ-node in this subset. The exact default preference criteria to be used is outside the scope of this document, and is a matter of implementation. Finally, implementations MAY also allow the user to override the default preference criteria, by providing a policy configuration for the same.

This document proposes that implementations SHOULD use a default preference criteria for PQ-node selection which will put a score on each PQ-node, proportional to the number of primary interfaces for which it provides coverage, its distance from the computing router, and its router-id (or system-id in case of IS-IS). PQ-nodes that cover more primary interfaces SHOULD be preferred over PQ-nodes that cover fewer primary interfaces. When two or more PQ-nodes cover the same number of primary interfaces, PQ-nodes which are closer (based on metric) to the computing router SHOULD be preferred over PQ-nodes farther away from it. For PQ-nodes that cover the same number of primary interfaces and are the same distance from the computing router, the PQ-node with smaller router-id (or system-id in case of IS-IS) SHOULD be preferred.

Once a subset of PQ-nodes is found, computing router shall run a forward SPF on each of the PQ-nodes in the subset to continue with procedures proposed in Section 2.3.2.

3. Manageability of Remote-LFA Alternate Paths

3.1. The Problem

With the regular Remote-LFA [RFC7490] functionality the computing router may compute more than one PQ-node as usable Remote-LFA alternate nexthops. Additionally [RFC7916] specifies a LFA (and Remote-LFA) manageability framework, in which an alternate selection policy may be configured to let the network operator choose one of them as the most appropriate Remote-LFA alternate. For such policy-based alternate selection to run, the computing router needs to collect all the relevant path characteristics (as specified in section 6.2.4 of [RFC7916]) for each of the alternate paths (one through each of the PQ-nodes). As mentioned before in Section 2.3 the R-LFA alternate path through a given PQ-node to a given destination is comprised of two path segments. Section 6.2.5.4 of [RFC7916] specifies that any kind of alternate selection policy must consider path characteristics for both path segments while evaluating one or more RLFA alternate path(s).

The first path segment (i.e. from the computing router to the PQ-node) can be calculated from the regular forward SPF done as part of standard and remote LFA computations. However without the mechanism proposed in Section 2.3.2 of this document, there is no way to determine the path characteristics for the second path segment (i.e. from the PQ-node to the destination). In the absence of the path characteristics for the second path segment, two Remote-LFA alternate paths may be equally preferred based on the first path segments characteristics only, although the second path segment attributes may be different.

3.2. The Solution

The additional forward SPF computation proposed in Section 2.3.2 document shall also collect links, nodes and path characteristics along the second path segment. This shall enable collection of complete path characteristics for a given Remote-LFA alternate path to a given destination. The complete alternate path characteristics shall then facilitate more accurate alternate path selection while running the alternate selection policy.

As already specified in Section 2.3.4 to limit the computational overhead of the proposed approach, forward SPF computations must be run on a selected subset from the entire set of PQ-nodes computed in the network, with a finite limit on the number of PQ-nodes in the subset. The detailed suggestion on how to select this subset is specified in the same section. While this limits the number of possible alternate paths provided to the alternate-selection policy, this is needed to keep the computational complexity within affordable limits. However if the alternate-selection policy is very restrictive this may leave few destinations in the entire topology without protection. Yet this limitation provides a necessary tradeoff between extensive coverage and immense computational overhead.

The mechanism proposed in this section does not modify or invalidate [RFC7916] or any parts of it. This document specifies a mechanism to meet the requirements specified in section 6.5.2.4 in [RFC7916].

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5. IANA Considerations

N/A. - No protocol changes are proposed in this document.

6. Security Considerations

This document does not introduce any change in any of the protocol specifications. It simply proposes to run an extra SPF rooted on each PQ-node discovered in the whole network.

7. References

7.1. Normative References

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7.2. Informative References

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