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A. Deshmukh
K. Kompella
Juniper Networks, Inc.
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RSVP Extensions for RMR
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Abstract

Ring topology is commonly found in access and aggregation networks. However, the use of MPLS as the transport protocol for rings is very limited today. `{!I-D.ietf-mpls-rmr}` describes a mechanism to handle rings efficiently using MPLS. This document describes the extensions to the RSVP-TE protocol for signaling MPLS label switched paths in rings.

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[1.](#) Introduction

This document extends RSVP-TE [[RFC3209](#)] to establish label-switched path (LSP) tunnels in the ring topology. Rings are auto-discovered using the mechanisms mentioned in the `{!I-D.ietf-mpls-rmr}`. Either IS-IS [[RFC5305](#)] or OSPF[RFC3630] can be used as the IGP for auto-discovering the rings.

After the rings are auto-discovered, each node in the ring knows its clockwise(CW) and anti-clockwise (AC) ring neighbors and its ring links. All of the express links in the ring also get identified as part of the auto-discovery process. At this point, every node in the ring informs the RSVP protocol to begin the signaling of the ring LSPs.

[Section 2](#) covers the terminology used in this document. [Section 3](#) presents the RSVP protocol extensions needed to support MPLS rings. [Section 4](#) describes the procedures of RSVP LSP signaling in detail.

1.1. Requirements Language

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "NOT RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in [BCP 14](#) [[RFC2119](#)] [[RFC8174](#)] when, and only when, they appear in all capitals, as shown here.

2. Terminology

Assuming there are n nodes in the network, a ring gets formed by a subset of those n nodes $\{R_i, R_{i+1}, R_{i+2}, \dots, R_n\}$. We define the direction from node R_i to R_{i+1} as "clockwise" (CW) and the reverse direction as "anti-clockwise" (AC). As there might be several rings in a graph, each ring is identified by its own distinct ring ID - RID.

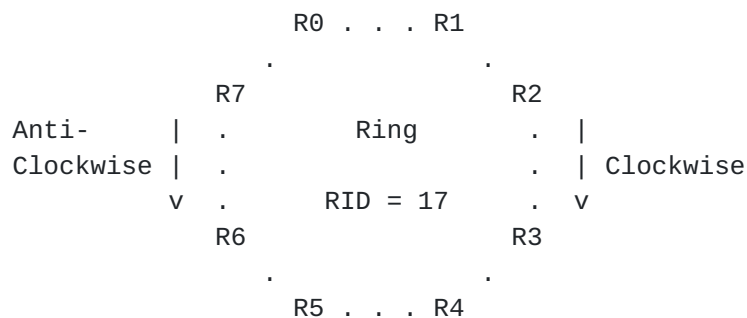


Figure 1: Ring with 8 nodes

The following terminology is used for ring LSPs:

Ring ID (RID): A non-zero number that identifies a ring; this is unique in a Service Provider's network. A node may belong to multiple rings.

Ring node: A member of a ring. Note that a device may belong to several rings.

Node index: A logical numbering of nodes in a ring, from zero up to one less than the ring size. Used purely for exposition in this document.

Ring neighbors: Nodes whose indices differ by one (modulo ring size).

Ring links: Links that connect ring neighbors.

Ring Flags: For each ring, the anchor node starts signaling of a ring LSP. Ring LSP named RL_i , anchored on node R_i , consists of two counter-rotating unicast LSPs that start and end at R_i . One LSP will be in the clockwise direction and other LSP will be in

the anti-clockwise direction. A ring LSP is "multipoint": any node along the ring can use LSP RLi to send traffic to Ri; this can be in either the CW or AC directions, or both (i.e., load balanced). Two new flags are defined in the SESSION object which define the ring direction of the corresponding Path message.

Clockwise(CW) Direction 0x01: This flag indicates that the corresponding Path message is traveling in the Clockwise(CW) direction along the ring.

Anti-Clockwise(AC) Direction 0x02: This flag indicates that the corresponding Path message is traveling in the Anti-Clockwise(AC) direction along the ring.

Express Link 0x04: This flag indicates that the corresponding Path message is traveling along the Express link in the ring.

3.2. SENDER_TEMPLATE, FILTER_SPEC Objects

There will be no changes to the SENDER_TEMPLATE and FILTER_SPEC objects. The format of the above 2 objects will be similar to the definitions in [RFC 3209](#). [[RFC3209](#)] Only the semantics of these objects will slightly change. This will be explained in [Section 4.6](#) below.

4. Ring Signaling Procedures

A ring node indicates in its IGP updates the ring LSP signaling protocols that it supports. This can be LDP and/or RSVP-TE. Ideally, each node should support both. If the ring is configured with RSVP as the signaling protocol, then once a ring node R_i knows the RID, its ring links and directions, it kicks off ring RSVP LSP signaling automatically.

4.1. Differences from regular RSVP-TE LSPs

Ring LSPs differ from regular RSVP-TE LSPs in several ways:

1. Ring LSPs (by construction) form a loop.
2. Ring LSPs are multipoint-to-point. Any ring node can inject traffic into a ring LSP.
3. The bandwidth of a ring LSP can change hop-by-hop.
4. Ring LSPs are protected without the use of bypass or detour LSPs. Protection is handled by the ring LSP traversing in the opposite direction.

[4.2.](#) LSP signaling

After the ring auto-discovery process, each anchor node creates a LSP addressed to itself. This ring LSP contains of a pair of counter-rotating unicast LSPs. So, for a ring containing N nodes, there will be 2N total LSPs signaled.

There is no need for ERO object in the Path message. The Path message for ring LSPs has the following format:

```
<Path Message> ::= <Common Header> [ <INTEGRITY> ]
                        <SESSION> <RSVP_HOP>
                        <TIME_VALUES>
                        <LABEL_REQUEST>
                        [ <SESSION_ATTRIBUTE> ]
                        <sender descriptor list>

<sender descriptor list> ::= <sender descriptor>|
                                <sender descriptor list> <sender
descriptor>
<sender descriptor> ::= <SENDER_TEMPLATE> <SENDER_TSPEC>
```

The anchor node creates 2 Path messages traveling in opposite directions. The SESSION format MUST be as per the description in [Section 3.1](#). The anchor node which creates the LSP will insert it's own address in the "Ring anchor node address" field of the SESSION object. So effectively, the Path messages are addressed to the originating node itself.

The SESSION flags of these 2 Path messages are different. The Path message sent to the CW neighbor MUST have the CW flag set in the SESSION object to signal the LSP going in the clockwise direction. The Path message sent to the AC neighbor MUST have the AC flag set to signal the LSP in the anti-clockwise direction.

When an incoming Path message is received at the ring node R_i , it consults the results of auto-discovery to find the appropriate ring neighbor. If the incoming Path message has CW direction flag set, then R_i includes its own SENDER_DESCRIPTOR in the path message and forwards the Path message to its CW ring neighbor(R_{i+1}). Similarly if the incoming Path message has AC direction flag set, then R_i includes its own SENDER_TEMPLATE and forwards that Path message to it's AC ring neighbor(R_{i-1}). Thus, there is no need of ERO in the Path message. The Path message is routed locally at each ring based on the ring auto-discovery calculations.

The RESV message for ring LSPs also uses the new RING_IPv4 SESSION object. When the Path message originated from the anchor node R_i reaches back to R_i , R_i generates a Resv message. Note that this means that anchor node is both Ingress and Egress for the Path message. The Resv message copies the same ring flags as received in the corresponding Path message. So, a Resv message for a CW LSP goes in the AC direction (unlike the Path message, which goes CW). This is done to correctly match Path and corresponding Resv messages at transit ring nodes. Upon receiving Resv message with CW flag set, the ring node will forward the Resv message to its AC neighbor.

Each ring node R_i allocates CW and AC labels for each ring LSP RL_x (x between 1..n). As the signaling propagates around the ring, CW and AC labels are exchanged. When R_i receives CW and AC labels for LSP RL_x from its ring neighbors, primary and fast reroute (FRR) paths for RL_x are installed at R_i .

Consider the following three nodes of the ring, and their signaling interactions for LSP RL_5 originating from anchor node R_5 :

```

                P5_CW ->      P5_CW ->
                Q5_CW <-      Q5_CW <-
... ----- R7 ----- R8 ----- R9 ----- ...
                P5_AC <-      P5_AC <-
                Q5_AC ->      Q5_AC ->

```

P corresponds to the Path message and Q corresponds to the Resv message.

As explained above, an RMR LSP consists of two counter-rotating ring LSPs that start and end at the same node, say R_1 . As such, this appears to cause a loop, something that is normally avoided by RSVP-TE. There are some benefits to this:

Having a ring LSP form a loop allows the anchor node R_1 to ping itself and thus verify the end-to-end operation of the LSP. This, in conjunction with link-level OAM, offers a good indication of the operational state of the LSP. Also, having R_1 to be the ingress means that R_1 can initiate the Path messages for the two ring LSPs. This avoids R_1 having to coordinate with its neighbors to signal the LSPs, and simplifies the case where a ring update changes R_1 's ring neighbors. The cost of this is a little more signaling and a couple more label entries in the LFIB. However, we will let experiences from implementation guide us when we evaluate this approach.

4.2.1. Path Propagation for RMR

Ring LSPs are MP2P in nature. It means that every non-egress node is also an ingress and a merge-point for the LSP. Focussing on ring-LSP-0 (i.e ring-LSPs starting at R0):

```
R0---->R1---->R2---->R3---->R4---->R5---->R6--->R7--->R0(CW LSP)
R0---->R7---->R6---->R5---->R4---->R3---->R2--->R1--->R0(ACW LSP)
```

Each ring node inserts a new SENDER_TEMPLATE object into an incoming Path message. The procedure for that is as follows:

When a ring node R3 receives a Path message initiated by anchor node R0(for anchor lsp "lsp0"), R3 SHOULD make a copy of the received Path message for "lsp0". R3 then inserts a new sender-template object into the Path message for "lsp0". In the sender-template object, R3 uses the sender address as the loopback address of node R3 and lsp-id = X. R3 then forwards this modified Path message to it's ring neighbor.

So at this point, when Path messages heads out at R3, there will be 4 different SENDER_TEMPLATE objects in the outgoing Path message for lsp0:

```
-----
|SENDER_TEMPLATE_0 : SENDER_ADDRESS = R0, LSP_ID = 1 |
-----
|SENDER_TEMPLATE_1 : SENDER_ADDRESS = R1, LSP_ID = 1 |
-----
|SENDER_TEMPLATE_2 : SENDER_ADDRESS = R2, LSP_ID = 1 |
-----
|SENDER_TEMPLATE_3 : SENDER_ADDRESS = R3, LSP_ID = 1 |
-----
```

4.2.2. Resv Processing for RMR

When Egress node R0 receives the modified Path message, it replies with the a Resv message containing multiple FLOW_DESCRIPTOR objects. There should be 1 FLOW_DESCRIPTOR object corresponding to each of the SENDER_TEMPLATE object in the incoming Path message. The SESSION object of the Resv message will exactly match with the received Path message.

[RFC 3209](#)[\[RFC3209\]](#) already supports receiving a Resv message with multiple flow-descriptors in it, as described in [section 3.2](#) in that document. In each flow-descriptor there is a separate:

- a. FLOW_SPEC object corresponding to the SENDER_TSPEC that was sent in the Path message which could be admitted after admission-control downstream, and
- b. FILTER_SPEC object corresponding to SENDER_TEMPLATE that was sent in the Path message that could be admitted after admission-control downstream.

Each transit node removes the FLOW-DESCRIPTOR corresponding to itself from the Resv message before sending the Resv message upstream.

4.3. Protection

In the rings, there are no protection LSPs -- no node or link bypass LSPs, no standby LSPs and no detours. Protection is via the "other" direction around the ring, which is why ring LSPs are in counter-rotating pairs. Protection works in the same way for link, node and ring LSP failures.

Since each ring LSP is a MP2P LSP, any ring node can inject traffic onto a LSP whose anchor might be a different ring node. To achieve the above, an ingress route will be installed as follows at every ring node J, for a given ring-LSP with anchor Rk (say 1.2.3.4).

```
1.2.3.4  -> (Push CL_J+1,K, NH: R_J+1)      # CW
          -> (Push AL_J-1,K, NH: R_J-1)      # AC
```

```
CL = Clockwise label
AL = Anti-Clockwise label
```

Traffic will either be load balanced in the CW and AC directions or the traffic will be sent on just CW or AC lsp based on parameters such as hop-count, policy etc.

Also, 2 transit routes will be installed for the anchor LSP transiting from node Rj as follows:


```

CL_J,K -> SWAP(CL_J+1,K, NH: R_J+1)      #CW
        -> SWAP(AL_J-1,K , NH: R_J-1)      #AC

```

CL = Clockwise label
 AL = Anti-Clockwise label
 CW NH has weight 1, AC NH has higher-weight.

```

AL_J,K -> SWAP(AL_J-1,K , NH: R_J-1)      #AC
        -> SWAP(CL_J+1,K, NH: R_J+1)      #CW

```

CL = Clockwise label
 AL = Anti-Clockwise label
 AC NH has weight 1, CW NH has higher weight.

Suppose a packet headed in anti-clockwise direction towards R5 and it arrives at node R7. Lets say that now R7 learns there is a link failure in the AC direction. R7 reroutes this packet back onto the clockwise direction. This reroute action is pre-programmed in the LFIB, to minimize the time between detection of a fault and the corresponding recovery action.

At this time, R7 also sends a notification to R0 that the AC direction is not working. R0 modifies it's ingress route(for R5 LSP) by removing the AC direction LSP's route. Thus, R0 switches traffic to the CW direction.

These notification propagate CW until each traffic source on the ring CW of the failure uses the CW direction. For RSVP-TE, this notification is sent in the form of PathErr message.

To provide this notification, the ring node detecting failure SHOULD send a Path Error message with error code of "Notify" and an error value field of ("Tunnel locally repaired"). This Path Error code and value is same as defined in [RFC 4090](#)[[RFC4090](#)] for the notification of local repair.

Note that the failure of a node or a link will not necessarily affect all ring LSPs. Thus, it is important to identify the affected LSPs and only switch the affected LSPs.

[4.4.](#) Ring changes

A ring node can go down resulting in a smaller ring or a new node can be added to the ring which will increase the ring size. In both of

the above cases, the ring auto-discovery process SHOULD kick in and it SHOULD calculate a new ring with the changed ring nodes.

When the ring auto-discovery process is complete, IGP will signal RSVP to begin the MBB process for the existing ring LSPs. For this MBB process, the anchor node will create a new Path message with a different Ring Instance ID in the SESSION object. All other fields in the SESSION Object will remain same as the existing Path message(before the ring change).

This new Path message will then propagate along the ring neighbors in the same way as the original Path message. Each ring neighbor SHOULD forward the Path message to it's appropriate neighbor based on the new auto-discovery calculations.

For the ring links which are common between the old and new LSPs, the LSPs will share resources(SE style reservation) on those ring links. Note that here we are using Ring Instance ID in the SESSION object to share resources instead of the LSP_ID in the SENDER_TEMPLATE Object(which is used in RSVP-TE for sharing resources as described in [RFC 3209](#) [[RFC4090](#)])). The LSP_ID use is reserved for a different functionality as described in section [Section 4.6](#).

[4.5](#). Express Links

Express links are discovered once ring nodes, ring links and directions have been established. As defined earlier, express links are links joining non-neighbor ring nodes. Express links are both clockwise and anti-clockwise.

A ring node with an Express link replicates the incoming Path message over the Express link. The "Express Link" flag is set in the SESSION object of the replicated Path message. Also, the ring node R_i includes an additional SENDER_DESCRIPTOR with a new LSP_ID in the outgoing PATH message.

When this Path message with Express link flag is received at the other end of Express link, the other ring node replies with the Resv message. It does not forward this Path message to any of it's ring neighbors. Thus, the "Express" LSPs are effectively 1 hop LSPs formed over the "Express Links".

[4.6](#). Bandwidth management

For RSVP-TE LSPs, bandwidths may be signaled in both directions. However, these are not provisioned either; rather, one does "reverse call admission control". When a service needs to use an LSP, the ring node where the traffic enters the ring attempts to increase the

bandwidth on the LSP to the egress. If successful, the service is admitted to the ring.

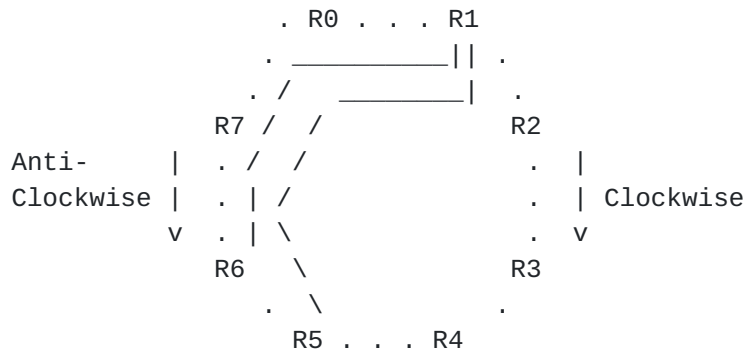


Figure 2: BW Management in Ring with 8 nodes

Let's say that Ring node R5 wants to increase the BW for the LSP whose egress is at node R1. To achieve this BW increase, Ring node R5 has to increase BW along the LSP anchored at node R1(say lsp1).

R5 makes a copy of the existing ring Path message for lsp1. R5 then modifies the sender-template object from the copied Path message for "lsp1". In the sender-template object, R5 uses the sender address as the loopback address of node R5 and lsp-id = X+1. R5 also modifies the TSPEC object which represents the BW increase/decrease in this new Path message. R5 then forwards this new Path message to its ring neighbor. The original anchor Path message has sender address as loopback address of R1.

Now, let's say, node 5 wants to increase BW again for lsp1, then R5 adds a new SENDER_TEMPLATE object in the existing Path message for "lsp1" with sender address as loopback of node 5 and lsp-id = X+2. So at this point, there will be 2 different SENDER_TEMPLATE objects corresponding to node 5 in the outgoing path message.

```

-----
|SENDER_TEMPLATE_0 : SENDER_ADDRESS = R0, LSP_ID = 1 |
-----
|SENDER_TEMPLATE_1 : SENDER_ADDRESS = R1, LSP_ID = 1 |
-----
| ..... |
-----
|SENDER_TEMPLATE_5 : SENDER_ADDRESS = R5, LSP_ID = 1 |
-----
|SENDER_TEMPLATE_5 : SENDER_ADDRESS = R5, LSP_ID = 2 |
-----

```


Similarly, if node R6 wants to increase the BW for "lsp1", it SHOULD create a new Path message containing SENDER_TEMPLATE object with sender address = loopback of node 6 and lsp-id = Y+1. Thus, it should be noted that each ring-node independently tracks its own lsp-ID that is currently in-use on a given RMR sub-LSP. This lsp-ID value will (could) be different for each ring-node for a given ring sub-LSP.

If sufficient BW is available all the way towards ring node R1, then this new Path message reaches node R1. R1 generates a Resv message with the correct FILTER_SPEC object corresponding to the received SENDER_TEMPLATE object. This Resv message will also have the correct FLOWSPEC object as per the requested bandwidth.

If sufficient BW is not available at some downstream (say node R9), then ring node R9 SHOULD generate a PathErr message with the corresponding Sender Template Object. When node R5 receives this PathErr message, R5 understands that the BW increase was not successful. Note that the existing established bandwidths for lsp1 are not affected by this new PathErr message.

When ring node R5 no longer needs the BW reservation, then ring node R5 SHOULD originate a new Path message with the appropriate Sender Template Object containing 0 BW as described above. Every downstream node SHOULD then remove bandwidth allocated on the corresponding link on receipt of this Path message.

Also, note that as part of this BW increase or decrease process, any ring node does not actually change any label associated with the LSP. So, the label remains same as it was signaled initially when the anchor LSP came up.

5. Security Considerations

It is not anticipated that either the notion of MPLS rings or the extensions to various protocols to support them will cause new security loopholes. As this document is updated, this section will also be updated.

6. Contributors

Ravi Singh
Juniper Networks, Inc.
1133 Innovation Way
Sunnyvale, CA 94089
USA

Email: ravis@juniper.net

Santosh Esale
Juniper Networks, Inc.
1133 Innovation Way
Sunnyvale, CA 94089
USA

Email: sesale@juniper.net

Raveendra Torvi
Juniper Networks, Inc.
10 Technology Park Dr
Westford, MA 01886
USA

Email: rtorvi@juniper.net

7. IANA Considerations

Requests to IANA will be made in a future version of this document.

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Authors' Addresses

Abhishek Deshmukh
Juniper Networks, Inc.
10 Technology Park Dr
Westford, MA 01886
USA

Email: adeshmukh@juniper.net

Kireeti Kompella
Juniper Networks, Inc.
1133 Innovation Way
Sunnyvale, CA 94089
USA

Email: kireeti@juniper.net

