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Fast Reroute Extensions to RSVP-TE for LSP Tunnels

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Status of this Memo

Abstract

This document defines extensions to and describes the use of RSVP to establish backup label-switched path (LSP) tunnels for local repair of LSP tunnels. These mechanisms enable the re-direction of traffic onto backup LSP tunnels in 10s of milliseconds in the event of a failure.

Two methods are defined here. The one-to-one backup method creates detour LSPs for each protected LSP at each potential point of local repair. The facility backup method creates a bypass tunnel to protect a potential failure point; by taking advantage of MPLS label stacking, this bypass tunnel can protect a set of protected LSPs that

have similar backup constraints. Both methods can be used to protect links and nodes during network failure. The described behavior and extensions to RSVP allow nodes to implement either or both methods and to interoperate in a mixed network.

0. Background

Several years before work began on this draft, operational networks had deployed two independent methods of doing fast reroute, called herein one-to-one backup and facility backup. Vendors trying to support both methods were experiencing incompatiblity problems in attempting to produce a single implementation capable of interoperating with both. There are technical tradeoffs between the methods. However these tradeoffs are so topologically dependent, that the community has not converged on a single approach.

This draft rationalizes the RSVP signaling for both methods such that any implementation can recognize all FRR requests and clearly respond, either positively if they are capable of performing the method, or with a clear error such that requester is informed and can seek alternate means of backup. This draft also allows a single implementation to support both methods, thereby providing a range of capabilities. Thus the described behavior and extensions to RSVP allow LERs and LSRs to implement either or both methods.

While the two methods could in principle be used in a single network, it is expected that operators will continue to choose to deploy either one or the other. The goal of this draft is to standardize the RSVP signaling such that either a network with LSRs that implement both methods or an network composed of some LSRs that support one method and others that support both, can properly signal among those LSRs to achieve fast restoration through the chosen method.

Contents

1. Introduction

This document extends RSVP [RSVP] to establish backup LSP tunnels for the local repair of LSP tunnels. This technique is presented to meet the needs of real-time applications, such as voice over IP, for which it is highly desirable to be able to re-direct user traffic onto backup LSP tunnels in 10s of milliseconds. This timing requirement can be satisfied by computing and signaling backup LSP tunnels in advance of failure and by re-directing traffic as close to failure point as possible. In this way, the time for the redirection does not include any path computation or signaling delays, including delays to propagate failure notification between LSRs. The speed of repair made possible by the techniques and extensions described herein is the primary advantage of this method. We use the term local repair when referring to techniques which accomplish this, and refer to an explicitly routed LSP which is provided with such protection as a protected LSP. These techniques are applicable only to explicitly routed LSPs; Application of the techniques discussed herein to LSPs which dynamically change their routes such as those used in unicast IGP routing is beyond the scope of this document.

Section 2 covers new terminology used in this document. The two basic strategies for creating backup LSPs are described in Section 3. In Section 4, the protocol extensions to RSVP to support local protection are described. In Section 5, the behavior of an LER which wishes to request local protection for an LSP is presented.

The behavior of a potential point of local repair (PLR) is given in Section 6; this describes how to determine the appropriate strategy to use for protecting an LSP and how to implement each of the strategies. The behavior of a merge node, the LSR where a protected LSP and its backup LSP rejoin, is described in Section 7. Finally, the required behavior of other nodes in the network is discussed in Section 8.

For the techniques discussed in this document to function properly, there are three assumptions which must be made. First, an LSR which is on the path of a protected LSP SHOULD always assume that it is a merge point; this is necessary because the facility backup method does not signal backups through a bypass tunnel before failure. Second, if the one-to-one backup method is used and a DETOUR object is included, the LSRs in the traffic-engineered network should support the DETOUR object; this is necessary so that the Path message containing the DETOUR object is not rejected. Third, understanding of the DETOUR object is required to support the path-specific method which requires that LSRs in the traffic-engineered network be capable of merging detours.

2. Terminology

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 [RFC-WORDS].

The reader is assumed to be familiar with the terminology in [RSVP] and [RSVP-TE].

LSR - Label Switch Router

LSP - An MPLS Label Switched Path. In this document, an LSP will always refer to an explicitly routed LSP.

Local Repair - Techniques used to repair LSP tunnels quickly when a node or link along the LSPs path fails.

PLR - Point of Local Repair. The head-end LSR of a backup tunnel or a detour LSP.

One-to-one Backup - A local repair technique where a backup LSP is separately created for each protected LSP at a PLR.

Facility Backup - A local repair technique where a bypass tunnel is used to protect one or more protected LSPs which traverse the PLR, the resource being protected and the Merge Point in that order.

Protected LSP - An LSP is said to be protected at a given hop if it has one or multiple associated backup tunnels originating at that hop.

Detour LSP - The LSP that is used to re-route traffic around a failure in one-to-one backup.

Bypass Tunnel - An LSP that is used to protect a set of LSPs passing over a common facility.

Backup Tunnel - The LSP that is used to backup up one of the many LSPs in many-to-one backup.

NHOP Bypass Tunnel - Next-Hop Bypass Tunnel. A backup tunnel which bypasses a single link of the protected LSP.

NNHOP Bypass Tunnel - Next-Next-Hop Bypass Tunnel. A backup tunnel which bypasses a single node of the protected LSP.

Backup Path - The LSP that is responsible for backing up one

protection LSP. A backup path refers to either a detour LSP or a backup tunnel.

MP - Merge Point. The LSR where one or more backup tunnels rejoin the path of the protected LSP, downstream of the potential failure. The same LSR may be both an MP and a PLR simultaneously.

DMP - Detour Merge Point. In the case of one-to-one backup, this is an LSR where multiple detours converge and only one detour is signaled beyond that LSR.

Reroutable LSP - Any LSP for which the head-end LSR requests

local protection. See Section 9.1 for more detail.

CSPF - Constraint-based Shortest Path First.

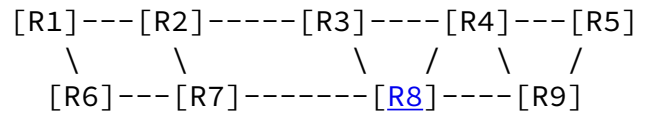
SRLG Disjoint - A path is considered to be SRLG disjoint from a given link or node if the path does not use any links or nodes which belong to the same SRLG as that given link or node.

3. Local Repair Techniques

Two different techniques for local protection are presented here. The one-to-one backup technique has a PLR compute a separate backup LSP, called a detour LSP, for each LSP which the PLR protects using this technique. With the facility backup technique, the PLR creates a single bypass tunnel which can be used to protect multiple LSPs.

3.1. One-to-one backup

In the one-to-one technique, a label switched path is established which intersects the original LSP somewhere downstream of the point of link or node failure. For each LSP which is backed up, a separate backup LSP is established.




```
Protected LSP:  [R1->R2->R3->R4->R5]
R1's Backup:    [R1->R6->R7->R8->R3]
R2's Backup:    [R2->R7->R8->R4]
R3's Backup:    [R3->R8->R9->R5]
R4's Backup:    [R4->R9->R5]
```


Example 1: One-to-One Backup Technique

In the simple topology shown above in Example 1, the protected LSP runs from R1 to R5. R2 can provide user traffic protection by creating a partial backup LSP which merges with the protected LSP at R4. We refer to a partial one-to-one backup LSP

[R2->R7->R8->R4] as a detour.

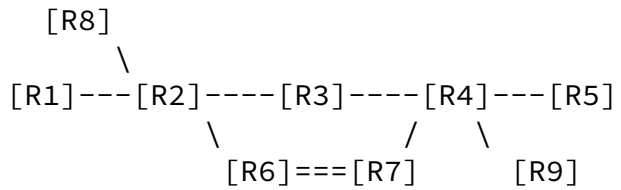
To fully protect an LSP that traverses N nodes, there could be as many as (N - 1) detours. The paths for the detours necessary to fully protect the LSP in Example 1 are given there. To minimize the number of LSPs in the network, it is desirable to merge a detour back to its protected LSP when feasible. When a detour LSP intersects its protected LSP at an LSR with the same outgoing interface, it will be merged.

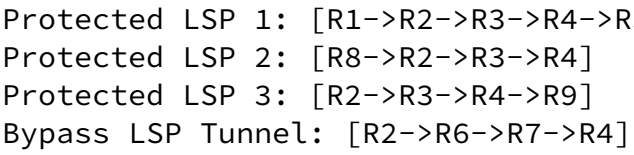
When a failure occurs along the protected LSP, the PLR redirects traffic onto the local detour. For instance, if the link [R2->R3] fails in Example 1, R2 will switch traffic received from R1 onto the protected LSP along link [R2->R7] using the label received when R2 created the detour. When R4 receives traffic with the label provided for R2's detour, R4 will switch that traffic onto link [R4-R5] using the label received from R5 for the protected LSP. At no point does the depth of the label stack increase as a result of taking the detour. While R2 is using its detour, traffic will take the path [R1->R2->R7->R8->R4->R5].

3.2. Facility backup

The facility backup technique takes advantage of the MPLS label stack. Instead of creating a separate LSP for every backed-up LSP, a single LSP is created which serves to backup up a set of LSPs. We call such an LSP tunnel a bypass tunnel.

The bypass tunnel must intersect the path of the original LSP(s) somewhere downstream of the PLR. Naturally, this constrains the set of LSPs being backed-up via that bypass tunnel to those that pass through some common downstream node. All LSPs which pass through the point of local repair and through this common node which do not also use the facilities involved in the bypass tunnel are candidates for this set of LSPs.





Example 2: Facility Backup Technique

In Example 2, R2 has built a bypass tunnel which protects against the failure of link [R2->R3], link [R3->R4] or node [R3]. The doubled lines represent this tunnel. The scalability improvement this technique provides is that the same bypass tunnel can also be used to protect LSPs from any of R1, R2 or R8 to any of R4, R5 or R9. Example 2 describes three different protected LSPs which are using the same bypass tunnel for protection.

As with the one-to-one technique, to fully protect an LSP that traverses N nodes, there could be as many as (N-1) bypass tunnels. However, each of those bypass tunnels could protected a set of LSPs.

When a failure occurs along a protected LSP, the PLR redirects traffic into the appropriate bypass tunnel. For instance, if link [R2->R3] fails in Example 2, R2 will switch traffic received from R1 on the protected LSP onto link [R2->R6]; the label will be switched for one which will be understood by R4 to indicate the protected LSP and then the bypass tunnel's label will be pushed onto the label-stack of the redirected packets. If penultimate-hop-popping is used, then the merge point in Example 2, R4, will receive the redirected packet with a label indicating the protected LSP that the packet is to follow. If penultimate-hop-popping is not used, then R4 will pop the bypass tunnel's label and examine the label underneath to determine the protected LSP that the packet is to follow. When R2 is using the bypass tunnel for protected LSP 1, the traffic takes the path [R1->R2->R6->R7->R4->R5]; the bypass tunnel is the connection between R2 and R4.

4. RSVP Extensions

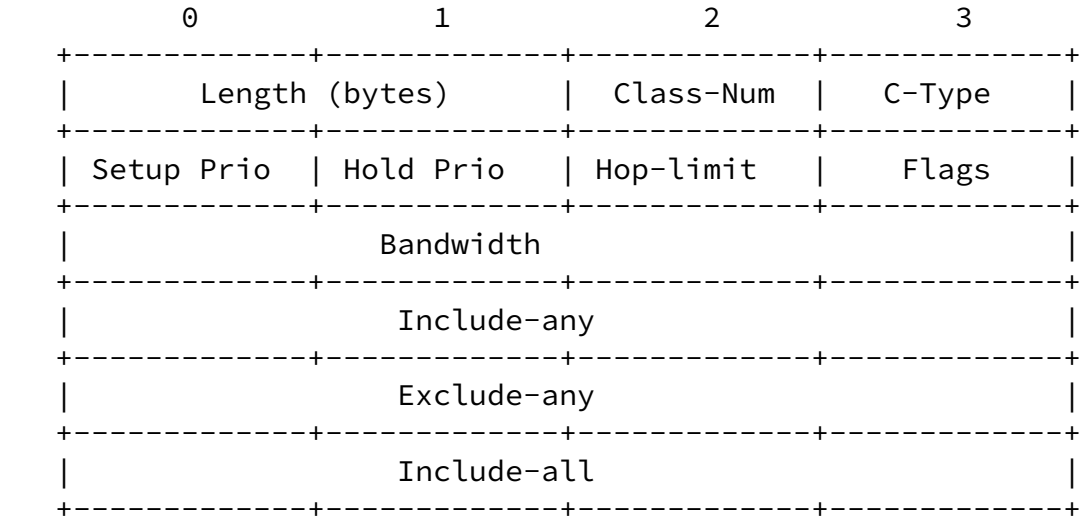
We propose two additional objects, FAST_REROUTE and DETOUR, to extend RSVP-TE for fast-reroute signaling. These new objects are backward compatible with LSRs that do not recognize them (see section 3.10 in [RSVP]). Both objects can only be carried in RSVP Path messages.

The SESSION_ATTRIBUTE and RECORD_ROUTE objects are also extended to support bandwidth and node protection features.

4.1. FAST_REROUTE Object

The FAST-REROUTE object is used to control the backup used for the protected LSP. This specifies the setup and hold priorities, the session attribute filters, and bandwidth to be used for protection. It also allows a specific local protection technique to be requested. This object MUST only be inserted into the PATH message by the head-end LER and MUST NOT be changed by downstream LSRs. The FAST-REROUTE object has the following format:

Class = TBD (use form 11bbbbbb for compatibility)
C-Type = 1



Setup Priority

The priority of the backup path with respect to taking resources, in the range of 0 to 7. The value 0 is the highest priority. Setup Priority is used in deciding whether this session can preempt another session. See [RSVP-TE] for the usage on priority.

Holding Priority

The priority of the backup path with respect to holding resources, in the range of 0 to 7. The value 0 is the highest priority. Holding Priority is used in deciding whether this session can be preempted by another session. See [RSVP-TE] for

the usage on priority.

Hop-limit

The maximum number of extra hops the backup path is allowed

to take, from current node (a PLR) to a MP, with PLR and MP excluded in counting. For example, hop-limit of 0 means only direct links between PLR and MP can be considered.

Flags

0x01 One-to-one Backup Desired

Indicates that protection via the one-to-one backup technique is desired.

0x02 Facility Backup Desired

Indicates that protection via the facility backup technique is desired.

Bandwidth

Bandwidth estimate (32-bit IEEE floating point integer) in bytes-per-second.

Exclude-any

A 32-bit vector representing a set of attribute filters associated with a backup path any of which renders a link unacceptable.

Include-any

A 32-bit vector representing a set of attribute filters associated with a backup path any of which renders a link acceptable (with respect to this test). A null set (all bits set to zero) automatically passes.

Include-all

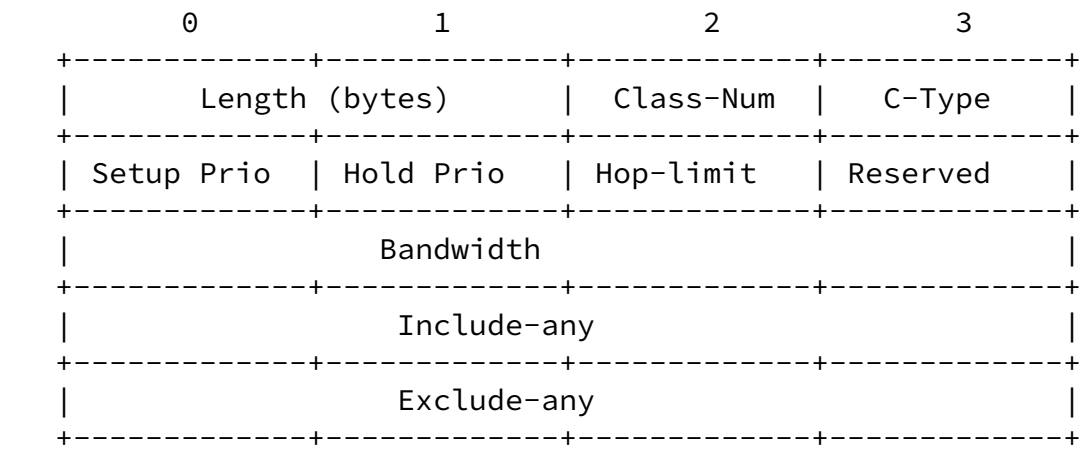
A 32-bit vector representing a set of attribute filters associated with a backup path all of which must be present for a link to be acceptable (with respect to this test). A null set (all bits set to zero) automatically passes.

The two high-order bits of the Class-Num (11) indicate that nodes that do not understand the object should ignore it and pass if forward unchanged.

For informational purposes, a different C-type value and format for the FAST_REROUTE object are specified below. This is used by

existing implementations. The meaning of the fields is the same as described for C-Type 1.

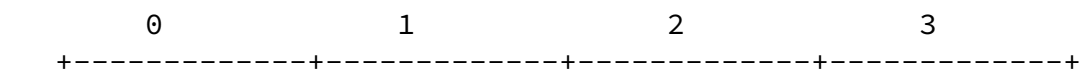
C-Type = 7

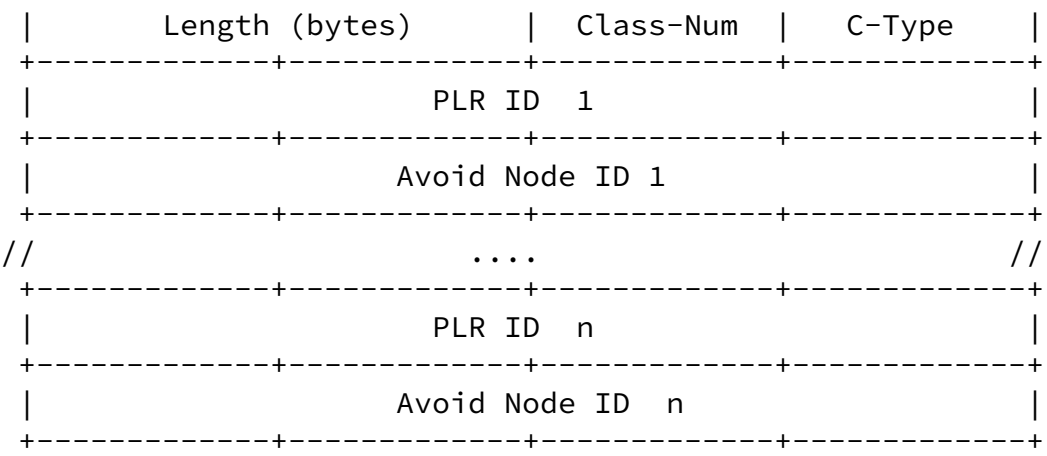


4.2. DETOUR Object

The DETOUR object is used in one-to-one backup to identify detour LSPs. It has the following format:

Class = TBD (to conform 0bbbbbbb format for compatibility)
C-Type = 7





PLR ID (1 - n)

IPv4 address identifying the beginning point of detour which is a PLR. Any local address on the PLR can be used.

Avoid Node ID (1 - n)

IP address identifying the immediate downstream node that the PLR is trying to avoid. Router ID of downstream node is preferred. This field is mandatory, and is used by the MP for merging rules discussed below.

There can be more than one pair of (PLR_ID, Avoid_Node_ID) entries in a DETOUR object. If detour merging is desired, after each merging operation, the Detour Merge Point should combine all the merged detours in the subsequent Path messages.

The high-order bit of the C-Class is zero; LSRs that do not support the DETOUR objects MUST reject any Path message containing a DETOUR object and send a PathErr to notify the PLR. This PathErr SHOULD be generated as specified in [RSVP] for unknown objects with a class-num of the form "0bbbbbbb".

4.3. SESSION_ATTRIBUTE Flags

To explicitly request bandwidth and node protection, two new flags

are defined in the SESSION_ATTRIBUTE object.

For both C-Type 1 and 7, the SESSION_ATTRIBUTE object currently has the following flags defined:

Local protection desired: 0x01

This flag permits transit routers to use a local repair mechanism which may result in violation of the explicit route object. When a fault is detected on an adjacent downstream link or node, a transit node may reroute traffic for fast service restoration.

Label recording desired: 0x02

This flag indicates that label information should be included when doing a route record.

SE Style desired: 0x04

This flag indicates that the tunnel ingress node may choose to reroute this tunnel without tearing it down. A tunnel egress node SHOULD use the SE Style when responding with a Resv message. When requesting fast reroute, the head-end LSR SHOULD set this flag; this is not necessary for the path-specific method of the one-to-one backup technique.

The following new flags are defined:

Bandwidth protection desired: 0x08

This flag indicates to the PLRs along the protected LSP path that a backup path with a bandwidth guarantee is desired. The bandwidth to be guaranteed is that of the protected LSP, if no FAST_REROUTE object is included in the PATH message; if a FAST_REROUTE object is in the PATH message, then the bandwidth specified therein is that to be guaranteed.

Node protection desired: 0x10

This flag indicates to the PLRs along a protected LSP path that a backup path which bypasses at least the next node of

the protected LSP is desired.

4.4. RRO IPv4/IPv6 Sub-Object Flags

To report whether bandwidth and/or node protection are provided as requested, we define two news flags in the RRO IPv4 sub-object.

RRO IPv4 and IPv6 sub-object address:

These two sub-objects currently have the following flags defined:

Local protection available: 0x01

Indicates that the link downstream of this node is protected via a local repair mechanism, which can be either one-to-one or facility backup.

Local protection in use: 0x02

Indicates that a local repair mechanism is in use to maintain this tunnel (usually in the face of an outage of the link it was previously routed over, or an outage of the neighboring node).

Two new flags are defined:

Bandwidth protection: 0x04

The PLR will set this when the protected LSP has a backup path which is guaranteed to provide the desired bandwidth specified in the FAST_REROUTE object or the bandwidth of the protected

LSP, if no FAST_REROUTE object was included. The PLR may set this whenever the desired bandwidth is guaranteed; the PLR MUST set this flag when the desired bandwidth is guaranteed and the "bandwidth protection desired" flag was set in the SESSION_ATTRIBUTE object. If the requested bandwidth is not guaranteed, the PLR MUST NOT set this flag.

Node protection: 0x08

The PLR will set this when the protected LSP has a backup path which provides protection against a failure of the next LSR along the protected LSP. The PLR may set this whenever node protection is provided by the protected LSP's backup path; the PLR MUST set this flag when the node protection is provided and the "node protection desired" flag was set in the SESSION_ATTRIBUTE object. If node protection is not provided, the PLR MUST NOT set this flag. Thus, if a PLR could only setup a link-protection backup path, the "Local protection available" bit will be set but the "Node protection" bit will be cleared.

5. Head-End Behavior

The head-end of an LSP determines whether local protection should be requested for that LSP and which local protection technique is desired for the protected LSP. The head-end also determines what constraints should be requested for the backup paths of a protected LSP.

To indicate that an LSP should be locally protected, the head-end LSR MUST either set the "Local protection desired" flag in the SESSION_ATTRIBUTE object or include a FAST_REROUTE object in the PATH message or both. It is recommended that the "local protection desired" flag in the SESSION_ATTRIBUTE object always be set. If a head-end LSR signals a FAST_REROUTE object, it MUST be stored for Path refreshes.

The head-end LSR of a protected LSP MUST set the "label recording desired" flag in the SESSION_ATTRIBUTE object. This facilitates the use of the facility backup technique. If node protection is desired, the head-end LSR should set the "node protection desired" flag in the SESSION_ATTRIBUTE object; otherwise this flag should be cleared. Similarly, if a guarantee of bandwidth protection is desired, then the "bandwidth protection desired" flag in the SESSION_ATTRIBUTE object should be set; otherwise, this flag should be cleared.

If the head-end LSR determines that control of the backup paths for

the protected LSP is desired, then the LSR should include the FAST_REROUTE object. The attribute filters, bandwidth, hop-limit and priorities will be used by the PLRs when determining the backup paths.

If the head-end LSR desires that the protected LSP be protected via the one-to-one backup technique, then head-end LSR should include a FAST_REROUTE object and set the "one-to-one backup desired" flag. If the head-end LSR desires that the protected LSP be protected via the facility backup technique, then the head-end LSR should include a FAST_REROUTE object and set the "facility backup desired" flag. The lack of a FAST_REROUTE object, or having both these flags clear should be treated by PLRs as a lack of preference. If both flags are set a PLR may use either method or both.

The head-end LSR of a protected LSP MUST support the additional flags defined in Section 4.4 being set or clear in the RRO IPv4 and IPv6 sub-objects. The head-end LSR of a protected LSP MUST support the RRO Label sub-object.

If the head-end LSR of an LSP determines that local protection is newly desired, this should be signaled via make-before-break.

6. Point of Local Repair Behavior

Every LSR along a protected LSP (except the egress) MUST follow the PLR behavior described in this document.

A PLR SHOULD support the FAST_REROUTE object, the "local protection desired", "label recording desired", "node protection desired" and "bandwidth protection desired" flags in the SESSION_ATTRIBUTE object, and the "local protection available", "local protection in use", "bandwidth protection", and "node protection" flags in the RRO IPv4 and IPv6 sub-objects. A PLR MAY support the DETOUR object.

A PLR MUST consider an LSP as having asked for local protection if the "local protection desired" flag is set in the SESSION_ATTRIBUTE object and/or the FAST_REROUTE object is included. If the FAST_REROUTE object is included, a PLR SHOULD consider providing one-to-one protection if the "one-to-one desired" is set and SHOULD consider providing facility backup if the "facility backup desired" flag is set when determining whether to provide local protection and which technique to use to provide that local protection. If the "node protection desired" flag is set, the PLR SHOULD try to provide node protection; if this is not feasible, the PLR SHOULD

then try to provide link protection. If the "bandwidth protection guaranteed" flag is set, the PLR SHOULD try to provide a bandwidth guarantee; if this is not feasible, the PLR SHOULD then try to provide a backup without a guarantee of the full bandwidth.

The following treatment for the RRO IPv4 or IPv6 sub-object's flags must be followed if an RRO is included in the protected LSP's RESV message. Based on this additional information the head-end may take appropriate actions.

- Until a PLR has a backup path available, the PLR MUST clear the relevant four flags in the corresponding RRO IPv4 or IPv6 sub-object.

- Whenever the PLR has a backup path available, the PLR MUST set the "local protection available" flag. If no established one-to-one backup LSP or bypass tunnel exists, or the one-to-one LSP and the bypass tunnel is in "DOWN" state, the PLR MUST clear the "local protection available" flag in its IPv4 (or IPv6) address subobject of the RRO and SHOULD send the updated RESV.

- The PLR MUST clear the "local protection in use" flag unless it is actively redirecting traffic into the backup path instead of along the protected LSP.

- The PLR SHOULD also set the "node protection" flag if the backup path protects against the failure of the immediate downstream node and, if not, the PLR SHOULD clear the "node protection" flag. This MUST be done if the "node protection desired" flag was set in the SESSION_ATTRIBUTE object.

- The PLR SHOULD set the "bandwidth protection" if the backup path offers a bandwidth guarantee and, if not, SHOULD clear the "bandwidth protection" flag. This MUST be done if the "bandwidth protection desired" flag was set in the SESSION_ATTRIBUTE object.

6.1 Signaling a Backup Path

A number of objectives must be met to obtain a satisfactory signaling solution. These are summarized as follows:

1. Unambiguously and uniquely identify backup paths
2. Unambiguously associate protected LSPs with their backup paths
3. Work with both global and non-global label spaces

4. Allow for merging of backup paths
5. Maintain RSVP state during and after fail-over.

LSP tunnels are identified by a combination of the SESSION and SENDER_TEMPLATE objects. The relevant fields are as follows.

IPv4 (or IPv6) tunnel end point address

IPv4 (or IPv6) address of the egress node for the tunnel.

Tunnel ID

A 16-bit identifier used in the SESSION that remains constant over the life of the tunnel.

Extended Tunnel ID

A 32-bit (IPv4) or 128-bit (IPv6) identifier used in the SESSION that remains constant over the life of the tunnel. Normally set to all zeros. Ingress nodes that wish to narrow the scope of a SESSION to the ingress-egress pair may place their IP address here as a globally unique identifier.

IPv4 (or IPv6) tunnel sender address

IPv4 (or IPv6) address for a sender node

LSP ID

A 16-bit identifier used in the SENDER_TEMPLATE and the FILTER_SPEC that can be changed to allow a sender to share resources with itself.

The first three of these are in the SESSION object and are the basic identification of the tunnel. Setting the "Extended Tunnel ID" to an IP address of the head-end LSR allows the scope of the SESSION to be narrowed to only LSPs sent by that LSR. A backup LSP is considered to be part of the same session as its protected LSP; therefore these three cannot be varied.

The last two are in the SENDER_TEMPLATE. Multiple LSPs in the same SESSION may be protected and take different routes; this is common

when rerouting a tunnel using make-before-break. It is necessary that a backup path be clearly identified with its protected LSP, so that correct merging and state treatment can be done. Therefore, a backup path must inherit its LSP ID from the associated protected LSP. Thus, the only field in the SESSION and SENDER_TEMPLATE objects which could be varied between a backup path and a protected LSP is the "IPv4 (or IPv6) tunnel sender address" in the SENDER_TEMPLATE.

There are two different methods to uniquely identify a backup path. These are described below.

6.1.1. Backup Path Identification: Sender-Template-Specific

In this approach, the SESSION object and the LSP_ID are copied from the protected LSP. The "IPv4 tunnel sender address" is set to an address of the PLR. If the head-end of a tunnel is also acting as the PLR, it MUST choose an IP address different from the one used in the SENDER_TEMPLATE of the original LSP tunnel.

When using the sender-template-specific approach, the protected LSPs and the backup paths SHOULD use the Shared Explicit (SE) style. This allows bandwidth sharing between multiple backup paths. The backup paths and the protected LSP MAY be merged by the Detour Merge Points, when the ERO from the MP to the egress is the same on each LSP to be merged, as specified in [RSVP-TE].

6.1.2. Backup Path Identification: Path-Specific

In this approach, rather than varying the SESSION or SENDER_TEMPLATE objects, a new object, the DETOUR object, is used to distinguish between PATH messages for a backup path and the protected LSP.

Thus, the backup paths use the same SESSION and SENDER_TEMPLATE objects as the ones used in the protected LSP. The presence of DETOUR object in Path messages signifies a backup path; the presence of FAST_REROUTE object and/or the "local protection requested" flag in the SESSION_ATTRIBUTE object indicates a

protected LSP.

In the path-message-specific approach, when an LSR receives multiple Path messages which have the same SESSION and SENDER_TEMPLATE objects and also have the same next-hop, that LSR MUST merge the Path messages. Without this behavior, the multiple RESV messages received back would not be distinguishable as to which backup path each belongs to. This merging behavior does reduce the total number of RSVP states inside the network at the expense of merging LSPs with different EROs.

6.2 Procedures for Backup Path Computation

Before a PLR can create a detour or a bypass tunnel, the desired explicit route must be determined. This can be done using a CSPF.

Before CSPF computation, the following information should be collected at a PLR:

- The list of downstream nodes that the protected LSP passes through. This information is readily available from the RECORD_ROUTE objects during LSP setup. This information is also available from the ERO. However, if the ERO contains loose sub-objects, the ERO may not provide adequate information.

- The downstream links/nodes that we want to protect against. Once again, this information is learned from the RECORD_ROUTE objects. Whether node protection is desired is determined by the "node protection" flag in the SESSION_ATTRIBUTE object and local policy.

- The upstream uni-directional links that the protected LSP passes through. This information is learned from the RECORD_ROUTE objects; it is only needed for setting up one-to-one protection. In the path-specific method, it is necessary to avoid the detour and the protected LSP sharing a common next-hop upstream of the failure. In the sender-template-specific mode, this same restriction is necessary to avoid sharing bandwidth between the detour and its protected LSP, where that bandwidth has only been reserved once.

- The link attribute filters to be applied. These are derived from the FAST_REROUTE object, if included in the PATH message, and the SESSION_ATTRIBUTE object otherwise.

- The bandwidth to be used is found in the FAST_REROUTE object, if included in the PATH message, and in the SESSION_ATTRIBUTE object otherwise. Local policy may modify the bandwidth to be reserved.

- The hop-limit, if a FAST_REROUTE object was included in the PATH message.

When applying a CSPF algorithm to compute the backup route, the following constraints should be satisfied:

- For detour LSPs, the destination MUST be the tail-end of the protected LSP; for bypass tunnels (Section 6), the destination MUST be the address of the MP.

- When setting up one-to-one protection using the path-specific method, a detour MUST not traverse the upstream links of the protected LSP in the same direction. This prevents the

possibility of early merging of the detour into the protected LSP. When setting up one-to-one protection using the sender-template-specific method, a detour should not traverse the upstream links of the protected LSP in the same direction; this prevents sharing the bandwidth between a protected LSP and its backup upstream of the failure where the bandwidth would be used twice in the event of a failure.

- The backup LSP cannot traverse the downstream node and/or link whose failure is being protected against. Note that if the PLR is the penultimate hop, node protection is not possible and only the downstream link can be avoided. The backup path may be computed to be SRLG disjoint from the downstream node and/or link being avoided.

- The backup path must satisfy the resource requirements of the protected LSP. This includes the link attribute filters, bandwidth, and hop limits determined from the FAST_REROUTE

object and SESSION_ATTRIBUTE object.

If such computation succeeds, the PLR should attempt to establish a backup path. The PLR may schedule a re-computation at a later time to discover better paths that may have emerged. If for any reason, the PLR is unable to bring up a backup path, it must schedule a retry at a later time.

6.3 Signaling Backups for One-To-One Protection

Once a PLR has decided to locally protect an LSP with one-to-one backup, and has identified the desired path, it takes the following steps to signal the detour.

The following describes the transformation to be performed upon the protected LSP's PATH message to create the detour LSP's PATH message.

- If the sender-template specific method is to be used, then the PLR MUST change the "IPv4 (or IPv6) tunnel sender address" of the SENDER_TEMPLATE to an address belonging to the PLR that is not the same as was used for the protected LSP. Additionally, the DETOUR object MAY be added to the PATH message.

- If the path-specific method is to be used, then the PLR MUST add a DETOUR object to the PATH message.

- The SESSION_ATTRIBUTE flags "Local protection desired", "Bandwidth protection desired" and "Node protection desired" MUST

be cleared. The "Label recording desired" flag MAY be modified. If the Path Message contained a FAST_REROUTE object, and the ERO is not completely strict, the Include-any, Exclude-any, and Include-all fields of the FAST_REROUTE object SHOULD be copied to the corresponding fields of the SESSION_ATTRIBUTE object.

- If the protected LSP's Path message contained a FAST_REROUTE object, this MUST be removed from the detour LSP's PATH message.

- The PLR MUST generate an EXPLICIT_ROUTE object toward the egress. First, the PLR must remove all sub-objects preceding the first

address belonging to the Merge Point. Then the PLR SHOULD add sub-objects corresponding to the desired backup path between the PLR and the MP.

- The SENDER_TSPEC object SHOULD contain the bandwidth information from the received FAST_REROUTE object, if included in the protected LSP's PATH message.

- The RSVP_HOP object containing one of the PLR's IP address.

- The detour LSPs MUST use the same reservation style as the protected LSP. This must be correctly reflected in the SESSION_ATTRIBUTE object.

Detour LSPs are regular LSPs in operation. Once a detour path is successfully computed and the detour LSP is established, the PLR need not compute detour routes again, unless (1) the contents of FAST_REROUTE have changed, or (2) the downstream interface and/or the nexthop router for a protected LSP have changed. The PLR may recompute detour routes at any time.

6.3.1 Make-Before-Break with Detour LSPs

If the sender-template specific method is used, it is possible to do make-before-break with detour LSPs. This is done by using two different IP addresses belonging to the PLR (which were not used in the SENDER_TEMPLATE of the protected LSP). If the current detour LSP uses the first IP address in its SENDER_TEMPLATE, then the new detour LSP should be signaled using the second IP address in its SENDER_TEMPLATE. Once the new detour LSP has been created, the current detour LSP can be torn down. By alternating the use of these IP addresses, the current and new detour LSPs will have different SENDER_TEMPLATES and, thus, different state in the downstream LSRs.

This make-before-break mechanism, changing the PLR IP address in

the DETOUR object instead, is not feasible with the path-specific method because the PATH messages for new and current detour LSPs may be merged if they share a common next-hop.

6.3.2 Message Handling

LSRs must process the detour LSPs independent of the protected LSPs to avoid triggering the LSP loop detection procedure described in [RSVP-TE].

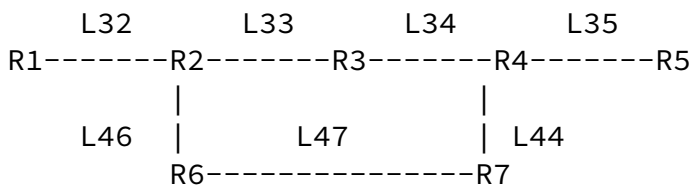
The PLR MUST not mix the messages for the protected and the detour LSPs. When a PLR receives Resv, ResvTear and PathErr messages from the downstream detour destination, the messages MUST not be forwarded upstream. Similarly, when a PLR receives ResvErr and ResvConf messages from a protected LSP, it MUST not propagate them onto the associated detour LSP.

A session tear-down request is normally originated by the sender via PathTear messages. When a PLR node receives a PathTear message from upstream, it MUST delete both the protected and the detour LSPs. The PathTear messages MUST propagate to both protected and detour LSPs.

During error conditions, the LSRs may send ResvTear messages to fix problems on the failing path. When a PLR node receives the ResvTear messages from downstream for a protected LSP, as long as a detour is up, the ResvTear messages MUST not be sent further upstream. PathErrs should be treated similiarly.

6.3.3 Local Reroute of Traffic onto Detour LSP

When the PLR detects a failure on the protected LSP, the PLR MUST rapidly switch packets to the protected LSP's backup LSP instead of the protected LSP's normal out-segment. The goal of this technique is to effect the redirection within 10s of milliseconds.



Protected LSP: [R1->R2->R3->R4->R5]
Detour LSP: [R2->R6->R7->R4]

Example 3: Redirect to Detour

In Example 3 above, if the link [R2->R3] fails, then R2 would do the following. Any traffic received on link [R1->R2] with label L32 would be sent out link [R2->R6] with label L46 (along the detour LSP) instead of out link [R3->R4] with lable L34 (along the protected LSP). The Merge Point, R4, would recognize that packets received on link [R7->R4] with label L44 should be sent out link [R4->R5] with label L35, and thus merged with the protected LSP.

6.4 Signaling for Facility Protection

A PLR may use one or more bypass tunnels to protect against the failure of a link and/or a node. These bypass tunnels may be setup in advance or may be dynamically created as new protected LSPs are signaled.

6.4.1. Discovering Downstream Labels

To support facility backup, it is necessary for the PLR to determine a label which will indicate to the MP that packets received with that label should be switched along the protected LSP. This can be done without explicitly signaling the backup path if the MP uses a label space global to that LSR.

As described in Section 5, the head-end LSR MUST set the "label recording requested" flag in the SESSION_ATTRIBUTE object for LSPs requesting local protection. This will cause (as specified in [RSVP- TE]) all LSRs to record their INBOUND labels and to note via a flag if the label is global to the LSR. Thus, when a protected LSP is first signaled through a PLR, the PLR can examine the RRO in the Resv message and learn about the incoming labels that are used by all downstream nodes for this LSP.

When MPs use per-interface-label spaces, the PLR must send Path messages (for each protected LSP using a bypass tunnel) via that bypass tunnel prior to the failure in order to discover the appropriate MP label. The signaling procedures for this are in Section 6.4.3 below.

6.4.2. Procedures for the PLR before Local Repair

A PLR which determines to use facility-backup to protect a given LSP should select a bypass tunnel to use taking into account whether node protection is to be provided, what bandwidth was requested and whether a bandwidth guarantee is desired, and what

link attribute filters were specified in the FAST_REROUTE object.

The selection of a bypass tunnel for a protected LSP is performed by the PLR when the LSP is first setup.

6.4.3. Procedures for the PLR during Local Repair

When the PLR detects a link or/and node failure condition, it needs to reroute the data traffic onto the bypass tunnel and to start sending the control traffic for the protected LSP onto the bypass tunnel.

The backup tunnel is identified using the sender-template-specific method. The procedures to follow are similar to those described in Section 6.3.

- The SESSION is unchanged.

- The SESSION_ATTRIBUTE is unchanged except as follows:
  The "Local protection desired", "Bandwidth protection desired", and "Node protection desired" flags SHOULD be cleared.
  The "Label recording desired" MAY be modified.

- The IPv4 (or IPv6) tunnel sender address of the SENDER_TEMPLATE is set to an address belonging to the PLR.

- The RSVP_HOP object MUST contain an IP source address belonging to the PLR. Consequently, the MP will send messages back to the PLR using as a destination that IP address.

- The PLR MUST generate an EXPLICIT_ROUTE object toward the egress. Detailed ERO processing is described below.

- The RRO object may need to be updated, as described in Section 6.5.

The PLR sends Path, PathTear, and ResvConf messages via the backup tunnel. The MP sends Resv, ResvTear, and PathErr messages by directly addressing them to the address in the RSVP_HOP object contents as specified in [RSVP].

If it is necessary to signal the backup prior to failure to determine the MP label to use, then the same Path message is sent. In this case, the PLR SHOULD continue to send Path messages for the protected LSP along the normal route. PathTear messages should be duplicated, with one sent along the normal route and one sent thru the bypass tunnel. The MP should duplicate the Resv and ResvTear messages and sent them to both the PLR and the LSR indicated by the protected LSP's RSVP_HOP object.

6.4.4. Processing backup tunnel's ERO

Procedures for ERO processing are described in [RSVP-TE]. This section describes additional ERO update procedures for Path messages which are sent over bypass tunnels. If normal ERO processing rules were followed, the Merge Point would examine the first sub-object and likely reject it (Bad initial sub-object). This is because the unmodified ERO might contain the IP address of a bypassed node (in the case of a NNHOP Backup Tunnel), or of an interface which is currently down (in the case of a NHOP Backup Tunnel). For this reason, the PLR invoke the following ERO procedures before sending a Path message via a bypass tunnel.

Sub-objects belonging to abstract nodes which precede the Merge Point are removed, along with the first sub-object belonging to the MP. A sub-object identifying the Backup Tunnel destination is then added.

More specifically, the PLR MUST:

- remove all the sub-objects proceeding the first address belonging to the MP.

- replace this first MP address with an IP address of the MP. (Note that this could be same address that was just removed.)

6.5. PLR Procedures During Local Repair

In addition to the technique specific signaling and packet treatment, there is common signaling which should be followed.

During fast reroute, for each protected LSP containing an RRO object, the PLR obtains the RRO from the protected LSP's stored

RESV. The PLR MUST update the IPv4 or IPv6 sub-object it inserted into the RRO by setting the "Local protection in use" and "Local Protection Available" flags.

6.5.1. Notification of local repair

In many situations, the route used during a Local Repair will be less than optimal. The purpose of Local Repair is to keep high priority and loss sensitive traffic flowing while a more optimal re-routing of the tunnel can be effected by the head-end of the tunnel. Thus the head-end needs to know of the failure so it may re-signal an LSP which is optimal.

To provide this notification, the PLR SHOULD send a Path Error

message with error code of "Notify" (Error code =25) and an error value field of ss00 cccc cccc cccc where ss=00 and the sub-code = 3 ("Tunnel locally repaired") (see [RSVP-TE])

Additionally a head-end may also detect that an LSP needs to be moved to a more optimal path by noticing failures reported via the IGP. Note that in the case of inter-area TE LSP (TE LSP spanning areas), the head-end LSR will need to rely exclusively on Path Error messages to be informed of failures in another area.

6.5.2 Revertive Behavior

Upon a failure event, a protected TE LSP is locally repaired by the PLR. There are two basic strategies for restoring the TE LSP to a full working path.

- Global revertive mode: The head-end LSR of each tunnel is responsible for reoptimizing the TE LSPs that used the failed resource. There are several potential reoptimization triggers - RSVP error messages, inspection of OSPF LSAs or ISIS LSPs, and timers. Note that this re-optimization process may proceed as soon as the failure is detected. It is not tied to the restoration of the failed resource.

- Local revertive mode: Upon detecting that the resource is

restored, the PLR re-signals each of TE LSPs that used to be routed over the restored resource. Every TE LSP successfully resignaled along the restored resource is switched back.

There are several circumstances where a local revertive mode might not be desirable. In the case of resource flapping (not an uncommon failure type), this could generate multiple traffic disruptions. Therefore, in the local revertive mode, the PLR should implement a means to dampen the re-signaling process in order to limit potential disruptions due to flapping.

In the local revertive mode, any TE LSP will be switched back, without any distinction, as opposed to the global revertive mode where the decision to reuse the restored resource is taken by the head-end LSR based on the TE LSP attributes. When the head-end learns of the failure, it may reoptimize the protected LSP tunnel along a different and more optimal path, because it has a more complete view of the resources and TE LSP constraints; this means that the old LSP which has been reverted to may not be optimal any longer. Note that in the case of inter-area LSP, where the TE LSP path computation might be done on some Path Computation Server, the reoptimization process can still be triggered on the Head-End

LSP. The local revertive mode is optional.

However, there are circumstances where the Head-end does not have the ability to reroute the TE LSP (e.g if the protected LSP is pinned down, as may be desirable if the paths are determined using an off-line optimization tool) or if Head-end does not have the complete TE topology information (depending on the path computation scenario). In those cases, the local revertive might be a interesting option.

It is recommended that one always use the globally revertive mode. Note that a link or node "failure" may be due to the facility being permanently taken out of service. Local revertive mode is optional. When used in combination, the global mode may rely solely on timers to do the reoptimization. When local revertive mode is not used, head-end LSRs SHOULD react to RSVP error messages and/or IGP indications in order to make a timely response.

Interoperability: If a PLR is configured with the local revertive

mode but the MP is not, any attempt from the PLR to resignal the TE LSP over the restored resource would fail as the MP will not send any Resv message. The PLR will still refresh the TE LSP over the backup tunnel. The TE LSP will not revert to the restored resource; instead it will continue to use the backup until it is re-optimized.

7. Merge Node Behavior

An LSR is a Merge Point if it receives the Path message for a protected LSP and one or more messages for a backup LSP which is merged into that protected LSP. In the one-to-one backup technique, the LSR is aware that it is a merge node prior to failure. In the facility backup technique, the LSR may not know that it is a Merge Point until a failure occurs and it receives a backup LSP's Path message. Therefore, an LSR which is on the path of a protected LSP SHOULD always assume that it is a merge point.

When a MP receives a backup LSP's Path message thru a bypass tunnel, the Send_TTL in the Common Header may not match the TTL of the IP packet within which the Path message was transported. This is expected behavior.

7.1. Handling Backup Path Messages Before Failure

There are two circumstances where a Merge Point will receive Path messages for a backup path prior to failure. In the first case, if a PLR is providing local protection via the one-to-one backup

technique, the detour will be signaled and must be properly handled by the MP. In this case, the backup LSP may be signaled via the sender-template-specific method or via the path-specific method.

In the second case, if the Merge Point does not provide labels global to the MP and record them in a Label sub-object of the RRO or if the PLR does not use such recorded information, the PLR may signal the backup path, as described above in Section 6.4.1, to determine the label to use if the PLR is providing protection according to the facility backup technique. In this case, the backup LSP is signaled via the sender-template-specific method.

The reception of a backup LSP's path message does not indicate that a failure has occured and the incoming protected LSP will no longer be used.

7.1.1. Merginging Backup Paths using the Sender-Template Specific Method

An LSR may receive multiple Path messages for one or more backup LSPs and, possibly, the protected LSP. Each of these Path messages will have a different SENDER_TEMPLATE. The protected LSP can be recognized because it will either include the FAST_REROUTE object, have the "local protection desired" flag set in the SESSION_ATTRIBUTE object or both.

If the outgoing interface and next-hop LSR are the same, then the Path messages are eligible for merging. Similar to that specified in [RSVP-TE] for merging of RESV messages, only those Path messages whose ERO from that LSR to the egress is the same can be merged. If merging occurs and one of the Path messages merged was for the protected LSP, then the final Path message to be sent MUST be that of the protected LSP. This merges the backup LSPs into the protected LSP at that LSR. Once the final Path message has been identified, the MP MUST start to refresh it downstream periodically.

If merging occurs and all the Path messages were for backup LSPs, then the DETOUR object, if any, should be altered as specified in Section 8.1

7.1.2. Merging Detours using the Path-Specific Method

An LSR (that is, an MP) may receive multiple Path messages from different interfaces with identical SESSION and SENDER_TEMPLATE objects. In this case, Path state merging is REQUIRED.

The merging rule is the following:

For all Path messages that do not have either a FAST_REROUTE or a DETOUR object, or the MP is the egress of the LSP, no merging is required. The messages are processed according to [RSVP-TE].

Otherwise, the MP MUST record the Path state as well as their incoming interface. If the Path messages do not share outgoing interface and next-hop LSR, the MP MUST consider them as independent LSPs, and MUST NOT merge them.

For all the Path messages that share the same outgoing interface and next-hop LSR, the MP runs the following procedure to select one of them as the Path message to forward downstream.

1. Eliminate from consideration those that traverse nodes that other Path messages want to avoid.

2. If one LSP is originated from this node, this must be the final LSP. Quit.

3. If only one Path message contains FAST_REROUTE object, this becomes the chosen Path message. Quit.

4. If there are several LSPs, and not all of them have a DETOUR object, then eliminate those with DETOUR from consideration.

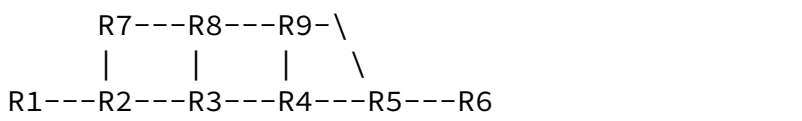
5. If several candidates remain (that is, there are both detour and protected LSPs), prefer the ones with FAST_REROUTE object.

6. If none found, prefer the ones without DETOUR object. If none found, prefer the ones with DETOUR object.

7. If several candidate Path message still remain, it is a local decision to choose which one will be the final LSP. The decision can be based on the number of IP hops in ERO, bandwidth requirements, or others.

Once the final Path message has been identified, the MP MUST start to refresh it downstream periodically. Other LSPs are considered merged at this node. For bandwidth reservation on the outgoing link, any merging should be considered to have occured before bandwidth is reserved. Thus, even though Fixed Filter is specified, multiple detours and/or their protected LSP which are to be merged due to sharing an outgoing interface and next-hop LSR will reserve only the bandwidth of the final Path message on that outgoing interface.

7.1.2.1. An Example on Path Message Merging




```
Protected LSP:  [R1->R2->R3->R4->R5->R6]
R2's Detour:    [R2->R7->R8->R9->R4->R5->R6]
R3's Detour:    [R3->R8->R9->R5->R6]
```

Example 4: Path Message Merging

In Example 4 above, R8 will receive Path messages that have the same SESSION and SENDER_TEMPLATE from detours for R2 and R3. During merging at R8 since detour R3 has a shorter ERO path length (that is, ERO is [R9->R5->R6], and path length is 3), R8 will select it as the final LSP, and only propagate its Path messages downstream. Upon receiving a Resv (or a ResvTear) message, R8 must relay on the messages toward both R2 and R3.

R5 needs to merge as well, and will select the main LSP, since it has the FAST_REROUTE object. Thus, the detour LSP terminates at R5.

7.1.3. Message Handling for Merged Detours

When an LSR receives a ResvTear for an LSP, the LSR must determine whether it has an alternate associated LSP. For instance, if the ResvTear was received for a protected LSP, but an associated backup LSP has not received a ResvTear, then the LSR has an alternate associated LSP. If the LSR does not have an alternate associated LSP, then the MP MUST propogate the ResvTear toward the LSP's ingress and, for each backup LSP merged into that LSP at this LSR, the ResvTear SHOULD also be propogated along the backup LSP.

The MP may receive PathTear messages for some of the merging LSPs. PathTear messages SHOULD NOT be propagated downstream until the MP has received PathTear messages for each of the merged LSPs. However, the fact that one or more of the merged LSPs has been torn down should be reflected in the downstream message, such as by changing the DETOUR object, if any.

7.2. Handling Failures

When a downstream LSR detects a local link failure, for any protected LSPs routed over the failed link, Path and Resv state

MUST NOT be cleared and PathTear and ResvErr messages MUST NOT be sent immediately; if this is not the case, then the facility backup technique will not work. Further a downstream LSR SHOULD reset the refresh timers for these LSPs as if they had just been refreshed. This is to allow time for the PLR to begin refreshing state via the bypass tunnel. State MUST be removed if it has not been refreshed before the refresh timer expires. This allows the facility backup technique to work without requiring that it signal backup paths thru the bypass tunnel before failure.

After a failure has occured, the MP must still send Resv messages for the backup LSPs associated with the protected LSPs which have failed. If the backup LSP was sent through a bypass tunnel, then the PHOP object in its Path message will have the IP address of the associated PLR. This will ensure that Resv state is refreshed.

Once the local link has recovered, the MP may or may not accept Path messages for existing protected LSPs which had failed over to their backup.

8. Behavior of all LSRs

The objects defined and the techniques defined in this document require behavior from all LSRs in the traffic-engineered network, even if that LSR is not along the path of a protected LSP.

First, if a DETOUR object is included in the backup LSP's path message for the sender-template-specific method, the LSRs in the traffic-engineered network should support the DETOUR object.

Second, if the Path-Specific Method is to be supported for the one-to-one backup technique, it is necessary that the LSRs in the traffic-engineered network be capable of merging detours as specified below in Section 8.1.

It is possible to avoid specific LSRs which do not support this behavior by assigning an link attribute to all the links of those LSPs and then requesting that backup paths exclude that link attribute.

8.1. Merging Detours in Path-Specific Method

If multiple Path Messages for different detours are received with the same SESSION, SENDER_TEMPLATE, outgoing interface and next-hop LSR, then the LSR must function as a Detour Merge Point and merge the detour Path Messages. This merging should occur as specified

in Section 7.1.2 and shown in Example 4.

In addition, it is necessary to update the DETOUR object to reflect the merging which has taken place. This is done using the following algorithm to format the outgoing DETOUR object for the final LSP:

- Combine all the (PLR_ID, Avoid_Node_ID) pairs from all the DETOUR objects of all merged LSPs, and create a new object with all listed. Ordering is insignificant.

9. Security Considerations

This document does not introduce new security issues. The security considerations pertaining to the original RSVP protocol [RSVP] remain relevant.

It should be noted that the facility backup technique requires that a PLR and its selected Merge Point will trust RSVP messages received from each other.

10. IANA Guidelines

IANA [RFC-IANA] will assign RSVP C-class numbers for FAST_ROUTE and DETOUR objects. Currently, in production networks, FAST_REROUTE uses C-class 205, and DETOUR uses C-class 63.

11. Intellectual Property Considerations

Cisco Systems and Juniper Networks may have intellectual property rights claimed in regard to some of the specification contained in this document

12. Full Copyright Statement

13. Acknowledgments

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