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**RSVP-TE Signaling Procedure for End-to-End GMPLS Restoration and
Resource Sharing
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Abstract

In non-packet transport networks, there are requirements where Generalized Multi-Protocol Label Switching (GMPLS) end-to-end recovery scheme needs to employ restoration Label Switched Path (LSP) while keeping resources for the working and/or protecting LSPs reserved in the network after the failure occurs.

This document reviews how the LSP association is to be provided using Resource Reservation Protocol - Traffic Engineering (RSVP-TE) signaling in the context of GMPLS end-to-end recovery scheme when using restoration LSP where failed LSP is not torn down. In addition, this document discusses resource sharing-based setup and teardown of LSPs as well as LSP reversion procedures. No new signaling extensions are defined by this document, and it is strictly informative in nature.

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1. Introduction

Generalized Multi-Protocol Label Switching (GMPLS) [[RFC3945](#)] defines a set of protocols, including Open Shortest Path First - Traffic Engineering (OSPF-TE) [[RFC4203](#)] and Resource ReserVation Protocol - Traffic Engineering (RSVP-TE) [[RFC3473](#)]. These protocols can be used to setup Label Switched Paths (LSPs) in non-packet transport networks. The GMPLS protocol extends MPLS to support interfaces capable of Time Division Multiplexing (TDM), Lambda Switching and Fiber Switching. These switching technologies provide several protection schemes [[RFC4426](#)][[RFC4427](#)] (e.g., 1+1, 1:N and M:N).

Resource Reservation Protocol - Traffic Engineering (RSVP-TE) signaling has been extended to support various GMPLS recovery schemes, such as end-to-end recovery [[RFC4872](#)] and segment recovery [[RFC4873](#)]. As described in [[RFC6689](#)], ASSOCIATION object can be used to identify the LSPs for restoration using Association Type set to "Recovery" [[RFC4872](#)] and also identify the LSPs for resource sharing using Association Type set to "Resource Sharing" [[RFC4873](#)]. [[RFC6689](#)] [Section 2.2](#) reviews the procedure for providing LSP associations for GMPLS end-to-end recovery and [Section 2.4](#) reviews the procedure for providing LSP associations for sharing resources.

In GMPLS end-to-end recovery schemes generally considered, restoration LSP is signaled after the failure has been detected and notified on the working LSP. For revertive recovery mode, a restoration LSP is signaled while working LSP and/or protecting LSP are not torn down in control plane due to a failure. In non-packet transport networks, as working LSPs are typically signaled over a nominal path, service providers would like to keep resources associated with the working LSPs reserved. This is to make sure that the service (working LSP) can be reverted to the nominal path when the failure is repaired to provide deterministic behavior and guaranteed Service Level Agreement (SLA).

In this document, procedures are reviewed for GMPLS LSP associations, resource sharing based LSP setup, teardown and LSP reversion for non-packet transport networks, including following:

- o Review the procedure for providing LSP associations for the GMPLS end-to-end recovery using restoration LSP where working and protecting LSPs are not torn down and resources are kept reserved in the network after the failure.
- o In [[RFC3209](#)], the make-before-break (MBB) method assumes the old and new LSPs share the SESSION object and signal Shared Explicit (SE) flag in SESSION_ATTRIBUTE object for sharing resources. According to

[RFC6689], ASSOCIATION object with Association Type "Resource Sharing" enables the sharing of resources across LSPs with different SESSION objects. Procedure for resource sharing using the SE flag in conjunction with ASSOCIATION object is discussed in this document.

- o When using end-to-end recovery with revertive mode, methods for LSP reversion and resource sharing are summarized in this document.

This document is strictly informative in nature and does not define any RSVP-TE signaling extensions.

2. Overview

The GMPLS end-to-end recovery scheme, as defined in [RFC4872] and being considered in this document, "fully dynamic rerouting switches normal traffic to an alternate LSP that is not even partially established only after the working LSP failure occurs. The new alternate route is selected at the LSP head-end node, it may reuse resources of the failed LSP at intermediate nodes and may include additional intermediate nodes and/or links". Two examples, 1+R and 1+1+R are described in the following sections.

2.1. 1+R Restoration

One example of the recovery scheme considered in this document is 1+R recovery. The 1+R recovery is exemplified in Figure 1. In this example, working LSP on path A-B-C-Z is pre-established. Typically after a failure detection and notification on the working LSP, a second LSP on path A-H-I-J-Z is established as a restoration LSP. Unlike protection LSP, restoration LSP is signaled per need basis.

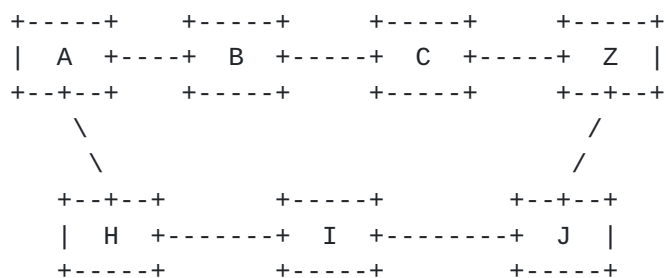


Figure 1: An Example of 1+R Recovery Scheme

During failure switchover with 1+R recovery scheme, in general, working LSP resources are not released so that working and restoration LSPs coexist in the network. Nonetheless, working and restoration LSPs can share network resources. Typically when failure is recovered on the working LSP, restoration LSP is no longer required and torn down, while the traffic is reverted to the original working LSP.

2.2. 1+1+R Restoration

Another example of the recovery scheme considered in this document is 1+1+R. In 1+1+R, a restoration LSP is signaled for the working LSP and/or the protecting LSP after the failure has been detected, and this recovery is exemplified in Figure 2.

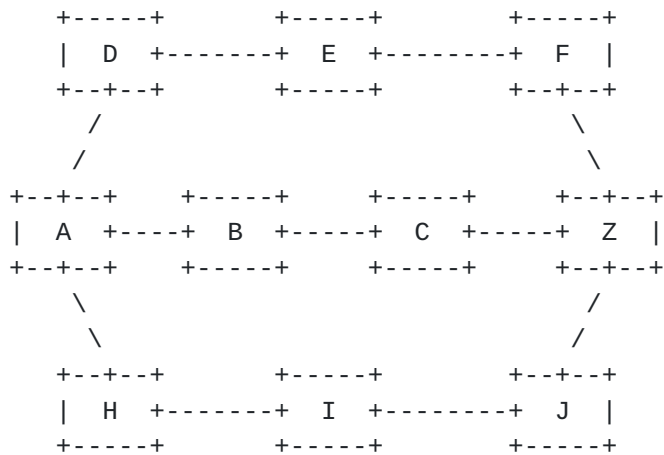


Figure 2: An Example of 1+1+R Recovery Scheme

In this example, working LSP on path A-B-C-Z and protecting LSP on path A-D-E-F-Z are pre-established. After a failure detection and notification on a working LSP or protecting LSP, a third LSP on path A-H-I-J-Z is established as a restoration LSP. The restoration LSP in this case provides protection against a second order failure. During failure switchover with 1+1+R recovery scheme, in general, failed LSP resources are not released so that working, protecting and restoration LSPs coexist in the network. Nonetheless, restoration LSP with working LSP it is restoring as well as restoration LSP with protecting LSP it is restoring can share network resources. Typically, restoration LSP is torn down when the failure on the original (working or protecting) LSP is repaired and the traffic is reverted to the original LSP.

There are four possible models when using restoration LSP with 1+1+R

recovery scheme:

- o A restoration LSP is signaled after either working or protecting LSP fails. Only one restoration LSP is present at a time.
- o A restoration LSP is signaled after either working or protecting LSP fails. Two different restoration LSPs may be present, one for the working LSP and one for the protecting LSP.
- o A restoration LSP is signaled after both working and protecting LSPs fail. Only one restoration LSP is present.
- o Two different restoration LSPs are signaled after both working and protecting LSPs fail, one for the working LSP and one for the protecting LSP.

In all models discussed, if the restoration LSP also fails, it is torn down and a new restoration LSP is signaled.

2.3. Resource Sharing By Restoration LSP

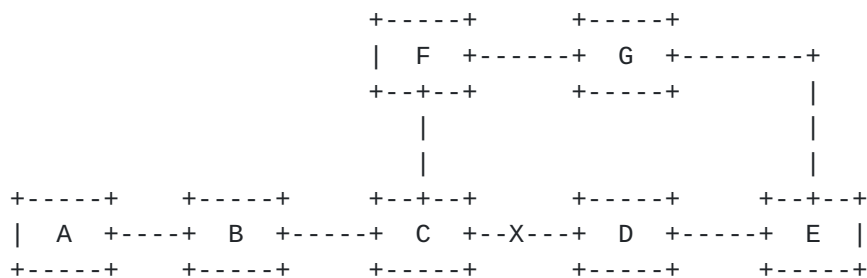


Figure 3: Resource Sharing in 1+R Recovery Scheme

Using the network shown in Figure 3 as an example, LSP1 (A-B-C-D-E) is the working LSP and it allows for resource sharing when the LSP traffic is dynamically restored after the link failure. Upon detecting the failure of a link along the LSP1, e.g. Link C-D, node A needs to decide which alternative path it will use to signal restoration LSP and reroute traffic. In this case, A-B-C-F-G-E is chosen as the restoration LSP path and the resources on the path segment A-B-C are re-used by this LSP when the working LSP is not torn down (e.g. in 1+R recovery scheme).

3. RSVP-TE Signaling Procedure

3.1. Restoration LSP Association

Where GMPLS end-to-end recovery scheme needs to employ a restoration LSP while keeping resources for the working and/or protecting LSPs reserved in the network after the failure, the restoration LSP is signaled with an ASSOCIATION object that has Association Type set to "Recovery" [[RFC4872](#)], the Association ID and the Association Source set to the corresponding Association ID and the Association Source signaled in the LSP it is restoring. For example, when a restoration LSP is signaled for a failed working LSP, the ASSOCIATION object in the restoration LSP contains the Association ID and Association Source set to the Association ID and Association Source signaled in the working LSP for the "Recovery" Association Type. Similarly, when a restoration LSP is signaled for a failed protecting LSP, the ASSOCIATION object in the restoration LSP contains the Association ID and Association Source set to the Association ID and Association Source signaled in the protecting LSP for the "Recovery" Association Type.

The procedure for signaling the PROTECTION object is specified in [[RFC4872](#)]. Specifically, the restoration LSP used for a working LSP is signaled with P bit cleared in the PROTECTION object and the restoration LSP used for a protecting LSP is signaled with P bit set in the PROTECTION object.

3.2. Resource Sharing-based Restoration LSP Setup

GMPLS LSPs can share resources during LSP setup if they have Shared Explicit (SE) flag set in their SESSION_ATTRIBUTE objects and:

- o As defined in [[RFC3209](#)], LSPs have identical SESSION objects and/or
- o As defined in [[RFC6689](#)], LSPs have matching ASSOCIATION object with Association Type set to "Resource Sharing". LSPs in this case can have different SESSION objects i.e. different Tunnel ID, Source and/or Destination.

As described in [[RFC3209](#)], [Section 2.5](#), the purpose of make-before-break is "not to disrupt traffic, or adversely impact network operations while TE tunnel rerouting is in progress". In non-packet transport networks, the label has a mapping into the data plane resource used and the nodes along the LSP need to send triggering commands to data plane for setting up cross-connections accordingly during the RSVP-TE signaling procedure. Due to the nature of the non-packet transport networks, node may not be able to fulfill this

purpose when sharing resources in some scenarios.

For LSP restoration upon failure, as explained in [Section 11 of \[RFC4872\]](#), reroute procedure may re-use existing resources. The behavior of the intermediate nodes during rerouting process to reconfigure cross-connections does not further impact the traffic since it has been interrupted due to the already failed LSP.

The node behavior for setting up the restoration LSP can be categorized into the following three categories:

Table 1: Node Behavior during Restoration LSP Setup

Category	Node Behavior during Restoration LSP Setup
C1	<ul style="list-style-type: none"> + Reusing existing resource on both input and output interfaces (nodes A & B in Figure 3). + This type of nodes only needs to book the existing resources and no cross-connection setup command is needed.
C2	<ul style="list-style-type: none"> + Reusing existing resource only on one of the interfaces, either input or output interfaces and need to use new resource on the other interface. (nodes C & E in Figure 3). + This type of nodes needs to book the resources and send the re-configuration cross-connection command to its corresponding data plane node on the interfaces where new resources are needed and re-use the existing resources on the other interfaces.
C3	<ul style="list-style-type: none"> + Using new resources on both interfaces. (nodes F & G in Figure 3). + This type of nodes needs to book the new resources and send the cross-connection setup command on both interfaces.

Depending on whether the resource is re-used or not, the node behaviors differ. This deviates from normal LSP setup since some nodes do not need to re-configure the cross-connection, and it should not be viewed as an error. Also, the judgment whether the control plane node needs to send a cross-connection setup/modification command to its corresponding data plane node(s) relies on the check

whether the LSPs are sharing resources.

3.3. LSP Reversion

If the end-to-end LSP recovery is revertive, as described in [Section 2](#), traffic can be reverted from the restoration LSP to the working or protecting LSP after its failure is recovered. The LSP reversion can be achieved using two methods:

1. Make-while-break Reversion, where resources associated with working or protecting LSP are reconfigured while removing reservations for the restoration LSP.
2. Make-before-break Reversion, where resources associated with working or protecting LSP are reconfigured before removing reservations for the restoration LSP.

In non-packet transport networks, both of the above reversion methods will result in some traffic disruption when the restoration LSP and the LSP being restored are sharing resources and the cross-connections need to be reconfigured on intermediate nodes.

3.3.1. Make-while-break Reversion

In this reversion method, restoration LSP is simply requested to be deleted by the head-end. Removing reservations for restoration LSP triggers reconfiguration of resources associated with working or protecting LSP on every node where resources are shared. Whenever reservation for restoration LSP is removed from a node, data plane configuration changes to reflect reservations of working or protection LSP as signaling progresses. Eventually, after the whole restoration LSP is deleted, data plane configuration will fully match working or protecting LSP reservations on the whole path. Thus reversion is complete.

Make-while-break, while being relatively simple in its logic, has few limitations as follows which may not be acceptable in some networks:

- o No rollback

Deletion of restoration LSPs is not a revertive process. If for some reason reconfiguration of data plane on one of the nodes to match working or protection LSP reservations fails, falling back to restoration LSP is no longer an option, as its state might have already been removed from other nodes.

- o No completion guarantee

Deletion of an LSP provides no guarantees of completion. In particular, if RSVP packets are lost due to nodal or DCN failures it is possible for an LSP to be only partially deleted. To mitigate this, RSVP could maintain soft state reservations and hence eventually remove remaining reservations due to refresh timeouts. This approach is not feasible in non-packet transport networks however, where control and data channels are often separated and hence soft state reservations are not useful.

Finally, one could argue that graceful LSP deletion [[RFC3473](#)] would provide guarantee of completion. While this is true for most cases, many implementations will time out graceful deletion if LSP is not removed within certain amount of time, e.g. due to a transit node fault. After that, deletion procedures which provide no completion guarantees will be attempted. Hence, in corner cases completion guarantee cannot be provided.

- o No explicit notification of completion to head-end node

In some cases, it may be useful for a head-end node to know when the data plane has been reconfigured to match working or protection LSP reservations. This knowledge could be used for initiating operations like enabling alarm monitoring, power equalization and others. Unfortunately, for the reasons mentioned above, make-while-break reversion lacks such explicit notification.

3.3.2. Make-before-break Reversion

This reversion method can be used to overcome limitations of make-while-break reversion. It is similar in spirit to MBB concept used for re-optimization. Instead of relying on deletion of restoration LSP, head-end chooses to establish a new LSP to reconfigure resources on the working or protection LSP path, and uses identical ASSOCIATION and PROTECTION objects from the LSP it is replacing. Only if setup of this LSP is successful will other (restoration and working/protecting) LSPs be deleted by the head-end. MBB reversion consists of two parts:

A) Make part:

Creating a new reversion LSP following working or protection LSP's path. Reversion LSP is sharing resources both with working and restoration LSPs. As reversion LSP is created, resources are reconfigured to match its reservations. Hence, after reversion LSP is created, data plane configuration essentially reflects working or

protecting LSP reservations.

B) Break part:

After "make" part is finished, working and restoration LSPs are torn down. Removing reservations for working and restoration LSPs does not cause any resource reconfiguration on reversion LSP's path - nodes follow same procedures as for "break" part of any MBB operation. Hence, after working and restoration LSPs are removed, data plane configuration is exactly the same as before starting restoration. Thus, reversion is complete.

MBB reversion uses make-before-break characteristics to overcome challenges related to make-while-break reversion as follow:

o Rollback

If "make" part fails, (existing) restoration LSP will still be used to carry existing traffic. Same logic applies here as for any MBB operation failure.

o Completion guarantee

LSP setup is resilient against RSVP message loss, as Path and Resv messages are refreshed periodically. Hence, given that network recovers its DCN eventually, reversion LSP setup is guaranteed to finish with either success or failure.

o Explicit notification of completion to head-end node

Head-end knows that data plane has been reconfigured to match working or protection LSP reservations on intermediate nodes when it receives Resv for the reversion LSP.

4. Security Considerations

This document reviews procedures defined in [[RFC3209](#)] [[RFC4872](#)] [[RFC4873](#)] and [[RFC6689](#)] and does not define any new procedure. This document does not introduce any new security issues other than those already covered in [[RFC3209](#)] [[RFC4872](#)] [[RFC4873](#)] and [[RFC6689](#)].

5. IANA Considerations

This informational document does not make any request for IANA action.

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