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Extensions to GMPLS Resource Reservation Protocol (RSVP) Graceful Restart

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Abstract

This document describes extensions to the Resource Reservation Protocol (RSVP) Graceful Restart mechanisms defined in RFC 3473. The extensions enable the recovery of RSVP signaling state based on the Path message last sent by the node being restarted.

Previously defined Graceful Restart mechanisms, also called recovery from nodal faults, permit recovery of signaling state from adjacent nodes when the data plane has retained the associated forwarding state across a restart. Those mechanisms do not fully support signaling state recovery on ingress nodes or recovery of all RSVP objects.

The extensions defined in this document build on the RSVP Hello extensions defined in RFC 3209, and extensions for state recovery on nodal faults defined in RFC 3473. Using these extensions, the restarting node can recover all previously transmitted Path state, including the Explicit Route Object and the downstream (outgoing) interface identifiers. The extensions can also be used to recover signaling state after the restart of an ingress node.

These extensions are not used to create or restore data plane state.

The extensions optionally support the use of Summary Refresh, defined in RFC 2961, to reduce the number of messages exchanged during the Recovery Phase when the restarting node has recovered signaling state locally for one or more Label Switched Paths (LSPs).

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1. Introduction

RSVP Graceful Restart is defined in [RFC3473] and uses mechanisms defined in [RFC3209]. When data/forwarding plane state can be retained across the restart of the RSVP agent that established such state, RSVP Graceful Restart provides the ability for the RSVP agent to resynchronize its state based on updates received from its neighboring RSVP agents, and, reconcile such state with the retained data/forwarding plane state. [RFC3209] describes a mechanism, using RSVP Hello messages, to detect the state of an adjacent RSVP agent. [RFC3473] extends this mechanism to advertise the capability of retaining data/forwarding plane state across the restart of a node or a "nodal fault". [RFC3473] also defines the Recovery Label object for use in the Path message of the RSVP neighbor upstream of a restarting node, to indicate that the Path message is for existing data plane state.

This document presents extensions to address two aspects of graceful restart not previously supported. The presented extensions enable a restarting node to recover all objects in previously transmitted Path messages, including the Explicit Route Object (ERO), from its downstream neighbors, thus recovering the control plane state. The extensions do not facilitate the recovery or creation of data/forwarding plane state, and can only be used to reestablish control plane state that matches in-place data/forwarding state. The extensions also enable graceful restart of an ingress node that does not preserve full RSVP state across restarts. The presented extensions are equally applicable to LSPs of various switching types as defined in [RFC3471].

Per [RFC3473], a restarting node can distinguish Path messages associated with LSPs being recovered by the presence of the Recovery Label object. To determine the downstream (outgoing) interface and associated label(s), the restarting node must consult the data plane. This may not be possible for all types of nodes. Furthermore, data plane information is not sufficient to reconstruct all previously transmitted Path state. In these cases, the only source of RSVP state is the downstream RSVP neighbor.

For example, when the restarting node is an ingress node, all previously transmitted Path state may need to be recovered. Such Path state may include (but is not restricted to) the Protection object, the Admin Status object, the Session Attribute object, the Notify Request object, and the Sender Tspec object. A restarting transit node may have modified received Path state in its previously transmitted Path message, which cannot be reconstructed internally during recovery.

Another example of state that cannot be completely recovered from the data plane in some cases is the previously transmitted ERO. Recovery of the previously transmitted ERO minimizes subsequent change of downstream LSP state. On a restarting ingress node, the ERO may have been based on configuration or the result of a previous path computation. A restarting transit node may have previously performed some form of path computation as a result of not receiving an ERO or receiving a loose hop in the ERO. In addition to the ERO, the restarting node may have modified other received Path state in its previously transmitted Path state, which cannot be reconstructed internally during recovery.

The defined extensions provide a restarting upstream node with all information previously transmitted by the node in Path messages. This is accomplished by the downstream RSVP neighbor sending a new message for every Path message it has previously received from the restarting node, after reestablishing RSVP communication with a restarted node that supports the recovery procedures defined in Section 4.5.2 of this document.

The new message is called the RecoveryPath message. The message conveys the contents of the last received Path message back to the restarting node. The restarting node can use the RecoveryPath message, along with the state in the received Path message to associate control and data plane state and to validate the forwarding state with the state presented by the neighboring RSVP nodes.

The restarting node indicates its desire to receive and process the RecoveryPath message by including a new object called the Capability object with the RecoveryPath Desired bit set, in its Hello messages sent to the downstream RSVP neighbor. The downstream RSVP neighbor can indicate its ability to send RecoveryPath messages by including the Capability object with the RecoveryPath Transmit Enabled set in its Hello messages to the restarting node. Thus, both the restarting node and its RSVP neighbor, with the help of the Capability object, can detect if the RecoveryPath message extensions defined in this document can be used to recover signaling state after a restart.

If the restarting node is a transit node, it will receive a Path message with a Recovery Label object from its upstream RSVP neighbor. In addition, the RecoveryPath message allows such transit nodes to reconstruct any state that was previously dynamically constructed by the node, e.g., ERO sub-objects. If the restarting node is an ingress node, all significant signaling state can be recovered based on the RecoveryPath message.

Selective transmission of the RecoveryPath message is supported by enhancing the Summary Refresh mechanisms defined in [RFC2961]. When Recovery Summary Refresh is supported, the restarting node can select the LSPs for which it would like to receive RecoveryPath messages. This is useful when the restarting node is able to locally recover the signaling state for a subset of the previously active LSPs.

Restarting egress nodes, and Resv message processing are not impacted by the presented extensions, see [RFC3473] for details.

2. Conventions Used in This Document

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].

3. Terminology

The reader is assumed to be familiar with the terminology defined in [RFC3209] and [RFC3473].

Throughout this document, the term "node", when used in the context of a restarting or restarted node, generally refers to the control plane component, which is the signaling controller for a data plane switch.

4. Extensions to Nodal Fault Handling

This section presents the protocol modifications to Section 9 of [RFC3473].

4.1. RecoveryPath Message Format

The format of a RecoveryPath message is the same as the format of a Path message, as defined in [RFC3473], but uses a new message number (30) so that it can be identified correctly.

```
<RecoveryPath Message> ::= <Path Message>
```

The destination address used in the IP header of a RecoveryPath message MUST be the same as the destination address used in the IP header of the corresponding Resv message last generated by the sending node. Except as specified below, all objects in a RecoveryPath message are identical to the objects in the corresponding Path message last received by the sending node.

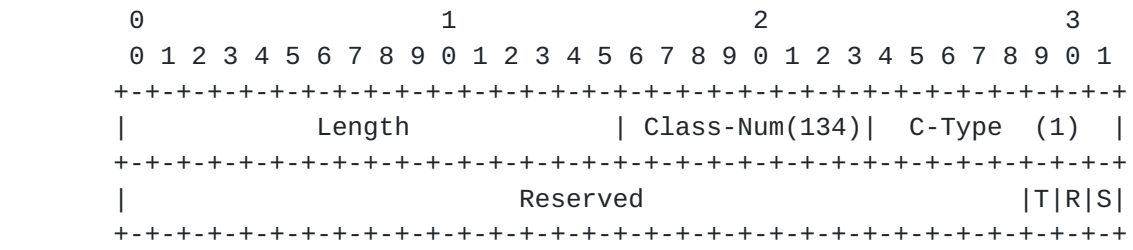
4.2. Capability Object

Capability objects are carried in RSVP Hello messages. The Capability object uses Class-Number 134 (of form 10bbbbbb) and C-Type of 1.

The message format of a Hello message is modified to be:

```
<Hello Message> ::= <Common Header> [ <INTEGRITY> ] <HELLO>
                    [ <RESTART_CAP> ] [ <CAPABILITY> ]
```

The format of a Capability object is:



RecoveryPath Transmit Enabled (T): 1 bit

When set (1), indicates that the sending node is enabled to send RecoveryPath messages. Absence of the Capability object MUST be treated as if the T-bit is cleared (0).

RecoveryPath Desired (R): 1 bit

When set (1), indicates that the sending node desires to receive RecoveryPath messages. Absence of the Capability object MUST be treated as if the R-bit is cleared (0).

RecoveryPath Srefresh Capable (S): 1 bit

When set (1), along with the R-bit, indicates that the sending node is capable of receiving and processing Srefresh messages with the RecoveryPath Flag set (1) in the MESSAGE_ID LIST object. Absence of the Capability object MUST be treated as if the S-bit is cleared (0). Related procedures are defined in Section 5.2.1.

Reserved bits

Reserved bits MUST be set to zero on transmission and MUST be ignored on receipt.

4.2.1. Conformance

All nodes supporting the extensions defined in this document MUST be able to transmit, and properly receive and process RecoveryPath messages. All nodes MUST be able to set both the T and R bits. Both the T and R bits SHOULD be set (1) by default. A node MAY allow RecoveryPath message transmission and reception to be independently disabled based on local policy. When RecoveryPath message transmission is disabled, the T-bit MUST be set to zero (0). When RecoveryPath message reception is not desired, the R-bit MUST be set to zero (0).

Any node that supports the extensions defined in this document and sets the Refresh-Reduction-Capable bit [RFC2961] SHOULD support setting of the S-bit and support the mechanisms defined in Section 5.

4.3. Related Procedures

This document does not modify existing procedures for sending and receiving RSVP Hello messages, as defined in [RFC3209], and the Restart_Cap object in RSVP Hello messages as defined in [RFC3473]. The procedures for control channel faults are defined in [RFC3473] and are not changed by this document.

The presented extensions require the use of RSVP Hellos, as defined in [RFC3209], and the use of the Restart_Cap object extension as defined in [RFC3473]. The presented extensions address only "Nodal Faults" as defined in [RFC3473]. Control channel faults are fully addressed in [RFC3473].

Note: There are no changes to the procedures defined in Section 9.5.3 in [RFC3473] (Procedures for the Neighbor of a Restarting node). There are no changes to the procedures defined in Section 9.5.2 in [RFC3473] if the restarting node is an egress node.

There are no changes to the procedures with respect to the data/forwarding plane as described in [RFC3473]. In particular, a restarting node MUST NOT create data/forwarding plane state as the result of any of the extensions defined in this document.

The following sections assume previously defined procedures are followed, except where explicitly modified.

4.4. Procedures for the Capability Object

4.4.1. Procedures for the Downstream Neighbor

If a node is capable of sending RecoveryPath messages, it MUST include the Capability object with the RecoveryPath Transmit Enabled (T) bit set (1) in all its Hello messages.

If the downstream RSVP neighbor receives Hello messages from a restarting node, with the Restart_Cap object, as defined in [RFC3473], and with the Capability object with the RecoveryPath Desired (R) bit set (1), it MUST treat the restarting node as capable of receiving and processing RecoveryPath messages as defined in this document.

If the downstream RSVP neighbor receives a Capability object in a Hello message with the RecoveryPath Desired (R) bit set (1), but without the Restart_Cap object, it MUST process the Hello message as if the RecoveryPath Receive Desired (R) bit is cleared (0) in the Hello message.

If the downstream RSVP neighbor does not receive the Capability object in Hello messages sent by the restarting node or the RecoveryPath Desired (R) bit is cleared (0) in the Capability object, it MUST treat the restarting node as not capable of supporting the RecoveryPath message procedures defined in this document, and MUST revert to recovery procedures as defined in [RFC3473].

4.4.2. Procedures for the Restarting Node

A node that expects to recover RSVP state by the receipt and processing of RecoveryPath messages according to procedures defined in this document, MUST include the Capability object with the RecoveryPath Desired (R) bit set (1) in its RSVP Hello messages to its neighbors. The node MUST also include the Restart_Cap object, as defined in [RFC3473], in all those Hello messages.

If the Recovery Time is zero (0) or the restarting node does not support/desire the use of RecoveryPath messages, the RecoveryPath Desired (R) bit MUST be cleared (0) in the Capability object included in Hello messages, or the Capability object MAY be omitted from Hello messages sent by the restarting node.

During the Recovery Period, if the restarting node receives Hello messages from a downstream RSVP neighbor with the RecoveryPath Transmit Enabled (T) bit set (1) in the Capability object and the Restart_Cap object, as defined in [RFC3473], it MUST treat the downstream RSVP neighbor as capable of sending RecoveryPath messages

according to procedures defined in Section 4.5.1. If the restarting node expects to recover RSVP state by the receipt and processing of RecoveryPath messages, it MUST follow procedures defined in Section 4.5.2, with the downstream RSVP neighbor.

During the Recovery Period, if the restarting node receives Hello messages from a downstream RSVP neighbor with the RecoveryPath Transmit Enabled (T) bit cleared (0) in the Capability object, or, with the Capability object not present, it MUST treat the downstream RSVP neighbor as not capable of the RecoveryPath message procedures defined in this document, and, it MUST revert to the recovery procedures defined in [RFC3473] immediately, with the downstream RSVP neighbor.

4.5. Procedures for the RecoveryPath Message

4.5.1. Procedures for the Downstream Neighbor

After a downstream RSVP neighbor has detected that its upstream node has restarted, is capable of recovery as defined in [RFC3473], and, is capable of receiving RecoveryPath messages as defined in Section 4.4, the downstream RSVP neighbor MUST send a RecoveryPath message for each LSP associated with the restarting node for which it has sent a Resv message. During the Recovery Period, if the downstream RSVP neighbor detects that the restarting node is not capable of receiving RecoveryPath messages by the absence of the Capability object or the RecoveryPath Desired (R) bit cleared (0) in the Capability object in the restarting node's Hello messages, the downstream RSVP neighbor SHOULD NOT send the RecoveryPath messages to the restarting node.

The RecoveryPath message is constructed by copying all objects from the last received associated Path message, with the following exceptions:

- The MESSAGE_ID, MESSAGE_ID_ACK and MESSAGE_ID_NACK objects are not copied. Any MESSAGE_ID, MESSAGE_ID_ACK and MESSAGE_ID_NACK objects used in RecoveryPath messages are generated based on procedures defined in [RFC2961].

- The Integrity object is not copied. Any Integrity objects used in RecoveryPath messages are generated based on procedures defined in [RFC2747].

- The RSVP Hop object is copied from the most recent associated Resv message sent to the restarted node for the LSP being recovered.

In the sender descriptor, the Recovery Label object MUST be included, with the label value copied from the label value in the Label object in the most recent associated Resv message sent to the restarted node, for the LSP being recovered.

All other objects from the most recent received Path message MUST be included in the RecoveryPath message.

All RecoveryPath messages SHOULD be sent at least once within approximately 1/2 of the Recovery Time advertised by the restarted neighbor. If there are many LSPs to be recovered by the restarted node, the downstream RSVP neighbor should avoid sending RecoveryPath messages in a short time interval to avoid overloading the restarted node's CPU. Instead, it should spread the messages across 1/2 the Recovery Time interval. The range of Recovery Time is dependent on many factors including, but not limited to, the CPU processing power on the restarting node as well as the upstream and downstream neighbors, the amount of CPU available for processing RSVP recovery procedures, and the implementation specifics that affect the amount of time taken to verify the received recovery state against existing forwarding plane state. Such discussion is out of scope of this document.

After sending a RecoveryPath message and during the Recovery Period, the node SHOULD periodically resend the RecoveryPath message until it receives a corresponding response. A corresponding response is a Message ID acknowledgment or a Path message for the LSP the RecoveryPath message represents. Each such resend attempt is at the end of any Message ID rapid retransmissions, if the Message ID mechanism is used. If the Message ID mechanism is not in use, the period between resend attempts SHOULD be such that at least 3 attempts are completed before the expiry of 3/4 the Recovery Time interval. Each such resend attempt MUST treat the RecoveryPath message as a new message and update the MESSAGE_ID object according to procedures defined in [RFC2961]. Note, per [RFC3473], Resv messages are suppressed during this recovery period until a corresponding Path message is received.

4.5.2. Procedures for the Restarting Node

These procedures apply during the "state recovery process" and "Recovery Period" as defined in Section 9.5.2 of [RFC3473]. Any RecoveryPath message received after the Recovery Period has expired SHOULD be matched against local LSP state. If matching fully resynchronized state is located, the node SHOULD send a Path message downstream. If non-resynchronized or no LSP state matching the RecoveryPath message is located, the restarted node MAY send a PathTear message constructed from the RecoveryPath message to

expedite the cleanup of unrecovered RSVP and associated forwarding state downstream of the restarted node. The restarting node MUST NOT create data plane or forwarding state to match the received RecoveryPath message.

The remaining procedures are broken down into three sub-sections. The term "resynchronized state", originally defined in [RFC3473], is used and modified in these sections. This term refers to LSP state that is fully recovered.

Signaling state may be recovered from sources other than the mechanisms defined in this document. The restarting node SHOULD consider signaling state as resynchronized for all such LSPs and follow corresponding procedures defined below. Further, recovery procedures defined below may be overridden by local policy.

Again, there are no changes to the procedures defined in Section 9.5.2 in [RFC3473] if the restarting node is an egress node.

4.5.2.1. Path and RecoveryPath Message Procedures

When a node receives a RecoveryPath message during the Recovery Period, the node first checks if it has resynchronized RSVP state associated with the message. If there is resynchronized state, and when both reliable message delivery [RFC2961] is supported and a MESSAGE_ID object is present in the RecoveryPath message, the node MUST follow Message ID acknowledgment procedures, as defined in [RFC2961], and consider the message as processed. If there is resynchronized state and there is no MESSAGE_ID object or reliable message delivery [RFC2961] is not supported, the node SHOULD send a trigger Path message, and, consider the message as processed.

If a non-resynchronized state is found or the node is the ingress, the node saves the information contained in the RecoveryPath message and continues with processing as defined in Section 4.5.2.2.

If no associated RSVP state is found and the node is not the ingress node, the node saves the information contained in the RecoveryPath message for later use.

Note the following modifies Section 9.5.2 of [RFC3473]:

When a node receives a Path message during the Recovery Period, the node first locates any RSVP state associated with the message. If resynchronized RSVP state is found, then the node handles this message according to previously defined procedures.

If a non-resynchronized state is found, the node saves the information contained in the Path message, including the Recovery_Label object, and continues with processing as defined in Section 4.5.2.2.

Per [RFC3473], if matching RSVP state is not found, and the message does not carry a Recovery_Label object, the node treats this as a setup for a new LSP, and handles it according to previously defined procedures.

If a matching RSVP state is not found and the message carries a Recovery_Label object, the node saves the information contained in the Path message, including the Recovery_Label object for later use.

4.5.2.2. Re-Synchronization Procedures

After receipt of the RecoveryPath message and, for non-ingress LSPs, the corresponding Path message with a Recovery Label object, the restarting node SHOULD locate and associate corresponding forwarding state using the received information. The restarting node associates the corresponding active forwarding plane state from the following signaled information:

- The upstream data interface is recovered from the RSVP HOP object in the received Path message.

- The label on the upstream data interface is recovered from the Recovery Label object in the received Path message. If the LSP is bidirectional, the label for the upstream direction is recovered from the Upstream Label object in the received Path message.

- The downstream data interface is recovered from the RSVP HOP object in the received RecoveryPath message.

- The label on the downstream data interface is recovered from the Recovery Label object in the received RecoveryPath message. If the LSP is bidirectional, the label for the upstream direction is recovered from the Upstream Label object in the RecoveryPath message.

If complete forwarding state is located, the restarted node MUST treat the LSP as resynchronized and MUST send a trigger Path message downstream. The Explicit Route object in the Path message SHOULD match the Explicit Route object received in the RecoveryPath message. In addition, the restarted node SHOULD recover state from the other objects received in the RecoveryPath message. Optimally, the resulting Path message should not cause any redundant or unnecessary reprocessing of state along the remaining downstream nodes. Ideally,

except for MESSAGE_ID processing and recovery processing, the transmitted Path message will be treated as a refresh by the downstream RSVP neighbor (and hence, should not trigger any generation of Path messages with changed state further downstream).

If no forwarding state is located, the node treats the received Path message as a setup request for a new LSP. The outgoing interface and label(s) indicated in the RecoveryPath message SHOULD be reused when possible. All other information contained in the RecoveryPath message MAY also be used. That is, forwarding state MUST NOT be created except after receipt of a Path message from upstream or, at an ingress node, the receipt of a command from the management plane. Further, the forwarding state created is subject to local policy and the information received from downstream in the RecoveryPath message is treated only as advisory.

4.5.2.3. Procedures on Expiration of Recovery Period

There are several cleanup steps to follow at the end of the Recovery Period. At the end of the Recovery Period, any state that was installed as the result of a received RecoveryPath message that is not resynchronized SHOULD be discarded.

Any Path messages that were received containing a Recovery_Label that has not been resynchronized, MUST be treated as being received during the Recovery Period and processed as per [RFC3473].

Per [RFC3473], any other state that is not resynchronized during the Recovery Period SHOULD be removed at the end of the Period.

4.6. Compatibility

This document introduces a new RSVP signaling message called the RecoveryPath message to be generated by the downstream RSVP neighbor of a restarting node. To advertise the capability of sending and receiving RecoveryPath messages, this document introduces the Capability object to be included in Hello messages by a restarting node and its downstream RSVP neighbors.

If a restarting node does not support the Capability object, it will discard the object, as the Class-Number is of the form 10bbbbbb, and revert to recovery processing as defined in [RFC3473]. The restarting node will not include the Capability object in its Hello messages. Hence, all downstream RSVP neighbors that detect that the restarting node is not capable of supporting the extensions defined in this document will not send the RecoveryPath messages to the restarting node and will revert to recovery processing as defined in [RFC3473].

If a downstream RSVP neighbor does not support the Capability object, it will discard the object received in Hello messages and revert to recovery processing as defined in [RFC3473]. The downstream RSVP neighbor will not include the Capability object in its Hello messages. Hence, the restarting node will detect that the downstream RSVP neighbor is not capable of supporting the extensions defined in this document and will revert to recovery processing as defined in [RFC3473].

5. RecoveryPath Summary Refresh

This section describes a mechanism to control which LSP state is communicated in RecoveryPath messages. This mechanism enhances the Summary Refresh mechanism defined in [RFC2961], and uses the RecoveryPath Srefresh Capable (S) bit in the Capability object, as defined in Section 4.2, carried in the Hello message defined in [RFC3209] and [RFC3473]. The described mechanism is referred to as RecoveryPath Summary Refresh.

Selective transmission of RecoveryPath messages is controlled much the same way transmission of Path or Resv messages is controlled with standard Summary Refresh, see [RFC2961]. In standard Summary Refresh, an Srefresh message is sent by a node to identify to its neighbor about Path and Resv state that is locally installed and available. The receiver of the Srefresh message can then attempt to locate matching Path and Resv state. If no matching state is found, the receiver can request that the missing state be sent to it by sending an Srefresh NACK to the sender of the Srefresh message. When the Srefresh NACK is received, the corresponding Path or Resv message is sent. MESSAGE_ID information is used to identify Path and Resv state in this process.

The mechanism described in this section extends the Summary Refresh process to the Path state that can be represented in RecoveryPath messages. In this case, the Srefresh messages represent previously received Path messages, rather than previously transmitted Path messages. This is the primary difference between standard Summary Refresh and RecoveryPath Summary Refresh described in this section.

When a node restarts, and is capable of supporting the mechanisms described in this section, it includes the Capability object with the RecoveryPath Desired (R) bit set and the RecoveryPath Srefresh Capable (S) bit set in Hello messages it sends to its RSVP neighbors.

When a neighbor of the restarting node detects a restart (see [RFC3209]), it detects that the restarted node is capable of receiving RecoveryPath messages, as defined in Section 4.4, and that the restarted node is requesting RecoveryPath Srefresh messages by

the RecoveryPath Srefresh Capable (S) bit set in the Capability object. When such an indication is found, the neighbor generates one or more Srefresh messages. Each message indicates the Path state that can be represented in a RecoveryPath message. Within such Srefresh messages, the Path state that can be represented in RecoveryPath messages is represented using MESSAGE_ID information, and this information is communicated within MESSAGE_ID LIST objects. To indicate that the MESSAGE_ID LIST object is for recovery purposes, a new flag is set in the MESSAGE_ID LIST object. This flag is called the RecoveryPath Flag and is defined below.

The restarted node can then use the Srefresh message and the MESSAGE_ID LIST object to try to identify matching transmitted Path state. The node identifies local state by matching Epoch and Message ID tuples against Path messages transmitted downstream prior to the restart.

If matching state is located, then the restarted node operates as if a RecoveryPath message has been received, per Section 4.5.2. If no matching state can be located, the restarted node generates a Srefresh NACK, see Section 5.4 of [RFC2961]. The Srefresh NACK is also marked with the new RecoveryPath Flag to indicate that the NACK is related to RecoveryPath messages.

Upon receiving a Srefresh NACK, the downstream node generates a RecoveryPath message for the Path state indicated by each entry in the MESSAGE_ID LIST. The procedures defined in Section 4 above are then followed by the restarted node and the downstream RSVP neighbor.

5.1. MESSAGE_ID ACK/NACK and MESSAGE_ID LIST Objects

The MESSAGE_ID ACK/NACK objects and the MESSAGE_ID LIST object, defined in [RFC2961], are updated by this document. A new bit within the existing Flags field of each object is defined. This bit indicates that the object carries MESSAGE_ID information related to Path state that can be recovered using RecoveryPath messages. The same flag value is used in all the objects for consistency.

MESSAGE_ID_ACK object
MESSAGE_ID_NACK object

See Section 4.3 of [RFC2961] for definition of other fields.

MESSAGE_ID LIST object

See Section 5.1 of [RFC2961] for definition of other fields.

Flags: 8 bits

0x02: RecoveryPath Flag

Indicates that the associated object carries MESSAGE_ID information related to one or more Path messages that can be recovered using a RecoveryPath message.

5.2. RecoveryPath Srefresh Capable Bit

The Capability object and the RecoveryPath Srefresh Capable (S) bit are defined in Section 4.2.

5.2.1. Procedures

To support the selective receipt of RecoveryPath messages as defined in this section, a restarting node MUST support the receipt and processing of RecoveryPath messages as defined in Section 4.5.2, and MUST indicate this capability by including the Capability object with the RecoveryPath Desired (R) bit set as defined in Section 4.4.2 in its Hello messages.

To indicate to an RSVP neighbor that selective transmission of RecoveryPath messages is desired, a node MUST set (1) the S-bit in the Capability object in all Hello messages it sends. When the restarting node does not desire the receipt of RecoveryPath messages (see Section 4.4.2) or the selective transmission mechanism defined in this section, it MUST clear (0) the S-bit in the Capability object if included in Hello messages.

The downstream RSVP neighbor checks the R-bit and the S-bit upon detecting a restart of a node that supports state recovery with RecoveryPath messages. Detection of neighbor restarts with state recovery using RecoveryPath messages is defined in Section 4. If both the R-bit and the S-bit are set, then the procedures defined below in Section 5.3.1 MUST be followed. If the S-bit is cleared, the downstream RSVP neighbor MUST revert to normal procedures defined in Section 4.5.1. If the R-bit is cleared, but the S-bit is set, the

downstream RSVP neighbor MUST treat it as if the Capability object was received with the S-bit cleared. See Section 4.4 for handling of Hello messages without the Capability object.

5.2.2. Compatibility

There are no compatibility issues introduced in the procedures defined in Section 5.2.1.

The restarting node will detect that its neighbor does not support selective transmission of RecoveryPath messages when a RecoveryPath message is received prior to the receipt of a Srefresh message containing a MESSAGE_ID LIST object with the RecoveryPath Flag set (1). When this occurs, any received RecoveryPath messages MUST be processed as defined in Section 4.

5.3. RecoveryPath Summary Refresh Procedures

Related processing occurs in the following logical order:

- Generation of RecoveryPath-related Srefresh messages
- RecoveryPath-related Srefresh message receive processing and NACK generation
- Message ID NACK receive processing and generation of RecoveryPath messages
- Receive processing of RecoveryPath messages

Actual processing MAY result in the above occurring in an interlaced fashion when multiple LSPs are being recovered. Both the restarted node and the downstream RSVP neighbor MUST be able to process in this fashion.

5.3.1. Generation of RecoveryPath-Related Srefresh Messages

A neighbor of a restarting node generates one or more RecoveryPath-related Srefresh messages when the S-bit is set in the restarted node's Hello messages as described in Section 5.2.1. The procedures for generating an Srefresh message are defined in [RFC2961]. Only modifications to these procedures are described in this section. Also, Srefresh message transmit and receive processing may occur simultaneously during the Recovery Period and are not impacted by the procedures defined in this section.

To generate RecoveryPath-related Srefresh messages, a node must identify which Path state can be represented in RecoveryPath messages

and which Srefresh message or messages can be used to carry the related information. As previously mentioned, the Path state that can be represented in RecoveryPath messages is indicated in Srefresh messages using the MESSAGE_ID information from the most recently received Path message associated with the state.

After processing the S-bit as described in Section 5.2.1, the node identifies all state associated with Path messages received from the restarted neighbor. Only a Path state that has not been updated since the restart may be represented in the Srefresh messages. Received Path state containing a MESSAGE_ID object whose Epoch value matches the Epoch received in the most recent Hello message is considered as updated after the upstream neighbor has restarted. Such Path state MUST NOT be represented in the Srefresh messages. Each Srefresh message contains one or more MESSAGE_ID LIST objects. Each such MESSAGE_ID LIST object MUST have the RecoveryPath Flag set (1).

Multiple MESSAGE_ID LIST objects MAY be included in order to accommodate multiple Epoch values. The MESSAGE_ID LIST objects represent the identified, non-updated, Path state. A Message_Identifier field created for each identified, non-updated Path state MUST be included in an appropriate MESSAGE_ID LIST object. The Message_Identifier field is created based on the MESSAGE_ID object from the most recently received Path message associated with identified Path state. If any identified Path state does not have an associated MESSAGE_ID object, this state MUST be processed as defined above in Section 4.5.1.

The source IP address for the Srefresh message SHOULD be the source IP address in the IP header of the corresponding Resv messages previously sent to the restarted node. The Srefresh message SHOULD be destined to the IP address in the HOP object in the corresponding Path messages. This may result in multiple Srefresh messages being generated. Per [RFC2961], implementations may choose to limit each Srefresh message to the MTU size of the outgoing link, and to not bundle Srefresh messages. RecoveryPath-related Srefresh messages SHOULD be sent using reliable delivery, as defined in [RFC2961].

During the Recovery Period, unacknowledged RecoveryPath-related Srefresh messages SHOULD be periodically transmitted. The retransmission algorithm used can be the same algorithm used for retransmitting RecoveryPath messages during the Recovery Period (see Section 4.5.1). Note that prior to each such periodic retransmission, the Srefresh message SHOULD be updated to exclude the Message ID's of Path state that has been updated by the receipt of a Path message.

To allow sufficient processing time for the restarted node, the downstream RSVP neighbor MAY choose to generate multiple RecoveryPath-related Srefresh messages containing partial but mutually exclusive sets of Message Identifiers spread across 1/4 of the Recovery Time advertised by the restarted node.

5.3.2. RecoveryPath-Related Srefresh Receive Processing and NACK Generation

Upon receiving an Srefresh message containing a MESSAGE_ID LIST object with the RecoveryPath Flag set), the restarted node attempts to locate matching previously transmitted Path state. The Epoch in the MESSAGE_ID LIST object, along with each Message Identifier in the object, is used to match against the MESSAGE_ID object in Path messages previously transmitted to the downstream RSVP neighbor. For each Message Identifier in the MESSAGE_ID LIST:

If matching transmitted Path state is found, the restarting node treats the corresponding LSP state as having received and processed a RecoveryPath message and perform any further processing necessary as defined in Section 4.5.2. Specifically, it MUST generate a trigger Path message for the LSP as defined in Section 4.5.2.2. The restarted node MAY spread the transmission of such trigger Path messages across 1/2 of the remaining Recovery Period to allow the downstream RSVP neighbor sufficient processing time.

If matching transmitted Path state is not found, the restarting node MUST generate a MESSAGE_ID NACK as defined in [RFC2961]. Each generated MESSAGE_ID NACK MUST have the RecoveryPath Flag set (1).

It is recommended that the restarted node combine multiple such MESSAGE_ID NACKs into a single ACK message, per [RFC2961].

5.3.3. RecoveryPath-Related MESSAGE_ID NACK Receive Processing

This section defines the procedures associated with the processing of received MESSAGE_ID NACKs that have the RecoveryPath Flag set (1). Procedures for processing of MESSAGE_ID NACKs without the RecoveryPath Flag present are defined in [RFC2961] and not modified in this document. Processing of MESSAGE_ID NACKs with the RecoveryPath Flag set (1) also follows procedures defined in [RFC2961] unless explicitly modified in this section.

For each MESSAGE_ID NACK with the RecoveryPath Flag set (1), the downstream RSVP neighbor must locate the matching received Path message. If a matching Path message is found, the downstream RSVP

neighbor MUST generate a RecoveryPath message as defined in Section 4.5.1. If a matching Path message is not found, the MESSAGE_ID NACK is ignored. An example where this may occur is when the restarted node has already generated an updated Path message after its restart.

6. Security Considerations

This document introduces a new RSVP message that is restricted to one RSVP hop. This document introduces no new security considerations beyond those already addressed for existing RSVP hop-by-hop messages.

This document introduces a new RSVP object to be included in RSVP Hello messages. This document introduces no new security considerations beyond those already addressed for existing objects in RSVP Hello messages.

This document introduces new procedures to be performed on RSVP agents that neighbor a restarting RSVP agent. In situations where the control plane in general, and the RSVP agent in particular, of a node carrying one or more LSPs is restarted due to external attacks, the procedures introduced in this document provide the ability for the restarting RSVP agent to recover the RSVP state corresponding to the LSPs with the least possible perturbation to the rest of the network. Ideally, only the neighboring RSVP agents should notice the restart and hence need to perform additional processing. This allows for a network with active LSPs to recover LSP state gracefully from an external attack without perturbing the data/forwarding plane state.

[RFC2747] provides mechanisms to protect against external agents compromising the RSVP signaling state in an RSVP agent. These mechanisms, when used with the new message and procedures introduced in this document, provide the same degree of protection to the restarting RSVP agent against installing compromised signaling state from an external agent during its RSVP signaling state recovery.

Note that the procedures assume a full trust model between RSVP neighbors. That is, although the protocol exchanges before and after restart can be secured, and although it is possible to authenticate the identity of the neighbors, no mechanism is provided to verify that the restart information is correctly mapped from the protocol information exchanged before the restart. This is considered acceptable because a similar trust model is required for normal operation of the protocol.

The procedures defined in this document introduce additional processing overhead for the RSVP agents that neighbor a restarting RSVP agent. If an RSVP agent restarts due to external attacks, such

added processing on the neighboring RSVP agents may impact their ability to perform other control plane tasks, including any processing for other LSPs that do not involve the restarting node. Such impact can be minimalized by the restarting RSVP agent using a large enough Recovery Time, so that its neighbors are provided sufficient time to handle the additional processing involved while continuing to perform their other control plane functions normally during the Recovery Period.

Note that the procedures defined in this document cannot be used to create false forwarding state. The restarting node that receives a RecoveryPath message that does not match the existing forwarding state MUST NOT create or modify its forwarding state to match. A restarting node SHOULD log such an event or otherwise notify the operator since it might represent an attack.

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Adrian Farrel edited the final revisions of this document as it progressed through IESG review.

8. IANA Considerations

[RFC2205] defines the Class-Number name space for RSVP objects. The name space is managed by IANA.

A new RSVP object using a Class-Number of form 10bbbbbb called the Capability Object is defined in Section 4.2 in this document. The Class-Number is 134.

A new RSVP message type called a RecoveryPath message is defined in Section 4.1 of this document. The RSVP message type is 30.

This document creates a new name space in the Capability object defined in Section 4.2. The new name space is a 32-bit-wide field. New registrations in this name space are to be allocated by IANA through an IETF Consensus action, per [RFC2434]. IANA also serves as the repository for this name space.

Section 4.2 defines the following bits in the 32-bit field of the Capability Object (134):

RecoveryPath Transmit Enabled (T): 1 bit
RecoveryPath Desired (R): 1 bit
RecoveryPath Srefresh Capable (S): 1 bit

9. Normative References

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