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RSVP Operation Over IP Tunnels

Status of this Memo

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Abstract

This document describes an approach for providing RSVP protocol services over IP tunnels. We briefly describe the problem, the characteristics of possible solutions, and the design goals of our approach. We then present the details of an implementation which meets our design goals.

1. Introduction

IP-in-IP "tunnels" have become a widespread mechanism to transport datagrams in the Internet. Typically, a tunnel is used to route packets through portions of the network which do not directly implement the desired service (e.g. IPv6), or to augment and modify the behavior of the deployed routing architecture (e.g. multicast routing, mobile IP, Virtual Private Net).

Many IP-in-IP tunneling protocols exist today. [IP4INIP4] details a method of tunneling using an additional IPv4 header. [MINENC] describes a way to reduce the size of the "inner" IP header used in [IP4INIP4] when the original datagram is not fragmented. The generic tunneling method in [IPV6GEN] can be used to tunnel either IPv4 or IPv6 packets within IPv6. [RFC1933] describes how to tunnel IPv6

datagrams through IPv4 networks. [RFC1701] describes a generic routing encapsulation, while [RFC1702] applies this encapsulation to IPv4. Finally, [ESP] describes a mechanism that can be used to tunnel an encrypted IP datagram.

From the perspective of traditional best-effort IP packet delivery, a tunnel behaves as any other link. Packets enter one end of the tunnel, and are delivered to the other end unless resource overload or error causes them to be lost.

The RSVP setup protocol [RFC2205] is one component of a framework designed to extend IP to support multiple, controlled classes of service over a wide variety of link-level technologies. To deploy this technology with maximum flexibility, it is desirable for tunnels to act as RSVP-controllable links within the network.

A tunnel, and in fact any sort of link, may participate in an RSVP-aware network in one of three ways, depending on the capabilities of the equipment from which the tunnel is constructed and the desires of the operator.

1. The (logical) link may not support resource reservation or QoS control at all. This is a best-effort link. We refer to this as a best-effort or type 1 tunnel in this note.
2. The (logical) link may be able to promise that some overall level of resources is available to carry traffic, but not to allocate resources specifically to individual data flows. A configured resource allocation over a tunnel is an example of this. We refer to this case as a type 2 tunnel in this note.
3. The (logical) link may be able to make reservations for individual end-to-end data flows. We refer to this case as a type 3 tunnel. Note that the key feature that distinguishes type 3 tunnels from type 2 tunnels is that in the type 3 tunnel new tunnel reservations are created and torn down dynamically as end-to-end reservations come and go.

Type 1 tunnels exist when at least one of the routers comprising the tunnel endpoints does not support the scheme we describe here. In this case, the tunnel acts as a best-effort link. Our goal is simply to make sure that RSVP messages traverse the link correctly, and the presence of the non-controlled link is detected, as required by the integrated services framework.

When the two end points of the tunnel are capable of supporting RSVP over tunnels, we would like to have proper resources reserved along the tunnel. Depending on the requirements of the situation, this might mean that one client’s data flow is placed into a larger aggregate reservation (type 2 tunnels) or that possibly a new,

separate reservation is made for the data flow (type 3 tunnels). Note that an RSVP reservation between the two tunnel end points does not necessarily mean that all the intermediate routers along the tunnel path support RSVP, this is equivalent to the case of an existing end-to-end RSVP session transparently passing through non-RSVP cloud.

Currently, however, RSVP signaling over tunnels is not possible. RSVP packets entering the tunnel are encapsulated with an outer IP header that has a protocol number other than 46 (e.g. it is 4 for IP-in-IP encapsulation) and do not carry the Router-Alert option, making them virtually "invisible" to RSVP routers between the two tunnel endpoints. Moreover, the current IP-in-IP encapsulation scheme adds only an IP header as the external wrapper. It is impossible to distinguish between packets that use reservations and those that don't, or to differentiate packets belonging to different RSVP Sessions while they are in the tunnel, because no distinguishing information such as a UDP port is available in the encapsulation.

This document describes an IP tunneling enhancement mechanism that allows RSVP to make reservations across all IP-in-IP tunnels. This mechanism is capable of supporting both type 2 and type 3 tunnels, as described above, and requires minimal changes to both RSVP and other parts of the integrated services framework.

2. The Design

2.1. Design Goals

Our design choices are motivated by several goals.

* Co-existing with most, if not all, current IP-in-IP tunneling schemes.
* Limiting the changes to the RSVP spec to the minimum possible.
* Limiting the necessary changes to only the two end points of a tunnel. This requirement leads to simpler deployment, lower overhead in the intermediate routers, and less chance of failure when the set of intermediate routers is modified due to routing changes.
* Supporting correct inter-operation with RSVP routers that have not been upgraded to handle RSVP over tunnels and with non-RSVP tunnel endpoint routers. In these cases, the tunnel behaves as a non-RSVP link.

2.2. Basic Approach

The basic idea of the method described in this document is to recursively apply RSVP over the tunnel portion of the path. In this new session, the tunnel entry point Rentry sends PATH messages and the tunnel exit point Rexit sends RESV messages to reserve resources for the end-to-end sessions over the tunnel.

We discuss next two different aspects of the design: how to enhance an IP-in-IP tunnel with RSVP capability, and how to map end-to-end RSVP sessions to a tunnel session.

2.2.1. Design Decisions

To establish a RSVP reservation over a unicast IP-in-IP tunnel, we made the following design decisions:

One or more Fixed-Filter style unicast reservations between the two end points of the tunnel will be used to reserve resources for packets traversing the tunnel. In the type 2 case, these reservations will be configured statically by a management interface. In the type 3 case, these reservations will be created and torn down on demand, as end-to-end reservation requests come and go.

Packets that do not require reservations are encapsulated in the normal way, e. g. being wrapped with an IP header only, specifying the tunnel entry point as source and the exit point as destination.

Data packets that require resource reservations within a tunnel must have some attribute other than the IP addresses visible to the intermediate routers, so that the routers may map the packet to an appropriate reservation. To allow intermediate routers to use standard RSVP filterspec handling, we choose to encapsulate such data packets by prepending an IP and a UDP header, and to use UDP port numbers to distinguish packets of different RSVP sessions. The protocol number in the outer IP header in this case will be UDP.

Figure 1 shows RSVP operating over a tunnel. Rentry is the tunnel entry router which encapsulates data into the tunnel. Some number of intermediate routers forward the data across the network based upon the encapsulating IP header added by Rentry. Rexit is the endpoint of the tunnel. It decapsulates the data and forwards it based upon the original, "inner" IP header.

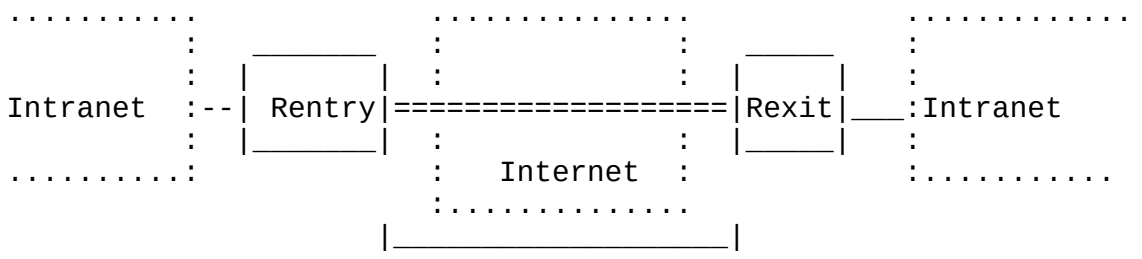


Figure 1. An example IP Tunnel

2.2.2. Mapping between End-to-End and Tunnel Sessions

Figure 2 shows a simple topology with a tunnel and a few hosts. The sending hosts H1 and H3 may be one or multiple IP hops away from Rentry; the receiving hosts H2 and H4 may also be either one or multiple IP hops away from Rexit.

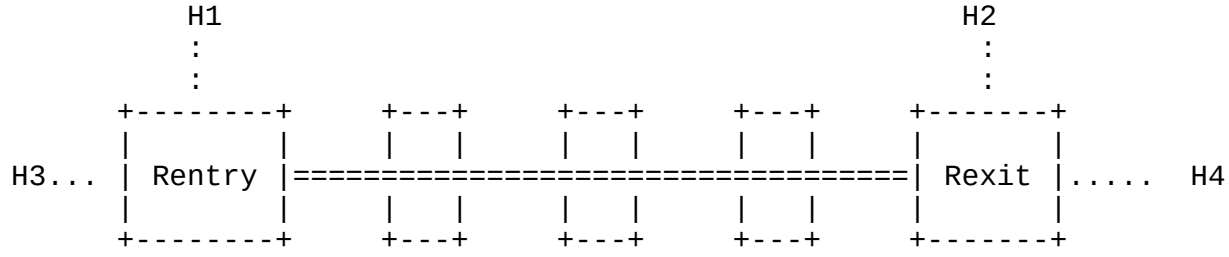


Figure 2: An example end-to-end path with a tunnel in the middle.

An RSVP session may be in place between endpoints at hosts H1 and H2. We refer to this session as the "end-to-end" (E2E for short) or "original" session, and to its PATH and RESV messages as the end-to-end messages. One or more RSVP sessions may be in place between Rentry and Rexit to provide resource reservation over the tunnel. We refer to these as the tunnel RSVP sessions, and to their PATH and RESV messages as the tunnel or tunneling messages. A tunnel RSVP session may exist independently from any end-to-end sessions. For example through network management interface one may create a RSVP session over the tunnel to provide QoS support for data flow from H3 to H4, although there is no end-to-end RSVP session between H3 and H4.

When an end-to-end RSVP session crosses a RSVP-capable tunnel, there are two cases to consider in designing mechanisms to support an end-to-end reservation over the tunnel: mapping the E2E session to an existing tunnel RSVP session (type 2 tunnel), and dynamically creating a new tunnel RSVP session for each end-to-end session (type

3 tunnel). In either case, the picture looks like a recursive application of RSVP. The tunnel RSVP session views the two tunnel endpoints as two end hosts with a unicast Fixed-Filter style reservation in between. The original, end-to-end RSVP session views the tunnel as a single (logical) link on the path between the source(s) and destination(s).

Note that in practice a tunnel may combine type 2 and type 3 characteristics. Some end-to-end RSVP sessions may trigger the creation of new tunnel sessions, while others may be mapped into an existing tunnel RSVP session. The choice of how an end-to-end session is treated at the tunnel is a matter of local policy.

When an end-to-end RSVP session crosses a RSVP-capable tunnel, it is necessary to coordinate the actions of the two RSVP sessions, to determine whether or when the tunnel RSVP session should be created and torn down, and to correctly transfer error and ADSPEC information between the two RSVP sessions. We made the following design decision:

* End-to-end RSVP control messages being forwarded through a tunnel are encapsulated in the same way as normal IP packets, e.g. being wrapped with the tunnel IP header only, specifying the tunnel entry point as source and the exit point as destination.

2.3. Major Issues

As IP-in-IP tunnels are being used more widely for network traffic management purposes, it is clear we must support type 2 tunnels (tunnel reservation for aggregate end-to-end sessions). Furthermore, these type 2 tunnels should allow more than one (configurable, static) reservation to be used at once, to support different traffic classes within the tunnel. Whether it is necessary to support type 3 tunnels (dynamic per end-to-end session tunnel reservation) is a policy issue that should be left open. Our design supports both cases.

If there is only one RSVP session configured over a tunnel, then all the end-to-end RSVP sessions (that are allowed to use this tunnel session) will be bound to this configured tunnel session. However when more than one RSVP session is in use over an IP tunnel, a second design issue is how the association, or binding, between an original RSVP reservation and a tunnel reservation is created and conveyed from one end of the tunnel to the other. The entry router Rentry and the exit router Rexit must agree on these associations so that

changes in the original reservation state can be correctly mapped into changes in the tunnel reservation state, and that errors reported by intermediate routers to the tunnel end points can be correctly transformed into errors reported by the tunnel endpoints to the end-to-end RSVP session.

We require that this same association mechanism work for both the case of bundled reservation over a tunnel (type 2 tunnel), and the case of one-to-one mapping between original and tunnel reservations (type 3 tunnel). In our scheme the association is created when a tunnel entry point first sees an end-to-end session's RESV message and either sets up a new tunnel session, or adds to an existing tunnel session. This new association must be conveyed to Rexit, so that Rexit can reserve resources for the end-to-end sessions inside the tunnel. This information includes the identifier and certain parameters of the tunnel session, and the identifier of the end-to-end session to which the tunnel session is being bound. In our scheme, all RSVP sessions between the same two routers Rentry and Rexit will have identical values for source IP address, destination IP address, and destination UDP port number. An individual session is identified primarily by the source port value.

We identified three possible choices for a binding mechanism:

1. Define a new RSVP message that is exchanged only between two tunnel end points to convey the binding information.
2. Define a new RSVP object to be attached to end-to-end PATH messages at Rentry, associating the end-to-end session with one of the tunnel sessions. This new object is interpreted by Rexit associating the end-to-end session with one of the tunnel sessions generated at Rentry.
3. Apply the same UDP encapsulation to the end-to-end PATH messages as to data packets of the session. When Rexit decapsulates the PATH message, it deduces the relation between the source UDP port used in the encapsulation and the RSVP session that is specified in the original PATH message.

The last approach above does not require any new design. However it requires additional resources to be reserved for PATH messages (since they are now subject to the tunnel reservation). It also requires a priori knowledge of whether Rexit supports RSVP over tunnels by UDP encapsulation. If Rentry encapsulates all the end-to-end PATH messages with the UDP encapsulation, but Rexit does not understand this encapsulation, then the encapsulated PATH messages will be lost at Rexit.

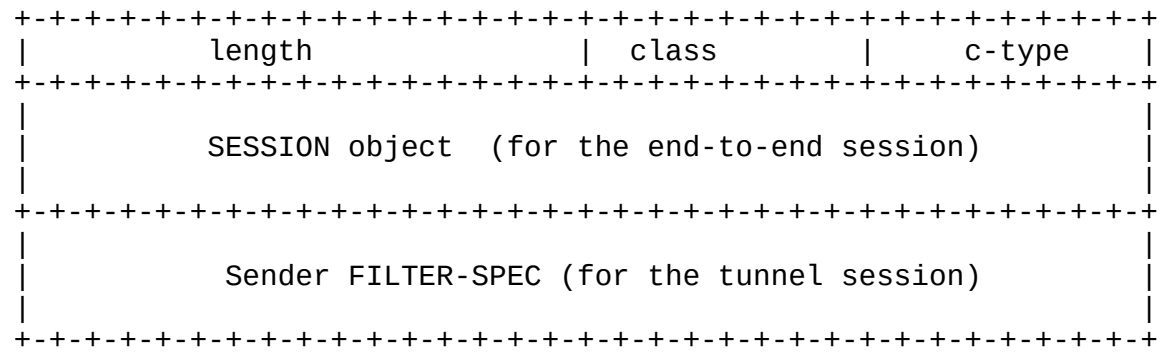
On the other hand, options (1) and (2) can handle this case transparently. They allow Rexit to pass on end-to-end PATHs received via the tunnel (because they are decapsulated normally), while throwing away the tunnel PATHs, all without any additional configuration. We chose Option (2) because it is simpler. We describe this object in the following section.

Packet exchanges must follow the following constraints:

1. Rentry encapsulates and sends end-to-end PATH messages over the tunnel to Rexit where they get decapsulated and forwarded downstream.
2. When a corresponding end-to-end RESV message arrives at Rexit, Rexit encapsulates it and sends it to Rentry.
3. Based on some or all of the information in the end-to-end PATH messages, the flowspec in the end-to-end RESV message and local policies, Rentry decides if and how to map the end-to-end session to a tunnel session.
4. If the end-to-end session should be mapped to a tunnel session, Rentry either sends a PATH message for a new tunnel session or updates an existing one.
5. Rentry sends a E2E Path containing a SESSION_ASSOC object associating the end-to-end session with the tunnel session above. Rexit records the association and removes the object before forwarding the Path message further.
6. Rexit responds to the tunnel PATH message by sending a tunnel RESV message, reserving resources inside the tunnel.
7. Rentry UDP-encapsulates arriving packets only if a corresponding tunnel session reservation is actually in place for the packets.

2.3.1. SESSION_ASSOC Object

The new object, called SESSION_ASSOC, is defined with the following format:



SESSION_ASSOC Object

Length

This field contains the size of the SESSION_ASSOC object in bytes.

Class

Should be 192.

Ctype

Should be sent as zero and ignored on receipt.

SESSION object

The end-to-end SESSION contained in the object is to be mapped to the tunnel session described by the Sender FILTER-SPEC defined below.

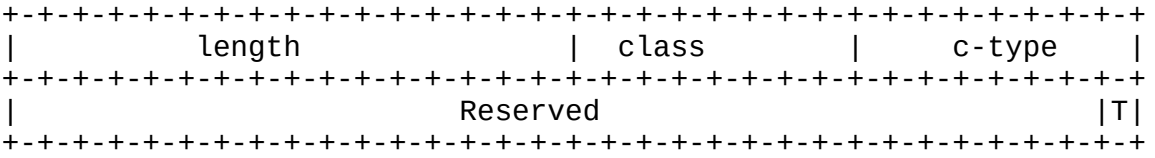
Sender FILTER-SPEC

This is the tunnel session that the above mentioned end-to-end session maps to over the tunnel. As we mentioned above, a tunnel session is identified primarily by source port. This is why we use a Sender Filter-Spec for the tunnel session, in the place of a SESSION object.

2.3.2. NODE_CHAR Object

There has to be a way (other than through configuration) for Rexit to communicate to Rentry the fact that it is a tunnel endpoint supporting the scheme described in this document. We have defined for this reason a new object, called NODE_CHAR, carrying this information. If a node receives this object but does not understand it, it should drop it without producing any error report. Objects with Class-Num = 10bbbbbb ('b' represents a bit), as defined in the RSVP specification [RFC2205], have the characteristics we need. While for now this object only carries one bit of information, it can be used in the future to describe other characteristics of an RSVP capable node that are not part of the original RSVP specification.

The object NODE_CHAR has the following format:



Length

This field contains the size of the NODE_CHAR object in bytes. It should be set to eight.

Class

An appropriate value should be assigned by the IANA. We propose this value to be 128.

Ctype

Should be sent as zero and ignored on receipt.

T bit

This bit shows that the node is a RSVP-tunnel capable node.

When Rexit receives an end-to-end reservation, it appends a NODE_CHAR object with the T bit set, to the RESV object, it encapsulates it and sends it to Rentry. When Rentry receives this RESV message it deduces that Rexit implements the mechanism described here and so it creates or adjusts a tunnel session and associates the tunnel session to the end-to-end session via a SESSION_ASSOC object. Rentry should remove the NODE_CHAR object, before forwarding the RESV message upstream. If

on the other hand, Rentry does not support the RSVP Tunnels mechanism it would simply ignore the NODE_CHAR object and not forward it further upstream.

3. Implementation

In this section we discuss several cases separately, starting from the simplest scenario and moving to the more complex ones.

3.1. Single Configured RSVP Session over an IP-in-IP Tunnel

Treating the two tunnel endpoints as a source and destination host, one easily sets up a FF-style reservation in between. Now the question is what kind of filterspec to use for the tunnel reservation, which directly relates to how packets get encapsulated over the tunnel. We discuss two cases below.

3.1.1. In the Absence of End-to-End RSVP Session

In the case where all the packets traversing a tunnel use the reserved resources, the current IP-in-IP encapsulation could be used. The RSVP session over the tunnel would simply specify a FF style reservation (with zero port number) with Rentry as the source address and Rexit as the destination address.

However if only some of the packets traversing the tunnel should benefit from the reservation, we must encapsulate the qualified packets in IP and UDP. This allows intermediate routers to use standard RSVP filterspec handling, without having to know about the existence of tunnels.

Rather than supporting both cases we choose to simplify implementations by requiring all data packets using reservations to be encapsulated with an outer IP and UDP header. This reduces special case checking and handling.

3.1.2. In the Presence of End-to-End RSVP Session(s)

According to the tunnel control policies, installed through some management interface, some or all end-to-end RSVP sessions may be allowed to map to the single RSVP session over the tunnel. In this case there is no need to provide dynamic binding information between end-to-end sessions and the tunnel session, given that the tunnel session is unique and pre-configured, and therefore well-known.

Binding multiple end-to-end sessions to one tunnel session, however, raises a new question of when and how the size of the tunnel reservation should be adjusted to accommodate the end-to-end sessions

mapped onto it. Again the tunnel manager makes such policy decision. Several scenarios are possible. In the first, the tunnel reservation is never adjusted. This makes the tunnel the rough equivalent of a fixed-capacity hardware link. In the second, the tunnel reservation is adjusted whenever a new end-to-end reservation arrives or an old one is torn down. In the third, the tunnel reservation is adjusted upwards or downwards occasionally, whenever the end-to-end reservation level has changed enough to warrant the adjustment. This trades off extra resource usage in the tunnel for reduced control traffic and overhead.

We call a tunnel whose reservation cannot be adjusted a "hard pipe", as opposed to a "soft pipe" where the amount of resources allocated is adjustable. Section 5.2 explains how the adjustment can be carried out for soft pipes.

3.2. Multiple Configured RSVP Sessions over an IP-in-IP Tunnel

It is straightforward to build on the case of a single configured RSVP session over a tunnel by setting up multiple FF-style reservations between the two tunnel endpoints using a management interface. In this case Rentry must carefully encapsulate data packets with the proper UDP port numbers, so that packets belonging to different tunnel sessions will be distinguished by the intermediate RSVP routers. Note that this case and the one described before describe what we call type 2 tunnels.

3.2.1. In the Absence of End-to-End RSVP Session

Nothing more needs to be said in this case. Rentry classifies the packets and encapsulates them accordingly. Packets with no reservations are encapsulated with an outer IP header only, while packets qualified for reservations are encapsulated with a UDP header as well as an IP header. The UDP source port value should be properly set to map to the corresponding tunnel reservation the packet is supposed to use.

3.2.2. In the Presence of End-to-End RSVP Session(s)

Since in this case, there is more than one RSVP session operating over the tunnel, one must explicitly bind each end-to-end RSVP session to its corresponding tunnel session. As discussed previously, this binding will be provided by the new SESSION_ASSOC object carried by the end-to-end PATH messages.

3.3. Dynamically Created Tunnel RSVP Sessions

This is the case of a type 3 tunnel. The only differences between this case and that of Section 4.2 are that:

- The tunnel session is created when a new end-to-end session shows up.
- There is a one-to-one mapping between the end-to-end and tunnel RSVP sessions, as opposed to possibly many-to-one mapping that is allowed in the case described in Section 4.2.

4. RSVP Messages handling over an IP-in-IP Tunnel

4.1. RSVP Messages for Configured Session(s) Over A Tunnel

Here one or more RSVP sessions are set up over a tunnel through a management interface. The session reservation parameters never change for a "hard pipe" tunnel. The reservation parameters may change for a "soft pipe" tunnel. Tunnel session PATH messages generated by Rentry are addressed to Rexit, where they are processed and deleted.

4.2. Handling of RSVP Messages at Tunnel Endpoints

4.2.1. Handling End-to-End PATH Messages at Rentry

When forwarding an end-to-end PATH message, a router acting as the tunnel entry point, Rentry, takes the following actions depending on the end-to-end session mentioned in the PATH message. There are two possible cases:

1. The end-to-end PATH message is a refresh of a previously known end-to-end session.
2. The end-to-end PATH message is from a new end-to-end session.

If the PATH message is a refresh of a previously known end-to-end session, then Rentry refreshes the Path state of the end-to-end session and checks to see if this session is mapped to a tunnel session. If this is the case, then when Rentry refreshes the end-to-end session, it includes in the end-to-end PATH message a SESSION_ASSOC object linking this session to its corresponding tunnel session It then encapsulates the end-to-end PATH message and sends it over the tunnel to Rexit. If the tunnel session was dynamically created, the end-to-end PATH message serves as a refresh for the local tunnel state at Rentry as well as for the end-to-end session.

Otherwise, if the PATH message is from a new end-to-end session that has not yet been mapped to a tunnel session, Rentry creates Path state for this new session setting the outgoing interface to be the tunnel interface. After that, Rentry encapsulates the PATH message and sends it to Rexit without adding a SESSION_ASSOC message.

When an end-to-end PATH TEAR is received by Rentry, this node encapsulates and forwards the message to Rexit. If this end-to-end session has a one-to-one mapping to a tunnel session or if this is the last one of the many end-to-end sessions mapping to a tunnel session, Rentry tears down the tunnel session by sending a PATH TEAR for that session to Rexit. If, on the other hand, there are remaining end-to-end sessions mapping to the tunnel session, then Rentry sends a tunnel PATH message adjusting the Tspec of the tunnel session.

4.2.2. Handling End-to-End PATH Messages at Rexit

Encapsulated end-to-end PATH messages are decapsulated and processed at Rexit. Depending on whether the end-to-end PATH message contains a SESSION_ASSOC object or not, Rexit takes the following steps:

1. If the end-to-end PATH message does not contain a SESSION_ASSOC object, then Rentry sets the Non_RSVP flag at the Path state stored for this end-to-end sender, sets the global break bit in the ADSPEC and forwards the packets downstream. Alternatively, if tunnel sessions exist and none of them has the Non_RSVP flag set, Rexit can pick the worst-case Path ADSPEC params from the existing tunnel sessions and update the end-to-end ADSPEC using these values. This is a conservative estimation of the composed ADSPEC but it has the benefit of avoiding to set the break bit in the end-to-end ADSPEC before mapping information is available. In this case the Non_RSVP flag at the end-to-end Path state is not set.

2. If the PATH message contains a SESSION_ASSOC object and no association for this end-to-end session already exists, then Rexit records the association between the end-to-end session and the tunnel session described by the object. If the end-to-end PATH arrives early before the tunnel PATH message arrives then it creates PATH state at Rexit for the tunnel session. When the actual PATH message for the tunnel session arrives it is treated as an update of the existing PATH state and it updates any information missing. We believe that this situation is another transient along with the others existing in RSVP and that it does not have any long-term effects on the correct operation of the mechanism described here.

Before further forwarding the message to the next hop along the path to the destination, Rexit finds the corresponding tunnel session's recorded state and turns on Non_RSVP flag in the end-to-end Path state if the Non_RSVP bit was turned on for the tunnel session. If the end-to-end PATH message carries an ADSPEC object, Rexit performs composition of the characterization parameters contained in the ADSPEC. It does this by considering the tunnel session's overall (composed) characterization parameters as the local parameters for the logical link implemented by the tunnel, and composing these parameters with those in the end-to-end ADSPEC by executing each parameter's defined composition function. In the logical link's characterization parameters, the minimum path latency may take into account the encapsulation/decapsulation delay and the bandwidth estimate can represent the decrease in available bandwidth caused by the addition of the extra UDP header. ADSPECs and composition functions are discussed in great detail in [RFC2210].

If the end-to-end session has reservation state, while no reservation state for the matching tunnel session exists, Rexit send a tunnel RESV message to Rentry matching the reservation in the end-to-end session.

If Rentry does not support RSVP tunneling, then Rexit will have no PATH state for the tunnel. In this case Rexit simply turns on the global break bit in the decapsulated end-to-end PATH message and forwards it.

4.2.3. Handling End-to-End RESV Messages at Rexit

When forwarding a RESV message upstream, a router serving as the exit router, Rexit, may discover that one of the upstream interfaces is a tunnel. In this case the router performs a number of tests.

Step 1: Rexit must determine if there is a tunnel session bound to the end-to-end session given in the RESV message. If not, the tunnel is treated as a non-RSVP link, Rexit appends a NODE_CHAR object with the T bit set, to the RESV message and forwards it over the tunnel interface (where it is encapsulated as a normal IP datagram and forwarded towards Rentry).

Step 2: If a bound tunnel session is found, Rexit checks to see if a reservation is already in place for the tunnel session bound to the end-to-end session given in the RESV message. If the arriving end-to-end RESV message is a refresh of existing RESV state, then Rexit sends the original RESV through tunnel interface (after adding the NODE_CHAR object). For dynamic tunnel sessions, the end-to-end RESV

message acts as a refresh for the tunnel session reservation state, while for configured tunnel sessions, reservation state never expires.

If the arriving end-to-end RESV message causes a change in the end-to-end RESV flowspec parameters, it may also trigger an attempt to change the tunnel session's flowspec parameters. In this case Rexit sends a tunnel session RESV, including a RESV_CONFIRM object.

In the case of a "hard pipe" tunnel, a new end-to-end reservation or change in the level of resources requested by an existing reservation may cause the total resource level needed by the end-to-end reservations to exceed the level of resources reserved by the tunnel reservation. This event should be treated as an admission control failure, identically to the case where RSVP requests exceed the level of resources available over a hardware link. A RESV_ERR message with Error Code set to 01 (Admission Control failure), should be sent back to the originator of the end-to-end RESV message.

If a RESV CONFIRM response arrives, the original RESV is encapsulated and sent through the tunnel. If the updated tunnel reservation fails, Rexit must send a RESV ERR to the originator of the end-to-end RESV message, using the error code and value fields from the ERROR_SPEC object of the received tunnel session RESV ERR message. Note that the pre-existing reservations through the tunnel stay in place. Rexit continues refreshing the tunnel RESV using the old flowspec.

Tunnel session state for a "soft pipe" may also be adjusted when an end-to-end reservation is deleted. The tunnel session gets reduced whenever one of the end-to-end sessions using the tunnel goes away (or gets reduced itself). However even when the last end-to-end session bound to that tunnel goes away, the configured tunnel session remains active, perhaps with a configured minimal flowspec.

Note that it will often be appropriate to use some hysteresis in the adjustment of the tunnel reservation parameters, rather than adjusting the tunnel reservation up and down with each arriving or departing end-to-end reservation. Doing this will require the tunnel exit router to keep track of the resources allocated to the tunnel (the tunnel flowspec) and the resources actually in use by end-to-end reservations (the sum or statistical sum of the end-to-end reservation flowspecs) separately.

When an end-to-end RESV TEAR is received by Rexit, it encapsulates and forwards the message to Rentry. If the end-to-end session had created a dynamic tunnel session, then a RESV TEAR for the corresponding tunnel session is send by Rexit.

4.2.4. Handling of End-to-End RESV Messages at Rentry.

If the RESV message received is a refresh of an existing reservation then Rentry updates the reservation state and forwards the message upstream. On the other hand, if this is the first RESV message for this end-to-end session and a NODE_CHAR object with the T bit set is present, Rentry should initiate the mapping between this end-to-end session and some (possibly new) tunnel session. This mapping is based on some or all of the contents of the end-to-end PATH message, the contents of the end-to-end RESV message, and local policies. For example, there could be different tunnel sessions based on the bandwidth or delay requirements of end-to-end sessions)

If Rentry decides that this end-to-end session should be mapped to an existing configured tunnel session, it binds this end-to-end session to that tunnel session.

If this end-to-end RSVP session is allowed to set up a new tunnel session, Rentry sets up tunnel session PATH state as if it were a source of data by starting to send tunnel-session PATH messages to Rexit, which is treated as the unicast destination of the data. The Tspec in this new PATH message is computed from the original PATH message by adjusting the Tspec parameters to include the tunnel overhead of the encapsulation of data packets. In this case Rentry should also send a PATH message from the end-to-end session this time containing the SESSION_ASSOC object linking the two sessions. The receipt of this PATH message by Rexit will trigger an update of the end-to-end Path state which in turn will have the effect of Rexit sending a tunnel RESV message, allocating resources inside the tunnel.

The last case is when the end-to-end session is not allowed to use the tunnel resources. In this case no association is created between this end-to-end session and a tunnel session and no new tunnel session is created.

One limitation of our scheme is that the first RESV message of an end-to-end session determines the mapping between that end-to-end session and its corresponding session over the tunnel. Moreover as long as the reservation is active this mapping cannot change.

5. Forwarding Data

When data packets arrive at the tunnel entry point Rentry, Rentry must decide whether to forward the packets using the normal IP-in-IP tunnel encapsulation or the IP+UDP encapsulation expected by the tunnel session. This decision is made by determining whether there is a resource reservation (not just PATH state) actually in place for the tunnel session bound to the arriving packet, that is, whether the packet matches any active filterspec.

If a reservation is in place, it means that both Rentry and Rexit are RSVP-tunneling aware routers, and the data will be correctly decapsulated at Rexit.

If no tunnel session reservation is in place, the data should be encapsulated in the tunnel's normal format, regardless of whether end-to-end PATH state covering the data is present.

6. Details

6.1. Selecting UDP port numbers

There may be multiple end-to-end RSVP sessions between the two end points Rentry and Rexit. These sessions are distinguished by the source UDP port. Other components of the session ID, the source and destination IP addresses and the destination UDP port, are identical for all such sessions.

The source UDP port is chosen by the tunnel entry point Rentry when it establishes the initial PATH state for a new tunnel session. The source UDP port associated with the new session is then conveyed to Rexit by the SESSION_ASSOC object.

The destination UDP port used in tunnel sessions should the one assigned by IANA (363).

6.2. Error Reporting

When a tunnel session PATH message encounters an error, it is reported back to Rentry. Rentry must relay the error report back to the original source of the end-to-end session.

When a tunnel session RESV request fails, an error message is returned to Rexit. Rexit must treat this as an error in crossing the logical link (the tunnel) and forward the error message back to the end host.

6.3. MTU Discovery

Since the UDP encapsulated packets should not be fragmented, tunnel entry routers must support tunnel MTU discovery as discussed in section 5.1 of [IP4INIP4]. Alternatively, the Path MTU Discovery mechanism discussed in RFC 2210 [RFC2210] can be used.

6.4. Tspec and Flowspec Calculations

As multiple End-to-End sessions can be mapped to a single tunnel session, there is the need to compute the aggregate Tspec of all the senders of those End-to-End sessions. This aggregate Tspec will the Tspec of the representative tunnel session. The same operation needs to be performed for flowspecs of End-to-End reservations arriving at Rexit.

The semantics of these operations are not addressed here. The simplest way to do them is to compute a sum of the end-to-end Tspecs, as is defined in the specifications of the Controlled-Load and Guaranteed services (found at [RFC2211] and [RFC2212] respectively). However, it may also be appropriate to compute the aggregate reservation level for the tunnel using a more sophisticated statistical or measurement-based computation.

7. IPSEC Tunnels

In the case where the IP-in-IP tunnel supports IPSEC (especially ESP in Tunnel-Mode with or without AH) then the Tunnel Session uses the GPI SESSION and GPI SENDER_TEMPLATE/FILTER_SPEC as defined in [RSVPESP] for the PATH and RESV messages.

Data packets are not encapsulated with a UDP header since the SPI can be used by the intermediate nodes for classification purposes. Notice that user oriented keying must be used between Rentry and Rexit, so that different SPIs are assigned to data packets that have reservation and "best effort" packets, as well as packets that belong to different Tunnel Sessions if those are supported.

8. RSVP Support for Multicast and Multipoint Tunnels

The mechanisms described above are useful for unicast tunnels. Unicast tunnels provide logical point-to-point links in the IP infrastructure, though they may encapsulate and carry either unicast or multicast traffic between those points.

Two other types of tunnels may be imagined. The first of these is a "multicast" tunnel. In this type of tunnel, packets arriving at an entry point are encapsulated and transported (multicast) to -all- of the exit points. This sort of tunnel might prove useful for implementing a hierarchical multicast distribution network, or for emulating efficiently some portion of a native multicast distribution tree.

A second possible type of tunnel is the "multipoint" tunnel. In this type of tunnel, packets arriving at an entry point are normally encapsulated and transported to -one- of the exit points, according to some route selection algorithm.

This type of tunnel differs from all previous types in that the ’ shape’ of the usual data distribution path does not match the ’shape’ of the tunnel. The topology of the tunnel does not by itself define the data transmission function that the tunnel performs. Instead, the tunnel becomes a way to express some shared property of the set of connected tunnel endpoints. For example, the "tunnel" may be used to create and embed a logical shared broadcast network within some larger network. In this case the tunnel endpoints are the nodes connected to the logical shared broadcast network. Data traffic may be unicast between two such nodes, broadcast to all connected nodes, or multicast between some subset of the connected nodes. The tunnel itself is used to define a domain in which to manage routing and resource management - essentially a virtual private network.

Note that while a VPN of this form can always be implemented using a multicast tunnel to emulate the broadcast medium, this approach will be very inefficient in the case of wide area VPNs, and a multipoint tunnel with appropriate control mechanisms will be preferable.

The following paragraphs provide some brief commentary on the use of RSVP in these situations. Future versions of this note will provide more concrete details and specifications.

Using RSVP to provide resource management over a multicast tunnel is relatively straightforward. As in the unicast case, one or more RSVP sessions may be used, and end-to-end RSVP sessions may be mapped onto tunnel RSVP sessions on a many-to-one or one-to-one basis. Unlike the unicast, case, however, the mapping is complicated by RSVP’s heterogeneity semantics. If different receivers have made different reservation requests, it may be that the RESV messages arriving at the tunnel would logically map the receiver’s requests to different tunnel sessions. Since the data can actually be placed into only one session, the choice of session must be reconciled (merged) to select the one that will meet the needs of all applications. This requires a relatively simple extension to the session mapping mechanism.

Use of RSVP to support multipoint tunnels is somewhat more difficult. In this case, the goal is to give the tunnel as a whole a specific level of resources. For example, we may wish to emulate a "logical shared 10 megabit Ethernet" rather than a "logical shared Ethernet". However, the problem is complicated by the fact that in this type of tunnel the data does not always go to all tunnel endpoints. This implies that we cannot use the destination address of the encapsulated packets as part of the packet classification filter, because the destination address will vary for different packets within the tunnel.

This implies the need for an extension to current RSVP session semantics in which the Session ID (destination IP address) is used -only- to identify the session state within network nodes, but is not used to classify packets. Other than this, the use of RSVP for multipoint tunnels follows that of multicast tunnels. A multicast group is created to represent the set of nodes that are tunnel endpoints, and one or more tunnel RSVP sessions are created to reserve resources for the encapsulated packets. In the case of a tunnel implementing a simple VPN, it is most likely that there will be one session to reserve resources for the whole VPN. Each tunnel endpoint will participate both as a source of PATH messages and a source of (FF or SE) RESV messages for this single session, effectively creating a single shared reservation for the entire logical shared medium. Tunnel endpoints MUST NOT make wildcard reservations over multipoint tunnels.

9. Extensions to the RSVP/Routing Interface

The RSVP specification [RFC2205] states that through the RSVP/Routing Interface, the RSVP daemon must be able to learn the list of local interfaces along with their IP addresses. In the RSVP Tunnels case, the RSVP daemon needs also to learn which of the local interface(s) is (are) IP-in-IP tunnel(s) having the capabilities described here. The RSVP daemon can acquire this information, either by directly querying the underlying network and physical layers or by using any existing interface between RSVP and the routing protocol properly extended to provide this information.

10. Security Considerations

The introduction of RSVP Tunnels raises no new security issues other than those associated with the use of RSVP and tunnels. Regarding RSVP, the major issue is the need to control and authenticate access to enhanced qualities of service. This requirement is discussed further in [RFC2205]. [RSVPCRYPTO] describes the mechanism used to protect the integrity of RSVP messages carrying the information described here. The security issues associated with IP-in-IP tunnels are discussed in [IPINIP4] and [IPV6GEN].

11. IANA Considerations

IANA should assign a Class number for the NODE_CHAR object defined in Section 3.3.2. This number should be in the 10bbbbbb range. The suggested value is 128.

12. Acknowledgments

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