The application of RSVP

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Abstract

Resource reservation protocol (RSVP) introduces quality of service signaling in IP networks. It is a part of the integrated services (int-serv) framework. In this document the use of RSVP for different types of traffic and connections over different kinds of network technology is studied. Also, scalability issues of RSVP are discussed.

Introduction

The original internet service model is very simple and it does not provide any support for quality of service (QoS) or bandwidth sharing in the network. The Integrated Services, described in RFC 1633 [2] proposes some extensions to the service model, to support also real-time services. Resource ReSerVation Protocol (RSVP), described in RFC 2205 [1] is a part of this concept. RSVP is used by hosts to request specific QoS from the network for particular application data streams (flows) and by routers to deliver QoS requests to all nodes along the path(s) of the flows. Provided that the nodes can handle reservations, and the resources are available, the resources are reserved in each node along the data path.

QoS in internet is not yet widely used, but of the approaches so far, RSVP/int-serv seems currently to be the most widely used. RSVP sets up QoS on per flow basis, i.e. for the applications that need it. Although RSVP is closely related to int-serv, it may also be used in non-int-serv-compliant networks.

There are also other suggestions for reservation protocols. An other approach than to use reservations is to rely on priorities, either (more or less) permanently configured by network management, or on per-packet base as in diff-serv [3]. The main difference between int-serv and diff-serv is that latter does not require per flow state in the network components. (The details of diff-serv are not considered here). Yet, another possibility, particularly for LANs, is to simple buy enough bandwidth.

If for example RSVP is used, quality guarantees cannot in general be given, if not every node on the path is either RSVP-compliant, or there is some means to translate the QoS requirements between the RSVP and non-RSVP parts. However, similar problems exist independently of which approach is chosen.

The first chapter handles application and service types and the second chapter connection configurations, reservation styles and scalability issues. Chapter 3 outlines the use of RSVP on different network technology and chapter 4 QoS on end-to-end traffic.

1. Applications and service types

1.1. *Real-time- and elastic applications*

The applications in Integrated Services architecture [2] are divided into real-time applications and elastic applications. Elastic applications are the typical ones for internet: Telnet, FTP, X etc. Real-time applications, in turn are described as either intolerant or tolerant, depending on their sensitivity to loss of fidelity. Elastic applications (e.g. ftp) are typically not very sensitive to delay but require error-free transfer. With typical real-time applications the situation is reversed. Some erroneous or lost data may be tolerated, but data must be delivered on time. In [4] it is stated that speech is understandable with up to 13% - 15% packet loss.

Because of the extra signaling required by RSVP, reservations are not worth the effort for flows with a very short lifetime, like typical web browsing.

1.2. *Types of real-time applications*

Real-time communication, which generally means audio and/or video, may be divided into playback applications and interactive applications. For interactive applications, the end-to-end delay is significant, e.g. for internet phone it should rather not exceed 0,3 s. For playback application, where the communication is only in one direction, delay as such is not critical, but jitter may be. [2] classifies real-time applications into rigid and adaptive applications. Rigid applications have a fixed playback point. Adaptive applications move the playback point so that the signal is replayed as soon as possible while the data loss rate is acceptable. Thus, adaptive playback applications work well on moderately loaded datagram networks. The bandwidth requirement may not be fixed, but some "rate-adaptive" playback applications may change their coding scheme according to network service available.

1.3. *Guaranteed service*

Guaranteed service is used by rigid intolerant applications. It provides a firm bound on delay and no packet loss for a flow that conforms to its token bucket specification. Guaranteed service does not attempt to minimize jitter. It merely controls the maximum queuing delay, enabling the application to set its playback point so that all packets arrive in time.

It is believed that this estimated total worst-case delay is not well suited as a quantitative guarantee. First, it is difficult to estimate upper limits on delay in a network element. Unexpected delays cannot be estimated, resulting in overly optimistic worst-case delays and possible violation of reservations. Second, it is in some cases impossible to control link layer queuing or to estimate delay bounds for link layer elements. On most legacy LANs, it is impossible to provide service guarantees. Third, the total worst-case delay of the path is the sum of the individual worst-case delays. Although it is very unlikely that a packet experiences worst-case delay in all network elements, a guarantee must take this case into account. The total worst-case delay can easily add up to several seconds.

1.4. Controlled load service

Controlled load service is the service designed for adaptive, tolerant applications. No quantitative guarantees are given, but the service under overload is about as good as best-effort service on a lightly loaded network.

A client provides the network with the token bucket specification of the traffic it will generate. The network ensures that enough resources will be available for that flow, as long as the flow conforms to the specification. Queuing delays are not significantly larger than the time it takes to clear a maximum burst at the requested transmission rate.

1.5. Implementation of traffic control

In addition to the *reservation setup protocol*, the reference implementation framework proposed in [2] includes three other components: the *packet scheduler*, the *admission control* routine and the *classifier*. These three components implement the *traffic control*.

The packet scheduler manages the forwarding of different packet streams using a set of queues and other mechanisms like timers. It is implemented at the output driver level and corresponds to the link layer protocol. The details of the scheduling algorithm may be specific to the particular output medium.

The classifier maps the incoming packets into different classes, according to parameters in the protocol headers, incoming ports, etc. The implementation of the classes are local to the router.

Admission control implements the decision algorithm that a router or host uses to determine whether a new flow can be granted the requested QoS without impacting guarantees. The admission control algorithm must be consistent with the service model.

The scheduling algorithms and queuing mechanisms vary between routers. One possible implementation framework is given by the Integrated Services working group [2]. Weighted fair queuing (WFQ) is used to isolate flows from each other. Each WFQ flow has a separate queue and packets are scheduled so that each flow receives a constant fraction of the link bandwidth during congestion.

Weighted round robin is only fair in terms of packets sent by each flow, not in terms of bandwidth used by each flow. For that reason, weighted round robin cannot be used to isolate flows[4].

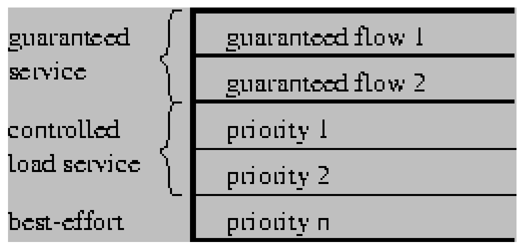

Figure 1: Hierarchical traffic control

At the top level, each guaranteed service flow gets its own WFQ queue. Thus, guaranteed flows are strictly separated from each other and from the rest of the traffic. All other traffic is assigned to a pseudo WFQ flow.

2. Reservation styles and scalability

1.6. Reservation styles

The following styles are currently defined in [1]:

- Wildcard-Filter (WF) Style

A WF-style reservation creates a single reservation shared by flows from all upstream senders. The reservation is propagated upstream towards all sender hosts, and it automatically extends to new senders as they appear. Symbolically, a WF-style reservation request can be represent by:

WF(* {Q})

where the asterisk represents wildcard sender selection and Q represents the flowspec.

- Fixed-Filter (FF) Style

An FF-style reservation request creates a distinct reservation for data packets from a particular sender, not sharing them with other senders' packets for the same session. The representation for an elementary FF reservation request is:

FF(S{Q})

where S is the selected sender. RSVP allows multiple elementary FF-style reservations to be requested at the same time, using a list of flow descriptors:

FF(S1{Q1}, S2{Q2}, ...)

The total reservation on a link for a given session is the `sum' of Q1, Q2, ... for all requested senders.

- Shared Explicit (SE) Style

An SE-style reservation creates a single reservation shared by selected upstream senders. Unlike the WF style, the SE style allows a receiver to explicitly specify the set of senders to be included. An SE reservation request can be represented by:

SE((S1,S2,...){Q})

where Q is a flowspec and S1, S2, ... a list of senders.

The RSVP rules disallow merging of different reservation styles, because they are either fundamentally incompatible or may lead to problems.

1.7. Scalability

WF and SE style reservations are appropriate for multicast applications in which multiple data sources are unlikely to transmit simultaneously, for example an audio conference. Each receiver might issue a WF or SE reservation request for twice the bandwidth required for one sender (to allow some over-speaking). The FF style, which creates distinct reservations for the flows from different senders, is appropriate for simultaneous video signals.

Because of the different reservation styles, the amount of control traffic in RSVP and reservation state scales better than linearly with the number of senders in large multicast sessions. In multicast sessions the PATH message is also sent as a multicast message. RESV messages from the receivers on the branch for the same flow are merged at the network node, so that only one RESV message is sent upstream. Thus, RSVP also scales better than linearly with the number of receivers in a session.

A minor drawback is that the reservation assumes that the flowspec in a multicast session is the same for all senders in a session. If some of the senders sends at a slower bitrate, network bandwidth will be wasted for a while [16].

Another scaling issue is the overhead for a large number of multicast sessions. The number of RSVP control messages processed by each router is proportional to the number of QoS flows going through the router. Reservation state is kept on a per-flow basis. Thus, managing state and processing control messages scales linearly with the number of flows. RSVP messages are sent quite infrequently, typically once per 30 s. The protocol is neither more complicated as typical routing protocols.

Classifying each packet onto the right flow may require much processing of the routers, especially as they have to look far into the packet. In addition to the routing itself, the packets should in any case be checked for policy and security, at least in some routers, especially as internet is becoming more and more commercialized. If the packets were classified strictly on priority basis, without any flow state information, the router would anyhow have to check TOS bits and some other fields and check these against the priority specified. The granularity of such approaches without RSVP may also be more inexact. Taken all this into account, wider implementation of RSVP should not be an impossible task, at least as long as not a large part of the traffic consists of QoS flows.

3. RSVP on different network technologies

Internet is not one network, but connections usually span over several networks of different technologies, for which IP traffic may be one information type among others. Thus, when new concepts like resource reservations are introduced in internet, the underlying technologies have to be taken into account. The different networks are also standardized by different bodies.

For resource reservation, link layer switches also need to have bandwidth allocators that keep track of reservations. A protocol is needed so bandwidth allocators can talk to each other. A requester module provides the interface between a layer 3 reservation protocol (such as RSVP) and the bandwidth allocator.

1.1. Ethernet

It is obvious that shared media with CSMA/CD access protocols cannot provide any service guarantees. CSMA/CD makes it impossible to predict when and how much a station will be able to send. The current trend in ethernet networking is ``micro-segmentation'', where each host has its own ethernet segment. This increases the bandwidth available for each host. However, without priorities, reserved and unreserved flows cannot be separated.

The IEEE is currently working on standards for expedited traffic classes in bridges/switches. The proposed standard requires three priority bits in the ethernet frame header. On shared ethernets with priority, at least some statistical guarantees can be given. To provide deterministic guarantees, ethernet would have to be deployed in a switched full duplex topology with priority. This means that there are only two devices on a segment, the host and the bridge/switch, and there is no access contention.

1.1. FDDI and Token ring

FDDI and token ring offer priorities in their current form. Thus, they have the potential to support QoS guarantees. The ISSLL working group (Integrated Services on Specific Link Layers) in the IETF describes a framework in [5]. To use this potential in subnetworks, a mechanism is needed. The local admission control entity within a client is responsible for mapping these layer-3 session-establishment requests into layer-2 language. The upper-layer entity makes a request, in generalized terms to ISSLL with sender TSpec, flowspec and source and destination IP addresses as parameters.

1.2. Frame Relay, SDMS

A router knows the capacity of the physical link, but it is not aware of the service contract with the frame-relay network. ([4]) Each frame relay PVC has a CIR (Committed Information Rate) associated with it. The network will give priority treatment to this amount of bandwidth. Traffic exceeding the CIR is marked ``discard-eligible''. The portion of reserved traffic that exceeds the CIR is likely to be dropped, violating the reservations. Integrated Services routers will need some kind of CIR discovery to avoid this disastrous situation. Link layer queuing delays in frame relay switches are not under control of any network layer mechanism. The CIR is not a 100% bandwidth guarantee. This means that Integrated Services network elements cannot control all queuing delays and packet losses. They can't even estimate the delays, because they don't see link layer switches. In the case of guarantees service, this will either result in under-estimated total delay estimates (if delay in the frame relay switch is not taken into account) or in over-estimated worst-case estimates (if the worst-case delay of the frame relay switch is taken into account). For controlled load queuing at frame relay switches can cause significant delay variation.

A similar problem arises with centralized switched technologies like SMDS (Switched Multimegabit Data Service). The way switches deal with temporary overload is queuing.

1.3. ATM

There are some basic differences between the RSVP/int-serv model and ATM [6]. In RSVP the quality requirements are stated by the receiver, from which RESV messages are sent through the routers among the path against the sender. In ATM, the sender requests the required QoS. This is not a main problem, because in RSVP the sender also sends the TSpec. In ATM the reservations are also explicitly done for a VC at the connection setup, and are maintained until the connection is released, whereas in the RSVP concept, the routers starts a timer, which must be continuously updated with PATH and RESV messages. If the messages are left out, and the timer expires, the resources are freed for other connections. The update requirement means also, that applications can change their QoS dynamically, whereas the reservations by ATM are static over the duration for the connection.

In ATM, VCs are also set up between the sender and the receiver, and is not later possible to be shared by other receivers of the same data flow. RSVP allows more than one receivers of the same dataflow to share the same bandwidth (multicast and broadcast connections). RSVP is also assigned with heterogeneity of applications in mind. The differences are summarized in table 1.

Table 1: RSVP vs. ATM

	RSVP	ATM
QoS is requested	by receiver	by sender
Reservation is	separated from routing	concurrently with VC-setup
variable QoS	dynamic	static
connection management	dynamic (soft states)	static (hard states)
reservation styles	fixed and shared	fixed
heterogenity	supported	not supported
scalability	merging	?

There are two traditional ways to carry IP over ATM, classical IP (CLIP) and LAN emulation (LANE). CLIP does not provide access to ATM QoS. LANE version 2 provides some QoS access inside an ELAN.

In cases where there are several logical IP-subnetworks (LIS) (or ELANs) supported in the same ATM network, there is a QoS problem. As the path is setup between the sender and receiver on hop-by-hop basis, it may not pass directly through the ATM network, but through several routers of the different LISes. Figure 2 outlines the problem. This would be a vast of resources both in the ATM switches and in the routers, and also cause unnecessary extra delays. To overcome this problem, shortcut methods over the ATM network should be used, which mean that ATM establishes direct connections between the incoming and outgoing routers, as the traffic exceeds some pre-defined treshold.

In ATM any common standard multicast solution doesn't

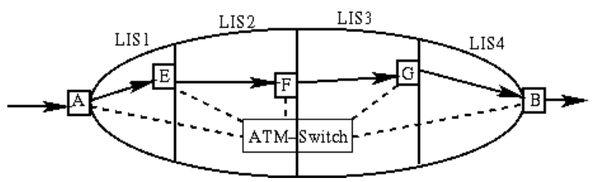

Figure 2. Flow through several LISes in ATM

exist. Possibilities are at least MARS, where a multicast server is used, and the FORE-specific SPANS protocol. Point-to-multipoint connections can, however, be used by RSVP. Suppose there is a connection between A and B in figure 3. If a RESV message is received from C, A could add this to the multicast session using the ADD-PARTY message. However, each leaf would get the same QoS, which is in conflict with the heterogenity requirement of RSVP.

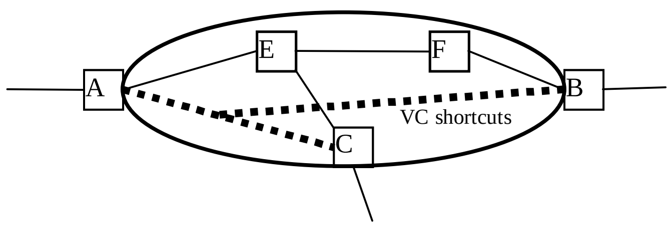

Figure 3 Point-to-multipoint session

In table 2 the correspondence between the int-serv and ATM service classes are outlined.

Table 2: Classes and values

Integrated services class	*ATM Service Class*
Guaranteed service	CBR or rt-VBR
Controlled Load	nrt-VBR or ABR (with MCR)
Best effort	UBR or ABR

The ATM trafic descriptor values should be within the following bounds [15]:

RSpec <= PCR <= min peak rate or min line rate
Receiver TSpec <= SCR <= PCR
0 <= MBS <= bucket depth

(PCR = peak cell rate, SCR = sustained cell rate, MBS = maximum burst size).

1.4. IPSOFACTO

IPSOFACTO is architecture to combine an IP router with an ATM switch [7, 8, and 9].

IP control messages are never switched in IPSOFACTO but are sent and received on a predefined control VC and will therefore be forwarded through the switch controller. As a result of processing these control messages, a per-flow forwarding state is established. The RECV messages trigger a call admission procedure at the controller followed by mapping the IP flow to an appropriate cell-level QoS within each switch. The merging of RSVP requests as well as QoS renegotiations by local modification of ATM-level traffic shapers is possible.

IPSOFACTO supports IP multicast, which is a fundamental requirement for efficient RSVP-based service provision. The direct use of IP multicast protocols on top of ATM entirely eliminates the need for complex protocols emulating a broadcast network on top of a non-broadcast multiple access (NBMA) networks.

Currently, the mapping of RSVP over IPSOFACTO still suffers some limitations. First, the GSMP protocol, which is used to control the ATM hardware, has not yet any support for QoS. Second, only a limited support of RSVP reservation styles is possible, due to the lack of multipoint-to-point VC in the ATM hardware. Third, the receiver heterogeneity needs to be limited to avoid exhaustion of the VC space and excessive amounts of identical data travelling on different VCs.

NEC and GMD Fokus have implemented RSVP on IPSOFACTO, with different classes from the Int-serv model appropriately mapped to ATM traffic classes. Thus, the ATM cell-scheduling hardware is used to provide QoS guarantees to IP flows.

1.5. Low speed links

Real-time applications over slow links such as modem or ISDN links are addressed in the ISSLOW architecture [10]. There are at least three problems:

- the amount of overhead in the protocols; for example HDLC/PPP - IP - UDP - RTP: 44 bytes
- the long delay, 1500 bytes packet at 28.8 kbit/s takes 400 ms
- negotiation protocols between routers (or hops and routers)

A compression algorithm for Ipv6 has been developed by Degermark et. Al [11], which compresses successive IP headers. An other compression scheme is described by Casper and Jacobson [12], which acts on IP/UDP/RTP. Both operate on hop-by-hop.

RFC 1990 [13] describes a multilink mode of the PPP-protocol that allows sharing bandwidth between applications. The peer routers/hosts can decide which real-time packet streams are to be compressed, which header fields are not to be sent at all, which multiplexing information should be used on the link, and how the remaining header fields should be encoded.

The compressor can operate best if it can make use of information that clearly identifies real-time streams and provides information about the payload data format in use. Sources of real-time information flows are already describing characteristics of these flows to their kernels and to the routers in the form of TSpecs in RSVP PATH messages.

Main components of isslow are:

- a real-time encapsulation format for asynchronous and synchronous low-bitrate links,
- a header compression architecture optimized for real-time flows,
- elements of negotiation protocols used between routers (or between hosts and routers), and
- announcement protocols used by applications to allow this negotiation to take place.

Additional RSVP objects could be defined that are included in PATH messages by those applications that desire good performance over low-bitrate links. Cooperation from PPP is also needed to negotiate the use of real-time encapsulations between systems.

4. End-to-end QoS provision

1.6. Non-RSVP clouds

If the backbone network does not support RSVP (as it usually doesn't), it can be treated as a non-RSVP cloud. On such cases absolute guarantees cannot be given, but if enough bandwidth is available or the flow could be signed an appropriate QoS level in advance, quality will be sufficient for most cases. The RSVP messages pass through the non-RSVP cloud unmodified and arrive at the first RSVP-complaint node.

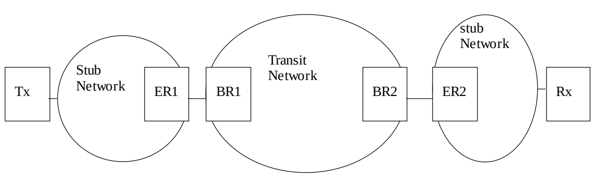

Figure 6. Network with int-serv and diff-serv regions

1.7. RSVP and Diff-serv networks

A special case of a non-RSVP cloud is a differentiated services compliant network. Figure 6 shows a sample network configuration where (at least some of the routers in) the stub networks are int-serv capable and (at least some of the routers in) the transit network diff-serv capable [14].

Within the int-serv regions QoS applications to invoke specific end-to-end service levels by using RSVP signaling to configure 'MF' classifiers which operate on IP addresses and port numbers. Within the diff-serv regions of the network, traffic is allotted service based on the contents of the DS-field in packet headers. Therefore, it is necessary to mark DS-fields before their packets are submitted to the diff-serv network. This can be done by the host itself, or by some router external to the diff-serv network may mark DS-fields on behalf of QoS applications based on MF classification.

End-to-end QoS requires that quantitative QoS applications and RSVP capable int-serv nodes be explicitly informed of admission control failure in the diff-serv network. This enables them to take corrective action and to avoid overdriving the diff-serv network.

The edge routers are special routers at the boundary between the RSVP/int-serv region and the diff-serv region can be modeled as consisting of two halves, the standard RSVP half and the diff-serv half. The RSVP half is at least partially RSVP capable; it is able to process PATH and RESV messages but it is not necessarily required to store full RSVP state and it is not required to provide MF classification. The diff-serv half of the router provides the interface to the admission control function in the diff-serv region.

The transit network is not capable of per-flow identification, signaling, and admission control. It provides two or more levels of service based on the DS-field in the packet headers. It also carries RSVP messages transparently.

Two possible schemes are proposed for mapping of int-serv - to - diff-serv service levels, static, "default mapping" (well-known mapping) and "customer-specified-mapping" where the edge devices of the diff-serv region may modify the well-known mapping.

End-to-end QoS is established as follows:
1. The RSVP PATH message is sent normally from the sender towards ER1. Standard RSVP processing will be applied at the RSVP capable nodes. The PATH state is installed at ER1.
2. The PATH message is sent transparently through the diff-serv network, and then towards the sender. Standard RSVP processing will be applied at the RSVP capable nodes of the receiving stub network.
3. The receiver sends the RSVP RESV message towards the sender. Standard RSVP processing is applied in the stub network. If the message is not rejected in it is carried transparently through the transit network to ER2.
4. In ER2 the RESV message triggers the DACS (diff-serv admission control service) processing. If the RESV message is admitted, i.e. the requested resources are available, the DACS updates the available capacity for the service class, by subtracting the approved resources from the available capacity.

5. The RESV message continues towards the sender, with standard RSVP processing in the RSVP capable nodes.
6. At the sending host, the QoS process receives the RESV message. It interprets receipt of the message as an indication that the specified traffic has been admitted for the specified int-serv service type (in the RSVP enabled regions of the network) and for the corresponding diff-serv service level (in the diff-serv enabled regions of the network). It begins to set the DS-field in the headers of transmitted packets, to the value which maps to the int-serv service type specified in the admitted RESV message.

Summary

RSVP is specified as the QoS signalling protocol in the integrated services framework. Guaranteed service may often not be possible, but controlled load service will still be better than best effort. Mostly, RSVP is suited for real-time applications. It scales well on multicast connections, but there are different opinions on the performance in large networks with a lot of sessions, as flow state is stored in the network nodes. Differentiating traffic on different kinds of networks requires methods to control traffic on the link layer.

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