Advance Resource Reservation and its Impact on Reservation Protocols[1]

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Abstract

To guarantee Quality of Services for continuous media like audio and video, intermediate nodes in networks must be able to reserve resources like buffer capacity, CPU time and bandwidth. Several methods have been introduced to verify that new connections can be accepted by the network without violating guarantees made for already established connections. One drawback of all proposed admission control algorithms is that they accept the reservation only at connection establishment time and it is not possible to reserve the resources in advance. This paper introduces a mechanism for advance reservation of network resources. It further compares the suitability of the proposed Internet reservation protocols ST-2 and RSVP to support this new reservation style.

1 Introduction

Throughout the last years distributed multimedia applications have become more and more popular. This imposes several problems on the network environment primarily related to the provision of support for realtime video and audio transmissions, which require both, high bandwidth and end-to-end control of delay and delay jitter. These Quality of Service (QoS) parameters need to be guaranteed from the network.

Within common packet switched networks there is no possibility to guarantee constant delay values for an application due to variable queuing delays and congestions. To solve these problems the network nodes must be aware of the data streams they have to handle and reserve adequate resources. These resources include bandwidth on the links, CPU time and buffer spaces.

Several proposals have been made how a router architecture should be designed to support QoS in packet switched networks [2],[7],[16]. All proposals lead to almost the same basic components the routers should consist of. The main components of a QoS router architecture are:

- The *flow specification (FlowSpec)* describes the flow characteristics of the sender's data stream. [1],[11],[15] have made proposals for possible contents and semantics of FlowSpecs. In general, a FlowSpec should carry information on the characteristics like sensitive to delay, delay jitter, accepted types of loss and the style of guarantees [12].

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- The *admission control algorithm* is responsible for verifying whether or not a new connection can be accepted without violating the guarantees made for other connections. It is invoked at each intermediate router to make local decisions. A possible admission control algorithm is described e.g. in [8].

- It is the task of the *routing algorithm* to find a path through the network that allows the support of the QoS specified in the FlowSpec. Current routing decision are only based on one metric e.g. the number of hops to the destination or current load on the connected links. In particular, the characteristics of the data streams are not included. A possible solution to provide QoS based routing is introduced in [10].

- A *packet scheduler* is responsible for the forwarding of the data packets in accordance with the reservations made for the flow. This includes queuing of incoming packets into the related output queues as well as filtering of packets in multicast scenarios that are not used downstream. It is the task of the packet scheduler to fulfil the guarantees made by the network node for this data stream.

- It is the responsibility of the *reservation protocol* to negotiate the necessary resource reservations along the paths from the senders to the receivers. Possible reservation protocols are ST-2 [15] or RSVP [18].

Co-operation of the component's tasks can briefly be described as follows (Figure 1.1): A new connection that requires guaranteed or predicted QoS invokes the reservation protocol to set-up the data stream across the network. If a router receives a connection set-up request it calls the routing function to find a route that is able to support the required QoS. Next, the admission control algorithm must verify whether or not the desired QoS parameters can be fulfilled without violating guarantees already made for other connections. If the new connection can be accepted the resources are reserved by setting up the packet scheduler, which will assign the incoming packets in accordance to the reserved resources.

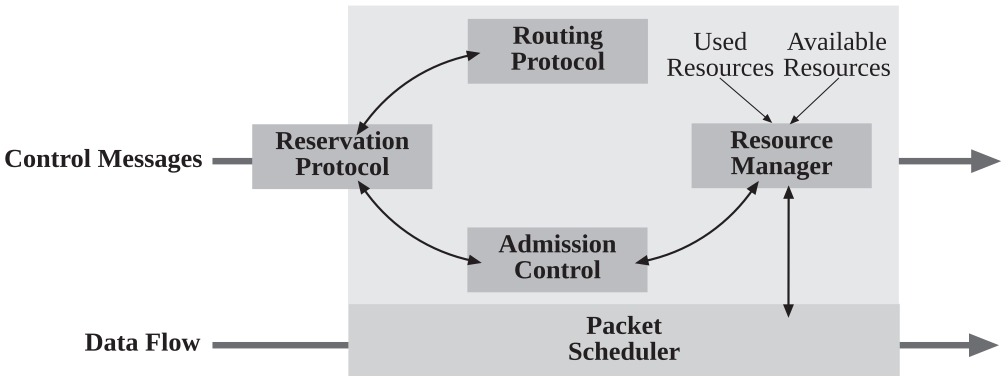

Figure 1.1 Architecture of a QoS router

2 Advance Resource Reservation Service

Most of the work in the area of resource reservation at the network layer has been done on reservation at connection establishment time. If the resources are available at that time they are reserved in accordance to the user demands. This is an element of uncertainty, which means that the resources are only reserved when they are available and not used by other connections. In the worst case, the connection request must be rejected or the connection will be established only with extremely reduced transmission quality. But even if QoS support is available the network is not always able to guarantee users a suitable connection upon their request. In this situation users have to try again later or they need a lot of patience since the offered performance of the network is not sufficient. Therefore it will be an useful service offered by the networks providers if users are able to allocate network resources at the time they make arrangements for using network services. Users should be able to reserve resources a certain time in advance.

To emphasise the need of an advance reservation service, multimedia applications are considered in the following that can make use of such a service.

With the introduction of broadband networks and desktop multimedia technology *video conference applications* are becoming more and more popular. Users can arrange meetings from their normal working environment without having to spend time for travelling. Meetings can be arranged for the discussion of specific items that do not need personal contact between the participants. If more participants are involved a date for the meeting might be arranged so that all participant are available at the scheduled time. What happens if they are not able to set up a conference due to the fact that not enough resources are available from the network? Especially the realtime video and audio streams of a video conference have to be handled from the network with particular care. The network has to guarantee QoS parameters by reserving adequate resources to avoid variations of the transmission quality. If the users wait for better conditions on the network, a new date will have to be arranged with all problems of setting up a time schedule between several partners and the risk that it is not sure that the resources are available at the new date.

Video on demand is another application scenario where advance resource allocation is useful. Today, users have the choice between various TV programs, but they have no influence on the information distributed on these channels. With future services we will be able to retrieve movies, information programs, video games, etc. from servers at any possible time. The servers deliver the requested data to subscribers on request. The resources at the server for providing the data as well as the network capacity might be limited, so user requests must possibly be rejected. The advance resource reservation mechanism will solve two problems: It can be used to allocate the necessary network resources for the transmission from the server to the subscriber, and it supports the order of retrieving at the server. Users with already reserved resources will be handled in a preferred manner.

Another application that will require advance resource reservation in particular situations is a *distributed hypermedia system*. If for example a number of video clips in a sequence that is generally retrieved from the users, the system can already reserve resources for the transmission channel of the following videos[2].

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[2] This assumes that a distributed hypermedia system is already able to open real time channels for video retrieval. Currently this is not the case. Parts of the video and audio files are downloaded and buffered at the destination before they are displayed. If a reservation system exists, an advance reservation systems will be a useful extension.

In summary it could be said that for most of the multimedia applications advance resource reservation is a useful service that should be investigated. Only a few papers are published in the field of advance reservations: Wolf et al. [17] describes the most important issues in reserving resources in advance and introduces a possible architecture for its design. Ferrari et al. [6] discusses the main issues and design principles of an advance reservation system as well as introduction how such a service is integrated into the Tenet service architecture. Degermark et al [3] describe the how the admission control for predicted services can be performed in an advance reservation service. Reinhardt [13] discusses general aspects of advance reservation as well as the necessary enhancements to use the reservation protocol ST-2 for the signalling. All these papers describes only issues of advance reservation. Currently their is no standardisation work in this area.

2.1 Reservation Phases

An advance resource reservation scheme works in three basic phases, the negotiation, intermediate and usage phase (Figure 2.1). The negotiation phase is performed at the time the users initiate the reservation for a future time period. It includes all activities from the first user request till the notification from the communication system that the reservation process is finished and the resources are reserved for the desired time period.The intermediate phase is the time interval between the end of the negotiation and the activation of the resources by the user. Within the channel usage phase the user transmit their data flows over the reserved channels. In the following the single phases are considered in more detail.

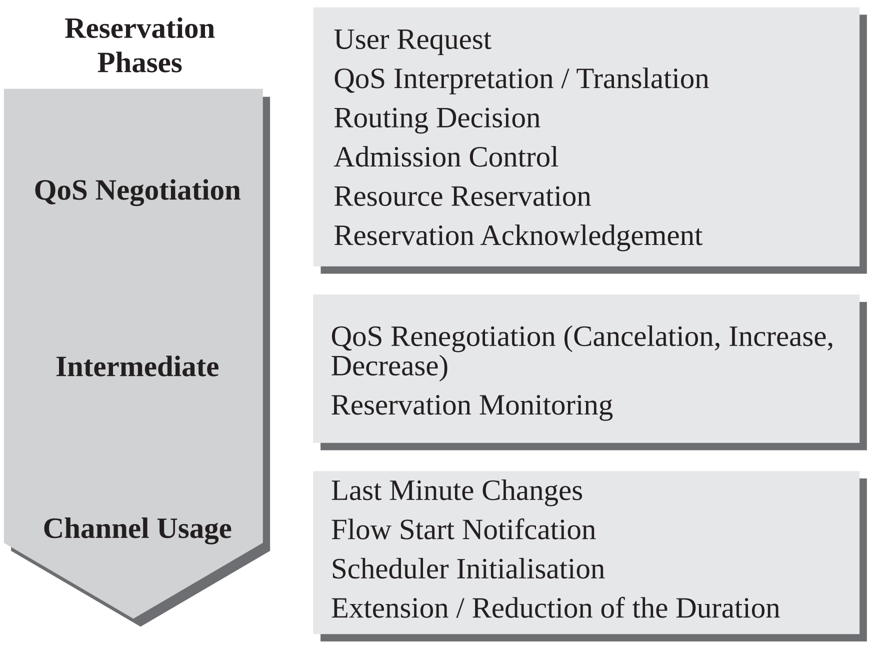

Figure 2.1 Reservation Phases of an Advance Resource Reservation System

Negotiation Phase

In the negotiation phase the user negotiates with the communication system the channel characteristics he requires at a certain time period. Within the connection set-up request the user specifies his demands within the FlowSpec. The communication system interprets the syntax and semantics of the parameters and translate it into the parameters offered by the communication system. Based on these QoS parameters the routing decision is made. It should be emphasised that the route of the data stream through the network is already fixed at the reservation phase and can be changed only with additional effort since the reservations along the complete path must be updated.

After finding an appropriated route which capacity is in principle sufficient to transmit the data with the requested QoS, the admission control algorithm verifies whether the new channel can be established at the particular time without influencing guarantees made for other connections during the requested time period. In contrast to traditional reservation schemes where the admission control algorithm only checks the availability of resources at the connection establishment, over the complete duration of the connection the availability of resources must be verified. If the admission control accepts the new request the resources for the new channel are reserved. The network informs the user whether the reservation request was successfully or not. This notification message completes the negotiation phase. Within the negotiation phase the steps are performed analog to a traditional channel establishment phase, with the exception that the resources are not reserved immediately but for a future time period and the admission control is more expensive.

Intermediate Phase

The time period between the successful notification that the resource have been reserved for the future time periods and the begin of the data transfer is called intermediate phase. During this period the users might want to renegotiate the channel’s resources. This may include the cancellation of the reservation as well as an in- or decrease of the requested resources. Furthermore the communication system is responsible for monitoring the advance reservations within the single nodes. Users making advance reservations to be sure that network resources are available for the time they request for a transmission channel. They would not accept that reservations fail due to errors within the intermediate network nodes. The reservation need to be kept in all intermediate system for a longer time period and not only for the duration of a connection. Therefore the probability that the parameters of a reservation will be lost due to system malfunction increases with the duration of the intermediate phase. A monitoring functionality is required to checks periodically if all reservations are still valid and perform a recovery of lost reservations if necessary.

Channel Usage Phase

Within the channel usage phase the connection is activated at the time the reservation is made for. As in traditional reservation scheme the packet scheduler is initiated to guarantee the negotiated parameters. It is a design decision whether the packet scheduler is automatically initiated or the user send a notification message that the data transmission will start. We prefer the second approach, since the resources are only assigned to a connection when data will be transmitted. In the case the users do not want to use the reservation the resources are made available for other connections. If a router receives a flow start notification for a channel reservations are made for, the packet scheduler is initiated with the parameters accepted within the negotiation phase. The transmission of the data streams takes places as in a traditional environment providing resource reservations.

Since all advance reserved connections are limited in their duration, problems may occur when the user exceeds the duration of the reservation. Since the duration of the reservation is limited the situation might occur that a user wants to exceed or reduce the reservation period. Adequate signalling mechanisms are needed to handle these situations. The reduction of the duration can be performed very easily by the disconnect service of the reservation protocol. For an extension of the reservation the following cases need to be considered:

- While the connection is active the user request for a extension or
- the reservation time expires, but the users want to continue the connection.

In the first case the extension can be requested via the reservation procedure used in the negotiation phase. If the reservation expires the system aborts the connection or tries to keep the reservation if enough resources are available and none of the guarantees made for other connections are violated. Another possibility is to move the connection into another class and to support it with a best effort quality.

2.2 Issues that need to be addressed

Several enhancement are necessary to integrate the advance reservation concept into the service architecture. The most important changes are described briefly:

- The traditional resource reservation concepts assume that the resource are reserved for immediately use and no assumption is made for the duration of the connection. The resources are allocated until the user explicitly release them. All new connection establishment requests have to be checked against the current channel reservations. If a new request is accepted the reservation are made for indefinite duration. Within an advance reservation scenario the provider of the service has do to some planning for the future allocation of the resources. At the requested starting of a transmission the resources might be available, but for a later time the available resources may already be reserved. Therefore it is impossible to accept a reservation with indefinite duration since the resources need to be reserved for the complete duration of the connection. To solve this problem two additional parameters are necessary one indicating the desired start of the connection, the other indicating the duration the reservation is made for.

- In the existing reservation architectures the intermediate nodes need to monitor only the resources that are currently allocated to the active connections. For an advance reservation system all the resources for future reservation have to be monitored. Therefore a calendar entity is required storing all the dates for future reservations. These information includes the negotiated starting time of the connections, their duration as well as the accepted performance characteristics. The calendar delivers the admission control algorithm the already allocated resources other the time period in question. These information are the basis for the decision whether a new advance reservation request can be accepted or not.

- While the negotiation of the reservation and the channel use is separated in terms of time, the packet scheduler needs to be initiated when the reserved connection is activated. Since the activation should be performed by the user a signalling message that indicates the start of the data transmission must be integrated into the reservation protocol.

- The systems response to a reservation request should not be limit to a simple yes or no. If the reservation request is rejected the system should include information on which service quality can be supported at the respective time or in which future time period the requested resources are available. This will be a useful feature for planning the re-scheduling of the communication system's usage.

3 Reservation Protocols for Advance Resource Allocation

To provide guaranteed QoS for data streams all network node on the way from the sender to the receivers have to be aware of the characteristics of the stream, in order to reserve adequate resources and support guaranteed service quality. To inform the involved network nodes about the necessary resources reservation protocols are suggested. In principle there are two strategies how a reservation protocol can operate. One approach is that the reservations are initiated and controlled from the sender. It is responsible for the reservation of the resources at all intermediate nodes. The second approach places the responsibility for reserving the resources on the side of the receiver.

Not only the question whether the sender or the receiver entities should be responsible for the resource reservations, but also how the reservation states are realised within the intermediate nodes is important. In principle their are two alternatives: Hard or soft states. Using the hard state approach (connection-oriented) the reservations are created and released in a deterministic manner. The hard state based reservation protocol must be reliable, in order to provide a deterministic behaviour in cases of connection set-up, release, and failures. To provide this, acknowledgement messages and re-transmission of lost packets are necessary.

While using a soft state based approach (connectionless) the states of the nodes are refreshed periodically. The reservations are stored as long as agents receive periodically messages updating the status. In the case refresh messages are not received any longer the agent waits for a negotiated period of time. If it doesn't receive any refresh messages it releases the reserved resources after the timeout, and they are available for other connections. The soft states approach used within a reservation protocol implies that reservation on alternative links due to route changes can be set-up without additional protocol overhead. Furthermore simple release of resources is enabled just by recognising that no further status messages are received.

Within the Internet community two approaches resource reservation protocols are currently under discussion, the *Internet Stream Protocol version 2 (ST-2)* [15] and its revised version [4] as well as the *ReSerVation Protocol (RSVP)* [18]. ST-2 follows the sender oriented approach using hard states whereas RSVP follows the receiver oriented one using soft states. Both protocols only provide the signalling of the resource demands. The realisation of the resource reservation, the admission control, as well as the routing function are not specified. ST-2 provides an additional forwarding protocol that allows an efficient transmission of the data packets over the paths established at connection set-up. RSVP relies on the IP multicast concept, with the extension that schedulers in the intermediate nodes are responsible for the assignment of the packets to the reserved resources.

In the following the suitability of ST-2 and RSVP to support advance resource reservation is considered. It is beyond the scope of the this paper to provide a general comparison of the protocols. Comparisons of the protocols are presented in [5],[9] and [14].

3.1 Criteria for Reservation Protocols to Support Advance Resource Reservation

To analyse the requirements for a reservation protocol that supports advance resource reservation the following issues have to be considered:

- Advance resource reservation is mainly a task that has to be performed by the involved routers. This presumes that all intermediate nodes are informed about the stream characteristics at the QoS negotiation phase. These information will be stored until the channel usage phase starts.

  Conclusion 1: Routes for the data streams are fixed during the negotiation phase.

- During the intermediate phase one or more intermediate agents may crash, thus corrupting advance booking within these nodes.

  Conclusion 2: A mechanism is needed that informs the agents on their neighbours' status, sets up new reservations, and/or informs the users abosdsut the failed advance reservation.

- Some users with advance reserved resources might not actually use them. In this case it should be possible for the intermediate agents to allow other connections to use these resources.

  Conclusion 3: A signalling message is needed that indicates the start of the data flow and the use of the resources reserved in advance.

3.2 Suitability of ST-2 and RSVP to support Advance Reservation

ST-2 follows the hard state approach. The connection and related reservations are set-up in a deterministic manner. At connection set-up time the ST-2 agents establish a distribution tree from the source to all receivers. Route changes at a particular router will be negotiated with the neighbouring agents which have to agree to the changes. Therefore, it is easy to achieve the advance reservation with ST-2, because the distribution tree is almost stable after the negotiation phase. The ST-2 FlowSpec can be enhanced by two additional parameters, the time the reservation request is made for and the expected duration of the connection. The starting time parameter may also be used to distinguish whether the user requests an immediate channel establishment or requires advance reservation. The intermediate ST-2 agents recognise by a staring time not set to zero that the user requests an advance reservation. In this case the resource manager is called to install the reservation for the desired time. Its task is to verify whether the reservation request can be accepted for this time without violating already confirmed reservations. When the application starts using the reserved resources during the channel use phase it sends a FlowStart message. If an intermediate ST-2 agent receives a *FlowStart message*, it establishes the advance reserved resource and from this moment they are exclusively available for the connection. The FlowStart message is the only additional message that must be integrated into *SCMP (ST Control Message Protocol)* providing the channel signalling within ST-2. See [13] for a more detailed description of advance reservation signalling procedure with ST-2.

The reservation set-up with RSVP follows the soft state approach. Senders start distributing *path messages* that install path states within all intermediate routes along the route. The path state includes information on the sender of flow as well as the offered stream characteristics. The path states within the intermediate routers already fixes the route later the data stream follows. If a receiver decides to receive the stream it sends *reservation messages* back to the sender. The reservation messages follow the inverse route of the path message, and cause the reservation of the resources at the intermediate nodes. Both, path states and reservation states within the routers are only based on soft states. If routers do not receive control messages any longer the path states and the reserved resources are deleted after a timeout. This has an impact on the advance reservation approach: The reservation states within the routers have to be updated periodically during the intermediate phase. Unlike ST-2, these state messages causes additional overhead within this time period. This effort can be reduced by negotiating a longer timeout value for the time the resources are pre-allocated. If the connection is activated this value can be re-negotiated to a decreased value. Within ST-2 control messages between neighbouring routers are exchanged anyway and they are related to the complete agent and not only to a single stream.

A more serious problem is the fact that due to the soft state approach of RSVP the routes may change in the time period between the reservation request and the start of the transmission. The reason is that path messages may be routed on different links, due to the fact that each single path message is newly routed. In this case the reservations within the routers that are not on the distribution path anymore can be released. On the new path a new admission control has to be executed. This causes problems since it may well happen that not enough resources are available on the new link and the admission may refuse the reservation request. This is a general problem of RVSP and until now no suitable solution has been found. But fixing the route during the negotiation phase is a mandatory condition to provide advance resource reservation.

When the connection is to be activated by the users, a message is sent from the origin to all destinations, informing all intermediate nodes that the advance allocated resources will be used within the agreed duration. Such an indication mechanism is a necessary feature since resources that were reserved in advance but are not used, can be assigned to other connections. Within ST-2 an additional message has to be integrated, since none of the available message type is suitable to transmit this information. Within RSVP the periodically path messages can be used to indicated the start of the data flow, since these messages have to be sent anyway down the distribution tree. If a receiver gets such a message it indicates that it intends to use the pre-reserved resources in the next reservation message.

In summary it may be said that both protocols can be extended to provide advance resource reservation. The hard state approach of ST-2 seams to be more suitable, since it avoids the problem of route changes. But an additional signalling message is needed which makes the protocol more complex. The handicap of RSVP is the soft state approach. The reservation state within the routers have to be updated periodically between reservation and flow start. This causes additional overhead within this time period. The main drawback is that the routes are not stable and may change during the intermediate and channel usage phase.

4 Conclusions

Within this paper the problem of advance resource reservation was considered. Applications were discussed for which advance resource reservation will be a desirable feature. Phases of an advance reservation system have been described detail and the necessary changes to support this service were discussed. The integration of this feature into the existing router architecture was introduced. Finally proposals for Internet resource reservation protocols were discussed with respect to their suitability for advance resource reservation.

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