Advance Reservation on Networks

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Abstract

The shift of applications running on the network towards more resource demanding and the increase demand on better Quality of Service has lead the international research community to the concept of Advance resource reservation. Resources that must be reserved in order to provide adequate Quality of Service include both bandwidth, buffer capacity, and CPU time. At the same time many of the new applications are imposing constraints such as time granularity, required for example in synchronization of audio and video streams. The new approach has impact on the resource management, call admission procedures, routing algorithms and the user culture. An important factor in the advance reservation algorithms is the time between the request for reservation and the actual utilization, and the traffic running on the network. An advance reservation might lead to either an increase or a decrease in network utilization.

In this paper the concept of the advance reservation and some of its aspects are presented.

Keywords: Advance Reservation, Routing, Quality Of Service

The purpose of this document is to present the Advance Reservation. No new ideas are introduced here and all sources used are found in the reference section.

1 Introduction

Due to the expansion of use of multimedia applications and services such as video conferences, audio conferences, video on demand, broadcasts of events and the extended use of high-end distributed applications such as distributed simulations running on multiple hosts, tele-immersion applications that require simultaneous access to databases, CAD tools and rendering devices, advance reservation has become an important enabler.

There are several parameters defining a call / connection such as duration, bandwidth requirements, start-time, duration, end-nodes. Advance reservation requires that at least some of these parameters are known when a request is made. Advance reservation is based on the assumption that the user knows in advance the time when the network utilization will start and usually its duration. This assumption is based on the fact that most of the reservations are reflecting real life events. A videoconference, which includes several parties from different parts of the world, requires scheduling and coordination among all its participants. An event like this is usually planned well in advance, a few days or weeks. In addition to one time events we also have periodically events such as the weekly team meeting.

Another significant impact of advance reservation is the provision of a more sophisticated system of call-level priority. The call-level priority is used by the various service nodes on the network to make decisions regarding the call.

Advance reservation requires enhancements in:

- protocol and signalling capabilities to allow users to express advance reservation requests
- extensions to resource management and call admission procedures to handle time shifted resource requests
- routing algorithms capable of identifying suitable paths based on both spatial and temporal request characteristics

There are two mainly approaches to support advance reservation on IP based networks. One approach is an agent-based infrastructure without requiring a complete upgrading of existing routers. Each routing domain is assigned to an agent. An agent is responsible for admission control for the routing domains it controls. An agent has full knowledge of the topology of its routing domain and also must be able to detect topology changes that require re-computation of forwarding state setup in routers, or renegotiations with adjacent reservation agents. Agents maintain reservation state information. The second approach is the extension of signalling protocols, reservation protocols and the introduction of states on the routers. This is totally against the IP state-less architecture and there are a lot of disadvantages but it has its supporters. The main protocols that extensions have been proposed for are the ST2 which uses hard states (connection oriented) and the RSVP which uses soft states (connectionless).

1.1 Outline

Section 2 presents the advance reservation, lists the requirements and discusses some of the benefits and disadvantages of the advance reservation. Section 3 presents the topic from the Quality of Service's point of view. Section 4 presents some of the reservation protocols and the impacts of advance reservation. Section 5 presents an alternative to support advance reservation through the introduction of agents. Section 6 presents issues that affect the routing algorithms.

2 Advance Reservation

The main reason for advance reservation is the need to decrease the blocking probability for certain calls/connections. According to [1] Wischik/Greenberg <<the reduction in blocking is a threshold effect: booking ahead a small time in advance has no effect, booking ahead a certain critical time in advance gives a dramatic reduction in blocking, and booking ahead further has no further advantage>>. What this means is that trying to reserve resources very near the time of their utilization increases the probability of these resources being in use by other connections. Wischik/Greenberg has proved this with simulations and they also remark that with sufficient notice, blocking hardly increases with the number of links occupied or with call bandwidth.

The advance reservation causes several problems that have to be solved:

- Time synchronization, all clocks within the involved nodes have to be synchronized with a central time so that the reserved resources are available at all nodes at the same time.

- Cancellation of the conference, how long must the resources be reserved without use after a scheduled time; a delay has to be agreed within which the reservation is still valid. Within this time period the resource may be used by other connections, but with the provision that the resources may be re-allocated when the delayed connection is activated.

- Failure within an intermediate node, in the time between advance resource reservation and the actual start of the data flow one or more intermediate nodes may fail, thus corrupting advance booking within this node. This will interrupt the complete routing path.

- Exceed of reservation duration, what will happen if the connection is exceeding its reserved time; Should we abort the connection immediately or support the connection with a degrade level of Quality Of Service or shall we support the connection on a best effort basis.

2.1 Definitions

In the domain of Advance Reservation there are a few keywords used often to describe a scenario.

Starting time, the point at which we establish the connection.

Ending time, the point at which the connection is finishing and the resources are released.

Bookahead time, the time from making an advance reservation until the point at which the resources are to be available.

Lookahead time, the point at which we actually start making resources available for approaching advance reservations by rejecting immediate requests.

Duration time/interval, the time between the starting time of the conection and the finishing time of the connection.

2.2 Requirements

Calls/Connections that will most benefit from advance reservation are these that in normal conditions will be denied service due to their high requirements in network resources. Overprovisioning the network is an option but not only a very expensive one but also a hard one to apply uniformly on the whole network.

One of the requirements for advance reservation to give best utilization of the network is the assumption that reserved calls are not the only ones on the network. The network will still have to serve a large amount of calls with immediate requests. Immediate calls must be preemptive. This is the only way to guarantee adequate quality of service to the advance reserved calls. What preemption really means is that we should expect a degradation on the quality of service. Also since there are two different service guarantees: deterministic and statistical, and the latest ensures only high probability of resource availability, we need a policy to describe how overbooking will be handled on the latest.

2.3 Benefits

Advance reservation fits very well in the user culture. Users of the services that benefit most from advance reservation are already used to reserve in advance resources tex. for their conference.

Advance reservation has several practical advantages. It increases the probability for call acceptance. It does not require overprovisioning of network resources. It moves control and responsibility away from the network and towards the user. It allows the network to better plan its resources taking advantage the knowledge of future calls.

2.4 Disadvantages

Planing ahead in advance is not a natural procedure for all users. Users are required to provide information about the start time of the call, the number of participants, the bandwidth required, the duration of the call etc.

In the meantime an established call that was previously reserved might require additional resources such as in case, an unexpected party enters a conference or the duration of the call is prolonged much more then the scheduled end time. Which means that the resource requirements of a connection may change at any time.

In order to setup the call that was reserved the network must start allocating resources well in advance. This can lead to pure network utilization.

The state information for the reserved calls must be saved in the network. All participating service nodes must store state information for the call for long duration, the whole bookahead time. If this information is handled by the routers it is arguable that they can handle to carry the extra load.

There are cases where advance reservation has minor effect, while in other cases it turns simple problems into intractable ones.

It is not clear which element on the network will handle the additional computational complexity.

3 Quality Of Service

Quality of Service means providing consistent, predictable data delivery service during periods of congestion. Some of the characteristics that qualify a Quality of Service are:

- minimizing delivery delay
- minimizing delay variations
- providing consistent data throughput capacity

The IP network is very popular due to its simplicity and its strength to support a variety of application but:

- IP network is designed on the requirement to provide a best effort service. IP will try to delivery the packets but there is no guarantee implied that the packet will arrive its destination neither it can ensure timely delivery. Reliability on IP network is handled by the higher level protocols (TCP, SCTP etc.).
- IP does not make any allocation of resources. This gives much more flexibility and more efficient use of the available bandwidth as it shares the available resources when needed. This does allow the IP to adapt more flexible to applications with varying need but also leads to unpredictable service.

Advance reservation provides a call-level priority, which implies also a call-level quality of service: a measure of how likely it is that the user who made a reservation will get all the requested resources. Being able to measure and report on service quality is also an important attribute of Quality of Service solutions. Class of Service is a more general term for such capabilities.

Quality of Service guarantees are general either:

- deterministic or
- statistical

A deterministic guarantee ensures that if the request for reservation is accepted then the resources will be available at the specified time. Deterministic guarantees give poor utilization of network resources since they must either reserve extra resources by refusing additional connections near the time of the reservation or by releasing calls in order to make place for the reserved call. Deterministic guarantees are not allowing overbooking.

A statistical guarantee ensures only that there is a high probability that resources will be available. Statistical guarantees permit higher utilization due to overbooking. Because of this there must be a policy of what to do when this occurs. The most natural is to degrade the service given to calls in reverse order to the order they were booked, most recently calls get degraded service first

3.1 Resource Administration

In order to achieve better utilization of the networks resources immediate calls and advance reserved calls must coexist [1]. The resource capacity can be managed in two ways:

- Partition the resource capacity into two parts so that one is assigned to immediate calls and the other to advance reserved calls
- Share the resource capacity between immediate and advance reserved calls.

Partitioning a resource's capacity gives a bad utilization of the resource but it is easier to implement.

Sharing the available capacity gives optimal utilization of the resource but the implementation of such a system is more complex because of the additional need of a reservation and preemption scheme.

Note that if the durations of all reservations are known, then it would be possible to apply the sharing strategy without preemption [3]. This can be achieved by the introduction of a default value.

3.2 Duration

Advance Reservation requires that the user will provide the starting time of the connection and the duration interval.

There are though some applications that cannot fix the duration and they require that the reservation will be prolonged, as it is in case of a video conference where the meeting is not over and must be extended.

Depending on the guarantees that the system provides, deterministic or statistical it is possible for the system to assume a distribution for the random duration of a call, based on measurements of typical durations.

An Advance Reservation System provides the means to extend the duration of a call. If this is the case, the system may or may not have sufficient amount of resources to serve the application with its needed Quality Of Service.

- If enough resources are available, one possibility is to not interrupt the service and to provide the application with the means to extend its previous reservation.

- If insufficient resources are available, the system may still attempt to serve the application on a best-effort basis with a degradation in the Quality Of Service. The system may degrade the Quality of Service of other connections depending on the current policy.

There are two ways to handle the expiration of the connection. One is that the user has responsibility about the connection and must take appropriate action to prolong the reservation and the other is that the system informs the user that the reservation is about to expire and queries whether it should be prolonged or not.

If the duration of a connection is shorter than the reserved time, exceeding resources should be freed and made available for other applications. In this case, resources can be made available for immediate use and for immediate reservations. Resources freed cannot be made available for a new advance reservation due to the short notice.

3.3 Bandwidth

Usually when speaking about Quality Of Service people are thinking about multimedia applications, like video on demand, live video, video conference. What is common in all these applications is the high requirements of bandwidth.

But there is a problem. In order to reserve bandwidth resources, we need to be able to measure them. The problem lies on the fact that there is still no consensus on how to do this.

Candidate measures of bandwidth include, effective bandwidth (applied at the packet level) and measurement-based prediction of bandwidth, in addition to the obvious peak bandwidth.

Depending on the measurement chosen the Quality Of Service guarantee is interpreted differently in each case.

3.4 Fault Handling

Quality Of Service requires that the network nodes are not any more stateless. State information at nodes might needed for long lasting time periods. State information must survive node failures and restart. In addition to that, adjacent nodes must be notified about the failure and if possible about the time of availability.

Depending on the approach chosen to support advance reservation, the failure must be detected and a corrective action must take place. The action depends on the available resources and network policies. In case of link failure or router failure the traffic must be rerouted. Upon detection of link failure the reservations on that link must be processed and a new route is recomputed. A check is made to find if there is capacity left for advance reservations on alternative routes. If capacity on alternative routes is insufficient, we can wait and retry or inform the users for a possible future problem. If capacity is sufficient in an alternative path we immediately allocate resources. We finally update the reservations states on the routers/network.

If the connection has already been established the same approach applies but the connection is treated with lower priority than others advance reserved connections on the new link. This implies that a significant degradation of Quality Of Service may be the result of a failure or even a total break.

Thus, when there are failures, routes will change only if there is an alternative path that can provide adequate resources, otherwise the traffic is served at best effort basis, or based on policy.

4 Impacts on Reservation Protocols

There are currently two protocols for advance resource reservation on the IP network, the Internet Stream Protocol version 2, ST-2 and its revised version as well as the ReSerVation Protocol (RSVP). The protocols are informing the involved network nodes in order to reserve adequate resources and support guaranteed service quality. The protocols are using two main different approaches. One is that the reservations are initiated and controlled by the sender and the other is that the receiving side is responsible for reserving the resources.

The two protocols only provide the signalling of the resource demands. The realization of the resource reservation, the admission control, as well as the routing function are not specified.

4.1 ST-2

ST-2 is using hard state (connection oriented) approach for the reservation set-up. The reservations are created and released in a deterministic manner. ST-2 follows the sender oriented approach. ST-2 provides an additional forwarding protocol that allows an efficient transmission of the data packets over the paths established at connection set-up.

ST-2 is classified as a network layer protocol according to the OSI model and as an Internet protocol according to the ARPANET model.

The main tasks performed are routing and signalling of data streams as well as the fast forwarding of data packets from the source host (called origin in the ST-2 terminology) to one or many remote hosts (called targets). Multicast communication is supported at the network layer by setting up a static routing tree from the origin to all targets, with the origin representing the root of the tree and the targets representing the leaves. Each intermediate node is an ST-2 router, forwarding the data downstream on the routing tree to the targets. Data are transported over the tree as streams [11].

The principle of ST-2 is to split connection management from data transfer. The stream set-up, maintenance and release are performed by the ST Control Message Protocol (SCMP).During connection establishment paths to all targets are installed. All intermediate nodes allocate, if possible, resources for the requested stream characteristics and establish connections to the next hops on the way to the targets. During the data transfer phase the data follow the established paths. In the header of each data packet the next intermediate node is identified by a hop identification number negotiated at connection set-up time, but it includes no control information. This leads to an efficient forwarding of all data packets since no control packets disturb the information flow along the path.

A few changes have to be made to use the ST-2 protocol for resource reservation.

Two additional parameters have to be added to the respective FlowSpec of the ST-2. The starting time of the data flow across the connection and the duration of the connection from the starting event. The starting time is used for advance resource reservation, to indicate the date and time the new connection will start. The duration parameter is needed for all requested connections to evaluate if the required resources conflict with already reserved resources in the near future. The starting time can further be used to indicate the immediate connection setup. If the value is set to zero the path is established for immediate use. The routing path is established immediately through a connect message, and all parameters and resource requests are negotiated as in the conventional ST-2 version. The only difference is, that all reservations are stored within the resource manager of each ST agent if the starting time parameter is not zero. The reservations are not performed immediately, but the resources are reserved for the time the connection will be used by the applications.

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 providing the channel signalling within ST-2.

4.2 RSVP

RSVP is using soft state (connectionless) approach for the reservation set-up. 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 recognizing that no further status messages are received.

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 from the time the reservation is made until the starting time of the connection. Unlike ST-2, these state messages causes additional overhead during 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 decrease value.

Within ST-2 control messages between neighboring routers are exchanged anyway and they are related to the complete agent and not only to a single stream

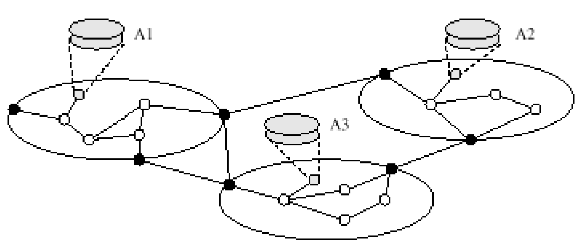
In RSVP, routers play a central role in admission control and routing. Routing decisions are not part of RSVP but instead made by the best effort mechanisms in the routers. Consequently the RSVP mechanism can easily reestablish reservations along changing routes. The fact that the routes may change in the time period between the reservation request and the start of the transmission is due to the soft state approach of RSVP. The reason is that path messages may be routed on different links, because each single path message is newly routed. In this case the reservations within the routers that are not on the distribution path any more 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. If one reservation will succeed over another depends on the order reservations arrive on the new path. This is the main drawback, that the routes are not stable and may change at any time from the time the reservation is made until the start of the call.

5 Advance Reservation Agents

The proposal for an agent-based infrastructure comes from Sweden, Schelen-Pink [7]. The idea is to deploy agents in end systems to maintain state about reservations that will be needed for future packet forwarding and avoid deploying state in routers until there are packets in the network whose forwarding depends on the reservation.

The agents can be deployed on the network and support advance reservation without requiring a complete upgrading of existing routers. Each routing domain is assigned to an agent.

An agent is responsible for admission control for the



routing domains it controls. An agent has full knowledge of the topology of its routing domain and also must be able to detect topology changes that require re-computation of forwarding state setup in routers, or renegotiations with adjacent reservation agents. Agents maintain reservation state information. This is the advantage with an agent-based approach that advance reservations can be provided without having to maintain reservation state in the routers through periods when the reservations have no effect on packet forwarding. Furthermore, the agent-driven approach does not require the reserving endpoints to be present until the session for which resources have been reserved is starting. Reservations can also be made for remote locations, thereby supporting third party reservations and nomadic computing, i.e., reservations for places where the host will be moving in the future.

Resources for advance reservations will be made available by rejecting immediate requests for a period before resources are to be allocated, or ultimately by preempting service for flows that were granted immediate access.

6 Impacts on Routings Algorithms

Routing decisions that are not influenced by advance reservation are based on the number of hops to the destination or the current load on the links. The characteristics of the stream are not considered.

Advance Reservation routing must find a path that supports the connection needs in the network. The path chosen may not be the traditional shortest path that is typically computed based on current metrics and policies. Advance reservation enabled routers are marking their packets for priority treatment. Marked packets are traveling on the path with higher priority, are sent first and are never dropped during congestion. A separate priority queue is maintained for marked packets and never oversold.

The network is expected to support several different type models of advance reservation each requiring different guarantees:

- Basic reservation, where users request bandwidth guarantees for some time in the future, while specifying, either explicitly or implicitly, an associated duration.
- Maximum duration, where users cannot specify a duration but there is a requirement to maximize the connection once it has established.
- Soonest completion, where starting time cannot be specified but the goal is to identify a path that minimizes the time at which the connection ends, hence the time at which it starts. This could be useful when the task is a gating factor for the start of a subsequent task.
- Maximum duration – Unknown starting time, where neither the starting time nor the duration of the connection are fixed and our aim is to establish the connection over a path and time

interval that maximize its duration. This could be useful in cases where once a task has started, it is more efficient to have it complete the maximum possible amount of work.

7 Conclusions

Durations must be specified for advanced reservations. A duration includes the starting time and the finishing time for the requested service.

Immediate reservations do not specify durations. Such requests are serviced immediately (if possible) and can be preempted later by advance reserved connections.

Preemption means that the connection loses its service quality. However it will still be serviced at a best-effort level.

In order to manage resources safely there may be limits on minimum and maximum bookahead times for advance reservations.

The advance resource reservation causes additional overhead for connection set-up and resource management.

There are two approaches to the advance reservation problem, additions to the reservation protocols ST-2 [4] and RSVP and the Advance Reservation Agents [7], both of which are briefly presented here.

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