Abstract—There is an emergence of Internet applications that have real-
time requirements. These applications require IP to support 
guaranteed capacity, higher priority and lower packet loss rate. To 
address this, the Internet Engineering Task Force (IETF) is developing a 
set of protocols and standards for Integrated Services on the Internet. 
Using RSVP and policies to manage the allocation of network resources 
in order to provide different levels of service is a topic of great interest to 
service providers. Currently, it is not possible to dynamically reallocate 
resources during an application’s session. This paper discusses how 
policies in conjunction with new service class can provide a more 
enhanced network resource allocation by allowing for this dynamic 
re-allocation.

Keywords: RSVP, QoS, policy

I. INTRODUCTION

There has been an increase in distributed applications that involve 
the exchange of data that is time-sensitive. Applications include video-on-
demand, distance education, tele-medicine, tele-conferencing, electronic 
commerce. Users of these applications expect them to perform at acceptable 
levels, that is, they expect a high level of quality of service (QoS). Quality 
of service in this context refers to non-functional, run-time (or operational) 
requirements, such as application performance or availability. Different 
applications have different QoS requirements. For example, e-mail has a high 
tolerance for delay and thus has no constraints on delivery, ftp has a high 
tolerance for delay but is synchronous and thus is time-sensitive but there is 
flexibility on delivery. Video-on-demand applications have low tolerance for 
delay.

Currently, IP networks provide best-effort delivery for all applications. 
At each router, data packets are queued and then forwarded with no 
distinction made between packets of different applications. This works well 
for e-mail, ftp and telnet. However, best-effort delivery does not work as well 
for delay-sensitive applications, such as Internet telephony, video 
conferencing and interactive games, since these applications have relatively 
strict requirements on throughput, loss and delay that must be satisfied.
This suggests that the Internet needs to be able to provide different levels 
of service in order to support the increasing diversity in the types of 
applications running on the Internet.

The Internet Engineering Task Force (IETF) is developing a set of 
protocols and standards for Integrated Services on the Internet [1,2]. In the 
IETF’s vision, applications request and reserve resources in the network and 
the hosts using the end-to-end Resource ReSerVation Protocol (RSVP) 
[3-4]. The IETF Integrated Service working group standardized two service 
classes: the Controlled Load (CL) service [5] and the Guaranteed Service 
(GS) [6]. The purpose of the CL service is to approximate the service a 
user would experience from a network that does not have a heavy load or 
congestion. However, if the network routers become overloaded no 
scheduling algorithm can be used that emulates a lightly loaded network for 
the CL flow. The purpose of the GS service class is to provide applications 
with mathematically provable end-to-end delay (deterministic) at all network 
elements. It guarantees conformant packets, lossless transmission and an 
upper bound on end-to-end delay. GS provides a deterministic service that 
tends to wastes resources, since more bandwidth is usually reserved than 
absolutely necessary. The work in [14] shows that an average load of only 
40% is on a link carrying GS flows. The customer who uses the GS service 
is paying for the unused resource and another flow’s resource reservation 
may be blocked even though there are unused resources. This is costly to 
both users and vendors and thus only applications with hard real-time 
requirements should use GS [13]. CL has the potential to underallocate 
resources while GS has the potential to over-allocate resources. In either 
case, it may be desirable to dynamically reallocate resources during an 
application’s session which currently cannot be done. This paper addresses 
this problem with the introduction of a new service class: Modified 
Guaranteed Service with Pool (MGSP).

The IETF Resource Allocation Protocol (rap) working group has also 
standardized various architectural elements for allocating resources based on 
policies (i.e., rules). The use of policies allows the network elements to 
determine which flows are entitled to which service [7].

The use of RSVP and policies as an approach to manage the allocation of 
network resources in order to provide different levels of service is a topic of 
great interest to Service Providers. However, most of the recent research has 
focused on defining the framework and functionality of each element for 
provisioning network resources based on policies [8,9,10]. The primary application of policies has been for determining 
pricing based on usage [11]. This paper discusses how policies in 
conjunction with a new service class, Modified Guaranteed Service with 
Pool (MGSP) can provide a more dynamic network resource allocation.

II. ARCHITECTURE FOR POLICY-BASED RSVP

This section presents an overview of the RSVP protocol and the 
architecture for policy-based RSVP is described.

2.1 RSVP operation

RSVP is a signaling protocol designed to enable applications to reserve 
network resources to satisfy a requested level of QoS requirements. Using 
RSVP senders, receivers and routers communicate with each other to setup 
the necessary router state needed to obtain the network resources that satisfy 
the QoS requirements for their data flows [3]. RSVP can be applied to both 
multicast and unicast flows. RSVP is applied only after a route has been 
determined and hence RSVP is not a routing protocol. An RSVP flow is 
uniquely identified by the five-tuple (protocol, source address, source port, 
destination address, destination port). Filters can be setup at the routers and
2.2.1 The IETF Architecture

resources the requesting flow does not get its resource reservation request given the requested resources. Thus, even though there may be enough requesting the amount of bandwidth available to all games is applications have higher priority than games. The policies could specify that based admission control is not only based on the amount of available network resources. A policy is a set of rules. A rule is of the form then action that indicates the type of service required (GS or CL) may include information such as maximum delay and packet loss probabilities. Each router that receives the RESV message checks to see if sufficient resources are available and tries to reserve the required resources in the router. If there are not enough resources, a RESV ERROR message is sent to the receiver. Routers that receive a RESV ERROR message cancel the reservation for the flow.

The PATH and RESV messages are independent and a PATH message of a session might induce RESV messages to request different amount of resources. As the RESV messages from the receivers traverse upstream to the sender, they are merged by the routers at the merging points. After the reservation, the sender continues to send PATH REFRESH messages to maintain the soft state of the flow. The soft state information in the routers is periodically refreshed by using REFRESH messages. If there are no REFRESH messages for a particular flow then the entry in the soft state associated with that flow is deleted which implies that the resources reserved for that flow are released.

Figure 1 graphically depicts a network used for illustrating RSVP operation. There are three routers and five host machines, in which S1 and S2 are senders and D1, D2 and D3 are receivers in the same multicast group. PATH messages from S1 and S2 are sent to all of the receivers. D1 and D3 accept the PATH message from S1 and D2 accepts the PATH message from S2. Router R2 merges the RESV messages from D1 and D3 to make one reservation of resources on the flow from S1 on the link between R1 and R2. Router R1 also merges the RESV messages from D1 and D3 to make one reservation of resources on the flow from S1. After the reservation, S1 and S2 send the PATH REFRESH messages periodically in each refresh interval, D1, D2 and D3 send the RESV REFRESH messages in response to the PATH REFRESH messages.

2.2.2 Relationship Between Policy and Service Classes

As stated earlier, the IETF Integrated Service working group standardized two service classes: the Controlled Load (CL) service [5] and the Guaranteed Service (GS) [6]. The GS service class often results in a wastage of resources since more bandwidth is usually reserved than needed. The Guaranteed Service (GS) [6] provides a service level based on an approximation of

![Figure 2. Placement of Policy Elements in the Internet](image)

A flow may involve nodes (end-hosts and routers) in different administrative domains (AD) [8]. For example, in Figure 2 nodes A, B and C belong to AD-1 while D and E belong to AD-2 and AD-3, respectively. Each administrative domain has its own PDP. Only the edge routers of an administrative domain are required to have a PEP since the admission control decision and the service class only have to be determined for each administrative domain. Each node has to belong to at least one AD and all of nodes that have the PEP is administered by PDP or Local Decision Point (LDP). The LDP stores information about local policies i.e., policies that apply to the network element when the LDP is on. This reduces the load on the PDP and makes bottleneck less likely. The LEP will first use the LDP to reach a local decision. If the request is denied by the LDP then there is no need to go to the PDP. Otherwise, the partial decision made by the LDP and the original policy request are next sent to the PDP which renders a final decision (possibly overriding the LDP).

2.2.2 Relationship Between Policy and Service Classes

The use of policies proposed for RSVP is to control the allocation of network resources. A service level agreement (SLA) is defined as a contract specifying expected QoS requirements between a customer and a service provider. Customers and service providers are administrative domains. An end-user that initiates a communication is in an administrative domain. This administrative domain is a customer of an adjacent administrative domain that is on the path from the end-user to the target. Basically, the adjacent upstream administrative domain is a service provider for the adjacent downstream administrative domain. The adjacent administrative domains agree on a SLA. A request for resources is examined by the policy module and the admission control module of an administration domain. The policy module is invoked only at an egress router. The policy module checks the SLA and determines the appropriate service class, and the admission control module regulates resource allocation by result from the policy module.
the service a user would experience from a network that does not have a heavy load or congestion. However, if the network routers become overloaded no scheduling algorithm can be used that can emulate a lightly-loaded network for a CL flow. If the flow needs more resources, the QoS of the flow may not be guaranteed. This suggests the need to be able to dynamically reallocate resources during an application’s session. This can be supported through a new service class. This service class is defined and a description of how policies can be applied is described in the next section.

III. RSVP BASED QoS SERVICE WITH NEW SERVICE CLASSES

This section describes a new service class, Modified Guaranteed Service with Pool (MGSP) and how it can be incorporated into the RSVP operation. MGSP is similar to GS with the following difference: some portion of the resources reserved but not used by a flow will be returned to a pool of available resources that can be used by other flows. If extra resources are required, then it can use available resources from the pool. This allows for a dynamic allocation of resources i.e. during a session, it is possible to request additional resources from the pool without starting a new session (as must happen for a flow of the GS or CL service class).

3.1 Modified Guaranteed Service Class with Pool (MGSP)

Flows that request MGSP service are set up in a similar fashion as flows requesting GS service. It is assumed that each RSVP-enabled router has a monitoring agent that monitors the actual resource usage of the flow after completion of the reservation. The monitored value is an attribute of the soft state. Whenever a RESV REFRESH signal is received, the most recently monitored value and the reserved value are compared. If the monitored value is greater than or equal to the reserved value, the reserved value is maintained and the need for resources that exceeds the reserved value is satisfied by taking from the pool (if possible). Otherwise, the reserved value for the flow is set to the monitored value. The amount of the pool resource can be updated on the basis of the monitored and estimated value of the pool. One example equation that can be used is the following:

\[
(RB_{GS,i} - MB_{max}) + MB_{pool, avg}.
\]  

(1)

For a MGSP flow i, RB_{GS,i} represents the initial resources allocated to flow i. MB_{max} represents the current monitored value for flow i. MB_{pool, avg} represents the monitored current average value of the pool. \((RB_{GS,i} - MB_{max})\) represents the maximum difference among all flows between monitored amount and the initially reserved amount. Since a flow of type MGSP is setup as a flow of type GS, then the initial allocation of resources is based on worst case needs. \((RB_{GS,i} - MB_{max})\) represents the maximum difference for all flows between the reserved resource amount and the monitored resource usage. This difference is added to the pool. When the worst-case delay occurs and a flow needs resources, the flow can use some of the resources from the pool of available resources.

3.2 Policy-Based RSVP QoS Service

This section describes possible applications of policies in the RSVP operation with the new service class. There are two types of policies: static and operational. Static policies are applied when a device or process is configured. This often initializes variables to be used during the lifetime of the device or a process or at least is not changed very often. Basically, in this case the condition is always true and the action is the assignment. Operational policies describe the action to take place when some condition arises during the operation of the system.

3.2.1 Static Policies and Service classes

Using the MGSP service class and existing IETF service classes, we can clearly define a set of service classes. Policies can be used to set the priorities that the different classes have in being able to reserve resources. Assigning priorities to service classes is an example of static policies. They are static in the sense that the priority assignment is considered part of the router setup. The classes with possible priorities are defined below:

* The Guaranteed Service (GS): This is the service class of RFC 2212. As it uses more resources than what is actually used, its cost is very high. The level of service is the highest (priority = 1).
* The Modified Guaranteed Service with Pool (MGSP): This is the service class proposed in this paper. It is supposed to provide the same quality as GS, but efficient resource usage is considered (priority = 1).
* Prioritized Controlled Load Service (PCL): This is the service class to prioritize CL. It has precedence to use the available resources over CL only when the PCL flow needs more resources than reserved and there are unused resources available to PCL and CL flows (priority = 1).
* The Controlled Load Service (CL): This is the service class of RFC 2211 (priority = 2).
* Best-Effort: This represents current Internet traffic flow (priority=3).

This prioritization of the classes gives GS, MGSP and PCL the same level of priority and make all of them have equal privilege over unused resources. In case of PCL and CL, by assigning higher priority to PCL, implies that the flow of type PCL gets a precedence of unused resources over flow of type CL when both PCL and CL flows need more resources than what has been reserved.

2.2.3 Static Policies and the Pool

Policies can also be used to manage the buffer pool. Examples of possible policies include the following: (1) Policies can be used to state the percentage of the pool made available to each of the service classes. (2) Policies can be used to determine how much of the excess resources assigned to a flow is returned to the available pool (Equation 1 represents only one way to do this).

It is expected that these policies may change more often then the policies in Section 3.2.1. For example, an analysis of past history of usage of the resources by flows of each type of service class may suggest that the percentages should change.

3.2.2 Operations of Policy Module

The arrival of a RESV message at an egress router results in the PEP contacting the PDP. The PDP determines the service class(es) that the requesting flow can be assigned to. If there is more than one service class then an ordered list of service classes is returned where the order represents the preferences. The admission control module is then contacted. The admission control module assigns the flow available resources on the basis of the results from the policy module and the current availability of resources. Policies can be used to regulate this setup in a number of ways. For example, there may be a policy that states that if the requesting flow has higher priority then other existing flows and there are not currently enough resources for the requesting flow then pre-empt lower priority existing flows until there are enough resources. Another policy could state that if there are not enough resources then the flow is blocked until there are resources. The behavior of the admission control module differs depending on the actual policies used. The first policy described above allows the policy module to guarantee a specific entity/user some level of QoS (as defined by the SLA) by allowing the pre-emption of resources assigned to other flows.

The second policy described above is simpler and basically only ensures that flows are not admitted until there are sufficient resources. This policy does not interfere with existing flows that have resources assigned to them. If more than one flow is blocked waiting for resources then policies can be used to determine which flow next gets resources that are freed up. In this paper, only the second policy is considered.

If a flow requests more resources then allowed by the SLA, policies can be used to determine the action to be applied which could be that the flow is treated as best-effort or that the flow is assigned a lower level service class or is not allowed admission. Again, policies have an impact on the behavior of applications.
the blocking of new reservations of flows that are requesting more resources (as indicated by the requested service class) are not available then flow1. This assumes that the resources are available. If the requested resource_monitor interface method is used by the PDP to request resource usage information from the PEP which uses the network monitoring module to get this information. In the inner domain routers, each flow has already gotten permission for the proper service class from PEP in ER. Thus, the blocking_reservation and resource_monitor methods are needed in the inner domain routers.

IV. EXAMPLES

To clarify the characteristics of differentiated services such as MGSP and PCL and operations related with policy, we consider three simple examples with the network configuration in Figure 1. Resource amounts are stated in terms of data rates. It is assumed that two hosts, S1 and S2, have applications that multicast data to three hosts, D1, D2 and D3.

4.1 MGSP service classes

Assume that the applications in S1 and S2 (of Figure 1) transmit data at the 3Mbps rate and D1 and D2 make a reservation of resources for flows of type MGSP. For simplicity, assume that D2 tries to reserve after D1 reserves. The maximum rate of each link is assumed to be 20 Mbps.

Assume that S1 transmits the PATH message and D1 tries to reserve resources for a MGSP flow. The flow uses the same reservation procedure as a flow belonging to the GS service class. We will call this flow1. Since the queueing delay bound of a flow of the MGSP class can be calculated with the same approach as a flow in the GS service class for initially reserving resources, we assume that 8 Mbps is calculated. Thus, each router on the way from D1 to S1 makes a resource reservation of 8 Mbps. When the router receives the refresh signal, the admission control module can renew the reservation for flow1 using the average value of resource usage based on values monitored until the refresh signal. The required resource is determined on the basis of delay bound and the closer the router to destination host then the smaller the delay bound. Hence, the actual monitored usage shows that the hosts closer to the source requires more resources than the hosts closer to the destination. Therefore, the resource actually used at each router could be measured as 6 Mbps at R1, 5 Mbps at R2 and 4 Mbps at R3. Based on these measurements, when the refresh signal is received, R1 assigns 6 Mbps to flow1 and 2 Mbps to the pool, R2 assigns 5 Mbps to flow1 and 3 Mbps to the pool and R3 assigns 4 Mbps to flow1 and 4 Mbps to the pool.

After some time, an application in S2 sends the PATH message (see Figure 1) and D2 tries to make a reservation for a new flow from S2 to D2. Let us call this flow2. If the queueing delay bound is initially calculated as 9 Mbps, each router on the way from D2 to S2 makes a resource reservation for flow2 at 9 Mbps. After an appropriate period, if the refresh signal is received, the monitored value could be 7 Mbps at R1, 6 Mbps at R2 and 5 Mbps at R3. Thus, flow2 is assigned 7 Mbps at R1, 6 Mbps at R2, 5 Mbps at R3. If the monitored current average value of the pool is 1, equation (1) in section 3 makes each router reserve 3 Mbps for the pool at R1, 4 Mbps for the pool at R2 and 5 Mbps for the at R3.

Therefore, if the flows use only the GS service class, each router requires 17 Mbps reservation, but the MGSP flows require only 16 Mbps (=6+7+4 (pool)) at R1, 15 Mbps (=5+6+4(pool)) at R2, 14 Mbps (=4+5+5(pool)) at R3 for two flows. The MGSP service can provide a more efficient usage of resources (assuming there is more than one flow).

4.2 PCL and CL Service Classes

In this case, we assume that flow1 and flow2 in the example in Section 4.1 use the PCL service class and the CL service class respectively, and the maximum rate of each link is 10 Mbps.

As each flow follows the reservation sequence of the CL service class, each flow reserves 3 Mbps resource at each router. Assume that flow1 and flow2 actually need 6 Mbps and 7 Mbps, respectively. All of the flows require more than the maximum rate of the link. Therefore, if there are only two flows at the router R1, flow1 can use 6 Mbps and flow2 can use 4 Mbps.
because flow1 has precedence over flow2. The flow2 only gets resources if the PDP has a policy that states that if there are not enough resources for 6 Mbps then assign fewer resources. If this had not been stated in the policy, then the PDP could have invoked the blocking reservation() method. In addition, as total required amount of flow1 and flow2 at router R3 does not exceed the link capacity, thus priority does not influence usage of the flows.

4.3 Policy-Based QoS Service with RSVP

In Figure 1, we assume that a user in S1 tries to transmit data to D1 or D3 using three applications. We assume that flow1, flow2 and flow3 want to reserve (flow1 followed by flow2 followed by flow3) in the GS service class. It is also assumed that the link capacity is 40 Mbps and each application transmits the data at 3 Mbps and its delay bound is 7Msps. The user is assumed to be able to request a certain service class under the following contract: 10 Mbps for GS, 10 Mbps for MGSP; 5 Mbps for PCL and 5Mbps for CL.

As expected, flow1 can reserve the resources assigned to the GS service class based on its request. After that, when flow2 requests the GS service, the PDP knows that there is only 3 Mbps contracted for the GS service class as it inquires for this information using the resource_monitor() method. The PDP may have policies that assign flow2 to the MGSP service class after it compares the flow2’s requested 7 Mbps with 3 Mbps of residual resource contracted for GS + 10 Mbps of resource contracted for MGSP. Sometime later, the average usage of resources for flow2 in the MGSP service class may be determined to be 5 Mbps. In turn, when flow3 requests the reservation, the PDP can assign (based on policies) flow3 the 3 Mbps of residual resources contracted for GS + 4 Mbps from the MGSP service class. Basically, this allocation assumes that policies take as much of possible from the higher priority class before taking resources from the lower priority class.

V. RELATED WORK

As discussed earlier, research on policy based RSVP for QoS is led by IETF’s rap working group [7]. This working group discusses and organizes the basic concepts and framework. Based on this effort, Cisco, KT, Nortel and the other network-related companies have announced many policy-based QoS service and/or products with RSVP.

Research on improvement of IETF’s service classes and development for a new service has been carried out with a view focused mainly on the data link layer and/or ip layer – this has led to work on RSVP scalability [15,16,17]. We can see some effort for adopting various applications to the data link layer and/or ip layer – this has led to work on RSVP scalability.

VI. CONCLUSIONS

In this paper, in order to provide policy based QoS service with RSVP appropriately, we have proposed a new service class, MGSP and have considered a mechanism for the QoS service with the differentiated services – GS, MGSP, PCL and CL.

Led by IETF’s rap working group, there has been a good deal of research on policy-based QoS with RSVP. However, these research results have been mainly focused on concepts, protocols and frameworks. Little work has been done on the applicability of policies to RSVP. Therefore, this paper has discussed how the service could be provided practically, proposed a new service class, MGSP, and described a mechanism in which policies lets users/applications actually control the QoS with differentiated services. This policy-based QoS control mechanism is based on the SLA, so it needs to discriminate communication entities/users. In this paper we simply use “token” as an field of the policy data structure, but further study is needed for token to be tied up with an authentication system. The proposed MGSP service class may be supposed not to provide theoretically the complete lossless transmission, but we predict it to practically service it. We are currently implementing the proposed scheme.

REFERENCES