The Feasibility of Introducing ATM SVCs

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Abstract: This paper presents the results of a case study performed for SURFnet bv. to determine if the time is ripe to introduce ATM SVCs into the Dutch ATM research network. The current state of the art in ATM SVCs is that vendors have been shipping SVC capable equipment for some time now. SVCs seem attractive, in the sense that they can be created on demand and instantaneously by the user, and that they are guaranteed to provide the QoS level that the user requested. In case of overload, however, ATM will no longer be able to accept new connections and users will experience denial of service. The question being addressed in this paper is whether such denial of service situations can be managed using current equipment and standardized solutions. Three strategies are being examined: is it possible to introduce different access policies for different users; is it possible to intervene in existing connections and is it possible to reduce network load by calling users to account? The outcome of the case study is that denial of service problems can not yet be managed properly. For this reason, and despite the availability of SVC capable ATM products, SURFnet decided to call off the introduction of ATM SVCs. **Keywords**: Quality of Service management, case-study, ATM, SVCs, QoS, denial of service, SURFnet.

1 Introduction

SURFnet bv is the organisation responsible for running the research network between the Dutch universities. To enable the introduction of advanced multi-media applications like video conferencing and tele-education, SURFnet investigated the introduction of new network technologies. Until recently, the most promising technology to support multi-media applications was Asynchronous Transfer Mode (ATM). ATM allows users to set up Switched Virtual Circuits (SVCs) that have a guaranteed Quality of Service (QoS) and is therefore perfectly suited to support multi-media applications.

To deliver the guaranteed QoS for a connection, an ATM network allocates network resources (like link bandwidth and cell buffer space) for that connection. Current ATM networks allocate the scarce network resources to incoming connection requests on a first-come first-served basis. Furthermore, a new connection can claim *all* of the remaining free resources. This can result in an unwanted distribution of network resources over connections, as illustrated by the following example. On a university ATM network, a student starts a video conference to discuss last night's soccer match with a friend. Next a teacher tries to start a video conference for a remote guest lecture; this fails due to lack of resources. The teacher experiences the failure to establish an ATM connection as denial of service. Denial of service due to an unwanted distribution of network resources is therefore an important problem to be addressed when deploying network technologies like ATM that provide QoS guarantees.

This paper presents the results of a study we have performed for SURFnet to investigate how problems like service denial can be managed, and to determine whether the time is ripe

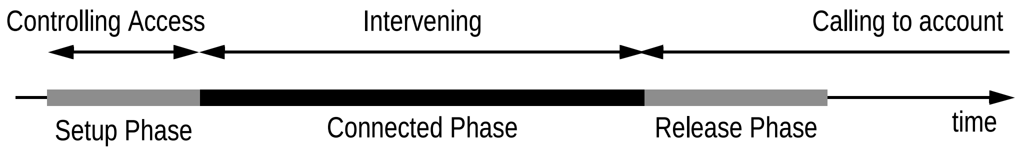

Figure 1: The Life-cycle of a ATM SVC Connection

to introduce ATM SVCs. Because the SURFnet ATM network consists of equipment from multiple vendors, the emphasis of the study had to be on existing products and standardized solutions.

The approach taken in the study is to address the problem from three different perspectives with respect to the life-cycle of a SVC (Figure 1):

- Is it possible to *control access* (section 2) in the connection setup phase, as to enforce different admission policies for different types of users? Such policies should prevent that certain (categories of) users establish connections at less desirable moments, for example “economy class users” at working hours or at times the network is highly loaded.
- Is it possible to *intervene* (section 3) in existing connections, for example to reduce the resources allocation for a connection or to abort a connection?
- Is it possible to take measures after the fact that make denial of service less likely? A common strategy to achieve this is to *call users to account* (section 4). Section 4 therefore discusses current options to do ATM-SVC accounting.

The conclusions of this feasibility study are presented in Section 5.

2 Controlling Access in the Setup Phase

Denial of service occurs when the network does not have sufficient resources left to support the new connection. The first opportunity to minimize denial of service due to lack of resources is therefore to control the user’s access to network resources in the connection setup phase. This controlled access should result in a good distribution of the scarce network resources over connections.

When investigating capabilities of some of today’s ATM switches we found no switches that are able to perform such controlled access. We found switches to have only a Connection Admission Control (CAC) function. The CAC function accepts a new connection if the required resources for it are currently available, irrespective of the amount of requested resources or of the requesting user. So with only CAC, any user can claim all remaining network resources at any time. If that happens, all subsequent connection requests will fail. This shows that CAC alone is not sufficient to prevent unwanted distributions of network resource over connections from occurring. We therefore investigated a solution to this problem.

First possible criteria for a connection admission policy are discussed in section 2.1. Next an approach to actually enforcing such policy is discussed in section 2.2.

2.1 Criteria for a connection admission policy

We have identified at least four criteria on which to base connection admission decisions. Each of these criteria is illustrated by an example.

- *Individual Users:* The maximum amount of network resources a particular user can claim for a connection can be specified. This can be done per individual user or per group of users. This allows different users to get a different maximum QoS from the network. Example: users in the “economy” class can use at most 1 megabits per second (Mbps) per connection, users in the “premium” class can use up to 3 Mbps.
- *Remaining Credits:* A user or group of users can be allowed to use a limited amount of resources per measurement period. Example: A user is allowed 10 hours worth of 1 Mbps connections per week.
- *Network Status:* Policies can depend on the current overall network status. Example: “economy” class users can not set up new connections when the network is over 60% loaded.
- *Current Time:* Policies can depend on the current time of day. Example: “economy” class users can use up to 1 Mbps connections during business hours, and up to 3 Mbps connections in other hours.

Enforcement of an admission policy based on these criteria results in users experiencing different QoS from the network. This should be reflected in the Service Level Agreement between users and provider of the ATM network service.

2.2 An Approach to Enforcing a Connection Admission Policy

This section proposes an approach to verifying the connection admission policy for each connection request. An admission policy server is introduced into the network for this purpose.

A connection request arrives over a User Network Interface (UNI) at a switch in the ATM network. This switch performs its normal CAC function to see if sufficient resources are available to accept the connection. In addition to that it must also be verified if the request meets all the criteria prescribed by the connection admission policy. The signalling system of the switch therefore forwards the request to the admission policy server in the network. This server verifies if the request meets all of the policy criteria, and either accepts or rejects the request. The server sends the outcome of the verification back to the switch. If the request is approved by both the CAC function and the policy server then the connection set up continues along the connection path, and provided that all subsequent switches have sufficient resources available the set up succeeds.

The admission policy server needs to have access to all the information needed to verify the criteria identified in section 2.1. This is shown in Figure 2.

The admission policy server has access to a database of user profiles. Such a profile contains for each user the information needed to check the admission policy criteria. Examples are the maximum allowed bandwidth per connection, remaining usage credits and allowed times of day for connections.

The network will have a monitoring process to gather per-user information on usage of the network resources. This information is available to the admission policy server for admission criteria that depend on how much use a user has made of the network in the past. Such criteria in fact make use of accounting information (discussed in section 4) for connection admission decisions.

Another process monitors the status of the network, e.g. the load percentage of the network. The total amount of bandwidth reservations on each link or the average fill level of the switch cell buffers could be used to calculate a value for the network load percentage.

Finally the admission policy server will have access to the current time, to allow for policies that depend on the time of day, day of the week etc.

At the time this feasibility study was performed, none of the standardisation organisations was addressing these particular policy issues, but fortunately the RSVP Admission

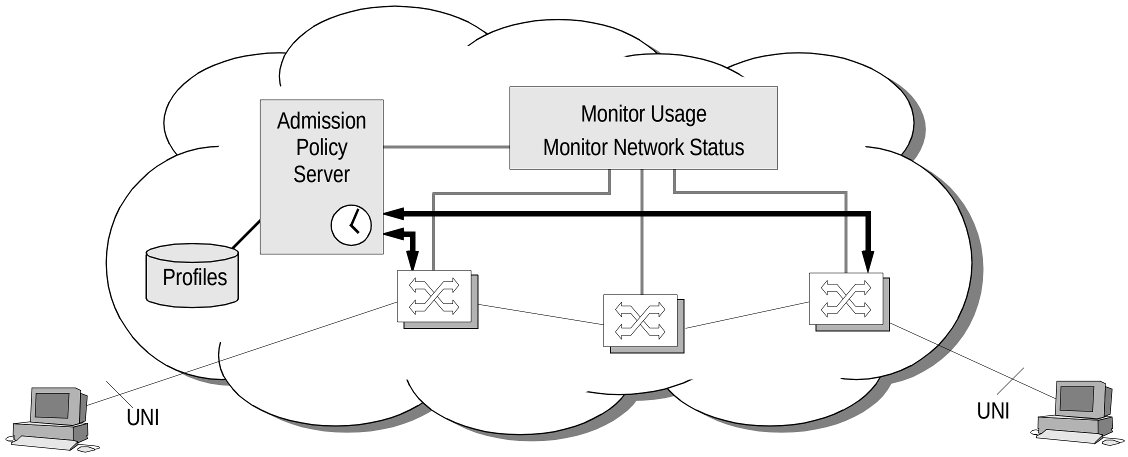

Figure 2: ATM network with Admission Policy function

Policy group of the IETF has now started work on this subject (admission control framework [11], COPS [3] and OOPS [7]).

3 Intervening During the Connected Phase

To enable the creation of a high priority connection, a human manager might want to reclaim resources from other existing connections with a lower priority. This can be done by either lowering the resource usage of such connection somewhat, thus degrading its QoS, or by aborting the connection altogether, thus freeing up all of its resources. Intervening in existing connections may be necessary in cases where controlled access to network resources (section 2) is not possible, and accounting (to be discussed in section 4) is either not possible or does not have the desired effect. Degrading or even aborting connections may have far-reaching consequences; the provider should therefore discuss the possible use of this option with its customers as part of the Service Level Agreements (SLAs).

3.1 IETF MIB Support for Intervening

Based on the MIBs defined by the IETF, this section explains how managers should be able to abort existing SVCs. The MIBs that can be used for this purpose are the ‘AToM-MIB’ [1] and the ‘Supplemental MIB’ [2]. The AToM-MIB defines general ATM management information and has currently the status of proposed standard; the supplemental MIB defines information specific for SVCs and has currently the status of working draft.

Whenever a connection is set up by the signalling system, a row is created in the *Cross-connect table* of each switch on the path between the source and destination. The row contains, amongst others, the Interface number (IF), Virtual Path Identifier (VPI) and Virtual Channel Identifier (VCI) of the incoming as well as outgoing link, but also an index value and a row status (Figure 3). The ATM addresses that belong to the connection can be found by using the row’s {IF, VPI, VCI} triples as an index into the *Address table*. The resources reserved for this connection can be found by using the row’s index parameter as index into the associated entries in the *Traffic parameter table* (this mapping uses another table, which is not shown in the figure). The connection can be aborted by setting the row status parameter to *destroy*, which removes the row from the cross connect table.

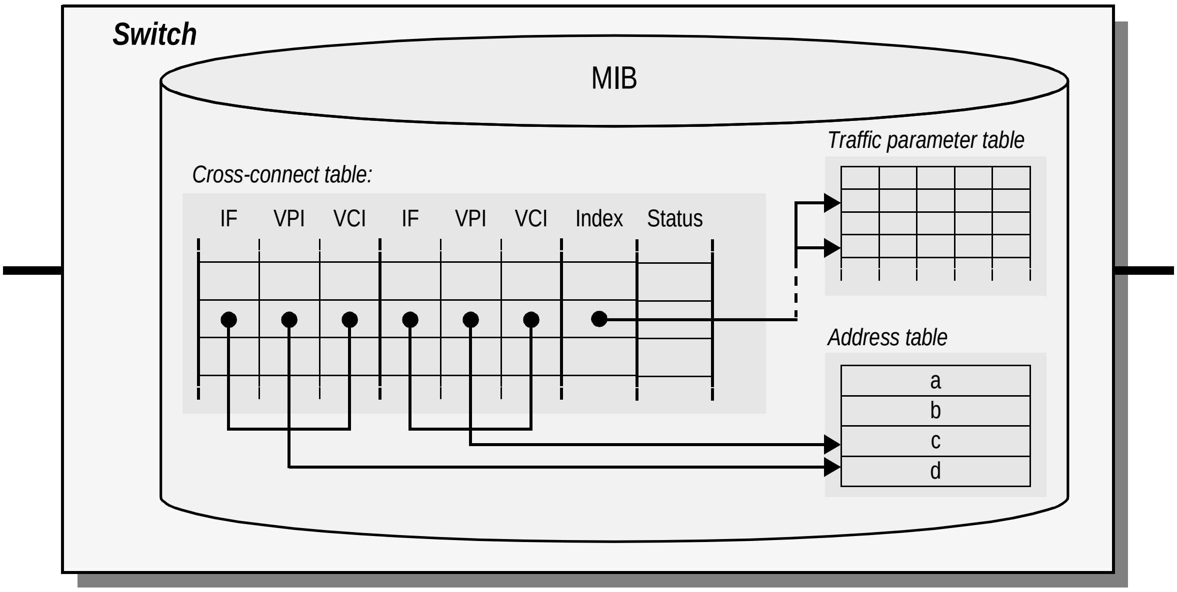

Figure 3: Aborting connections, based on IETF MIBs

After the manager removes a row in one of the switches along the path, the signalling system should inform the other switches along the path that the connection has been aborted and, as a result, all resources that have been reserved for the connection should be released.

As part of our research for SURFnet, we wanted to test this theory on commercially available switches. Since these switches do not (yet) implement the supplemental MIB, we had to use proprietary MIBs for these tests. Unfortunately the implementation of these MIBs contained a number of bugs that prevented us from performing the tests.

4 Charging for Network Use

In general a good approach to discourage the use of a scarce resource is to make users pay for it. Paying for the use of network resource will encourage them to set up only those connections they really need, and release them immediately after use. The mechanism that is needed to enable this is called accounting, and is generally divided into three phases [5].

- The first phase is to measure, at specific locations in the network, the use of network resources for each connection; this is called usage metering (section 4.1).
- The second phase is to collect the usage metering information for a connection from each provider and calculate a price for it; this is called charging (section 4.2).
- The third phase is to collect all the charging information for one user and to put it on a bill. This bill is sent to whoever has to pay for the connections set up by this user; this is called billing (section 4.3)

4.1 Usage metering

The usage metering process is responsible for the collection and storage of usage information per user per connection. This information is stored in a usage record. Usage metering shall in most cases be performed on the borders of the provider’s network. Because the service is defined on those borders, this ensures that the obtained metering information will be in complete agreement with the delivered service. A neighbour at the other side of the network border can either be a user or another provider.

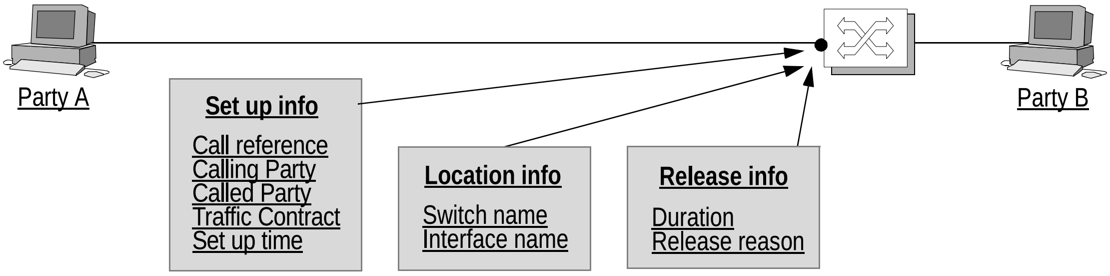

Figure 4: Usage Metering for a Connection

In the connection setup phase the setup request passes a number of switches between the end points of the connection. Each of those switches that does usage metering will create a separate usage record for the connection. Initially each usage record contains:

- the precise location where the usage information was metered;
- the time the connection was created;
- information describing the connection itself, like the end points involved in the connection and the traffic contract.

During the lifetime of the connection, usage information (e.g. amount of transported data) will be collected and also added to the record. When the connection finally is released the last usage information and the time of connection release are added to the record. Now the usage metering process for this connection is finished and the usage record is ready for further processing (see section 4.2).

Because SURFnet operates a multi vendor ATM network we had to look at a standard solution for usage metering. The IETF is one of the organisations that have drafted a proposal for the necessary parameters for a usage record [9]. Below we give an overview of the most important parameters in this proposal (see Figure 4):

- The metering location
  To be able to determine the location on the network border where the usage record is created, the name of ATM switch must be preserved. The name of the interface is necessary to pin-point the exact location within the switch.
- Connection setup information
  The connection can be uniquely identified by the calling party, the called party and the call reference value which is coming from Q.2931 [10]. The traffic contract describes the connection itself. The setup time specifies the moment the connection was created, which is useful in the charging phase to make a distinction between different times of the day.
- Connection release information
  When the connection is released, the duration - or life time - of the connection can be determined. The release cause is also useful, because a user would probably want to be charged less for a SVC terminated due to a network error, than for one released by himself.

At the moment there are no implementations of this IETF proposal, but a number of vendors has propriety solutions for usage metering [15][16][17][18].

4.2 Charging

The purpose of charging is to calculate a price for the use of network resource, and to generate charging records for that. We have split this process into three sections:

- *The installation costs* : A charging record for the installation costs is created once, when the user first subscribes to the ATM network service. The user is charged for the fact that from now on he has the possibility to use the network.
- *The subscription costs:* A charging record for these costs is issued periodically, and is used to charge the user for having access to the network during this subscription period.

- *The per-call costs:* these can be calculated in two different ways:
  - A *flat rate* charging scheme can be used. In a charging period each user pays the same fixed price each billing period, corresponding to the average user's use of the network. On balance this scheme reduces the per-call costs to zero; the height of the bill will be independent of how much a user has actually used the network. As such in a flat rate charging scheme there won't be a charging record per call, and the call related costs can be considered a component of the subscription costs. Note that in this case no metering records per call are needed either.
  - The *actual use* of network resource of each individual call can be charged. A call can consist of multiple connections, so the provider first has to collect all usage metering records for a call. Based on these usage metering records the price of the call is calculated. This can e.g. be a fixed price per call (reflecting the average costs per call), or it can be determined by looking at (a combination of) the duration of the call, the transmitted and received volume of data, the amount of resource that was reserved for the call, time of day the call occurred, etc.

At the moment there are two ACTS [12] projects working on this topic: Contract Negotiation and Charging in ATM Networks (CANCAN, [13]) and Charging and Accounting Schemes in Multi-Service ATM Networks (CA$hMAN, [14]).

4.3 Billing

The billing process is responsible for creating a bill for each user. In order to do this, a list must be made of all charging records belonging to one user. From this list a bill must be constructed for each user, specifying the installation costs, subscription costs and the costs for all the calls the user has made.

When all the connections of all calls of a user stay within the boundaries of the user's own provider, charging records will only be generated within the domain of the provider. In this case the provider has all the charging information needed to send his subscriber the bill for his connections.

When a connection crosses one or more provider boundaries, the billing process becomes more complex. For a single call, costs (and thus charging records) are generated within different providers, and there are now different ways in which the user can finally receive the bill for all of those costs. We have identified four options to deal with this problem, but other solutions are also possible [4]:

- *Settlement with the predecessor:* A provider can send the bill for its part in the call to the provider the call is directly coming from. The originating provider then finally charges the user for the complete call.
- *Settlement with the originating provider:* Another solution is to let each provider send his bill directly to the originating provider. The originating provider collects all bills and charges the user for the complete call.
- *Settlement with the originating user*: A third solution is to let each provider, including the originating provider, send their bill directly to the user.
- *Central billing system*: And finally it is also possible to establish a central billing system that collects all the bills from the providers and combines them into one bill the user.

5 Conclusions

This paper discussed the state of the art in ATM SVC management, in particular the problem of service denial due to lack of available network resources for a requested connection. As shown in Section 2, the Connection Admission Control (CAC) mechanisms of current ATM equipment are unable to give critical users precedence over others. Preventing ‘low priority’ users from (deliberately) taking all available resources is therefore not possible at this time. Given this impossibility, the question arises whether it is possible to manually abort unwanted connections to free up resources for other, wanted connections. As shown in Section 3, aborting connections is possible, but cumbersome. Finally Section 4 discussed a possible way to reduce the amount of requested network resources by calling users to account. Accounting can be divided into three different aspects: usage metering, charging and billing. For ATM usage metering a number of MIB standards are being developed by the IETF. Although these standards have not yet been implemented in existing switches, vendor specific MIBs with similar functionality have already been implemented. Usage metering is therefore possible, although not in a vendor independent way. Standards for ATM charging and billing do not yet exist.

This feasibility study showed that there are serious problems to ATM SVCs when it comes to actually deploying them; in particular the impossibility to prevent users from (deliberately) capturing all available network resources is a serious risk. For SURFnet the lack of adequate SVC management as outlined in this study was enough reason to postpone the introduction of SVCs into their network. Although SURFnet continues to use PVCs, it currently investigates alternatives to SVCs, such as IPv6 in combination with RSVP, and it is likely that ATM SVCs will never be introduced.

The problems with network resource allocation are not unique to ATM however. IPv6 and RSVP may face a similar fate as ATM SVCs, in the sense that they too guarantee a certain QoS by reserving network resource. The same denial of service problem therefore exist with IPv6 and RSVP. In fact every network that provides QoS guarantees faces this problem. Apparently the IETF has learnt from the problems with managing SVCs, since one of the IETF’s working groups has recently started to address policy issues (rapwg) and work is in progress on defining a framework for policy control [11] and policy service protocols (COPS [3] and OOPS [7]). Bringing forward standards and implementations for policy management will be a key issue for the success of these new Internet protocols!

Acknowledgements

The research reported on in this paper has been performed for SURFnet bv who also funded it. In particular we would like to thank Victor Reijs, Niels den Otter and Ronald van der Pol for bringing their expertise into this research project and for the comments and suggestions they gave on the material presented here.

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