Native ATM Support for ST2+

Status of This Memo

Abstract

   As the demand for networked realtime services grows, so does the need
   for shared networks to provide deterministic delivery services. Such
   deterministic delivery services demand that both the source
   application and the network infrastructure have capabilities to
   request, setup, and enforce the delivery of the data. Collectively
   these services are referred to as bandwidth reservation and Quality
   of Service (QoS).

   The IETF is currently working on an integrated services model to
   support realtime services on the Internet The IETF has not yet
   focused on the integration of ATM and its inherent QoS and bandwidth
   allocation mechanisms for delivery of realtime traffic over shared
   wires. (ATM hardware and interfaces provide the network
   infrastructure for the determinitic data delivery, however the host
   resident protocol stacks and applications need more attention.)

   Current IETF efforts underway in the IP over ATM (ipatm) working
   group rely on intserv, rsvp and ST2 to address QoS issues for ATM. As
   such, RFC 1577 and the ATM Forum's Lan Emulation do not provide
   direct QoS and bandwidth allocation capabilities to network
   applications. Without providing a mapping of reservations-style QoS
   to ATM signalling, ATM will remain a 'wire' rather than a shared
   media infrastructure component.

   This memo describes a working implementation which enables
   applications to directly invoke ATM services in the following
   environments:

        - ATM to internet,
        - internet to ATM, and
        - internet to internet across ATM.

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1.0 Introduction

   The ATM Forum and the IETF seem to approach ATM networking
   differently.

   The ATM forum appeaars to believe that host systems require no
   protocols beyond OSI layer 2 to deal with ATM. They define a layer 2
   API and Q.2931 signaling for all new applications.

   LAN Emulation, a mechanism to make the ATM interface appear to be a
   LAN/internet, is intended to support 'legacy' network applications.
   LAN emulation does not provide applications any visibility of the ATM
   features, nor does it provide a mechanism to allow applications to
   request specific ATM services. With LAN Emulation, application
   traffic shares virtual circuits with no policing or guarantees of
   service. LAN Emulation simply extends LAN characteristics to ATM.

Thus far, the IETF, through RFC 1577[1] treats an ATM network as a
wire. The ipatm working group has explicitly left issues of specific
QoS handling out of their specifications and working documents.
Current approaches do not give the application access to individual
virtualcircuits and their associated guaranteed bandwidth and QoS.
Instead, all IP traffic between two hosts shares virtual circuits
with no granularity assigned to application-specific traffic or QoS
requirements.

Thus, neither LAN Emulation nor RFC 1577 (IP over ATM) uses the
features of ATM that make it a unique and desirable technology. RFC
1821 (Integration of Realtime Services in an IP-ATM Network
Architecture) [2] raises many of the issues associated with current
IETF efforts towards integrating ATM into the Internet, but it does
not propose any solutions.

This document offers a framework for provision of native ATM
circuits for applications which require bandwidth guarantees and QoS.
It identifies the requirements of a native ATM protocol which is
complementary to standard IP and describes one working
implementation.

This document recognizes the fact that it is critical that such a
native ATM protocol is consistent in the four topologies described
in [2]:

*   Communication across an ATM-only network between two hosts
        directly connected to the ATM network,
*   Communication between ATM connected hosts which involves some
        non-ATM subnets,
*   Communication between a host on a non-ATM subnet and a host
        directly connected to ATM,
*   Communication between two hosts, neither of which has a direct
        ATM connection, but which may make use of one or more ATM
        networks for some part of the path.

That is, to the host systems, the underlying type of network remains
transparent even when QoS is involved in internet, ATM, and mixed
networking environments. To make this consistency possible, the
'native ATM' protocol must also be:

*   Multicast capable, to optimize transmission overhead and
        support ATM multipoint facilities,
*   Routable, to enable transmissions across subnets and
        internets,
*   QoS knowledgeable, to take advantage of ATM QoS facilities,
*   Capable of Bandwidth/QoS Reservation to allocate proper
        facilities for application traffic as it travels across

        different types of networks: to effectively extend virtual
        circuits across internets, and
*   Capable of policing to ensure proper packet scheduling
        behavior and to protect guaranteed services at merge points.

Clearly the protocol should support reservations. Reservation
protocols enable creation of 'virtual circuits' with guaranteed
bandwidth and QoS on the LAN or internet, and simultaneously can act
as signaling mechanisms to routers or ATM interfaces to request
provisioning of circuits. Use of a reservation protocol makes
characteristics of mixed networks (LANs, internet, ATM, ISDN)
transparent to the host systems.   That is, a reservation will allow
the host or router to provision ATM circuits which match the
reservation, but in mixed networks, will allow routers and host to
provide bandwidth reservation and QoS across the non-ATM interfaces
as well. Effectively, the reservation maps ATM virtual circuits to
reservations on subnets and internets.

This creates a consistent End-to-End, QoS-guaranteed service for
mixed network topologies.

While it is beyond the scope of this document, the same requirements
apply to mixed ISDN networks and are currently being explored by the
ITU for their H.323, H.223, and T.123 standards.

Arguably, the reservation protocol that provides this end-to-end
guaranteed service should be connection-oriented to facilitate
mapping of real connections (ATM or ISDN) with virtual connections on
the LAN/internet. [2] points out the shortcomings of IP and RSVP [3]
in the ATM environment. Most notable among these are the difficulty
of mapping connectionless traffic to ATM connections, the constant
softstate refreshes of RSVP (and merging of RESV messages), the
receiver orientation of RSVP, and the dependence on IP multicast.

[6] is an excellent document that proposes solutions to many of the
issues raised in [2], but the solutions recommend modifications to
the current RSVP and ATM implementations. Recently, issues of
incompatibility with the current IP over ATM model, VC explosions due
to use of multicast groups and VC explosions due to features
associated with heterogeneous receivers suggest that the current
version of RSVP may be inappropriate for ATM implementations.

Since ATM is connection-oriented, hard state, and origin-oriented for
transmission, signaling, and multicast, and is bandwidth and QoS
knowledgeable, perhaps the simplest and most elegant approach to a
native protocol for ATM would include a protocol that shares these
characteristics.

In surveying protocols described in IETF RFCs and Internet Drafts,
only two seem to meet these requirements: Experimental Internet
Stream Protocol: Version 2 (RFC 1190) [4] and Internet STream
Protocol Version 2+ (RFC 1819) [5]; ST2 and ST2+ respectively.

2.0 ST2 and ST2+

Both ST2 and ST2+ have been given the Internet Protocol Version 5
(IPv5) designation. In fact, ST2+ is an updated version of ST2.
Both protocols are origin-oriented reservation and multicast
protocols that provide bandwidth and QoS guarantees through
internets. Unlike IPv4 or IPv6, ST2 and ST2+ are connection-
oriented, subscribing to the philosophy that once a connection is
established, protocol and routing overhead can be substantially
reduced. This carries forward to QoS and Bandwidth Reservation as
well, simplifying the implementation of QoS guarantees. THESE
PROTOCOLS WERE INTENDED TO COMPLEMENT STANDARD CONNECTIONLESS IP,
RECOGNIZING THAT WHILE MOST INTERNET TRAFFIC BENEFITS FROM
CONNECTIONLESS NETWORKING, PERFORMANCE AND QoS GUARANTEES COULD BE
ACHIEVED MOST EASILY WITH INTERNET CONNECTIONS.

Both ST2 and ST2+ really consist of two protocols: SCMP and ST. SCMP
is analogous to ICMP in that it is the control and signaling
protocol, while ST is the low-overhead streaming protocol.   ST-2
uses standard IP addresses during connection setup, but then reduces
header overhead by including a stream identifier in each data packet.

ST2+ includes simplification of many of the original ST2 features as
well as clarification of the ST2 specification. Among these
simplifications and clarifications are:

1) Much simpler connection setup.
2) Flow Specification independence and consolidation of experimental
   Flow Specifications.
3) Clarification on the implementation of Groups of Streams.
4) Clarification of leaf-initiated JOINs in multicast trees (several
   ST2 implementations had done this).

While there continues to be a dramatic increase in the use of ST2
for videoconferencing, video on demand, telemetry applications and
networked virtual reality, ST2+ has no commercial implementations
and is not yet supported by any router vendors. This is because ST2+
was released as an RFC late in the summer of 1995. It is expected
that several implementations will appear over the coming months. As
such, the approach described in this document applies to both
protocols, and, in fact, would be valid for any other similar
protocol used to establish 'native' ATM circuits. Since ST2 and ST2+
are so similar, this document will refer to 'the ST2 protocols'

generically in describing an implementation approach to both. Where
particular features of ST2+ are required or affect implementation,
'ST2+ ' will be used specifically.

3.0 Implementation Issues for Reservations over ATM

   As described above, ST is a connection-oriented, hard state, origin-
   oriented multicast protocol and thus maps fairly well to ATM.
   However, ST-2 has several features that may be difficult to support
   in the current version of ATM signaling with Q.2931 and UNI 3.1.
   Among these are:

   1) Addressing.
   2) Changes to Bandwidth and QoS.
   3) Multicasting.
   4) Receiver initiated JOINs to multicast groups.
   5) Computation of certain QoS parameters.
   6) Use of HELLOs.

   The degree of difficulty in supporting these functions is dependent
   on the signaling mechanism chosen. See Section 4 for descriptions of
   possible signaling approaches and their respective impact on the
   features listed above.

3.1 Addressing

   Of course mapping an Internet address to ATM address is always
   problematic. It would be possible to set up a well known ARP server
   to resolve the IP addresses of targets. However, the widespread
   deployment of IP over ATM and LAN emulation in host-based ATM
   drivers, and the assumption that most host systems will be running
   some IP applications that do not need specific QoS and bandwidth
   provisioning, suggests that use of ARP facilities provided by IP
   over ATM and LAN Emulation is the most obvious choice for address
   resolution.

   It should be noted that ATMARP returns the ATM address. For some
   implementations (particularly kernel-based protocols), an NSAP
   address is also required. Since these addresses are often difficult
   to get from the ATM network itself in advance of the connection, it
   may be necessary to invoke out-of-band signaling mechanisms to pass
   this address, or it may be better to create an NSAP address server.

3.2 Changes to Bandwidth and QoS

   Both ST-2 and ST-2+ allow the origin to dynamically change the QoS
   and Bandwidth of a particular stream. At this time Q.2931 and UNI
   3.1 do not support this feature. Until this capability is available,

full support of the SCMP CHANGE message for dedicated ATM circuits
(one reservation = one ATM circuit) can only be implemented by
tearing down the existing VC for a stream and establishing a new one
if efficient use of ATM resources are to be preserved.

Of course, the CHANGE message can simply be passed across the ATM
virtual circuit to the hosts or routers. This would allow the hosts
to relax resource requirements locally, and permit routers to relax
access to downstream circuits, but the ATM VC itself, would still
retain excessive bandwidth.

In addition, if the implementation allows sharing of virtual circuits
by multiple streams, the bandwidth/QoS of individual streams within
the VC can be CHANGEd.

3.3 Multicasting

ST-2 and ST-2+ support origin-oriented multicasting. That is, the
origin of a stream explicitly specifies the addresses of the targets
it wants involved in the connection. In addition, the origin can Add
or drop targets as desired. Aside from receiver-initiated JOINs
(discussed in section 3.4), there is a one to one mapping between
ST-2 multicast and ATM multipoint connections. Origin-initiated
additions can be accomplished through an ADDPARTY, and drops can be
done through DROPPARTY.

A key goal in implementation of a native ATM protocol is to ensure
consistent implementation for unicast and multicast data transfers.
One difficulty in doing this with ATM Virtual Circuits is the fact
that point-to-point circuits are duplex, while multipoint circuits
are simplex. This means that for multicast connections to be mapped
to multipoint ATM Virtual Circuits, any two-way, end-to-end signaling
must be done out of band. An alternative is to let the local
reservation agent act as a split/merge point for the connection by
establishing point-to-point Virtual Circuits for each member of the
multicast group directly connected to the ATM network. For multicast
group members not directly connected to the ATM network, traffic can
be multicast to the router connected at the edge across a single
virtual circuit associated with the reservation.

Section 4 describes alternative mechanisms for implementing
signaling.

Included in each discussion is the optimal means for mapping
multicast to ATM point-to-point or multipoint circuits.

Note that the fact that ST-2 does not rely on IP multicast is a
strong advantage in implementation of a native protocol for ATM. The

   one-to-one mapping of ST-2 multicast connections to ATM multipoint
   virtual circuits minimizes the number of circuits required to support
   large multicast groups.

3.4 Receiver Initiated JOINs to Multicast Groups

   ST-2+ provides an in-band mechanism to permit receivers to join an
   existing stream. Based on an origin-established authorization level,
   the JOIN can be refused immediately, can be allowed with notification
   of the origin, or can be allowed without notifying the origin. This
   capability is made available through a new SCMP JOIN message. If the
   receiver knows the IP address of the origin and the Stream ID, he can
   join the stream if authorized to do so.

   Note that since the JOIN flows from the receiver to the origin, there
   will be issues in trying to support this feature with Q.2931 and UNI
   3.1. The JOIN may have to be sent out of band depending on the
   signaling mechanism chosen (section 4) because of the uni-directional
   flow for point to multipoint ATM connections. This is supposed to
   change with availability of UNI 4.0.

   ST-2 did not support receiver initiated JOINs (unlike ST-2+).
   However, most implementations created an out-of-band, or SCMP
   extension to support this facility. Again, depending on the SCMP
   signaling mechanism chosen, this feature may be difficult to support.

3.5 Computation of QoS Parameters

   The recommended flow specifications (flowspecs) for ST-2 and ST-2+
   include parameters that are not currently available to ATM virtual
   circuits through Q.2931 and UNI 3.1. The mapping of packet rate to
   cell rate, packet delay to cell delay, and other translatable QoS
   parameters is described in section 5. However, the ST-2 flowspecs
   also include parameters like accumulated end-to-end delay and
   accumulated jitter. These parameters assume that the SCMP messages
   follow the same path as the data. Depending on the signaling
   mechanism chosen, this may not be true with ATM and thus certain QoS
   parameters may be rendered useless.

   It should also be noted that since ST-2 connections are simplex, all
   QoS parameters are specified separately for each direction of data
   transfer. Thus two connections and two QoS negotiations are required
   for a duplex connection. To take advantage of the full duplex nature
   of point-to-point ATM connections, special multiplexing of ST
   connections would be required by ST-2 agents.

3.6 Use of HELLOs

   Both ST-2 and ST-2+ support HELLO messages. HELLOs are intended to
   assure that the neighboring agent is alive. Failure to respond to a
   HELLO indicates that the connection is down and that the reservation
   for that particular link should be freed.

   While the ATM network will notify an ST-2 agent if the network
   connection is down, there is still the possibility that the
   connection is intact but that the ST-2 agent itself is down.
   Knowledge of the neighboring agent's status is increasingly important
   when multiple ST-2 connections share virtual circuits, when the
   neighboring agents are routers, and when there are multiple dedicated
   virtual circuits between agents.

   As such, HELLO is a desirable feature. Note that some signaling
   schemes (section 4), provide less than optimal support for HELLO.

4.0 Reservation Signaling with ATM

   Use of Permanent Virtual Circuits (PVCs) for reservation signaling
   presents no problem for ST-2, ST-2+, or RSVP. Each circuit is
   considered to be a dedicated link to the next hop. If the PVCs are
   to be shared, reservation protocols can divide and regulate the
   bandwidth just as they would with any other link type.

   Where ATM connections become more interesting is when the ATM network
   takes on the role of an extended LAN or internet. To do this,
   Switched Virtual Circuits are used to establish dynamic connections
   to various endpoints and routers. The ITU-TS Q.2931 SETUP message is
   used to request a connection from the network with specific bandwidth
   and QoS requirements, and a CONNECT message is received by the origin
   to indicate that connection establishment is complete.

   For IP over ATM and LAN Emulation, SVCs are established between
   endpoints and data traffic for a given destination shares the SVCs.
   There is no mechanism to allow specific QoS guarantees for the
   traffic, nor is there a mechanism to set up virtual circuits with
   specific bandwidth and QoS for a particular type of traffic. This is
   what reservation protocols will attempt to do. The goal is to use
   reservations to request establishment of individual virtual circuits
   with matching bandwidth and QoS for each reservation. This will
   guarantee the requirements of the application while taking full
   advantage of the ATM network's capabilities.

   There are four possible mechanisms to perform reservation signaling
   over ATM:

   1) Embedding reservation signaling equivalents within the ATM Q.2931
      controls.
   2) Signaling in-band with the data.
   3) Signaling over dedicated signaling VCs.
   4) Implicitly sharing existing VCs for IP over ATM or LAN Emulation.

   Note that ATM circuits are not necessarily reliable. As such, the
   reliability mechanisms provided by SCMP must be maintained to assure
   delivery of all reservation signaling messages.

4.1 Embedded Reservation Signaling Equivalents within ATM Q.2931
    Controls

   The basic idea in embedding reservation signaling within the ATM
   controls is to use the Q.2931 SETUP and CONNECT messages to establish
   both reservations and dedicated data paths (virtual circuits) across
   the ATM network. This eliminates the need for dedicated signaling
   channels, in-band signaling, or out of band mechanisms to communicate
   between endpoints. Since SETUP and CONNECT include bandwidth and QoS
   information, the basic concept is sound. In fact, this approach will
   speed network connection by preventing multiple passes at
   establishing a reservation and associated connection. This normally
   results from the fact that most higher layer protocols (network and
   transport) first require a link to signal their connection
   requirements. As such, with ATM, the ATM virtual circuit must be
   established before the network and/or transport protocols can do
   their own signaling.

   Embedded reservation signaling allows the reservation information to
   be carried in the SETUP and CONNECT messages, allowing the
   reservation protocol to do its signaling simultaneously with the ATM
   signaling.

   [7] describes a clever way of combining the reservation signaling
   with the ATM control plane signaling for ST-2. This 'simultaneous
   connection establishment' process will optimize the establishment of
   circuits and minimize connection setup time while simultaneously
   eliminating unnecessary network layer signaling in ST-2. To be
   effective, [7] requires enhancements to Q.2931 signaling and to the
   ST-2 protocol implementations. In addition, it currently only
   applies to point-to-point connections and will not work with
   multipoint largely due to the simplex nature of multipoint
   communication in current ATM implementations.

   Implementation of multicast for Embedded Reservation Signaling is
   done as described above: the reservation agent at the edge of the ATM
   network must create point-to-point virtual circuits for each target
   that is directly connected to the ATM network, and for each router

that supports downstream targets. This ensures two-way signaling
between targets and the origin.

Signaling itself is quite simple:

        CONNECT maps directly to one or more (multicast) Q.2931
                SETUPs and CONNECTs.
        ACCEPT maps directly to Q.2931 CONNECTACK.
        CHANGE/CHANGE REQUEST are not supported.
        DISCONNECT maps directly to Q.2931 RELEASE.
        HELLOs are not needed.

Unfortunately, the flowspec in the reservation protocol CONNECT
message cannot be passed across the ATM network in the signaling
messages and thus must be regenerated by the receiving agent.

In addition, User Data, which can be sent in most SCMP messages
cannot be supported without substantial changes to current Q.2931
signaling.

One of the additional complexities with embedding the reservation
signaling occurs in heterogeneous networks. Since ATM signaling only
operates point to point across the ATM network itself, if the
endpoints reside on other types of networks or subnets, the routers
at the edge of the ATM networks must generate and regenerate
endpoint-based signaling messages on behalf of the host reservation
agents. In particular, CONNECT and ACCEPT messages and their
associated flowspecs must be regenerated. Refer to Section 5 for
details on the QoS mappings and on which QoS parameters can be
recreated for the generated flowspecs.

This approach is worth revisiting as an optimal signaling method in
pure ATM network environments once ATM signaling capabilities expand.

However, for heterogeneous networks, other signaling mechanisms may
be more appropriate.

4.2 In-Band Reservation Signaling

In-Band Reservation Signaling is the easiest signaling mechanism to
implement. When the applications requests a reservation, the
reservation agent simply sets up ATM virtual circuits to the
endpoints with the QoS specified in the CONNECT request. When
ACCEPTed, all subsequent data transmissions proceed on the virtual
circuits.

Once again, to support multicast, the reservation agent must create
individual point-to-point virtual circuits to the targets which are

directly connected to the ATM network, as well as to routers which
can access downstream targets.

Since signaling is done in-band, all reservation signaling messages
can be passed between agents. However, some minimal additional
bandwidth must be allocated in the Q.2931 SETUP to allow for the
signaling messages themselves.

Note that the primary disadvantage to In-Band Reservation Signaling
is the fact that it does not make use of the multipoint capabilities
of ATM and will thus overreserve ATM network bandwidth and create a
larger than necessary number of virtual circuits.

4.3 Dedicated Reservation Signaling Virtual Circuits

One mechanism that can be used to take advantage of the full data
transmission capabilities of ATM networks is to use Dedicated Virtual
Circuits for reservation signaling. This guarantees a two-way
signaling pipe between the endpoints in a connection while enabling
the data transmission to take advantage of the multipoint
capabilities of ATM. Data and Signaling are done over separate
virtual circuits.

When an application requests a reservation, the reservation agent
reviews the list of targets in the CONNECT request. For any targets
which have no current signaling virtual circuits established, the
agent establishes UBR (unspecified bit rate) virtual circuits and
forwards the CONNECT message to the targets over these virtual
circuits. ATMARP is used to resolve any endpoint addresses. For any
targets for which there already exist signaling virtual circuits, the
agent simply forwards the CONNECT message over the existing virtual
circuit.

Once an ACCEPT message is received, the agent issues a Q.2931 SETUP
to the associated target. Upon receipt of a CONNECTACK, data can
begin to flow. As additional ACCEPTs are received, the Q.2931
ADDPARTY message is used to add a target to the multicast and
multipoint connection. Depending on the cause of any ADDPARTY
failure, the agent may attempt to establish a dedicated point-to-
point virtual circuit to complete the multicast group.

DISCONNECT requests result in Q.2931 DROPPARTY messages and will
cause a member to be dropped from a multicast and multipoint
connection. When all targets are dropped from a multipoint
connection, a RELEASE can be issued to take down the virtual circuit.

Signaling virtual circuits are shared among reservations while data
circuits are dedicated to a particular reservation.   Once all

reservations to a given endpoint are terminated, the signaling
virtual circuit to that endpoint can be RELEASEd.

Note that this approach would allow the NSAP address to be passed as
user data in the ACCEPT message to enable a kernel-based reservation
protocol to establish the dedicated data circuit. In addition,
because the connectivity to the endpoint is identical to that of the
data circuit, this approach assures the fact that accumulated
information in the flowspecs retains it validity.

4.4 Reservation Signaling via IP over ATM or LAN Emulation

As described in the previous section, it would be possible to set up
unique SVCs for SCMP signaling, however, since the streaming,
connection-oriented data transport offered by ST-2 is intended to be
complementary to IP and other connectionless protocol
implementations, it would be simpler and more elegant to simply use
classical IP over ATM (RFC 1577) mechanisms, or to use LAN Emulation.
The widespread deployment of IP over ATM and LAN emulation in host-
based ATM drivers, and the assumption that most host systems will be
running applications that do not need specific QoS and bandwidth
provisioning, makes this the most straightforward (if not performance
optimal) solution for signaling. Once an end-to-end acceptance of a
reservation request is completed via normal LAN or IP transmission,
then a unique direct virtual circuit can be established for each data
flow.

If LAN Emulation is used, as long as the ST-2 implementation allows
for different paths for SCMP and data, there would be no changes to
the signaling mechanisms employed by the reservation agent.

For IP over ATM, all SCMP messages would be encapsulated in IP as
described in both RFC 1190 and RFC 1819. This is required because
current ATM drivers will not accept Ipv5 packets, and most drivers do
not provide direct access to the shared signaling virtual circuits
used for IP.

In either case, LAN Emulation or IP over ATM, the reservation agent
would handle SCMP messages as it normally does. However, once the
first ACCEPT is received for a reservation request, a dedicated
virtual circuit is established for the data flow. Subsequent ACCEPTs
will result in the use of ADDPARTY to add multicast targets to the
multipoint virtual circuit. In fact, processing of
multipoint/multicast is identical to that described in section 4.3.

Once again, the use of an out-of-band signaling mechanism makes it
possible to carry the NSAP address of the target in the ACCEPT
message.

One potential drawback to using LAN Emulation or SCMP messages
encapsulated in IP over ATM, is the fact that there is no guarantee
that the connectivity achieved to reach the target via signaling has
any relationship to the data path. This means that accumulated
values in the flowspec may be rendered useless.

In addition, it is possible that the targets will actually reside
outside the ATM network. That is, there may be no direct ATM access
to the Targets and it may be difficult to identify ATM addresses of
the associated ATM connected routers. This approach will involve
some additional complexity in routing to the targets. However, since
ST-2 is intended to run with IP, if ATM vendors would accept IPv5
packets or would allow direct access to the IP over ATM signaling
virtual circuits, this approach would be optimal in minimizing the
number of virtual circuits required.

4.5 Summary of Reservation Signaling Approaches

Embedded Reservation Signaling (section 4.1) is ideal for homogeneous
ATM connections, but requires extensions to existing ATM signaling
to support multipoint connections. In-Band Reservation Signaling
(section 4.2) is the easiest to implement, but cannot employ
multipoint connections either.

Perhaps the simplest way to do this is similar to what is suggested
in [6]: separate the reservation signaling from the actual data
flows, mapping the data flows directly to ATM circuits while doing
the signaling separately.

While there is significant complexity in doing this for IP traffic
and RSVP, the ST2 protocols lend themselves to this quite well. In
fact, because SCMP reservation signaling results in streaming,
multicast connections, the 'Shortcut' mechanism described in [6],
which can bypass routers where direct ATM connections are possible,
is automatically available to ST2 streams.

Using Reservation Signaling over LAN Emulation or IP over ATM
(section 4.4) is one multipoint-capable approach to implement in
hosts since most ATM drivers shipping today provide both IP over ATM
and LAN Emulation, as well as associated address resolution
mechanisms. However, it is not complete in its ability to accurately
depict flowspec parameters or to resolve host ATM addresses. In
addition, to be optimal, ATM vendors would either have to support
IPv5 in their drivers or allow direct access to the IP signaling
virtual circuits. Thus the current ideal approach to implementation
of the ST2 protocols over ATM is to use shared Dedicated Reservation
Signaling Virtual Circuits (section 4.3) for signaling of
reservations, and then to establish appropriate multipoint ATM

   virtual circuits for the data flows.

5.0 Mapping of Reservation QoS to ATM QoS

   QoS negotiation in ST-2 (and ST-2+) is done via a two-way
   negotiation.

   The origin proposes a QoS for the connection in a Flow Specification
   (Flowspec) associated with the CONNECT message. Most of the
   network-significant QoS parameters in the Flowspec include both a
   minimum and a desired value. Each ST agent along the path to the
   Target validates its ability to provide the specified QoS (at least
   the minimum value for each), updates certain values in the Flowspec,
   and propagates the CONNECT until it reaches the Target. The Target
   can either ACCEPT the Flowspec or REFUSE it if it cannot meet at
   least the minimum QoS requirements. Negotiation takes place as part
   of the process in that the Target can specify changes to the desired
   QoS values as long as the new value meets at least the minimum
   requirements specified by the Origin system. In addition, both the
   Target and the Origin can assess actual network performance by
   reviewing the values that are accumulated along the path.

   The primary Reservation QoS parameters that impact an ATM network
   are:

ST-2 (RFC 1190)   ST-2+ (RFC 1819)

Desired PDU Bytes,   Desired Message Size,
Limit on PDU Bytes (minimum).   Limit on Message Size.

Desired PDU Rate,   Desired Rate,
Limit on PDU Rate (minimum).   Limit on Rate.
Minimum Transmission Rate in Bytes.

Limit on Delay (maximum).   Desired Delay,
                                         Limit on Delay.

Maximum Bit Error Rate.

Accumulated Delay.
Accumulated Delay Variance (Jitter).

Q.2931 ATM signaling offers the following QoS parameters:

-       Cumulative Transit Delay,
-       Maximum End to End Transit Delay.

-       Forward Peak Cell Rate (PCR),
-       Backward Peak Cell Rate (PCR).

-          Forward Maximum CPCS-SDU size,
-          Backward Maximum CPCS-SDU size.

-          Forward QoS Class,
-          Backward QoS Class.

-          B-LLI (one byte user protocol information).

   As previously noted, reservation protocols (ST and RSVP) make QoS
   reservations in one direction only. Thus, depending on the type of
   signaling used (see Section 4), the 'Backward' ATM parameters may not
   be useful. In particular, if Multipoint ATM connections are used to
   map multicast reservations, these parameters are not available.

   However, it would be possible to implement a multiplexing scheme to
   enable reservations to share bi-directional point-to-point ATM
   connections if the reservation agent creates a split/merge point at
   the ATM boundary and sets up only point-to-point VC connections to
   targets.

   The CPCS-SDU parameters are AAL Parameters which are used by the AAL
   entity to break packets into cells. As such, these parameters are
   not modified by the network and could conceivably be used for
   additional end-to-end signaling, along with the B-LLI.

   Finally, QoS Class is somewhat limited in its use and implementation.
   While IP over ATM recommends use of Class 0 (Unspecified QoS), this
   is not sufficient for guaranteed connections. Instead, Class 1 with
   CLP=0 will provide at least minimum QoS services for the traffic.

5.1 CPCS-SDU Size Computation

   The CPCS-SDU size computation is the easiest QoS mapping. Since ST-2
   does not require a Service Specific Convergence Sublayer (SSCS), if
   AAL 5 is used, the ST packet size plus 8 bytes (for the AAL 5
   Trailer) will be the CPCS-SDU size. Note that the ST-2 packet size
   also includes an 8-byte header for ST-2. Thus the CPCS-SDU size is:

        CPCS-SDUsize = PDUbytes + 8 + 8.

   For ST-2+, the header is larger than for ST-2, so the CPCS-SDU size
   is:

        CPCS-SDUsize = PDUbytes + 12 + 8.

5.2 PCR Computation

   The Peak Cell Rate (PCR) computation is only slightly more complex.
   The PCR will be the peak packet rate divided by the ATM payload size.

   Since PDU rates in ST-2 are specified in tenths of packets per
   second, AAL 5 requires an 8 byte trailer, and the ATM payload size is
   48 bytes, the computation for PCR proceeds as follows:

        The requested maximum byte transmission rate for ST-2 is:

                PDUbytes * PDUrate * 10.

        Accounting for the AAL 5 and ST headers, the maximum byte rate
        is:

                Bytes per second = (PDUbytes + 8 + 8) * PDUrate * 10.

        Translating into cells and eliminating the possibility of a
        fractional PDU:

                PCR = ((PDUbytes + 8 + 8 + 48) / 48) * PDUrate * 10.

   For ST-2+, not only is the header size 12 bytes, but the Rate is in
   messages per second, not tenths of packets per second. Thus, the PCR
   for ST-2+ is:

                PCR = ((PDUbytes + 12 + 8 + 48) / 48) * PDUrate.

5.3 Maximum End to End Transit Delay.

   The End to End Transit Delay is a little more complex.   The
   requested end to end delay must account for not only the PDU size as
   requested by the user, but the additional 8-byte AAL 5 header as
   well. The translation of the user-requested LimitOn Delay is
   preserved as long as the delay computation is based on the CPCS-SDU
   size instead of the PDU size.

   In addition to the end to end delay introduced by the ATM network,
   there is additional delay created by the fragmentation of packets.
   Reassembly of these packets can only be accomplished at the rate at
   which they are received. The time (in milliseconds) required to
   receive a cell (inter-cell arrival time) is:

        T = 1000 / PCR.

The number of cells in a CPCS-SDU is:

        C = (CPCS-SDUsize + 48) / 48.

Thus the delay for a packet is:

        LimitonDelay = (C - 1) * T + MaxCellTransitDelay.

Therefore, the requested Maximum End to End Transit delay is:

        MaxCellTransitDelay = Limiton Delay - (C-1) * T.

5.4 Maximum Bit Error Rate

   Q.2931 signaling does not offer the ability to directly specify the
   requested bit error rate or a corresponding cell error rate.
   Instead, this service is supposed to be offered through selection of
   QoS class.

   Since these classes have few actual implementations, at this time,
   there is no effective mapping for bit error rate.

5.5 Accumulated Mean Delay

   ST allows accumulation of the Mean Delay generated by each ST agent
   node and intervening circuits. With an ATM circuit each agent should
   factor in the overhead of the ATM connection. The delay associated
   with the ATM circuit is reflected in the Q.2931 CONNECT message as
   the Cummulative Transit Delay. Since this is a cell-based
   computation, the delay experienced for an ST packet, including the
   CPCS-SDU header and ST header is, as computed in Section 5.3:

        Delay = (C - 1) * T + CummulativeTransit Delay.

5.6 Accumulated Delay Variance (Jitter)

   Cell Delay Variance is not currently available as a Q.2931 parameter.

   Thus, we can assume that the reassembly of cells into packets will
   be consistent, since the cell transmission rate should be constant
   for each packet. As such, except as noted by the specific ATM
   service, the ST agent should use its standard mechanisms for tracking
   packet arrival times and use this for Accumulated Delay Variance.

6.0 Data Stream Transmission

   Once virtual circuits for data transmission are established though
   one of the mechanisms described in section 4, the ST data must be

   transmitted over the connection. RFC 1483 describes mechanisms for
   encapsulating packet transmissions over AAL5. While the LLC
   encapsulation could be used, it is not necessary. If it is used, the
   computations in section 5 should be redone to include the LLC headers
   in addition to the AAL5 trailer currently used. These new values
   should be substituted for the QoS values in the SETUP message.

   Instead, ST data packets can be encapsulated in standard AAL5 format
   with an 8 byte trailer and sent directly over the data virtual
   circuit.   The mechanisms for computing the QoS values in the SETUP
   message are described in section 5.

7.0 Implementation Experience and Conclusions

   All of the signaling mechanisms described in Section 4 were
   implemented and tested in a mixed ATM network/routed LAN environment.

   Initially it appeared that the best approach was to do signaling via
   IP over ATM or LANE. However, because it required IP encapsulation
   of the SCMP packets (for IP over ATM), and because some applications
   use the accumulated values in the flowspecs (which are not guaranteed
   to be accurate in LANE and IP/ATM), using virtual circuits dedicated
   to SCMP signaling turned out to be the best implementation for
   taking full advantage of the ATM features.

   Also, the issue of mapping ATM address to E.164 NSAP addresses was
   resolved through an external signaling mechanism (the User Data field
   of the ST-2 CONNECT and ACCEPT messages). It appears that ATM
   vendors need to implement a consistent addressing mechanism
   throughout their interfaces.

   From a performance point of view, using ST over ATM provided more
   than triple the performance of raw IP. The differences became
   increasingly clear as more simultaneous applications were run. This
   resulted in dedicated virtual circuits for the ST traffic while the
   IP traffic suffered (saw inconsistent performance) over shared
   circuits. Even more dramatic were results in mixed network
   environments where all traffic shared the same LAN/router
   connections, and, when both IP and ST traffic was sent, the ST
   traffic maintained its quality while the IP traffic saw increasing
   variation in performance.

   Clearly, using a connection-oriented, origin-oriented reservation
   protocol to provide consistent end-to-end guaranteed QoS and
   bandwidth in mixed ATM/internet environments is not only feasible, it
   results in dramatic performance and quality improvements for
   transmission of realtime traffic.

8.0 Security Considerations

   This memo raises no security considerations. However, with their
   connection-oriented and origin controlled natures, ST-2 and ST-2+
   lend themselves to better internet security. Discussion of this is
   beyond the scope of this document.

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