                ATM Signaling Support for IP over ATM

Status of this Memo

   This document specifies an Internet standards track protocol for the
   Internet community, and requests discussion and suggestions for
   improvements. Please refer to the current edition of the "Internet
   Official Protocol Standards" (STD 1) for the standardization state
   and status of this protocol. Distribution of this memo is unlimited.

Abstract

   This memo describes the ATM call control signaling exchanges needed
   to support Classical IP over ATM implementations as described in RFC
   1577 [LAUB94]. ATM endpoints will incorporate ATM signaling services
   as specified in the ATM Forum User-Network Interface (UNI)
   Specification Version 3.1 [ATMF94]. IP over ATM implementations
   utilize the services of local ATM signaling entities to establish and
   release ATM connections. This memo should be used to define the
   support required by IP over ATM implementations from their local ATM
   signaling entities.

   This document is an implementors guide intended to foster
   interoperability among RFC 1577, RFC 1483, and UNI ATM signaling. It
   applies to IP hosts and routers which are also ATM endsystems and
   assumes ATM networks that completely implement the ATM Forum UNI
   Specification Version 3.1. Unless explicitly stated, no distinction
   is made between the Private and Public UNI.

UNI 3.1 is considered an erratum to the UNI 3.0 specification. It has been produced by the ATM Forum, largely for reasons of alignment with Recommendation Q.2931. Although UNI 3.1 is based on UNI 3.0 there are several changes that make the two versions incompatible. A description of how to support IP over ATM using UNI 3.0 is found in Appendix B.

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1. Conventions

The following language conventions are used in the items of
specification in this document:

    o   MUST, SHALL, or MANDATORY -- the item is an absolute requirement
         of the specification.

    o   SHOULD or RECOMMEND -- this item SHOULD generally be followed for
         all but exceptional circumstances.

    o   MAY or OPTIONAL -- the item is truly optional and MAY be followed
         or ignored according to the needs of the implementor.

2. Overview

    In a Switched Virtual Connection (SVC) environment, ATM virtual
    channel connections (VCCs) are dynamically established and released
    as needed. This is accomplished using the ATM call/connection control
    signaling protocol, which operates between ATM endsystems and the ATM
    network. The signaling entities use the signaling protocol to
    establish and release calls (association between ATM endpoints) and
    connections (VCCs). Signaling procedures include the use of
    addressing to locate ATM endpoints and allocation of resource in the
    network for the connection. It also provides indication and
    negotiation between ATM endpoints for selection of end-to-end
    protocols and their parameters. This memo describes how the
    signaling protocol is used in support of IP over ATM, and, in
    particular, the information exchanged in the signaling protocol to
    effect this support.

    IP address to ATM address resolution and routing issues are not in
    the scope of this memo, and are treated as part of IP in figure 1.

```
        +--------------+     +------+     +----------+
        |              |     |      |<--->| IP / ARP |
        |              |<--->| This |     | RFC 1577 |
        |     ATM      |     | Memo |     +----------+
        |   signaling  |     |      |<--->| RFC 1483 |
        |              |     +------+     +----------+
        |              |    ------------> |  AAL 5   |
        |              |                  +----------+
        |              |    ------------> |   ATM    |
        +--------------+                  +----------+
```
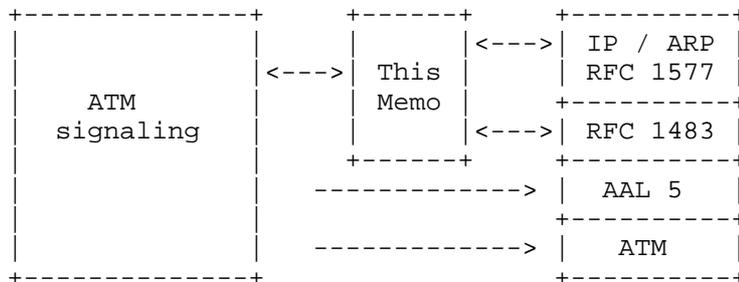
                         Figure 1.
            Relationship of this memo to IP, RFC 1483,
                  ATM signaling, ATM and AAL5

3. Use of Protocol Procedures

   The following requirements are motivated to provide implementation
   guidelines on how multiple ATM connections between peer systems
   SHOULD be managed, to prevent connection thrashing and related
   problems.

3.1. VC Establishment

   The owner of an existing VCC is defined to be the entity within the
   ATM endsystem that establishes the connection. An ATM endsystem MAY
   establish an ATM call when it has a datagram to send and either there
   is no existing VCC that it can use for this purpose, it chooses not
   to use an existing VCC, (e.g., for reasons of route optimization or
   quality of service), or the VCC owner does not allow sharing.

   To reduce the latency of the address resolution procedure at the
   called station, the following procedure MAY be used:

   If a VCC is established using the LLC/SNAP encapsulation, the calling
   endstation of the VCC MAY send an InARP_REQUEST to the called
   endstation after the connection is established (i.e. received a
   CONNECT message) and before the calling endstation sends the first
   data packet. In addition, the calling endstation MAY send its data
   packets without waiting for the InARP_REPLY. An endstation MAY
   respond, generate, and manage its ATMARP table according to the
   procedures specified in RFC1293 [BRAD92], Section 7, "Protocol
   Operation", during the life time of the VCC.

   To avoid establishing multiple VCCs to the same endstation, a called
   endstation MAY associate the calling party number in the SETUP
   message with the established VCC. This VCC MAY be used to transmit
   data packets destined to a endstation whose ATMARP resolution results
   in an ATM address that is the same as the associated calling party
   number. Sharing of VCCs is subject to the policies configured at the
   endstation as described in section 4.3 of this recommendation.

3.2. Multiprotocol Support on VCs

   When two ATM endsystems run multiple protocols, an ATM connection MAY
   be shared among two or more datagram protocol entities, as long as
   the VCC owner allows sharing and if the encapsulation allows proper
   multiplexing and demultiplexing (i.e. the LLC/SNAP encapsulation).
   This indication of sharing a VCC MAY be by configuration or via an
   API. Similarly, the Internet layer supports multiplexing of multiple
   end-to-end transport sessions. To properly detect idle connections
   while sharing a VCC among more than one higher layer protocol
   entities, the ATM endsystem MUST monitor the traffic at the lowest

multiplexing layer.

3.3. Support for Multiple VCs

   An ATMARP server or client MAY establish an ATM call when it has a
   datagram to send and either there is no existing VCC that it can use
   for this purpose, it chooses not to use an existing VCC, or the owner
   of the VCC does not allow sharing. Note that there might be VCCs to
   the destination which are used for IP, but an ARP server might prefer
   to use a separate VCC for ARP only. The ATMARP server or client MAY
   maintain or release the call as specified in RFC 1577. However, if
   the VCC is shared among several protocol entities, the ATMARP client
   or server SHALL NOT disconnect the call as suggested in RFC 1577.

   Systems MUST be able to support multiple connections between peer
   systems (without regard to which peer system initiated each
   connection). They MAY be configured to only allow one such
   connection at a time.

   If a receiver accepts more than one call from a single source, that
   receiver MUST then accept incoming PDUs on the additional
   connection(s), and MAY transmit on the additional connections.
   Receivers SHOULD NOT accept the incoming call, only to close the
   connection or ignore PDUs from the connection.

   Because opening multiple connections is specifically allowed,
   algorithms to prevent connection call collision, such as the one
   found in section 8.4.3.5 of ISO/IEC 8473 [ISO8473], MUST NOT be
   implemented.

   While allowing multiple connections is specifically desired and
   allowed, implementations MAY choose (by configuration) to permit only
   a single connection to some destinations. Only in such a case, if a
   colliding incoming call is received while a call request is pending,
   the incoming call MUST be rejected. Note that this MAY result in a
   failure to establish a connection. In such a case, each system MUST
   wait at least a configurable collision retry time in the range 1 to
   10 seconds before retrying. Systems MUST add a random increment,
   with exponential backoff.

3.4. VC Teardown

   Either endsystem MAY close a connection. If the connection is closed
   or reset while a datagram is being transmitted, the datagram is lost.
   Systems SHOULD be able to configure a minimum holding time for
   connections to remain open as long as the endpoints are up. (Note
   that holding time, the time the connection has been open, differs
   from idle time.) A suggested default value for the minimum holding
   time is 60 seconds.

   Because some public networks MAY charge for connection holding time,
   and connections MAY be a scarce resource in some networks or
   endsystems, each system implementing a Public ATM UNI interface MUST
   support the use of a configurable inactivity timer to clear
   connections that are idle for some period of time. The timer's range
   SHOULD include a range from a small number of minutes to "infinite".
   A default value of 20 minutes is RECOMMENDED. Systems which only
   implement a Private ATM UNI interface SHOULD support the inactivity
   timer. If implemented, the inactivity timer MUST monitor traffic in
   both directions of the connection.

4. Brief Overview of UNI Call Setup Signaling Procedures and Messages

   This section provides a summary of point-to-point signaling
   procedures. Readers are referred to [ATMF93].

   UNI signaling messages used for point-to-point call/connection
   control are the following:

               Call Setup   Call Release
               ----------   ------------
                 SETUP   RELEASE
                 CALL PROCEEDING   RELEASE COMPLETE
                 CONNECT
                 CONNECT ACKNOWLEDGE

   An ATM endpoint initiates a call request by sending a SETUP message
   to the network. The network processes the call request to determine
   if the call can be progressed. If so, the network indicates the value
   of the newly allocated VPCI/VCI in its first response to the the
   SETUP message, which is either a CALL PROCEEDING or CONNECT message.
   If a call cannot be accepted, by the network or destination ATM end-
   point, a RELEASE COMPLETE is sent. At the destination ATM endpoint,
   the network offers the call using the SETUP message. If the
   destination endpoint is able to accept the call, it responds with a
   CONNECT message (which MAY be preceded by a CALL PROCEEDING);
   otherwise, it sends a RELEASE COMPLETE message. See Appendix A,
   Section 2 for guidance on the use of the CALL PROCEEDING message.

Call release can be initiated by either endpoint or (rarely) by the
network. When an endpoint wishes to release a call, it sends a
RELEASE message to the network. The network responds with a RELEASE
COMPLETE message, frees up resources associated with the call, and
initiates clearing toward the other endpoint. The network initiates
clearing by sending a RELEASE message to the ATM endpoint, which
reponds by sending a RELEASE COMPLETE message. Upon receipt of the
RELEASE COMPLETE message, the network frees any resources associated
with the call.

5. Overview of Call Establishment Message Content

   Signaling messages are structured to contain mandatory and optional
   variable length information elements (IEs).   IEs are further
   subdivided into octet groups, which in turn are divided into fields.
   IEs contain information related to the call, which is relevant to the
   network, the peer endpoint or both. Selection of optional IEs and
   the content of mandatory and optional IEs in a call establishment
   message determines the parties to and nature of the communication
   over the ATM connection. For example, the call establishment message
   for a call which will be used for constant bitrate video over AAL 1
   will have different contents than a call which will be used for IP
   over AAL 5.

   A SETUP message which establishes an ATM connection to be used for IP
   and multiprotocol interconnection calls MUST contain the following
   IEs:

        AAL Parameters
        ATM Traffic Descriptor
        Broadband Bearer Capability
        Broadband Low Layer Information
        QoS Parameter
        Called Party Number
        Calling Party Number

   and MAY, under certain circumstance contain the following IEs:

        Calling Party Subaddress
        Called Party Subaddress
        Transit Network Selection

   In UNI 3.1, the AAL Parameters and the Broadband Low Layer
   Information IEs are optional in a SETUP message. However, in support
   of IP over ATM these two IEs MUST be included. Appendix A shows an
   example SETUP message coded in the manner indicated in this memo.

6. Information Elements with Endpoint to Endpoint Significance

   This section describes the coding of, and procedures surrounding,
   information elements in a SETUP message with significance only to the
   endpoints of an ATM call supporting IP.

6.1. ATM Adaptation Layer Parameters

   The AAL Parameters IE (see section 5.4.5.5 and Annex F of [ATMF93])
   carries information about the ATM Adaptation Layer (AAL) to be used
   on the connection. RFC 1483 specifies encapsulation of IP over AAL 5.
   Thus, AAL 5 MUST be indicated in the "AAL type" field.

   Coding and procedure related to the 'Forward and Backward Maximum
   CPCS-SDU Size' fields are discussed in [ATKI94]. Values may range
   from zero to 65,535. Although the default IP over AAL 5/ATM is 9188
   bytes, endstations are encouraged to support MTU sizes up to and
   including 64k.

   Ordinarily, no Service Specific Convergence Sublayer (SSCS) will be
   used for multiprotocol interconnect over AAL5. Therefore, the SSCS
   'type' field SHOULD be absent or, if present, coded to Null SSCS.

           Format and field values of AAL Parameters IE

           | aal_parameters |

           | aal_type   5   (AAL 5) |
           | fwd_max_sdu_size_identifier 140 |
           | fwd_max_sdu_size   65,535   (desired IP MTU) |
           | bkw_max_sdu_size_identifier 129 |
           | bkw_max_sdu_size   65,535   (desired IP MTU) |
           | sscs_type identifier   132 |
           | sscs_type   0   (null SSCS) |

6.2. Broadband Low Layer Information

   Selection of an encapsulation to support IP over an ATM VCC is done
   using the Broadband Low Layer Information (B-LLI) IE, along with the
   AAL Parameters IE, and the B-LLI negotiation procedure.

   RFC 1577 specifies LLC/SNAP as the default encapsulation. This
   encapsulation MUST be implemented by all endstations. LLC
   encapsulation MUST be signaled in the B-LLI as shown below.
   Signaling indication of other encapsulations is discussed in Appendix
   D, Section 4. Note that only LLC is indicated in the B-LLI. It is up

to the LLC layer to look into the encapsulation header of the packets
following call setup. A B-LLI specifying both LLC and a layer_3_id
SNAP layer is not recommended. If in those packets, the SNAP header
indicates IP, it is the LLC layer's job to hand the packets up to IP.

        Format of B-LLI IE indicating LLC/SNAP encapsulation

```
        -----------------------------------------------------------
        | bb_low_layer_information                                |
        -----------------------------------------------------------
        |  layer_2_id                 2                           |
        |  user_information_layer    12  (lan_llc - ISO 8802/2)   |
        -----------------------------------------------------------
```

6.2.1. Framework for Protocol Layering

   The support of connectionless services from a connection oriented
   link layer exposes general problems of connection management,
   specifically the problems of connection acceptance, assignment of
   quality of service, and connection shutdown. For a connection to be
   associated with the correct protocol on the called host, it is
   necessary for information about one or more layers of protocol
   identification to be associated with a connection "management entity"
   or "endpoint". This association is what we call a binding in this
   memo. In this section we attempt to describe a framework for a
   usable binding or service architecture given the available IEs in the
   ATM call control messages.

   It is important to distinguish between two basic uses of protocol
   identification elements present in the UNI setup message. The first
   is the description of the protocol encapsulation that will be used on
   the data packet over the virtual connection, the second is the entity
   that will be responsible for managing the call. All protocols present
   in various IEs MUST be used to encapsulate the call, but the most
   specific, or highest, layer specified SHOULD manage the call. This
   defines a hierarchy of services and provides a framework for
   applications, including LLC and IP, to terminate calls. This
   hierarchy provides a clear mechanism for support of higher level
   protocol and application bindings, when their use and specification
   is defined in the appropriate standards bodies.

   In general, it would be desirable to allow data packets to be stored
   directly into an application's address space after connection is
   established. This is possible only if we have both encapsulation and
   managing entity indications in the signaling message.

The B-LLI is the only information element currently available in UNI
3.1 for designating protocol endpoints. It contains codepoints that
describe layer 2 and layer 3 protocol entities associated with the
call. There are other information elements under consideration in the
ATM Forum and ITU, which could come to play a significant role in the
description of application to connection binding, but their use is
not yet defined, and they are not part of the framework described by
RFC 1577. They include B-HLI, for containing information for a higher
layer protocol, Network Layer Information (NLI) to contain
information for the network layer, and UUI, which is meant to carry
information for use by the top level application.

The following figure shows a B-LLI that MAY be used for specifying in
call setup that IP will manage the call and that this VC will be used
only for IP traffic. Called parties MUST accept this B-LLI. The
caller using VC MUST use LLC-SNAP encapsulation on all IP datagrams,
despite the fact that the caller views the VC as dedicated to IP.
The reason for this requirement is that while we require receivers to
accept this form of call setup, they may choose whether or not to
multiplex the call through LLC, in other words to ignore the Layer 3
information. This choice is dependent on the receiver's
implementation's protocol architecture and is local to the receiver.

         Format of B-LLI IE indicating VC ownership by IP
            (NOTE: LLC/SNAP encapsulation is still used)

```
    -----------------------------------------------------------
    | bb_low_layer_information                                |
    -----------------------------------------------------------
    |   layer_2_id                 2                          |
    |   user_information_layer     12  (lan_llc - ISO 8802/2) |
    |   layer_3_id                 3                          |
    |   ISO/IEC TR 9577 IPI        204 (0xCC)                 |
    -----------------------------------------------------------
```

Null-encapsulated VCs are described in RFC 1483. Such a VC would
result in the most direct form of binding a VC to IP. However, the
method of signaling for this type of VC has not yet been integrated
into the IP over ATM context. For completeness, we mention that the
signaling would use a B-LLI containing the layer 3 identifier with
the ISO/IEC TR-9577 protocol codepoint and omitting the layer 2
identifier [ATMF93]. Since no layer 2 is specified, frames produced
by AAL processing would be given directly to IP. Processing of this
B-LLI is not required at this time.

7. Information Elements with Significance to the ATM Network

   This section describes the coding of, and procedures surrounding,
   information elements with significance to the ATM network, as well as
   the endpoints of an ATM call supporting multiprotocol operation.

   The standards, implementation agreements, research and experience
   surrounding such issues as traffic management, quality of service and
   bearer service description are still evolving. Much of this material
   is cast to give the greatest possible latitude to ATM network
   implementation and service offerings. ATM endsystems need to match
   the traffic contract and bearer service they request from the network
   to the capabilities offered by the network. Therefore, this memo can
   only offer what, at the present time, are the most appropriate and
   efficient coding rules to follow for setting up IP and ATMARP VCCs.
   Future revisions of this memo may take advantage of ATM services and
   capabilities that are not yet available.

7.1. ATM Traffic Descriptor

   The ATM traffic descriptor characterizes the ATM virtual connection
   in terms of peak cell rate (PCR), sustainable cell rate (SCR), and
   maximum burst size. This information is used to allocate resources
   (e.g., bandwidth, buffering) in the network. In general, the ATM
   traffic descriptor for supporting multiprotocol interconnection over
   ATM will be driven by factors such as the capacity of the network,
   conformance definition supported by the network, performance of the
   ATM endsystem and (for public networks) cost of services.

   The most convenient model of IP behavior corresponds to the Best
   Effort Capability (see section 3.6.2.4 of [ATMF93]). If this
   capability is offered by the ATM network(s), it MAY be requested by
   including the Best Effort Indicator, the peak cell rate forward
   (CLP=0+1) and peak cell rate backward (CLP=0+1) fields in the ATM
   Traffic Descriptor IE. When the Best Effort Capability is used, no
   guarantees are provided by the network, and in fact, throughput may
   be zero at any time. This type of behavior is also described by RFC
   1633 [BRAD94].

Format and field values of ATM Traffic Descriptor IE

```
---------------------------------------------------------
| traffic_descriptor                                     |
---------------------------------------------------------
|   fwd_peak_cell_rate_0+1_identifier    132             |
|   fwd_peak_cell_rate_0+1               (link rate)     |
|   bkw_peak_cell_rate_0+1_identifier    133             |
|   bkw_peak_cell_rate_0+1               (link rate)     |
|   best_effort_indication               190             |
---------------------------------------------------------
```

When the network does not support Best Effort Capability or more
predictable ATM service is desired for IP, more specific traffic
parameters MAY be specified and the Best Effort capability not used.
Doing so includes use of two other traffic-related IEs and is
discussed in the following paragraphs and sections.

The Traffic Descriptor IE is accompanied by the Broadband Bearer
Capability IE and the QoS Parameter IE. Together these define the
signaling view of ATM traffic management. In this memo, we present
an agreed-on, required subset of traffic management capabilities, as
specified by using the three IEs. The figure immediately below shows
the set of the allowable combinations of traffic parameters which all
IP over ATM endsystems MUST support in their ATM signaling. The
subset includes Best Effort in the form of a non-guaranteed bitrate
combination (the rightmost column of the table below); a type of
traffic description that is intended for ATM "pipes", for example
between two routers (the middle column); and a type of traffic
description that will allow initial use of token-bucket style
characterizations of the source, as presented in RFC 1363 [PART92]
and RFC 1633, for example (the leftmost column).

Combinations of Traffic Related Paramenters
that MUST be supported in the SETUP message

```
|-------------------------------|
|Broadband Bearer               |
|Capability                     |
|-------------------------------|
|Broadband Bearer    | C | X | X |
|--------------------|---|---|---|
|Traffic Type        |   |   |   |
|(CBR,VBR)           |   |CBR| & |
|--------------------|---|---|---|
|Timing Required     |   |YES| &&|
|-------------------------------|
|Traffic Descriptor             |
|Parameter                      |
|-------------------------------|
|PCR (CLP=0)         |   |   |   |
|--------------------|---|---|---|
|PCR (CLP=0+1)       | S | S | S |
|--------------------|---|---|---|
|SCR (CLP=0)         |   |   |   |
|--------------------|---|---|---|
|SCR (CLP=0+1)       | S |   |   |
|--------------------|---|---|---|
|MBS (CLP=0)         |   |   |   |
|--------------------|---|---|---|
|MBS (CLP=0+1)       | S |   |   |
|--------------------|---|---|---|
|Best Effort         |   |   | S |
|--------------------|---|---|---|
|Tagging             | NO| NO| NO|
|-------------------------------|
|-------------------------------|
|QOS Classes         | 0 | 0 | 0 |
---------------------------------
```

   S = Specified
   & = Parameter is coded to either "no indication" or VBR or octet 5a
       (Traffic Type/Timing Required) is absent; these three codings are
       treated as equivalent
   && = Parameter is coded to either "no indication" or "No" or octet 5a
        is absent; these three codings are treated as equivalent

   Use of other allowable combinations of traffic parameters listed in
   the large table in Appendix C may work, since they are allowed by
   [ATMF94], but this will depend on the the calling endsystem, the
   network, and the called endsystem.

If Best Effort service is not use, link rate SHOULD not be requested as the peak cell rate. Without any knowledge of the application, it is RECOMMENDED that a fraction, such as 1/10th, of the the link bandwidth be requested.

[ATMF93] does not provide any capability for negotiation of the ATM traffic descriptor paramenters. This means that:

  a) the calling endsystem SHOULD have some prior knowledge as to the traffic contract that will be acceptable to both the called endsystem and the network.

  b) if, in response to a SETUP message, a calling endsystem receive a RELEASE COMPLETE message, or a CALL PROCEEDING message followed by a RELEASE COMPLETE message, with cause #37, User Cell Rate Unavailable, it MAY examine the diagnostic field of the Cause IE and reattempt the call after selecting smaller values for the parameter(s) indicated. If the RELEASE COMPLETE or RELEASE message is received with cause #73, Unsupported combination of traffic parameter, it MAY try other combinations from table 5-7 and 5-8 of [ATMF93].

  c) the called endsystem SHOULD examine the ATM traffic descriptor IE in the SETUP message. If it is unable to process cells at the Forward PCR indicated, it SHOULD clear the call with cause #37, User Cell Rate Unavailable.

7.2. Broadband Bearer Capability

   Broadband Bearer Connection Oriented Service Type X (BCOB-X) or Type
   C (BCOB-C) are both applicable for multiprotocol interconnection,
   depending on the service(s) provided by the ATM network and the
   capabilities (e.g., for traffic shaping) of the ATM endsystem. The
   table in the previous section showed the use of BCOB-X and BCOB-C
   with other parameters. The figure below shows format and field
   values for a BCOB-X when the Traffic Descriptor IE indicates Best
   Effort.

          Format and field values of Broadband Bearer Capability IE

```
          ----------------------------------------------------------
          | bb_bearer_capability                                   |
          ----------------------------------------------------------
          |   spare                         0                       |
          |   bearer_class                  16       (BCOC-X)       |
          |   spare                         0                       |
          |   traffic_type                  0        (no indication)|
          |   timing_reqs                   0        (no indication)|
          |   susceptibility_to_clipping    0        (not suscept)  |
          |   spare                         0                       |
          |   user_plane_configuration      0        (point_to_point)|
          ----------------------------------------------------------
```

   IP over ATM signaling MUST permit BCOB-C and BCOB-X, in the
   combinations shown in the previous section. It MAY also permit one
   of the allowable combinations shown in Appendix C.

   Currently, there is no capability for negotiation of the broadband
   bearer capability. This means that:

     a) the calling endsystem SHOULD have some prior knowledge as to
        the broadband bearer capability that will be acceptable to
        both the called endsystem and the network.

     b) if, in response to a SETUP message, a calling endsystem
        receives a RELEASE COMPLETE message, or a CALL PROCEEDING
        message followed by a RELEASE COMPLETE message, with cause
        #57, bearer capability not authorized or #58 bearer capability
        not presently available, it MAY reattempt the call after
        selecting another bearer capability.

7.3. QoS Parameter

   The Unspecified QoS class (Class 0) is the only QoS class that must
   be supported by all networks and the only QoS class allowed when
   using the Best Effort service. The Specified QoS Class for Connection
   Oriented Data Transfer (Class 3) or the Specified QoS Class for
   Connectionless Data Transfer (Class 4) may be applicable to
   multiprotocol over ATM, but their use has to be negotiated with the
   network provider. The combinations of QoS parameters with the ATM
   Traffic Descriptor and the Broadband Bearer Capability are detailed
   in the Traffic Descriptor section and in Appendix C.

           Format and field values of QoS Parameters IE

        | qos_parameter |

        | qos_class_fwd   0   (class 0) |
        | qos_class_bkw   0   (class 0) |

   [ATMF93] does not provide any capability for negotiation of Quality
   of Service parameters. This means that:

     a) the calling endsystem SHOULD have some prior knowledge as to
        the QoS classes offered by the ATM network in conjunction with
        the requested Broadband Bearer Service and Traffic Descriptor.

     b) if, in response to a SETUP message, a calling endsystem
        receives a RELEASE COMPLETE message, or a CALL PROCEEDING
        message followed by a RELEASE COMPLETE message, with cause
        #49, Quality of Service Unavailable, it MAY reattempt the call
        after selecting another QoS class.

   Note: The two-bit 'coding standard' field of the General Information
   octet in the IE header, SHOULD be set to '00' now that the ITU-T has
   standardized QoS class 0. Endsystems SHOULD treat either value ('11'
   or '00') as requesting the ITU-T QoS class.

7.4. ATM Addressing Information

   ATM addressing information is carried in the Called Party Number,
   Calling Party Number, and, under certain circumstance, Called Party
   Subaddress, and Calling Party Subaddress IE. Section 5.8 of [ATMF93]
   provides the procedure for an ATM endsystem to learn its own ATM
   address from the ATM network, for use in populating the Calling Party
   Number IE. Section 5.4.5.14 [ATMF94] describes the syntax and
   semantics of the calling party subaddress IE.

RFC 1577 RECOMMENDS that a router be able to provide multiple LIS
support with a single physical ATM interface that may have one or
more individual ATM endsystem addresses. Use of the Selector field
in the NSAPAs and E.164 addresses (in the NSAP format) is identified
as a way to differentiate up to 256 different LISs for the same ESI.
Therefore, an IP router MAY associate the IP addresses of the various
LISs it supports with distinct ATM addresses differentiated only by
the SEL field. If an IP router does this association, then its
signaling entity MUST carry in the SETUP message the ATM addresses
corresponding to the particular IP entity requesting the call, and
the IP entity it is requesting a call to. These ATM addresses are
carried in the Calling and Called Party Number IEs respectively.
Native E.164 addresses do not support a SEL field. For IP routers
residing in a Public UNI where native E.164 addresses are used it is
RECOMMENDED that multiple E.164 addresses be used to support multiple
LISs. Note: multiple LIS support is the only recommended use of the
SEL field. Use of this field is not recommended for selection of
higher level applications.

Resolution of IP addresses to ATM addresses is required of hosts and
routers which are ATM endsystems that use ATM SVCs. RFC 1577 provides
a mechanism for doing IP to ATM address resolution in the classical
IP model.

       Format and field values of Called and Calling Party Number IE

       | called_party_number |

       | type_of_number   (international number / unknown) |
       | addr_plan_ident   (ISDN / ATM Endsystem Address) |
       | addr_number   (E.164 / ATM Endsystem Address) |

       | calling_party_number |

       | type_of_number   (international number / unknown) |
       | addr_plan_ident   (ISDN / ATM Endsystem Address) |
       | presentation_indic   (presentation allowed) |
       | spare   0 |
       | screening_indic   (user provided verified & passed) |
       | addr_number   (E.164 / ATM Endsystem Address |
       ----

8. Dealing with Failure of Call Establishment

   If an ATM call attempt fails with any of the following causes, the
   situation SHOULD be treated as Network Unreachable (if the called ATM
   endsystem is a router) or Host Unreachable (if the called ATM
   endsystem is a host). See the treatment of Network and Host
   Unreachable conditions in RFC 1122 [BRAD89].

        # 1 unallocated (unassigned) number
        # 3 no route to destination
        # 17 user busy
        # 18 no user reponding
        # 27 destination out of order
        # 38 network out of order
        # 41 temporary failure
        # 47 resource unavailable, unspecified

   If an ATM call attempt fails with any of the following causes, the
   ATM endsystem MAY retry the call, changing (or adding) the IE(s)
   indicated by the cause code and diagnostic.

        # 2 no route to specified transit network
        # 21 call rejected
        # 22 number changed
        # 23 user rejects call with CLIR
        # 37 user cell rate unavailable
        # 49 quality of service unavailable
        # 57 bearer capability not authorized
        # 58 bearer capability not presently available
        # 65 bearer capability not implemented
        # 73 unsupported combination of traffic parameter
        # 88 incompatible destination
        # 91 invalid transmit network selection
        # 78 AAL parameter cannot be supported

9. Security Considerations

   Not all of the security issues relating to IP over ATM are clearly
   understood at this time, due to the fluid state of ATM
   specifications, newness of the technology, and other factors. Future
   revisions of this specification will address the security
   capabilities that future signaling standards may offer to IP over ATM
   signaling.

10. Open Issues

    o   This document version is specifically an RFC 1577/RFC 1483
         implementation document. Although RFC 1577 and RFC 1483
         specify an LLC/SNAP encapsulation, which is inherently a
         multiprotocol encapsulation, it is beyond to scope of this
         document to go into any multiprotocol specifications other than
         to point out some examples (see Appendix D for an example of
         NLPID encapsulation).

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    the needs of multiprotocol over ATM could be expressed in the ATM
    signaling protocol.

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Appendix A. Sample Signaling Messages

1. SETUP and CONNECT messages

   This appendix shows sample codings of the SETUP and CONNECT signaling
   messages. The fields in the IE header are not shown.

```
   +--------------------------------------------------------------------+
                            SETUP

   Information Elements/
     Fields                            Value/(Meaning)
   -------------------                 --------------

   aal_parameters
     aal_type                          5         (AAL 5)
     fwd_max_sdu_size_ident            140
     fwd_max_sdu_size                  (send IP MTU value)
     bkw_max_sdu_size_ident            129
     bkw_max_sdu_size                  (recv IP MTU value)
     sscs_type identifier              132
     sscs_type                         0         (null SSCS)

   user_cell_rate
     fwd_peak_cell_rate_0_1_ident      132
     fwd_peak_cell_rate_0_1            (link rate)
     bkw_peak_cell_rate_0_1_ident      133
     bkw_peak_cell_rate_0_1            (link rate)
     best_effort_indication            190

   bb_bearer_capability
     spare                             0
     bearer_class                      16        (BCOC-X)
     spare                             0
     traffic_type                      0         (no indication)
     timing_reqs                       0         (no indication)
     susceptibility_to_clipping        0         (not susceptible to
                                                  clipping)
     spare                             0
     user_plane_configuration          0         (point_to_point)

   bb_low_layer_information
     layer_2_id                        2
     user_information_layer            12        (lan_llc (ISO 8802/2)

   qos_parameter
     qos_class_fwd                     0         (class 0)
     qos_class_bkw                     0         (class 0)
```

```
    called_party_number
      type_of_number                (international number / unknown)
      addr_plan_ident               (ISDN / ATM Endsystem Address)
      number                        (E.164 / ATM Endsystem Address)

    calling_party_number
      type_of_number                (international number / unknown)
      addr_plan_ident               (ISDN / ATM Endsystem Address)
      presentation_indic            (presentation allowed)
      spare                         0
      screening_indic               (user_provided verified and passed)
      number                        (E.164 / ATM Endsystem Address)

  +-------------------------------------------------------------------+
                          Figure 1.
                  Sample contents of SETUP message

  [* : optional, ignored if present]
```

In IP over ATM environments the inclusion of the "AAL parameters" IE
is *mandatory* to allow for MTU size negotiation between the source
and destination. The "Broadband Low Layer Information" IE is also
mandatory for specifying the IP encapsulation scheme.

```
+------------------------------------------------------------------+
                    CONNECT


  Information Elements/
    Fields                        Value
  -------------------             -----
  aal_parameters
    aal_type                      5         (AAL 5)
    fwd_max_sdu_size_ident        140
    fwd_max_sdu_size              (send IP MTU value)
    bkw_max_sdu_size_ident        129
    bkw_max_sdu_size              (recv IP MTU value)
    sscs_type identifier          132
    sscs_type                     0         (null SSCS)

  bb_low_layer_information
    layer_2_id                    2
    user_information_layer        12        (lan_llc (ISO 8802/2)

  connection identifier
    spare                         0
    vp_assoc_signaling            1         (explicit indication of VPCI)
    preferred_exclusive           0         (exclusive vpci/vci)
    vpci                          (assigned by network)
    vci                           (assigned by network)
+------------------------------------------------------------------+
```

Figure 2.
Sample contents of CONNECT message

As in the SETUP message, IP over ATM environments demand the
inclusion of the "AAL parameters" IE so that the destination may
specify the MTU size that it is willing to receive.

2. Hints on Use of CALL PROCEEDING Message

Use of the CALL PROCEEDING message is beneficial in implementations
where the called party's ATM signaling entity and AAL Users are
decoupled. An arriving SETUP may result in an immediate CALL
PROCEEDING response from the called party's ATM signaling entity,
while it locally queries the called IP-ATM entity to see if the
SETUP's conditions are acceptable. The acceptance of the SETUP's
conditions would then cause the ATM signaling entity to issue a
CONNECT back to the switch. The two possible refusal modes at the

called party then become:

a) Called party has no IP-ATM entity resident. Issue RELEASE
COMPLETE in response to SETUP.

b) Called party has a resident IP-ATM entity, so CALL PROCEEDING
was issued. The IP-ATM entity rejects the call request, so a
RELEASE is issued instead (to be acknowledged by the network
with RELEASE COMPLETE).

Appendix B. IP over ATM using UNI 3.0 Signaling

This appendix describes how to support IP over ATM using UNI 3.0
signalling. Differences in the coding or semantics of each relevant
IE is given.

1. AAL parameter

Values for maximum SDU size may range from one (not zero) to 64K.

A 'mode' field is an allowable field in UNI 3.0. Nevertheless, this
'mode' field SHOULD be omitted from the AAL Parameters IE and MUST be
ignored by the destination endsystem.

2. Traffic Management Related IEs

In UNI 3.0 issues of traffic management were less understood than in
UNI 3.1. UNI 3.0 does not contain a guide to coordinating the use of
the User Cell Rate IE (Traffic Descriptor IE in UNI 3.1), Broadband
Bearer Capability IE, and QoS parameters IE. Therefore, the
recommendation for specifying parameters in these IEs is the same as
that given above when using UNI 3.1. The following section merely
describes relevant differences in names and code values.

2.1 ATM User Cell Rate (instead of ATM Traffic Descriptor)

The ATM Traffic Descriptor IE is refered to as 'ATM User Cell Rate'
IE in UNI 3.0. Also, the value for the cause 'user cell rate
unavailable' is #51.

2.3 QoS parameters

The two-bit 'coding standard' field of the General Information octet
in the IE header, should be set to '11' inidicating that the IE is a
standard defined for the network (as opposed to an ITU-TS standard)
present on the network side of the interface.

3. ATM Addressing Information

In UNI 3.1, the 'ATM Endsystem Address' type was introduced to
differentiate ATM addresses from OSI NSAPs. In UNI 3.0, 'ATM
Endsystem Address' is not a valid type. Therefore, in the called and
calling party subaddress IEs the three-bit 'type of subaddress' field
MUST specify 'NSAP' (value = 001) when using the subaddress IE to
carry ATM addresses.

4. Dealing with Failure of Call Establishment

In UNI 3.0 the there are certain cause values which are different
than UNI 3.1. Two relevant differences are the following:

    'AAL Parameter Cannot Be Supported' is #93 (#78 in UNI 3.1), and

    'User Cell Rate Unavailable' is #51 (#37 in UNI 3.1).

Appendix C.

Combinations of Traffic Related Parameters
tha MAY be supported in the SETUP message

Broadband Bearer Capability												
Broadband Bearer	A,C	X	X	C	X	C	X	A,C	X	X	C	X
Traffic Type (CBR,VBR)		CBR	&		&		&		CBR	&	&	&
Timing Required		Y	&&		&&		&&		Y	&&		&&
Traffic Descriptor Parameter												
PCR (CLP=0)	S	S	S									
PCR (CLP=0+1)	S	S	S	S	S	S	S	S	S	S	S	S
SCR (CLP=0)					S	S						
SCR (CLP=0+1)							S	S				
MBS (CLP=0)					S	S						
MBS (CLP=0+1)							S	S				
Best Effort											S	S
Tagging	Y/N	Y/N	Y/N	Y/N	Y/N	N	N	N	N	N	N	N
QOS Classes	*	*	*	*	*	*	*	*	*	*	0	0

(Table 2 is a reproduction of Table F-1 of Appendix F in [ATMF 94].)

    PCR = Peak Cell Rate, SCR = Sustainable Cell Rate,
    MBS = Maximum Burst Size

    Y = Yes, N = No, S = Specified

    Y/N = either "Yes" or "No" is allowed

     * = allowed QoS class values are a network option. Class 0 is
         always supported for alignment with ITU-T

     & = parameter is coded to either "no indication" or VBR or
         octet 5a(Traffic Type/Timing Required) is absent; these three
         codings are treated as equivalent

     && = parameter is coded to either "no indication" or "No" or
          octet 5a(Traffic Type/Timing Required) is absent; these three
          codings are treated as equivalent

     A blank entry in the table indicates that the parameter is not
     present.

Appendix D.   Frame Relay Interworking

1.   RFC 1490 over FR-SSCS vs. RFC 1483 over null-SSCS

     Procedures for Frame Relay to ATM signaling interworking have not yet
     been specified by ITU-T, the ATM Forum, or the Frame Relay Forum. If
     an ATM endsystem wishes to use FR-SSCS, FR-SSCS and RFC 1490
     encapsulation must both be be specified in the SETUP message.
     Nevertheless, since neither LLC encapsulation nor VC-multiplexing
     will interoperate when used over FR-SSCS, these two encapsulations
     cannot be negotiated as alternatives to RFC 1490 encapsulation (see
     Section 4, Encapsulation Negotiation).

     In ATM environments the SSCS layer is part of the AAL functionality.
     The SSCS serves to coordinate the needs of a protocol above with the
     requirements of next lower layer, the Common Part Convergence
     Sublayer (CPCS). For example, the UNI ATM signaling protocol runs on
     top of a signaling SSCS which among other things provides an assured
     transfer service for signaling messages. Since the SSCS is considered
     part of the AAL, the SSCS type is specified as one of the parameters
     in the AAL Parameters IE. To date there has not been an SSCS defined
     for data transmission in ATM and this type field is usually set to
     'null'.

     The exception occurs when doing FR interworking where an ATM
     endsystem may choose to use the FR-SSCS over AAL 5 in order to
     communicate with a FR endsystem. In that case the SSCS type in the
     AAL Parameters IE of the SETUP message is set to 'FR-SSCS'.

     Also included in a SETUP message is an indication in the B-LLI IE of
     the protocol layers to be used above the AAL. In particular, ATM
     connections established to carry connectionless network interconnect
     traffic require a layer above the AAL for multiplexing multiple
     protocols over a single VC [HEIN 93]. As mentioned above, RFC 1577

defines LLC as default multiplexing layer for IP over AAL5.

Specification of the SSCS restricts the encapsulation protocol used
over it, since RFC 1483 (in addition to applicable ITU standards)
defines the use of RFC 1490 encapsulation over the FR-SSCS, and LLC
or null encapsulation otherwise. The fact that it is not possible,
in the UNI 3.0 signaling specification, to negotiate between the FR-
SSCS and null-SSCS can result in interoperability restrictions
between stations that implement and wish to use the FR-SSCS and those
that do not, even though they both are using IP. The guidelines in
the following section were developed to decrease the chance that such
interoperability restrictions occur.

2. Scenarios for Interworking

   The following discussion uses the terms "network interworking" and
   "service interworking". "Network interworking" uses FR-SSCS over
   AAL5 between the InterWorking Unit (IWU) and the ATM endsystem, and
   the ATM endsystem is aware that the other endpoint is a FR/ATM
   Network IWU. "Service interworking" aims to make the operation
   transparent to the ATM endsystem by adding encapsulation translation
   and other payload processing in the FR/ATM Service IWU to allow the
   ATM endsystem to operate as if it were talking to another ATM
   endsystem.

   The most common scenario where FR-SSCS could be negotiated is between
   an ATM endsystem and a FR/ATM network IWU to allow connectivity among
   an ATM endsystem and a FR endsystem residing behind a FR/ATM network
   IWU.

```
                      --------          --------
      -------         |      |          |      |         -------
     |   A   |        | FR/ATM |        |  ATM  |        |   B   |
     |  (FR) |----->  |  IWU   |----->  | switch |----->  | (ATM) |
      -------         |      |          |      |         -------
                      --------          --------


        |     |        |                        |
         ----->         -------------------->
         FR call              ATM call
```
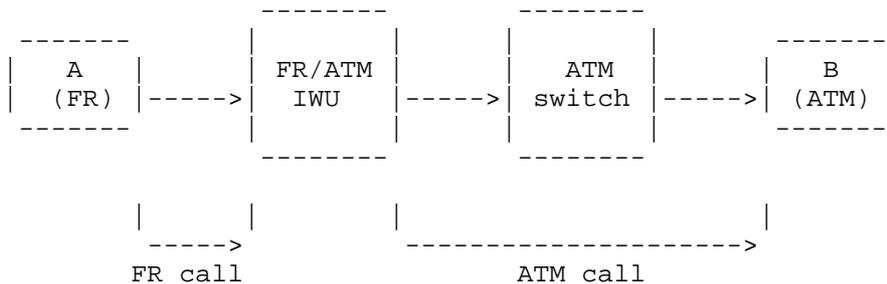
   A network IWU can place a call to an ATM host (on behalf of a FR
   host) by signaling for FR-SSCS and assuming that the ATM endsystem
   supports FR-SSCS. The B-LLI IE SHALL be encoded to indicate RFC 1490
   encapsulation and the SSCS type field of the AAL Parameters IE SHALL
   be coded to indicate FR-SSCS. If the FR-SSCS negotiation fails
   because the called ATM host does not support FR-SSCS, the IWU can
   retry the call negotiating for LLC encapsulation or VC-multiplexing.

However, the IWU can only attempt the retry if it is able to do FR-
ATM service interworking. Such service interworking adds extra
processing overhead during the call.

The even more problematic case occurs when a call is requested in the
opposite direction, i.e. when an ATM host places a call to a host
residing behind an IWU.

```
                      --------        --------
    -------           |        |      |        |         -------
   |   B   |          | FR/ATM |      |  ATM   |        |   A   |
   | (FR)  |<-----|   IWU  |<-----|  switch |<-----|  (ATM) |
    -------           |        |      |        |         -------
                      --------        --------


     |      |         |                        |
      <-----          <---------------------
       FR call              ATM call
```
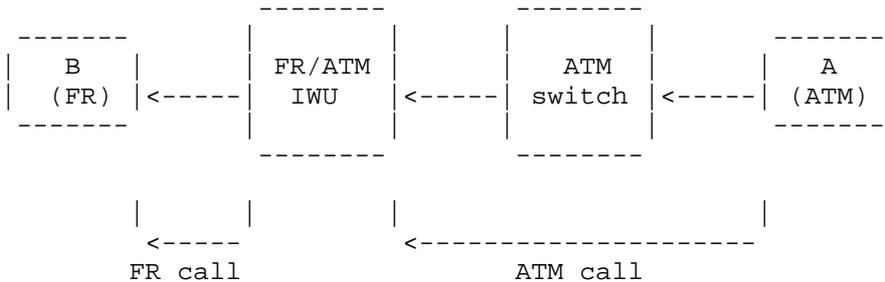
Not knowing that the destination resides behind an IWU, the calling
host will negotiate for the default LLC encapsulation (possibly
requesting VC-multiplexing as an alternative). In this situation the
IWU can accept the call and do the necessary service interworking or
reject the call specifying 'AAL Parameters not supported'. If the IWU
rejects the call it risks the possibility that calling host does not
support FR-SSCS or simply does not retry and the call will never be
established.

3. Possible Alternatives

While Frame Relay interworking is possible, it is not possible to
negotiate FR-SSCS with LLC encapsulation or VC-multiplexing, which
decreases the chances of completing an ATM call. However,
interoperability can be increased using the following alternatives:

1. Maintaining external knowledge that a particular destination uses
FR-SSCS. This knowledge can be configured, or in the future added to
some network host database.

2. In the absence of such external knowledge, an ATM endsystem is
required to negotiate for the default LLC encapsulation (possibly
requesting VC-multiplexing as an alternative). There are three sub-
cases:

2a. The IWU supports service interworking and network interworking,
and prefers service interworking. The IWU simply accepts the call
using LLC encapsulation.

2b. The IWU supports service interworking and network interworking,
and prefers network interworking. The IWU simply accepts the call,
but attempts to open a parallel connection back to the original ATM
endsystem negotiating the FR-SSCS use. If the connection is
accepted, the IWU closes the service interworking connection.

2c. The IWU supports network interworking only. The IWU rejects the
call specifying 'AAL Parameters not supported', and then attempts to
open a connection back to the original ATM endsystem negotiating the
FR-SSCS use.

4. Encapsulation negotiation

   The call/connection control signaling protocol includes a mechanism
   to support negotiation of encapsulation for endsystems that support
   more than one. This section describes the procedures for negotiation
   of an encapsulation.

   The B-LLI negotiation procedures (see Annex C of [ATMF93]) are
   initiated by the calling ATM endsystem by including up to three
   instances of the B-LLI IE in the SETUP message in descending order of
   preference (following the rule for repeating IE in section 5.4.5.1 of
   [ATMF93]).

   The following is the list of the three possible combinations that B-
   LLI IE instances MAY be included in the SETUP message. Each instance
   is referred to by its encapsulation name as it appears in RFC 1483,
   and corresponding section labels from Appendix D of the ATM Forum UNI
   3.0 specification.

     a) LLC/SNAP encapsulation (D.3.1)

   In this case, the calling ATM endsystem can only send and receive
   packets preceded by an LLC/SNAP identification. This memo requires
   that hosts and routers which are ATM endsystems implement LLC/SNAP
   encapsulation.

     b) VC-multiplexing (D.3.2) and LLC/SNAP (D.3.1)

   The calling ATM endsystem prefers to use VC multiplexing, but is
   willing to agree to use LLC/SNAP encapsulation instead, if the called
   ATM endsytem only supports LLC/SNAP.

     c) RFC 1490 encapsulation (NLPID multiplexing) over FRSSCS
        (D.3.3, omitting octets 7a and 7b and MUST have FR-SSCS in SSCS
        type of AAL Parameters IE.)

The calling ATM endsystem can only send and receive packets using RFC
1490 encapsulation (NLPID multiplexing) over FRSSCS. Use of RFC 1490
encapsulation presently cannot be negotiated as an alternative to LLC
encapsulation or VC-multiplexing. If the B-LLI IE is encoded to
indicate RFC 1490 encapsulation, the SSCS type field of the AAL
Parameters IE SHALL coded to indicate FRSSCS. Note that the AAL
Parameters IE can not be coded to indicate both NULL and FR-SSCS and
neither LLC encapsulation nor VC-multiplexing will be interoperable
when used over FR-SSCS.

The called ATM endsystem SHALL select the encapsulation method it is
able to support from the B-LLI IE present in SETUP message. If it
supports more than one of the encapsulations indicated in the SETUP
message, it MUST select the one which appears first in the SETUP
message. The called ATM endsystem then includes the B-LLI IE content
corresponding to the selected encapsulation in the CONNECT message.
If the called endsystem does not support any encapsulation indicated
in the incoming SETUP message, it SHALL clear the call with cause
#88, incompatible destination. If the received SETUP message does
not include the B-LLI IE, the call SHALL be cleared with cause #21,
"call rejected", with diagnostics indicating rejection reason =
information element missing and the B-LLI IE identifier. As
described in Annex C of [ATMF93], if the calling ATM endpoint
receives a CONNECT message that does not contain a B-LLI IE, it SHALL
assume the encapsulation indicated in the first BLLI IE that it
included in the SETUP message.