The ATM Forum

Technical Committee

ATM-MPLS Control Plane Network Interworking

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Preface

In most team endeavors, the efforts of several individuals deserve special recognition. This specification was no exception. The ATM Forum gratefully thanks the following individuals and respective employers for their contributions to this document:

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This specification uses three levels for indicating the degree of compliance necessary for specific functions, procedures, or coding. They are indicated by the use of key words as follows:

- **Requirement:** "Shall" indicates a required function, procedure, or coding necessary for compliance. The word "shall" used in text indicates a conditional requirement when the operation described is dependent on whether or not an objective or option is chosen.
- **Objective:** "Should" indicates an objective which is not required for compliance, but which is considered desirable.
- **Option:** "May" indicates an optional operation without implying a desirability of one operation over another. That is, it identifies an operation that is allowed while still maintaining compliance.

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1 Introduction

Many telecom carriers use ATM technology to deliver services (e.g. voice, leased line, frame relay, native ATM) at the edge of their networks. At the same time, there is a belief that it may be advantageous to employ MPLS technology within the network core. The use of ATM-MPLS network interworking allows a network operator to deploy MPLS in the core of the network while continuing to leverage ATM technology at the network edge.

In many networks that use MPLS as a transport for ATM cell relay traffic, one cannot assume that the edge technologies using the MPLS network as a transport mechanism are completely static in nature, i.e. ATM PVCs. In many instances service providers signal SVCs or SPVCs across their ATM networks. Therefore, in addition to support of static connections, there is also a need to set up dynamic ATM connections across the MPLS network.

This document defines the reference models, mechanisms and procedures that are required to support control plane network interworking between ATM and MPLS networks where an INE supports both ATM routing and signalling as well as IP/MPLS routing and signalling.

2 Scope

This specification provides guidelines and defines procedures to support ATM-MPLS control plane network interworking for all ATM connection types (i.e., SVCCs, soft PVCCs, SVPCs, or soft PVPCs).

This specification supports the ATM-MPLS network interworking user plane encapsulation modes defined in [8], [9], [10]and[11]. This specification supports the ATM-MPLS Network Interworking Signalling Specification[7].

The scope of this specification is to describe the overall architecture for ATM-MPLS control plane network interworking. Additionally, this specification defines coding and procedures for control channel establishment of ILMI and PNNI signalling and routing channels between two peer Interworking Functions (IWFs).

3 References

[1] IETF: RFC 4447 (April 2006): Pseudowire Setup and Maintenance using LDP

[2] IETF: RFC3036 (January 2001): LDP Specification.

[3] IETF: RFC 4446 (April 2006): IANA Allocations for pseudo Wire Edge to Edge Emulation (PWE3)

[4] IETF: RFC 3031 (January 2001): Multiprotocol Label Switching Architecture

[5] ATM Forum: af-pnni-0055.002 (April 2002): Private Network-Network Interface Specification Version 1.1

[6] IETF: RFC 4090 (April 2006): Fast Reroute Extensions to RSVP-TE for LSP Tunnels

[7] ATM Forum: af-cs-0197.000 (August 2003): ATM-MPLS Network Interworking Signalling Specification, Version 1.0

[8] ATM Forum: af-aic-0178.001(August 2003): ATM-MPLS Network Interworking Version 2.0

[9] IETF: RFC 4717 (November 2006): Encapsulation Methods for Transport of ATM Over MPLS Networks

[10] ITU-T Recommendation: Y.1411 (2003): ATM-MPLS Network Interworking – Cell Mode User Plane Interworking

[11] ITU-T Recommendation: Y.1412 (2003), ATM-MPLS Network Interworking – Frame Mode User Plane Interworking

[12] IETF: RFC3209 (December 2001): RSVP-TE: Extensions to RSVP for LSP Tunnels

[13] IETF: RFC3916 (September 2004): Requirements for Pseudo-Wire Emulation Edge-to-Edge (PWE3)

4 Acronyms and Terminology

4.1 Acronyms

AAL5 ATM Adaptation Layer Type 5

AGI Attachment Group Identifier

AI Attachment Identifier

AII Attachment Individual Identifier

ATM Asynchronous Transfer Mode

CDV Cell Delay Variation

CLP Cell Loss Priority

CPCS Common Part Convergence Sub-layer

CPII Control Plane Instance Identifier

EXP Experimental Bits

FEC Forwarding Equivalence Class

ILMI Integrated Link Management Interface

INE Interworking Network Element

IWF Interworking Function

IWL Interworking Label

LDP Label Distribution Protocol

LER Label Edge Router

LSP Label Switched Path

LSR Label Switching Router

MPLS Multi-Protocol Label Switching

OAM Operation Administration and Management

PNNI Private Network-Network Interface

PSC Per-Hop Behavior Scheduling Class

PVC Permanent Virtual Channel

PVCC Permanent Virtual Channel Connection

PVP Permanent Virtual Path

PVPC Permanent Virtual Path Connection

RCC Routing Control Channel

RSVP Resource Reservation Protocol

RSVP-TE Resource Reservation Protocol with Traffic Engineering

SAII Source Attachment Individual Identifier

SVC	Switched Virtual Channel
SVCC	Switched Virtual Channel Connection
SVP	Switched Virtual Path
SVPC	Switched Virtual Path Connection
TAII	Target Attachment Individual Identifier
TLV	Type Length Value
TTL	Time To Live
VCC	Virtual Channel Connection
VCI	Virtual Channel Identifier
VPC	Virtual Path Connection
VPI	Virtual Path Identifier

4.2 Terminology

Interworking: The term interworking is used to express interactions between networks, between end systems, or between parts thereof, with the aim of providing a functional entity capable of supporting an end-to-end communication. The interactions required to provide a functional entity rely on functions and on the means to select these functions[8].

Interworking Function (IWF): An IWF includes the conversion between protocols and the mapping of one protocol to another. The functionality required between networks can be separated from the functionality, if any, required in end systems. The former functionality is considered to reside in an internetworking network element (INE). Additional details may be found in[8].

Interworking Network Element (INE): The INE is an entity where user plane, control plane and management plane interworking functions (IWFs) may be implemented. The INE could be a standalone network element, part of the ATM switch or part of an LSR located at the entrance to the MPLS network (LER).

Network interworking: In network interworking, the PCI (Protocol Control Information) of the protocol used in two similar networks and the payload information are transferred, transparently, across an intermediate network by a pair of IWFs.

Bundle: A set of one or more transport LSPs in each direction that provide the appearance of a virtual ATM interface to the ATM control protocols.

Downstream INE: The INE receiving MPLS frames on an LSP.

Upstream INE: The INE sending MPLS frames on an LSP.

5 Reference Diagram

Figure 1 shows the reference model for ATM-MPLS network interworking, where a MPLS network interconnects two ATM networks. INEs perform network interworking between the MPLS network and the ATM networks, enabling end-to-end ATM services between users on different ATM networks to be carried across the MPLS network.

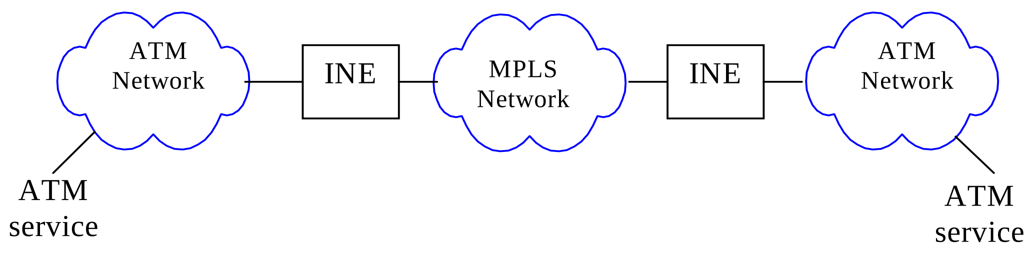

Figure 1: ATM-MPLS-ATM Interworking Reference Model

6 ATM-MPLS Control Plane Network Interworking Architecture

The goal of the specification is to allow for the dynamic establishment of ATM connections across an MPLS core. This can be accomplished by tunneling all ATM traffic at the INE from an attached ATM switch through an Interworking LSP encapsulated with N:1 mode [10] where at minimum an entire ATM VP is tunneled on an interworking LSP.

This specification describes another method using the ATM control plane on the INEs. The ATM control plane operates both between the INEs over an MPLS network, and between INEs and their directly connected ATM networks.

The ATM control channels are transported across the MPLS network as interworking LSPs. These interworking LSPs are carried across the MPLS network in transport LSPs. Transport LSPs are established with standard MPLS mechanisms, e.g. as described in [2], [12]. The connectivity between a pair of INEs appears as one or more logical links to the ATM control plane. One logical link is established for each set of ATM control channels between INEs.

In the ATM-MPLS control plane network interworking architecture, the role of PNNI routing protocols and ILMI is the same as in a traditional ATM network. The role of ATM signalling at the INE is to establish Interworking LSPs between INEs during ATM VCC or VPC establishment and to perform related signalling functions defined in the PNNI specification. These mechanisms are defined in [7]. These interworking LSPs are carried in transport LSPs across the MPLS network. It may be desirable to use more than one transport LSP in each direction between the INEs. The set of transport LSPs carrying the interworking LSPs for a logical link, for both control channels and dynamically established ATM connections, is known as an LSP bundle.

Figure 2 shows various interworking LSPs (user ATM connections, signalling channel, routing control channel and ILMI channel) aggregated within a bundle of transport LSPs.

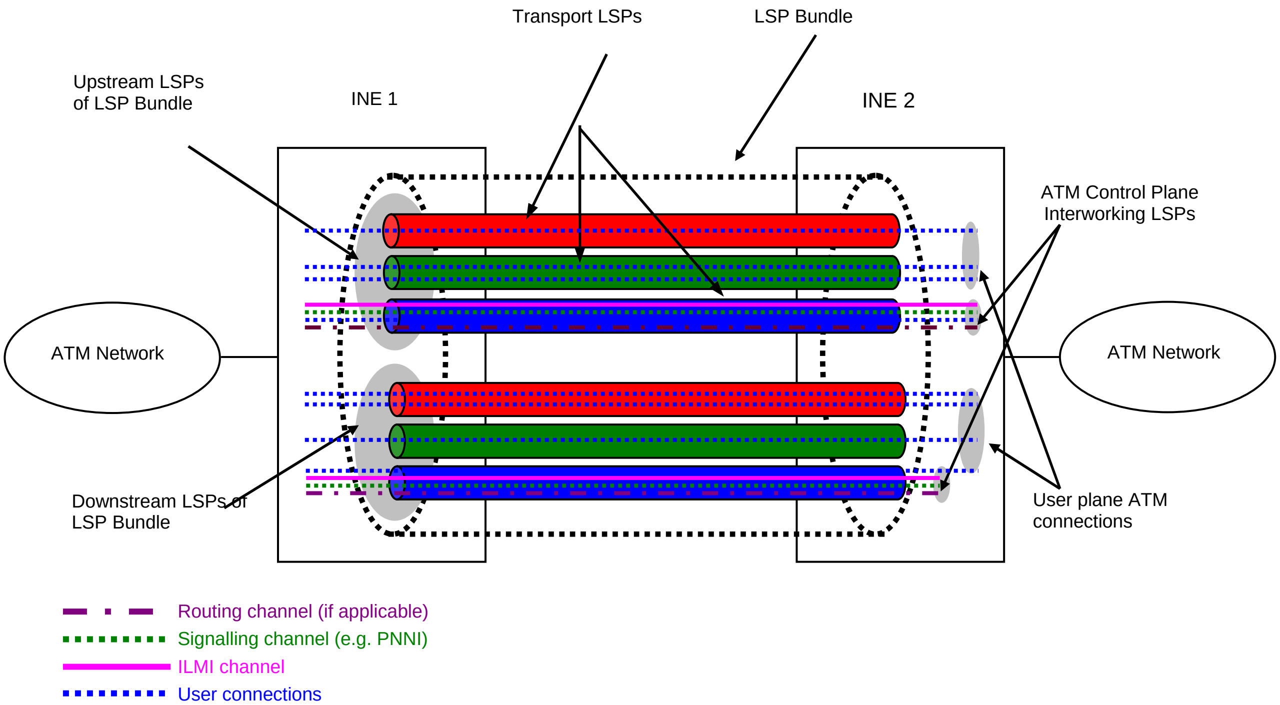

Figure 2: Connections to Support Control Plane Interworking

6.1 Interworking LSP Signalling

In order to establish an interworking LSP that carries an ATM SVC or SPVC over a transport LSP, the INE negotiates the interworking label for each direction and then binds them to the corresponding VPI/VCI values on the ATM interfaces. Signalling mechanisms to accomplish this are specified in [7].

6.2 Routing

The PNNI RCC is provisioned across a bundle of transport LSPs. The bundle between the two INEs is seen as a single hop link by the PNNI routing protocol. Each INE advertises connectivity and resource availability for the bundle, as specified in PNNI [5].

6.3 Quality of Service

The interaction between the routing and signalling planes of the INE is necessary to assure adequate treatment is provided for flows that are to cross the interworking boundary. If the PNNI source node can see the resources available on both the ATM and MPLS portions of the network, path selection can occur such that an ATM VC can be multiplexed into a transport LSP with adequate resources for the ATM connection. In addition, each INE may use connection admission control (CAC) to decide which, if any, of the Transport LSPs can satisfy the requested ATM resources.

If there are insufficient available resources on the existing transport LSPs, the following provisioning procedures may be used to increase the available resources:

- If MPLS network resources are available, more transport LSPs can be added to the bundle between the INEs.

- Existing transport LSPs of a transport LSP bundle can be deleted and replaced with LSPs with more resources allocated on the same bundle. Connections on the transport LSPs being replaced are moved onto these larger transport LSPs.
- INEs can use capabilities in the transport LSP signalling protocols to signal for more or less resources to be reserved on existing transport LSPs (if available).
- If insufficient MPLS resources are available, the ATM call is rejected back to the source as would normally occur.

6.4 Resiliency

MPLS fault management mechanisms such as MPLS Fast Reroute [6] may be used to protect transport LSPs from failures. The attached ATM networks may not see individual LSP failures if these recovery mechanisms operate sufficiently rapidly.

An INE can be thought of as containing 3 logical processes for ATM-MPLS control plane interworking: ATM routing and signalling, IP / MPLS routing and signalling, and an Interworking Function (IWF). The IWF hides the details specific to each control component from the other. For example, if there is a fault in the MPLS network that causes a transport LSP to fail, existing MPLS resiliency methods can re-establish the transport LSP or failover to a backup transport LSP. The ATM control plane will remain stable as long as the transport LSP is available sufficiently rapidly, and the ATM control plane will not become aware of the transport LSP failure.

It is a provisioning task to ensure that MPLS transport LSPs are adequately protected via MPLS fault recovery mechanisms.

7 Transport LSP Bundling

A Transport LSP bundle is defined as a set of one or more transport LSPs in each direction that provide the appearance of a logical ATM interface to the ATM control protocols. The default case is as follows:

- There is one bundle between a pair of peer INEs
- There is one pair of transport LSPs, one in each direction, in the bundle.

Supporting more than one transport LSP in each direction within a bundle is optional. Support for more than one bundle between a pair of peer INEs is also optional.

A transport LSP bundle is a logical construct that is a way to group information about transport LSPs that interconnect a pair of peer INEs. This information is used by PNNI for the purpose of path computation, and by signalling. Transport LSP bundling assumes that the set of resources that form the transport LSP bundle are available to PNNI.

The purpose of bundling multiple transport LSPs in each direction is to improve routing scalability by reducing the amount of information that has to be handled by PNNI. Only one instance of PNNI exists between INEs connected by a particular bundle of transport LSPs. Otherwise, PNNI would have to treat each transport LSP between a pair of INEs as a separate PNNI interface. Additionally, transport LSP bundles allow for a more granular path selection process. Multiple transport LSPs can traverse the same or different paths through the MPLS network between a pair of peer INEs. These LSPs can have varying levels of QoS assigned such that paths can be engineered through the network to match the service categories and conformance definitions of ATM connections using the transport LSP bundles. The transport LSP bundles also contribute to the reliability of the ATM service. The individual transport LSPs can serve as backup for one another if a failure occurs in the MPLS network.

7.1 Label Space of Transport LSP Bundle

A Transport LSP Bundle shall use a per-platform label space to establish interworking LSPs. Implementations should provide a mechanism to restrict the maximum number of Interworking LSPs that can be established on the

INE to a configurable value. This is to ensure that the interworking label space in the INE does not become exhausted by ATM connections.

7.2 Restrictions on Transport LSP Bundling

All LSPs in a bundle must originate and terminate on the same pair of peer INEs.

7.3 Transport LSP Selection Rules

When establishing interworking LSPs for either ATM user or control connections, the IWF shall select one of the transport LSPs of the corresponding transport LSP bundle. If there is no transport LSP in a transport LSP bundle that can accommodate traffic management requirements of the interworking LSP, the IWF shall not attempt to find other transport LSPs outside of that transport LSP bundle.

8 Establishment of control channels

The support of dynamic ATM connections across an intervening MPLS network requires the transport of signalling and, in the case of PNNI, routing information between INEs.

ATM uses reserved VPI/VCI values to identify connections associated with various protocols or functions. These values have per-interface context. In other words, an ATM device can receive the same VPI/VCI from every device attached with the understanding that {VPI, VCI, interface} provides a combination that uniquely identifies the sender. MPLS uses a per-platform label range. As such, when ATM control traffic is tunneled across an MPLS network, a small set of reserved values cannot be used to identify the routing and signalling messages to uniquely distinguish between senders. Instead, values from the per-platform label range, and a method of associating these values with an identified upstream INE, are required.

Before ILMI, Signalling, or PNNI Routing can be carried across a PSN tunnel, the INE at each end of the PSN tunnel must be made aware of the IWLs that will carry the control channel traffic for that instance of the ATM control plane between the INEs. These ATM control channels must be identified so that the data on the corresponding interworking LSPs is delivered to the IWF on the INE and not forwarded on an egress interface.

The establishment and use of ILMI and/or the PNNI routing control channel is optional.

8.1 Provisioning

This mapping of control channels to IWL values can be done via provisioning. As this mapping is only relevant between a pair of peer INEs, the process must be repeated in each direction for each pair.

To configure a static mapping of ATM control channels to IWL values between a pair of peer INEs, the user must configure the IWL values for each of the ATM control channels in both the send and receive directions the encapsulation mode the control information will use for transport and bind these values to a transport LSP bundle.

8.2 Signalling

Alternatively, the ATM control channel to IWL bindings can be distributed as defined in [1] using the LDP downstream unsolicited mode described in [2]. The INEs will establish an LDP session using the Extended Discovery mechanism. An LDP Label Mapping message is used to establish the relationship between ATM control channels and IWLs. An LDP Label Mapping message contains a FEC TLV, a Label TLV, and zero or more optional parameter TLVs.

This specification requires the Generic Label TLV be used. If the PWid is configured as the same in both the upstream and downstream INEs, then the PWid FEC Element [1] can be used; otherwise, the Generalized ID FEC Element [1] shall be used. INEs determine which FEC to use by configuration.

8.2.1 The PWid FEC Element

The format of the PWid FEC Element is shown in [1].

The use of certain fields within the PWid FEC element are specified to be used as follows:

- PW type
A 15 bit quantity containing a value which represents the type of Interworking LSP. Assigned Values are specified in "IANA Allocations for Pseudo Wire Edge to Edge Emulation (PWE3)" [3].

- Group ID

An arbitrary 32 bit value which represents a group of Interworking LSPs that is used to create groups in the Interworking LSP space. The group ID is intended to be used as a port index, or a virtual tunnel index. To simplify configuration a particular PW ID at ingress could be part of the virtual tunnel for transport to the egress router. The Group ID is very useful to send wild card label withdrawals, or Interworking LSP wild card status notification messages to remote INEs upon physical port failure.

The Group ID field may be set such that the ATM control channels are all configured in the same group. This Group ID can have additional significance in that it may also be used to identify the LSP bundle that the ATM control channels can control. The value of the Group ID is network specific.

- PW ID

A non-zero 32-bit connection ID that together with the PW type, identifies a particular Interworking LSP. Note that the PW ID and the PW type must be the same at both endpoints.

Three PW IDs need to be signaled for the ILMI, Signalling and PNNI Routing ATM control channels. The value of these PW IDs is network specific.

The full label distribution and withdraw procedures, status monitoring, etc. are detailed in [1] and[2].

8.2.2 The Generalized ID FEC Element

There are cases where the PWid FEC element cannot be used, because both endpoints have not been provisioned with a common 32-bit PWid. In such cases, the "Generalized ID FEC Element" is used instead. It differs from the PWid FEC element in that the PW ID and the Group ID are eliminated, and a generalized identifier field as described below takes their place. The Generalized ID FEC element includes a PW type field, a C bit, and an interface parameters field; these three fields are identical to those in the PWid FEC, and are used as discussed in the previous section. Detailed procedures for the establishment of interworking LSPs using the Generalized ID FEC element are provided in [1, Section 5.2].

FEC element type 129 is used. The FEC element is encoded as shown in[1].

MPLS packets on a given Interworking LSP are forwarded within an INE by a forwarder. The concept of an attachment identifier (AI) is used to identify the forwarder to which an Interworking LSP is attached. In the PWid FEC, the PW ID effectively serves as the as the AI. However, the Generalized ID FEC represents a more general form of AI, which is structured, and is of variable length. The AI is unique within the context of the INE in which the forwarder resides, so the combination of <INE, AI> is globally unique in the network.

Forwarders within an INE can be associated with a group, where interworking LSPs may only be set up among members of the group. Forwarders associated with the group are identified by an Attachment Group Identifier (AGI) and an Attachment Individual Identifier (AII). This pair represents the AI.

The AGI, SAII, and TAII are encoded as TLVs.

This specification does not define any restrictions on the contents of the AGI.

The SAII shall be set as follows:

```
0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|     SAII      |    Length     |Control Channel| Control Plane |
| (type =       |               |     Type      |   Instance    |
| ATM_FR_CC)    |               |               |  Identifier   |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                                                               |
|               Control Plane Instance Identifier               |
|                           (cont'd)                            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 3: SAII Format

SAII (type) field

The SAII type filed shall be set to a value of 0x03, indicating an ATM_FR_control channel.

Length field

The length field specifies the length of the SAII in octets.

Control Channel Type

This one byte field indicates the control channel type as specified in Table 1 below.

Control Channel Type	Meaning
0	PNNI_Routing Control Channel
1	ATM Signalling
2	ILMI

Table 1: Control Channel Type Field Values

Control Plane Instance Identifier

The Control plane instance identifier (CPII) is used to distinguish between multiple client control plane instances running between the same two INEs.

Control Channels for the same ATM logical link shall use the same value of the CPII in the TAII. Control Channels for different ATM logical links that use the same value for the AGI shall use different values in the TAII. The value used for the CPII should be a human readable ASCII string. This string may be of variable length. The default value for the CPII is the null string specified by setting the length field to 1. The TAII shall be set to the same value as the SAII.

Informative Appendix I: PNNI QoS Advertisement

Since a bundle of LSPs may exist between a pair of INEs, and PNNI only operates once over any LSP bundle, PNNI must deal with the segmented resources that the bundle presents. Each LSP will have some finite set of resources and these cannot be treated in summation by PNNI. For example, there may be a bundle of LSPs with bandwidth reserved on each LSP. A case exists where an ATM call setup requests more bandwidth available on any single LSP in the bundle. In this case, the call should be rejected.

- Case 1: A bundle containing one pair of transport LSPs in each direction between INEs.

  In the simplest case, there is only a single pair of transport LSPs in a bundle. In this instance, PNNI should advertise the available resources for each ATM service class with the resources assigned to the LSP. In this case all ATM service classes whose QoS objectives are supported by the transport LSP may be multiplexed over the bundle.

- Case 2: A bundle containing more than one transport LSP in each direction between INEs

  In this instance, there are several transport LSPs between INEs in a bundle all controlled by one instance of PNNI routing and signalling.

  - Case 2A:

    When there is more than one LSP in a bundle, it is recommended that bundles be created with separate LSPs to support individual ATM service classes. PNNI then can advertise the MaxBW and AvailableBW on a per service category basis with an understanding of the bandwidth assigned to each transport LSP in the bundle.

  - Case 2B:

    Optionally, there can exist multiple LSPs in each direction between INEs where each transport LSP pair can support more than one ATM service category. Here, PNNI should not advertise the cumulative bandwidth assigned for each service category. If that occurred, PNNI may see more bandwidth in a service category that is actually available for a connection. Instead, PNNI should advertise the maximum bandwidth available based on that assigned for a particular service category on the largest individual LSP.

    Example: There exist two transport LSPs between INEs assigned to carry ATM CBR traffic. There are 5Mpbs and 6Mbps assigned to these LSPs respectively. PNNI should advertise 6Mbps available for CBR connections to the rest of the ATM network. If a call uses those resources, CAC will subtract the used bandwidth from the individual LSP (regardless of which LSP was chosen) and then re-advertise the largest single LSP available for the service category. If a 5Mbps ATM CBR connection is established, the call is mapped to the 5Mbps LSP is used and 6 Mbps can still be advertised.

Informative Appendix II: ATM Forum / IETF Terminology

In some instances the ATM Forum and the IETF use different terminology to represent similar concepts. The following provides a mapping between terminologies used by these two organizations. IETF definitions of these terms are available in [13].

IETF	ATM Forum
Pseudowire	Interworking LSP
Pseudowire label	Interworking label
Provider Edge (PE)	Interworking Network Element
Packet Switched Network Tunnel	Transport LSP

Table 2: Terminology Cross Reference

Note: In the IETF, a PSN tunnel can be one of a number of IP tunneling technologies such as MPLS, L2TPv3 or GRE.

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