# ND1121:2001/01

# ATM ACCESS AND INTERCONNECT BETWEEN UK LICENSED OPERATORS

# OVERVIEW

Issue 3

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## Normative Information



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## 0.2 Contents

## 0.3 History

| Revision | Date of Issue | Updated By | Description |
|---|---|---|---|
| Issue 1.0 | March 1997 | | Agreed for release to the PNO-IG steering committee |
| Issue 2.0 | October 1998 | | Updated to reflect new material incorporated within the ATM Task Group documentation on TMN, QofS, Signalling, and the UNI and NNI interfaces used to support interconnect for ATM services and transport. |
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## 0.4 Issue Control

| SECTION | ISSUE | DATE |
|---|---|---|
| All | Issue 3 | January 2001 |

## 0.5 References

[1] PNO-IG/ATM/TG CP(97) 37, “PVC User Network Interface Recommendation”

[2] PNO-IG/ATM/TG CP(97) 13, Interconnect Between UK Licensed Operators Based Upon Permanent ATM PVC Connections, Issue 1.0, 27th February 1997

[3] PNO-IG/ATM/TG CP(98) 53, “Signalling ATM Adaptation Layer (SAAL) UNI Technical Recommendation”, Draft v1.1, 29th June 1998.

[4] ITU-T Recommendation I.311 “B-ISDN General Network Aspects”, Revision 2, March 1993.

[5] ITU-T Recommendation I.113, “Vocabulary of Terms for Broadband Aspects of ISDN”, Revision 2, June 1997.

[6] ITU-T Recommendation Q.2100 “B-ISDN Signalling ATM Adaptation Layer, (SAAL) Overview Description” June 1994.

[7] ITU-T Recommendation E.164, “Numbering Plan for the ISDN Era”, August 1991.

[8] ITU-T Recommendation X.213, “Information Technology—Network Service Definition for OSI”, September 1992.

[9] ATM Forum AF-UNI-0010, “ATM User-Network Interface (UNI) Specification Version 3.0”, Sept 1993.

[10] ATM Forum AF-UNI-0010, “ATM User-Network Interface (UNI) Specification Version 3.1”, 1994.

[11] ATM Forum AF-UNI-0011, “ATM User-Network Interface (UNI) Specification Version 4.0”, April 1996.

[12] ITU-T Recommendation Q.2931, “Broadband Integrated Services Digital Network (B-ISDN); Digital Subscriber Signalling No. 2 (DSS2); User-Network Interface (UNI) Layer 3 Specification for Basic Call/Connection Control”, February 1995.

[13] ATM Forum AF-PNNI-0026, “Interim Inter-Switch Signaling Protocol”, 1994.

[14] ATM Forum AF-PNNI-0055, “Private Network-Node Interface Version 1.0”, March 1996.

[15] ATM Forum AF-BICI-0013, “B-ISDN Inter Carrier Interface (B-ICI) Specification Version 2.0”, December 1995.

[16] ITU-T Recommendation I.371, “Traffic Control and Congestion Control in B-ISDN”, March 1993.

[17] ATM Forum AF-TM-0056, “ATM Traffic Management Specification Version 4.0”, April 1996.

[18] ITU-T Recommendation I.356, “B-ISDN ATM Layer Cell Transfer Performance”, November 1993.

[19] PNO-IG/ATM/CP(97) 45, "Overview of the TMN", Issue 97/056, July 1997

[20] ITU-T Recommendation M.3010, “Principle for a Telecommunications Management Network”, May 1996.

[21] ITU-T Recommendation M.3400, “TMN Management Functions”, April 1997

[22] ITU-T Recommendation M.3320, “Management Requirements Framework for the TMN X Interface”, April 1997

[23] ITU-T Recommendation M.3610, “Principles for Applying the TMN Concept to the Management of B-ISDN”, May 1996.

[24] ETSI Draft ETS 300 820-1, “Asynchronous Transfer Mode (ATM); Configuration Management Information Model for the X-type Interface between Operation Systems (OSs) of a Virtual Path (VP)/Virtual Channel (VC) Cross Connected Network", December 1996.

## 0.6 Glossary of terms

### 0.7.1 Abbreviations

**ATM** Asynchronous Transfer Mode (also called cell relay)

**B-ISDN** Broadband ISDN (Integrated Services Digital Network)

**Connections**

The terms below are used to describe ATM connections between end systems. The term channel is used to refer to the smallest unit of connection between systems, and a path is an aggregation of channels. A connection can be one of either a channel or path, and these can be established by signalling (switched) or under administrative control (permanent). The term circuit is sometimes used synonymously with connection. A connection refers to end-to-end connectivity between two end systems, whilst the term link refers to the individual switch to switch segments of the end-to-end connection.

- **VC** Virtual Channel
- **VCC** Virtual Channel Connection
- **VCL** Virtual Channel Link
- **VP** Virtual Path
- **VPC** Virtual Path Connection
- **VPL** Virtual Path Link
- **PVC** Permanent Virtual Connection (or Permanent Virtual Circuit)
- **PVCC** Permanent Virtual Channel Connection
- **PVCL** Permanent Virtual Channel Link

- **PVPC** Permanent Virtual Path Connection
- **PVPL** Permanent Virtual Path Link
- **sPVC** Soft Permanent Virtual Connection
- **SVC** Switched or Signalling Virtual Connection (or Switched Virtual Circuit)
- **SVCC** Switched or Signalling Virtual Channel Connection
- **SVPC** Switched or Signalling Virtual Path Connection

**Signalling**

The following terms are used in conjunction with ATM signalling:

- **AINI** ATM Inter-Network Interface
- **B-ICI** Broadband Inter-Carrier Interface
- **B-ISUP** Broadband ISDN Signalling User Part
- **B-NT2** Broadband Network Termination of type two
- **B-TA** Broadband Terminal Adapter
- **ES** End System
- **IISP** Interim Inter-switch Signalling Protocol
- **NNI** Network Node Interface
- **P-NNI** Private Network-Network Interface
- **SAAL** Signalling AAL (ATM Adaptation Layer)
- **SSCF** Service-Specific Coordination Function
- **TE** Terminal Equipment
- **UNI** User Network Interface

**ATM Traffic**

The following terms are used to describe ATM quality of service and service classes:

- **ABR** Available Bit Rate
- **ABT** ATM Block Transfer
- **CBR** Constant Bit Rate (ATM Forum equivalent of DBR)
- **CDV** Cell Delay Variation
- **CER** Cell Error Rate
- **CLR** Cell Loss Ratio
- **CMR** Cell Mis-insertion Rate
- **DBR** Deterministic Bit Rate (ITU-T equivalent of CBR)

- **QofS** Quality of Service[1]
- **RM** Resource Management
- **SBR** Statistical Bit Rate (ITU-T equivalent of nrt-VBR)
- **SECBR** Severely Errored Cell Block Ratio
- **UBR** Unspecified Bit Rate
- **VBR** Variable Bit Rate
- **nrt-VBR** non-real time VBR (ATM Forum equivalent of SBR)
- **rt-VBR** real time VBR

## 0.7 Scope

This overview document presents a discussion of the issues associated with establishing ATM interconnects between different operators' public networks, service providers and users. To put the approach in context it discusses the different recommendations of the ITU and the ATM Forum, and highlights the different points in the network where technical recommendations are required. It goes on to discuss the issues associated with both switched virtual circuits and permanent virtual circuits, and the different classes of service that may be run over them.

Concentrating on permanent virtual circuits the document goes on to discuss the different interconnect and user access configurations. This is further expanded in the area of interconnect by concentrating on an underlying SDH infrastructure for providing the interconnect. This approach has been adopted within the task group, as it is felt that it will provide the most resilient configuration, and by building on existing recommendations expedite the production of the PNO-IG ATM's technical recommendations.

[1] The ITU-T abbreviate "Quality of Service" to "QofS", as opposed to the ATM Forum's "QoS". The ITU-T abbreviation is used throughout this document.

# 1 Introduction

The great increase in computer network bandwidths and the demand for real time multi-media applications has led to a significant emerging demand for high-speed communications networks capable of delivering a wide range of services. Stemming out of the work of the ITU on broadband ISDN and the work of the ATM Forum on LAN/WAN connectivity, ATM is the emerging technology designed to satisfy this demand. A number of private ATM networks run by telecommunications operators are already in existence, and public ATM networks are being deployed by the same operators.

The establishment of a competitive ATM market in the UK, will benefit both users and service providers, and allow operators running rival networks to compete with one another. To achieve this a common user-access interface to ATM networks needs to be established. Additionally, interconnects need to be established between different operators' ATM networks, so that users may transfer from one network operator to another. To make this possible the correct technical and regulatory frameworks need to be defined and put in place.

The PNO-IG ATM is a task group managed by the Public Network Operators' Interest Group (PNO-IG) on behalf of the Network Interfaces Co-ordination Committee (NICC). It has been set up to consider the technical issues raised by the introduction of public ATM services into the UK marketplace. It considers user and service provider access to public ATM networks and the interconnection of the different networks operated by public network operators.

The role of the PNO-IG ATM is to provide a set of technical recommendations for ATM interconnects between public operators' networks, and access requirements from users and service providers to these networks. The initial focus of the task group is to establish recommendations for permanent virtual circuits using constant bit rate and variable bit rate traffic types. Whilst this will initially limit functionality, it will enable a technical framework to be speedily established using currently available technology. In the future it is envisaged that recommendations for switched virtual circuits will be established, building upon the experience of the permanent virtual circuits, and taking advantage of emerging standards and technology.

The PNO-IG ATM is tasked with fulfilling the following objectives:

- To define the UK ATM interconnect regime suitable for the UK market environment.
- To recommend UK interconnect interfaces with reference to international and European standards setting fora as appropriate.
- To recommend ATM access interface requirements for the UK.

Objective 1 is achieved through the adoption of the existing interconnect regime which PNO-IG ATM deem to be suitable for the UK market. This approach has the benefit of consistency with the existing interconnect arrangements, in particular with the SDH regime which can form the physical layer for ATM interconnection.

Objectives 2 and 3 are realised through delivery of technical recommendations to define ATM interconnect between UK licensed operators and customer access to UK public ATM networks.

The present document provides an overview of ATM interconnect. Note that there are no separate documents for service provider interfaces. This is because it is felt that at the present time their requirements can be met either by the user network interface or operator interconnect. This is true whilst only permanent virtual connections are supported, but will need to be reviewed when support for switched virtual connections is developed.

# 2 Overview of ATM

This section is intended to provide an overview of ATM principles and the associated terminology. It presents a brief introduction to the different types of ATM connection and the service classes that can be supported. As the standards relating to ATM and equipment vendor support of them is still emerging, this will be reflected by the evolution of the Public Network Operators ATM Interconnect and Access series of recommendations.

Bearing this in mind, this section attempts to provide a more complete overview of the whole area of ATM interconnects and access, with the intention that it should provide a view as to the future direction of the recommendations. The subsequent sections in this document deal more specifically with the development of the first phase of the interconnect and access recommendations, and provide more detail of the specific permanent virtual connection recommendations.

## 2.1 Traffic in ATM Networks

Traffic is carried across ATM networks by using point to point (or point to multi-point, multi-point to point, or multi-point to multi-point) virtual channel connections (VCCs). Broadly speaking there are two types of connection: Permanent Virtual Connections (PVCs) and Switched Virtual Connections (SVCs). PVCs are established under administrative control of the network, and SVCs by end user signalling. When a connection is established, either by administrative control or signalling, a Quality of Service is specified (QofS), and traffic types such as Constant Bit Rate (CBR) and Variable Bit Rate (VBR) can be allocated for that particular connection (see later).

In addition to Virtual Channels (VCs) there are also Virtual Paths (VPs). A virtual path is an aggregation of virtual channels that can be switched through the network as a single entity. Virtual paths can have quality of service parameters applied to them in the same way as virtual circuits.

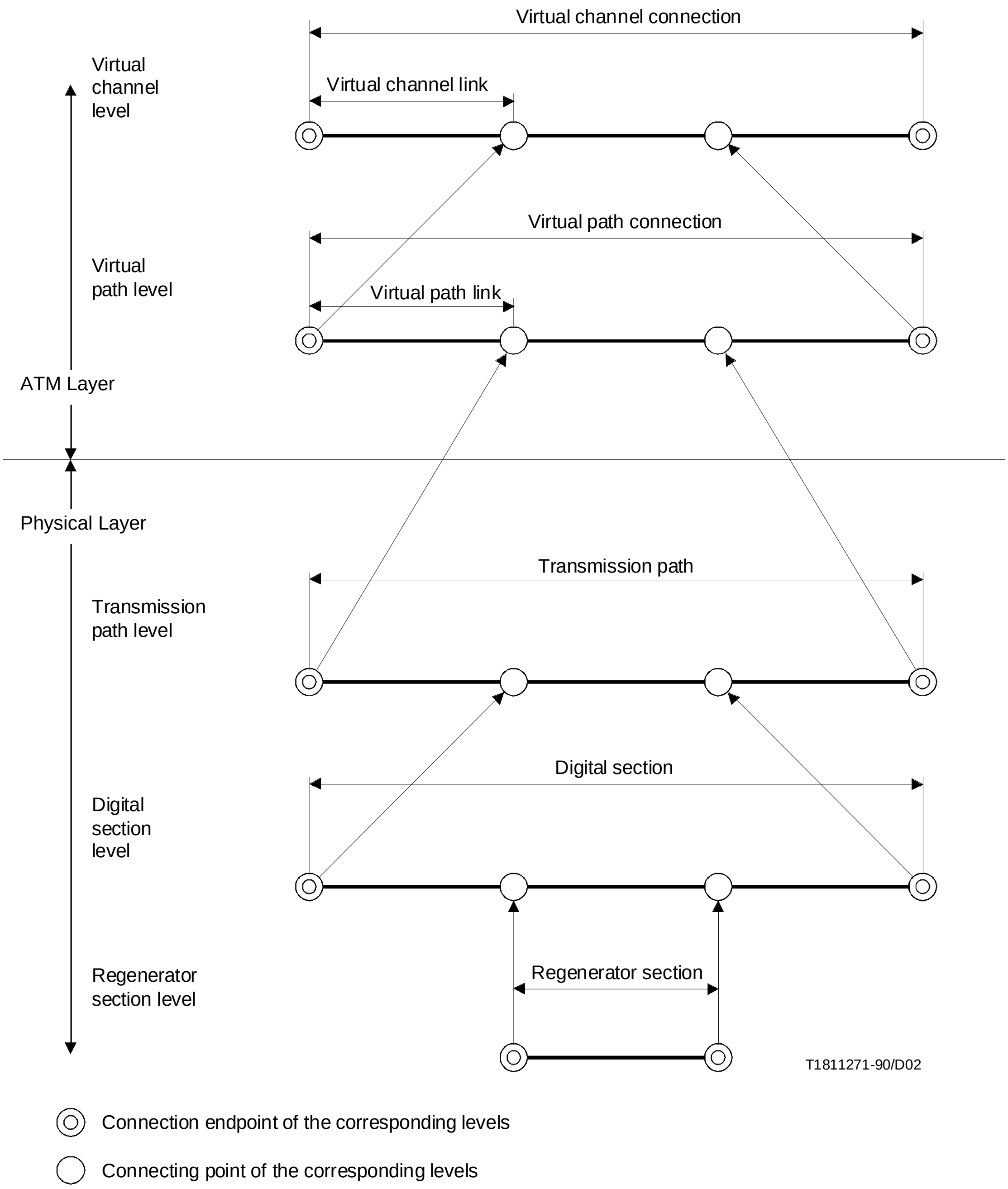



FIGURE 2 – **Hierarchical ATM Layer-to-Layer Relationship**

A connection refers to the end-to-end service provided between two end systems. An individual connection is made up of a concatenation of virtual links. An individual link is the part of the connection between two ATM switches. The concepts of channels, paths, connections and links are illustrated in Figure 2. For detailed information on ATM connections refer to ITU-T recommendation I.311 [4], and for definitions of the vocabulary of broadband ISDN terms, ITU-T recommendation I.113 [5].

## 2.2 Virtual Connections

Permanent Virtual Channel Connections (PVCCs) and Permanent Virtual Path Connections (PVPCs) are established by administrative control in the network; each switch is configured with information regarding how to switch traffic for that particular virtual channel or path.

### 2.2.1 Permanent Virtual Channel Connections

Permanent virtual channel connections are a well-established form of ATM connection, and they are available on all ATM switches. Because PVCCs do not require signalling there should be few inter-working issues when using PVCCs between different ATM switches.

### 2.2.2 Permanent Virtual Path Connections

Virtual paths are an aggregation of virtual channels that are routed as a single entity across a network of switches. PVPCs do not require signalling support. Consequently, there should be few inter-working issues when using PVPCs between different ATM switches.

### 2.2.3 Soft Permanent Virtual Connections

The term ‘Soft’ when applied to Permanent Virtual Paths and Permanent Virtual Channels describes connections established under administrative control of the network, which are able to re-route under failure conditions. The re-routing is performed without operator intervention, using signalling within the network. In an interconnect scenario, the use of SPVCs raises the possibility of signalling incompatibilities between UKLOs networks.

### 2.2.4 Switched Virtual Connections

Switched Virtual Connections (SVCs) are established by signalling. To achieve this a signalling protocol is required between the end points of the connection and between the switches in the network. The advantage of SVCs is that they are more flexible than PVCs in that they allow connections to be set up on demand by the user.

## 2.3 Signalling

### 2.3.1 Signalling ATM Adaptation Layer (SAAL) principles

The Signalling ATM Adaptation Layer (SAAL) operates between the ATM layer and the higher layer signalling layer, (P-NNI, B-ISUP, UNI3.1, Q.2931 etc). The SAAL procedures are applicable to both Soft PVC (S-PVC) and SVC based services. Its role is very similar to that of the user plane defined AALs, and as such is based upon the AAL5 procedures. Thus, the SAAL not only performs the adaptation between the signalling layer Protocol Data Units (PDUs) to the ATM cell layer and vice versa, but also provides additional services over and above of AAL5 such as, error detection and correction using re-transmission, flow control, and a keep alive functionality.

The international standards body, ITU-T which was responsible for developing the SAAL procedures, made a distinction between the Service-Specific Coordination Function (SSCF) at the UNI and the NNI. ATM-F NNI based signalling protocols, such as Private Network-Network Interface (P-NNI) and ATM Inter-Network Interface (AINI) plus ITU-T Access signalling protocols make use of the SSCF at the UNI. Conversely, the ITU-T internodal signalling protocol Broadband ISUP (B-ISUP) and the ATM-F Broadband Inter-Carrier Interface (B-ICI) makes use of the SSCF at the NNI procedures, as can be seen in Figure 3. Further information on the SAAL functionality can be found in ITU-T Recommendation Q.2100 - B-ISDN SAAL Overview Description [6].

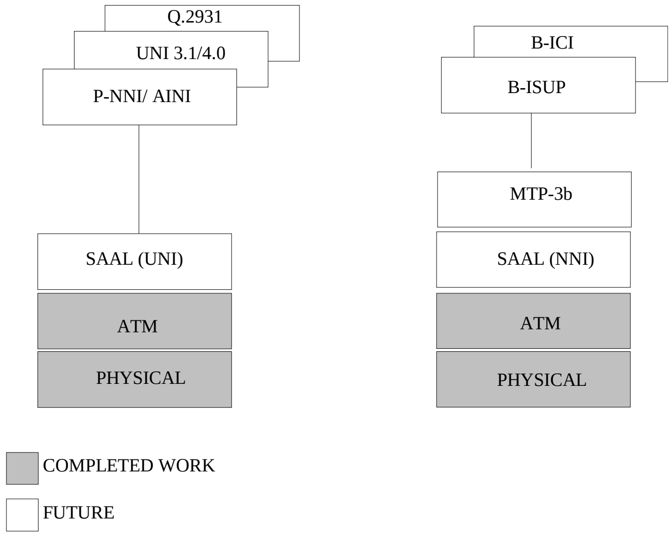



FIGURE 3 – **SAAL Relationship with Signalling Protocols**

### 2.3.2 Access Signalling

When an SVC is required the user requests one by signalling to the ATM switch to which he is attached. The access signalling forms part of the User to Network Interface (UNI). There are currently a number of important versions of this, and these are described in Section 5.4 below.

### 2.3.3 Network Signalling

Once a user has requested an SVC via the UNI, this information must be signalled between the switches constituting the ATM network, so that an end-to-end connection can be established. This inter-switch signalling forms part of the Network Node Interface (NNI). There are a number of different NNIs defined, and these are described in the section 5.4 below.

### 2.3.4 Signalling Support

Because ATM signalling has been developed relatively recently, and enhancements to it are still being made, support for SVCs is not as widely available as that for PVCs. Even when switches do support SVCs, this may be using an old, or pre-standard, signalling protocol. It is likely that some form of inter-operability testing will be required between switch vendors to ensure satisfactory operation.

If a transit network does not support signalling, signalling can be transparently tunnelled across it using a Permanent Virtual Path Connection (PVPC). This allows originating and terminating ATM networks to establish SVCCs between themselves within the PVPC. The signalling associated with this is transparently carried over one of the VCs in the PVPC, and appears as simply another data stream to the transit network.

### 2.3.5 ATM Addressing Schemes

To provide SVC support, not only does the network signalling protocol need to be agreed, but also a uniform addressing scheme would need to be defined across different operators networks. There are public addressing schemes defined by the ITU-T and private addressing schemes defined by the ATM Forum. The ITU-T have specified that the numbering and addressing within a public B-ISDN network conform to ITU-T Recommendation E.164 [7].

The ATM Forum private addressing is based upon NSAP addressing (OSI Network Service Access Point is defined in ITU-T Recommendation X.213 [8]). There are three different types of address format defined by the ATM Forum:

Data Country Code (DCC), International Code Designator (ICD), and NSAP encapsulation of E.164. The DCC format is based upon a country code having the most significance, whilst the ICD format is based upon an organisation identifier having the most significance and would be used by large international organisations.

When connecting a private ATM domain to a public ATM network, only the UNIs directly connected to the public network would normally be assigned E.164 addresses. There is still considerable ongoing discussion about what NSAP addressing plan should be adopted within national and organisation's networks. There are also still some issues to be resolved with mixing ATM Forum private NSAP addresses, and ITU-T E.164 addresses. This is particularly apparent when calls are made from a private host (NSAP addressing) to a public host (E.164 addressing).

## 2.4 Interconnect Reference Model

There are two principal organisations that are working to develop specifications for ATM. The International Telecommunications Union (ITU) is the United Nations agency which deals with telecommunications standardisation and has membership by country. It provided the initial standards for Broadband ISDN (B-ISDN) with ATM as the underlying transport mechanism. Although the ITU is still active in the standardisation process, much work has been done by the ATM Forum in taking the specifications forward. The ATM Forum is composed of industry representatives from equipment manufacturers, operators and users, and is consequently much more responsive to market demands.

Whilst the ATM Forum endeavours to base its specifications on ITU standards and remain compatible with them, there is inevitably some conflict between the two bodies. This is as a result of the different emphasises of the two organisations, and their different paces of development. This is particularly apparent in the area of interconnects between different public ATM networks. The different network interfaces that have been standardised by these two bodies are shown in the reference model below.

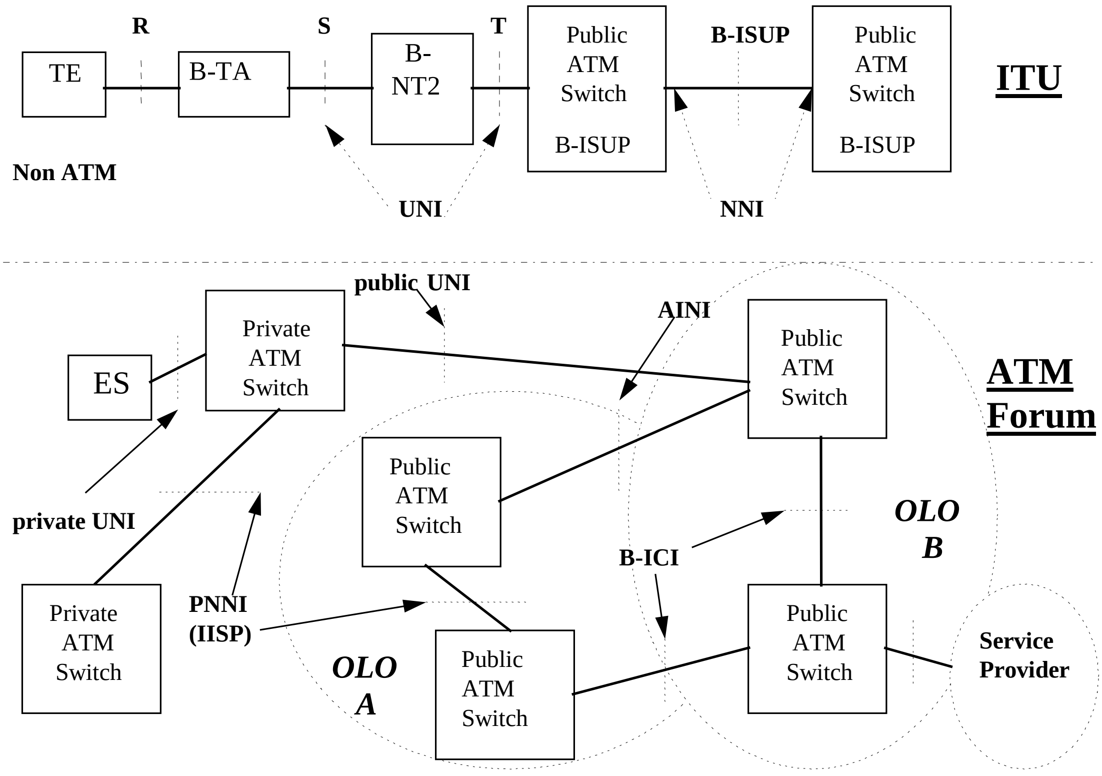



FIGURE 4 – **ITU-T and ATM Forum Reference Models**

### 2.4.1 User Network Interface (UNI)

The User Network Interface (UNI) is a connection between a user and an ATM network. There are two slight variants of this, namely:

- **Private UNI**—This forms the connection between a user and a private ATM network.
- **Public UNI**—This forms the connection between a user and a public ATM network. It is virtually the same as the private UNI, but may use public (E.164) ATM addressing, rather than the private NSAP based ATM addressing. This will only be important for switched virtual connections.

The UNI has been defined in great detail by the ATM Forum in the UNI 3.0, 3.1 and 4.0 specifications [9] [10] [11]. The ATM Forum UNI 3.0 was produced before the ITU-T had fully specified their UNI signalling recommendations in Q.2931 [12], and consequently the two are incompatible. The ATM Forum then developed UNI 3.1, a modified version of UNI 3.0, to be more compatible with the Q.2931 signalling recommendation . By doing this they made UNI 3.1 incompatible with UNI 3.0. There are still some technical differences between UNI 3.1 signalling and Q.2931, and these are listed in Appendix E of the UNI 3.1 document.

Both UNI 3.0 and 3.1 specify the signalling procedures and the underlying AAL, ATM and physical layers. Recently the ATM Forum has produced a UNI 4.0 signalling specification. This document specifies signalling procedures, and not any of the underlying layers (which are still specified in UNI 3.1). It is based upon the 1996 edition of Q.2931.

Rather than produce one recommendation for all UNI layers, the ITU-T split this up into a number of recommendations. The ITU-T have been adding extra functionality to Q.2931 in the form of Capability Sets (CS). At present the ITU-T have completed the CS-1 and CS2-1 work, and progress on CS2-2 is now being started. At present ETSI have endorsed the ITU-T's UNI signalling recommendation, Q.2931, which is referred to as ETS 300-433-1. Progress has also been made on endorsing a number of ITU-T UNI CS2-1 recommendations as well.

### 2.4.2 Network Node Interface (NNI)

The Network Node Interface forms the connection between switches in the ATM networks. There are a number of protocols that may be used at the NNI. Some of these protocols have been designed to meet private network needs, whereas others have been developed for use in a public NNI for interconnections between operators. In reality, one would expect some overlap in the use of these protocols in both private and public networking.

- **IISP**—The Interim Inter-Switch Signalling Protocol [13] (originally called P-NNI phase 0), was defined as an interim method of supporting SVCs between switches, before a full P-NNI was defined. It relies upon static routing tables in the switches, and UNI signalling, and provides limited resilience.
- **P-NNI**—The ATM Forum Private Network-Network Interface is much more sophisticated than IISP. It consists of a signalling protocol and a source based dynamic routing protocol. The signalling is based upon UNI 3.1 & 4.0 and the routing protocol is similar to Open Shortest Path First (OSPF), which provides source based routing. Version 1.0 of P-NNI [14] supports quality of service routing, and re-routing in the event of failure. By using aggregation into peer groups of routing information it supports routing in very large networks.
- **B-ISUP**—Broadband ISUP (ISDN Signalling User Part) is a Public Network Node Interface defined by the ITU-T which is based upon the narrow-band ISDN Signalling System Number 7 (SS7). It is designed to provide control of ATM services between public networks. B-ISUP uses the services of the Message Transfer Part level 3 (MTP-3) for hop-by-hop routing and management of its signalling links and the Signalling Connection Control Part (SCCP) for non-call related signalling. It is enhanced by a number of capability sets. At present CS-1 and CS2-1 have been completed, with work in progress on CS2-2. At present ETSI have endorsed the ITU-T's NNI signalling recommendations Q.2761, Q.2762, Q.2763 and Q.2764.
- **B-ICI**—The Broadband Inter-Carrier Interface connects ATM networks of two different network operators, and is standardised by the ATM Forum. The B-ICI defines services and signalling between network operators. The services supported are: Frame Relay Service (FRS), Switched Multi-megabit Data Service (SMDS), Cell Relay Service (CRS), and Circuit Emulation Service (CES). Version 1.0 of the B-ICI (1993) supported PVC based services. Version 1.1 added extra support for usage metering and operations. Version 2.0 (1995) added support for SVCs and is based upon B-ISUP signalling release 1 with some CS2-1 extensions. B-ICI uses the services of the Message Transfer Part level 3 (MTP-3) for hop-by-hop routing and management of its signalling links. For known differences between B-ICI and B-ISUP see the ATM Forum B-ICI v2.0 specification [15].
- **A-INI** — The ATM Inter Network Interface has been defined by the ATM Forum. This protocol addresses interworking issues between separate P-NNI networks, *and* between P-NNI and B-ISUP networks. It looks similar to P-NNI signalling with static routing. There are still some areas that need resolving with regard to inter-working between the various NNI formats, in that they are based on quite different routing protocols, and

addressing formats. As the current UK recommendations being defined are only based upon PVCs, these issues do not need to be addressed as yet.

## 2.5 Service Classes

When an ATM connection is established a traffic contract is agreed between the user and the network, and between the nodes within the network which are used by the connection. The connection will only be accepted by the network providing that the network can support the requested traffic contract and if the request does infringe on any existing traffic contracts. ATM traffic types have been categorised into a number of service classes or categories. Both the ITU-T and the ATM Forum have been involved in specifying these traffic types, and Table 1 shows the traffic types currently defined.

| ITU-T I.371<br>ATM Transfer Capability | ATM Forum TM 4.0<br>ATM Service Category | Characteristics |
|---|---|---|
| Deterministic Bit Rate (DBR) | Constant Bit Rate<br>(CBR) | Real time, with QofS guarantee |
| Statistical Bit Rate (SBR) | Real Time Variable Bit Rate<br>(rt-VBR) | Statistical multiplexing, real time, guaranteed delay |
| | Non-Real Time VBR<br>(nrt-VBR) | Statistical multiplexing, no delay guarantees |
| Available Bit Rate (ABR) | Available Bit Rate<br>(ABR) | Resource exploitation, with feedback control |
| *(no equivalent)* | Unspecified Bit Rate<br>(UBR) | Best efforts, no guarantees |
| ATM Block Transfer (ABT) | *(no equivalent)* | Burst level, with feedback control |

TABLE 1 – **Comparison of ITU-T and ATM Forum Traffic Types**

It is important to note that the terminology used by the two standardisation bodies for some of the traffic types differ. The ATM Forum Traffic Management v4.0 has a list of differences between the ITU-T and ATM Forum traffic types. The following gives a brief description of each traffic type.

- **CBR/DBR:** This category is used by connections that require a constant amount of bandwidth which is continuously available during the lifetime of the connection. The required bandwidth is characterised by a peak cell rate value, which should be continuously available. It is used for delay sensitive applications such as uncompressed telephony.
- **VBR/SBR:** This category is used by connections that require an amount of bandwidth that varies within defined limits. The ATM Forum further divides VBR into real time and non-real time services. Real time VBR is used for delay sensitive applications such as MPEG video, whilst non-real time VBR is used for applications that are insensitive to delay such as file transfers.
- **ABR:** As its name suggests this category is based on the available bandwidth within the network. The amount of bandwidth provided can vary with time under the control of the network, either up or down, although the user does specify a minimum bandwidth for the service. ABR is a rate based scheme which relies on network feedback. ABR is designed to effectively utilise the available capacity in the network, and is intended for non-real time applications such as LAN traffic.
- **UBR:** This category is only defined by the ATM Forum. No explicit bandwidth allocation is needed, and therefore neither a QofS or bandwidth allocation is specified. UBR is a best efforts service for non-real time traffic, and is used extensively for LAN traffic.
- **ABT:** This category is only defined by the ITU-T. It is based on a block or burst allocation methodology. The idea is that the network resources can be negotiated and allocated on a per block basis rather than on a per connection basis which is the technique used by the other traffic categories.

For a detailed definition of these traffic types refer to ITU-T Recommendation I.371 [16] and ATM Forum Traffic Management Specification v4.0 [17].

## 2.6 Quality of Service (QofS)

This section describes the different ways in which the ITU-T and the ATM Forum have chosen to specify their QofS schemes. Further information on QofS can be found in Appendix A.

The ITU-T have adopted a class based approach, whereas the ATM Forum have adopted a parameter based approach for their most recent specifications.

At present the ITU-T have defined four QofS classes. These classes are specified in ITU-T Recommendation I.356 [18]. Each class contains a number of parameters which make up the QofS definition. These parameters include: Cell Transfer Delay (CTD), Cell Delay Variation (CDV), Cell Loss Ratio (CLR), Cell Error Rate (CER), Cell Mis-insertion Rate (CMR), and Severely Errored Cell Block Ratio (SECBR). (For details see Appendix A). The four different QofS classes are listed below:

- Class 1—Stringent Class
- Class 2—Tolerant Class
- Class 3—Bi-level Class
- Class 4—Unbounded Class

The ATM Forum specifications use both a class based and a parameterised QofS approach. The most recent specifications: P-NNI v1.0 [14] and UNI v4.0 [11] both use individual QofS parameters, whilst the older B-ICI v2.0 [15] and UNI v3.1 [10] use a class based approach.

The purpose of the Extended QofS parameters is to indicate individual QofS parameter values on a per call basis by indicating the cumulative QofS parameter values. The cumulative QofS values allow each switch involved in a connection to add its expected QofS impairments to a running total. If by the time the connection reaches the destination and the calling user’s request has not been exceeded then the connection is established otherwise the connection is released. The use of QofS classes is retained in UNI v4.0 and P-NNI v1.0 for backward compatibility.

For more detailed information on QofS issues refer to ITU-T Recommendation I.356 [18] or ATM Forum Traffic Management Specification v4.0 [17] and ATM Forum UNI Signalling Specification v4.0 [11].

## 2.7 TMN Architecture and Related Standards Activities

Within the TMN Logical Architecture a number of logical function blocks and reference points are identified (see References [19] and [20]). All of the reference points identified as being within the TMN are subject to ITU recommendations. Of these reference points only the x reference point, which manifests itself as an X interface, concerns more than one TMN. As a TMN is an administrative domain it is the x reference point that is applied between administrative domains which are within the jurisdiction of different PLOs. The x reference point is used for the purpose of exchanging management information between different administrative domains concerning network connections and services than span more than one administrative domain.

In addition, the ITU TMN Logical Architecture defines several management layers (see References [19] and [20]). x reference points may be applied between TMN function blocks at the Element Management Layer, Network Management Layer, or Service Management Layer within this architecture. From the definition of the various layers, the exchange of management information across an X interface for an ATM PVC interconnect should be applied at x reference points at the Service Management Layer (as this is concerned with the overall connection and its associated QofS) and partly at the Network Management Layer (for the control of topological information).

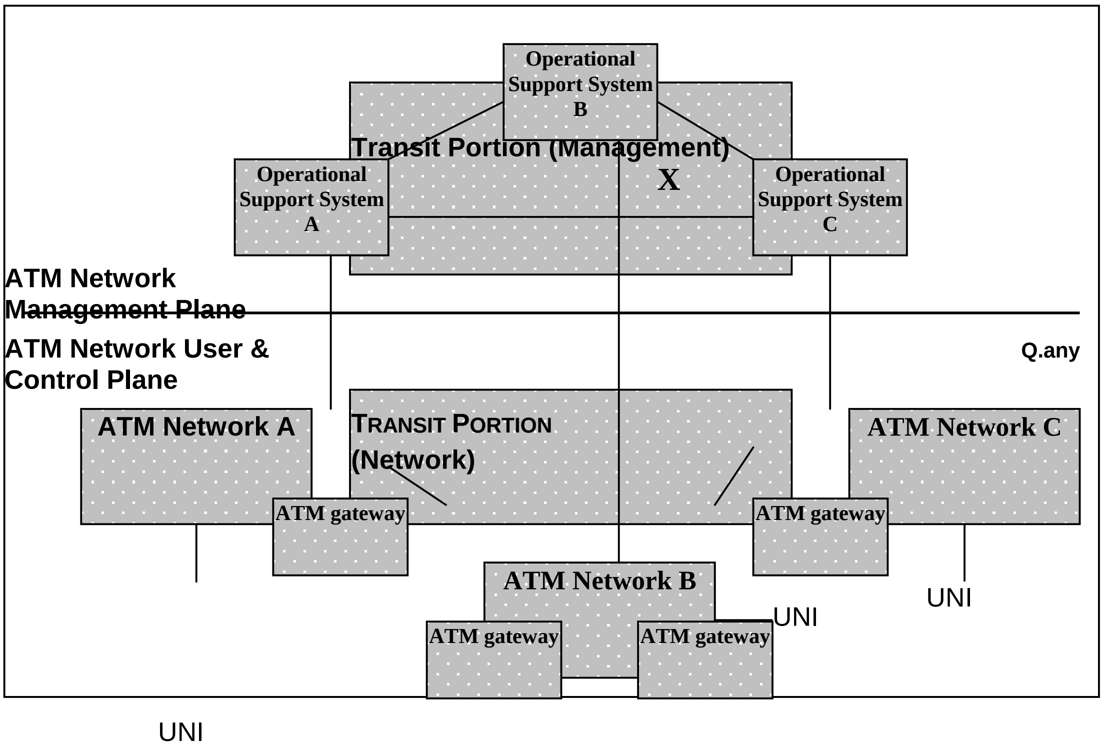



FIGURE 5 – **Relationship between Network and Management Interfaces**

### 2.7.1. TMN Architecture Stack

Having identified which specific reference point within the TMN Architectures concern an ATM PVC interconnect, the next task is to identify what happens across this interface. Generally, management operations can be divided into five area: Fault Management, Configuration Management, Performance Management, Security Management, and Accounting Management (see Reference [21]). All of these functional areas can concern the management of an ATM PVC interconnect, but all are concerned with different aspects of an ATM PVC interconnect.

At the Service Management Layer of an ATM PVC interconnect, the various Management Functional Areas are principally concerned with the following:

**Fault Management**: Reporting and resolution of faults that affect the service to the end-user.

**Configuration Management**: The provisioning and maintaining an inventory of an end-to-end ATM PVC.

**Performance Management**: Monitoring and controlling the aspects of an ATM PVC that affect the QofS.

**Security Management**: Ensuring the integrity of an ATM PVC.

**Accounting Management**: Collection and transmission of accounting data for an ATM PVC.

For the Management Functional Areas the specific operations that need to be applied to an ATM PVC need to be determined and the information that is to be exchanged between PLOs to manage the interconnect aspects of an ATM PVC using these operations automatically across an X interface identified.

### 2.7.2 ATM Forum

The ATM Forum has developed a reference model for all interfaces in ATM networks that could be the subject of ATM Forum specifications.

### 2.7.3 Network Management Forum

The Network Management Forum has produced a number of ATM related and generic management specifications but, to date, no work has resulted in anything that is of use to PNO-IG ATM Task Group for management of ATM interconnects.

### 2.7.4 European Commission

The EC has stimulated effort in the area of interconnect TMN work in the form of its Open Network Provisioning (ONP) programme. ONP is designed to aid interconnects supporting the availability of universal service and interoperability throughout the EU by providing directives and guidelines on open interfaces between PLOs and the information that is available at these interfaces.

### 2.7.5 EURESCOM

The European Institute for Research and Strategic Studies in Telecommunications (EURESCOM) was founded by 20 Public Network Operators from 16 European countries on 14 March 1991 to carry out a number of pre-competitive R&D projects in support of the development of Europe-wide telecommunication networks and services. EURESCOM projects have greatly stimulated the development of pan-European ATM networks and has performed ground breaking work on ATM interconnects leading to the delivery of specifications and the execution of experiments.

The P105 project on European ATM Network Studies produced the first full specification of an X-interface (known as "Xcoop") for ATM networks. The P408 project on Pan-European TMN - Experiments and Field Trial Support, resulted in the first trials of ATM interconnects including the TMN aspects of Fault and Configuration Management and the establishment of a Europe wide TMN laboratory (PET-Lab). The specifications resulting from P408 are being used in the JAMES ATM trial network. Today, the P708 project is extending this work in TMN X-interface studies and experiments for ATM in the areas of Fault, Configuration, Performance, Accounting and Security Management.

The EURESCOM work represents a major step forward in the development and testing of specifications for ATM interconnects but is only available to Shareholders. However, a significant portion of the EURESCOM specifications on X-interfaces has resulted in contributions to ETSI.

### 2.7.6 ITU

The ITU were responsible for the creation of the TMN concept and has devoted a large amount of effort to the development of TMN recommendations which started in 1986. The ITU defined the TMN architectures and identified the "x reference point" within its TMN architectures. The "X interface" is applied at the x reference point and serves as the point for the exchange of management information between network and service providers where network connections and services span several administrative domains under the jurisdiction of different network and service providers.

The ITU recommendations covering TMN are spread across the series of recommendations with the M series defining the principles and architectures for TMN. For the TMN aspects of ATM interconnects no specific current ITU recommendations exist other than for establishing general principles. The appropriate ITU recommendations are contained in References [22] and [23].

These recommendations provide reasonable background on X-interfaces and ATM, they fall short of providing source material that could be adopted for the purposes of defining the TMN aspects of an ATM PVC interconnect.

#### 2.7.6 ETSI

ETSI has been probably the most active in X-interface specification work. ETSI adopts the ITU TMN concept and actively contributes TMN specifications to the ITU. A significant proportion of the EURESCOM specification work on TMN X interfaces for ATM resulted in ETSI contributions. In particular Reference [24] covering Fault, Configuration and Performance Management contains source material for the TMN aspects of ATM PVC interconnects.

# 3 Principles of ATM Access and Interconnect

The recommendations for ATM Access and Interconnect between UK Licensed Operators are to be split into a number of phases so that interconnects can be established today using the available technology, whilst not limiting the future functionality and resilience. The first phase of interconnect development will be based upon the following connection types and traffic categories:

- Permanent Virtual Channel Links (PVCLs) and Permanent Virtual Path Links (PVPLs), to offer Permanent Virtual Channel Connections (PVCCs) and Permanent Virtual Path Connections (PVPCs) to users.
- Constant (or Deterministic) Bit Rate (CBR/DBR) and non-real time Variable (or Statistical) Bit Rate (nrt-VBR/SBR)

The following principles need to be recognised when planning an interconnect agreement between two ATM network operators:

- The end-to-end performance of a service should be defined by Service Level Agreements (SLAs) between the operators whose networks carry the service. This should be specified with an end-to-end quality of service, with measurements and statistics available to quantify this.
- Procedures for establishing, modifying and clearing connections based upon the needs of the users—as PVCCs and PVPCs are established under administrative control, inter-operator procedures will be required to set them up.
- The resilience of the interconnect itself, and the two networks on either side of the interconnect need to be considered. A service level agreement needs to be defined for the availability of connections, and how re-routing will be performed if required.
- Inter-operators procedures need to be defined for fault finding and fault resolution. Target interconnect fault clearance times should form part of the service level agreement.
- Mechanisms need to be put in place for collecting interconnect accounting information, and exchanging it between operators.

# 4 Interconnect and Access Configurations

There are a number of ways of connecting different operators ATM networks together, which can rely on direct ATM connections or connections carried over an existing transport mechanism. Additionally equipment may be co-located or the connection formed between equipment at the two operators' premises.

The diagrams below illustrates some examples of the different types of interconnection that are possible for ATM:

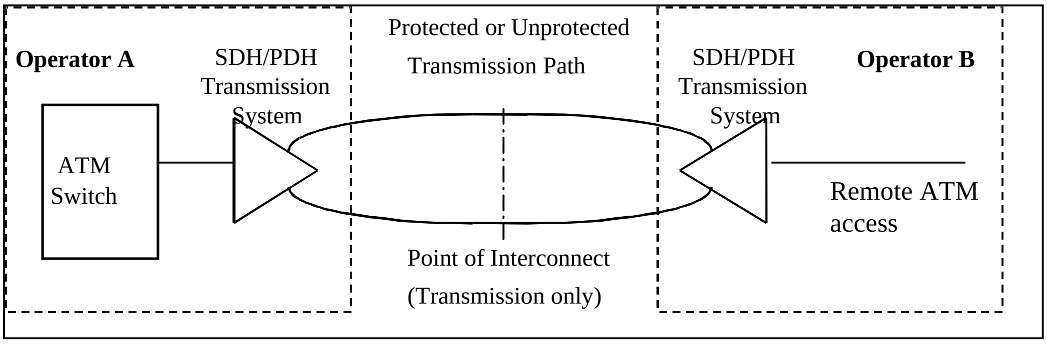



FIGURE 6 – **ATM service extended over existing Transmission system**

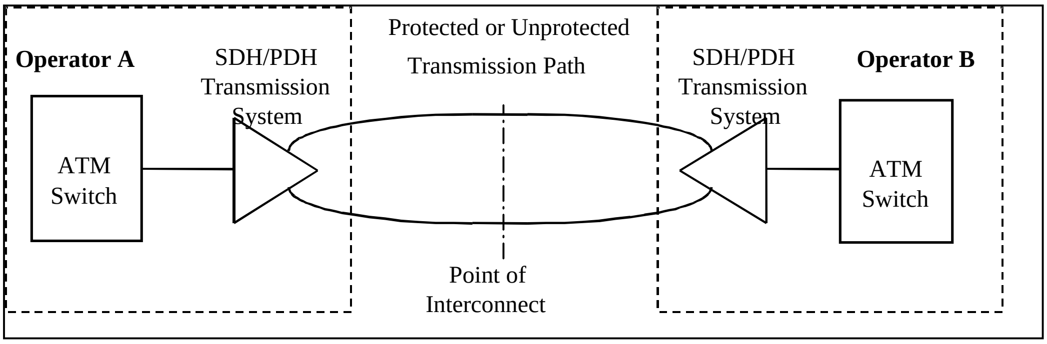



FIGURE 7 – **Interconnect using Existing Transmission Systems**

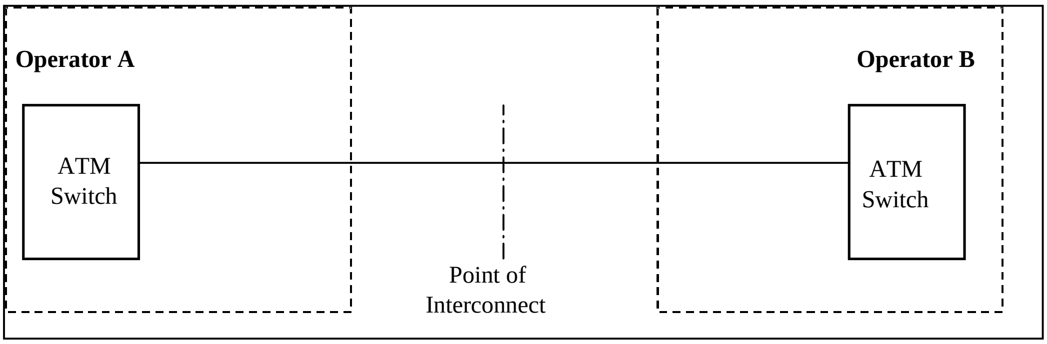



FIGURE 8 – **Direct Mid-Span ATM Interconnect**

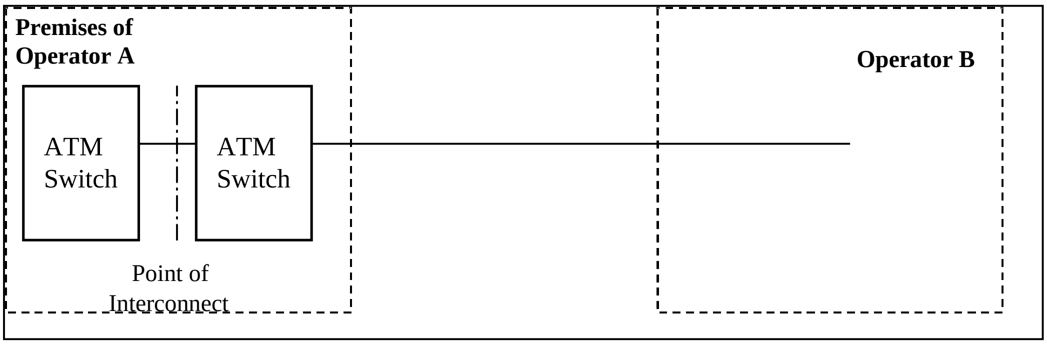



FIGURE 9 – **Direct In-Station ATM Interconnect**

Figure 6 depicts a transmission interconnect being used by Operator A to extend their ATM service by means of a tail circuit. Unlike Figures 7 through 9, this does not involve ATM Interconnection between the operators.

Both Figure 7 and Figure 8 show a Mid-Span Interconnection, Figure 9 shows an In-Station Interconnection. Figure 7 shows an interconnect using existing transmission systems (which may be a protected SDH link), whilst Figure 8 and Figure 9 show direct ATM connections. The characteristics of these different forms of interconnection are listed below:

- The Mid-Span Interconnection avoids the need for one operator to locate any of his equipment on the premises of the other operator (and vice versa). This eliminates a number of the issues that are encountered when implementing an In-Station Interconnection (access to equipment, security, power arrangements, rental of space etc.)
- In most situations, both operators are likely to own a proportion of the fibre link. In the case of the Mid-Span Interconnection, the Point Of Interconnect can be located at the point where fibre ownership changes. For the In-Station Interconnection, on the other hand, there may be a difference between the point where fibre (or electrical cable) ownership changes and the point where a service is actually handed over from the management domain of one operator to that of the other; this can complicate the Service Level Agreement, since one operator is managing services across a length of fibre belonging to the other operator.
- The interconnect using existing transmission systems can provide a longer reach, and greater resilience using SDH technology than direct ATM connections can provide.
- SDH interconnect recommendations have been defined by UKLOs [25]
- Direct ATM connections should be lower cost than those carried over a transmission system as the extra transmission equipment is not required.

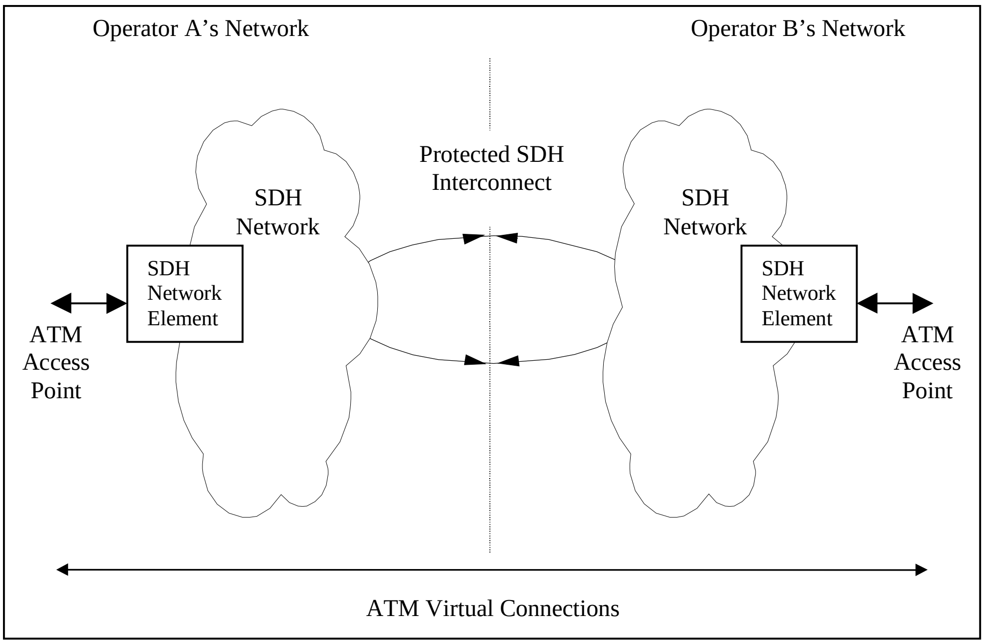
For reasons of resilience and maintenance, Mid-Span Interconnections over existing SDH transmission systems is preferred for fixed link interconnection between ATM networks.

In the future as higher bandwidths are required and network resilience can be provided by the NNI routing protocol, direct ATM connections may become more appropriate.

## 4.1 Interconnect Topology

Figure 10 illustrates one possible configuration of an ATM Mid-Span Interconnection running over an SDH transmission network. ATM traffic enters the SDH network of Operator A at an access point on an SDH network element.

It then traverses that network crosses the SDH interconnect link to Operator B's network where it is dropped from one of B’s SDH network elements and connected to B’s ATM network.



SDH network based interconnections offer increased resilience and longer transmission distances. ATM connections can be provided over an SDH interconnect at: E1, E3, T3 or STM-1.

### 4.2 Access Configurations

Customer access configurations are relatively straightforward and could either be provided by direct ATM connections, or by using additional transmission systems. Additionally customer access could be provided using something other than ATM—for example a frame relay interconnect could be provided which would be inter-worked across the ATM network. For customer access there is generally no concept of mid-span meet, and the network operator typically deploys equipment on the customer's premises to act as a termination point for the service. Whether a direct ATM connection is provided, or if it is carried across separate transmission systems, the network termination would be a standard ATM UNI presentation. Physical interfaces currently considered by the PNO-IG ATM Task Group are detailed in the PVC User Network Interface Recommendation [1].

## 5 Virtual Connection Configurations

A number of different configurations are possible for an end-to-end ATM user connection that is carried across an ATM interconnect. Two of these are illustrated in the sections below. One of the configurations is based upon a PVCL interconnect, whilst the other is based upon PVPL. The latter configuration can potentially offer a greater level of end-to-end resilience in some circumstances as signalling can be tunnelled across the network (see below).

### 6.1 Example PVCL Interconnect

Figure 11 shows the end-to-end service that would typically be provided across a PVCL interconnect between two users connected to operators A and B. Each PVCC across the interconnect requires manual configuration by both operators to set up the individual links (PVCLs) from the originating ATM switch to the terminating ATM switch. Network resilience at the interconnect is provided by diverse, protected transmission systems, however, the connection is still vulnerable to the failure of the interconnect ATM switches.

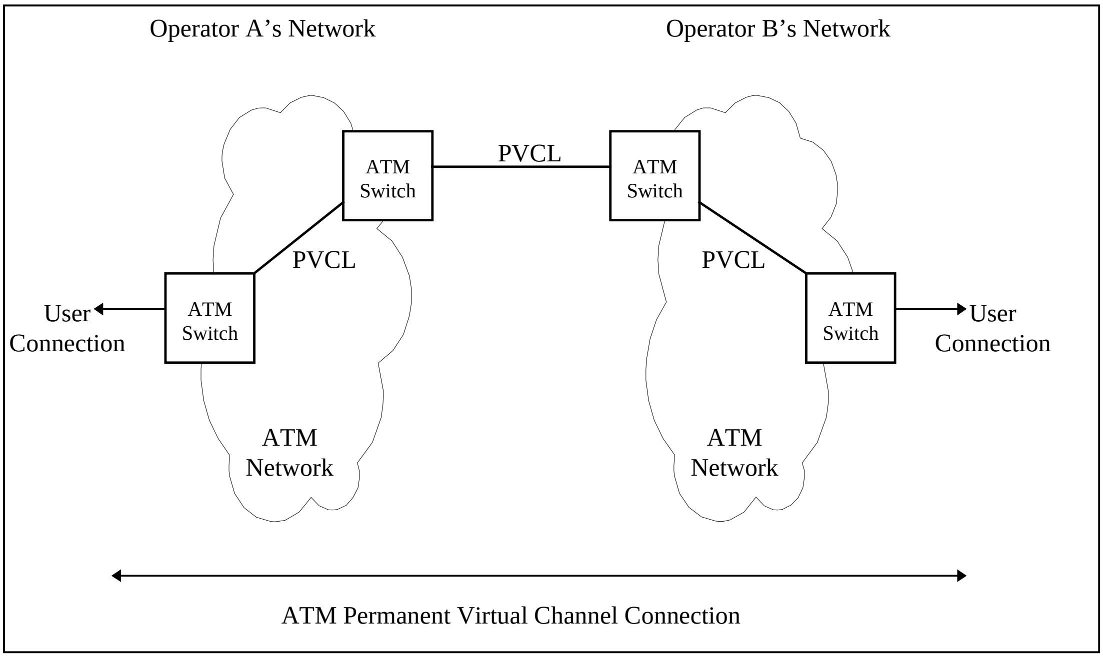



FIGURE 11 – **PVCL Interconnect**

Resilience within each operator's network can be improved by using soft PVCCs within that operator's network. If used, these soft PVCCs will re-route in the event of failure of a node within an operator's network. The signalling required to support soft PVCCs can be proprietary when confined to a single operator's network; they are a tool to simplify provisioning and/or help an operator improve the resilience of their network and meet the required service level agreements.

Soft PVCCs could also be used across an interconnect. This could provide automated restoration in the event of a network failure. In this scenario, the signalling needs to be compatible between the interconnecting networks.

A further option to improve PVCC resilience would be to establish a second interconnect path for the PVCC. However, the switching over to this path if the first interconnect failed would necessarily be a manual process.

## 5.2 Example PVPL Interconnect

Figure 12 shows a PVPL interconnect. Setting up the PVPL interconnect requires manual configuration by both operators, as for the PVCL interconnect above. However once set up the PVPL can support multiple PVCCs. As ATM signalling can be tunnelled across a PVPC, the user will be able to set-up and tear-down SVCCs as they require, subject to the underlying QofS of the PVPC.

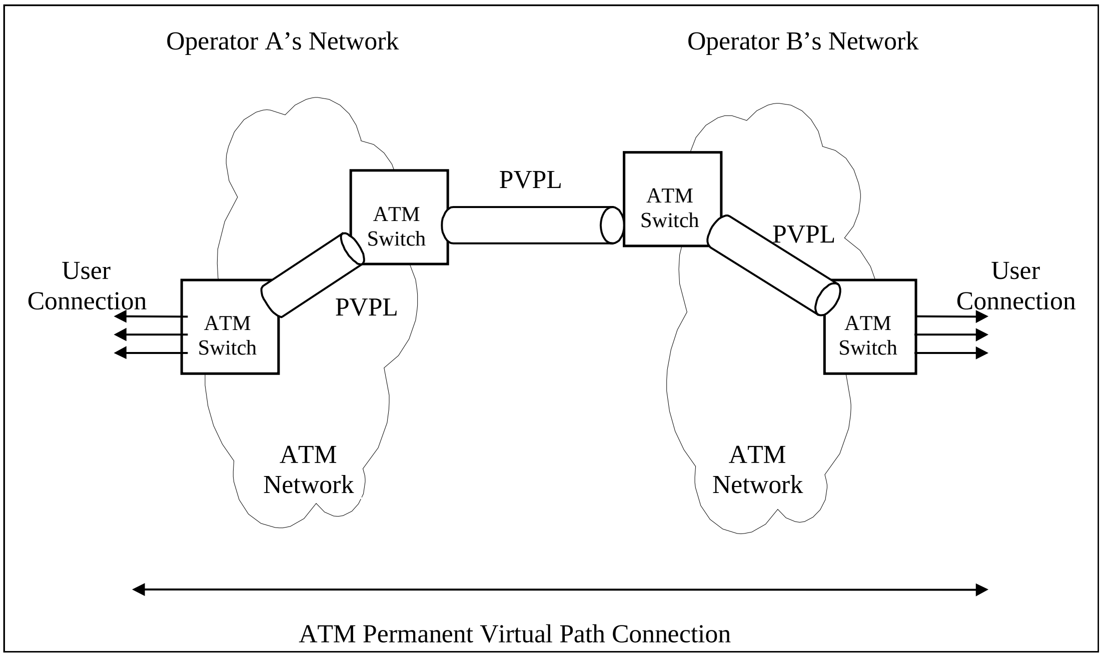



FIGURE 12 – **PVP Interconnect**

## 5.3 Example PVPL Interconnect Tunnel

A second application for PVPL interconnection is to provide an ATM tunnel for one operator though another operator's network. Figure 13 shows originating and terminating networks owned by operator A and a transit network owned by operator B. Again because the links are permanent, they require manual configuration by both operators. The advantage of this configuration is that operator A can set-up and tear-down VCC connections (Switched or Permanent) through the tunnel without reconfiguration of operator B's links.

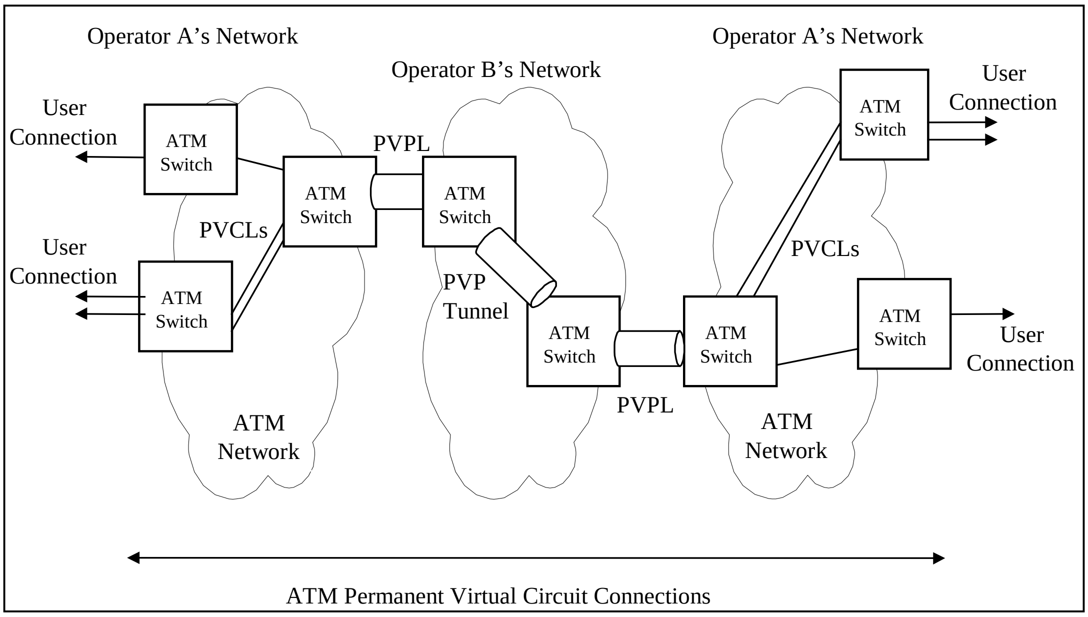



FIGURE 13 – **PVP Interconnect for Tunnelling**

## 5.4 Example Multiple PVPL Interconnect Tunnel

Multiple PVPL interconnects provide increased resilience. Figure 14 shows originating and terminating networks owned by operator A and a transit network owned by operator B. Multiple tunnels are established over the network owned by operator B to interconnect operator A's subnets. The diagram shows a soft PVCC tunnelled across the transit network (this is also possible with SVCCs). If the interconnect route fails then the virtual connection will be re-routed via the other interconnect path. If in the diagram operator A allows the user to use SVCCs then this configuration also allows the end user to signal across the transit network from their UNI interface and set up switched virtual circuits from end to end. (Note that only one PVPL interconnect is required, the one shown in the diagram is for resilience only.)

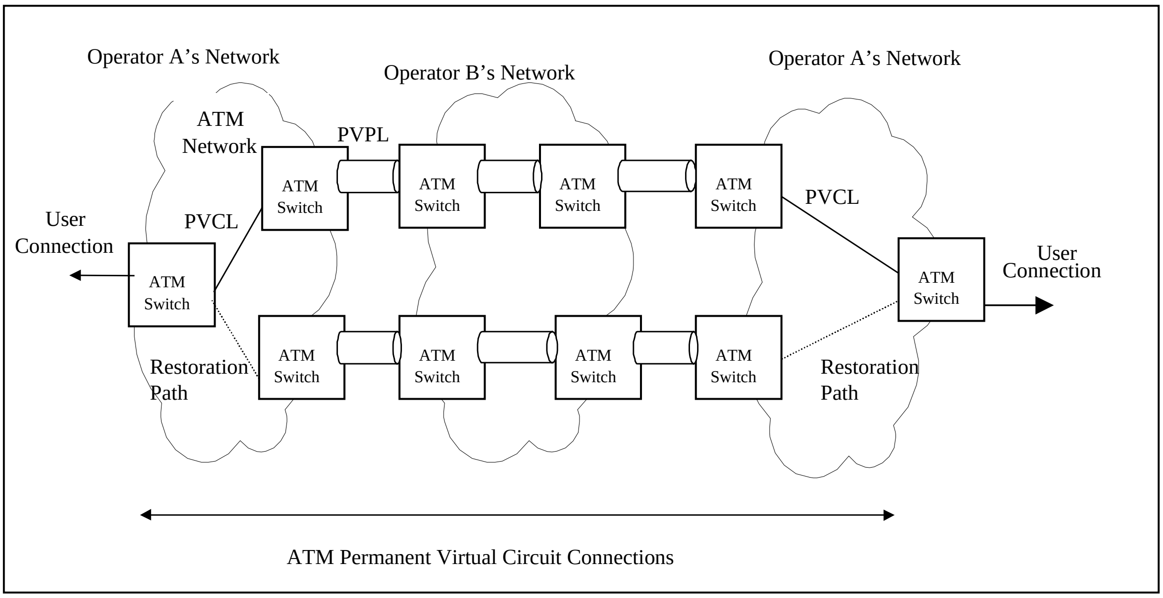



FIGURE 14 – **Multiple PVP Int Interconnects for Tunnelling**

## 5.5 Example SVC Interconnect

In contrast to the examples previously presented in Sections 8.1 to 8.4, no on-going manual configuration will be required with a pure SVC interconnect shown in Figure 15. In this situation the switches at the interconnect will negotiate the set-up and tear-down of connections on a call by call basis. Call requests will be generated by the end-user equipment and signalling will be passed through both operator networks to create an end-to-end connection. As with the multiple PVP tunnel example above, multiple POI will enable interconnected networks to restore connections in the event of a failure.

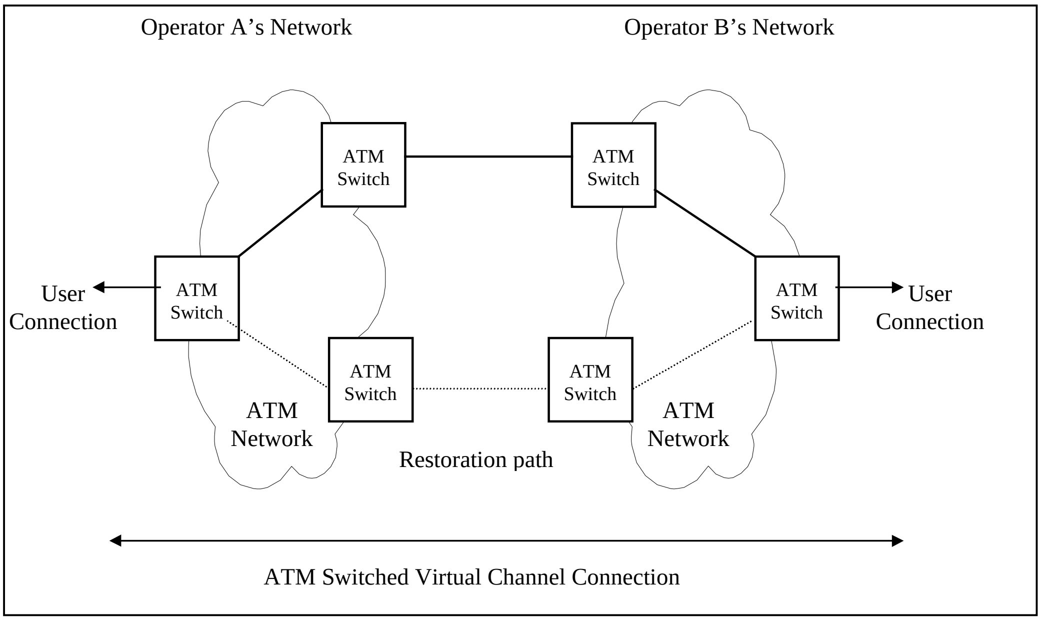



FIGURE 15 – **Multiple PVP Interconnects for Tunnelling**

# 6 Interconnect Accounting

This section does not propose to define the interconnect accounting regime, which is a commercial issue, but to suggest two examples of accounting mechanisms. The examples are based upon cell counts and traffic contracts. In the future other accounting mechanisms may become available, and these are not specifically excluded here.

Once an interconnect counting regime has been defined then the appropriate mechanisms for the collection and exchange of accounting information will need to be put in place.

**Note:** End user charging is outside of the scope of this document.

## 6.1 Accounting Based on Cell Counting

ATM switches generally support the concept of receive and transmit cell counting either on a virtual channel, virtual path or switch port basis. Such counters can provide a figure for the total number of cells across the interconnect or for each virtual channel across the interconnect. Whilst these counters provide figures for the interconnect they do not indicate whether the cell has reached its end point or been discarded. This should not be a problem for CBR and VBR traffic provided that the networks have been designed to meet the allowable cell loss ratios. Incorrect figures may occur if the network fails beyond the interconnect and traffic continues to be sent. This will depend upon the higher level protocol used to transmit the traffic which would normally detect a connection failure and stop sending the vast majority of the traffic.

Another potential problem with cell counting is that a single discarded cell can potentially invalidate a whole, much larger, higher level packet. This will result in the packet being re-sent, and the original cells counted not reflecting the true "good put" to the user. This should not be a problem if low cell loss ratios are set and maintained for CBR and VBR traffic.

Note that if UBR traffic is allowed across the interconnect then cell counting will become inaccurate as networks are free to discard UBR cells when they become congested.

### 6.2 Charging Based on Traffic Contracts

As the establishment of PVCCs and PVPCs is an administrative function interconnect accounting can also be performed on the traffic contracts established. This can include information relating to the quality of service, bandwidth, duration and the source or destination user connection. This charging mechanism does not rely upon support from ATM switches, and consequently it can be implemented easily by manual processes. By using information on the location of the user connection, accounting can also be based upon the distance the connection is conveyed across the terminating network.

The disadvantage of traffic contract based accounting is that it does not necessarily reflect how much traffic is passed across the connection, just how much the user said he would pass. This would be true for VBR type traffic, but would be a much more serious drawback if in the future ABR traffic was supported. Similar problems would also occur when separate routes were reserved across an interconnect for resilience, but only one was actually used to send traffic.

Note that a combination of cell counting on a per VC basis, and accounting based on traffic contracts could be deployed. This would, for example, allow charging to be based upon the number of cells and the distance traversed in the terminating network.

## 7 Summary

This document provides an overview of the approach being adopted by the PNO-IG task group on ATM for the establishment of recommendations for ATM interconnects between public licensed operators, and customer access to these operators' public ATM networks. A phased approach is suggested with permanent virtual channel and permanent virtual path connections being the initial step. A discussion is presented of some of the issues relating to user and network signalling which would be required for future support of switched connections.

The different parameters affecting quality of service are discussed, and the different traffic types or service classes that should be supported. For the first phase of implementation, it is proposed that only constant bit rate and variable bit rate (non-real time) be supported. In the future it envisaged that this would be expanded to include real time variable bit rate and available bit rate.

It is recognised that the existing UK SDH interconnect recommendations represent the preferred mechanism for the establishment of an ATM interconnect. This is because it provides a high level of resilience at the transmission level, and a longer reach than would be provided by direct ATM interconnections. It addition to SDH transmission system interconnects, it is also recognised that PDH transmission system and direct ATM interconnections are perfectly possible and feasible.

# 8 Appendix A - QofS Definition for ATM Connections

The following text gives a brief description of the various parameters which when combined form the QofS definition for an ATM connection. For a more detailed description of these QofS parameters, refer to ITU-T Rec. I.356, [18].

## 8.1 Delay Parameters

**Cell Transfer Delay (CTD)**

Cell Transfer Delay is generally composed of propagation delay (generally fixed for each VCC/VPC) plus other variable delays caused by queuing, switching, the insertion of OAM/RM cells and effects of the physical layer framing overheads.

Maximum Cell Transfer Delay (CTDmax) is the time, $t_2 - t_1$, between the occurrence of two corresponding successful cell transfer events, $CRE_1$ at time $t_1$ and $CRE_2$ at time $t_2$. See F 16 below.

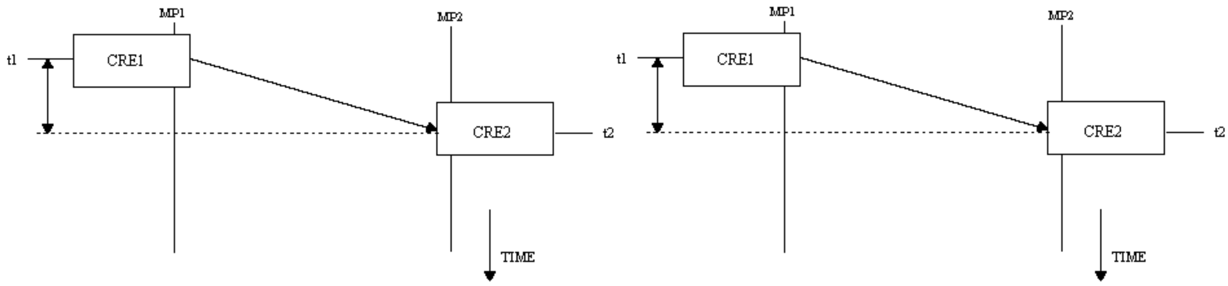



FIGURE 16 **– CTD example**

**Cell Delay Variation (CDV)**

Cell Delay Variation is mainly caused by the effects of queuing and switching cells within the overall connection. The effect of CDV can cause cells to arrive either ‘late’ compared to their expected arrival time which will in turn degrade the performance of the end-to-end application, especially CBR services. In addition to cells arriving late cells can also arrive earlier than their expected arrival time, this causes ‘bunching or clumping’ of cells which causes the agreed PCR to be exceeded, thus causing network congestion and buffer overflow within the switches.

Two cell transfer performance parameters associated with Cell Delay Variation (CDV) have been defined. The first parameter, known as 1-point CDV, is defined on the basis of observing a sequence of consecutive cell arrivals at a single Measurement Point (MP). In general 1-pt CDV is of use only when the cells are transmitted at a known fixed rate as in AAL-1 type services, otherwise it does not offer any value in QofS measurements. The second parameter, known as 2-point CDV, is defined on the basis of observing cell arrivals times at two MPs that delimit a virtual connection. 2-point CDV is explained in more detail below.

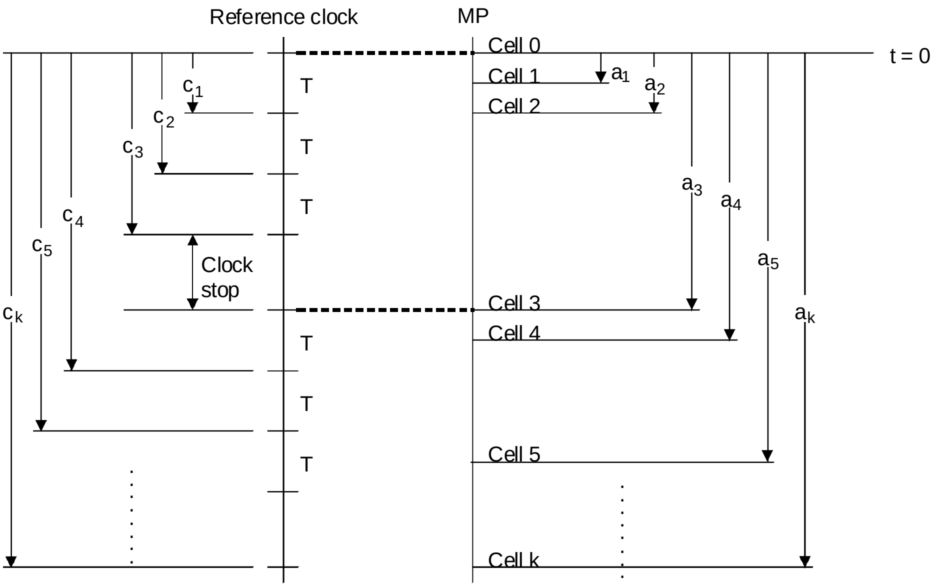
**2-point Cell Delay Variation**

The 2-point CDV parameter describes variability in the pattern of cell arrival events at the output of a connection portion (e.g. measurement point $MP_2$) with reference to the pattern of corresponding events at the input to the portion (e.g. measurement point $MP_1$); it includes only variability introduced within the connection portion. It provides a direct measure of portion performance and an indication of the maximum (aggregate) length of cell queues that may exist within the portion. It is the 2-point CDV parameter which is used to define the QofS values, within I.356.

The 2-point CDV ($v_k$) for cell k between $MP_1$ and $MP_2$ is the difference between the absolute cell transfer delay ($x_k$) of cell k between the two MPs and a defined reference cell transfer delay ($d_{1,2}$) between those MPs [see Figure 17]: $v_k = x_k – d_{1,2}$. The absolute cell transfer delay ($x_k$) of cell k between $MP_1$ and $MP_2$ is the difference between the cell's actual arrival time at $MP_2$ ($a_{2k}$) and the cell's actual arrival time at $MP_1$ ($a_{1k}$): $x_k = a_{2k} – a_{1k}$[5) ]. The reference cell transfer delay ($d_{1,2}$) between $MP_1$ and $MP_2$ is the absolute cell transfer delay experienced by cell 0 between the two MPs.

- Positive values of 2-point CDV correspond to cell transfer delays greater than that experienced by the reference cell.
- Negative values of 2-point CDV correspond to cell transfer delays less than that experienced by the reference cell.

[5)] Variables $a_{2k}$ and $a_{1k}$ are measured with reference to the same reference clock.

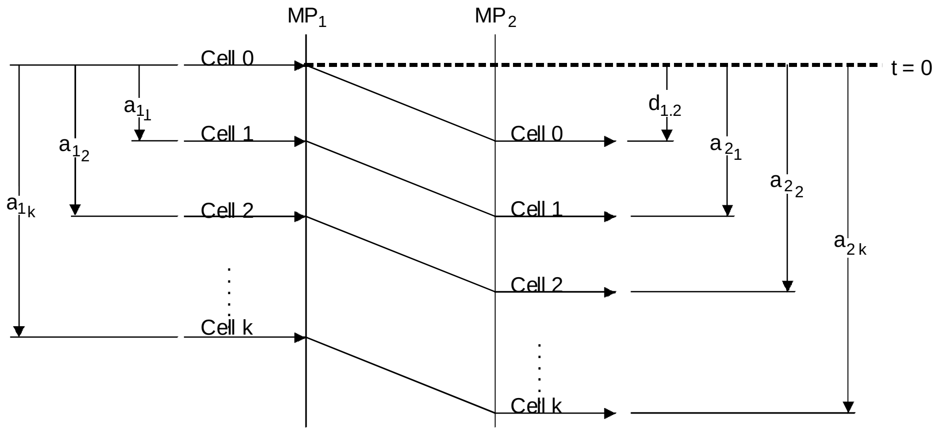



Variables:

$a_k$ Cell k actual arrival time at MP
$c_k$ Cell k reference arrival time at MP
$y_k$ 1-point CDV

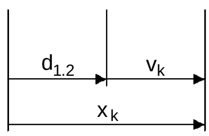
$$y_k = c_k - a_k$$

**a) Call delay variation – 1-point definition**




Variables:

$a_{1k}$ Cell k actual arrival time at $MP_1$
$a_{2k}$ Cell k actual arrival time at $MP_2$
$d_{1.2}$ Absolute cell O transfer delay between $MP_1$ and $MP_2$
$x_k$ Absolute cell k transfer delay between $MP_1$ and $MP_2$
$v_k$ 2-point CDV value between $MP_1$ and $MP_2$




$x_k = a_{2k} - a_{1k}$

$$v_k = x_k - d_{1.2}$$

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**b) Cell delay variation – 2 point definition**

FIGURE 17 – **Cell delay variation parameter definition**

## 8.2 Error and Loss Parameters

**Cell Loss Ratio (CLR)**

Cell Loss Ratio is the ratio of total lost cells to total transmitted cells in a population of interest. ATM cells are lost due to congestion resulting in queue overflow, physical layer impairments corrupting the cell header (where the cell header error correction rules discard cells) and network equipment failure. In order that bursts of errors do not distort the true background CLR, cells lost during such bursts are not considered as part of the CLR, but are captured within the Severely Errored Cell Block Ratio (SECBR) parameter. The SECBR parameter is described later.

The CLR definition has been divided into a number of categories, namely $CLR_{0+1}$ $CLR_1$ and $CLR_0$. These are explained below.

# $CLR_{0+1}$

CLR 0+1 is the CLR for an aggregate cell stream, containing both CLP=0 and CLP=1 cells.

**NOTE 1:** Tagged cells are not considered lost from an aggregate CellStream.

**NOTE 2:** When all cells have a CLP=1 then $CLR_{0+1}$ is equal to the $CLR_1$

# $CLR_0$

$CLR_0$ is the CLR for only high priority cells, (i.e. those cells with a CLP=0).

**NOTE 1:** Tagged cells, (i.e. Cells which have their CLP changed from a 0 to a 1) are considered lost from the high priority stream. Thus the $CLR_0$ calculation only applies to the conforming CLP=0 cells.

# $CLR_1$

$CLR_1$ is the CLR for only low priority cells, (i.e. those cells with a CLP=1).

**Cell Error Ratio (CER)**

Cell Error Ratio is the ratio of total errored cells to total successfully transferred cells, plus tagged cells and errored cells in a population of interest. The primary causes of errored cells are due to physical layer impairments and network failures. Successfully transferred cells and errored cells contained in cell blocks counted as severely errored cell blocks should be excluded from the population used in calculating the cell error ratio.

**Cell Mis-insertion Rate (CMR)**

Cell Mis-insertion is defined as the arrival of a cell within a VCC or VCC which was NOT originally sent, by the sender in that particular VCC or VPC. The Cell Mis-insertion Rate is the total number of mis-inserted cells observed during a specified time interval divided by the time interval duration (or equivalently, the number of mis-inserted cells per connection second[2)]. Cell mis-insertion can occur when the bit errors in the cells header cause corruption in the VPI/VCI fields such that the any errors still pass through the HEC procedures, or when network equipment fails. Mis-inserted cells and time intervals associated with cell blocks counted as severely errored cell blocks should be excluded from the population used in calculating cell mis-insertion rate.

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[2)] By definition, a mis-inserted cell is a received cell that has no corresponding transmitted cell. Cell mis-insertion on a particular connection is most often caused by an undetected error in the header of a cell being transmitted on a different connection. Since the mechanism that most often causes mis-inserted cells has nothing to do with the number of cells transmitted on the observed connection, this performance parameter cannot be expressed as a ratio, only as a rate.

**Severely Errored Cell Block Rate (SECBR)**

A cell block is a sequence of N cells transmitted consecutively on a given connection. A severely errored cell block outcome occurs when more than M errored cell, lost cell, or mis-inserted cell outcomes are observed in a received cell block. These blocks of bursts of errors are usually caused due to physical layer impairments corrupting a group of cells.

**NOTE:** The severally errored cell block outcome and parameter provide a means of quantifying bursts of cell transfer failures and preventing those bursts from influencing the observed values for CER, CLR, CMR and the associated availability parameters. The table below summarises the main attributes which impair the QofS parameters.

| Attribute | CTD | CDV | CLR | CER | CMR | SECBR |
|---|---|---|---|---|---|---|
| Propagation Delay | X | | | | | |
| Media Error Statistics | | | X | X | X | X |
| Switch Architecture | X | X | X | | | |
| Buffer Capacity | X | X | X | | | X |
| No. of Tandem Nodes | X | X | X | X | X | X |
| Traffic Load | X | X | X | | X | |
| Failures | | | X | X | | X |
| Resource Allocation | X | X | X | | | |

Table 2: Attributes effecting QofS Parameters

**END**