



TECHNICAL REPORT

## **TR-042**

### **ATM Transport over ADSL Recommendation (Update to TR-017)**

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**Abstract:**

This is an update to TR-017 with recent developments in ATM Forum and others.

# 1. Scope

This technical report addresses implementation aspects specific to the transport of Asynchronous Transfer Mode (ATM) traffic over Access Networks based on Asymmetric Digital Subscriber Line (ADSL) technology.

The scope for this report is to provide a specification for the transport of ATM over ADSL that is consistent with the ADSL PHY Recommendations (ANSI T1.413 [4], ITU-T G.992.1 (G.dmt) [24], and ITU-T G.992.2 (G.lite) [25]). Future issues of this technical report will seek to preserve backward compatibility with this document.

This specification provides descriptions of the Access Node (AN) and Broadband Network Termination (B-NT) functions.

## 1.1. Introduction

This document is organized with the main body containing all mandatory, recommended, and optional features. Supporting information is provided in five informative annexes. Throughout this document, mandatory features are identified with “SHALL”, recommended features are identified with “SHOULD”, and optional features are identified with “MAY”.

This report concentrates on ATM network layer protocols up to the ATM layer; higher layers are considered to be transported transparently by the ADSL based access network. Interfaces towards both the Local Exchange and towards Premises Distribution Network (PDN) are covered. All configurable parameters and a means for managing their configuration are defined.

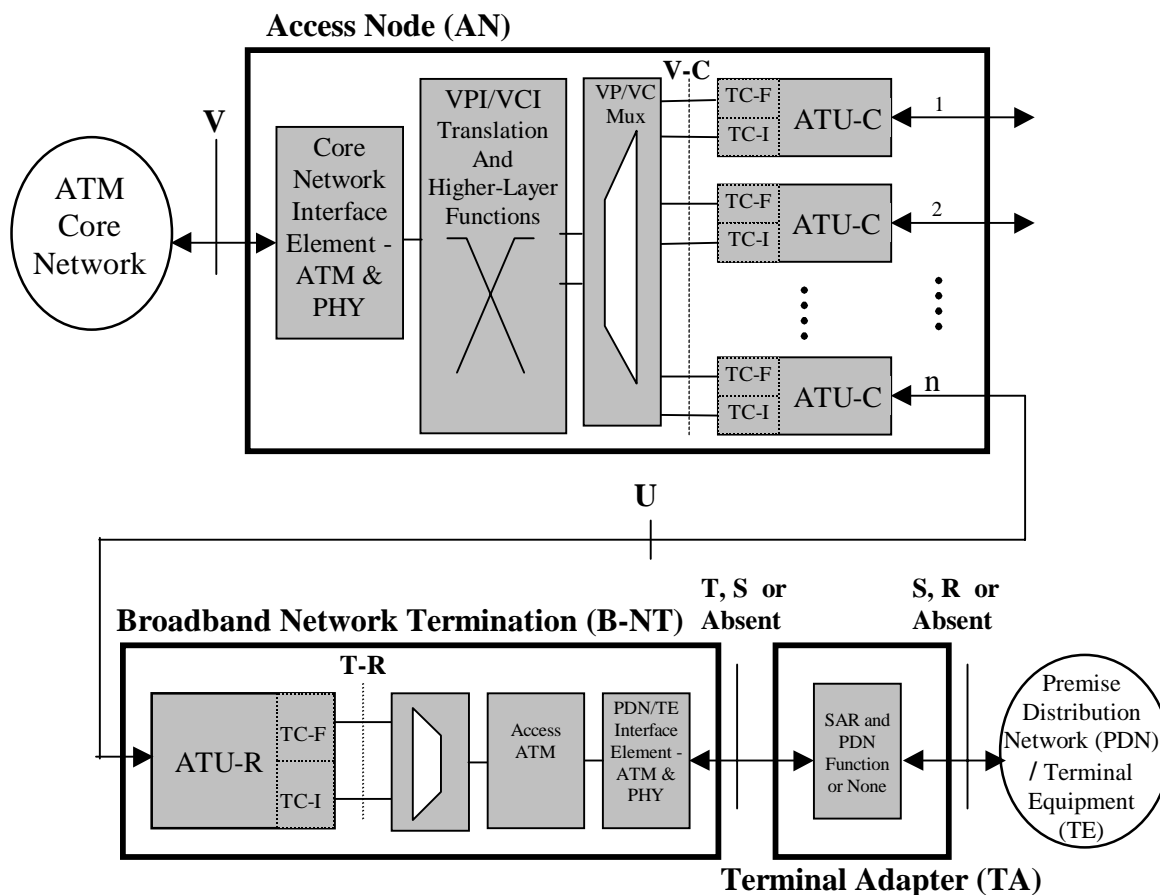
With reference to Figure 1, it is the intention of this report to describe the functional blocks of the ADSL based access network from the V interface to the T (or other) interface, and not to specify the physical layer of the interfaces.

There are four types of dynamic rate change behavior, which have been identified for ADSL and are being discussed in other standards bodies. ANSI and ITU-T are investigating Dynamic Rate Adaptation (DRA) and Dynamic Rate Repartitioning (DRR) at the physical layer. DRA and DRR consist of rate and/or partitioning changes performed during normal operation (i.e., without losing the ADSL connection). G.992.2 specifies Fast Retrain during which the connection may be reestablished at a higher or lower rate than previously connected. Events that cause Fast Retrain may result in service interruptions of up to 3 seconds. It is assumed that Fast Retrain will not cause loss of established ATM connections. G.992.2 specifies a Power Management technique, which has power down states, which result in an IDLE or SLEEP state where little or no traffic is transmitted.

## 2. Specific Reference Model

The ATM mode specific ADSL Reference Model for the user data plane is shown in Figure 1 below. This reference model is based on the System reference model and ATM transport model sections of ADSL PHY Recommendations. The highlighted functional blocks and interfaces are addressed in this report. The following sections define these functional blocks: Access Node (AN) and Broadband Network Termination (B-NT). Section 5 provides the description of these

functional blocks in detail. Specific Core Networks, Premises Distribution Networks or the V and T or S or R interfaces are not discussed in this report.



Notes: (1) Although the above figure shows two paths (“Fast” and “Interleaved”), it is optional for both paths to carry data simultaneously. Dual latency is optional for T1.413 and G.992.1.

(2) The functional groups AN & B-NT (Broadband-NT1 / B-NT2) and the reference points V, U, T, S, & R are defined in T1.413 [4], ITU-T recommendation I.413 [19], I.432 [20] and RBB Framework [6]

Figure 1: Specific ADSL Reference Model for ATM Mode

## 2.1. Definition of functional blocks

This section provides functional descriptions of the two main blocks in the ADSL Access Network.

### 2.1.1. Access Node (AN)

The Access Node serves as an ATM layer Multiplexer/Concentrator between the ATM Core Network and the Access Network. In the downstream direction it may perform routing/demultiplexing, while in the upstream direction it may perform multiplexing/ concentration and higher layer functions.

The Access Node contains a Core Network Interface Element that performs the ATM and PHY layer functions to interface the AN to the Core ATM Network. Non-ATM core networks are not precluded. The VPI/VCI Translation and Higher-Layer function performs the Multiplexing/Demultiplexing of the VCs between the Access Network interfaces (ATU-Cs) and the Core Network interface on a VPI and/or VCI basis. This block may also perform other higher layer protocol functions. The Access Network side ATM layer functions, if present, support the ATU-Cs which terminate the Access Network lines in the Access Node.

An ATU-C MAY support dual latency per G.992.1. In this case, if both 'Fast' and 'Interleave' channels carry ATM then two ATM TC sublayer functions SHALL be implemented. Traffic Management functions should be performed to support rate matching between V and U interfaces.

### **2.1.2. Broadband Network Termination (B-NT)**

This functional block performs the functions of terminating the ADSL signal entering the user's premises via the twisted pair cable and providing either the T, S, or R interface towards the Premises Distribution Network (PDN) or the Terminal Equipment (TE). Such an interface may be absent in the case of integration of this functional block with the PDN/TE.

The ATU-R in the B-NT performs terminating/originating the transmission line and TC-F and/or TC-I functions (If optional dual latency is supported, then the B-NT SHALL support both TC-F and TC-I functions). The Access ATM and VP/VC Mux functional blocks perform the ATM layer functions to support the TC layers in the ATU-R. The B-NT may contain VPI/VCI Translation functions to support multiplex/demultiplex of VCs between the ATU-R and the PDN/TE interface element on a VPI and/or VCI basis. The PDN/TE element, if present, performs ATM and PHY layer functions to interface the B-NT to the PDN/TE. Traffic Management functions should be performed to support rate matching between the U and T or S or R interfaces.

## **2.2. Definition of Interfaces**

### **2.2.1. V Interface**

The V interface connects the Core Network and Access Node. Inside the Access Node, a logical interface called V-C, as defined in T1.413 [4], connects the individual ATU-C functions to the corresponding ATM layer functions.

### **2.2.2. U Interface**

The U interface connects individual ATU-Rs in the remote B-NT to the corresponding ATU-Cs in the Access Node.

### **2.2.3. T or S Interface**

The T or S interface, if present, connects the Network Termination block to the Premises Distribution Network (PDN) or Terminal Equipment (TE). Inside the Network Termination, a logical interface called T-R, as defined in the ADSL PHY Recommendations, connects the ATU-R function to the ATM layer function.



## 2.2.4. S or R Interface

The S or R interface, if present, connects the Terminal Adapter block to the non-ATM Premises Distribution Network (PDN) or Terminal Equipment (TE)..

# 3. Transport of ATM over ADSL

## 3.1. General

For the transport of ATM on modems compliant with the ADSL PHY Recommendations, channels shall be independently set to any bit rate that is an integer multiple of 32 kbit/s, up to a maximum aggregate capacity determined by the start-up process. In addition, for each channel the bit rates for the upstream and downstream directions may be set independently from each other.

## 3.2. Channelization

For ATM systems, the channelization of different payloads is embedded within the ATM data stream using different Virtual Paths and/or Virtual Channels. For ADSL systems, the physical layer bandwidth may be channelized into multiple physical bearers (called AS0, AS1 downstream and LS0, LS1 upstream). Implementations SHALL support AS0 and LS0 in the single latency configuration.

ANSI T1.413 [4] and ITU G.992.1 [24] provides an “Interleaved” path and a “Fast” path typically corresponding to a lower bit error rate, higher latency path and a higher bit error rate, lower latency path, respectively. Consequently, different configurations of the ADSL access could be considered. More specifically, possibly three “latency classes” could be envisaged:

- Single latency, not necessarily the same for each direction of transmission.
- Dual latency downstream, single latency upstream.
- Dual latency both upstream and downstream.

For the transport of ATM over ADSL, all modems shall use the ATM0 channel (i.e., AS0 downstream and LS0 upstream) for the single latency class as defined in ANSI T1.413 [4] and ITU G.992.1 [24]. The ATM1 channel (i.e., AS1 downstream and LS1 upstream) shall be used for the second channel if the optional dual latency is supported.

The VP/VC mux function in Figure 1, Figure 2, Figure 3, and Figure 4 is part of the ATM layer, and if present, combines the cell streams from the “Fast” and “Interleaved” buffers into a single ATM cell stream. In the direction towards the ADSL PHY, cell routing is performed on a VPI and/or VCI basis to the “Fast” or “Interleaved” paths as defined in Section 8.

## 3.3. Dynamic Rate Change Behavior

The default mode of ATM over ADSL uses a single latency, either Fast or Interleaved. The optional Dual-Latency, and Dynamic Rate Repartitioning (DRR) and Dynamic Rate Adaptation (DRA) in a dual latency environment for ATM over ADSL, and their implications are described in Annex E.

ATM layer effects of rate change transitions and power management are for further study.

Dynamic behaviors of ADSL (i.e., DRA and DRR) for a B-NT1 are for further study.

## 4. Quality of Service (QoS)

The following Quality of Service parameters apply at the service boundary between the ADSL PMD and TC layers.

### 4.1. Data Rates

Modems compliant to the ADSL PHY Recommendations can be programmed to provide bearer channel data rates, which are multiples of 32 kbit/s. This facility may be exploited for the transport of ATM data. Channel data rates can be set on a semi-permanent basis depending upon the loop characteristics for the particular user. Complete flexibility is therefore given to the Network Operator.

### 4.2. Bit Error Ratio (BER)

The ADSL PHY Recommendations specify a BER of  $10^{-7}$  with an operator provisioned margin.

The Network Operator MAY decide on a BER/ Latency/ Range combination that meets the required service quality for the network.

### 4.3. Latency

The ADSL PHY Recommendations specify a configurable interleaver for protection against impulse noise. The interleaver configuration allows the Network Operator to deliver different service qualities by adjusting the effectiveness of the Forward Error Correction mechanism over the ADSL Access Network. This interleaver mechanism introduces additional latency as a side-effect.

Recommendations on the process for assigning ATM user connections to ADSL latency paths where dual latency is implemented are discussed in Section 8.

### 4.4. Traffic Management for ATM over ADSL

In general, ATM Forum Traffic Management 4.0[8] and/or ITU-T I.371 [18] service categories SHOULD be supported by appropriate buffering and queuing at all interfaces within ADSL systems. In addition, the Access Node SHOULD support the capability to police traffic at the V and U interfaces. The Access Node SHALL support frame-based discard as a configurable option on a connection-by-connection basis for AAL5 connections (see also TM 4.0 and I.371).

When the source end-point of the ATM connection is known (and possibly within the span of control of the Access Node operator) traffic shaping may be performed at that end-point to ensure conformance to the traffic contract. To this end, equipment that contains the ATU-R or ATU-C and providing ATM layer terminations SHOULD be capable of shaping all traffic generated at the ATM connection source to conform to any traffic contract in TM 4.0 or I.371.

Note: For some classes such as UBR that the shaping function is null or Peak Cell Rate shaping only. Not all ATM termination functions (e.g., CPE) need to support all classes.

In addition, when SVCs/SPVCs are supported at the V and/or U interfaces, the signaling entity SHOULD implement a configurable Connection Admission Control (CAC) policy.

Note: CAC algorithms are not standardized, but rather are a service provider issue.

Various ADSL events (e.g., Dynamic Rate Repartitioning, Dynamic Rate Adaptation, Fast Retrain) can have a significant impact on traffic management and QoS because they may involve an interruption of service in the bearer channel. The means to minimize the impact of these traffic management affecting events are for further study. It is observed that buffering may be used to minimize some impacts on traffic in non-real-time service categories. Buffering of traffic in real-time service categories, however, will affect cell delay variation and cell transit delay, two key parameters of real-time service categories.

Specific support for dual latency paths in ADSL systems is for further study (Refer to Appendix E).

## 5. Description of functional blocks

### 5.1. Access Node

Figure 2 shows a detailed view of data, control and management planes in the Access Node. Any of these functions may be absent in the Access Node.

Note: The V interface (see Figure 2) may be an internal interface. Combined Access and Core Nodes are not precluded.

#### 5.1.1. Core ATM Network Interface Element

The Core ATM Network Interface Element function SHALL contain ATM & PHY layers to interface the Access Node to the Core ATM Network over the V interface.

Some examples of ATM Core Network Interface PHY include N x DS1, DS3, and SONET/SDH. Non-ATM Core Networks are not covered in this report. In addition to the PHY functions, this block SHALL perform ATM layer functions as specified in ATM Forum UNI specification 3.1, Section 3.4 and Section 3.6 [9], and Traffic Management 4.0 [8]. Examples of such functions are listed in Table 1.

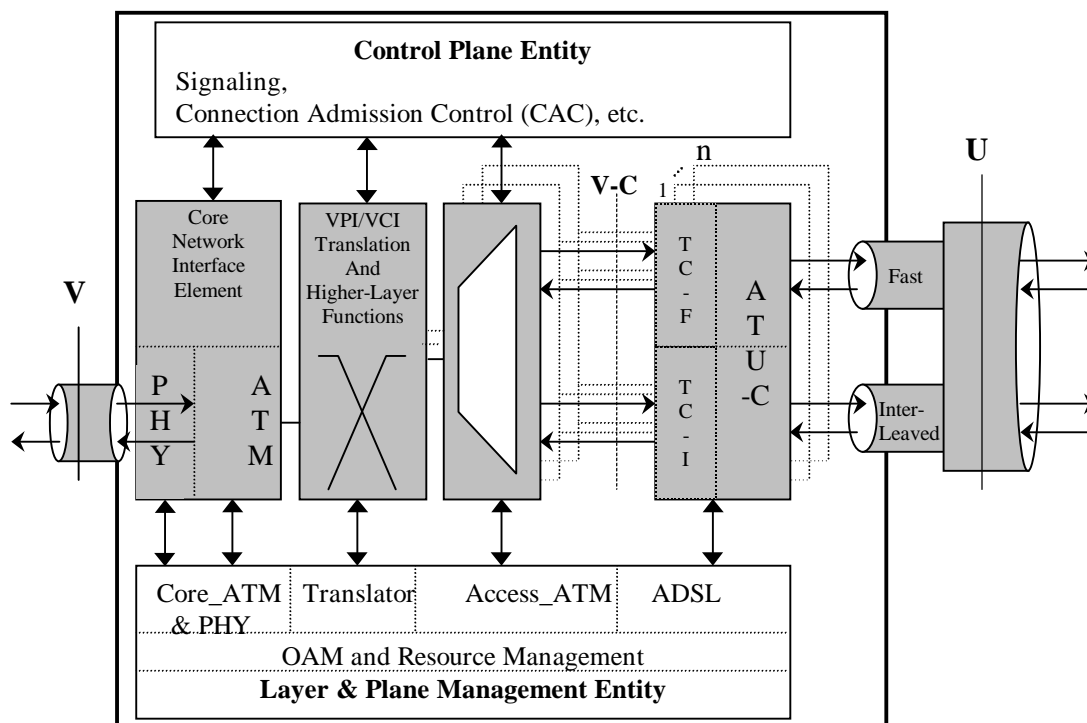


Figure 2: Access Node, Detailed Logical Reference Model

Table 1: Possible PHY and ATM Layer Functions in an AN

Multiplexing among different ATM connections with different QoS requirements
Point-to-Multipoint Switched Channel Connections for broadcast services
Cell rate decoupling
Cell discrimination based on pre-defined header field values
Cell discrimination based on Payload Type (PT) Identifier field values
Cell loss priority indication and selective cell discarding
Traffic Shaping
Policing
Congestion Control (EFCI, Frame Discard, flow control, etc.)

### 5.1.2. VPI/VCI Translation and Higher-Layer Function

In the downstream direction, this block shall perform cell routing on a VPI and/or VCI basis to the appropriate ATU-C and to the “Fast” or “Interleaved” path of that modem. Where downstream broadcast services are offered in the Access Node support for Point to Multipoint switched channels should be provided. In the upstream direction, this block combines/concentrates the cell streams from the ATU-Cs to form a single ATM cell stream to the Core ATM Network. This block may also perform other higher-layer functions.

### 5.1.3. ATU-C

The ATU-C is the ADSL Transceiver Unit – Central Office, as specified in the ADSL PHY Recommendations. It performs the Central Office ADSL PHY layer functions to support ATM transport. The ADSL PHY Recommendations specifies the ATM transport mode ATU-C

functions which include the ATM Transmission Convergence (TC) functions within the ATU-C definition. The ADSL PHY Recommendations also define the interface V-C between the ATU-C-TC and the ATM layer function. The ATU-C shall perform the TC functions specified in ATM Transport Protocol Specific functionality of the ADSL PHY Recommendations. Examples of such functions are listed in Table 2.

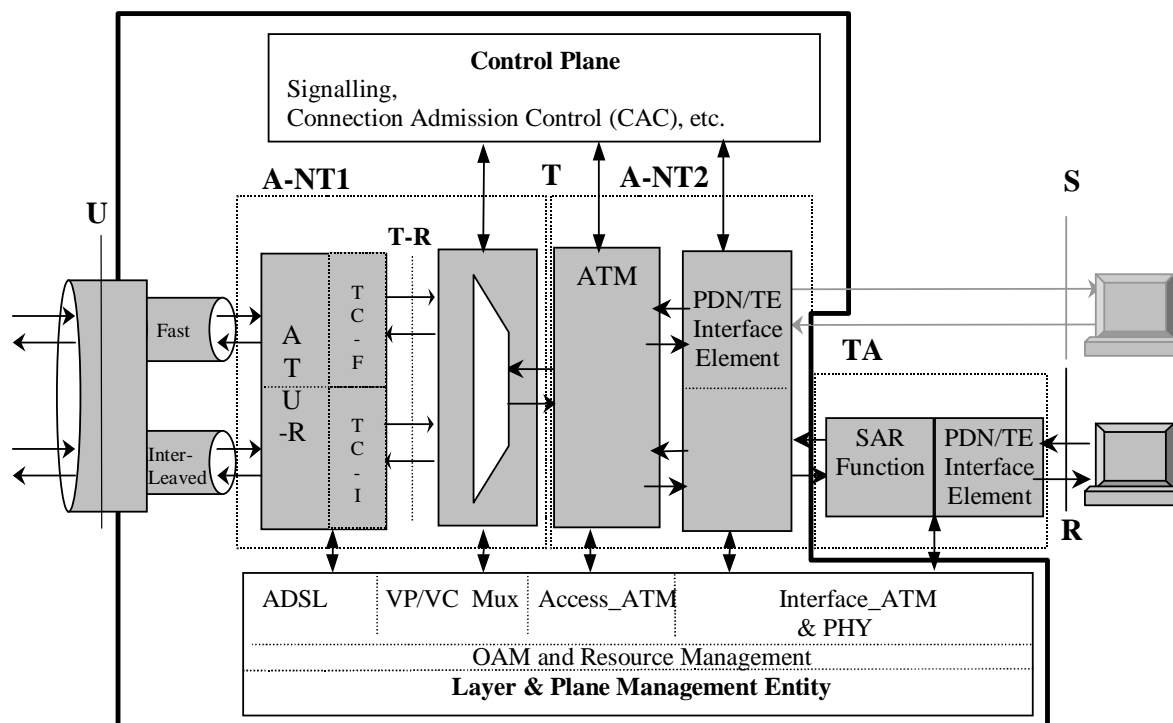
**Table 2: ATM Transport Protocol Specific functionality**

Idle Cell Insertion
Header Error Control Generation
Cell Payload Scrambling
Bit Timing Ordering
Cell Delineation
Header Error Control Verification
Cell Rate Decoupling

All these blocks MAY interface to the control and management entities to facilitate signaling, connection admission control (CAC), resource management, and layer/plane management functions.

## 5.2. Broadband Network Termination (B-NT)

Figure 3 shows a detailed view of data, control and management planes in the Broadband Network Termination (B-NT). Some of these functions may be absent in the B-NT.



**Figure 3: Broadband Network Termination (B-NT1/2), Detailed Reference Model**

Note: The A-NT1 and A-NT2 definitions in Figure 3 align with the ITU-T definitions for B-NT1 and B-NT2 respectively for the single latency mode. However, in the dual latency mode, the A-NT1 functions shown violate the ITU-T definition. For the case of the B-NT1 (Figure 4), only single latency is supported.

### 5.2.1. ATU-R

The ATU-R is the ADSL Transceiver Unit – Remote, as specified in the ADSL PHY Recommendations. It performs the Remote ADSL physical layer functions to support ATM transport. The ATU-R shall perform the ATM Transport Protocol Specific (TC) functions specified in the ADSL PHY Recommendations.

Note: The ADSL PHY Recommendations specifies the ATM transport mode ATU-R functions which include the ATM Transmission Convergence (TC) functions within the ATU-R definition. The ADSL PHY Recommendations also define the interface T-R between the ATU-R TC and the ATM layer functions.

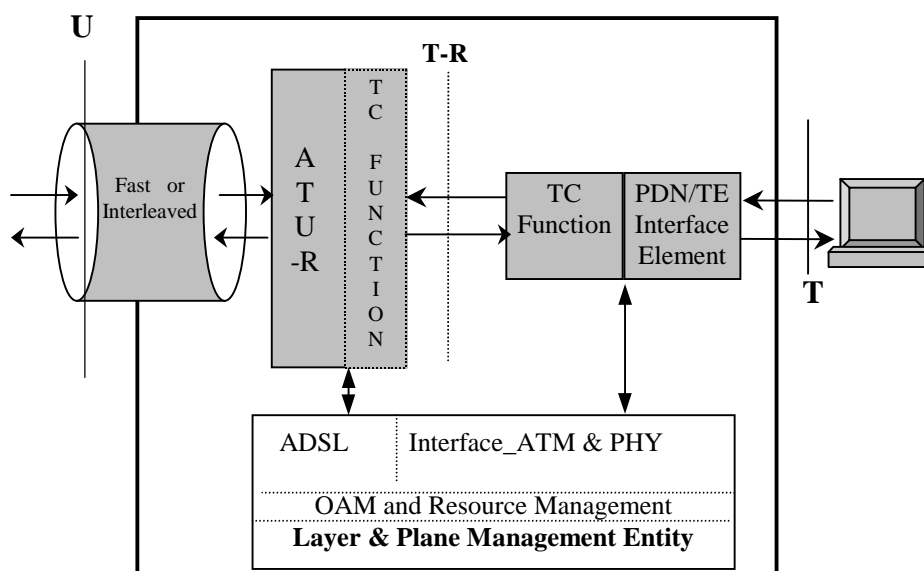


Figure 4: B-NT-1, Detailed Logical Reference Model

### 5.2.2. ATM Layer

The ATM layer in the B-NT, if present, performs the functions described in Table 3 as well as VPI/VCI translation. This block MAY also interface to control and management entities as specified in ATM Forum UNI specification 3.1, section 3.4 [9].

**Table 3: Possible PHY and ATM Layer Functions in B-NT1/2**

Multiplexing among different ATM connections with different QoS requirements	MAY
Cell rate decoupling	SHALL
Cell discrimination based on pre-defined header field values	SHALL
Cell discrimination based on Payload Type (PT) Identifier field values	SHALL
Cell loss priority indication and selective cell discarding	MAY
Traffic Shaping	MAY
Policing	MAY
Congestion Control (EFCI, Frame Discard, flow control, etc.)	MAY

### 5.2.3. PDN/TE Interface Element

The PDN/TE Interface Element function, if present, contains the PHY layer interface of the B-NT to the PDN or TE over T or S interface.

### 5.2.4. AAL Function

This function, if present, performs ATM termination and ATM Adaptation Layer processing (see ITU-T Rec. I.363 [33]).

## 6. SIGNALING

This section presents the options for signaling at the U, T, S and V interfaces and the Signaling Interworking requirements in the Access Node if SVCs are supported in the AN. Signaling requirements may be regional dependent.

In an Access Network the usage of signaling protocol at any interface is independent of signaling protocol usage at any other interface (e.g., SIG 4.0 signaling at the U interface and VB5.2 at the V interface may be used). Annex D describes an example of the SVC call load for Access Node.

### 6.1. ATM Forum Signaling

#### 6.1.1. Signaling at the U, T, and S Interfaces

For SVCs at the U, T or S interfaces, in an ATM Forum environment, ATM Forum Signaling 4.0 specification [7] including the respective ILMI procedures [5] SHOULD be implemented. UNI 3.1 signaling specification [9] MAY be implemented for compatibility with legacy networks. For optional support of Dual Latency or DRA/DRR, SIG 4.0 along with the ‘PHY/MAC Identifier Addendum to UNI Signaling 4.0 [29]’ SHOULD be implemented. Multiple user terminals within the premises SHALL share a single UNI at the U interface. Virtual UNI functions [7] are MAY be supported.

#### 6.1.2. Signaling at the V Interface

The ATM Forum ATM Inter-Network Interface (AINI) Specification [30] SHOULD be used at the V interface. When both the Access Node and the ATM Switch do not support AINI, then UNI SHOULD be used.

### **6.1.2.1. The ATM Inter-Network Interface (AINI)**

The ATM Inter-Network Interface (AINI) Specification [30] defines an interface to interconnect ATM networks and uses a 12-bit VPI field. The design of the AINI is based on considerations derived from existing intra-network protocol specifications including BISUP and PNNI. However, the use of AINI between networks using other intra-network protocols is not precluded. In particular, interworking between UNI and AINI and PNNI is supported. AINI SHOULD be used in support of SPVC signaling across the V interface.

### **6.1.2.2. The ATM User-Network Interface (UNI)**

An ATM Forum environment MAY use a UNI as defined in the UNI 3.1 [9] and/or SIG 4.0 Specifications [7] at the V interface. Use of SIG 4.0, ILMI 4.0, and TM 4.0 is strongly recommended for new implementations. UNI 3.1 may be implemented for compatibility with legacy networks. Although it is defined as a User-Network Interface, it can also be used at the V interface with the Access Node side chosen to behave as the User side and the Core ATM Network as the Network side.

Virtual UNI functions across the V interface SHOULD NOT be used in systems where dynamic data rate behavior occurs (i.e., Rate adaptation at startup, DRR, or DRA).

## **6.2. ITU-T Signaling**

### **6.2.1. Signaling at the U, T, and S Interfaces**

For SVCs at the U, T or S interface in an ITU-T environment, DSS2 signaling Recommendation [26] should be implemented. For Dual Latency or DRA/DRR support 'PHY/MAC Identifier Addendum to UNI Signaling 4.0 [29]' should be implemented. Multiple user terminals within the premises SHALL share a single UNI at the U interface.

### **6.2.2. Signaling at the V Interface**

If SVCs are supported at the V interface in an ITU-T environment, VB5 according to G.967.1 [27] and G.967.2,[28] SHOULD be implemented and could use either DSS2 [26] or ATM Forum SIG 4.0 [7] signaling.

These interfaces are based on the ITU-T network architecture model as described in ITU-T Recommendation G.902 [23].

VB5.1 SHOULD NOT be used in systems where dynamic data rate behavior occurs (i.e., Rate adaptation at startup, DRR, or DRA). For optional Dual Latency or DRA/DRR support 'PHY/MAC Identifier Addendum to UNI Signaling 4.0 [29]' SHOULD be implemented.

## **7. Management**

### **7.1. General**

Generally, standard ATM management functions should be implemented. This section details requirements in this area. Management issues for interworking of ATM and non-ATM interfaces are for further study.



## 7.2. Network Management at the U, S, and T interfaces

Where ATM and ADSL terminate in the same device (i.e., TA and B-NT1/2 in same device, Figure 4), then ILMI 4.0 [5] SHOULD be used for PVC management. ILMI 3.1 [10][31][32] MAY be implemented for compatibility with legacy networks.

Management of dual latency is for further study.

## 7.3. Network Management across the V interface

If UNI is used at the V-interface, ILMI 4.0 [5] SHOULD be used for PVC management. ILMI 3.1 [9] MAY be implemented for compatibility with legacy networks.

If VB5 is used at the V-Interface, BCC and/or RTMC mechanism SHOULD be used.

The AN should generate F5-AIS cells upstream on its network interface on all effected VCCs due to ADSL PHY Failure detected at an ATU-C or associated DSL UNI e.g., loss of signal. The F5-AIS cells shall be generated as described in clause 9.2.2.1.1.1/I.610.  
The AN may support the origination of end-to-end F5 loopback cells.

Other transactions between the Access Node and the Core network are for further study.

## 7.4. Operation, Administration and Maintenance (OAM)

OAM functions specific to ATM (described in ITU-T recommendations - I.610 [22]) SHOULD be implemented.

For meeting the different requirements on CPE for residential or business use the following two groups of minimum requirements are specified.

### 7.4.1 Minimum requirements fault management ITU-T I.610 CPE for residential use

The CPE SHALL support VC-RDI, VC-Loopback and VP-Loopback as per ITU I.610.

- In order to check the correct configuration of the VCC from the network to the CPE, the CPE should support VC Loopback.
- End-to-end (e-t-e rather than segment) OAM is preferred, but segment-OAM support over the U-interface SHALL be supported whenever e-t-e is not supported.

Segment Loopback provides the possibility to narrow down the proper function of the connection to the individual network element provided all network elements along the connection support segment Loopback.

### 7.4.2 Enhanced requirements fault management ITU-T I.610 CPE for business use

The full set of fault management as per ITU-T I.610 should be implemented.

OAM Performance Management issues are for further study.

### **7.4.3 G.992.2 (G.lite) requirements**

If the link is in the L3 power management state then there are two options for handling F4 and F5 OAM cells in the AN and the B-NT.

Option 1 is for the case where the operator of the ADSL link considers the L3 state to be a "down" condition for the link; in this condition, OAM cells shall be ignored.

Option 2 is for the case where the operator of the ADSL link considers the L3 state to be an "up" condition for the link; in this condition, the AN or NT shall drop the OAM cell, and initiate the PHY layer procedures to transition the link to the L0 or L1 state in the expectation that a subsequent OAM cell will be received.

## **8. Default ATM VC Assignment in Dual Latency Modes**

This section presents the default assignment of ATM VCs to Fast and/or Interleaved paths when optional dual latency is supported. Any default values shall be overwritten by any combination of manual configuration, network management system, or signaling.

All connection VCCs and VPCs SHALL default to the interleave path. This includes the ATM signaling channel (VPI/VCI 0/5) and the ILMI channel (VPI/VCI 0/16).

## 9. References

The following Specifications, Recommendations and other references contain provisions that, through reference in this text, constitute provisions of this Technical report. At the time of publication, the editions indicated were valid. All Specifications, Recommendations and other referenced Standards are subject to revision; all users of this Technical Report are therefore encouraged to investigate the possibility of applying the most recent editions of the Specifications, Recommendations and other references listed below. A list of currently valid Recommendations is regularly published.

- [1] The Broadband Forum Reference model, TR-001.
- [2] The Broadband Forum, TR-002, ATM over ADSL Recommendations
- [3] The Broadband Forum, TR-012, Broadband service architecture for access to legacy data networks over ADSL
- [4] ANSI, Network and Customer Installation Interfaces - Asymmetric Digital Subscriber Line (ADSL) Metallic interface, T1.413-Issue 2, T1E1.4/98-007/R5 1998
- [5] ATM Forum, Integrated Local Management Interface (ILMI) Specification, V4.0, AF-ILMI-0065.000, September 1996.
- [6] ATM Forum, Residential Broadband Architecture Framework, af-rbb-0099.000, May 1998
- [7] ATM Forum, ATM UNI Signaling Specification Version 4.0, af-sig-0061.000, July 1996
- [8] ATM Forum, Traffic Management Specification V4.0, af-tm-0056.000, April 1996
- [9] ATM Forum, ATM User Network Interface Specification (UNI) V3.1, af-uni-0010.002, 1994
- [10] Digital Audio-Visual Council, 1.2 Specifications “Short Range Baseband Asymmetric PHY on Copper, June 1997
- [11] ETSI Technical Report, ETR 328 Transmission and Multiplexing - ADSL Requirements and Performance.
- [12] ETSI Signaling Protocols and Switching (SPS); V interfaces at the digital Service Node (SN); Interfaces at the VB5.1 reference point for the support of broadband or combined narrowband & broadband Access Networks (AN). Part 1 Interface Specification DE/SPS-03046-1
- [13] ETSI Signaling Protocols and Switching (SPS); V interfaces at the digital Service Node (SN); Interfaces at the VB5.1 reference point for the support of broadband or combined narrowband & broadband Access Networks (AN). Part 2 Interface Specification DE/SPS-03047-1
- [14] ETSI TS101272 v1.1.1 (1998-06) “Optical access networks (OANs) for evolving services; ATM passive optical networks (PONs) and the transport of ATM over digital subscriber lines
- [15] FCC, Working Paper Series 29, “Digital Tornado: The Internet and Telecommunications Policy”, March 1997 (Available at <http://www.fcc.gov>)
- [16] ITU-T Recommendation I.321 - B-ISDN Protocol Reference Model and its application.

- [17] ITU-T Recommendation I.361 - B-ISDN ATM Layer specification, March 93.
- [18] ITU-T Recommendation I.371 - Traffic control and congestion control in B-ISDN, August 96.
- [19] ITU-T Recommendation I.413 - B-ISDN User-Network Interface.
- [20] ITU-T Recommendation I.432 - B-ISDN UNI Physical layer specification, March 1993.
- [21] ITU-T Recommendation I.432.5 - B-ISDN User-Network Interface Physical layer for 25600 kbit/s.
- [22] ITU-T Recommendation I.610 - B-ISDN Operation and Maintenance principles and functions, November 1995
- [23] ITU-T Recommendation G.902: ‘Framework Recommendation on functional access networks (AN); Architecture and functions, access types, management and service node aspects’
- [24] ITU-T Recommendation G.992.1, Asymmetrical Digital Subscriber Line (ADSL) Transceivers
- [25] ITU-T Recommendation G.992.2, Splitterless Asymmetric Digital Subscriber Line (ADSL) Transceivers
- [26] ITU-T Recommendation Q.2931, B-ISDN Digital Subscriber Signaling System No. 2 (DSS 2) – User Network Interface (UNI) Layer 3 Specification for Basic/Connection Control, February 1995
- [27] ITU-T Recommendation G.967.1 (06/1998); V-interfaces at the service node (SN) – VB5.1 reference point specification
- [28] ITU-T Recommendation G.967.2 (02/1999); V-interfaces at the service node (SN) – VB5.2 reference point specification
- [29] ATM Forum, ‘PHY/MAC Identifier Addendum to UNI Signaling 4.0, af-cs-0135.000, October 1999
- [30] ATM Forum, ‘ATM Inter-Network Interface (AINI) Specification’, af-cs-0125.000, July 1999
- [31] TR37 BBF TR-37 (March 2001); Auto-Configuration for the Connection Between the DSL Broadband Network Termination (B-NT) and the Network using ATM
- [32] ATM Forum, af-nm-0122.000 (May 1999); Auto-configuration of PVCs
- [33] ITU-T Recommendation I.363 (09/97); B-ISDN ATM Adaptation Layer Specification

## Annex A. Glossary (Informative)

**Access Node:** Performs adaptation between the core network and the access network

**ADSL:** Asymmetric Digital Subscriber Line

**ANSI:** American National Standard Institution

**AN:** Access Node

**AS0-3:** Downstream simplex sub-channel designators

**ATM:** Asynchronous Transfer Mode

**ATU-C:** ADSL Transceiver Unit, central office end

**ATU-R:** ADSL Transceiver Unit, remote terminal end

**BCC:** Bearer Channel Control

**BER:** Bit Error Ratio

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

**CAC:** Call Admission Control

**CBR:** Constant Bit Rate

**CCS:** Hundred Call Seconds

**CLP:** Cell Loss Priority

**DAVIC:** Digital Audio-Visual Council

**DRA:** Dynamic Rate Adaptation

**DRR:** Dynamic Rate Repartition

**EFCI:** Explicit Forward Congestion Indication

**ETSI:** European Telecommunications Standards Institute

**FTTC:** Fiber to the Curb

**FTTH:** Fiber to the Home

**HAN:** Home ATM Network

**HEC:** ATM cell Header Error Control

**HFC:** Hybrid Fiber Coaxial

**ILMI:** Integrated Local Management Interface

**ISDN:** Integrated Services Digital Network

**ISP:** Internet Service Provider

**ITU-T:** International Telecommunications Union –Telecommunications

**LAC:** Local Access Concentrator

**LCD:** Loss of Cell Delineation

**LS0-3:** Duplex sub-channel designators

**NT:** Network Termination

**B-NT1:** B-ISDN Network Termination Type 1

**MIB:** Management Information Base

<b>OAM:</b>	Operation, Administration and Maintenance
<b>PC:</b>	Personal Computer
<b>PCR:</b>	Peak Cell Rate
<b>PDN:</b>	Premises Distribution Network. System for connecting the B-NT1 to the Service Modules
<b>PHY:</b>	Physical layer function
<b>PMD:</b>	Physical Medium Dependent sublayer
<b>PVC:</b>	Permanent Virtual Connection
<b>QoS:</b>	Quality of Service
<b>R:</b>	Reference point between the Terminal Adapter and the PDN or Terminal Equipment
<b>RBB:</b>	(ATM Forum) Residential Broadband (Working Group)
<b>RTMC:</b>	Real Time Management Control
<b>S:</b>	Reference point between the B-NT2 and the ATM PDN or Terminal Equipment
<b>SM:</b>	Service Module; performs terminal adaptation functions
<b>SPVC:</b>	Soft PVC
<b>STB:</b>	Set-Top-Box
<b>SVC:</b>	Switched Virtual Connection
<b>T:</b>	Reference point between the B-NT1 and the ATM PDN or Terminal Equipment
<b>TA:</b>	Terminal Adapter
<b>TC:</b>	Transmission Convergence sublayer
<b>T-R:</b>	Interface between ATU-R and ATM Layer
<b>TE:</b>	Terminal Equipment
<b>TM:</b>	Traffic Management
<b>U:</b>	Reference point between the ATU-C and ATU-R
<b>UBR:</b>	Unspecified Bit Rate
<b>UNI:</b>	User-Network Interface
<b>V:</b>	Reference point between Access Node and Core ATM Network
<b>V-C:</b>	Reference point between the ATU-C and ATM Layer
<b>VDSL:</b>	Very high speed Digital Subscriber Line
<b>VCC:</b>	Virtual Channel Connection
<b>VCI:</b>	Virtual Channel Identifier. Identification number for the (logical) connection hierarchy “channel” (virtual channel) in B-ISDN networks
<b>VPC:</b>	Virtual Path Connection
<b>VPI:</b>	Virtual Path Identifier. Identification number for the (logical) connection hierarchy “path” (virtual path) in B-ISDN networks.

## Annex B. Relationship to other reference models (Informative)

### B1. ATM Forum

ATM Forum Residential Broadband (RBB) Group has defined a complete end to end ATM system both to and from the home and within the home, to a variety of devices, e.g., STB, PC, and other home devices. The ATM Forum RBB group has produced an Architectural Framework [6].

ADSL, together with other technologies such as HFC, FTTC, FTTH, and VDSL, has been accepted as one of the methods to connect an ATM access network to the Home ATM Network (HAN).

Section 3.3 of the RBB specification [6] presents how the RBB reference model may be mapped into the ADSL reference model as shown in Figure B.1 below.

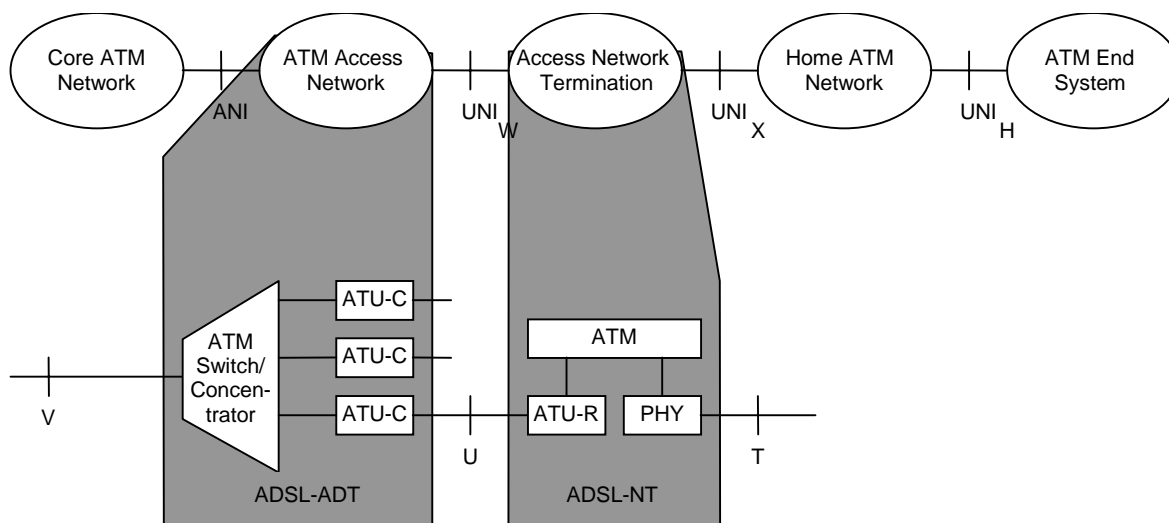


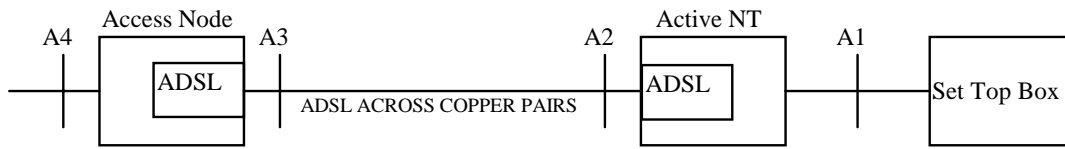
Figure B-1: ATM Forum RBB Model for ADSL Access Network with active NT

### B2. DAVIC

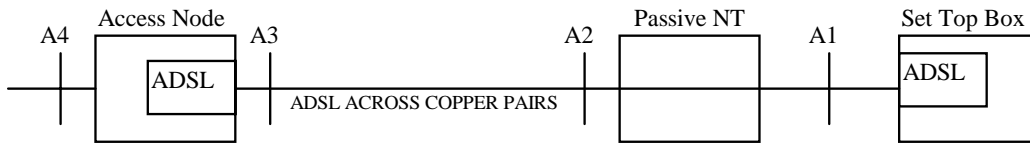
The pertinent parts of the DAVIC specification [10] are the following:

- Part 2: System reference models and scenarios
- Part 4: Delivery system architectures and APIs
- Part 8: Lower layer protocols and physical interfaces

Part 4 of the DAVIC specification [10] gives two options for the placement of the ADSL modem at the customer premises; inside the NT, resulting in an access network architecture with an Active NT; or located in the Set-Top Box, resulting in an Access network architecture with a Passive NT. The two architectures are depicted in figures B.2 and B.3 below.



**Figure B-2: DAVIC ADSL Access Network with active NT**



**Figure B-3: DAVIC ADSL Access Network with passive NT**

DAVIC is not concerned with the specification of the A2 and A3 interfaces, therefore for the case of an access network with active NT the ADSL signals are not specified. However in the case of a passive NT the medium and the protocols at reference points A1, A2 and A3 are equal. In this scenario ADSL signals are specified as they cross the A1 reference point.



## Annex C. Standards Work Cross Reference (Informative)

**Table C-1: Summary of ADSL Physical Layer Features by Standard**

<b>Standard</b> <b>Feature</b>	<b>T1.413</b> <b>[4]</b>	<b>ETR 328</b> <b>[11]</b>	<b>G.992.1</b> <b>[24]</b>	<b>G.992.2</b> <b>[25]</b>
Rate Adaptation at Startup (Single Latency)	X		X	X
Fast Retrain				X
Dual Latency	X	X	X	
Dynamic Rate Repartitioning	X		X	
Dynamic Rate Adaptation	X		X	
Power Management				X

## Annex D. SVC Call Load Analysis (Informative)

This Annex contains an analysis demonstrating that the expected ATM/ADSL SVC call load is well within the range of today's ATM network elements and that the technology to build ANs, Routers, and Local Access Concentrators (LACs) for supporting the ADSL SVC feature.

### D1. Assumptions

We assume that PPP over ATM [3] is the method of communication with SVCs. Assume that the arrival rate and call holding time are described by the following relationship (fluid model):

$$\text{Erlang} = (\text{Average Holding Time}) \times (\text{Average Arrival Rate})$$

where Erlangs represent the offered call load on the network.

Assume 27 CCS is the call load present on a switch trunk port to ISPs.<sup>1</sup>

Assume that the average call holding time is 16 minutes [15].

Assume 10:1 ratio of ISP customers to ISP modems which is the industry "norm" for "high quality" ISPs. Other common ratios are 15:1 and 20:1, but 10:1 is the most conservative value driving the AN and ATM switch call processing capacity requirements.

Assume that the blocked customers at this 10:1 "high quality" ratio have an insignificant impact on the overall conclusion.

Assume that there are 600 SVC users on an AN.

### D2. AN Analysis

Using the assumptions in section 0, the load on the ISP trunks measured in erlangs during the peak busy hour can be computed as:

$$27 / 36 = 0.75 \text{ erlangs}^1$$

From this result, we can compute the average arrival rate on the trunk ports during the peak busy hour as

$$0.75 / 16 \text{ minutes} = 0.047 \text{ calls/minute} = 2.81 \text{ calls/hour}$$

Assuming that the call arrival rate is described by a Poisson process, noting that Poisson processes are "infinitely divisible", and using the assumption that the ratio of ISP customers to ISP modems/trunks is 10:1, we conclude that the average offered call load by each ISP customer is:

$$(2.81 \text{ calls/hour})/10 = 0.281 \text{ calls/hour} = 78 \times 10^{-6} \text{ calls/second}$$

---

<sup>1</sup> Erlangs and CCS are measures of traffic load. Erlangs are used in general queuing/traffic engineering while CCS is typically used for telephony engineering. 1 erlang = 36 CCS. The 27 CCS (highest RBOC referenced busy hour usage rate in FCC Report "Digital Tornado" [15]) is the call load present on switch trunk ports to ISPs.

Assuming ISP customers call at the same rate as ADSL customers call, then the average arrival rate on the AN from 600 customers is

$$\text{AN Call Load: } 600 \times 0.281 \text{ Calls/hour} = 169 \text{ calls/hour} = 0.05 \text{ calls/second}$$

This average is approximately four orders of magnitude less than what is available from many currently available ATM switches (e.g., many current switches support 100s of call attempts per second).

### **D3. ATM Edge Switch Analysis**

Using the same set of assumptions (section 0) and in addition assuming a maximum of 15 ANs per ATM Edge Switch, we compute the offered load on the edge switch. For reference, if each AN connects to the ATM switch using an OC-3 port, the switch capacity equals 2.3 Gbps. If each ADSL user was allocated 100 kbps, this is equal to 900 Mbps of transport over an ATM switch supporting 9000 customers.

$$\text{ATM Switch Call Load: } 15 \times 0.05 \text{ calls/second} = 0.75 \text{ calls/second}$$

This is about three orders of magnitude below the expected ATM switch rate of more than 100 call attempts per second.

### **D4. ATM Tandem Switch, Router, and LAC Analysis**

Another approach to the problem is to ask “How many ADSL subscribers would be needed to approach the call processing capacity of a tandem switch, ISP/Corporate router, or LAC?” First, assume that the call rate capacity of the switch is 100 call attempts per second. We can compute the number of ADSL subscribers needed to consume this capacity as:

$$100 / 78 \times 10^{-6} = 1.3 \text{ million ADSL subscribers}$$

Note: With an allocation of just 10 kbps to each active SVC call, this network element would require 13 Gbps of allocated capacity. It is much more likely that multiple network elements would be used to support this many ADSL customers thereby reducing the call load well within the range of today’s technology. This analysis shows that operators will run out of bandwidth, ports, VCs, and courage (i.e., want fewer customers per NE) before they run out of SVC call processing resources.

### **D5. Conclusion**

This analysis demonstrates that the expected ADSL SVC call load is several orders of magnitude less than that supported by today’s typical ATM switches. Equivalent or greater capacity is expected for new equipment including ANs, routers, and LACs supporting SVC technology.

## Appendix E. Dual Latency Mode, Dynamic Rate Adaptation (DRA) and Dynamic Rate Repartitioning (DRR) (Informative)

Dual latency may not be desirable for use in typical deployments of ATM over ADSL. As of publication, little to no interoperability testing has been done on the mechanisms supporting dual latency. All known deployments to date have used single latency.

The use of Dynamic Rate Repartitioning introduces additional interoperability concerns beyond the use of dual latency in a statically partitioned environment. The operational issues surrounding DRR are of concern to service providers: the failure modes of DRR and methods of failure isolation have had insufficient study and testing and are not understood. The impact on the ATM layer of the dynamically changing cell rate produced by DRR is also not known, especially in an environment where real time traffic is carried. The impact of a dynamically changing cell rate is particularly a concern when the change of the partitioning is due to normal service, rather than due to a fault situation, and so may occur frequently.

When dual latency, DRA or DRR are supported, this annex may be used as guidance.

### E1. Dynamic Rate Repartitioning Definition

Dynamic Rate Repartitioning (DRR) is an optional ADSL specific function that reallocates bandwidth between the ADSL bearer channels and potentially between the fast and interleaved paths. The total aggregate bandwidth of the link does not change during DRR adjustments. The rate repartitioning may be performed with less than 125 msec of service interruption as per T1.413 Annex K [4] and ITU G.992.1 [24]

Dynamic Rate Repartitioning and latency mapping are always initiated from the control/management plane in the Access Node. The NT may be able to influence the latency mapping decision during VC establishment, but the mapping decision is made by the AN. Support of DRR is further discussed in section 6 and 8.

For DRR, the following definitions are used in this Appendix:

**Minimum Contract Aggregate Bit Rate:** Minimum bit rate reserved for real time services. This may be guaranteed as the minimum bandwidth for one or more ADSL bearer channels when DRR is active. If this threshold is ever violated an alarm is triggered.

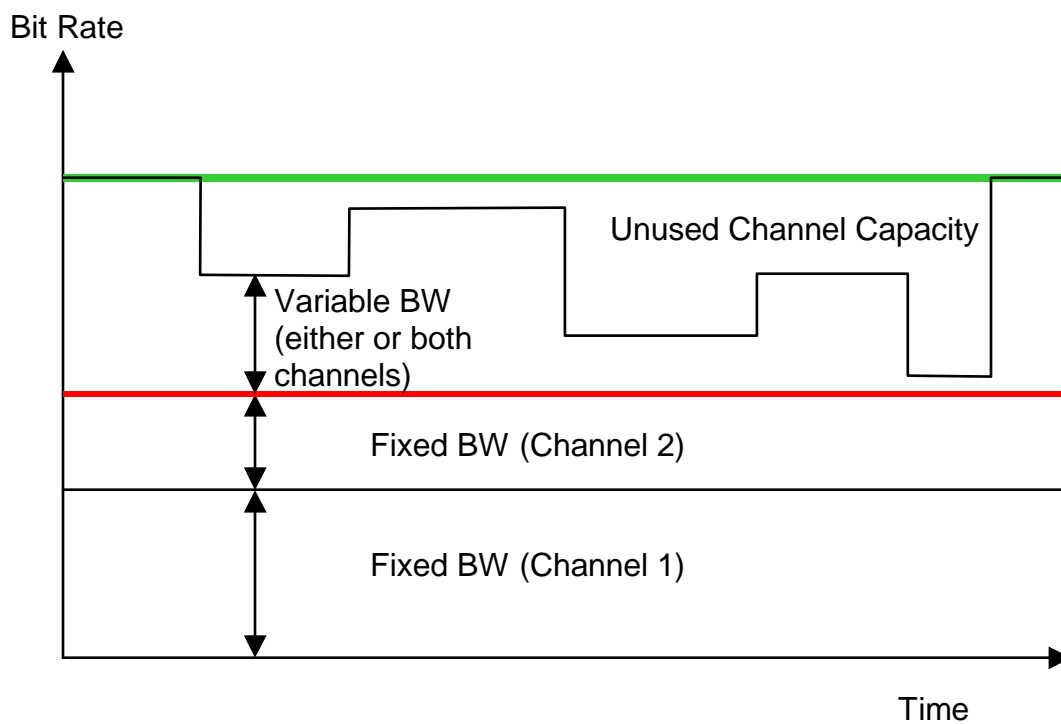
**Maximum Variable Bit Rate:** Difference between the Maximum Contract Aggregate Bit Rate (aka ADSL line capacity) and the Minimum Contract Aggregate Bit Rate. This is the amount of bandwidth under control of DRR actions where bandwidth is not guaranteed.

**Maximum Contract Aggregate Bit Rate:** The maximum total bandwidth allowed on the line. This is also called the ADSL line capacity or ADSL link speed. This is the total of the guaranteed and variable bit rate components in the system.

## E2. Multiple Bearer Channels on ADSL

ADSL systems defined in ANSI T1.413 and ITU-T G.992.1 support multiple bearer channels over the physical layer. These multiple bearer channels are used in the dual latency configuration but may also be used in the single latency configuration. For example, two bearer channels could be used to support ISDN transport embedded in ADSL where one bearer carries the B channels and the other bearer carries the D channels. Alternatively, multiple bearer channels can be used to provide different QoS parameters for ATM traffic.

Figure E-1 provides a graphic representation of ADSL with two bearer channels. In this example, the general case is assumed where there are fixed bandwidth and variable bandwidth elements on each bearer channel. Thus, the minimum aggregate contract bit rate is the total fixed bandwidth on the ADSL link and the variable bandwidth elements are allowed to vary up to the maximum contract aggregate bit rate.



**Figure E-1: Multiple Bearer Channels over ADSL**

One consequence of using multiple ADSL bearer channels is that once training is completed, the bandwidth allocation of these bearer channels can only be changed by Dynamic Rate Change mechanisms such as DRR. Thus, for dynamic connection environments, when the variable bandwidth requirements on one channel are less than the bearer channel allocation, this capacity is unavailable to other traffic on the other bearer channel unless DRR or other dynamic bandwidth change mechanisms are activated.

The fixed configuration where DRR is not active provides the minimum impact of multiple bearers on ATM layer processing. Where no communications link is available between the

control planes of the DSL PHY and the ATM, DRR may be disabled to simplify scheduling, CAC, and traffic management.

### **E3. Impact of DRR on ATM QoS and CAC**

Rate changes at the physical layer due to DRR can cause variability in the buffering of ATM data which results in impacts on ATM parameters such as SCR, CDV, and CTD. The DRR events can be viewed as adding more bandwidth to a bearer channel. The minimum contract aggregate bit rate defines the ATM QoS parameters for protected or guaranteed service quality. When call loading and the ATM layer allows, additional bandwidth may be allocated to the ATM path which reduces CDV and CTD for the link.

Implementations of ATM traffic management usually assume a fixed bandwidth channel and usually cannot cope with dynamic adjustments of bandwidth (either up or down) at the ATM layer. The development of connection admission control and cell scheduling algorithms that can cope with dynamic rate adjustments is for further study.

#### **E3.1 DRR Management Layer Control**

DRR at the physical layer could include a PHY layer management entity capable of communicating with local or remote ATM layer management entities, and DRR changes are not performed autonomously when communication with such entities is established. Any physical layer solution supporting DRR allows this function to be disabled (ie. fixed bandwidth operation) and the default setting is disabled. Communications between the physical layer management controlling DRR events and the ATM layer are established to enable bandwidth sharing. The ATM Layer CAC is able to reject a DRR request. If a DRR request is rejected, then no modification will occur at the DSL physical layer. Reasons a DRR request could be rejected include:

- ATM Layer policy for priority connections
- Insufficient resources in the Network core (B-NT initiated requests)
- Insufficient resources on the A10 interface (B-NT initiated requests)
- Insufficient resources on the U interface (Network initiated requests)
- Insufficient resources on the T/S/R interface (Network initiated requests)

Note: There are no standards or specifications relating to inter-layer management. When these functions are embedded in a single system, the manufacturer may choose to allow inter-layer communication, but this is an implementation issue.

#### **E3.2 DRR Where No Inter-Layer Communications Exist**

For environments where no interlayer communications between the ATM and DSL physical layers exists, the ATM layer performs all traffic and contract estimation based on worst case allocations. That is, the ATM layer uses the Minimum Contract Aggregate Bit Rate of its bearer for all traffic management decisions.

If DRR is enabled at the physical layer, increased capacity beyond these worst case conditions will be available to the ATM bearer at some times. However, since the ATM layer is unaware of the improved bandwidth availability, it will have limited ability to respond or benefit from this improvement. The only mechanisms for using any extra capacity at the physical layer will be through UBR services with adaptive buffer management. Thus, UBR connections that use buffer

level as flow control could adapt to the physical layer bandwidth availability without direct communications between the DSL and ATM layer management elements. All other variable ATM data streams (VBR and ABR) must be managed within the Minimum Contract Aggregate Bit Rate specified for the ATM bearer channel.

### **E3.3 Inter-Layer Communications when ATM and DSL Exist in Separate Network Elements**

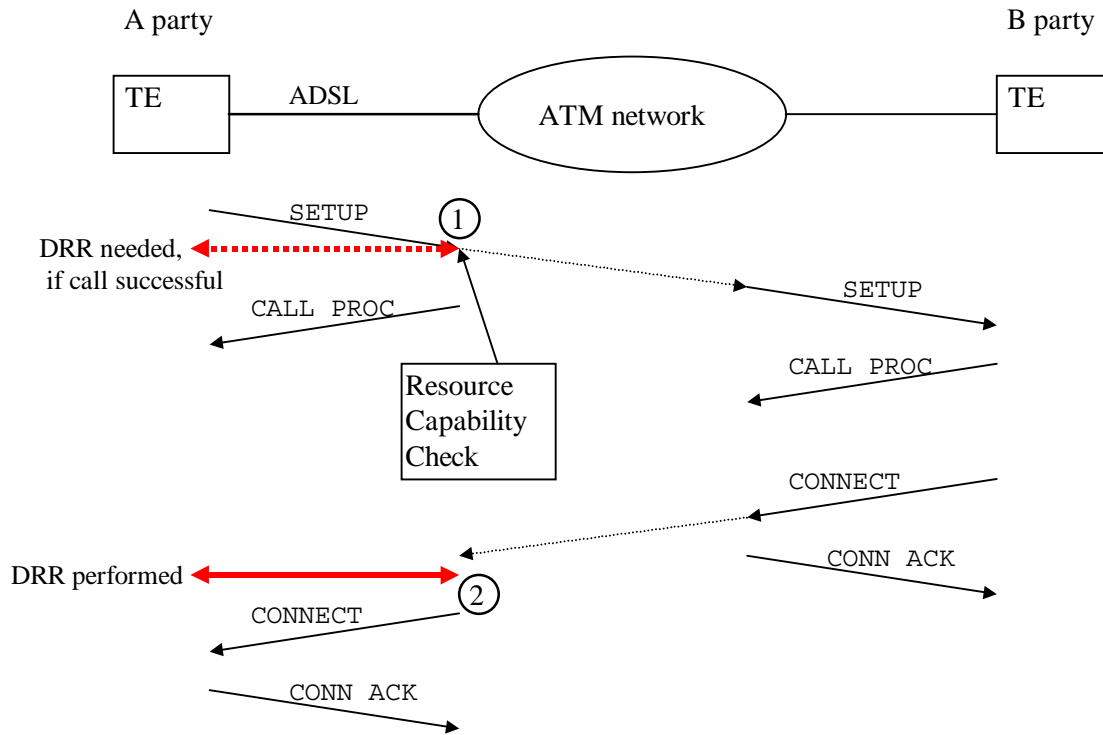
For environments where the ATM and DSL management functions exist in separate network elements, communications between the physical layer management (which controls DRR events) and ATM layer CAC management can provide improved system performance for all ATM connections. The “Resource Capability Check” function shown in Section E.4 determines if adequate resources exist in the DSL, ATM, and external interfaces to support the requested DRR modification. Since the interaction of DRR with ATM is similar to SVC environments, the DRR request can be modeled as an SVC Connection Request for CBR connection across the link between the separate network elements. This communications can be performed using existing ATM signaling (ie. Q.2931) messages with Call Setup/Teardown requests containing the DRR bandwidth change. DRR changes modify the ATM cell rate and associated CTD which may also impact scheduling and fair queuing allocations. The impact of this variation on non-UBR VCs is for further study.

### **E3.4 ATM and PHY Layers Co-existing in the Access Node**

For architectures where the ATM and DSL physical layers terminate in the same unit, interlayer communications are entirely under the control of the equipment designer and outside the scope of standardization. However, the ATM and PHY behaviors in this case are equivalent to Section 3.4.2.3 where management communications are visible and external.

## **E4. Call Connection and Rate Repartitioning**

If optional Dynamic Rate Repartitioning and ATM SVCs are supported, it is possible that an ATM call setup request could trigger a DRR event. Figure E-2 and E-3 demonstrate the rate repartitioning process. Rate repartitioning is performed before sending CONNECT (2) to the end system but may be performed after receiving SETUP (1). Forwarding the CONNECT message allows verification of available capacity outside the ADSL link before performing the rate repartitioning. The rate repartitioning is initiated by the Access Node and may interrupt active ATM connections resulting in potential data loss.



**Figure E-2: Rate Repartition Based on Access Network Call Request**

Note: When the call setup originates with the ATM/ADSL TE, the called party may get call setup confirmation (CONN ACK) an additional 125 msec before the called party receives CONNECT confirmation due to DRR delays. (The messages in Figure 4 and 5 are SIG 4.0 (Q.2931) call control messages.) The impact of this delay is for further study.



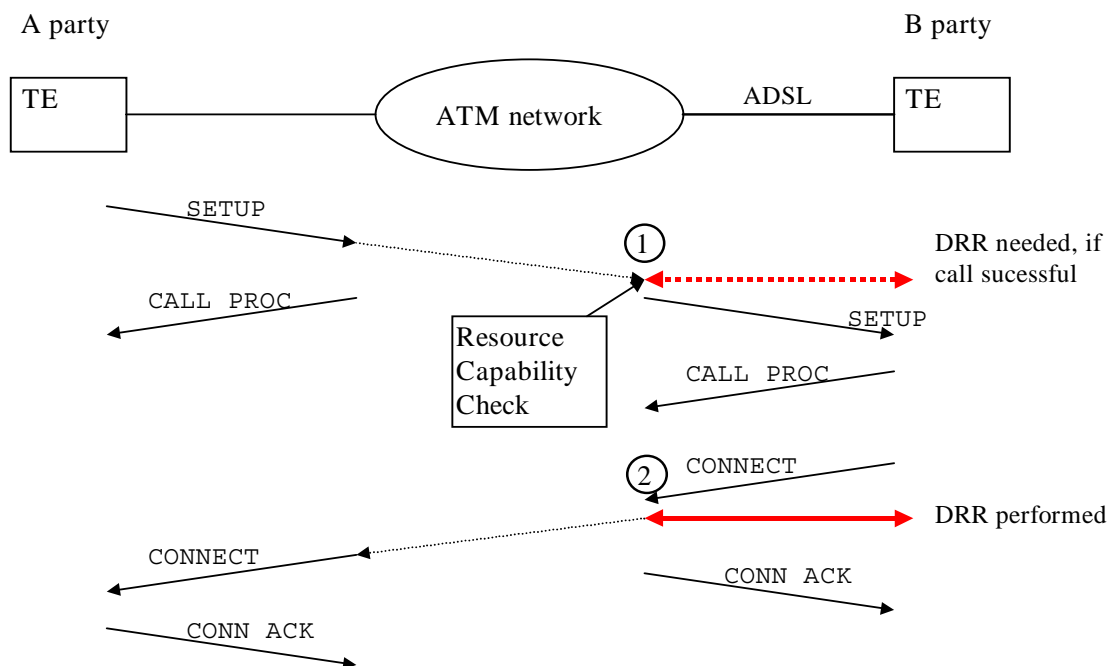


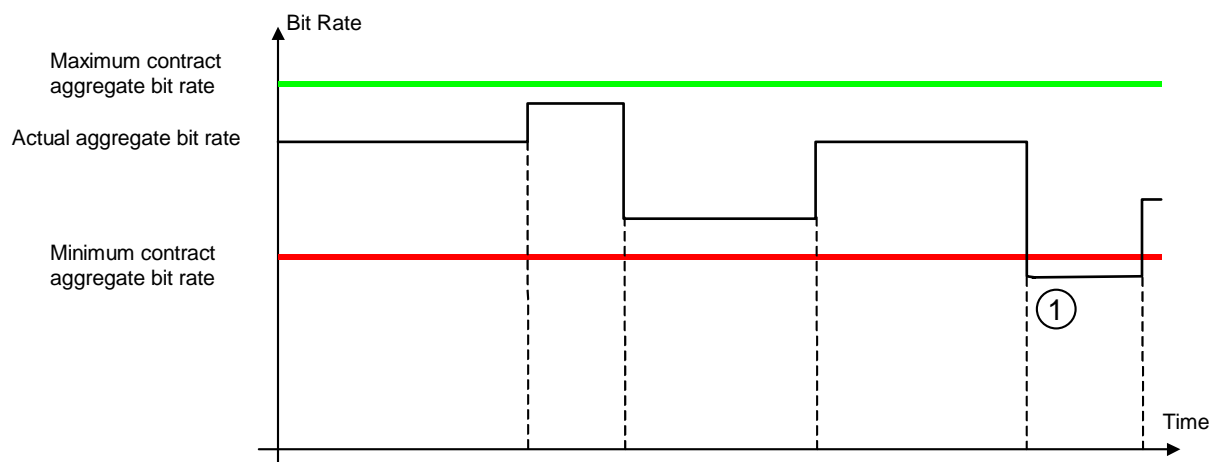
Figure E-3: Rate Repartition Based on ATM Network Call Request.

## E5. Dynamic Rate Change Definition

Whereas most physical links have known, fixed capacity, the ADSL link may change rates over time based on the physical environment or other factors. The variable nature of the ADSL link capacity poses a unique set of problems to the network which spans network management, traffic management, signaling, and operations management functions.

Dynamic Rate Changes include both optional Dynamic Rate Adaptation (DRA) as per G.992.1 [24] and T1.413 [4] and Fast Retrain as per G.992.2 [25]. During rate change transitions, the bit rate provided by the PHY layer may be zero for up to 3 seconds. The physical layer notifies the ATM layer when any Dynamic Rate Change occurs.

ADSL link transport capacity may be partitioned into guaranteed and non-guaranteed ATM resource, where the non-guaranteed resource is subject to change through Dynamic Rate Change. If the available link capacity remains below the guaranteed rate, a link failure alarm is generated, but the link continues to operate at a lower sustainable rate to preserve network management functionality and optionally to provide partial service. Figure E-4 shows an example for Dynamic Rate Adaptation (DRA) where the link capacity initially changes between the maximum contract aggregate bit-rate and the minimum contract aggregate bit-rate. In this region, the transport of guaranteed services (e.g., CBR) up to the minimum contract aggregate bit-rate and transport of non-guaranteed services (e.g., UBR) up to the actual contract aggregate bit-rate is supported. The actual aggregate bit rate does not exceed the maximum contract aggregate bit rate. The rate change is initiated by the PHY layer. The example also shows a change to the actual aggregate capacity to below the minimum contract aggregate bit-rate so that some or all of the current connections may need to be dropped. At this point (1), a link failure alarm is generated.



**Figure E-4: Dynamic Rate Adaptation Example**

Note: Interruptions of bit rate (down to zero) at DRA change boundaries may occur and are 0 to 125 msec in duration. Fast retrain may cause longer data interruptions up to 3 seconds in duration.