The ATM Forum

Technical Committee

Residential Broadband Architectural Framework

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1. Introduction

The ATM Forum Residential Broadband (RBB) Architectural Framework defines ATM access systems and home networks.

It describes the Access-Network Interface (ANI) and the User-Network Interface (UNI).

This specification references, where appropriate, other standards and specifications.

1.1 Reference Architecture

The Residential Broadband reference architecture identifies the RBB interfaces in the context of different access and home networks.

The RBB generic reference architecture consists of five elements:

1. Core ATM Network
2. ATM Access Network
3. Access Network Termination
4. Home ATM Network
5. ATM end system

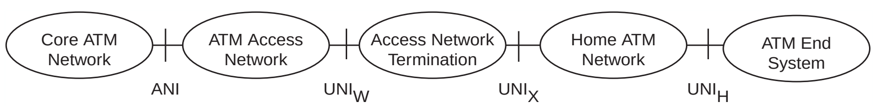

Figure 1-1 RBB Reference Architecture

One or more of the elements in the reference architecture may be null in some scenarios; therefore, the interfaces at one or more of these reference points may be the same.

There may be more than one interface specification for each of these reference points.

Notes:

1. There are no U_B, T_B or S_B reference points shown in Figure 1-1 as there is no direct mapping at these reference points to the interfaces identified that apply in all cases.

In particular, the S and T reference points used in the ITU-T Recommendation I.310 have specific significance to the signaling system and definitions of the functional elements that are not appropriate to the RBB environment. Therefore, the exact interpretation at these reference points will depend upon the local network architecture and regulatory environment.

The reference configurations in this section and subsequent sections show abstract functional groupings, which generally correspond to real devices. Real devices may comprise one abstract functional grouping, more than one abstract functional grouping or a portion of an abstract functional grouping. In the last case, the interface between the devices or subsystems that comprise the functional grouping are not the subject of this specification but may be the subject of other standards or specifications.

The reference configurations also show interfaces which are the subject of this specification, whether by inclusion or by reference to other standards or specifications.

When two or more functional groupings are present in a real device, the interface between them need not be exposed, even if it is the subject of this specification.

1.2 Reference Elements

1.2.1 Core ATM Network

The Core ATM network (Figure 1-2) is comprised of the following functional groupings:

1. A network of one or more ATM switches
2. Servers (which provide network-specific functions)
3. Network management

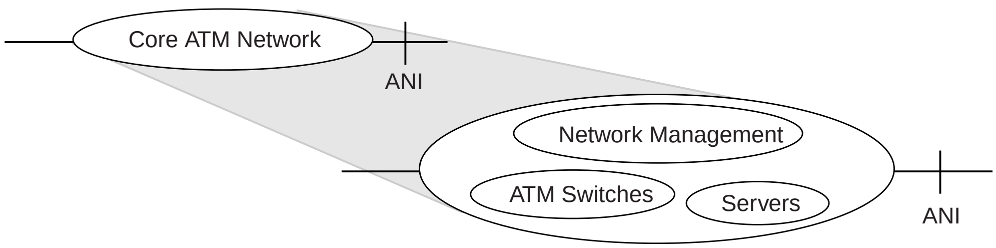

Figure 1-2 Functional Decomposition of the Core ATM Network

1.2.2 ATM Access Network

The ATM Access Network (Figure 1-3) is comprised of the following functional groupings:

1. ATM Digital Terminal (ADT)
2. Access Distribution Network

ADT is a generic term used throughout this specification. Individual Access Network technologies have their own nomenclature corresponding to this function.

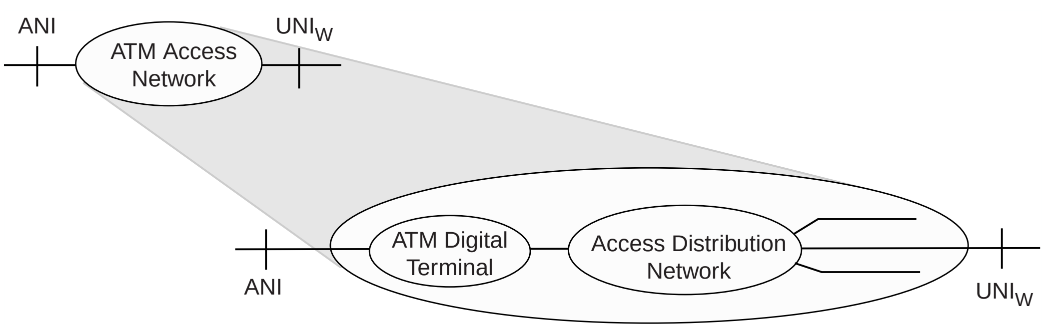

Figure 1-3 Functional Decomposition of the ATM Access Network

1.2.3 Access Network Termination

The Access Network termination (NT) is a functional grouping that connects the ATM Access Network to the home ATM network. UNI_W is the interface at the Access Network side of the NT. UNI_X is the interface at the home side of the NT.

The function of the NT is dependent upon the Access Network and home network technologies. The NT may be either passive or active. A passive NT is defined such that the interfaces at the UNI_X and UNI_X are identical at all layers. It may contain only passive components (e.g. electrical protectors) or components that are active in the electrical or optical domain (e.g. filters or amplifiers) but does not contain components that are active in the digital domain (i.e., it does not contain modulation/demodulation or higher layer functions).

An active NT may contain PMD layer functions in the digital domain, such as modulation/demodulation and media conversion. It may also contain functions at the TC and MAC layers. The physical device which contains the NT may also contain other functions (e.g. a home distribution device).

> Note: Whether or not the NT is provided as part of the Access Network, and thus whether the customer interface is at UNI_W or UNI_X, is not determined by this specification.

1.2.4 Home ATM Network

The Home ATM Network (HAN) connects the Access Network Termination and the ATM End System(s). Realizations of the HAN may range from a simple transparent-pass-through passive network to a complete local network with switching functions.

The HAN is comprised of the following functional groupings (Figure 1-4):

1. Home Distribution Device.
2. Home Distribution Network.

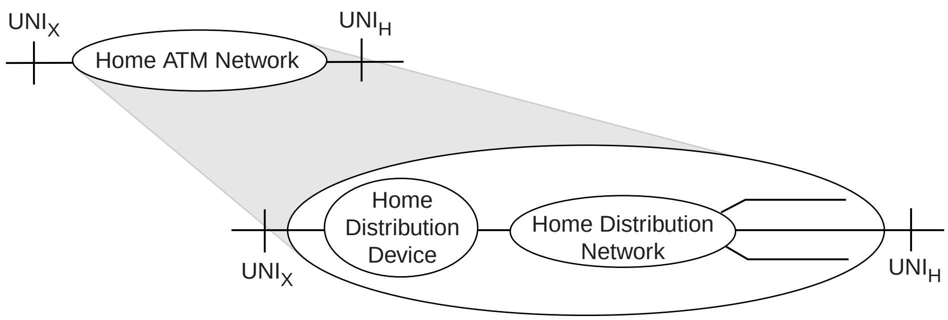

Figure 1-4 Functional Decomposition of the Home ATM Network

The Home Distribution Device performs switching and/or concentration of ATM virtual connections between the UNI_X and devices connected to the home ATM network at UNI_H (including support for ATM virtual connections between such devices.. It may contain PHY, MAC or ATM layer functionality and may also contain signaling. The Home Distribution Device is optional and need not be present in all Home ATM Networks. Some of its functions could be realized together with the Network Termination in a single device.

The Home Distribution Network transports ATM traffic to and from the ATM End System and may be implemented with a single point to point link, with a star configuration or with a shared media tree and branch topology.

Suitable Home ATM Networks are described in this document, and a residential specific PHY is defined in [1]. Other Home ATM Network implementations are not precluded.

1.2.5 ATM End System

The ATM End System contains functions above the ATM layer, possibly including end-user applications.

1.3 Reference Interfaces

1.3.1 Access Network Interface

The Access Network Interface (ANI) is the interface between the Access Network and the Core ATM network. It is independent of any specific Access Network technology. Section 5 provides a description of ANI interfaces.

1.3.2 UNI_W, UNI_X and UNI_H Interfaces

The UNI_W, UNI_X and UNI_H interfaces are specific to the Access Network technology, Access Network termination, Home Network and ATM End System. These interfaces support a cell-based UNI, or optionally a frame-based UNI [2], for ATM transport between these elements.

2. Services

The services and capabilities specified for ATM Residential Broadband networks are the same as those specified for other ATM networks. Network operators may elect to offer, and equipment in the home may elect to use if offered, all or a subset of these services and capabilities. It is intended that seamless interoperation be possible between ATM End Systems attached to RBB networks and ATM End Systems attached to other ATM networks.

2.1 Connection Configurations

Point-to-point and unidirectional point-to-multipoint connections are specified for RBB networks, as in the UNI 3.1 specification. Additional connection types are being studied in the ATM Forum and the ITU-T and may be specified in the future for RBB networks.

2.2 Connection Types

Virtual Path Connections and Virtual Channel Connections are specified for RBB networks as in the UNI 3.1 specification.

2.3 Establishment of Connections

Permanent virtual connections are specified for RBB networks as in the UNI 3.1 specification.

Switched virtual connections are specified for RBB networks, as in the UNI 3.1 specification. Mechanisms and capabilities for SVCs are described in Section 5.

2.4 Traffic Management Considerations

The CBR, rt-VBR, nrt-VBR, ABR and UBR service categories, their associated traffic contract parameters and QoS parameters are specified for RBB networks, as in the TM 4.0 specification. The PHY layers of some RBB Access Network technologies have characteristics (e.g., asymmetrical bandwidth, shared media, dynamic rate) which are atypical of PHY layers used in non-residential environments. The effect of these characteristics on ATM traffic management is being studied. They may also affect Connection Admission Control policies and the contribution of the Access Network to end-to-end QoS in ways that are network specific.

3. ATM Access Networks

This section describes several ATM Access Networks which have been considered by the ATM Forum. This section is not meant to provide an exhaustive list of RBB access technologies.

The following Access Network descriptions include only that portion of the network which deals with the transport of ATM services. The carriage of non-ATM services by these networks is beyond the scope of this specification.

3.1 ATM over Hybrid Fiber Coax Reference Architecture

Figure 3-1 shows the Reference Architecture for ATM over Hybrid Fiber coax (HFC) cable television (CATV) transmission systems with a passive NT. In an HFC transmission system, modulated digital signals are frequency division multiplexed onto the optical and coaxial physical medium along with analog television signals. Service is delivered to the subscriber at a coaxial CATV interface. Equipment at a central location (which is called a headend), broadcasts signals on the medium in the downstream direction (i.e., toward the subscribers). Any signal can be received (but not necessarily understood) by subscriber equipment by tuning to the corresponding frequency division multiplexed (FDM) channel. In the upstream direction, the physical medium is shared among subscriber equipment (which are called stations), which transmit signals that are received only by the headend. A Media Access Control (MAC) layer protocol arbitrates access by stations to the upstream medium. For an overview of CATV systems in North America refer to the Cablelabs website [14]; similar networks are used in other countries and regions, although system parameters and engineering practices vary.

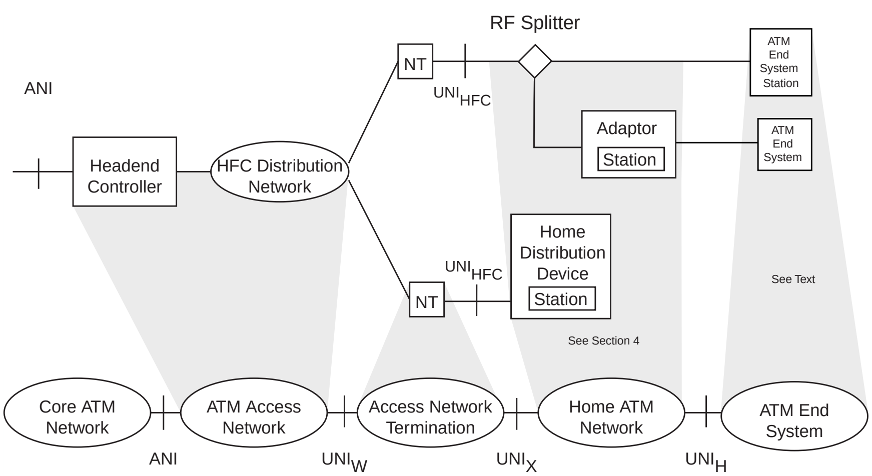

Figure 3-1 ATM Over HFC Passive NT Reference Architecture

The Headend Controller (HC) provides the necessary functionality to support ATM over the shared HFC media. It includes ATM switching and/or concentration, signaling, MAC layer functions, TC functions and upstream and downstream PMD functions.

The HFC distribution network is the fiber and coax distribution plant, including elements such as diplexers, fiber nodes, amplifiers and directional couplers. Non-ATM services will ordinarily share the HFC plant, but are not the subject of this specification.

The NT function in CATV networks is present only for reasons of safety and signal integrity. It consists of grounding facilities and possibly other electrical protection, splitters or directional couplers.

The Station is the entity in the home that incorporates necessary support for ATM transport over the CATV media. It contains PMD, TC and MAC layer functions. The station is a component of other entities in the RBB reference model.

Two cases are identified for the NT and the Home ATM network (HAN):

In the passive home distribution scenario (the term ‘passive NT scenario’ is also used, but is inaccurate for CATV distribution), the HAN is structured as a branching tree of coaxial cable, with RF splitters at the branching points. Station functions are present either in the ATM End System or in an external adapter device. There may be more than one ATM End System or adapter device in the home, each containing a Station.

In the active distribution scenario the home distribution device contains a Station, this HAN is described in Section 4.

The IEEE 802.14 is developing a standard for ATM transport over HFC Access Networks. The standard is to include upstream and downstream physical layers and a MAC protocol. The MAC protocol ensures that the services of Section 2 of this specification can be provided, despite the shared media nature of the HFC Access Network. It is intended that an addendum to this specification will reference the IEEE 802.14 standard when it is completed.

3.2 ATM Passive Optical Network Based Access Networks

This section describes ATM optical networks and access architectures based on this type of system. Figure 3-2 shows possible local access architectures, ranging from FTTH (Fiber to the Home), through FTTB/C(Fiber to the Building/Curb) to FTTCab (Fiber to the Cabinet). The OAN (Optical Access Network), which can be configured in a variety of ways such as ring, point-to-multipoint, or point-to-point, is common to all architectures shown is Figure 3-2. The FTTC and FTTCab cases use metallic media as described in Section 3.3 and Section 3.4.

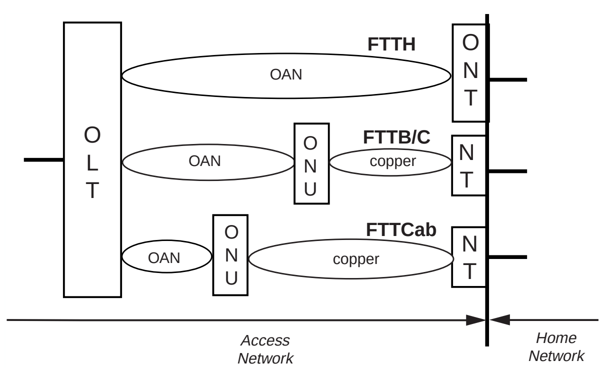

Figure 3-2 Network Architecture

The ATM Passive Optical Network (ATM-PON) is one of these OAN configurations. Passive optical splitters enable the PON's capacity to be shared across several terminal/ONUs (Optical Network Unit) over multiple subscribers.

Because of the shared media, functions in a PON-based Access Network are required to provide privacy and security. In addition, a medium access control (MAC) is required to arbitrate access to the medium in the upstream direction.

The ITU-T SG 15 is developing a recommendation, G.983, for ATM PONs. It is intended that an addendum to this specification will reference the ITU-T recommendation when it has been approved.

3.2.1 ATM Passive Optical Network for FTTH

Figure 3-3 shows the Reference Architecture for ATM over a FTTH architecture using a PON. The Optical Line Termination (OLT) provides the necessary functionality to support ATM over the shared PON media. The OLT will generally contain the following functions:

1. ATM layer cross-connection or switching.
2. MAC layer functions, including downstream addressing and upstream transmission control.
3. PHY layer functions, including E/O (Electrical/Optical) and O/E (Optical/Electrical) conversion.
4. Access network security.
5. Interface to the Core ATM network.

The PON distribution network is comprised of the fiber distribution plant with a passive optical splitter function.

The PON network termination provides the necessary functionality to support ATM over the shared PON media. The NT will generally contain the following functions:

1. ATM layer multiplexing.
2. MAC layer functions, including downstream addressing, upstream transmission control.
3. PHY layer functions, including E/O and O/E conversion.
4. Access network security.
5. Interfaces to the HAN.

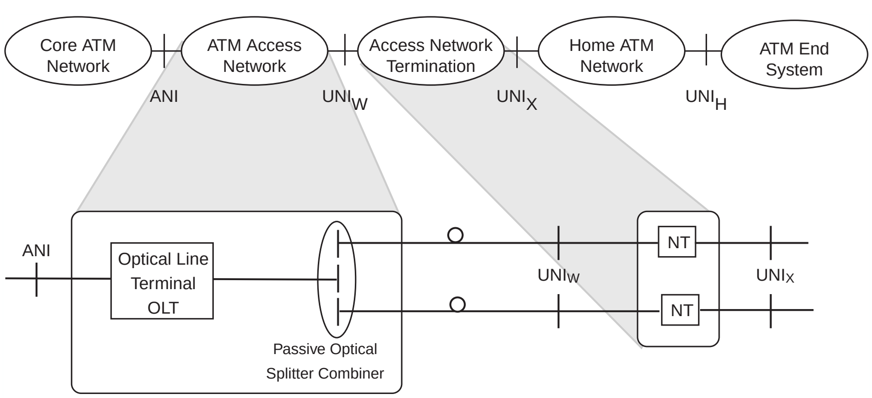

Figure 3-3 ATM over FTTH using PON Reference Architecture

3.2.1.1 Functional Aspects of Network Elements

3.2.1.1.1 The Optical Line Termination (OLT)

The OLT consists of three parts; the Access Node Interface Line Terminal (ANI-LT), PON Line Terminal (PON-LT) and Virtual Path and Virtual Channel Cross Connect (managed/dynamic) (VP/VC-CC) for VP grooming.

1. ANI-LT

The Access Node Interface Line Terminal (ANI-LT) connects the OLT to the core ATM network or an ATM node.

2. VP/VC-XC

The Virtual Path and Virtual Channel Cross Connect (VP/VC-CC) provides connections between the ANI-LT and the PON-LT.

3. PON-LT

The PON Line Terminal handles the opto-electronic conversion process, inserts ATM cells into the downstream PON payload and extracts ATM cells from the upstream PON payload. Downstream frame timing is performed by the PON-LT.

3.2.1.1.2 The Optical Network Termination (NT)

The PON NT is active and connects the Access Network delivery mechanism from the in-house distribution. The NT consists of three parts; PON Line Termination (PON-LT), Virtual Path Multiplexer (VP-MUX) for VP multiplexing, and the User Network Interface Line Terminal (UNI-LT).

1. PON-LT

The PON Line Termination (PON-LT) handles the opto-electronic conversion process. The PON-LT extracts ATM cells from the downstream PON payload and inserts ATM cells into the upstream PON payload based on synchronization acquired from the downstream frame timing.

2. VP-MUX

The Virtual Path Multiplexer (VP-MUX) multiplexes UNI-LTs to PON-LT. Only valid ATM cells can be passed through the VP-MUX, so many VPs can share the assigned upstream bandwidths effectively.

3. UNI-LT

The User Network Interface Line Terminal (UNI-LT) interfaces over UNIx to a Home ATM Network (HAN).

3.2.1.2 ATM Transport Protocol Model

Figure 3-4 illustrates an ATM transport protocol model aligned with the reference architecture shown in Figure 3-3.

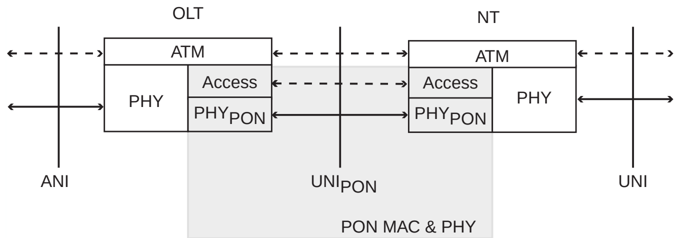

Figure 3-4 ATM Transport Protocol Model

In this architecture, the ATM transport protocols at a UNI_{PON} consists of Physical, Access, and ATM layers. This architecture is only intended to address the transport of ATM user data and not to address the control or management of ATM (hence there are no management or signaling protocols shown).

3.2.2 ATM Passive Optical Network for FTTC/Cab

Figure 3-5 shows the Reference Architecture for ATM over a FTTC/Cab architecture using PON and xDSL systems. The Optical Line Termination (OLT) provides the necessary functionality to support ATM over the shared PON. The OLT will generally contain the following functions:

1. ATM layer cross connection and switching.
2. MAC layer functions, including downstream addressing, upstream transmission control.
3. PHY layer functions, including E/O and O/E conversion.
4. Access network security.
5. Interface to the Core ATM network.

The PON distribution network is comprised of the fiber distribution plant with a passive optical splitter. Non-ATM services may be carried over the PON network; the means for doing so are not the subject of this specification. Any of the Passive or Active NT Scenarios may apply.

The Optical Network Unit (ONU) provides the necessary functionality to support ATM over the shared PON media. The ONU will generally contain the following functions:

1. ATM layer multiplexing.
2. MAC layer functions, including downstream addressing, upstream transmission control.
3. PHY layer functions, including E/O and O/E conversion.
4. Access network security.
5. Interface to the xDSL transmission system.

The xDSL ATM Interface Unit (xDSL-AIU) provides the network termination function, i.e. conversion from the xDSL transmission system to the interface to the end system. It contains the following functions:

1. xDSL Transceiver Unit - Remote Terminal end (xTU-R).

2. Mux/Demux.
3. ATM layer functions
4. Interface to the HAN.

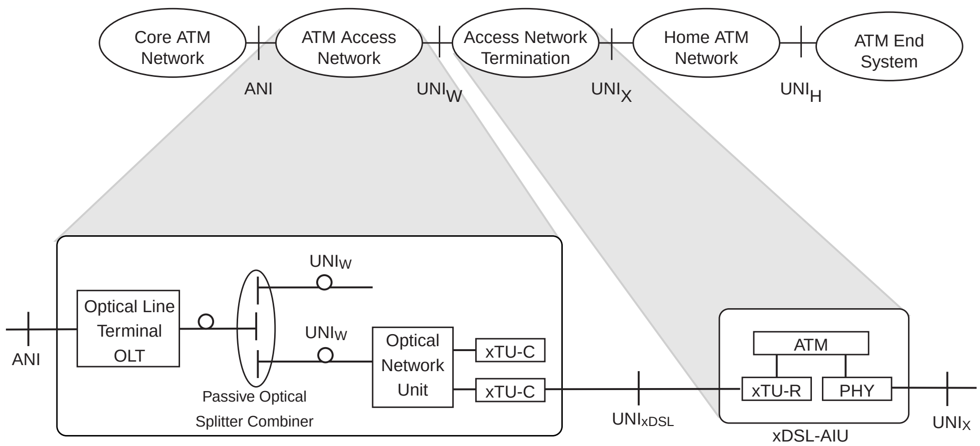

Figure 3-5 ATM over FTTC/Cab using PON and xDSL Reference Architecture

3.2.2.1 Functional Aspects of Network Elements

3.2.2.1.1 The Optical Line Termination (OLT)

The OLT consists of three parts; the Access Node Interface Line Terminal (ANI-LT), Virtual Path and optionally Virtual Channel Cross Connect (VP-XC) for VP/VC grooming and the PON Line Termination (PON-LT).

1. ANI-LT

The Access Node Interface Line Termination (ANI-LT) connects the OLT to the core ATM network or an ATM node.

2. VP/VC-XC

The Virtual Path and Virtual Channel Cross Connect (VP/VC-CC) provides connections between the ANI-LT and the PON-LT.

3. PON-LT

The PON Line Terminal handles the opto-electronic conversion process, inserts ATM cells into the downstream PON payload and extracts ATM cells from the upstream PON payload. Downstream frame timing is performed by the PON-LT.

3.2.2.1.2 Optical Network Unit and xTU-C

The ONU connects the PON Access Network delivery mechanism from the xDSL transmission system. The ONU consists of three parts; PON Line Terminal (PON-LT) and Virtual Path/Virtual Channel Multiplexer (VP-MUX) for VP multiplexing and multiple xDSL Transceiver Unit - Central office (xTU-C) line cards.

1. PON-LT

The PON Line Terminal (PON-LT) handles the opto-electronic conversion process. The PON-LT extracts ATM cells from the downstream PON payload and inserts ATM cells into the upstream PON payload based on synchronization acquired from the downstream frame timing.

2. VP-MUX

The Virtual Path Multiplexer (VP-MUX) multiplexes xTU-Cs (xDSL Transceiver Unit-Central Office) to PON-LT. Only valid ATM cells can be passed through the VP-MUX, so many VPs can share the assigned upstream bandwidths effectively.

3. xTU-C

For details of the xDSL Transceiver Unit - Central Office see sections 3.4 and 3.5.

3.2.2.1.3 xDSL-AIU

For details of the xDSL ATM Interface Unit see sections 3.4 and 3.5.

3.2.2.2 ATM Transport Protocol Model

Figure 3-6 illustrates an ATM transport protocol model aligned with the reference architecture shown in Figure 3-5.

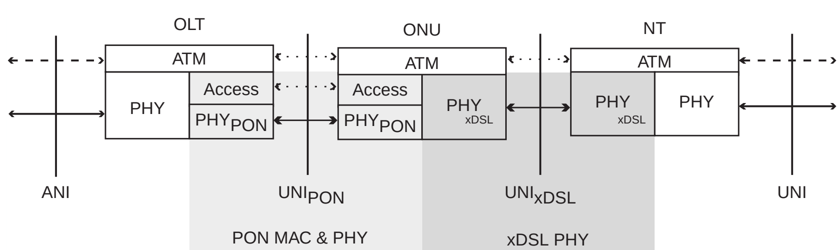

Figure 3-6 PON Transport Protocol Mapping

For details of an example short-range FTTC PMD Layer specification refer to the DAVIC specification [3].

3.3 Asymmetric Digital Subscriber Line (ADSL)

Asymmetric Digital Subscriber Line (ADSL) is a transmission system which supports high bit rates over existing metallic twisted pair Access Networks. ADSL provides a high bit rate downstream channel (towards the ATM End System) and a lower bit rate upstream channel (from the ATM End System towards the network). ADSL may support bit rates up to 6 Mb/s in the downstream direction and up to 640 Kb/s in the upstream direction, depending on loop length.

Figure 3-7 compares the RBB reference architecture with the ADSL functional model

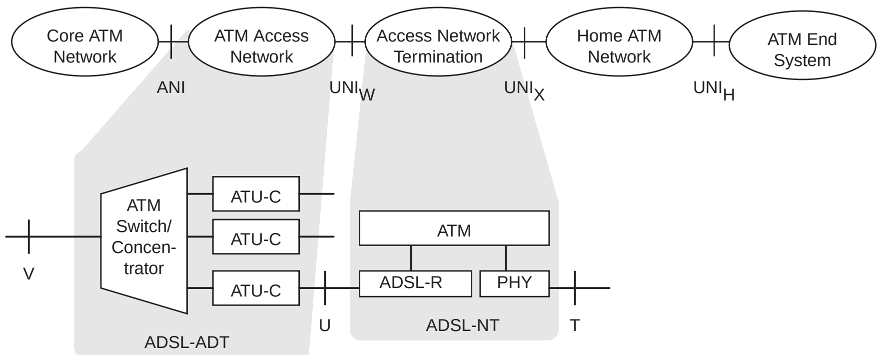

Figure 3-7 Mapping of ADSL (Active NT) Functional Model on the RBB Reference Architecture

The ADSL-ADT may contain the following functions:

1. Concentrator and/or switch
2. ADSL Transceiver Unit-Central Office (ATU-C)
3. ATM layer functions
4. Interface to the Core ATM network
5. POTS splitter to separate the POTS and ADSL channels

The ADSL Transceiver Unit-Central Office end (ATU-C) provides the necessary functionality to support transmission over point-to-point metallic twisted pair media. Typically, it includes the following functions:

1. PMD layer functions, such as, upstream demodulation, downstream modulation, Scrambling, FEC and interleaving
2. TC layer functions, e.g., OAM, cell delineation
3. POTS splitter functions

The ADSL-AIU typically consists of the following functions:

1. ADSL Transceiver Unit - Remote Terminal end (ATU-R)
2. Mux/Demux
3. ATM layer functions
4. Interface to the HAN

The ATU-R is the inverse of the ATU-C. It may include:

1. PMD layer functions, such as downstream demodulation, upstream modulation, Scrambling, FEC and interleaving
2. TC layer functions, e.g., OAM, cell delineation
3. POTS splitter functions

3.3.1 Transport of ATM over ADSL.

ADSL transport has three unique characteristics which affect operation of the ATM layer. These are:

1. asymmetry and channel capacity

2. forward error correction and interleaving
3. dynamic rate adaptation and rate repartitioning.

The asymmetry ratio and channel capacity is a function of the link attenuation and noise environment, and is normally established at power up by the selection of one of a number of possible rates (with a granularity of 32 kb/s). A mechanism needs to exist so the capacity selected is known for the purpose of CAC. Channeling the total capacity into a number of independent sub-channels is possible, but not required for ATM where the same functionality can be achieved by VC based multiplexing, except where dual latency (discussed below) needs to be supported.

In order to achieve an acceptable BER, FEC with interleaving is often required. This spreads the effect of impulsive noise interference over many widely separated bits which allows error correcting codes to be effective. However the time scale of the noise events is such that interleaving delays of ~20 ms can result. Such a delay may not be acceptable for all applications, in particular those which are more concerned with delay than error rate. Therefore the concept of dual latency is supported which allows both interleaved and non-interleaved channels.

The prevailing noise environment will change on both a short and a long time scale. It is possible to allow for the worst case noise situation at start up, but this will then not be using the full link capacity. It is possible to dynamically adapt the bit-rate after start-up to maximize the instantaneous throughput, but this offers many challenges for maintaining an agreed QOS on existing calls, and CAC.

The basic mechanisms for the transport of ATM over ADSL have been specified by the ADSL Forum [4]. This covers basic architecture, channelization, TC issues and Physical Layer OAM, but the more complex matters relating to dual latency and dynamic rate adaptation are not specified. Technical Subcommittee T1E1 is developing Issue 2 of ANSI T1.413 which incorporates relevant work of the ADSL Forum. It is intended that an addendum to this specification will reference the T1.413 Issue II or the equivalent ITU-T recommendation when approved.

3.4 Very High Speed Digital Subscriber Line (VDSL)

Very high speed Digital Subscriber Line (VDSL) is a transmission system which aims to support very high bit rates over at least parts of the existing copper Access Network. It is very similar to ADSL in concept, but has the following distinctions. The maximum downstream bit rate is higher but the reach is significantly less. Both asymmetrical and symmetrical VDSL systems are under consideration.

VDSL will use more spectrum than ADSL. From the transmission point of view, the main concerns are RF egress given this increased bandwidth, and spectral compatibility with ADSL.

From the ATM point of view the issues are very similar to those of ADSL i.e. channel capacity, dual latency and dynamic rate adaptation. There are however two additional considerations. VDSL's enhanced capacity enables it to offer more applications, and VDSL represents a potential migration path from ADSL. Therefore, the definition of the ATM HAN must take into account the distribution of VDSL delivered services from the point of view of bit-rate, multiple services, multiple QOS, and having many attached devices.

VDSL standardization is at a less advanced state than that of ADSL. Bodies known to be active in this area include ANSI T1E1.4, ETSI (TM3 and TM6), the GX FSAN initiative and the ITU-T SG15 WP4.

Figure 3-8 compares the RBB reference architecture with the VDSL functional model

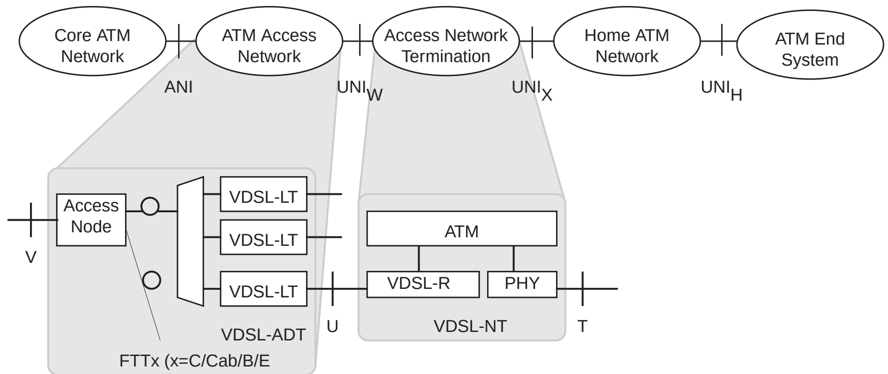

Figure 3-8 Mapping of VDSL (Active NT case) Functional Model on the RBB Reference Architecture

The VDSL-ADT (VDSL ATM Digital Terminal) may contain the following functions:

1. VDSL Transceiver Units - Central Office (VTU-C).
2. POTS splitter to segregate the POTS and VDSL channels.
3. Concentrator and/or switch.
4. Mux/Demux.
5. Interface to some kind of an Optical Access Network (PON or point-to-point links), in the case of FTTC/Cab/B architectures.
6. Interface to the Core ATM Network, in the case in which the ADT is located at the Central Office (FTTE - Fiber To The Exchange).

The VDSL Transceiver Unit - Central Office VTU-C provides the necessary functionality to support transmission over the point-to-point metallic twisted pair media. Typically, it includes the following functions:

1. PMD layer functions, such as, upstream demodulation, downstream modulation, Scrambling, FEC and interleaving.
2. TC layer functions, such as OAM and cell delineation.
3. POTS splitter functions

The VDSL distribution network consists of a metallic twisted pair plant.

The VDSL-AIU may contain the following functions:

1. VDSL Transceiver Unit - Remote terminal (VTU-R).
2. Mux/Demux.
3. ATM layer functions.
4. Interface(s) to the Home ATM network.

The VDSL Transceiver Unit - Remote terminal (VTU-R) is the inverse of the VTU-C. Typically, it includes the following functions:

1. PMD layer functions, such as upstream modulation, downstream demodulation, scrambling, FEC and interleaving.

2. TC layer functions, such as OAM and cell delineation.
3. POTS splitter functions

For details of an example short-range FTTC PMD Layer specification refer to the DAVIC specification[3].

4. Home ATM Network (HAN)

As defined in Section 1.2.4, The Home ATM Network (HAN) connects the Access Network Termination and the ATM End System.

As shown in Figure 4-1 Functional Decomposition of the HAN, it consists of the following functional groupings:

1. Home Distribution Device.
2. Home Distribution Network.

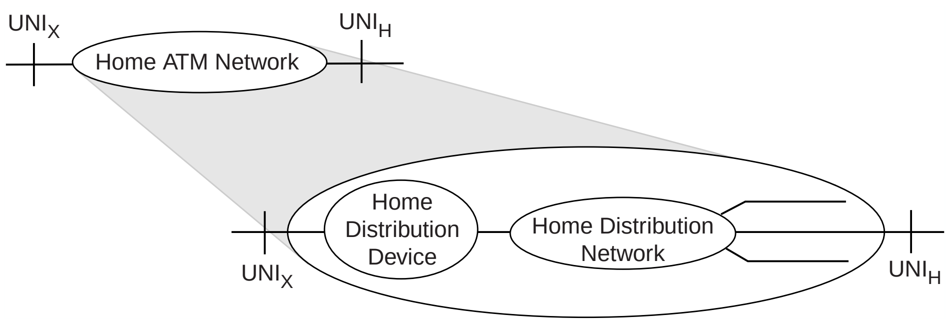

Figure 4-1 Functional Decomposition of the HAN

The Home Distribution Device performs cross-connecting, switching and/or multiplexing of ATM Virtual Connections between the UNI_X and one or more ATM End Systems. It may contain PHY, MAC or ATM layer functionality and may also contain signaling. The Home Distribution Device is optional.

The Home Distribution Network may, for example, be implemented with a single point-to-point link, with a star configuration or with a shared media tree and branch topology.

Suitable Home ATM Networks are described in this document, and a residential specific PHY is defined in ATM Forum Residential Broadband Physical Interfaces Specification[1]. Other Home ATM Network implementations are not precluded.

4.1 Infrastructure

This specification includes a home infrastructure reference model, which is described below. This is based on two guiding principles:

1. the required reach is 50 meters rather than the 100 meters used in the commercial building wiring environment, due to the smaller area of the home. There is an advantage in using a shorter reach from the transmission point of view for both copper and plastic fiber (POF) based systems. In the case of copper, shorter reach means that lower transmit power can be used which helps the EMC egress situation. For plastic fiber, the shorter reach means that the (attenuation limited) transmission systems can use a launch power which meets eye safety limits.
2. allowance must be made for the way in which the infrastructure is likely to be installed by an unskilled person who may be more concerned with aesthetics than specifications. This means that retrofitted cables may be routed around features such room corners and door frames, and may be subject to tight bends.

The description of the home infrastructure is therefore as follows, and as shown in Figure 4-2. The Residential Broadband Physical Interface Specifications have been developed so as to operate over such an infrastructure.

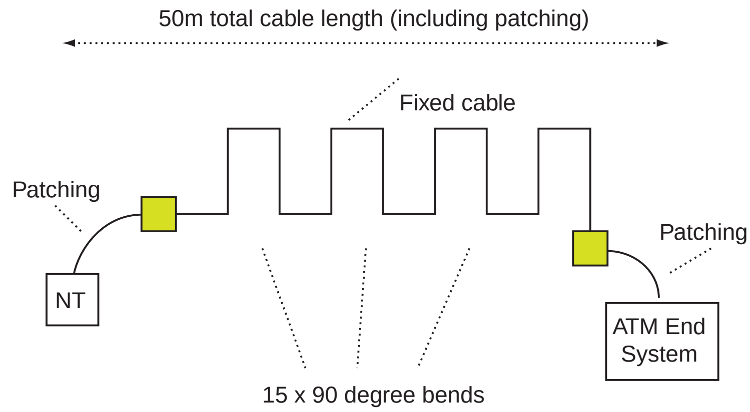

Figure 4-2 Infrastructure Reference Model

4.1.1 Infrastructure Topology

The only topology defined is the classical ATM point to point topology.
Other topologies are not precluded by this specification.

4.1.2 Patching

Three patching scenarios are supported, of increasing complexity, as shown in Figure 4-3.

1. direct connection to an end device via a free standing cable (e.g. a patch cord).
2. direct connection to a fixed cable which terminates in a (wall mounted) connection box into which end equipment can be plugged.
3. connection via a patch cord into a fixed cable infrastructure terminating in a wall box.

Connectors which are part of terminal equipment are not counted in the connector pair budget therefore these configurations require 1, 2 and 3 mated connector pairs respectively.

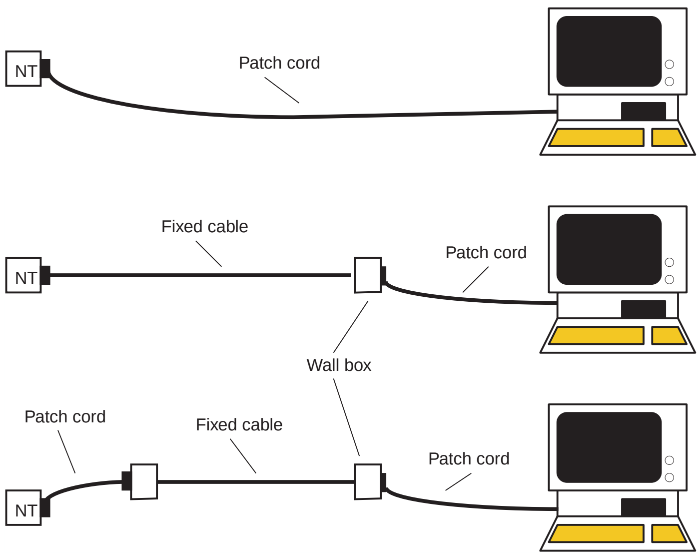

Figure 4-3 Patching Configuration

4.1.3 Cables

Three media types are supported:

1. 100 Ohm Category 5 TP
2. 120 Ohm Category 5 TP
3. Plastic optical fiber

The nominal maximum reach between nodes (i.e. NT or switching device, and item of CPE) is 50m. This includes the length of any patch cords.

A maximum of 15 bends not less than 90 degrees each is supported in any point-to-point link.

In the HAN there is a minimum bend radius limit for POF, but not for either twisted-pair media.

The full details of the link specification for both UTP and POF cable are given in the residential PHY specification [1].

4.1.4 Connectors

The supported connectors types are:

1. 8 position keyed miniature modular connector [5] for Category 5 UTP. Commonly referred as an "RJ-45 connector".
2. F07 [6] (see also [1])
3. Fiber Jack [7] (see also [1])

No more than 3 mated connector pairs may be supported in a point-to-point link.

4.1.5 Timing References

Certain applications, in particular those which involve interworking with narrowband services at some point in the (external) network, may require the delivery of a network referenced (e.g. 8 kHz) clock.

The in-home transmission system shall provide the means to distribute a timing reference. There is no requirement for the PHY to support loop timing at the ATM End System.

5. Signaling

5.1 Access Network Functionality

Access networks can broadly be categorized as having or lacking the need and means to perform dynamic resource management at the level of ATM virtual connections (VCs), or aggregations of ATM VCs.

In an Access Network that performs dynamic resource management, either there is a resource that is dynamically shared among NTs or ATM End Systems, and this sharing has a VC-level component, and/or there is a resource which has a variable capacity. A shared resource may be a shared media (e.g., HFC upstream channels) or a point-to-point trunk (e.g., a SONET/SDH trunk between an ONU and an AN). Resources with variable capacity may be shared (e.g., there have been proposals for multicarrier modulation for upstream channels) or point-to-point (e.g., rate-adaptive ADSL lines).

In order to perform dynamic resource management, the Access Network needs the following:

1. The capability to distinguish between cells belonging to different VCs (as well as to different subscribers) and to perform ATM or MAC layer concentration and/or switching.
2. The capability to perform cell level scheduling.
3. Connection admission control (unless only the UBR service category and/or and/or ABR service category without MCR service categories are offered).
4. Ability to process and possibly negotiate ATM service categories, traffic contracts and QoS objectives (i.e., by signaling or possibly bearer connection control protocol).
5. Knowledge of its own resources and the capability to allocate them.

An Access Network which performs its own resource management makes more efficient use of shared or variable capacity resources, but at a cost in complexity.

Access networks may be operated by the same organizational entity as the core network, or by a different entity. In the latter case, the business relationship between the access and core network providers depends on factors such as national and regional regulations and contractual agreements. The ATM Forum does not deal directly in these matters, but must write its specifications to accommodate a spectrum of possible arrangements. In particular, the Access Network operator may:

1. Have a greater or lesser role in offering services, such as switching of VCCs between endpoints on the same Access Network, supplementary services, and higher layer services.
2. Have greater or lesser control over subscriber data, including access control and service profile.
3. Perform usage accounting, or leave this functionality to the Core ATM network.

In some cases, the ADT in the Access Network will serve as an ATM concentrator; i.e., all ATM virtual connections carried by the Access Network cross an ANI, the mapping from the UNI_W to the ANI is established by provisioning, and the Access Network does not provide switching of VCs between two endpoints (including endpoints which are servers) on the Access Network. In other cases, the Access Network provider will wish to provide higher layer services, or provide switching of VCs between subscriber endpoints which are connected to the Access Network. In these cases, the Access Network serves as an ATM switch.

> Note: Incorporation of support for dynamic resource management, control plane services, usage accounting, access controls, service profiles and switching into the Access Network will necessarily increase the complexity of the Access Network. Complexity may be manifested in functions incorporated in such elements as ONUs and ADTs; as requirements in areas such as reliability, and in possible need for new network elements such as servers and interfaces between these and other elements. This complexity may be regarded by the Access Network provider as being justified by business requirements.

5.2 Taxonomy of System Scenarios

Five scenarios are identified that correspond to the various combinations of Access Network technologies, business relationships and balance-of-complexity tradeoffs.

5.2.1 Scenario 1

In Scenario 1, the Access Network serves as an ATM concentrator, and does not perform any dynamic resource management. In the control plane, all services and capabilities and usage accounting and billing are located in the Core ATM network. At the ANI, there is a signaling VCC, an ILMI VCC, and possibly other reserved VCCs for each UNI (see Figure 5-1 below and Annex 8 of the SIG 4.0 specification[8]). Messages on these reserved VCCs are not interpreted or modified by the Access Network. The core network may authenticate the NT or the ATM End System, or may rely on a static binding of the service profile and accounting records to some portion of the VPI/VCI field at the ANI (where there is a unique mapping of that portion of the VPI/VCI field to an individual UNI). The ANI in this scenario corresponds to the VB5.1 interface (see Section 5.4).

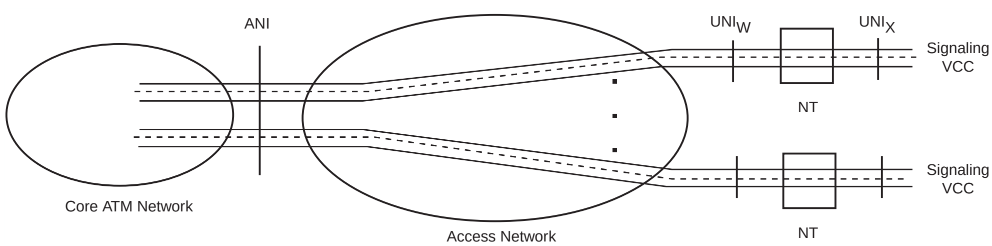

Figure 5-1 Scenario 1

5.2.2 Scenario 2

In Scenario 2, the Access Network serves as an ATM concentrator, and performs dynamic resource management. In the control plane, all services and capabilities, switching, higher layer services and usage accounting are located in the Core ATM network. At the ANI, there is a signaling VCC, an ILMI VCC, and possibly other reserved VCCs for each UNI (see Figure 5-2). Signaling messages are not interpreted or modified by the Access Network. There is also a Bearer Connection Control protocol, and one VCC is reserved to carry it. The BCCP requires an additional information flow across the ANI. The core network may authenticate the NT or the ATM End System, or may rely on a static binding of the service profile and accounting records to some portion of the VPI/VCI field at the ANI (where there is a unique mapping of that portion of the VPI/VCI field to an individual UNI). The ANI in this scenario corresponds to the VB5.2 interface (see Section 5.4).

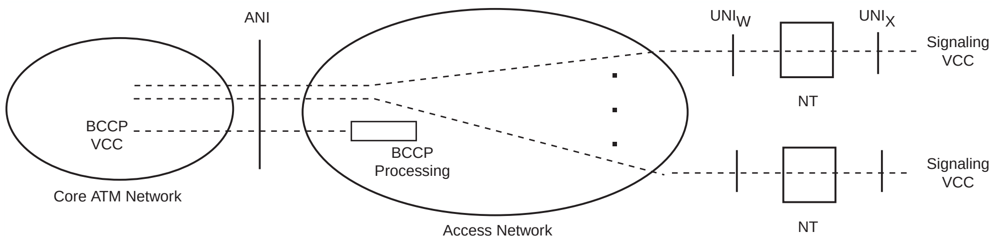

Figure 5-2 Scenario 2

5.2.3 Scenario 3

In Scenario 3, the Access Network may perform dynamic resource management. It serves as either an ATM concentrator or as an ATM switch. The Access Network may provide services and capabilities in the control plane, but does not perform usage accounting. It may also provide switching and/or higher layer services, as long as there is no ATM layer usage based accounting for these capabilities. In order to provide these services, a service profile is present in the Core ATM network. At the ANI, the signaling VCC is shared among subscribers. Signaling messages are interpreted and possibly modified to the extent that the Access Network is able to:

1. negotiate the service category traffic contract and QoS parameters for the VCC
2. support control plane services offered by the Access Network
3. validate the Calling Party Number for the Core ATM network

This requires the Core ATM network to operate signaling protocol state machines at the UNI and ANI. In order to validate the Calling Party Number (i.e., in the SETUP or ADD PARTY message), the Access Network may authenticate the NT or the ATM End System, or may rely on static bindings of the service profile and accounting records to individual UNIs. Usage accounting records are located in the Core ATM network, and the binding between a user SVCC and a subscribers' accounting record is through the validated Calling Party Number. This requires that the core network trust the Access Network to ensure that the Calling Party Number is valid. The ANI is either an ATM Inter-Network Interface (AINI) [9], or a UNI [8, 10]. In the latter case, the Access Network is the user side of the interface and the ATM core network is the network side (see Section 5.4).

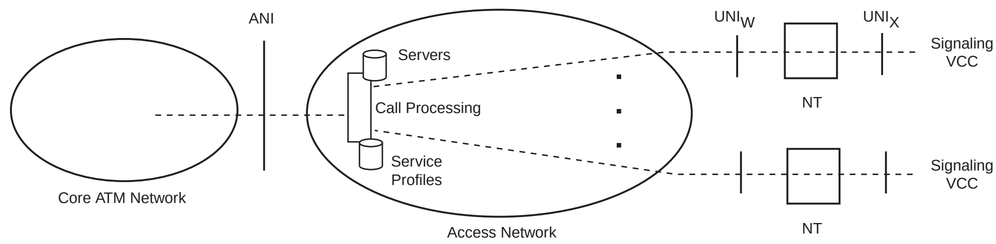

Figure 5-3 Scenario 3

5.2.4 Scenario 4:

In Scenario 4, the Access Network may perform dynamic resource management. It serves as an ATM switch. The Access Network may provide services in the control plane and/or higher layer services, and provides usage accounting. The Access Network includes a service profile and usage accounting records. At the ANI, the signaling VCC is shared among subscribers. Signaling messages are interpreted and modified to the extent that the Access Network is able to:

1. negotiate the service category, traffic contract and QoS parameters for the VCC
2. remap VPI/VCI at the UNI_W to VPI/VCI at the ANI
3. perform usage accounting
4. support any other control plane services that it offers.

This requires the Core ATM network to operate signaling protocol state machines at the UNI and ANI. The Access Network may authenticate the NT or the ATM End System, or may rely on static bindings of the service profile and accounting records to an individual UNI_W. The ANI is either an ATM Inter-Network Interface (AINI) [9], or a UNI [8, 10]. In the latter case, the Access Network is the user side of the interface and the ATM core network is the network side (see Section 5.4).

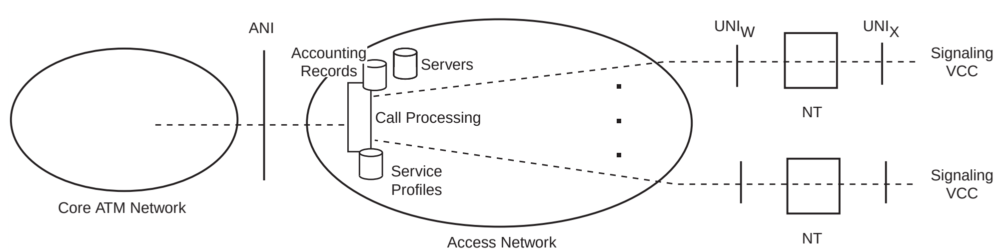

Figure 5-4 Scenario 4

5.2.5 Scenario 5:

Scenario 5 represents the case where proxy signaling is used in Scenarios 3 and 4. In this case, the signaling channel (or channels) between the Access Network and the Core ATM network does not traverse the ANI but is present on a different interface. This other interface may be either a UNI or an NNI between the access call processing agent and the Core ATM network.

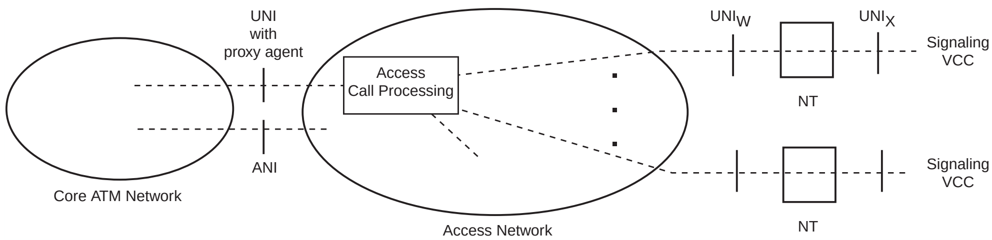

Figure 5-5 Scenario 5

5.3 Signaling at the UNI_X, UNI_W and UNI_H

The signaling protocol for SVCs shall be according to the SIG 4.0 specification[8], including ILMI 4.0 address resolution procedures. End Systems and NTs may learn about PVC configuration using the ILMI 4.0 specification. Alternative protocols may be specified as an option in future issues of this specification.

5.4 Signaling at the ANI

5.4.1 VB5 Interface

This interface is based on the ITU-T network architecture model is described in ITU-T Recommendation G.902 [11]. The ANI (referred to as a Service Node Interface by the ITU-T) in this case may be further classified into two types:

1. VB5.1

The ITU-T is developing a recommendation, G.967.1[12], which will define the VB5.1 interface.

VB5.1 provides for ATM multiplexing/cross-connecting in the Access Network at VP or VC level under management control via the Q3 interface. The ITU-T is also developing a recommendation Q.832.1 which will be the associated VB5.1 management specification.

It is intended that an addendum to this specification will reference these ITU-T recommendations when approved.

2. VB5.2

The ITU-T is developing a recommendation, G.967.2[13], which will define the VB5.2 interface.

In addition to VB5.1, VB5.2 provides on-demand connection allocation in the Access Network under control of the service node (e.g. initiated by user signaling). The ITU-T is also developing a recommendation Q.832.2 which will be the associated VB5.2 management specification.

It is intended that an addendum to this specification will reference these ITU-T recommendations when approved.

5.4.2 The ATM Inter-Network Interface

The ATM Inter-Network Interface (AINI) is an interface between two ATM networks.

Note: The design of the AINI is based on existing intranetwork protocol specifications, i.e., B-ISUP and PNNI. However, the use of an AINI between networks using other intranetwork protocols is not precluded.

The AINI uses a subset of PNNI signaling to provide SVC services.

5.4.3 The User-Network Interface

A UNI as defined in the UNI 3.1 and SIG 4.0 Specifications[10, 8] may be used as an ANI. Although it is defined as a User-Network Interface, it can also be used as the ANI with the Access Network side of the interface chosen to behave as the User side and the ATM Core Network as the Network side. Further capabilities (e.g., for billing) may be required in some cases.

6. References

6.1 Normative References

[1] The ATM Forum Technical Committee “Residential Broadband Physical Interfaces Specification”, under development, expected to be available in 1998.

[2] ATM Forum Technical Committee, "Frame-Based User-To-Network Interface (FUNI) Specification V2.0", AF-SAA-0088.000, July 1997.

[3] DAVIC 1.2 Specifications Part 8, Section 7.6 "Short Range Baseband Asymmetric PHY on Copper and Coax". Digital Audio-Visual Council, June 1997.

[4] The ADSL Forum, "ADSL Forum Technical Report TR-002: ATM over ADSL Recommendations"; March 1997.

[5] IEC 603-7 “Connectors for Frequencies Below 3 MHz for use with Printed Boards”, Part 7; 1996. Electrical specifications may be found in ISO/IEC 11801:1195, “Information Technology - Generic cabling for customer premises”.

[6] IEC 1754-AA Interface Standard, New Work Item Proposal.

[7] TIA/EIA PN-3871 Intermateability Standard, Work in Progress.

[8] The ATM Forum Technical Committee "ATM User-Network Interface (UNI) Signalling Specification" Version 4.0, af-sig-0061.000, July, 1996.

[9] The ATM Forum Technical Committee, “ATM Inter-Network Interface (AINI)”, Work in progress, expected to be available in 1998.

[10] The ATM Forum Technical Committee "User-Network Interface (UNI) Specification 3.1", September 1994.

[11] ITU-T Recommendation G.902 (11/95): “Framework Recommendation on functional Access Networks (AN); Architecture and functions, access types, management and service node aspects”.

[12] Draft new ITU-T Recommendation G.967.1 (12/97). V-interfaces at the service node (SN) - VB5.1 reference point specification.

[13] Draft new ITU-T Recommendation G.967.2 (12/97). V-interfaces at the service node (SN) - VB5.2 reference point specification.

6.2 Informative References

[14] http://www.cablelabs.com/

7. Glossary

AAL	ATM Adaptation Layer
ABR	Available Bit Rate
ADSL	Asymmetric Digital Subscriber Line
ADT	ATM Digital Terminal
AINI	ATM Inter-Network Interface
AIU	ATM Interworking Unit
ANI	Access Network Interface
ATM	Asynchronous Transfer Mode
ATE	ATM Terminating Equipment
ATU	ADSL Transceiver Unit
BCCP	Bearer Connection Control protocol
BER	Bit Error Ratio
B-ISUP	Broadband Integrated Services User Part
CBR	Constant Bit Rate
CDV	Cell Delay Variation
CTD	Cell Transfer Delay
FEC	Forward Error Correction
FTTC	Fiber-to-the-curb
FTTH	Fiber-to-the-home
HAN	Home ATM Network
HDN	Home Distribution Network
HFC	Hybrid Fiber Coax
ILMI	Integrated Local Management Interface
MAC	Media Access Controller
MCR	Minimum Cell Rate
NNI	Network Node Interface
NT	Network Termination
OAM	Operations and Management
OAN	Optical Access Network
OLT	Optical Line Termination
ONU	Optical Network Unit
PC	Personal Computer
PHY	Physical (layer)
PMD	Physical Media Dependent (sub-layer)
PNNI	Private Network Node Interface
POF	Plastic Optical Fiber
PON	Passive Optical Network
PVC	Permanent Virtual Connection
QoS	Quality of Service
RBB	Residential Broadband
SDH	Synchronous Digital Hierarchy
SONET	Synchronous Optical Network
STB	Set Top Box
SVC	Switched Virtual Circuit
TC	Transmission Convergence (sub-layer)
UBR	Unspecified Bit Rate
UNI	User Network Interface
UPI	User Premises Interface
VBR	Variable Bit Rate
rt-VBR	Real-Time Variable bit Rate
nrt-VBR	Non-Real-Time Variable bit Rate

VDSL	Very High Speed Digital Subscriber Line
VC	Virtual Channel
VCC	Virtual Channel Connection
VCI	Virtual Channel Identifier
VP	Virtual Path
VPI	Virtual Path Identifier

Appendix A Example Home ATM Network Implementations

A.1 Home Network Fabric

The combination of the Home Distribution Device and Home Distribution Network can be thought of as a Home Network Fabric. Most of the functionality of this fabric is associated with the Distribution Device, but the Distribution Network is included also as the functionality of the distribution device can itself be distributed. An additional element of this fabric could be an Interworking Unit which would allow interconnection to other network types.

The home network fabric can consist of a number of different options, examples of which are shown in Figure A-1 and described below.

1. a virtual wire (i.e., null fabric)
2. a simple broadcast fabric which copies all cells to multiple ports. Upstream, this fabric must multiplex the cells together appropriately.
3. a selective broadcast fabric which selects which cells are to go to which port, but which can also broadcast selected VCs
4. an ATM switch fabric which is capable of local switching within the home as well as handling the interface to the network. There are a number of possible variations of this fabric.
5. This switch fabric could be centralized (one box) or distributed (many boxes).

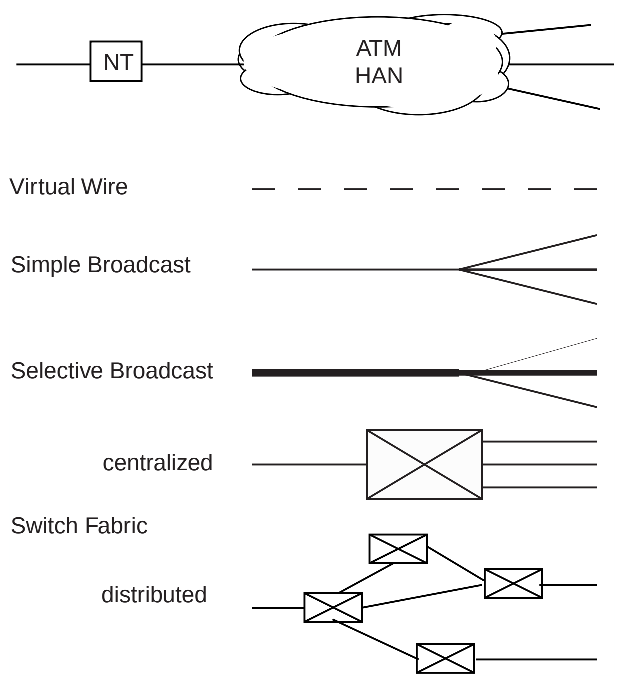

Figure A-1 Home Network Fabric

A.1.2 Higher level switching

It is also possible to have an additional component such as that needed to perform IP routing. This would perform the IP layer interconnection required in the home and would be part of the home network fabric and could be considered an adjunct to the home network fabric. Additional control intelligence may be required to manage this function.

A.1.3 Interworking Unit

An interworking unit would be required to provide interconnection to non-ATM based items of TE and/or other network types such as 10/100BaseT (Ethernet), IEEE 1394, Universal Serial Bus (USB), POTS or ISDN. However the functionality required to implement such interworking can be quite complex, and does not form part of this specification, although the relationship between ATM and IEEE 1394 in the home is considered in slightly more detail in Section A.4.

A.1.4 Example Home Network Fabric

An example home network fabric which might be relevant to VDSL delivery is shown in Figure A-2. A VDSL interface has the capacity to support a number of terminals in the home. In this case, the home network is simply copying all of the incoming ATM traffic to all of the outgoing ports by using a simple broadcast fabric. The end devices would select their traffic. This type of home network allows for multiple copies of movies to be available on several televisions in the home. The upstream multiplexing could be handled in a number of ways with differing degrees of control.

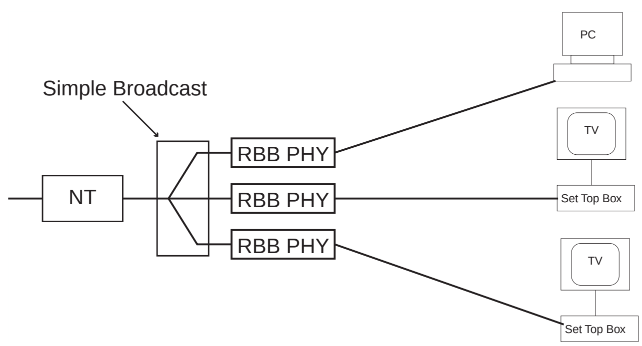

Figure A-2 VDSL interface to multiple ATM interfaces using simple broadcast

A.2 Example Configurations Permitting Multiple Attachment

The purpose of the home ATM network is to allow the attachment of a number of devices. Full and unrestricted support of TM 4.0 functions requires full ATM switching functions. However, reduced complexity implementations which potentially limits full TM 4.0 support may be desirable. This section outlines possible ways in which a small number of devices could be attached without requiring a full switch.

A.2.1 Minimum Network Configuration

There are two distinct types of service likely to be offered in early deployment:

1. video based entertainment to a STB
2. data/information services to a PC.

It can therefore be argued that the minimum useful number of ports to be provided is 2. In order to avoid the cost, logistical and perceptual problems associated with having to have a separate box to provide more than one connection, such functionality could be incorporated into an existing network element, in particular the device containing the NT, but this discussion does not depend on this.

A simple way of providing 2 ports is shown in Figure A-3. Downstream traffic is copied to both ports, thereby avoiding having to perform cell routing in the Home Distribution Device. Upstream traffic is simply multiplexed together. There is no provision for intra-home communication.

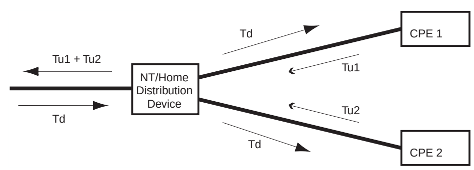

Figure A-3 Simple 2 device connection

This approach has the following functional and system implications.

QoS

Downstream QoS will be preserved automatically, but upstream QoS will only be preserved if there is some means of communicating a mapping of VCs to the appropriate priority queue.

Device signaling

Devices cannot share the default signaling VCI, and so have to use meta-signaling to get a dedicated signaling channel. The downstream broadcast does not prevent this from working properly however as there is an identifier with the signaling request. Metasignaling is not included in the ATM Forum SIG 4.0 or UNI 3.1 specifications. Therefore, devices connected to such an arrangement will need to implement metsignaling (ITU-T Recommendation Q.2120) in addition to the protocols specified in SIG 4.0.

Addressing

The end devices have to know which VCs pertain to them as all cells are transmitted to all attached devices. However they have to know this anyway to deliver the cell stream to the correct SAP.

Queues/buffers

Downstream - sufficient buffering is required in the Home Distribution Device to allow for rate adaptation.

Upstream - sufficient buffering is required in the Home Distribution Device to multiplex together all the traffic and to allow for rate adaptation. Capabilities may be required to permit objectives for maxCTD and CDV to be offered and to provide adequate CLR performance.

A.2.2 Adding Additional Ports

The same approach could be used with an increased number of ports thereby allowing the connection of a greater number of devices but without any other additional functionality. However the more ports that are added, the greater the need to control the upstream quality of service.

A.3 Adding Additional Functionality

A.3.1 Downstream demultiplexing

The next step up in functionality is to demulitplex the downstream cells. The Home Distribution Device is now carrying out some routing and so needs to associate a VPI/VCI or range thereof with a physical port. This could be done by having a VP permanently associated with each port which could be established by default/manufacture. However this is both inflexible, and likely to cause problems of VP availability to the operator. The alternative is some kind of signaling. Having service specific ports i.e. having to connect to a particular port to get a particular service, should be avoided.

However, it is debatable whether this is of any great use on its own. In this scenario, the only downstream traffic source is via the Access Network connection, so as long as the in-home transmission system can transport the full downstream bit-rate, it does not matter how efficiently it does it; there is nothing else the wasted bandwidth can be used for. Where intra-home communications is not supported, the only real advantage is that devices would not now receive unexpected streams of cells.

A.3.2 Intra-home communications

There is clearly some benefit to the user in having computing related intra-home communications over the home ATM network. This would allow both Access Network connection and in-home LAN type communication to take place using the same interfaces and physical infrastructure. From the user point of view it is highly desirable that this does not take place via the Access Network for two reasons:

1. the upstream bandwidth limitation of an xDSL transmission system would significantly limit the performance
2. the potential security/confidentiality risks of private data going outside the home.

The simplest way to achieve intra-home communication is to have a predetermined VP dedicated for this purpose. Any traffic with this VP arriving at the Home Distribution Device is simply routed to the other home port(s) on the Home Distribution Device, all other traffic is sent to the Access Network. Using an extra VP for this purpose does not pose the same VP availability problem as with Access Network connections, as the same VP can be used for this purpose in all homes. Also this pre-provisioning is not a disadvantage from a flexibility point of view.

Some simple, VP based, upstream routing is obviously now needed but this does not necessarily mean that downstream routing is required.

However there is a very important bandwidth and Quality of Service issue. There is now additional traffic over and above that from the Access Network, and yet this must not be allowed to interfere with the tariffed Access Network traffic. This could be done by signaling, or by keeping the two separate. Since the in-home transmission system has a significantly greater capacity than that xDSL based Access Network transmission systems, then the two could be interleaved in a simple way which did not affect the quality of service. In this simple case the downstream broadcast method could be retained. If the in-home capacity is not significantly greater than that of the Access Network delivery system, it would be necessary to demultiplex the downstream Access Network traffic.

A.4 Non ATM Home Networks

The proposal in Section A.3 mainly addresses the case of Access Network connection, and computing related home LAN traffic supported on the same network. However there are potentially other sources of in-home traffic, in particular digital video recorder and Camcorder related. While in principle these could be transported on the same network, there is a difference of scale as very large bit-rates can be involved in these types of transfer.

While the desire is to avoid a proliferation of types of in-home network, having more than one may be unavoidable. One possibility is some kind of segregation into local clusters served by IEEE1394, with WAN connection being achieved via ATM.

A possible architecture is shown in Figure A-4 where there is a separation into two domains. The STB has both ATM and IEEE1394 interfaces, but connection between the two is done at the application layer. Interconnection could also be done in a PC.

The ATM network could support intra-home communications with the addition or incorporation of the functionality described in Section A-3. This would be intended for PC type networking rather than as a backbone between IEEE1394 clusters because of bandwidth limitations. The IEEE1394 network inherently supports intra-cluster communications, but would depend on the development of a long reach version to allow inter-cluster connection. PC networking could be done on either the ATM or IEEE1394 network, subject to the above developments.

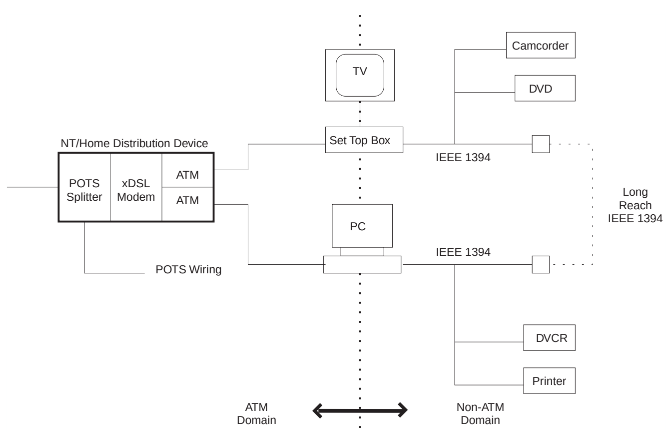

Figure A-4 Connection between ATM and non ATM home networks