TECHNICAL REPORT

DSL Forum TR-032

CPE Architecture Recommendations for Access to Legacy Data Networks

May 2000

Abstract:
This document describes four protocol architectures for connecting a remote ADSL termination unit (ATU-R) to hosts in a customer premise in a legacy data environment. The architectures confirm to Technical Report TR-012 and the requirements outlined in TR-018.

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1 Introduction

This document provides recommendations for the protocol architectures to be used in the deployment of ADSL Customer Premise Equipment. The architectures are developed in response to the requirements presented in ADSL Forum document TR-018, ÒReferences and Requirements for CPE Architectures for Data AccessÓ and in the context of TR-012, ÒBroadband Service Architecture for Access to Legacy Data Networks over ADSLÓ Issue 1, June 1998. Four models covering single-user and multiple-user Customer Premise scenarios are presented. These models are intended to be independent of the physical layer interfaces in the customer premise and can support a variety of dedicated connection technologies for single-user ATU-Rs as well as multiple access networks based on wireless standards, wired Local Area Network standards, or other physical layer media. References to specific physical layer technologies are included solely as examples.

The four models are connectivity offered to:
1. Single Host
2. Multiple Host, ATM Premises Distribution
3. Multiple Host, PPP extension via Local Tunneling
4. Multiple Host, Layer 3 Routing

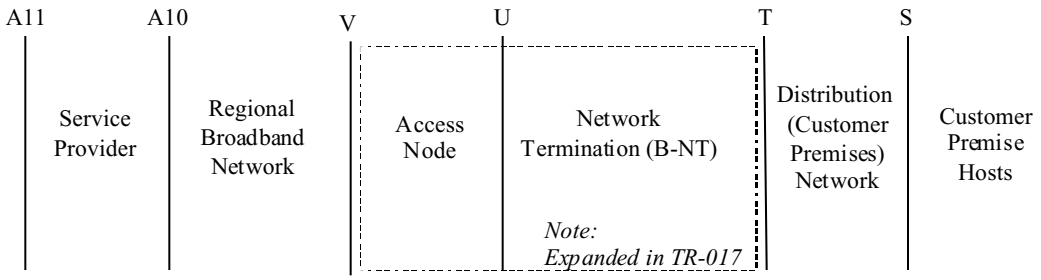
Each model is evaluated with the following outline:
- Application Benefit
- Architecture Requirements
- Core Network Implications
- Service Provider Net Implications

Terms and Acronyms

ATM	Asynchronous Transfer Mode
ATMF	ATM Forum
ATU-R	ADSL Termination Unit - Remote
CPE	Customer Premise Equipment
FB-UNI	Frame-Based User-Network Interface
L2TP	Layer 2 Tunneling Protocol
NSP	Network Service Provider
POTS	Plain Old Telephone Service
PPP	Point-to-Point Protocol
PPPoE	Point-to-Point Protocol over Ethernet
PPTP	Point-to-Point Tunneling Protocol
PVC	Permanent Virtual Circuit
QoS	Quality of Service
SVC	Switched Virtual Circuit
UNI	User-Network Interface
USB	Universal Serial Bus

2 Requirements

The ADSL Forum has adopted a reference model for consistent definition of interfaces in a broadband architecture. A refinement of that model has been used throughout the development of CPE architecture requirements, included as Figure 1 below.



NOTE: V, U, S and T correspond to ITU practice
A10 and A11 are borrowed from DAVIC as there are no ITU equivalents

Figure 1: Reference Model

The ADSL Forum ATM Architectures Group has developed a set of requirements that must be addressed by the architecture of ADSL customer premise equipment (CPE) and, if present, the customer premise network (CPN). That document, ADSL Forum TR-018, ÒReferences and Requirements for CPE Architectures for Data AccessÓ is incorporated by reference here as the background for these architectures. Note that TR-018 also assumes that the architecture conforms to TR-012, which specifies a PPP over ATM architecture at the U interface.

TR-018 describes requirements in 9 significant areas:

- Connectivity Requirements
- Simultaneous sessions to multiple NSPs
- Service Transparency
- Access Transparency
- Reliability
- Configuration
- Connectivity Administration
- Quality Capability
- Evolution

The compliance between the reference architectures and the usage scenarios is presented in Appendix A.

3 Reference Architectures

Four architectures have been identified that will fulfill the requirements of TR-018. The simplest architecture collapses the S and T interfaces inside a single host, usually by means of an internal ATU-R. The other three architectures all provide support for multiple hosts in the customer premise but can obviously support the simple case of a single host. Architectures 2 and 3 provide extension of the PPP session directly from the host, through the ATU-R to PPP termination at the network service provider. The fourth architecture moves the PPP termination from the host PCs to the ATU-R or a gateway directly connected to the ATU-R.

Single Host

This is the simplest model, providing a broadband connection to a single host in the customer premise. The S & T interfaces are internal to the host in the case of an internal modem (either directly on the host circuit board, or in an internal expansion slot, for example, PCI). This model is most applicable to the Work At Home and Internet Access Only usage scenarios.

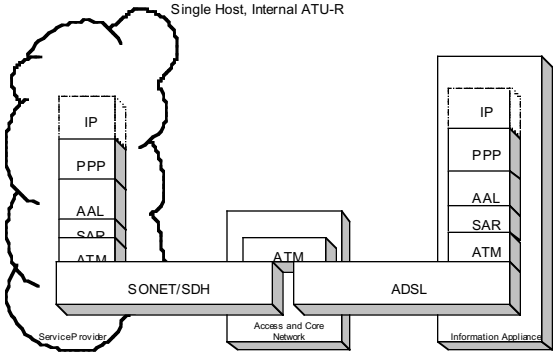


Figure 2: Single Host, Internal ATU-R

For external modems, the interface may be a private protocol or a public interface over a variety of different physical media.

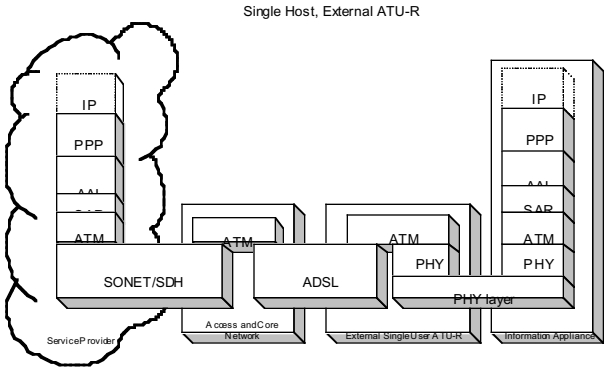


Figure 3: Single Host example, External ATU-R

3.1.1 Application Benefit

The simplest model to deploy is likely the PC with a factory configured DSL modem. In this case, the PC manufacturer can configure the hardware, drivers and operating system support for true "out-of-the-box" plug and play operation. The user only needs to connect the modem port on the host to the ADSL wall jack. Once ADSL service is provisioned to the customer premise, access to legacy data services will be available following the TR-012 PPP over ATM over ADSL model.

3.1.2 Architecture Requirements

The host must support PPP over ATM, either through native operating system support or through software distributed with the ADSL network interface equipment.

3.1.3 User Configuration Issues

The architecture requires configuration, via default settings or some administrative interface or protocol, of the ATM VPI/VCI values for each virtual channel connection. The use of PPP requires configuration of authentication information, including user identifier and password.

3.1.4 Core Network Implications

As the architecture fully complies with TR-012, there are no implications beyond the restrictions imposed by TR-012 on the core network.

3.1.5 Service Provider Network Implications

An underlying requirement for TR-012 was to minimize the impact on existing AAA systems at the network service provider. Transparent integration with the deployed PPP-based authentication and accounting infrastructures would speed deployment of high-speed DSL equipment.

Multiple Hosts, ATM Premise Distribution

The multiple hosts, ATM Premise Distribution model assumes an ATM connection from the host to an ATM termination point in the core network or at the network service provider. An example of this architecture would consist of an ATM multiplexer or switch integrated with an ATU-R, providing VCC multiplexing or switching facilities to hosts with ATM interfaces. The SOHO and Multi-Purpose Residential usage scenarios would be well served by this model.

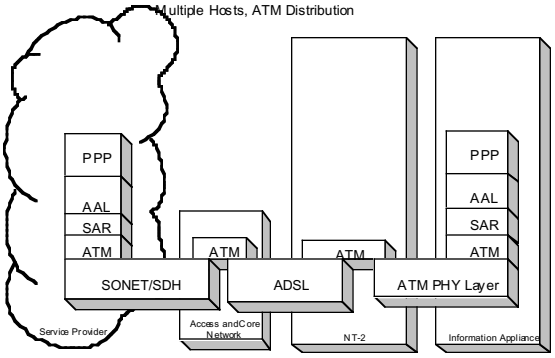


Figure 4: Multiple Hosts, ATM Local Distribution

3.1.6 Application Benefit

In this model, all the facilities of ATM are available from the host through the ADSL access network and all the way to the ATM termination in the network. If the ATM termination is integrated with the desired service hardware, ATM traffic management capabilities are available all the way from the requestor to the server. The connection-oriented nature of this model brings with it the benefits of the existing telephony model, particularly if the host operating system and supporting infrastructure support end-to-end switched virtual circuits (SVCs). Security, qualities of service and access policy models are particularly easy to provision and administer with this model.

3.1.7 Architecture Requirements

This model requires interfaces that support ATM for all hosts and network-connected devices on the local area network and support for ATM protocols in the host. The ATM protocol support may be distributed with the interface cards or may be native to the host operating system. The ATM Forum has developed physical layer specifications that may be appropriate.

3.1.8 User Configuration Issues

Each host will need to be configured to operate on the ATM network. In the absence of a set of standard defaults, switched virtual connections or some other automated provisioning system (e.g. ILMI PVC autoconfiguration), this model will require setting up ATM parameters including VPI, VCI and ATM service category and traffic contract parameters for each VC to be used from each host. In addition, the user will need to configure the user identifier and password for each PPP connection that will be used.

3.1.9 Core Network Implications

As the architecture encompasses TR-012, there are no implications beyond the restrictions imposed by TR-012 on the core network.

3.1.10 Service Provider Network Implications

This model provides the most homogeneous transport model, particularly if the ATM service is extended directly to the content server, providing true host-to-server ATM transport.

Multiple Hosts, PPP Extension via Local Tunneling

This architecture is designed to take advantage of low-cost, ubiquitously supported LANs like Ethernet while providing some of the benefits of the ATM premise distribution model. This model, which supports multiple hosts, is applicable to the SOHO and Multi-Purpose Residential usage scenarios.

The PPP Extension model uses tunneling technology to create a connection between a host and a gateway (which may be integrated with the ATU-R) over a connectionless media. Three technologies have been identified for use in this local tunneling application - the Point-to-Point Tunneling Protocol (PPTP), the Layer 2 Tunneling Protocol (L2TP) and PPP over Ethernet (PPPoE). These three protocols have been evaluated against the requirements outlined in TR-018 and comply as shown in Appendix A. Since the tunnel terminates at the gateway, the protocol stack at the U interface is PPP over AAL5. Thus, none of the tunneling protocol (including headers and packets associated with discovery or tunnel establishment) is carried across the U interface.

While the actual implementations are different, all three tunneling alternatives provide a way for the gateway to identify an individual user or service on a host and, using that identification, map the traffic into an ATM VC originating on the gateway. The gateway serves as a connection switch, directing packets between local tunnels at the T interface in the customer premise and ATM VCs over the U interface. This connection switch replaces the ATM switch of the ATM distribution architecture.

Each of the three tunneling technologies identified has different strengths. Those features are outlined in the table below:

	PPTP	L2TP	PPPoE
Standard status	Information track	Standards Track	Information Track
Multi-vendor	No	Yes	No
Local Transport Restrictions	IP only	Frame Relay, ATM and IP transports are currently defined	Ethernet
Current Deployment Status	Widely distributed with PC Operating System	Not widely deployed	Separately installable with a variety of operating systems

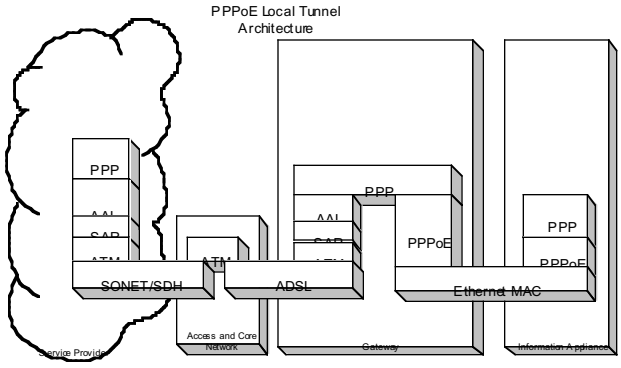


Figure 5: Multiple Hosts, PPPoE Local Tunnel Example

3.1.11 Application Benefit

This architecture takes advantage of the existing large scale deployment of Ethernet, adding the ability to extend the PPP model from the U interface into the customer premise to individual hosts. It provides many of the benefits of a true circuit-switched system including the ability to support end-to-end authentication at a fairly low protocol level. It also leverages the presence of PPP in host operating systems and PPP's capabilities to negotiate support for encryption, compression and other value-added features.

3.1.12 Architecture Requirements

Hosts on the LAN must have support for the chosen tunneling technology and interface cards for Ethernet or similar LAN technology. The tunneling technology may be native to the host operating systems or available through a user-installable upgrade package.

3.1.13 User Configuration Issues

This architecture requires the installation of a new protocol stack or shim to provide the tunneling technology. However, existing network applications and interfaces would be leveraged into this new environment, minimizing the complexity of end-user installation. For example, a PPPoE "shim" is a fairly "lightweight" addition to the existing PPP and Ethernet capabilities of most modern operating systems. Similarly, PPTP is available in many current PC operating systems, but not all legacy versions. This installation is no more complex than a standard application installation.

As in the previous PPP models, the user needs to provide authentication information (user identifier and password).

3.1.14 Core Network Implications

As the architecture fully complies with TR-012, there are no implications beyond the restrictions imposed by TR-012 on the core network.

3.1.15 Service Provider Network Implications

The PPPoE termination in the gateway has no fragmentation capabilities. Therefore, the Service Provider's nearest upstream router (BAS/LNS) must perform fragmentation when the packet size exceeds the PPPoE-specified MTU of 1492. In addition, the PPP termination device on the network side of the PPP connection MUST support PPP MTU negotiation.

Multiple Hosts, Layer 3 Routing

The fourth architecture leverages existing models that support multiple hosts over a shared WAN link. When the information appliance and one or more NSPs use the same Layer 3 protocol (typically IPv4), then the gateway performs Layer 3 routing to forward packets to an NSP. The Layer 3 forwarding process selects an ATM VCC, which connects the gateway to the NSP. When the information appliance uses a different Layer 3 protocol than the NSP, the gateway must perform any necessary encapsulation and address translation. A LAN provides connectivity between the Information Appliance and the gateway.

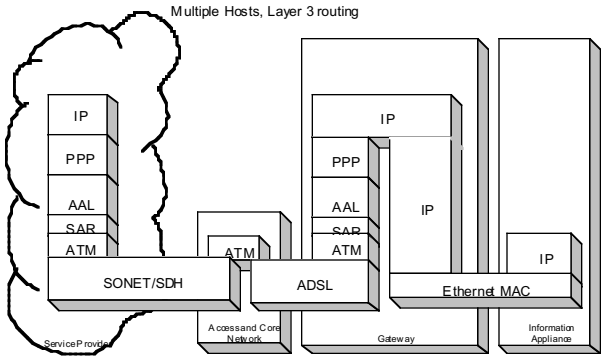


Figure 6: Multiple Hosts, Layer 3 Routing

3.1.16 Application Benefit

In general, this architecture requires no new software installation on the hosts in the customer premise. All current desktop operating systems provide support for Ethernet and TCP/IP. In addition, they all support configuration of the TCP/IP stack using Dynamic Host Configuration Protocol (DHCP) to minimize configuration requirements. Broad market penetration has made the CPN hardware widely available and inexpensive.

3.1.17 Architecture Requirements

The premises network must support TCP/IP, either with native operating system support or an operating system upgrade. Services on the local network should be located within the CPN to eliminate dependence on the access link for basic functions. Implementation of IP DiffServ support is recommended to support traffic prioritization.

3.1.18 User Configuration Issues

Most hosts that are connected to a network can participate in this model with no changes to their configuration. The gateway will need to be configured to match the configuration of the internal customer premise network and the external WAN. Use of configuration protocols like PPP and DHCP can automate much of this configuration. A TCP/IP stack, if embedded within the gateway, can support, for example, a web -based interface between each host and the gateway. Such interface can be used for NSP selection, service attribute selection, gateway monitoring and configuration.

Techniques that interwork private CPN Layer 3 addresses with NSP Layer 3 addresses, such as Network Address Translation and Port Address Translation in the IP environment, are often used in this architecture and are mandatory to support Dynamic NSP Selection (Requirement 11.1 of TR-018). The benefits of translation may come at the cost of restricting the use of some applications and protocols.

The gateway must provide a configuration mechanism for ATM, PPP and possibly Layer 3 parameters. A web-based interface could be used for such configuration.

3.1.19 Core Network Implications

Since the core network is simply transport for the Layer 3 protocols, this protocol architecture has no impact on the core network.

3.1.20 Service Provider Net Implications

Where there is a subnet in the home that is visible to the NSP network, service interruption in the ADSL connection will be propagated through the NSP network by routing protocols.

References

ADSL Forum Technical Report 12, ÒBroadband Service Architecture for Access to Legacy Data Networks over ADSLÓ Issue 1, June 1998.

ADSL Forum Technical Report 17, ÒATM Transport over ADSL RecommendationÓ March 1999.

ADSL Forum Technical Report 18, ÒReferences and Requirements for CPE Architectures for Data AccessÓ Issue 1, May 1999

ATM Forum Final Ballot Specification AF-FBATM-0139.00, ÒFrame-based ATM Transport over Ethernet (FATE),Ó February 2000.

Internet Engineering Task Force RFC 2364, ÒPPP over AAL5Ó G. Gross et al., July 1998.

Internet Engineering Task Force RFC 2516, ÒA Method for Transmitting PPP Over Ethernet (PPPoE)Ó L. Mamakos et al., February 1999.

Internet Engineering Task Force RFC 2637 ÒPoint-to-Point Tunneling ProtocolÓ K. Hamseh et al., May 1999.

Internet Engineering Task Force RFC 2661 ÒLayer Two Tunneling Protocol L2TPÓ W. Townsley et al., August, 1999.

Appendix A: Expected Compliance with TR-018 Requirements

These tables describe compliance in the most likely implementations of the protocol architectures. Compliance beyond what is indicated could be achieved through enhanced capabilities. Incorrect implementation may result in non-compliance.

C (Compliance) in this table implies that the capability is presented at the host interface by the referenced protocol suites.

Table 5.1 Connectivity Requirements				
Feature	**Single Host**	**Multiple Hosts**		
		ATM Dist.	**PPP Ext., Local Tunnel**	**Layer 3 Routing**
Sessions to Individual Appliances (5.1)	C	C	C	
Multi-Homing of Individual Appliances (5.2)	C		C	
Multiple sessions to a single NSP (5.3)	C			C
Simultaneous sessions to multiple NSPs (5.4)	C	C	C	C
Administer and Control Network Connectivity (5.5)	C	C	C	C
Support Intra-premise networking (5.6)	C	C	C	C
Simultaneous access via multiple access providers (5.7)	C	C	C	C

Table 6.1 Multi-Domain Requirements				
Feature	**Single Host**	**Multiple Hosts**		
		ATM Dist.	**PPP Ext., Local Tunnel**	**Layer 3 Routing**
Domain isolation/binding (6.1)	C	C	C	C
Security (6.2)	C	C	C	C

Table 7.1 Service Transparency Requirements				
Feature	**Single Host**	**Multiple Hosts**		
		ATM Dist.	**PPP Ext., Local Tunnel**	**Layer 3 Routing**
Support at least one layer 3 protocol (7.1)	C	C	C	C
Does not interfere with layer 3 service set (7.2)	C	C	C	C
Access Technology agnostic (7.3)	C	C	C	C
Premise technology agnostic (7.4)	C	C	C	C
Compatible with AAA services (7.5)	C	C	C	C
Does no preclude side by side w/ non-data services (7.6)	C	C	C	C
Support standard interfaces in the Premise (7.7)	C	C	C	C
Information Appliance Agnostic (7.8)	C	C	C	C

Table 8.1 Access Transparency Requirements				
Feature	**Single Host**	**Multiple Hosts**		
		ATM Dist.	**PPP Ext., Local Tunnel**	**Layer 3 Routing**
Access network isolation from premise configuration (8.1)	C	C	C	C
Fault isolation capability for access/premise boundary (8.2)	N/A	C	[1]	C

Table 9.1 Reliability Requirements				
Feature	**Single Host**	**Multiple Hosts**		
		ATM Dist.	**PPP Ext., Local Tunnel**	**Layer 3 Routing**
Minimize single points of failure (9.1)	[2]	[2]	[2]	[2]
Isolation of premise from network faults (9.2)	C	C	C	C
Premise not dependent on the network (9.3)	C	C	C	C

Table 10.1 Configuration Requirements				
Feature	**Single Host**	**Multiple Hosts**		
		ATM Dist.	**PPP Ext., Local Tunnel**	**Layer 3 Routing**
Simple Installation, Administration and Management (10.1)	C	C	C[3]	C
Provide Configuration Information (10.2)	N/A	C	C[4]	C

Table 11.1 Connectivity Administration Requirements				
Feature	**Single Host**	**Multiple Hosts**		
		ATM Dist.	**PPP Ext., Local Tunnel**	**Layer 3 Routing**
Dynamic NSP selection (11.1)	C	C	C	C
Subscriber Initiated Selection (11.2)	C	C	C	C
Always Accessible (11.3)	C	C	C	C

[1] Compliance depends on access to Layer 2 status information at the CPE.
[2] This document describes protocol models, not specific implementations. As such, it does not address reliability issues that are tied to the physical implementation of the functions.
[3] Use of PPTP or L2TP may require establishment of an IP network in the CPN, which would not be required for simple intra-premise services.
[4] PPPoE includes a discovery protocol that will provide configuration information. PPTP and L2TP require specific manual configuration.

Table 12.1 Quality Capability Requirements				
Feature	**Single Host**	**Multiple Hosts**		
		ATM Dist.	**PPP Ext., Local Tunnel**	**Layer 3 Routing**
Traffic prioritization (12.1)	C	C		C
Flexible bandwidth reservation and Management (12.2)	C	C		C
Latency appropriate for voice (12.3)	C	C		C[5]
Select VC based on QoS or CoS parameters (12.4)	C	C	C	C

Table 13.1 Configuration Requirements				
Feature	**Single Host**	**Multiple Hosts**		
		ATM Dist.	**PPP Ext., Local Tunnel**	**Layer 3 Routing**
Native ATM Services not Precluded (13.1)	C	C		
Independent evolution of PC and ATU-R (13.2)	C	C	C	C

[5] Requires massive bandwidth overprovisioning and a prioritization mechanism (for example, 802.1p) in the CPN.