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March 01, 2002

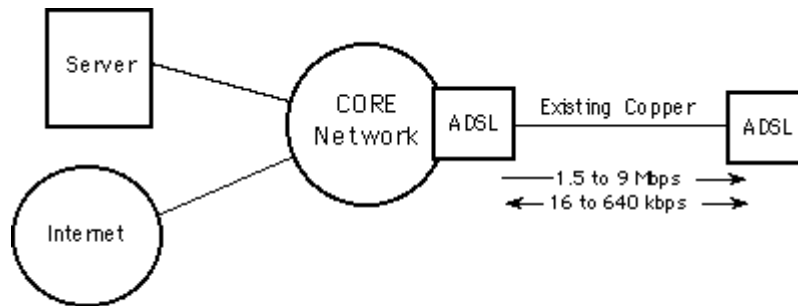
1.1. Introduction

Asymmetric Digital Subscriber Line (ADSL), a new modem technology, converts existing twisted-pair telephone lines into access paths for multimedia and high speed data communications. ADSL transmits more than 6 Mbps (optionally up to 8 Mbps) to a subscriber, and as much as 640 kbps (optionally up to 1 Mbps) more in both directions. Such rates expand existing access capacity by a factor of 50 or more without new cabling. ADSL can literally transform the existing public information network from one limited to voice, text and low resolution graphics to a powerful, ubiquitous system capable of bringing multimedia, including full motion video, to everyone's home this century.

ADSL will play a crucial role over the next ten or more years as telephone companies enter new markets for delivering information in video and multimedia formats. New broadband cabling will take decades to reach all prospective subscribers. But success of these new services will depend upon reaching as many subscribers as possible during the first few years. By bringing movies, television, video catalogs, remote CD-ROMs, corporate LANs, and the Internet into homes and small businesses, ADSL will make these markets viable, and profitable, for telephone companies and application suppliers alike.

Asymmetric Digital Subscriber Lines (ADSL) are used to deliver high-rate digital data over existing ordinary phone-lines. A new modulation technology called Discrete Multitone (DMT) allows the transmission of high speed data.

ADSL facilitates the simultaneous use of normal telephone services, ISDN, and high speed data transmission, eg., video.



ADSL Connection

DMT-based ADSL can be seen as the transition from existing copper-lines to the future fiber-cables. This makes ADSL economically interesting for the local telephone companies. They can offer customers high speed data services even before switching to fiber-optics.

1.1.1 System Architecture

ADSL is a newly standardized transmission technology facilitating simultaneous use of normal telephone services, data transmission of 6 Mbit/s in the downstream and Basic-rate Access (BRA). ADSL can be seen as a FDM system in which the available bandwidth of a single copper-loop is divided into three parts. The baseband occupied by POTS is split from the data channels by using a method which guarantees POTS services in the case of ADSL-system failure (eg. passive filters).

A flexible way to connect various servers to corresponding application's device is to use ATM-switches. Local ATM-switch is connected to an access module in a telephone central office. The access module is used to connect the ATM network to phone-lines. In the access

module ATM data stream from server is decomposed and routed to the corresponding phone-lines.

There is a large number of different kind of servers that can be accessed by an ADSL system. An employee using a work-at-home-server can take full advantage of the high-speed capabilities of an ADSL-system in many ways, e.g., running licensed software, downloading CAD, documents etc.

Video-on-Demand-service is one of the most interesting aspect of ADSL. By using MPEG-coded video it is possible to deliver video-quality movies over existing copper-loops to customers. A video-quality can be achieved by only 1.5 Mbps data rate. Together with pure VoD-services there might exist combined movie/information/advertiser-services in which commercial and non-commercial information providers and advertisers can deliver their information.

Popular culture has suddenly embraced telecommunications with great fervor, viewing the telecommunications industry as the vehicle to bring mass voice, data, and video communications to everyone in the world. Telecom companies are working to satisfy the massive demand for telecommunications services, but are quickly finding that the demand is far outweighing their current capacities.

While the interexchange carriers have been quietly renovating their long-haul networks to fiber, high-bandwidth networks, the local telephone companies have been content with their current hardware, servicing customers locked into a monopoly environment. As the interexchange carriers and cable television carriers move into the local telephone market, the

Regional Bell Operating Companies (RBOC) and other local telephone outfits are scurrying to meet their customer's new demands.

Customers, both residential and small business, are beginning to look beyond simple analog voice services. While the prices of dedicated T1's and fractional T1's have prohibited them from other services in the past, they are noticing their neighbors and competitors enjoying access to the Internet, their corporate intranet, and video conferences. The customers want high-quality voice service, high-speed data service, video-on-demand, and video conferencing capabilities. And they want it cheap.

1. 2. ADSL Transport Capacity

1.2.1 Current Limitations on the Local Loop

An ADSL circuit connects an ADSL modem on each end of a twisted-pair telephone line, creating three information channels -- a high speed downstream channel, a medium speed duplex channel, depending on the implementation of the ADSL architecture, and a POTS (Plain Old Telephone Service) or an ISDN channel. The POTS/ISDN channel is split off from the digital modem by filters, thus guaranteeing uninterrupted POTS/ISDN, even if ADSL fails. The high speed channel ranges from 1.5 to 6.1 Mbps, while duplex rates range from 16 to 640 kbps. Each channel can be submultiplexed to form multiple, lower rate channels, depending on the system.

ADSL modems provide data rates consistent with North American and European digital hierarchies and can be purchased with various speed ranges and capabilities. The minimum configuration provides 1.5 or 2.0 Mbps downstream and a 16 kbps duplex channel; others provide rates of 6.1 Mbps and 64 kbps duplex. Products with downstream rates up to 8 Mbps and

duplex rates up to 640 kbps are available today. ADSL modems will accommodate ATM transport with variable rates and compensation for ATM overhead, as well as IP protocols.

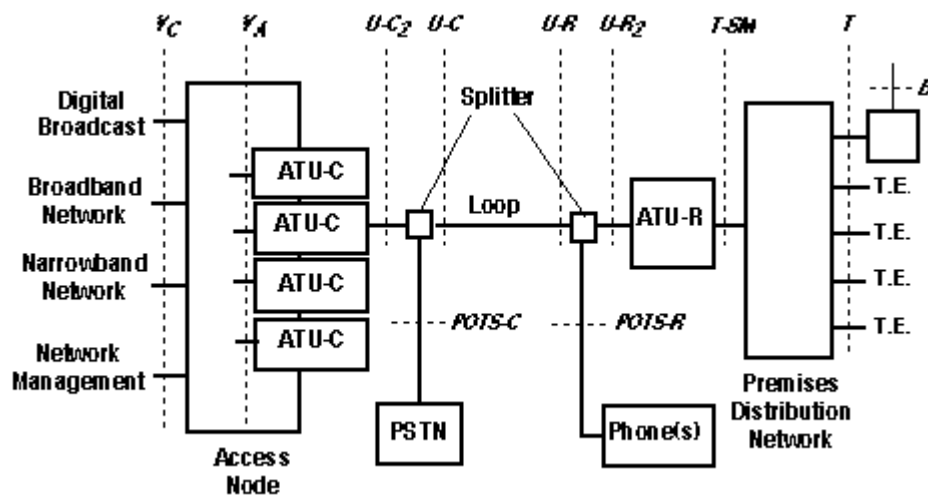
Downstream data rates depend on a number of factors, including the length of the copper line, its wire gauge, presence of bridged taps, and cross-coupled interference. Line attenuation increases with line length and frequency, and decreases as wire diameter increases. Ignoring bridged taps, ADSL will perform as follows:

1.2.2 Data Rate	Wire Gauge	Distance	Wire Size	Distance
1.5 or 2 Mbps	24 AWG	18,000 ft	0.5 mm	5.5 km
1.5 or 2 Mbps	26 AWG	15,000 ft	0.4 mm	4.6 km
6.1 Mbps	24 AWG	12,000 ft	0.5 mm	3.7 km
6.1 Mbps	26 AWG	9,000 ft	0.4 mm	2.7 km

While the measure varies from telco to telco, these capabilities can cover up to 95% of a loop plant depending on the desired data rate. Customers beyond these distances can be reached with fiber-based digital loop carrier systems. As these DLC systems become commercially available, telephone companies can offer virtually ubiquitous access in a relatively short time.

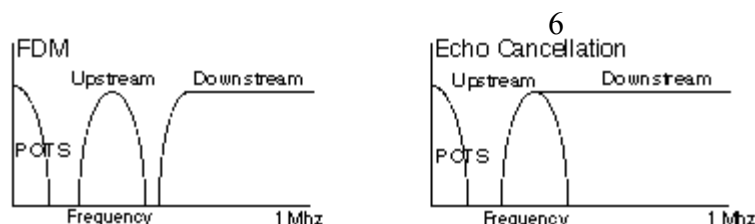
Many applications envisioned for ADSL involve digital compressed video. As a real time signal, digital video cannot use link or network level error control procedures commonly found in data communications systems. ADSL modems therefore incorporate forward error correction that dramatically reduces errors caused by impulse noise. Error correction on a symbol by symbol basis also reduces errors caused by continuous noise coupled into a line.

ADSL depends upon advanced digital signal processing and creative algorithms to squeeze so much information through twisted-pair telephone lines. In addition, many advances have been required in transformers, analog filters, and A/D converters. Long telephone lines may attenuate signals at one megahertz (the outer edge of the band used by ADSL) by as much as 90 dB, forcing analog sections of ADSL modems to work very hard to realize large dynamic ranges, separate channels, and maintain low noise figures. On the outside, ADSL looks simple --



transparent synchronous data pipes at various data rates over ordinary telephone lines. On the inside, where all the transistors work, there is a miracle of modern technology.

To create multiple channels, ADSL modems divide the available bandwidth of a telephone line in one of two ways -- Frequency Division Multiplexing (FDM) or Echo Cancellation. FDM assigns one band for upstream data and another band for downstream data. The downstream path is then divided by time division multiplexing into one or more high speed channels and one or more low speed channels. The upstream path is also multiplexed into corresponding low speed channels. Echo Cancellation assigns the upstream band to over-lap the



downstream, and separates the two by means of local echo cancellation, a technique well known in V.32 and V.34 modems. With either technique, ADSL splits off a 4 kHz region for POTS at the DC end of the band.

The installed subscriber line to many residential customers and small businesses is the standard two-wire local loop circuit. The original intention of the unshielded twisted-pair circuit was to transmit one analog voice channel, ranging from 300 Hz to 3400 Hz, over copper or aluminum wire, ranging in gauge and diameter. A subscriber loop's line attenuation may well vary from link to link

Modems allow customers to convert their computer's data stream into an analog format and transmit that data over their POTS (Plain Old Telephone Service) line, and with recent advances in modulation and compression, some modems now claim a 28.8 kb/s throughput over a standard POTS circuit. Unfortunately, the multimedia applications found on many computer networks are unusable at even 28.8 kb/s.

1.2.3 Barriers to the Fiber Market

One method to increase the available bandwidth to customers is to install a new circuit to their premises, most notably, using fiber optics. Fiber, however, is an expensive endeavor, considering the cost of the actual cable and the equipment needed to transmit and propagate a fiber signal to and from the central office. Many customers (and local telephone companies) are not willing to pay for fiber to every customer's premises.

1.2.4 Use the Existing Copper Pair

Why not take full advantage of the copper pair already installed to the customer's premises? With more than 800 million twisted pair copper telephone lines deployed worldwide, Local Exchange Carriers have a tremendous incentive to leverage this substantial asset against their new competitors. Asymmetric Digital Subscriber Line, or ADSL, allows LEC's to use existing copper plant in offering new bandwidth-intensive services. An ADSL modem is placed on each end of the loop to create a high speed link using the existing telephone network.

The idea for ADSL was spawned by Joe Lechleider, a Bellcore researcher, in the late 1980's. It was a natural extension of the digital subscriber line (DSL) access technology developed for Basic Rate Interface (BRI) ISDN. ANSI has assigned the number ``T1.413" to the ADSL standard.

1.2.5 An ADSL Network Architecture

Using the existing subscriber line already installed from the central office to the customer's premises, two ADSL devices are connected to both ends of the local loop. The ADSL functions at the central office are handled by the ATU-C (ADSL Terminal Unit). The ATU-C transmits high-speed simplex channels downstream, and sends and receives lower-speed duplex channels. The ATU-C units may either be standalone, or mounted with others in an equipment shelf. In the future, the ATU-C will be integrated into access nodes and remote access nodes.

The ATU-C is paired with its mirror image, an ADSL remote terminal unit (ATU-R). The ATU-R is generally a standalone device, and receives downstream data and transceives corresponding duplex data.

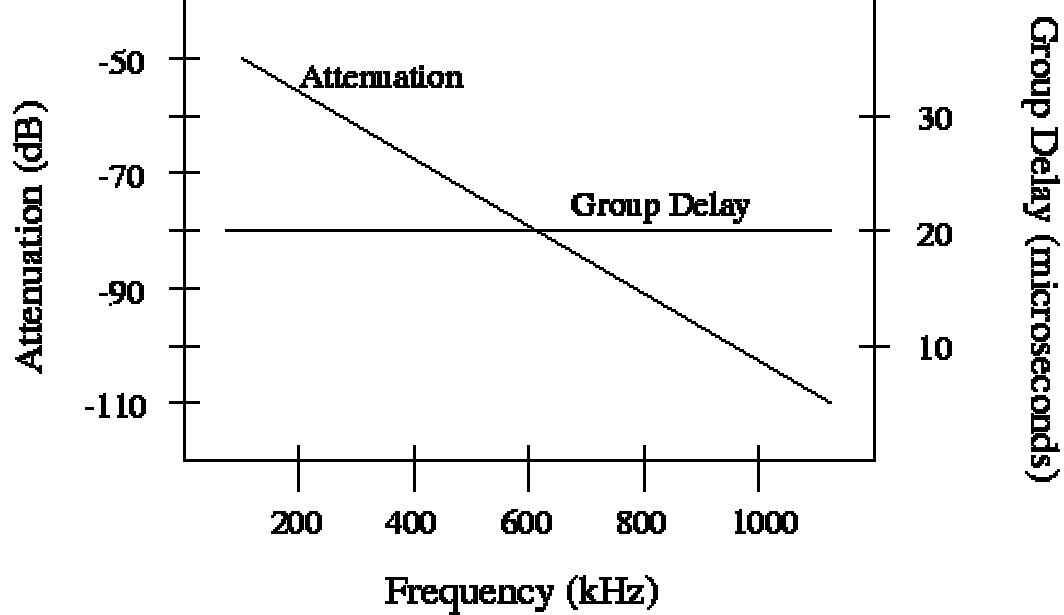
Local Exchange Carriers are beginning to analyze how to migrate from their current, analog voice service world, to a Full Service Network (FSN), offering voice, PC interconnection (LAN, Internet access, and CD-ROM), and residential entertainment video. ADSL is a cost effective way to begin that migration because:

- While solutions such as Hybrid Fiber-Coax (HFC) require large scale upgrades and depend on break-even points and a minimum number of subscribers within a geographic area, ADSL costs the same for every subscriber. "Serving the first home costs no more than serving the 500th home," says Bill Rodey, director of marketing at Westell Corp. There are no large "one-time" costs associated with major upgrades of wireline facilities.

- If another technology appears in a few years and some ADSL subscribers abandon their ADSL service, the service provider can recover their ADSL equipment and reuse them on future ADSL customers. The modularity of ADSL equipment permits the provider to reuse the equipment on many different customers

1.2.6 Loop Lengths and Requirements

Within the last ten years, it was recognized that unshielded twisted pair cables were being used in local area networks, carrying digital data at rates greater than 10 Mb/s. Bell Laboratories (U.S.) and British Telecom (U.K.) began researching the RF characteristics of the local loop. Figure indicates how the line attenuation and group delay varies for a typical section on UTP (Unshielded Twisted Pair) for frequencies up to 1 MHz (the upper limits of the ADSL spectrum)

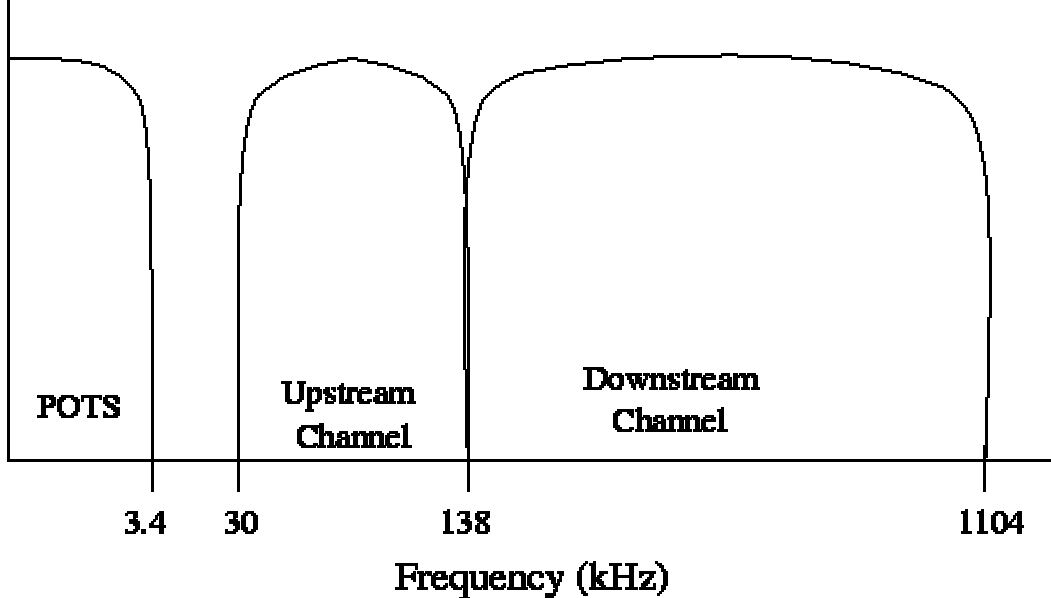


Attenuation is high for most of the ADSL spectrum, but the characteristic is fairly linear and easily equalized. More importantly, the group delay is practically constant so that any pulse distortion will be small

The downstream (high capacity) data rate is largely dependent on the length of the subscriber line from the central office and the gauge of the twisted pair cable.

1.2.7 ADSL Channel Configurations

Frequency Division Multiplexing (FDM) is used for ADSL over a 1 MHz spectrum. Figure 2 illustrates the general allocation of the frequency spectrum above the voice band



Besides the 0-3.4 MHz band of voice communications, ADSL provides for a low speed upstream channel (from subscriber to central office) and a high speed downstream channel (from central office to subscriber). The baseband occupied by POTS (Plain Old Telephone Service) is split from the data channels which guarantees POTS services in the case of ADSL system failure (e.g. passive filters).

Depending on the loop length and cable gauge, an upstream channel of 9.6 to 384 kb/s provides for the subscriber's need to transmit data, while a downstream channel of 1.544 to 7.000 Mb/s delivers TV, video on demand and computer network connectivity. ADSL can provide VCR-type functionality, like fast forward, rewind, freeze frame, pause, etc. - on demand.

1.3.0 System Issues

As the ADSL standard was being developed, many system issues were addressed, including:

1.3.1 Spectrum Compatibility

Other transmissions systems already installed (e.g. DS1 T-Carrier) could tamper with spectral compatibility and mutual crosstalk with ADSL systems. Analysis of the interaction between ADSL and DS1 T-Carrier resulted in specific deployment guidelines depending on whether T-Carrier was present and whether the two systems shared the same binder group.

1.3.2 Impulse Noise

While impulse noise has not appeared to be a significant performance impairment for DSL, HDSL, or T1 systems, data indicated that impulse levels were on the same order as ADSL signals and the spectra overlapped. ADSL system designs include forward error correction and coding schemes to counteract the burst error effects of noise impulses.

1.3.3 Radio Frequency Interference

While not expressed in the ADSL standard, there exists potential radio frequency interference from ADSL signal radiation leakage from the loop and inside wiring. Additionally, the AM broadcast band overlaps the ADSL frequency spectrum. It appears that as long as accepted practices for maintaining electrical balance between each of the two loop conductors, and the connecting circuitry and the external environment are followed, there should be minimum concern for radio frequency interference.

1.3.4 Modulation

While the ADSL standard specifies only one type of modulation, researchers have tested and implemented three different modulation techniques for use with ADSL: Quadrature Amplitude Modulation (QAM), Carrierless Amplitude-Phase Modulation (CAP), and Discrete Multi-Tone Modulation (DMT).

1.3.5 Quadrature Amplitude Modulation (QAM)

The binary data stream is split into two sub-streams and separately modulated onto orthogonal versions of the same carrier frequency. The two modulated signals are then added and low pass filtered before transmission to the network. This is the least used modulation technique for ADSL.

1.3.6 Carrierless Amplitude-Phase Modulation (CAP)

CAP ADSL equipment is available as an alternative to the industry standard DMT. CAP products were available before DMT equipment, and some vendors invested in CAP technology instead of waiting for the DMT equipment to mature. The bit stream is divided into two symbol streams and fed to two parallel in-phase and quadrature digital-shaping filters. The transfer functions of the two filters have the same amplitude characteristics, but the phase characteristics differ by 90 degrees. The outputs are added, passed through a digital-to-analog converter and filtered before being sent to the transmission network. Data encoded using CAP has the same spectral characteristics and provides the same theoretical performance as QAM, but does so without a carrier frequency. Eliminating carrier modulation (mixing) provides two key advantages. First, it facilitates a less expensive all-digital transceiver implementation by eliminating the computation-intensive multiply operations that are needed for carrier modulation and demodulation. Second, the absence of a carrier provides increased flexibility, because changing the spectrum's center frequency, symmetry and shape can be done easily by downloading a new set of filter coefficients.

1.3.7 Discrete Multi-Tone Modulation (DMT)

This modulation technique was decided upon as the ADSL standard. DMT was developed by Amati Communications and Stanford University, and commercialized by Northern Telecom. Each serial digital input signal is first encoded into a parallel form and then passed through a fast-Fourier-transform processor. This converts the frequency domain samples into time domain values with a sliding time-window effect. These values are then transcoded into a serial format and converted from digital to analog before transmission through the ADSL circuit.

Some of the most important parameters for standardized ADSL DMT are described below.

1.3.8 Pilot

Carrier 64 ($f=276$ kHz) is reserved for a pilot. The data modulated onto the pilot subcarrier shall be constant 0,0. Use of this pilot allows resolution of sample timing in a receiver modulo-8 samples.

1.3.9 Nyquist Frequency

The carrier at the Nyquist Frequency (256) may not be used for data.

1.3.10 Synchronization Symbol

The synchronization symbol permits recovery of the frame boundary after the micro-interruptions that might otherwise force retraining.

1.3.11 Unresolved Issues with ADSL

Questions still remain for ADSL, such as:

- How can ADSL systems allow for the graceful evolution from ADSL system installations to possible future hybrid fiber-coax or fiber optic upgrades of the outside plant?
- How can ADSL systems be provisioned without the individual customer service design or loop conditioning? How robust is ADSL to loop structure conditions, common loop faults, and interference from other transmission systems?
- How can ADSL systems accommodate the transport of existing analog broadband services, like non-premium television channels, without requiring a set-top box for each customer's premises?

2.0 Framing and Encapsulation Standards for ADSL

2.1. INTRODUCTION

This technical report defines a method for transferring variable length Layer 2 frames and/or Layer 3 packets over an ADSL link. This document describes:

- the framing mechanisms and
- protocol encapsulation capabilities

required to provide a transmission facility over ADSL links regardless of transmission layer line code. This is one document in a series of ADSL Forum technical reports that address transferring variable length frames over an ADSL link. Future documents in this specification series will describe:

- implementation specifics for different physical layers
- signaling
- management requirements
- other features

required to insure multivendor interoperability for these ADSL links. This specification makes no recommendations or requirements for the wide area network interface between the ATU-C and the Network Service Provider.

This specification relies heavily on existing standards, defined by the ISO, ITU-T, ATM Forum, and IETF standards bodies, applying them with only minimal modification to the transport of data link layer frames over ADSL links. In particular, it defines two allowable operating modes:

- PPP in HDLC-like frames (RFC 1662 mode)
- ATM Frame UNI (FUNI) frames (FUNI mode)

For this specification, the ADSL physical layer is viewed as simply a point-to-point bit stream provider. The ADSL Forum Reference Model, a Reference Diagram for this specification and some critical terminology is presented below.

2.1.2 Packet Mode Reference Diagram

This document uses some additional terms to describe the service points and administrative domains that play a role in this specification. In particular, the document

separates the concept of network access from network service. A Network Access Provider (NAP) is the administrative entity that terminates the central office end of an ADSL line. The Network Service Provider (NSP) is the administrative entity that provides access to higher-level network services. Examples of Network Service Providers are Internet Service Providers or corporate offices providing network services to a remote office or telecommuter. Note that the NAP and NSP might be in the same administrative domain, but need not be. For example, an operator could provide both ADSL service and Internet Access. The NAP and NSP are defined separately in this document to clarify the roles that each play in an end-to-end service scenario. Figure 1-2 shows these entities.

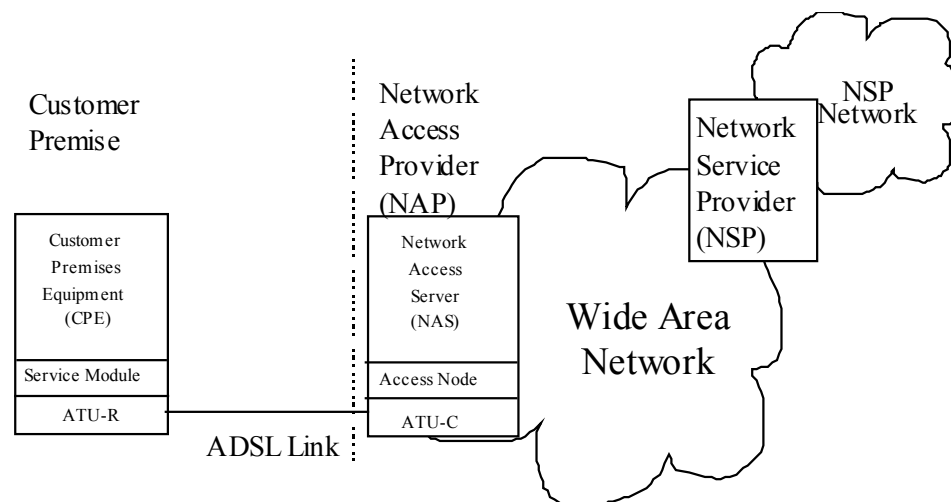


Figure 2.1-2: ADSL Packet Mode Reference Diagram

2.2. RFC 1662 MODE

This section describes one of two operating modes allowed under this standard for transporting variable length frames between an ATU-R and ATU-C over the ADSL link (across

the U interface in the ADSL Forum reference diagram above Figure 1-1). This operating mode leverages existing implementations¹ of the Point-to-Point Protocol (PPP) by following, exactly, the Internet Engineering Task Force Request for Comments (IETF RFC) document RFC 1662 *PPP in HDLC-like Framing*,¹ Simpson, W., Ed.

2.2.1 PPP in HDLC-like Framing

Implementations operating in this mode MUST conform to RFC 1662, specifically following the recommendations for bit-synchronous links and ignoring specifications for asynchronous and octet-synchronous links. There are several references in RFC 1662 to ISO 3309, the standard for HDLC frame structure; implementers may refer to that ISO document for clarification, but where there are differences, implementations over the ADSL facility MUST follow RFC1662. Figure 2-1 below shows the format of packets transported using this operating mode.

¹ For example, this mode would allow an existing PPP device to be connected to a Packet Mode ATU-C using a bit-synchronous ATU-R "modem".

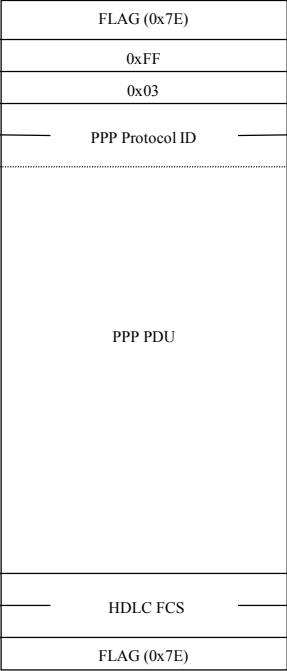


Figure 2-1: RFC 1662 framed PPP Format

2.2.2 *PPP Encapsulation*

Data encapsulation within RFC1662 framing is described in many other RFCs that provide a rich system for transporting multi-protocol data over Point-to-Point links. In particular, implementers are referred to the following RFCs as examples of the supporting IETF standards documents:

- RFC 1661 - The Point-to-Point Protocol
- RFC 1332 - The PPP Internet Protocol Control Protocol (IPCP)

Additional RFCs extend PPP for other protocols, bridging, encryption, compression, and authentication. All such implementations² that are valid over RFC 1662 are valid over an ADSL facility implementing this PPP operating mode with the following exception. Section 4.3 below allows a compliant implementation to switch between operation in this RFC 1662 mode and FUNI mode operation.

2.3. FRAME USER NETWORK INTERFACE (FUNI) MODE

The second allowed operating mode for standard-compliant implementations is based on the FUNI specifications from the ATM Forum. In particular, ADSL end points transmitting variable length frames or packets across the U interface MUST implement the FUNI variant described in this specification when operating in this FUNI mode. Currently, the only FUNI features specified by this document are basic frame structure and encapsulation methods. Other features such as ILMI and OAM support are under study for future technical reports in this series.

2.3.1 FUNI Framing

ATM Frame UNI (currently under revision to version 2, defined in ATM Forum document *str-saa-funi_01.01*) is a derivative of ATM Data Exchange Interface (ATM DXI, ATM Forum *af-dxi-0014_000.doc*). Like the PPP operating mode, the framing is a member of the HDLC family of data link control protocols and, in this implementation, uses the same number of header bytes. It uses standard HDLC start and stop flag bytes to guarantee flag recognition and bit-stuffing to achieve data transparency. The ATM FUNI frame header contains address and control fields. The address field encodes the Service Data Unit's (SDU) virtual connection Virtual Path Identifier (VPI) and Virtual Connection Identifier (VCI).

The multiplexing of multiple network layer protocols on a single FUNI virtual connection using RFC1483 LLC or PPP is discussed below in section 3.2, entitled *Protocol Encapsulation*.

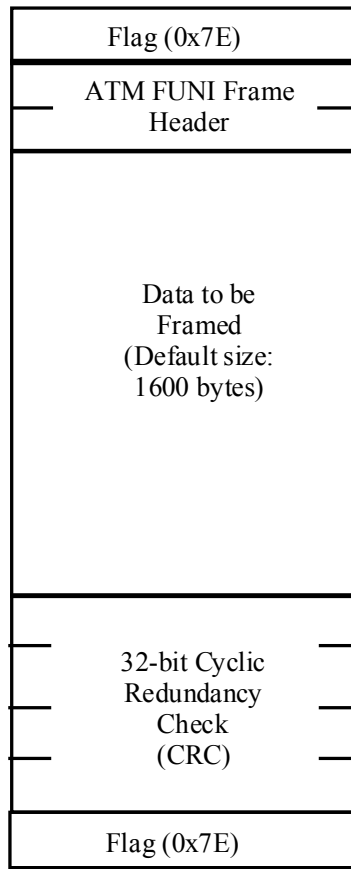


Figure 2-2: ATM Frame UNI Format

2.3.1.1 Frame Structure

Implementations of this specification operating in FUNI mode **MUST** frame data using the ATM FUNI derivative of HDLC framing as described in ATM Forum *str-saa-funi-01.01* with specific restrictions as outlined below. This framing **MUST** include a two-byte frame header and four-byte CRC. Implementations **SHOULD** support the Congestion Notification (CN) and Cell Loss Priority (CLP) bits as described in ATM Forum *str-saa-funi-01.01* section 3.2. At initialization, the default maximum size of the data framed between the FUNI header and the CRC **MUST** be 1600 bytes to allow interoperation with most foreseeable encapsulations of

1500 byte Ethernet frames. Implementations MAY negotiate other maximum size frames through mechanisms that are outside the scope of this document.

2.3.1.2 Address Assignment

Specific VPI/VCI addresses for ADSL physical layer management, vendor-specific channel and default user data channel will be defined in future technical reports in this series.

2.3.2 Protocol Encapsulation

A conforming FUNI mode implementation at the ADSL U interface MUST support the protocol multiplexing techniques defined in RFC 1483 iMulti-Protocol Encapsulation Over ATM AAL5¹. The specifics of applying RFC1483 to FUNI mode implementations are described in this section 3.2.

RFC 1483 describes two multiplexing techniques (refer to RFC 1483 section 2):

- LLC encapsulation
- Virtual circuit based multiplexing.

If an implementation supports this FUNI mode, it MUST support one of these RFC 1483 multiplexing modes over the Frame UNI and SHOULD support the PPP over FUNI virtual circuit based encapsulation described in section 3.2.2 below.

2.3.2.1 LLC Encapsulation

One encapsulation technique specified in RFC1483 uses a multi-protocol IEEE 802.1 LAN Logical Link Control (LLC) header to encapsulate the payload. FUNI mode

implementations may use this technique for all FUNI payloads, with one important exception for PPP. PPP PDUs over ADSL FUNI circuits MUST be transported using the Virtual circuit based multiplexing described in section 3.2.2 below.

2.3.2.2 Virtual circuit based multiplexing

RFC 1483 also allows alternate encapsulations by using virtual circuit based multiplexing. Any payload may be transported in a FUNI frame without any additional encapsulation; there is no in-band LLC based protocol type discriminator at the beginning of the frame's information field. In this scenario, the end systems create a distinct parallel virtual circuit connection for each payload protocol type. See Figure 5-4 and Figure 5-5 of Section 5 for example frame diagrams. The lack of any protocol type discriminator means that there MUST be some other (out-of-band) method for the endpoints to agree on the interpretation of the payload that immediately follows the FUNI header. See RFC 1483 for further explanation of this multiplexing mode.

This ADSL Forum standard defines a special case for PPP payloads inside FUNI frames. A compliant implementation that chooses to carry Point-to-Point Protocol (PPP) PDUs inside a FUNI frame (PPP over FUNI) MUST carry the PPP PDUs directly over FUNI using Virtual circuit based multiplexing. PPP MUST NOT be encapsulated within an LLC header when framed by a FUNI header across the ADSL U interface.

2.4. IMPLEMENTATION REQUIREMENTS

Section 2 (RFC 1662 mode) and section 3 (FUNI mode) define two methods for framing and encapsulating packet data over the **U** interface specified in Figure 1-1: The ADSL Reference Model. This section defines procedural aspects as they pertain to the ATU-R and the ATU-C.

2.4.1 ATU-C Attributes

The ATU-C **MUST** support the following:

- RFC 1662 mode, as described in Section 2
- FUNI mode, as described in Section 3.

2.4.2 ATU-R Attributes

The ATU-R **MUST** support **AT LEAST ONE** of the following:

- RFC 1662 mode, as described in Section 2
- FUNI mode, as described in Section 3.

2.4.3 General Attributes

Both the ATU-C and the ATU-R **MAY** support the following:

- The Vendor-specific channel for FUNI framing, as described in 4.4 Vendor

Specific Channel

An OPTIONAL vendor-specific channel is defined only for FUNI mode. This standard assigns a dedicated PVC channel for this connection. A well-known (TBD) VPI/VCI pair identifies the vendor-specific channel. For payloads that are outside the scope described in section 3.2 above, the vendor-specific virtual connection **MUST** be implemented and used. Examples of such uses might include

- Negotiation of or indication of private extension,
- Flash ROM updates
- Proprietary debugging
- And other vendor-specific actions.

All packets exchanged over the vendor specific channel **MUST** use RFC 1483 LLC encapsulation. Those packets containing vendor specific information **MUST** use a SNAP header having the IEEE assigned Organizationally Unique Identifier (OUI) value of the implementing vendor. Packets containing unrecognized OUI values **MUST** be silently discarded. Compliant devices **MUST** be able to interoperate without using this vendor-specific channel.

The Vendor Specific Channel may be used to negotiate extensions outside the standard. If both peers indicate agreement to such extensions (in some vendor-specific manner), then those extensions are not restricted in any way by this standard, including use of non-vendor-specific VPI/VCI pairs.

2.5. PACKET FORMATS

2.5.1 RFC 1662 Mode Packets

The packet format for PPP-based framing is:

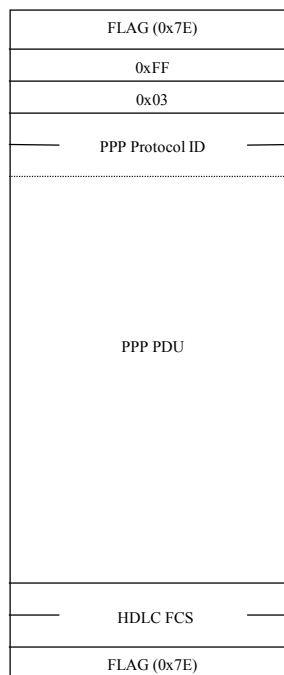


Figure 5-1: HDLC-like-framed PPP PDU

2.5.2 FUNI mode Packets

For FUNI implementations, packets (and frames) in the data plane are multiplexed and encapsulated per RFC 1483, using either LLC encapsulation or VC based multiplexing.

PPP frames, if transmitted, **MUST** be virtual circuit-multiplexed. Since, with VC-multiplexing, the carried network interconnect protocol is identified implicitly by the corresponding virtual connection, there is no need to include explicit multiplexing information. Therefore, the LLC multiplexing field is not included, and the PPP frame starts at the first byte of the FUNI Service Data Unit field.

The Vendor-specific channel, if implemented, **MUST** be LLC-encapsulated.

Packet formats for FUNI-based framing are:

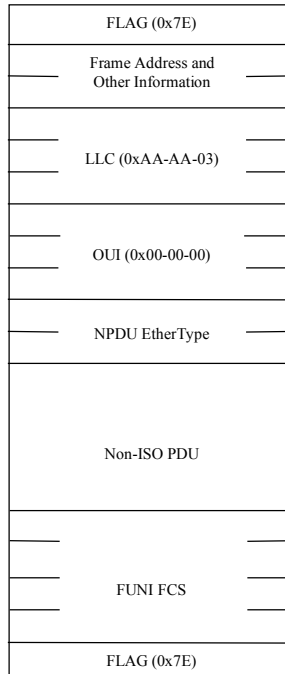


Figure 5-2: FUNI-based LLC-encapsulated non-ISO PDU

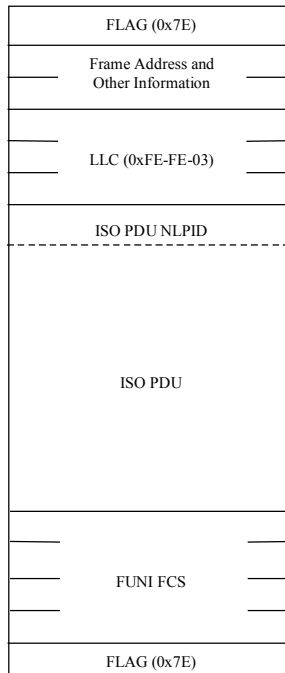


Figure 5-3: FUNI-based LLC-encapsulated ISO PDU

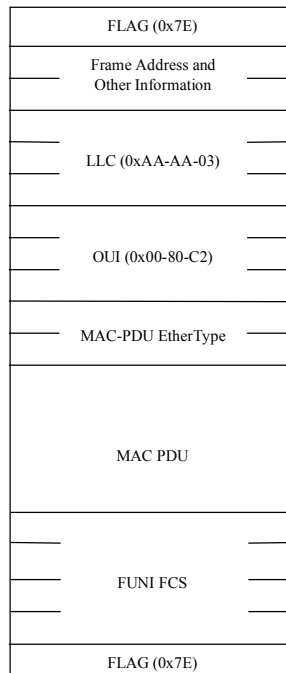


Figure 5-4: FUNI-based LLC-encapsulated MAC PDU

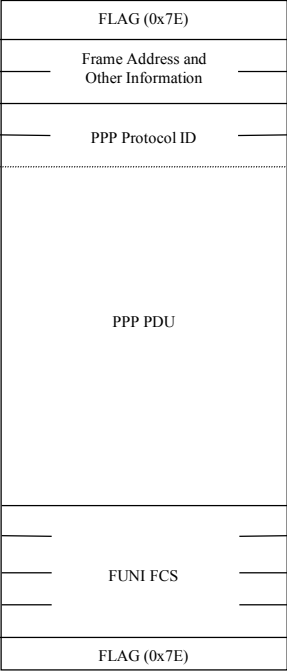


Figure 5-5: FUNI-based, VC-multiplexed PPP PDU

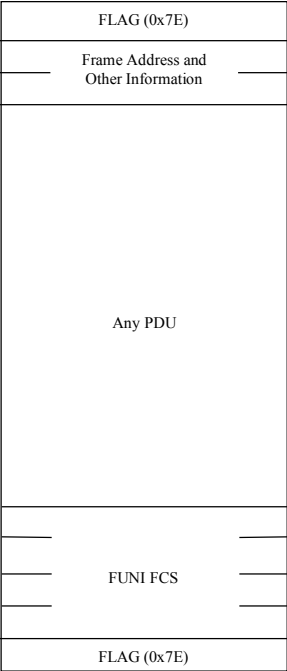


Figure 5-6: FUNI-based VC-multiplexed PDU
(requires pair-wise agreement of ADSL endpoints)

3.0 ADSL Network Element Management

3.1 Introduction

This document describes various network management elements required for proper management of ADSL physical layer resources where elements refer to parameters or functions within an ADSL modem pair, either collectively or at an individual end.

These elements have been defined without reference to a specific ADSL line code or means of communication between ATU-C and ATU-R.

The network management framework will be covered in Section 3 and SNMP specific implementation will be covered in Section 5.

3.2 Reference Model

Figure 1 below shows the system reference model adopted by the ADSL Forum. The network management elements covered by this project exist within ATU-C and ATU-R, and are accessed across the V interfaces. By intention, no network management element shall be accessible via the T interface (that is, by the customer). Glossary contains definitions of each interface in Figure 1.

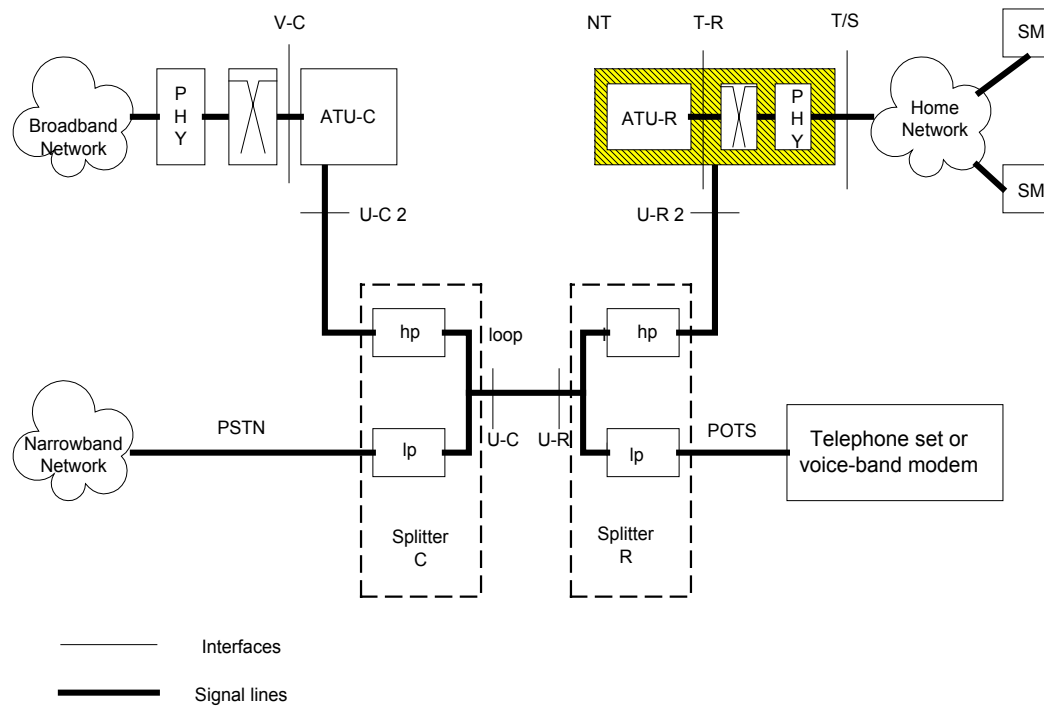


Figure 1 ADSL Forum System Reference Model

3.3 Network Management Framework

A network management framework consists of at least four components:

1. One or more managed nodes, each containing an agent. The managed node could be a router, bridge, switch, ADSL modem, or other.

2. At least one NMS (Network Management System), which is often called the manager. The manager monitors and controls managed nodes and is usually based on a popular computer.

3. A network management protocol, which is used by the manager and agents to exchange management information.

4. Management information. The unit of management information is an object. A collection of related objects is defined as a Management Information Base (MIB).

The MIB definition assumes the Agent is located at the ATU-C and acts as a proxy for the ATU-R.

To allow for potential expansion, the MIB will be defined to accommodate the aggregation, so an agent can be located in either a single ATU-C or Common Equipment to handle multiple ATU-Cs. Indexing scheme is used to accommodate this. The profile concept for configuration parameters will be used as an option to facilitate parameter management by the NMS. In case the use of the individual parameters is preferred, a profile can be created for each ATU-C.

Line code (DMT/CAP) specific objects will be defined in separate MIBs.

3.4 Network Management Elements

3.4.1 General

Network management refers to parameter, operations, and protocols for the following functions:

- a. Configuration Management: configuring an ADSL modem pair and maintaining inventory information
- b. Fault Management: discovering and correcting faults
- c. Performance Management: reporting operating conditions and history

Management includes five elements within the ADSL reference model:

- a. Management communications protocol across the Network Management sub-interface of the V interface.
- b. Management communications protocol across the U interface (i.e., between modems)
- c. Parameters and operations within the ATU-C
- d. Parameters and operations within the ATU-R
- e. ATU-R side of the T interface.

Note that issues presented here do not address management of POTS or metallic line testing, the T interface beyond the ATU-R (i.e., the premises distribution network or any interconnected CPE), or protocols above the physical layer. This Working Text does not cover protocols on the U interface. Standards groups ANSI T1E1.4 and ETSI TM6 are responsible for any standardized protocols at the U interface.

Network Management System as used in this document will refer specifically to any information or procedure that can be controlled or instituted via the V interface operations port, without prejudice to the nature of this port (which can be separated and embedded).

Management of all ATU-R parameters specified in this document may only be performed by an NMS via the “V” interface.

3.4.2 Element List

Table 1 lists the required set of elements for an ADSL system, divided into three categories: configuration, fault, and performance management. The ATU-C/ATU-R/ADSL Line column indicates for each element whether or not it should be managed at the ATU-C only, ATU-C & ATU-R, or ADSL Line. The Physical / Fast/Interleave column indicates for each element whether or not it is a physical layer element or a channelized element. The Read/Write column indicates for each element whether or not it is read only or read/write. N/A means not applicable. Please note that the location of the elements is not specified here.

The following terms used in Table 1 are described a little more to make it clear:

- ADSL Line - ADSL transmission facility, including the two ADSL Transmission

Units – ATU-C/R

- ATU-C – Central Office ADSL Modem
- ATU-R – Remote ADSL Modem
- Physical – The ADSL facility physical transmission medium
- Fast – The ADSL Fast transmission Channel as per ANSI T1.413
- Interleaved – The ADSL Interleaved Channel as per ANSI T1.413

Network Management Elements

Category Element ATU-C / ATU-R /Physical /Read/Write ADSL Line Fast/Interleave

Configuration

ADSL Line Type	ADSL Line	N/A	Read only
ADSL Line Coding	ADSL Line	N/A	Read only
Target Noise Margin	ATU-C & ATU-R	Physical	Read/Write
Maximum Noise Margin	ATU-C & ATU-R	Physical	Read/Write
Minimum Noise Margin	ATU-C & ATU-R	Physical	Read/Write
Rate Adaptation Mode	ATU-C & ATU-R	Physical	Read/Write
Upshift Noise Margin	ATU-C & ATU-R	Physical	Read/Write
Minimum Time Interval for	ATU-C & ATU-R	Physical	Read/Write

Upshift Rate Adaptation

Downshift Noise Margin	ATU-C & ATU-R	Physical	Read/Write
------------------------	---------------	----------	------------

Minimum Time Interval for	ATU-C & ATU-R	Physical	Read/Write
---------------------------	---------------	----------	------------

Downshift Rate Adaptation

Desired Maximum Rate	ATU-C & ATU-R	Fast/Interleave	Read/Write
----------------------	---------------	-----------------	------------

Desired Minimum Rate	ATU-C & ATU-R	Fast/Interleave	Read/Write
----------------------	---------------	-----------------	------------

Rate Adaptation Ratio	ATU-C & ATU-R	Physical	Read/Write
-----------------------	---------------	----------	------------

Maximum Interleave Delay	ATU-C & ATU-R	Interleave	Read/Write
--------------------------	---------------	------------	------------

Alarm (Event) Thresholds: 15 minute count threshold on

Loss of Signal	ATU-C & ATU-R	Physical	Read/Write
----------------	---------------	----------	------------

Loss of Frame	ATU-C & ATU-R	Physical	Read/Write
---------------	---------------	----------	------------

Loss of Power	ATU-C & ATU-R	Physical	Read/Write
---------------	---------------	----------	------------

Loss of Link	ATU-C only	Physical	Read/Write
--------------	------------	----------	------------

Errored Seconds	ATU-C & ATU-R	Physical	Read/Write
-----------------	---------------	----------	------------

Rate Up Threshold	ATU-C & ATU-R	Fast/Interleave	Read/Write
-------------------	---------------	-----------------	------------

Rate Down Threshold	ATU-C & ATU-R	Fast/Interleave	Read/Write
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Vendor ID	ATU-C & ATU-R	Physical	Read only
-----------	---------------	----------	-----------

Version Number	ATU-C & ATU-R	Physical	Read only
----------------	---------------	----------	-----------

Serial Number	ATU-C & ATU-R	Physical	Read only
---------------	---------------	----------	-----------

3.4.3 Configuration Management

Paragraphs below describe each element for configuration management.

All elements can be used for fast channel and / or interleaved channel except physical layer elements. Interleaving adds delay but provides greater immunity to impulse noise.

3.4.3.2 ADSL Line Type

This parameter defines the type of ADSL physical line. Five (5) ADSL line types are defined as follows:

- No channels exist
- Fast channel exists only
- Interleaved channel exists only
- Either fast or interleaved channels can exist, but only one at any time
- Both fast and interleaved channels exist

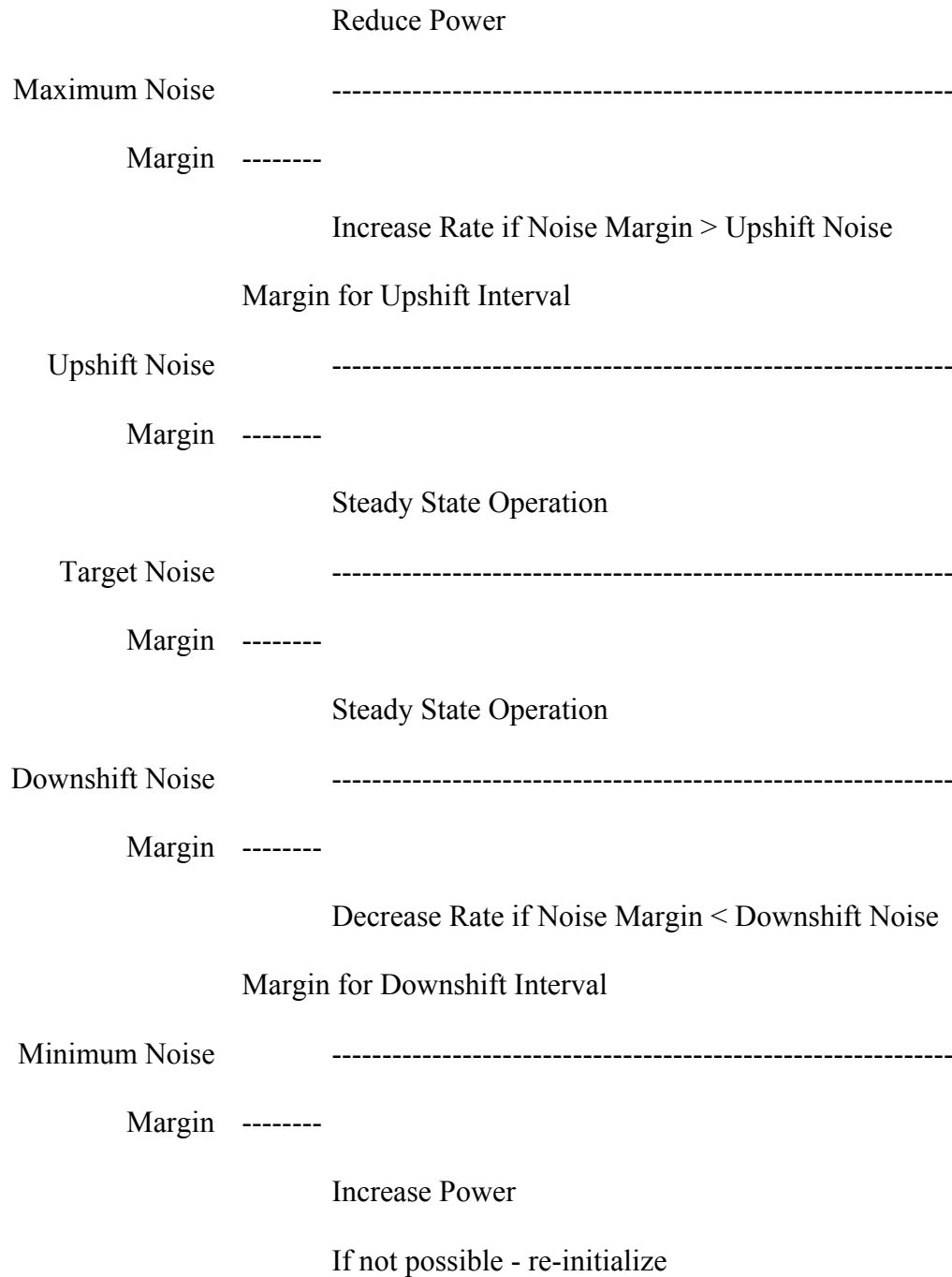
3.4.3.3 ADSL Line Coding

This parameter defines the ADSL coding type used on this line.

3.4.3.4 Noise Margin parameters

The following parameters are defined to control the Noise Margin in the transmit direction in the ATU-C & ATU-R. NOTE: The Noise Margin should be controlled to ensure a

BER (Bit Error Rate of 10^{-7} or better). Figure 2 shows the relationship between these parameters. They will be described in detail in the following paragraphs.



Noise Margins

NOTE:

1. Upshift Noise Margin, and Downshift Noise Margin are only supported for Rate Adaptive Mode.
2. Minimum Noise Margin \leq Downshift Noise Margin \leq Target Noise Margin \leq Upshift Noise Margin \leq Maximum Noise Margin

3.4.3.4.1 Target Noise Margin

This is the Noise Margin the modem (transmit from ATU-C and ATU-R) must achieve with a BER of 10^{-7} or better to successfully complete initialization.

3.4.3.4.2 Maximum Noise Margin

This is the maximum Noise Margin a modem (transmit from ATU-C and ATU-R) should try to sustain. If the Noise Margin is above this, the modem should attempt to reduce its power output to optimize its operation.

3.4.3.4.3 Minimum Noise Margin

This is the minimum Noise Margin the modem (transmit from ATU-C and ATU-R) should tolerate. If the noise margin falls below this level, the modem should attempt to increase its power output. If that is not possible, the modem will attempt to re-initialize.

3.4.3.5 Dynamic Rate Adaptation parameters

The following parameters are defined to manage the Rate-Adaptive behavior in the transmit direction for both ATU-C and ATU-R.

3.4.3.5.1 Rate Adaptation Mode

This parameter specifies the mode of operation of a rate-adaptive modem (transmit from ATU-C and ATU-R). (If this functionality is supported)

- Mode 1: MANUAL - Rate changed manually.

At startup:

The Desired Minimum Rate parameter specifies the bit rate the modem must support, with a noise margin which is at least as large as the specified Target Noise Margin, and a BER of better than 10^{-7} . If it fails to achieve the bit rate the modem will fail, and NMS will be notified. Although the modem might be able to support a higher bit rate, it will not provide more than what is requested.

When the noise margin for the selected transport configuration is higher than the Maximum Noise Margin, then the modem shall reduce its power to get a noise margin below this limit. (If this functionality is supported)

At showtime:

The modem shall maintain the specified Desired Minimum Rate. When the current noise margin falls below the Minimum Noise Margin then the modem will fail, and NMS will be notified.

When the current noise margin rises above Maximum Noise Margin, then the power shall be reduced to get the noise margin below this limit. (If this functionality is supported)

- Mode 2: AT_INIT- Rate automatically selected at startup only and does not change after that.

At startup:

The Desired Minimum Rate parameter specifies the minimum bit rate the modem must support, with a noise margin which is at least as large as the specified Target Noise Margin, and a BER of better than 10^{-7} . If it fails to achieve the bit rate the modem will fail, and NMS will be notified. If the modem is able to support a higher bit rate for that direction at initialization, the excess bit rate will be distributed amongst the fast and interleaved latency path according to the ratio (0 to 100%) specified by the Rate Adaptation Ratio parameter. The ratio is defined as Fast / (Fast + Interleave) bit rate x 100%. A ratio of 30% means that 30% of the excess bit rate should be assigned to the fast latency path, and 70% to the interleaved latency path. When the Desired Maximum Rate is achieved in one of the latency paths, then the remaining excess bit rate is assigned to the other latency path, until it also reaches its Desired Maximum Rate. A ratio of 100% will assign all excess bit rate first to the fast latency path, and only when the Desired Maximum Rate of Fast channel is obtained, the remaining excess bit rate will be assigned to the interleaved latency path, a ratio of 0% will give priority to the interleaved latency path.

When the noise margin for the selected transport configuration is higher than the Maximum Noise Margin, then the modem shall reduce its power to get a noise margin below this limit. Note: This can happen only when Desired Maximum Rates are reached for both latencies, since bit rate increase has priority over power reduction. (if this functionality is supported)

At showtime:

During showtime, no rate adaptation is allowed. The bit rate which has been settled during initialization shall be maintained. When the current noise margin falls below the Minimum Noise Margin then the modem will fail, and NMS will be notified.

When the current noise margin rises above Maximum Noise Margin, then the power shall be reduced to get the noise margin below this limit. (If this functionality is supported)

- Mode 3: DYNAMIC- Rate is automatically selected at startup and is continuously adapted during operation (showtime).

At startup:

In Mode 3, the modem shall start up as in Mode 2.

At showtime:

During showtime, rate adaptation is allowed with respect to the Ratio Adaptation Ratio for distributing the excess bit rate amongst the interleaved and fast latency path (see Mode 2), and assuring that the Desired Minimum Rate remains available at a BER of 10^{-7} or better. The bit rate can vary between the Desired Minimum Rate , and the Desired Maximum Rate. Rate Adaptation is performed when the conditions specified for Upshift Noise Margin and Upshift Interval - or for Downshift Noise Margin and Downshift Interval - are satisfied. This means:

For an Upshift action: allowed when the current noise margin is above Upshift Noise Margin during Minimum Time Interval for Upshift Rate Adaptation.

For a Downshift action: allowed when the current noise margin is below Downshift Noise Margin during Minimum Time Interval for Downshift Rate Adaptation.

When the current noise margin falls below the Minimum Noise Margin then the modem will fail, and NMS will be notified.

When Desired Maximum Rates have been reached in both latency paths, and when the current noise margin rises above Maximum Noise Margin, then the power shall be reduced to get the noise margin below this limit.

3.4.3.5.2 Upshift Noise Margin

If the Noise Margin is above the Upshift Noise Margin and stays above that for more than the time specified by the Minimum Upshift Rate Adaptation Interval, the modem should increase its data rate (transmit from ATU-C and ATU-R).

3.4.3.5.3 Minimum Time Interval for Upshift Rate Adaptation

This parameter defines the interval of time the Noise Margin should stay above the Upshift Noise Margin before the modem will attempt to increase data rate (transmit from ATU-C and ATU-R).

3.4.3.5.4 Downshift Noise Margin

If the Noise Margin is below the Downshift Noise Margin and stays below that for more than the time specified by the Minimum Downshift Rate Adaptation Interval, the modem should decrease its data rate (transmit from ATU-C and ATU-R).

3.4.3.5.5 Minimum Time Interval for Downshift Rate Adaptation

This parameter defines the interval of time the Noise Margin should stay below the Downshift Noise Margin before the modem will attempt to decrease data rate (transmit from ATU-C and ATU-R).

3.4.3.6 Bit Rate Parameters

These bit rate parameters refer to the transmit direction for both ATU-C and ATU-R. The two desired bit rate parameters define the desired bit rate as specified by the operator of the

system (the operator of the ATU-C). It is assumed that ATU-C and ATU-R will interpret the value set by the operator as appropriate for the specific implementation of ADSL between the ATU-C and ATU-R in setting the line rates. This model defined in this interface makes no assumptions about the possible range of these attributes. The Management System used by the operator to manage the ATU-R and ATU-C may implement its own limits on the allowed values for the desired bit rate parameters based on the particulars of the system managed. The definition of such a system is outside the scope of this model.

3.4.3.6.1 Desired Maximum Rate

These parameters specify the desired maximum rates (transmit from the ATU-R and ATU-C) as desired by the operator of the system.

3.4.3.6.2 Desired Minimum Rate

These parameters specify the desired minimum rates (transmit from the ATU-R and ATU-C) as desired by the operator of the system.

3.4.3.6.3 *Rate Adaptation Ratio*

These parameters (expressed in %) specify the ratio that should be taken into account for distributing the bit rate considered for rate adaptation amongst the fast and interleaved channels in case of excess bit rate. The ratio is defined as: $[\text{Fast} / (\text{Fast} + \text{Interleaved})] * 100$. Following this rule a ratio of 20% means that 20% of the additional bit rate (in excess of the fast minimum plus the interleaved minimum bit rate) will be assigned to the fast channel, and 80% to the interleaved channel.

3.4.3.7 Maximum Interleave Delay

The transmission delay is introduced by the interleaving process. The delay is defined as per ANSI T1.413, and is $(S \times d) / 4$ milli-seconds, where 'S' is the S-factor, and 'd' is the "Interleaving Depth".

3.4.3.8 Alarm (Event) Thresholds

Each ATU maintains current 15 minute interval counts. Each count may trigger an alarm (event) if it reaches or exceeds a preset threshold. Those thresholds shown in Table 1 will be set individually.

3.4.3.9 Rate Threshold

These parameters provide rate up and down thresholds which trigger a rate change alarm (event) when they are reached or crossed.

3.4.3.10 Inventory Information

Each ATU-R and ATU-C shall make accessible through the NMS port the following information: Vendor ID, Version Number and Serial Number. The hardware, software and firmware version are vendor specific fields and should be placed in an enterprise specific equipment MIB for SNMP implementation.

3.4.3.10.1 Vendor ID

The vendor ID is assigned by T1E1.4 according to T1.413 Appendix D, which contains a procedure for applying for numbers. The numbers are consecutively assigned, starting with 002.

3.4.3.10.2 Version Number

The version number is for version control and is vendor specific information.

3.4.3.10.3 Serial Number

The serial number is vendor specific and should be no longer than 32 bytes. Note that the combination of vendor ID and serial number creates a unique number for each ADSL unit.

3.4.4 Fault Management

3.4.4.1 Fault management applies to the process of the identifying the existence of a fault condition, determining its cause, and taking corrective action. For purposes here, faults will be notified by alarms (events) presented over the NMS port from the ATU-C. Network management systems may also determine faults, such as line deterioration, by examining performance reports. However, current telephone company practices favor alarm (event) driven fault management. For this reason the number of alarm (event) conditions, and range of configurability, is rather large. Note that some alarms (events) may not represent faults as such, but require operations notice because they interrupt service or represent sources for service calls. Unpowered ATU-Rs and unpowered connected CPE are examples.

3.4.4.2 ADSL Line Status

ADSL Line Status shows the current state of the line. The possible states are defined as follows:

- Operational
 - Loss of Frame
 - Loss of Signal
 - Loss of Power
 - Loss of Link (ATU-C only)

A Loss of Link condition is declared at the ATU-C if a Loss of Signal is not preceded by a 'dying-gasp' message from the ATU-R

- Loss of Signal Quality
- Initialization failure due to Data Error (ATU-C only)
- Initialization failure due to Configuration Error (ATU-C only)
- Initialization failure due to Protocol Error (ATU-C only)
- Initialization failure due to no Peer ATU present (ATU-C only)

3.4.4.3 Alarms (Events)

3.4.4.3.1 There is no distinction between major and minor alarms (events).

To generate alarm (event) on Loss of Signal, Loss of Frame, Loss of Power, Loss of Link, Error Seconds depends on the value of the counter reaching or exceeding the threshold value in a single 15 minute interval. The threshold value is configurable. When those alarms (events) clear, it will not report a trap to show the status change. The reason is if the alarm (event) condition

persists in next 15 minutes, it will generate another alarm. If no alarm (event) is generated in next 15 minutes, the NMS knows the alarm (event) clears.

Unable to initialize ATU-R from ATU-C will generate an alarm (event). When ATU-C is able to initialize the ATU-R, a clear alarm (event) will be generated.

Rate change will generate an alarm (event) consisting of configurable rate up and down thresholds on upstream and downstream rates, respectively.

All alarms (events) can be enabled/disabled. The default is disabled. Please refer to ANSI T1.413 for more detailed definitions of alarms (events).

Loss of Signal at ATU-R

Loss of Signal at ATU-C

Loss of Frame at ATU-R

Loss of Frame at ATU-C

Loss of Power at ATU-R

Loss of Power at ATU-C

Loss of Link at ATU-R for ATU-C

Error Seconds at ATU-R

Error Seconds at ATU-C

Unable to initialize with ATU-R (implies knowledge that power is on at ATU-R)

Rate change at ATU-R

Rate change at ATU-C

3.4.4.4 Fault Isolation

3.4.4.4.1 Fault isolation falls more to operations strategy and practices than anything necessarily inherent in the modems and may need to be coordinated with other forms of testing, such as MLT. However, modem tests and test sequences can be helpful in isolating faults to a particular element in a link, comprising an ATU-C, its POTS splitter, the line, the ATU-R POTS splitter, the ATU-R, and equipment attached at the T interface.

3.4.4.4.2 To assist fault isolation the modem systems shall provide the following diagnostics under control of commands transmitted across an NMS port:

3.4.5 Performance Management

Each ATU-R and ATU-C shall make accessible through the NMS port the following performance/status related information:

3.4.5.1 Status

3.4.5.1.1 *Line attenuation*

This is the measured difference in the total power transmitted by the peer ATU and the total power received by this ATU in dB.

3.4.5.1.2 *Noise Margin*

This is the Noise Margin as seen by this ATU with respect to its received signal in dB.

3.4.5.1.3 *Total Output Power*

This is to show total output power from the modem.

3.4.5.1.4 *Maximum Attainable Rate*

This is to indicate the maximum currently attainable data rate by the modem.

3.4.5.1.5 Current Rate

These parameters report the current rate (transmit from the ATU-R and ATU-C) to which the ATU-C or ATU-R is adapted. It can be read by the operator of the system.

3.4.5.1.6 Previous Rate

These parameters report the rate (transmit from the ATU-R and ATU-C) to which the previous "rate change" event occurred.

3.4.5.1.7 Channel Data Block Length

This per channel parameter indicates the size of the data block subject to CRC check. This includes the number of redundant check bytes and the number of message bytes over which these check bytes provide protection. This value may be different for the fast and interleaved channel as the number of check bytes for each channel is individually negotiated and the number of bytes per symbol depends upon the rate of each channel. It will be read only information.

3.4.5.1.8 Interleave Delay

The transmission delay is introduced by the interleaving process. The delay is defined as per ANSI T1.413, and is $(S \times d) / 4$ milli-seconds, where 'S' is the S-factor, and 'd' is the "Interleaving Depth".

3.4.5.2 Performance Monitoring

The following raw counters (counters that begin at 0 when the device is started and continue forever wrapping at the maximum count) shall be kept for both the ATU-C and ATU-R:

Loss of Signal Failure

Loss of Frame Failure

Loss of Power Failure

Loss of Link Failure

Errored Seconds

This is a count of one second intervals containing one or more uncorrectable block errors in either the fast or interleaved channel, or one or more los or sef defects.

Transmitted Blocks

This counter is available per channel and indicates the number of blocks that have been transmitted by this ATU. This counter should only be incremented when there is a reasonable expectation of end-to-end communication (e.g. showtime).

Received Blocks

This per channel counter indicates the number of blocks received by this ATU. This counter should only be incremented when valid framing is detected.

Corrected Blocks

This is the count of received blocks which were errored when received but corrected by the built-in forward error correction.

Uncorrectable Blocks

This is the count of the received blocks which were unable to be corrected by the forward error correction mechanism.

Note: Since the counting of corrected and uncorrected errors is based on the

forward error correction block this is the definition which must also be used for counting transmitted and received blocks.

The following seconds counters should be available for the current and previous day and current and from 1 to 96 previous 15-minute intervals. A seconds counter is incremented when one or more of the relevant events occurred or the condition persisted throughout that second. The counts should be kept for each of the following items with respect to both the ATU-C and ATU-R:

- Loss of Signal Seconds

- Loss of Frame Seconds

- Loss of Power Seconds

- Loss of Link Seconds

- Errored Second Seconds

- Transmit Blocks

- Receive Blocks

- Corrected Blocks

- Uncorrectable Blocks

4. Interfaces and System Configurations for ADSL: Customer Premises

Statement of project

This project intends to define electrical interfaces, connectorization, and wiring topology for ADSL customer premises installations. Where possible, technical information will be obtained by reference to existing specifications, and by liaison to technical standards groups. The work on this project is limited to addressing the interfaces necessary to support existing single user connections methods as well as multi-user connection methods utilizing Premises Distribution Networks (passive and active) for Bit Synchronous data, ATM data, and Packet data. Future work may be undertaken that addresses the use of emerging Premises Distribution Networks and the interfaces required to support them.

Customer Premises Specific Reference Model

This project utilizes the Customer Premises specific Reference Model as shown in Figure 2. The interfaces identified in this model are logical interfaces and not necessarily physical implementations. Physical topology and implementation is covered in later sections.

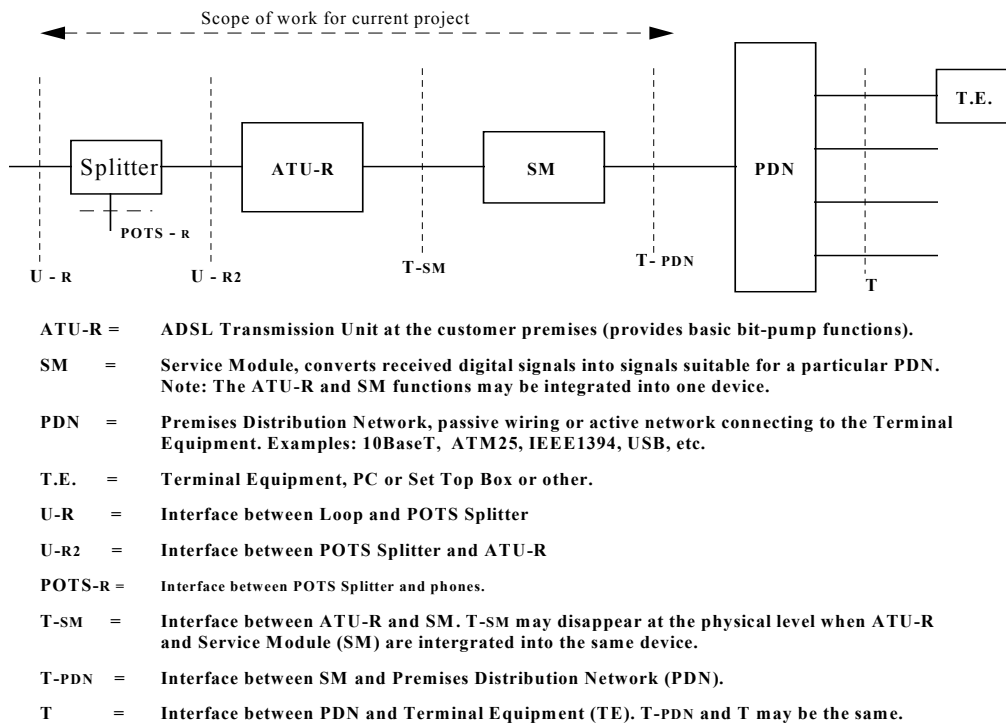


Figure 2 Customer Premises Specific Reference Model

The premises end of a DSL link starts with the access line (twisted-pair telephone line) delineated in the figure above by the U-R interface, and ends with one or more Terminal Equipments (T.E.) (including but not limited to a personal computer or a television) delineated in the figure above by the T interface. The telephone line may or may not be used for Plain Old Telephone Service (POTS) as well as ADSL. If it is used for POTS, then the customer premises installation must include a POTS splitter that provides the POTS-R interface as well as the U-R2 interface.

The ATU-R terminates the access line and provides digital signals at the T-SM interface. A Service Module (SM) may be installed to convert the received digital signals into signals suitable for a particular Premises Distribution Network or Terminal Equipment at the T-PDN interface. The ATU-R and SM functionality may be integrated in a common device, obviating the need for the T-SM interface.

The U-R, POTS-R, U-R2, T-SM, and T-PDN interfaces will be specified in this document.

4.1 Applications

The primary applications supported by ADSL will be POTS and data communications and video on demand. These applications require the transport of packet data, ATM data or bit synchronous data. The T-SM interface will depend on the application being supported.

In some cases, POTS may not be used, in which case the POTS splitter and POTS-R interface may not be needed.

4.2 System Implications

Serving these applications will likely involve connecting more than one Terminal Equipment (T.E.) within a premises, with the second, third, or more terminal connected at some time after the installation of the ADSL modem itself. Furthermore, the installation and use of the ADSL modem should be as simple as possible, with the most reuse of existing wiring as possible, and with the least amount of trouble in migrating from one T.E. to another as possible.

4.3 ATU-R / Splitter Installation

4.3.1 General Considerations

Conceptually, in the most common case to be considered, the installation of an ADSL modem requires breaking an existing telephone line with active POTS service and attached telephones, inserting a POTS splitter, and then reattaching the premises side POTS wiring back to the POTS splitter (see Figure 3 which depicts both logical and physical attributes). In the US, a Network Interface Device (NID, usually comprising surge protectors) establishes the physical demarcation between network and customer premises. The ability to install the POTS Splitter prior to the ATU-R has particular appeal when the ATU-R is owned and installed by the user and not the network provider.

This project will only consider examples of installing the POTS splitter on the CPE side of the primary protection. Country specific installations of POTS splitters may need to address additional safety regulations.

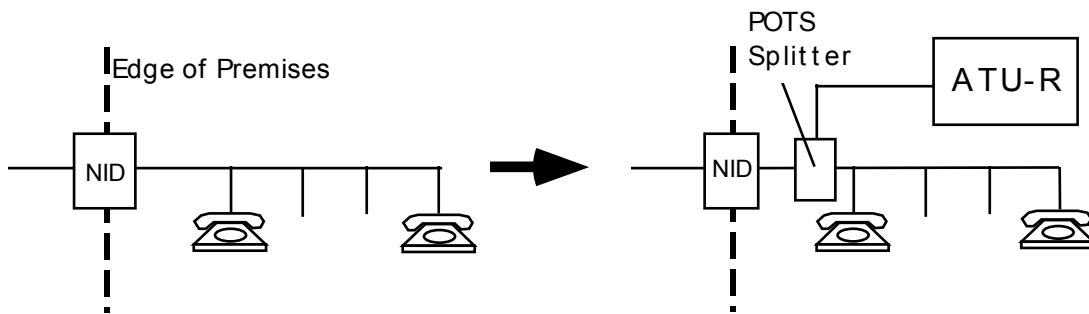


Figure 3. Conceptual ADSL ATU-R/Splitter Installation

4.3.2 POTS Splitter

Splitter Definition

The POTS splitter, for the purposes of this project, is considered to be the device that splits the POTS signals from the ADSL signals thus preventing the ADSL signals from reaching the telephone devices.

The POTS Splitter may be:

- active or passive, comprise the LPF section and the HPF section or comprise the LPF section only
- adjacent to the NID or housed within the NID
- adjacent to each telephone device, adjacent to the ATU-R or integrated within the ATU-R

The Low Pass Filter (LPF) section contains circuitry that passes POTS frequencies (approx. 0 to 4 kHz ³) to and from the telephone equipment and blocks the ADSL signal. The POTS Splitter (LPF only variation) may allow for the complete spectrum, including the ADSL signals (above approx. 20 kHz) to pass to the ATU-R.

³ Out of band signaling tones may need to be passed in some applications (this is outside the scope of this document).

In the case that a High Pass Filter (HPF) section is needed to prevent low frequency, high level POTS signals from entering the ATU-R front end components, the circuitry may be included in and be considered part of the ATU-R or the circuitry may be included as part of POTS Splitter (along with the LPF).

The ATU-R manufacturer should not assume that the HPF has been implemented external to his equipment. It is recommended that all manufactures of ATU-R equipment plan on explicitly implementing the appropriate HPF.

4.3.3 POTS Splitter Characteristics

POTS Splitter characteristics will not be specified in this text. Instead the POTS Splitter is used as an existing system component and is shown along with the other system components such as ATU-R and wiring to comprise the configurations detailed in sections to follow.

The ANSI standard T1.413- 1995 specifies the loop conditions under which the splitter and ADSL must be able to operate without causing significant degradation to the POTS signal and these characteristics will be incorporated in this document by reference.

Work applicable to the POTS Splitters that is completed in other groups , such as ETSI or ITU, will be addressed when specifics are available.

4.3.4 ATU-R / Splitter Configurations

Various ATU-R/Splitter configurations are discussed in the following sections.

-

- 4.3.5 ATU-R adjacent to T.E. with Separate POTS Splitter
- 4.3.8 ATU-R adjacent to T.E. and Split POTS Splitter
- 4.3.9 ATU-R adjacent to T.E. and Distributed POTS Splitter
- 4.3.9 ATU-R with integral POTS splitter adjacent to NID
- 4.3.10 ATU-R with integral POTS splitter adjacent to T.E.

A brief introduction for each configuration is presented along with a figure depicting both logical and physical attributes (topology & implementation).

This is followed by a list of advantages and disadvantages for each configuration. These advantages and disadvantages can be utilized in order to choose the configuration that best suits the needs of any particular deployment.

A suggested list of criteria is provided below that when used in conjunction with specific priorities or importance values (as determined by the provider) would allow a selection of the best configuration to be made for any particular ADSL system deployment.

Criteria:

Type of Splitter - Active or Passive

Equipment Ownership - Customer or Network owned Splitter, ATU-R

Network demarcation point

Failure effects of Splitter, ATU-R

Installation Complexity

Testing and Maintenance - Splitter, ATU-R

4.3.5 ATU-R adjacent to T.E. with Separate POTS Splitter

Figure 4 shows a configuration with the POTS splitter separate from the ATU-R. The POTS splitter mounts near the NID while the ATU-R is located at a more convenient installation location, perhaps next to the T.E. Wiring to the ATU-R may be existing or new, depending on the quality of the existing wire and the desired location of the ATU-R.

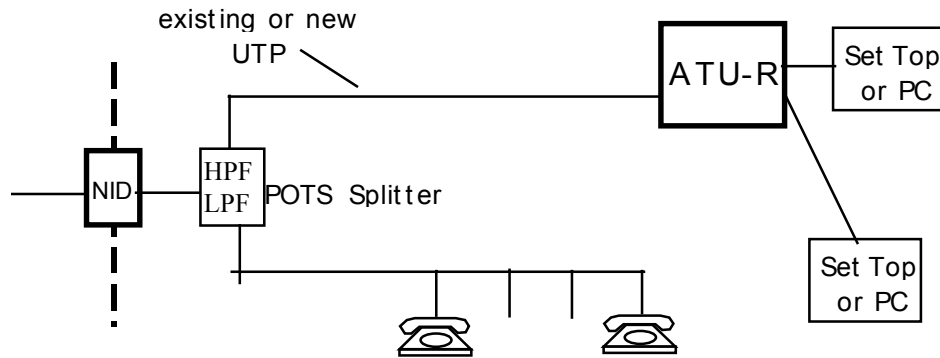


Figure 4. ATU-R adjacent to T.E. and Separate POTS Splitter {LPF & HPF}

Advantages:

- Putting the ATU-R adjacent to or within T.E. ensures proximity to power.
- T-sm interface cabling will be short or non-existent (integral to the T.E.).
- Accessibility- additional T.E. may be connected easily to the ATU-R.
- The POTS splitter can be installed at some time before the ATU-R.
- Isolates the ADSL signal path wiring from the CP POTS wiring imperfections (i.e. bridged lines, nonstandard wiring gauges, etc.) and allows for the reduction of cross-coupled noise⁴.

Disadvantages:

- In countries that require an active POTS splitter, the ATU-R may have to power the splitter over the line or another supply provided.
- Currently, POTS splitter from one manufacturer won't necessarily work with the ADSL modem of another manufacturer. This is primarily due to the required characteristics of the HPF located in the ADSL signal path.

⁴Cross-coupled noise would again become a factor if a telephone at the set top or PC uses the same cable for connection back to house telephone wiring.

A variant on the POTS splitter is a system where the low pass filter portion of the splitter is physically separate from the high pass filter. Two logical configurations are shown in Figure 5 and Figure 6.

4.3.8 ATU-R adjacent to T.E. and Split POTS Splitter

Figure 5 shows the configuration with the LPF located at the physical split in signal paths. This configuration is as efficient in isolating the premises POTS wiring from the ADSL signal path as the explicit integrated splitter of Figure 4 shown above; however, it offers an advantage because now each manufacture of ATU-R equipment has control of the HPF characteristics. (It is assumed that the LPF requirements are basically the same regardless of a manufacturer's ADSL implementation).

This split POTS Splitter configuration is the most prevalent configuration currently planned to be deployed.

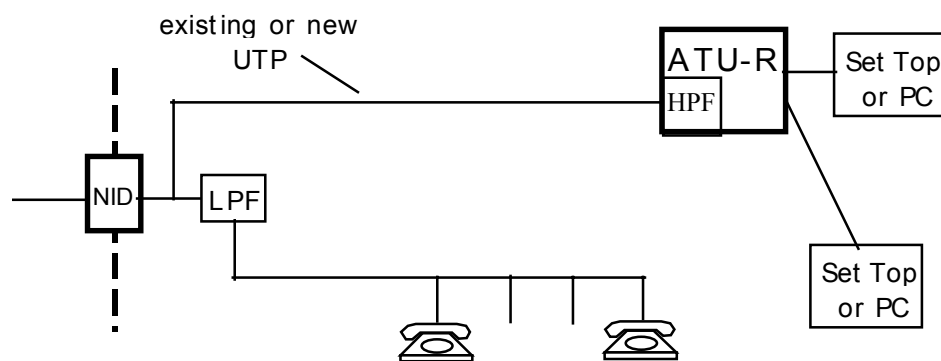


Figure 5. ATU-R (w/HPF) adjacent to T.E. and Split POTS Splitter (LPF-only)

Advantages:

- Putting the ATU-R adjacent to or within T.E. ensures proximity to power.
- T-sm interface cabling will be short or non-existent (integral to the T.E.).
- Accessibility- additional T.E. may be connected easily to the ATU-R.
- The POTS splitter can be installed at some time before the ATU-R.
- Isolates the ADSL signal path wiring from the premises POTS wiring imperfections (i.e. bridged lines, nonstandard wiring gauges, etc.) and allows for the reduction of cross-coupled noise⁵.
- Increases the probability of compatibility between different manufactures of ATU-R equipment and LPF hardware.

Disadvantages:

⁵Cross-coupled noise would again become a factor if a telephone at the set top or PC uses the same cable for connection back to house telephone wiring.

- In countries that require an active POTS splitter, the ATU-R may have to power the splitter over the line or another supply be provided.

4.3.9 ATU-R adjacent to T.E. and Distributed POTS Splitter

Figure 6 shows a variant in which the high pass filter is implemented within the ATU-R and low pass filters are installed in front of each telephone (distributed).

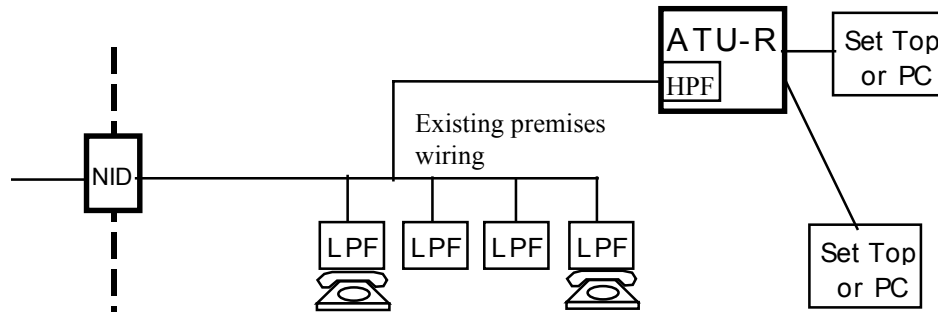


Figure 6. ATU-R (w/HPF) Adjacent to T.E. and Distributed (Split) POTS Splitter (LPF-only)

Advantages:

- Putting the ATU-R adjacent to or within T.E. ensures proximity to power.
- T-sm interface cabling will be short or non-existent (integral to the T.E.).
- Accessibility- additional T.E. may be connected easily to the ATU-R.
- The POTS splitter(s) can be installed at some time before the ATU-R.
- Increases the probability of compatibility between different manufacturers of ATU-R equipment and LPF hardware.
- Obviates reconfiguration of customer premises wiring entirely.

Disadvantages:

- In countries that require an active POTS splitters, the ATU-R may have to power the splitter over the line or another supply be provided.
- Customer premises wiring becomes a potential bridging network that can cause frequency response discontinuities⁶ and is a factor in determining ATU-R performance. The exact nature of the network frequency response is dependent upon the installation wiring each individual CP.
- Improper installation of the LPF at each phone, or the omission of the LPF, can cause significant termination problems on the network, which in turn can have an impact on ATU-R performance.
- Use of unbalanced line within the CP POTS wiring network can result in additional noise ingress into the ATU-R signal spectrum.
- Increased mechanical installation complexities are involved (i.e. wall phones).

⁶ The frequency response discontinuities manifest themselves as increased insertion loss notches and lower than expected ATU-R line termination impedances. The later can upset the ATU-R hybrid networks by introducing driving impedances that can be 50% or more lower than expected.

4.3.9 ATU-R with integral POTS splitter adjacent to NID

Figure 7 shows the installation with the ATU-R adjacent to or close to (within 5 meters) the NID. Except for short stubs to connector blocks, this configuration requires no new telephone wiring at the U interface, but will usually require some longer cabling for the T-sm interface.

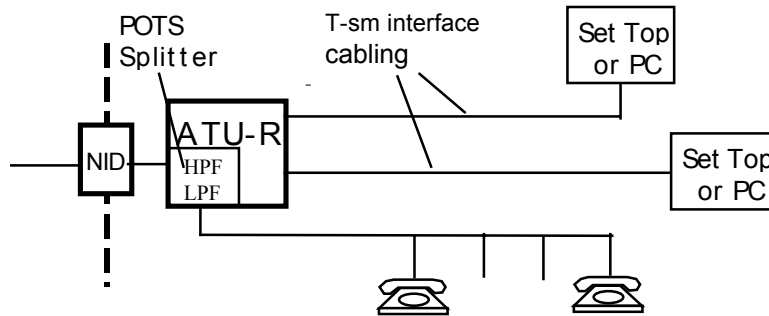


Figure 7. ATU-R with integral POTS Splitter (LPF & HPF) adjacent to NID

Advantages:

- ADSL signals pass over virtually no pre-existing premises telephone wiring thus minimizing potential premises wiring related problems.

Disadvantages:

- NIDs and entrance telephone wiring are usually not favorably located for access to power.
- ATU-Rs placed in attics, basements, garages, or outside premises may be subject to environmental extremes.
- The installation complexity and length of the T-sm interface wiring to the T.E. (This potentially limits the use of some of the Premises Distribution Networks currently in use)

4.3.10 ATU-R with integral POTS splitter adjacent to T.E.

Figure 8 shows a configuration with the ATU-R adjacent to one T.E. and therefore likely removed from the NID by as much as 100 feet. This installation requires cutting the telephone line just after the NID, connecting it to the ATU-R over new or existing premises telephone wiring, and then reconnecting the POTS output to the premises telephone system originally serviced by the wire from the NID. In addition, any telephone connected at the ATU-R location must be reconnected on the POTS side.

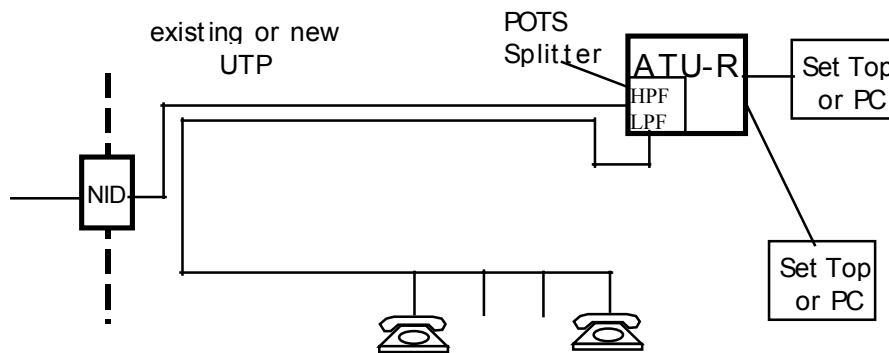


Figure 8. ATU-R with integral POTS Splitter (LPF & HPF) adjacent to T.E.

Advantages:

- Putting the ATU-R adjacent to or within T.E. ensures proximity to power.
- T-sm interface cabling will be short or non-existent (integral to the T.E.).
- Accessibility- additional T.E. may be connected easily to the ATU-R.
- This configuration enables a self-contained ADSL NIC for PCs or Set Top boxes (POTS is supported via integral POTS Splitter)
- Good topology for customer owned (and powered) POTS Splitter (Active)

Disadvantages:

- The premises telephone service now connects through the ATU-R, which could accidentally be disconnected from the line, severing POTS service.
- This configuration may require diverse routing of two wire pairs in order to reduce cross-talk.
- Not good topology for network owned (and powered) POTS Splitter (Active)

4.4 Wiring Considerations

Recent telephone company experience suggests that the quality of in-home wiring varies so much, and that so much of it falls below a level suitable for ADSL transmission, that new wiring of some form or another will be the rule rather than the exception. However, some of the configurations shown in Section 0 may have reused existing premises wiring.

- **New Wiring**
If new wiring is pulled, it should be UTP Category 5 as specified in EIA/TIA 570. A wall plate shall be installed to terminate the new wiring for DSL.
- **Interference and the Use of Existing Wiring**

The running of ADSL signals and POTS signals together through a single two-pair cable, cross-couples POTS noises generated by ringing, trip ringing, pulse dialing, and hook switch signaling into the low level ADSL receive signals. Studies have shown that just a few feet of adjacent wiring causes cross-coupling of sufficient magnitude to cause errors in received data. This problem could be reduced by the high pass filtering in the ATU-R. This liability is also mitigated by error control protocols and by interleaving (the noise appears as impulses), but must be recognized as having potential effects on quality of service. However, there is also concern that there may be detrimental effects (unacceptable noise in the telephone user's ear) from cross-coupling of ADSL signals into the post splitter POTS lines. This potential for crosstalk may affect voice band usage that extends near 4000 Hz such as with V.pcm or other high speed voice band modems.

4.4.1 U-R

Screw terminals or RJ11 jack/plug as required by specific configuration wired to center pair (pins 3 and 4).

4.4.2 POTS-R

Screw terminals or RJ11 jack/plug as required by specific configuration wired to center pair (pins 3 and 4).

4.4.3 Connections for the ATU-R

- **External POTS Splitter** as described in Section 3.3.2.

The U-R2 connector at the wall jack shall be RJ14 (sometimes known as RJ11, 4-wire) with ADSL wired

to pins 2 and 5. POTS (optional) will be wired to pins 3 and 4. This wiring precludes the use of a POTS second line on a wire pair connected to pins 2 and 5 for this particular wall jack.

In cases where wiring other than UTP Category 5 is being used, the ADSL signal path from the POTS Splitter to the U-R2 connector at the wall jack must be isolated in a separate sheath. This may require a new cable run.

- Internal POTS Splitter as described in Sections 3.3.4 and 3.3.5.

The U-R2 connector at the wall jack shall be as specified in the physical characteristics section of ANSI T1.413-1995.

4.4.3 T-sm Interface

If the ATU-R is merely implementing the basic functions of a bit pump, an external T-sm interface will be necessary to interconnect the ATU-R to a separate Service Module. This interface will have to carry those data, timing and control signals necessary to permit operation of a variety of services which may be carried on the ADSL link.

The minimum signal set will be one downstream data circuit plus its clock and one upstream data circuit plus its clock. A number of optional signals may be supported for particular applications:

1. Secondary data channels. These may be simplex or duplex channels and will always have an associated clock. Some duplex channels may have a common clock.
2. Auxiliary data timing signals. Some channels may require an out-of-band frame or byte start signal which is extracted from the ADSL framing structure.
3. Network Timing Reference. Some service modules may require the 8kHz timing reference when this is carried by the ADSL link.
4. Control and Status circuits. The ATU-R and SM may each be required to control the other and/or to receive status indications. These may be global signals or be channel associated.

A basic interface providing the minimum signal set on an RJ45 connector is specified here where this is sufficient. It is recommended that interfaces which provide additional signals use one of the existing ISO data communications interfaces. The data rate of ADSL equipment requires that only those interfaces using balanced circuits should be used. Suitable interfaces are: ISO.4903 (X.21), ISO.2110-Amd1 (TIA.530) or ISO.2593 (V.35). The use of such interfaces will allow existing data communications equipment to connect to an ATU-R without modification. Guidance is given below as to the mapping of the T-sm signals onto these interfaces.

4.5 Signal Specifications

Each simplex data channel consists of one data circuit (DD or DU) and one clock circuit (CD or CU). The clocks are normally generated by the ATU-R, but in some instances the upstream clock (CU) may be generated by the SM. These clocks should have a nominal 50% duty cycle at the maximum data rate. Extended OFF periods may be inserted when burst clocking is being used. The downstream data is generated by the ATU-R and the upstream data by the SM. The data is NRZ encoded with the OFF and ON states representing logic 1 and 0 respectively. Data changes state at OFF to ON clock transitions, with the receiver strobing the data at ON to OFF clock transitions.

In addition to the clock and data signals, each channel or group of channels may have other signals associated with them. ATU-R and SM equipment not generating these signals shall leave these circuits unconnected, and equipment receiving these signals shall provide pullups/pulldowns so as to force an ON state in the event an undriven input.

The channel-associated signals may include:

1. Data Qualifier (QD or QU). A signal driven by the data source to indicate valid data on its transmitter. This signal may be used in place of, or in addition to, burst clocking.
2. Channel Control (CC). A signal generated by the SM to enable channel(s).
3. Channel Indication (CI). A signal generated by the ATU-R to indicate that channel(s) are in a data-forwarding state.
4. Byte Sync (BS). A signal generated by the ATU-R to provide a data alignment signal for byte-structured channels such as G.711 PCM. This signal shall transition from OFF to ON on the byte boundary and may transition from ON to OFF at any other bit boundary.
5. Frame Sync (FS). A signal generated by the ATU-R to provide data alignment for frame-structured channels which do not have an embedded frame delimiter. This signal shall transition from OFF to ON at the frame boundary and may transition from ON to OFF at any other bit boundary.
6. Network Timing Reference (NR). This is a signal with a frequency of 8 kHz which may be carried by some ADSL links.

Global control and indication signals may be used which relate to the entire ADSL link:

1. Equipment Status (SD or SU): A signal generated by either equipment to indicate that it is operational and to qualify all other signals.
2. Link Control (LC): A signal generated by the SM to enable the ADSL link.
3. Link Indication (LI): A signal generated by the ATU-R to indicate that the ADSL link is operational.

Notes:

1. In both the above lists, item 1 is an alternative to 2 plus 3. This equates to the alternative definitions of circuit 108 in ITU-T V.24 as either Data Terminal Ready or Connect Data Set to Line.
2. Where only one pair of channels is supported, Channel Control/Indication and Link Control/Indication are essentially the same signals.
3. No signals relating to flow control or SM-sourced clocks are specified. It cannot be assumed that an ATU-R is capable of either flow control or speed buffering and therefore all data flow must be slaved to the ATU-R clocks. Where SM equipment needs such facilities, they should be provided internally by the SM.

4.5.1 ISO Interfaces and Connectors

All these interfaces provide one downstream and one upstream channel plus clocks and control signals. The ISO.4903 (X.21) interface uses a 15 pole D connector and supports two control circuits and two timing circuits. The ISO.2110-Amd1 (TIA.530) interface uses either a 25 pole D connector or a 26 pole miniature connector and supports more control circuits. The ISO.2593 (V.35) is an obsolete interface but which is still commonly used. It uses 34 pole connector and supports the same signal set as ISO.2110.

Where ATU-R and SM have different interfaces, inter-working by means of an adapter cable will be possible on circuits where both transmitter and receiver are balanced (which is true for data and clocks on all these interfaces) or where a satisfactory unbalanced to balanced conversion can be made. The ISO and ITU-T standards documents address this issue in more detail.

In the ADSL context, the ATU-R is the DCE and will have female connectors, and the SM is the DTE with male connectors. The mapping of T-sm signals to the V.24 and X.24 signals is suggested below:

T-sm	V.24	X.24	Notes
DD	104 (RXD)	R	
DU	103 (TXD)	T	
CD	115 (RXC)	S	
CU	113 or 114 (TXC)	X	3
QD	109 (DCD)	C	
QU	105 (RTS)	I	
CC	109 (DCD)	C	
CI	105 (RTS)	I	
SD	107 (DSR)	C	
SU	108/2 (DTR)	I	
LC	108/1 (DTR)	C	
LI	107 (DSR)	I	
BS	106 (CTS)	B	2
FS	106 (CTS)	F	2
NR	106 (CTS)	X	1,2

Notes:

1. For this application, the X signal is driven by the DCE towards the DTE.
2. The CTS circuit does not have its usual function as these are timing signals. It was chosen because it is a balanced signal on the ISO.2110-Amd1 interface. When the B, F or X circuit is used to carry these signals, it can only be on either a simplex channel or a full duplex channel pair with identical data rate as circuit S will need to be a common clock.
3. Where CU is generated by the ATU-R, the X signal is driven by the DCE toward the DTE.

4.5.2 Basic RJ45 Interface

A data and clocks only interface, providing one downstream channel plus one upstream channel, can be implemented using an RJ45 plug. The drivers and receivers should conform to ITU-T V.11 (TIA-422) and be connected as shown:

CDa	_____	Pin #1
CDb	_____	Pin #2
DUa	_____	Pin #3
CUa	_____	Pin #4
CUb	_____	Pin #5
DUb	_____	Pin #6
DDa	_____	Pin #7
DDb	_____	Pin #8

Figure 9. RJ45 Plug for the T-SM Interface

It may be necessary to use screened RJ45 jacks, plugs and cables to meet radiated emissions requirements.

4.6 T-PDN Interfaces - existing Premises Distribution

4.6.1 Networks

With the addition of a Service Module, the T-SM interface may be converted to a more commonly available interface. When the ATU-R and SM functions are intergrated into one device, the T-SM interface will disappear at the physical level and the applicable interface then becomes the T-PDN.

The Premises Distribution Networks included in the body of this issue will be some of the commonly available PDNs in use for Bit Synchronous (serial interface data communications) Mode, Packet Mode and ATM Mode of operation. Evolving Premises Distribution Networks are presented in Annex B for reference only.

4.6.2 Bit Synchronous Interfaces

Terminal Equipment such as routers or Set Top boxes may support some of the more common serial interface data communications connections (DTE interfaces) at the T-PDN interface. The Terminal Equipment expects the device attached at the T-PDN interface to act as a Data Communications Equipment (DCE).

The following specifications are incorporated in this document by reference and will not be further detailed herein:

- TIA-530 or v.35 (ISO 2593) for high speed serial DTE interface.
- T1 - 1.544 Mbps ANSI T1.403
- E1 - 2.048 Mbps ITU G.703/G.704

4.6.2 Ethernet 10BaseT interface

The following specifications are incorporated in this document by reference and will not be further detailed herein:

- 10BaseT on a RJ-45 connector
 - Ethernet Version 2.0: A CSMA/CD Local Area Network Specification
ANSI/IEEE 802.3, CSMA/CD Access Method and Physical Layer Specifications

The information in this Annex is informative and included to provide visibility into the possible use of emerging PDNs for use with ADSL systems. It is not exclusive of other possible PDNs but provides guidance as to how these emerging PDNs may be used in conjunction with ADSL access at the customer premises.

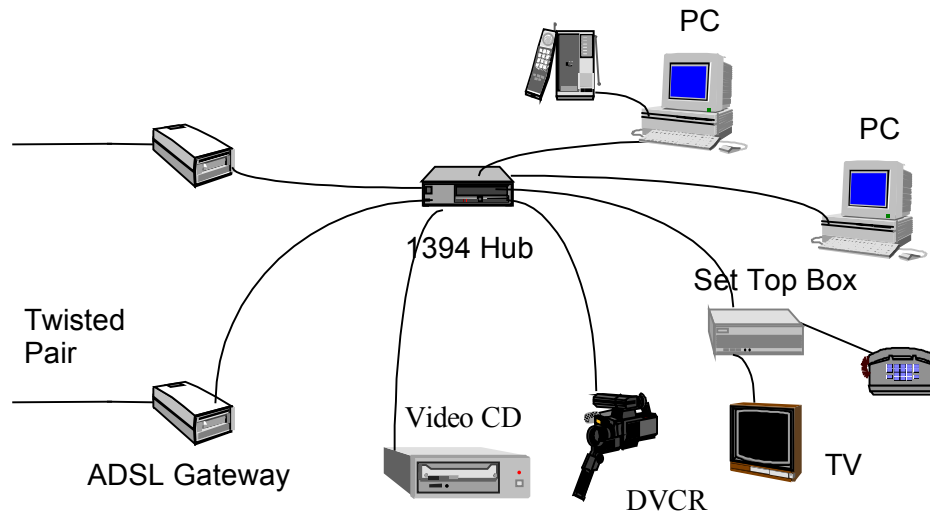
A high speed digital home network serving the needs of ADSL signal distribution and digital information distribution from other local or network resources can be implemented on a high quality unshielded twisted pair wiring system. This type of infrastructure has been proposed by the CEBus (Consumer Electronics Bus) committee which recommends the installation of Category 5 unshielded twisted pair in a star topology for both voice and data transmission purposes. Category 5 unshielded twisted pair is also the transmission media for 100BaseTX Ethernet and several other systems. Such an infrastructure would be suitable for the ATM based system being proposed by the ATM Forum. Two other possible systems which use different media are described.

IEEE 1394 (Firewire)

IEEE 1394 (1995) is an IEEE serial bus standard originally designed for the inter-connection of computer peripheral devices. The 1394 standard defines a serial interface which can be used to replace traditional PC parallel, serial, or SCSI bus. The 1394 could be very effective at inter-connecting the new generation high capacity and high speed storage and I/O devices. The 1394 standard is designed to handle both isochronous and asynchronous data transmission. A 1394 based Premises Distribution Network (PDN) can be used to distribute ADSL traffic for both data access and video on demand applications, subject to the limitations described below.

The current 1394 standard requires the use of a special purpose shielded twisted pair cable. The twisted pair cable consists of two data pairs and one power pair. Each data pair is individually shielded and three pairs are then all shielded together. Hence, there are two signal links (TPA,TPB) on a physical connection. A typical 1394 twisted pair cable is only about 4.5 meters long. That cable length may be just long enough for connecting a local cluster of equipment together, but may be insufficient to provide interconnection between rooms. There is activity aimed at producing a longer reach version of IEEE 1394, a sub-working group has produced a draft document.

This PDN should have a star topology with a 1394 root device at the center of the star, but daisy chaining of 1394 devices is also permitted. Other data traffic from in-house or other access networks can also be shared on this PDN. A gateway/router is used to connect the ADSL to this PDN, but may require a longer reach technology.



Univer: Figure 10. A 1394 -based Premises Distribution Network

The Universal Serial Bus (USB) standard was originally designed around the PC architecture for the connection of telephony devices such as telephone/fax/modem adapters, answering machines, scanners as well as PDA's, keyboards, mice, etc. The standard was specified and the standard document is available through the USB Forum. Additional assistance is also available through the membership of the Forum. The USB can be used to handle isochronous data transmission. A USB based Premises Distribution Network (PDN) might be used to distribute ADSL traffic for both data access and video on demand applications.

The current USB standard requires the use of a 28 AWG shielded twisted pair cable with a non-twisted power distribution pair of a variable gauge ranging from 20 AWG to 28 AWG. The shielding covers both signal and power distribution pairs. The maximum transmission throughput is 12 Mbps for a maximum cable length of 5 meters. A non-shielded cable can also be used for sub-channel, where the transmission rate is 1.5 Mbps, applications.

Data is carried over a USB in packets. The USB employs NRZI data encoding when transmitting packets.

USB Topology

A USB is configured around a host, normally a PC, with devices attached directly or through hubs. A hub can connect a host to multiple devices. All devices are logically connected to the host. There are three layers of communication links between a host and its devices. Shown below are first, the physical topology and then the logical topology.

