Chapter 13

Broadband Network Management:
Wired and Optical Access Networks

Objectives

- (Wired) Broadband access networks
    - Cable or HFC (hybrid fiber cable) network
    - ADSL (asymmetrical digital subscriber line) network
    - PON (passive optical network)
- **Cable access network**
    - Popular in North American continents
    - "Triple play" service can be provided
    - DOCSIS (data over cable system interface specifications) standards
- **ADSL**
    - Predominant throughout the rest of the world
    - Uses conventional telephone local loop medium
    - Broadband voice and data services
    - Adopts IETF and DSL forum standards
    - VDSL2 for performance improvement of broadband service
- **PON**
    - PON deployment configurations
    - Ethernet-based PON, EPON
    - EPON protocol architecture
    - EPON management
    - EPON MIBs

Broadband Access Networks

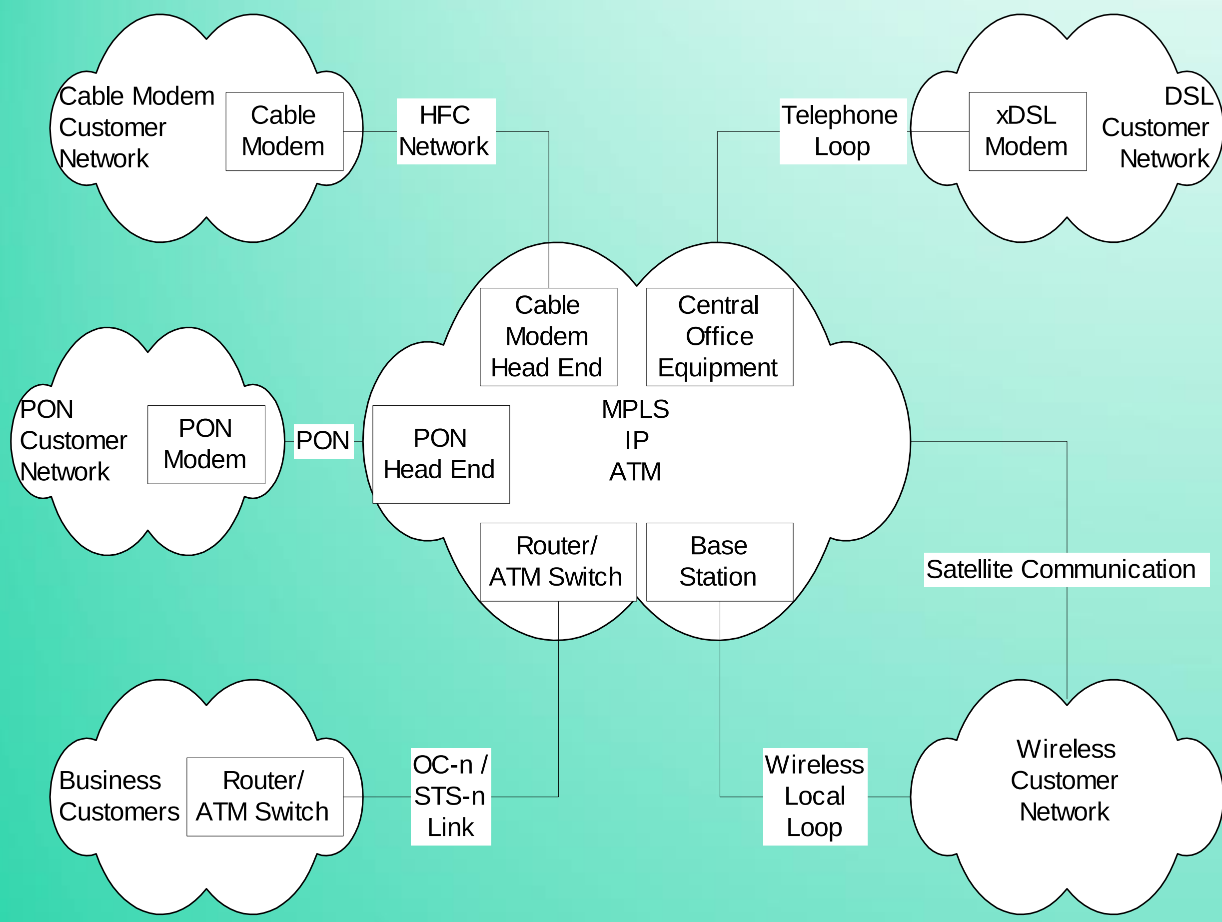


Figure 13.1 Broadband Access Network

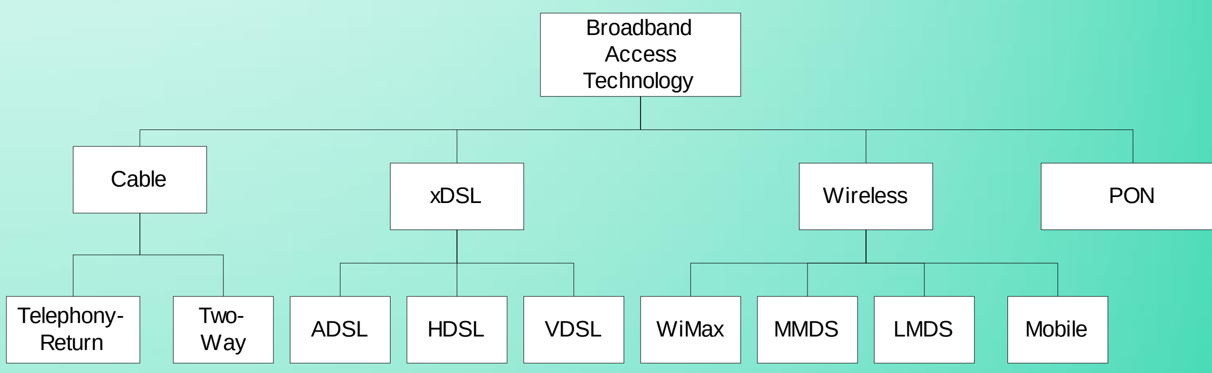


Figure 13.2 Broadband Access Technologies

Notes

- **Access network between WAN and home network**
- Four access network technologies
- OC-n an extension of WAN for enterprise

Notes

- Cable popular in North America
- ADSL more extensively deployed elsewhere in the world
- Wireless:
  - Fixed: MMDS, LMDS, and WiMax
  - Mobile: CDMA, GPRS
- PON on fiber medium

Cable Access Network

CM technology, also known as HFC (Hybrid fiber-coaxial) technology

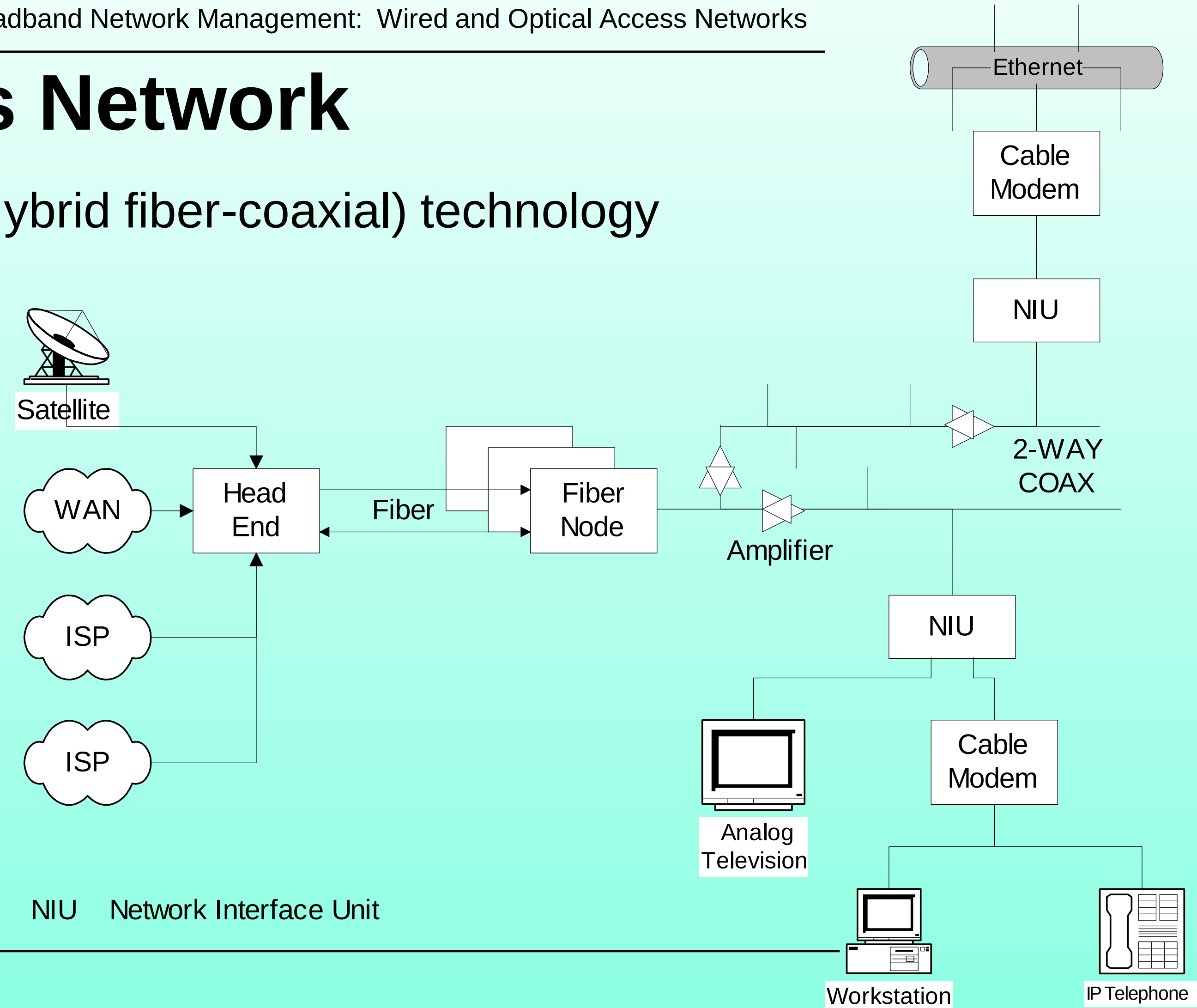


Figure 13.3 Cable Access Network

Notes

- Head end:
  - Signals from multiple sources are multiplexed and up-converted from an electrical (radio frequency (RF)) to an optical signal
  - Frequency conversion for local signal
- Traffic Flow:
  - Downstream: Head end to NIU
  - Upstream: NIU to head end
- Network interface device (NID) / unit (NIU): Demarcation point between customer network and service provider networks
- Cable modem: RF signals ⟷ voice-over-IP, video and digital data in general

Comparative Speeds

The broadband cable access system with the CM can process data at a much faster rate than a conventional telephone modem or integrated services digital network (ISDN).

Table13.1 Comparative Data Transmission Speeds

Telephone Modem 28.8 kbps	6 - 8 minutes
ISDN 64 kbps	1 -1.5 minutes
Cable Modem 10 Mbps	Approximately 1 second

Cable Access Network Technology

- Broadband 2-way cable access network
- Asymmetric bandwidth allocation for 2-way communication
- **Transmission Mode**
  - Downstream: TDM broadcast mode
  - Upstream: TDMA / S-CDMA
- RF spread-spectrum that carries multiple signals over HFC
- RF spectrum allocation to carry multimedia services - voice, video, and data

Time-division multiplexing (TDM) is a method of putting multiple data streams in a single signal by separating the signal into many segments, each having a very short duration. Each individual data stream is reassembled at the receiving end based on the timing.

Time division multiple access (TDMA) is **a channel access method for** shared medium networks. It allows several users to share the same frequency channel by dividing the signal into different time slots. The users transmit in rapid succession, one after the other, each using its own time slot. This allows multiple stations to share the same transmission medium (e.g. radio frequency channel) while using only a part of its channel capacity.

- **What**
  - **Synchronous Code Division Multiple Access (S-CDMA) is an upstream technology added in D2.0, and enhanced in D3.0**
- **Why**
  - **S-CDMA technology is particularly robust against impulse noise, a critical requirement at the low end (<20 MHz) of the band**
- **How**
  - **S-CDMA *stretches* QAM symbols out in time by 128 times**
  - **Symbols multiplied by (-1 or 1) via CDMA spreading “code”**
  - **Transmits all sets of stretched symbols in parallel**
  - ***Zero* theoretical interference among transmissions due to special code properties**
  - **No decrease in channel capacity**

Cable Access Network

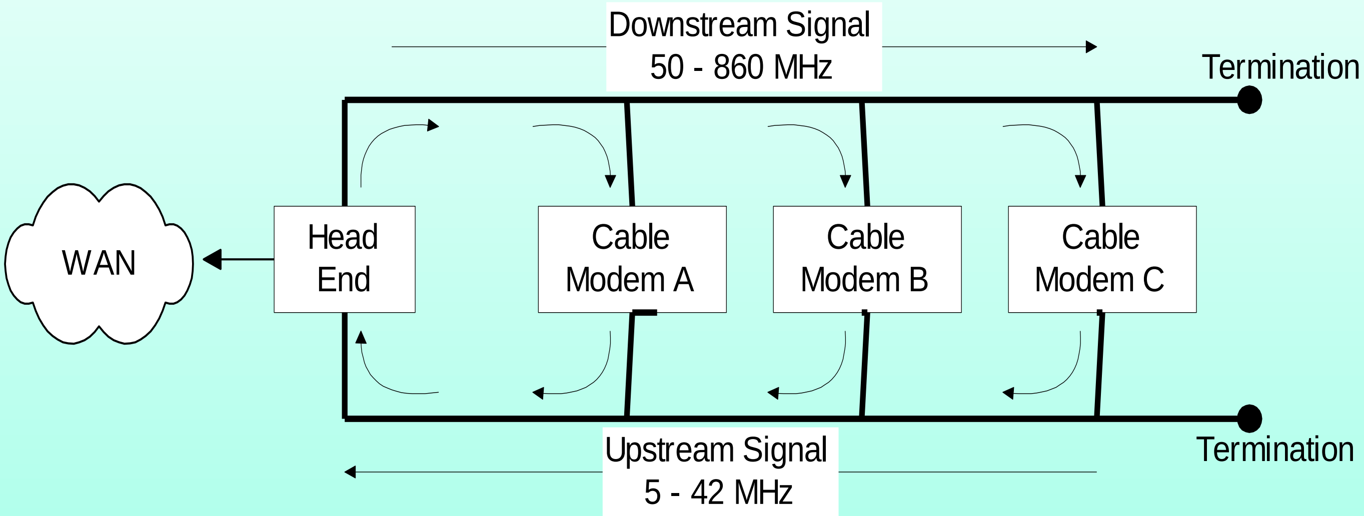


Figure 13.4 Two-way Transmission in a Coaxial Cable

Figure 13.4 shows the architecture of several **CMs communicating with each other on a coaxial cable**. Although the modems share a common coaxial cable to communicate in both directions, the figure shows the downstream (forward) and upstream (reverse) paths separated to represent the concept clearly.

Notes

- Single physical medium, 2 logical data streams
- Downstream 6 MHz (North American) / 8 MHz (Europe, Asia) channels
- Upstream Variable speed channels 160 kbps to 5.2 Mbps
- Downstream TDM broadcast mode
- Upstream TDMA in DOCSIS 1.0 and 1.1
- Upstream S-CDMA in DOCSIS 2.0

DOCSIS: **Data Over Cable Service Interface Specification**.

Digital-to-Analog Encoding

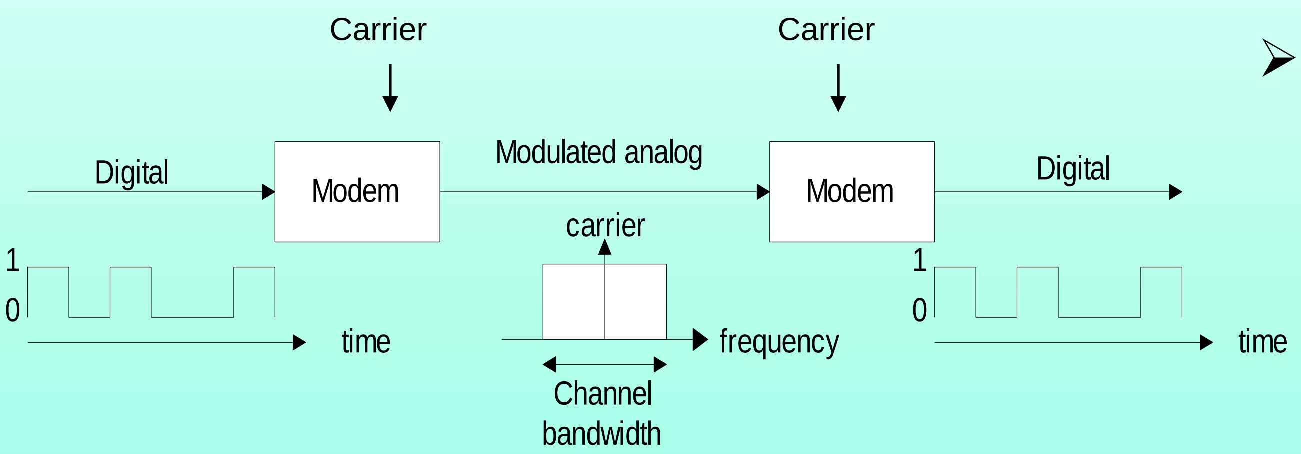


Figure 13.5 Digital-to-Analog Encoding

- The CM modulates and demodulates the digital signal from the customer's equipment to the RF signal that is carried on the cable. A similar operation is done at the head end equipment
- Figure 13.5 shows the basic concept. A digital signal, for example from a computer, is converted to an analog signal by the modem, in our case a CM. The converted analog signal modulates an RF carrier. The modulated signal occupies a band of frequencies around the carrier frequency, shown as the channel bandwidth.
- We should clearly understand telecommunication transmission terminology used in managing and evaluating modems. They are bit rate, baud rate, carrier frequency, and bandwidth.

Notes

• bit rate: The bit rate is the number of bits per second that traverses the medium
• symbol (baud) rate: . The baud rate is the signal units/symbols per second
• number of levels $n = 2^k$; **k..number of bits per symbol**; The input signal could also be quantized into multiple levels, for example, into four levels (2 pow 2). We would then need two bits to represent each signal unit (00, 01, 10, and 11). In this situation, the bit rate would be twice the baud rate.
• bit rate = symbol rate x k

Modulation Schemes

- Basic modulation techniques
  - ASK (Amplitude Shift Keying)
  - FSK (Frequency Shift Keying)
  - PSK (Phase Shift Keying)
- Cable technology uses
  - QPSK (Quadrature Phase Shift Keying)
  - QAM (Quadrature Amplitude Modulation)

The CM modulates and demodulates the digital signal from the customer's equipment to the RF signal that is carried on the cable. **Different modulation techniques support different capabilities.** There are three modes of modulation schemes . They are amplitude shift keying (ASK), frequency shift keying (FSK), and phase shift keying (PSK). Variations and combinations of these schemes are used in CM technology. Of these, **the more common modulation techniques used are quadrature phase shift keying (QPSK) and quadrature amplitude modulation (QAM).** In order to appreciate how the different modulation schemes accomplish the desired objectives, we need to understand the digital-to-analog encoding schemes, which we will now briefly review

Notes

- Quadrature phase shift keying
  - Four levels (00, 01, 10, 11) encodable on 2 bits
  - Relatively insensitive to noise
  - Used for low-band upstream
  - 8 MHz channel: 8x2=16 Mbps
- Quadrature amplitude modulation (16 levels — 4bits)
  - Combination of AM and PM
  - 16-QAM = 8 PM x 2 AM or 4 PM x 4 AM
  - Used for higher-band downstream
  - 8 MHz channel 8x4=32 Mbps

Digital Subscriber Line Access Networks

DSL Access Technology

- **Why is DSL attractive?**
  - **The main motivating factor to employ xDSL (x digital subscriber line) for access technology in multimedia services is the pre-existence of local loop facilities to most households.**

- Shannon limit of data rate is 30,000 bps (3-KHz, 30 dB S/N channel)
  - Shannon's fundamental limitation of data rate that is prevalent in an analog modem **can be overcome by direct digital transmission.** This is the basic concept behind xDSL technology,

- Digital transmission over loop (DSL) improves data rate
  - 8-15 Mbps downstream
  - 0.8-1.5 Mbps upstream
  - Limit on distance: max to 18,000 feet

Shannon's channel capacity criteria for noisy channels

Given a communication channel with bandwidth of B Hz. and a signal-to-noise ratio of S/N, where S is the signal power and N is the noise power, Shannon's formulae for the maximum channel capacity C of such a channel is

C = B log (1 + S/N)

For example, for a channel with bandwidth of 3 KHz and with a S/N value of 30 DB, like that of a typical telephone line, the maximum channel capacity is

C = 3000 * log (1 + 30) = 30000 bps (approx.)

DSL Limitations

- local loop with no direct copper to the house
- Loaded coils (used to increase analog distance) in local loop cannot carry digital signal
  - Modern subdivisions have fiber to the neighborhood or curb with digital mux (multiplexer):
- Operating company inventory dated (administrative issue)

the local loop is the physical link or circuit that connects from the demarcation point of the customer premises to the edge of the common carrier or telecommunications service provider's network.

Notes

Definitions of loading coil

noun

a coil used to provide additional inductance in an electric circuit in order to reduce distortion and attenuation of transmitted signals or to reduce the resonant frequency of an aerial

Adding a loading coil in a long telephone line reduces the loss that would normally comes with a long line. …. . Long lines do have a lower pass band or frequency response.

The longer the telephone line, the higher the loss is at high frequencies, not too noticeable in the voice range, but still there. Too long a line, without any amplification, and this loss becomes noticeable. Adding an amplifier, in days past, was expensive. To overcome this loss one or more loading coils were used. The effect was less loss at the voice frequencies where the power (speaking volume) was around 800 Hertz, and higher loss at the upper range of the voice, were the sounds made a voice more distinct and recognizable. Overall, it was a good design at the time.

Along came digital transmission, at first T1s, and then DSL or ASDL. Now the high frequencies were needed and loading coils had to go on these lines. Central Offices were improved and could provide some amplification very easily and cheaply.

Distance can be increased for analog telephony if we use loaded cables that compensate for loss and dispersion. However, they cannot support the DSL as the loaded coils attenuate high frequencies. Many modern communities have been cabled with fiber coming to the curb with the digital multiplexer at the end of the fiber. The length limitation of the copper cable in this configuration is practically eliminated. This is being taken advantage of in later releases of xDSL such as very high data rate DSL (VDSL).

xDSL Technologies

Table 13.8 DSL Technologies

Name	Meaning	Max Data Rate*	Mode	Cable	Applications
ADSL / ADSL2 / ADSL2+	**Asymmetric Digital Subscriber Line**	**7/12/24 Mbps 0.8/1/1 Mbps**	**Down Up**	**1-pair**	**Most common type**
SHDSL	Symmetric High data rate DSL	5.6 Mbps	Duplex Duplex	2-pair	Business Connections
VDSL 1 Km	Very high data rate Digital Subscriber Line	55 Mbps 15 Mbps	Down Up	2-pair	Triple Play (No QoS)
VDSL2- Long Reach 3 Km	Very high data rate Digital Subscriber Line	55 Mbps 30 Mbps	Down Up	2-pair	Triple Play
VDSL Short Reach 500 m	Very high data rate Digital Subscriber Line	100 Mbps 100 Mbps	Down Up	2-pair	Triple Play

* Max Data Rate as per Broadband Forum

Notes

ADSL Network

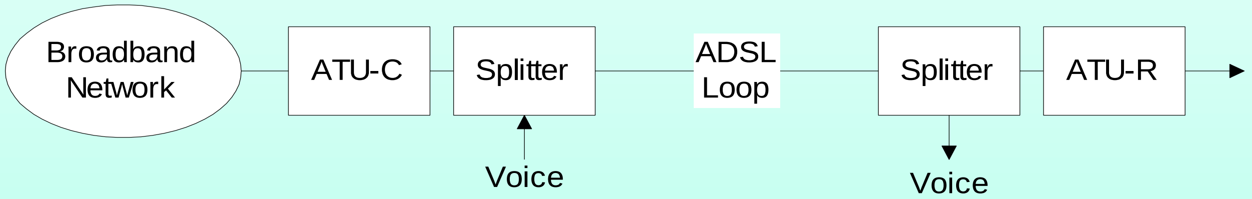


Figure 13.15 ADSL Access Network

Among all the xDSLs, the asymmetric digital subscriber line (ADSL) is the technology that is being deployed now in most of the world.
A simplified access network using ADSL is shown in Figure 13.15 and consists of an **ADSL transmission unit (ATU)** and splitter at each end of **the ADSL line**. The ATU at the central office is ATU-C and the one at the customer residence is ATU-R . The ATU is also called the ADSL modem.

The data and video signal from the broadband network is converted to an analog signal by the ATU-C and multiplexed and demultiplexed. The splitter at the central office combines the plain old telephone service (POTS) voice signal and the broadband signal. The reverse process occurs at the splitter and ATU-R at the customer premises (residence). There are modems available that embed the splitter and thus eliminate a separate splitter at the customer site. This configuration is referred to as ADSL-Lite, also known as GLite.

Notes

- ADSL .. Asymmetric Digital Subscriber Line
- ATU-C ADSL transmission unit - central office
- ATU-R ADSL transmission unit - remote/residence
- Splitter separates voice and data

ADSL Spectrum Allocation with Guard Band

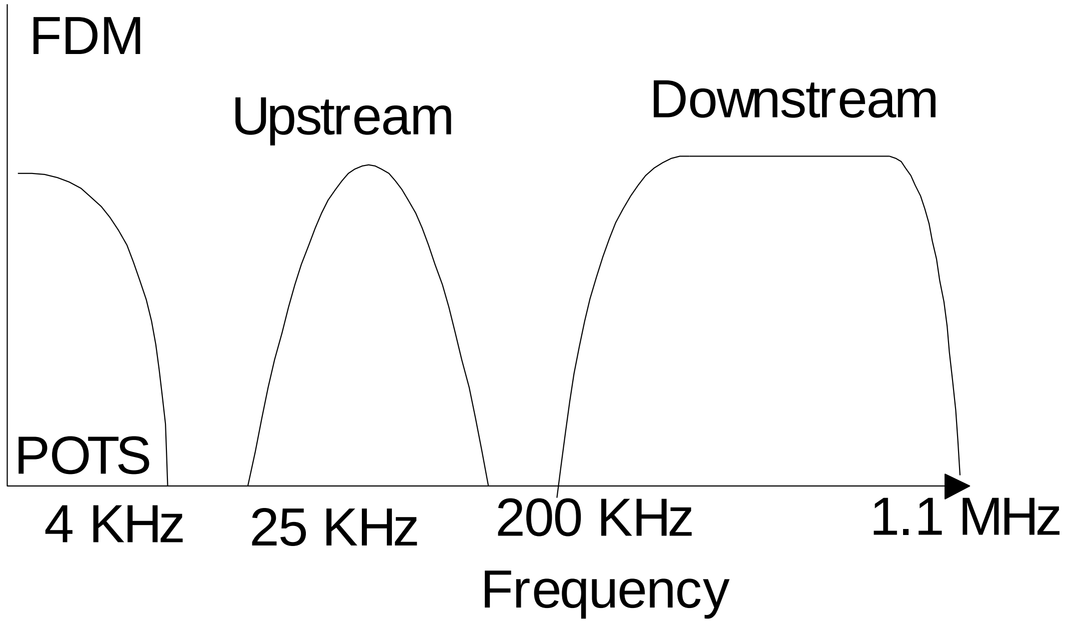


Figure 13.16 ADSL Spectrum Allocationd (FDM)

Notes

- POTS .. Plain old telephone service

As mentioned above, upstream and downstream signals are placed asymmetrically in the frequency spectrum, as shown in Figure 13.16. The POTS signal is always allocated the baseband of 4 kHz and separated from the broadband signal by a guard band. There are two schemes for separating the upstream and downstream frequency bands: frequency division multiplexing (FDM) or echo cancellation. In FDM, after separating the upstream and downstream bands, each band is then divided into one or more high-speed channels and one or more low-speed channels. In echo cancellation, upstream and downstream bands overlap, but are separated by a technique known as echo cancellation. Using echo cancellation, the low frequency end of the spectrum is made available for downstream, thus increasing the overall downstream spectral band.

ADSL Spectrum Allocation with Echo Cancellation

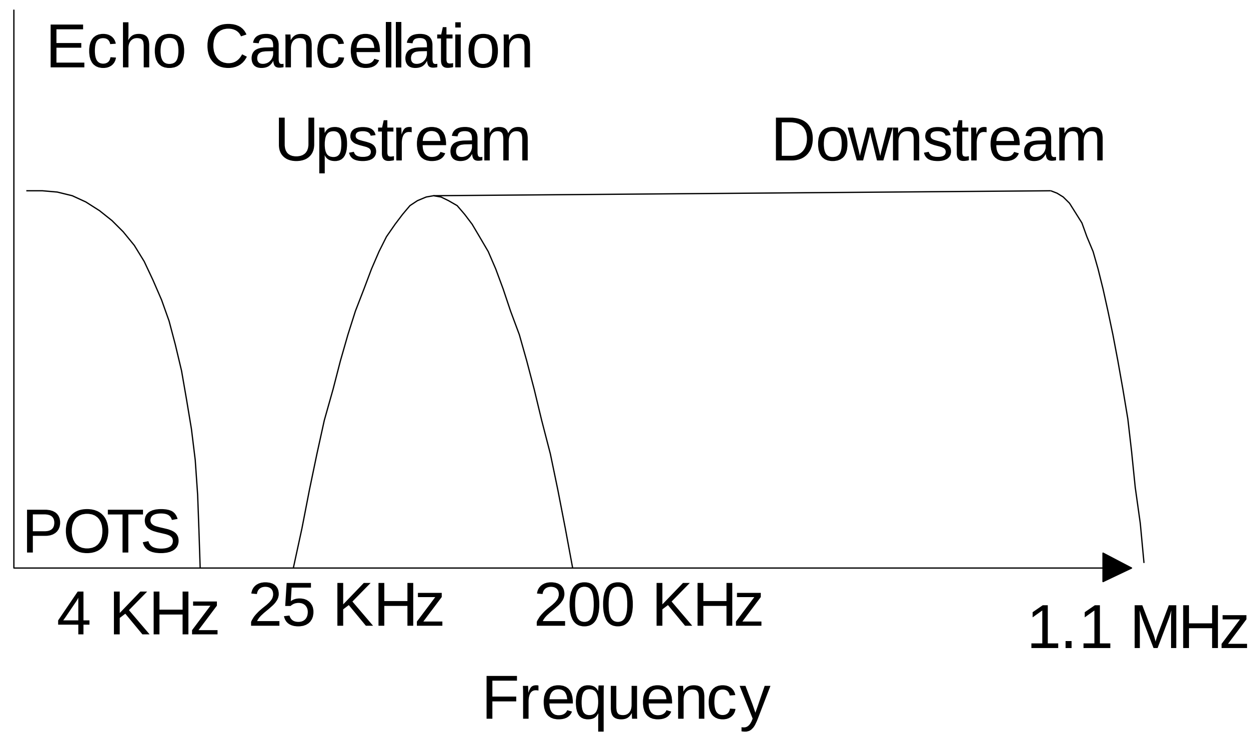


Figure 13.16 ADSL Spectrum Allocation (Echo Cancellation)

Notes

- Echo cancellation separates upstream and downstream signals
- Increases (low-frequency) upstream bandwidth

Modulation Schemes

- ADSL management is dependent on the line-encoding scheme used
  - Carrierless amplitude phase (CAP) modulation
  - Discrete MultiTone modulation (DMT): 4kHz tones
- Both CAP and DMT are QAM-based
- DMT outperforms CAP
  - Higher downstream throughput > 4 times
  - Higher upstream throughput > 10
  - Rate adaptive
  - Ongoing active monitoring
  - Maximum loop variation coverage
  - Standard and hence interoperable

DSL / Broadband Forum

- ADSL (now Broadband) Forum is an industry consortium formed to
  - Achieve interoperability
  - Accelerate DSL implementation
  - Address end-to-end system operation
  - Security
  - Management
- 3 sets of complementary standards adopted
  - ITU-T standards
    - G.992.x
    - G.997.x
    - T1-413 (ANSI)
  - Forum Standards
    - Technical reports TR-xxx
  - IETF standards
    - RFC xxxx

Notes

Selected Documentation from DSL / Broadband Forum

Table 13.9 ADSL Management Documents

TR-001	ADSL Forum System Reference Model	May 1996
TR-005	ADSL Network Element Mgmt	March 1998
TR-015	CAP Line Code Specific MIB	February 1999
TR-024	DMT Line Code Specific MIB	June 1999
TR-027	SNMP-based ADSL LINE MIB	September 1999
TR-028	CMIP Specification for ADSL Network Element Mgmt	May 1999
TR-066	ADSL Network Element Mgmt (Update to TR-005)	March 2004
TR-090	Protocol Independent Object Model for Managing Next Generation ADSL Technologies	December 2004
TR-113	MCM Specific Managed Objects in VDSL Network Element	December 2005
TR-128	Addendum to TR-090	September 2006

Notes

VDSL Network

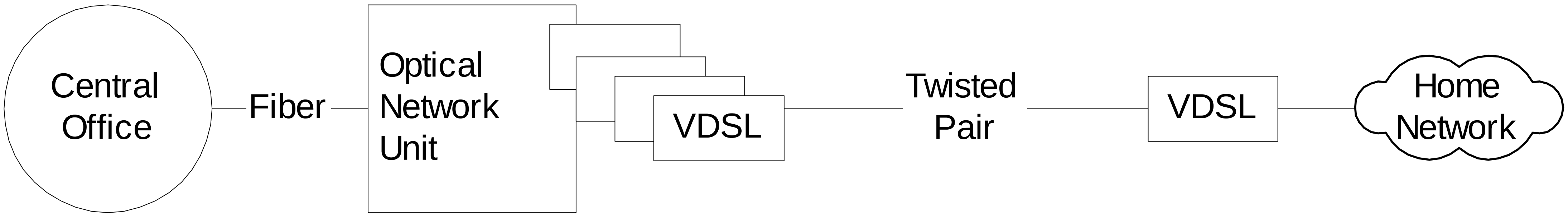


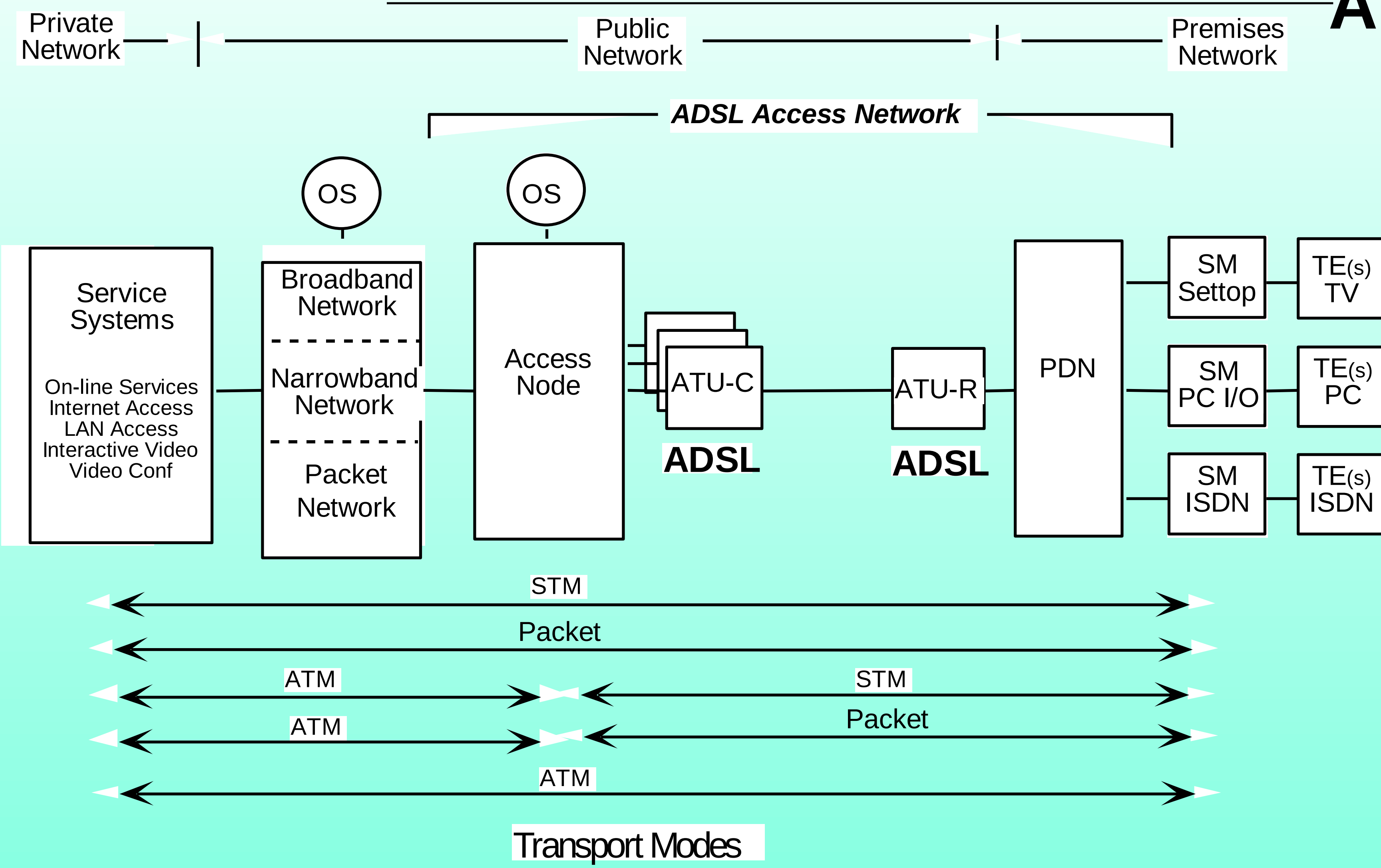
Figure 13.17 VDSL Access Network

Fiber to the node (FTTN) is one of several options for providing cable telecommunications services to multiple destinations. Fiber to the node helps to provide broadband connection and other data services through a common network box, which is often called a node.
Fiber to the node may also be called fiber to the neighborhood.

Notes

- Used in FTTN configuration
- Asymmetric band allocation (similar to ADSL)
- Fiber carries multiple channels to ONU
- Channels demultiplexed at ONU and carried to customer premises on multiple twisted pairs
- Shorter distance of multiple twisted pairs
- Higher data rate : 55.2 Mbps downstream and 2.3 Mbps upstream

ADSL Network



ADSL	Asynchronous Digital Subscriber Line
ATM	Asynchronous Transfer Mode
STM	Synchronous Transfer Mode
TE	Terminal Equipment
OS	Operations System
PDN	Premises Distribution Network
SM	Service Module

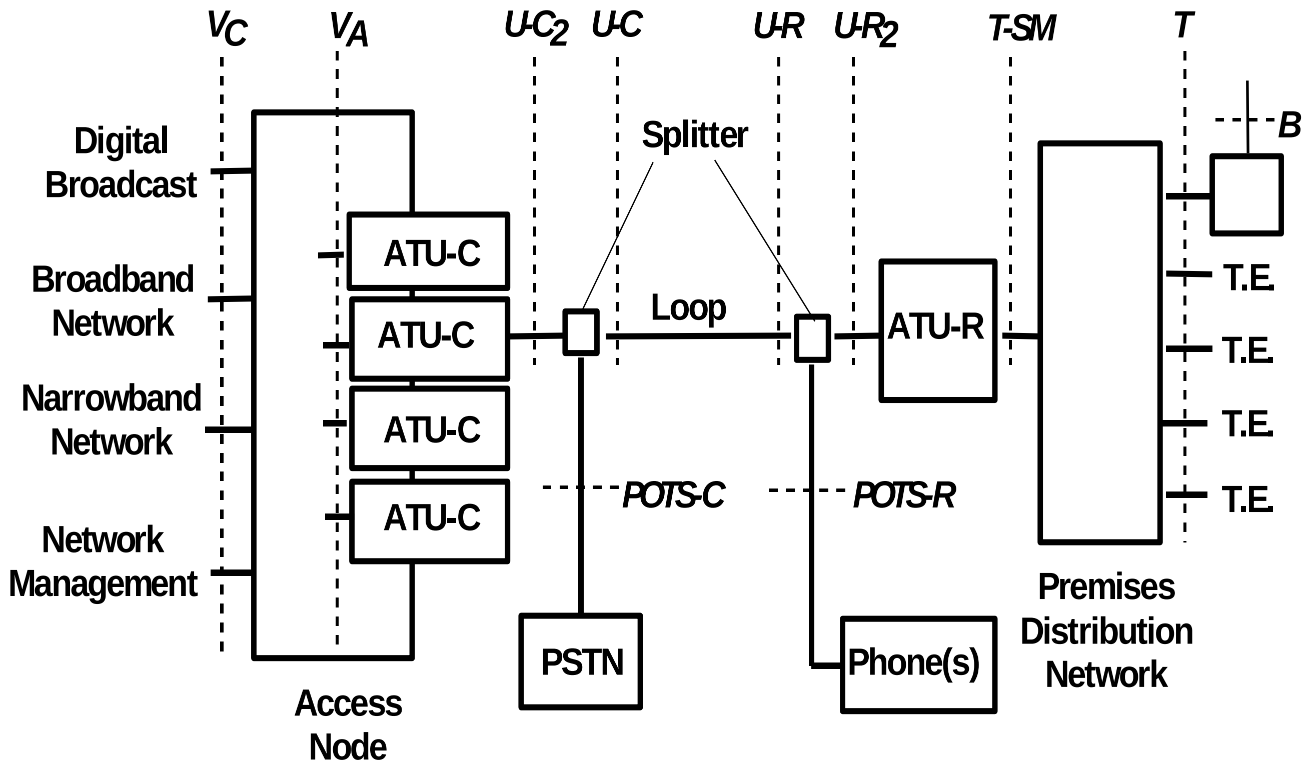
Figure 13.16 Overall Network and ADSL

Transport Modes

- Synchronous transport mode (STM)
  - Bit synchronous transmission (T1/E1)
- End-to-end packet mode
  - Used for SOHO (IP packets)
- ATM / STM
  - ATM WAN (Public network) and STM access network
- ATM / Packet
  - ATM WAN and packet access network (IP)
- End-to-end ATM

- T1 is a digital transmission link with a total transmit and receive rate of 1.544 Mbps (1544000 bits per second).
- E1 is a digital transmission link with a total transmit and receive rate of 2.048 Mbps (2048000 bits per second).
- T1 is used in North America and Asia and E1 is used in Europe and Australia.
- T1 and E1 links enable simultaneous transmission and receiving of several data or voice channels or of unchannelized raw bit stream.
- T1 and E1 interfaces belong to the physical layer (layer 1) in the OSI reference model, thus higher layer technologies such as ISDN, ATM, Frame Relay, TCP/IP and VoIP can be carried over T1 and E1.

ADSL System Reference Model



Interfaces:

B Auxiliary data input such as a satellite feed to Service Module (TE)
POTS-C Interface between PSTN and POTS splitter at network end
POTS-R Interface between phones and POTS splitter at premises end
T Interface between Premises Distribution Network and Service Modules
T/SM Interface between ATU-R and Premises Distribution Network
U-C Interface between Loop and ATU-C (analog)
U-C2 Interface between POTS splitter and ATU-C
U-R Interface between Loop and ATU-R (analog)
U-R2 Interface between POTS splitter and ATU-R
V_A Logical interface between ATU-C and Access Node
V_C Interface between Access Node and network

TE Terminal Equipment
POTS Plain Old Telephone Service
PSTN Public Switched Telephone Network

Figure 13.19 ADSL System Reference Model

Interfaces

- An interface can have multiple physical connections
- V interface
  - V_C interface between access node and external network and interfaces
- U interfaces - off the splitters; Will be eliminated with ADSL-Lite
- POTS interfaces – low-pass filter interfaces for POTS
- T and B are customer premises network interfaces
  - T between PDN and service modules
  - B auxiliary data input (e.g., satellite feed)

ADSL Channeling Schemes

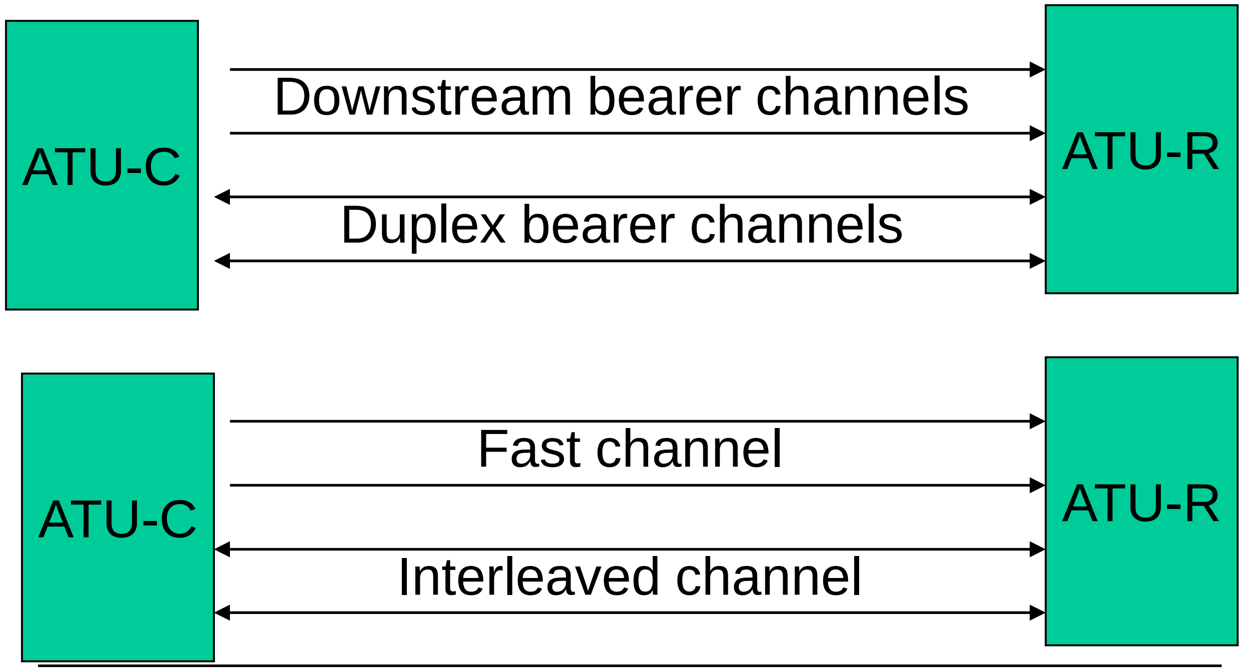


Figure 13.20 ADSL Channeling

Notes

See next slide for details

- **Transport bearer channels**
  - Seven AS downstream channels
    - multiples (1-, 2-, 3- or 4-) T1 rate of 1.536 Mbps
  - Three LS duplex channels
    - 160, 384, and 576 Kbps
- **Buffering scheme**
  - Fast channel: uses fast buffers for real-time data
  - Interleaved channel: used for non-real-time data
  - Both fast and interleaved channels carried on the same physical channel

ADSL Channeling Schemes

There are two perspectives in discussing transport channels in an ADSL access network. The first perspective is the traditional transport bearer channels as they are defined in ISDN. For ADSL transport frames, there are seven "AS " bearer channels defined for the downstream signal operating in a simplex mode. The AS bearer channels are in multiples (one, two, three, or four) of T1 rate of 1.536 Mbps or E 1 rate of 2.048 Mbps. In addition to downstream AS channels, there could be three additional "LS "duplex channels carrying the signal in both downstream and upstream directions. The LS bearer channels are 576 ro ,384 ,160Kbps.

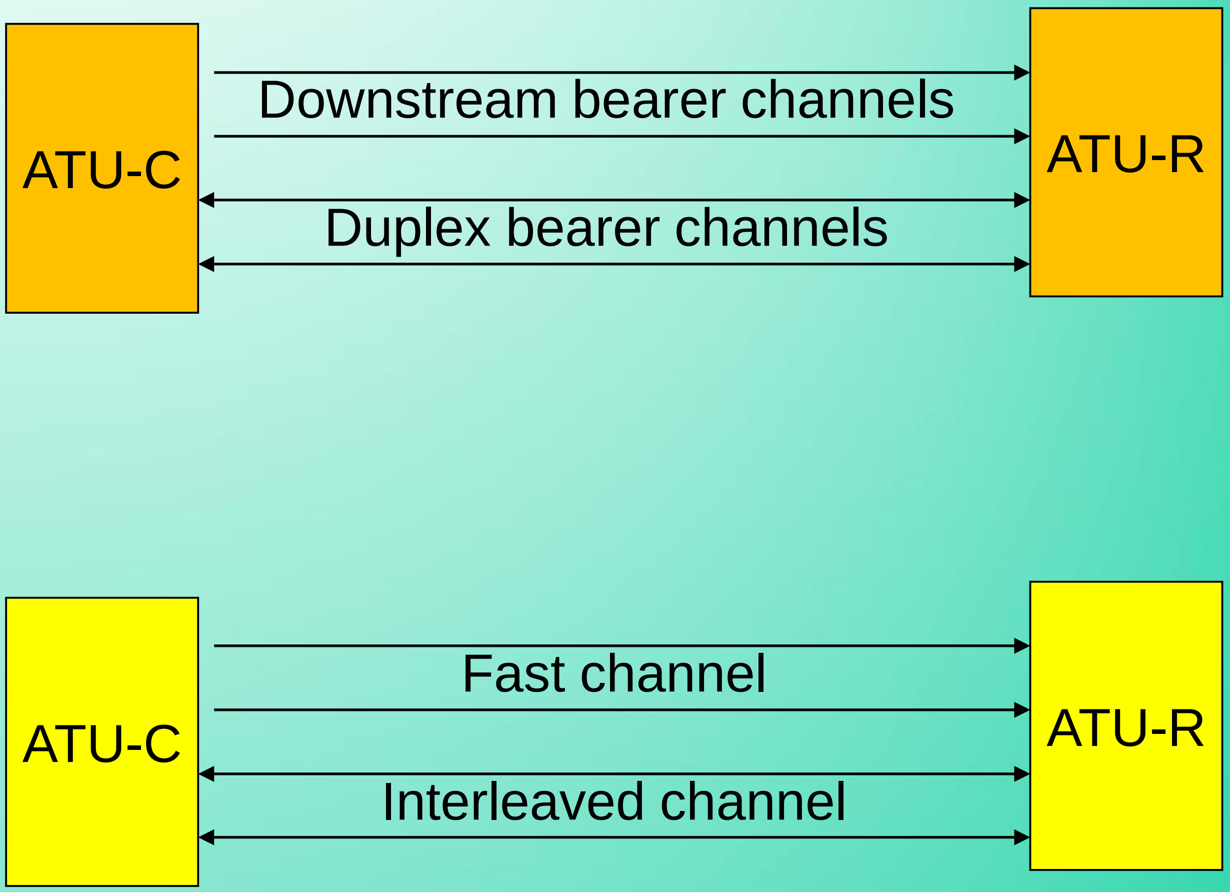


Figure 13.20 ADSL Channeling

The second perspective in discussing the channels is how the signal is buffered while traversing the ADSL link. This is represented in Figure 13.20. Real-time signals, such as audio and real-time video, use a fast buffering scheme and hence are referred to as the fast channel . Digital data that could tolerate delay use slow buffers that are interleaved between the fast signals. The digital data channel is referred to as the interleaved channel . Thus, a physical interface would carry both the fast channel and the interleaved channel and needs to be addressed in the network management of interfaces.

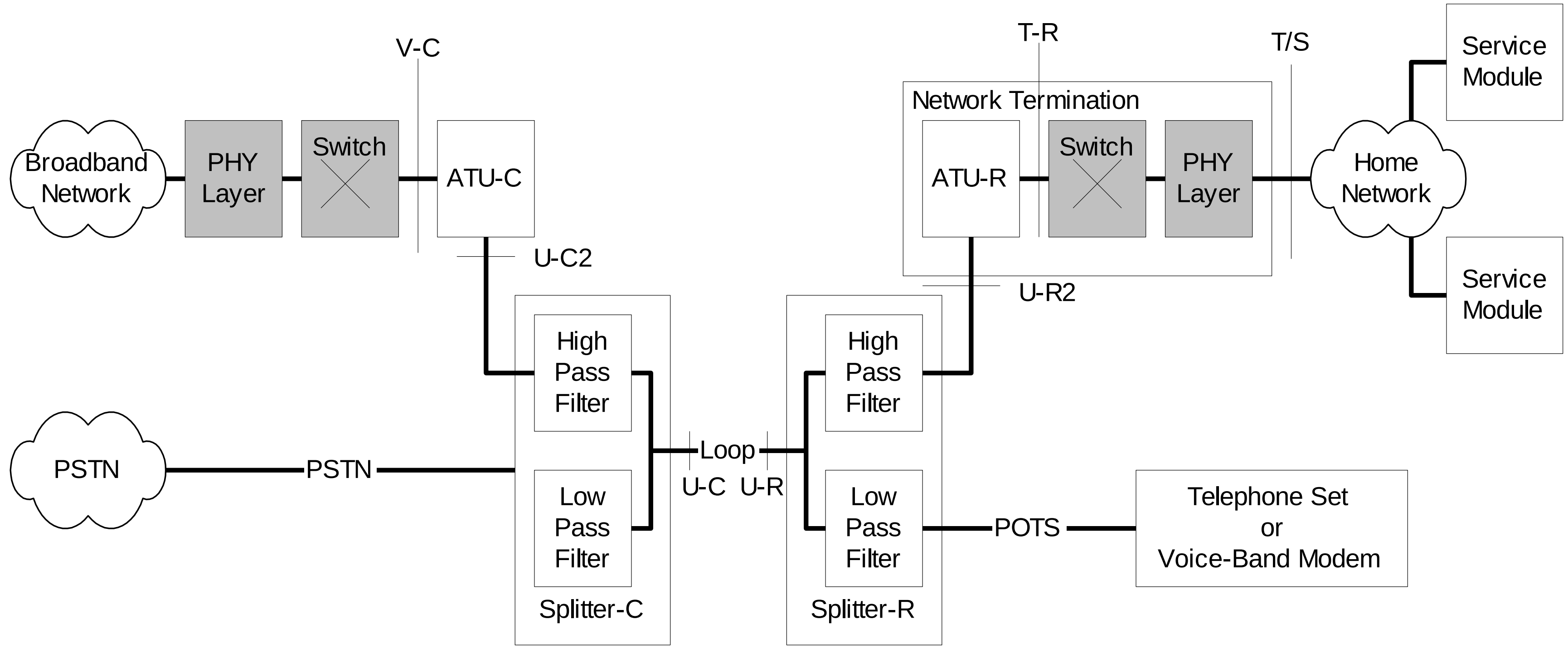
Incidentally, "AS" and "LS" are not specific acronyms.

ADSL management

ADSL network management deals with parameters, operations, and protocols associated with configuration, fault, and performance management.

Security and accounting management are not explicitly dealt with, although these are important management functions and are addressed by other models (for example, SNMP security management previously discussed in Chapters 7 and 11).

Management Reference Model



Interfaces:
- T-R Interface between ATU-R and Switching layers
- T/S Interface between ADSL Network Termination and customer installation or home network
- U-C Interface between Loop and ATU-C (analog)
- UC2 Interface between POTS splitter and ATU-C
- U-R Interface between Loop and ATU-R (analog)
- U-R2 Interface between POTS splitter and ATU-R
- V-C Logical interface between ATU-C and a digital network element such as one or more switching systems

Figure 13.21 ADSL Forum System Reference Model for Management

ADSL in the OSI Model

In the seven layer OSI model, ADSL is at the Physical Layer (Layer 1), an encoding technology over which may be deployed higher layer protocols, such as ATM. The Physical Layer handles the basic ADSL encoding, data rates, and offers compatibility with other technologies in the subscriber line. For example, ADSL can share the line with a POTS service.

Management Elements

- Management of elements done across V-interface:
  - Management communications protocol across V-interface
  - Management communications protocol across U-interfaces
  - Parameters and operations across ATU-C
  - Parameters and operations across ATU-R
  - ATU-R side of the T interface

Notes

- **Note addition of physical layer and switching in the management architecture representation**
- Management of physical layer involves:
  - Physical channel
  - Fast channel
  - Interleaved channel
- Management of type of line encoding
  - DMT
  - CAP

Signal Power and Data Rate Management

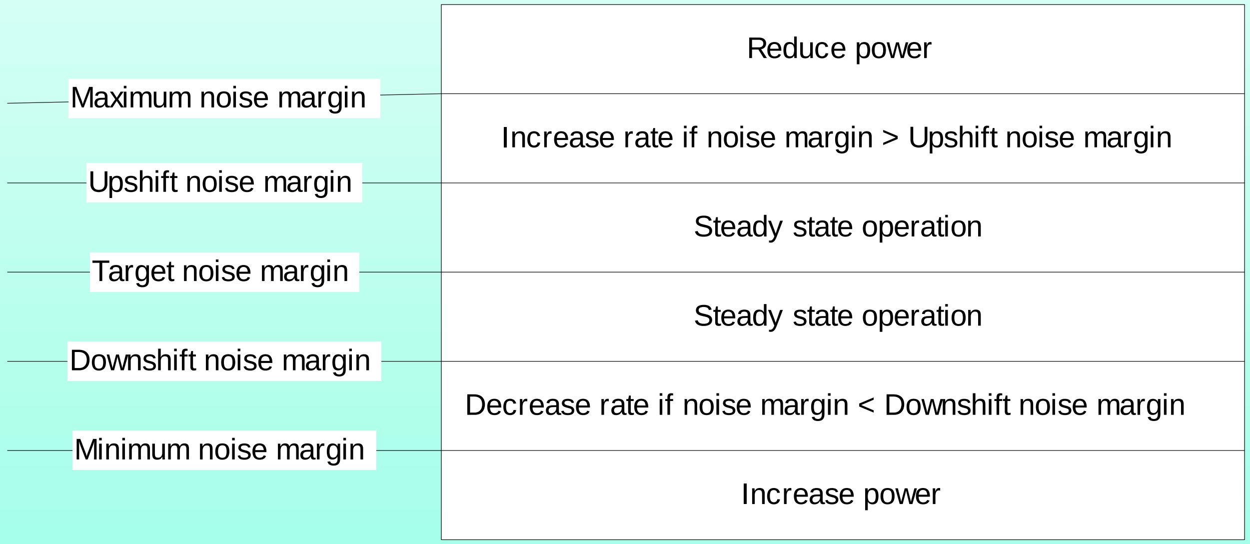


Figure 13.22 Noise Margins

Notes

- Five levels of noise margin
- Signal power controlled by noise margin
- Data rate: Increase or decrease based on threshold margins
- Data rate adaptation modes: Manual (1), automatic at start-up (2), and dynamic (3)

There are five levels of noise margin—from the highest defined by the maximum noise margin to the lowest defined by the minimum noise margin. The transmitted power of the modem needs to be decreased or increased, respectively, based on these thresholds. The transmission rate can be increased if the noise margin goes above a threshold level, which is beneath the maximum noise margin threshold. Similarly, the transmission rate should be decreased if the noise margin falls below a certain threshold, which is higher than the minimum noise margin. Right at the middle of all these thresholds is the steady-state operation. These levels are shown in Figure 13.22.

Configuration Mgmt Parameters

- Fast channel: uses fast buffers for real-time data
- Interleaved channel: used for non-real-time data

Table 13.10 ADSL Configuration Management Parameters

Parameter	Component	Line	Description
ADSL Line type	ADSL Line	N/A	Five types: no channel, fast, interleaved, either or both
ADSL Line coding	ADSL Line	N/A	ADSL coding type
Target noise margin	ATU-C/R	Phy	Noise margin under steady state (BER=<10^{-7})
Max. noise margin	ATU-C/R	Phy	Modem reduces power above this threshold
Min. noise margin	ATU-C/R	Phy	Modem increases power below this margin
Rate adaptation mode	ATU-C/R	Phy	Mode 1: Manual Mode 2: Select at start-up Mode 3: Dynamic
Upshift noise margin	ATU-C/R	Phy	Threshold for modem increases data rate
Min. time interval for upshift rate adaptation	ATU-C/R	Phy	Time interval to upshift
Downshift noise margin	ATU-C/R	Phy	Threshold for modem decreases data rate
Min. time interval for downshift rate adaptation	ATU-C/R	Phy	Time interval to downshift
Desired max. rate	ATU-C/R	F/I	Max rates for ATU-C/R
Desired min. rate	ATU-C/R	F/I	Min. rates for ATU-C/R
Rate adaptation ratio	ATU-C/R	Phy	Distribution ratio between fast and interleaved channels for available excess bit rate
Max. interleave delay	ATU-C/R	F/I	Max. transmission delay allowed by interleaving process
Alarm thresholds	ATU-C/R	Phy	15-minute count threshold on loss of signal, frame, power and error-seconds
Rate up threshold	ATU-C/R	F/I	Rate-up change alarm
Rate down threshold	ATU-C/R	F/I	Rate-down change alarm
Vendor ID	ATU-C/R	Phy	Vendor ID assigned by T1E1.4
Version No.	ATU-C/R	Phy	Vendor specific version
Serial No.	ATU-C/R	Phy	Vendor specific Serial No.

Fault Management

Table 13.11 ADSL Fault Management Parameters

Parameter	Component	Line	Description
ADSL Line status	ADSL Line	Phy	Indicates operational and various types of failures of the link
Alarms thresholds	ATU-C/R	Phy	Generates alarms on failures or crossing of thresholds
Unable to initialize ATU-R	ATU-C/R	Phy	Initialization failure of ATU-R from ATU-C
Rate change	ATU-C/R	Phy	Event generation when rate changes when crossing of shift margins in both upstream and downstream

Notes

- Failure indication of physical channel by NMS
- Failure indication of logical channels
- Failure indication of ATU-C/R
- Self-test of ATU-C/R as per T1.413
- Noise margin threshold alarms
- Rate change due to noise margin

Performance Management

Table 13.12 ADSL Performance Management Parameters

Parameter	Component	Line	Description
Line attenuation	ATU-C/R	Phy	Measured power loss in dB from transmitter to receiver ATU
Noise margin	ATU-C/R	Phy	Noise margin in dB of the ATU with respect to received signal
Total output power	ATU-C/R	Phy	Total output power from the modem
Max. attainable rate	ATU-C/R	Phy	Max. currently attainable data rate by the modem
Current rate	ATU-C/R	F/I	Current transmit rate to which the modem is adapted
Previous rate	ATU-C/R	F/I	Rate of the modem before the last change
Channel data block length	ATU-C/R	F/I	Data block on which CRC check is done
Interleave delay	ATU-C/R	F/I	Transmit delay introduced by the interleaving process
Statistics	ATU-C/R	Phy F/I	15 minute / 1 day failure statistics

Notes

- Line attenuation
- Noise margin
- Output power
- Data rate
- Data integrity check
- Interleave channel delay
- Error statistics

ADSL SNMP MIB

There are both SNMP and CMIP based specifications that have been developed for ADSL.

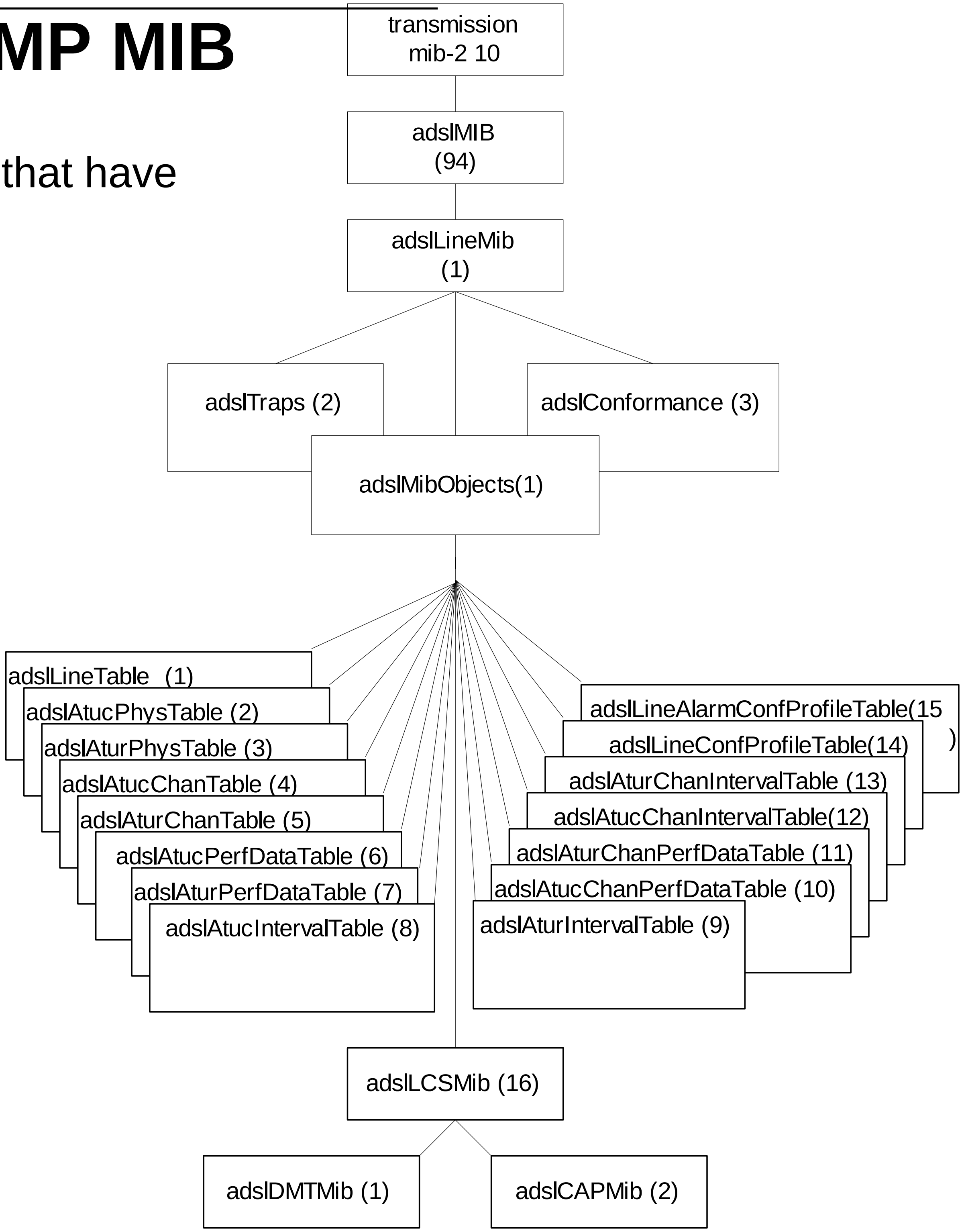
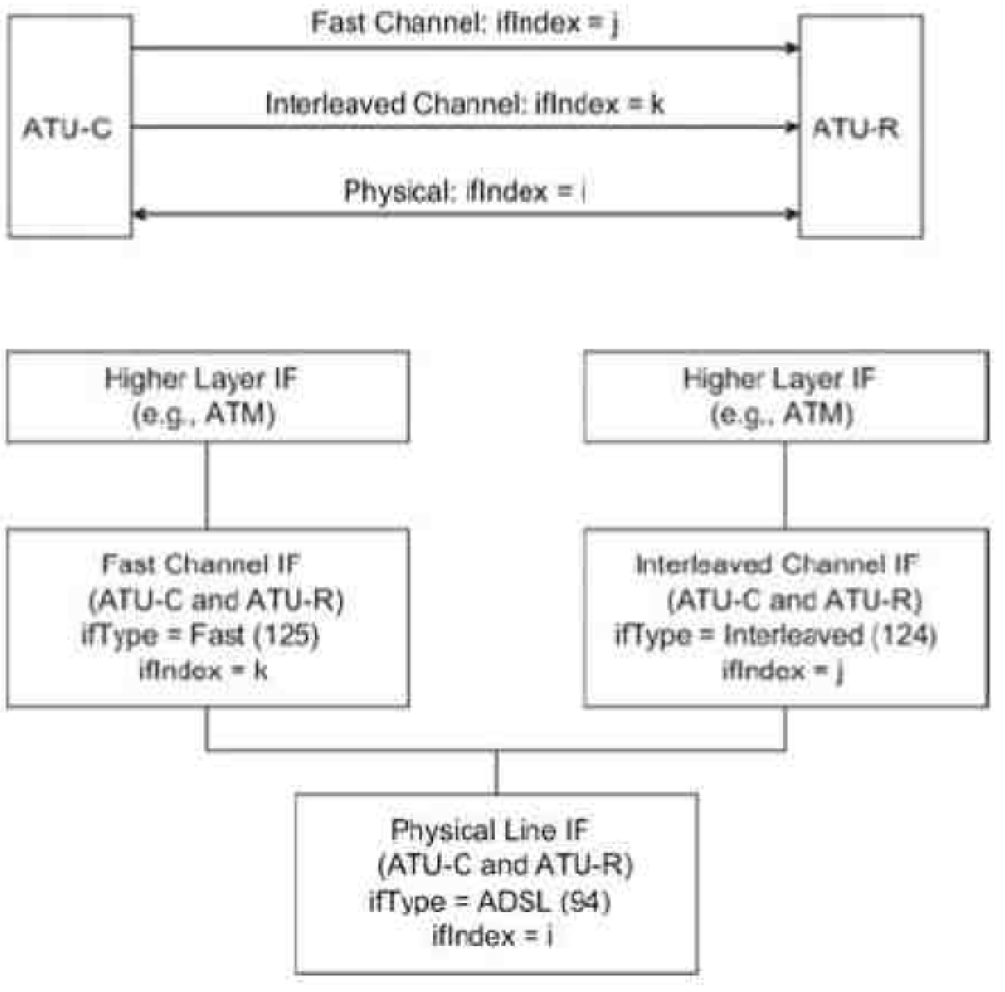


Figure 13.23 ADSL SNMP MIB

Proposed IF Types

Figure 13.24. Relationship between ADSL Entries



Notes

- Sublayers handled by ifMIB
  ifStackTable {ifMib.ifMIBObjects 2} (RFC 1573)
- Propose ifTypes
  adslPhysIf ::= {transmission 94}
  adslInterIf ::= {transmission 124}
  adslFastIf ::= {transmission 125}

The ifStackTable {ifMIB.ifMIBObjects 2}, which is the table containing information on the relationships between multiple sublayers of network interfaces, is used to associate the fast and interleaved channels with the physical line. The top of Figure 13.24 shows the logical representation of the channels. Their relationship with each other and with the higher layer is shown in the bottom of Figure 13.24. The fast channel and the interleaved channel, which are at the same level, are stacked on top of the physical layer. They interface above with a higher layer, for example ATM if ATM is over ADSL.

ADSL Interfaces Table

Table 13.13 Use of Interfaces Table for ADSL

MIB Variable	Physical Line (i)	Interleaved Channel (j)	Fast Channel (k)
ifDescr	NORMAL	NORMAL	NORMAL
ifType (IANA)	94	124	125
ifSpeed	ATU-C Line Tx rate	ATU-C channel Tx rate	ATU-C channel Tx rate
ifPhyAddress	NULL	NULL	NULL
ifAdminStatus	NORMAL	NORMAL	NORMAL
ifOperStatus	NORMAL	NORMAL	NORMAL
ifLastChange	NORMAL	NORMAL	NORMAL
ifLinkUpDownTrap Enable	NORMAL (default: Enable)	NORMAL (default: Enable)	NORMAL (default: Enable)
ifConnectPresent	True	False	False
ifHighSpeed	NULL	NULL	NULL

Table 13.14 ADSL Operational Profile for ifType File

ADSL Operational Configuration

Line type	Physical	Fast Channel	Interleaved Channel
Number of Channels (1)	Yes		Yes
Fast only (2)	Yes	Yes	
Interleave only (3)	Yes		Yes
Fast or Interleaved (4)	Yes	Yes	Yes
Fast and Interleaved (5)	Yes	Yes	Yes

ADSL Profiles Management

- Configuration profile
- Performance profile
- Alarm profile
- Traps
    - Generic
    - Loss of frame
    - Loss of signal
    - Loss of power
    - Error-second threshold
    - Data rate change
    - Loss of link
    - ATU-C initialization failure

Configuration Profile: Mode I - Dynamic

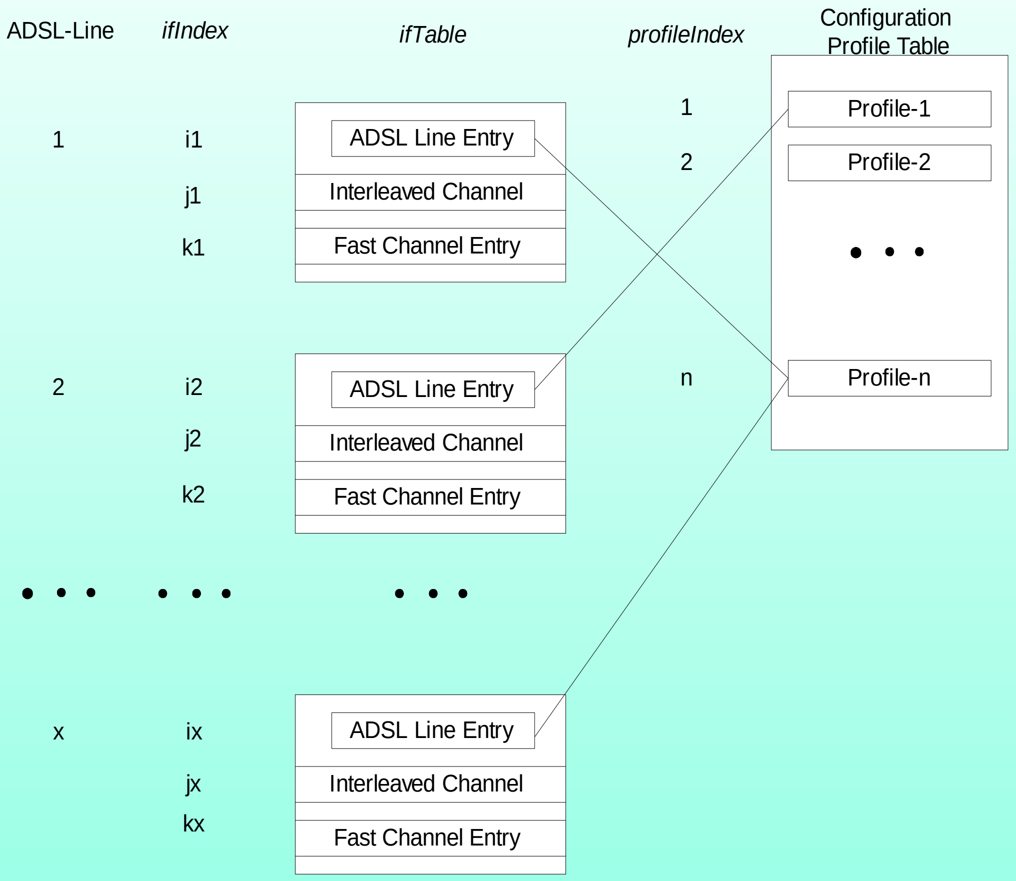


Figure 13.25 Use of Profiles in MODE-I (Dynamic)

Configuration of ADSL lines in an ADSL system

In a typical configuration of an ADSL system, the access node shown in Figure 13.19 has hundreds of ATU-Cs. It would be impractical to provision all the parameters for each ATU-C individually. There are two MIB tables to address this issue—one for configuration profile and another for the performance profile. One of the tables is adslLineConfProfileTable {adslMibObjects 14}, which contains information on the ADSL line configuration shown in Table 13.10. One or more ADSL lines may be configured to share common profile information. Figure 13.25 shows the dynamic mode, MODE-I, configuration profile scheme. Profile tables are created and indexed 1 to n. Each ADSL line interface, with the given value of ifIndex, shown ranging from 1 to x shares the configuration profiles from 1 to n. The three entries for the physical layer, the interleaved channel, and the fast channel for each ADSL line are represented by "i," "j," and "k" as discussed in Section 13.8.6. Only the ADSL line entry contains the pointer to the configuration profile table. The ifStackTable [RFC 2863] is used to link channel entries and the corresponding physical layer to acquire the channel configuration parameters.

Configuration Profile: Mode II - Static

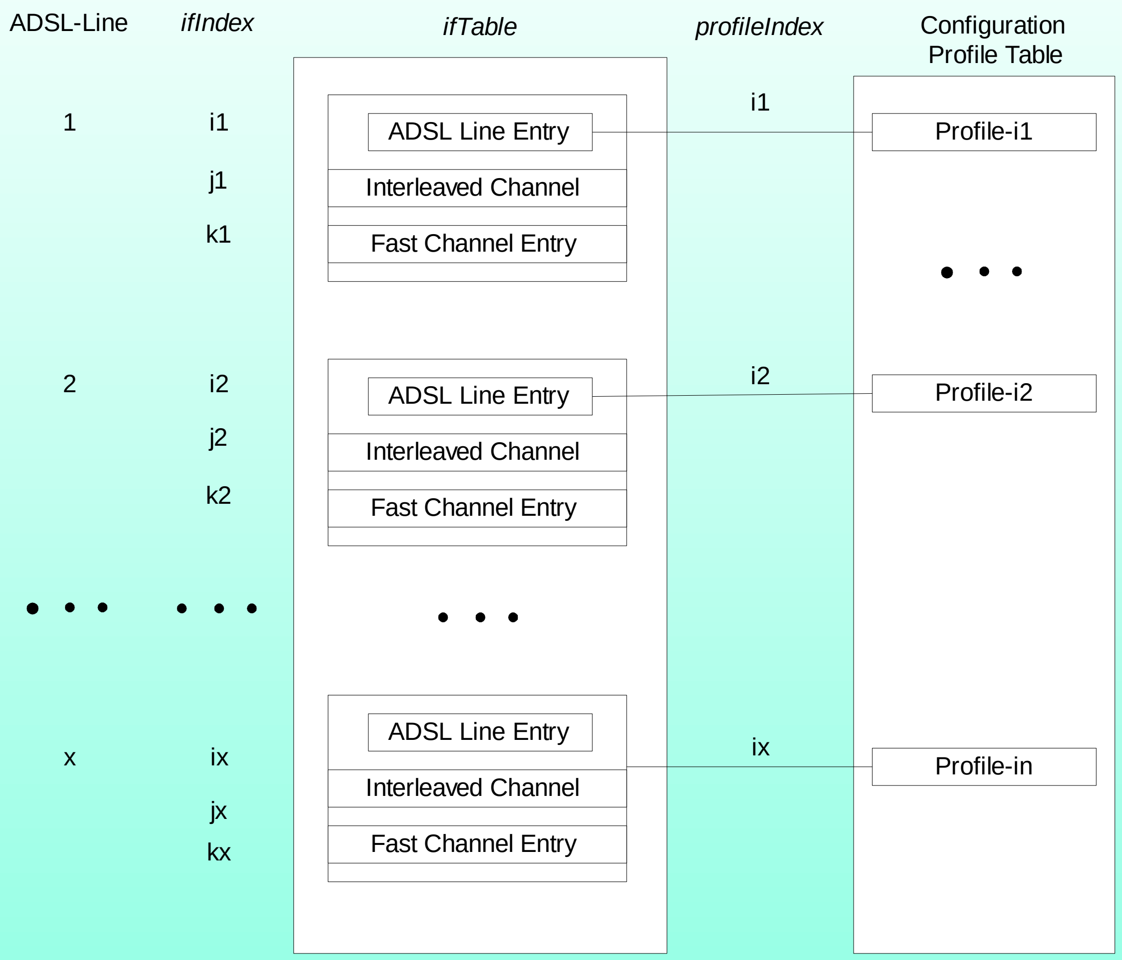
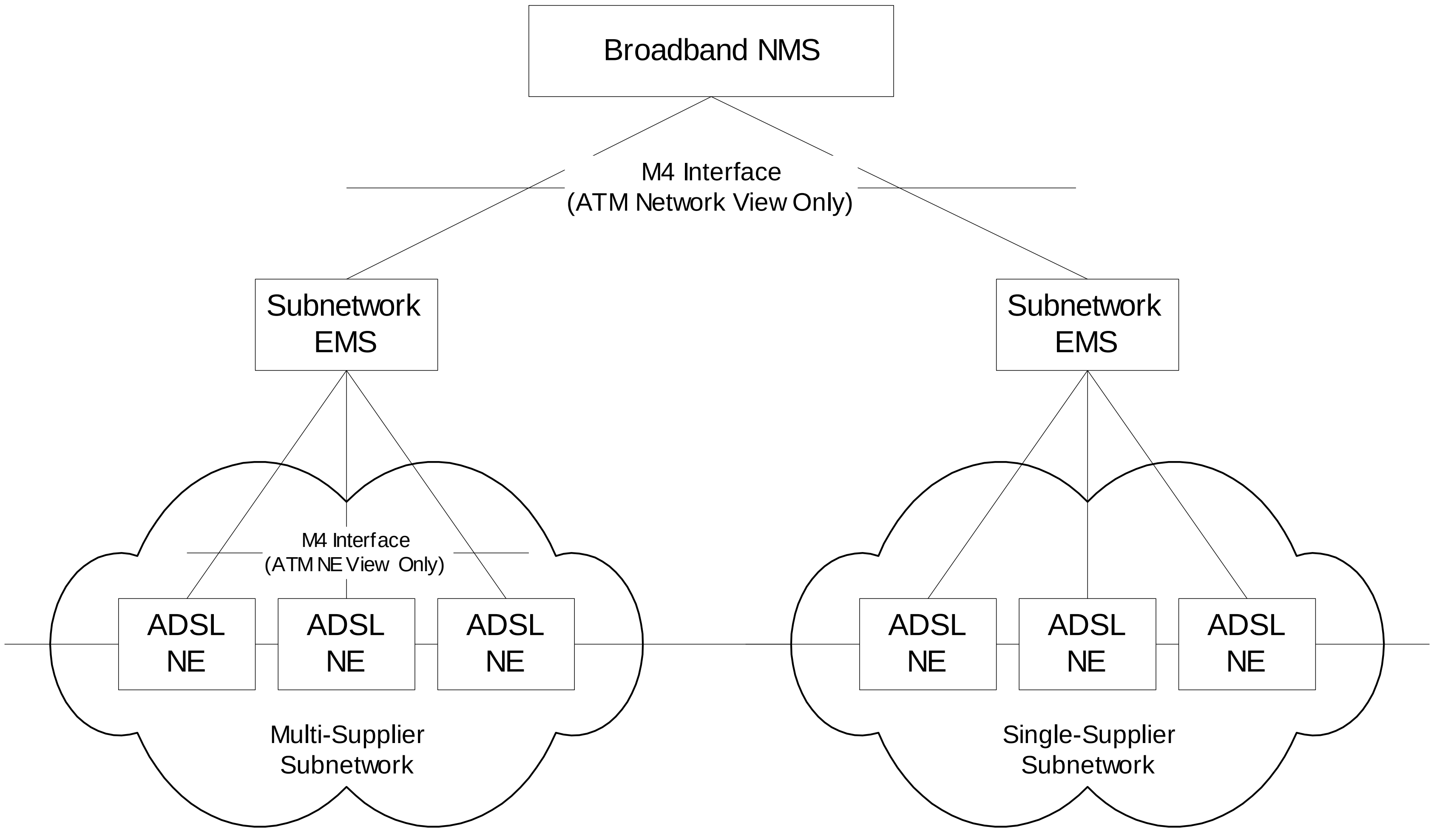


Figure 13.26 Use of Profiles in MODE-II (Static)

Configuration of ADSL lines in an ADSL system

The second mode, denoted by MODE-II, specifies the static mode of setting up ADSL configuration profile. Each ADSL line interface has a static profile, as shown in Figure 13.26. The ADSL line interfaces 1 through x; each has its own configuration profile i1 through ix, indicated by profile indices i1 through ix.

ADSL EMS-NMS Management



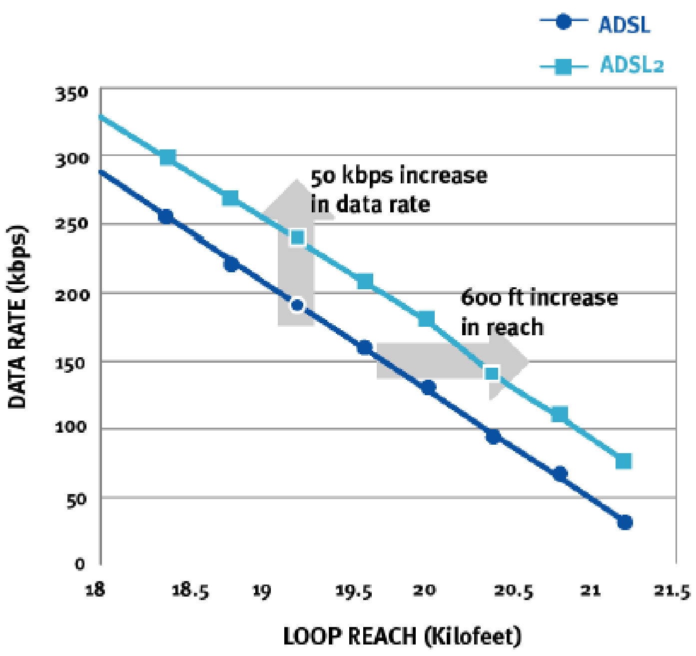
Notes

- TMN- and ATM-based model
- M4 is ATM Forum defined interface between public NMS and public network

ADSL2 and ADSL2+

- Rate and reach Improvements
- ADSL Speed Downstream/Upstream 1/.256 Mbps
- ADSL2 Standard G.992.3 July 2002
- ADSL2 Lite Standard G.992.4 July 2002
    - Speed Downstream/Upstream 12/1 Mbps
- ADSL2+ Standard G.992.5 January 2003
    - Speed Downstream/Upstream 24/2 Mbps
- Other Major Enhancements
    - Diagnostics
    - Power enhancements
    - Rate adaptation
    - Bonding for higher data rates
    - Channelization and Channelized Voice-over DSL (CVoDSL)
- Additional Benefits
    - Improved interoperability
    - Fast startup
    - All-Digital Mode
    - Support of packet-based services

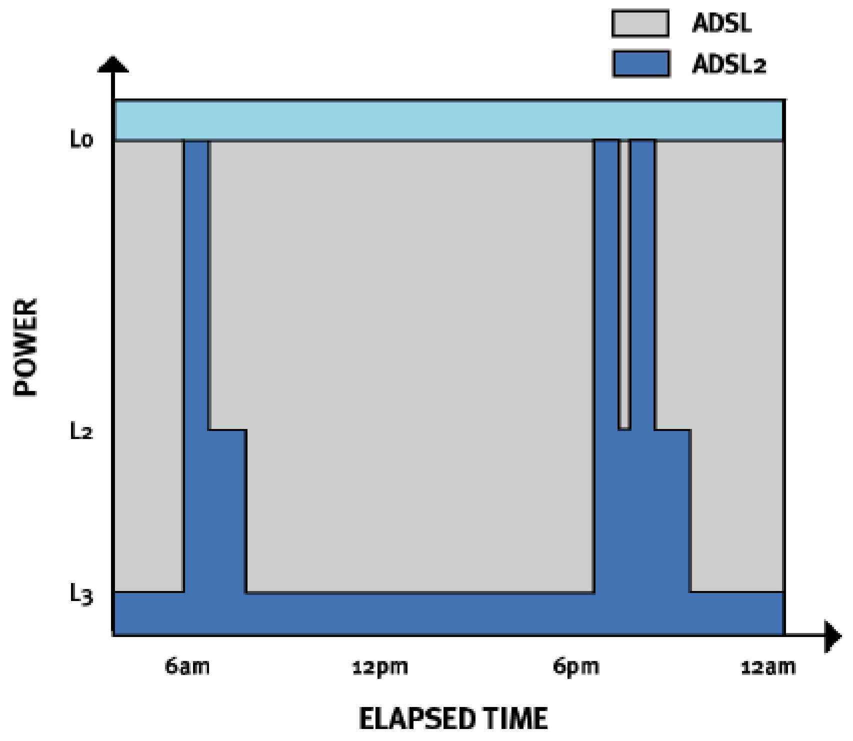
ADSL2 Rate and Reach



Notes

- Data rate increase of 50 kbps or increase of 600 feet reach achieved
- Programmable overhead
  - ADSL 32 kbps
  - ADSL2 4-32 kbps
- Higher coding gain from Reed-Solomon (RS) code

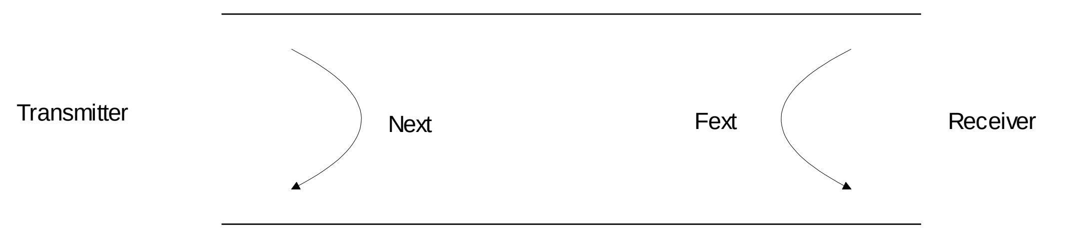
ADSL2 Power Enhancement



Notes

- Savings in ATU-C and ATU-R
- L0 Full power
- L2 Normal power
- L3 Sleep mode (user not on line)

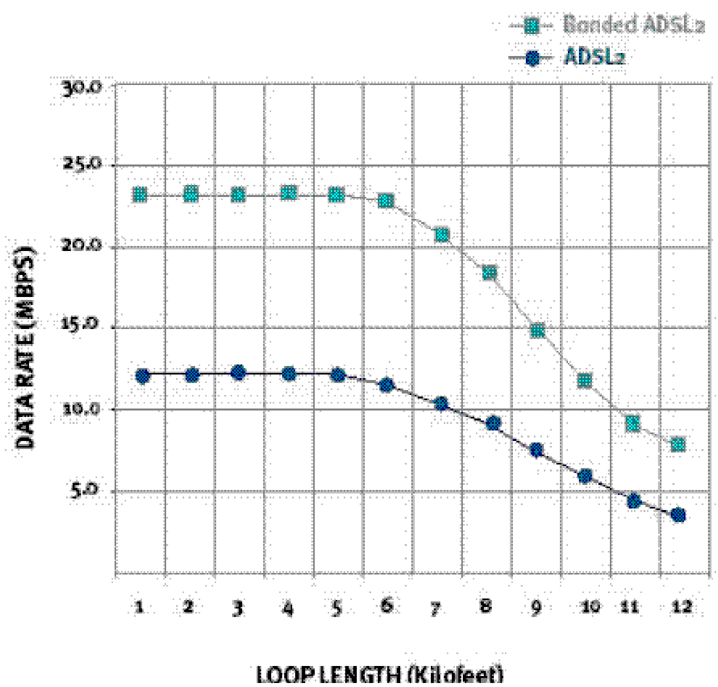
Seamless Rate Adaptation



Notes

- Telephone cable in bundle of 25 or more
- Next and Fext can cause connection drop
- SRA (Seamless Rate Adaptation) decouples modulation and framing layers

Bonding for Higher Data Rates



Notes

- Bonds two or more UTP using ATM IMA (Inverse Multiplexing for ATM)
- New sublayer between PHY and ATM

Other ADSL2 Enhancements

- Diagnostics by use of enhanced transreceivers
  - Line noise
  - Loop attenuation
  - SNR (Signal-to-Noise ratio)
- Improved interoperability due to initialization of state machine
- Fast startup
- Transmission of ADSL data in the voice bandwidth
- Ethernet over ADSL2

Notes

Basic ADSL Management Model

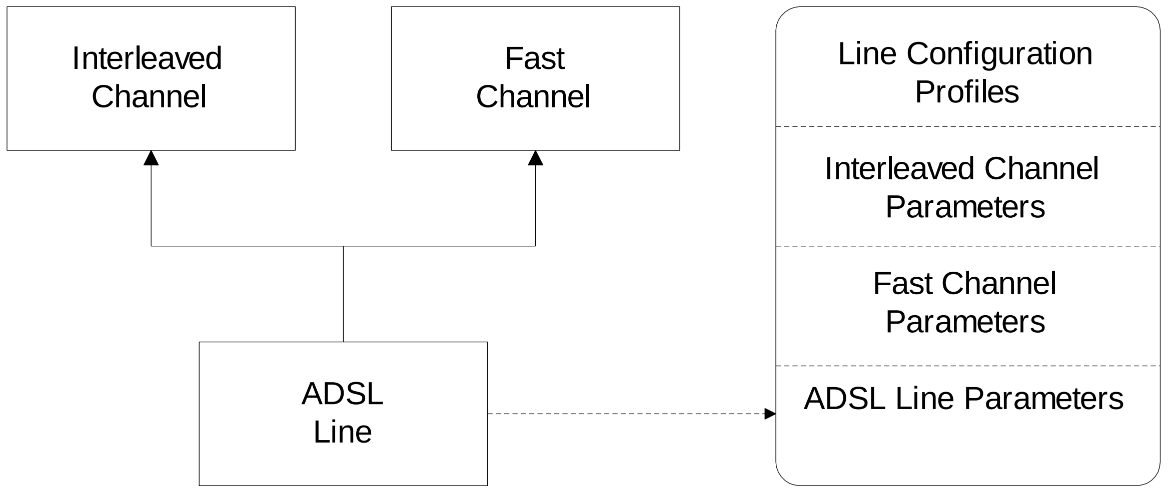


Figure 13.28 Basic ADSL Management Model

Notes

- Supports a simple and fixed channel
    - Fast channel
    - Interleaved channel or
    - Both

Multichannel DSL Management

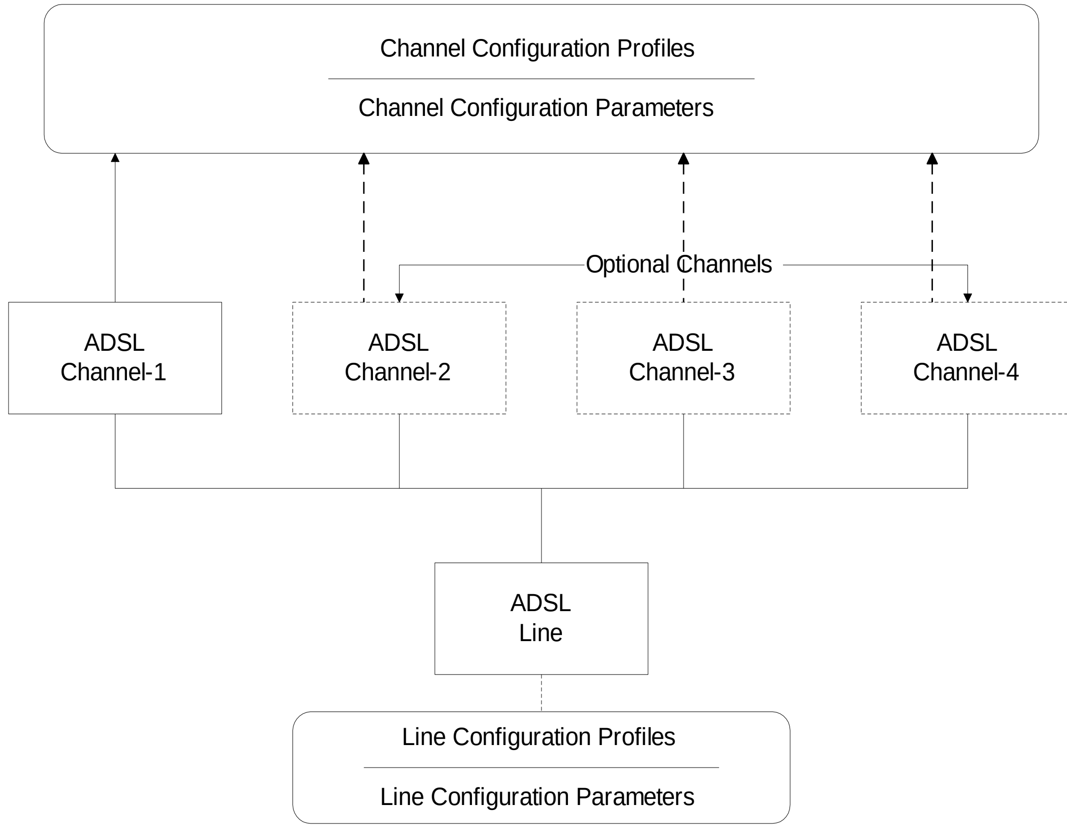


Figure 13.29 Revised Management Framework for a Multichannel DSL

Notes

- Decouple channel parameters from line parameters
- Up to four generic channels
- Flexible configuration
- Many combinations of parameters to manage

Passive Optical Network

Passive Optical Network

- Fiber Medium
- No active elements in the transmission medium
- Passive elements in the fiber medium
  - Beam splitter – Lossy
  - Wavelength Division Multiplexer (WDM)

Notes

Generic PON Architecture

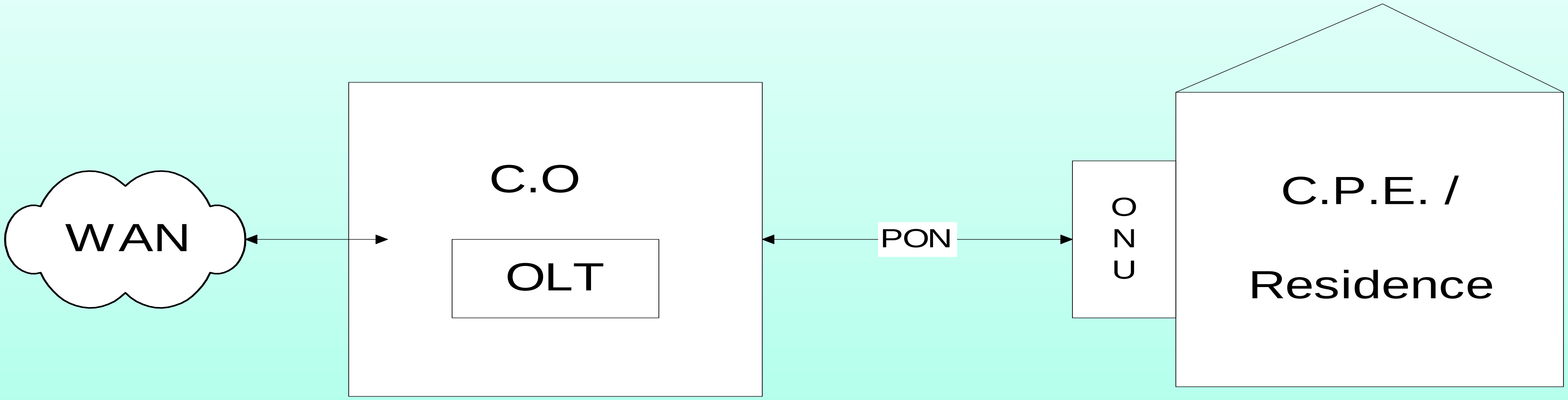


Figure 13.30 Generic PON

Notes

- Optical Line Termination (OLT) in central office
- Optical Network Unit (ONU) in customer residence
- Shared or dedicated optical path
- 1-way and 2-way transmission using separate physical or optical wavelength (λ) path
- Dedicated fiber (λ) vs. shared medium multiple (λ)
- 3 deployment configurations
    - Dedicated fiber
    - EPON
    - WDM

PON Configurations: Dedicated Fiber

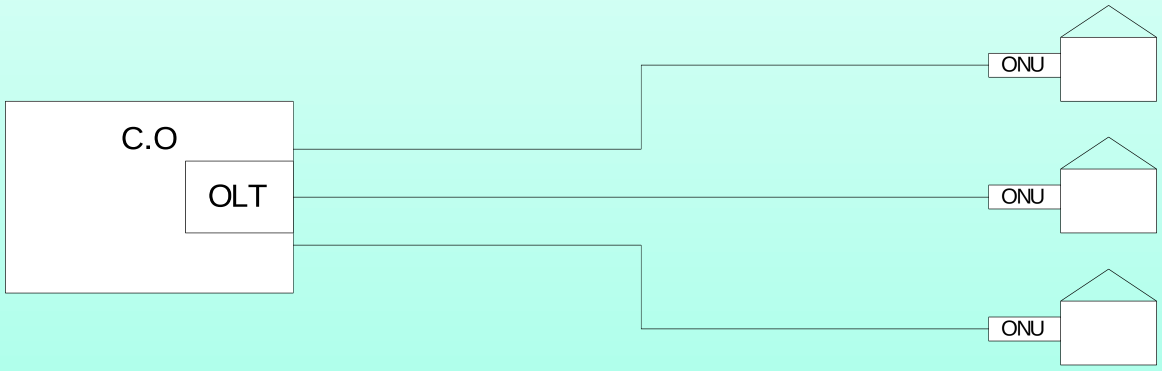


Figure 13.31(a) PON Configuration (Point-to Point PON)

Notes

- Dedicated fiber from OLT to each ONU
- ONU function similar to ONU in cable access network
- One-way in each fiber / Dual wavelength fiber for 2-way
- Expensive configuration

PON Configuration: EPON (Ethernet PON)

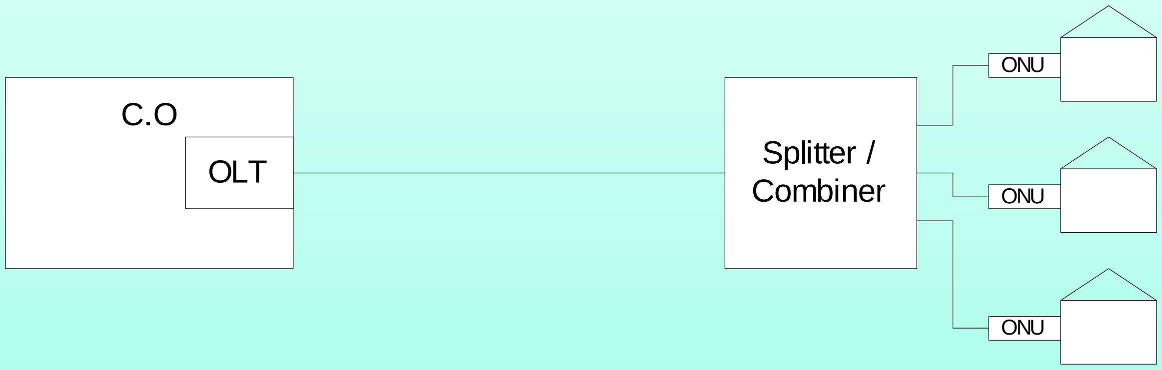


Figure 13.31(b) PON Configuration (EPON)

Notes

- Shared optical fiber from OLT to power splitter / combiner
- Twisted pair or Cat-x cable from splitter / combiner to ONU
- Modified Ethernet MAC protocol for EFM (Ethernet First Mile)
- Downstream TDM and upstream TDMA
- MIB specified only for EPON

Time-division multiplexing (**TDM**): **Time-division multiplexing** (**TDM**) is a method of transmitting and receiving independent signals over a common signal path

TDMA: Time division multiple access, a channel-access scheme

PON Configuration: WPON (WDM PON)

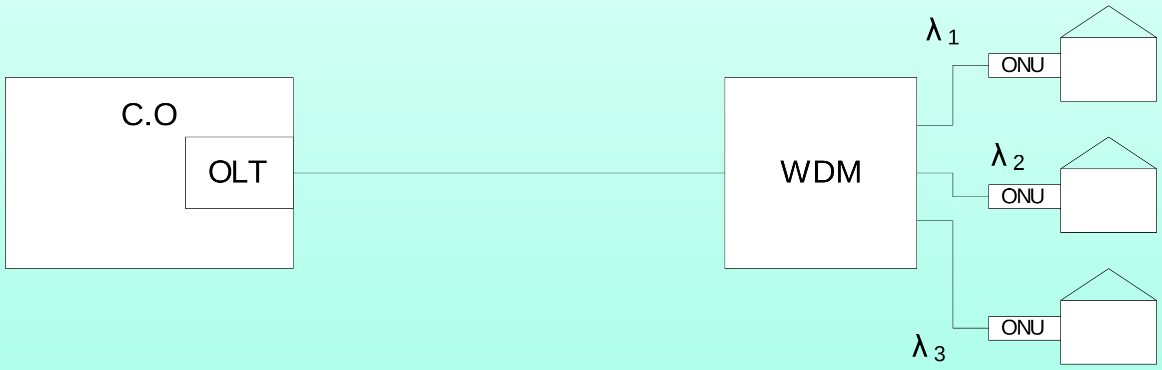


Figure 13.31(c) PON Configuration (WPON)

Notes

- Shared single fiber from OLT to WDM

In fiber-optic communications, **wavelength-division multiplexing** (WDM) is a technology which multiplexes a number of optical carrier signals onto a single optical fiber by using different wavelengths (i.e., colors) of laser light. This technique enables bidirectional communications over one strand of fiber, as well as multiplication of capacity.