CHAPTER CONTENTS

6.0 New Line Technologies

OBJECTIVES

This section will examine:

- The xDSL family
- Cable modems
- IEEE 1394 and FireWire
- Fibre Channel

6.1 xDSL

http://www.adsl.com/

http://www.dslcenter.com/

http://www.everythingdsl.com/

ADSL Tutorial

VDSL Tutorial

TR-001 ADSL System Reference Model

TR-003 ADSL Packet Framing

TR-007 CPE Interfaces

TR-017 ATM over ADSL

6.1.1 Standards and Associations

ANSI working group T1E1.4, approved the ADSL standards. ETSI contributed an Annex to reflect European requirements.

The ATM Forum and DAVIC both recognize ADSL as a physical layer transmission protocol for UTP media.

The ADSL Forum was formed in December of 1994 to promote ADSL development, system architectures, protocols, and interfaces.

6.1.2 Copper Access Transmission Technologies

Modem	Max Data Rate	Modulation	Comments
ADSL	1 Mbps up 8 Mbps down	DMT	Asymmetrical Digital Subscriber Loop
G.lite	1 Mbps up 1.5 Mbps down	DMT	Splitterless Asymmetrical Digital Subscriber Loop
RADSL	1 Mbps up 8 Mbps down	CAP	Rate Adaptive DSL
HDSL	1.544 Mbps symmetric	2B1Q	2 pairs, 370 KHz bandwidth
HDSL2	1.544 Mbps symmetric	16-PAM	1 pair, 300 KHz (up) 400 KHz (down) bandwidth
HDSL4	1.544 Mbps symmetric	16-PAM	2 pairs, 130 KHz (up) 400 KHz (down) bandwidth
SDSL	2.3 Mbps	2B1Q	700 KHz bandwidth
G.shdsl	2.3 Mbps	16-PAM	400 KHz bandwidth
VDSL	13 Mbps up 22 Mbps down	DMT or QAM	12 MHz bandwidth

ADSL requires high-speed modems at each end of the subscriber loop.

The copper loop in the PSTN is capable of carrying high signaling rates over limited distances. For 24 AWG twisted pair, the limitations are:

Signal Format	Bit Rate [Mbps]	Max Range [K ft]
DS1 (T1)	1.544	18
E1	2.048	16
DS2	6.312	12
E2	8.448	9
1/4 STS-1	12.960	4.5
1/2 STS-1	25.920	3
STS-1	51.840	1

In some countries, virtually all subscribers live within 18 Kft of a central office. In other countries such as the US, this covers only 80% of the population. To complicate matters further, about 20% of the remaining lines in the US have loading coils that prevent them from carrying any DSL service including ISDN.

To reduce the loop length, remote access nodes are being deployed. This often reduces the local loop length to 6 Kft. Remote access nodes are connected by a T1/E1 or fiber umbilical.

6.1.2.1 Potential Services

A number of services can be supported by these new transmission formats:

- Video on demand and Internet access can be supported on 18 Kft, 1.5 Mbps loops.

- Digital live television can be supported on 4.5 Kft, 6 Mbps loops. This is the main telco interest in digital TV
- HDTV, requiring 20 Mbps, can be supported over the shortest loops.

6.1.3 ADSL

Additional tutorials:

[3Com - xDSL Loop Technology]

[Cisco - DSL]

[AG - ADSL]

ADSL is intended for the drop cable to the customer's premises. It has an asymmetric data stream, with a higher downstream to the subscriber.

The asymmetry reduces crosstalk and therefore can support higher data rates over longer loops than most other alternatives.

An ADSL circuit has three information channels:

- A high speed downstream channel - 1.5 to 6.1 Mbps
- A medium speed duplex channel - 16 to 640 Kbps
- A POTS channel

Each channel can be divided into multiple, lower rate channels.

ADSL modems divide the bandwidth in one of two ways:

- FDM where one band is assigned for upstream data and another for downstream. These bands can be time division multiplexed
- Echo cancellation with high quality 2 to 4 wire hybrids can also be used to provide a full duplex path.

An ADSL modem organizes the data streams into blocks, and attaches error correction codes. It may also interleave data within subblocks to help error correction. The typical ADSL modem interleaves 20 ms of data, and can correct error bursts as long as 500 µSec. This is suitable for MPEG2 and other digital video compression schemes. However, this delay is too great for some applications. Consequently, the ADSL protocol allows this function to be disabled.

Domestic applications such as VoD, home shopping, Internet, remote LAN access, multimedia access, specialized PC can be supported, even when the ratio of downstream to upstream traffic is 10 to 1.

The ADSL bit rate is a function of distance:

Distance [Kft]	Bit Rate [Mbps]
18	1.544
16	2.048
12	6.312
9	8.448

Upstream speeds range from 16 to 640 Kbps depending on the manufacturer. However, in all cases ADSL operates in a frequency band above POTS. Thus POTS service is guaranteed even if the modem fails.

ADSL can be used for circuit switched, packet switched and eventually, ATM data.

6.1.4 DSL

DSL was originally implemented as a basic rate ISDN modem. It transmits full duplex data at 160 Kbps over 18 Kft, 24 AWG copper lines. The ANSI T1.601 and ITU I.431 standards require echo cancellation to separate transmit and receive paths.

DSL modems can also be used to combine two POTS services on a single twisted pair.

6.1.5 HDSL

HDSL addresses some of the limitations of DS-1 and E1. It occupies less bandwidth and does not require repeaters. However, it requires 2 or 3 twisted pairs of wires.

HDSL transmits 1.544 Mbps or 2.048 Mbps in bandwidths ranging from 80 KHz to 240 KHz, depending upon the technique. These rates can be sustained over 24 AWG, 12 Kft lines.

It is unlikely to be used in residential applications, but be deployed in trunk applications.

6.1.5.1 DS-1 and E1

The DS-1 is a North American 24 channel facility that operates at 1.544 Mbps. In Europe, the E1 multiplexing system combines 30 voice channels on a 2.048 Mbps link. This service is offered on 4-wire links.

These circuits are used for trunk facilities, private networks, PBXs and WANs. They can be used to connect Internet routers, cellular radio sites, or support multimedia servers.

Although telcos have a lot of experience deploying DS-1 and E1 services, they will not be offered residential environments because:

- The cross talk is too excessive.
- There is no 'killer application' for the home
- Most potential home applications such as the Internet or VoD, have asymmetrical data requirements

6.1.6 SDSL

SDSL is a single line version of HDSL. A single line can simultaneously support POTS and DS-1/E1. Consequently, it is suitable for customer premise equipment, which often uses only a single telephone line. Applications include symmetric access to servers and remote LANs. Its maximum usable range is about 10 Kft.

6.1.7 VDSL

VDSL transmits high-speed data over short lengths of twisted-pair copper telephone lines. It will be asymmetric at data rates above ADSL, but over shorter loops. While no standards yet exist, the downstream rates will be submultiples of the SONET rate.

Distance [Kft]	Format	Bit Rate [Mbps]
4.5	1/4 STS-1	12.96
3	1/2 STS-1	25.82
1	STS-1	51.84

Upstream rates range from 1.6 to 2.3 Mbps.

Shorter lines impose fewer transmission constraints and the transceiver technology is less complex, although it is faster. VDSL targets ATM networks. It also supports passive network terminations, enabling more than one modem to be connected to the same line.

VDSL must provide error correction and will likely support conventional circuit and packet switched traffic. It will also use passive filtering to separate ISDN and POTS services from the VDSL stream.

Passive filters will segregate POTS and ISDN services from the high-speed channel. At present, the two high-speed channels will be separated in frequency but some VDSL systems may use echo cancellation.

Three upstream rates are under consideration:

- 1.6 - 2.3 Mbps
- 19.2 Mbps
- Equal to downstream

VDSL must transmit compressed video. To achieve acceptable error rates, it will incorporate FEC with sufficient interleaving to correct impulse noise errors. Interleaving introduces a delay about 40 times the length of the impulse.

Upstream multiplexing is difficult in a multi-terminal environment. Systems using a passive NT must insert data onto a shared medium by TDMA or FDMA. TDMA may use a type of token called cell grants in the downstream to recognized devices, or contention for unrecognized devices.

6.1.7.1 Line codes

Four line codes have been proposed for VDSL:

- CAP† - a version of suppressed carrier QAM. For passive NT configurations, CAP would use QPSK upstream and a type of TDMA for multiplexing. TR-015 CAP Line Code
- DMT†- a multicarrier system using the DFT to create and demodulate individual carriers. For passive NT configurations, it would use FDM for upstream multiplexing. TR-014 DMT Line Code
- DWMT† - a multicarrier system using wavelet transforms to create and demodulate individual carriers. It uses FDMA for upstream multiplexing, but also allows TDMA. DWMT Overview
- SLC† - a version of four-level baseband signaling that filters the baseband and restores it at the receiver. For passive NT configurations, it would most likely use TDMA.

6.1.7.2 Channel Separation

Early versions of VDSL will use FDMA to separate downstream and upstream channels as well as POTS and ISDN. Echo cancellation may be developed for later generation systems with symmetric data rates. Standard practice places the downstream channel above the upstream channel. However, the DAVIC specification reverses this order to enable premises distribution of VDSL signals over coaxial cable systems.

6.1.7.3 Forward Error Control

The FEC uses a form of Reed Soloman coding and optional interleaving to correct error bursts. It has yet to be determined whether the 8% FEC overhead will be taken from the payload capacity or added as an out-of-band signal.

6.1.7.4 Upstream Multiplexing

If the premises VDSL unit contains an active network termination, the premise equipment performs the upstream multiplexing. The VDSL unit simply presents raw data streams in both directions. This could be done by connecting the CPE to a switching hub.

† Carrierless AM/PM

† Discrete Multitone

† Discrete Wavelet Multitone

† Simple Line Code

In a passive NT configuration, each CPE has an associated VDSL unit and all CPE share the upstream channel over a common wire.

One way to share the upstream channel is by a cell-grant protocol. Downstream frames contain a few bits that grant access to specific CPE during a specified period. A granted CPE can then send one upstream. The CPE transmitter must turn on, send a preamble to condition the receiver, send the cell, and then turn off. The protocol must insert enough silence to let line ringing clear. One method uses 77 octet intervals to transmit a single 53-octet cell.

A second technique divides the upstream channel into frequency bands and assigns one to each CPE. This has the advantage of avoiding any media access control with its associated overhead but restricts the data rate available to any one CPE. An alternative is to impose a dynamic inverse-multiplexing scheme that lets one CPE send more than its share for a period. This looks like a media access control protocol, but without the loss of bandwidth associated with carrier detect and clear needed for each cell.

Cost considerations favor a passive network interface for CPE VDSL. System management, reliability, regulatory constraints, and migration favor an active network termination that can operate like a hub.

At present five standards organizations/forums are working on VDSL:

- ANSI group T1E1.4 - This U.S. group is examining system requirements and protocol definition.
- ETSI - The HSAS project has compiled a list of objectives, problems, and requirements. Its preliminary findings include the need for an active NT and payloads in multiples of SDH Virtual Container VC-12 or 2.3 Mbps.
- DAVIC – Is defining a line codes, and a TDMA MAC for shared wiring. It presumes a passive NT, and further premises distribution from the NT over new coaxial cable or new copper wiring.
- The ATM Forum - Has defined a 51.84 Mbps interface for private network UNIs, transmission, premises distribution and ATM.
- The ADSL Forum - The Forum address network, protocol, and architectural aspects of VDSL for all applications, but leaves line code and transceiver protocols to T1E1.4 and ETSI and higher layer protocols to The ATM Forum and DAVIC.

6.1.7.5. CAP

CAP is similar to QAM. CAP performs the orthogonal signal modulation digitally. The digital input is divided into two streams and passed through a digital transversal bandpass filter. The two filters have equal amplitude response but a $\pi/2$ difference in phase response. This is known as a Hilbert pair. The signals are then combined and converted to the analog domain before being transmitted. This process allows more of the device to be implemented in silicon than the equivalent QAM modem.

6.1.7.6. DMT

The DMT technique divides a high bit rate serial data into numerous low speed sub-channels. Each sub-channel modulates its own carrier. Multi-carrier techniques require a great deal of digital processing. DMT is closely related to OFDM† or C-OFDM†, which is used in European DAB†.

The ANSI T1.413 DMT standard specifies 256 subcarriers, each with a 4 KHz bandwidth. They can be independently modulated from zero to a maximum of 15 bits/sec/Hz. This supports up to 60 Kbps per tone. Some implementations support 16 supporting rates of 64 Kbps per tone.

The specification allows modems to dynamically adjust both the bit rates and sub-channels used.

Bit rates of 10 bits/Hz are typical in the low frequency sub-bands. This is usually reduced to 4 bits/Hz or less if the line conditions deteriorate or cross-talk increases.

6.2 Cable Modems

Some tutorials on cable modems:

- ADC - Cable Modem Overview
- CableLabs - Cable Data Modem
- NextLevel - Cable Modems Tutorial
- Cadant - Cable Modems
- CableLabs - Terayon Cable Modem

http://www.cabledatacomnews.com/

Publicly released information on the RF specifications are as follows:

- Network Layer = IP
- Data Link Layer =
- Logical Link Control Sublayer conforms to Ethernet standards
- Link Security Sublayer provides privacy, authorization and authentication
- MAC Sublayer supports variable length protocol data units

MAC features:

- Headend controlled mix of concentration and reservation transmission opportunities
- Stream of mini-slots in the return
- Bandwidth efficiency through support of variable packet lengths

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† Orthogonal Frequency Division Multiplexing

† Coded OFDM

† Digital Audio Broadcast

Extensions provided for future support of ATM

Support for multiple grades of service
Support for a wide range of data rates

PHY features [Downstream]:

Based on North American Video Transmission Specs

64/256 QAM

Concatenation of Reed-Solomon and Trellis FEC

Variable depth interleaving supporting both latency-sensitive and latency-insensitive data

Contiguous serial bit-stream with no implied framing providing complete MAC/PHY decoupling

PHY features [Upstream]:

QPSK and 16QAM

Multiple symbol rates

Frequency agility

TDMA

Support of variable length and fixed frame PDU formats

Programmable Reed-Solomon block coding

Programmable preambles

Minimal coupling between physical and higher layers accommodating future PHYs

Downstream Transmission Convergence Sublayer features:

MPEG transport stream header as defined in ITU-T H.222.0

Fixed MCNS Data over Cable program identification field

MCNS MAC data carried in the private data PSI section

MPEG-2 packet stream encoded in compliance with ITU-T J.83-B, mode 2

The IEEE 802.14 Working Group is defining standards for data transport over cable TV networks. The reference architecture specifies a hybrid fiber/coax plant with an 80-km radius. The goal is to support ethernet connections however, it may be adapted to support ATM.

Cable modems provide rates up to 10 Mbps. However, this is reduced as more subscribers are connected to any given segment. Since segments are shared, there are some security and privacy concerns.

Cable modems may offer a less expensive network than ADSL because of its shared architecture, but this is offset by infrastructure costs required to upgrade existing networks to HFC[†].

Most cable modems use one of the 6 MHz TV channels above 50 MHz for a downstream channel although this may migrate to 550 MHz. It can operate at

[†] Hybrid Fiber Coax

about 30 Mbps using 64 QAM. Information is sent in the downstream channel, by cells or packets, addressed to a specific end-user.

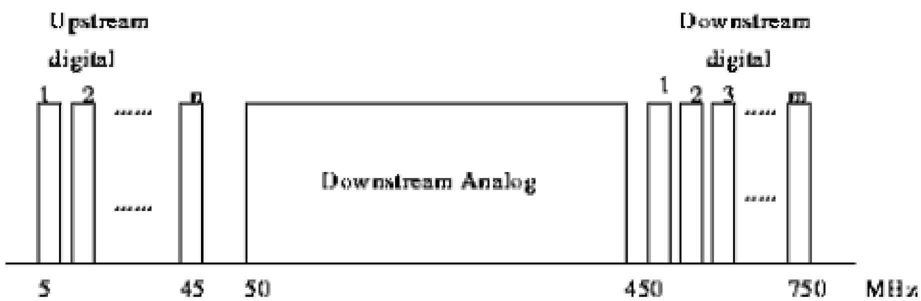
The upstream channel is located between 5 and 50 MHz. Upstream rates in low megabits should be available on good HFC systems. It has a media access control that places user packets cells onto a single channel. Collisions are avoided by sending control signals in the downstream.

Some cable modems assign upstream frequency channels to each user. Others combine the TDMA with FDMA. A few are proposing CDMA. Data rates do not depend upon cable length, since repeaters in the network boost signal power. Rather, capacity depends on system noise and number of simultaneous users.

6.2.1 Hybrid Fiber/Coax

ADC - HFC Telephony Tutorial

CableLabs - Cable Television in the US



HFC networks consist of a fiber feeder from the head-end to an ONU with a coaxial cable to the customer premises. Each coax requires a bidirectional repeater and can serve up to 100 customers.

A cable modem is required at both ends of the coax. In a typical Internet access configuration, an IP router would be situated at each head end. An ISP may also locate cache memory and proxy servers at the router point to smooth traffic and to reduce congestion.

Most CATV systems today are all coax tree and branch structures, with as many as 10,000 customers. They often contain uni-directional amplifiers that prevent upstream data flow. Since 1993 many CATV lines have been installed with bi-directional amplifiers, with an upstream path of 5 to 45 MHz. However, noise and channel problems prevent this capacity from being fully utilized.

Costs of upgrading to HFC vary from $25 to $200 per home passed.

6.2.1.1 Basic Network Distribution

CATV lines pass 180 million residences in the world with about half being in the U.S. Estimates vary, but upgraded CATV into HFC format has probably been accomplished for about 6 million subscribers in the U.S. All major U.S. CATV companies have upgrade programs underway.

The ITU estimates that there are 640 million telephone lines in the world. 70% are residential and the balance is business and pay phones. Despite emerging technologies for non-copper based telephony, the worldwide copper loop plant is still projected to exceed 900 million lines by 2001. In the U.S approximately 80% of these can accommodate 1.5 Mbps ADSL, and 50% can support rates of 6 Mbps or more.

Many other countries have more favorable cable length statistics. However, some countries or regions have very old loop plants, and the percentage of copper lines that are actually usable for megabit access may be well below 80%.

6.2.1.2 Concerns

Since many users share single coaxial line, there is a potential wiretapping problem. Encryption and authentication is therefore vital for cable modems.

Cutting a CATV cable or loosing a repeater will deny access to all users on that line.

As more users are attached to the line, the signal degrades and noise builds up. Quality of service will also degrade as applications shift from downloading text to real time video

Cable modems will usually require some new in-home wiring, since computers are not often in the same room as the family TV set.

6.2.1 DAVIC

Some of the DAVIC specifications can be found at:

- DAVIC Specification Part 1
- DAVIC Specification Part 2
- DAVIC Specification Part 3
- DAVIC Specification Part 4

DAVIC[†] has been working on interactive television standards for the past few years and have joined the cable modem standards effort. Their work is primarily for the European market. They are working closely with the IEEE 802.14 specification.

A cable modem is in DAVIC terminology called a “Set-top box” (STB).

DAVIC specifies three types of cable modems:

- Stand-alone modem with Ethernet if (IEEE 802.3)
- Stand-alone modem with FireWire if (IEEE 1394)
- Internal PC adapter

DAVIC specifies two tools for cable modems:

- Passband bi-directional PHY on coax

† Digital Audio Visual Counsel

- Passband unidirectional PHY on coax

The "Passband unidirectional PHY on coax" tool DAVIC 1.3 part 7, section 7, specifies the downstream physical layer and framing (QAM-modulation, MPEG-frames and ATM-frames). Downstream bit rates are up to 56 Mbps, which can be achieved when using 8 MHz carriers and 256QAM modulation. The usage of a QAM carrier for downstream is called In-band signaling (IB).

The "Passband bi-directional PHY on coax" tool, DAVIC 1.3 part 7, section 8, specifies the upstream and downstream physical layer, framing and MAC-layer protocols, The upstream physical layer protocol describes QPSK modulation with ATM cells. Upstream bit-rate is up-to 3 Mbps. Downstream physical layer is also QPSK with bit-rates of up to 3 Mbps. The usage of QPSK modulation for downstream is called Out-of-band (OOB) signaling.

The higher level protocols specifies ATM framing (UNI-format ITU-T I.361) using LLC/SNAP (RFC 1483) and AAL5 (ITU-T I.363.5) to encapsulate IP (RFC 791) packets. ATM signaling can be done with either UNI (ITU-T Q.2931) or by proxy using DSM-CC (Digital Storage Media Configuration and Control, ISO/IEC 13818-6).

For network management SNMP is specified.

DVB has defined the lower layers for CATV networks:

- DVB-RCC is identical to DAVIC "Passband bi-directional PHY on coax" with minor modifications. DVB-RCC is available as ETSI standard ETS 300 800: DVB Interaction channel for CATV distribution system.
- DVB-C is identical to DAVIC "Passband unidirectional PHY on coax" with minor modifications. DVB-C is available as ETSI standard ETS 300 429, title: DVB Framing structure, channel coding and modulation for cable systems

6.3 IEEE 1394

Kodak - IEEE 1394

The 1394 Trade Association was formed in September 1994 to accelerate the market adoption of IEEE 1394. It is composed of representatives from Adaptec, AMD, Apple, IBM, Lexmark, Microsoft, National Semiconductor, NCR, Philips, Seagate, Skipstone, Sony, TI, and Toshiba.

The IEEE 1394 standard is a non-proprietary, scaleable, flexible, low-cost digital interface suitable for consumer electronics and PCs. It can be implemented as a backplane or a point-to-point cable.

6.3.1 IEEE 1394 Backplane

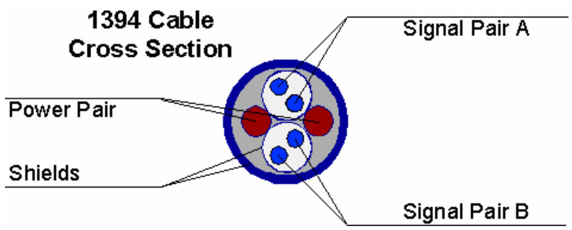
The backplane version operates at 12.5, 25 or 50 Mbps.

Implementation of the backplane specification lags that of the cable, but the internal 1394 hard drive in one computer could be directly accessed by another 1394 connected computer.

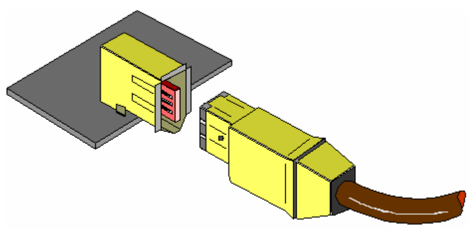
IEEE 1394 also defines the media, topology, and protocol. It supports both arbitrated asynchronous and isochronous data.

6.3.2 IEEE 1394 Cable

The cable version operates at 100, 200 and 400 Mbps. It contains two power conductors, and two twisted pairs for data signaling. Each signal pair is shielded, as is the entire cable.



Cable power ranges from 8 to 40 Vdc at 1.5 amps. It is used to power devices and maintains physical layer continuity when a device is powered down or malfunctioned.



The robust connector is derived from the Nintendo GameBoy. It is small and easy to blindly insert. There are no terminators, or manual IDs to be set.

The bus supports up to sixteen hops between any two devices. A splitter can be used to provide another port.

6.3.3 FireWire†

http://www.firewire.org/

http://www.microsoft.com/hwdev/1394/default.htm

What is Firewire?

FireWire is the Texas Instruments and Apple Computer implementation of the IEEE 1394. It is primarily being developed to address some of the limitations of SCSI interfaces. It allows devices to exchange data or commands between their internal memory spaces using small connectors and cables.

† Information in this section is based on a paper by Gary Hoffman, presented at COMPCON ‘95 in San Francisco, in March 1995.

FireWire is plug and play. Peripherals are connected in series and share a single port. It is suitable for multimedia applications and consumer electronics products. Some of its features include:

- A digital interface
- A physically small thin serial cable
- Easy to use - no need for terminators, device IDs, etc.
- Hot pluggable
- Scaleable - 100, 200, and 400 Mbps devices can be supported on a single bus
- Flexible - freeform daisy chaining, fast guaranteed bandwidth QoS
- Non-proprietary

FireWire supports asynchronous and isochronous data transfer.

It is a peer-to-peer interface thus supporting dubbing from one camcorder to another without a computer. It also allows multiple computers to share a given peripheral without any additional hardware. It can connect digital cameras and similar peripherals to PCs.

The IEEE 1394 has been endorsed by the DVC[†], the DVB[†] and is currently being evaluated by VESA[†].

In video editing applications, FireWire removes the need for analog video frame buffers in capturing digital video. It can also replace SCSI interfaces on scanners, CDROMs, disk drives, and printers.

Each IEEE 1394 segment may contain up to 63 devices, each spaced at 4.5 meters. A bus bridge allows data to be passed between segments. Over 1000 bus segments may be connected in this way.

The plug and play feature allows devices to be added or removed without powering down The system automatically recognized the topology change.

6.3.3.1 Operation

To transmit asynchronous data, a 1394 device first requests control of the physical layer. It then sends a data packet containing the originator and receiver address. A 64 message sliding window protocol is used to return an ACK.

When sending isochronous data, the originator requests a specific bandwidth channel. Channel IDs are transmitted with the data. The receiver accepts only data with the specified ID.

User application determines how many isochronous channels, and their required bandwidths are offered.

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† Digital VCR Conference

† European Digital Video Broadcasters

† Video Experts Standards Association

6.4 Fibre Channel

http://www.fibrechannel.com/

Applications Notes\Fibre Channel\Fibre Channel Industry Association.htm

This standard is being developed under the guidance of the ANSI X3T9.3 committee.

Fibre Channel is a high performance bidirectional, point to point link. It operates full duplex at speeds in excess of 100 Mbps over links as long as 10 km.

Fibre Channel requires a switch to interconnect multiple users. Larger networks can be constructed by bridges and routers. It support a number of communications protocols including FDDI, serial HIPPI, SCSI, IPI-3, IP, SBCCS†, Ethernet, token ring, and ATM.

Fibre Channel defines 5 layers:

- FC-0 Specifies the physical characteristics of the media, transmitters, receivers, and connections.
- FC-1 Defines the 8B/10B block code based on ESCON†.
- FC-2 Defines the framing and data transfer mechanisms.
- FC-3 Defines stripping and hunting services. This allows incoming packets to be directed to the first available terminal in a group.
- FC-4 This provides seamless integration of existing standards.

Fibre Channel supports several service classes:

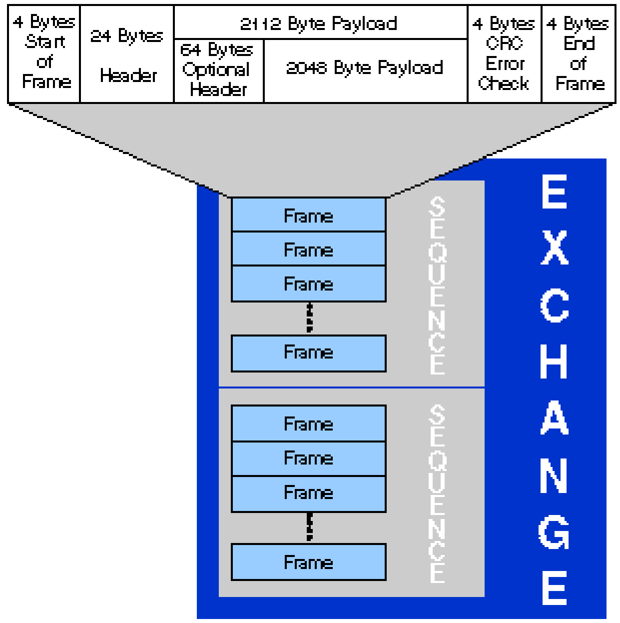
- Class 1 A dedicated channel between two devices.
- Class 2 A connectionless, frame-switched link. It provides guaranteed delivery with a receipt or acknowledgment.
- Class 3 A connectionless service with no acknowledgment.
- Intermix This optional mode reserves the entire bandwidth for a class 1 service, but will allow connectionless packets if resources become available.

Fibre channel frames consist of the following fields:

- Start-of-frame delimiter
- Frame header
- Optional headers
- Variable-length payload [0-2112 bytes]
- 32-bit CRC
- End-of-frame delimiter

† Single Byte Command Code Set, by IBM

† Enterprise System CONnection by IBM



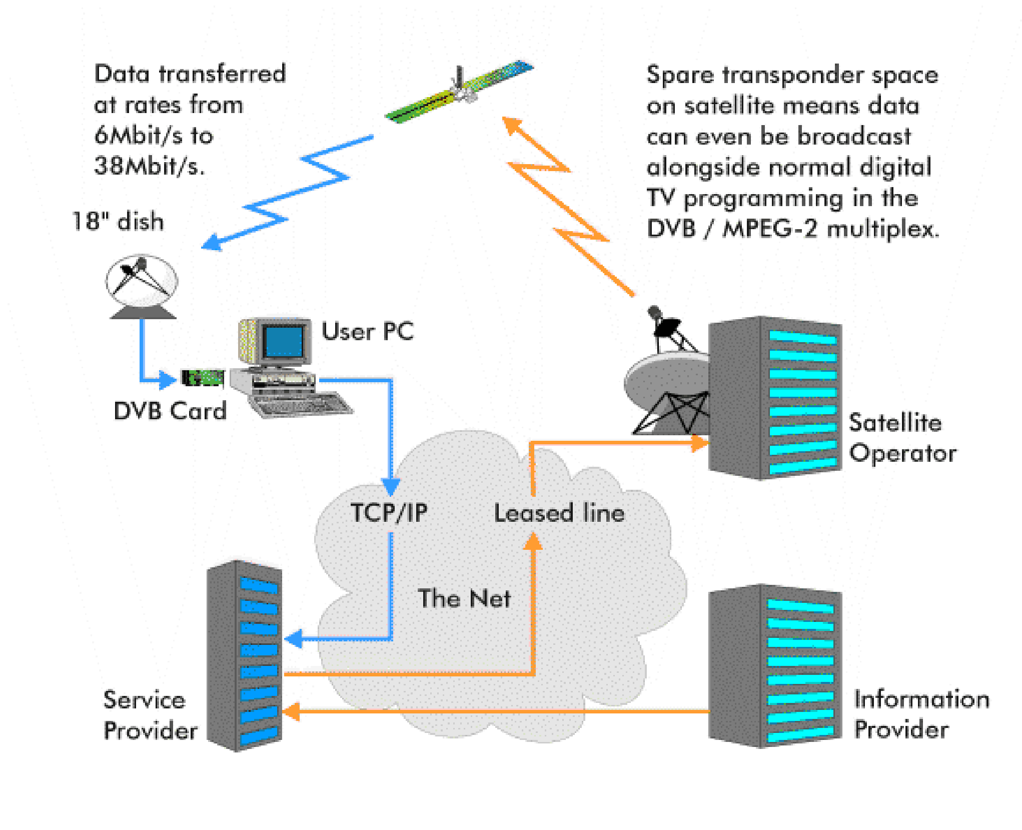
6.5 Digital Video Broadcasting

ATSC - DTV Satellite Modulation

6.5.1 DVB - Core Technology

The Data Broadcasting specification paves the way for high speed data transfer via satellite, cable and terrestrial television channels. Examples of data broadcasting applications include data-casting, downloading software, providing Internet services over broadcast channels, and interactive TV.

The forward channels are provided by a terrestrial ISP while the reverse channels are provided by the satellite.



For standard 6, 7 or 8 MHz TV channels, the DVB standard offers a data throughput potential of 6 - 38 Mbps.

Various European satellite operators including Astra, Eutelsat, and Hispasat have implemented satellite DBNs.

6.5.2. DVB-S

The DVB-S system is designed to cope with the full range of satellite transponder bandwidths. DVB-S is the oldest, most established of the DVB standards family, and arguably forms the core of the DVB's success. Services using DVB-S are on-air on 6 continents.

DVB-S is a single-carrier system.

The video, audio, and other data is inserted into fixed-length MPEG Transport Stream packets. The packetized data constitutes the payload.

The data is processed as follows:

1. The data are formed into a regular structure by inverting synchronization bytes, every eighth packet header.
2. The contents are randomised.
3. A Reed-Solomon Forward Error-Correction (FEC) overhead is then added to the packet data. This very efficient system adds only around 8%

overhead to the signal. It is called the Outer Code. There is a common Outer Code for all the DVB delivery systems.

4. Next, Convolutional Interleaving is applied to the packet contents.
5. Following this, a further error-correction system is added, using a punctured Convolutional Code. This second error-correction system, the Inner Code overhead can be adjusted to suit the needs of the service provider.
6. Finally, the signal is used to QPSK modulate the satellite carrier

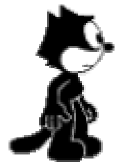
In essence, between the multiplexing and the physical transmission, the system is tailored to the specific channel properties. The system is arranged to adapt to the error characteristics of the channel. Burst errors are randomized, and two layers of forward error correction are added. The second level, or Inner Code, can be adjusted to suit the circumstances (power, dish size, bit rate available).

There are thus two variables for the service provider: the total size of the 'onion' and the thickness of the second error-correction outer 'skin'. In each case, in the home, the receiver will discover the right combination to use by very rapid trial and error on the received signal. An appropriate combination of payload size and Inner Code can be chosen to suit the service operator's environment.

One example of a parameter set would be for a 36 MHz (-1 dB) transponder to use a 3/4 Convolutional Code, in which case a useful bit rate of about 39 Mbit/s will be available as the payload.

The 39 Mbit/s (or other bit rates allowed by parameter sets for a given satellite transponder) can be used to carry any combination of MPEG-2 video and audio. Thus, service providers are free to deliver anything from multiple-channel SDTV, 16:9 Wide screen EDTV or single-channel HDTV, to Multimedia Data Broadcast Network services and Internet over the air.

Review Questions



Quick Quiz

1. ADSL is a physical layer transmission protocol for unshielded twisted pair media. [True, False]
2. ADSL [uses, does not use] data interleaving.
3. ADSL has [1, 2, 3] information channels.
4. ADSL [can, cannot] support VoD.
5. ADSL has a fail to POTS mode. [True, False]
6. ADSL can be used for circuit switched, packet switched and eventually, ATM data. [True, False]
7. DSL is [symmetrical, asymmetrical].
8. DSL modems can be used to combine two POTS services on a single twisted pair. [True, False]
9. HDSL requires 2 or 3 twisted pairs of wires. [True, False]
10. HDSL is likely to be used in [residential, trunk] applications.
11. DMT utilizes [a single, multiple] carrier(s).

Analytical Problems

Composition Questions

1. What are the two principle reasons DS-1 service is not offered to the home?

For Further Research

ADSL Forum TR-001, ADSL Forum System Reference Model

1394 High Performance Serial Bus: The Digital Interface for ATV, Adam J. Kunzman, Alan T. Wetzel, Texas Instruments

1394-based Digital Camera Specification, Version 1.04, 1394 Trade Association

1394 Technical Overview, Texas Instruments

The facts about FireWire, Ingrid J. Wickelgren, IEEE Spectrum April 1997

FireWire

www.ti.com/sc/docs/msp/1394/tech.htm

www.1394TA.org

www.ddx.com/fibre.html

http://www.firewire.org/

ADSL

http://www.adsl.com/adsl_home.html

http://www.ee.ubc.ca/home/comlab1/irenek/etc/www/techpaper/adsl/adsl.html

http://www.analog.com/publications/whitepapers/products/back_adsl/

http://www.dqnet.com/apps/adsl.html

http://alumni.caltech.edu:80/~dank/isdn/adsl.html

http://pilot.msu.edu/user/hsuhsuni/adsl.htm

http://www.rad.com/networks/1997/adsl/ADSLTechDis.htm

http://www.aware.com/

DWMT

http://bugs.wpi.edu:8080/EE535/hwk97/hwk3cd97/suska/suska.html

Cable Modem

http://www.cablemodem.com/

http://www.cablelabs.com/

http://www.davic.org/

http://www.cocom.dk/

http://www.ncta.com/modem.html

ftp://ftp.ietf.org/internet-drafts/draft-ietf-ipcdn-cable-device-mib-02.txt

http://www.rhk.com/index.htm

http://www.catv.org/modem/

Digital Video Broadcasting

http://www.dvb.org/

HFC

http://bugs.wpi.edu:8080/EE535/hwk97/hwk3cd97/murti/murti.html

http://conquest.oakridge.com/STel/modchip.html

http://www.ericsson.com/Connexion/connexion3-97/techno.htm

http://www.dqnet.com/apps/hfc.html

Fiber Channel

http://www.cern.ch/HSI/fcs/

http://www.fibrechannel.com/

FDDI

http://www.cisco.com/univercd/cc/td/doc/cisintwk/ito_doc/55773.html