Chapter 3

Basic Data Communication Technology

Objectives

This chapter deals with the:

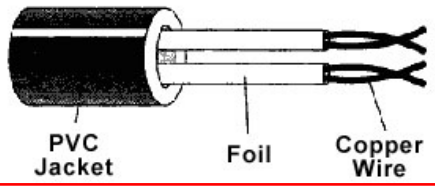
- Physical layer
- Unshielded Twisted Pair (UTP) and Shielded Twisted Pair (STP)
- Unshielded Twisted Pair Standards
- Signal Degradation

Physical Layer

- responsible for the establishment, maintenance and termination of physical connections between communicating devices.
- transmits and receives a stream of bits.
- no data recognition at the physical layer.
- operation is controlled by protocols that define the electrical, mechanical, and procedural specifications for data transmission.

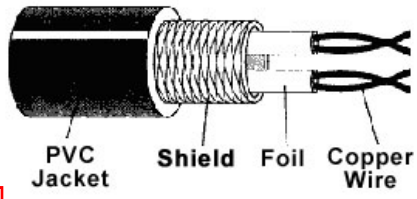
Two Types of Twisted-Pair

UNSHIELDED TWISTED-PAIR



Unshielded twisted-pair is installed nearly everywhere. Besides being inexpensive and readily available, it is flexible and familiar to cable installers. It has become the cable of choice for the departmental network.

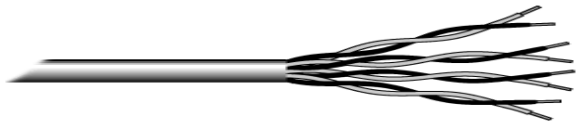
SHIELDED TWISTED-PAIR



Shielded twisted-pair's shield increases its immunity to electromagnetic interference which allows it to transmit data over longer distances than unshielded twisted pair.

Unshielded Twisted Pair (UTP)

- Consists of one or more pairs of insulated copper wire twisted around each other at varying lengths ranging from two to twelve twists per foot.
- The twisting is used as a mechanism to reduce interference between pairs and from outside sources that can cause data errors and necessitate retransmission.
- These individually twisted pairs are then grouped together and covered with a plastic or vinyl covering.



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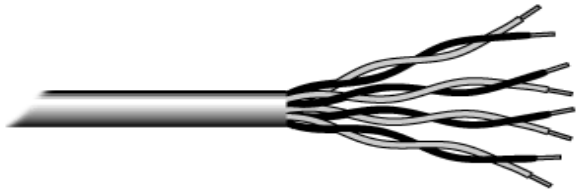
Unshielded Twisted Pair (UTP)

- Quality of UTP vary from telephone-grade wire to extremely high-speed cable
- Cable has four pairs of wires inside the jacket
- The tighter the twisting, the higher the supported transmission rate and the greater the cost per foot.



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Unshielded Twisted Pair Connector

- The standard connector for unshielded twisted pair cabling is an RJ-45 (8 wire) connector.
  - A plastic connector that looks like a large telephone-style connector.
  - RJ stands for Registered Jack; connector follows a standard borrowed from telephone industry.
  - Standard designates which wire goes with each pin inside the connector.

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Signal Degradation

- **Attenuation** is the decrease in the power of signal over a distance in a particular type of wire or media.
- **Near-End Crosstalk** (**NExT**) is signal interference caused by a strong signal on one-pair (transmitting) overpowering a weaker signal on an adjacent pair (receiving).
- Near End Crosstalk and Attenuation to Crosstalk Ratio (ACR) are both measured in decibels or dB.

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UTP Specifications



UTP Category	Maximum Data Speed	Attenuation /NEXT limit	Applications
Cat 1	< 1Mbps		Not recommended for data, Voice only (Telephone lines)
Cat 2	4 Mbps	4 MHz	4 Mbps Token-Ring over UTP
Cat 3	16 Mbps	16MHz	10baseT Ethernet. Tested for attenuation & near-end crosstalk up to 16MHz.
Cat 4	20 Mbps	20MHz	16 Mbps Token-Ring over UTP. Tested for attenuation & near-end crosstalk up to 20MHz.
Cat 5	100 Mbps (2 pair) 1 Gbps (4 pair)	100 MHz	100baseT (fast) Ethernet, 155 Mbps ATM, Gigabit Ethernet
Cat 5e	100 Mbps (2 pair) 1 Gbps (4 pair)	100 MHz	100baseT (fast) Ethernet, 155 Mbps ATM, Gigabit Ethernet Category 5e cable has a tighter quality control standard than Cat 5, like cross talk, etc.
Cat 6	2.5 Gbps (2 pair) potentially up to 1bps (4 pair)	200 MHz	None that **require** cat 6 at the time of this writing. The IEEE is working on a copper 10 Gbps Ethernet standard that would require cat 6 if released.

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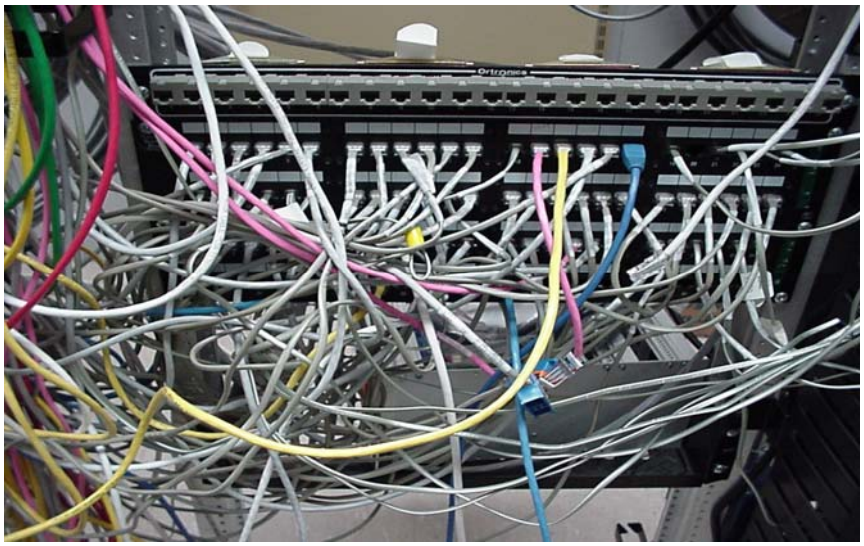
Twisted Pair



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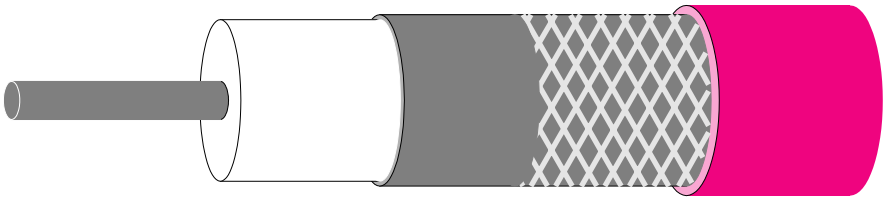
Shielded Twisted Pair (STP)

- Shielding is metallic foil or copper braid.
- Shielded from EMI (Electro-Magnetic Interference) and RFI (Radio-Frequency Interference).
- Shielding is metal and is therefore a conductor. So shielding is terminated in a drain wire that must be properly grounded.
- Improperly STP wiring can actually increase rather than decrease interference and data transmission problems.

Coaxial Cable (coax)

- Coaxial cable, more commonly known as coax or cable TV cable, has specialized insulators and shielding separating two conductors allowing reliable, high speed data transmission over relatively long distances.
- Coax comes in various thicknesses and has been historically used in Ethernet network architectures.
- Modern local area network implementations rarely use coaxial cable today.

Coax Cable: Cross-Section

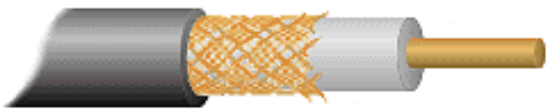


Solid metal inner core | *Plastic insulator - usually white* | *Foil shield* | *Braided shield/outer conductor* | *Plastic or vinyl jacket*

- With the advent of cable modems and the use of the cable television system as a mechanism to provide high speed Internet connectivity to homes coaxial cable continues to play an important role in data communication.

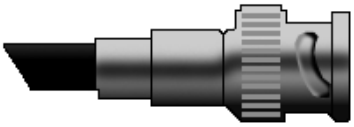
Coaxial Cable

- Outer conductor covered with a jacket or shield
- Diameter from 1 to 2.5 cm
- Shielded concentric construction reduces interference & crosstalk
- Can be used over longer distances & supports more stations on a shard line than twisted pair



Coaxial Cable Applications

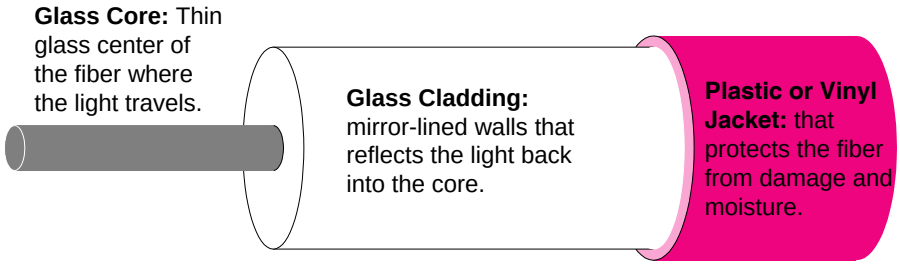
- Most versatile medium
- Television distribution
  - Ariel to TV, Cable TV
  - Can carry hundreds of TV channels for tens of kilometers.
- Long distance telephone transmission
  - Can carry 10,000 voice channels simultaneously
  - Being replaced by fiber optic
- Short distance computer systems links



Fiber Optic

- Fiber optic cable is one of the most secure of all media. It requires careful handling.
- Transmitting only pulses of light, unlike all other guided media which transmit varying levels of electrical pulses.
- Immune to EMI and RFI, contributing to its high bandwidth and data transmission capabilities.
- This is the most expensive media choice currently available.

Fiber Optic Cable: Cross-Section (Single Fiber)



	Glass core		Glass cladding
diameters	50 microns 62 microns 100 microns	Multimode	125 microns 125 microns 140 microns
	2-8 microns	Single mode	

Note: A micron (μm) is a millionth of a meter

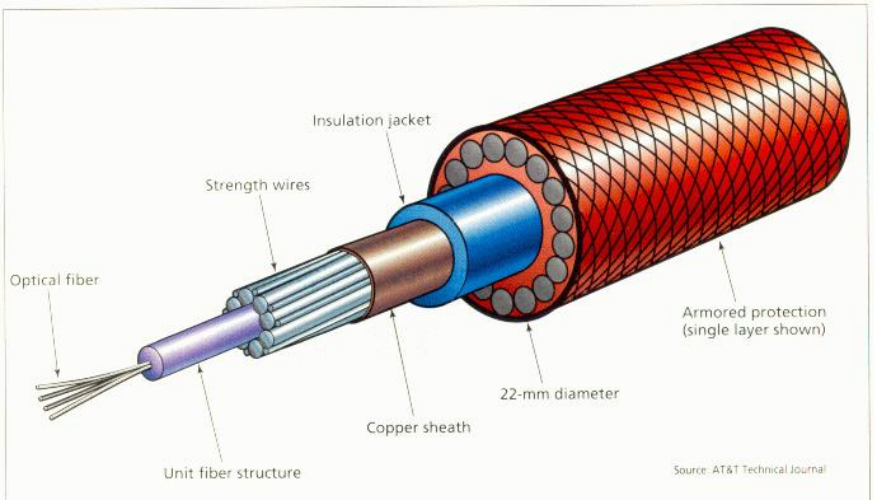
Fiber Optic Cable

- Fiber optic cable is the current **reliability and performance champion** in the data communication world.
- Thin, flexible material to guide optical rays
- Cylindrical cross-section
- Core:
  - Innermost section of fiber
  - One or more very thin (diameter 2-100 μm) strands or fibers.
- Cladding:
  - Surrounds each strand
  - Plastic or glass coating with optical properties different from core

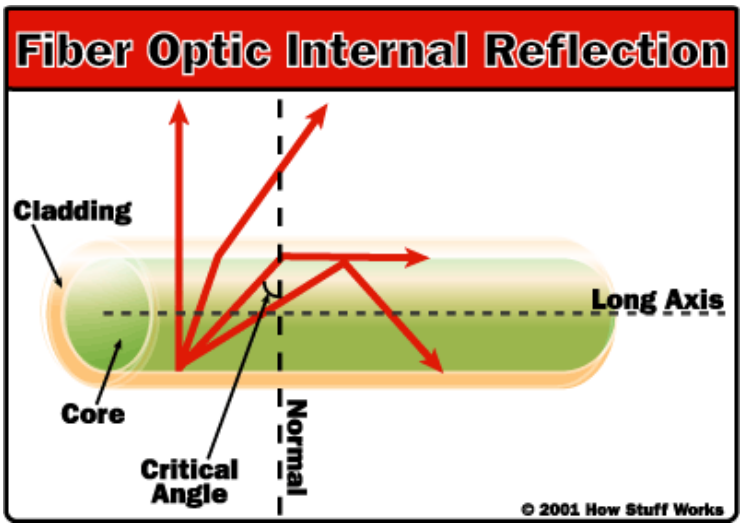
Fiber Optic Cable

- Jacket
  - Outermost layer, surrounding one or more claddings
  - Made of plastic and other materials
  - Protects from environmental elements like moisture, abrasions and crushing

Fiber Optic Cable (Multiple Fibers)



Fiber Optic: Principle



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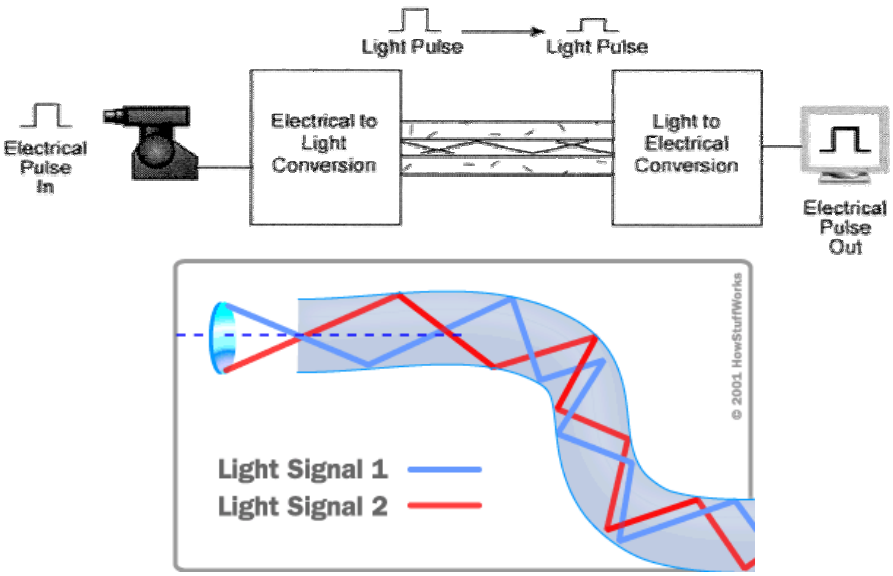
Fiber Optic Usage



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Light Transmission Modes

- Once a pulse of light enters the core of the fiber optic cable, it will behave differently depending on the physical characteristics of the core and cladding of the fiber optic cable.
- In a **Multimode** or **Multimode Step Index** fiber optic cable, the rays of light will bounce off of the cladding at different angles and continue down the core while others will be absorbed in the cladding.
- These multiple rays at varying angles cause distortion and limit the overall transmission capabilities of the fiber.
- This type of fiber optic cable is capable of high bandwidth transmission but usually over fairly short distances.

Fiber Optic: Attenuation

- Attenuation of optical fiber is a result of two factors, absorption and scattering.
- Absorption is caused by absorption of light and conversion to heat by molecules in the glass.
- Scattering occurs when light collides with individual atoms in the glass.
- Light scattered at angles outside the numerical aperture of fiber will be absorbed into the cladding or transmitted back toward the source.

Guided Media Characteristics

Media Type	Also Called	Bandwidth	Distance Limits	Connectors	Comments/Applications	Architectures: Ethernet	Fast Ethernet	Gigabit Ethernet	ATM
4-wire phone station wire	Quad RYGB	3 Kbps	200 feet	RJ-11 jacks	4 insulated wired- red,green, yellow, black. Home phone wiring; voice Applications				
Flat gray modular	Flat satin, telephone cable, silver satin	14.4 Kbps	10-20 feet	RJ-11 or RJ-45 plugs	Comes with 4,6,8 conductors; used for short data cables using modular (mod-tap) adapters	▪			
Unshielded twisted pair	UTP	100 Mbps	100 feet	RJ-45	5 Designated categories. Twists prevent interference, increase bandwidth; voice grade usually not suitable for data	▪	▪	▪	▪
Shielded twisted pair	STP	16 Mbps	100 feet	RJ-45 or IBM data connectors	Shielding reduces interference but complicates installation	▪	▪		▪
Coax- thick	Frozen yellow garden hose	10 Mbps	500 feet	AUI (attachment unit interface)	Original Ethernet cabling	▪			
Coax-thin	RG-58, thinnet, cheapernet	10 Mbps	200 feet	BNC connector	Looks like cable TV cable. Easier to work with than thick coax	▪			
Coax-thin	RG-62	2.5 Mbps	200 feet	BNC or IBM data connector	Similar to RG-58 (thinnet) but different electrical characteristics make these cables NOT interchangeable				
Fiber-optic cable	Fiber Glass	Several Gbps	Several kilometers	SI or SMA 905 or SMA 906	Difficult to install but technology is improving. High bandwidth, long distance, virtually error free, high security	▪		▪	▪

Point-to-Point Data Transmission Technologies

- The most basic data communication technologies are those used to directly connect two devices.
- These connections can be used to connect a computer to peripheral devices.
- Operating at layer one of the OSI Network Reference Model, these technologies provide a physical connection that can be used to carry many higher level protocols.

Serial Transmission Standards

- Serial transmission is the basis of most data communication between computers.
- There are several different serial communication standards available for use in modern computers including RS-232, USB, and IEEE 1394 (Firewire).

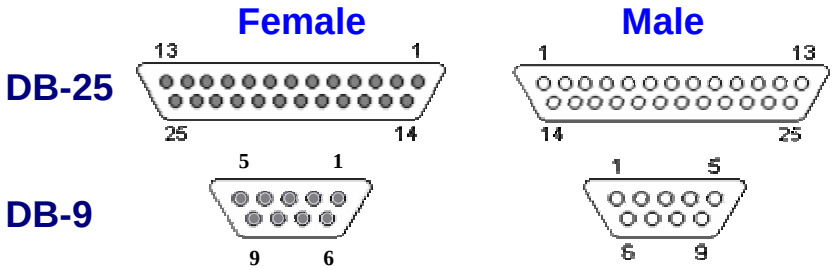
Next

Point-to-Point Data Transmission Technologies

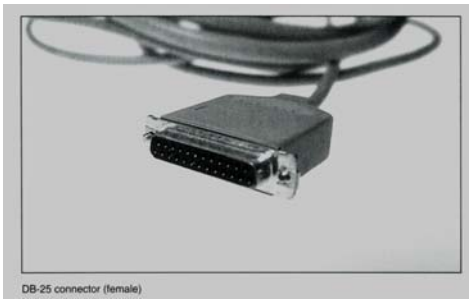
- RS232
- USB
- Firewire (IEEE1394)
- Infra Red (IR)
- Bluetooth

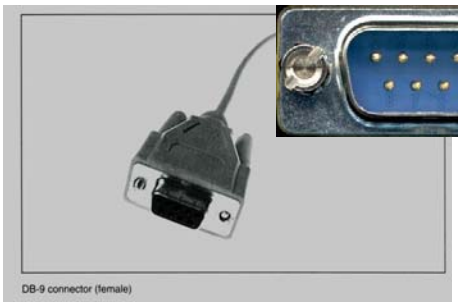
RS232 - History

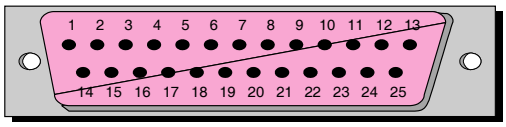
- PC: COM1, COM2 (MODEM & RS232)
- RS232 is serial a I/O interfacing standard (protocol) set by Electronics Industries Association (EIA) in 1960.
- 1963: RS232A
- 1965: RS232B
- 1969: RS232C
- RS232 is limited to 20Kbps for 50ft.



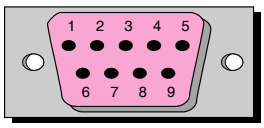

IEEE-1394 Connectors







Pin Number	Signal Designation	Pin Number	Signal Designation
1	Protective ground	14	Secondary transmit data
2	Transmit data	15	Transmit clock (DCE)
3	Receive data	16	Secondary receive data
4	Request to send	17	Receiver clock
5	Clear to send	18	Receiver dibit clock
6	Data set ready	19	Secondary request to send
7	Signal ground	20	Data terminal ready
8	Carrier detect	21	Signal quality detector
9	Positive DC test voltage	22	Ring indicator
10	Negative DC test voltage	23	Data signal rate selector
11	unassigned	24	Transmit clock (DTE)
12	Secondary carrier detect	25	Busy
13	Secondary clear to send		



Pin Number	Signal Designation
1	Carrier detect
2	Receive data
3	Transmit data
4	Data terminal ready
5	Protective ground
6	Data set ready
7	Request to send
8	Clear to send
9	Ring indicator

RS-232 Serial Transmission Protocol as Defined for DB-25 and DB-9 Connectors

RS-232

- RS-232 is currently the most commonly used serial standard for modem communication.
- Commonly referred to as a serial port.
- Most commonly implemented using DB-25 or DB-9 connectors.
- Problem with RS-232:
  - Slow.
  - Supports only one device per port.
  - Requires lots of configuration to attach a device.

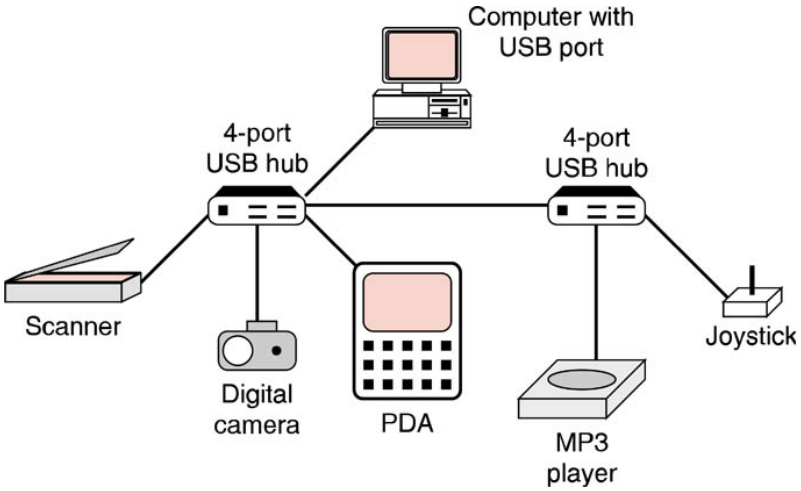
Universal Serial Bus (USB)

- USB has replaced RS-232 in most of the applications.
- a high speed, multi-point serial communications technology developed to resolve these shortcomings of RS-232.
- There are two versions of USB currently available: the original USB 1.1 specification and a newer higher speed USB 2.0 specification.
- USB 2.0 is backward compatible with USB 1.1

Universal Serial Bus - USB

- 2 data rates
- **USB 1.1:**
  - 12 Mbps for increased bandwidth devices.
  - 1.5 Mbps for lower-speed devices (joysticks, game pads).
- **USB 2.0:**
  - 480 Mbps
- Star topology can be used
  - One USB device (or hub) can be connected to PC. Hub can be embedded in devices like monitor, printer, or keyboard or can be standalone.
  - Multiple USB devices can be connected to hub. Up to 127 devices can be connected in this manner.

Universal Serial Bus - USB



- USB can be used to connect several devices on the same port using hubs.

USB Connector Cable

USB-A (on left) and USB-B (on right) connectors

- There are two styles of USB connector in current widespread use (A & B). These are also found in male and female forms when used in extension cables.

IEEE - 1394

- Developed by Apple and known as “**Firewire**”, Sony calls it “**i.Link**”
- Multipoint serial bus-based solution
- Faster than USB, it goes to nearly 1 Gbps
- Main application in consumer electronic market place, like HDTV, digital camcorders, DVDs, etc.
- Data transfer rates from 12.5 to 400 Mbs, 4.5m cable (FireWire 400-IEEE1394)
- Data transfer rate 800 Mbs to 1Gbps, 100m cable (FireWire 800-IEEE1394b)
- Plug-and-play capabilities
- Packet-based layered design structure

IEEE-1394

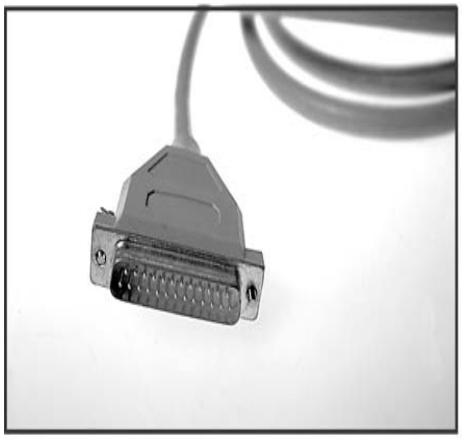
- IEEE-1394 includes support for **isochronous communication** which guarantees data delivery at a constant, pre-determined rate.
- Isochronous communication is the extreme case of synchronous communication. Source and destination are "in sync" in the absolute sense of real time, allowing continual transmission of bits.
- The constant data delivery rate reduces the need to buffer data thereby greatly reducing the cost of implementing the technology compared to a traditional asynchronous solution.

Firewire (IEEE-1394) Cable

IEEE-1394 Connectors

- Commonly used to connect multimedia devices to PC's

Centronics Cable



DB-25 (male) parallel interface

Centronics parallel interface

- A common means of connecting printers to PC's

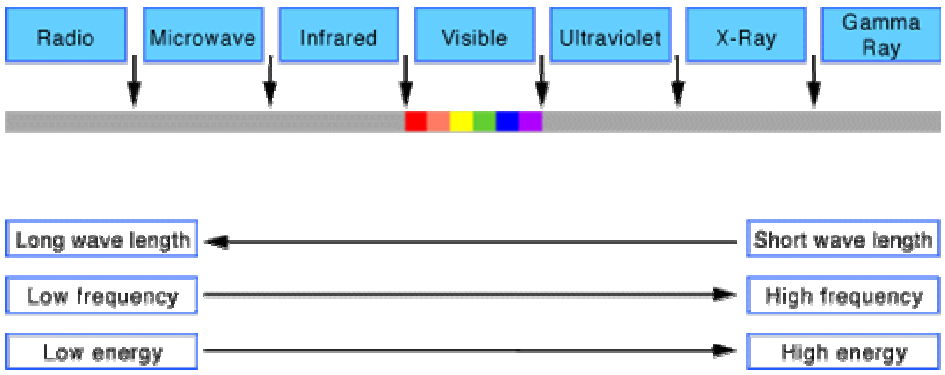
Wireless communication

- **Infrared (IR)**
  - Uses electronic wave frequencies just below visible light spectrum
  - Diode emits infrared light to generate signal
  - Infrared transistor detects signal, conducts when exposed to infrared light
  - Cheap to build transmitter and receiver circuits
  - Need line of sight, limited range
- **Radio frequency (RF)**
  - Uses electromagnetic wave frequencies in radio spectrum
  - Analog circuitry and antenna needed on both sides of transmission
  - Line of sight not needed, transmitter power determines range

Wireless protocols: IrDA

- IrDA (Infrared Data Association)
  - Created and promoted by the Infrared Data Association (IrDA).
  - Supports short-range point-to-point infrared data transmission (around 1 meter), have a narrow angle (30 degree cone).
  - Data transfer rate - between 9.6 kbps and 4 Mbps.
  - IrDA hardware deployed in notebook computers, printers, PDAs, digital cameras, public phones, cell phones (small, semi-transparent, red window in laptops).
  - Lack of suitable drivers has slowed use by applications.

The Electromagnetic Spectrum



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THE ELECTROMAGNETIC SPECTRUM		
Type	**Frequency Range**	**Wavelength Range**
Gamma rays	> 10^{21} Hz	< 0.003 nm
X- rays	3 x 10^{16} - 10^{21} nm	10 - 0.003 nm
Ultraviolet	750 - 30,000 THz	400 - 10 nm
VISIBLE LIGHT	400 - 750 THz	750 - 400 nm
Infrared	300 GHz - 400 THz	1mm - 750 nm
Radio waves (AM, FM, TV, amateur radio, aeronautical, portable phones, cellphones, taxis, police, satellites, wireless LANs)	Microwaves 1 - 300 GHz 3 Khz - 300 GHz	30cm - 1 mm 100 km - 1 mm
Low Frequency waves	< 3 KHz	> 100 km

higher frequencies
smaller wavelengths
larger wavelengths
lower frequencies

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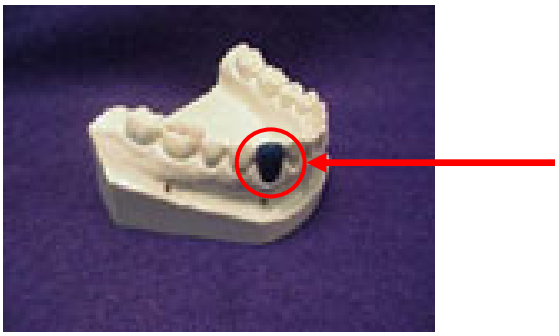
RF Table

Aeronautical/Maritime	9 KHz - 535 KHz
AM radio	535 KHz - 1,700 KHz
Shortwave radio	5.9 MHz - 26.9 MHz
Citizen's Band (CB)	26.96 MHz - 27.41 MHz
TV stations 2-6	54 MHz - 88 MHz
FM radio	88 MHz - 108 MHz
TV stations 7-13	174 MHz - 220 MHz
Cell phones CDMA	824 MHz - 849 MHz
Cell phones GSM	869 MHz - 894 MHz
Air Traffic Control	960 MHz - 1,215 MHz
GPS	1,227 MHz - 1,575 MHz
Cell phones PCS	1,850 MHz - 1,990 MHz

Wireless protocols: Bluetooth



- **Why is it called Bluetooth?**
  - Harald **Bluetooth** was king of Denmark in the late 900s (died in 986).
  - the Baltic region nations (including Denmark, Sweden, Norway and Finland) are leading in communications industry.

Bluetooth

- New global standard for wireless connectivity
- Based on low-cost, short-range radio link
- Connection established when within 10 meters of each other
- No line-of-sight required
  - e.g., Laptop connects to a printer in another room
- Bluetooth communicates at a frequency of **2.45 gigahertz**, which has been set aside by international agreement for the use of Industrial, Scientific and Medical devices (ISM).

Bluetooth Products

- The Sony Ericsson limited edition Car, with Bluetooth® wireless technology. It is a small race car, slightly larger than the size of a matchbox, that has two gears and is wirelessly controlled by a Bluetooth enabled Sony Ericsson mobile phone.

- Laptop, PDA, mobile communicating through Bluetooth

- Bluetooth USB adapter

Bluetooth Products

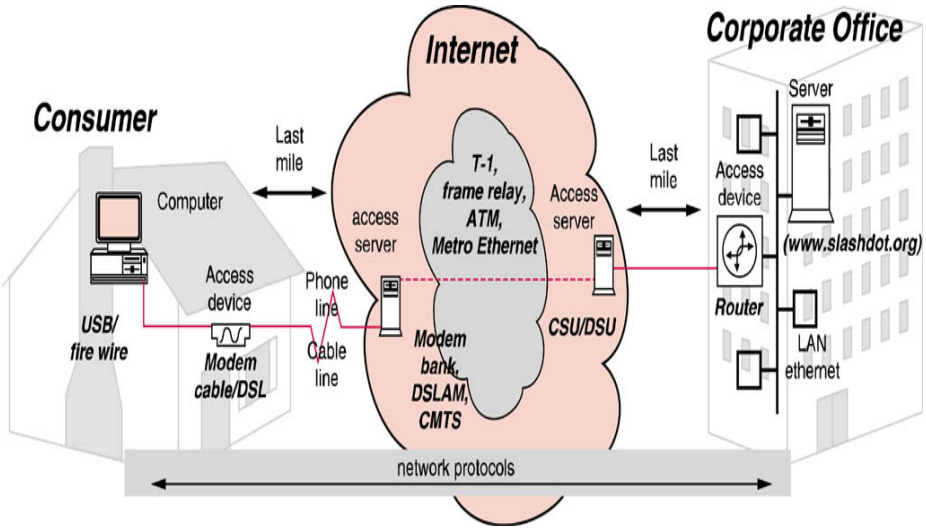
Connecting to the Internet

- After connecting to peripheral devices, people want to connect their computer to the Internet.
- Simple – need to create a link between computer & a device connected to the Internet.
- ISPs provide these services.
- ISPs vary widely in the access technologies, data speeds and pricing methods.

Connecting to the Internet

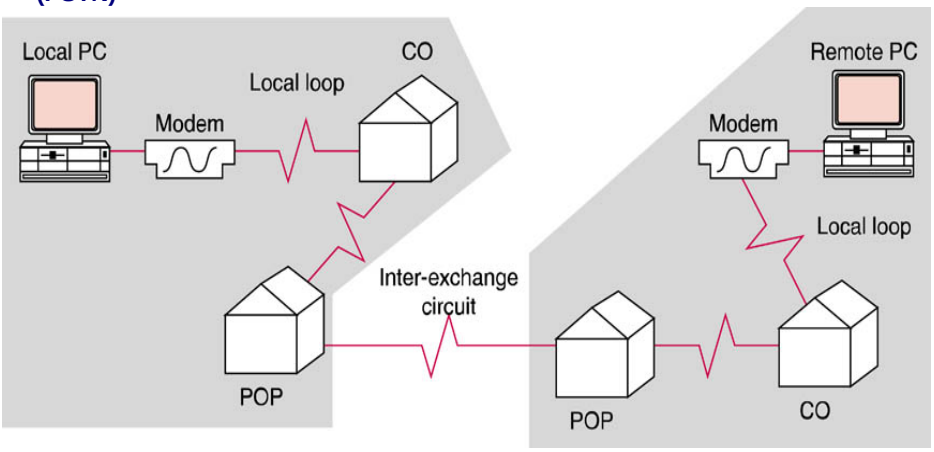
- All ISPs provide access to ***same*** Internet, so it is important to look at the four key criteria:
  - **Service hosting:** Need of ISP to host Web pages, domain names, e-mail addresses, etc.
  - **Performance:** Type of access technologies supported, data rates, throughput, etc.
  - **Cost:** Hourly/Monthly rates, rates per Mb, etc.
  - **Reliability:** ISPs multiple links to Internet, multiple links to the customer, etc.

Connecting to the Internet



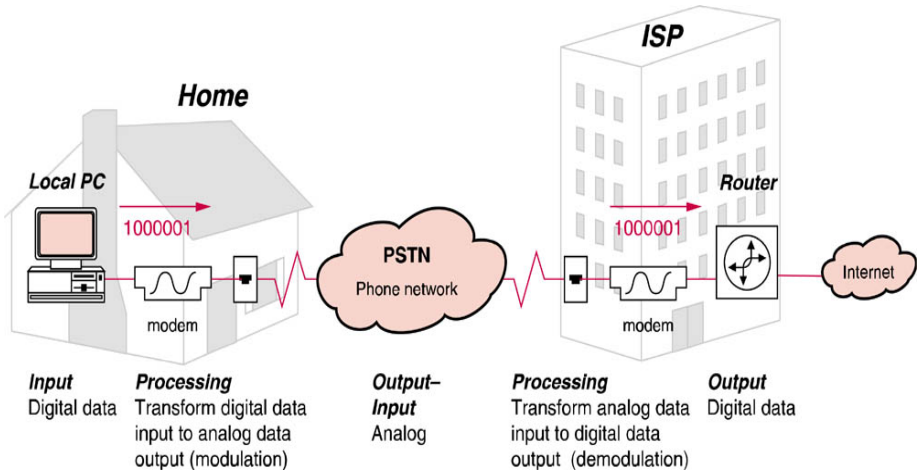
- Internet access architecture.

Public Switched Telephone Network
(PSTN)



- The public dial-up network is accessed using a dial-up modem.

Connecting to the PSTN



- The PSTN provides a switched circuit.

Modem Standards

Modem Standard	Transmission Rate	Baud Rate	Data Comp.	Error Correction	Modulation Method
V.90	56 Kbps down, 28.8 Kbps up	3200,3000, 2400,2743 ,2800, 3429	V.42bis/MNP5	V.42/MNP4	Digital downlink & 9QAM &TCM uplink
V.34	28.8 Kbps 33.6 Kbps (optional)	3200,3000, 2400,2743 ,2800, 3429	V.42bis/MNP5	V.42/MNP4	9QAM &TCM
V.32 ter	19.2 Kbps	2400	V.42bis/MNP5	V.42/MNP4	8QAM & TCM
V.32 bis	14.4 Kbps	2400	V.42bis/MNP5	V.42/MNP4	6QAM & TCM
V.32	9.6 Kbps	2400	V.42bis/MNP5	V.42/MNP4	4QAM & TCM
V.22 bis	2400 bps	600	V.42bis/MNP5	V.42/MNP4	4QAM & TCM
Bell 212A	1200 bps	600			4PSK
Bell 103	300 bps	300			FSK

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Glossary

- **bis:** second standard issued by a given standard committee
- **ter:** third standard issued by that same standard committee
- **FSK:** Frequency Shift Key
- **4PSK:** QPSK
- **TCM (Trellis Code Modulation):** A modulation technique with hardware error detection and correction.
- **MNP (Microcom Networking Protocols):** Error correction and data compression protocols originally developed by modem manufacturer Microcom.
- Baud really refers to is modulation rate or the number of times per second that a line changes state. This is not always the same as bits per second (BPS). If two serial devices are connected together using direct cables then baud and BPS are in fact the same but not in modems.

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Modems and the PSTN

- **Modem** is actually a contraction for **Mo**dulator/**dem**odulator.
- Most local loops that are used for connection to the PSTN to supply switched, dial-up phone service are physically described as **two-wire circuits**.
- Since one of these two wires serves as a ground wire for the circuit, that leaves only one wire between the two ends of the circuit for data signaling.
- Dial-up or switched two-wire circuits generate a dial-tone.

Full-duplex

- **Full-duplex** transmission supports simultaneous data signaling in both directions.
- Full-duplex transmission might seem to be impossible on two-wire circuits.
- Modems manufactured to the CCITT's V.32 standard (and the later V.34 standard) can transmit in full-duplex mode, thereby receiving and transmitting simultaneously over dial-up two-wire circuits.

Quantization Noise

- Conversion of an analog signal to digital format imparts “noise” into the signal. Why?
- Analog signals can consist of any possible level.
- Digital signals consist of only fixed levels.
- When analog signal is sampled and converted into a digital signal, certain level of detail is lost.
- When digital signal is converted back into analog, it will not be exactly same. This error is known as “**Quantization Noise”.**
- V.90 modem standard overcome this problem.

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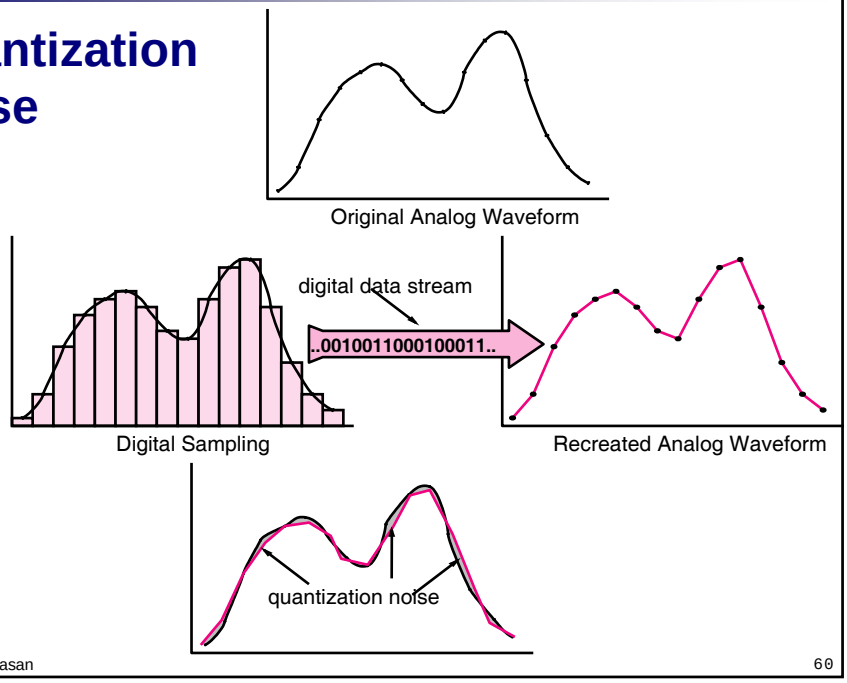
Quantization Noise



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V 42.bis

- Compression uses ***Lempel-Ziv algorithm***.
- Principle: Looks for repetitive pattern of up to 32 characters (bytes). ***Some modems support up to 256 characters (bytes).***
- Both modems store this pattern with an 11-bit key in a constantly updated library (also called dictionary). ***Library size can be from 1.5Kb to 6 Kb.***
- Next time this pattern of data comes along to be sent, the sending modem just sends 11-bit code that represents the 32-byte pattern.
- Receiving modem will decode the pattern.
- The more repetitive pattern, the higher the compression ratio.

MNP Class 5

- Uses two data compression algorithms:
- **Huffman encoding:** re-encodes frequently used ASCII characters, such as ***a, e, i, o,*** and ***s*** are encoded with only **4 bits**, whereas rarely occurring characters such as ***x*** or ***z*** are encoded using **11 bits**.
- **Run-length encoding:** exams a data stream in search of repeating characters. When any character repeats more than 3 times, the run-length encoding algorithm replaces the entire string of repeated characters with only 3 repetitions of the character followed by a count field indicating how many times the character is actually repeated.
  - E.g., A data string containing 10 repetitions of the same character would be replaced by 3 repetitions of that character by a 1-byte count character. This would reduce the string from 10 bytes to 4-bytes (60% saving). Repeated characters can include non-printing characters also.

Reliability

- Goal of reliable transmission is to minimize the error rate.
- Improved reliability implies faster data transmission. Fewer retransmission increase the throughput.
- First category of error correction technique is to ***prevent*** errors from happening by optimizing the condition of the transmission link.
- Second category-if errors occur, then ***detect*** and ***correct*** the errors.

Error Prevention

- Errors occur when data is misinterpreted due to noise or interference on transmission lines.
- Errors can be prevented by:
  - Reducing the amount of noise or interference on a given transmission line.
  - Employing modulation techniques that are able to adapt to and overcome noisy lines.

Line Conditioning

- Value added service provided by phone companies. Line conditioning is available for analog leased circuits. It helps eliminate noise and interference.
- Additional equipment is installed to guarantee signal quality.
- Signals tend to lose their strength over great distances due to the resistance of the wire, this is known as **attenuation**. Repeaters and amplifiers help assure signal quality over longer distances.

Repeaters and Amplifiers

- A **repeater** is used to overcome attenuation.
- A repeater regenerates the digital signal.
- A repeater on an analog circuit is called an **amplifier**.
- An amplifier does not distinguish between voice data signal and the background noise. So amplifies both.
- Repeaters on digital circuits are able to distinguish. So retransmit a digital signal free of noise.
- The use of digital leased lines could itself be seen as an error prevention technique.

Adaptive Protocols

- Adapt (adjust) transmission session parameters in response to various line conditions.
- Techniques play on one of two things:
  - Amount of data per packet (adaptive size packet assembly).
  - Transmission rate is varied according to line conditions (dynamic speed shifts).

Adaptive Size Packet Assembly

- MNP class 4 protocol.
- Increase and decrease amount of data per packet based on circuit condition.
- Protocol optimizes amount of data per packet by building packets containing the greatest amount of data that can be transmitted reliably without requiring retransmission.
- When errors are detected, packet size is reduced. When no errors are detected over time, packet sizes are increased.

Dynamic Speed Shifts

- MNP class 10 adaptive protocol.
- Allows two modems changing their speed up or down during the transmission session in response to varying line conditions.
- The adaptive nature of this protocol ensures that the highest practical transmission speed will be used at all times.
- Useful in cellular phone environments where line quality varies significantly over short periods of time.

Forward Error Correction

- Correction of the received data without the need for retransmission.
- A communications technique that can correct bad data on the receiving end. Before transmission, the data are processed through an algorithm that adds extra (redundant) bits for error correction.
- If the redundant bits calculated at the receiver do not match the received ones, the forward error correction circuitry at the receiver uses those bits to correct the incoming data signal.

Forward Error Correction

- Cost ➔ More redundant data is added to the transmitted blocks.
- Hence ➔ Reduction in data throughput
- Compromise:
  - Not enough redundant data, the overall throughput is reduced due to retransmissions.
  - Too much redundant data will also reduce the throughput due to time spent to send data and processing at the receiver.

Trellis Coded Modulation (TCM)

- Another way of overcoming errors without the need for retransmission.
- Modems that employ TCM can overcome twice as much noise on a given circuit as QAM modems without TCM.
- Uses technique called convolutional encoding.
- TCM adds a redundant bit to avoid misinterpreting the received sequence.

Error Control Standards

- **MNP 4**
  - Adaptive size packet assembly
- **V.42:**
  - Incorporates MNP 4 and the Link Access Protocol for Modems (LAP-M).
  - LAP-M uses selective ARQ.
  - Provides for negotiation during modem handshaking to allow modems to decide which protocol to use whether MNP 4 or LAP-M.
  - V.42 is not to be confused with CCITT V.42bis used for data compression.

MNP4 and V.42

- Error control protocols implemented within modems.
- Modems assure error-free transmissions.
- Error control protocol, supplied by communications software running on PC's, is not needed.

Hardware Flow Control (RTS/CTS)

- Involves the use of additional pins on the interface to start or stop the flow of data.
- RS-232 uses pins 4 & 5 for RTS (request to send) & CTS (clear to send):
  - CTS pin high ➔Transmitter sends data into buffer memory
  - CTS pin low ➔ Transmitter stops transmitting data

Software Flow Control (XON/XOFF)

- Instead of using pins 4 & 5
- Sends special characters in the data.
- The most popular flow control standard is known as **XON/XOFF**.
  - When a device cannot receive data it sends a XOFF (Ctrl-S).
  - To resume transfer of data receiving device sends an XON character (Ctrl-Q).

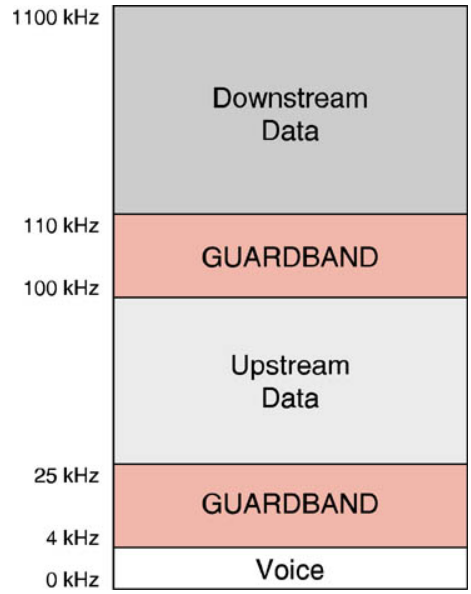
Digital Subscriber Line (DSL)

- One of the faster broadband technologies currently available is Digital Subscriber Line (DSL).
- DSL provides an “always on” connection to the Internet over the same copper wires that provide dial-up telephone service.
- DSL uses the same copper wire (local loop) as a POTS (Plain Old Telephone Service) line, but digital because of equipment used on both ends (user and CO).

DSL Standards and Technology

- Not like dial-up modems, there is less standardization in the DSL world.
- Different vendors have developed different solutions that use different frequencies and modulation schemes.
- The only two devices that have to agree on the DSL technology used are the DSL modem and the DSLAM (DSL Access Multiplexer).
- Most DSL service providers require customers to rent or purchase DSL modems directly from them.

Frequency Division in DSL



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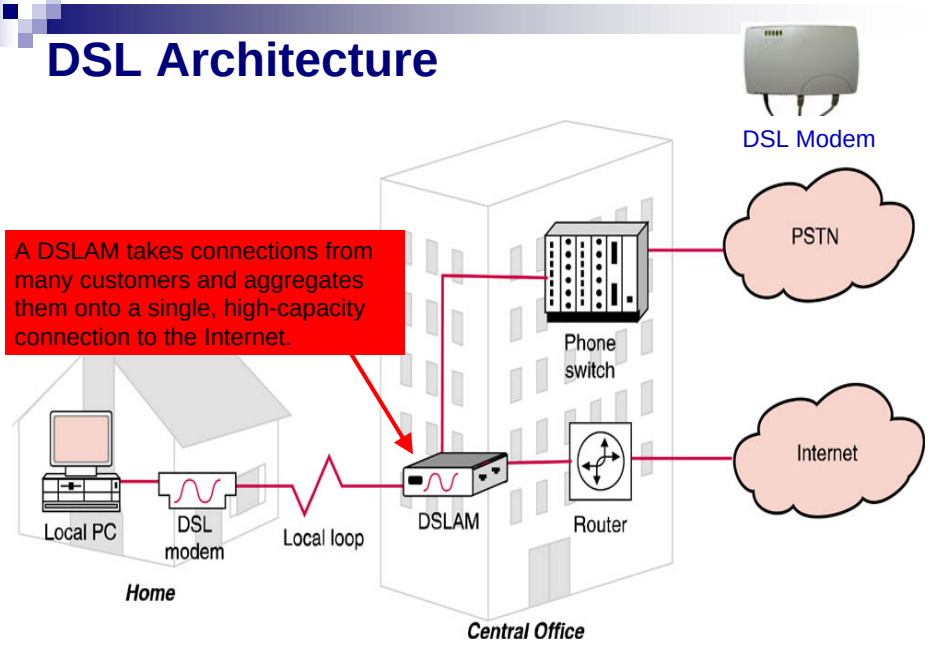
DSL Architecture



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Different DSL connections

DSL Technology	Max. Speed	Copper Pairs	Distance Limitation	Application
ADSL (Asymmetric DSL)	Up to 8Mbps downstream 640Kbps upstream	1	Up to 18,000 ft.	Consumer Internet access
IDSL (ISDN DSL)	144Kbps downstream & upstream	2	Up to 18,000 ft.	ISDN replacement & business Internet access
SDSL (Symmetric DSL)	1.544Mbps downstream & upstream	1	Up to 10,000 ft.	Business Internet access
HDSL (High bit rate DSL)	1.544Mbps downstream & upstream	2	12,000 to 15,000 ft.	T-1 replacement & business Internet access
VDSL (Very high bit rate DSL)	34Mbps downstream & upstream	1	Up to 4,000 ft.	Business Internet access

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Performance of DSL

- The quality of copper used in lines matters a lot.
- The distance from CO also matters.
- A splitter is installed to separate the data service from voice service by dividing the incoming signal into low frequencies to send to voice devices and high frequencies for data to the computer.
- A filter is used to absorb the frequency blips and allow the DSL modem to work without interruption.

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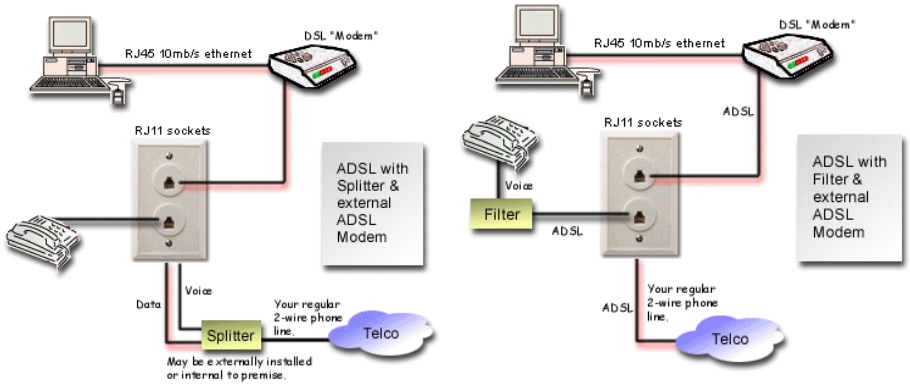
DSL Architecture

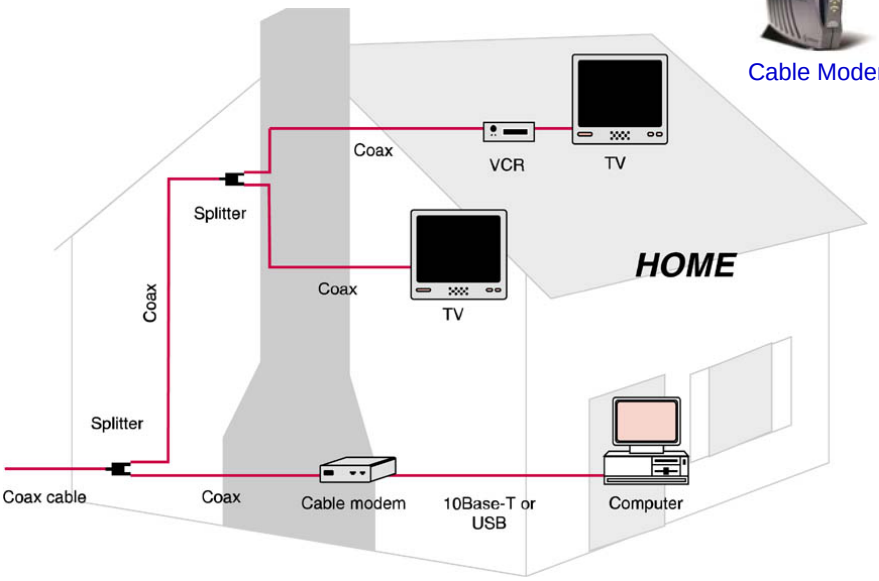


Cable Modems

- A provider of high bandwidth connectivity to customer premises is the television cable company.
- The cable provider's infrastructure offers a significantly higher bandwidth to the consumer than the local loop provided by the telephone company due to the coaxial cable media used for cable television transmission.

Cable Modem Connection

Cable Modem



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