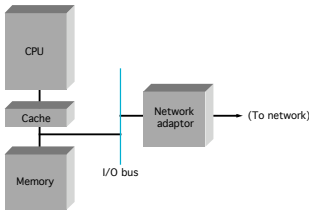
Direct Link Networks

Outline
- Building Blocks
- Encoding

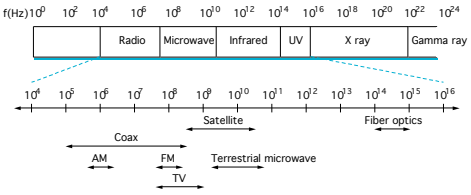
Nodes

- Network adaptor
- Device driver
- Memory bottleneck



Links

- Electromagnetic waves traveling at speed of light
- Frequency (Hertz, Hz) and wavelength (meters)



Links

- Cables:
  - Category 5 twisted pair 10-100 Mbps 100m
  - Thin-net coax 10-100 Mbps 200m
  - Thick-net coax 10-100 Mbps 500m
  - Multimode fiber 100 Mbps 2km
  - Single-mode fiber 100-2400 Mbps 40km
- Leased lines:
  - DS1 1.544 Mbps
  - DS3 44.736 Mbps
  - STS-1 51.840 Mbps
  - STS-3 155.250 Mbps
  - STS-12 622.080 Mbps
  - STS-48 2.488310 Gbps
  - STS-192 9.953280 Gbps

Cables

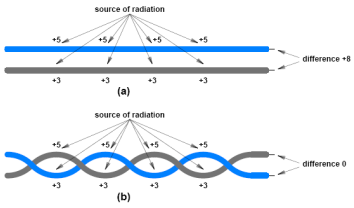


Figure 7.2 Unwanted electromagnetic radiation affecting (a) two parallel wires, and (b) twisted pair wiring.

Cables

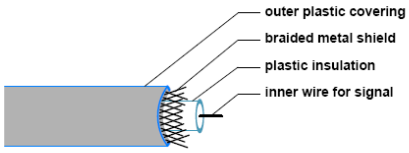


Figure 7.3 Illustration of coaxial cable with a shield surrounding the signal wire.

Categories of Twisted Pair Cables

Category	Description	Data Rate (in Mbps)
CAT 1	Unshielded twisted pair used for telephones	< 0.1
CAT 2	Unshielded twisted pair used for T1 data	2
CAT 3	Improved CAT2 used for computer networks	10
CAT 4	Improved CAT3 used for Token Ring networks	20
CAT 5	Unshielded twisted pair used for networks	100
CAT 5E	Extended CAT5 for more noise immunity	125
CAT 6	Unshielded twisted pair tested for 200 Mbps	200
CAT 7	Shielded twisted pair with a foil shield around the entire cable plus a shield around each twisted pair	600

Figure 7.4 Twisted pair wiring categories and a description of each.

Optical Fiber

- Each fiber consists of a thin strand of glass or transparent plastic encased in a plastic cover
  - An optical fiber is used for communication in a single direction
  - One end of the fiber connects to a laser or LED used to transmit light
  - The other end of the fiber connects to a photosensitive device used to detect incoming light

Optical Fiber

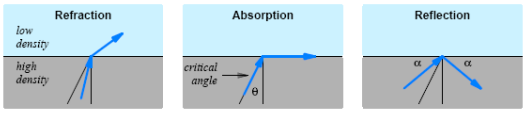
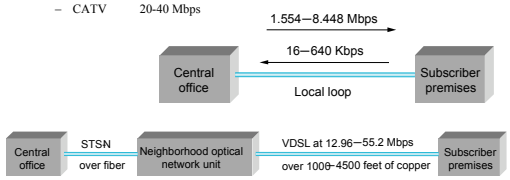


Figure 7.5 Behavior of light at a density boundary when the angle of incidence is (a) less than the critical angle θ, (b) equal to the critical angle, and (c) greater than the critical angle.

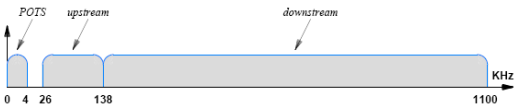
Links

- Last-mile links:
  - POTS 28.8-56 Kbps
  - ISDN 64-128 Kbps
  - xDSL 16 Kbps-55.2 Mbps
  - CATV 20-40 Mbps



Example: ADSL

- ADSL is the most widely deployed variant
  - and the one that most residential customers use
- ADSL uses FDM to divide the bandwidth of the local loop into three regions
  - one of the regions corresponds to traditional analog phone service, which is known as Plain Old Telephone Service (POTS)
  - and two regions provide data communication



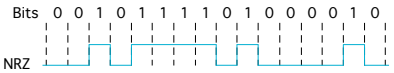
Links

- Wireless links
  - AMPS: Advanced Mobile Phone Systems
  - PCS: Personal Communication Services
  - GSM: Global System for Mobile Communication

  - infrared: 850-950 nm, 1 Mbps, 10m
  - HIPERLAN: High Performance European Radio LAN
  - IEEE 802.11
  - Bluetooth
  - WiMax

Encoding

- Signals propagate over a physical medium
  - modulate electromagnetic waves
  - e.g., vary voltage
- Encode binary data onto signals
  - e.g., 0 as low signal and 1 as high signal
  - known as Non-Return to zero (NRZ)



Problem: Consecutive 1s or 0s

- Low signal (0) may be interpreted as no signal
- Long strings of 0s or 1s lead to baseline wander
- Unable to recover clock

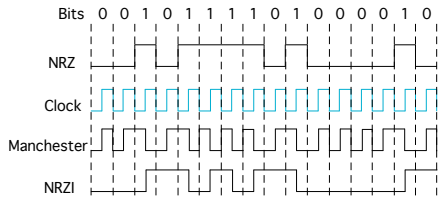
Alternative Encodings

- Non-return to Zero Inverted (NRZI)
  - make a transition from current signal to encode a one; stay at current signal to encode a zero
  - solves the problem of consecutive ones
- Manchester
  - transmit XOR of the NRZ encoded data and the clock
  - only 50% efficient (bit rate = 1/2 baud rate)

Encodings (cont)

- 4B/5B
  - every 4 bits of data encoded in a 5-bit code
  - 5-bit codes selected to have no more than one leading 0 and no more than two trailing 0s
  - thus, never get more than three consecutive 0s
  - resulting 5-bit codes are transmitted using NRZI
  - achieves 80% efficiency

Encodings (cont)



Manchester Encoding

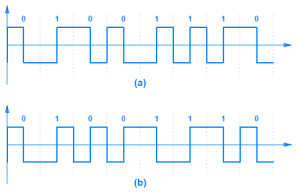


Figure 6.13 (a) Manchester and (b) Differential Manchester Encodings; each assumes the previous bit ended with a low signal level.

4B/5B

0000	11110
0001	01001
0010	10100
0011	10101
0100	01010
0101	01011
0110	01110
0111	01111
1000	10010
1001	10011
1010	10110
1011	10111
1100	11010
1101	11011
1110	11100
1111	11101

Framing

- Break sequence of bits into a frame
- Typically implemented by network adaptor

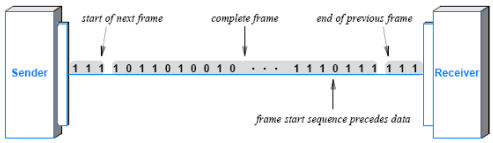
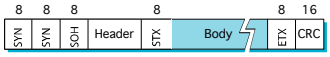
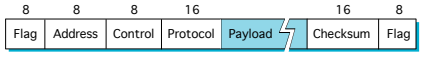


Figure 9.7 Illustration of framing on a synchronous transmission system.

Approaches

- Sentinel-based

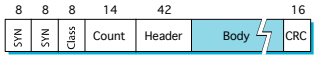




  - start frame with special pattern: 01111110

Approaches

- Counter-based
  - include payload length in header
  - e.g., DDCMP



  - problem: count field corrupted
  - solution: catch when CRC fails

Approaches

- Bit-oriented: HDLC

  - uses 01111110 for beginning and end, also sent during idle times for synchronization
  - bit stuffing: when 5 consecutive 1s have been transmitted, sender inserts 0

Approaches

- Clock-based (SONET)
  - each frame is 125us long
  - e.g., SONET: Synchronous Optical Network
  - STS-*n* (STS-1 = 51.84 Mbps)