

### **Direct Link Networks**

- Problems to solve to connect two links
  - Physical connection medium
  - Encoding of data on medium
  - *Framing* delineating sequences of bits into messages or frames
  - Error detection identifying corrupted frames
  - Reliability of link
  - Media access control, if link is shared



## **Building Blocks**

- Networks are composed of nodes and links
- Node: workstation, PC, switch, router
  - Typically includes a processor, memory, an I/O bus, and a *network adapter*
  - The network adapter is connection to the link
  - A software device driver controls the adapter
  - Processing is typically limited by memory size and speed, so memory efficiency is very important
  - Special nodes called Interface Message Processors (IMPs) were used in the original ARPANET – see http://www.livinginternet.com/i/ii\_imp.htm



# Building Blocks (cont.)

- Links
  - Different physical media: twisted pair (that's the "T" in "10Base-T"), coaxial cable, optical fiber, space
  - Media used to propagating electromagnetic waves that carry the data signal
  - EM waves have frequency f and wavelength  $\lambda$ ; speed of wave  $c = f \lambda$ .





# Building Blocks (cont.)

- Need to encode binary data onto signal

- Modulate signal's frequency, amplitude, and/or phase to somehow represent "0" and "1"
- Links can be differentiated by number of bit streams that are supported simultaneously
  - Half-duplex: signal travels in only one direction at a time
  - *Full-duplex*: signals can travel in both directions simultaneously



### More on Physical Media

10-100Mbps

10-100 Mbps

- Link types
   Cable
  - Cat-5
  - Thin-net coax
  - Thick-net coax 10-100 Mbps
  - Multimode fiber 100 Mbps
  - Single-mode fiber 100-2400 Mbps
     40 km
  - Cat-5 is the standard for within-building wiring; try to use this for new standards like Gigabit Ethernet

100 m

200 m

500 m

2 km



### Physical Media (cont.)

- Leased Lines
  - DS1 / T1 1.544 Mbps
  - -DS3 / T344.736 Mbps
  - STS-1
  - 51.840 Mbps **N\*STS-1** -STS-N
- T1 bandwidth represents 24 digital voice circuits of 64 kbps each; T3 is 28 T1s.





## Physical Media (cont.)

- Last-Mile Links
  - POTS 28.8-56 Kbps (Plain Old Telephone Service)
  - ISDN 64-128 Kbps
     (Integrated Services Digital Network)
  - xDSL 16Kbps 55.2 Mbps
     (Asymetric/Symmetric Digital Subscriber Line)
  - CATV 20-40 Mbps (Cable Television)



## Physical Media (cont.)

- Wireless links
  - Cell phone networks: AMPS (Advanced Mobile Phone System), PCS( Personal Communication Services), GSM (Global System for Mobile Communication)
  - Local area 2.45, 5.2, 17 GHz
    - IEEE 802.11 and Bluetooth use 2.4 GHz
  - Other "Metropolitan Area" frequencies 900 MHz, 1.4 GHz



#### Shannon's Theorem

- Claude Shannon's Capacity Theorem:
  - C = B log<sub>2</sub> (1 + S/N)
    C: Capacity B: Bandwidth S/N: Signal/noise
  - For example, if B = 3 kHz and S/N = 30 dB, 30 dB = 10  $\log_{10}$ S/N, so S/N = 1000 C = 3000  $\log_2 (1001) \approx 30$  kbps
  - Or if B = 1 MHz and S/N = 80 dB, C = 1MHz log<sub>2</sub>  $10^8 \approx 30$  Mbps

