CSCE 462/862
Communication Networks

The Physical Layer

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Transmission Media

- Magnetic Media
- Twisted Pair
- Baseband Coaxial Cable
- Broadband Coaxial Cable
- Fiber Optics
- Wireless

Transmission Media

- Magnetic Media
  - Cheap: $.10/Gigabyte
  - High bandwidth
  - High Latency
- Twisted Pair
  - Unshielded Twisted Pair (UTP)
  - Cat 3 or Cat 5
  - Phone lines implement a cut-off filter near 3000Hz
    - Limit of 38,400 baud
    - Can get > 38.4k bps by encoding multiple bits in a signal

Transmission Media

- Baseband Coaxial Cable (Coax)
  - 50 ohm Cable used for digital transmission
  - Better shielding than twisted pair
  - Bandwidth depends on cable length
    - 1 km cable can transfer 1 or 2 Gbps
- Broadband Coaxial Cable (> 4000Hz)
  - 75 ohm Cable used for analog transmission
  - Broadband networks use cable TV technology
    - up to 100km and 300-400 MHz
    - Bandwidth depends on number of bits encoded within each Hz.
  - Divided into multiple channels
    - Broadcast both TV and data on one cable

Transmission Media
Broadband Coax

- Amplifiers amplify the signal in one direction
  - Dual cable systems (Fig. 2.4a)
    - transmit on cable 1
    - receive on cable 2
  - Single cable systems (Fig. 2.4b)
    - Split the frequency for transmitting and receiving
      - Subsplit
        - receive on 4-30 MHz frequencies
        - transmit on 40-300 MHz frequencies
      - Midsplit
        - receive on 5-116 MHz frequencies
        - transmit on 168-300 MHz frequencies
- Inferior to Baseband, but ubiquitous

Fiber Optics

- Bandwidth
  - 1 Gbps today
  - 100 Gbps in lab
  - 1000 Gbps = 1Tbps soon
- Components of optical transmission
  - Transmission Media
  - Light source
  - Detector

Fiber Optics
Transmission Media

- Ultra-thin fiber of glass
  - » See Fig. 2-7
  - » Multi-mode fiber
    - 50 micron diameter: width of a human hair
    - light sent at an angle, Fig. 2.5(b)
    - multiple light sources create multiple signals on one fiber
  - » Single-mode fiber
    - 8-10 micron diameter
    - light travels a straight line
    - > 1 Gbps for 30+ km

Fiber Optics
Light Source

- Light source
  - » LED (Light Emitting Diode)
  - » Semiconductor laser
  - » Fig 2.8

Fiber Optics
Detector

- Detector
  - » Photodiode
  - » Generates a pulse when light hits it
    - 1 if light is on
    - 0 if light is off
  - » 1 *ns* response time
    - limits bandwidth

Fiber Optics
Network

- Ring Topology
  - » Passive interface
    - Failure of interface diode/LED does not affect rest of network
    - Attenuation of the signal can be a problem
  - » Active interface
    - Fig. 2-9
    - Failure of interface brings down the network
    - Signal is regenerated to full strength at each interface
- Passive Star Topology
  - » Fig. 2-10.
  - » connectivity is limited by sensitivity of diodes

Fiber vs. Wire

- Fiber
  - » High bandwidth
  - » Low attenuation
  - » Not affect by
    - power surge/failure
    - EMF
    - Harsh environment
  - » Thin and lightweight
    - 1km cable of 2 fibers weighs 100 kg
  - » Hard to tap: security
- Wire
  - » More familiar material
  - » Bi-directional
  - » Cheap interfaces
  - » Thick and heavy
    - 1km cable of 1000 twisted pair weighs 8000 kg

Wireless Transmission

- When electrons move, they create electromagnetic waves
  - » # of oscillations/sec = frequency (f)
  - » Distance from maxima to maxima = wavelength (λ)
  - » Attach antenna to circuit to broadcast/receive waves
- Transmit signals by modulating
  - » Amplitude,
  - » Frequency, or
  - » Phase

Wireless Transmission
Electromagnetic Spectrum

- Fig. 2-11 shows frequency bands used for communication
  - » Notice where Fiber Optics lies
- Bit encoding increases transmission rate
  - » Encode 3 bpHz at low f
  - » Encode 40 bpHz at high f
    - 500 MHz cable can transmit > 2 Gbps

Wireless Transmission
Electromagnetic Spectrum

- Low frequency signals
  - » omni-directional
  - » penetrate objects
- High frequency signals
  - » narrow, focused signal
  - » absorbed/deflected by objects

The Telephone System

- WAN
  - » Expensive to run lines for WAN
  - » Therefore, most WAN use PSTN (Public Switched Telephone Network)
- Evolution of PSTN
  - » See Fig. 2-14
    - ❶ Phones were hard-wired to each other
    - ❷ Switching center created for a city
    - ❸ Multi-level switching offices to connect cities

The Telephone System (cont.)

- Today's U.S. telephone network
  - » See Fig. 2-16
    - 160 LATAs (Local Access and Transport Area)
    - usually one LEC (Local Exchange Carrier) per LATA
    - All inter-LATA traffic is handled by an IXC (InterXchange Carrier)
    - Any IXC can build a POP (Point of Presence) in a LATA and gets equal access to inter-LATA traffic

The Telephone System (cont.)

- 3 main components
  - » Local Loops
    - twisted pair
    - analog signaling
  - » Trunks
    - Fiber optics or microwave
    - mostly digital
  - » Switching Offices

Local Loop
Computer Communications

- Modem (modulator-demodulator)
  - » Send digital data over analog lines
  - » See Fig. 2-17
- Problem with using analog communications
  - » Attenuation
    - loss of energy as signal propogates
  - » Delay distortion
    - Fourier components travel at different speeds
  - » Noise
    - unwanted energy from external sources

Local Loop
Computer Communications

- AC signal is used to handle attenuation and delay distortion
- Sine wave carrier signal used to modulate
  - » Amplitude
    - 0, 1 represented by varying voltage level
  - » Frequency
    - 2 or more tones
  - » Phase
    - wave is shifted 45, 135, 225, or 335 degrees
    - each phase shift represents 2 bits of info
- Combining modulation techniques increases bps per baud

Local Loop
High Speed Communications

- Shorter twisted pair local loop
  - » FTTC
  - » See Fig. 2-23
- Different media in the local loop
  - » Coax: cable modems
  - » FTTH
  - » Wireless ?

Trunks and Multiplexing

- Frequency Division Multiplexing: FDM
  - » Frequency spectrum is divided into logical channels
  - » Each user has exclusive use of a frequency band
  - » See Fig. 2-24
- Wavelength Division Multiplexing: WDM
  - » FDM over fiber: Fig.2-25
  - » Completely passive
- Time Division Multiplexing: TDM
  - » Each user gets entire bandwidth is used to transmit data
  - » Round-robin access: Fig 2-28.