

Recap: Last Class

- Introduction to computer networks
 - Definition of a computer network
- Circuit switching versus packet switching
- Elements of a computer network
- Layered network architecture
 - Protocol stacks: TCP/IP, OSI
- History of networks

Today: Physical Layer

- Physical media used for constructing a network
 - Twisted pair
 - Broadband cable
 - Fiber optics
 - Wireless
- Architectures used to reach end-users (at home)
 - Cable modems
 - ADSL
 - ISDN
- Brief introduction to the data link layer

The Physical Layer

"You can never be too rich, too thin, or have too much bandwidth"

Our goals:

- understand characteristics of various transmission media (fiber, cable, twisted pair, wireless)
- examine system architectures closely tied various media (cable networks, ADSL, ISDN)

Reading: Tannenbaum, chapter 2

Media: Twisted Pair

- two insulated copper wires, helically wound
- "standard" telephone line
 - ♦ category 3 twisted pair: can transmit data at several megabits/sec over a few kilometers
 - ♦ category 5 twisted pair: high-speed Ethernet (100Mbit/sec) and ATM (155Mbit/sec)

Media: Baseband Cable

- bi-directional digital transmission on co-axial cable (e.g., Ethernet)
 - ♦ digital: no modem needed
- single channel
- data rates up to 1-2 Gbps over 1 km

Media: Broadband Cable

- uses standard cable TV technology
 - ♦ analog transmission
 - ♦ modems needed for digital-> analog transmission -> digital conversion
 - ♦ traditionally unidirectional (cable TV) transfer, bi-directional transfer possible using upstream/downstream channels

Broadband Cable (cont.)

- multiple "channels" possible on same physical cable
 - ♦ each channel uses different frequency band: frequency division multiplexing
 - ♦ each channel: several megabits/sec
 - ♦ question: how to share channel (the multi-access problem!)
- repeaters every 5 km (copper)

Media: Fiber Optics

- digital transmission using light pulses
- bandwidth: 100 Gbps over short distances, 10's Gbps deployed
- unidirectional
- repeaters every 30 km

Aside: communication versus computation

- **computing:** 1 instruction/100 nsec in 1970 to 1 instruction/nsec in 1990's (two orders of magnitude)
- **communication:** 56 Kbps lines in 1970's to 10's Gbps in 1990s (six orders of magnitude)
- **question:** is bandwidth cheaper than CPU cycles? What are implications for protocol design?

Media: Wireless

- use electromagnetic spectrum for transmission
- channel capacities depend strong on frequency, transmission technology
- link characteristics:
 - ♦ noisier (more bit errors) than fiber, cable
 - ♦ wireless LAN's 2-10Mbps using spread spectrum, narrowband, infrared
 - ♦ long distance transmission:
 - ♦ 128kbps in 50kHz range
 - ♦ 2-3Mbps in 900Mhz range

Network architectures for reaching end user

Our "implicit" focus so far: corporate/office environment

- ♦ end users on LANs
- ♦ LANs connected in campus/company
- ♦ campus/company connected to ISP

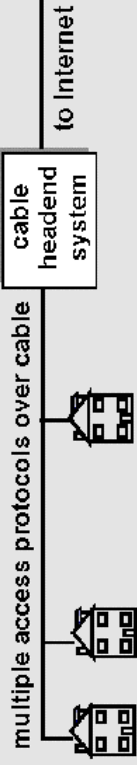
What about data to residential user?

- ♦ multimedia Internet access
- ♦ video on demand

Networking via the cable system:

cable modems

- can use one or more channels on existing cable system to network residential user to cable head end



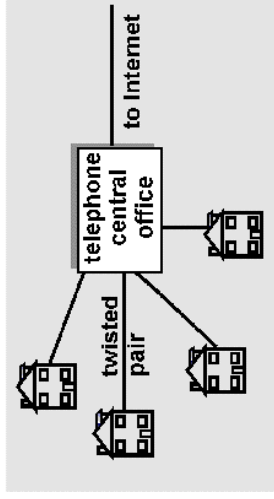
- symmetric versus asymmetric upstream/downstream channels
 - 4Mbps symmetric cable modems
 - 10M to home, 768K upstream

• multiple access techniques

- Zenith: CSMA/CD
- Motorola: polling
- Baynetworks: TDMA
- hybrid fiber cable (HFC): fiber to the curb, cable to the home
- note: only 5% of existing cable nets have 2-way amplifiers

Networking via the phone company: ADSL

- ADSL: asymmetric digital subscriber line
- high-speed data over existing twisted pair
- 6Mbps downstream to home, 640kbps upstream on existing phone wire
- 50% of 560M phone lines ADSL capable



Networking via the phone company: ISDN

- phone company working 15 years on narrowband ISDN standard
 - twisted pair
 - basic rate: 2 64Kbit channels plus 1 16bit channel 2B+D
- a technology being leapfrogged before being widely deployed?

The Physical Layer: Summary

We have seen:

- capabilities of various transmission media
- network architectures to the home based on these technologies

Excellent reference: [the high bandwidth home page](#)

(<http://www.specialty.com/hiband/beginner.html>)

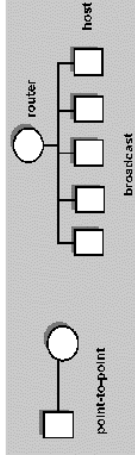
The Data Link Layer

- introduction
- point-to-point data link protocols
- the multiple access problem
- local area networks
- required reading:
 - ♦ Tannenbaum 3.6, 4
 - ♦ Ross, Kurose 5

Data Link Layer : Introduction

Services: reliably deliver a data link packet between two physically connected machines

- two link types: point-to-point, broadcast



Point-to-point links: one sender, one receiver

- framing: recognizing bits on the wire as packets
- reliable communications

Data Link Layer : Introduction

broadcast links: many senders, potentially many receivers

- framing
- reliable communication
- accessing a shared medium
- addressing
- many senders many receivers

Data Link Layer: Introduction

- reliable communication: ARQ, checksum, timers, sequence numbers
- addressing
 - data link level addresses different from network layer addresses!
 - why do we need different data link address?

