CSEE 4119 Computer Networks

Chapter 1
Introduction (2/4)
Chapter 1: roadmap

1.1 What is the Internet?
1.2 Network edge
   - end systems, access networks, links
1.3 Network core
   - circuit switching, packet switching, network structure
1.4 Delay, loss and throughput in packet-switched networks
1.5 Protocol layers, service models
1.6 Networks under attack: security
1.7 History
A closer look at network structure:

- network edge: applications and hosts
- access networks, physical media: wired, wireless communication links
- network core:
  - interconnected routers
  - network of networks
The network edge:

- **end systems (hosts):**
  - run application programs
  - e.g. Web, email
  - at “edge of network”

- **client/server model**
  - client host requests, receives service from always-on server
  - e.g. Web browser/server; email client/server

- **peer-peer model:**
  - minimal (or no) use of dedicated servers
  - e.g. Skype, BitTorrent
Access networks and physical media

Q: How to connect end systems to edge router?
- residential access nets
- institutional access networks (school, company)
- mobile access networks

Keep in mind:
- bandwidth (bits per second) of access network?
- shared or dedicated?
Dial-up Modem

- uses existing telephony infrastructure
  - home directly-connected to central office
- up to 56Kbps direct access to router (often less)
- can’t surf, phone at same time: not “always on”
Digital Subscriber Line (DSL)

- uses existing telephone infrastructure
- up to 1 Mbps upstream (today typically < 256 kbps)
- up to 8 Mbps downstream (today typically < 1 Mbps)
- dedicated physical line to telephone central office
Residential access: cable modems

- uses cable TV infrastructure, rather than telephone infrastructure
- **HFC: hybrid fiber coax**
  - asymmetric: up to 30Mbps downstream, 2 Mbps upstream
- **network of cable, fiber attaches homes to ISP router**
  - homes *share access* to router
  - unlike DSL, which has dedicated access
Residential access: cable modems

Diagram: http://www.cabledatacomnews.com/cmic/diagram.html
Cable Network Architecture: Overview

Typically 500 to 5,000 homes
Cable Network Architecture: Overview
Cable Network Architecture: Overview
Cable Network Architecture: Overview

FDM (more shortly):

Cable headend

Cable distribution network

Home

Channels

Introduction 1-13
Fiber to the Home

- optical links from central office to the home
- two competing optical technologies:
  - Passive Optical network (PON)
  - Active Optical Network (PAN)
- much higher Internet rates; fiber also carries television and phone services
**Ethernet Internet access**

- typically used in companies, universities, etc
- 10 Mbps, 100Mbps, 1Gbps, 10Gbps Ethernet
- today, end systems typically connect into Ethernet switch
Wireless access networks

- shared wireless access network connects end system to router
  - via base station aka “access point”
- wireless LANs:
  - 802.11b/g (WiFi): 11 or 54 Mbps
- wider-area wireless access
  - provided by telco operator
  - ~1Mbps over cellular system (EVDO, HSDPA)
  - next up (?): WiMAX (10’s Mbps) over wide area
Home networks

Typical home network components:
- DSL or cable modem
- router/firewall/NAT
- Ethernet
- wireless access point
Physical Media

- **bit**: propagates between transmitter/rcvr pairs
- **physical link**: what lies between transmitter & receiver
- **guided media**:  
  - signals propagate in solid media: copper, fiber, coax
- **unguided media**:  
  - signals propagate freely, e.g., radio

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**Twisted Pair (TP)**

- two insulated copper wires
  - Category 3: traditional phone wires, 10 Mbps Ethernet
  - Category 5: 100Mbps Ethernet
Physical Media: coax, fiber

Coaxial cable:
- two concentric copper conductors
- bidirectional
- baseband:
  - single channel on cable
  - legacy Ethernet
- broadband:
  - multiple channels on cable
  - HFC

Fiber optic cable:
- glass fiber carrying light pulses, each pulse a bit
- high-speed operation:
  - high-speed point-to-point transmission (e.g., 10’s-100’s Gbps)
- low error rate: repeaters spaced far apart; immune to electromagnetic noise
Physical media: radio

- signal carried in electromagnetic spectrum
- no physical “wire”
- bidirectional
- propagation environment effects:
  - reflection
  - obstruction by objects
  - interference

Radio link types:
- terrestrial microwave
  - e.g. up to 45 Mbps channels
- LAN (e.g., WiFi)
  - 11Mbps, 54 Mbps
- wide-area (e.g., cellular)
  - 3G cellular: ~ 1 Mbps
- satellite
  - Kbps to 45Mbps channel (or multiple smaller channels)
  - 270 msec end-end delay
  - geosynchronous versus low altitude
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The Network Core

- mesh of interconnected routers
- the fundamental question: how is data transferred through net?
  - circuit switching: dedicated circuit per call: telephone net
  - packet-switching: data sent thru net in discrete “chunks”
Network Core: Circuit Switching

- end-end resources reserved for “call”
  - link bandwidth, switch capacity
  - dedicated resources: no sharing
  - circuit-like (guaranteed) performance
  - call setup required
Network Core: Circuit Switching

- network resources (e.g., bandwidth) divided into “pieces”
  - pieces allocated to calls
  - resource piece *idle* if not used by owning call (*no sharing*)
- dividing link bandwidth into “pieces”
  - frequency division
  - time division
Circuit Switching: FDM and TDM

**FDM**

- Frequency
- Time

**TDM**

- Frequency
- Time

Example:
- 4 users
- [Color bars representing different frequencies and time slots]
Numerical example

How long does it take to send a file of 640,000 bits from host A to host B over a circuit-switched network?

- all link speeds: 1.536 Mbps
- each link uses TDM with 24 slots/sec
- 500 msec to establish end-to-end circuit

Let’s work it out!
Network Core: Packet Switching

- Each end-end data stream divided into packets
  - User A, B packets share network resources
  - Each packet uses full link bandwidth
  - Resources used as needed

- Resource contention:
  - Aggregate resource demand can exceed amount available
  - Congestion: packets queue, wait for link use
  - Store and forward: packets move one hop at a time
    - Node receives complete packet before forwarding
 Packet Switching: Statistical Multiplexing

- sequence of A & B packets has no fixed timing pattern
  - bandwidth shared on demand: statistical multiplexing.

- TDM: each host gets same slot in revolving TDM frame.
Packet-switching: store-and-forward

- takes $L/R$ seconds to transmit (push out) packet of $L$ bits on to link at $R$ bps
- **store and forward:** entire packet must arrive at router before it can be transmitted on next link
- delay $= 3L/R$ (assuming zero propagation delay)

**Example:**
- $L = 7.5$ Mbits
- $R = 1.5$ Mbps
- transmission delay $= 15$ sec

more on delay shortly …
Packet switching versus circuit switching

Packet switching allows more users to use network!

Example:
- 1 Mb/s link
- each user:
  - 100 kb/s when “active”
  - active 10% of time

- circuit-switching:
  - 10 users

- packet switching:
  - with 35 users, probability > 10 active at same time is less than .0004

Q: how did we get value 0.0004?
Q: what happens if > 35 users?
Packet switching versus circuit switching

Is packet switching a “slam dunk winner?”

- great for bursty data
  - resource sharing
  - simpler, no call setup
- excessive congestion: packet delay and loss
  - protocols needed for reliable data transfer, congestion control
- Q: How to provide circuit-like behavior?
  - bandwidth guarantees needed for audio/video apps
  - still an unsolved problem (see chapter 7 of book)

Q: human analogies of reserved resources (circuit switching) versus on-demand allocation (packet-switching)?