1.264 Lecture 33

Telecom: Wired LAN, WAN

Next class: Green chapter 8, 32. Exercise due before class
Exercise

• What’s on a telephone pole?
  – Three types of network; name them
• Which is highest on the pole? Why?
• Which of these are point to point connections?
• Which are shared (point to many)?
• Which of these can carry data?
• Which of these can carry voice?
• Which have competitive (open) access?
• What type(s) of wiring does each use?
Solution

• What’s on a telephone pole?
  – Electric
  – Phone
  – Cable TV
• Which is highest on pole? Why?
  – Electric, high voltage/current
• Which of these are point-to-point connections?
  – Phone only
• Which are shared (point-to-many)?
  – Electric, cable
• Which can carry data?
  – Phone, cable, electric
• Which can carry voice?
  – Phone, cable, electric
• Which have competitive access?
  – Phone: unbundled to CLEC
  – Cable: not competitive
  – Electric: distribution monopoly, generation competitive
• What type(s) of wiring does each use?
  – Phone: copper, fiber
  – Cable: coax, fiber
  – Electric: copper
Telecom systems management

- Your project/system must estimate the amount of data to be exchanged with partners/servers
  - Warehouse RFID example from last lecture
- You must choose appropriate technologies
  - Wired: higher bandwidth/reliability (~gigabits/sec/circuit)
  - Wireless: mobile, flexible, low bandwidth (~megabits/sec/cell)
- You must choose between build, lease, or service
  - Depends on right of way, scale
- You will interconnect different network types
  - Local area (LAN), metro area (MAN), wide area (WAN)
- Your networks will be standards based
- You must choose carriers, bandwidths, service levels, costs, etc., similar to physical transport
  - You are likely to need a lot of bandwidth
Telecom bandwidth

• **Bandwidth is a key issue**
  – All data carried over analog (continuous) circuits at the physical level
  – None were designed for data: telecom circuits for voice, broadcast and CATV for radio and TV
  – All have been repurposed to carry data while retaining their historic physical structure ($$$ existing capital)
  – Analog bandwidth measured in Hz: cycles/second
    • Wireless communications can carry 2 bits/Hz in 5 GHz band
    • Wired communications have vastly more bandwidth
    • Formula for digital bandwidth based on signal/noise ratio
  – These factors determine the building blocks you’ll use
    • Most channels have more bandwidth than 1 user needs
    • Multiple users are multiplexed (shared) on comm channels
Telecom networks

• Data travels over different network segments
  – LAN at your site: cheap, high bandwidth (1 Gbps+)
  – Connection from your site to local switch/cable headend:
    • Copper: ~5 Mbps, cost variable
    • CATV: ~20 Mbps, cost variable
    • Fiber: essentially unlimited, cost variable
  – Telecom or CATV network: fiber, high bandwidth, cheap
    • Synchronous optical network (SONET) rings
    • Very high availability (99.999%), recover from many faults
  – Data circuits are permanent, unlike voice calls
    • Data packet flow over the permanent network is variable
    • Carrier IP networks handle most voice, data and video
    • Large routers exist at carrier switch facilities for IP traffic
  – Carrier networks are generally not encrypted; rely on physical security
Review: Data communication protocols

Image by MIT OpenCourseWare.
Review: TCP/IP

TCP/IP Protocols Compared to OSI Model

TCP/IP Protocols

- Simple Mail Transfer Protocol
- File Transfer Protocol
- TELNET
- Hypertext Transport Protocol
- Domain Name System
- Simple Network Management Protocol
- Netbios

TCP, UDP

- IP, Routing Information Protocol, Interior Gateway Routing Protocol, Open Shortest Path First, Integrated IS-IS.
- Address Resolution Protocol, Reverse ARP
- Logical Link Control
- UTP, Wireless, Fiber, Coaxial, Etc.

A TCP/IP Network

TCP/IP Host

LAN

WAN

TH = Transport Header

Image by MIT OpenCourseWare.
LANs and WANs

And/or MAN if within a metro area

Image by MIT OpenCourseWare.
Local area network (LAN)

- High speed, privately owned, short range network
  - IEEE 802.3 or Ethernet is nearly universal
  - Speeds of 10Mbps to 1Gbps (1000Mbps)
  - Limited range: building or campus (1-5 km typical length)
    - No permission for right of way on streets
  - Carriers can extend Ethernet over metro area using Carrier Ethernet, a metro-area network (MAN)
    - The technology is not Ethernet per se, but it looks like and is managed like Ethernet from the customer’s point of view
    - We cover MANs later.
Repeater, bridge/hub, router, gateway at customer site

1. **SIGNAL TO SIGNAL REPEATER**
   - Physical to Physical
   - Application
   - Presentation
   - Session
   - Transport
   - Network
   - Data Link
   - Physical

2. **FRAME TO FRAME BRIDGE**
   - Physical to Physical
   - Application
   - Presentation
   - Session
   - Transport
   - Network
   - Data Link
   - Physical

3. **ETHERNET TO ETHERNET ROUTER**
   - Physical to Physical
   - Application
   - Presentation
   - Session
   - Transport
   - Network
   - Data Link
   - Physical

4. **ETHERNET TO X.25 GATEWAY**
   - Physical to Physical
   - Application
   - Presentation
   - Session
   - Transport
   - Network
   - Data Link
   - Physical

Image by MIT OpenCourseWare.
Protocol is carrier sense multiple access/collision detection (CSMA/CD). Earliest wired Ethernet used this protocol also, now superseded.
Exercise - Maximum traditional LAN length

- Maximum LAN length: $L = \frac{ct}{2}$
- Speed of signal: $c$ (2 x $10^8$ m/sec, 2/3 speed of light)
- Ethernet speed: $s$ (e.g., $10^8$ bits/sec, or 100Mb/sec)
- Slot time $t$: 512/s (min Ethernet frame size=512 bits)

- Compute $L$ for a 100 Mb/sec LAN (s)
- Compute $L$ for a 1 Gb/sec LAN (s)

- You’ll see the 1 Gb/sec LAN isn’t feasible with traditional LAN. 1 Gb/sec LAN uses:
  - Full duplex (two wires per station, one to send, one to receive)
  - Switches only, no repeaters or bridges, and no collisions
  - Fiber optics (often), with 500 to 5000 meter segments
  - Distance limited by signal fading, etc. (more on this later)
Solution

- Maximum LAN length: \( L = \frac{ct}{2} \)
- Speed of signal: \( c = 2 \times 10^8 \text{ m/sec}, \frac{2}{3} \text{ speed of light} \)
- Ethernet speed: \( s = 10^8 \text{ bits/sec}, \text{ or } 100\text{Mb/sec} \)
- Slot time \( t = \frac{512}{s} \) (min Ethernet frame size=512 bits)

- Compute \( L \) for a 100 Mb/sec LAN (s)
  - \( L = \frac{(2 \times 10^8 \times 512/10^8)}{2} = 512 \text{ meters} = 0.5 \text{ km} \)

- Compute \( L \) for a 1 Gb/sec LAN (s)
  - \( L = \frac{(2 \times 10^8 \times 512/10^9)}{2} = 51.2 \text{ meters} = 0.05 \text{ km} \)

- Even though collisions are avoided in full duplex, switched LANs, signal attenuation and other losses are limiting
- LANs typically are 5 km or less
WAN: Telecom carrier network facilities

• Wide area networks (WANs)
• Carried over same physical facilities as voice (next lecture)
  – Local loop, local switch, tandem switch, trunk
• Carried on permanent circuits of much higher bandwidth than for a single voice call; no switching
• Protocols based on ISO 7-layer model
  – Mostly HTTP (Web services), tcp, and ip
  – Regulated by routers and data switches
• Data sessions are highly variable compared to voice, e.g.,
  – Web browsing
  – Bank ATM machine
  – Database backup
  – LAN interconnection
• Data addresses are Ethernet addresses or IP addresses
  – Not phone numbers
• Carrier data network speeds 56 kbps to 40 Gbps per circuit
• Carrier voice network secure without encryption
Wide area networks (WANs)

- Differences from metro-area (MAN) or local-area (LAN) net:
  - Global in scope
  - Usually provided by multiple carriers (one is lead)

- Legacy WANs are present but usually not good choices for new data comm needs:
  - Private (point to point) circuits: expensive
  - Dialup circuits: low bandwidth
  - Frame relay: still viable, being superseded by IP (cost, reach)
  - Multidrop networks
    - Used for bank ATMs, point-of-sale (POS) terminals, lottery terminals
    - Now that banks, stores have general Internet access, encrypted ATM and POS traffic often goes over the general access
  - Packet networks (X.25): expensive, limited bandwidth
  - VSAT (satellite): widely dispersed, low bandwidth service

- IP-based networks becoming dominant
  - Typically over a business-only, carrier-provided infrastructure separate from the open Internet
Telecom service areas

Image by MIT OpenCourseWare.
SONET

• SONET uses time division multiplexing (TDM)
  – All clocks in the network sync to a master clock
  – Multiplexer/demultiplexers start/end a SONET circuit
  – Add/drop multiplexers insert/extract subset of signals

• An OC-1 signal is 51.84 Mbits/sec
  – A voice call is 64 kbits/sec, or 0.064 Mbits/sec
  – Maximum capacity= 51.84/0.064, or 810 voice channels
  – However it has about 15% overhead (framing, control)
  – It actually carries 672 voice channels
  – Or 7 to 28 video channels (1.5 Mbps to 6 Mbps)

• An OC-192 signal is 192 times higher capacity
  – Maximum SONET rate (though fiber can go higher)
Fiber optic (SONET) rings

Image by MIT OpenCourseWare.
Exercise: SONET

• You are a large airline with a single server site that handles all your reservations
  – Average transaction is 10,000 bytes (80,000 bits)
  – You must handle 2,000 transactions/second

• Where can you locate your servers on the network in the previous slide:
  – At central office A, in a telco colocation site?
  – At a SONET hub on one of the OC-12 rings?
  – At a multiplexer on one of the OC-3 rings?

• Compute the server bandwidth and compare to the network bandwidth
  – OC-3 is 3 * OC-1; OC-12 is 12 * OC-1; OC-48 is 48 * OC-1
Solution

- You need 80,000 * 2,000 = 160 Mbits/sec
- OC-1 is 51 Mbits/sec
- OC-3 is 155 Mbits/sec. Not enough
- OC-12 is 622 Mbits/sec. Clearly enough
- You need to be at central office A or at a SONET hub on one of the OC-12 rings.
  - You don’t need the full OC-12 or OC-48 capacity. Carriers will sell you an appropriate fraction.
Glossary

- Repeater: layer 1 LAN device
- Bridge: layer 2 LAN device
- Router: layer 3 LAN device
- Gateway: layer 7 LAN device
- VSAT: Very Small Aperture Terminal (satellite)
- X.25: Packet service, pre-Internet (replaced by IP)
- PBX: Private branch exchange, to switch voice calls in an office (now mostly IP-PBX)
- LATA: Local access and transport area, defines service areas for regulatory, pricing issues