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

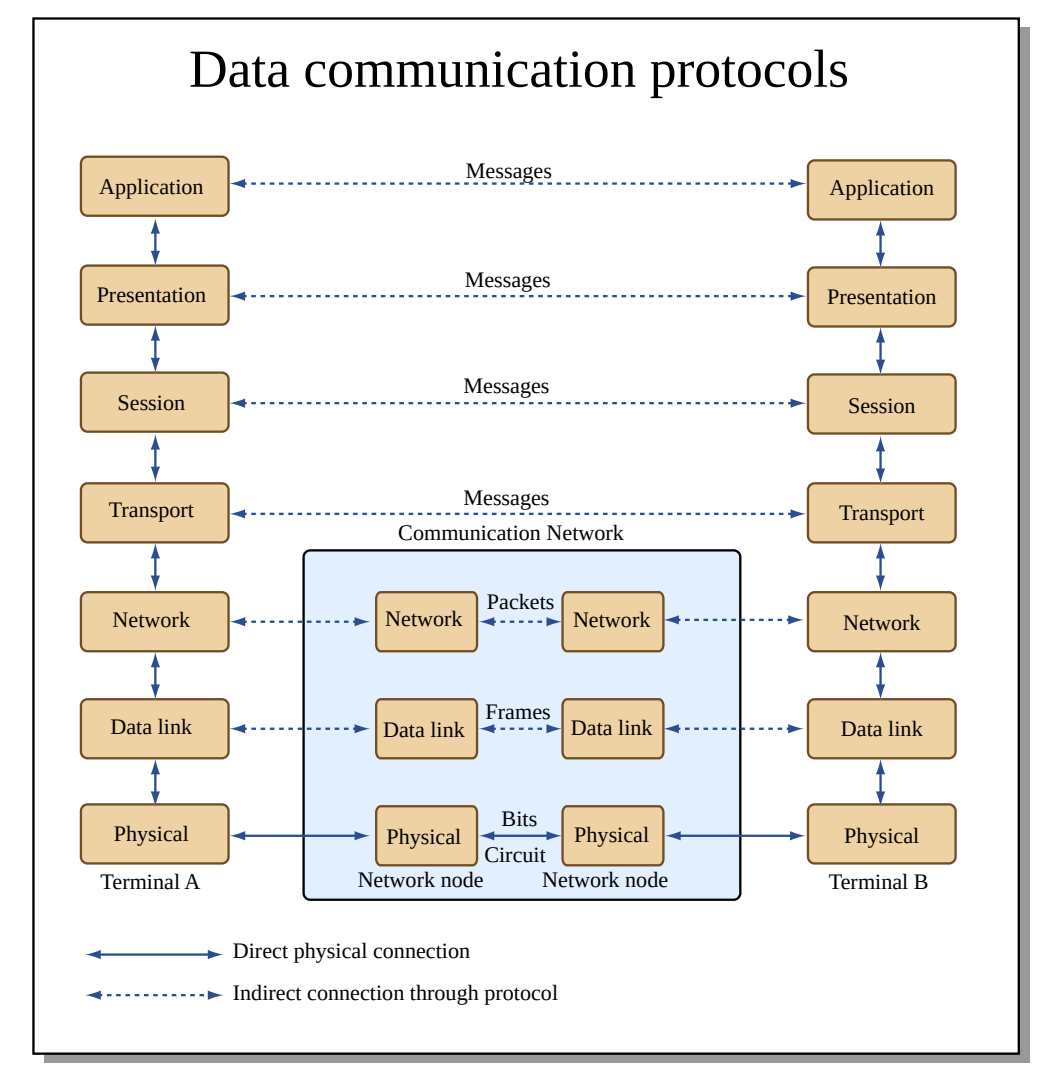


Image by MIT OpenCourseWare.

Review: TCP/IP

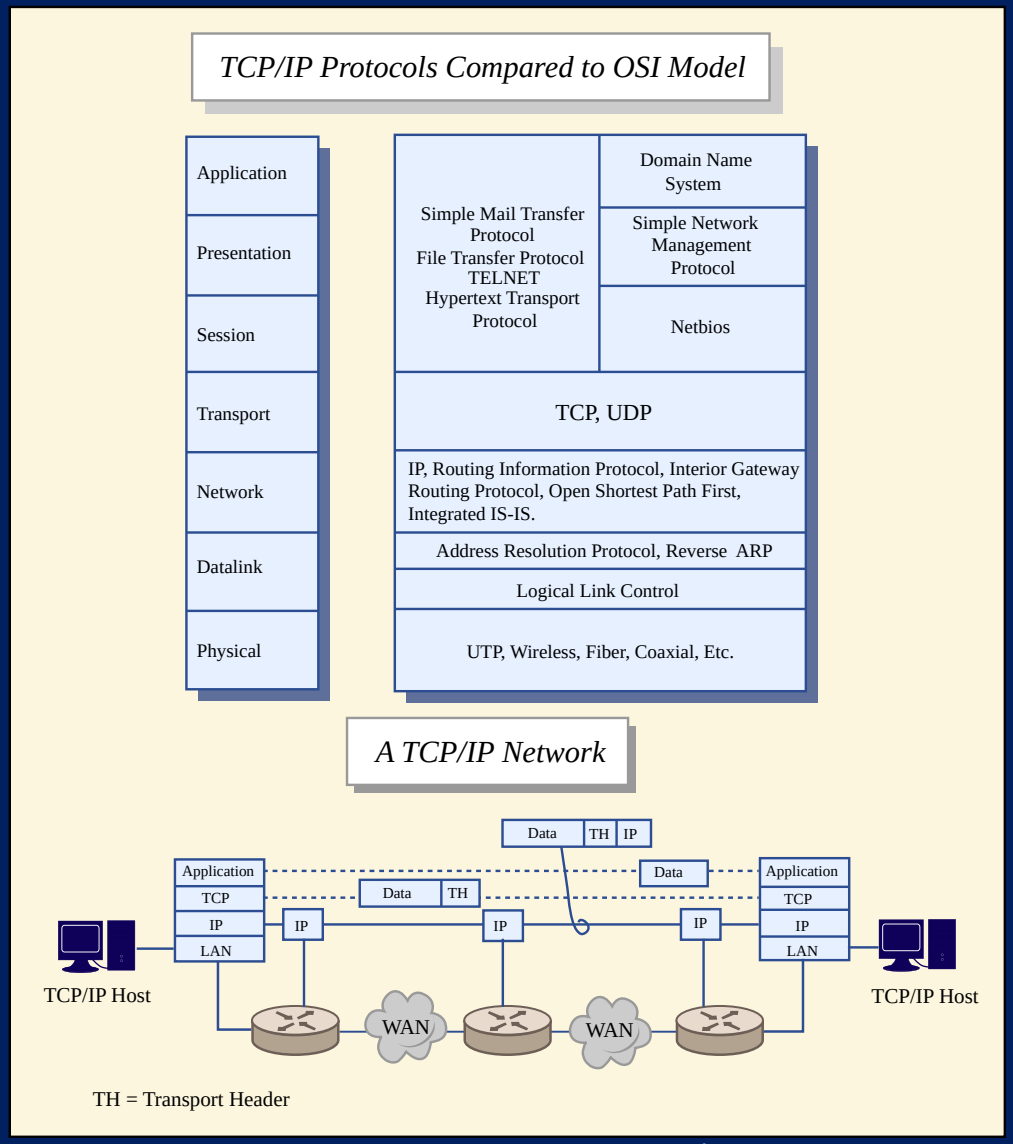


Image by MIT OpenCourseWare.

LANs and WANs

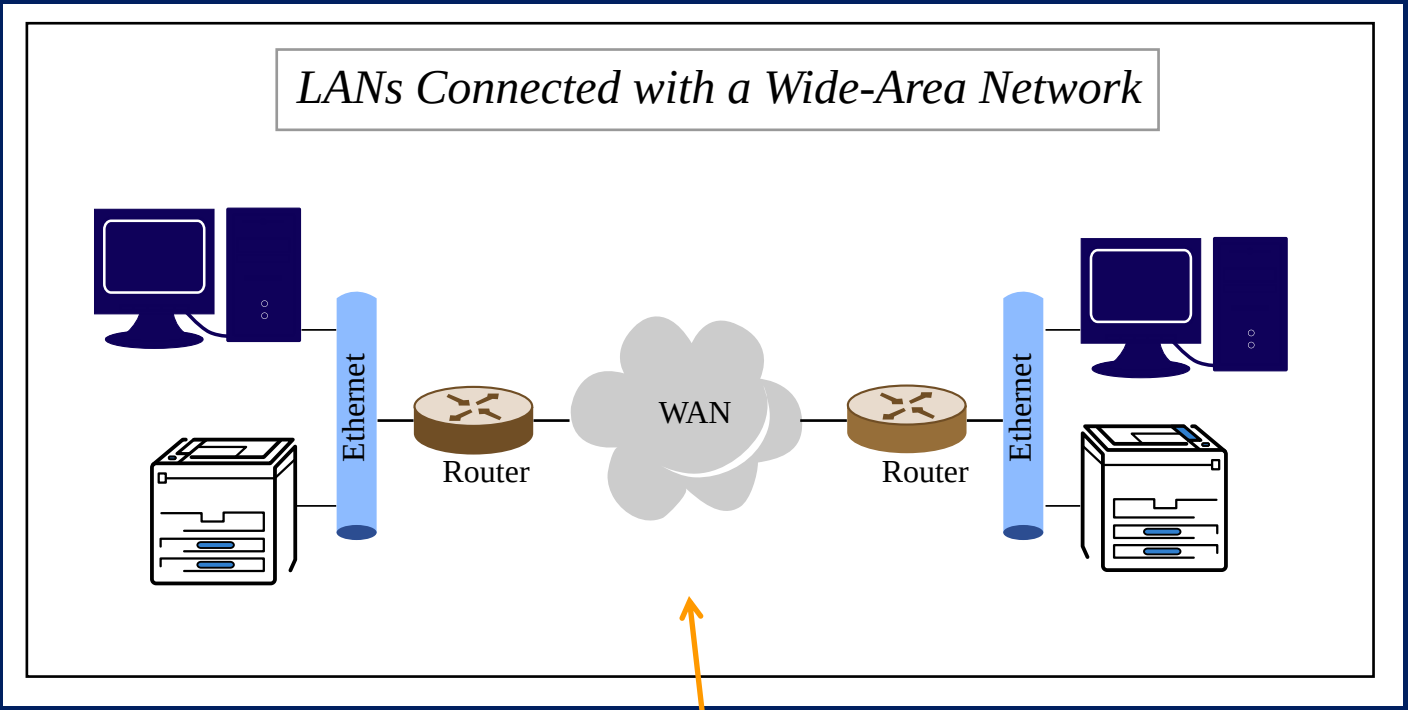


Image by MIT OpenCourseWare.

And/or MAN if within a metro area

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

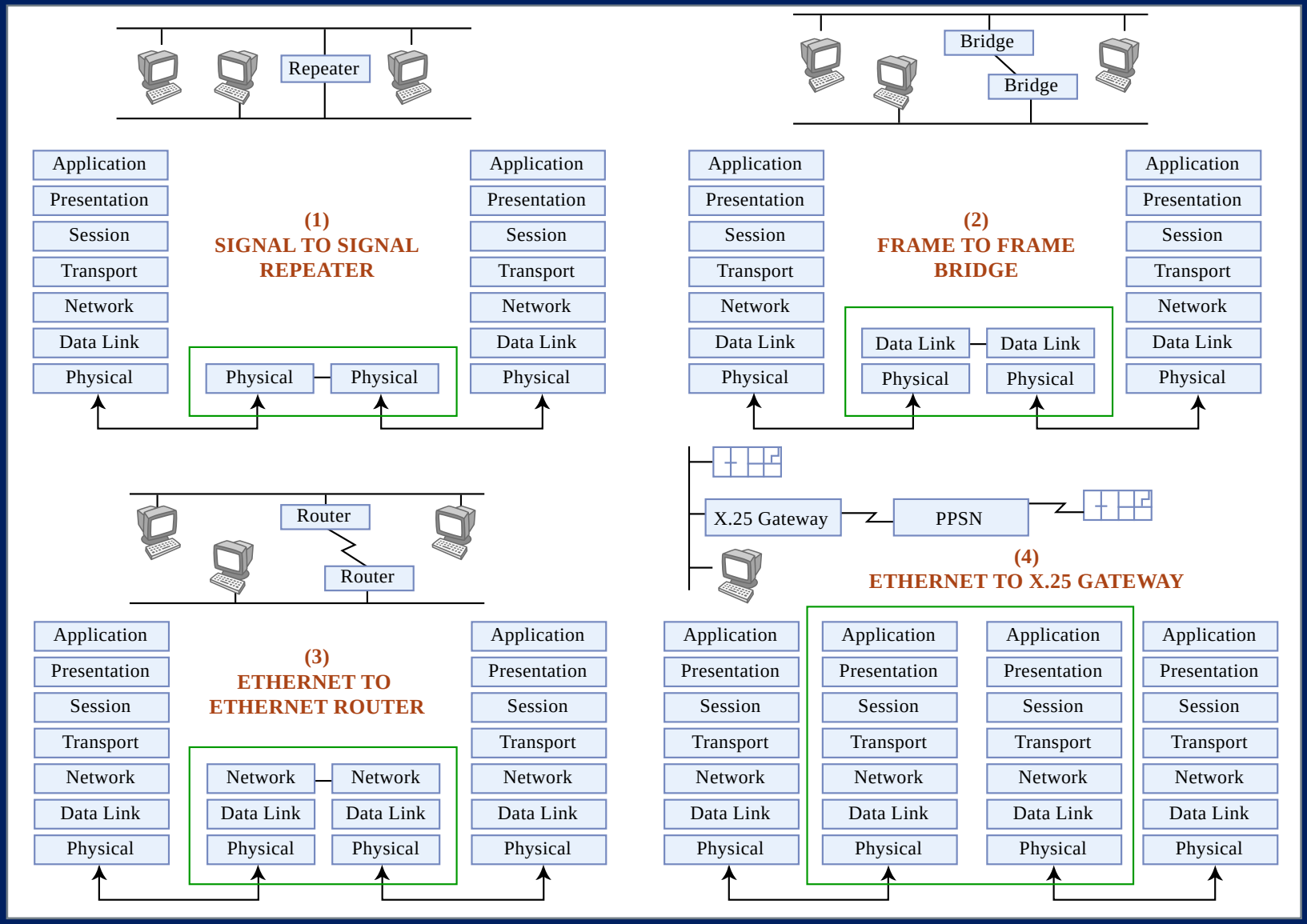
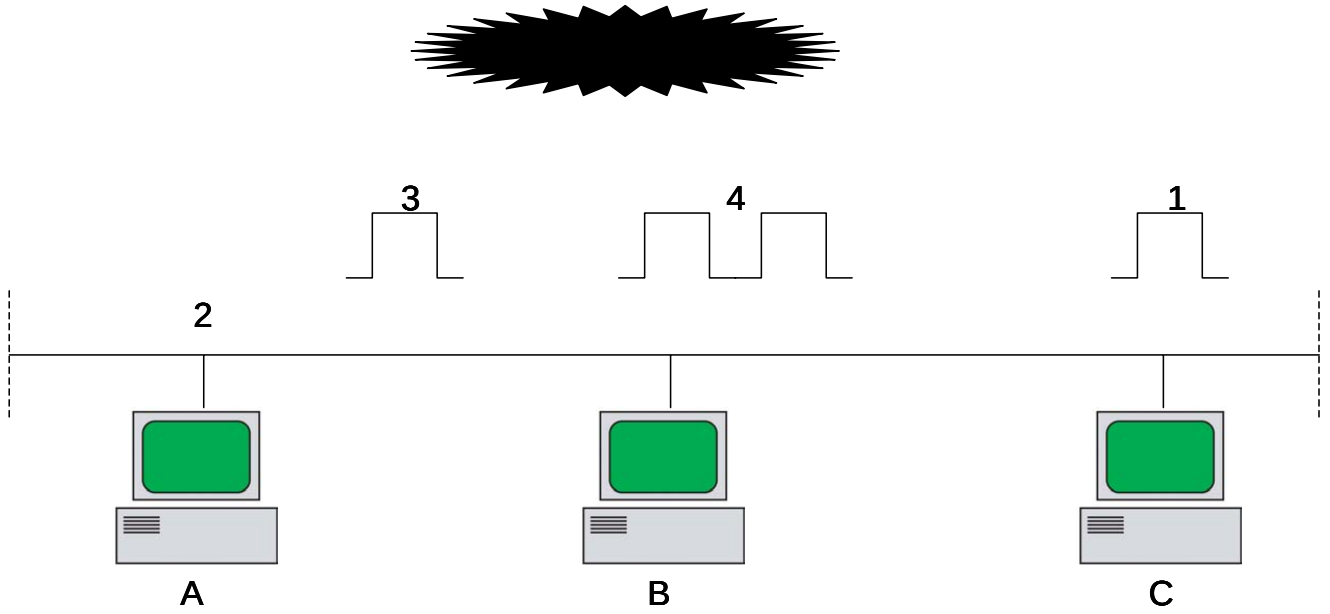


Image by MIT OpenCourseWare.

Ethernet (initial wired, current wireless version)



Min frame= 512 bits
If sender sends 512 bits and has heard no jamming signal, it can continue w/o interruption.
Worst case is farthest station collides and sends jam signal, which must reach sender before it sends more than 512 bits.

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= 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= 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)
  - L= ($2x10^8$ * $512/10^8$)/2 = 512 meters= 0.5 km
- Compute L for a 1 Gb/sec LAN (s)
  - L= ($2x10^8$ * $512/10^9$)/2 = 51.2 meters= 0.05 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

Carrier/public network: major components

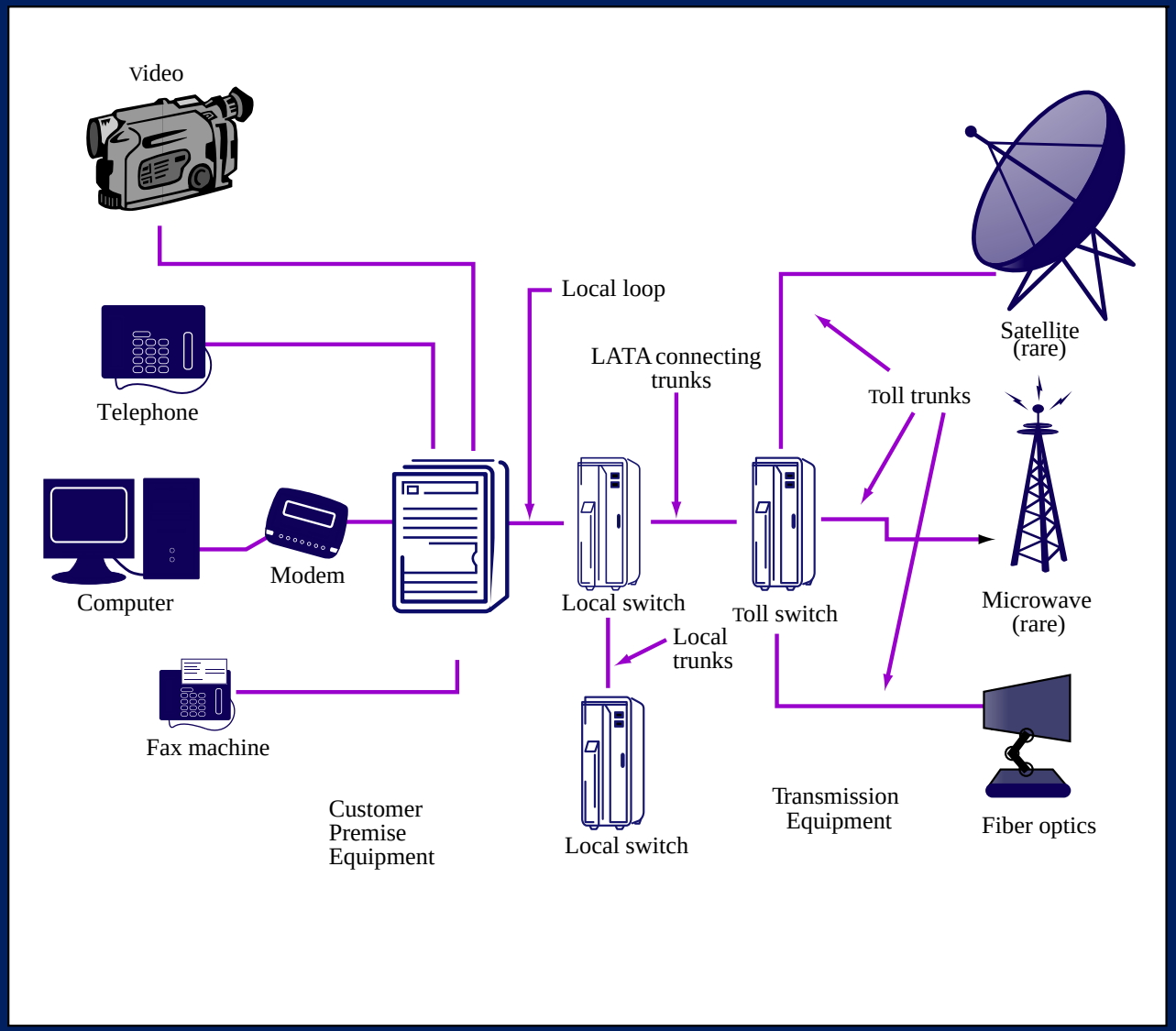


Image by MIT OpenCourseWare.

Telecom service areas

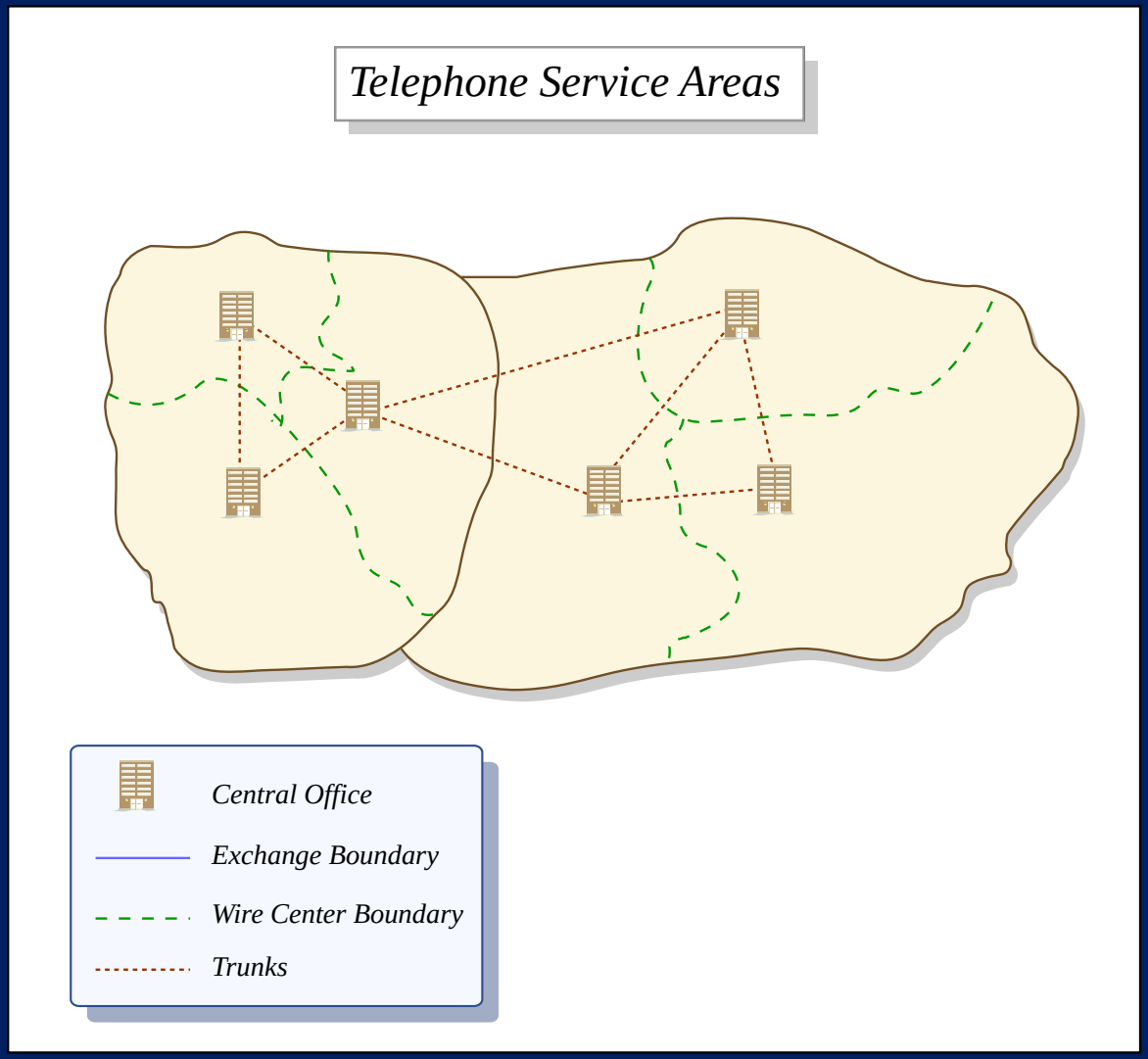


Image by MIT OpenCourseWare.

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

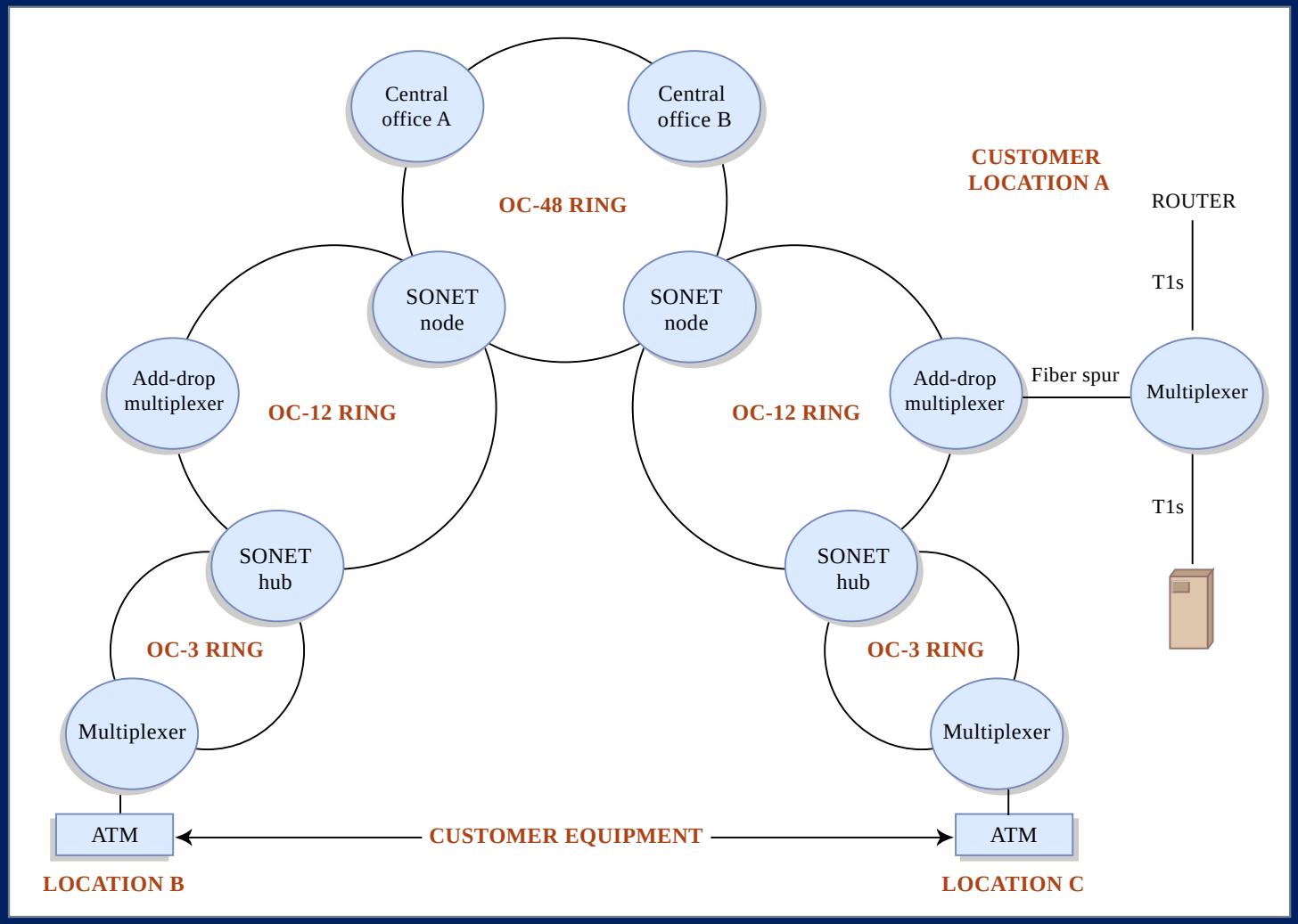


Image by MIT OpenCourseWare.

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

1.264J / ESD.264J Database, Internet, and Systems Integration Technologies
Fall 2013