1.264 Lecture 34

Telecom: Connecting wired LAN, WAN

Next class: Green chapter 17. Exercise due before class
Exercise

• Your transportation brokerage company also handles billing for freight shipments, collecting from shippers and forwarding payment to carriers.
  – This data must be secure; you route funds directly to banks in some cases and between customers in other cases.

• How would you communicate between your three major sites in New Jersey, Houston and Los Angeles?
  – You transfer approximately 10,000 bills of lading in a 1 hour window at the end of each day from Houston and Los Angeles to New Jersey, which is the only site connected to banks and customers
  – Each bill is about 500 kB of data (documents and signatures are scanned)

• Select the technology and bandwidth
  – Will you use LAN, WAN or MAN technology, or combination?
  – Which specific technologies will you use? Discuss options, pros/cons briefly.
  – Discuss broader options surrounding your choice.
Solution

• Bandwidth:
  – 500 kB x 8 bits/byte x 10 000 docs / 3600 seconds/hr
  – Approximately 11 Mbps raw data rate
  – Connection should be at least 15 Mbps, for overhead, etc.
  – If we route LA traffic via Houston, Houston-NJ needs 25-30 Mbps
  – Either case requires OC-1 (45-51 Mbps) bandwidth

• Technology: WAN between LANs at each site
  – With only two links (LA-Houston and Houston-NJ), two point to point fiber optic links are a possible solution
    • Used only 1 hour a day, though…
  – Internet could handle it but large bursty traffic across the country would have reliability problems
    • Business traffic has security issues on open Internet
  – Satellite bandwidth too low (network video has special deal).
• Business process can/must change:
  – Established years ago with small amount of data and expensive telecom
  – Cheaper to send documents in real time now
  – If docs sent in real time 10 hrs/day, bandwidth = 1.5Mbps, which can be handled by T1, DSL, ... much less expensively. 1.5 Mbps is a sweet spot.
  – Or, look further: do we need to send all 500 kB to the bank? If we store the full document, can we send just the part the bank needs? Trade off complexity vs cost

• Another reason why we use spiral model
  – Telecom considerations at the very end can require changing a business process
    • Which requires changing requirements among channel partners
    • And changes UML, database (maybe), Web services, etc.
  – If we find this in the first spiral, we can change it
  – If we find this at the end of chaos/waterfall, it can be desperate
LAN, WAN and access (last mile)

Image by MIT OpenCourseWare.
Outside plant

MAJOR COMPONENT OF OUTSIDE PLANT

Remote subscriber loop carrier terminal
Pole lines
Aerial distribution cable
Aerial drop wire
Pedestal terminal
Burled cable
Burled drop wire
Burled distribution cable
Conduit
Trunks to other central offices

Switching compartment
Subscriber loop carrier
Feeder cables
Protector frame
Telephone central office

Image by MIT OpenCourseWare.
Feeder and distribution cable

Image by MIT OpenCourseWare.
Metropolitan area networks (MANs)

• MAN is public network that bridges LAN and WAN, typically spanning 5 to 50 km
  – Metro area Ethernet becoming dominant:
    • Simple for customer, extends Ethernet LANs
    • Carrier technology sophisticated but available, reliable, fairly low cost
  – Runs over carrier fiber optic networks
  – Shared across business users
    • Security options: encryption or physical separation
  – Not connected to open Internet or consumers

• Applications
  – Connecting LANs (sites) within a metro area
  – Storage area networks (SANs)
  – Connect many sites to one WAN point of presence (POP)
  – Video, voice, graphics: bursty, high bandwidth data
Metro area Ethernet

• **Gigabit Ethernet (1,000 Mbps)**
  – Compatible with Gigabit Ethernet LAN
  – 5 to 50 km range per hop
    • Multiple Ethernet switches needed per metro area
  – Available in many metro areas; can buy fractions of Gb

• **10G Ethernet (10 Gbps or 10,000 Mbps)**
  – Almost completely compatible with slower Ethernet
  – Essentially compatible with SONET
    • 10G Ethernet is close to OC-192, and protocols map
  – Range up to 40 km
  – Becoming available; can buy fractions of bandwidth

• **Both options have technology ("tags") to allow network to scale**
  • Ethernet switches discover all devices
  • MAN Ethernet can have 100,000s of devices
Access to metro area Ethernet

- **Ethernet in the First Mile (EFM)**
  - **Copper**: encapsulate Ethernet within modified DSL
    - 2 Mbps up to 2.7 km, 10 Mbps up to 0.8 km
  - **Fiber**: essentially Gigabit Ethernet, up to 20 km
  - Does not provide self-healing or diverse routing

- **Resilient Packet Ring (RPR)**
  - Provides alternate routes and failover, like SONET
    - Dual counter-rotating rings
  - Keeps Ethernet simplicity for applications, management
MAN Ethernet

Metropolitan Area Ethernet

Image by MIT OpenCourseWare.
# Exercise: MAN

<table>
<thead>
<tr>
<th></th>
<th>LAN</th>
<th>MAN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance (kilometers)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Owner</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of devices</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bandwidth (Mbps)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Resiliency/redundancy (yes/no)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Is there a service level agreement (contract)?</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Give approximate ranges for distance, devices, bandwidth.
## Solution

<table>
<thead>
<tr>
<th></th>
<th>LAN</th>
<th>MAN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance (kilometers)</td>
<td>1-5 km</td>
<td>5-50 km</td>
</tr>
<tr>
<td>Owner</td>
<td>Company/user</td>
<td>Carrier</td>
</tr>
<tr>
<td>Number of devices</td>
<td>10-1000</td>
<td>1000-100,000</td>
</tr>
<tr>
<td>Bandwidth (Mbps)</td>
<td>100Mbps-1 Gbit/sec</td>
<td>2 Mbps-10 Gbit/sec</td>
</tr>
<tr>
<td>Resiliency/redundancy</td>
<td>No</td>
<td>Yes, usually</td>
</tr>
<tr>
<td>(yes/no)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Is there a service</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>level agreement</td>
<td></td>
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<tr>
<td>(contract)?</td>
<td></td>
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</tbody>
</table>
Access technologies to connect LAN to WAN, if there is no MAN

• Known as ‘last mile’ problem
  – High bandwidth at LAN and MAN, but little in ‘last mile’

• Digital subscriber line (DSL)
  – Provided over existing copper lines to telco switch
  – VZ (and others) moving DSL users to 4G LTE, in preparation of abandoning copper plant

• Cable access
  – Provided over existing coax cable to CATV head end

• Wireless access
  – 4G cellular “long term evolution” (LTE)
  – Satellite, in remote/ocean/air settings

• Fiber to the business/home/curb
Digital Subscriber Line (DSL)

Many technical variations: ADSL, HDSL, SDSL, VDSL
Typically 12-18,000 foot limit; data rates of 500 kbps up to 8 Mbps
Asymmetric DSL (ADSL)

• Copper line from customer to central office can handle 1.1 MHz, in theory
  – Many impairments (noise, crosstalk, etc.) exist
• Upstream ADSL uses 24 4.3kHz channels
  – Almost same as voice channel, carries 60 kbps (not 64)
  – In theory, we get $24 \times 60 \text{ kbps}$, or 1.44 Mbps up
  – In practice, we get 500 kbps
• Downstream ADSL uses 224 4.3kHz channels
  – In theory, we get 13.4 Mbps
  – In practice, we get 8 Mbps or less
• Other variations
  – HDSL uses 2 pairs for 1.5 Mbps up to 12,000 ft
  – SDSL uses 1 pair for 768 kbps up to 18,000 ft
  – VDSL may get 3-25 Mbps over 3,000+ ft
Cable access

- Cable channel is 6MHz wide for broadcast video
  - Cable bandwidth is 750 MHz approximately (coax)
  - Downstream video: 45-550 MHz: 80 channels at 6 MHz
  - Downstream data: 550-750 MHz: 33 channels at 6 MHz
  - Upstream data: 5-42 MHz: 6 channels at 6 MHz
  - Each channel can carry ~10 Mbps of data downstream, ~5-10 Mbps upstream
  - Bandwidth shared across all cable users in segment

- DOCSIS is cable standard for data
  - Ethernet-like protocol. Users contend/collide to send.
  - Data seen by all devices on cable segment, so it’s sometimes encrypted using RSA (public key encryption) and other protocols
Cable TV

Image by MIT OpenCourseWare.
Wireless access

• 4G cellular data (“long term evolution”: LTE)
  – 20 Mbps, though bandwidth may saturate
  – Replacing fiber to homes, small businesses

• Satellite
  – Downstream speeds acceptable (a few Mbps)
  – Upstream links either not available or very expensive
    • 128-256kbps can cost $800-$1,000/month
    • Satellites have limited power, long paths, high losses
    • Satellite paths have high delays, unsuitable for interaction
  – Can serve rural areas

• We cover wireless in detail later
Exercise

• You have a depot in an industrial area without carrier fiber optics
• You have 1,000 buses that return to the depot every evening and upload video to a remote site
• Each bus has 10 hours of 384 kbps video.
• Data goes via WiFi (wireless LAN) from each bus to a depot server, and then to the remote server.
• You want all data to transmit in 2 hours.
• Choose between DSL, cable TV and 4G wireless access. Which of these 3 can handle it?
  – If they can’t, what do you need?
Solution

- Data/sec = 1,000 veh * 384 kbps = 384 Mbps
- Time to send = 2 hr
- Time to record = 10 hr
  - Thus, the data must be sent 5 times as fast as it was recorded.
- Bandwidth = 5 * 384 Mbps = 1920 Mbps = 1.92 Gbps
- DSL, CATV or 4G/LTE cannot handle this
- You need OC-48 (2.5 Gbps) over fiber to do this.
  - You might be better off having each bus send real time video over LTE, though it would be expensive… You could sample, have driver control it (usually), etc.
Glossary

- **ISP**: Internet Service Provider
- **NAP**: Network Access Point: ISP interconnect point
- **Feeder**: Telecom cable from central office (CO) to service area interface (SAI) in neighborhood
- **Distribution**: Telecom cable from SAI to end point
- **EFM**: Ethernet in First Mile: access to MAN
- **RPR**: Resilient Packet Ring: access to MAN
- **DSL**: Digital Subscriber Line: Internet access over copper
- **DSLAM**: DSL access multiplexer, at central office
- **LEC**: Local exchange carrier (e.g., Verizion, AT&T)
- **DOCSIS**: Cable TV data standard, Ethernet-like