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

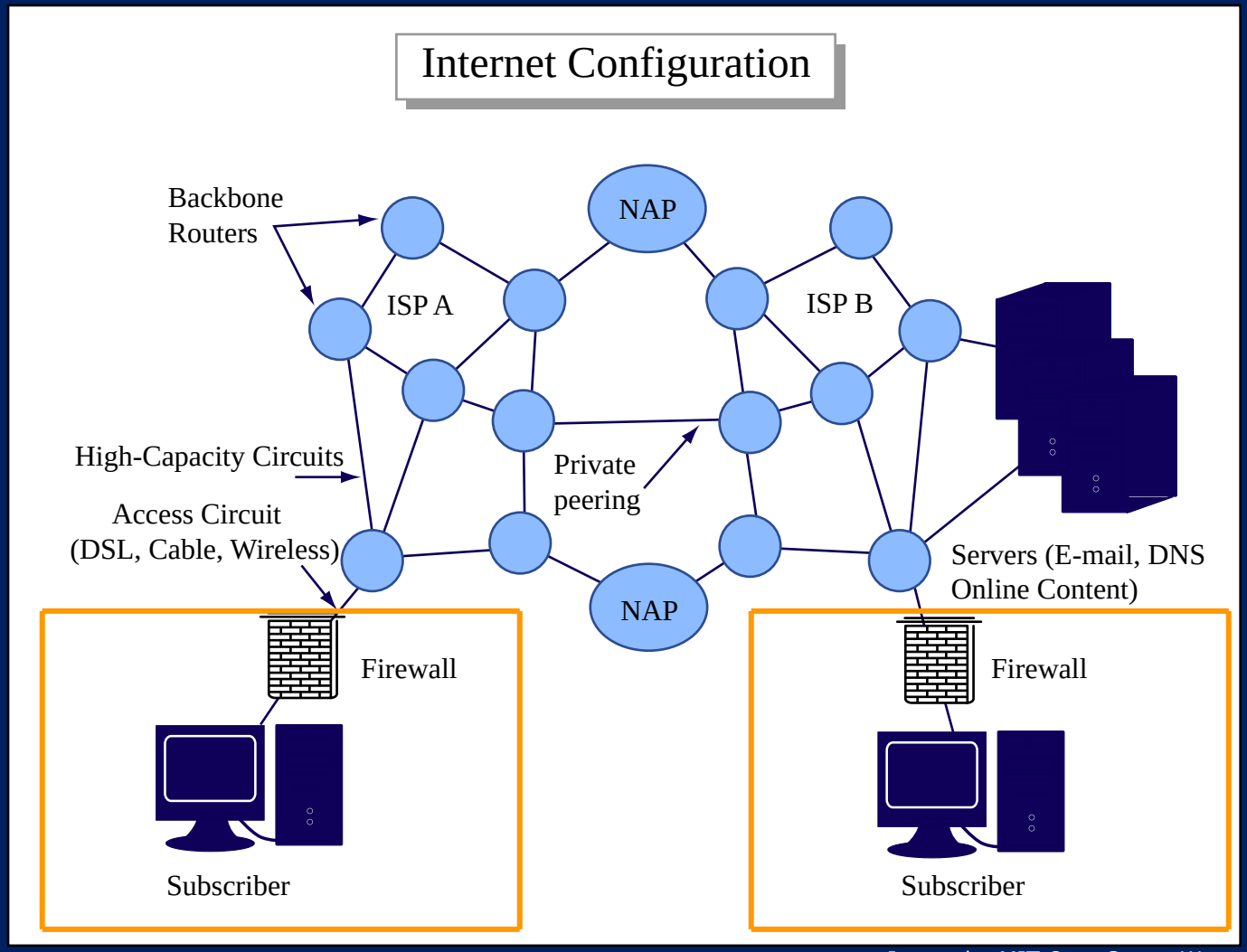
- **Bandwidth:**
  - 500 kB x 8 bits/byte x 10 000 docs / 3600 seconds/hr
  - Approximately 11 Mbps raw data rate
  - Connection should be at least 15 Mbps, for overhead, etc.
  - If we route LA traffic via Houston, Houston-NJ needs 25-30 Mbps
  - Either case requires OC-1 (45-51 Mbps) bandwidth
- **Technology: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

Solution, p.2

- 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)

WAN/
MAN



LAN

LAN

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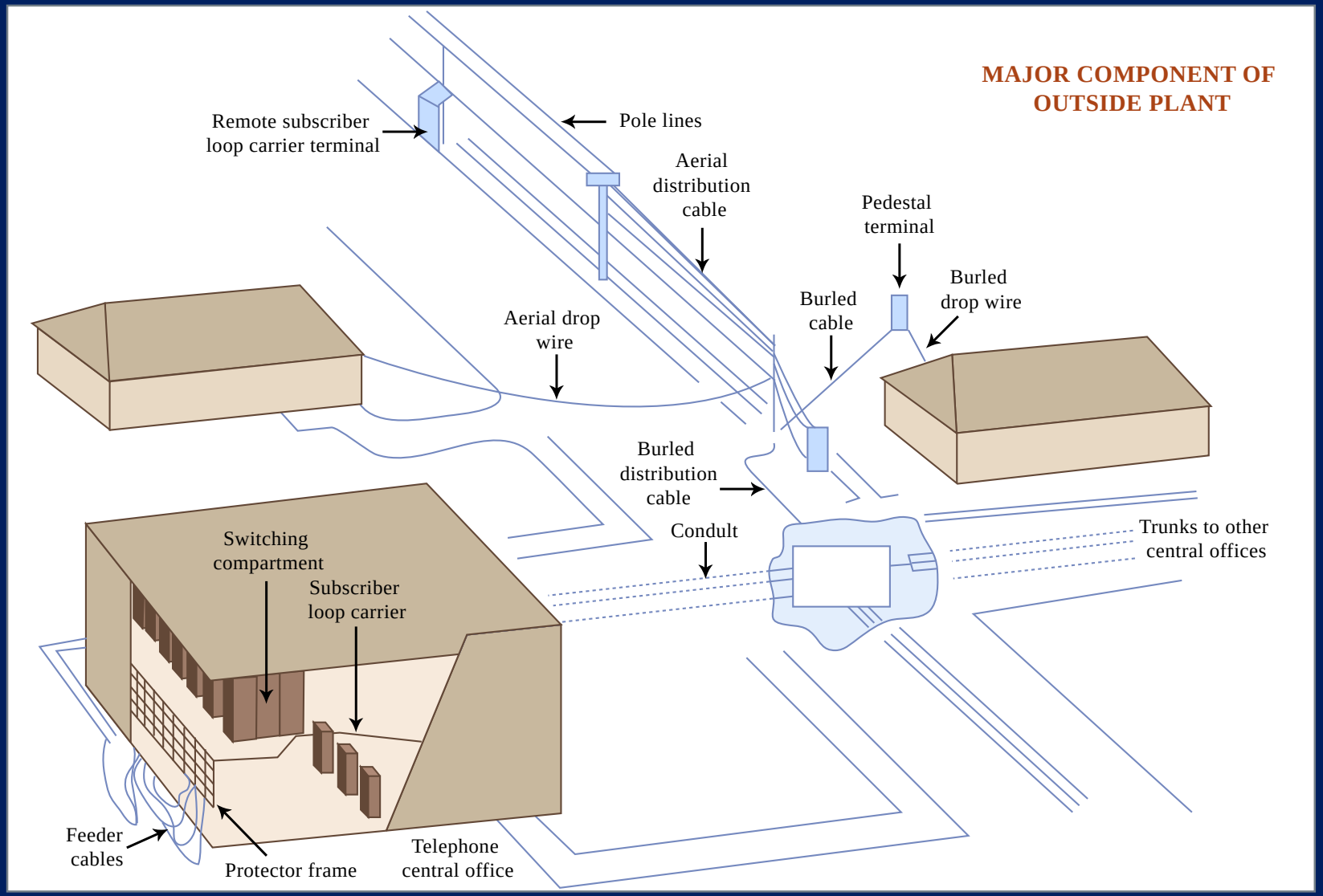
Outside plant



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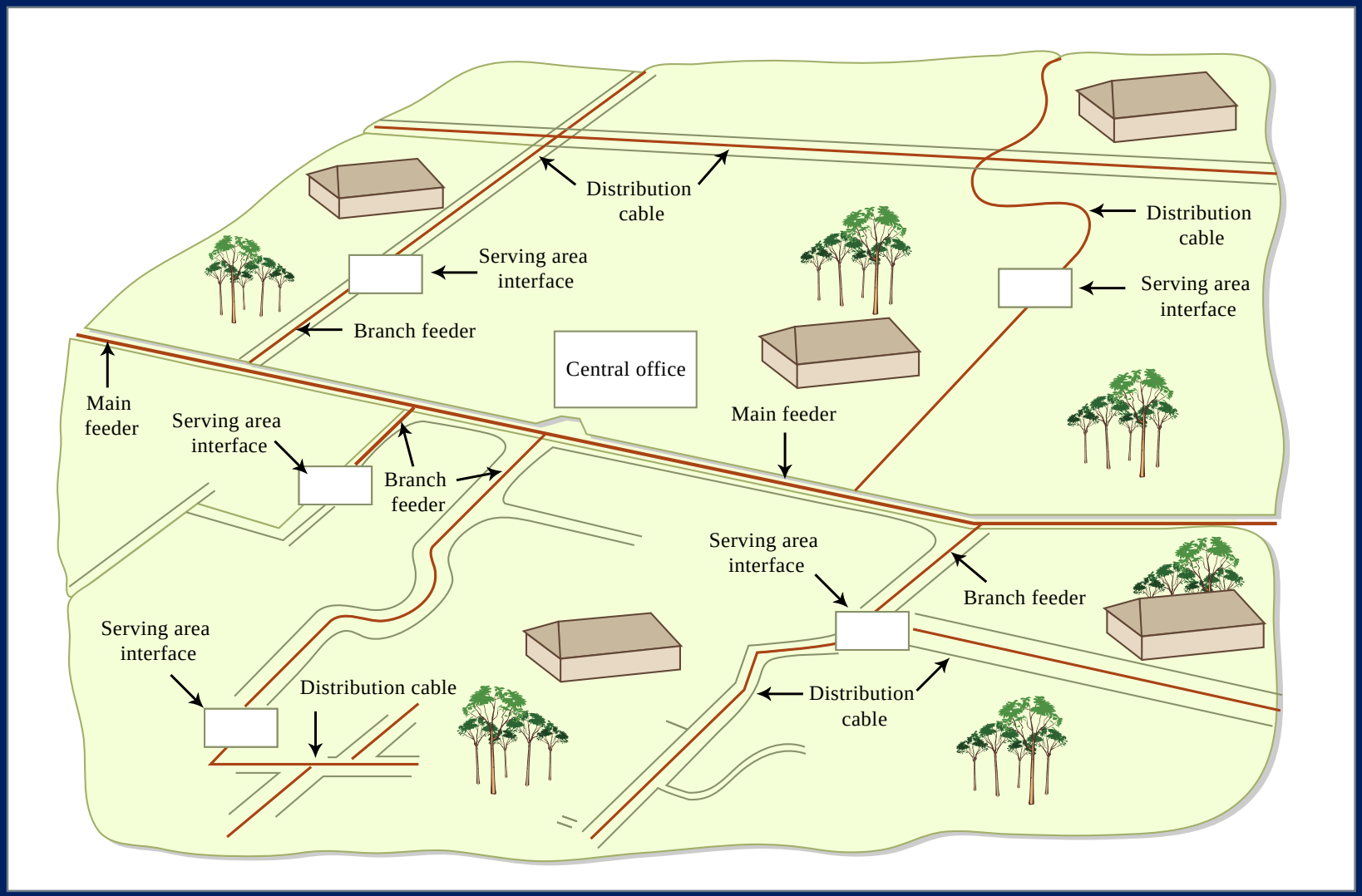
Feeder and distribution cable



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

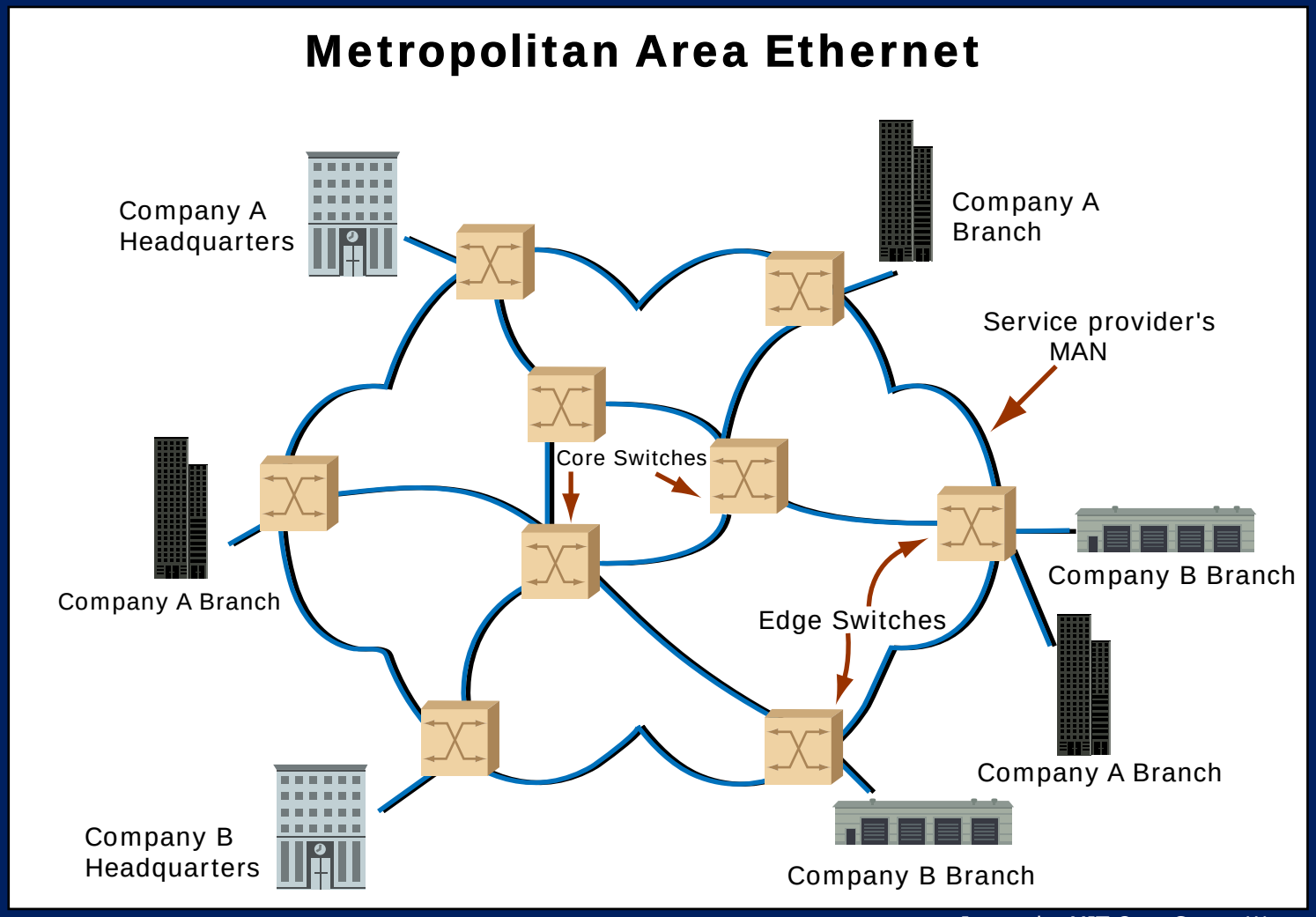
Metro area Ethernet

- 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



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Exercise: MAN

	LAN	MAN
Distance (kilometers)		
Owner		
Number of devices		
Bandwidth (Mbps)		
Resiliency/redundancy (yes/no)		
Is there a service level agreement (contract)?		

Give approximate ranges for distance, devices, bandwidth.

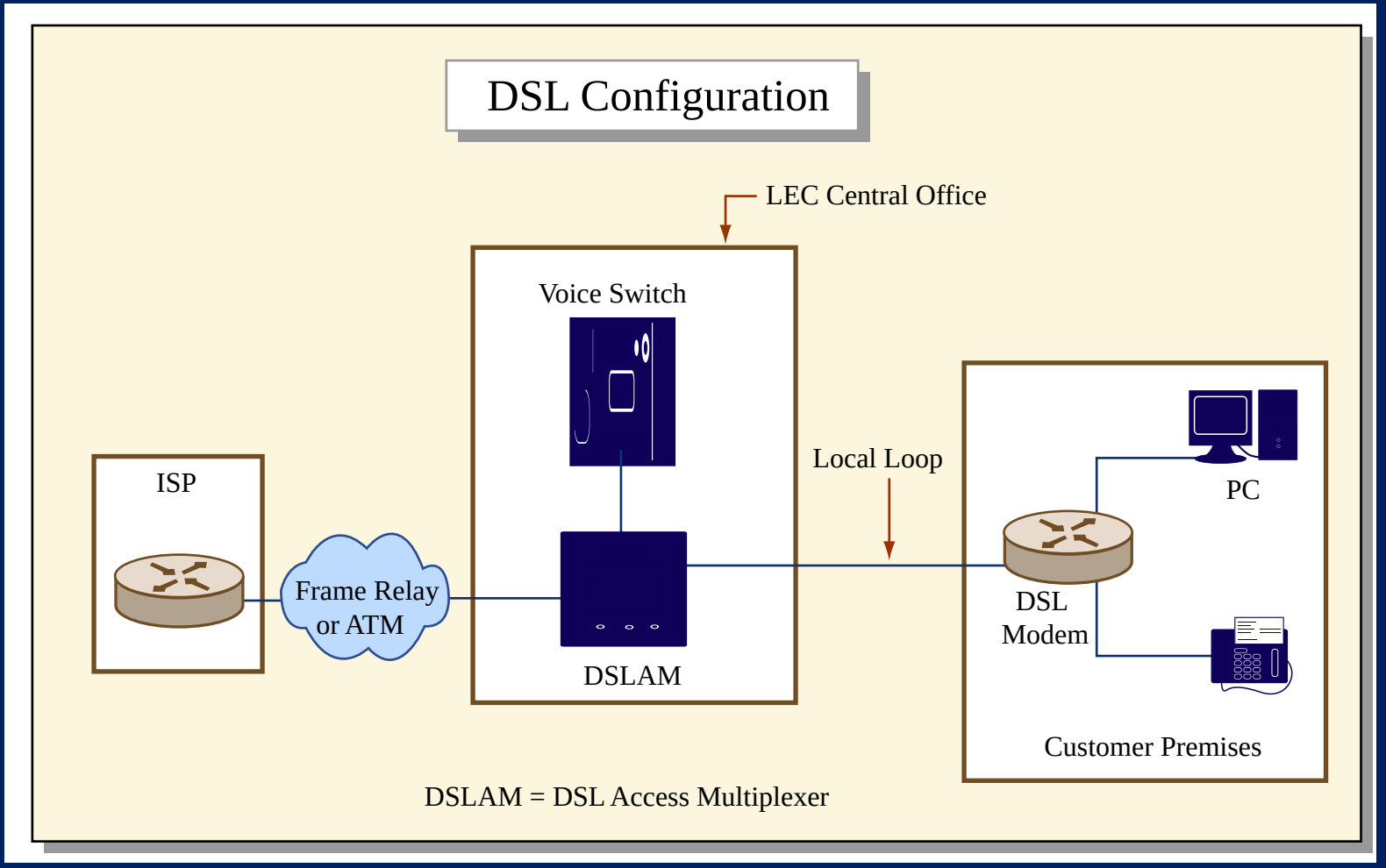
Solution

	LAN	MAN
Distance (kilometers)	1-5 km	5-50 km
Owner	Company/user	Carrier
Number of devices	10-1000	1000-100,000
Bandwidth (Mbps)	100Mbps-1 Gbit/sec	2 Mbps-10 Gbit/sec
Resiliency/redundancy (yes/no)	No	Yes, usually
Is there a service level agreement (contract)?	No	Yes

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

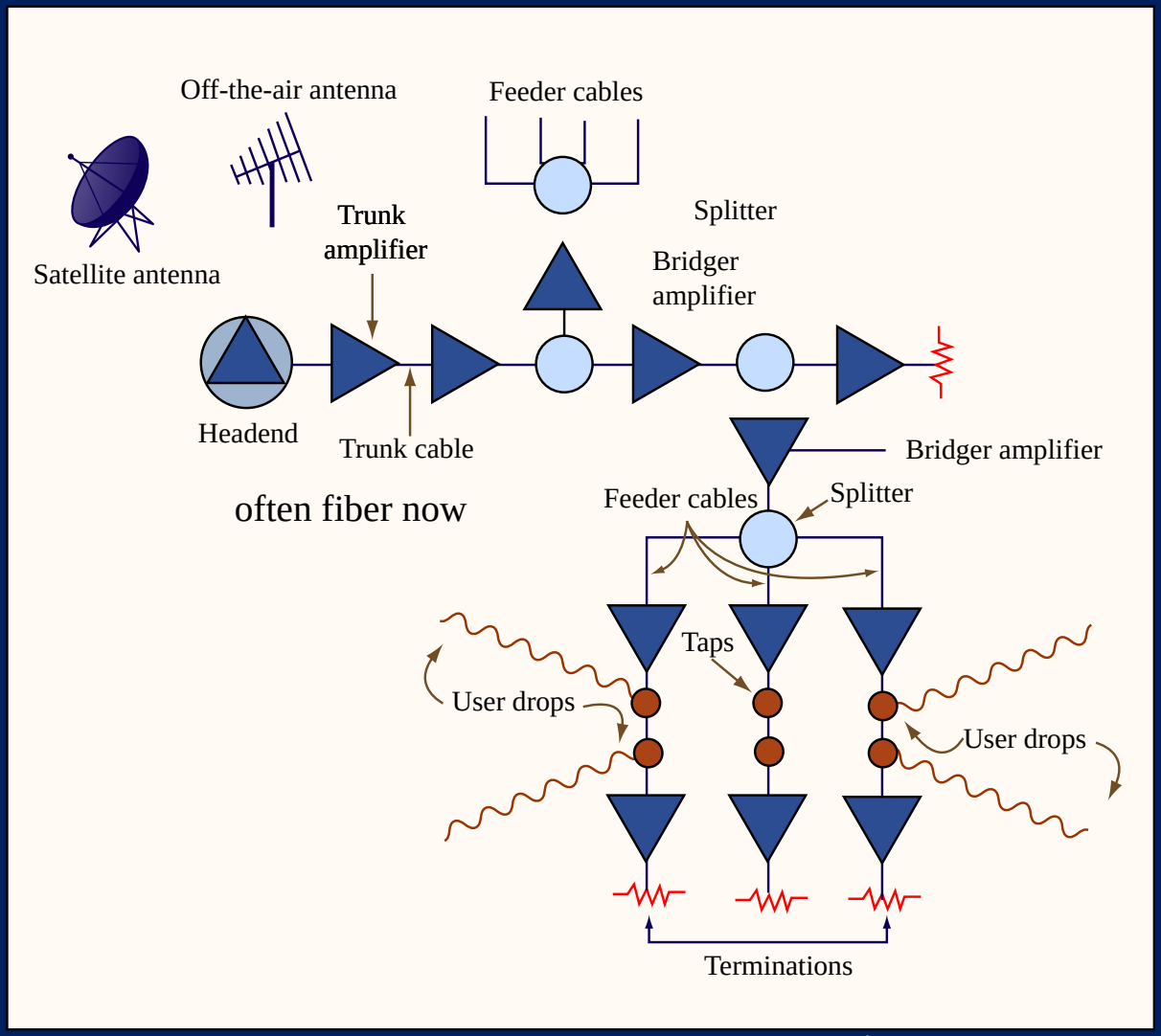
Asymmetric DSL (ADSL)

- 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 * 60 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



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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

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