


1.264 Lecture 21

**Telecom: Local area networks
Fiber optics, wireless**

Local area networks (LANs)

- **Ethernet is dominant:**
 - Cheap, universal, good enough
- **Token ring offers better utilization of capacity and better performance**
 - But its complexity and cost are not worth it in LANs
 - Token ring ideas are dominant in WANs, though
- **Ethernet topology is a star**
 - Individual devices are connected to an Ethernet switch
 - It eliminates collisions, filters traffic 
- **Cabling is usually twisted pair**
 - Fiber optics also coming into use in LANs
 - Fewer crosstalk and shielding problems but doesn't provide power

Ethernet standards

- **Steady increase in speed from 10 Mbps to 10 Gbps in near future**
 - Most computers have Fast Ethernet (100 Mbps) cards
- **Increase in range from 2 km to perhaps 10-40 km for certain kinds of links**
 - If carriers will provide 'dark fiber' to a company, it can run its corporate Ethernet these distances to other sites
- **Traffic prioritization is possible though not yet often done (802.1p)**
 - Voice and video traffic need priority on congested LANs
- **Power over Ethernet (PoE) for phones is possible**

Repeaters, Bridges, Routers, Gateways

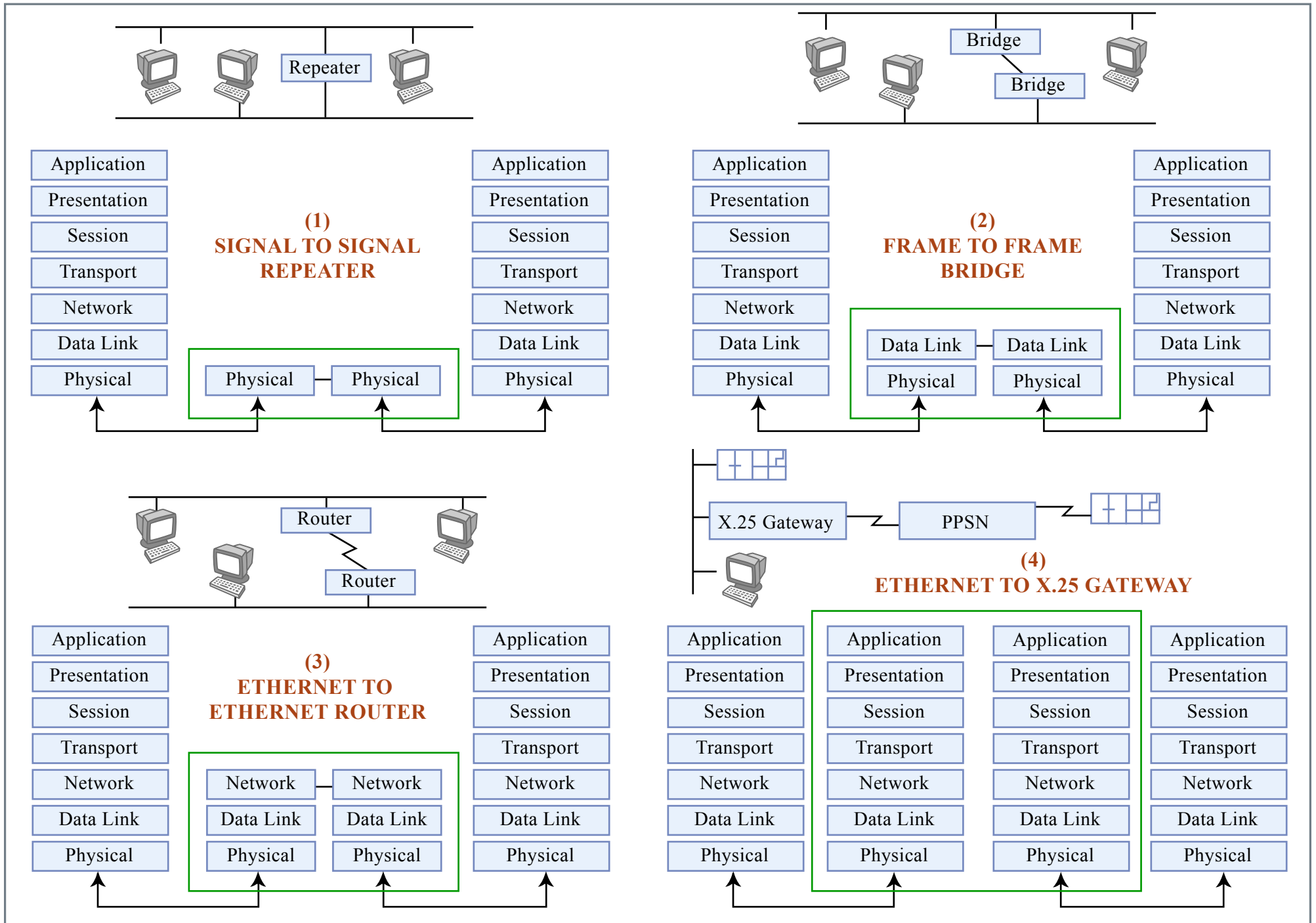


Figure by MIT OCW.

Ethernet switches

- **Ethernet switches are a smart bridge**
 - Operate at level 2 (Ethernet hardware or MAC address)
 - Switch multiple segments, not just two like a bridge
 - Switches are often large enough to eliminate hubs (layer 1, like a repeater) and bridges
 - Collisions cannot occur, which boosts throughput
 - Switches operate in full duplex (both directions at same time)
 - This can double network throughput
 - Switches are self-configuring
 - Administration of LANs is the most costly element
 - Layer 3 switches look at IP addresses in a LAN to route
 - More flexible but 10 times slower than layer 2 switch

Ethernet services

- **Network operating system**
 - Connects printers, files over LAN
 - Manages security
 - Manages LAN
 - Simple network management protocol (SNMP)
 - Very insecure (v1: passwords in clear; v2,v3: no key mgt)
 - Can be peer-to-peer (computers share their printers and disks)
 - Or server-based (central printer and disks)

Optical networking hardware

Lightwave Transmission System

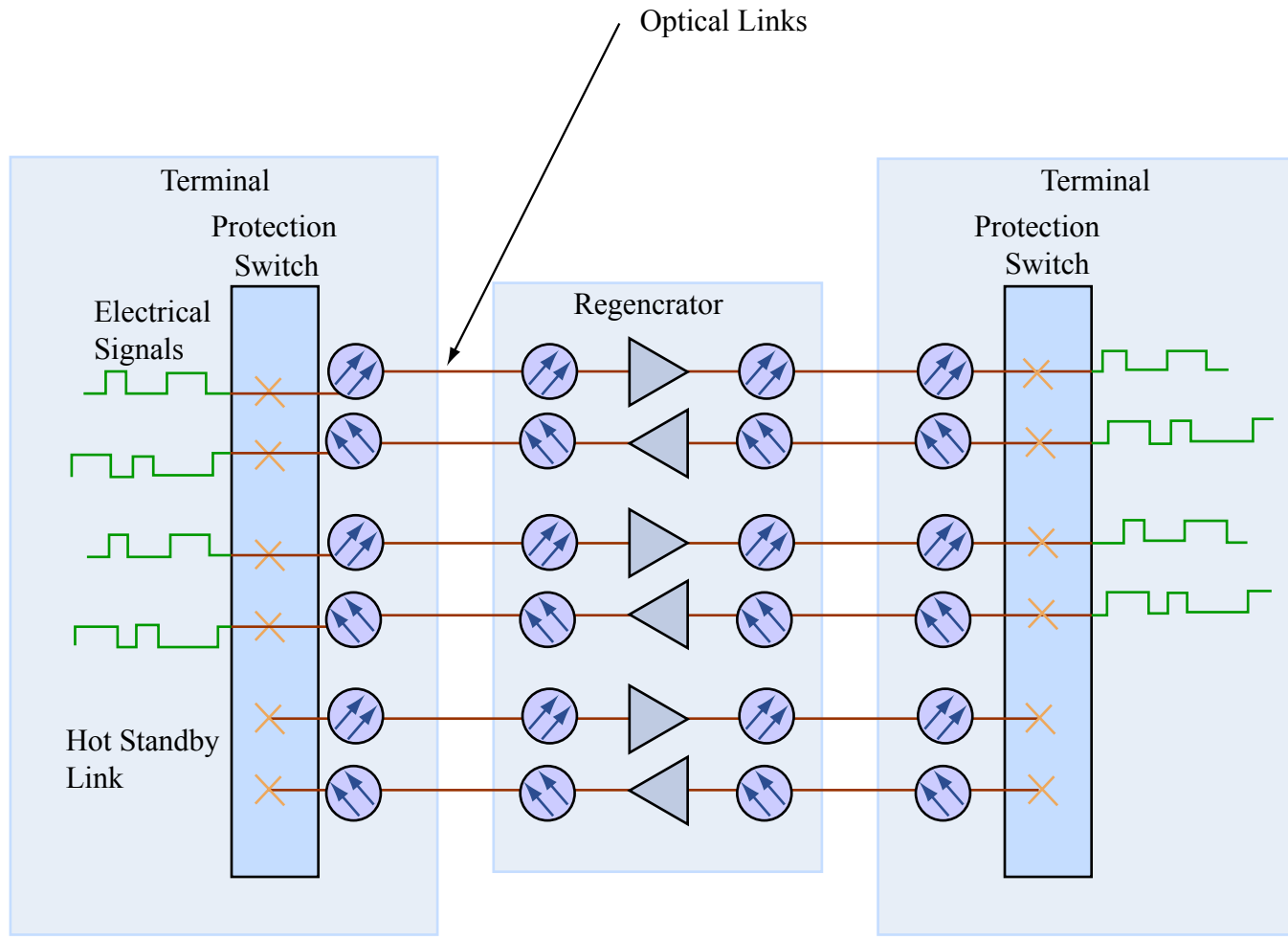


Figure by MIT OCW.

Optical networking cable

- **Long spans possible**
 - 0.2 db/km loss implies 1% of signal carries 100 km without amplification
 - 400 km spans common on land, longer undersea
- **Protection switching is common**
 - If fiber pair goes down, a hot standby pair is available
- **Two kinds of fiber cable**
 - Multimode fiber (MMF): used in LANs, more loss, more expensive (!) but easier to work with
 - Single mode fiber (SMF): used in carrier networks, low loss, less expensive, requires precision equipment to install and repair
- **Splicing and connecting fiber has been a big challenge in its deployment**
 - Much less problematic now than even 5 years ago

Optical networking terminals and muxes

- **Fiber optic terminals were another big problem**
 - Converting optical to/from electrical signals is slow and expensive
 - Optical amplifiers now exist: fast, low power
 - Amplifiers available for 5 Tbps (5000 Gbps) signals
- **Wavelength division multiplexing (WDM)**
 - We can send light of different colors in the same fiber to increase capacity
 - Coarse WDM has 16 wavelengths
 - Dense WDM has 40 wavelengths, going to 80-160
- **Wavelength add-drop multiplexers, cross connects**
 - Drop and add wavelengths as needed
 - Need to be able to switch at intermediate points
 - All-optical muxes, cross connects available now
 - Opto-electronics was bottleneck

Optical network operations

- **Common fiber operation in telecom trunks:**

- OC-48 to OC-768 (2.5 to 40 Gb/sec) on a single pair of fibers**

- Separate receive and transmit paths (no circuits)

- 32,000 to 512,000 64kb/sec circuits for voice or data

- About 1,000 to 16,000 video channels at 1.5 Mbps

- Nationwide systems in US:**

- Typically 48-fiber bundles over 25,000 mile network

- Several competing networks exist

- Diverse routing a problem for reliability (principally fiber cuts)**

- Rights of way limited; multiple carriers often hit by same outage

- Dark fiber becoming available for users**

- Over metro area, can run corporate Ethernet to multiple sites

- Fiber to the premises (home, small business, ...) is available now**

- Passive optical network (splitters) used

- Teething problems with clocks, splices but working well

- Fiber used within corporate buildings and campuses**

- No fiber to desktop yet, but likely to come

Optical network bandwidth

- **Fiber is faster than coax, copper or other electronics due to basic physics**
 - There can be many bosons (photons) in one place at the same time
 - There can only be one meson (quark pairs, such as electrons) in one place at a time
- **This won't change unless physics changes**
 - Fiber networks can haul 5,000,000 Mbps on a single wavelength on a single pair of fibers
 - Fiber nets are often 48 pairs
 - Dense wavelength division multiplexing can put 40+ wavelengths on a fiber pair
 - Wireless LANs (WiFi) can haul 30 Mbps (60% of 54 Mbps)
 - 2.5G metro wireless can haul 0.5 Mbps
- **All other telecom technologies serve to provide access to fiber optic links**

Microwave radio

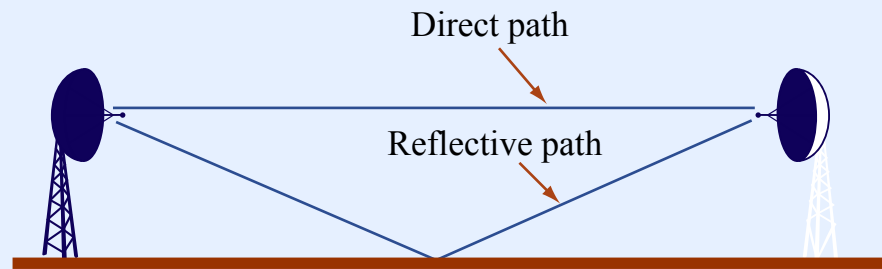
- **Classical microwave is of little current interest, but we look at it briefly as precursor of satellite and mobile telephony**
- **Microwave spectrum (2 to 3 GHz range) being used for other applications today:**
 - **Satellites**
 - **Wireless LANs (WiFi), WiMax**
 - **Microwave ovens (2.45 GHz is frequency of water molecule)**

Radio propagation

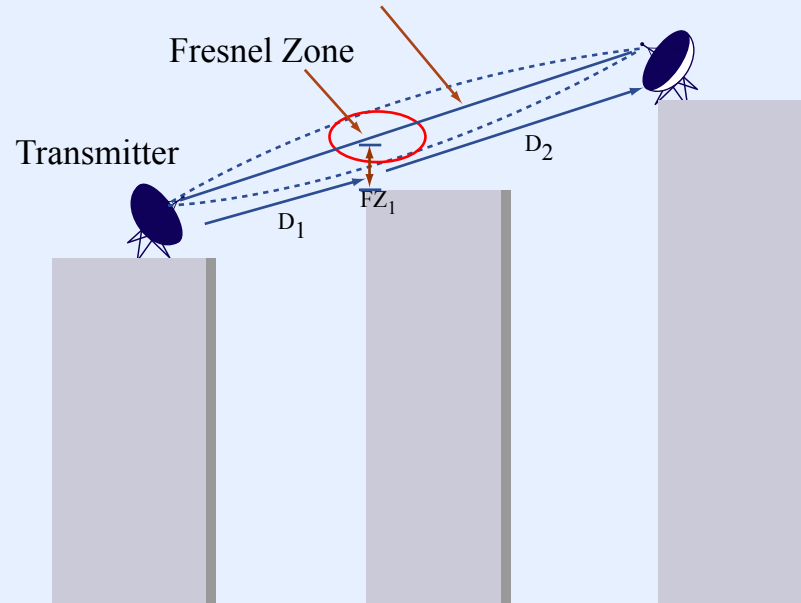
- **Losses:**
 - Free space loss
 - Atmospheric attenuation: water, dust
 - Multipath loss: water body or fog causes reflections, and signal arrive out of phase at destination
 - Diffraction: hills, buildings, obstructions
 - Rain attenuation: rain drops (size matters)
- **Antenna problems:**
 - Snow, icing (use heaters, radomes)
 - Zoning restrictions (hide antennas in buildings)
- **Microwave frequencies are line of sight**
 - Behave like light, can be focused and reflected
- **These issues hold for mobile phones, wireless data, satellites also**

Radio loss

Direct and Reflected Path Between Antennas



Fresnel Zone Clearance Over an Obstruction



Technology comparison

- **Fiber optics**
 - Bandwidth up to 5 Tbps (5000 Gpbs) per fiber pair
 - Bit error rate: 10^{-14}
 - Distance spanned: 400 km between repeaters, global
- **Copper (existing telephone plant)**
 - Bandwidth up to 1.5 Mbps (T1) for long distances
 - Up to 5 Mbps (DSL) up to 5 kilometers
 - Up to 100 Mbps (LAN UTP) up to 100 meters
 - Bit error rate: 10^{-10}
 - Distance spanned: 2 km between repeaters, on land
- **Radio (microwave, mobile phone, wireless data)**
 - Bandwidth up to ~50 Mbps (microwave, WLAN), ~ 1 Mbps (mobile)
 - Bit error rate: 10^{-6}
 - Distance spanned: 100m (WLAN) to 20 km (microwave, mobile)
 - Satellite has very high distance but same bandwidth, error rates
- **Error rates are critical; we'll return to them**

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?**
- **Which are shared?**
- **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 on top? Why?

Electric, high voltage/current

Which of these are point-to-point connections?

Phone only

Which are point-to-many?

Electric, cable

Which can handle data?

Phone, cable, electric

Which can handle 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