1.264 Lecture 21

Telecom network technology:
Fiber, satellite, cellular telephony,
cable modems, DSL

Network technology

- We've just covered the basic components of transmission, switching/routing and physical plant
- We next cover:
  - Long haul nets (layer 1-2) in this and next lecture
  - Local area nets (layer 1-2) at end of next lecture
  - Higher level protocols (TCP/IP at layers 3-4) in lecture after next
  - Interconnection of local and long haul nets, principally by routers (a layer 3 device) in lecture after next
  - A few other long haul nets (layer 3 alternatives, interwork with TCP/IP) in lecture after next
- TCP/IP runs as dominant protocol on virtually all these technologies
  - Radically different than 10 years ago, when there were many protocols in use

Fiber optics

- Common fiber operation in telecom trunks:
  - OC-48 to OC-192 (2.5 to 10 Gb/sec) on a single pair of fibers
    - Separate receive and transmit paths (no circuits)
  - 32,000 to 128,000 64kb/sec circuits for voice or data
  - Largest circuits for individual customers are OC-1 (T-3) or 50Mb/sec
    - Costs are about $10,000-20,000/month cross-country and dropping
  - Nationwide systems:
    - Typically 48-fiber bundles over 25,000 mile network
    - There are several of these, and more being built
    - Repeaters every 2-50 miles, placed in telecom buildings
  - Diverse routing a problem for reliability (principally fiber cuts)
    - Rights of way limited; multiple carriers often hit by same outage
  - 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
  - Dark fiber not generally available: issue for users

Typical fiber optic system

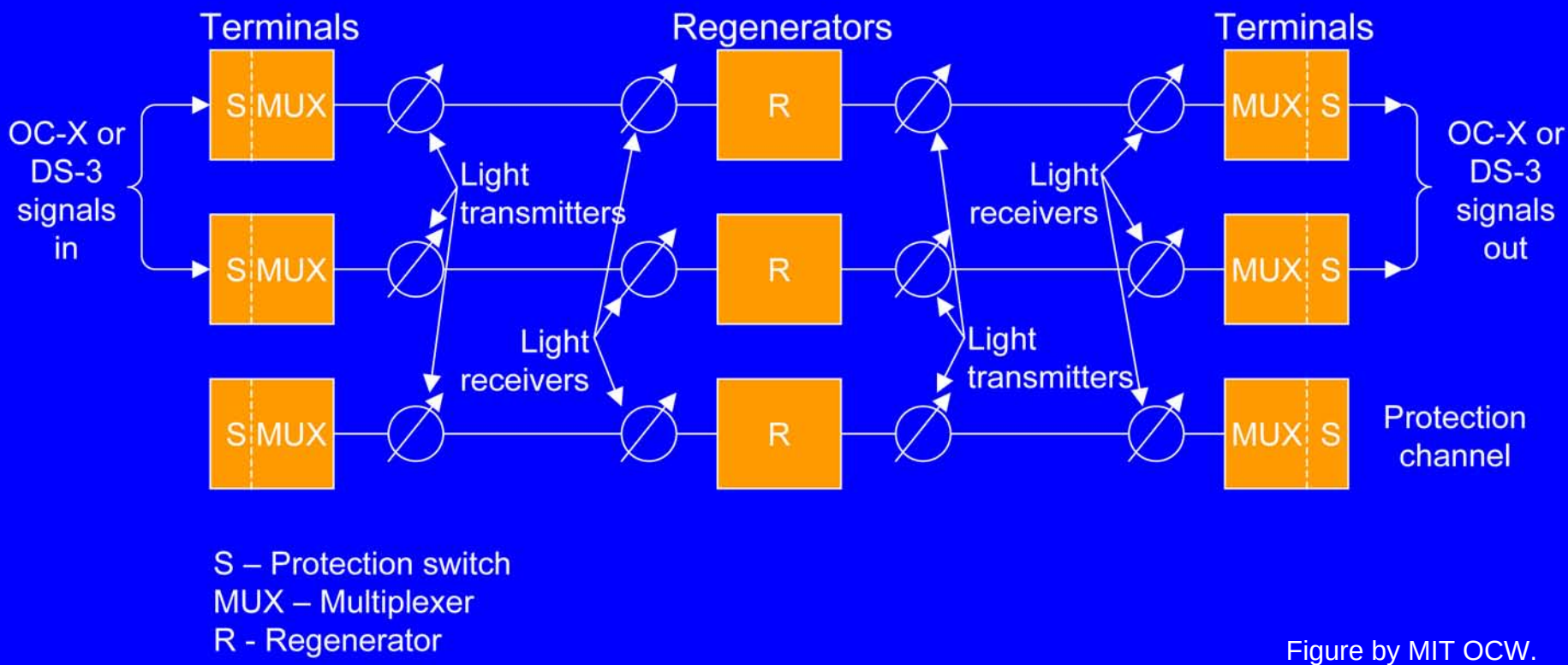


Figure by MIT OCW.

Lasers used in high bandwidth fiber, LEDs in low bandwidth
Single mode fibers used in high bandwidth: 10 micron diameter
Low attenuation (few repeaters), 100x bandwidth
Multimode fibers used in low bandwidth: 62 micron diameter
Wave division multiplexing: multiple colors to increase capacity

Satellite communications

- **Fiber dominates satellite except for:**
  - **Places fiber doesn't reach (remote areas, oceans) for voice, data**
  - **Broadcast (video)**
  - **Mobile users (trucks, ships, pagers)**
  - **Global positioning (GPS)**
  - **Low bandwidth (e.g. POS terminals) over a wide area**
  - **Very long circuits (cost-effective versus fiber)**
- **Satellite disadvantages**
  - **Up to 1/4 second delay earth-satellite, longer if multiple hops**
  - **Lower reliability, low bandwidth**

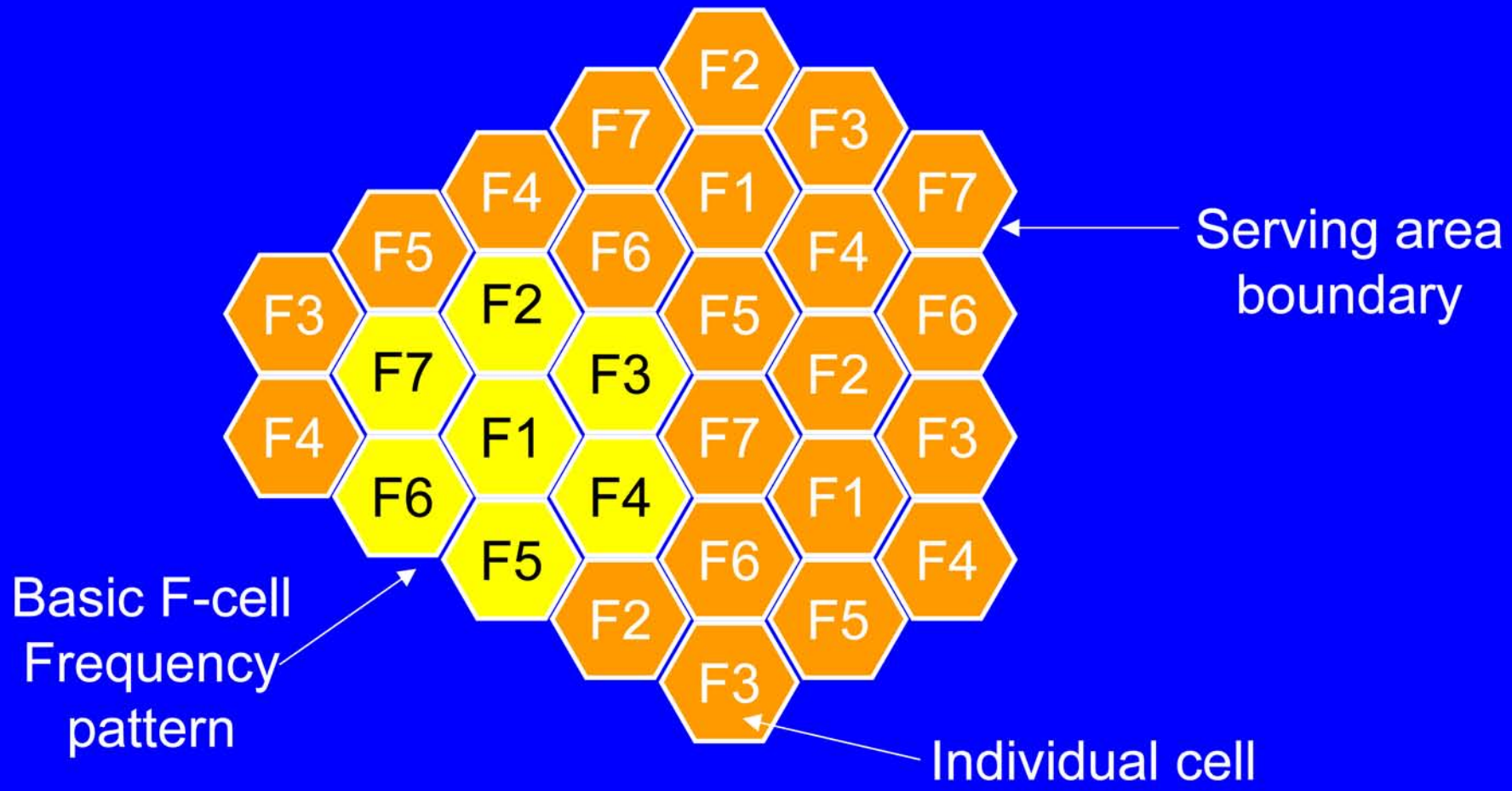
Satellite applications

- INMARSAT
  - Shipping data link, also occasionally used in remote areas on land
- Direct broadcast satellite (DBS)
  - 200 channels, proprietary compression of digital video signals
    - Standard TV signal is 90 Mb/sec; standard compression to 45Mb/s
  - Attempt to provide ISP service over unused channels
- International aircraft calls via satellite
  - Domestic aircraft services use ground stations
- VSAT (very small aperture terminal) used for low bandwidth applications (9.6-56kbps)
  - Kmart point of sale, for example
  - Big ugly dishes (BUDs), typically 2 meter diameter
- Global Positioning System (GPS), remote sensing

Mobile (cellular) telephony

- We cover US technology and practice (European GSM differs)
- A cell phone is a radio
- Before cell phones, there was mobile radio, with one tower per metro area and about 25 channels
  - Car phones had to be high powered but for little usage
- Cellular telephony divides a metro area into cells for much, much more capacity
- 832 channels in standard cellular radio spectrum band
  - A band used by wireline carriers (LECs)
  - B band used by non-wireline carriers
  - Up to 5 more bands allocated via auction for new carriers in US
  - Both analog and digital telephony in use
  - Phone can operate on any of these 1,664 channels
    - Dual mode phones can operate digital or analog as well
- Cellular switches are called Mobile Telephone Switching Offices, or MTSOs
  - Functions same as standard switch, plus handoff across cells

Frequency reuse in cellular telephony



Each cell uses 1/7 of total channels= 119.

- **Analog calls take two channels: 60 channels/cell**
- **Digital takes about 2/3 channel per call: 180 channels/cell**

Figure by MIT OCW.

Frequency reuse, cont.

- Simple pattern rarely holds due to topography, demand, buildings, water
- Repeat this pattern for n channels per cell
  - Can get reasonable maximum of 70 channels per cell for one carrier (A or B)
  - Absolute maximum of 128 channels per cell
- Channel assignment is an interesting optimization problem
  - Integer programming, GIS (DTM, DLG), radio engineering, …
  - Can sectorize into 3 120 degree sectors in a cell
- Diagnosing cellular troubles is also an interesting problem
  - Uses GIS, network analysis to match trouble reports to tower data

Cellular telecom technology

- **Analog cellular:**
  - **FDMA (frequency division multiple access)**
- **Digital cellular:**
  - **TDMA (time division multiple access).**
  - **CDMA (code division multiple access).**
  - **GSM: TDMA with data support, encryption**
  - **PCS (personal communications service) is a marketing term: PCS carriers use TDMA, CDMA or GSM**
- **Competitors, with metro, rural area coverage:**
  - **Nextel, in SMR band (different frequencies,**
  - **Paging, numeric or alphanumeric. Mostly terrestrial, some satellite.**
  - **Satellite phones: Expensive, have not been viable (LEO to keep call quality high, but requires many satellites)**

Mobile data

- Ordinary modems don't work
  - Too much noise
  - No dial tone at start of connection
- Cellular modems ok for long files
  - Circuit switched connection, high minimum charge
- Cellular Digital Packet Data (CDPD) and now GPRS uses true packets
  - Ok for short messages (police, taxi, some remote sensors)
  - CDPD is TCP/IP variant at 19.2 kbps; GPRS at 60-100 kbps
  - Major expected use was transportation, but it's not happening
- Mobile users currently follow varied strategies:
  - Cellular modems for long connections
  - CDPD, GPRS or SMR where available for short data transfers
  - Satellite in rural areas
  - PCS (GSM) modems for international
  - WiFi in 'hot spots' in urban areas. WiMax coming in next 2 years.

Cable TV

- Allowed to carry voice, data as well as video
- Broadcast video is dominant content on CATV
  - VOD or NVOD (video on demand) is speculative but will enable fiber plant and high speed data networks if it happens
  - DBS is limiting CATV demand, though
  - Much CATV in US is analog, one-way plant
  - CATV passes about 100 million households, serves 50 million
- CATV network is completely different than telco
  - Shared, rather than dedicated links from user to switch/head-end
  - Lower quality construction, too many amps, upstream noise, poor operations in many areas (5 mile limit on typical cable plant)
  - Some major metro CATV is exemplary, though

Telecom company (ADSL, VDSL) over copper

- Asymmetric digital subscriber line (ADSL)
  - Offered by LEC or IEC
  - 0.5 to 1.5 Mb/s over existing copper to customers
  - 18,000 foot maximum range
  - ADSL modems use 1MHz of bandwidth on copper (DMT ADSL)
    - 0-4kHz is regular voice channel
    - Each 4kHz band above first has a 28.8 modem channel
    - Many 4kHz bands unusable at full speed due to noise
    - Modems use standard technology (two standards, in fact!)
    - Need matching modem at telco switch; telco is ISP
  - VDSL is 6Mb/s over 3,000 feet; need fiber to neighborhood
    - Intended for video to home: 4 MPEG-1 channels

Summary: telecom technologies for data

Technology	Bandwidth	Error	Distance
Fiber	45 Mb/s ++	10^{-14}	Any
Cellular	19.2 kb/s	10^{-6}	5 miles from base
Satellite	9.6 kb/s	10^{-6}	1000s of miles
CATV	1 Mb/s	10^{-10}	5 miles from base
DSL	1 Mb/s 1.5Mb/s	10^{-10}	3 miles from CO

All except fiber are access technologies; fiber is linehaul and access technology.

The low fiber and wireline error rates are crucial to the network protocols and Internet as we know it today.