1.264 Lecture 20

Telecom: switched network and data communications
Intro to public network: major components

Video

Telephone

Computer

Modem

Fax machine

Customer Premise Equipment

PBX

Local loop

LATA connecting trunks

Toll trunks

Satellite (rare)

Microwave (rare)

Fiber optics

Local trunk

Toll switch

Local switch

Transmission Equipment

Figure by MIT OCW.

[TE] Chapter 2
Telecom service areas

Telephone Service Areas

Exchange A

Exchange B

Central Office

Exchange Boundary

Wire Center Boundary

Trunks

Figure by MIT OCW.
Frequency division multiplexing

Traditional method of carrying multiple channels on a cable
Similar to radio broadcasting with stations at different frequencies
Being used again in ADSL, CATV, satellite, ...
Basic frequency is 4kHz band, based on voice needs
Voice hears from 20 to 20,000 Hz, but mostly 300 to 3500 Hz

Figure by MIT OCW.
Time division multiplexing

Time division samples each 4kHz channel
Shannon/Nyquist: Sample at twice the bandwidth to code and decode all possible information
So, sample 8000 times/second at 8 bits per second (or 256 levels) Yields 64kb/sec channel, which is the basic rate of voice and data comm

24 64kb/sec channels is a T-1 (32 in Europe form an E-1) US channels are often only 56kb/sec because of bit robbing TDM used in fiber optic technologies; lasers can do both TDM and FDM (colors)
### Transmission: PCM Framing in T-1 circuits

<table>
<thead>
<tr>
<th>Calculation</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>8,000 samples per second</td>
<td></td>
</tr>
<tr>
<td>x 8</td>
<td>bits per sample</td>
</tr>
<tr>
<td>64,000 bits per channel</td>
<td></td>
</tr>
<tr>
<td>x 24</td>
<td>channels</td>
</tr>
<tr>
<td>1,536,000 bits per second</td>
<td></td>
</tr>
<tr>
<td>+ 8,000 framing bits per second</td>
<td>framing bits per second (not enough!)</td>
</tr>
<tr>
<td>1,544,000 bits per second total in T-1 circuit</td>
<td></td>
</tr>
</tbody>
</table>

Framing used to keep sync between ends of circuit. If all 24 circuits are quiet, only framing bits keep the clocks at both ends of the circuit in sync (several framing systems used). T-1 is often the backbone for both voice and data, carries both T-1s operate over both copper and fiber. Higher bandwidth is fiber only.
SONET

Fiber bandwidth, beyond T-1
STS-1, or OC-1, is same as T-3, or 28 T-1s
SONET can be divided into channels as small as 64kbps
  Voice carried at 64kbps
  Data carried at many rates
  Video carried at MPEG-1 (1.5Mb/sec) or MPEG-2 (6Mb/sec); these are highly compressed
  Can’t compress Hollywood video! Uncompressed video can be 200Mb/sec or more

<table>
<thead>
<tr>
<th>SONET</th>
<th>SDH</th>
<th>SPEED (Mb/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>STS-1</td>
<td></td>
<td>51.840</td>
</tr>
<tr>
<td>STS-3</td>
<td>STM-1</td>
<td>155.520</td>
</tr>
<tr>
<td>STS-9</td>
<td>STM-3</td>
<td>466.560</td>
</tr>
<tr>
<td>STS-12</td>
<td>STM-4</td>
<td>622.080</td>
</tr>
<tr>
<td>STS-18</td>
<td>STM-6</td>
<td>933.120</td>
</tr>
<tr>
<td>STS-24</td>
<td>STM-8</td>
<td>1,244.160</td>
</tr>
<tr>
<td>STS-48</td>
<td>STM-16</td>
<td>2,488.370</td>
</tr>
<tr>
<td>STS-192</td>
<td>STM-64</td>
<td>9,953.280</td>
</tr>
</tbody>
</table>

Figure by MIT OCW.
SONET Rings

- **OC-48 Ring**
  - Central office A
  - Central office B
  - Multiplexer
  - Add-drop multiplexer
  - SONET node
  - SONET node
  - OC-12 Ring
  - OC-12 Ring
  - OC-3 Ring
  - OC-3 Ring
  - Multiplexer
  - Multiplexer
  - SONET hub
  - SONET hub
  - Central office A
  - Central office B

- **Customer Equipment**
  - ATM
  - T1s
  - Router

- **Location**
  - Location A
  - Location B
  - Location C

Figure by MIT OCW.
Intro to data communications: carrier facilities

- Wide area networks (WANs)
- Carried over same physical facilities as voice
  CPE, local loop, local switch, tandem switch, trunk
- Carried on permanent circuits of much higher bandwidth than for a single voice call
- Protocols based on ISO 7-layer model
  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 from 56 kbps to 40 Gbps
Intro to data communications: customer facilities

- 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 (2000 meters) for inexpensive versions
  - Carriers can extend Ethernet over metro area
Wide area data networks (WANs)

LANs Connected with a Wide-Area Network

Figure by MIT OCW.
Wide area network options

Point to point circuits
  Dedicated private line wired between two end points, expensive
  Common for corporate, being replaced by Internet-based virtual private networks

Multi-drop circuits
  Used in banking; combine multiple circuits into one
  Low traffic (ATM machine, POS terminal)

Frame switching (frame relay)
  Used by corporations for security and reliability, reasonable cost
  Frame traffic unencrypted but physically secure (same as wired voice)

Cell switching (ATM- asynchronous transfer mode)
  Or label switching (MPLS- multiprotocol label switching)
  Supports voice, data, video: ATM expensive, MPLS cheaper
  Used for much Internet traffic and voice traffic by carriers

IP networks
  Often provided by Internet Service Providers (ISPs), not carriers
  Carried over same physical facilities as other options
  More reach, cheaper in theory than others
  Security (virtual private net) raises costs to level of other options
Internet configuration

This spans LANs and WANs

Figure by MIT OCW.
Data communication protocols
1. Station C begins to transmit.
2. Station A listens to network, but signal from C has not arrived.
3. Station A transmits.
4. Signals from A and C collide.
5. Station B detects the collision and transmits a jamming signal.
TCP/IP Protocols Compared to OSI Model

- Application
  - Simple Mail Transfer Protocol
  - File Transfer Protocol
  - Telnet
  - Hypertext Transport Protocol
- Presentation
- Session
- Transport
  - Domain Name System
    - Simple Network Management Protocol
    - Netbios
- Network
  - TCP, UDP
    - IP, Routing Information Protocol, Interior Gateway Routing Protocol, Open Shortest Path First, Integrated IS-IS.
    - Address Resolution Protocol, Reverse ARP
    - Logical Link Control
    - UTP, Wireless, Fiber, Coaxial, Etc.
- Datalink
- Physical

A TCP/IP Network

TCP/IP Host

TCP/IP Host

TH = Transport Header

Figure by MIT OCW.
IP details

• IP addresses
  32 bits -> 4 billion addresses in IPv4
  E.g., 18.58.4.33
  128 bits in IPv6, slowly being implemented
• Network address translation (NAT)
  Nonroutable, private addresses (e.g., 192.168.x.x)
• Address resolution protocol (ARP)
  Associates Ethernet and IP address of device
• Dynamic host control protocol (DHCP)
  Dynamically assigns IP address from pool; conserves addresses
• Domain name service (DNS)
  Maps IP addresses to names
Outside plant

MAJOR COMPONENT OF OUTSIDE PLANT

- Pole lines
- Pedestal terminal
- Aerial distribution cable
- Burled cable
- Burled drop wire
- Trunks to other central offices
- Switching compartment
- Feeder cables
- Protector frame
- Subscriber loop carrier
- Telephone central office
- Manhole

Figure by MIT OCW.
Feeder cable becoming all-fiber. Some distribution is fiber, more planned
Access technologies

- Digital subscriber line (DSL)
  - Provided over existing copper lines to telco switch
- Cable access
  - Provided over existing coax cable to CATV head end
- Wireless access
  - WiFi
  - WiMax
  - Satellite
  - 3G cellular
Many technical variations: ADSL, HDSL, SDSL, G.lite, VDSL
Typically 18,000 foot limit; data rates of 1.5 Mbps up to 6 Mbps (VDSL)
Cable access

• Cable channel is 6MHz wide for broadcast video
  Each channel can carry ~20 Mbps of data downstream, 300 kbps to 1 Mbps upstream
• DOCSIS is cable standard for data
  Allows 1-8 channels of data
  Ethernet-like protocol
  Asymmetric upstream and downstream, like most DSL
  Data seen by all devices on cable segment, so it’s sometimes encrypted using RSA
  DHCP used to assign IP addresses
• Cable plants are sometimes low quality
  Not all upgraded to two-way with fiber trunks yet
Cable TV

- Satellite antenna
- Off-the-air antenna
- Headend
- Trunk cable
- Trunk amplifier
- Feeder cables
- Splitter
- Bridger amplifier
- Feeder cables
- Splitter
- Bridger amplifier
- Taps
- User drops
- User drops
- Terminations

often fiber now

Figure by MIT OCW.
Wireless access

- WiFi (802.11x)
  - Hot spots common, but unscalable
  - Range ~100 meters
  - Bandwidth nominally 11-55 Mbps, actual much lower
  - Security protocol problematic (WEP keys breakable)
  - Municipal network plans problematic (30+ points/sq mi)

- WiMax (802.16)
  - Uncertain market response, but large potential
  - Range up to 15 km
  - Bandwidth ~10 Mbps potentially
  - Scalable, of interest to carriers and ISPs
Wireless access, p.2

• Satellite
  – Downstream speeds acceptable (a few Mbps)
  – Upstream links either not available or very expensive
    Satellites have limited power, long paths, high losses
    Satellite paths have high delays, unsuitable for interaction
  – Can serve rural areas

• 3G (and 4G) cellular data
  – 3G data rates typically 300-500 kbps in each direction
  – Mobile phones as user device, for email, video, IM, …
  – Can support applications