BASIC COMMUNICATIONS TECHNOLOGY AND CONCEPTS (TRADITIONAL)
TELECOMMUNICATIONS

WHAT IS THE PROBLEM?
BINARY TRANSMISSION

MAJOR PROBLEMS ARE:

- **RESISTANCE** PRODUCES SIGNAL DELAY
- **CAPACITANCE** PRODUCES DISTORTION
- **INDUCTANCE** PRODUCES DISTORTION
- **NOISE** HAS RANDOMIZING EFFECT

DISTORTION = CAUSED BY CAPACITANCE, INDUCTANCE, RESISTANCE (SYSTEMATIC)
NOISE = EXTERNAL SIGNAL INTRODUCED (RANDOM)

**HOW CAN THESE PROBLEMS BE MINIMIZED?**
-- USE *AMPLIFIERS* TO BOOST SIGNAL, TYPICAL ABOUT 4 MI. APART

**Shannon’s Law** *(theoretical maximum)*:  \( C = W \log_2 (1 + \frac{S}{N}) \)
- \( W \): Bandwidth (in Hz);
- \( S/N \): signal to noise ratio (in dB, decibels)
- \( C \): Maximum data ratio of a circuit (in bps)

* Not to be confused with the Arizona law or western book by Charles Friend with same name (ISBN 0-8034-9410-6)
TRANSMISSION TYPES (Analog vs Digital)

ANALOG (VOICE) --
ANALOG AMPLIFIER SEEKS SMOOTH SIGNALS, ELIMINATES EDGES THEREFORE ONE CANNOT TRANSMIT DIGITAL SIGNALS EFFECTIVELY OVER ANALOG LINES

DIGITAL --
APPROACH 1:
USE MODEMS TO CONVERT DIGITAL MESSAGES TO ANALOG TONES (SEE SLIDE 5)

APPROACH 2: USE DIGITAL AMPLIFIERS (REPEATERS)

• REPEATERS ON DIGITAL NETWORK CAN DO MUCH BETTER CLEAN UP, THUS ONE CAN TRANSMIT AT A FASTER RATE

• MANY VOICE COMMUNICATIONS ARE DIGITIZED THEN REANALOGED -- MOST NEW SYSTEMS ARE INSTALLED AS DIGITAL LINES (E.G., MIT’s Telephone System)

• COMMENT: ORIGINAL ELECTRONIC COMMUNICATION WAS DIGITAL -- THE TELEGRAPH
MOVEMENT TOWARD DIGITAL
DIGITIZED VOICE

ANALOG-TO-DIGITAL (A-TO-D) CONVERSION

(1) ORIGINAL ANALOG SIGNAL

(2) DIGITAL MESSAGE

0 - 1 - 2 - 3 - 4 - 2 - 2 - 3 - 4

(3) RECONSTRUCTED ANALOG SIGNAL

• DIGITIZED VOICE (T1 CARRIER)
  – SAMPLE RATE = 8000/SEC
  – EACH SAMPLE = 7 BITS + 1 BIT SIGNALING
  – TOTAL = 64,000 BITS/SEC PER LINE
  – T1 CARRIER = 24 LINES (1.544M BITS/SEC) [E0 = 2M bps, T3/DS3 = 45 M bps]
DIGITAL CONVERGENCE

Today

Over-the-air TV
Radio (am/fm)
Cable TV
Telephone
FAX
Computer/modem
Wireless telephone
Meter readings
Electricity
Gas

separate delivery methods

Future?

single digital “pipe” to deliver all services
PUBLIC SWITCHED VS. PRIVATE LEASED LINES

• SWITCHED
  – GOES THROUGH TELEPHONE SWITCHING EQUIPMENT
  – ADVANTAGES
    • ONLY CONNECTED WHEN NEEDED
    • CAN ONLY CONNECT TO ANYONE

• LEASED
  – “DIRECT” END-TO-END CONNECTION
  – ADVANTAGES
    • PERMANENT CONNECTION, NO CONNECT DELAYS
    • “ECONOMY OF SCALE” PRICING OVER SWITCHED
    • LESS NOISE
    • CAN BE CONDITIONED
  – ISSUES
    • MAJOR CORPORATE “ASSET” (?)
    • INFORMATION “HIGHWAYS” (INFRASTRUCTURE)
# TRANSMISSION MEDIA FACTORS

<table>
<thead>
<tr>
<th>MEDIA TYPE</th>
<th>TYPICAL DATA RATES</th>
<th>ADVANTAGES</th>
<th>DISADVANTAGES</th>
</tr>
</thead>
<tbody>
<tr>
<td>TWISTED PAIR WIRE</td>
<td>1-4 M bps</td>
<td>- Low Cost</td>
<td>- Low speed</td>
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<tr>
<td></td>
<td></td>
<td>- Already in most buildings</td>
<td>- Noise</td>
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<tr>
<td>COAX</td>
<td>10-100M bps</td>
<td>- Higher Speed</td>
<td>- More costly</td>
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<td></td>
<td></td>
<td></td>
<td>- Installation difficulties</td>
</tr>
<tr>
<td>OPTICAL FIBER</td>
<td>10-1000M bps</td>
<td>- Much higher speeds</td>
<td>- Costly</td>
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<td></td>
<td></td>
<td></td>
<td>- Difficult installation</td>
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<td></td>
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<td>- Less mature</td>
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</tbody>
</table>

Others: Microwave, Radio (Wireless), Satellite
MULTIPLEXORS

24 LINES FROM L.A.

WITHOUT MULTIPLEXOR

64K bps = DS1

24 LINES FROM L.A.

WITH MULTIPLEXOR

64K bps

1.5M bps = T1

• COST OF 24 64K bps LINES MORE THAN COST OF ONE 1.5M BPS LINE
METHODS OF MULTIPLEXING

FDM (FREQUENCY DIVISION MULTIPLEXOR) - EACH LINE HAS ITS OWN FREQUENCY RANGE AND THE SIGNALS ARE SENT OVERLAPPED

- TYPICAL VOICE CHANNEL NEEDS: 300 - 3400 Hertz (CPS) -- USUALLY 4000 Hertz
- TYPICAL PHYSICAL LINK PROVIDES: 300 - 1,500,000 Hertz

Signal strength

300 1000 5000 9000 13,000 150,000

CHANNEL 1

CHANNEL 2

CHANNEL 3

e.g., RETAIL PHYSICAL LINK INTO 36 VOICE CHANNELS

VOICE CHANNEL 1 = 1000 - 5000 Hertz
VOICE CHANNEL 2 = 5000 - 9000 Hertz
VOICE CHANNEL 3 = 9000 - 13,000 Hertz
METHODS OF MULTIPLEXING

TDM (TIME DIVISION MULTIPLEXOR) - EACH OF THE N LINES (Li) SENDS (RECEIVES) EVERY NTH BIT

E.G., N = 4

\[ \begin{array}{ccccccccc}
L1 & L2 & L3 & L4 & L1 & L2 & L3 & L4 & \cdots \\
\hline
1 & 0 & 1 & 1 & 1 & 1 & 0 & 0 & 0 & 1 & 1 & 1 & 1 \\
L2 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 0 & 0 & 0 & 0 \\
L3 & 0 & 1 & 1 & 1 & 1 & 0 & 0 & 0 & 0 \\
L4 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
\end{array} \]

TDM EXAMPLE

Actual Sequence Transmitted (to be De-Multiplexed)
CONCENTRATORS (STAT MUX)

- CONCENTRATOR IS USUALLY A DEDICATED COMPUTER
- MEMORY NEEDED FOR BUFFERING AND SOFTWARE CONTROL
- ESPECIALLY VALUABLE IF LINE USAGE IS “BURSTY”
- WHAT IF 48 LINES FED IN?
OTHER ISSUES

• COMMUNICATIONS INDUSTRY CULTURE

• LEGAL
  -- REGULATION (MONOPOLY IN MANY COUNTRIES)
  -- PRIVACY

• POLITICAL
  -- TRANSNATIONAL DATA FLOW
  • DATA EXPORTING (VALUE PRIVACY)
  • DATA IMPORTING (DEPENDENCE)
  • RELOCATION OF PROCESSING (JOBS)
  • TAX THOSE BITS!