

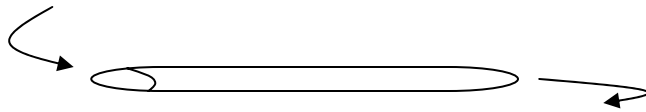


# TELECOMMUNICATIONS



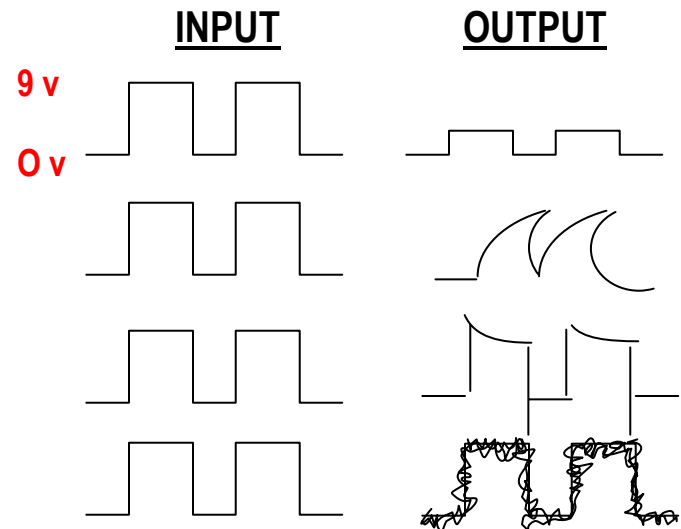
WHAT IS THE PROBLEM?

# 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):  $C = W \log_2 (1 + S/N)$**

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) --**

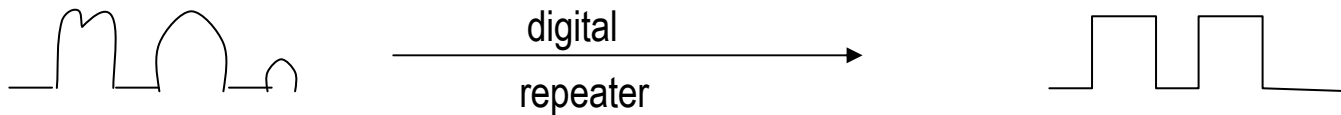
ANALOG AMPLIFIER SEEKS SMOOTH SIGNALS, ELIMINATES EDGES THEREFORE ONE CANNOT TRANSMIT DIGITAL SIGNALS EFFECTIVELY OVER ANALOG LINES

**DIGITAL -- APPROACH 1:**

USE MODEMS TO CONVERT DIGITAL MESSAGES TO ANALOG TONES (SEE SLIDE 5)

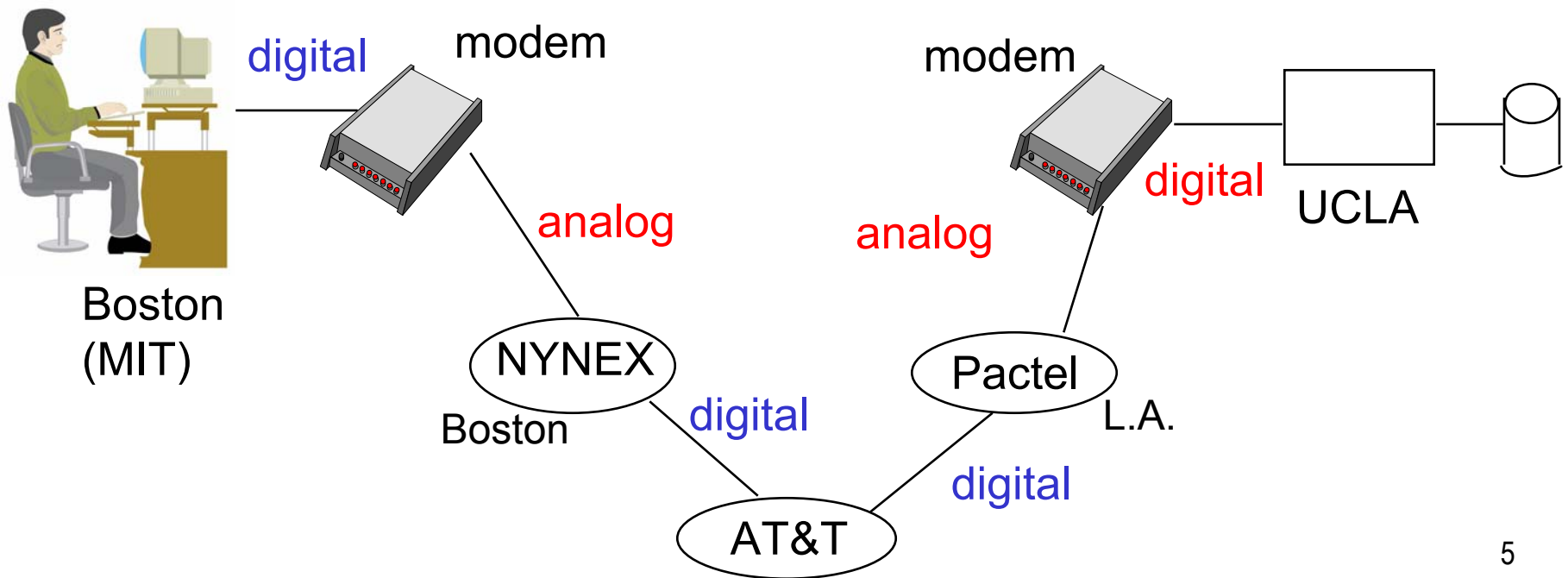
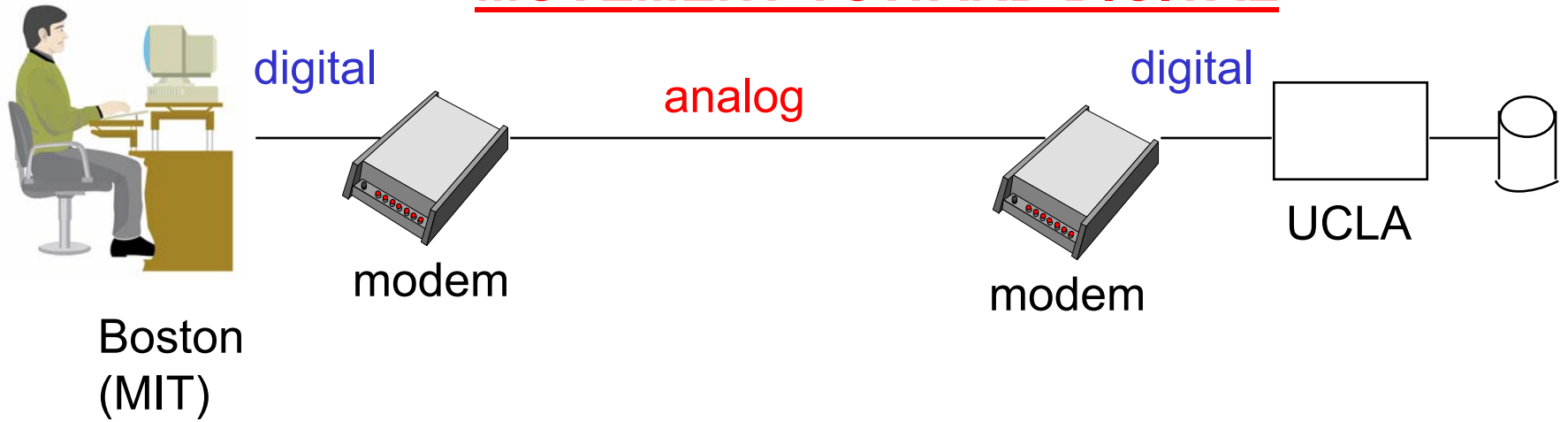


**APPROACH 2: USE DIGITAL AMPLIFIERS (REPEATERS)**



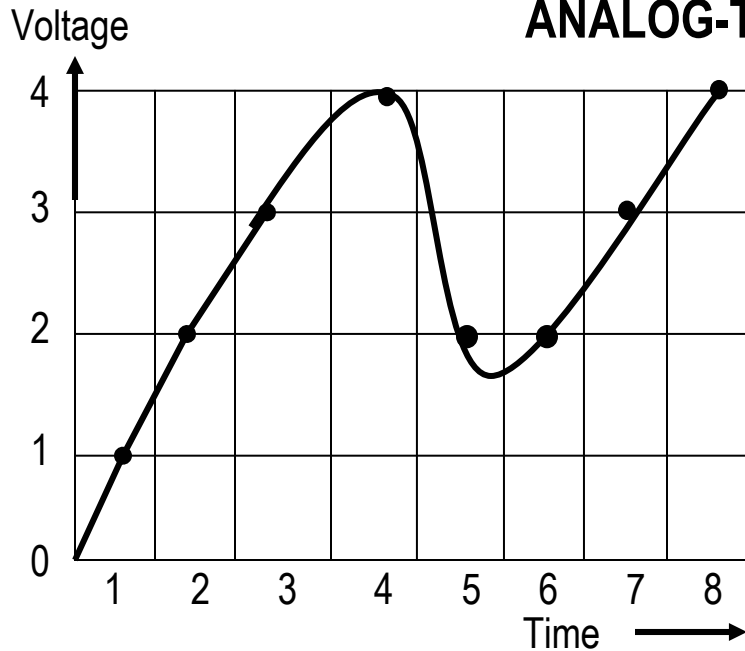
- REPEATERS ON DIGITAL NETWORK CAN DO MUCH BETTER CLEAN UP, THUS ONE CAN TRANSMIT AT A FASTER RATE
- MANY VOICE COMMUNICATIONS ARE DIGITIZED THEN REANALOGED  
-- MOST NEW SYSTEMS ARE INSTALLED AS DIGITAL LINES (E.G., MIT's Telephone System)
- COMMENT: ORIGINAL ELECTRONIC COMMUNICATION WAS DIGITAL -- THE TELEGRAPH

# MOVEMENT TOWARD DIGITAL

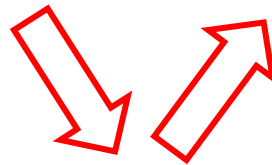


# DIGITIZED VOICE

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

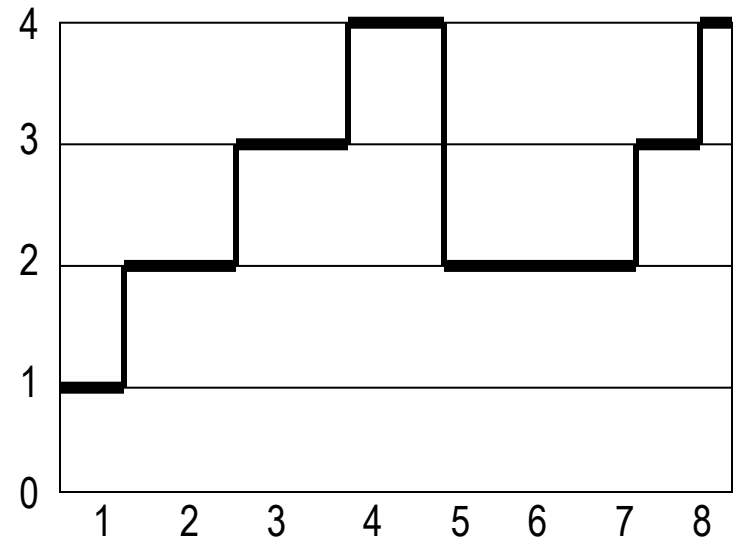


(1) ORIGINAL  
ANALOG SIGNAL



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

(2) DIGITAL MESSAGE

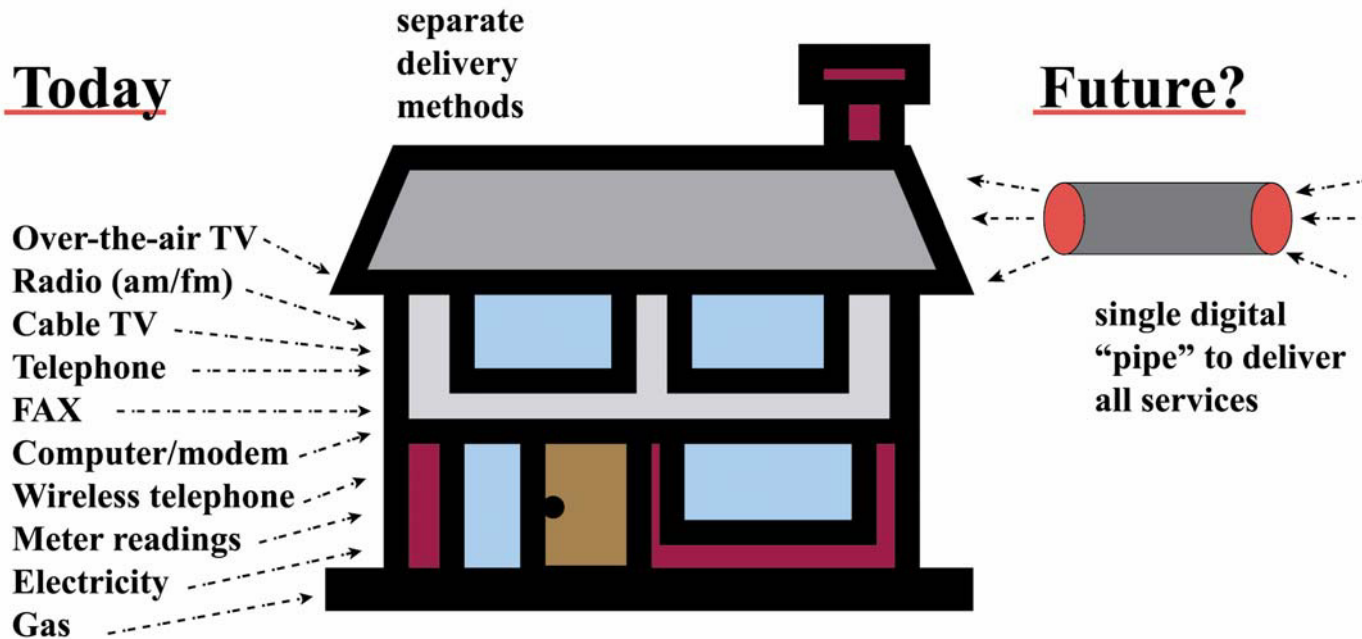


(3) RECONSTRUCTED  
ANALOG SIGNAL

- **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]6

# DIGITAL CONVERGENCE



# PUBLIC SWITCHED VS. PRIVATE LEASED LINES

- **SWITCHED**

- GOES THROUGH TELEPHONE SWITCHING EQUIPMENT
- ADVANTAGES
  - ONLY CONNECTED WHEN NEEDED
  - CAN ONLY CONNECT TO ANYONE

- **LEASED**

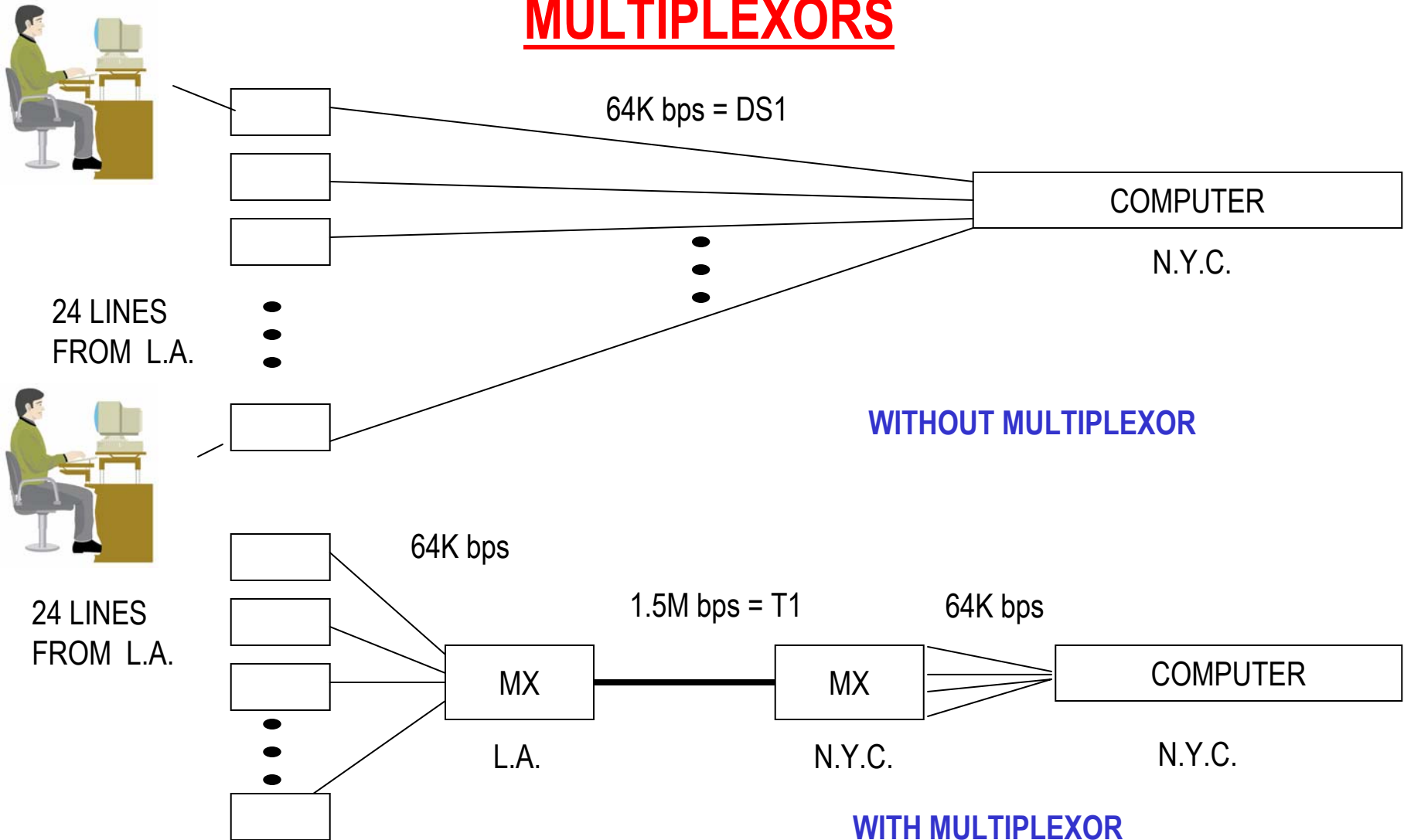
- “DIRECT” END-TO-END CONNECTION
- ADVANTAGES
  - PERMANENT CONNECTION, NO CONNECT DELAYS
  - “ECONOMY OF SCALE” PRICING OVER SWITCHED
  - LESS NOISE
  - CAN BE CONDITIONED
- ISSUES
  - MAJOR CORPORATE “ASSET” (?)
  - INFORMATION “HIGHWAYS” (INFRASTRUCTURE)

# TRANSMISSION MEDIA FACTORS

	<b>TYPICAL DATA RATES</b>	<b>ADVANTAGES</b>	<b>DISADVANTAGES</b>
<b>TWISTED PAIR WIRE</b>	1-4 M bps	<ul style="list-style-type: none"><li>- Low Cost</li><li>- Already in most buildings</li></ul>	<ul style="list-style-type: none"><li>- Low speed</li><li>- Noise</li></ul>
<b>COAX</b>	10-100M bps	<ul style="list-style-type: none"><li>- Higher Speed</li></ul>	<ul style="list-style-type: none"><li>- More costly</li><li>- Installation difficulties</li></ul>
<b>OPTICAL FIBER</b>	10-1000M bps	<ul style="list-style-type: none"><li>- Much higher speeds</li></ul>	<ul style="list-style-type: none"><li>- Costly</li><li>- Difficult installation</li><li>- Less mature</li></ul>

Others: Microwave, Radio (Wireless), Satellite

# MULTIPLEXORS

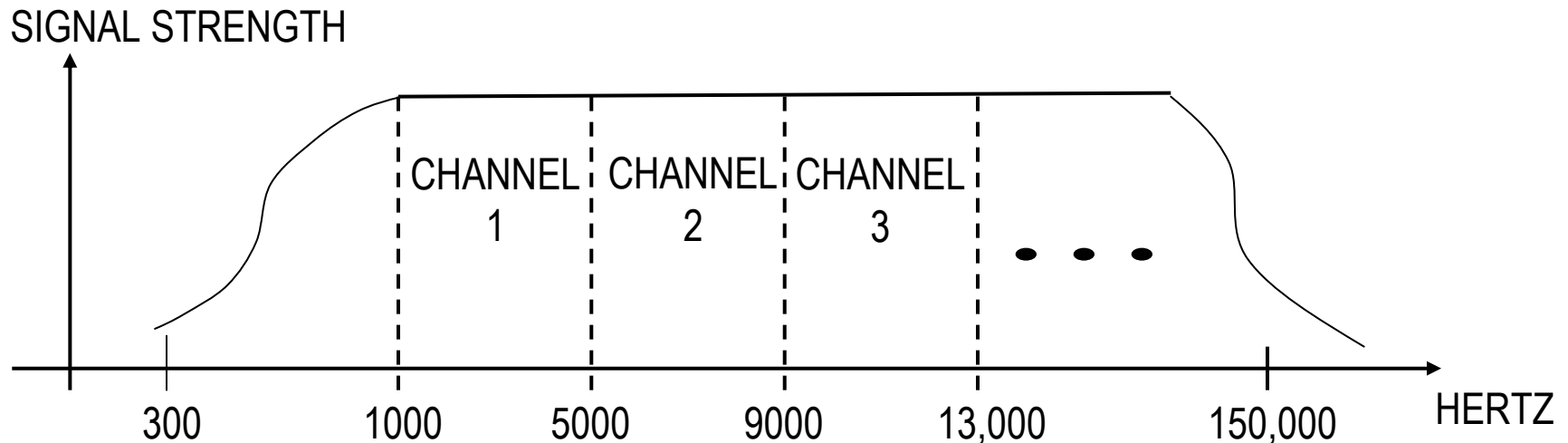


- COST OF 24 64K bps LINES MORE THAN COST OF ONE 1.5M BPS LINE

# 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



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

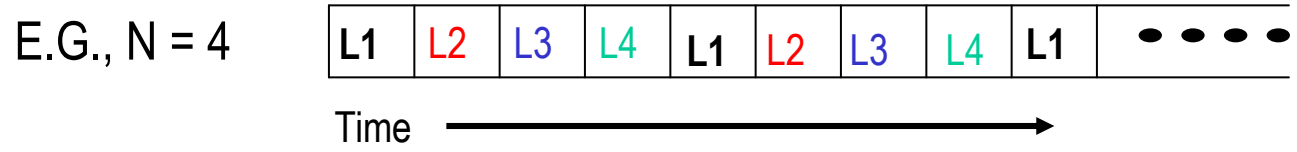
VOICE CHANNEL 1 = 1000 - 5000 HERTZ

VOICE CHANNEL 2 = 5000 - 9000 HERTZ

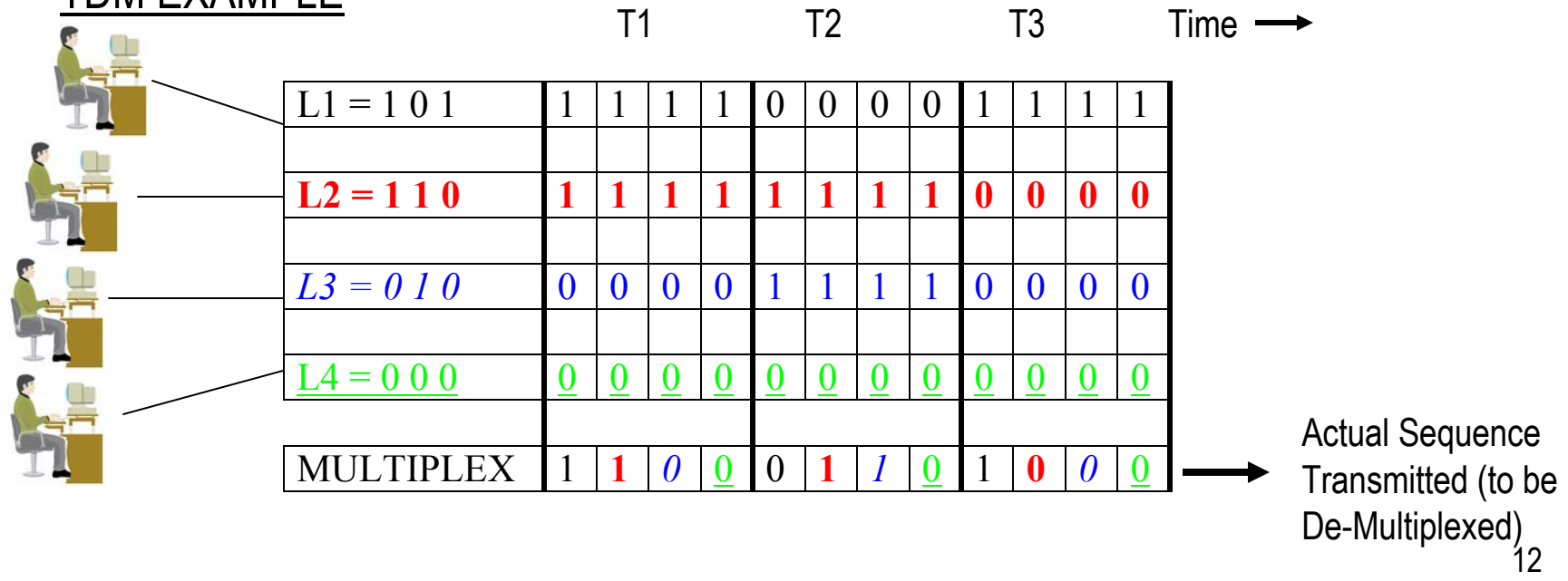
VOICE CHANNEL 3 = 9000 - 13,000 HERTZ

# METHODS OF MULTIPLEXING

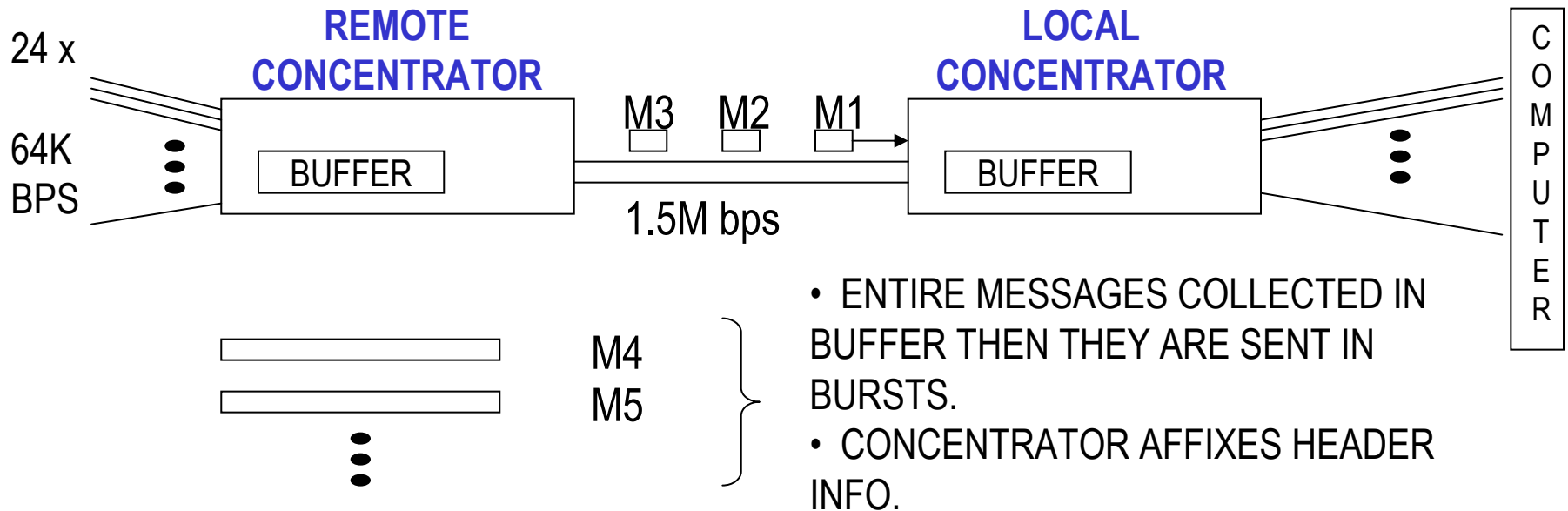
**TDM** (TIME DIVISION MULTIPLEXOR) - EACH OF THE N LINES (L<sub>i</sub>) SENDS (RECEIVES) EVERY N<sup>TH</sup> BIT



## TDM EXAMPLE



# 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!