MASSACHUSETTS INSTITUTE OF TECHNOLOGY
SLOAN SCHOOL OF MANAGEMENT

15.565 Integrating Information Systems:

Technology, Strategy, and Organizational Factors

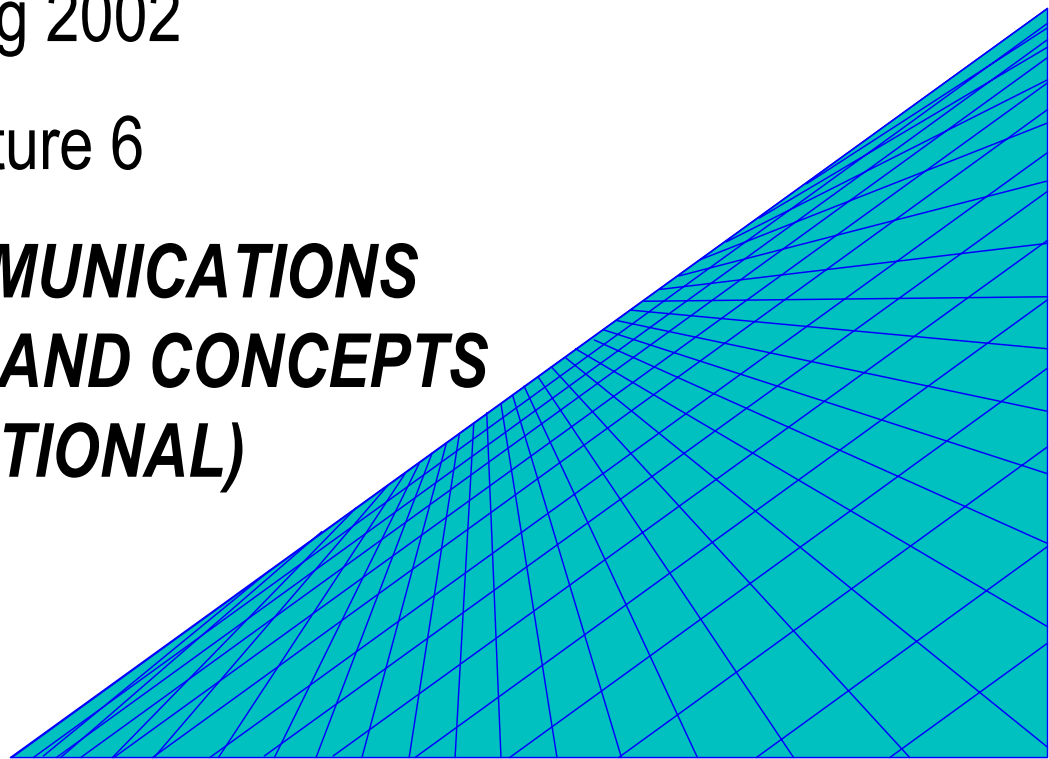
15.578 Global Information Systems:

Communications & Connectivity Among Information Systems

Spring 2002

Lecture 6

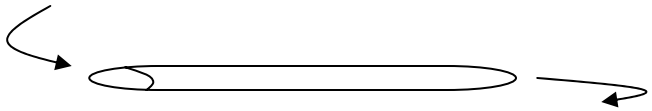
BASIC COMMUNICATIONS TECHNOLOGY AND CONCEPTS (TRADITIONAL)



TELECOMMUNICATIONS

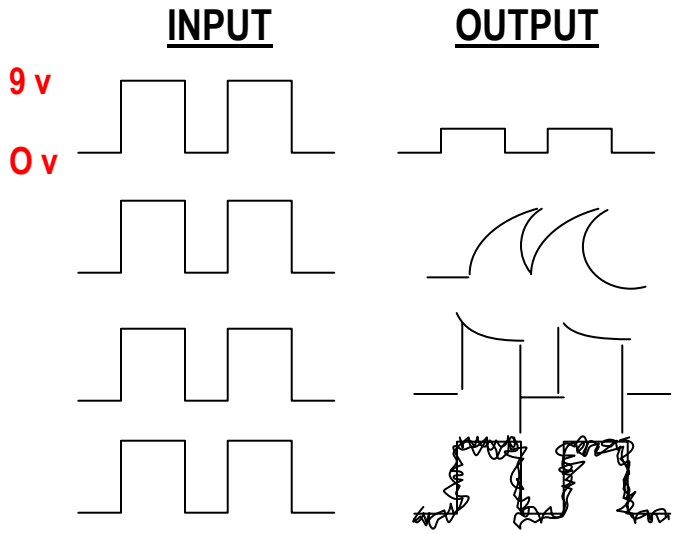
WHAT IS THE PROBLEM?

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

W: Bandwidth (in Hz); S/N: signal to noise ratio (in dB, decibels)

C: Maximum data ratio of a circuit (in bps)

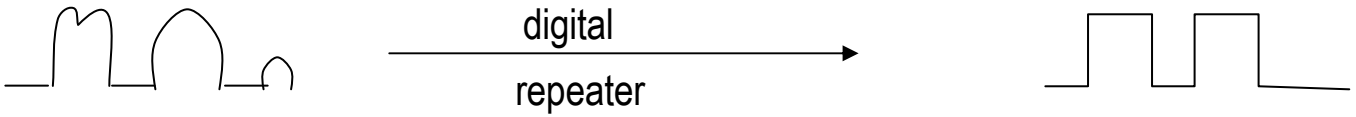
* Not to be confused with the Arizona law or western book by Charles Friend with same name (ISBN 0-8034-9410-6)

TRANSMISSION TYPES (Analog vs Digital)

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

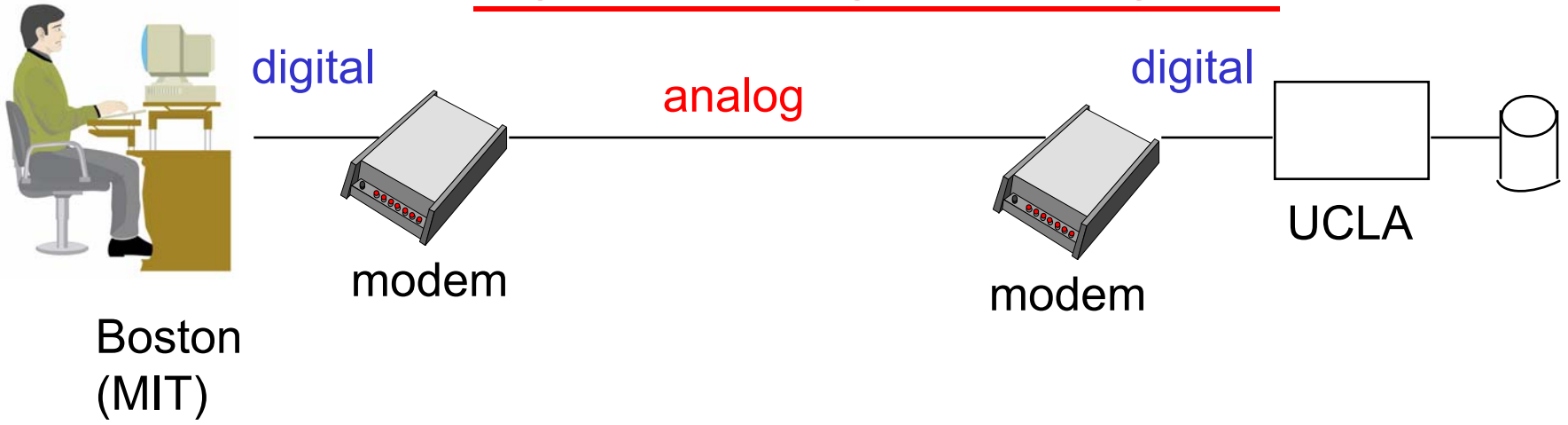
DIGITAL -- APPROACH 1: USE MODEMS TO CONVERT DIGITAL MESSAGES TO ANALOG TONES (SEE SLIDE 5)

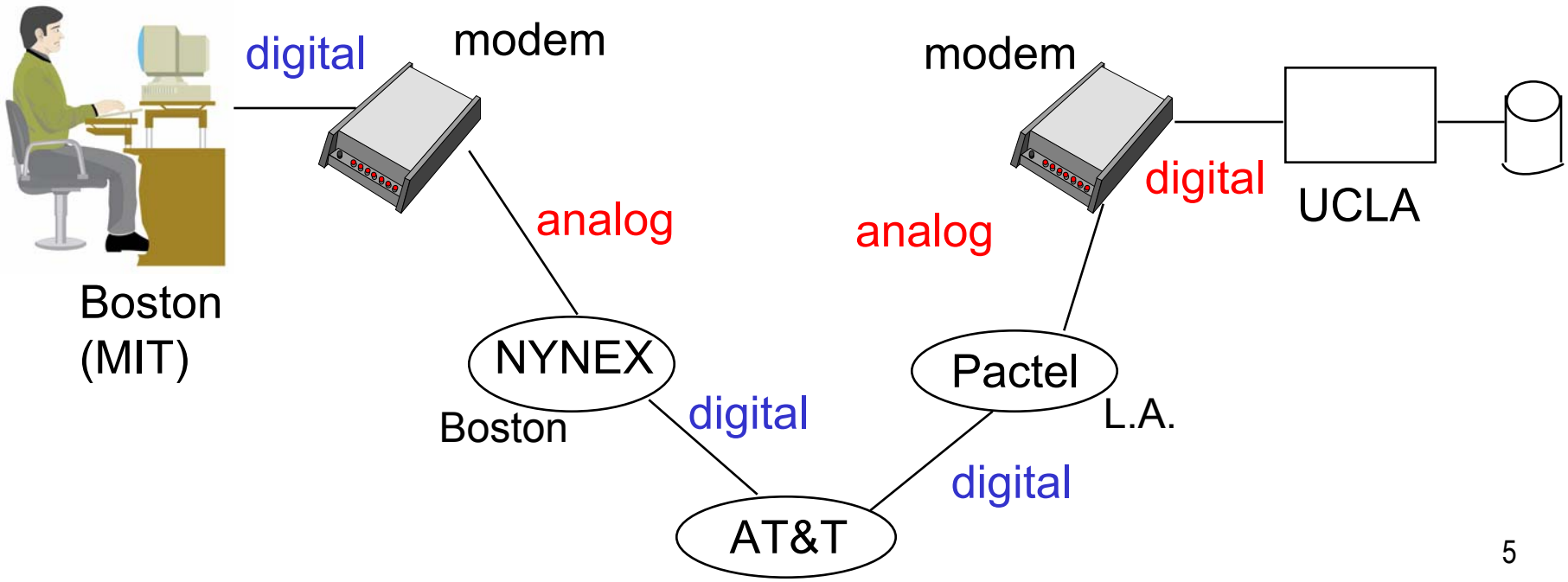
APPROACH 2: USE DIGITAL AMPLIFIERS (REPEATERS)



- 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

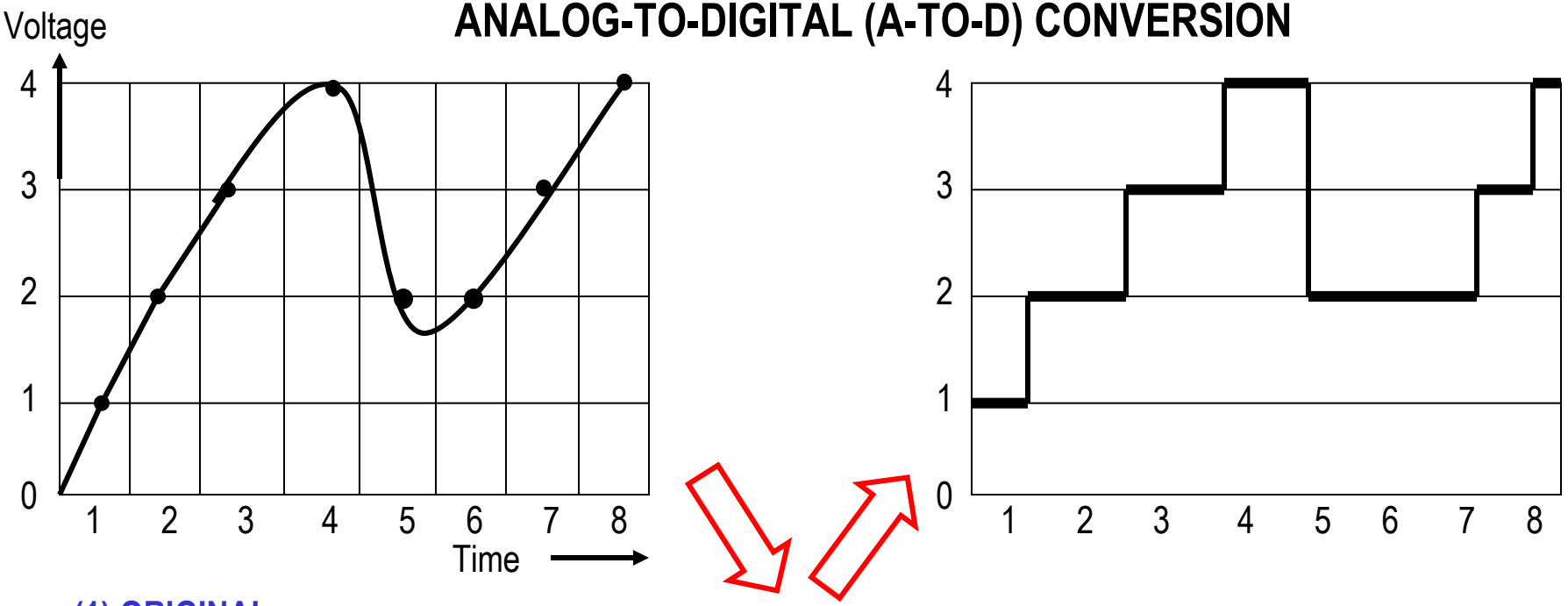
MOVEMENT TOWARD DIGITAL





DIGITIZED VOICE

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



(1) ORIGINAL ANALOG SIGNAL

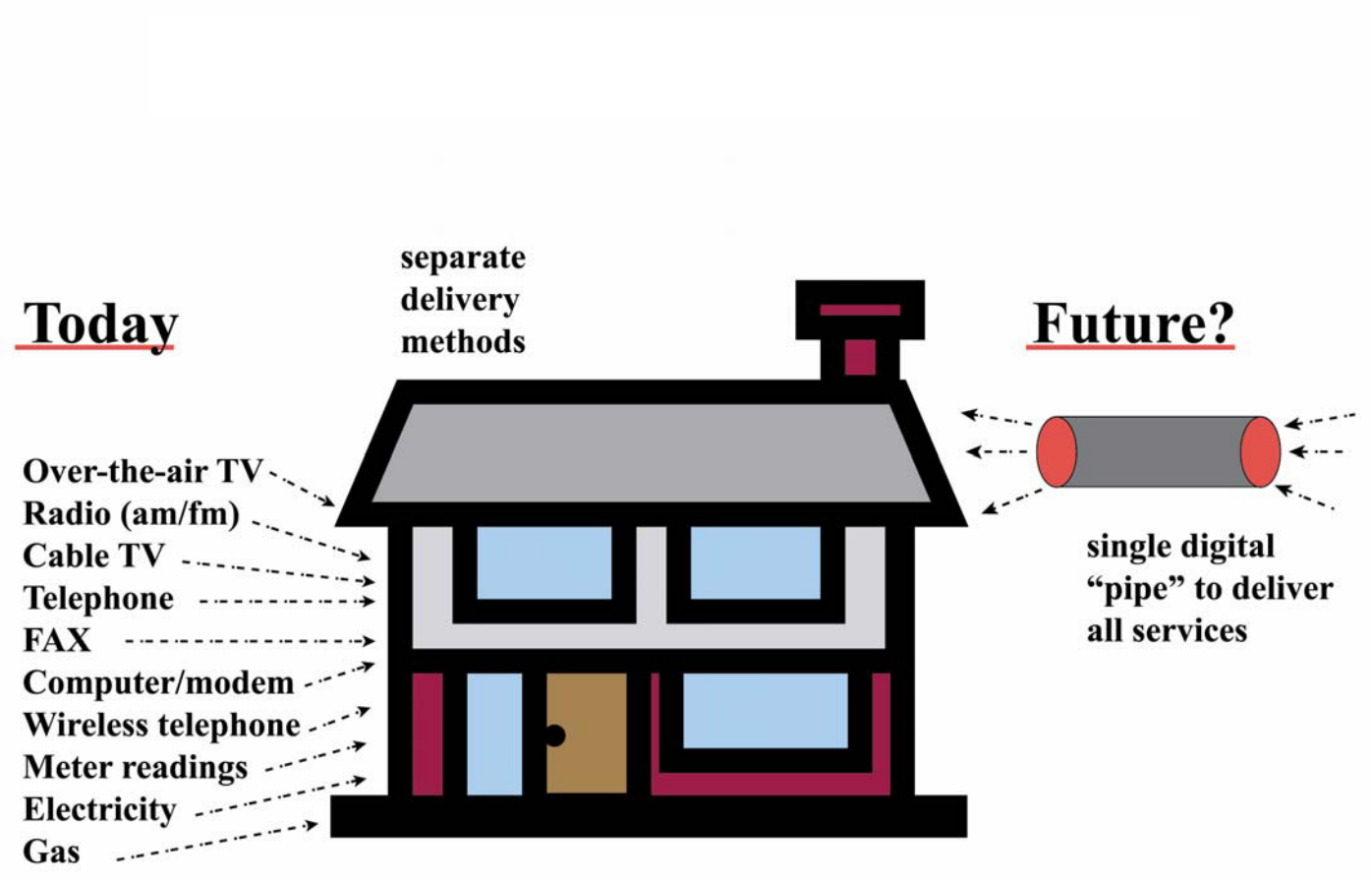
0 - 1 - 2 - 3 - 4 - 2 - 2 - 3 - 4

(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]

DIGITAL CONVERGENCE



PUBLIC SWITCHED VS. PRIVATE LEASED LINES

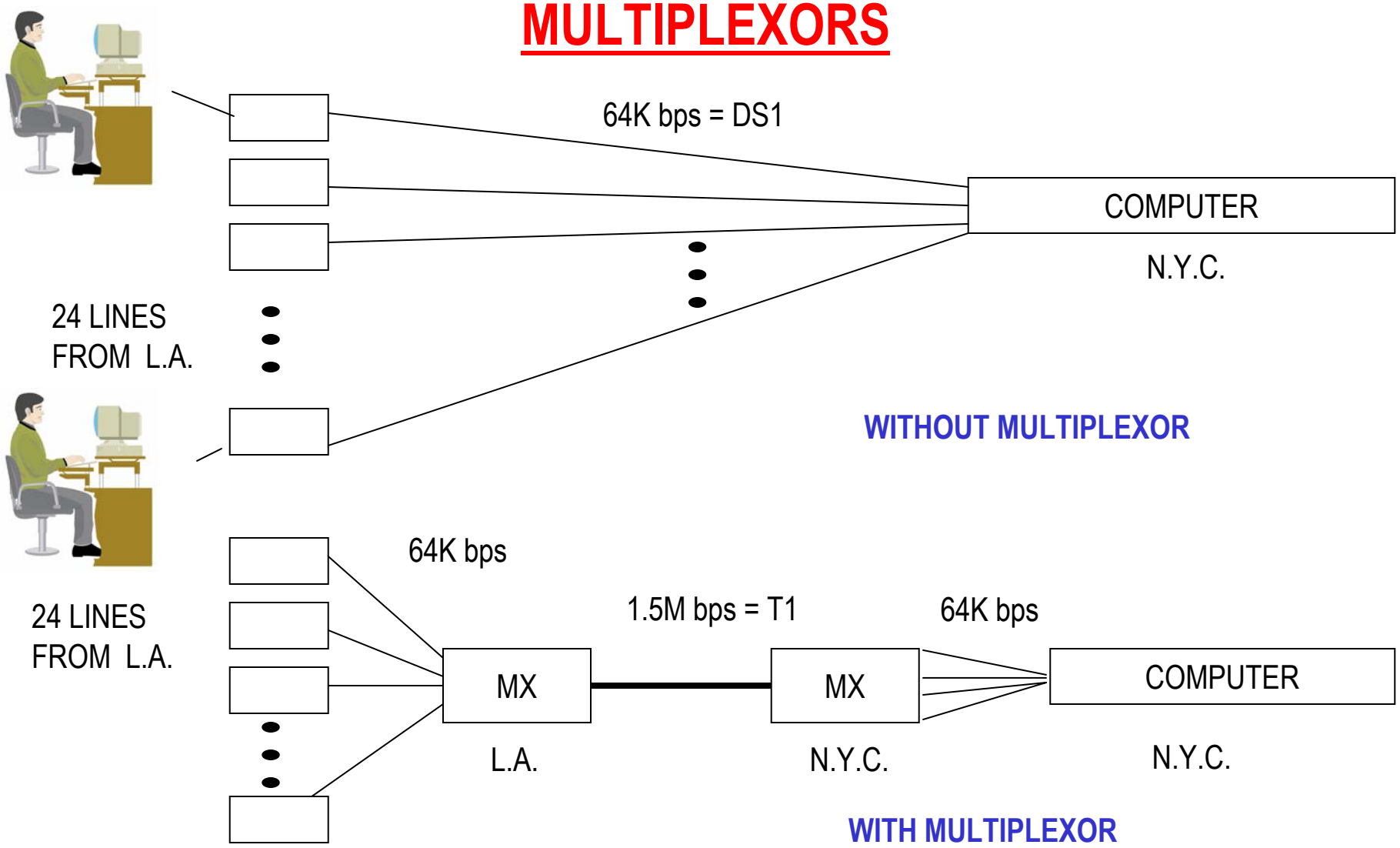
- **SWITCHED**
  - GOES THROUGH TELEPHONE SWITCHING EQUIPMENT
  - ADVANTAGES
    - ONLY CONNECTED WHEN NEEDED
    - CAN ONLY CONNECT TO ANYONE
- **LEASED**
  - "DIRECT" END-TO-END CONNECTION
  - ADVANTAGES
    - PERMANENT CONNECTION, NO CONNECT DELAYS
    - "ECONOMY OF SCALE" PRICING OVER SWITCHED
    - LESS NOISE
    - CAN BE CONDITIONED
  - ISSUES
    - MAJOR CORPORATE "ASSET" (?)
    - INFORMATION "HIGHWAYS" (INFRASTRUCTURE)

TRANSMISSION MEDIA FACTORS

	TYPICAL DATA RATES	ADVANTAGES	DISADVANTAGES
TWISTED PAIR WIRE	1-4 M bps	- Low Cost - Already in most buildings	- Low speed - Noise
COAX	10-100M bps	- Higher Speed	- More costly - Installation difficulties
OPTICAL FIBER	10-1000M bps	- Much higher speeds	- Costly - Difficult installation - Less mature

Others: Microwave, Radio (Wireless), Satellite

MULTIPLEXORS

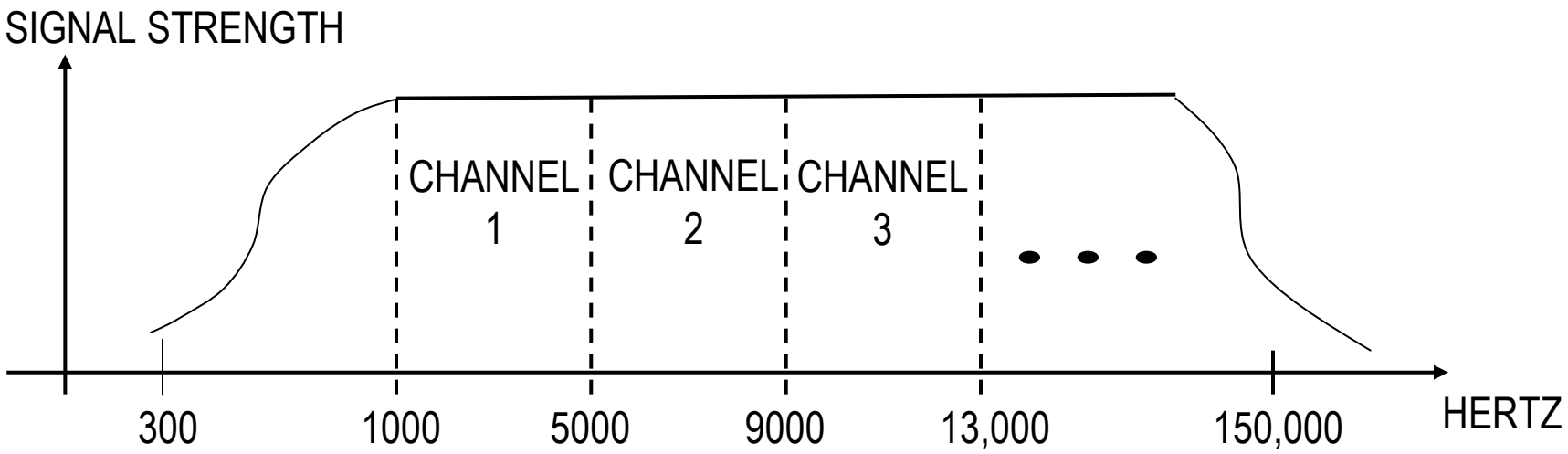


- COST OF 24 64K bps LINES MORE THAN COST OF ONE 1.5M BPS LINE

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

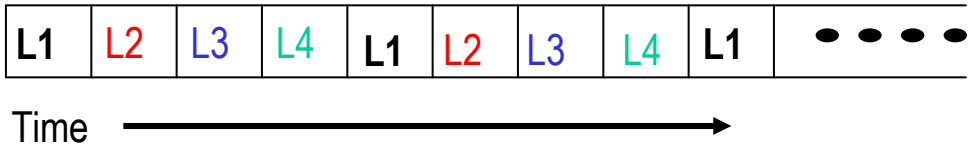
VOICE CHANNEL 2 = 5000 - 9000 HERTZ

VOICE CHANNEL 3 = 9000 - 13,000 HERTZ

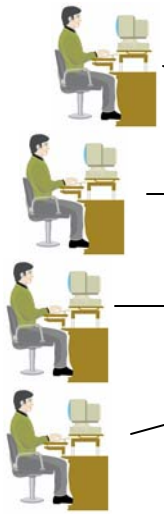
METHODS OF MULTIPLEXING

TDM (TIME DIVISION MULTIPLEXOR) - EACH OF THE N LINES (Li) SENDS (RECEIVES) EVERY N^{TH} BIT

E.G., N = 4



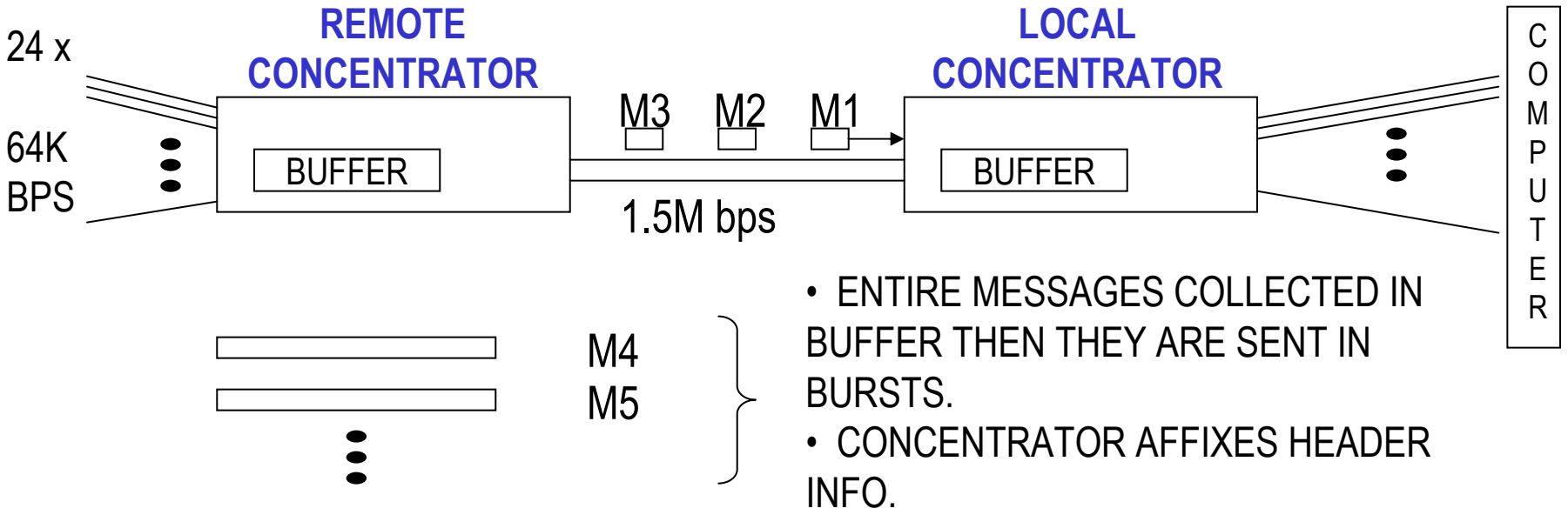
TDM EXAMPLE



	T1				T2				T3				Time →
L1 = 1 0 1	1	1	1	1	0	0	0	0	1	1	1	1	
L2 = 1 1 0	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**0**	**0**	**0**	**0**	
L3 = 0 1 0	0	0	0	0	1	1	1	1	0	0	0	0	
L4 = 0 0 0	0	0	0	0	0	0	0	0	0	0	0	0	
MULTIPLEX	1	**1**	*0*	0	0	**1**	*1*	0	1	**0**	*0*	0	→

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!