MASSACHUSETTS INSTITUTE OF TECHNOLOGY
SLOAN SCHOOL OF MANAGEMENT

15.565 Integrating Information Systems:

Technology, Strategy, and Organizational Factors

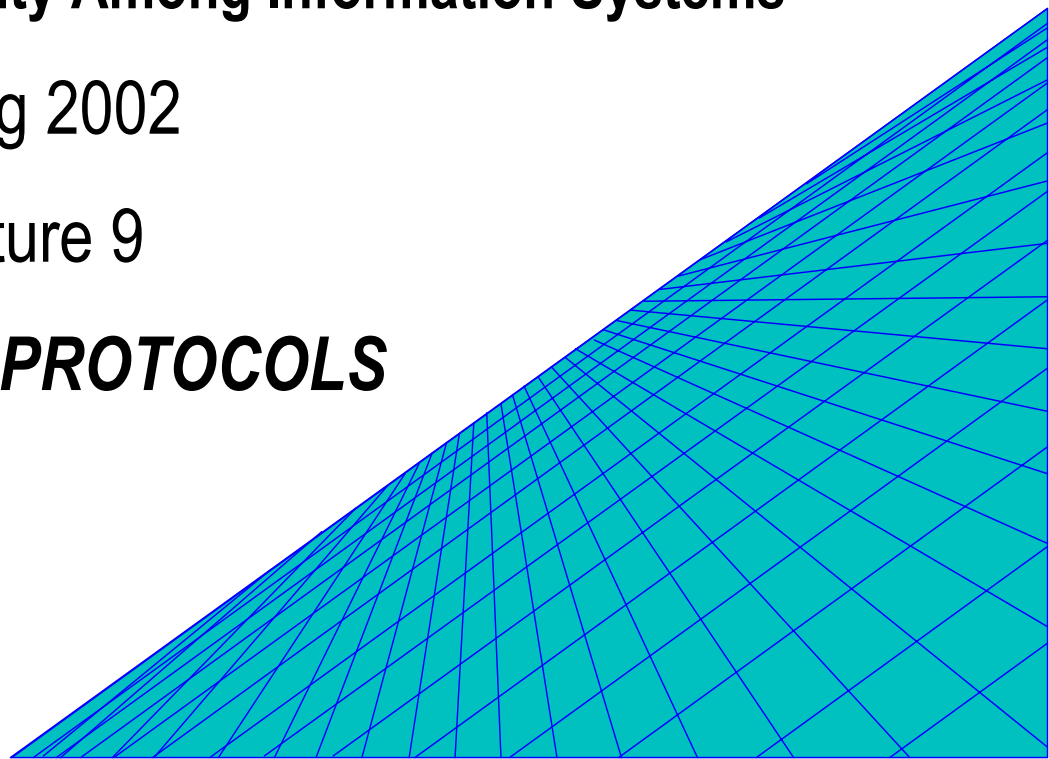
15.578 Global Information Systems:

Communications & Connectivity Among Information Systems

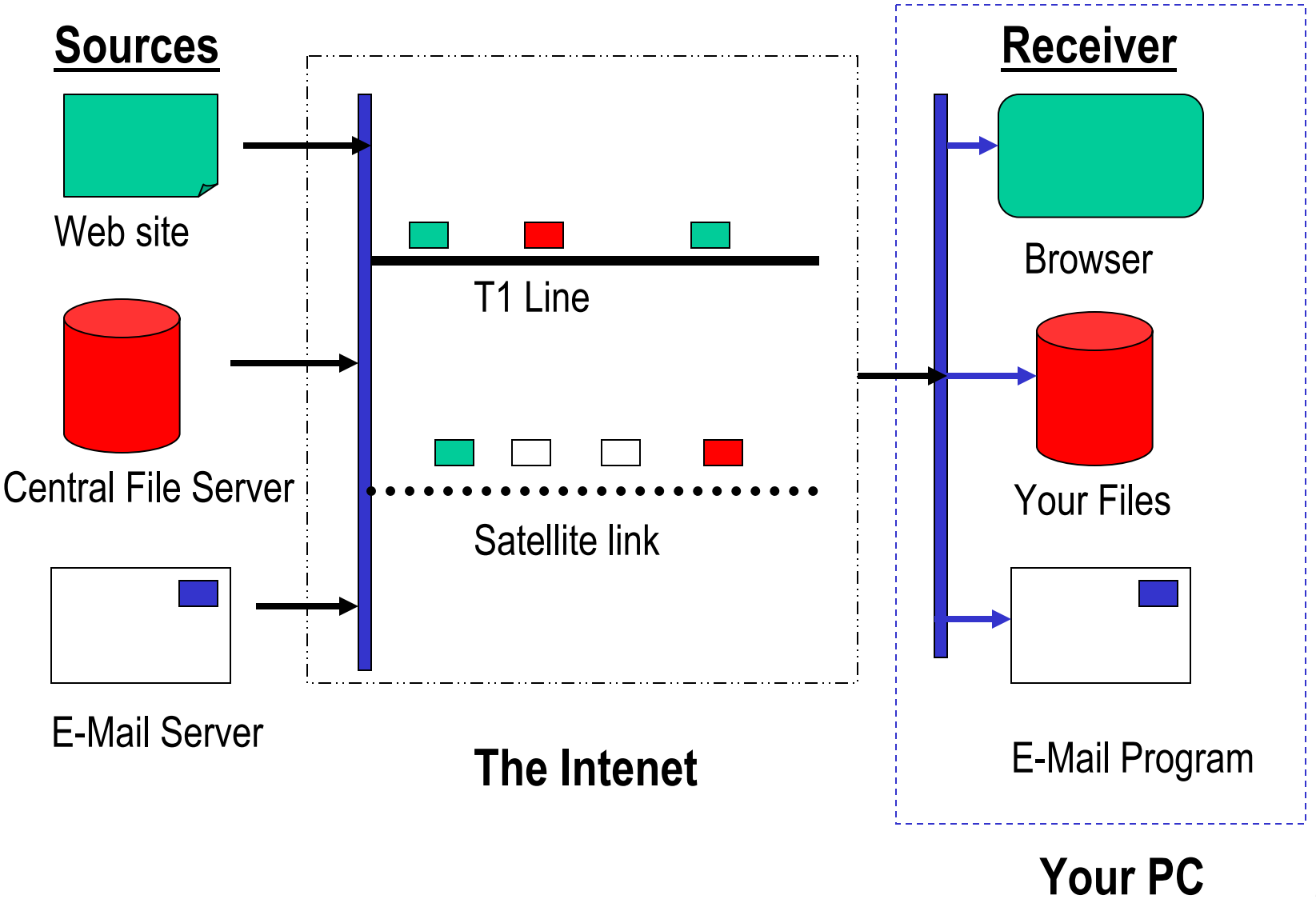
Spring 2002

Lecture 9

NETWORK PROTOCOLS



COMPLEXITY OF COMMUNICATION NETWORKS



ROLE OF PROTOCOLS

EXAMPLES FROM NORMAL TELEPHONE CONVERSATION

- **ASSUMING SENDER (S) AND RECEIVER (R) SPEAK ENGLISH –** ITSELF A PROTOCOL ISSUE
- **ESTABLISHING CONNECTON:**
  S: "IS JOHN THERE?" R: "YES, THIS IS JOHN."
- **ERROR CHECKING:**
  S: "DID YOU HEARD WHAT I JUST SAID?" R: "YES."
- **FLOW CONTROL (E.G., DICTATING LETTER OVER PHONE):**
  S: "ARE YOU READY FOR NEXT SENTENCE?"
  R: … pause … "YES."

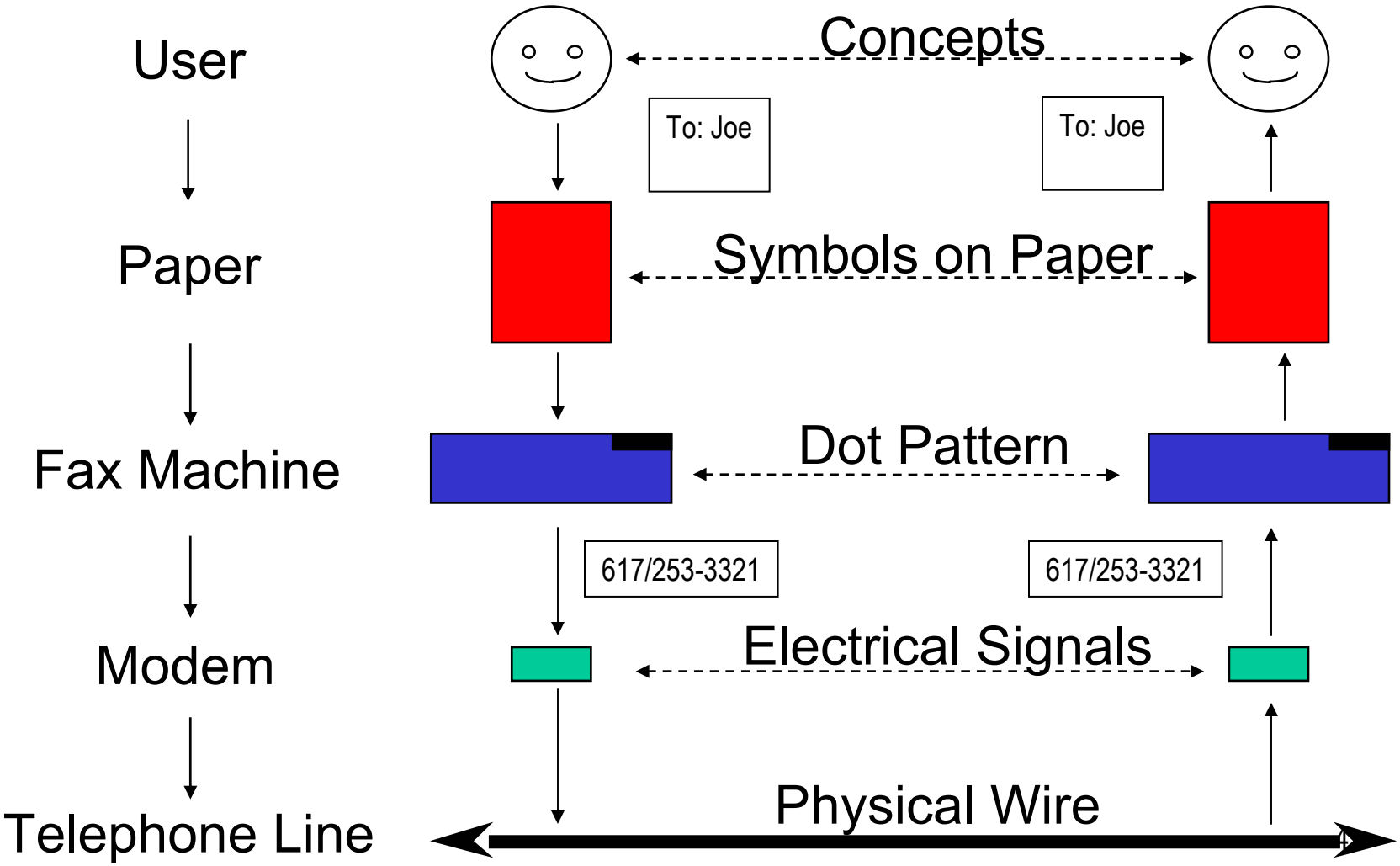
BOTH SENDER AND RECEIVER MUST FOLLOW SAME RULES.

- **OTHER EXAMPLES ?**

LAYERING OF PROTOCOLS AND COMMUNICATIONS

Issues: Abstractions & Substitutions/Alternatives

Example: Sending a fax



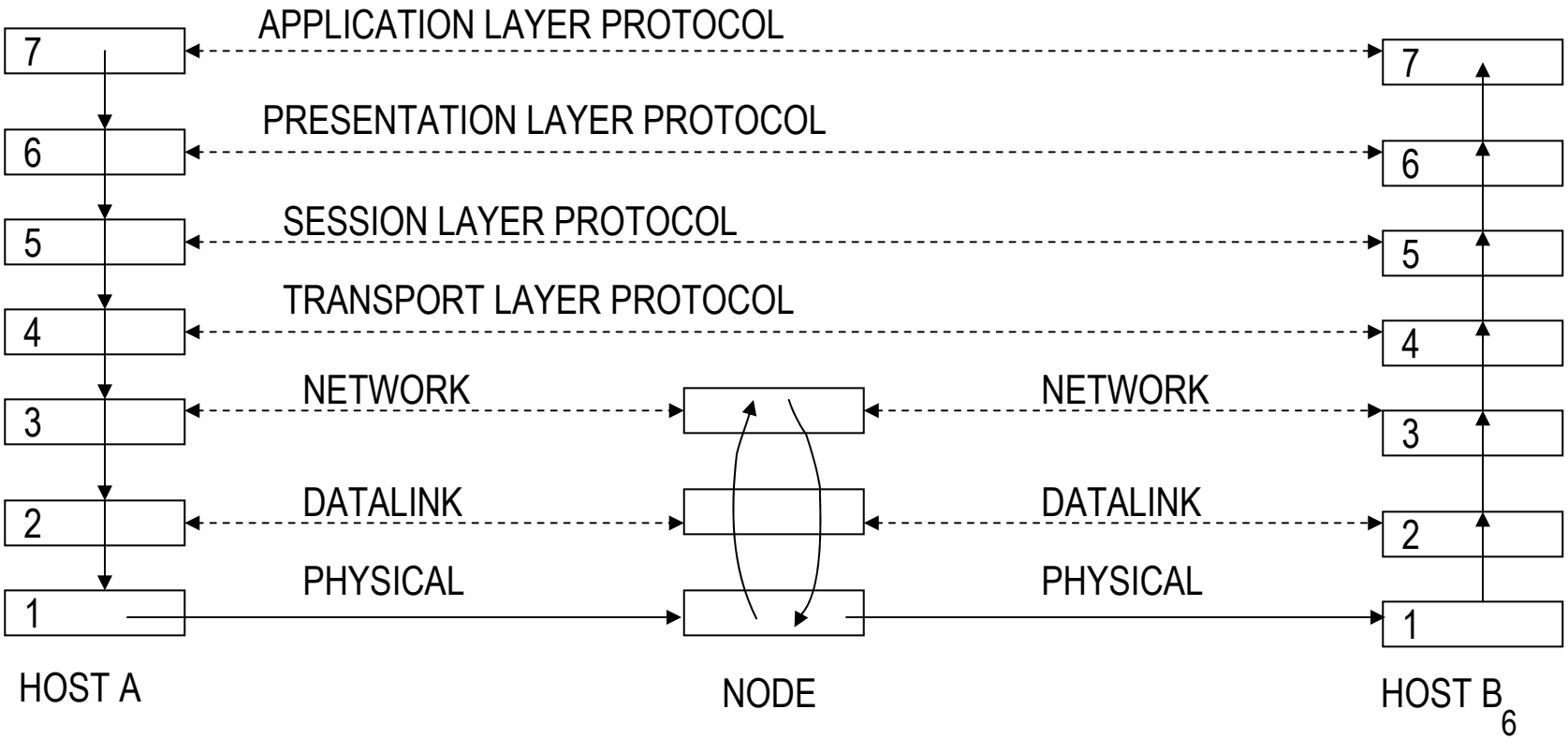
ISO OSI REFERENCE MODEL

- **ISO = INTERNATIONAL STANDARDIZATION ORGANIZATION**
- **OSI = OPEN SYSTEMS INTERCONNECTION**
- **ISO OSI REFERENCE MODEL:**
  - -- IS A FRAMEWORK AND SET OF NOMENCLATURE
  - -- IS NOT A PROTOCOL STANDARD
- **STANDARDS DEVELOPERS:**

  CCITT, IFIP, ANSI, IEEE

ISO REFERENCE MODEL FOR OSI

7. APPLICATION: APPLICATION DEPENDENT (E.G., USER PROGRAM)
6. PRESENTATION: COMPRESSION AND CONVERSIONS (E.G., LIBRARY)
5. SESSION: PROCESS-TO-PROCESS (E.G., OS SOFTWARE)
4. **TRANSPORT**: HOST-TO-HOST (E.G., OS SOFTWARE)
3. NETWORK: ROUTING (E.G., DEVICE DRIVER)
2. **DATA**: RELIABLE BIT STREAM (E.G., SPECIAL CHIP)
1. PHYSICAL: RAW BIT STREAM (E.G., HARDWARE)

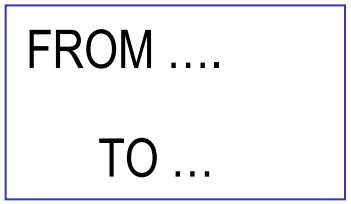


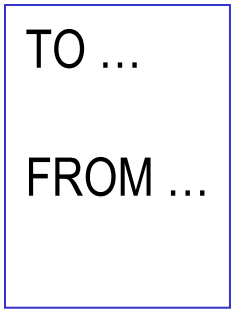
THE SEVEN-LAYER ISO REFERENCE MODEL

SIMPLE MAIL DELIVERY ANALOGY

7. APPLICATION: SPECIFIC HANDLING (e.g., PAY BILL, INQUIRY)
6. PRESENTATION: LANGUAGE TRANSLATION SERVICE
5. SESSION: GROUP IN COMPANY (e.g., A/P) or PERSON (e.g., E53-321)
4. **TRANSPORT**: SOURCE COMPANY TO RECEIVER COMPANY
3. NETWORK: ROUTING FROM POST OFFICE TO POST OFFICE
2. **DATA**: FLOW CONTROL AND TRAFFIC HANDLING ON HIGHWAY
1. PHYSICAL: TRUCKS AND PLANES USED

- MUST USE SAME STANDARDS





1. PHYSICAL LAYER

- SUBNET TYPES
  - CIRCUIT SWITCHING (DEDICATED CHANNEL)
  - MESSAGE SWITCHING
  - PACKET SWITCHING (SHARED CHANNEL)
- COMMUNICATION TECHNOLOGIES (SOME EXAMPLES)
  - **TELEPHONE**
    - T1 = 1.544M bps (USA & CANADA) OR 2.048M (ELSE)
  - **SHARED CABLE (ETHERNET)**
    - 10-100M bps (Typical)
    - CSMA/CD (CARRIER SENSE MULTIPLE ACCESS/COLLISION DETECT)
  - **SATELLITE**
    - 5-10 CHANNELS, EACH 50M bps
    - UP-LINK & DOWN-LINK = 270 MILLISECONDS
    - VSAT
  - **FIBER-OPTIC**
    - 100M - 10G bps (Typical)
    - INTERNET II (622M -> 2G)
    - PROJECT OXYGEN = 1.28T bps (before 2003)

2. DATA LINK LAYER

FOCUS: RELIABLE TRANSMISSION: ERROR HANDLING & FLOW CONTROL

ERROR HANDLING: DETECTION AND CORRECTION

- **CHECK SUM** FOR ERROR DETECTION (AND OTHER ERROR DETECT/CORRECT CODES)

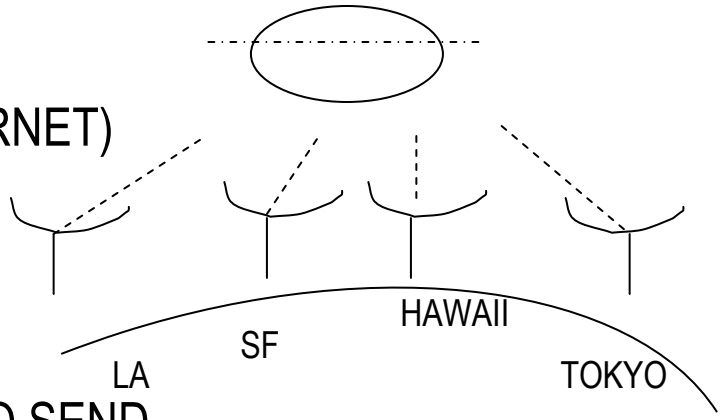
BEGIN CODE					END CODE
01111110	ADDRESS	CONTROL	INFORMATION	**CHECKSUM**	01111110
8	8	8	?	16	8

FLOW CONTROL

- TO HANDLE CONGESTION & SEQUENCING
- RECEIVER INDICATES WILLINGNESS TO RECEIVE
  - LIKE RESERVATION FOR DINNER
- POSITIVE AND NEGATIVE ACKNOWLEDGEMENTS TO RECEIPT
  - SEQUENCE NUMBERS TO HELP KEEP COORDINATED
  - RECYCLE SEQUENCE NUMBERS
- MAY HAVE MULTIPLE OUTSTANDING MESSAGES
  - ESPECIALLY FOR SATELLITE -- 1/4 SEC ROUND TRIP
  - TYPES OF INFO USED:
    - SEQUENCE (THIS FRAME)
    - P/F (POLL OR FINAL)
    - NEXT (ACK RECEIVED UP TO)

DYNAMIC CHANNEL SHARING

- **SATELLITE**
  - MULTIPLEX (TIME OR FREQUENCY)
  - "SLOTTED" ALOHA (PRE-DATES ETHERNET)



    - EACH "SLOT", EITHER SEND OR NO SEND
    - IF SEND, LISTEN FOR COLLISION (270 MS)
    - IF COLLIDE, TRY AGAIN LATER -- BUT WHEN?
    - "BEST ATTAINABLE UTILIZATION" ABOUT 37%
- **SIMILAR FOR SHARED LAN (E.G., ETHERNET)**
- **IEEE 802 STANDARDS**
  - MEDIA ACCESS: CSMA/CD AND TOKEN RING

3. NETWORK LAYER

ROUTE DETERMINATION (TO BE DISCUSSED MORE LATER)

- **VIRTUAL CIRCUIT**
- **vs DATAGRAM**

- E.G., X.25 NETWORK CCITT 3-LAYER PROTOCOL
- -- VIRTUAL CIRCUIT ORIGINALLY

- PROCEDURE
  1. SET UP VIRTUAL CIRCUIT (CALL REQUEST)
     -- RECEIVER ACCEPTS OR REJECTS
  2. IF ACCEPT, SEND DATA PACKETS (FULL-DUPLEX)
  3. TERMINATE BY EITHER PARTY

- EXTENSIONS
  -- DATAGRAM
  -- FAST SELECT (ONE PACKET MESSAGE)

4. TRANSPORT LAYER

- PROVIDE “TRANSPARENT” USER-TO-USER (END-TO-END)

- HANDLE RECOVERY, ETC. TRANSPARENTLY

- EXAMPLE FUNCTIONS:
  CONNUM = CONNECT (LOCAL, REMOTE)
  CONNUM = LISTEN (LOCAL)
  STATUS = CLOSE (CONNUM)
  STATUS = SEND (CONNUM, BUFFER, BYTES)
  STATUS = RECEIVE (CONNUM, BUFFER, BYTES)

- CCITT STANDARD X.25 ADDRESS = 14 DIGITS
  -- 3 = COUNTRY (MAYBE MULTIPLE CODES)
  -- 1 = COUNTRY NET
  -- 10 = NETWORK OPERATOR CHOICE
  (E.G., 5 = HOST #, 5 = USER #)

SYNCHRONIZATION AND MULTIPLEXING ISSUES

- **SYNCHRONIZATION ISSUES:**
  - -- UNEXPECTED MESSAGE RECEIVED
  - -- MULTIPLE PACKETS (DUE TO TIME-OUT & RETRANSMIT)
  - -- CLOSING CONNECTIONS
    (E.G., TWO ARMY DIVISION PROBLEM:
    "YOU ATTACK WHEN YOU GET MY MESSAGE")
  - -- NEED TO HANDLE THESE CASES

- **CONNECTION MULTIPLEXING**
  - -- TO SHARE "VIRTUAL CIRCUIT"
    - FOR EFFICIENCY/COST SAVINGS
      (LIKE SOFTWARE MULTIPLEXING)
  - -- TO USE MULTIPLE "VIRTUAL CIRCUITS"
    - FOR INCREASED TRANSMISSION CAPACITY

5. SESSION LAYER

- PROVIDE PROCESS-TO-PROCESS COMMUNICATION
  (E.G., WEB BROWSER VS. FILE TRANSFER VS. E-MAIL -- SIMULTANEOUS)

6. PRESENTATION LAYER

- TYPICAL ACTIVITIES
  - -- TEXT COMPRESSION & ENCRYPTION (OFTEN AT DATA LAYER)
  - -- CONVERSION
- "VIRTUAL" TERMINAL PROTOCOLS
  - -- MANY TERMINAL DIFFERENCES
  - -- TYPES: SCROLL, PAGE (CURSOR), FORM (E.G. ARPANET TELNET)
  - -- E.G., X-WINDOWS
- FILE TRANSFER PROTOCOLS
  - -- BIT-FOR-BIT OR CONVERTED?
    (E.G. ASCII - > EBCDIC, FLOATING POINT #'s)

7. APPLICATION LAYER

- ELECTRONIC MAIL, WEB BROWSER & OTHERS

<table>
<tr><th>Layer</th><th>ISO</th><th>INTERNET</th><th>SNA</th><th>DECNET</th></tr>
<tr><td>7</td><td>Application</td><td>User</td><td>End user</td><td rowspan="2">Application</td></tr>
<tr><td>6</td><td>Presentation</td><td>Telnet, FTP, Web</td><td>NAU services</td></tr>
<tr><td>5</td><td>Session</td><td rowspan="2"></td><td>Data flow control</td><td rowspan="2"></td></tr>
<tr><td rowspan="2">4</td><td rowspan="2">Transport</td><td>Transmission Control</td><td>Transmission control</td></tr>
<tr><td rowspan="2">Internet Protocol</td><td rowspan="2">Path control</td><td>Network services</td></tr>
<tr><td rowspan="2">3</td><td rowspan="2">Network</td><td rowspan="3">Network Access</td><td>Transport</td></tr>
<tr><td rowspan="2">Data link control</td><td rowspan="2">Data link control</td></tr>
<tr><td>2</td><td>Data link</td></tr>
<tr><td>1</td><td>Physical</td><td>Physical</td><td>Physical</td><td>Physical</td></tr>
</table>

Approximate correspondences between the various networks.

TCP/IP Protocol Architecture

Application layer

Provides communication between applications on separate machines
(e.g., email, file transfer, web browsing)

Transport layer

Provides end-to-end reliable data transfer across multiple networks
(e.g., TCP - Transmission Control Protocol)

Internet layer

Routes data from source to destination through one or more networks
(IP - Internet Protocol)

Network access layer

Manages logical interface between a machine and its local network
(e.g., Ethernet)

Physical Layer

Converts bits to signals and back (e.g., wires, radio, etc.)