

**Unit 01.01.02**

**CS 5220:**

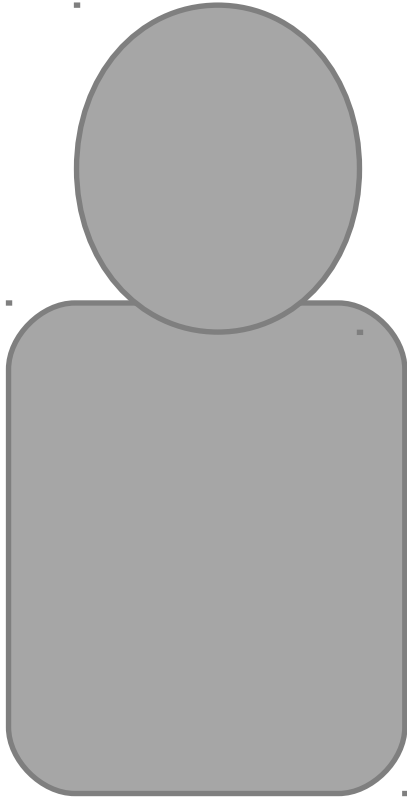
**COMPUTER COMMUNICATIONS**

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## Computer Network Evolution

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# Computer Network Evolution

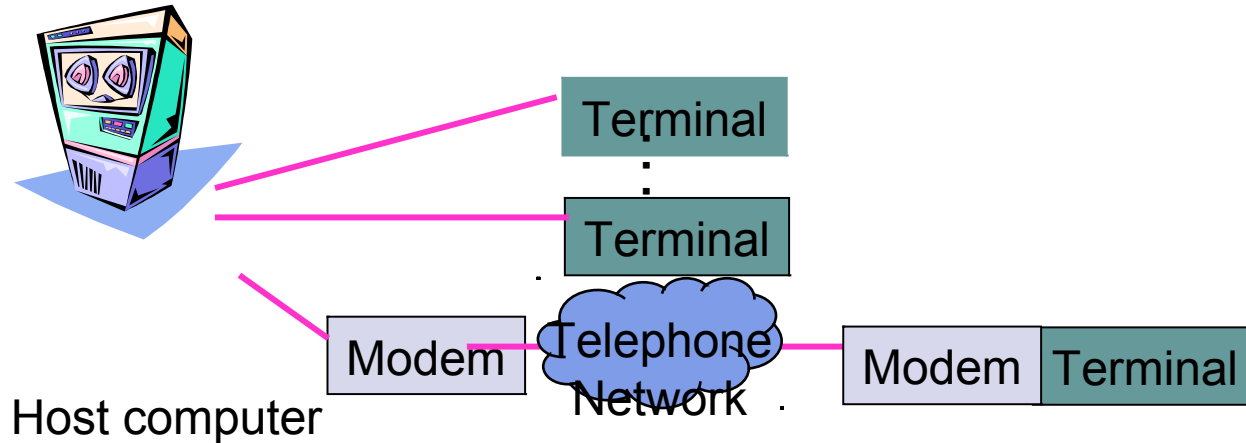


- **1960s:** Terminals access shared host computer
  - SAGE; SABRE airline reservation system
  - Tree-topology terminal-oriented networks
- **1970s:** Computers connect directly to each other
  - ARPANET packet switching network
  - TCP/IP Internet protocols
  - Ethernet local area network
- **1980s - 2000s:** New applications and Internet growth
  - Commercialization of Internet
  - E-mail, file transfer, web, P2P, . . .
  - Internet traffic surpasses voice traffic

# Terminal-Oriented Networks



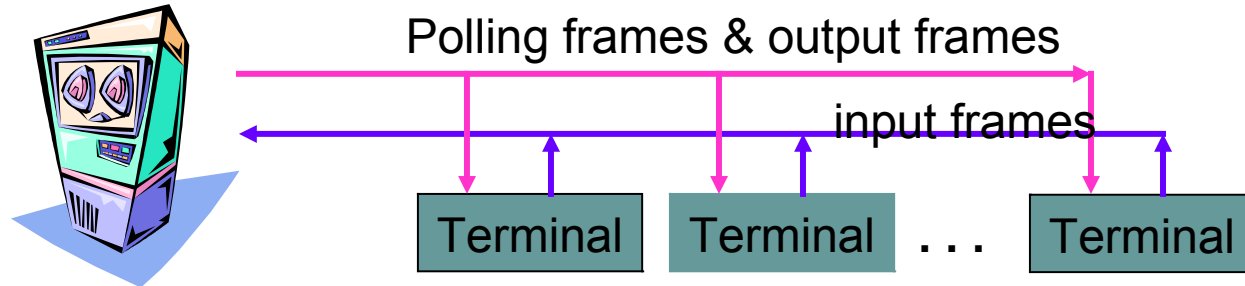
- Early computer systems very expensive; Time-sharing methods allowed multiple terminals to share local computer
- Remote access via telephone modems





# Medium Access Control

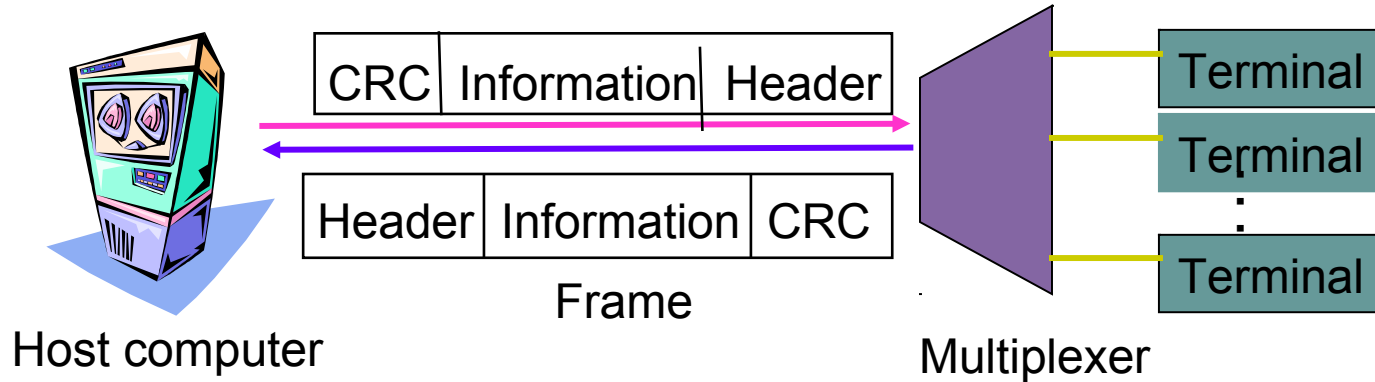
- Dedicated communication lines were expensive
- Terminals generated messages sporadically
- Frames carried messages to/from attached terminals
- Address in frame header identified terminal
- *Medium Access Controls* for sharing a line in **arbitrated** manner
- Example: Polling protocol on a multi-drop line



# Multiplexing



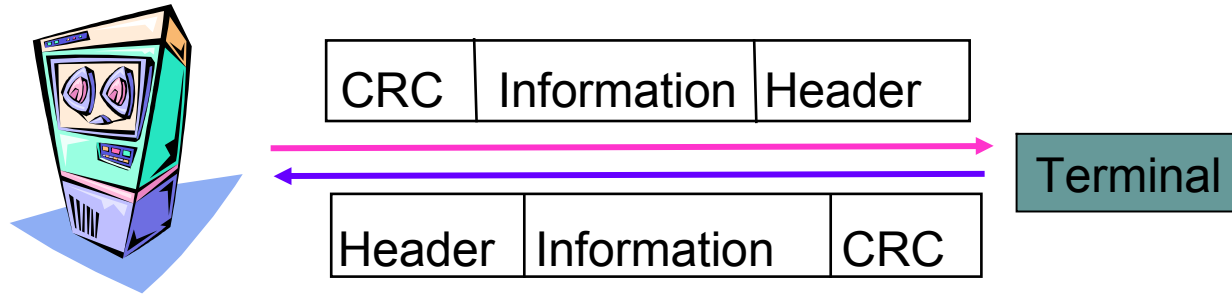
- Multiplexer allows a line to carry *frames* to/from multiple terminals
- Frames are *buffered* at *multiplexer* until line becomes available, i.e. store-and-forward
- Header carries other *control* information for framing

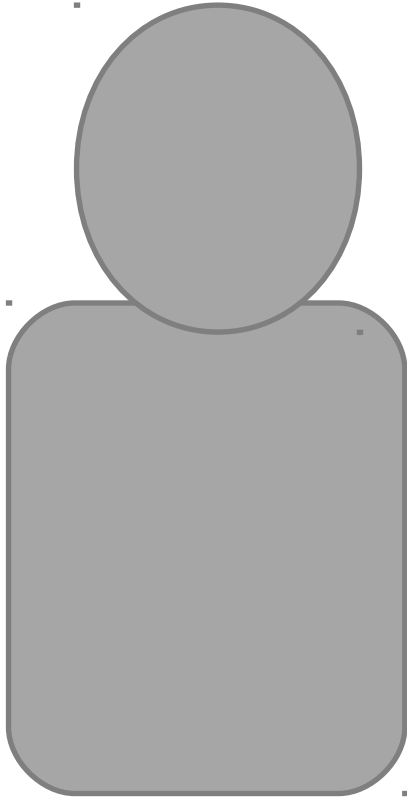




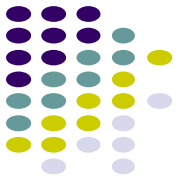
# Error Control Protocol

- Communication lines introduced errors
- Error checking codes used on frames
  - “Cyclic Redundancy Check” (CRC) calculated based on frame header and information payload, and appended
  - Header also carries ACK/NAK control information
- Retransmission requested when errors detected





# Computer-to-Computer Networks



- As cost of computing dropped, terminal-oriented networks viewed as too inflexible and costly
- Need to develop flexible computer networks
  - Interconnect computers as required
  - Support many applications
- Application Examples
  - File transfer between arbitrary computers
  - Execution of a program on another computer

# Packet Switching



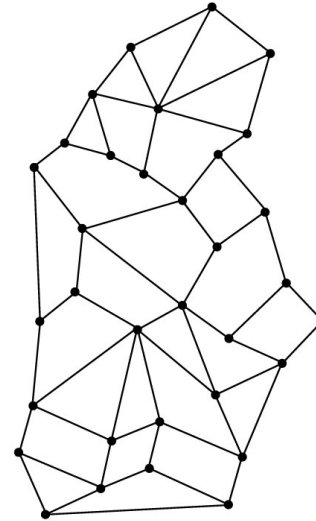
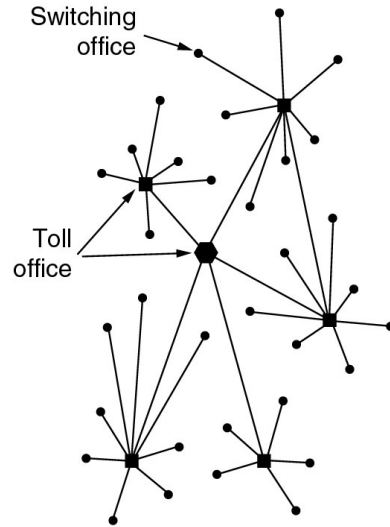
- Network should support multiple applications
  - Transfer arbitrary message size
  - Low delay for interactive applications
  - Store-and-forward operation could induce high delay on interactive messages
- Packet switching introduced
  - Network transfers **packets** using store-and-forward
  - Packets have maximum length
  - Break long messages into multiple packets
  - By switching, packets delivered (and reassembled) at destination



# The ARPANET



- The vulnerability of the telephone system was a concern.



(a) Telephone system structure; (b) Distributed switching system structure



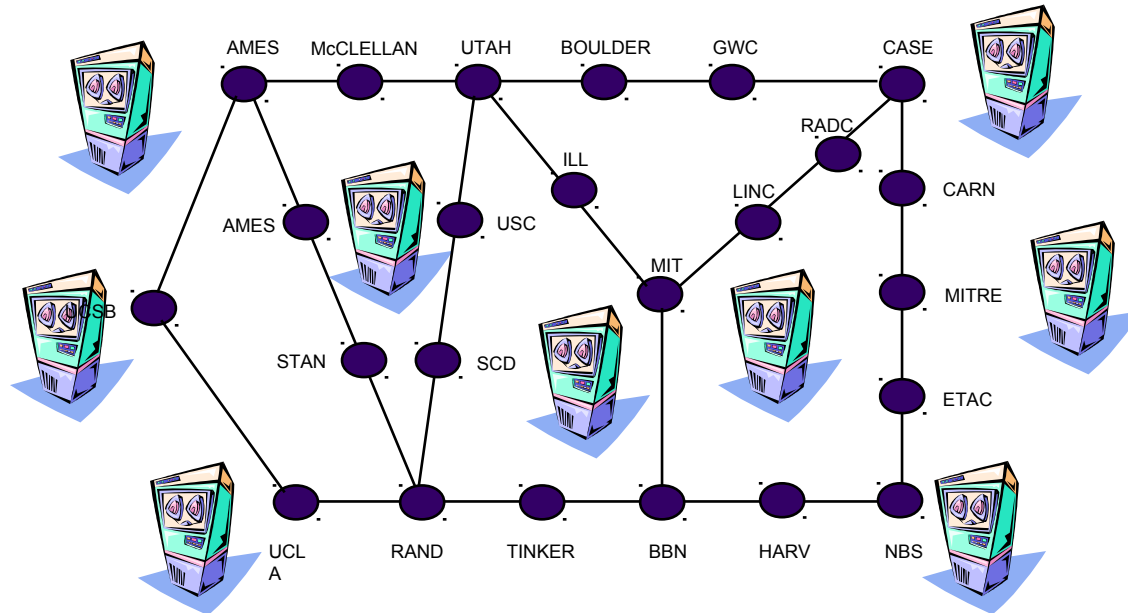
# The ARPANET Design

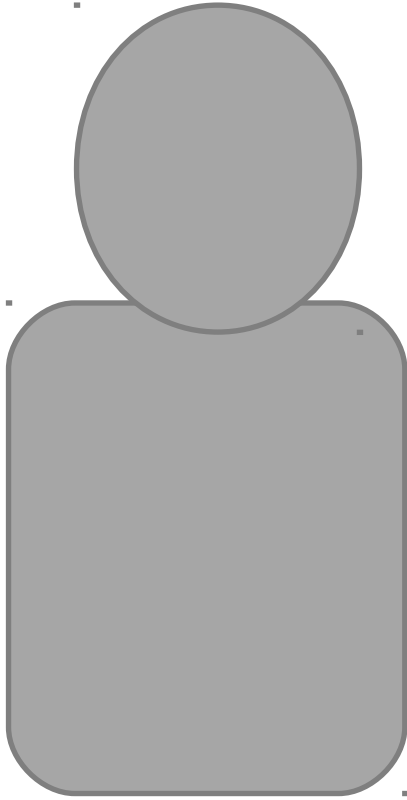
- Connection-less packet transmission
- Packets are encapsulated in frames
- Error control uses check bits
- Destinations identified by unique addresses
- Routing tables at the packet switches
- Messages are segmented into packets
- End-to-end congestion control
- Flow control prevents buffer overflow

# ARPANET Applications



- ARPANET (NSF-NET) introduced new applications
  - Email, remote login, file transfer, ...





# Ethernet Local Area Network



- In 1980s, affordable workstations available
- Need for low-cost, low error rate, high-speed network, possible using coaxial cable
- Broadcasting, medium access control
- Network interface card with a unique address
- Ethernet is the standard for high-speed wired access to computer networks

# Summary of the Lesson



- Services and Applications drive network architecture design