Computer Networks: LANs, WANs The Internet

Required reading: Garcia 1.1 and 1.2

CSE 3213, Fall 2010
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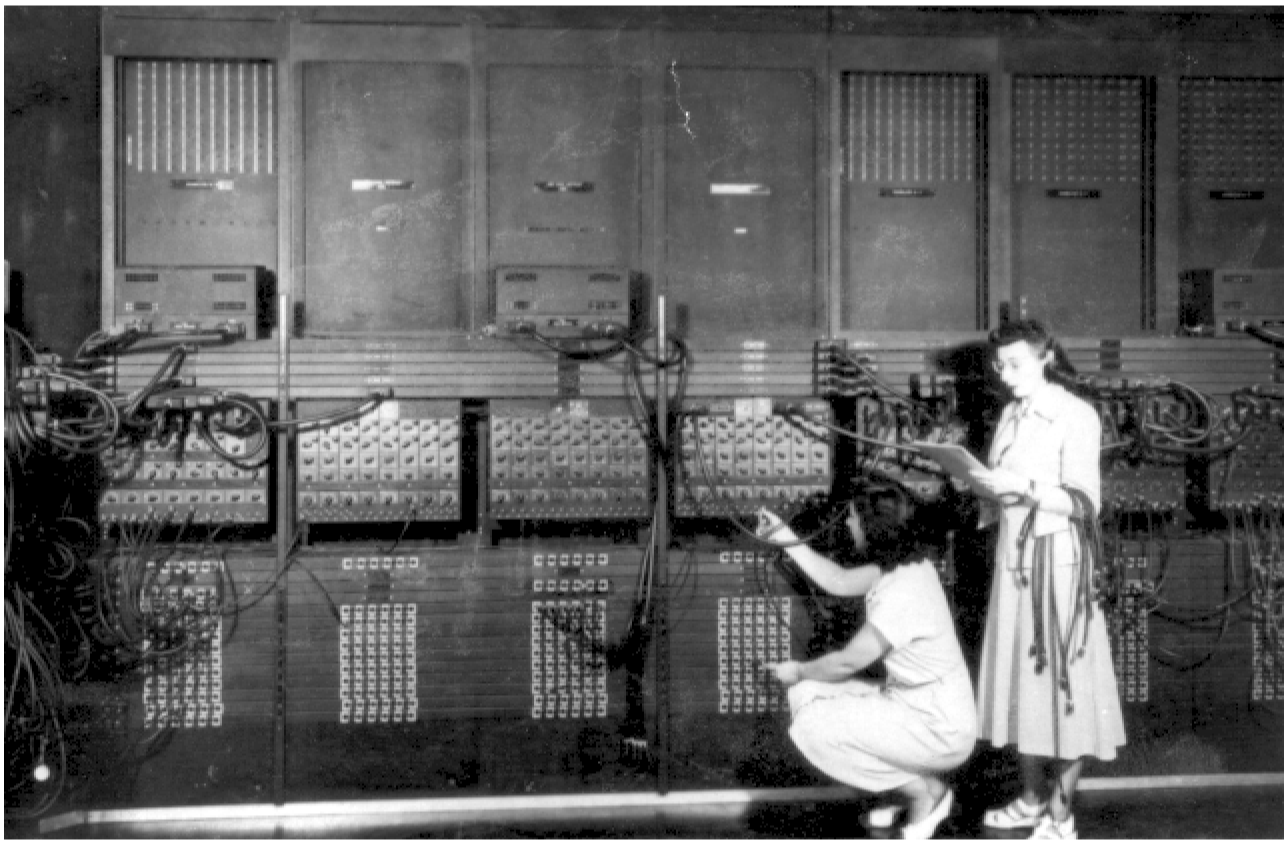
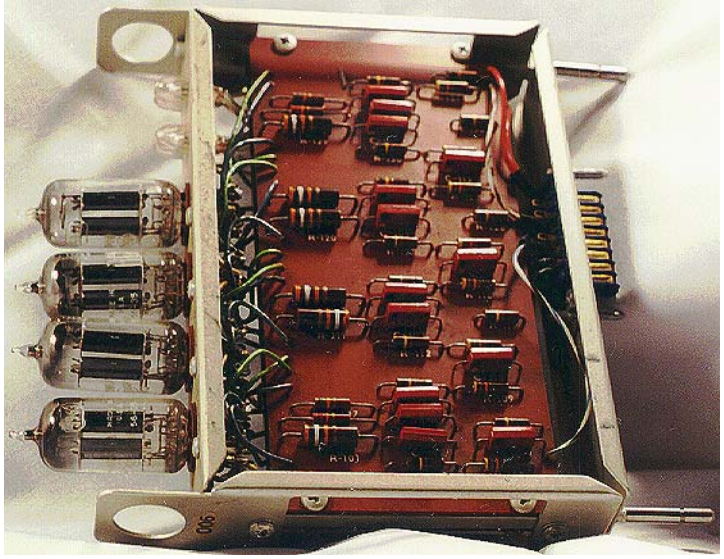
History of Computers

Computer – **a machine that manipulates data according to a set of instructions**



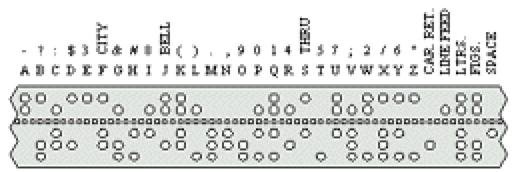
Eniac – the first modern electronic computer. (1950s)

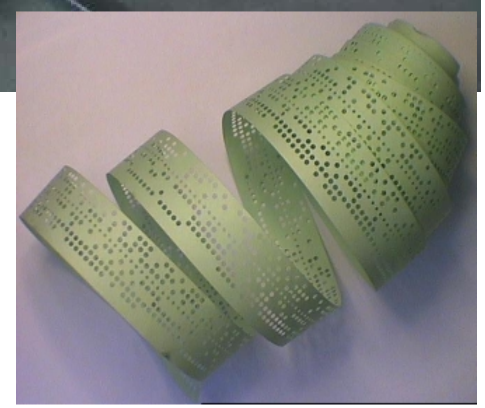
http://ftp.arl.army.mil/ftp/historic-computers/gif/eniac4.gif



“Four dual triodes are used to count and store the 4 bits needed to represent a decimal digit. “

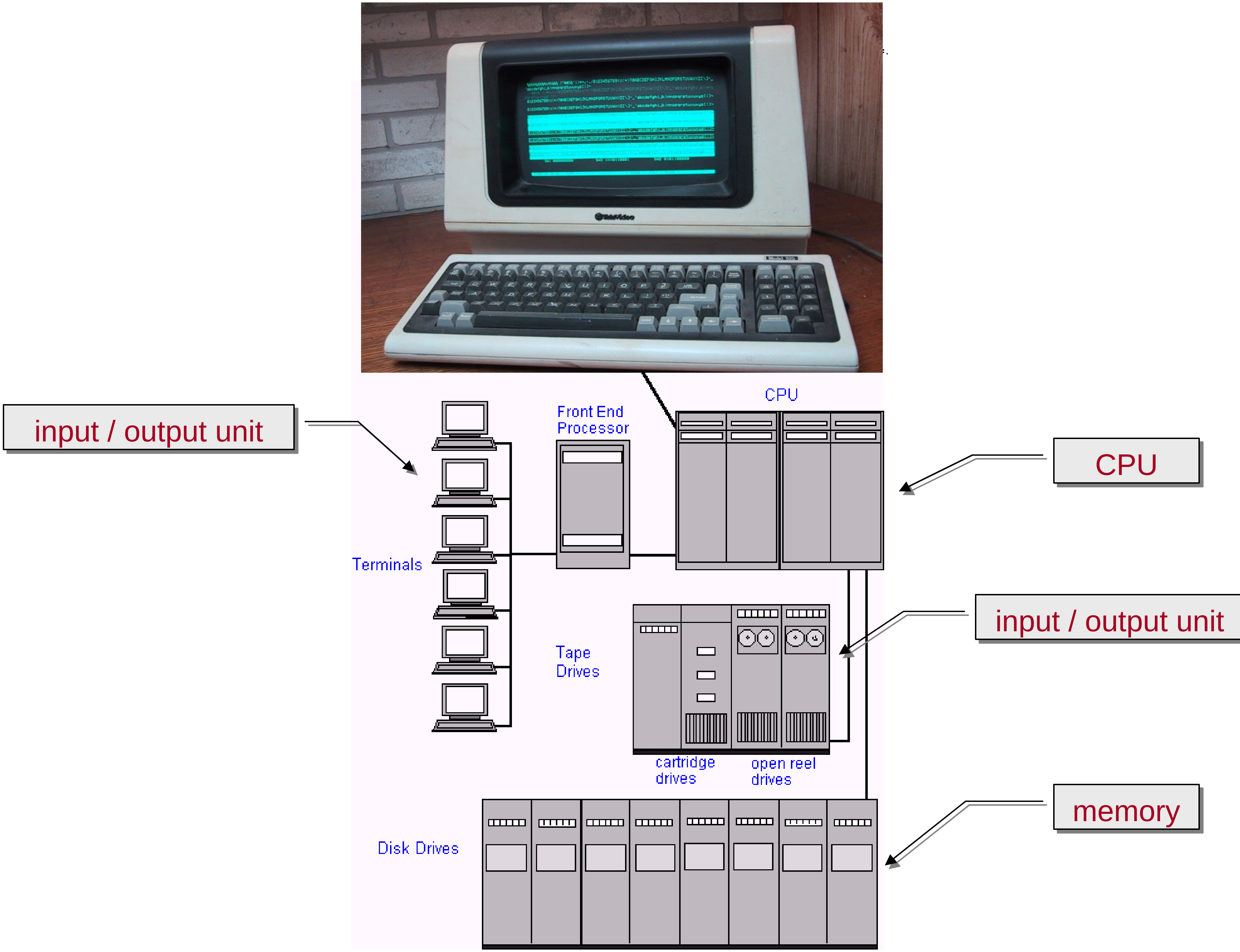
www.cs.virginia.edu/brochure/museum.html





“A teletype was a motorized typewriter that could transmit your keystrokes to the mainframe and then print the computer's response on its roll of paper. You typed a single line of text, hit the carriage return button, and waited for the teletype to begin noisily printing the computer's response (at a whopping 10 characters per second). On the left-hand side of the teletype in the prior picture you can observe a paper tape reader and writer (i.e., puncher).”

www.computersciencelab.com/ComputerHistory/HistoryPt4.htm



http://www.answers.com/topic/mainframe?cat=biz-fin

History of Computer Networks

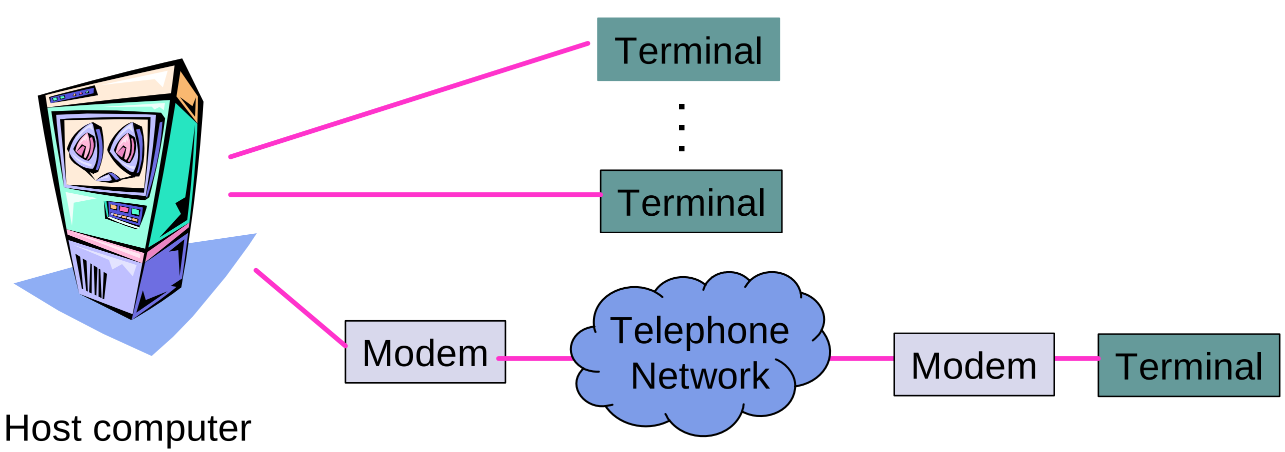
1950s - 1960s:	**Terminal-Oriented Computer Networks**
1960s – 1970s:	**Computer-to-Computer Networks:** **the ARPANET – first Wide Area Network (WAN)**
1980s:	**Local Area Networks (LANs)**
1980s:	**The Internet**

most superior telecommunication network

Terminal-Oriented Computer Networks

Terminal-Oriented Computer Networks of 1960s and 1970s

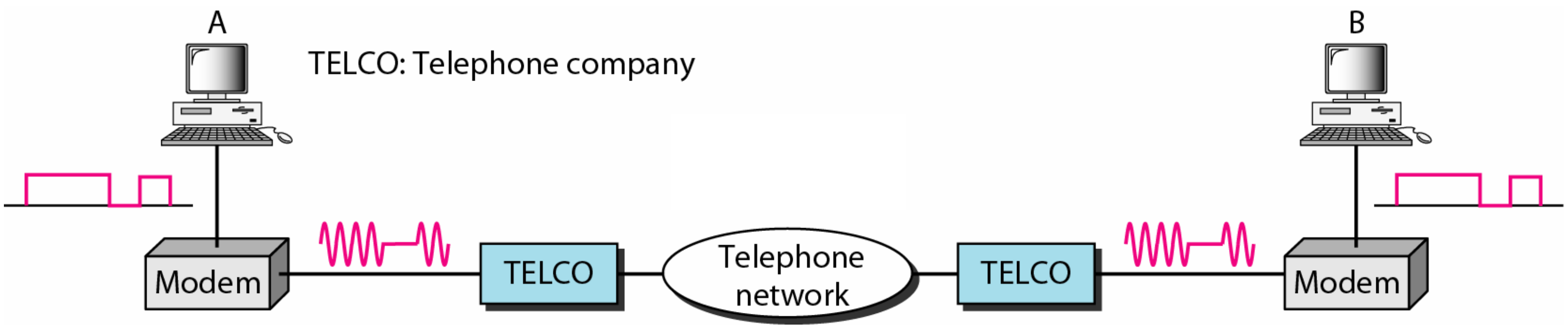
- early computers were extremely expensive, so **time-sharing techniques** were developed to allow them to be shared by many users
- through use of **video terminals** multiple users were able to simultaneously input instructions and obtain results from the host computer
- **modem devices*** further enabled that terminals reach the host computer via telephone network, over a grater distance



(*) modem – device for sending digital data over phone line / analog network

Terminal-Oriented Computer Networks (cont.)

Example **[modulation / demodulation]**

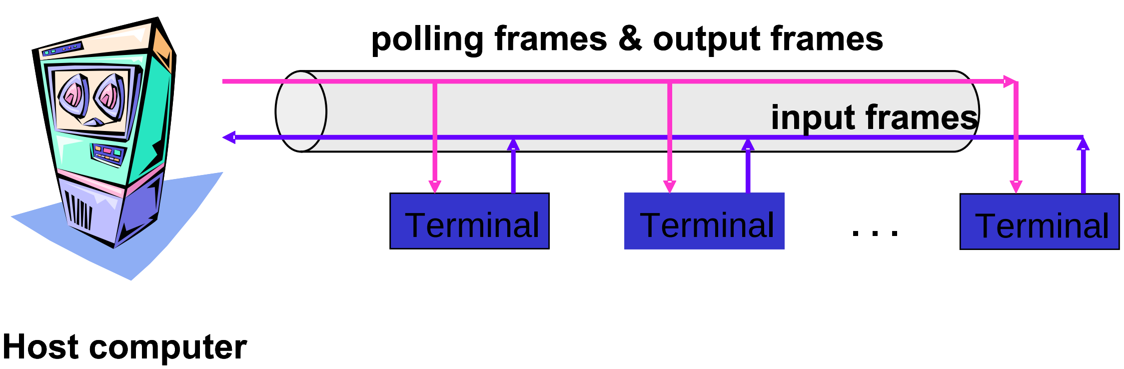


Terminal-Oriented Computer Networks (cont.)

Line Sharing Challenges:

- in a mainframe system, a large number of terminals had to be connected to a central computer
- cost of providing individual lines to each terminal was prohibitive
- line sharing was more practical, but - how to chare a commonmedium in manner that is:
  - **fair** – each machine gets a chance to send, long waits prevented
  - **orderly** – packets from each machine can be properly assembled and reassembled
  - **error-free** – recognize erroneous packets/data

Line-sharing challenges:
- medium access control
- framing
- addressing
- error control

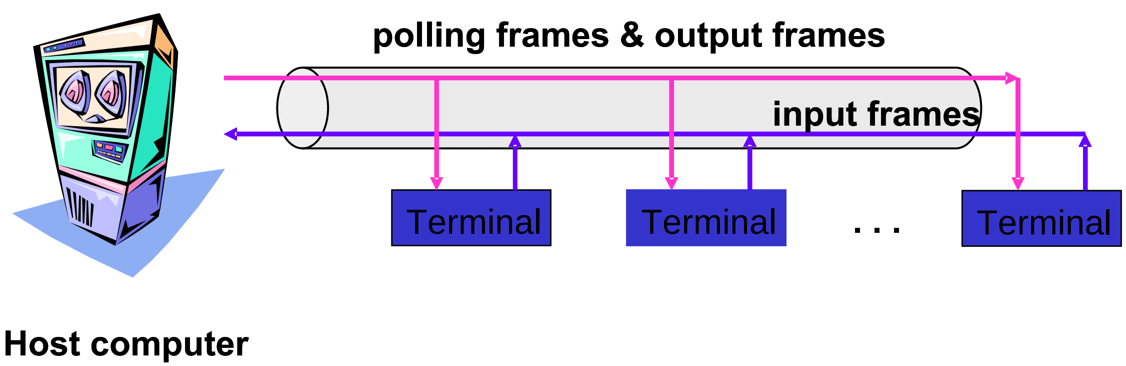


Terminal-Oriented Computer Networks (cont.)

Line Sharing Challenges:

Medium Access Control, Frame-ing, Addressing

- **medium access control** methods allowed a number of terminals to communicate with central computer using a shared comm. line
  - **example**: **polling protocol**
- line sharing required that messages be partitioned into **frames** (header + data)
- frames / headers had to carry '**address**' to identify receiving terminal



Terminal-Oriented Computer Networks (cont.)

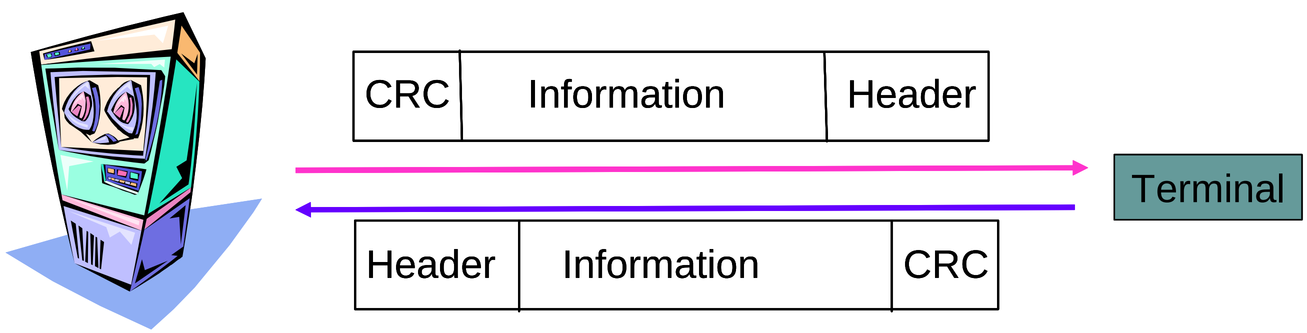
Frame-based Error Control Techniques

- communication lines and analog switching equipment introduced errors in transmission
- error-control techniques were developed to ensure error-free communication
- example: Cyclic Redundancy Check (CRC) algorithm – an error-detection scheme

  (1) CRC is calculated based on frame header and payload

  (2) CRC is appended to frame

  (3) if receiver detects error, retransmission is requested
- some error-control techniques attempt to send enough redundant info to enable both error-detection and error-correction



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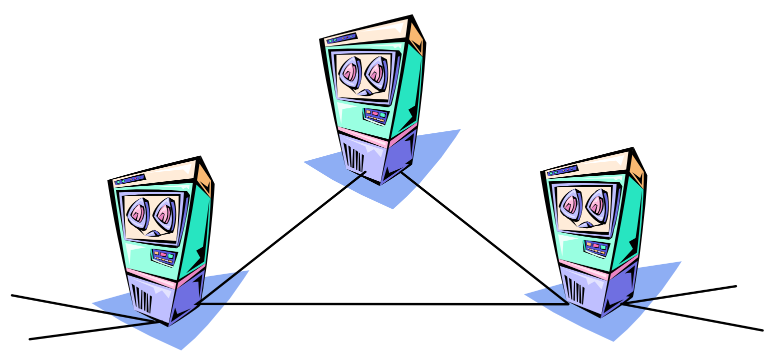
1980s:	Local Area Networks (LANs)
1980s:	The Internet

Computer-to-Computer Networks

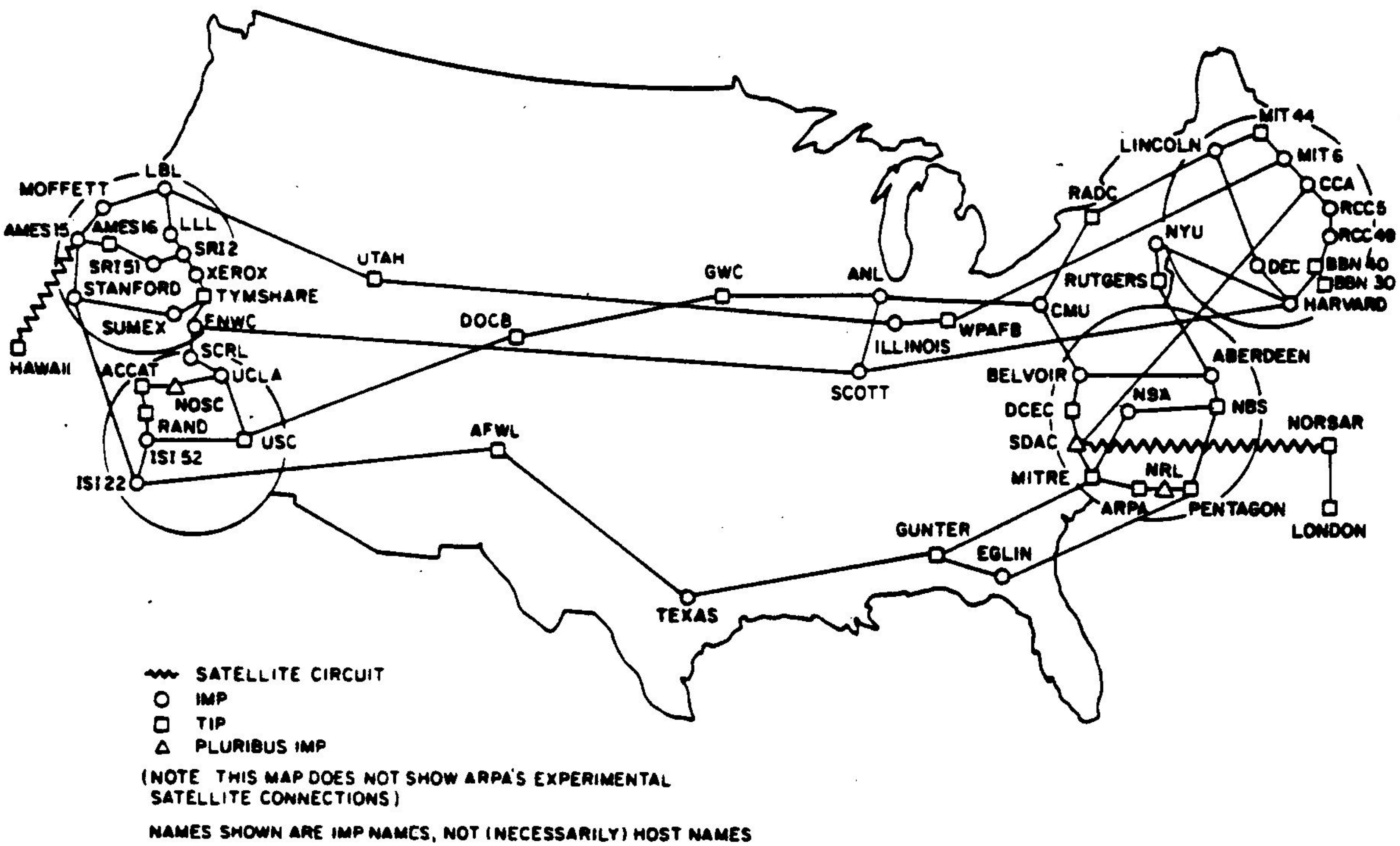
Computer-to-Computer Networks

- as cost of computers dropped and new applications emerged, it became necessary to enable mainframe computers (not terminals!) to interconnect and communicate over long geographic distances
- application examples:
  - file transfer between computers
  - multiprocess operation over multiple computers
- ARPANET (1960s) - 1st major effort at developing a network to interconnect computers over a wide geographic area – first major WAN
- Internet (1970s) - emerged from ARPANET – network of interconnected networks



Computer-to-Computer Networks (cont.)

Example [ARPANET in 1977]

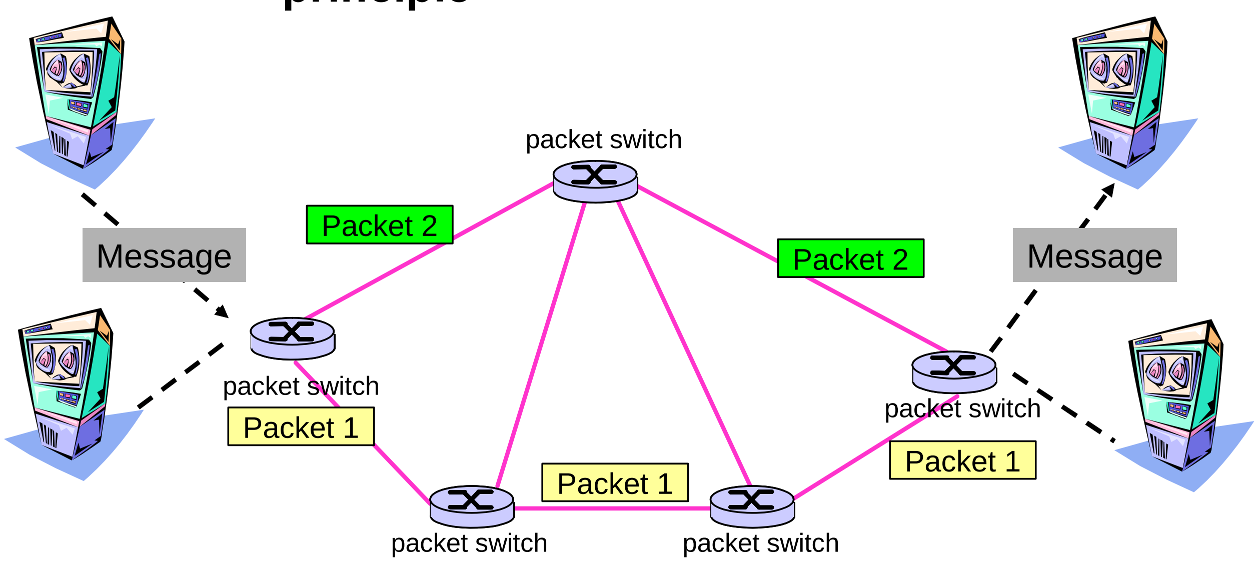


http://som.csudh.edu/cis/lpress/history/arpamaps/f15july1977.jpg

Computer-to-Computer Networks (cont.)

ARPANET: Architecture

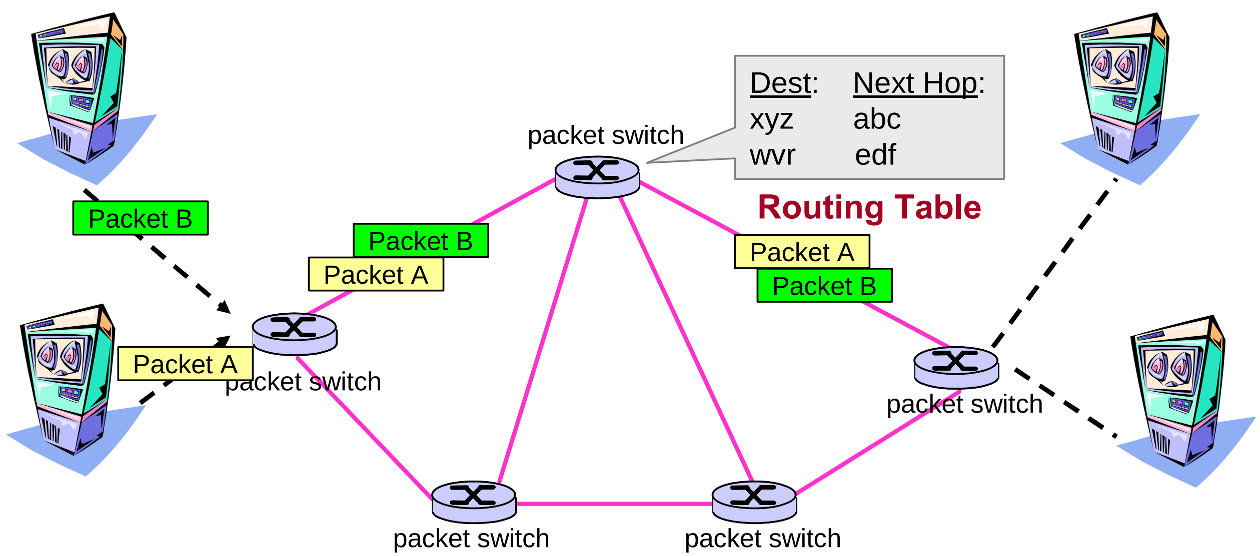
- **network core consists of packet switches (dedicated minicomputers) to avoid costly full mesh topology**
  - **each packet switch connects to at least two other switches to provide alternative paths in case of failure**
- **network transfer messages by breaking them into packets of fixed size**
  - **long messages ⇒ long delays & higher prob. of error**
  - **each packet has a header with destination address – packets are transmitted independently !!!**
- **network transfers packets using "store and forward" principle**



Computer-to-Computer Networks (cont.)

ARPANET: Routing

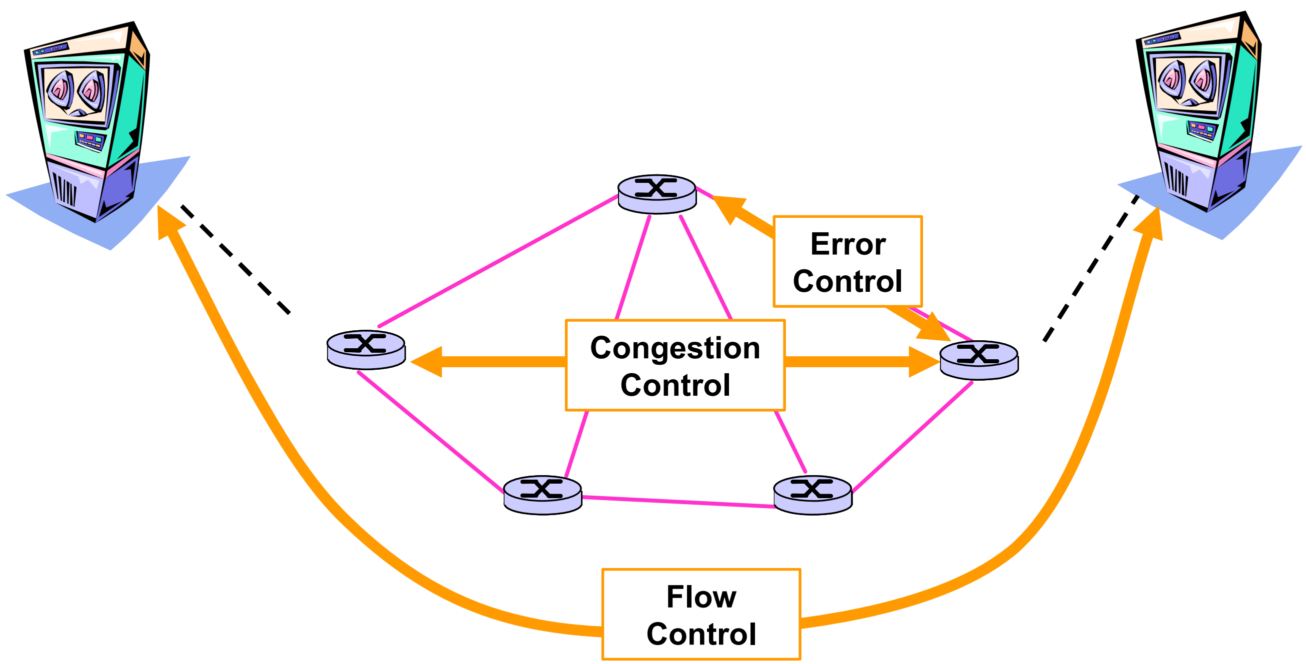
- **each packet switch contains routing / forwarding tables** (‘next hop per destination’ tables)
  - **each packet contains destination address ⇒ packet switch looks at routing table and forwards packet in right direction**
- **connectionless service**
  - **no connection setup is required prior to packet transmission**
  - **packets are buffered at packet switches to await transmission on appropriate link**
  - **packets from different users are multiplexed on links between packet switches**



Computer-to-Computer Networks (cont.)

ARPANET:
Other Challenges!

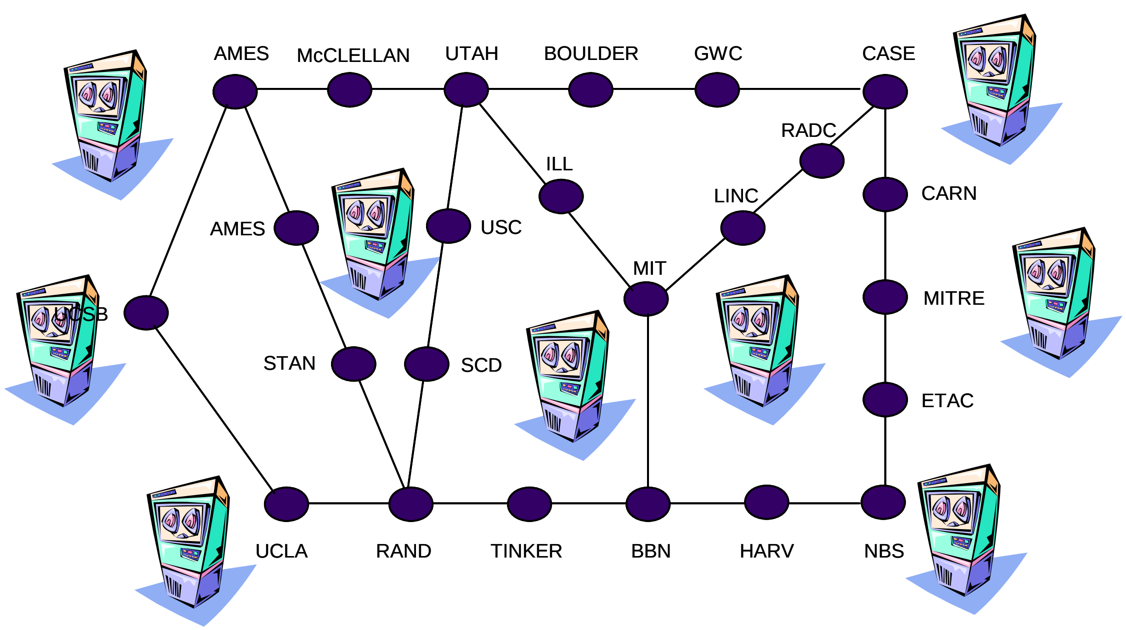
- **error control <u>between adjacent packet switches</u> enables faster error recovery**
  - **partial responsibility of IP protocol**
- **congestion control inside the network prevents buffer overflow at core packet switches**
- **end-to-end flow control prevents buffer overflow at receiver / sender**
  - **responsibility of TCP protocol**



Computer-to-Computer Networks (cont.)

ARPANET: Applications

- **"dumb core, intelligent edges" enabled development of many interesting and useful applications: e-mail, file transfer (FTP), remote login (Telnet)**
  - **dumb core – packet switches are only required / capable of packet forwarding**
  - **intelligent edges – end-devices have considerable CPU and memory capabilities**



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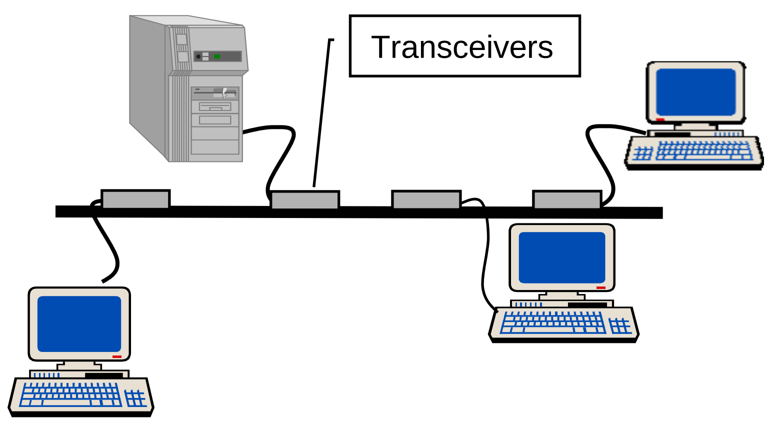
Local Area Networks

LAN History

- in 1980s affordable computers become available
- subsequently, need for low-cost, high-speed, and low error-rate networks arose
  - to interconnect local workstations over small radius < 1km
  - to enable sharing of local resources (printers, servers, etc.)
- complex packet switching, congestion and flow control were unnecessary
- variety of LAN topologies emerged, including: bus, ring

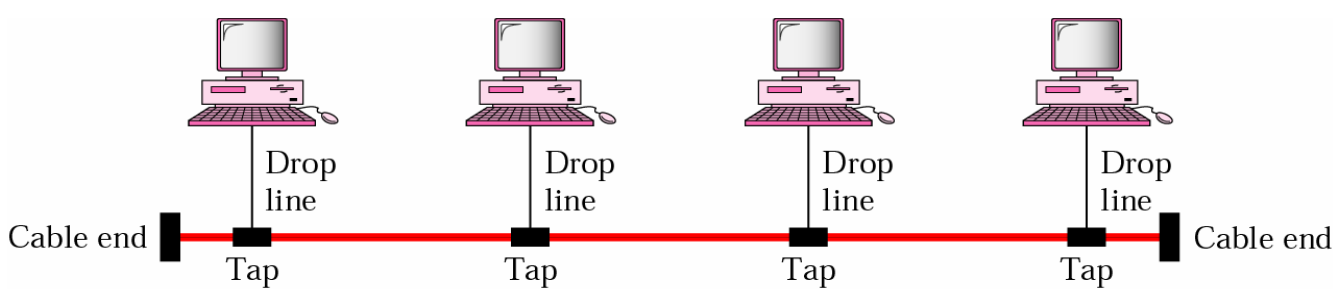


Local Area Networks (cont.)

Bus Topology (Ethernet)

– **one long cable, so-called backbone, links all devices in the network** – **similar to single-line mainframe architecture**

- **each workstation connects to backbone through Network Interface Card (NIC); each NIC has globally unique address**
- **data frames are broadcast into coaxial cable**
- **receive: NIC listens to medium for frames with its address**
- **send: NIC listens to medium for presence of ongoing transmission – if no transmission is found, send frame**
- **collision: if frame collides with somebody else's frame, abort transmission and retry later**



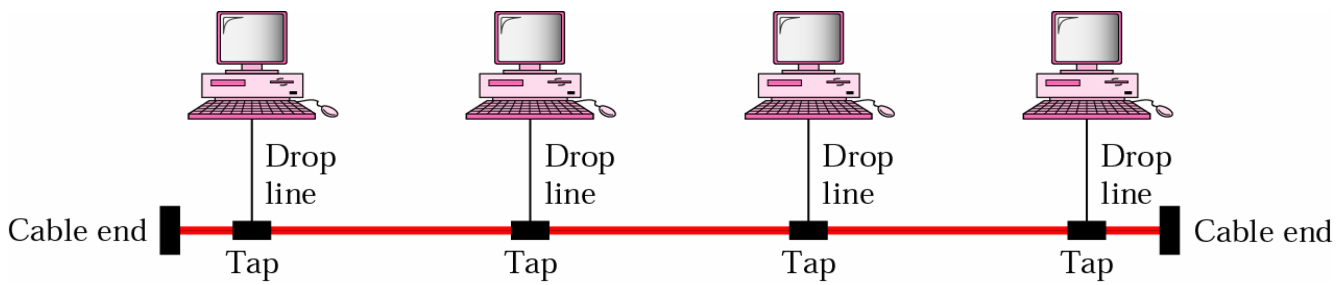
Local Area Networks (cont.)

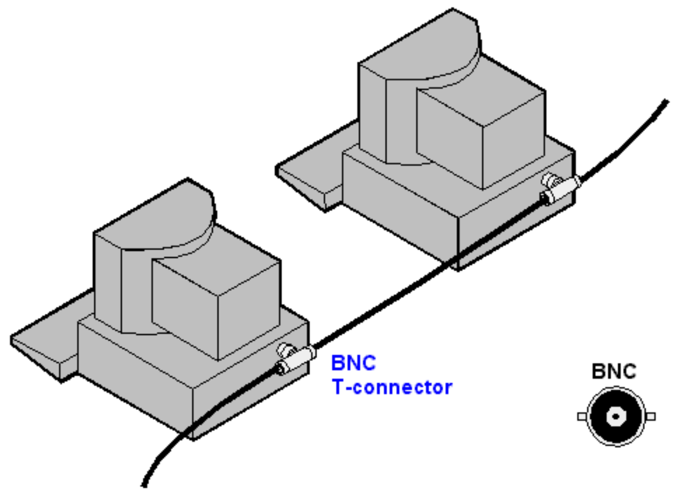
Bus Topology (Ethernet)

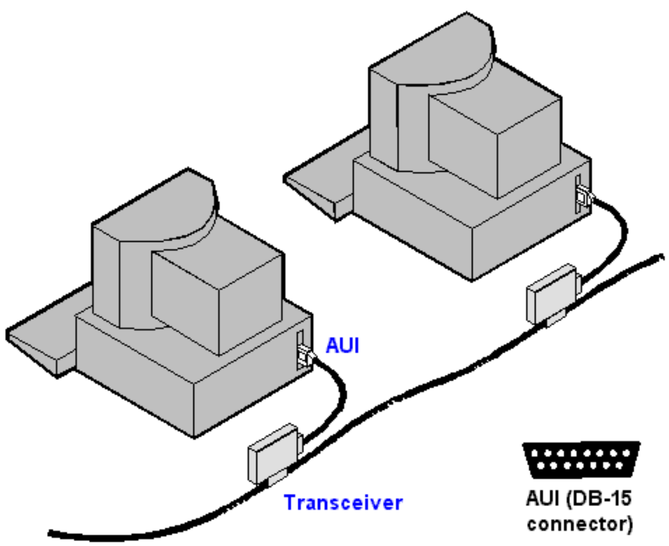
- **advantages**: simple & inexpensive installation
- **disadvantages**: 1) backbone = single point of failure

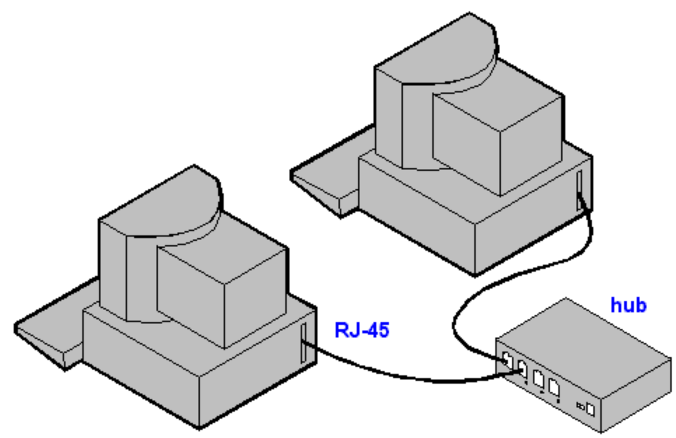
  2) collisions ⇒ diminishing capacity

  - if two or more devices transmit simultaneously their signals will interfere




BNC
T-connector
BNC

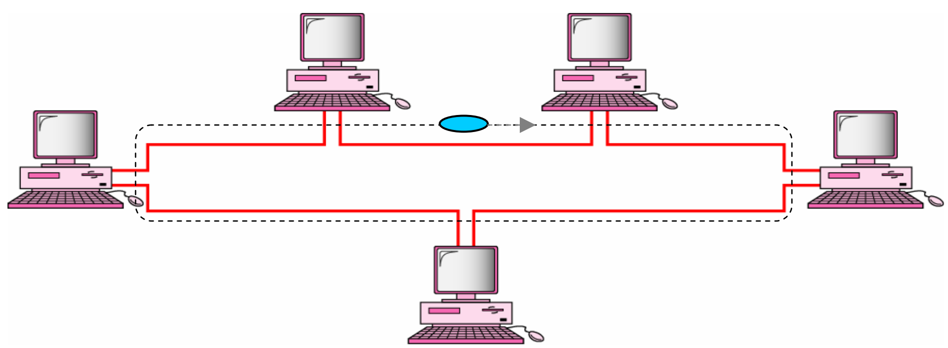

AUI
Transceiver
AUI (DB-15
connector)


hub
RJ-45

Local Area Networks (cont.)

Ring Topology – each device has a dedicated point-to-point connection only with the two devices on either side of it

- a small frame – **token** – circulates around the ring; only the station that possesses the token is allowed to transmit at any given time
- signal is passed along the ring in one direction, from device to device, until it reaches its destination
- **advantages**:
- **disadvantages**:



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The Internet

Internet = Internetwork – two or more interconnected networks – network of networks

The Internet: Past

- LANs that emerged in 1970s were different in terms of their underlying technology and operation
- a **protocol that would enable communication across multiple dissimilar networks** was needed
  - “higher level of abstraction” protocol
- **Internet Protocol** / **Addressing** were soon developed and enabled creation of a single global internetwork

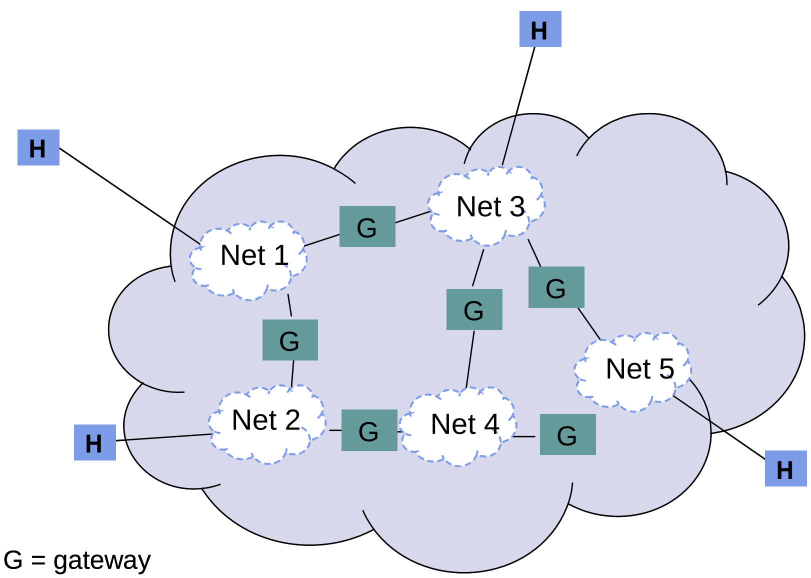
The Internet: Present

- spread over 200 countries
- made up of 100,000s of interconnected networks, 10,000,000s of interconnected hosts, and 100,000,000s of users
- still grows exponentially …

The Internet (cont.)

IP Network = the Internet

- **each component network must contain special packet switch, gateway / router, through which it interconnects with rest of the Internet**
- **host computers place data in IP packets (data + IP header) and deliver them to nearest router**
- **router, with help of other routers, attempts to forward packet across the Internet**
- **"best effort service" – IP provides no mechanism to deal with packet loss, corruption, reordering**



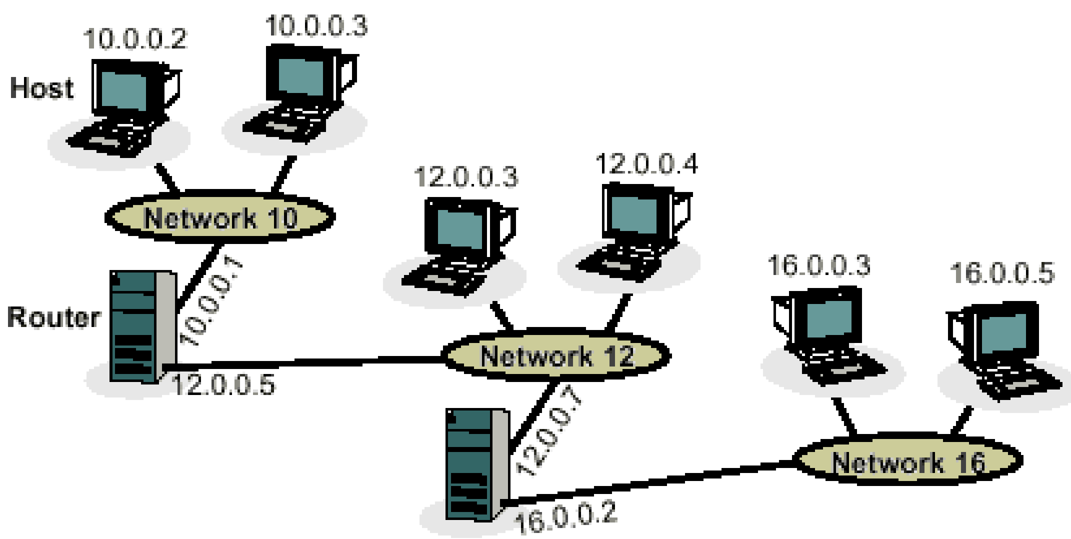
G = gateway
H = host

The Internet (cont.)

IP Addressing

- **addressing scheme that fits (inter)network structure:**
  IP address = Net ID + Host ID

- **IP packets are routed only based on Net ID in destination IP address**
  - **routers have to know only major networks, not every single host ⇒ less memory / network update requirements**
  - **smaller routing tables ⇒ faster routing**



The Internet (cont.)

Network Card – from Wikipedia …

Network card - Wikipedia, the free encyclopedia - Microsoft Internet Explorer

Address http://en.wikipedia.org/wiki/Network_card

Sign in / create account

article | discussion | edit this page | history

Network card

From Wikipedia, the free encyclopedia

For the discount card available for rail travel in South East England, previously called the "Network Card", see Network Railcard.

A **network card**, **network adapter**, **LAN Adapter** or **NIC** (network interface card) is a piece of computer hardware designed to allow computers to communicate over a computer network. It is both an OSI layer 1 (physical layer) and layer 2 (data link layer) device, as it provides physical access to a networking medium and provides a low-level addressing system through the use of MAC addresses. It allows users to connect to each other either by using cables or wirelessly.

Although other network technologies exist, Ethernet has achieved near-ubiquity since the mid-1990s. Every Ethernet network card has a unique 48-bit serial number called a MAC address, which is stored in ROM carried on the card. Every computer on an Ethernet network must have a card with a unique MAC address. No two cards ever manufactured share the same address. This is accomplished by the Institute of Electrical and Electronics Engineers (IEEE), which is responsible for assigning unique MAC addresses to the vendors of network interface controllers.

Whereas network cards used to be expansion cards that plug into a computer bus, the low cost and ubiquity of the Ethernet standard means that most newer computers have a network interface built into the motherboard. These either have Ethernet capabilities integrated into the motherboard chipset, or implemented via a low cost dedicated Ethernet chip, connected through the PCI (or the newer PCI express bus). A separate network card is not required unless multiple interfaces are needed or some other type of network is used. Newer motherboards may even have dual network (Ethernet) interfaces built-in.

The card implements the electronic circuitry required to communicate using a specific physical layer and data link layer standard such as Ethernet or token ring. This provides a base for a full network protocol stack, allowing communication among small groups of computers on the same LAN and large-scale network communications through routable protocols, such as IP.

There are four techniques used to transfer data, the NIC may use one or more of these techniques.

Network Card

A 1990s Ethernet network interface controller card which connects to the motherboard via the now-obsolete ISA bus.

Connects to:
- *Motherboard* via one of
  - Integrated
  - PCI Connector
  - ISA Connector
  - PCI-E
- *Network* via one of
  - Fast Ethernet
  - Gigabit Ethernet
  - Optical fiber
  - Token ring

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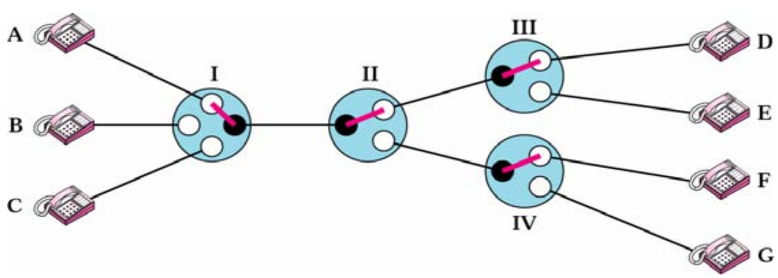
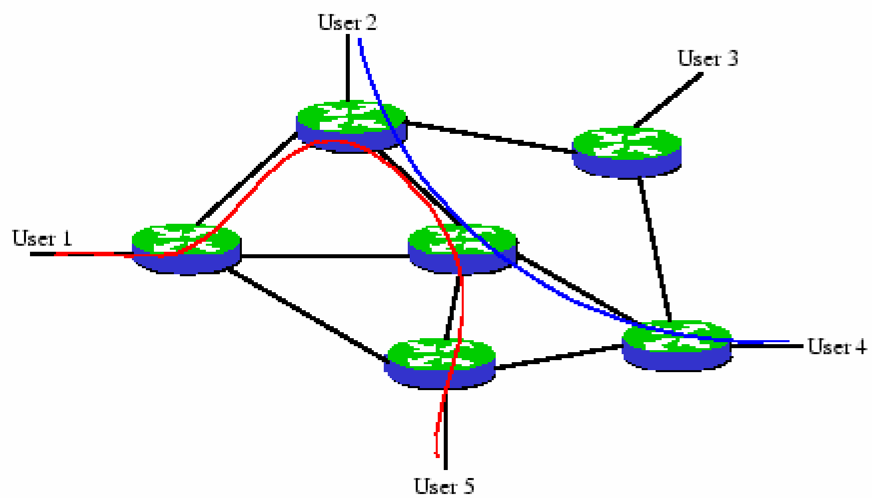
Circuit vs. Packet Switching

Circuit-Switched Networks
(telephone networks)





Advantages

- **guaranteed Quality of Service** – data is transmitted at fixed (guaranteed) rate; delay at nodes is negligible

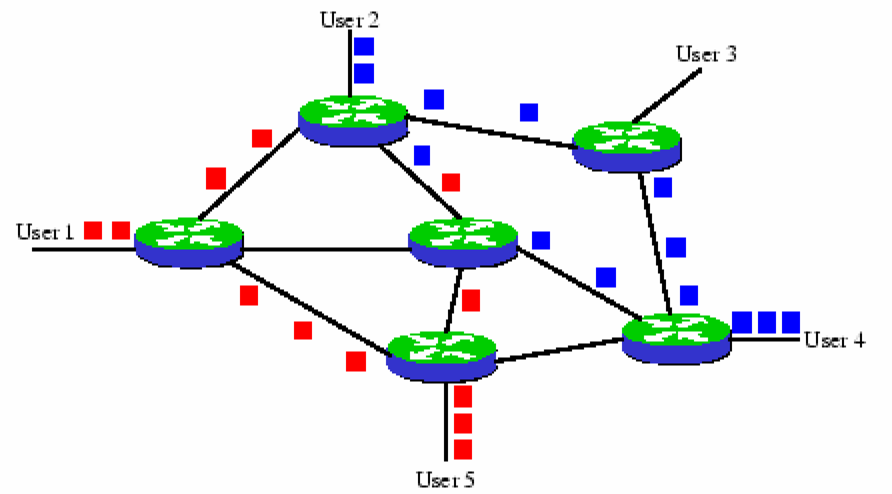
Disadvantages

- **circuit establishment delay** – circuit establishment introduces 'initial delay'
- **inefficient use of capacity** – channel capacity is dedicated for the duration of a connection, even if no data is being transferred (e.g. silent periods in speech)
- **network complexity** – end-to-end circuit establishment and bandwidth allocation requires complex signaling software to coordinate operation of switches

Circuit vs. Packet Switching (cont.)

Packet-Switched Networks

(the Internet)



Advantages

- **greater line efficiency – network links are dynamically shared by many packets / connections**
- **no blocked traffic – packets are accepted even under heavy traffic, but delivery delay may increase**

Disadvantages

- **variable delay – each node introduces additional variable delay due to processing and queueing**
- **overhead – to route packets through a packet-switching network, overhead information including the address of destination and/or sequence information must be added to each packet**