

HISTORY OF THE INTERNET

Notes prepared for EEDG/CE 6345

by

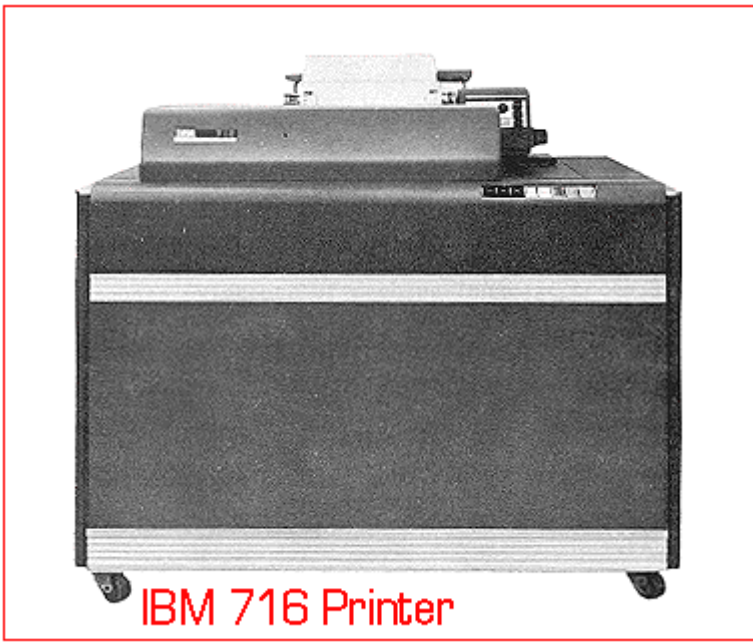
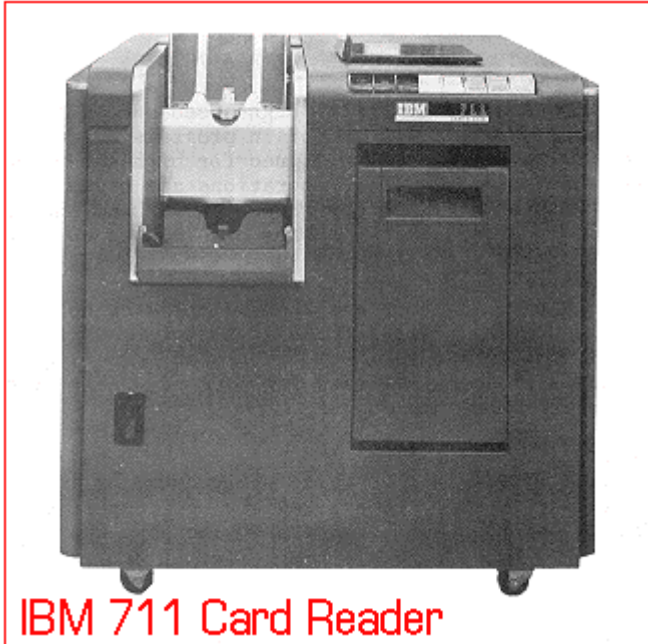
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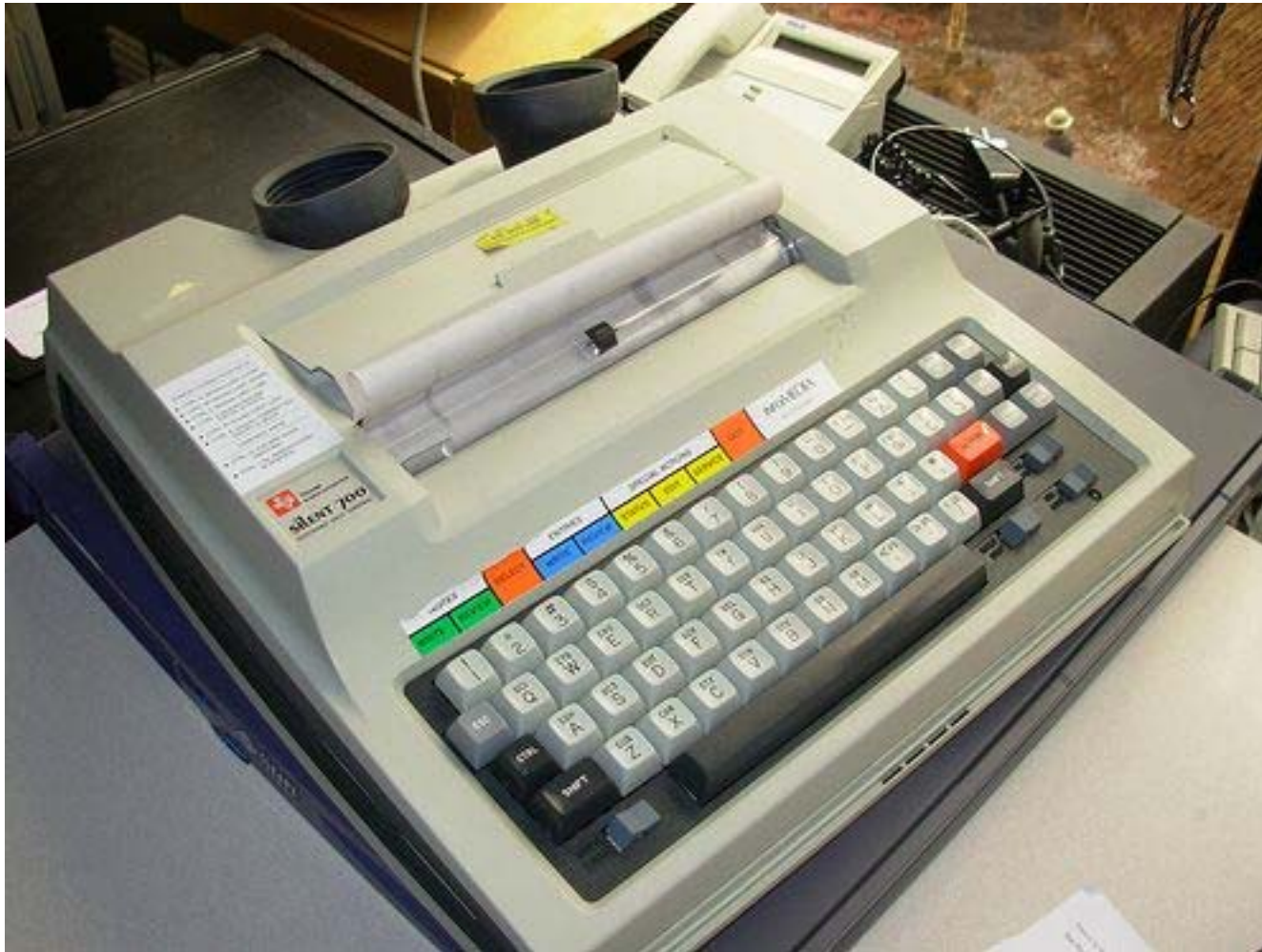
TIME-SHARING SYSTEMS (1)

- ARPA-funded work beginning in 1962–3 that led to an early data network
 - ▷ Interactive computing and time-sharing
 - Intended to replace batch processing
 - ◇ Cards in, paper out, only one job running at a time
 - In time-sharing, each user
 - ◇ sat at a terminal,
 - ◇ typed in his/her own program,
 - ◇ ran it, and
 - ◇ saw the results almost immediately on a CRT screen
 - Multiple jobs appeared to be running simultaneously
 - ◇ Origin of multitasking
 - ▷ The network was a “star” of wireline links between dumb terminals and a mainframe computer

I/O IN THE DAYS OF BATCH PROCESSING



TERMINAL-BASED I/O: TI SILENT 700 SERIES



TIME-SHARING SYSTEMS (2)

- J. C. R. Licklider
 - ▷ Originated the “Galactic Network” concept
 - A globally interconnected set of computers through which everyone could quickly access data and programs from any site
 - ▷ Headed the ARPA Information Processing Techniques Office (IPTO) after October 1962
 - ▷ Funded the Compatible Time-Sharing System (CTSS)
- Attempts to maximize the usable length of mainframe-terminal links
 - ▷ Users didn’t have to be in a room next to the mainframe
 - ▷ Most widely installed network: The telephone system
 - Need for improved data throughput over telephone lines
- Cooperative network of time-shared computers
 - ▷ Study carried out at MIT Lincoln Laboratory under Lawrence Roberts (1966); evolved into the ARPANET plan

PACKET-SWITCHED NETWORKS

- Leonard Kleinrock, 1961
 - ▷ “Information Flow in Large Communication Nets” — Ph.D. proposal
 - ▷ First paper on packet-switched networks
- Paul Baran, RAND Corp., 1960–4
 - ▷ Highly interconnected network \Rightarrow highly survivable network
 - No single point of failure
 - No small set of points of failure
 - ▷ Store-and-forward switching *vs.* circuit switching
 - ▷ Localized (not centralized) control of switching \Rightarrow routing
 - ▷ Use of intermediate switching points to eliminate requirement for full connectivity
- The term “packet” originated in a 1966 paper by Donald Davies and Roger Scantlebury of the National Physical Laboratory (NPL), U.K.
 - ▷ The experimental NPL packet-switching network used 768 kb/s lines

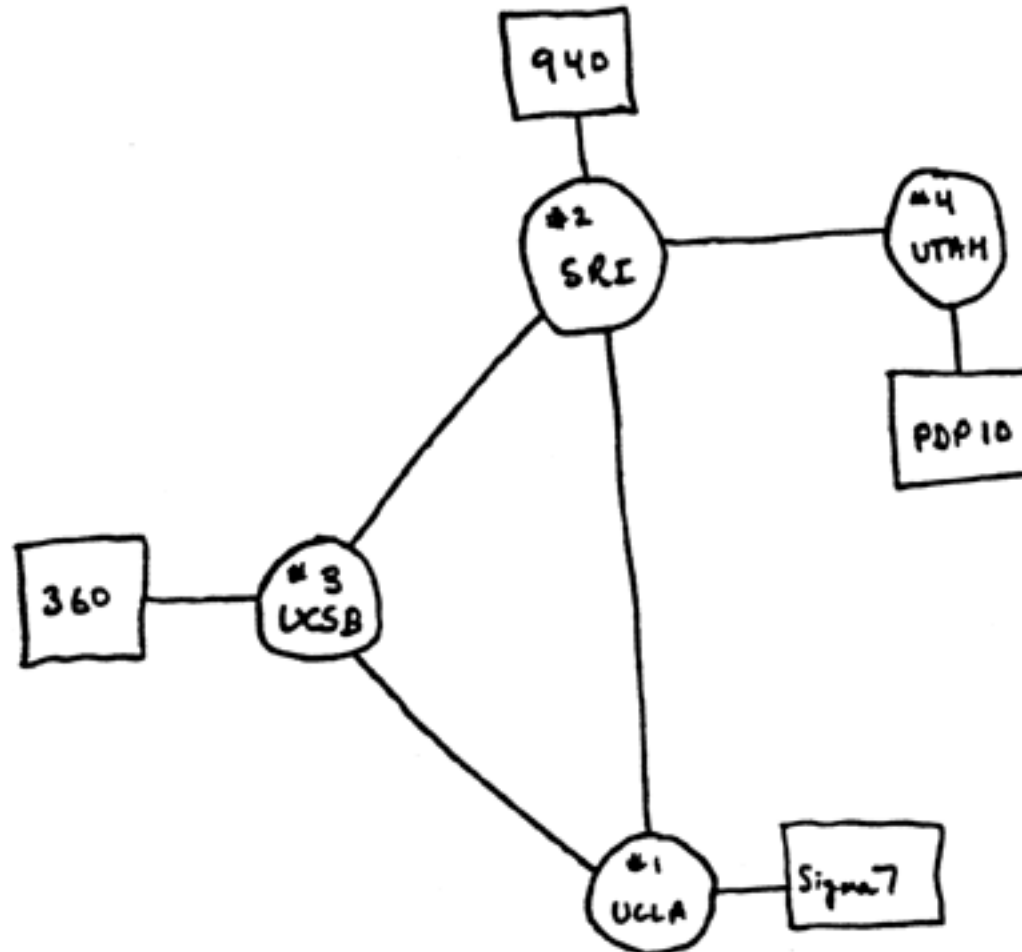
ARPANET (1)

- Plan originated with Lawrence Roberts in 1967
- Purpose was to connect computers over a highly survivable shared network
- Funded in 1968 by IPTO
 - ▷ Bolt Beranek and Newman, Inc. (BBN) awarded Packet Switch contract to build Interface Message Processors (IMPs)
 - Honeywell DDP-516 minicomputer with 12 KB of core memory
 - ▷ AT&T provided 56 kb/s lines
 - ▷ University of California Los Angeles (UCLA) awarded Network Measurement Center contract
 - Graduate students included Steve Crocker and Vint Cerf
 - Steve Crocker organized the Network Working Group (NWG) to develop host level protocols for the ARPANET
 - ◇ First Request For Comments (RFC), April 7, 1969
 - ▷ Tymnet started

ARPANET (2)

- First host-to-host protocol was NCP (Network Control Protocol)
- 1969 ARPANET had 4 nodes
 - ▷ Each node had different host hardware, running a different OS
 - ▷ Different interface hardware and network software
- First email program to send messages across a distributed network (1971)
 - ▷ Adapted by Ray Tomlinson of BBN from an intra-host messaging program and an experimental file transfer program
 - ▷ A “killer app” as soon as it was adapted for ARPANET (1972)
 - ▷ @ sign introduced
- As the ARPANET expanded, BBN started building IMPs using the cheaper Honeywell 316 (1971)
 - ▷ IMPs were limited to 4 host connections
 - ▷ BBN developed a terminal IMP (TIP) that supported up to 64 terminals
- Telnet developed (RFC 318, 1972)

4-NODE ARPANET



ARPANET (3)

- ALOHAnet developed by Norman Abramson, Univ of Hawaii
 - ▷ The first packet radio network
 - ▷ Connected to the ARPANET in 1972
- Bob Metcalfe's Ph.D. thesis outlined the basis for Ethernet (1973)
 - ▷ Concept was tested at Xerox-PARC using Xerox's Alto computers
 - ▷ First Ethernet was called the Alto Aloha System
- File Transfer Protocol (FTP) (RFC 454, 1973)
- Louis Pouzin originated the term "internet" (1974)
 - ▷ An internet = a network of independent networks
 - ▷ Pouzin had worked on CTSS at MIT
 - ▷ Returned to France to work on Cyclades (a packet-switched network)
 - ▷ Also originated the term CATENET
 - "an aggregate of networks [which would] behave like a single logical network"

ARPANET (4)

- Vint Cerf and Bob Kahn presented the basic ideas of the Internet (1973–4)
 - ▷ “A Protocol for Packet Network Interconnection”
 - Detailed design of a Transmission Control Program (TCP)
 - TCP guaranteed reliable delivery of datagrams
 - ▷ The early TCP did not distinguish between TCP and IP
 - IP was separated from TCP (1978)
 - UDP was developed to give users access to unreliable datagram delivery
 - ◇ Motivation was delivery of voice packets
 - ◇ Time out and retransmission interfere with voice reception
- NCP was eliminated in favor of TCP/IP in 1982 (see [RFC 801](#))
- USENET was established in 1979
- BITNET (“Because It’s Time NETwork”) (1981)
- ARPANET split into ARPANET and MILNET (1983)

NSFNET

- The National Science Foundation (NSF)
 - ▷ Division of Network and Communications Research and Infrastructure (1987)
 - 3-tier network
 - ◇ U.S. backbone (NSFNET)
 - ◇ Regional networks
 - ◇ Campus or access networks
- NSFNET gradually replaced the ARPANET
 - ▷ 4 phases of expansion
 - First backbone (1987–88): Built to interconnect supercomputer centers
 - ◇ 56 kb/s links
 - Second backbone (1988–89)
 - Third backbone (1989–93): DS-1 links (1.544 Mb/s)
 - Advanced Networks & Services (private company, not for profit)
 - ◇ ANSNET backbone (1993–95): DS-3 links (45 Mb/s)

SUCCESSORS OF NSFNET

- very high performance Backbone Network Service (vBNS)
 - ▷ Partnership of NSF with MCI/WorldCom
 - ▷ Research & education network
 - OC-3 (155 Mb/s optical) links originally (running IP over ATM)
 - Now OC-12 (622 Mb/s), migrating to OC-48 (2.5 Gb/s)
- Internet 2
 - ▷ Consortium led by more than 180 universities
 - ▷ Goal is to develop and deploy advanced network technologies and applications
 - Backbone is provided by Qwest
 - Participating networks include Abilene and vBNS
 - GigaPOPs (high-capacity, shared Points of Presence)

THE COMMERCIAL INTERNET

- There are now many commercial backbones
 - ▷ Can be visualized using [Mapnet](#)
 - ▷ The owner of a commercial backbone is an ISP to ISPs
 - ▷ Traffic is exchanged between backbones at peering points
 - Enables a customer of one carrier to send packets to a customer of another carrier