

Evolution of Computer Networks

- Telegraphy Networks
- Terminal-Oriented Networks
- Computer-to-Computer Networks

Approaches to Network Design

<i>Function</i>	<i>Telegraph Network</i>	<i>Telephone Network</i>	<i>Internet</i>
Basic User Service	Transmission of telegrams	Bi-directional real-time transfer of voice signals	Datagram & reliable stream service between computers
Switching Approach	Message switching	Circuit switching	Connectionless packet-switching
Terminal	Telegraph, Teletype	Telephone, modem	Computer
Information representation	Morse, Baudot, ASCII	Analog voice or PCM digital voice	Any binary information
Transmission system	Digital over various media	Analog and digital over various media	Digital over various media
Addressing	Geographical addresses	Hierarchical numbering plan	Hierarchical address space
Routing	Manual routing	Route selected during call setup	Each packet routed independently
Multiplexing	Character multiplexing, Message multiplexing	Circuit multiplexing	Packet multiplexing, shared media access networks

Telegraphy Networks

Morse telegraph (1837)

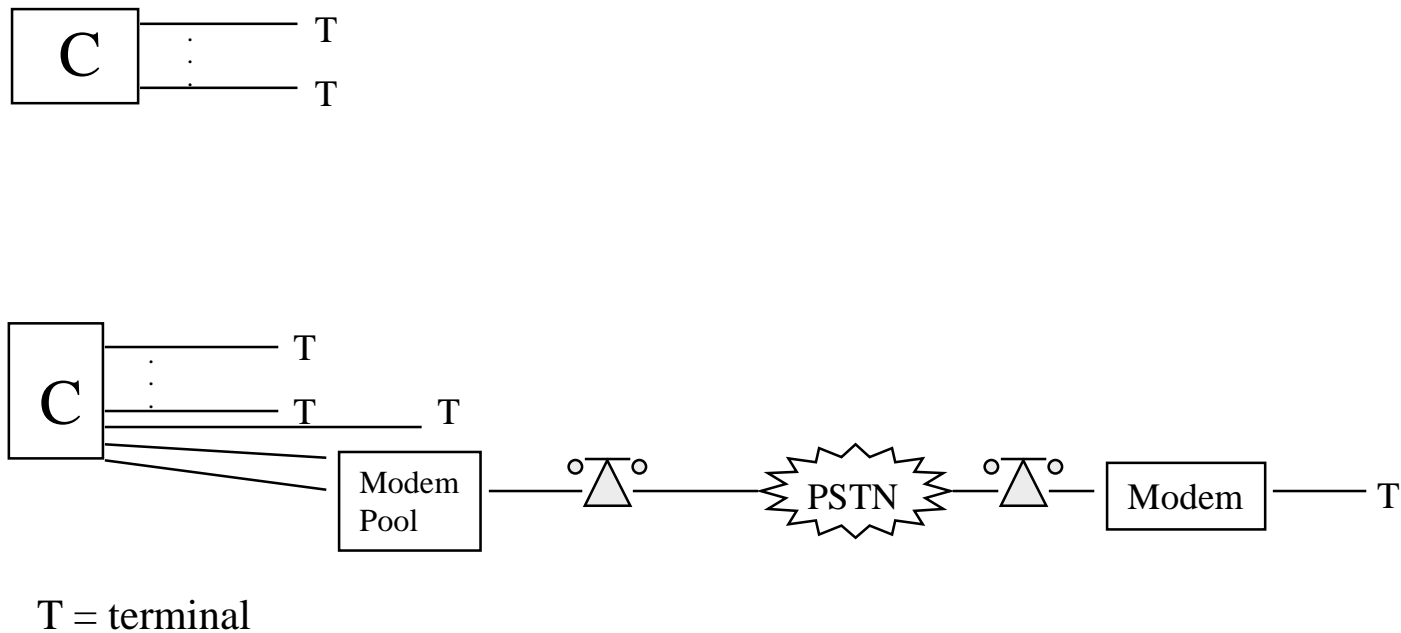
- binary communications using dots & dashes
- Morse code maps alphabet to sequences of dots/dashes
- maximum distance of 32 km over copper wires
- text messages transmitted hop-by-hop across a network of relay stations
- local hand delivery

Marconi radio telegraph (1894)

- dots & dashes modulating bursts of electromagnetic radiation
- ship-to-shore and transatlantic communications

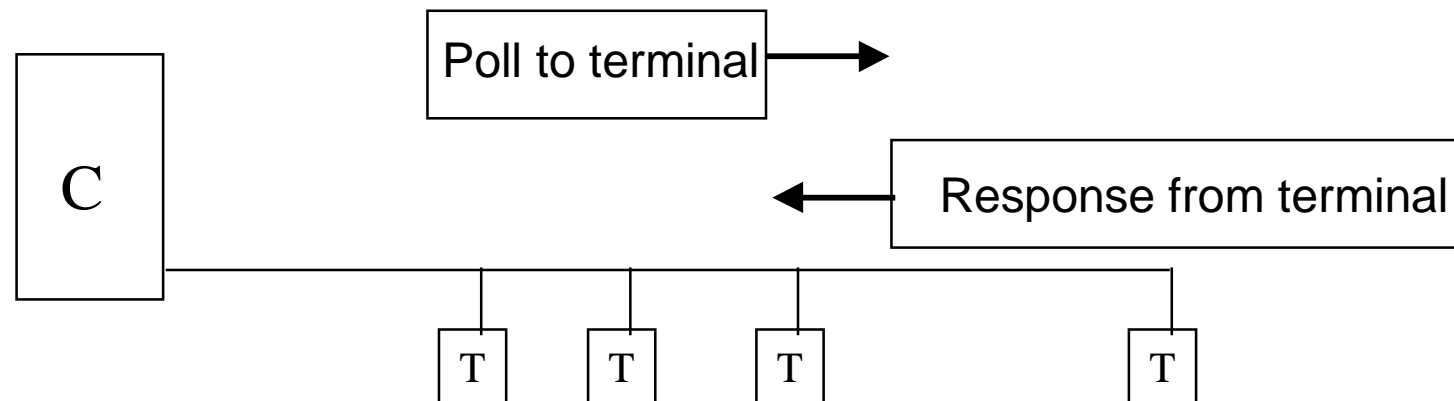
Terminal-Oriented Networks

- Allow expensive host computers to be shared by a number of terminals



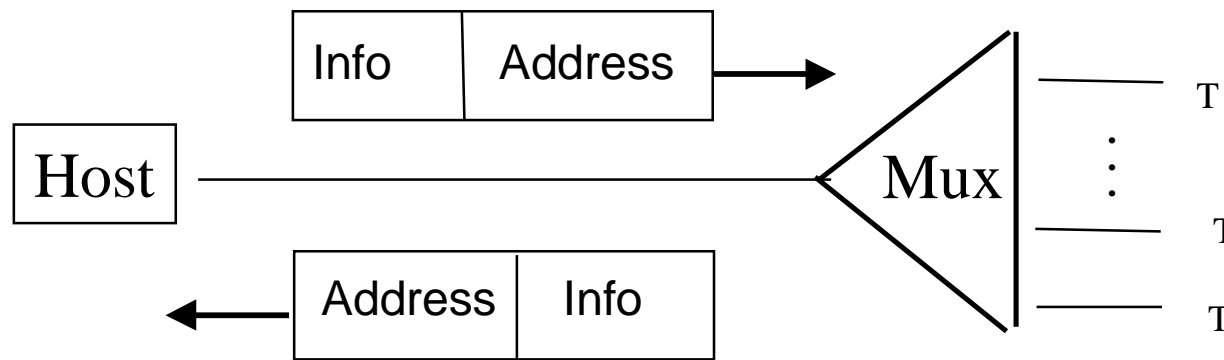
Line-Sharing Techniques

- Transmissions from terminals very bursty, so dedicated lines inefficient
- Polling protocols for controlling the sharing of a transmission line were developed



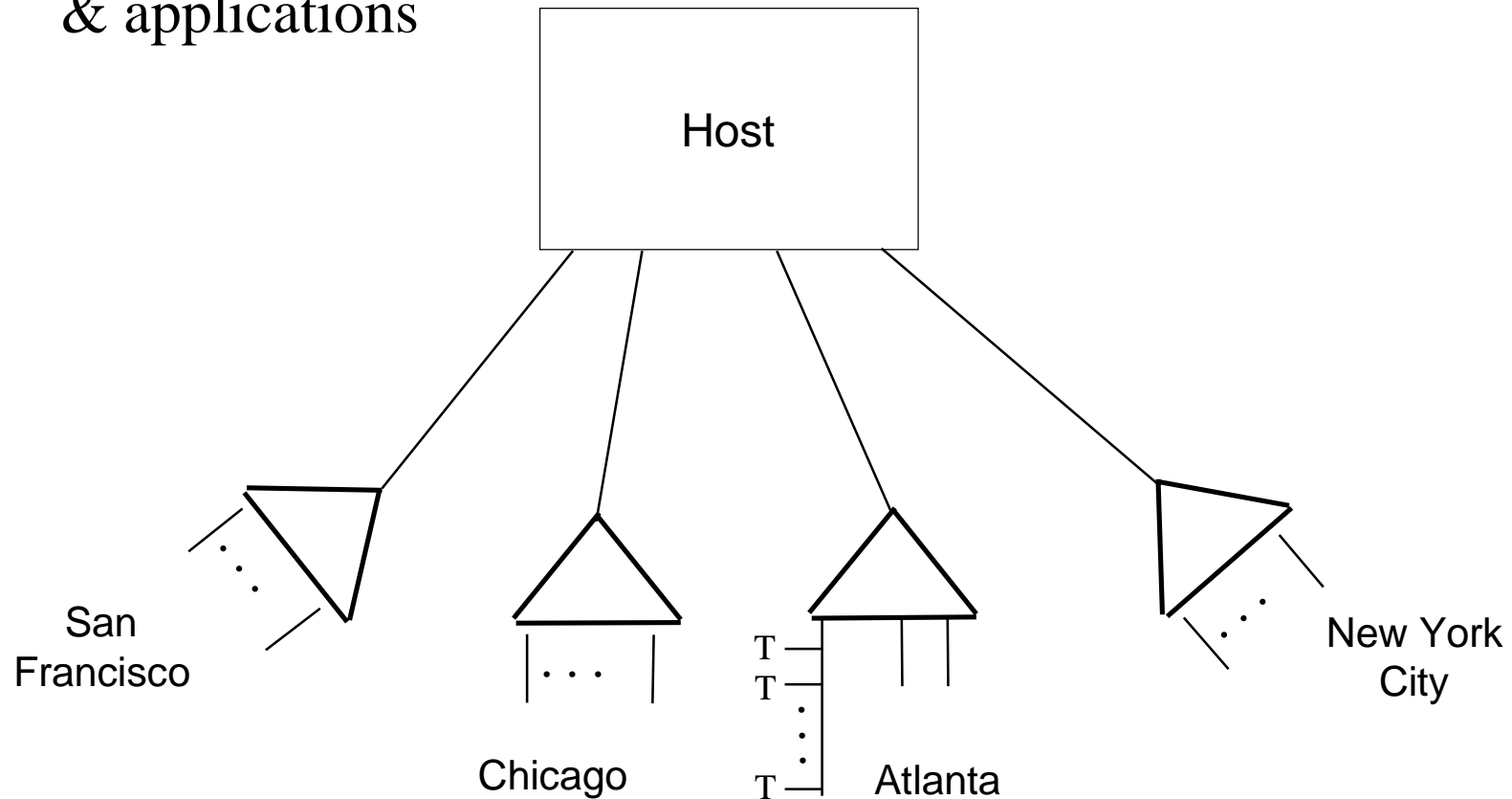
Statistical Multiplexing Techniques

- Statistical multiplexers developed to allow the sharing of a transmission line
- Messages from a terminal encapsulated in a frame that has a header that contains the terminal address
- A message must wait for line to become available



Typical Terminal-Oriented Network

- Tree-topology network connecting terminals to centralized shared computers
- Not flexible: could not handle proliferation of computers & applications

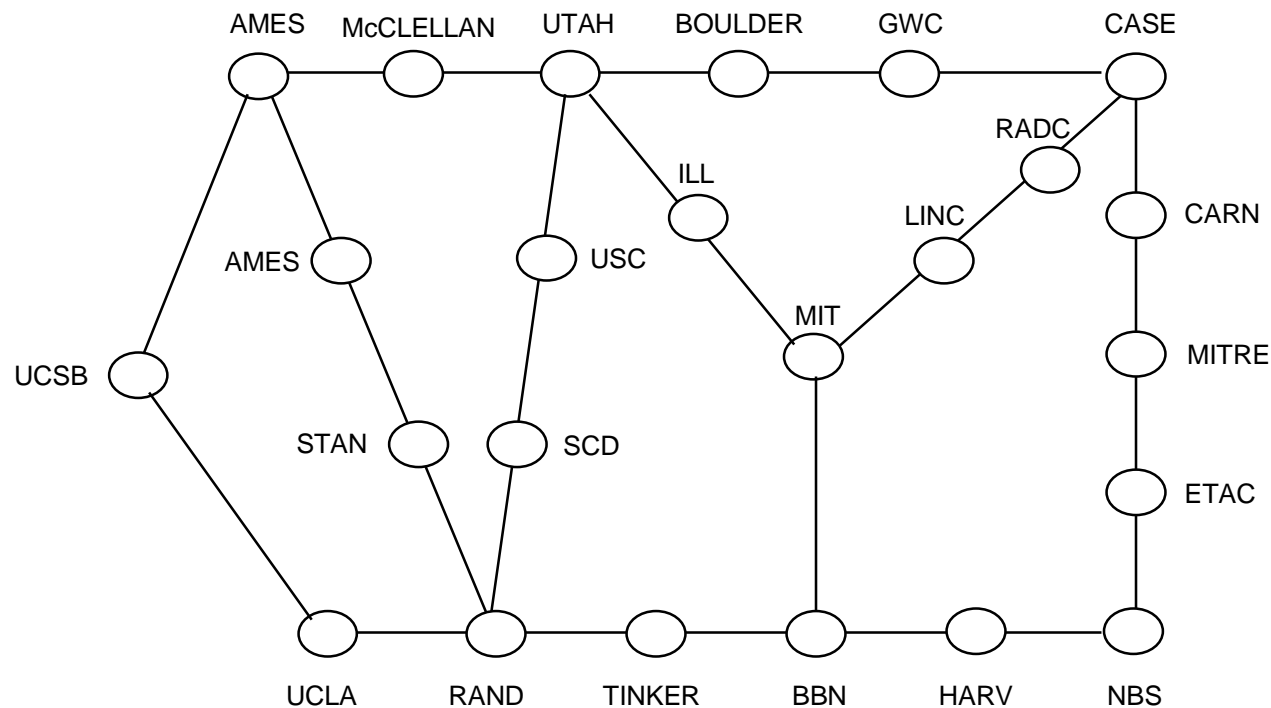


Computer-to-Computer Networks

- The proliferation of computers led to a need to develop networks to interconnect computers
- Fundamentally different than connecting terminals to computers, because now *both* parties are intelligent
- Interactive applications required quick response
 - implying that messages cannot be too long, because this will cause long delays
- Solution: Packet switching
 - variable-length messages up to some maximum allowed
 - longer messages are broken into several packets
 - connectionless transfer vs. connection-oriented transfer

ARPANET

- Testbed for wide-area network packet switching research
- Interconnection of computers using a mesh networks
- Packet switches route packets from source to destination

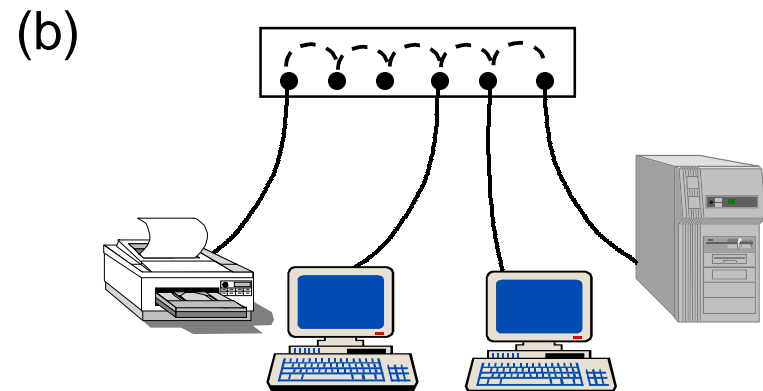
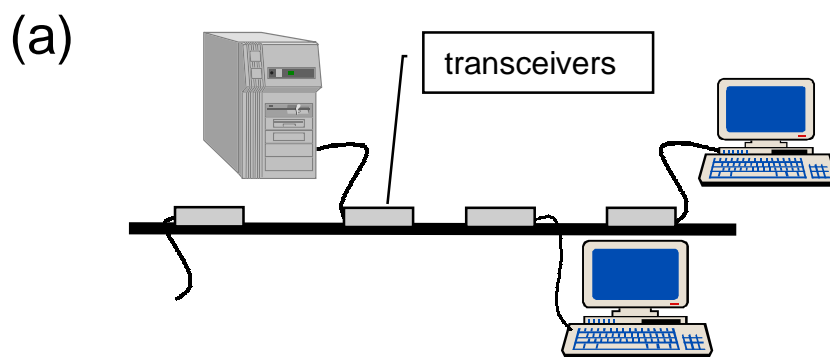


ARPANET Packet Switching Innovations

- Flexible interconnection of computers
- Connectionless transfer of packets
- Distributed synthesis of routes
- Adaptation to failures and traffic variations
- Layered architecture
- Investigation of complex network dynamics

Local Area Networks

- Development of workstations led to LANs to allow sharing of resources (file servers, printers, ...)
- LAN different than WAN
 - bandwidth is cheap, transmission relatively error-free
 - use broadcast packet transmissions, flat address space

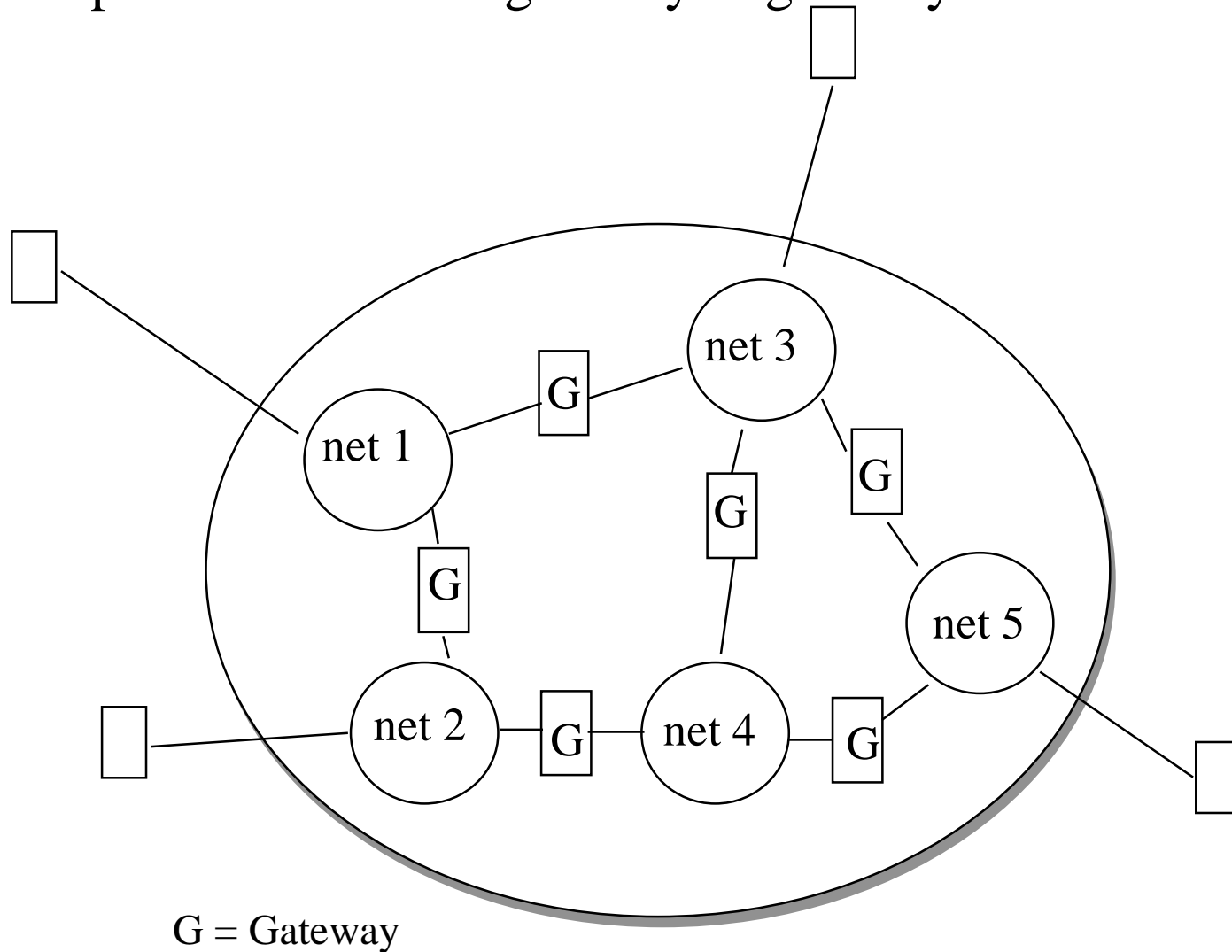


Internetworking

- Different protocols were developed to transmit packets across different types of networks
 - packet switch networks, radio networks, satellite networks
- Problem: How to exchange information between computers attached to *any* of these networks?
- Internet Protocol (IP): creating a network of networks

Communication Networks

- Gateways provide interconnection across networks
- IP packets sent from gateway to gateway



Internet Innovations

- Keep gateways simple, complexity at the edge
- Best-effort transfer of IP datagrams
- Route IP packets according to destination address
- Domain Name System to map between host names (people-friendly) and IP addresses (machine-friendly)
- Transmission Control Protocol (TCP) to provide reliable connections over unreliable datagram transfer
- Any application that can run over TCP/IP can immediately run over the entire Internet

Definition of the Internet

“Internet” (capital i) the global information system that:

- is logically linked together by a globally unique address space based on the Internet Protocol (IP) or its subsequent extensions/follow-ons;
- is able to support communications using the Transmission Control Protocol/Internet Protocol (TCP/IP) suite or its subsequent extensions/follow-ons, and/or other IP-compatible protocol
- provides, uses or makes accessible, either publicly or privately, high level services layered on the communications and related infrastructure described herein
- Federal Networking Council (1995)