Introduction: what is a network?
- elements of network architecture
- layered network architecture
- examples
- history
- internetworking

What is a Computer Network?
- a set of computers and/or switches connected by communication links
- many "topologies" possible:
  - general mesh
  - bus
  - ring

- local area networks (LAN) versus wide-area networks (WAN)
- many different media: fiber optic, coaxial cable, twisted pair, radio, satellite

For us: topology and media unimportant

Reading: Tannenbaum - 1.1-1.5, 1.7-1.9
Ross, Kurose - Chapter 1
What is a Computer Network?

- A software/hardware infrastructure
- Allows shared access to computing resources (e.g., computers, files, data)
- A medium through which geographically dispersed users communicate (e.g., email, teleconferencing)
- An electronic village
- An information highway, national information infrastructure
- "A consensus environment" experienced daily by billions of operators, in every nation, ...

Packet-Switching

- Data entering network divided into chunks called "packets"
- Packets traversing network share network resources (e.g., link bandwidth, buffers) with other packets
- On-demand resource use: statistical resource sharing

"packets"
- resources demands may exceed resources available:
- e.g., A and B packets arrive at R1, destined for C
- resource contention: queuing (waiting), delay, loss

Circuit Switched Networks

- all resources (e.g. communication links) needed by call dedicated to that call for duration
  - example: telephone network
resource demands may exceed resources available
A and B want to call C
resource contention: **blocking** (busy signal)
drawbacks: ??
advantages: ??

### Why statistically share resources?

- save/make money!
- example: 1 Mbit/sec link; each user requires 100 Kbits/sec when transmitting; each user has data to send only 10% of time.
- **circuit-switching**: give each caller 100 Kbits/sec capacity. Can support 10 callers.
- **packet-switching**: with 35 ongoing calls, probability that 10 or more callers simultaneously active is less than 0.0004!
- can support many more callers, with small probability of "contention."
- if users are `bursty` (on/off), then packet-switching is advantageous (Baran, 1965)
Elements of a Network

- **communication links:**
  - point-to-point (e.g., A-to-B)
  - broadcast (e.g., Ethernet LAN)
- **host:** computer running applications which use network (e.g.: H1)
- **router:** computer (often w/o applications-level programs) routing packets from input line to output line. (e.g., A->C)
- **gateway:** router directly connected to 2+ networks (e.g. A)
- **network:** set of node (hosts/routers/gateways) within single administrative domain
- **internet:** collection of interconnected networks

Protocols

- **protocol:** rules by which active network elements (applications, hosts, routers) communicate with each other
- **protocols define:**
  - format/order of messages exchanged
  - actions taken on receipt of message
  - rules by which two or more people communicate to provide a service, or to get something done
- **protocols in every day life:**
Layered Architecture

- Complex system architecture simplified by layering.
- Layer N relies on services of layer N-1 to provide a service to layer N+1.
- Service from lower layer independent of how that service implemented.
  - Information/complexity hiding.
  - Layer N change doesn't affect other layers.
- Interfaces define how services requested.

Layered network architecture

- The network consists of geographically distributed hardware/software components.
- A distributed layered view.
Layering and protocols

- peer entities (e.g., processes) in layer N provide service by communicating (sending "packets") with each other, using communication service provided by layer N-1.
- logical versus physical communication:

The Internet and ISO/OSI reference models

- Hotlink: an IETF view of standards
## Layers of a protocol architecture

- **application layer**
  - process-to-process communication
  - examples: WWW, email, teleconferencing, info. Retrieval

- **socket layer (Internet only)**
  - buffering and delivery of data at end systems

- **presentation layer (OSI only)**
  - conversion of data to a common format (e.g., little endian versus big-endian byte orders, integer and floating point numbers).
  - Internet stack: data conversion a user-level concern

## Layers of a protocol architecture (cont)

- **session layer (OSI only)**
  - session set up (e.g., authentication), recovery from failure (broken session)
  - a “thin” layer

- **transport layer**
  - transport service: end-to-end delivery of data
  - may multiplex several streams from higher layers
  - sender/receiver speed matching
  - Internet: TCP and UDP
Layers of a protocol architecture (cont)

- network layer
  - at end hosts: start packets on their way
  - at routers: control packet routing
  - bottleneck avoidance, congestion control
  - Internet: IP packets, BGP, RIP

Layers of a protocol architecture (cont)

- data link layer
  - point-to-point error free communication over a single link
  - multiaccess LAN protocols
  - speed matching between sender/receiver
  - Ethernet, HDLC, PPP
- physical layer: stuff of EE's
  - transmitting raw bits (0/1) over wire
**Internetworks: the Internet**

- an internet: interconnection of many networks
  - a network of networks
  - each network *administered separately*
- *the* Internet: each network runs same software: the Internet protocols

**Protocol packets**

- **packet:** unit of data exchanged between protocol entities in a given layer
- data at one layer **encapsulated** in packet at lower layer
- “envelope within envelope”

*HotLink: info on new (post 1995) Internet structure in US*
Generic issues in a layer

- **error control**: make “channel” more reliable
- **flow control**: avoid flooding slower peer
- **fragmentation**: dividing large data chunks into smaller pieces; reassembly
- **multiplexing**: several higher level sessions share single lower level connection
- **connection setup**: handshaking with peer
- **addressing/naming**: locating, managing identifiers associated with entities

Layering Considered Harmful or Difficult

- layering has conceptual, structuring advantages but …
- layer N may duplicate lower level functionality, e.g., error recovery hop-hop versus end-end
- different layers may need same info (e.g., timestamp)
- layer N may need layer N-2 information (e.g., lower layer packet sizes)
Network, distributed system, parallel processor?

Distributed system
- application-level concerns and semantics: distributed file system, atomic remote actions
- relies on network communication service to implement higher-level services

Multiprocessors
- processors connected by high-speed interconnect
- “finer-grained” communication than network communication
- link length limited to several meters
- network/multiprocessor distinction can be blurred: network of workstations with high-speed interconnect

A Brief History of Networking

1830: telegraph
1876: telephone (circuit-switching)
1960's: packet switching (Baran, Davies)
  - Arpanet has 4 nodes
1970's:
  - companies: DECnet, IBM SNA
  - Arpanet has 100 nodes
A Brief History of Networking

1980’s:
- local area networks
- late 80’s: 100 Mbps
- proliferation of wide area networks: CSNET, MILNET, NSFNET, ARPANET
- Internet passes 100,000 nodes in 1989

1990’s:
- Arpanet, NSFnet retired: gov’t no longer provides backbone service
- explosive growth: 10 million hosts in 1996
- 150Mbps, 660 Mbps
- wireless networks
- WWW drives Internet mania

Current trends:
- continued expansion
- commercialization
- security

Hotlink: Vint Cerf on Internet History
Hotlink: Hobbe’s Internet Timeline
Summary

- packet-switching versus circuit-switching
- the pieces of a network architecture
- layering