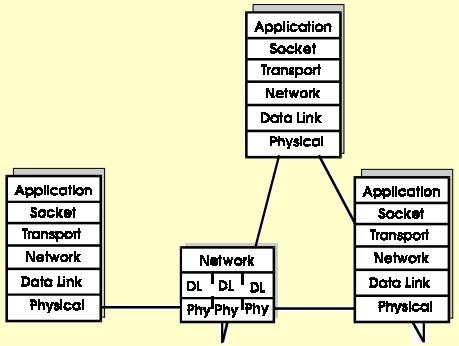
Introduction to Networking

Introduction: what is a network?

- elements of network architecture
- layered network architecture
- examples
- history
- internetworking

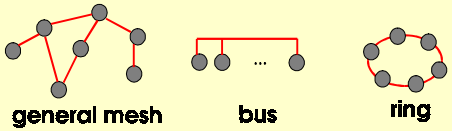


Reading: Tannenbaum - *1.1-1.5, 1.7-1.9*

Ross, Kurose - *Chapter 1*

What is a Computer Network?

- a set of computers and/or switches connected by communication links
- many ``topologies'' possible:



- 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*

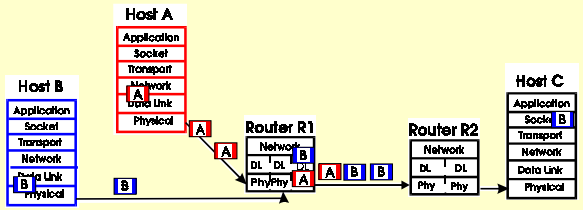
What is a Computer Network?

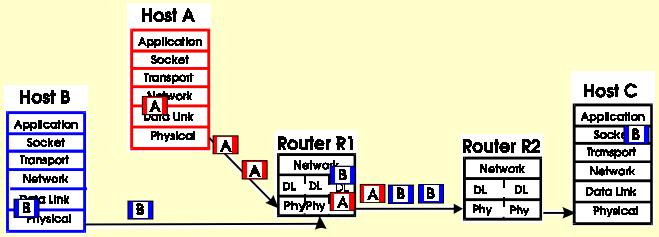
a software/hardware infrastructure:

- ***original justification:*** allows shared access to computing resources (e.g., computers, files, data)
- a ***medium*** through which geographically dispersed users communicate (e.g., email, teleconferencing)
- a medium through which distributed services/applications are implemented
- an electronic village
- an information highway, national information infrastructure
- ***cyberspace:*** "a consensual [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

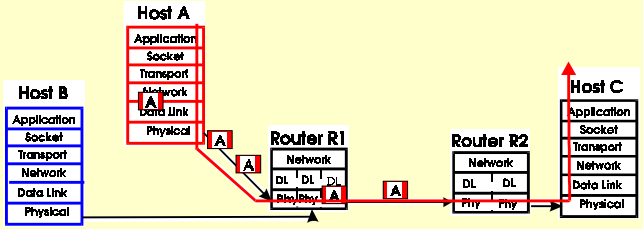


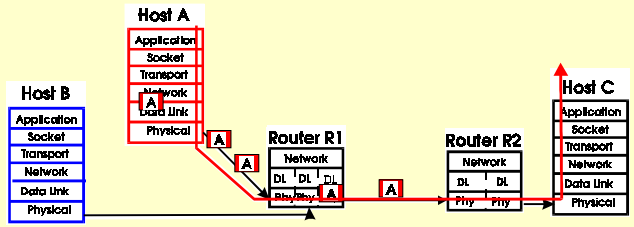


- resources demands may exceed resources available:
- e.g., A and B packets arrive at R1, destined for C
- ***resource contention:*** queuing (waiting), ***delay, loss***

Circuit Switched Networks

- all resources (e.g. communication links) needed by call dedicated to that call for duration
  - example: telephone network



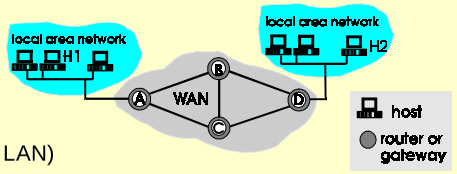


- resource demands may exceed resources available
- A and B want to call C
- resource contention: ***blocking*** (busy signal)
- drawbacks: ??
- advantages: ??Hotlink K.Ross on circuit switching vs packet switching

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)

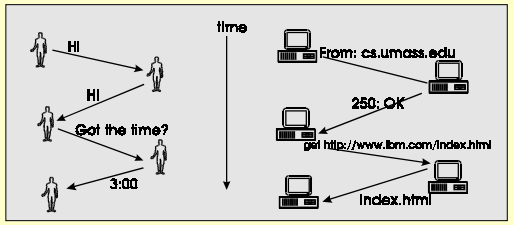
Elements of a Network



- ***communication links:***
  - point-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

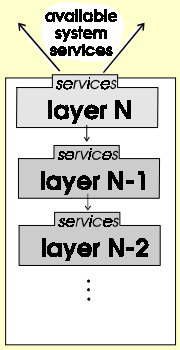
Protocols

- ***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:



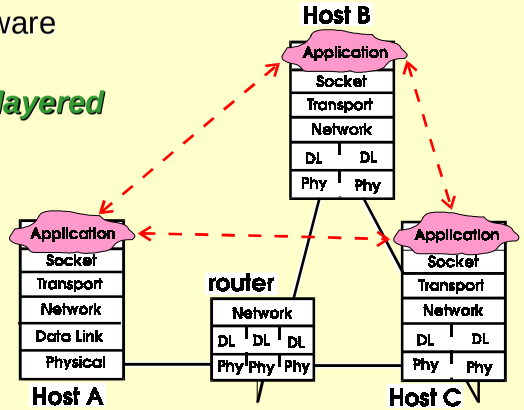
Layered Architecture

- 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



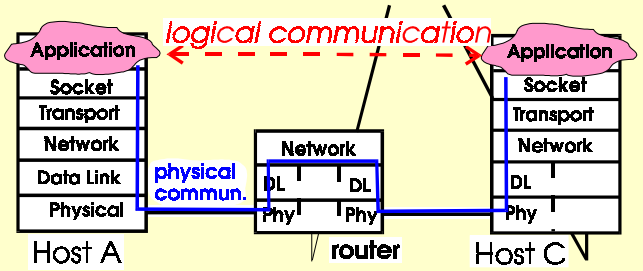
Layered network architecture

- the network consists of geographically distributed hardware/software components
- a ***distributed layered*** view

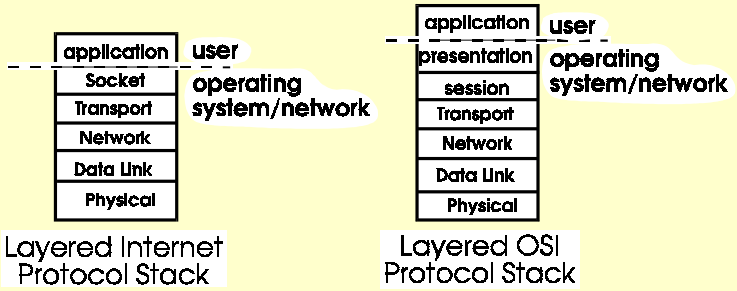


Layering and protocols

- 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:

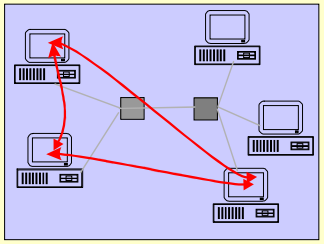


The Internet and ISO/OSI reference models



Hotlink: an IETF view of standards

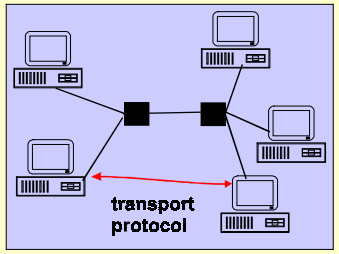
Layers of a protocol architecture



- **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

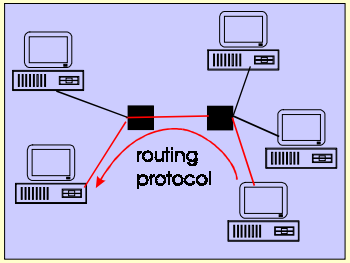
Layers of a protocol architecture (cont)

- **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



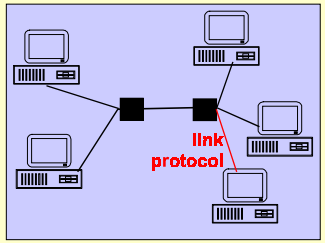
Layers of a protocol architecture (cont)

- **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)

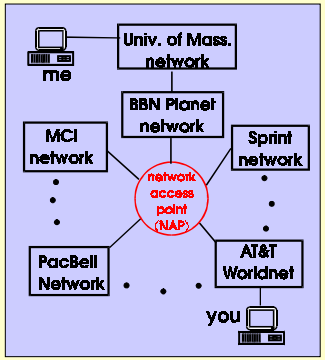
- **data link layer**
  - point-to-point error free communication over a single link
  - multiaccess LAN protocols
  - speed matching between sender/receiver
  - Ethernet, HDLC, PPP



- **physical layer**: stuff of EE's
  - transmitting raw bits (0/1) over wire

Internetworks: the Internet

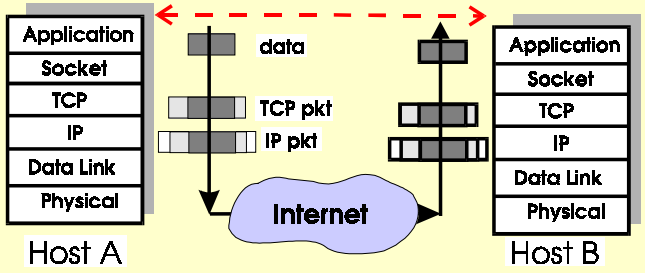
- an internet: interconnection of many networks
  - a network of networks
- each network ***administered separately***
- *the* Internet: each network runs same software: the Internet protocols



HotLink: info on new (post 1995) Internet structure in US

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"*



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

A Brief History of Networking

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: Vinton Cerf on Internet History
Hotlink: Hobbe's Internet Timeline

Summary

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