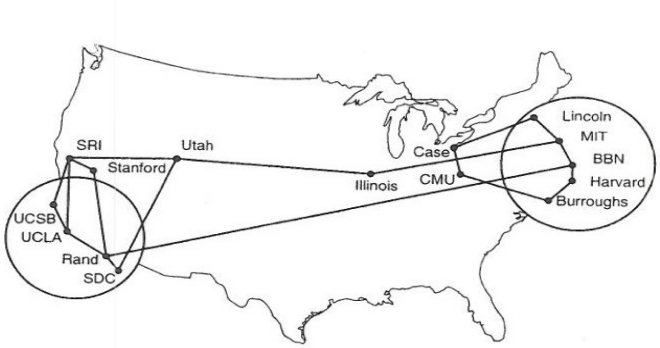


Suppose You Want to Build A Network

Potential to…

- Grow to Global Proportions
- Support Diverse Applications
  - teleconferencing
  - video-on-demand
  - distributed computing
  - digital libraries
  - any new application, e.g., text messaging, phone,

Suppose You Want to Build A Network, cont

Potential to…

- Built from general purpose ideas
- Not optimized for particular application or technology or company
- Support Explosive Growth
- Ease of incorporating new applications
- Ease of changes to core technologies
- Ease of supporting new devices
- Ease of implementation – software & hardware

Suppose You Want to Build A Network

Potential to Support Different Perspectives…

User: services applications need, I.e., guarantee that each message sent is delivered without error in ‘reasonable’ time.

Designer: cost-effective design, e.g., network resources are efficiently utilized and fairly allocated to different users

Providers: system that is easy to administer and manage, eg., faults can be isolated, cost allocation

Suppose You Want to Build A Network

What available technologies would serve as building blocks?

What software architecture would you use?

How would you incorporate the future?

What principles would you enforce?

How would you management development?

Start with: Fundamental Requirement

A Computer Network must provide: general, cost-effective, fair, robust, secure, and high performance connectivity among a large diverse set of nodes/users/apps.

Solution: Internetworking

- Abstraction that deals with complexity of multiple underlying communication technologies tied together in a global network, i.e., no specific network technology
- Essence of this course – chase Internetworking abstraction
  - Architecture
  - Protocols

  While stressing a set of guiding principles

Solution: The Internet

This Course:

Investigate Interneting at all levels in all ways.

In particular the Internet

Today:

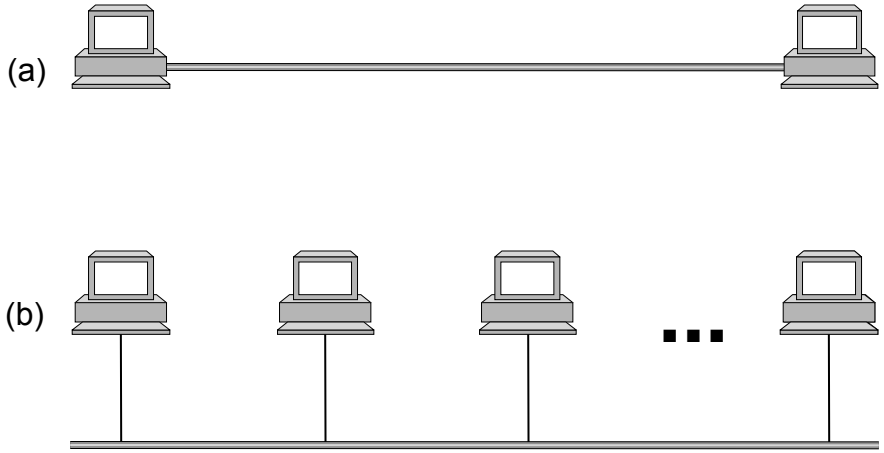
Terms and concepts that you will see throughout the semester

Building Blocks

- Nodes: PC, special-purpose hardware…
  - Hosts, servers…any machine connected to network
  - Switches, routers, gateways…any networking device

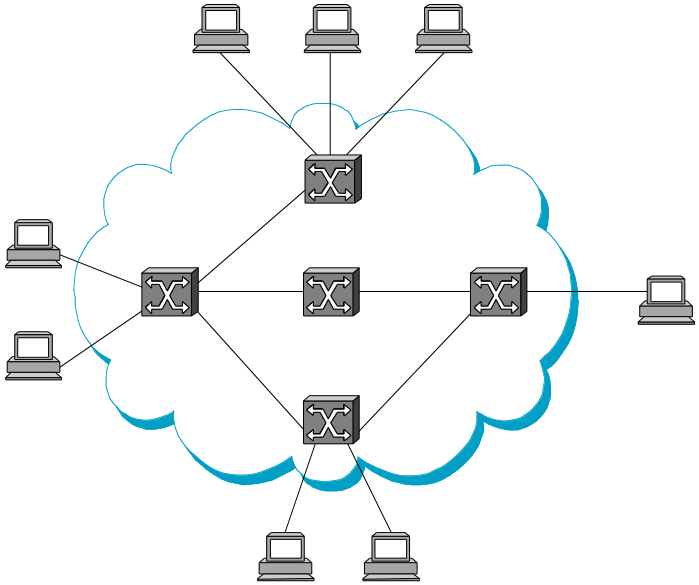
- Links: coax cable, optical fiber, twisted pair, avian carrier, …
  - point-to-point

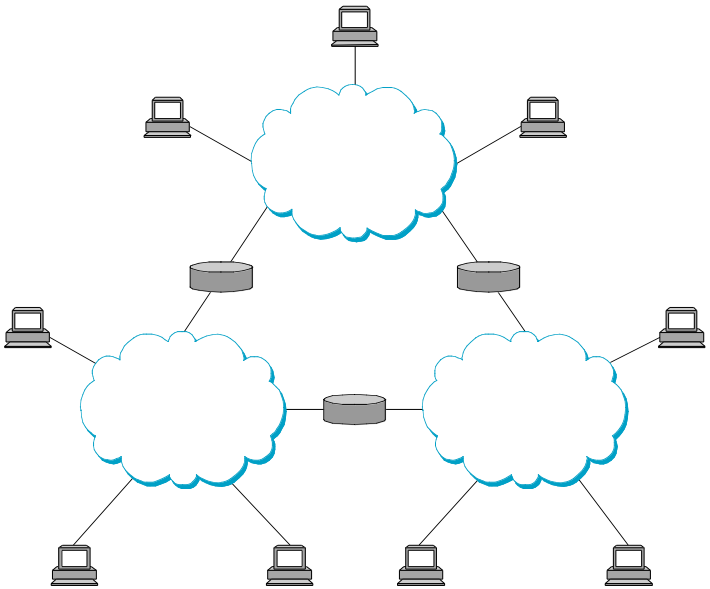
    or
  - multiple access



Switched Networks

- A network can be defined recursively as...
  - two or more nodes connected by a link, or
  - two or more networks connected by a node





The monolithic view

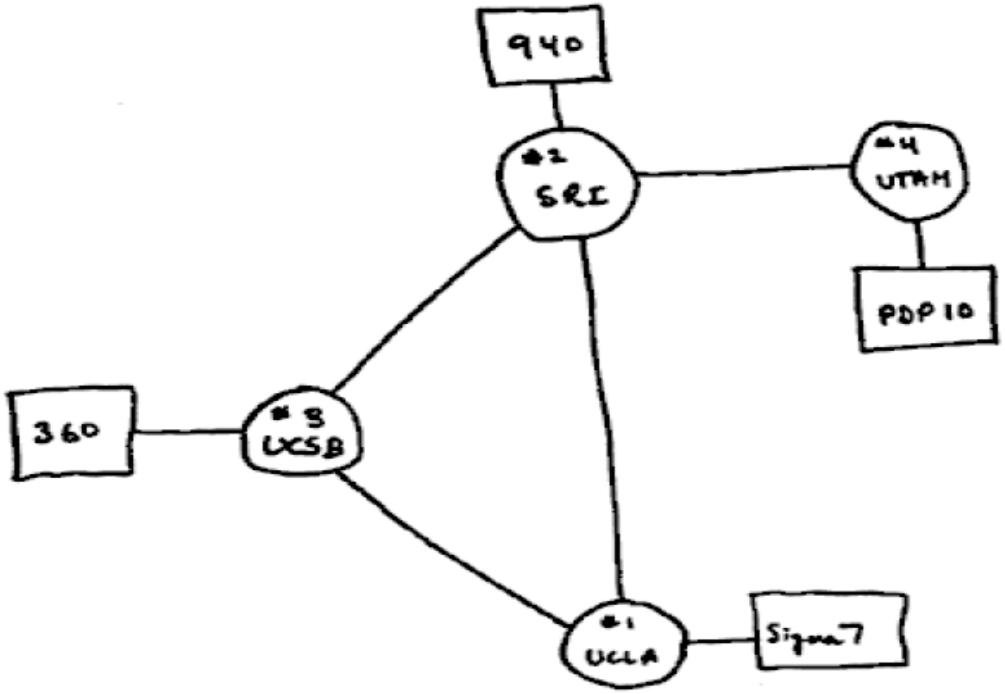
THE
INTERNET
!!!!

Client
Browser

Web server

Why "Internet"

- Network of networks
- Standardized format and protocols for speaking between HETEROGENOUS networks



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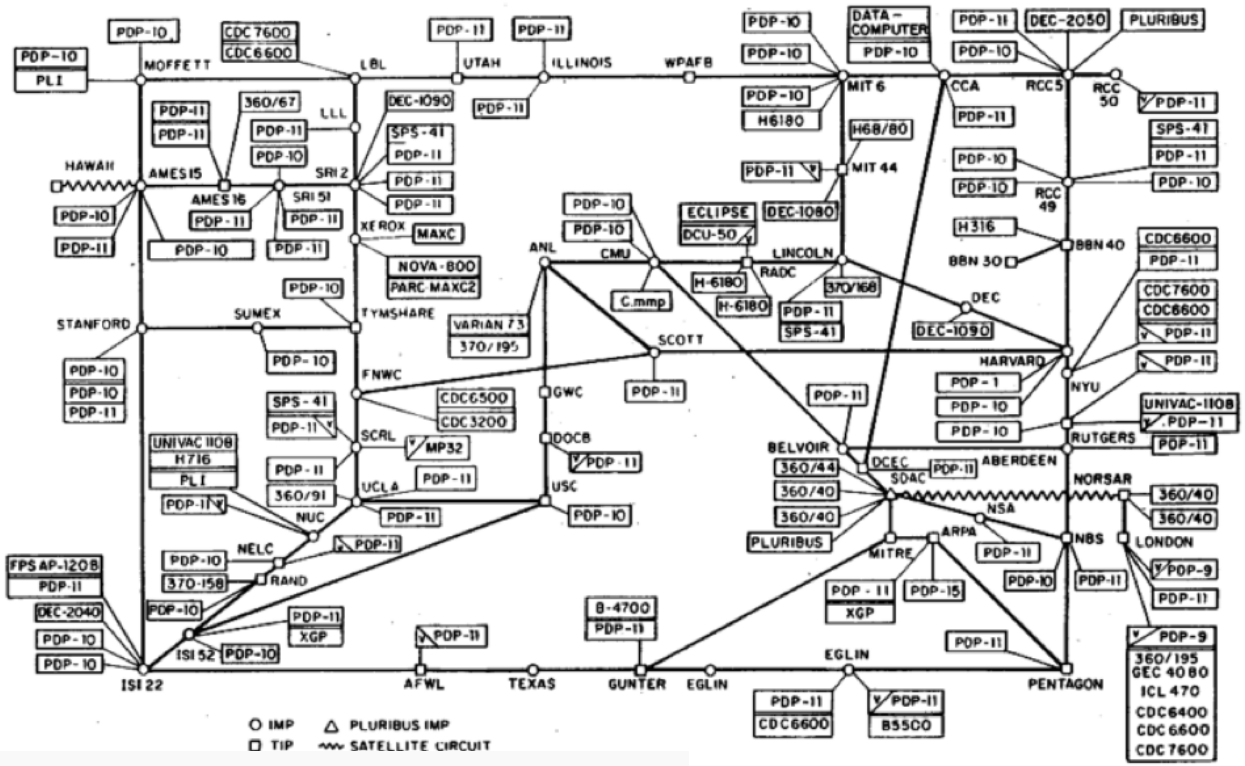


ARPANET logical map, March 1977

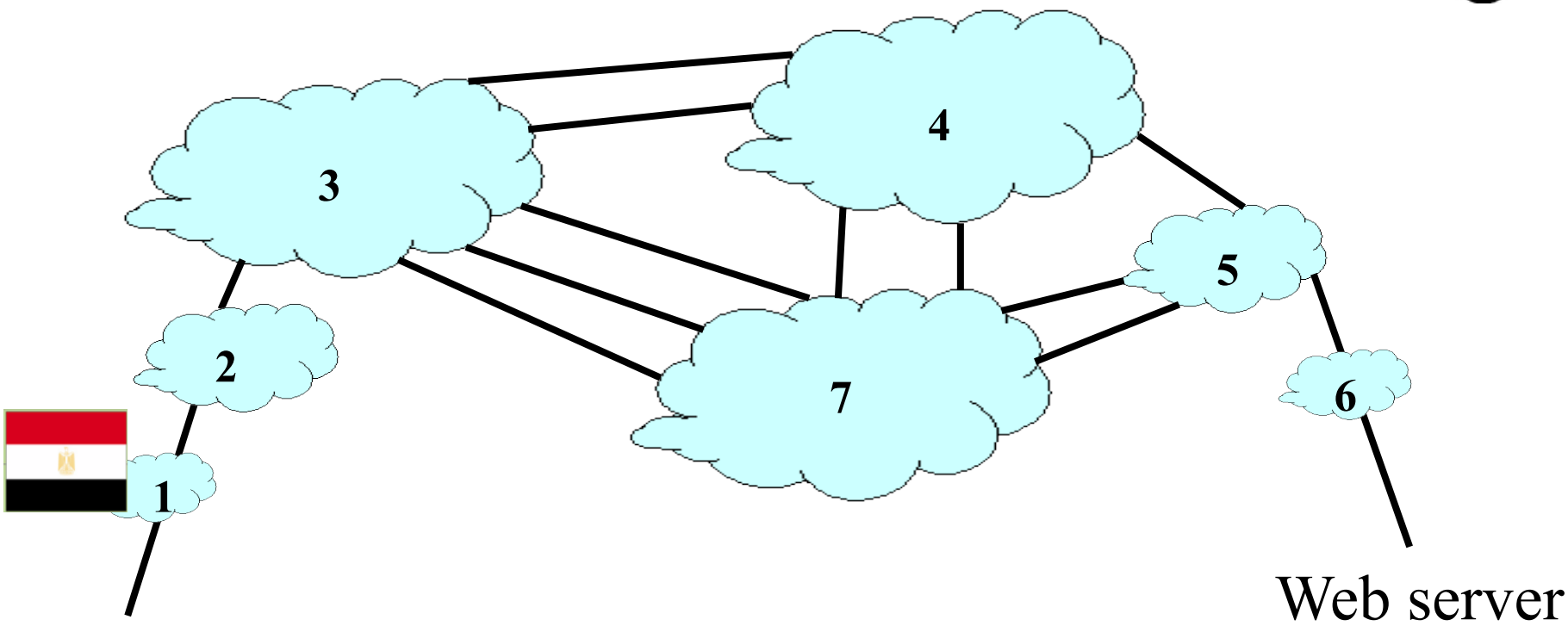
Connection Strategies: lowest level

- Circuit switching: carry bit streams through a known connected network -- setup for each connection
  - original telephone network
- Packet switching: store-and-forward messages, at each hop the next path is pre-determined
  - US postal system
  - Internet

Node Addressing and Message Routing

- Address: byte-string that identifies a node
  - usually unique, is uniqueness necessary or desired?
- Routing:
  - two processes:
    - process of forwarding messages to the destination node based on its address,
    - process of determining table of forwarding addresses which define next node on path to destination
- Types of addresses
  - unicast: node-specific
  - broadcast: all nodes on the network
  - multicast: some subset of nodes on the network
  - Others? (anycast)

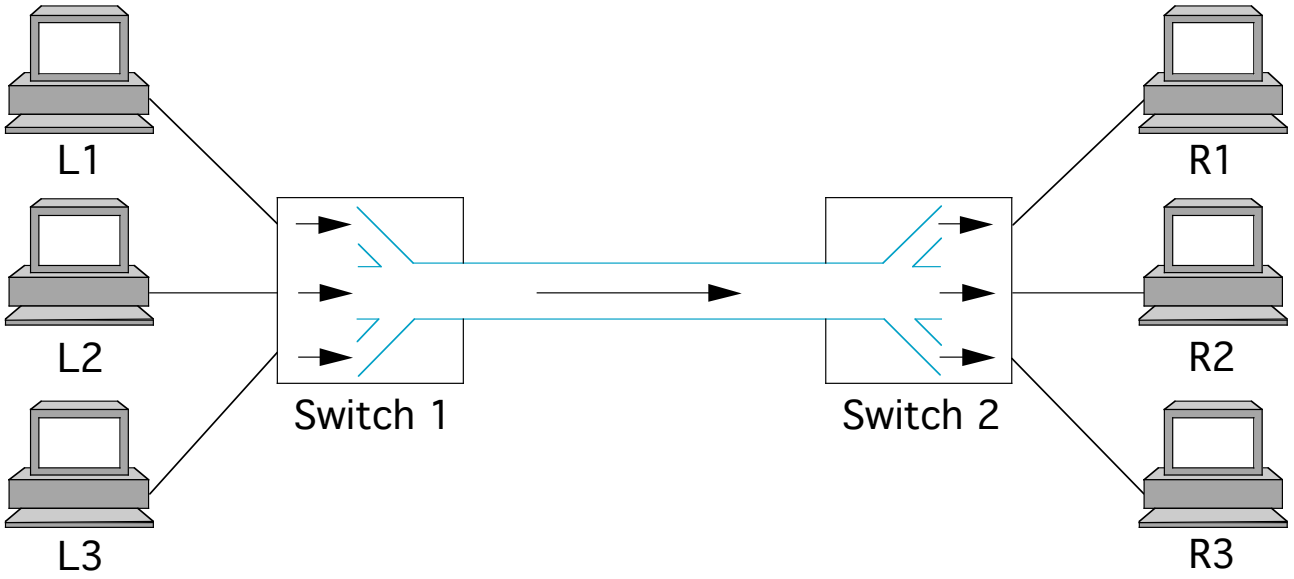
A network of "Autonomous Systems"



- How do you name?
- How do you find a name?

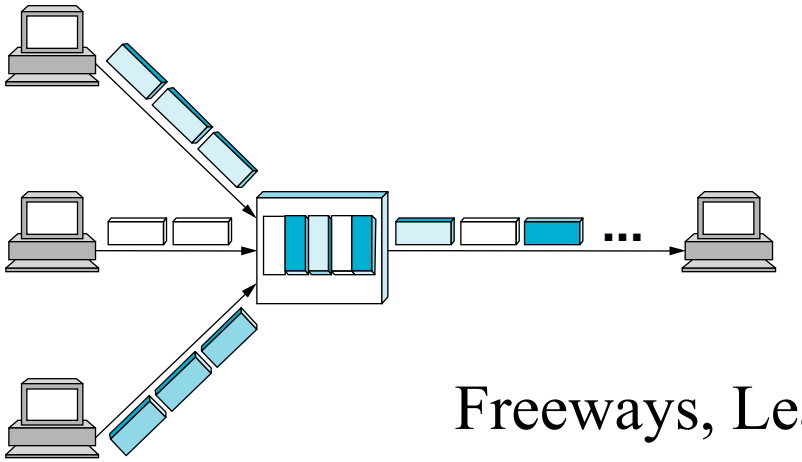
Traffic Multiplexing

- Time-Division Multiplexing (TDM)
- Frequency-Division Multiplexing (FDM)



Statistical Multiplexing

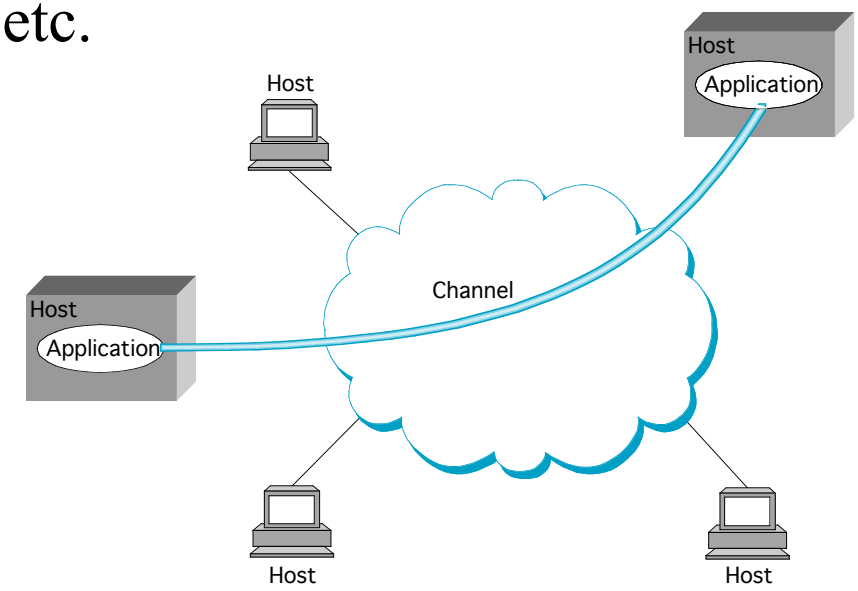
- On-demand time-division
- Schedule link on a per-*packet* basis (what is a packet?)
- Packets from different sources interleaved on link
- Buffer packets that are *contending* for the link
- Buffer (queue) overflow is called *congestion*



Freeways, Leaky Bucket

Inter-Process Communication (IPC)

- Turn host-to-host connectivity into process-to-process communication.
- Fill gap between what applications expect and what the underlying technology provides, I.e., order of packets, reliability, etc.



IPC Abstractions

- Request/Reply
  - distributed file systems
  - digital libraries (web)
- Stream-Based
  - video: sequence of frames
    - 1/4 NTSC = 352x240 pixels
    - (352 x 240 x 24)/8=247.5KB
    - 30 fps = 7500KBps = 60Mbps
  - video applications
    - on-demand video
    - video conferencing

Is this all???

What Goes Wrong in the Network?

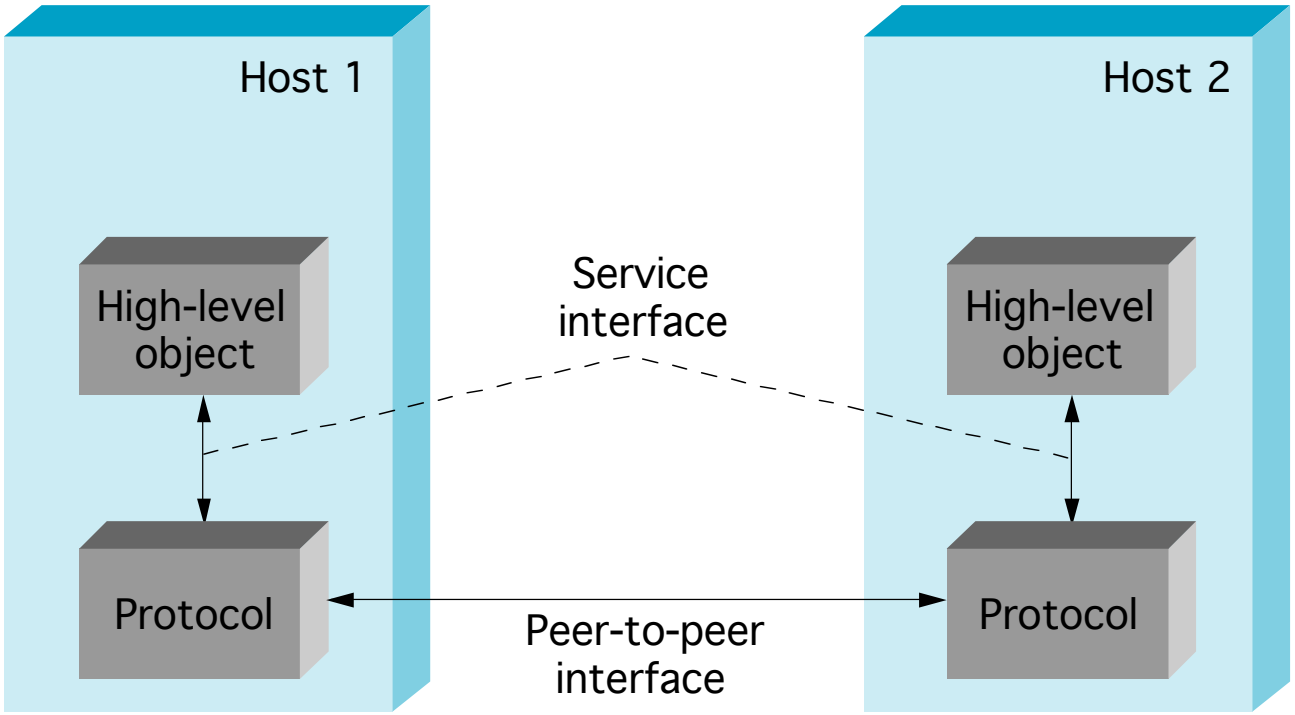
- Bit-level errors (electrical interference)
- Packet-level errors (congestion, dropped)
- Link and node failures (new path)
- ??
- Packets are delayed
- Packets are deliver out-of-order
- Third parties eavesdrop
- ??
- Today's Internet can barely support apps, yesterday's and tomorrow's Internet have same problem

Protocols??

- Define a Protocol??
- Building blocks of a network architecture
- Each protocol object has two different interfaces
  - *service interface*: operations on this protocol (API)
  - *peer-to-peer interface*: messages exchanged with peer (RFC)
- Term "protocol" is overloaded
  - specification of peer-to-peer interface
  - module that implements this interface

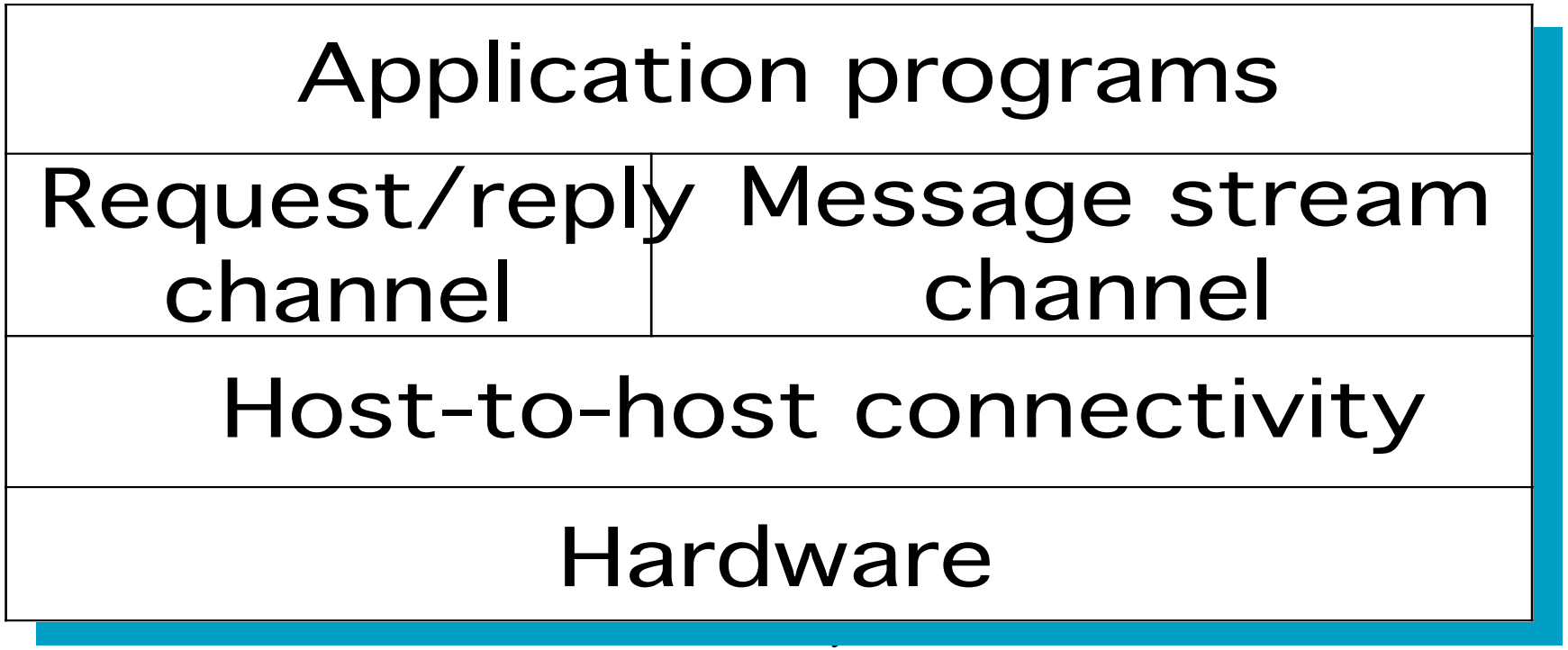
Interfaces


HMC CS


Host 1
Host 2
High-level object
High-level object
Service interface
Protocol
Protocol
Peer-to-peer interface

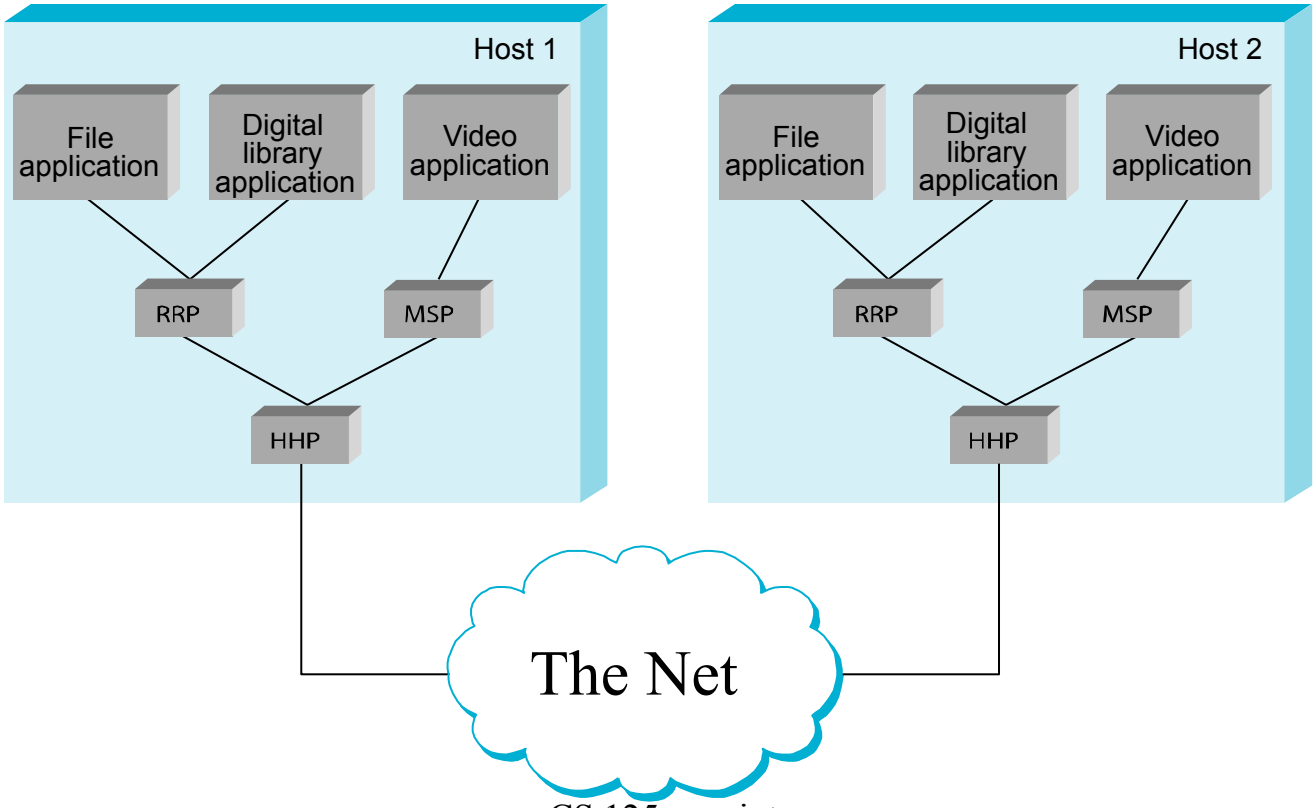
Layering??

- Use layering abstraction to hide complexity
- Abstraction naturally leads to layering
- Alternative abstractions at each layer



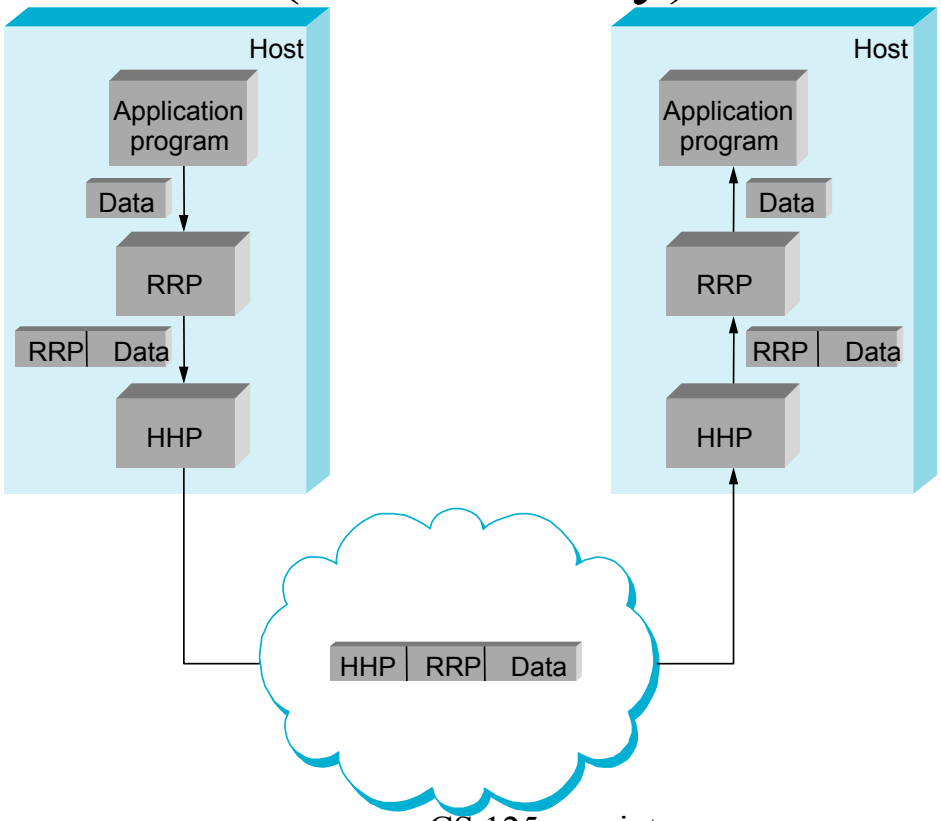
Protocol Machinery

- Protocol Graph
  - most peer-to-peer communication is indirect
  - peer-to-peer is direct only at hardware level

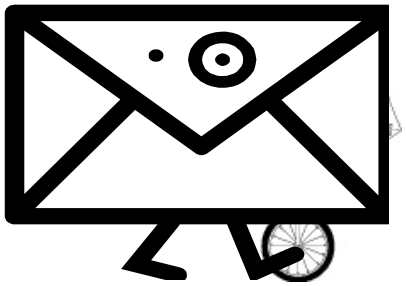


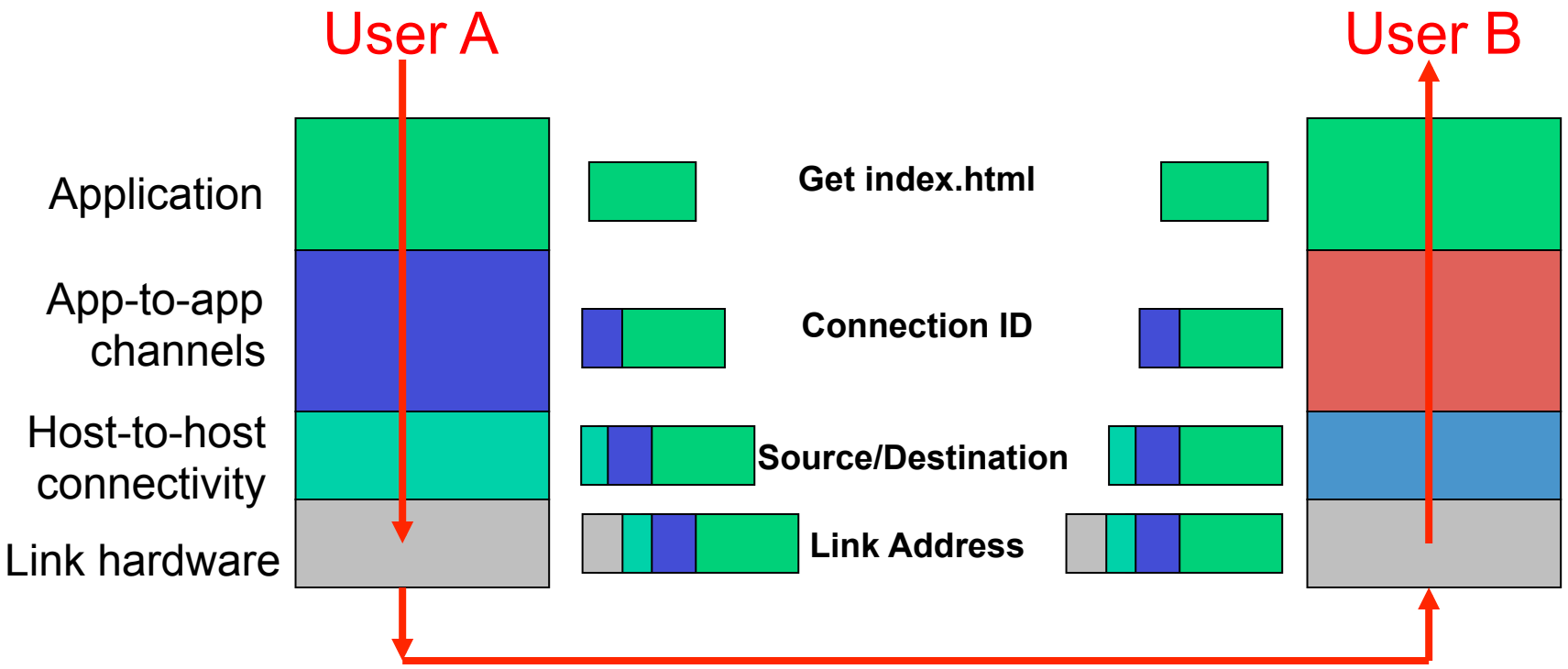
Protocol Machinery (cont)

- Multiplexing and Demultiplexing (demux key)
- Encapsulation (header/body)

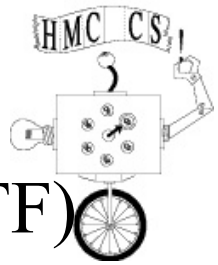


Layer Encapsulation in



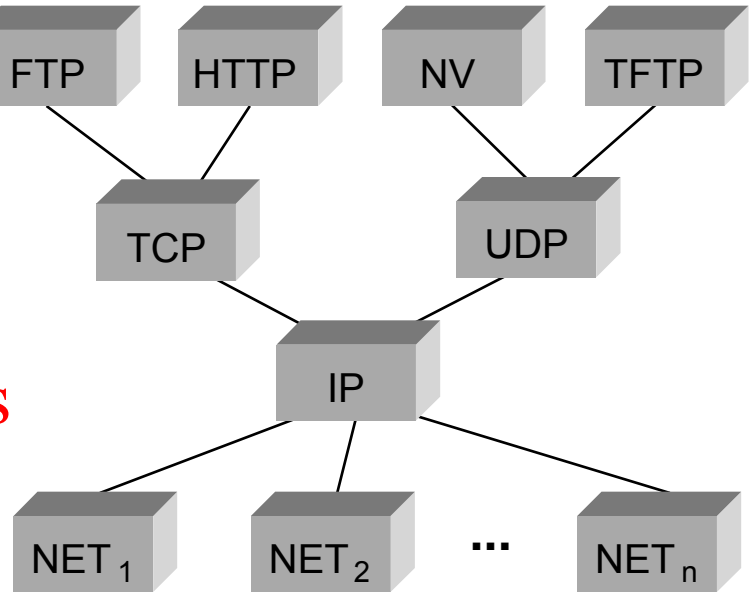


Internet Architecture



- Defined by Internet Engineering Task Force (IETF)
- Hourglass Design
- Overload: Application vs Application Protocol (FTP, HTTP)

Hour Glass



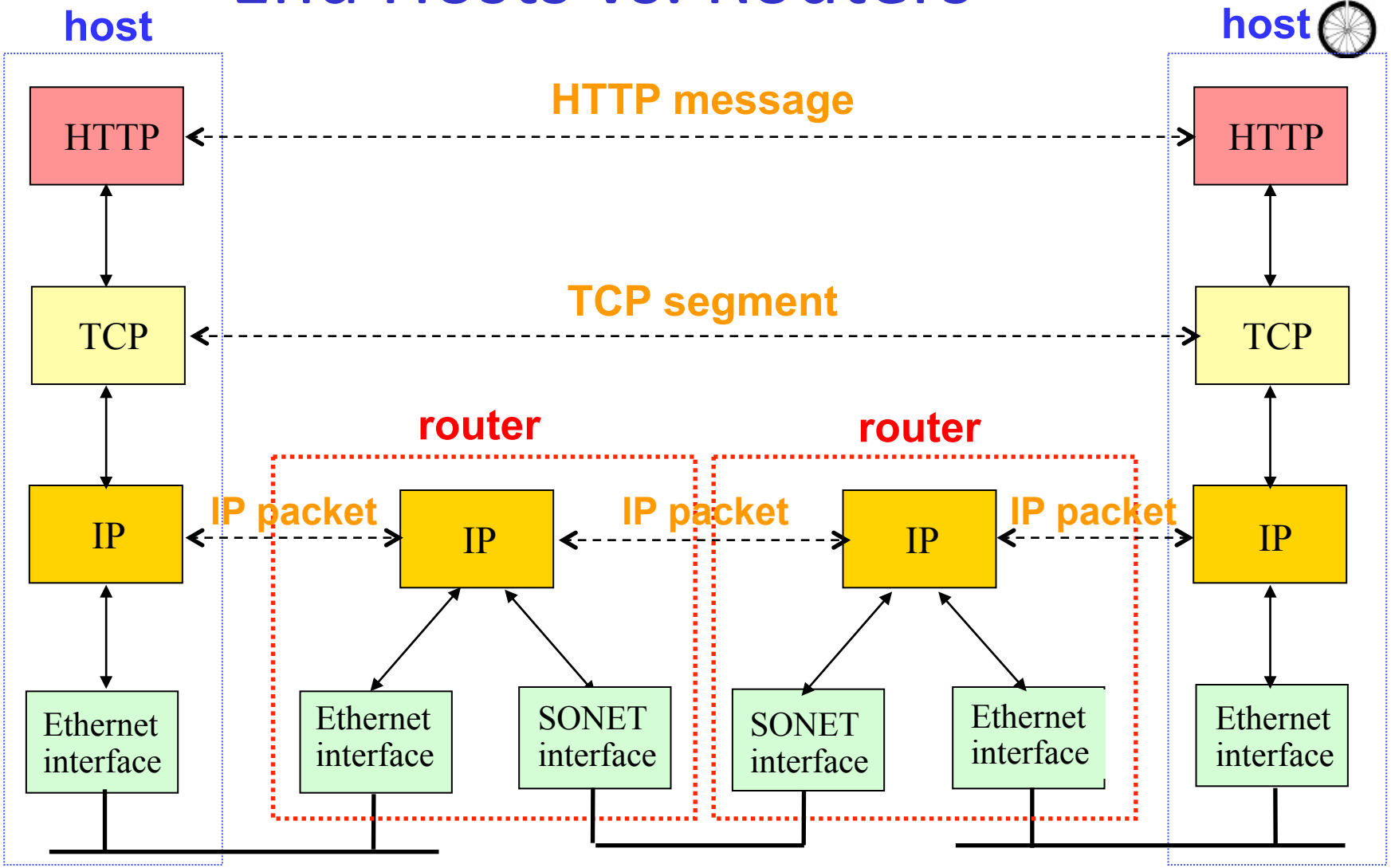
Apps

Transport

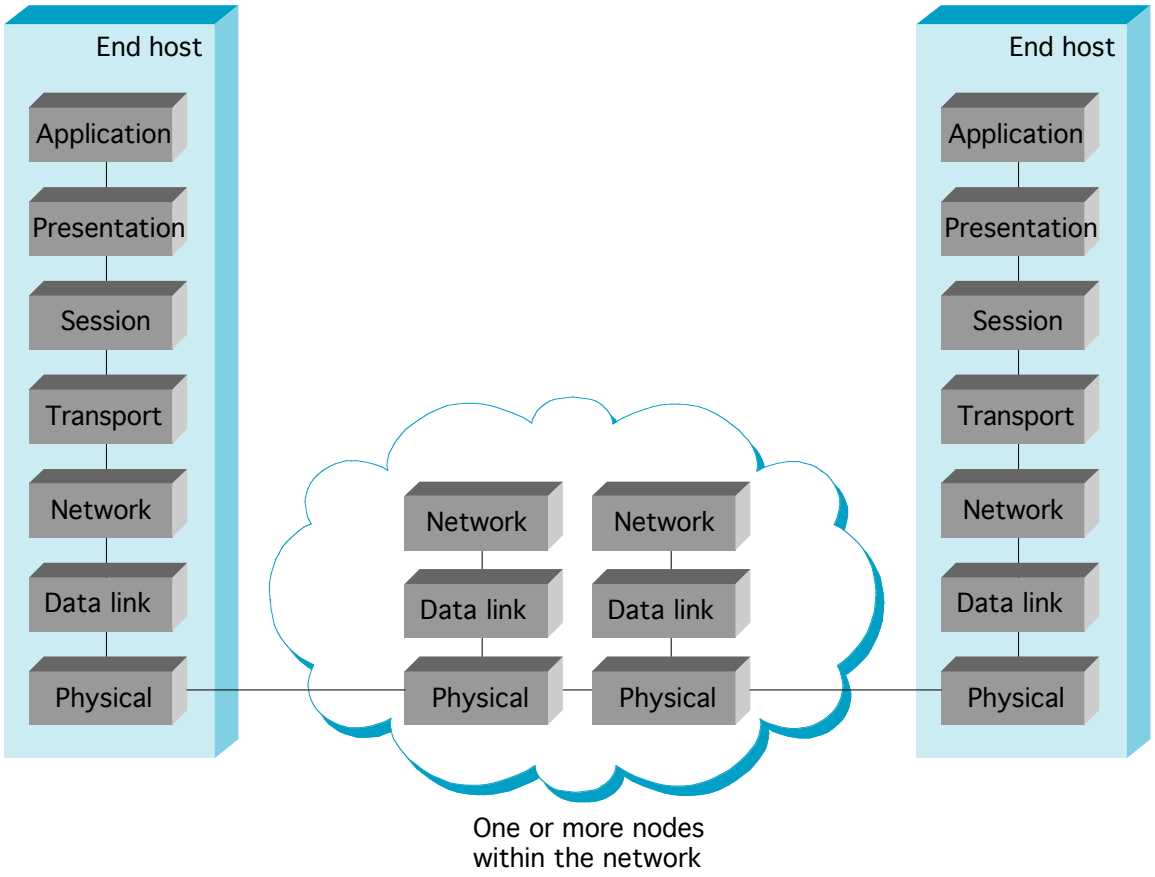
Network

Link/Data

IP Suite In Action: End Hosts vs. Routers



ISO Architecture



OSI levels

- Physical – electro-mechanical interface
- Data Link – transmission, framing, error control over link. Divided into media dependent and independent
- Network – data transfer across network, independent of media or topology
- Transport – reliability and multiplexing of data
- Session – adds control mechanisms to data exchange, e.g., start stop, port numbers
- Presentation – structure and coding (ASCII, little-endian, big-endian
- Application – User application, e.g., ftp, telnet

Internet: Systems Approach

We reject kings, presidents, and voting. We believe in rough consensus and running code…

- Implies doing experimental performance studies
- Do not accept existing artifacts as gospel, but instead strive to understand the concept that are fundamental to the system.
- Draw on a collection of design principles that have evolved from experience with computer systems in
- Study successful, working examples: systems cannot be studied in the abstract
- Look at the big picture
- Build and test, build and test, ….
- Specify and document, specify and document,…

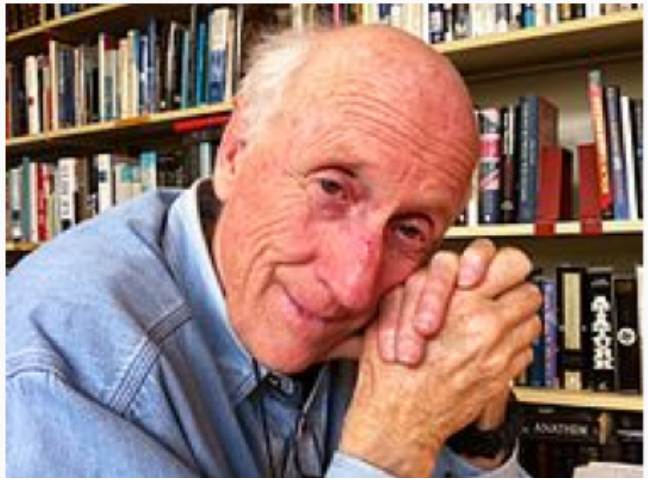
CS 125 About:

- Principles and concepts
- General purpose computer networks
- Internet Perspective
  - Network software
  - Designing and building a protocol system
  - Analysis of the Internet
  - Network applications.
- Web page for course
- You will learn
  - Knowledge – How Internet Works
  - Insight – Naming, layering, …
  - Skill – Network programming, Network analysis

Networking is Relevant

Information wants to be free because it has become so cheap to distribute, copy, and recombine... It wants to be expensive because it can be immeasurably valuable to the recipient. (1985)

Stewart Brand



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The End