Master Course
Computer Networks
IN2097

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Chapter roadmap

Packet Networks

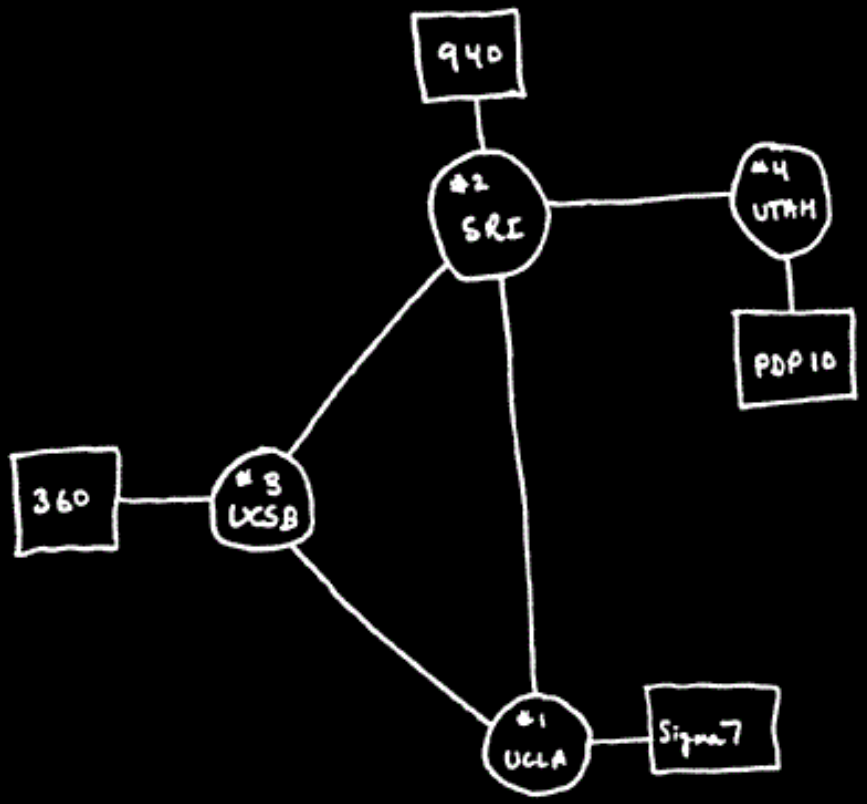
Link Layer

Internet Protocol

The Internet

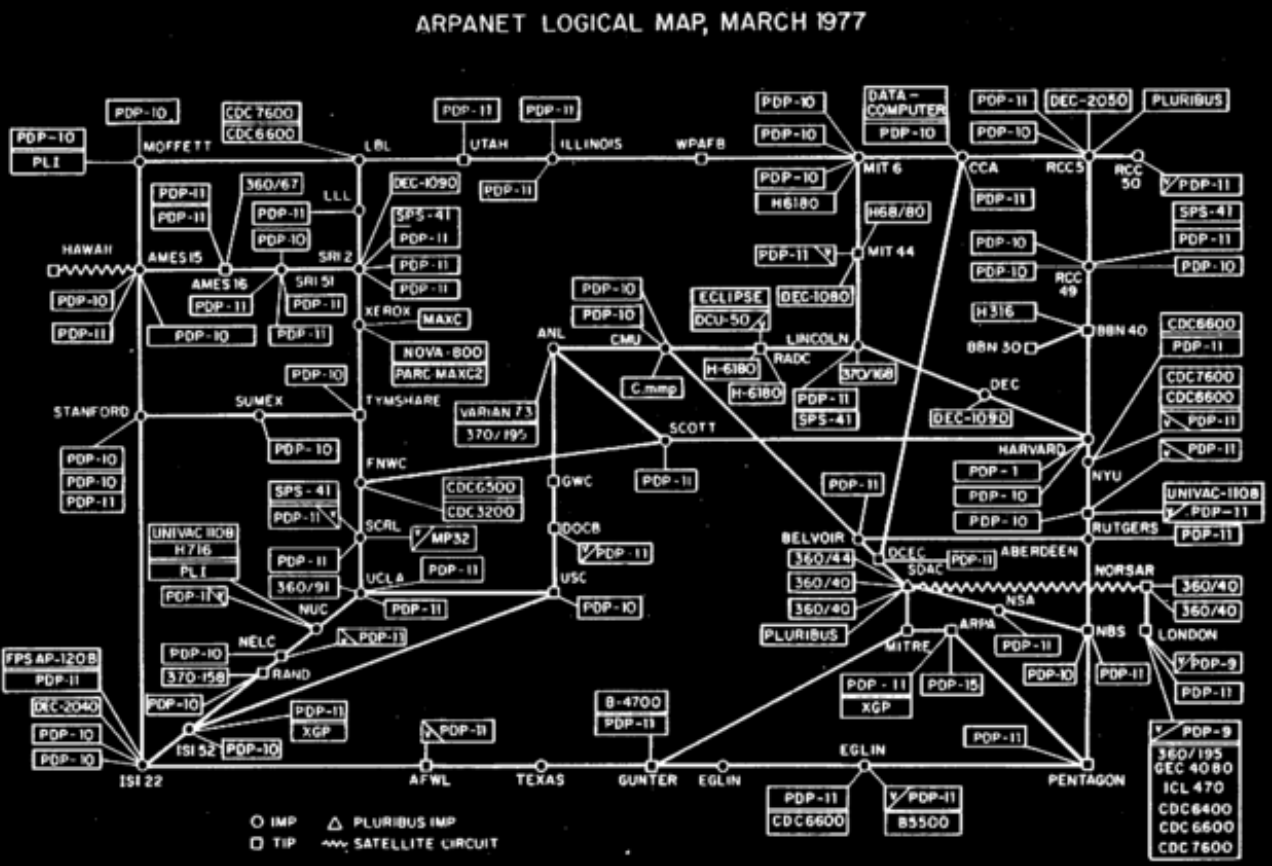
Delay, loss and throughput in packet-switched networks

ARPANET, 1969.

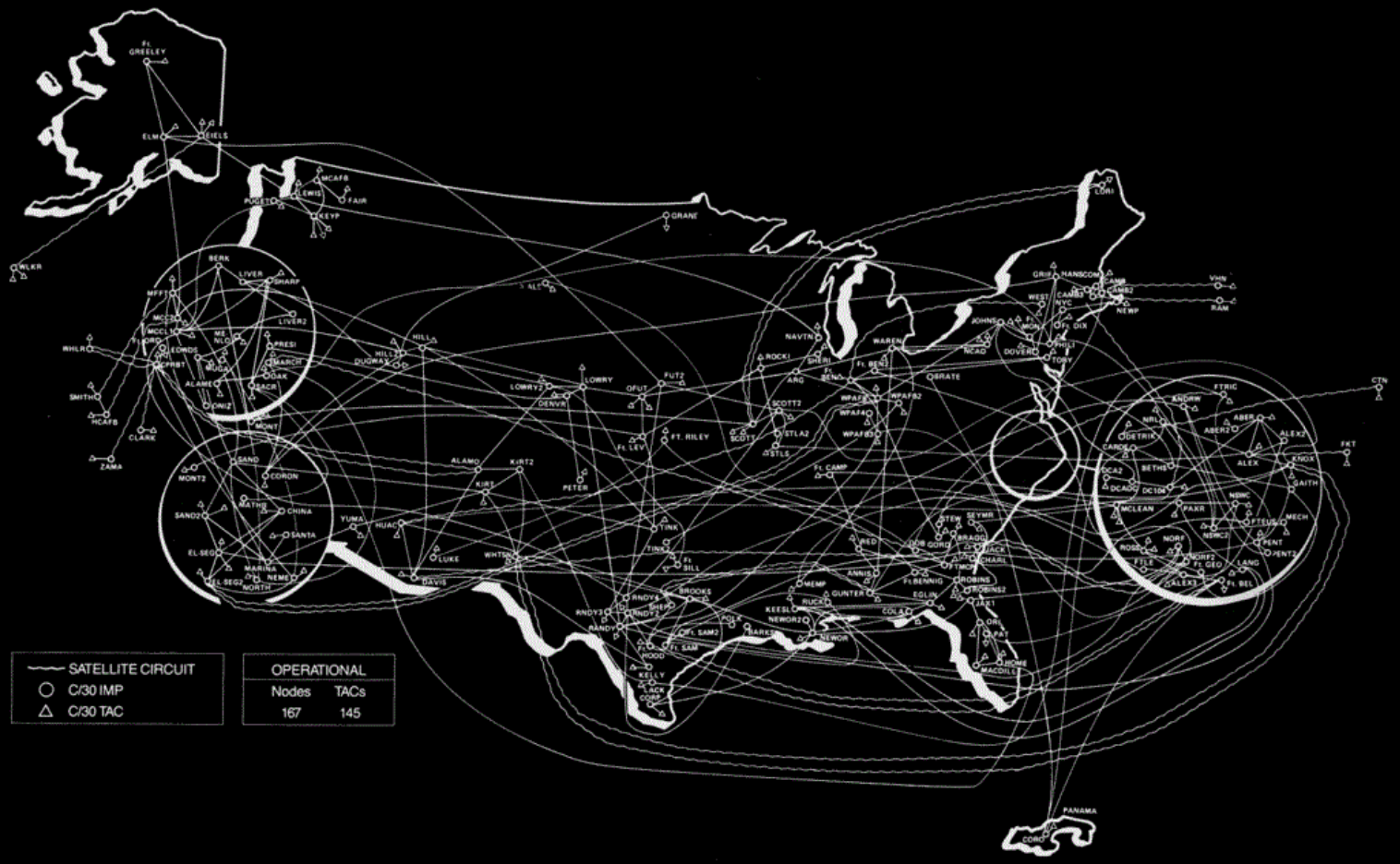


Internet Structure

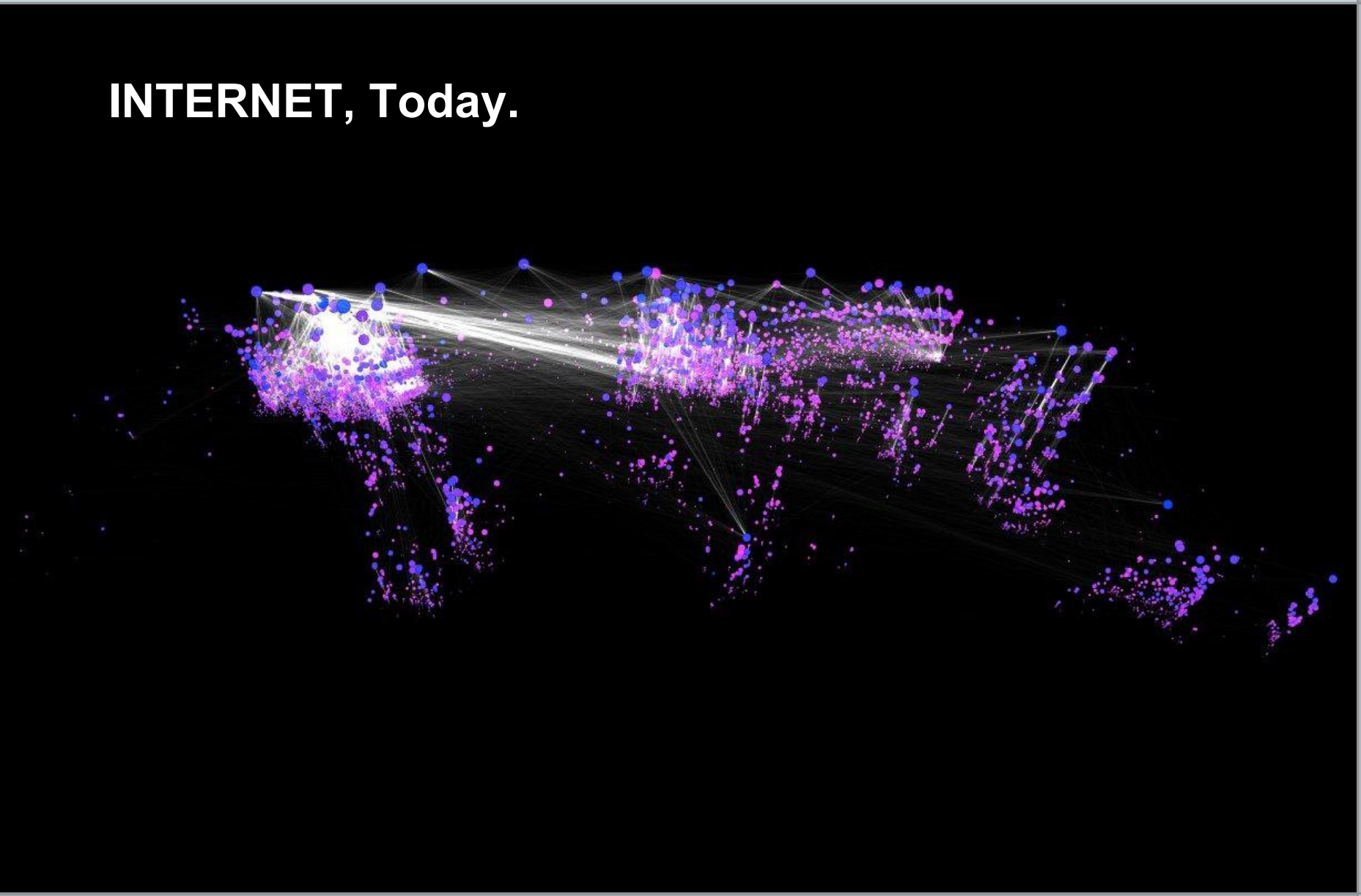
ARPANET, 1977.



MILNET, 1983.

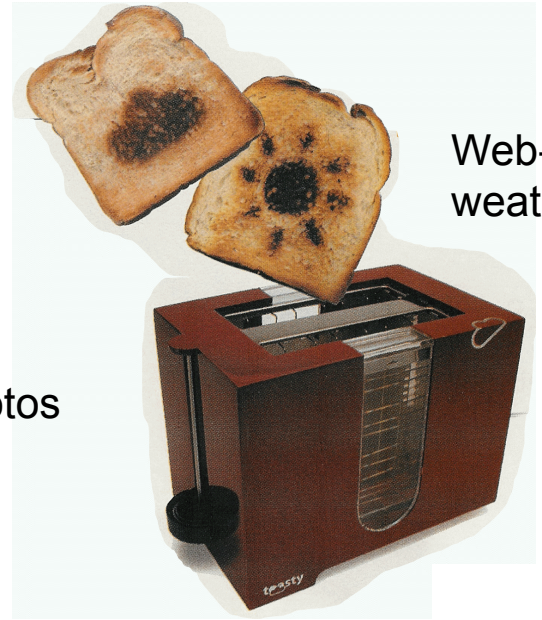

SATELLITE CIRCUIT
C/30 IMP
C/30 TAC
OPERATIONAL
Nodes TACs
167 145

INTERNET, Today.

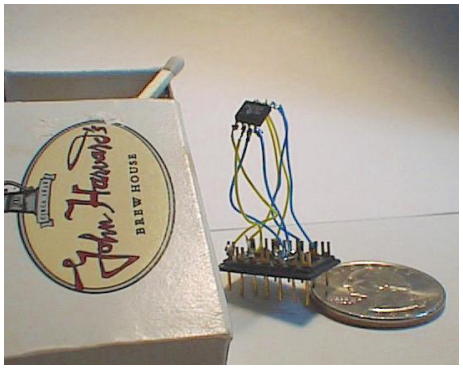


“Cool” internet appliances

IP picture frame
http://www.ceiva.com/
Free invitations for guests to send photos



Web-enabled toaster +
weather forecaster



World’s smallest web server
in 1999

Internet phones

⇨ Who knows other cool internet appliances?

What's the Internet: "nuts and bolts" view

- millions of connected computing devices: *hosts = end systems*
  - running *network apps*

PC

server

wireless laptop

cellular handheld

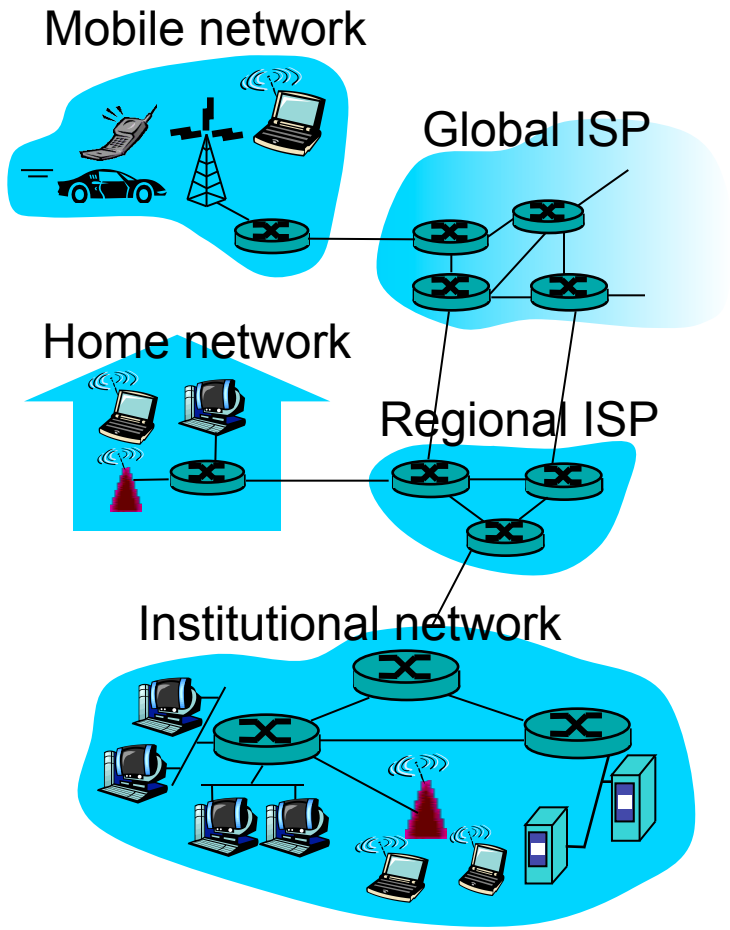
- *communication links*
  - fiber, copper, radio, satellite
  - transmission rate = *bandwidth*

access points

wired links

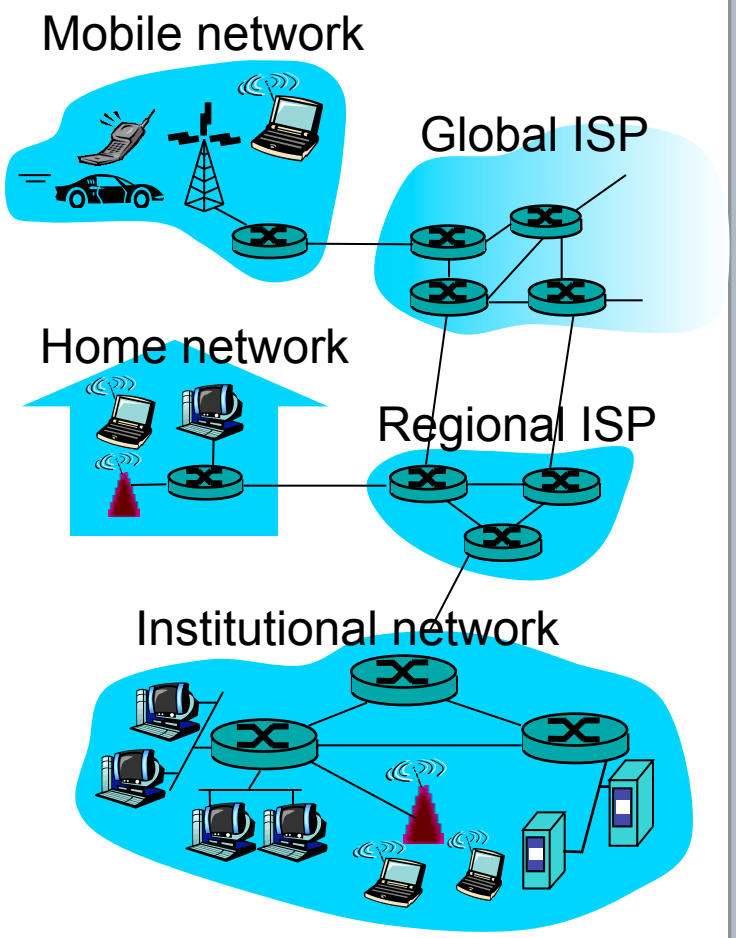
- *routers:* forward packets (chunks of data)

router



What's the Internet: "Nuts and Bolts" view

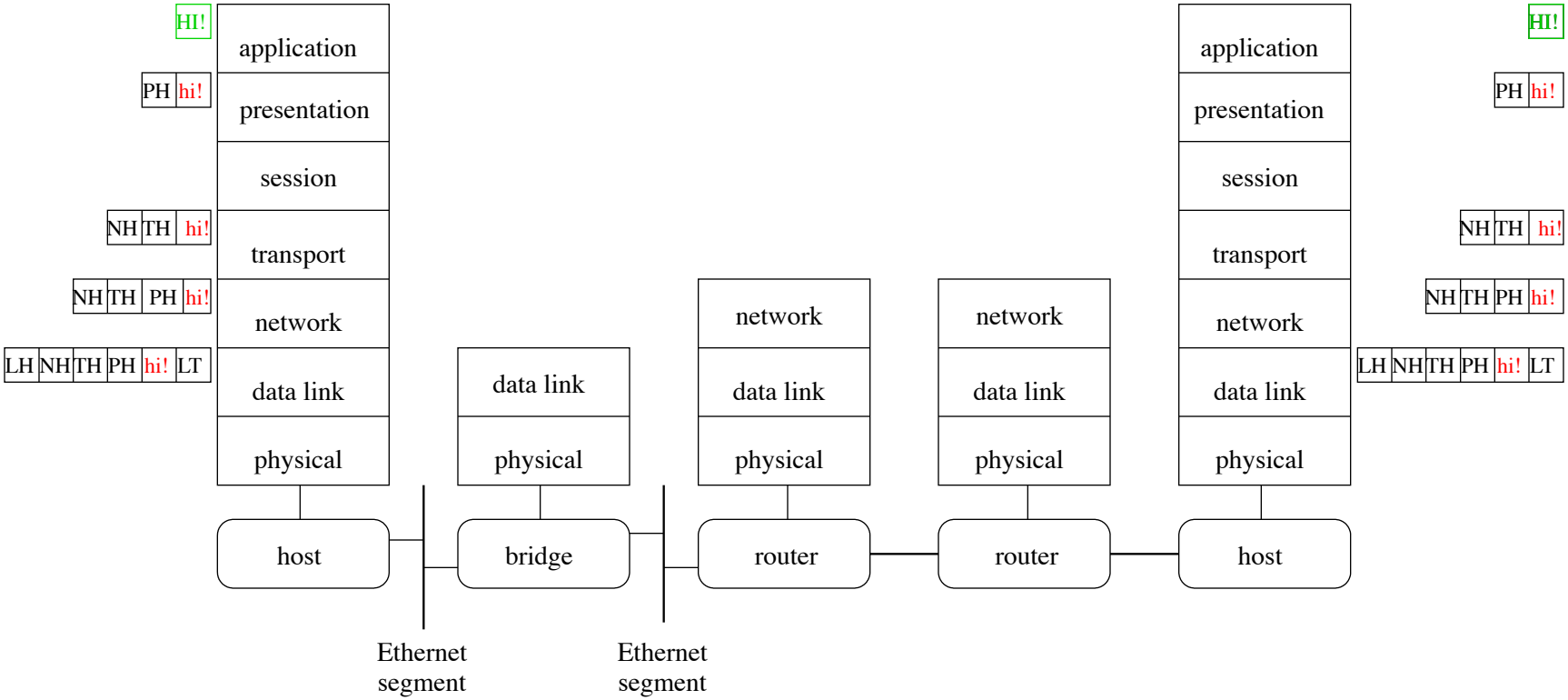
- *Protocols* control sending, receiving of messages
  - e.g., TCP, IP, HTTP, Skype, Ethernet
- *Internet:* "network of networks"
  - loosely hierarchical
  - public Internet versus private intranet
- Internet standards
  - RFC: Request for comments
  - IETF: Internet Engineering Task Force
  - IANA: Internet Assigned Numbers Authority
- Communication *infrastructure* enables distributed applications:
  - Web, VoIP, email, games, e-commerce, file sharing
- Communication services provided to applications:
  - reliable data delivery from source to destination
  - "best effort" (unreliable) data delivery



Protocol Mechanisms

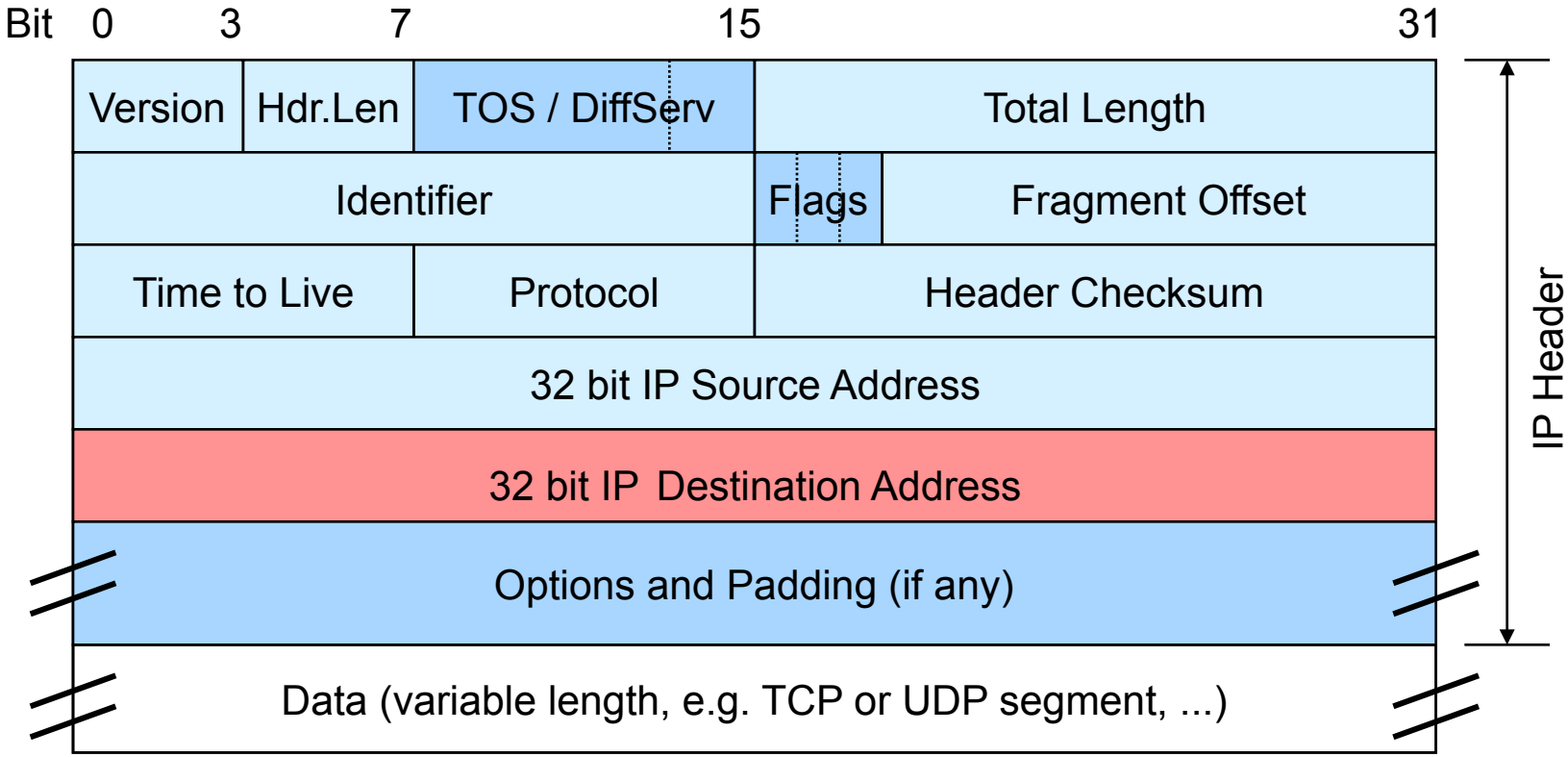
- All or some of the following:
  - addressing/naming: manage identifiers
  - fragmentation: divide large message into smaller chunks to fit lower layer
  - re-sequencing: reorder out-of-sequence messages
  - error control: detection and correction of errors and losses
    - retransmission; forward error correction
  - flow control: avoid flooding/overwhelming of slower receiver
  - congestion control: avoid flooding of slower network nodes/links
  - resource allocation: administer bandwidth, buffers among contenders
  - multiplexing: combine several higher-layer sessions into one “channel”
  - compression: reduce data rate by encoding
  - privacy, authentication: security policy (others are listening)

Protocol Layering



- **send side** layer N takes protocol data (PDU) from layer N +1, adds header, and passed to N-1
- **receive side** layer N takes PDU from N –, strips N headers, processes and passes rest to N + 1

IPv4 Datagram



Ethernet Frame Structure

- Sending adapter encapsulates IP datagram (or other network layer protocol packet) in **Ethernet frame**

PR 56 bit	SFD (8 bit)	DA (16/48 bit)	SA (16/48 bit)	Type/Len (16 bit)	Data (≤12.000 bit)	PAD (0-368 bit)	FCS (32 bit)

PR	Preamble (1010101010...)
SFD	*Start-of-frame Delimiter* (10101011)
DA	*Destination Address*
SA	*Source Address*
Type	Protocol type of payload (e.g. IP, ARP, ...) - in Ethernet II frame format
Len	Length of payload in Byte - in Ethernet I and IEEE 802.3 frame format
Data	Data
PAD	*Padding (if data length is less than 46 byte)*
FCS	*Frame Check Sequence:* CRC32

Layering Considered Harmful?

- Benefits of layering
  - need layers to manage complexity
    - don't want to reinvent Ethernet-specific protocol for each application
  - common functionality
    - "ideal" network
- but:
  - layer N may duplicate lower layer functionality (error recovery)
  - different layers may need same information
  - layer N may need to peek into layer N+x

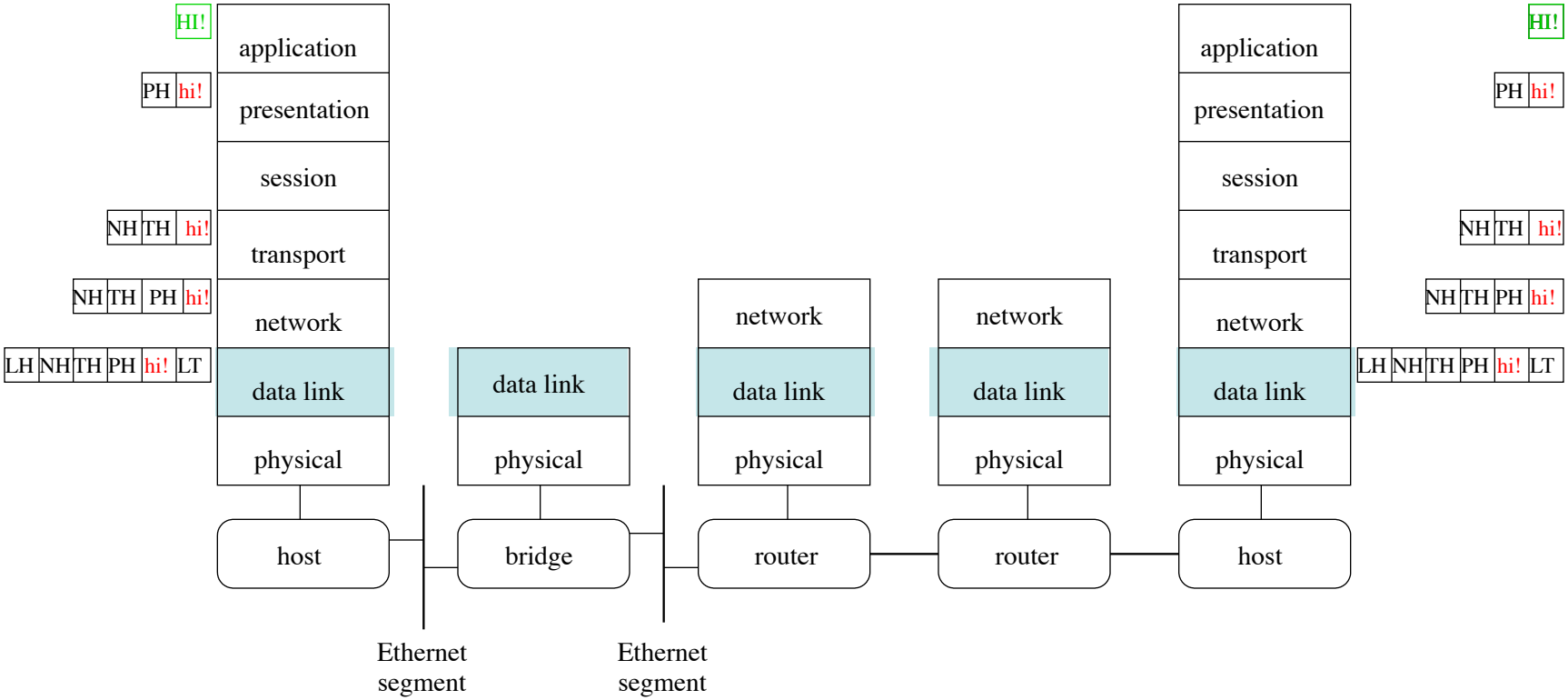
Link Layer

The Data Link Layer

Our goals:

- understand principles behind data link layer services:
  - error detection, correction
  - sharing a broadcast channel: multiple access
  - link layer addressing
  - reliable data transfer, flow control: *c.f. transport layer*
- instantiation and implementation of various link layer technologies

Protocol Layering



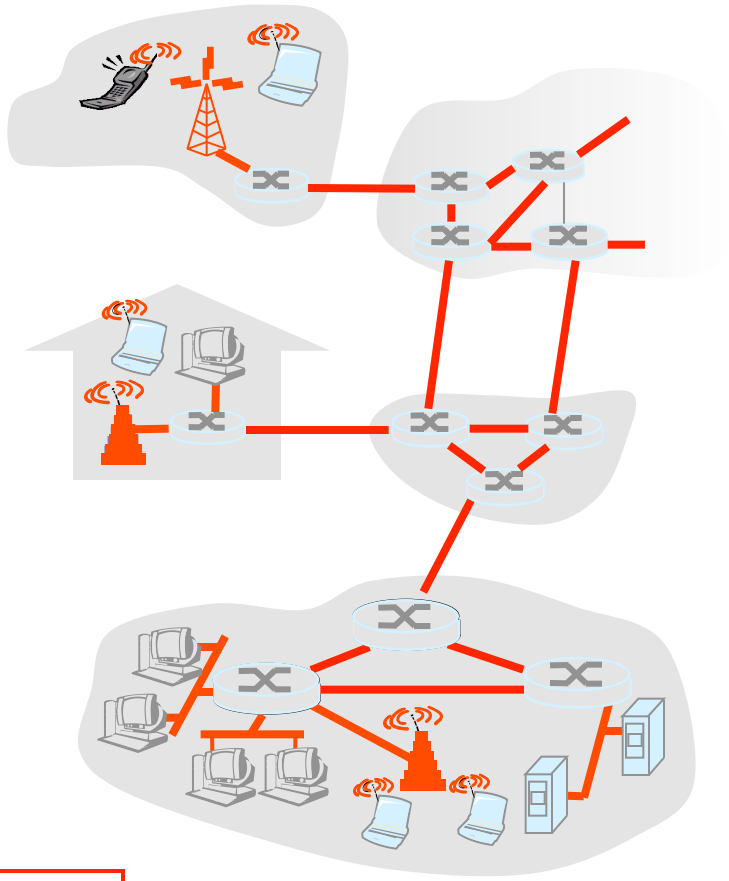
Link Layer

- Introduction and services
- Multiple access protocols
- Link-layer Addressing
- Ethernet
- Link-layer switches
- Link virtualization

Link Layer: Introduction

Some terminology:

- hosts and routers are **nodes**
- communication channels that connect adjacent nodes along communication path are **links**
  - wired links
  - wireless links
  - LANs
- layer-2 packet is a **frame**, encapsulates datagram



data-link layer has responsibility of transferring datagram from one node to adjacent node over a link

Link layer: context

- datagram transferred by different link protocols over different links:
  - e.g., Ethernet on first link, frame relay on intermediate links, 802.11 on last link
- each link protocol provides different services
  - e.g., may or may not provide reliable data transmission over link

transportation analogy

- trip from town A to town B
  - taxi: city center to airport A
  - plane: airport A to airport B
  - train: airport B to city center
- tourist = datagram
- transport segment = communication link
- transportation mode = link layer protocol
- travel agent = routing algorithm

Link Layer Services

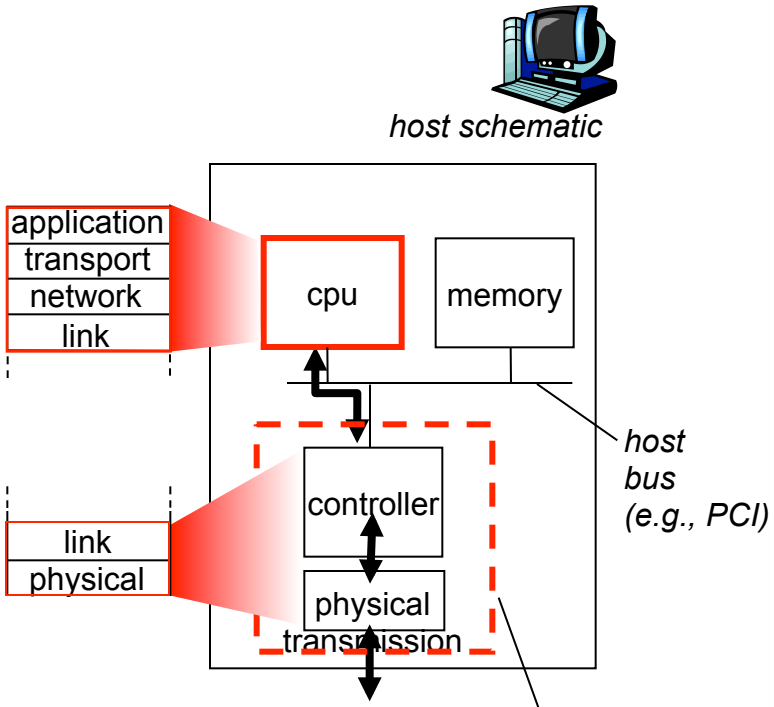
- framing, link access:
  - encapsulate datagram into frame, adding header, trailer
  - channel access if shared medium
  - "MAC" addresses used in frame headers to identify source and destination node
    - different from IP address!
- reliable delivery between adjacent nodes
  - seldom used on low bit-error link (fiber, some twisted pair)
  - wireless links: high error rates
    - Q: why both link-level and end-end reliability?

Link Layer Services (more)

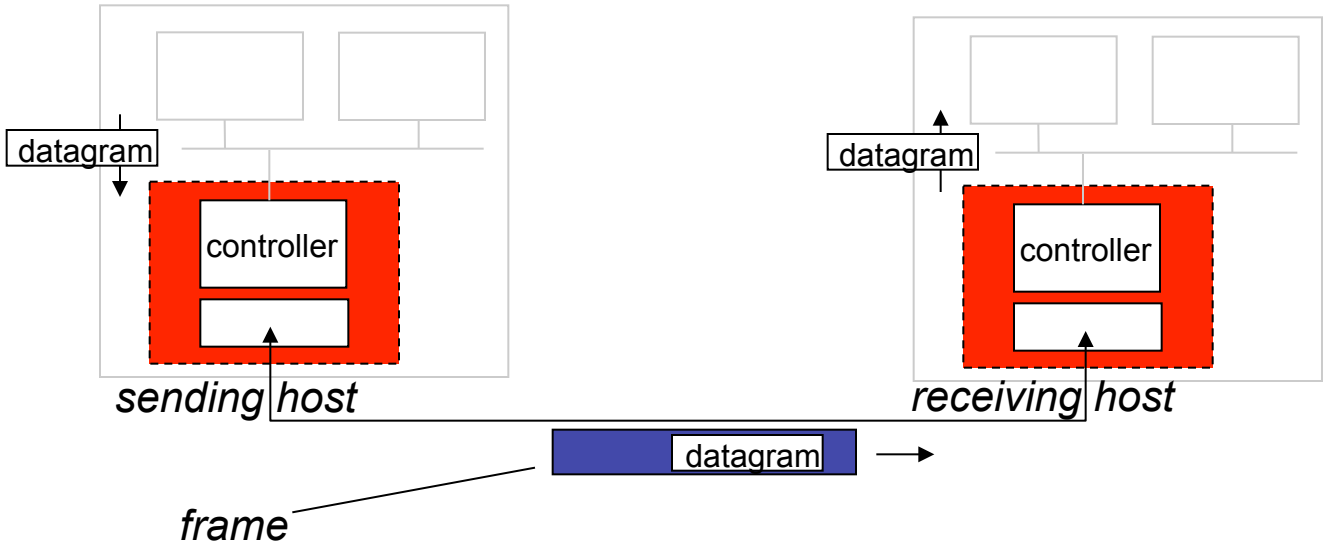
- *flow control:*
  - pacing between adjacent sending and receiving nodes
- *error detection*:
  - errors caused by signal attenuation, noise
  - receiver detects presence of errors:
    - signals sender for retransmission or drops frame
- error correction:
  - receiver identifies *and corrects* bit error(s) without resorting to retransmission
- *half-duplex and full-duplex*
  - with half duplex, nodes at both ends of link can transmit, but not at same time

Where is the link layer implemented?

- in each and every host
- link layer implemented in "adaptor" (aka *network interface card* NIC)
  - Ethernet card, 802.11 card
  - implements link layer and physical layer
- attaches into host's system buses
- combination of hardware, software, firmware



Adaptors Communicating



- sending side:
  - encapsulates datagram in frame
  - adds error checking bits, flow control, etc.
- receiving side
  - looks for errors, flow control, etc.
  - extracts datagram, passes to upper layer at receiving side