EPL606

Topic 1
Introduction
Part A

The majority of the slides in this course are adapted from the accompanying slides to the books by Larry Peterson and Bruce Davie and by Jim Kurose and Keith Ross. Additional slides and/or figures from other sources and from Vasos Vassiliou are also included in this presentation.

Outline

- Our goal:
- get “feel” and terminology
- more depth, detail later in course
- approach:
  - use Internet as example
- Network Requirements?
- Connectivity
- Services
- Resource sharing
- Performance

What is the Objective of Networking?

- Communication between applications on different computers
- Must understand the different requirements that exist
- Who defines the requirements?

Requirement Definition

- Requirements and Constraints depend on your perspective:
  - Network users want the network to provide services that their applications need; e.g., guarantee that each message will be delivered in order, without errors, and within a pre-defined delay
  - Network designers want a cost-effective design; e.g., network resources are efficiently utilized and fairly allocated to users
  - Network providers want a system that is easy to administer and manage; e.g., faults can be easily found, system can be hotswapped, and easy to track usage of users

Four Steps to Networking

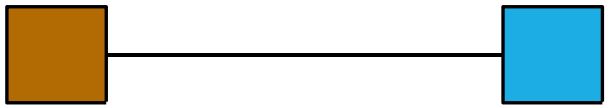
- Communicating across a link
- Connecting together multiple links (internetworking)
- Finding and routing data to nodes on internetwork
- Matching application requirements

A First Step

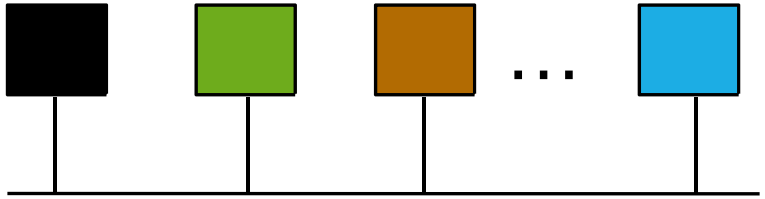
- Creating a link between nodes
- Link: path followed by bits
  - Wired or wireless
  - Broadcast or point-to-point (or both)
  - copper wires (coax cable, twisted pair), optical fiber,
- Node: any device connected to a link
  - Computers or servers
  - Routers or switches
  - Mobile terminal

Types of Links

Point-to-Point



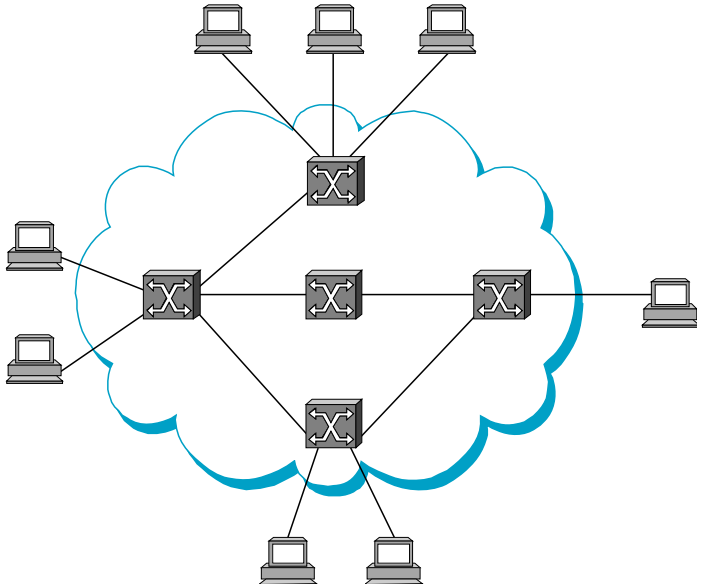
Multiple Access



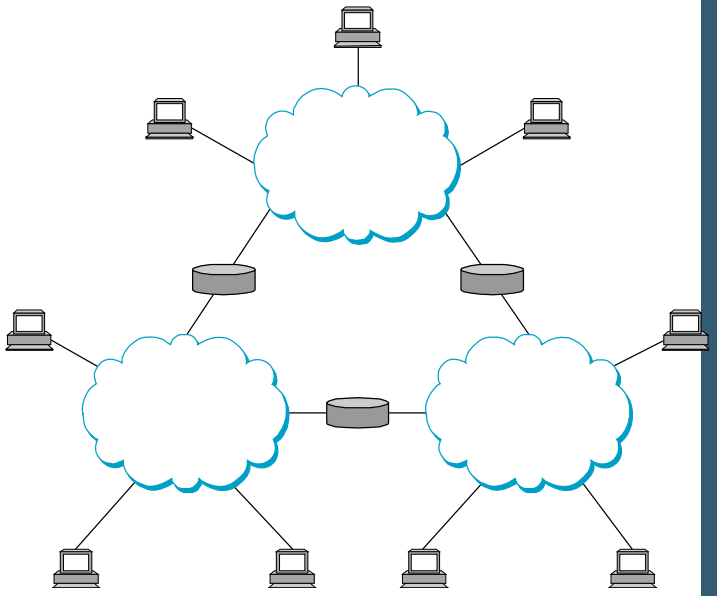
Connectivity Requirement

- "A network is two or more nodes connected by a direct link, or two or more networks connected by one or more nodes"
- Hosts connected directly or indirectly
  - Need global addressability
  - Need routing ability
  - Unicast/Broadcast/Multicast
- Network Edge vs. Network Core; does it make a difference?

Types of Networks



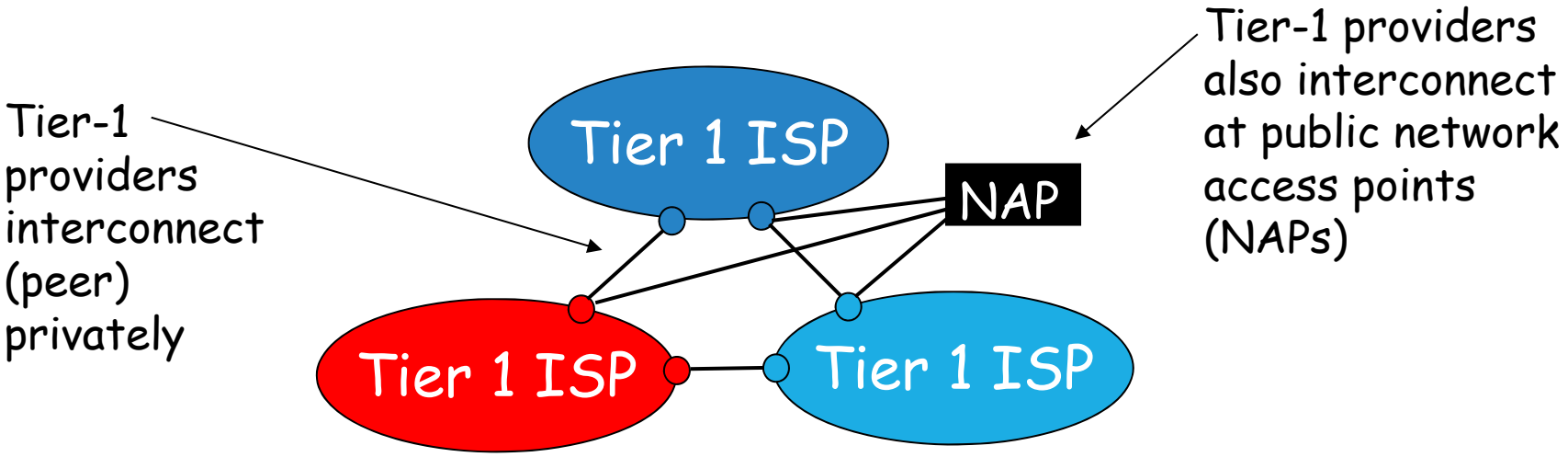
Two or more connected nodes



Two or more connected networks

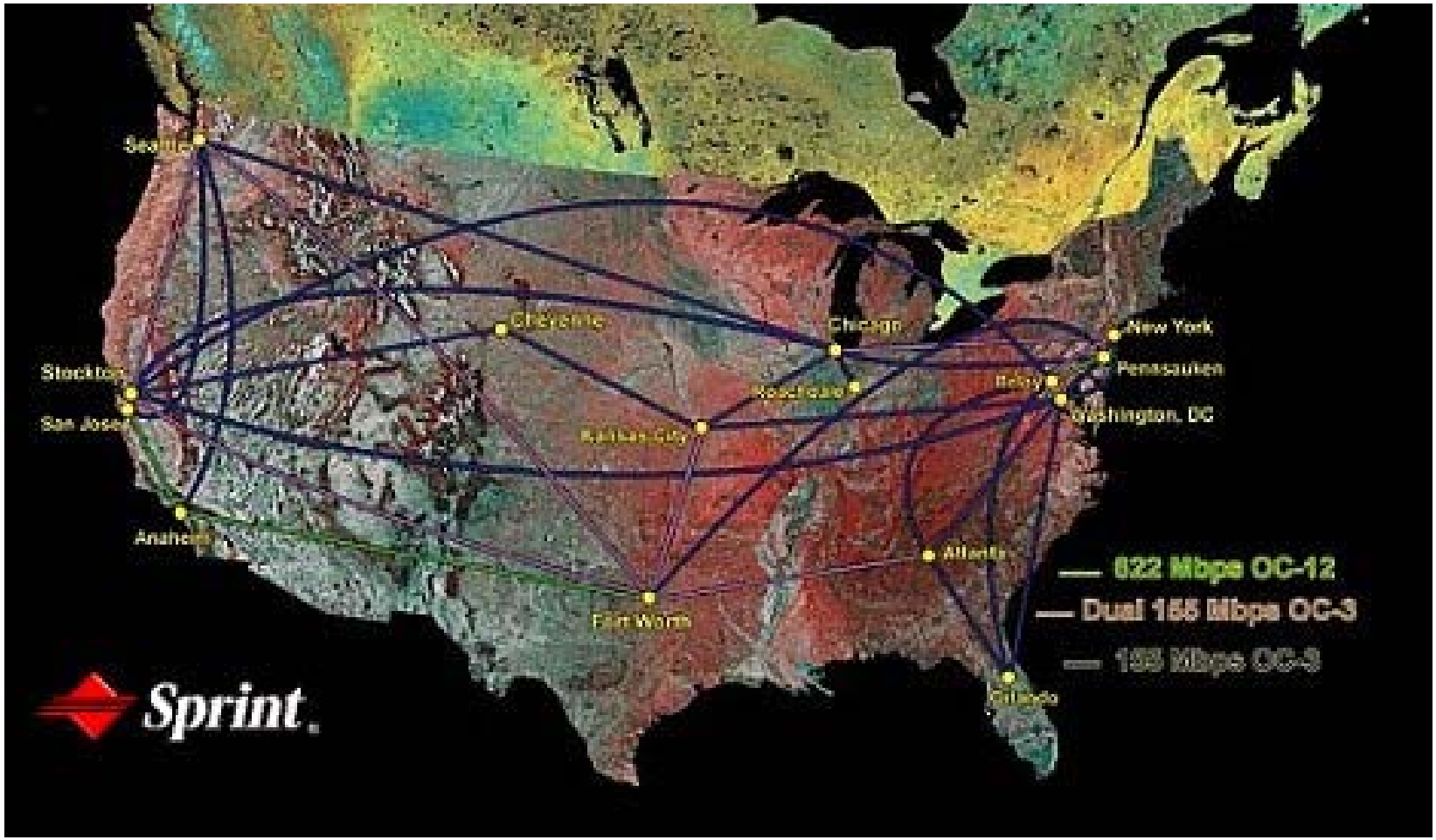
Internet structure: network of networks

- roughly hierarchical
- at center: "tier-1" ISPs (e.g., UUNet, BBN/Genuity, Sprint, AT&T), national/international coverage
  - treat each other as equals

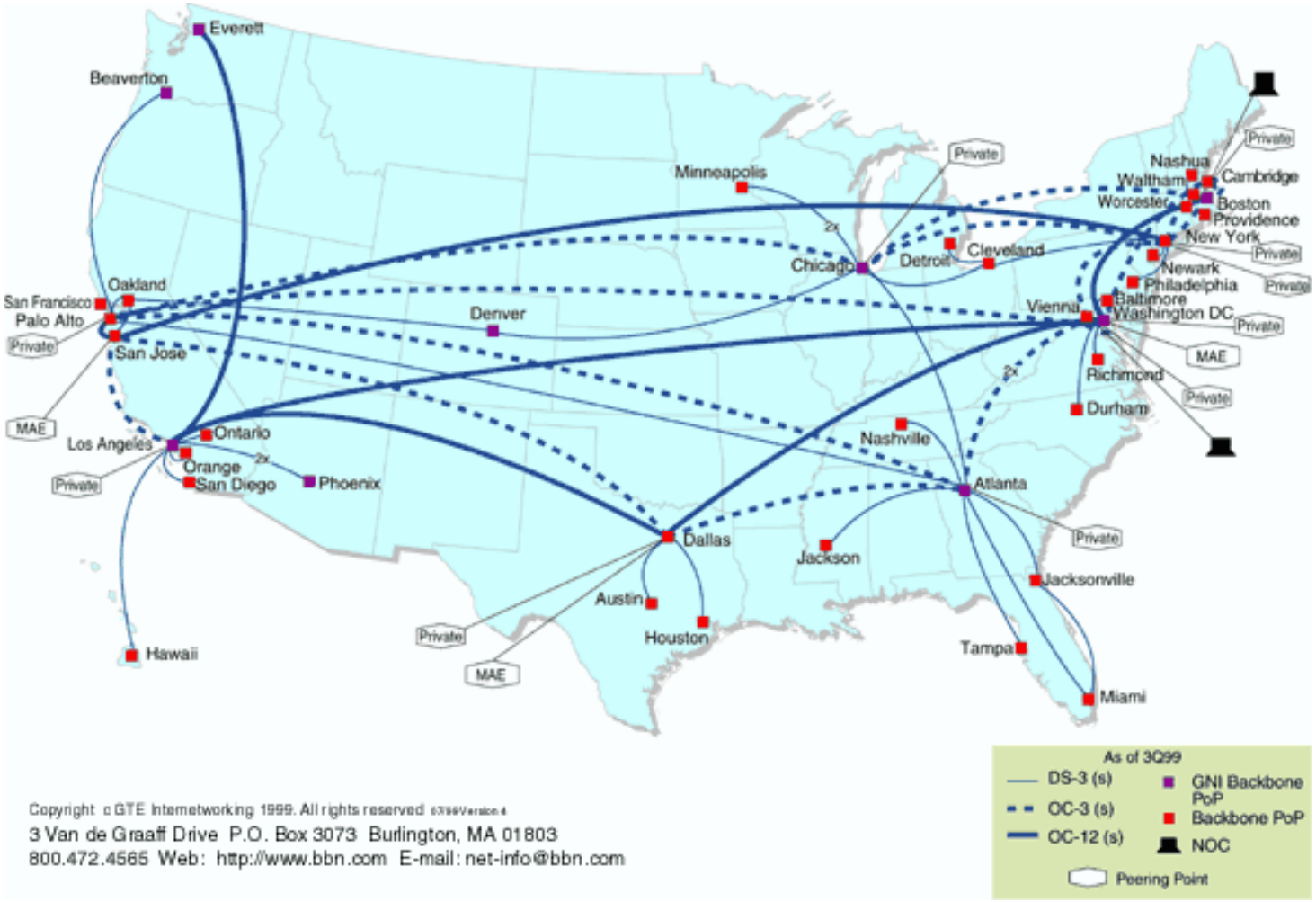


Tier-1 ISP: e.g., Sprint

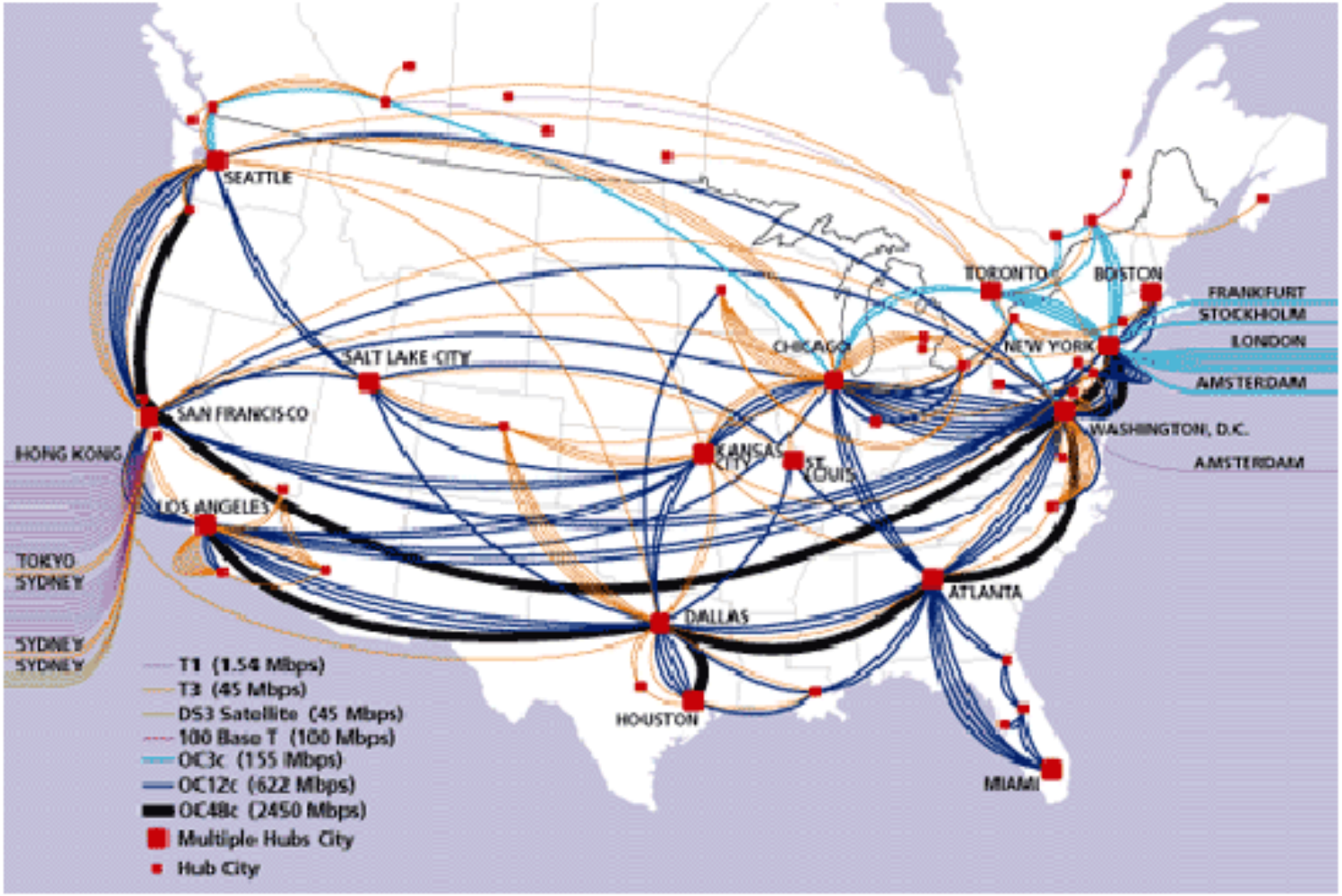
Sprint US backbone network



Tier-1 ISP: e.g., BBN/GTE

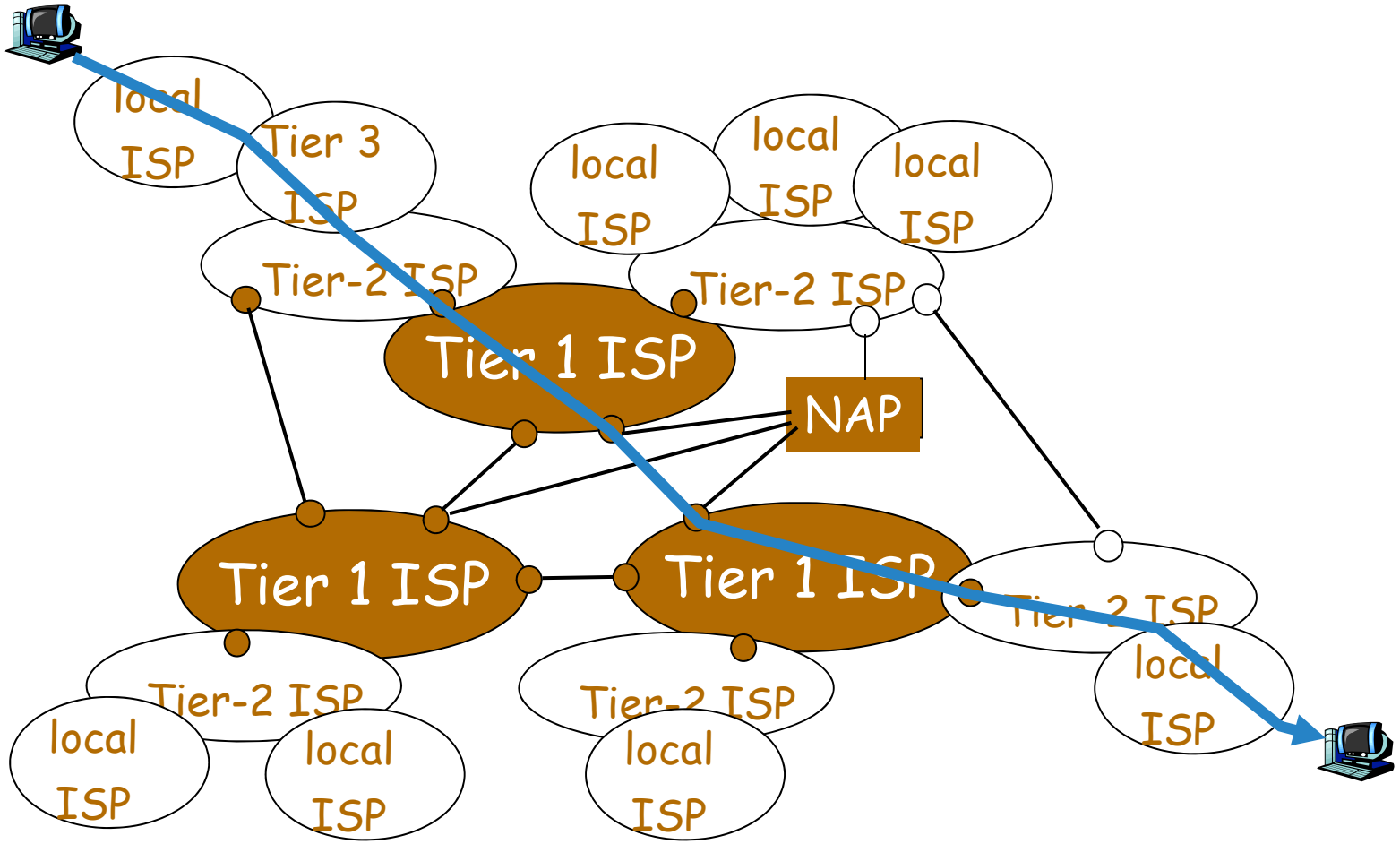


Tier-1 ISP: e.g., UUnet



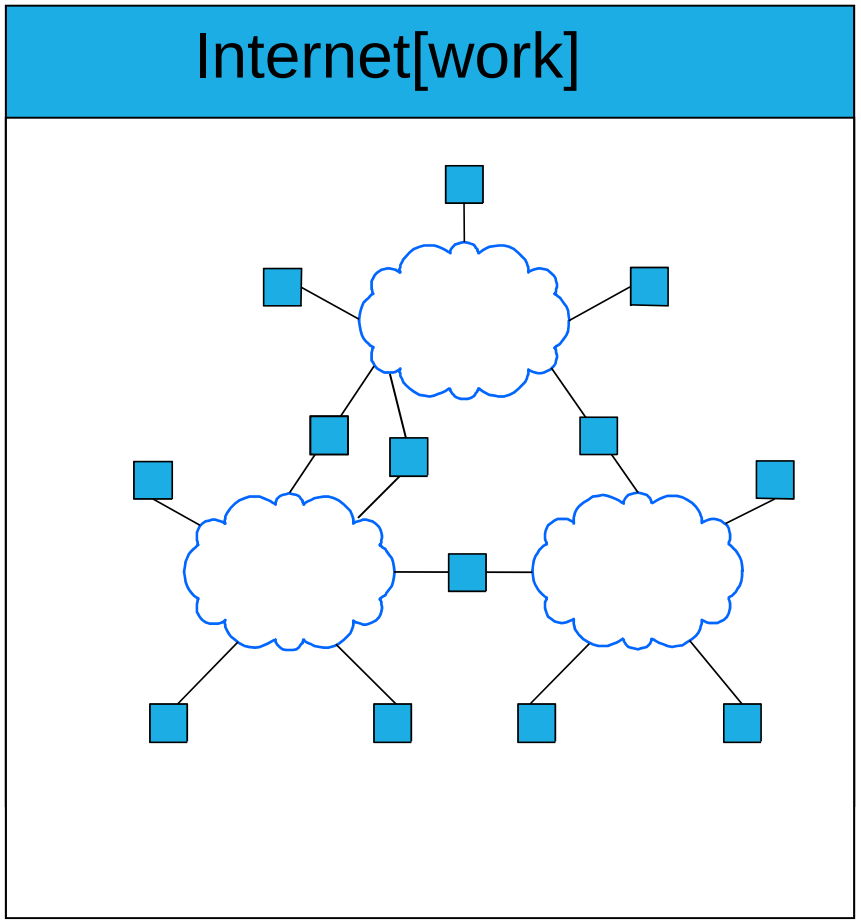
Internet structure: network of networks

- a packet passes through many networks!



Second Step: Internet[work]

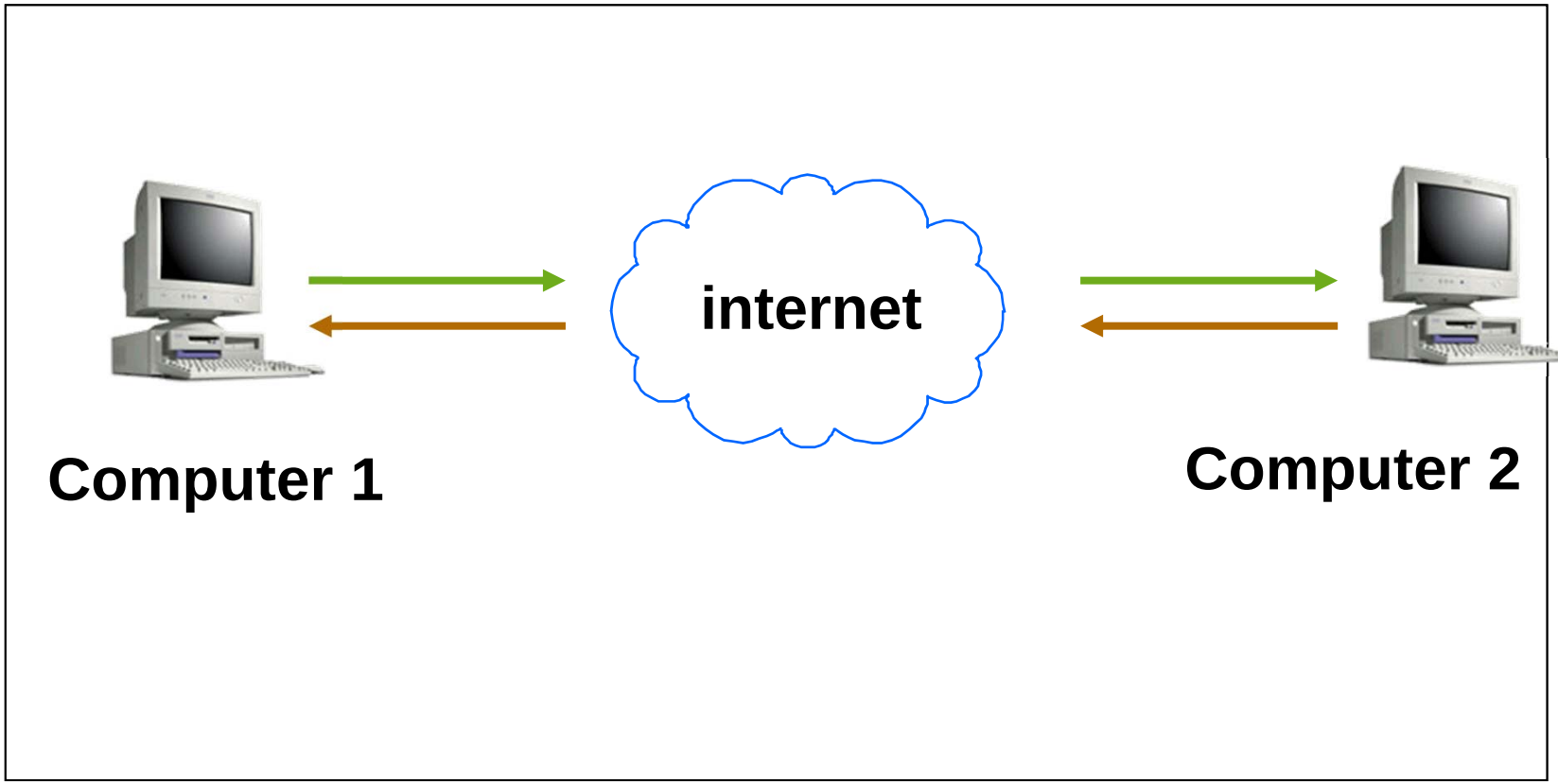
- A collection of interconnected networks
- Host: network endpoints (computer, PDA, light switch, …)
- Router: node that connects networks



Challenge

- Many differences between networks
  - Address formats
  - Performance – bandwidth/latency
  - Packet size
  - Loss rate/pattern/handling
  - Routing
- How to translate between various network technologies

Third Step: How To Find Nodes?



Naming

- Humans use readable host names
  - E.g. www.gatech.edu, www.ucy.ac.cy
  - Globally unique (can correspond to multiple hosts)
- Naming system translates to physical address
  - E.g. DNS translates name to IP Address (e.g. 128.2.11.43)
  - Address reflects location in network

Domain Name System

What's the IP address for www.cmu.edu?

It is 128.2.11.43

Computer 1

Local DNS Server

DNS server address manually configured into OS

Packet Routing/Delivery

- Each network technology has different local delivery methods
- Address resolution provides delivery information within network
  - E.g., ARP maps IP addresses to Ethernet addresses
  - Local, works only on a particular network
- Routing protocol provides path through an internetwork

Network:Address Resolution Protocol

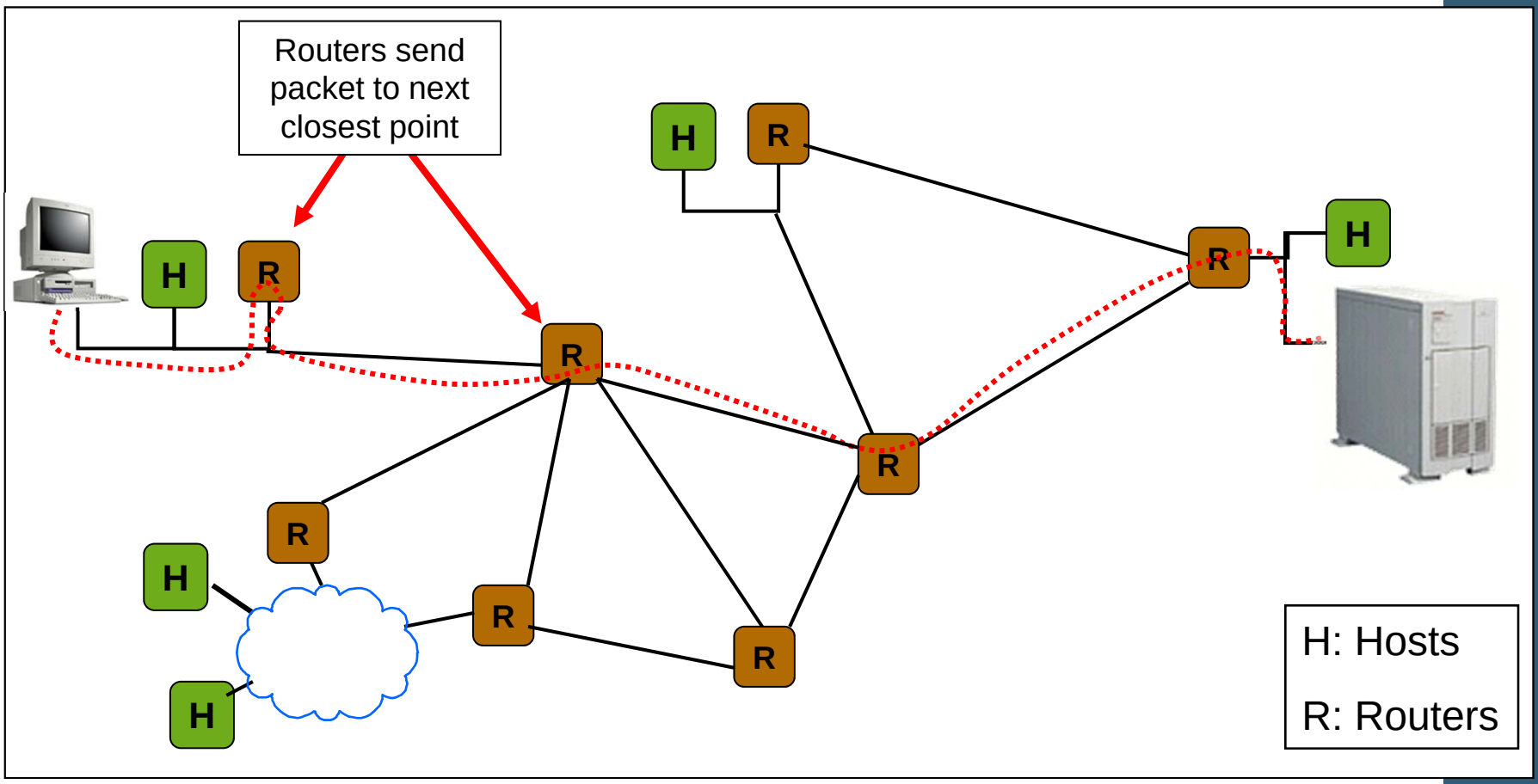
Broadcast: who knows the Ethernet address for 128.2.11.43***?***

Ethernet

Broadcast: Yes, it is
08-00-2c-19-dc-45

Ethernet

Internetwork: Datagram Routing



Routing

- Forwarding tables at each router populated by routing protocols.
- Original Internet: manually updated
- Routing protocols update tables based on “cost”
  - Exchange tables with neighbors or everyone
  - Use neighbor leading to shortest path

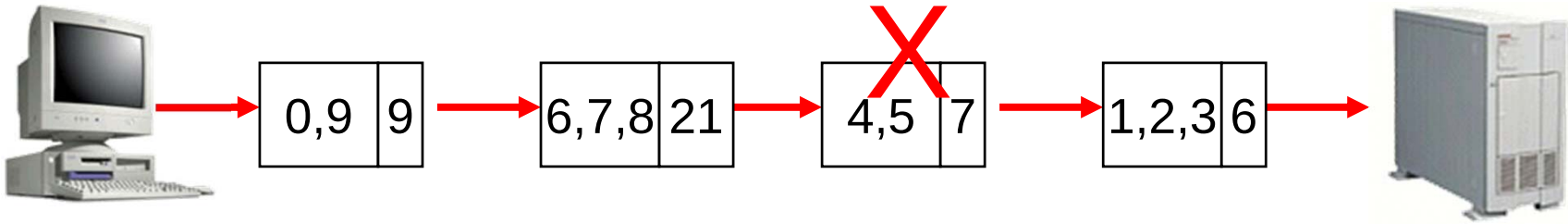
Fourth Step: Application Demands

- Reliability
  - Corruption
  - Lost packets
- Flow and congestion control
- Fragmentation
- In-order delivery
- Etc…

What if the Data gets Corrupted?

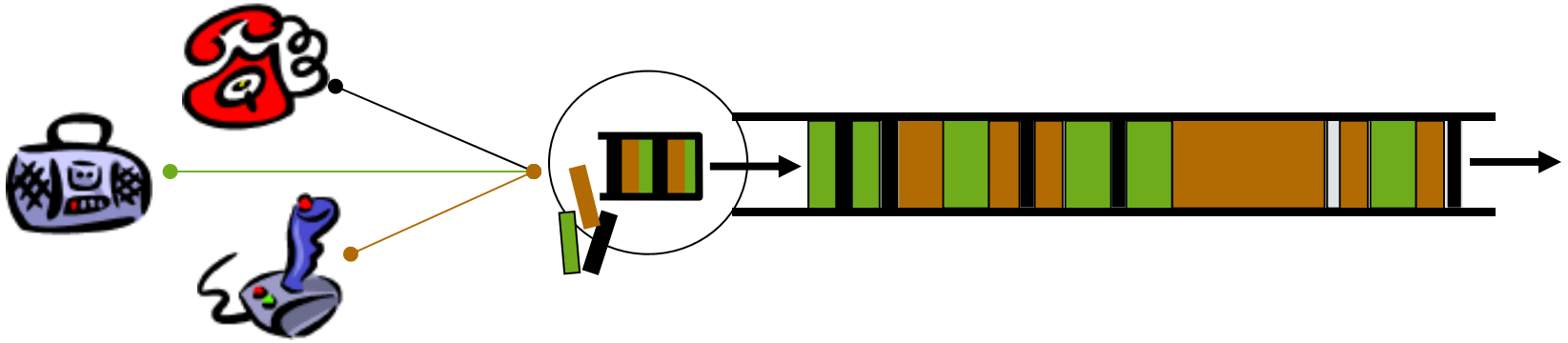
Problem: Data Corruption

Solution: Add a *checksum*



What if Network is Overloaded?

Problem: Network Overload



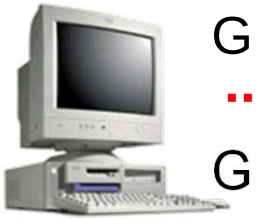
Solution: Buffering and Congestion Control

What if the Data gets Lost?

Problem: Lost Data

GET index.html

Solution: Timeout and Retransmit



GET index.html

GET index.html

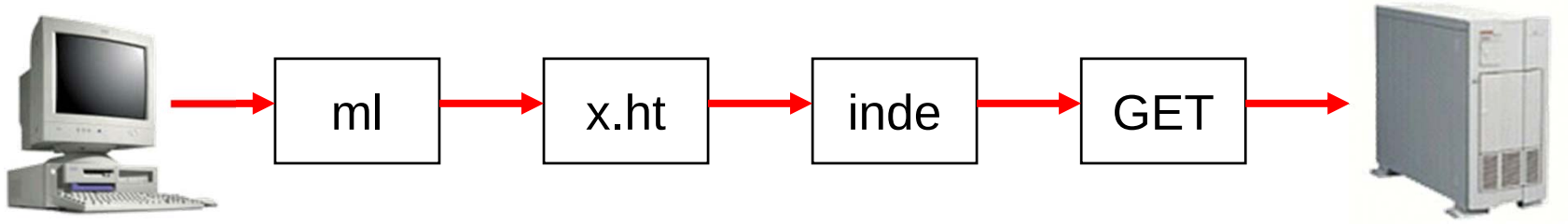
GET index.html

What if the Data Doesn't Fit?

Problem: Packet size

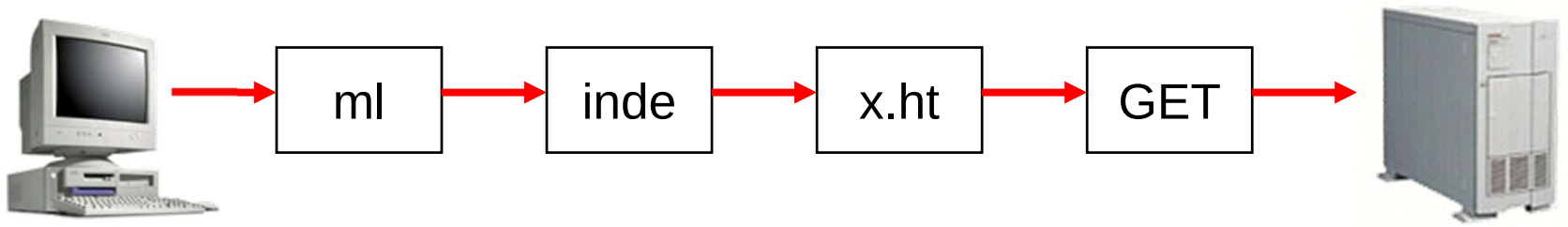
- On Ethernet, max IP packet is 1.5kbytes
- Typical web page is 10kbytes

Solution: Fragment data across packets



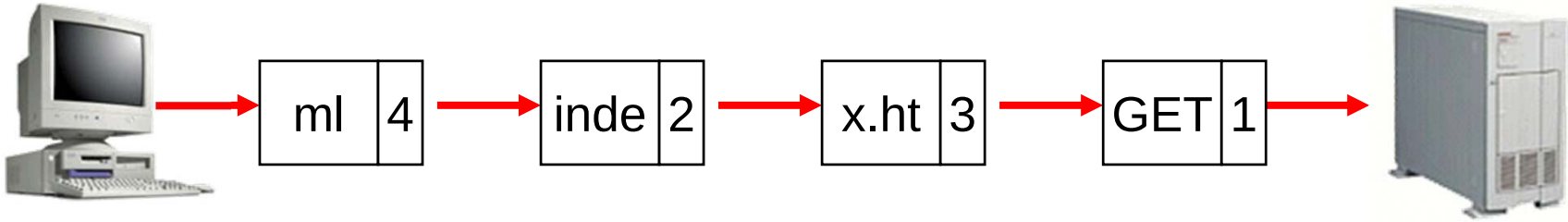
What if the Data is Out of Order?

Problem: Out of Order



GET x.htindeml

Solution: Add Sequence Numbers



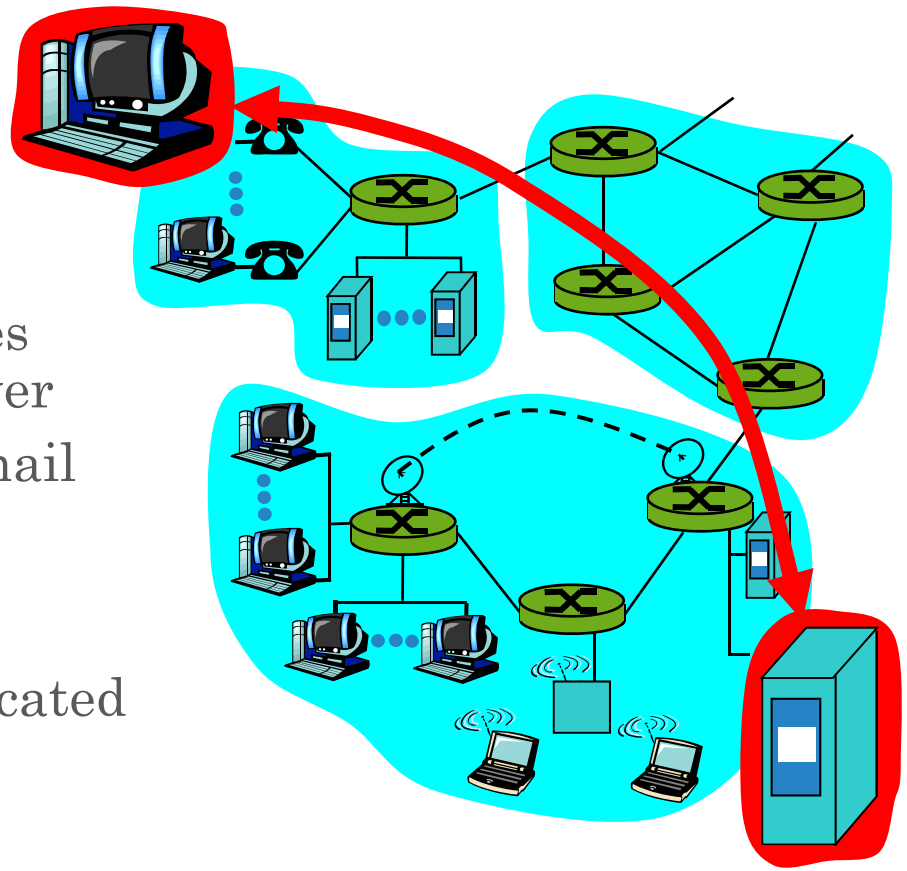
GET index.html

Network Functionality Summary

- Link
- Multiplexing
- Routing
- Addressing/naming (locating peers)
- Reliability
- Flow control
- Fragmentation
- Etc….

The network edge:

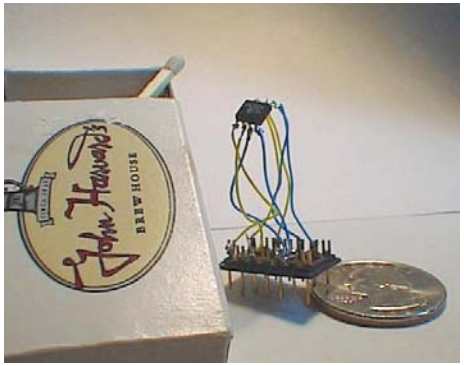
- end systems (hosts):
  - run application programs
  - e.g. Web, email
  - at “edge of network”
- client/server model
  - client host requests, receives service from always-on server
  - e.g. Web browser/server; email client/server
- peer-peer model:
  - minimal (or no) use of dedicated servers
  - e.g. Gnutella, KaZaA



“Cool” internet appliances

IP picture frame
http://www.ceiva.com/

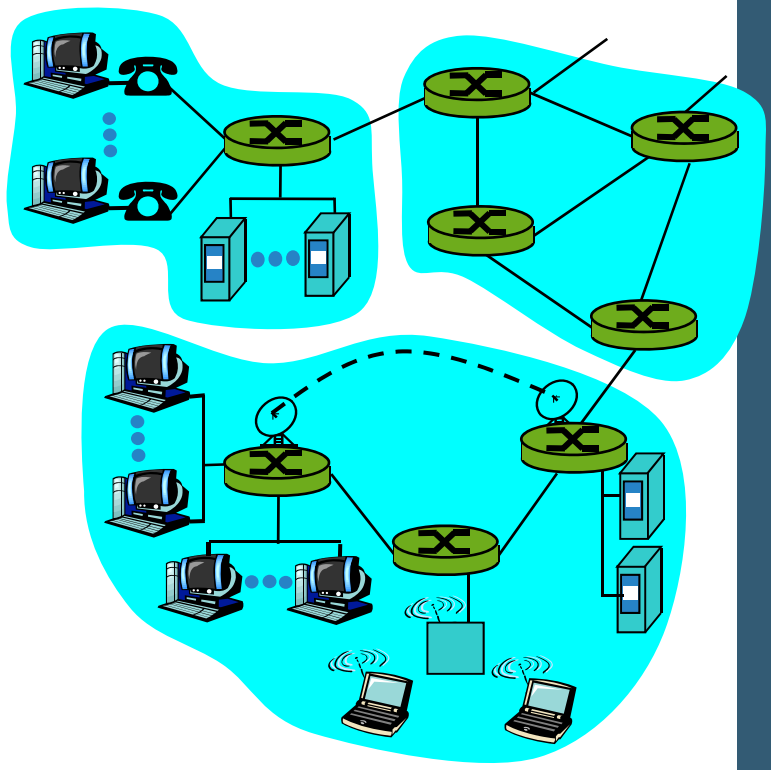
Web-enabled toaster+weather forecaster



World’s smallest web server
http://www-ccs.cs.umass.edu/~shri/iPic.html

What's the Internet: a service view

- communication *infrastructure* enables distributed applications:
  - Web, email, games, e-commerce, file sharing
- communication services provided to apps:
  - Connectionless unreliable
  - connection-oriented reliable



Application Support Requirement

- How should we go about building the network that will realize our wish-list of requirements?
  - Many requirements, including general, efficient, fair, reliable, high performance connectivity among a large number of computers
  - Technology and application demands constantly changing
  - Hardware is heterogeneous

Why layering?

- Dealing with complex systems:
- Modular approach to network functionality
- explicit structure allows identification, relationship of complex system's pieces
  - layered reference model for discussion
- modularization eases maintenance, updating of system
  - change of implementation of layer's service transparent to rest of system
  - e.g., change in gate procedure doesn't affect rest of system

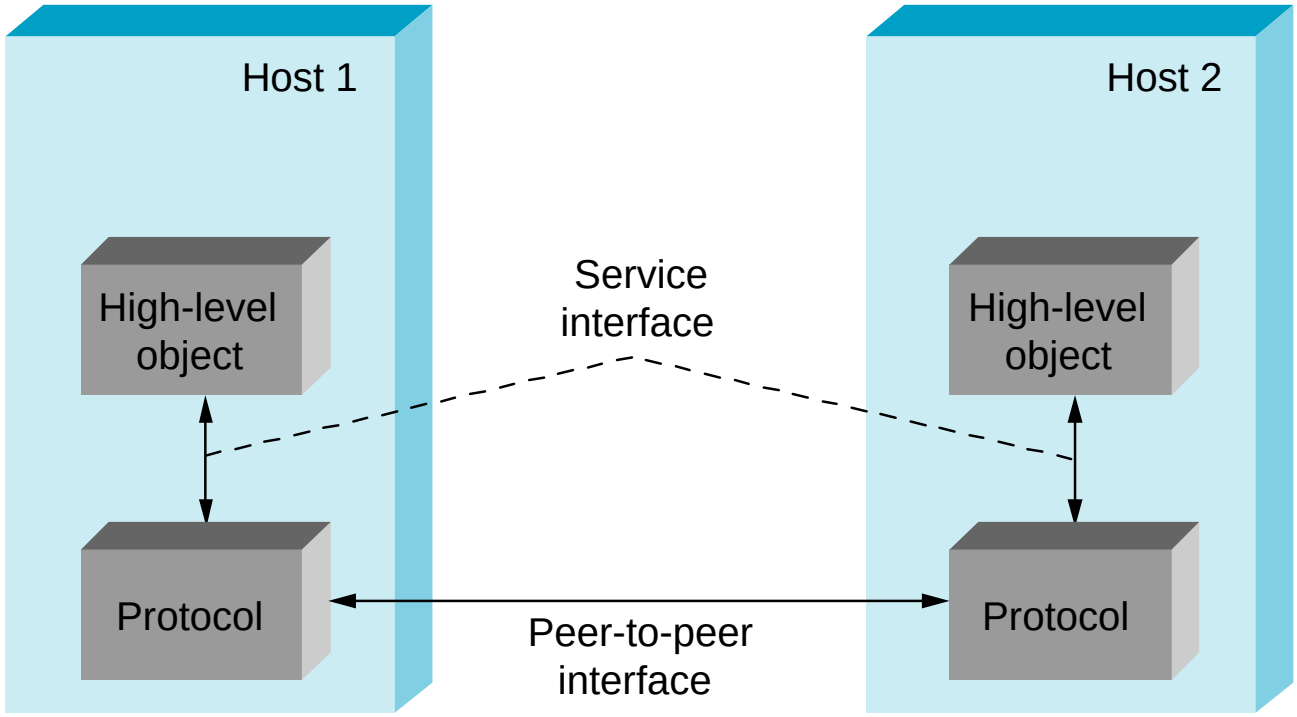
Layering Characteristics

- Each layer relies on services from layer below and exports services to layer above
- Interface defines interaction
- Hides implementation - layers can change without disturbing other layers (black box)

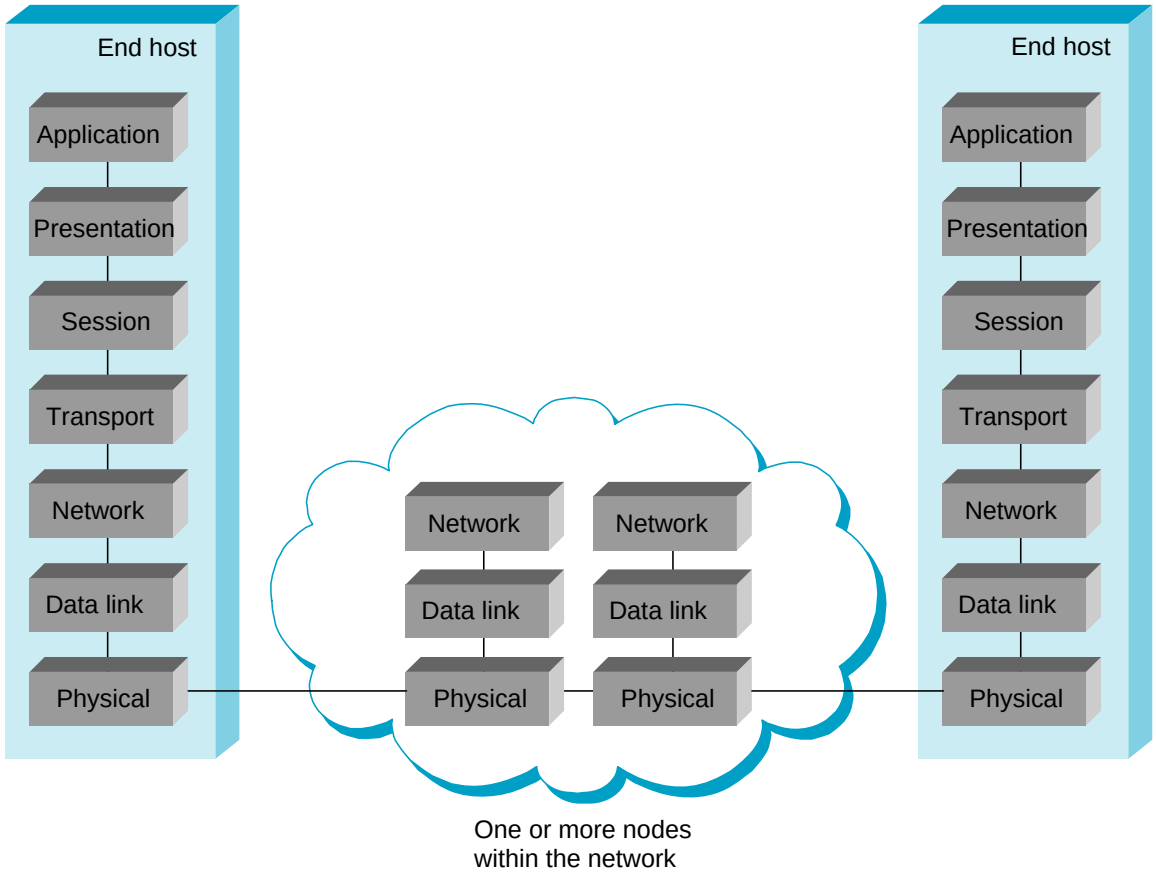
Protocols

- Module in layered structure
- Set of rules governing communication between network elements (applications, hosts, routers)
- Protocols define:
  - Interface to higher layers (API)
  - Interface to peer
    - Format and order of messages sent and received among network entities
    - Actions taken on receipt or transmission of a message

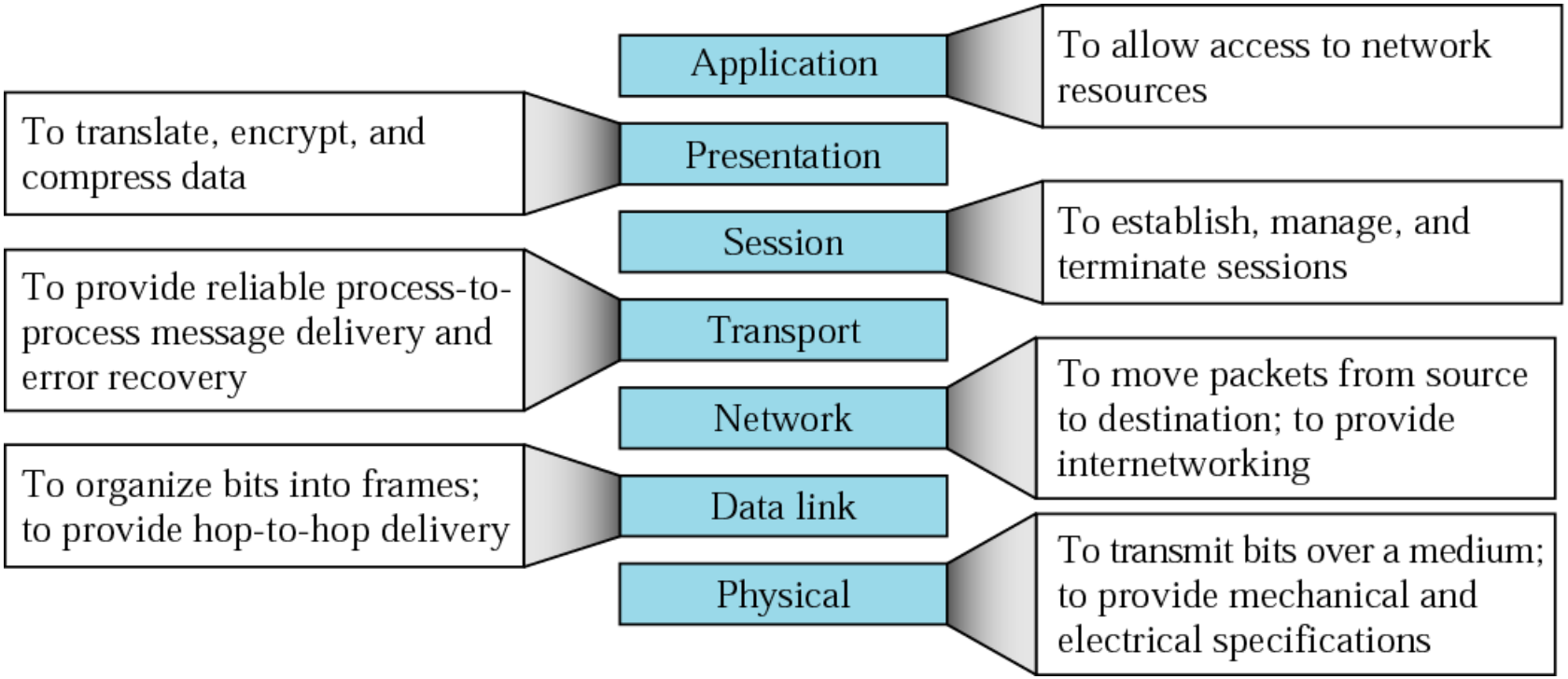
Interfaces


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

ISO Architecture



Summary of layers



Μοντέλο OSI

- Φυσικό στρώμα (Physical Layer)
  - Μετάδοση ακατέργαστων bits (0 ή 1) από τον αποστολέα στον δέκτη.
- Στρώμα Ζεύξης Δεδομένων (Data Link Layer)
  - Τεμαχίζει τα δεδομένα σε πλαίσια δεδομένων (frames)
  - Επιβεβαιώνει ότι η επικοινωνία του Φυσικού στρώματος είναι αξιόπιστη (Πλαίσια επαλήθευσης - acknowledgement frames)
  - Ανίχνευση και επιδιόρθωση λαθών (Error detection and correction).
  - Έλεγχος ροής (flow control).

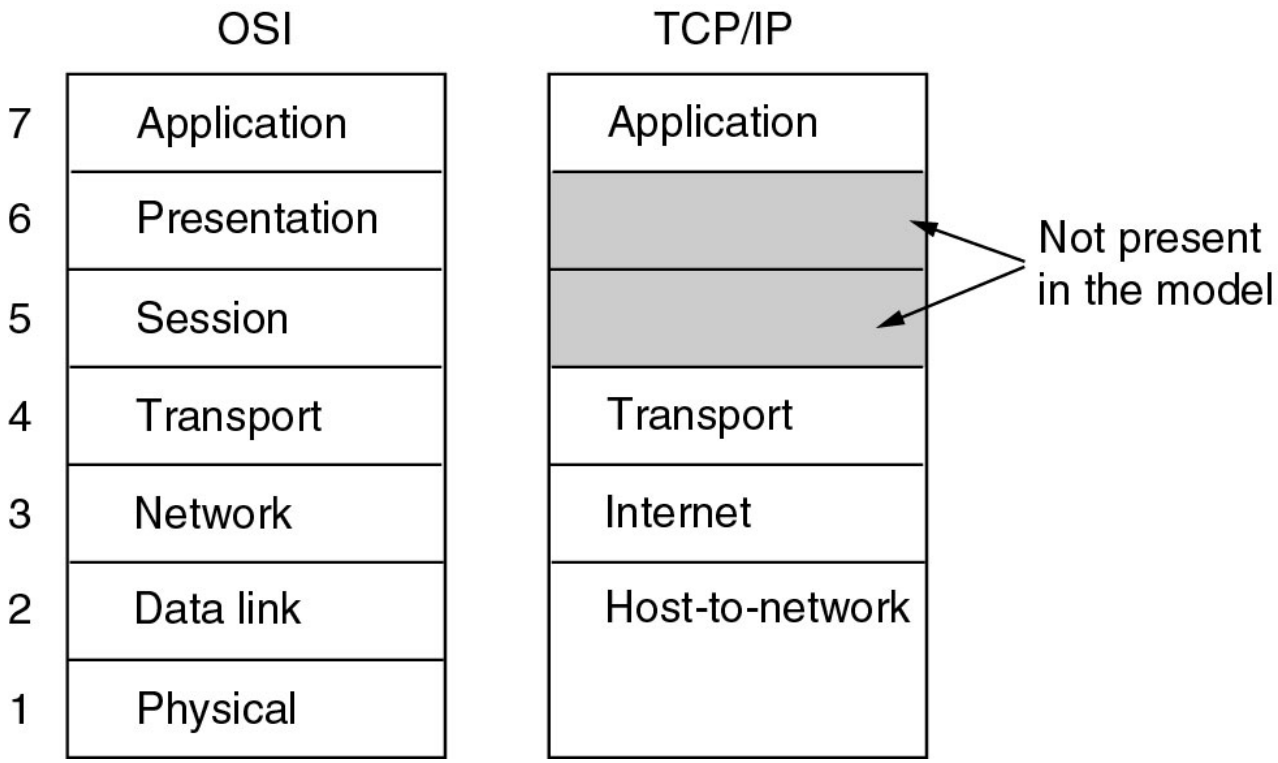
Μοντέλο OSI

- Στρώμα Δικτύου (Network Layer)
  - Δρομολόγηση πακέτων
  - Έλεγχος συμφόρησης
  - Έκδοση λογαριασμών (billing)
- Στρώμα Μεταφοράς (Transport Layer)
  - Τεμαχίζει τα μηνύματα σε μικρότερες μονάδες
  - Επιβεβαιώνει ότι όλες οι μονάδες φτάνουν στο άλλο άκρο και επανασυναρμολογεί το μήνυμα.
  - Πολυπλεξία συνδέσεων/συρμών (steams)
  - Υπηρεσίες μεταφοράς πακέτων από άκρο σε άκρο (end-to-end). (π.χ., αξιόπιστη μεταφορά δεδομένων στον δέκτη).
  - Έλεγχος συμφόρησης (congestion) και ροής πακέτων

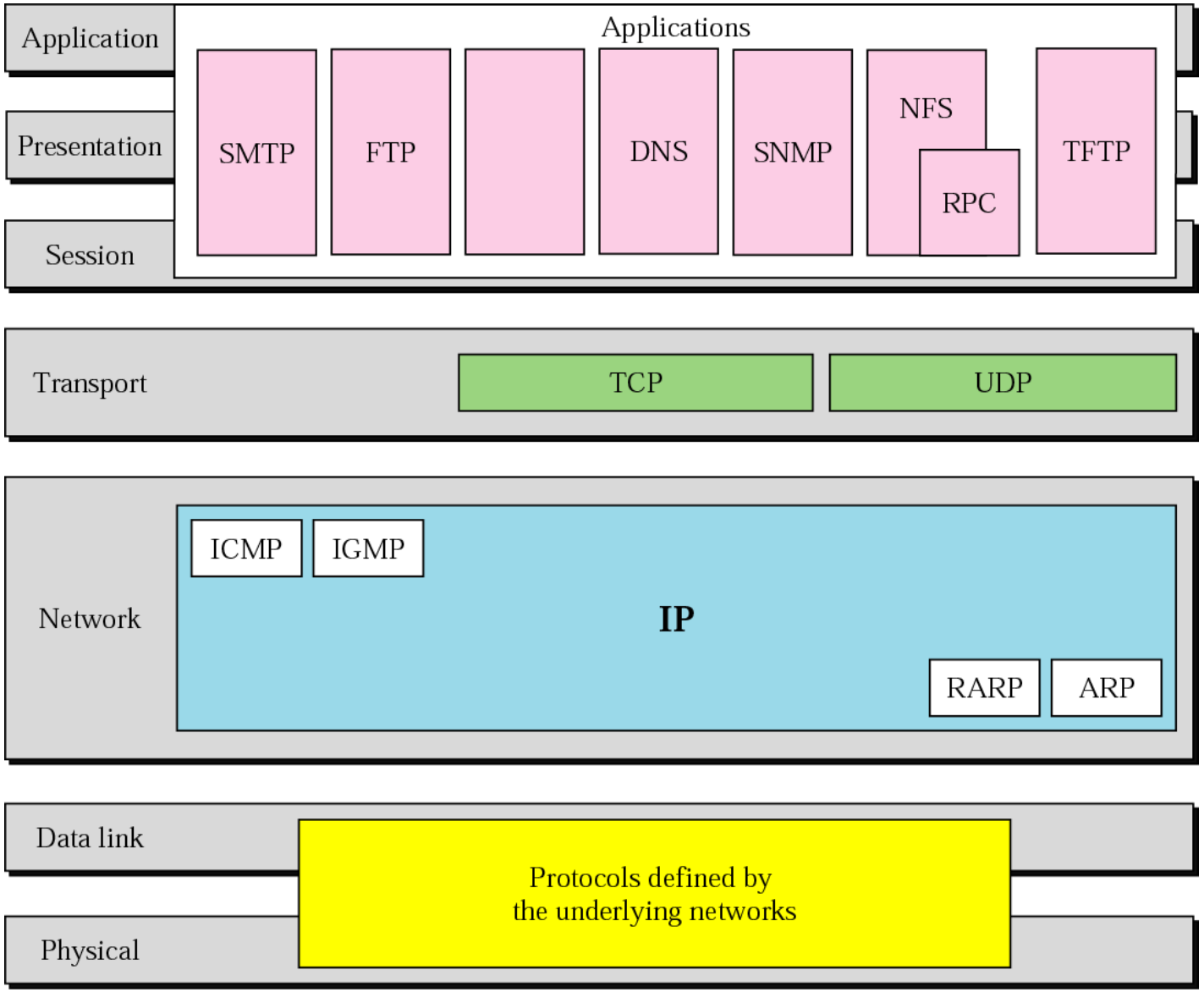
Μοντέλο OSI

- Στρώμα Συνόδου (Session Layer)
  - Αποκατάσταση συνόδων μεταξύ διαφόρων μηχανών (sessions)
  - Διαχείριση σκυτάλης (token management)
  - Συγχρονισμός (synchronization)
- Στρώμα Παρουσίασης (Presentation Layer)
  - Κωδικοποίηση δεδομένων
- Στρώμα Εφαρμογή (Application Layer)
  - Συμβατότητα μεταξύ εφαρμογών

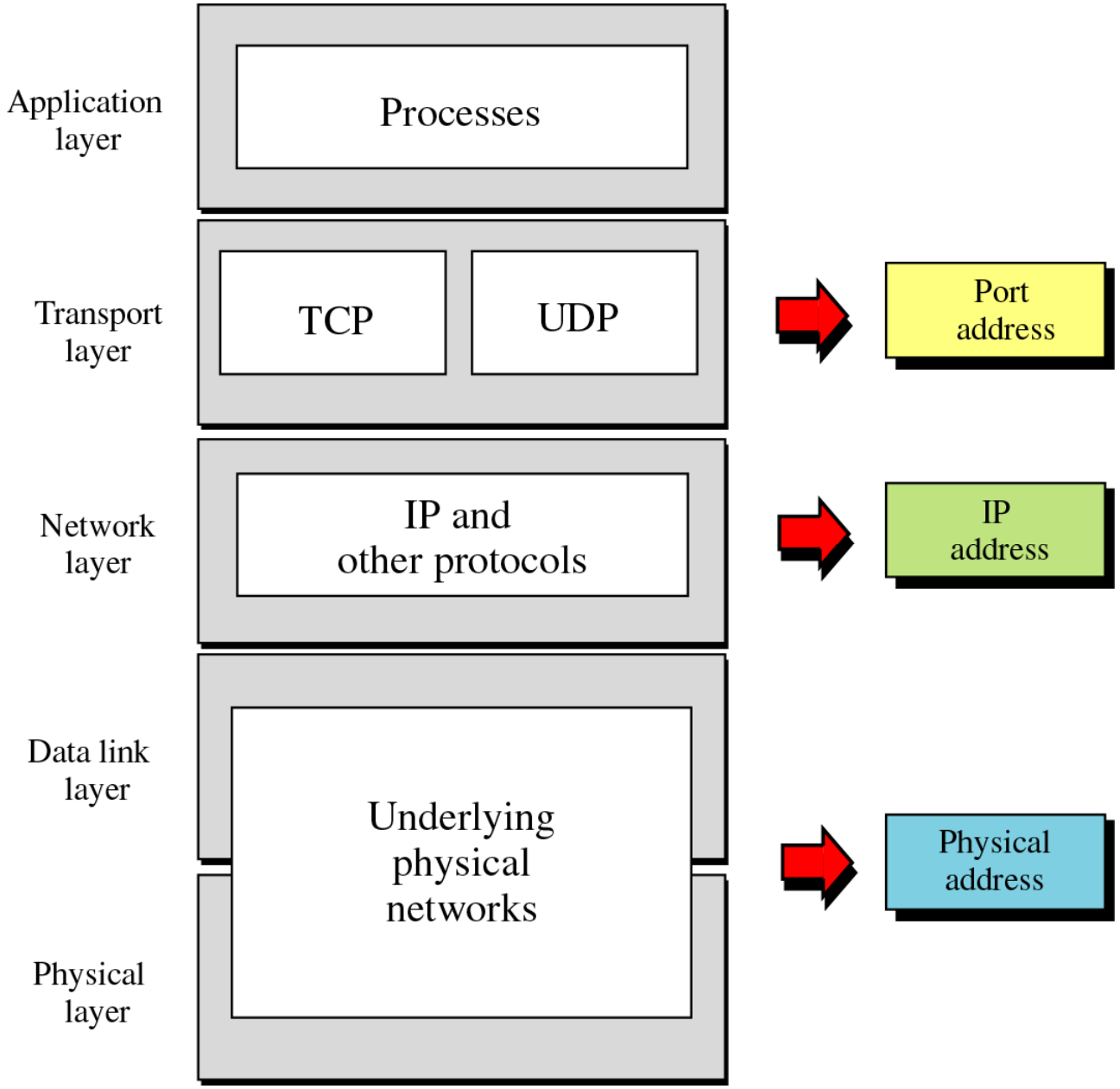
TCP/IP Protocol stack



TCP/IP and OSI model



Relation-ship of layers and addresses in TCP/IP



Is Layering Harmful?

- Sometimes..
  - Layer N may duplicate lower level functionality (e.g., error recovery)
  - Layers may need same info (timestamp, MTU)
  - Strict adherence to layering may hurt performance

Design Considerations

- How to determine split of functionality
  - Across protocol layers
  - Across network nodes
- Assigned Reading
  - [SRC84] End-to-end Arguments in System Design
  - [Cla88] Design Philosophy of the DARPA Internet Protocols