EE 542
Lecture 2: Networking

Internetwork and Cloud Computing

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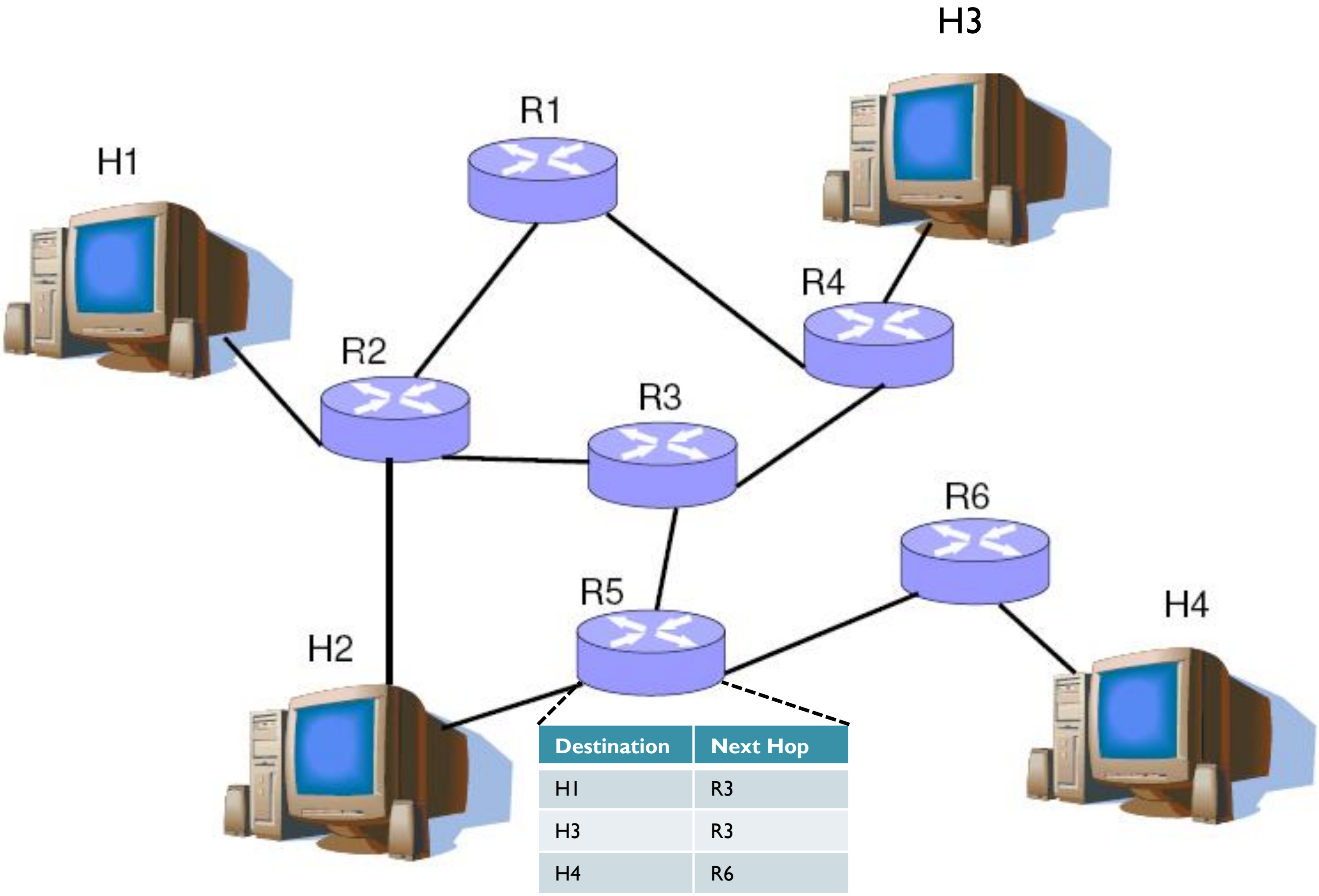
Slides adopted from Berkeley and Rice

The Internet

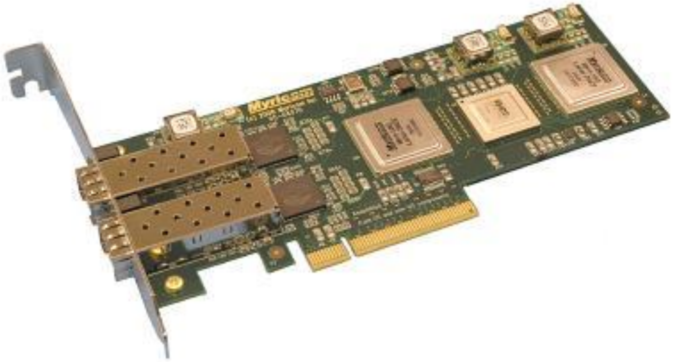
- Computer Networks
  - Network interfaces
  - Switches
  - Routers
  - Firewalls and etc…
- Software
  - Network protocols
  - Operating System interface
  - Application level interface
- Hardware
  - Lightweight microprocessors
  - Hardware accelerators
  - Network processors

Computer Network

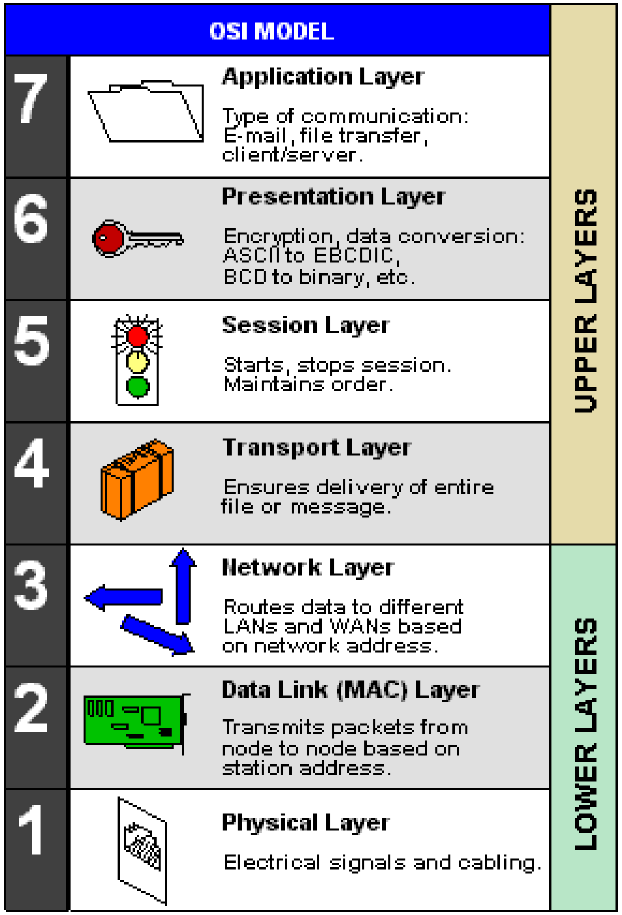


Destination	Next Hop
H1	R3
H3	R3
H4	R6

Computer Network Hardware



Open System Interconnection



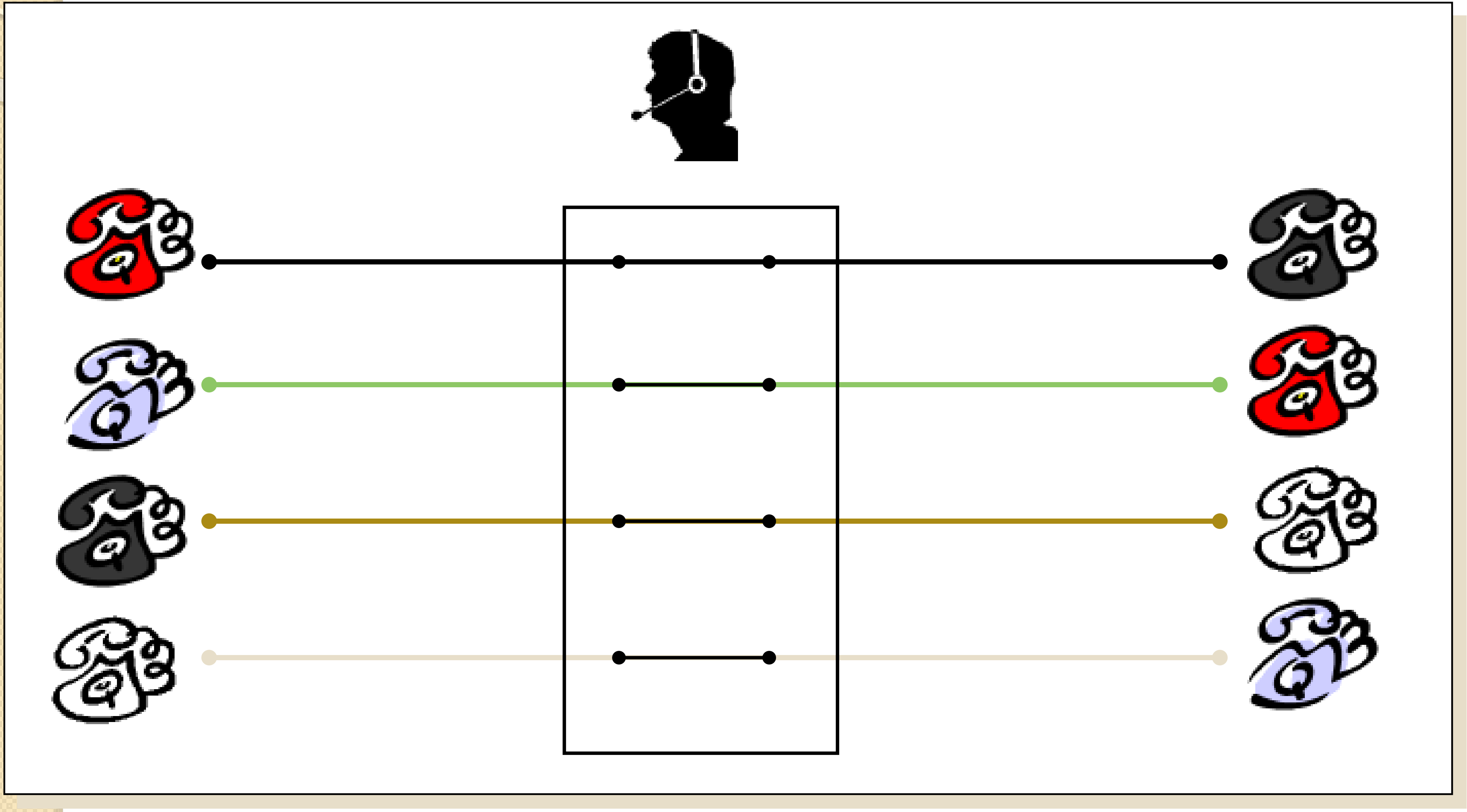
OSI MODEL		
7	**Application Layer** Type of communication: E-mail, file transfer, client/server.	UPPER LAYERS
6	**Presentation Layer** Encryption, data conversion: ASCII to EBCDIC, BCD to binary, etc.	
5	**Session Layer** Starts, stops session. Maintains order.	
4	**Transport Layer** Ensures delivery of entire file or message.	
3	**Network Layer** Routes data to different LANs and WANs based on network address.	LOWER LAYERS
2	**Data Link (MAC) Layer** Transmits packets from node to node based on station address.	
1	**Physical Layer** Electrical signals and cabling.	

From computer desktop encyclopedia © 2004

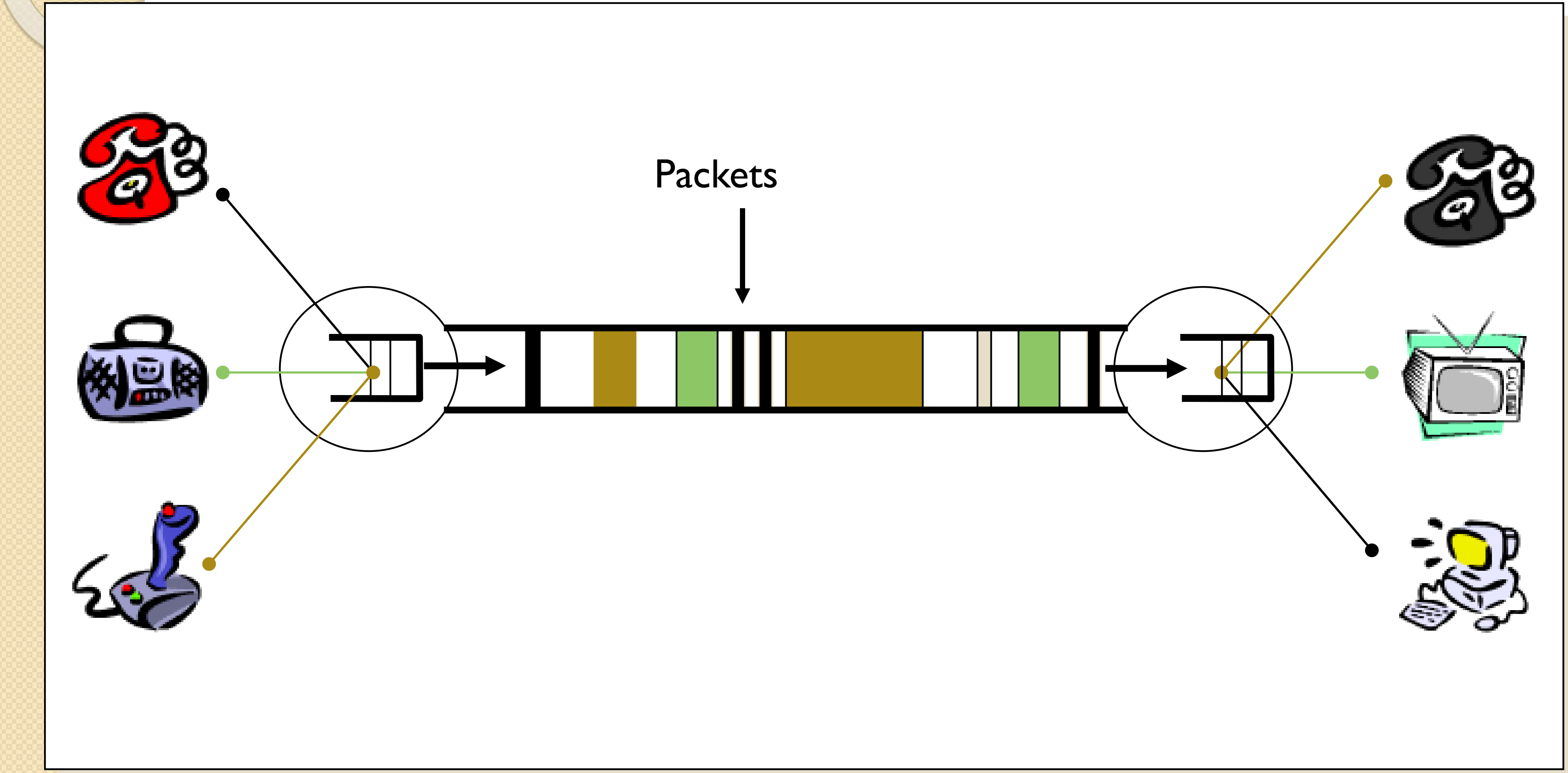
Networking

- Communication
  - Between Applications on different computers
- Application Resource Needs/Demands
  - Traffic data rate
  - Traffic pattern (bursty or constant bit rate)
  - Traffic target (multipoint or single destination, mobile or fixed)
  - Delay sensitivity
  - Loss sensitivity

Back in the Old Days…



Packet Switching (Internet)



Packet Switching

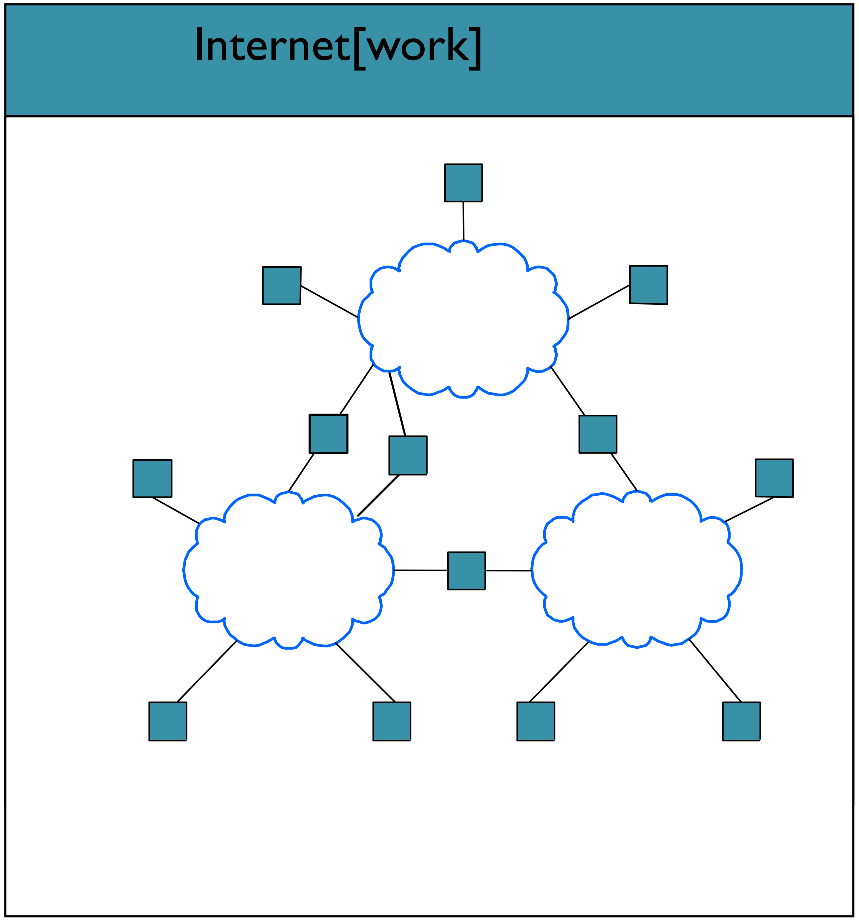
- Interleave packets from different sources
- Efficient: resources used on demand
  - Statistical multiplexing
- General
  - Multiple types of applications
- Accommodates bursty traffic
  - Addition of queues

Characteristics of Packet Switching

- Store and forward
  - Packets are self contained units
  - Can use alternate paths – reordering
- Contention
  - Congestion
  - Delay

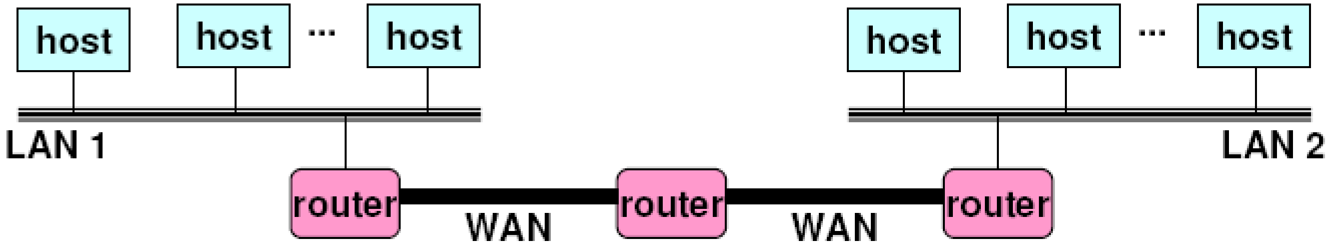
Internet[work]

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



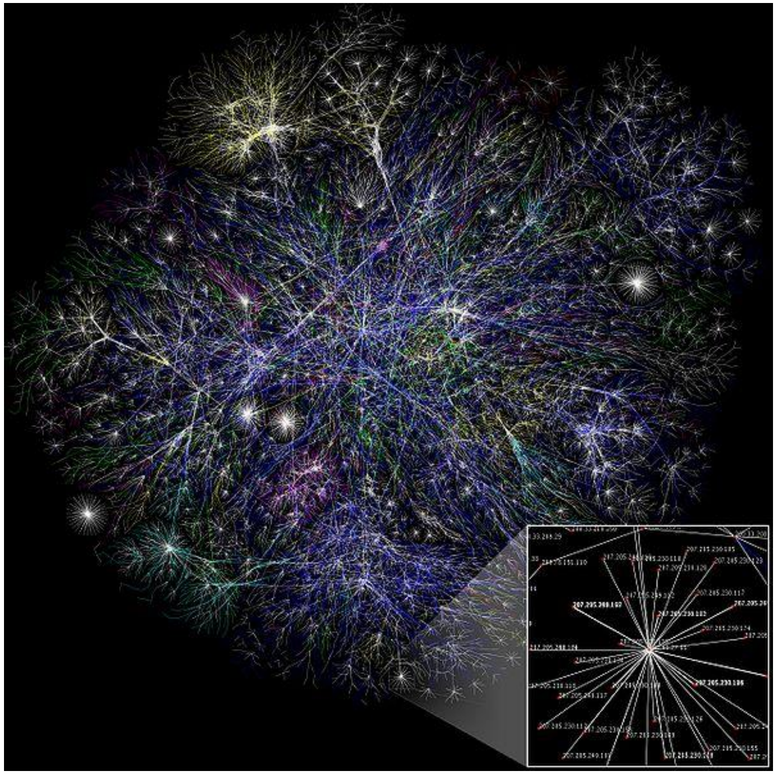
Internet

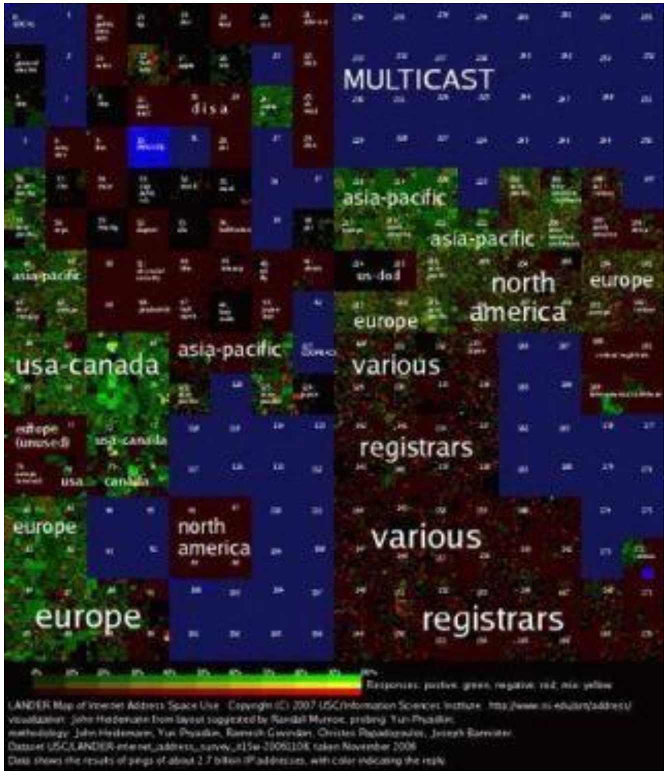
- Heterogeneous Computer Networks
  - Physical connection via routers and switches
- Largest Conglomeration of Such Networks



LAN 1 and LAN 2 might be completely different, totally incompatible LANs (e.g., Ethernet and WiFi, 802.11*, T1-links, DSL, …)

Internet



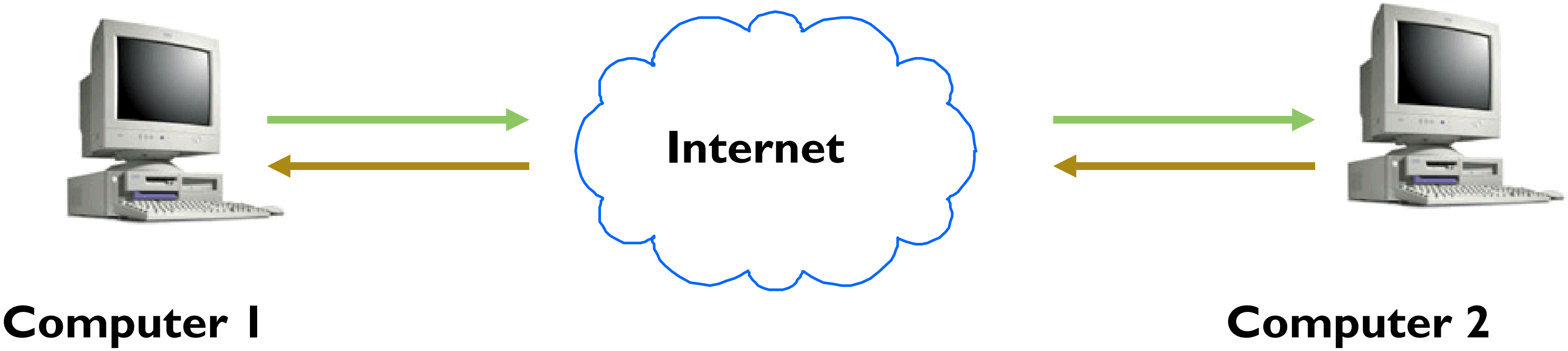

MULTICAST
disa
asia-pacific
asia-pacific
asia-pacific
asia-pacific
us-dod
north america
europe
europe
usa-canada
various
europe (unused)
usa-canada
usa
canada
registrars
europe
north america
various
europe
registrars
Responses: positive: green, negative: red, mix: yellow
LANDER Map of Internet Address Space Use Copyright (C) 2007 USC/Information Sciences Institute http://www.isi.edu/ant/address/
visualization: John Heidemann from layout suggested by Randall Munroe; probing: Yuri Pryadkin;
methodology: John Heidemann, Yuri Pryadkin, Ramesh Govindan, Christos Papadopoulos, Joseph Bannister.
Dataset USC/LANDER-internet_address_survey_it15w-20061108 taken November 2006
Data shows the results of pings of about 2.7 billion IP addresses, with color indicating the reply

Maps of the Internet

Challenge

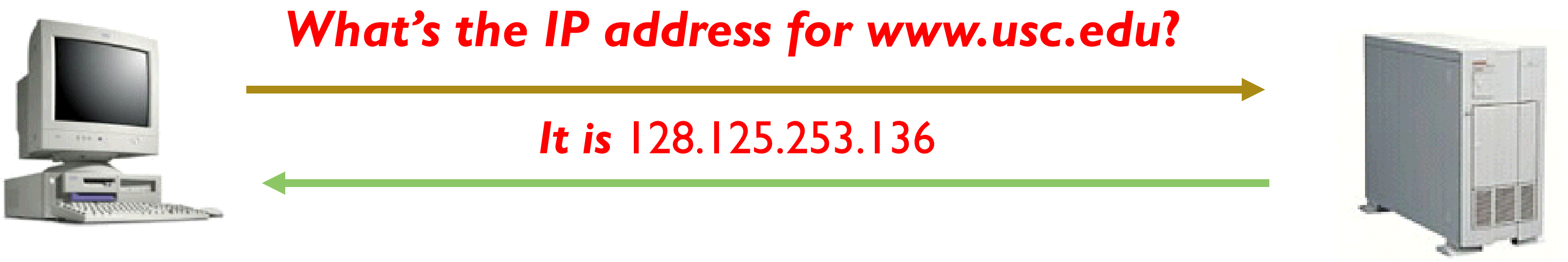
- Many differences between networks
  - Address formats
  - Performance – bandwidth/latency
  - Packet size
  - Loss rate/pattern/handling
  - Routing
- How to translate between various network technologies?

How To Find Nodes?



Need naming and routing

Naming



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

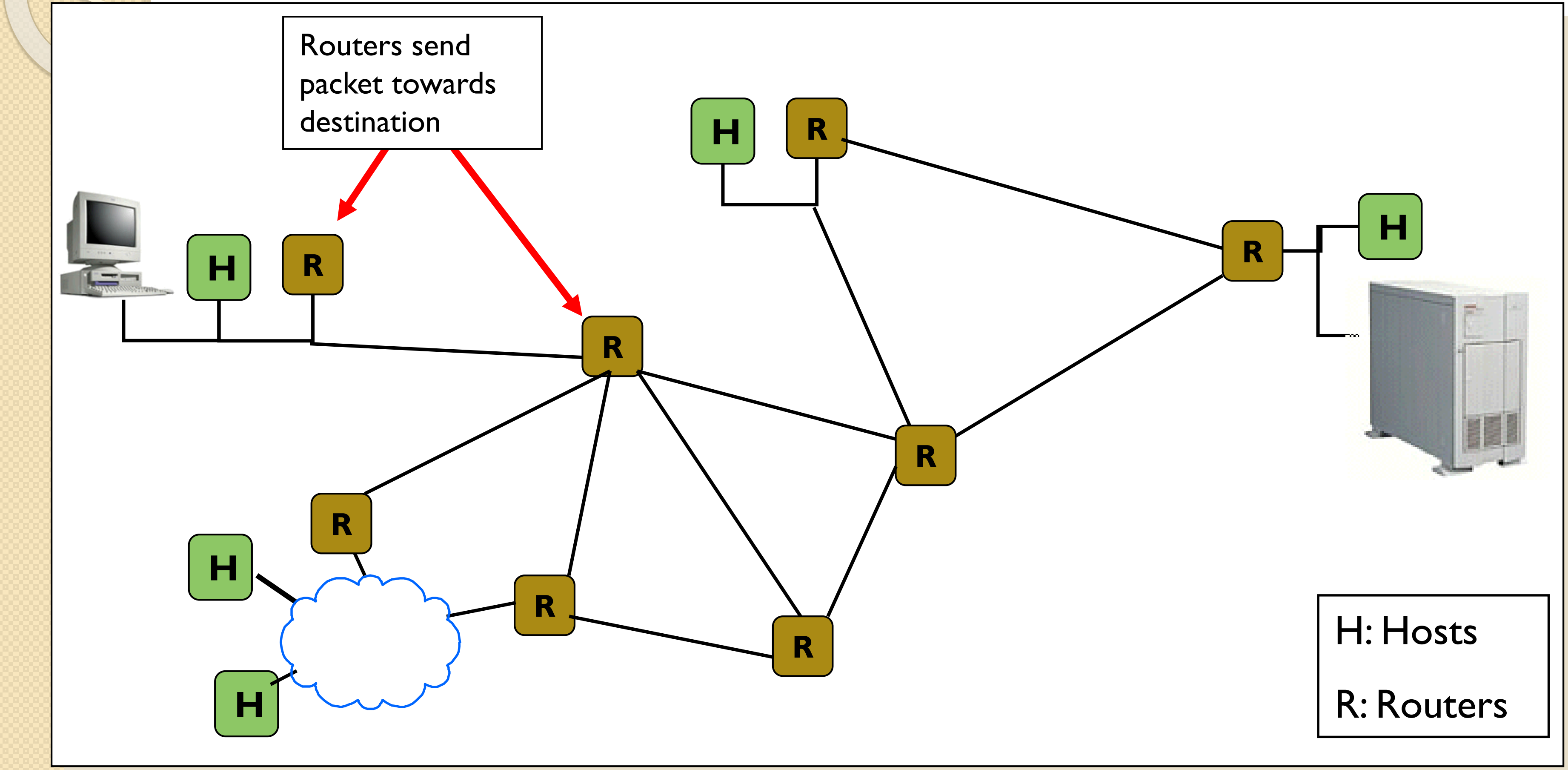
It is 128.125.253.136

Computer 1

Local DNS Server

Translates human readable names to logical endpoints

Routing



Routers send packet towards destination

H: Hosts

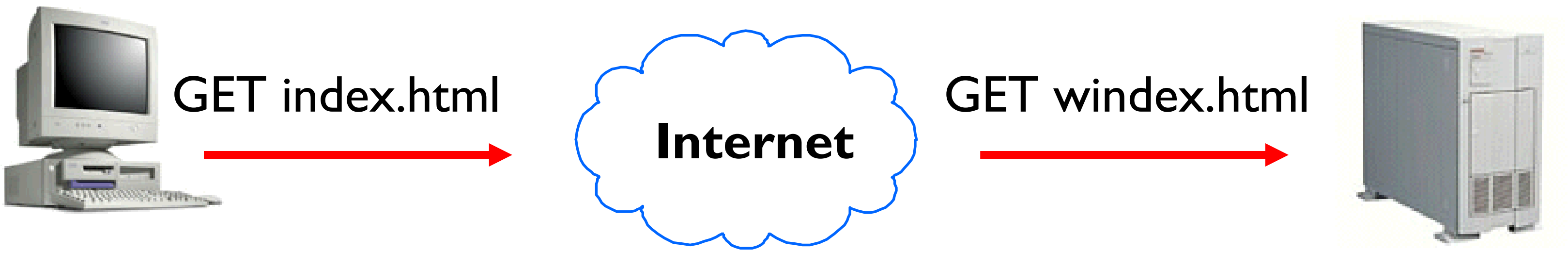
R: Routers

Meeting Application Demands

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

Data Corruption

Problem: Data Corruption

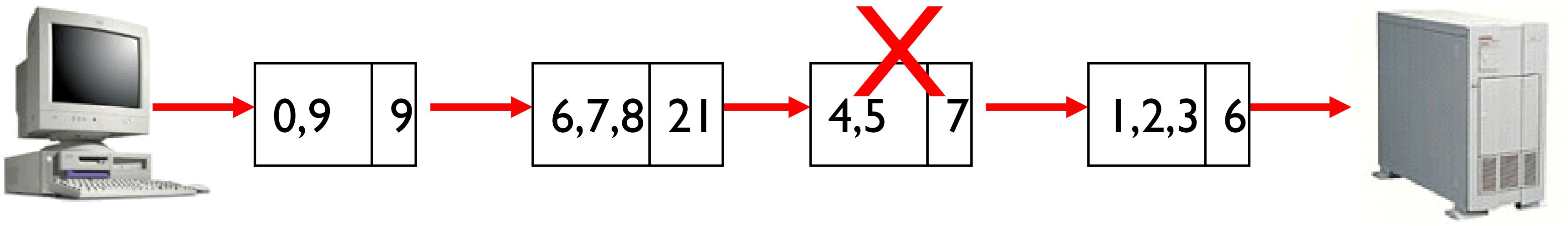


GET index.html

Internet

GET windex.html

Solution: Add a *checksum*



0,9 9

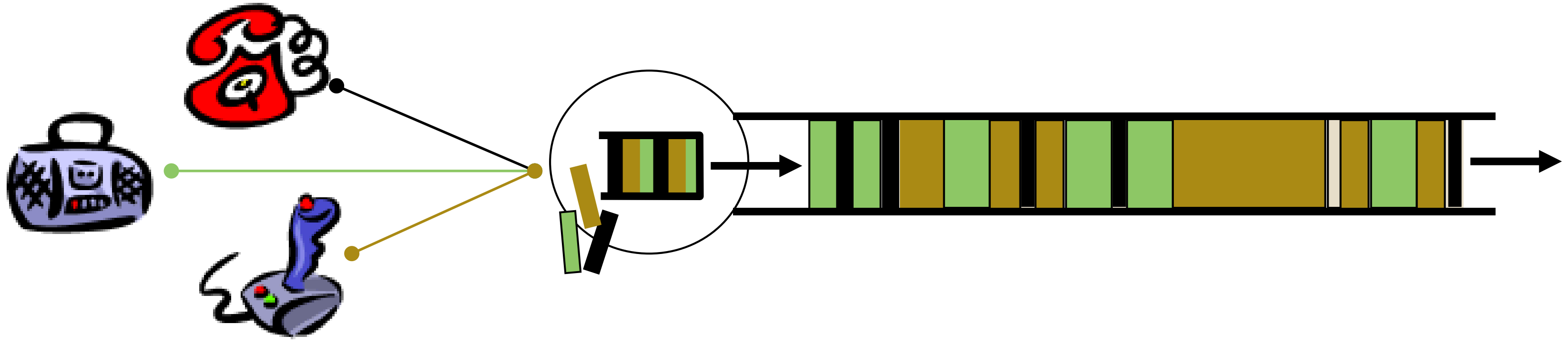
6,7,8 21

4,5 7

1,2,3 6

Bandwidth Bottleneck

Problem: Network Overload

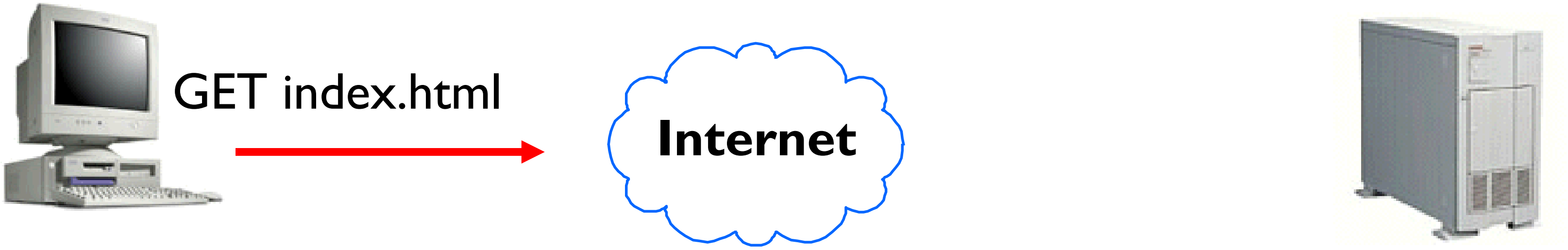


Solution: Buffering and Congestion Control

- Short bursts: buffer
- What if buffer overflows?
  - Packets dropped
  - Sender adjusts rate until load = resources → "congestion control"

Lost Packets

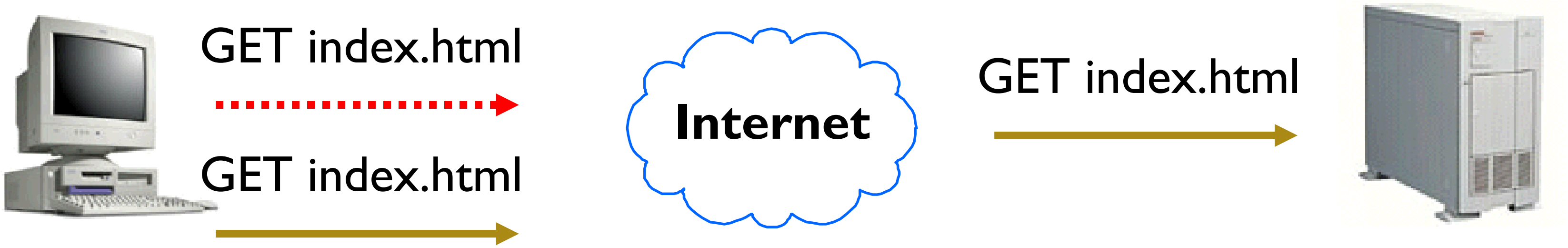
Problem: Lost Data



GET index.html

Internet

Solution: Timeout and Retransmit



GET index.html

GET index.html

Internet

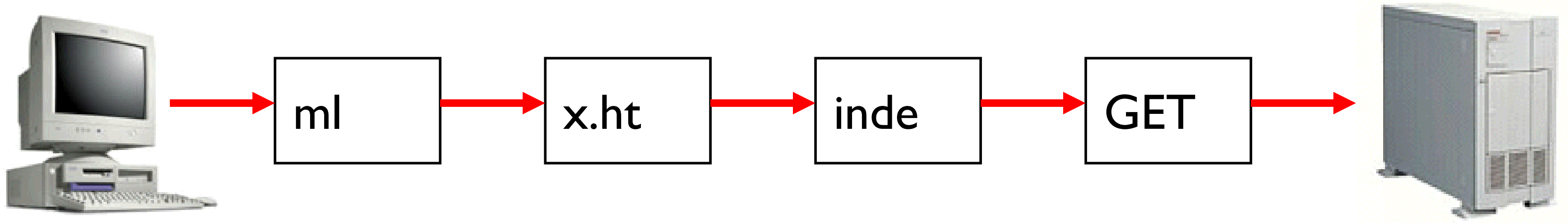
GET index.html

Large Data

Problem: Packet size

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

Solution: Fragment data across packets



ml

x.ht

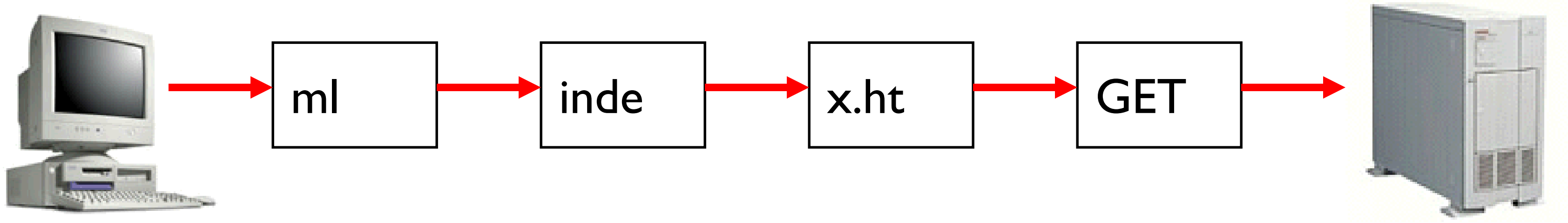
inde

GET

GET index.html

Out of Order Packets

Problem: Out of Order



ml

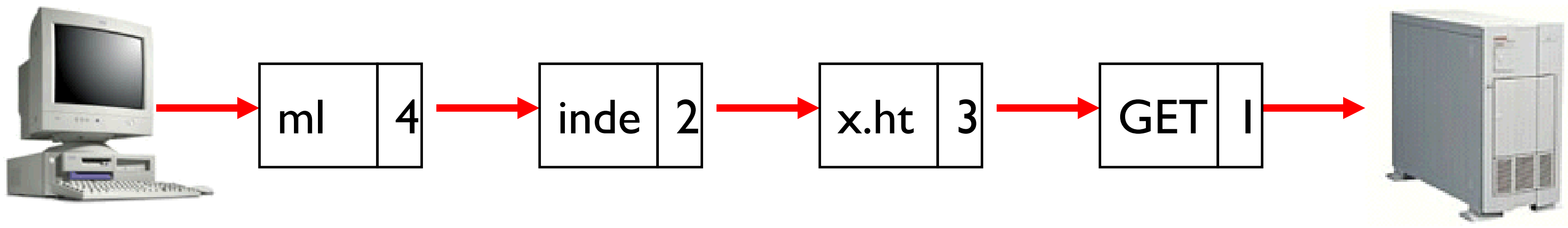
inde

x.ht

GET

GET x.htindeml

Solution: Add Sequence Numbers



ml 4

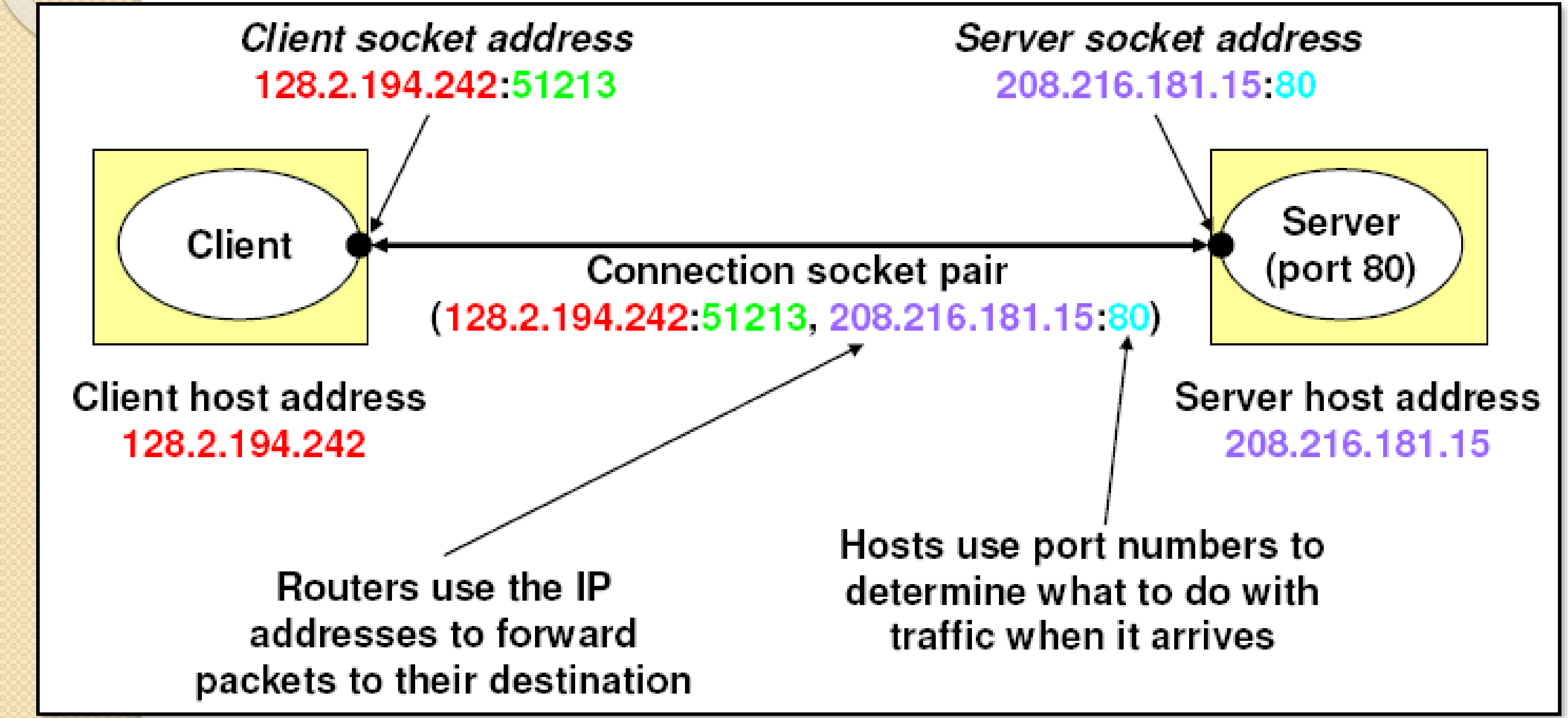
inde 2

x.ht 3

GET 1

GET index.html

An Internet Connection



Client socket address
128.2.194.242:51213

Server socket address
208.216.181.15:80

Client

Server
(port 80)

Connection socket pair
(128.2.194.242:51213, 208.216.181.15:80)

Client host address
128.2.194.242

Server host address
208.216.181.15

Routers use the IP addresses to forward packets to their destination

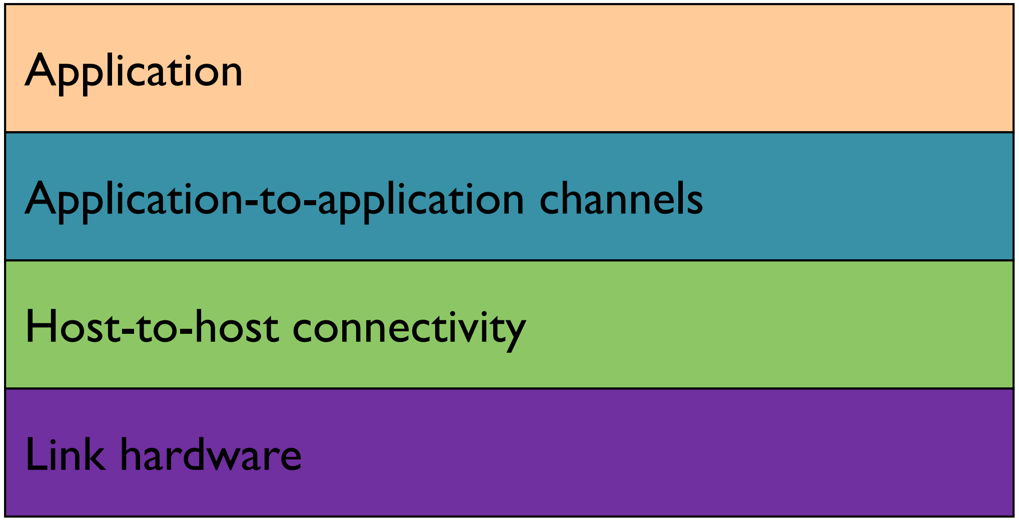
Hosts use port numbers to determine what to do with traffic when it arrives

Lots of Functions Needed

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

What is Layering?

- Modular approach to network functionality
- Example:



Application

Application-to-application channels

Host-to-host connectivity

Link hardware

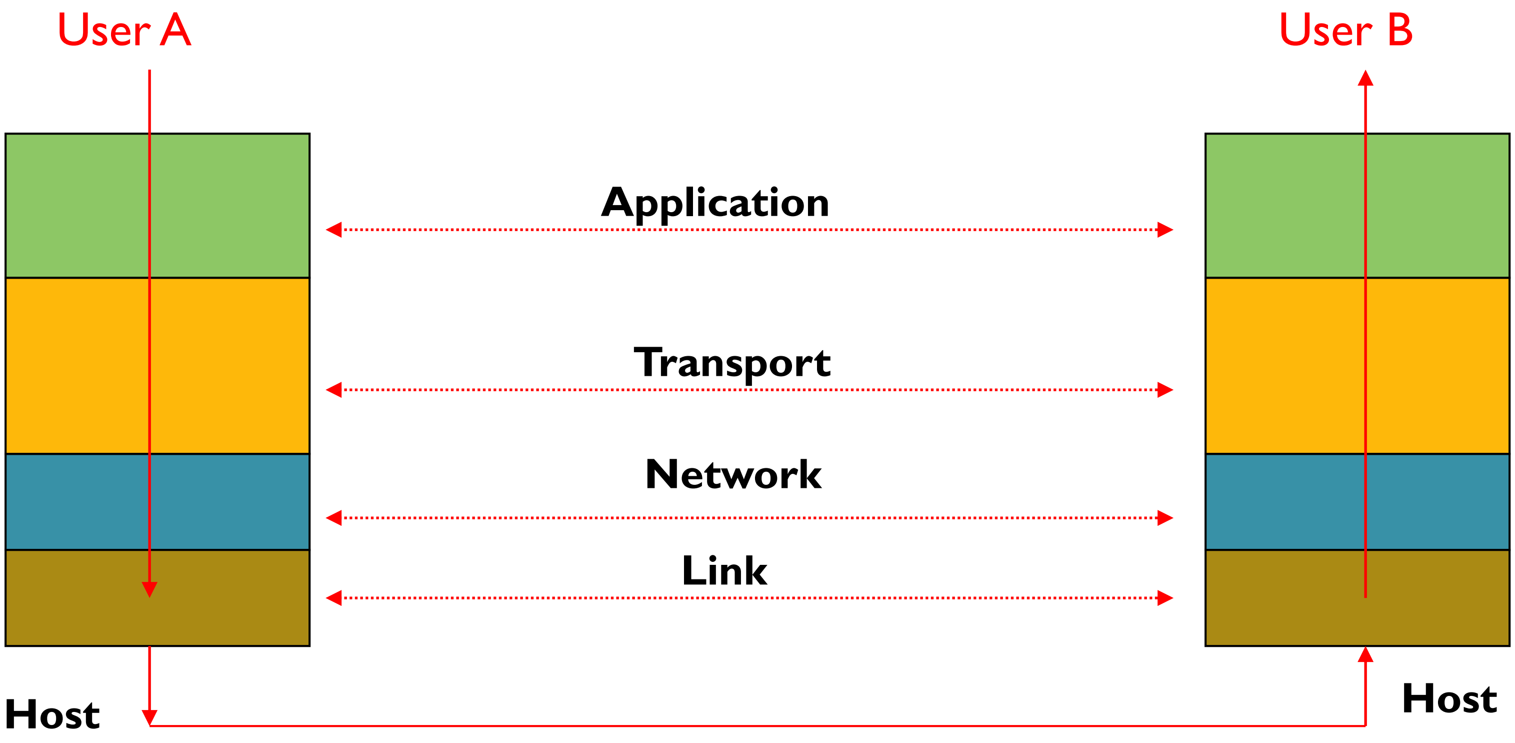
Protocols

- Module in layered structure
- Set of rules governing communication
  - Applications
  - Hosts
  - Routers
- Protocols define:
  - Interface to higher layers (API)
  - Interface to peer
    - Format and order of messages
    - Actions taken on receipt of a message

Layering Characteristics

- Services
  - Each layer relies on services from layer below
  - Each layer exports services to layer above
  - Provides interface that defines interaction
- Modularity
  - Hides implementation
  - Layers can change without disturbing other layers (black box)

Layering

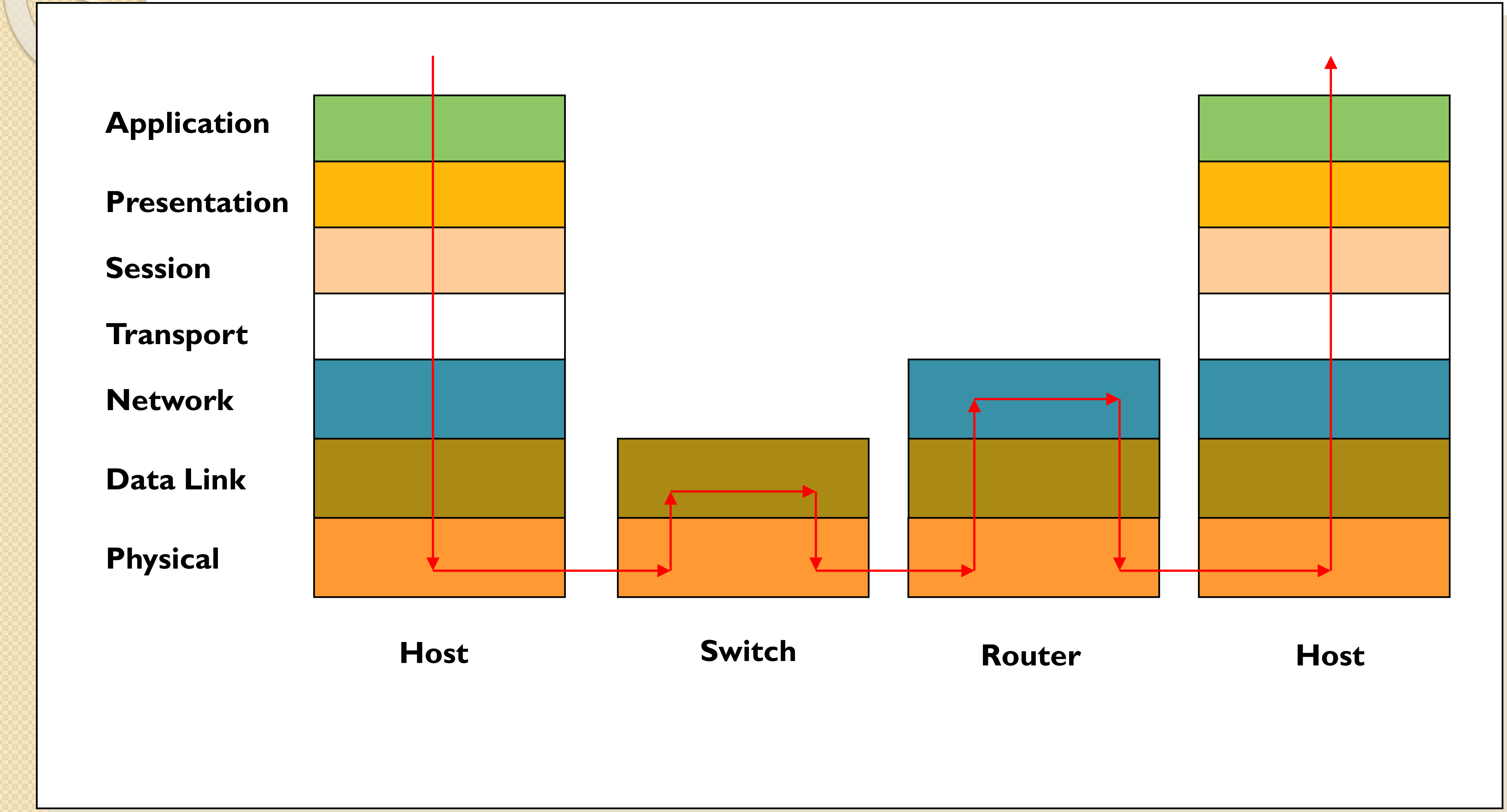


Layering: technique to simplify complex systems

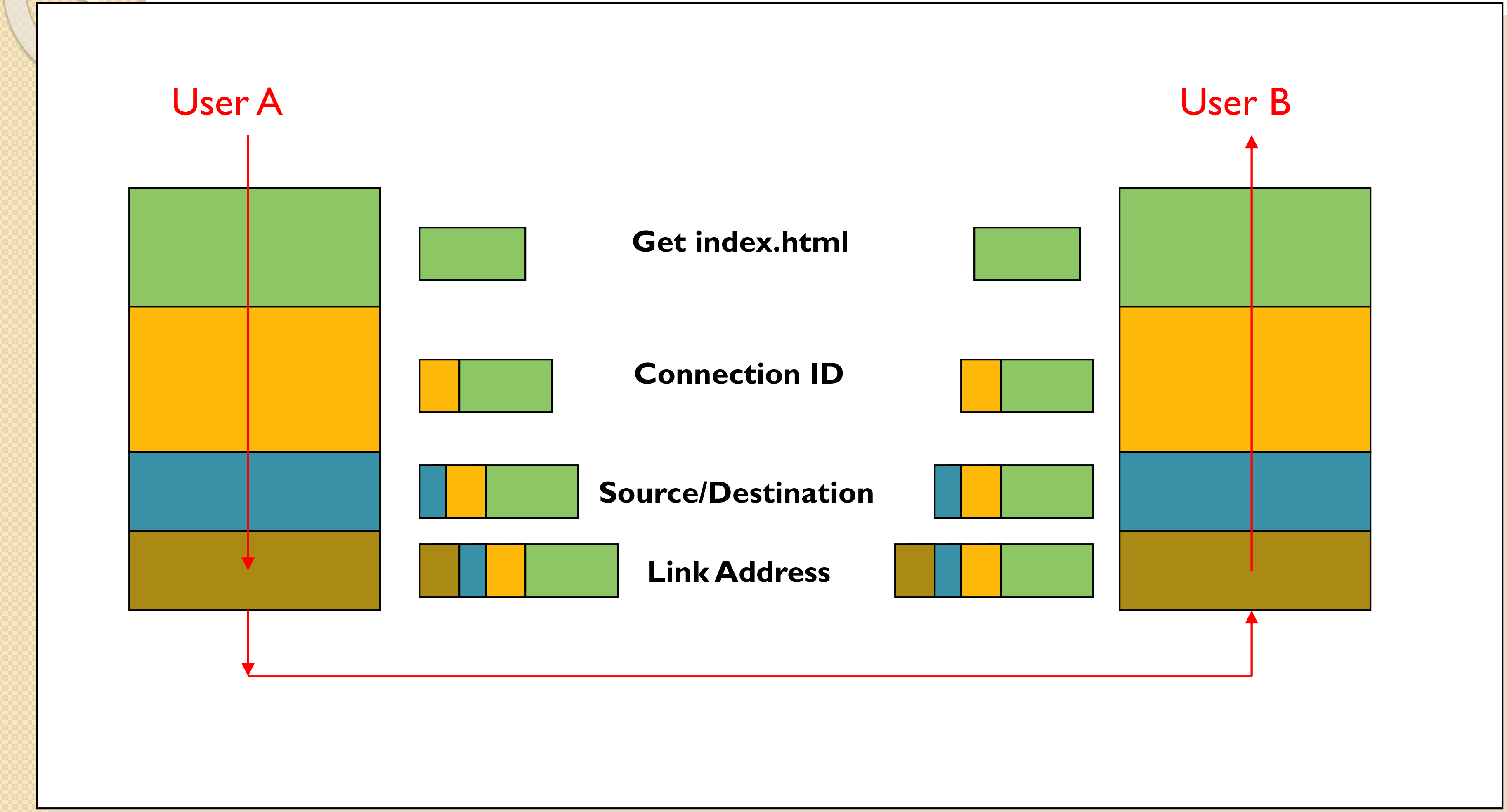
OSI Model: 7 Protocol Layers

- Physical: how to transmit bits
- Data link: how to transmit frames
- Network: how to route packets
- Transport: how to send packets end2end
- Session: how to tie flows together
- Presentation: byte ordering, security
- Application: everything else

OSI Layers and Locations



Layer Encapsulation



Remnants of Layering

- Redundancy
  - Layer N may duplicate lower level functionality (e.g., error recovery)
  - Layers may need same info (timestamp, MTU)
- Consequences
  - For assurance and guarantee
  - May hurt performance

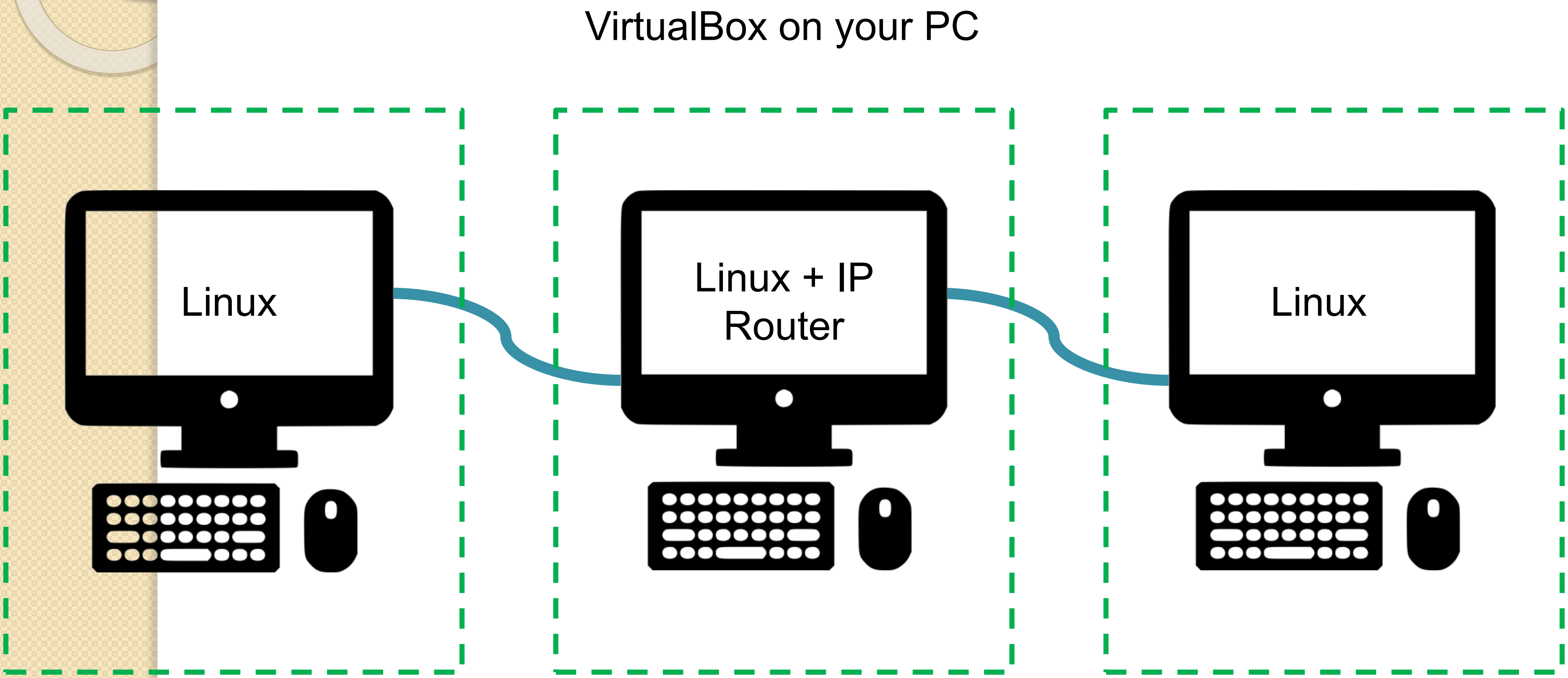
All About Generalization

- Many Years of the Same Thing
  - What's Left?
  - Any room for improvement?
  - We won't be able to replace it!
- Are There Any Problems????
  - Latency
  - Bandwidth
  - Performance
- 25-30 Years Ago
  - Supercomputing world
  - Huge emphasis on networking
- Since Then

Internet

- Understand Internet
  - Learn the computer network
  - Understand and manage routing tables
  - Low level network packet processing
- Building a Network Protocol
  - Application-Level Protocol
  - Handle basic control level protocol
  - Resolve communication problems on Internet
  - Modification to kernel level modules

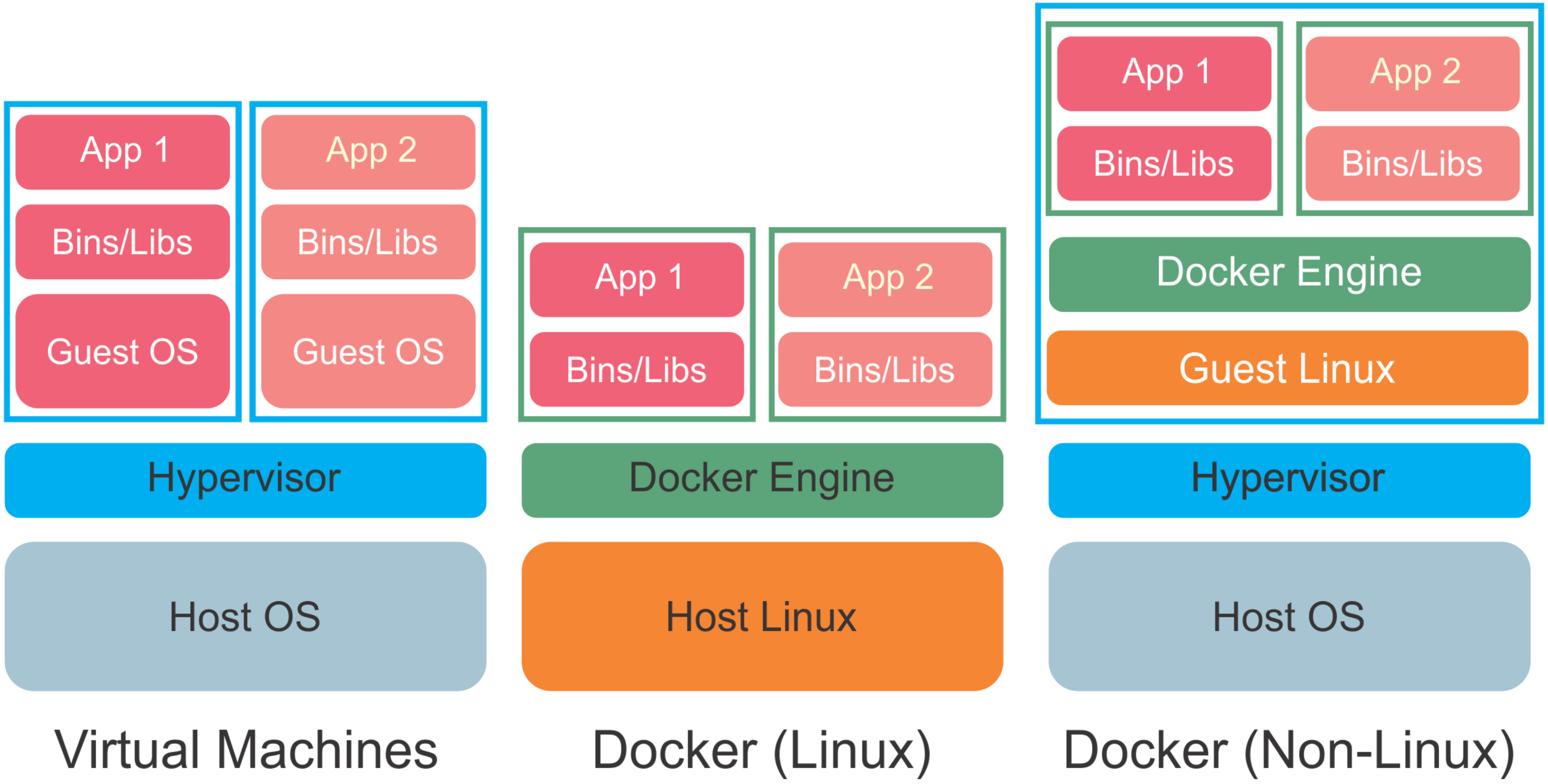
Laboratory 1



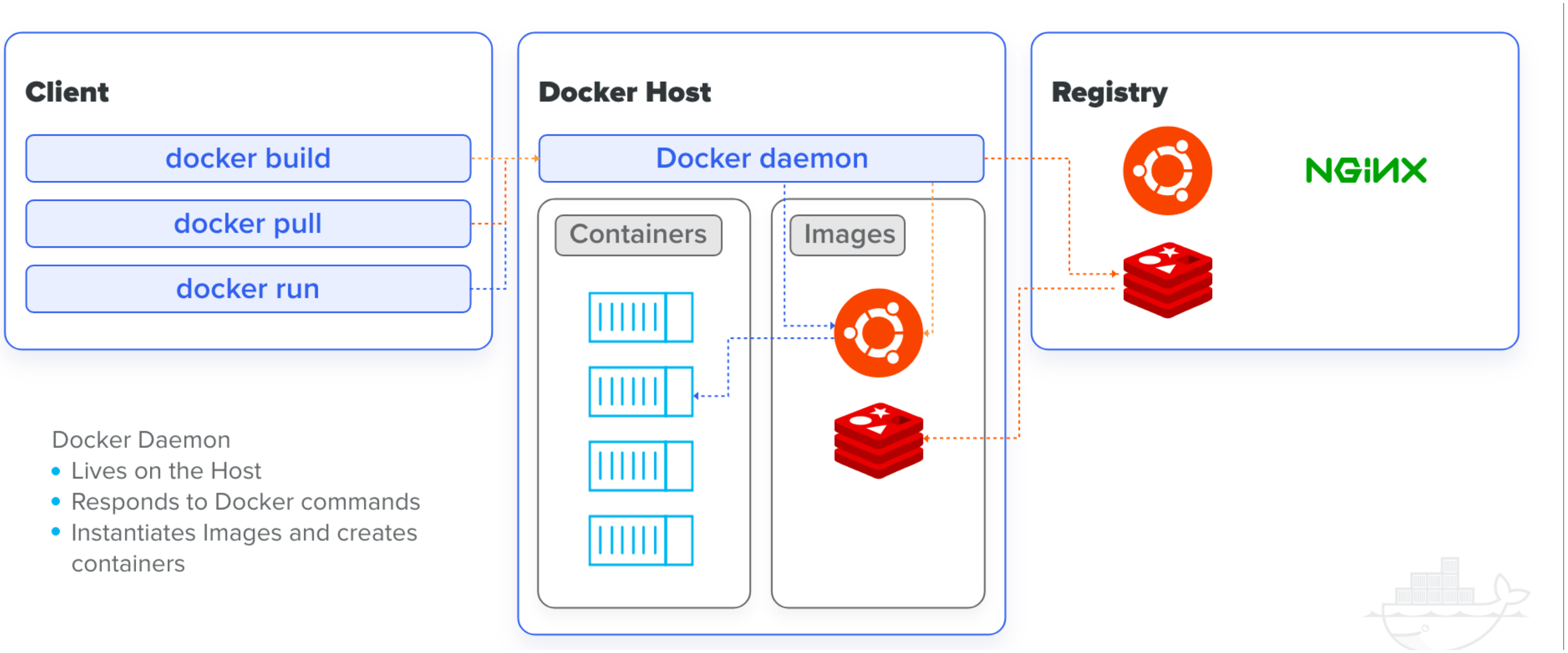
Virtualization

- Virtual Machines
  - Hypervisor Type 1 - a layer above HW
  - Hypervisor Type 2 - a layer above OS
- Containers
  - Docker Engine
  - Orchestrated with Kubernetes

Virtualization



Docker

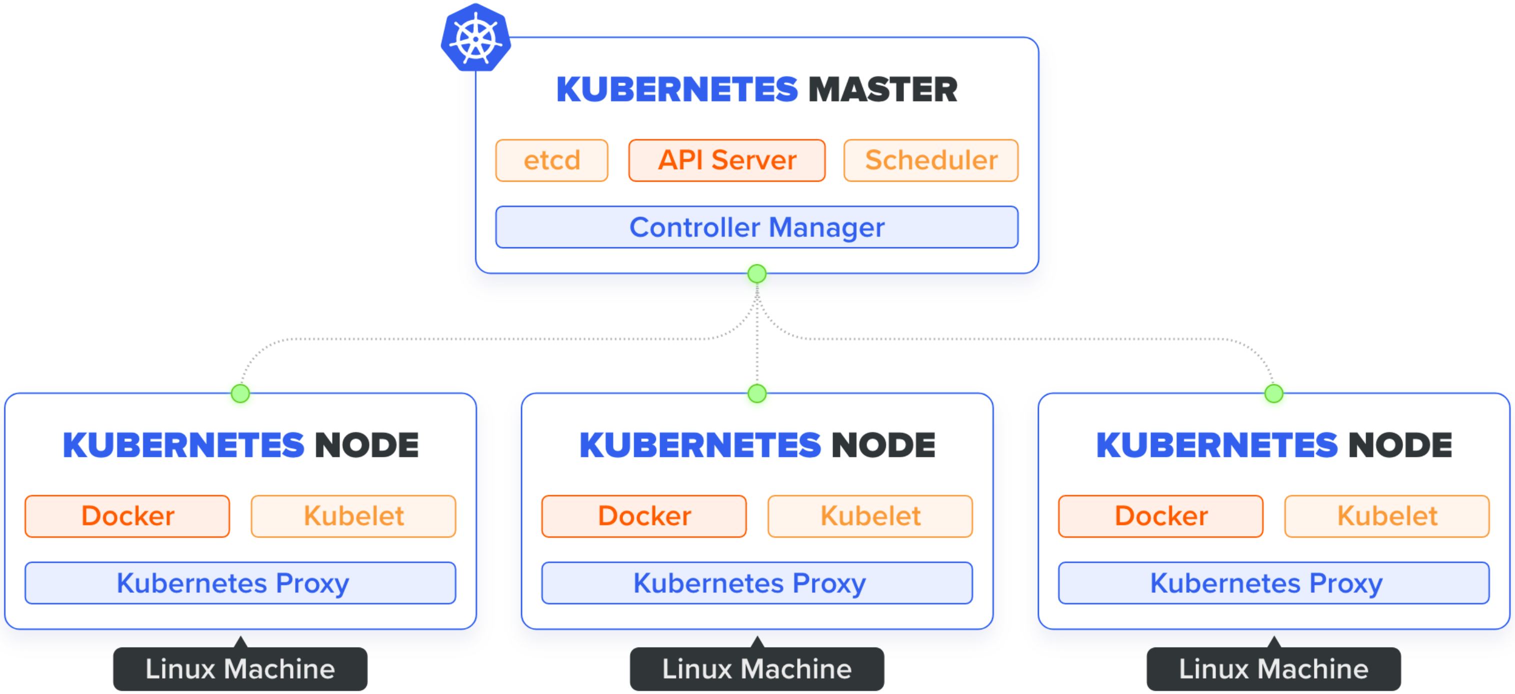


Docker Daemon

- Lives on the Host
- Responds to Docker commands
- Instantiates Images and creates containers

- Developed by Docker Inc.
- Containers - OS level Virtualization

Kubernetes

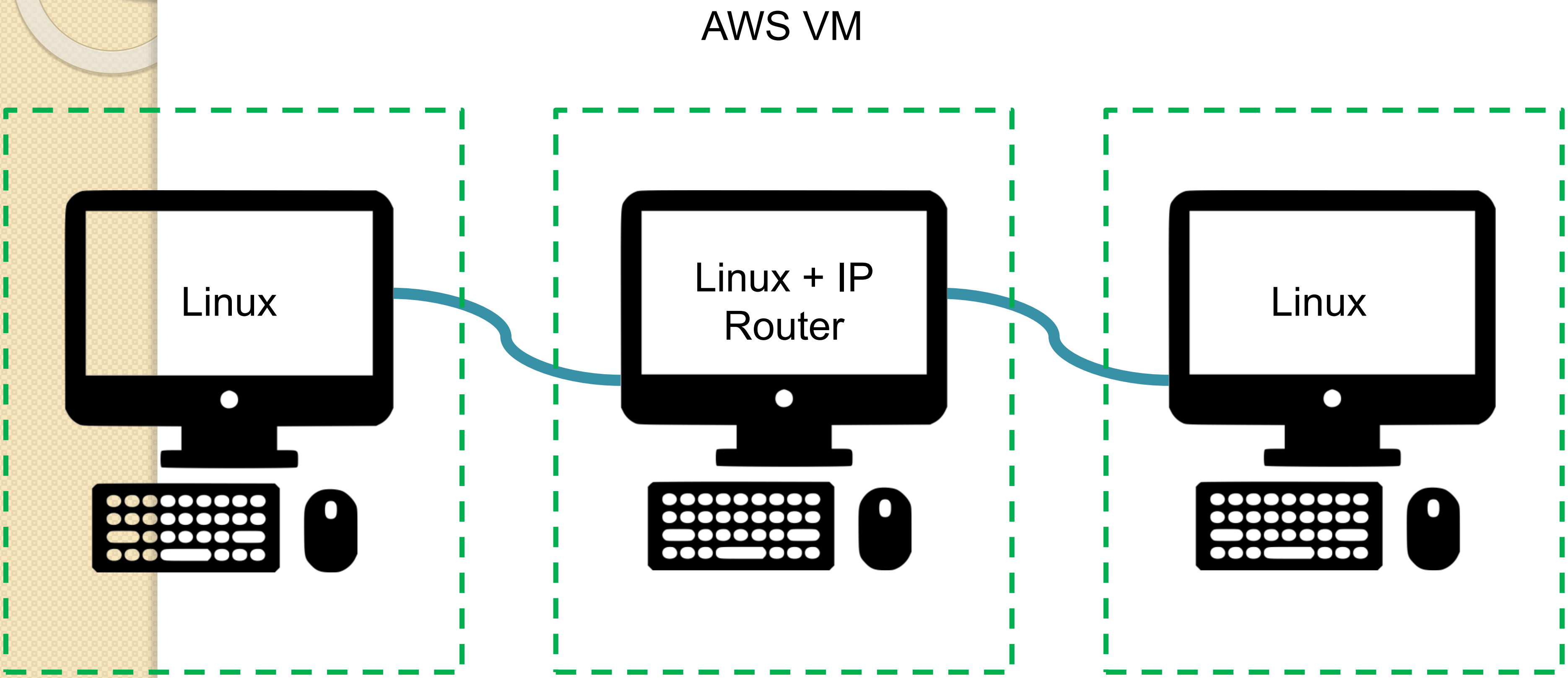


- From Google
- Uses Containerization Technology
- Allows to run containers across several nodes
- Deployment, scaling, and management of containerized applications

Hypervisors

- Type I - Single layer above bare metal
  - XEN
    - Pass-through access to CPU/Memory/NICs
    - Open source virtualization started 2004
    - Acquired by Citrix in 2007
- Type II - One layer above OS
  - VMWare ESXi
    - VMware Cloud solution
    - Runs on top of vSphere
  - Hyper-V
    - Microsoft Cloud solution
    - The best solution for Windows OS
  - Kernel-based Virtual Machine KVM
    - Introduced in 2007
    - More like VirtualBox
    - Acquired and taken over by RedHat 2008
    - Due to RedHat, better for Linux OS VMs
    - Most widely deployed open source environment

Laboratory 2



The Future of Cloud (my take)

- Taking Back Performance
  - Low Latency
  - High Bandwidth
  - Networking and Processor
- Need Engineers to Build
  - Application Specific
  - Hardware Component Specific
  - Custom Configuration Specific
  - Hardware Accelerated
  - Minimal Overhead HW/SW
  - Low-level Software (e.g. embedded software and kernel level)

Laboratory Assignments

- Submit Archive of Laboratory Results
  - Summary PowerPoint Slides
  - Source Code and README instructions for code
  - Usually Saturday 11:59 PM
- YouTube demonstration video
  - Usually, the following Monday 11:59 PM
- Scoring
  - On-time Submissions (no exceptions)
  - Multiplied by 1.0 if on-time
  - Multiplied by 0.5 if late
  - Demonstration Videos on YouTube
  - Internet Accessible Link to the Archive (ZIP) of all