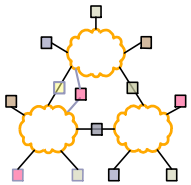
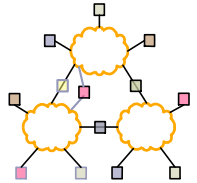
15-744: Computer Networking

L-1 Intro to Computer Networks

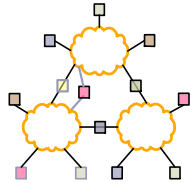


Outline



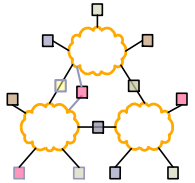
- Administrivia
- Layering

Who's Who?



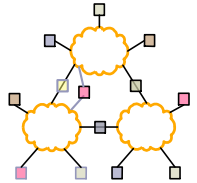
- Professor: Srinivasan Seshan
  - http://www.cs.cmu.edu/~srini
  - srini@cmu.edu
  - Office hours: Friday 4:00-5:00
- TA: Vijay Vasudevan
  - vrv+744@cs.cmu.edu
  - Office hours: Tuesday 2-3PM (or by appointment)
- Course info
  - http://www.cs.cmu.edu/~srini/15-744/S08/

Objectives



- Understand the state-of-the-art in network protocols, architectures and applications
- Understand how networking research is done
  - Teach the typical constraints and thought processes used in networking research
- How is class different from undergraduate networking (15-441)
  - Training network programmers vs. training network researchers

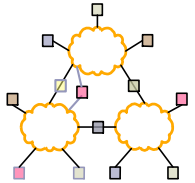
Web Page



- Check regularly!!

- Course schedule
- Reading list
- Lecture notes
- Announcements
- Assignments
- Project ideas
- Exams

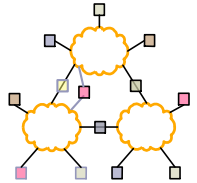
Discussion Site



- http://great-white.cmcl.cs.cmu.edu:8080/
  - Currently using slashcode → will be updated in a few weeks

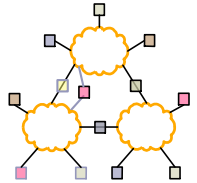
- For each lecture, two students will create a "public review" of paper(s) that:
  - Briefly summarizes paper (1-2 paragraphs)
  - Provides background/related material (1-2 paragraphs)
  - Critiques paper and suggests discussion topics (2-3 paragraph)
    - Try to be positive…
    - Why or why not keep this paper in syllabus?
    - What issues are left open for future research?
    - What are the important implications of the work?

Course Materials



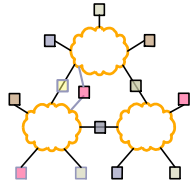
- Research papers
  - Links to ps or pdf on Web page
  - Combination of classic and recent work
  - ~40 papers
  - Optional readings
- Recommended textbooks
  - For students not familiar with networking
  - Peterson & Davie or Kurose & Ross

Grading



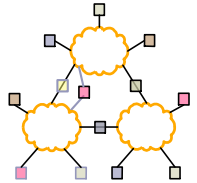
- Homework assignments (20%)
  - 4 Problem sets & hands-on assignments
- Class + discussion site participation (10%)
- 2 person project (35%)
- Midterm exam + final exam (35%)
  - Closed book, in-class

Waitlist



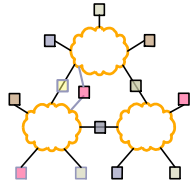
- Class is heavily over-subscribed
  - 26 enrolled, 22 on wait-list ➔ target size = low 20's
  - Unlikely to take any more students
- If you are trying to add class
  - Position on waitlist irrelevant
  - You must show up for the first couple lectures and sign in
  - Current wait-list order will not be used, priority will be given in the following order
    - Any PhD student
    - Any SCS student
    - Other students with research needs

Class Coverage



- Little coverage of physical and data link layer
- Little coverage of undergraduate material
  - Students expected to know this
- Focus on network to application layer
- We will deal with:
  - Protocol rules and algorithms
  - Investigate protocol trade-offs
  - Why this way and not another?

Lecture Topics



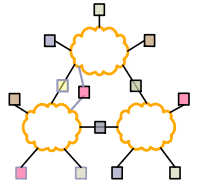
Traditional

- Layering
- Internet architecture
- Routing (IP)
- Transport (TCP)
- Queue management (FQ, RED)
- Naming (DNS)

Recent Topics

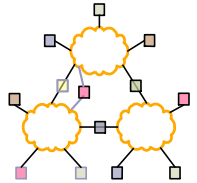
- Multicast
- Mobility/wireless
- Active networks
- QoS
- Security
- Network measurement
- Overlay networks
- P2P applications

Outline



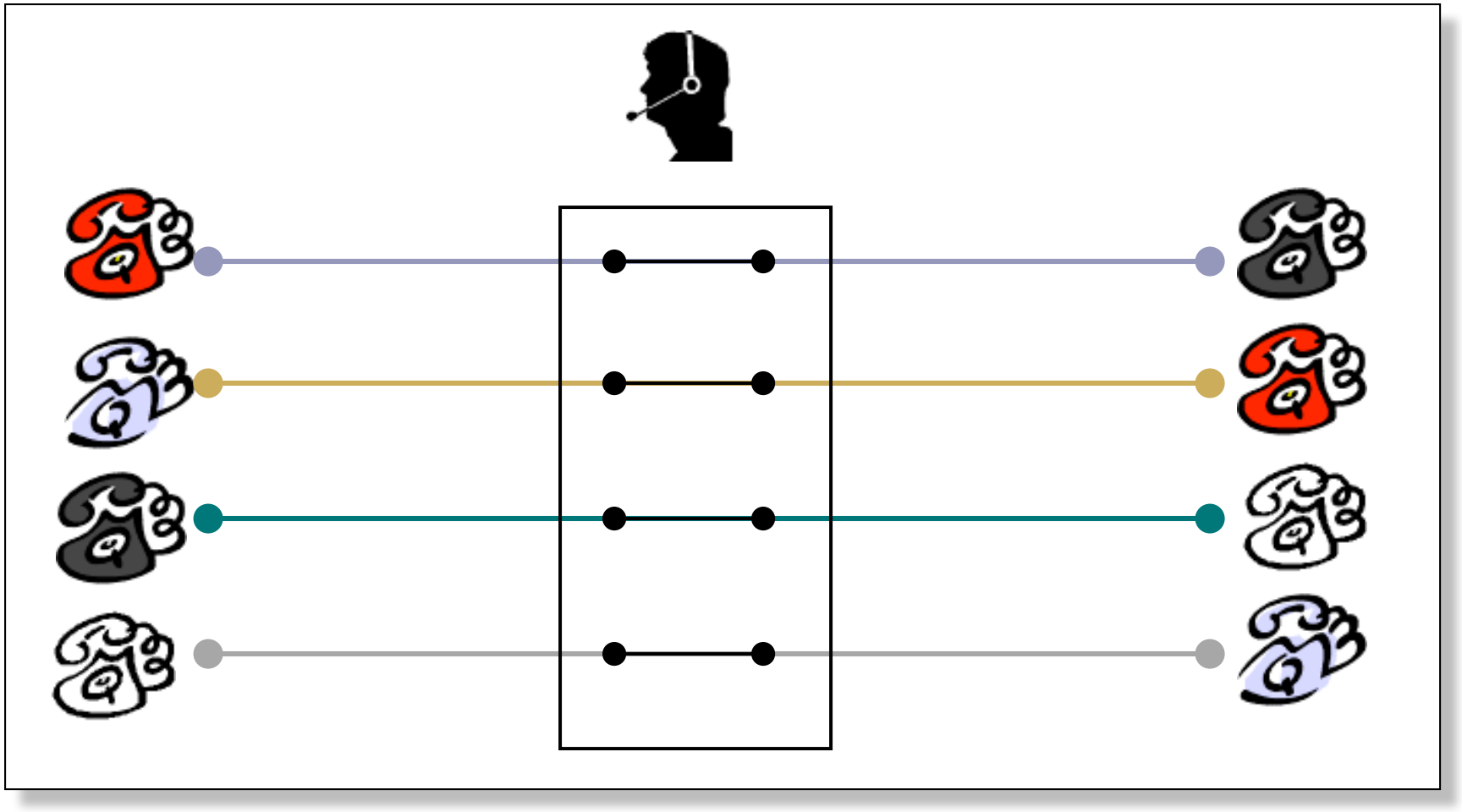
- Administrivia
- Layering

What is the Objective of Networking?

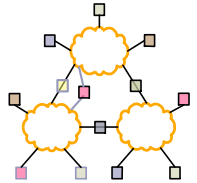


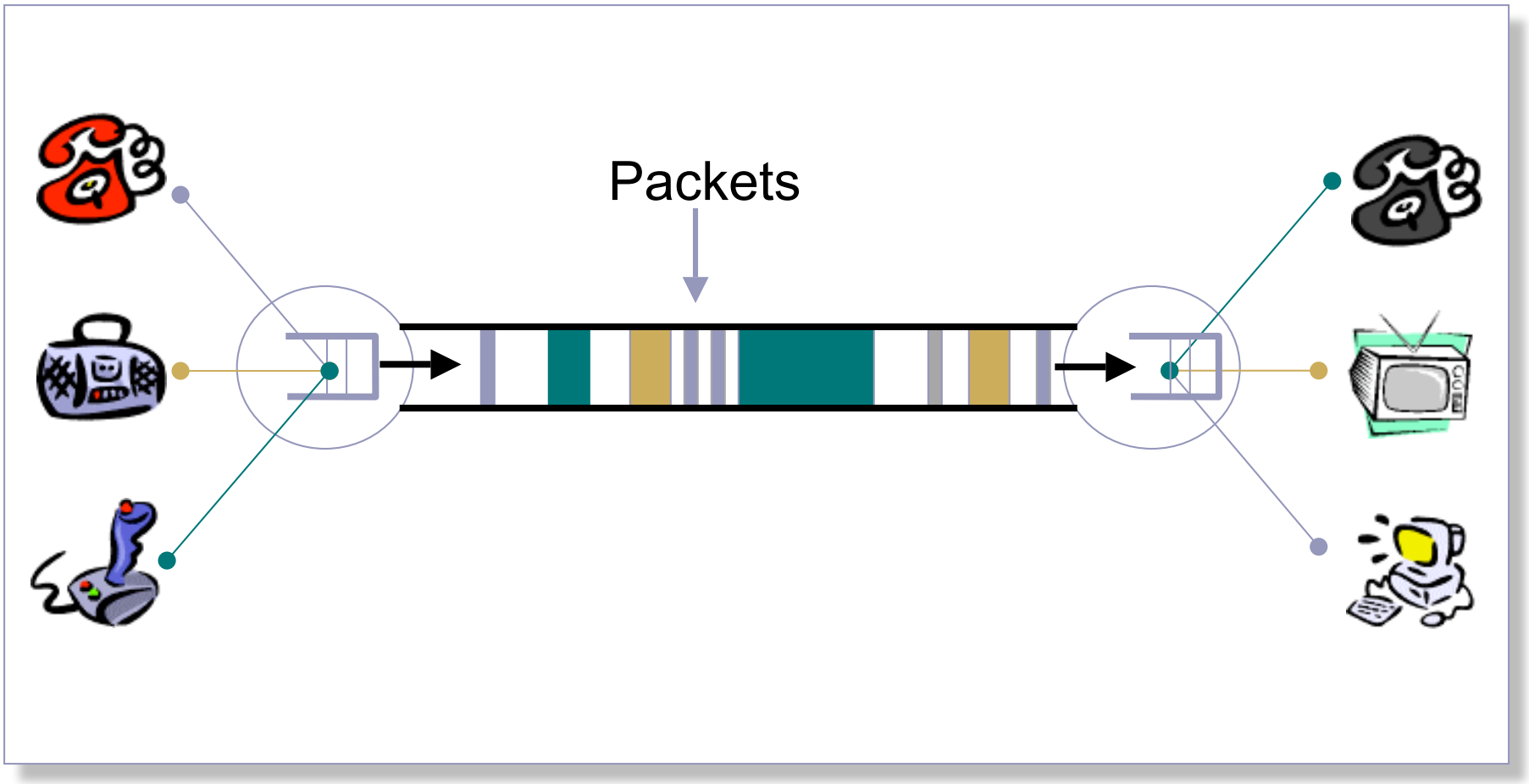
- Communication between applications on different computers
- Must understand application needs/demands
  - Traffic data rate
  - Traffic pattern (bursty or constant bit rate)
  - Traffic target (multipoint or single destination, mobile or fixed)
  - Delay sensitivity
  - Loss sensitivity

Back in the Old Days…

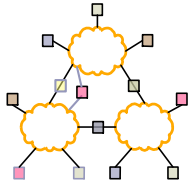


Packet Switching (Internet)



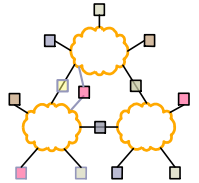


Packet Switching



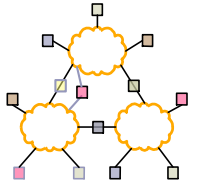
- Interleave packets from different sources
- Efficient: resources used on demand
  - Statistical multiplexing
- General
  - Multiple types of applications
- Accommodates bursty traffic
  - Addition of queues

Characteristics of Packet Switching

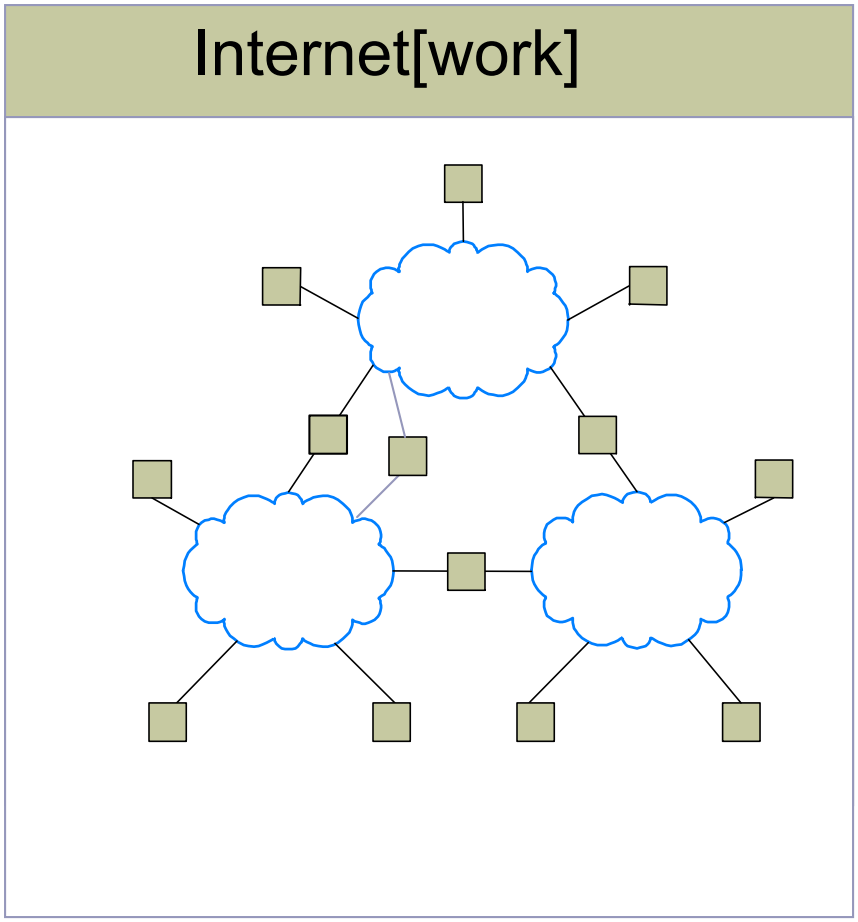


- Store and forward
  - Packets are self contained units
  - Can use alternate paths – reordering
- Contention
  - Congestion
  - Delay

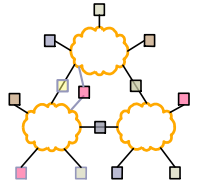
Internet[work]



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

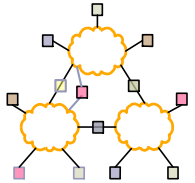


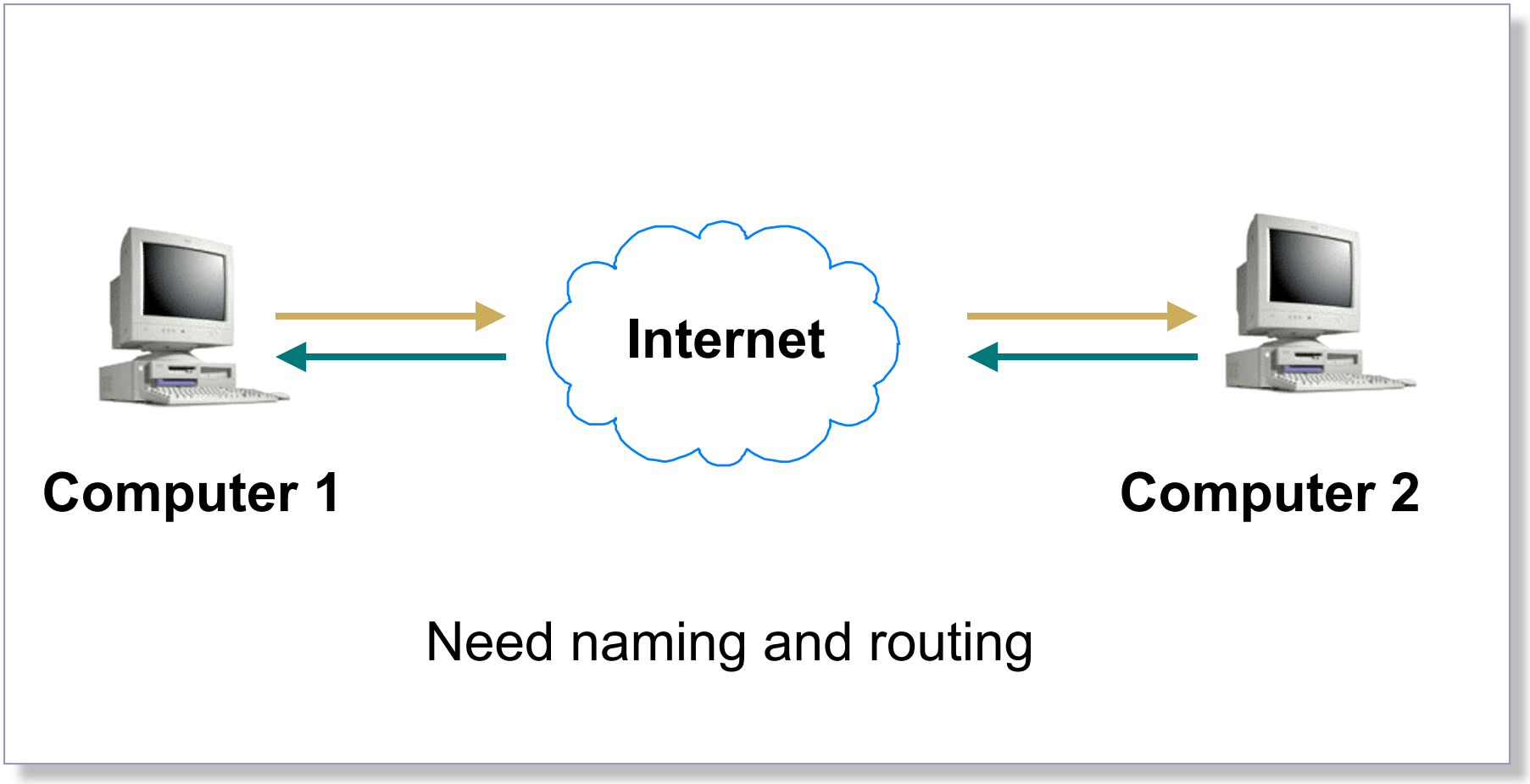
Challenge



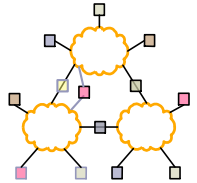
- Many differences between networks
  - Address formats
  - Performance – bandwidth/latency
  - Packet size
  - Loss rate/pattern/handling
  - Routing
- How to translate between various network technologies?

How To Find Nodes?





Naming



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

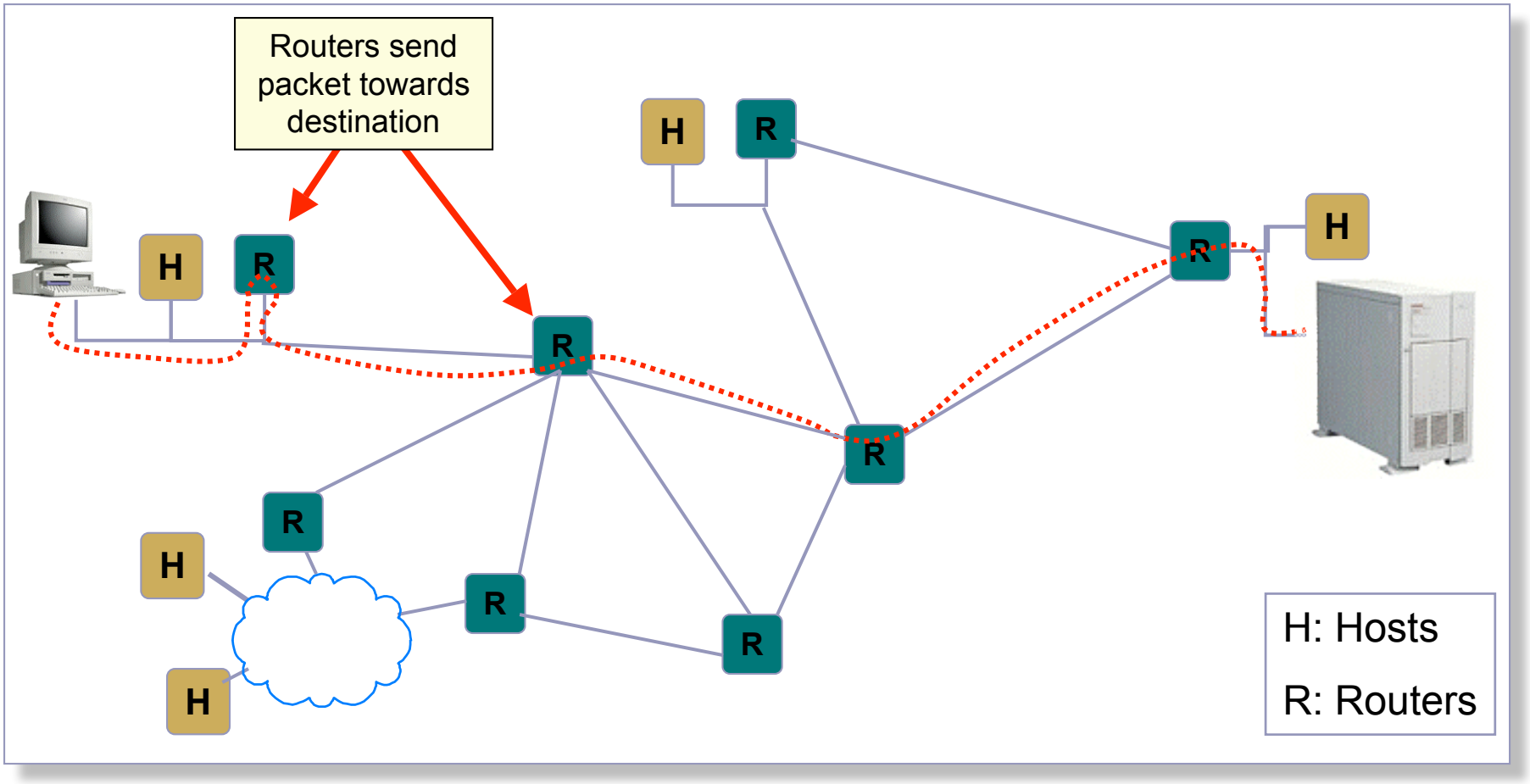
It is 128.2.11.43

Computer 1

Local DNS Server

Translates human readable names to logical endpoints

Routing


Routers send packet towards destination
H
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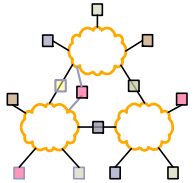
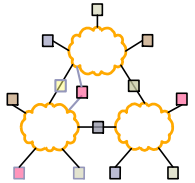
R
H
H: Hosts
R: Routers

Meeting Application Demands



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

What if the Data gets Corrupted?

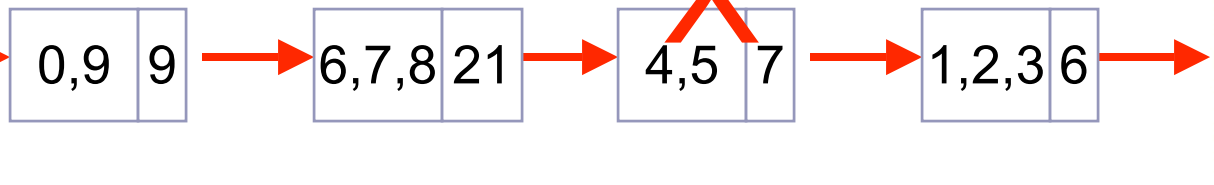


Problem: Data Corruption

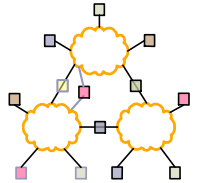
GET index.html

GET windex.html

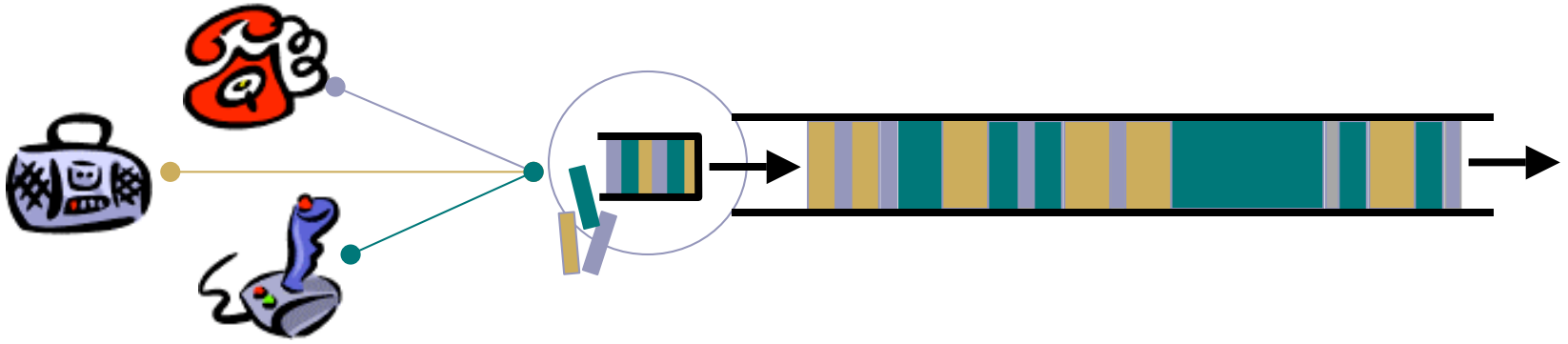
Solution: Add a *checksum*



What if Network is Overloaded?



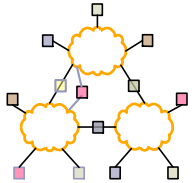
Problem: Network Overload



Solution: Buffering and Congestion Control

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

What if the Data gets Lost?



Problem: Lost Data

GET index.html

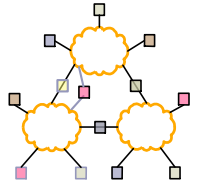
Solution: Timeout and Retransmit

GET index.html

GET index.html

GET index.html

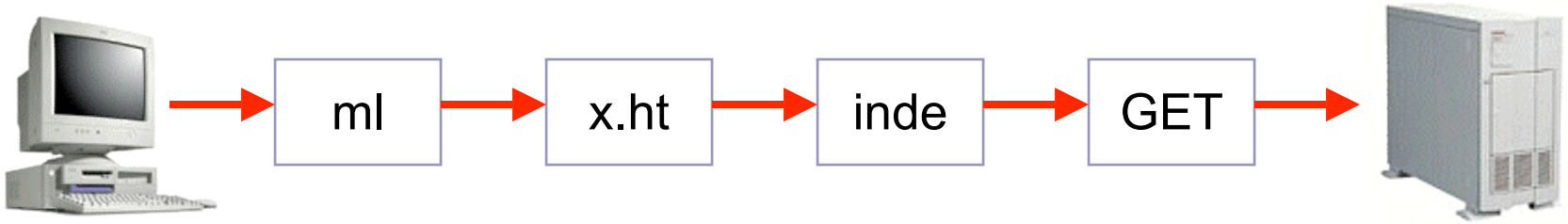
What if the Data Doesn't Fit?



Problem: Packet size

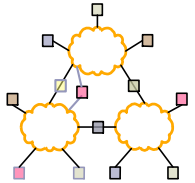
- On Ethernet, max IP packet is 1.5kbytes
- Typical web page is 10kbytes

Solution: Fragment data across packets



GET index.html

What if the Data is Out of Order?



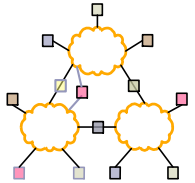
Problem: Out of Order

GET x.htindeml

Solution: Add Sequence Numbers

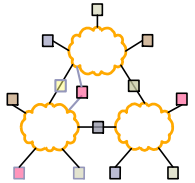
GET index.html

Lots of Functions Needed

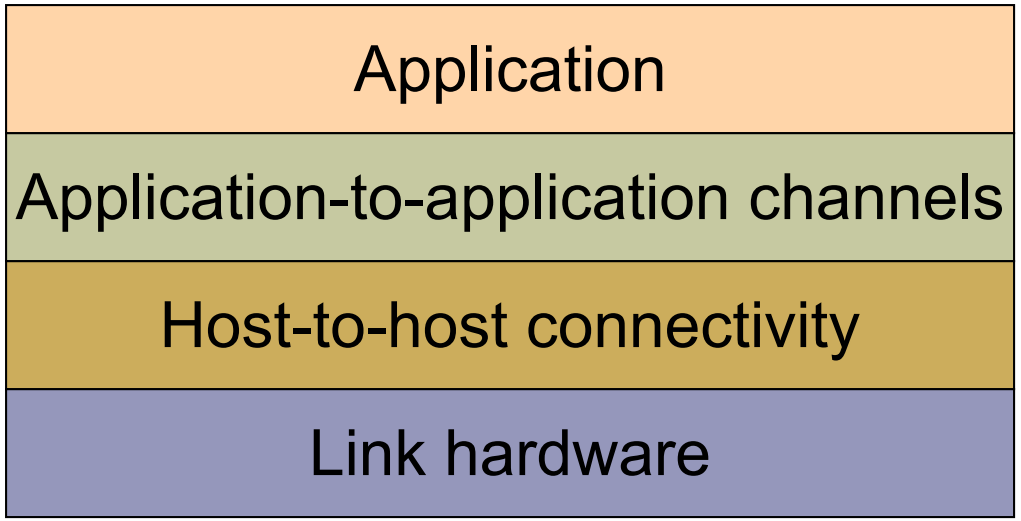


- Link
- Multiplexing
- Routing
- Addressing/naming (locating peers)
- Reliability
- Flow control
- Fragmentation
- Etc.…

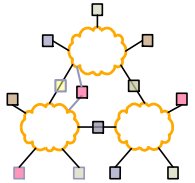
What is Layering?



- Modular approach to network functionality
- Example:

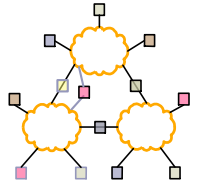


Protocols



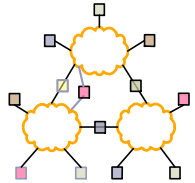
- Module in layered structure
- Set of rules governing communication between network elements (applications, hosts, routers)
- Protocols define:
  - Interface to higher layers (API)
  - Interface to peer
    - Format and order of messages
    - Actions taken on receipt of a message

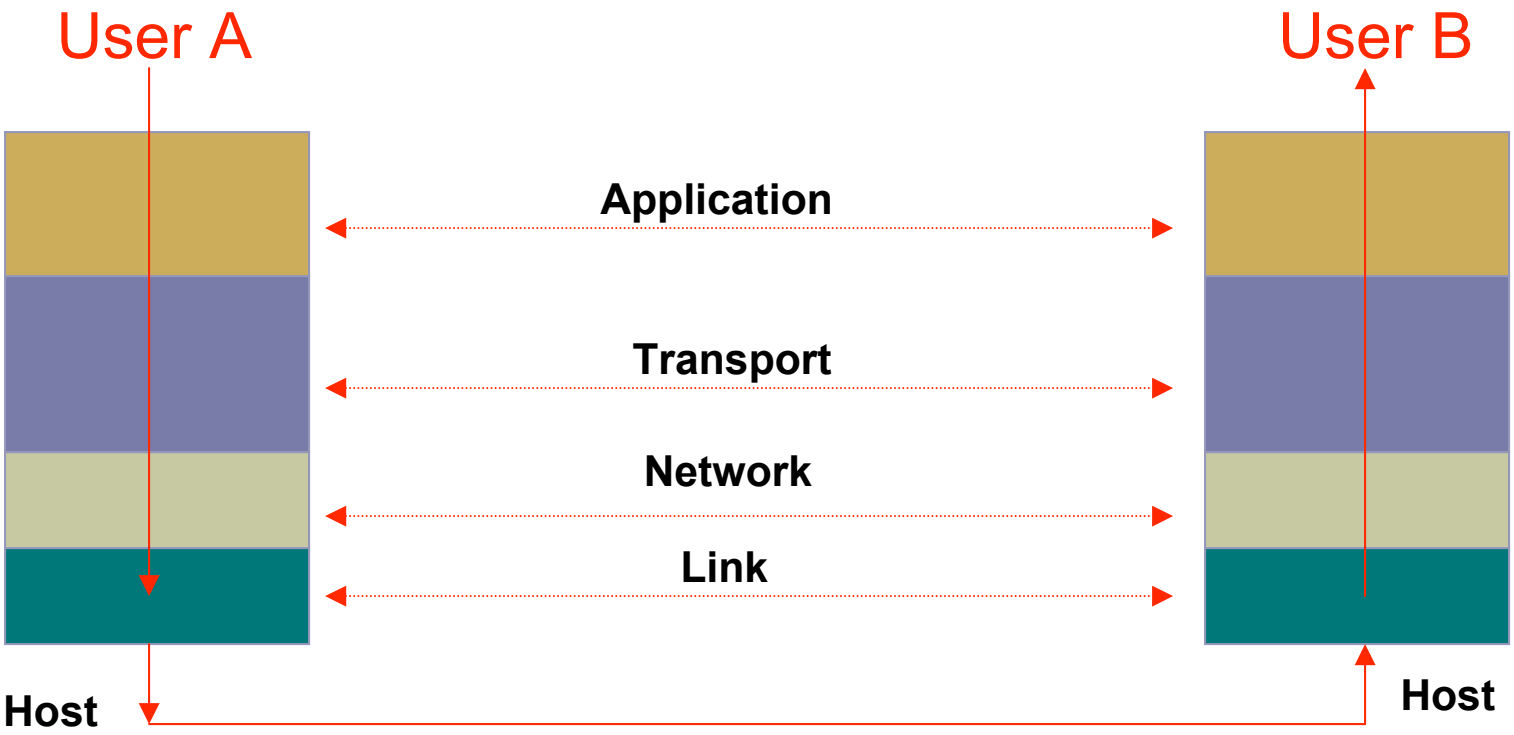
Layering Characteristics



- 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)

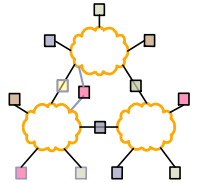
Layering





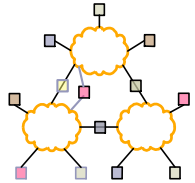
Layering: technique to simplify complex systems

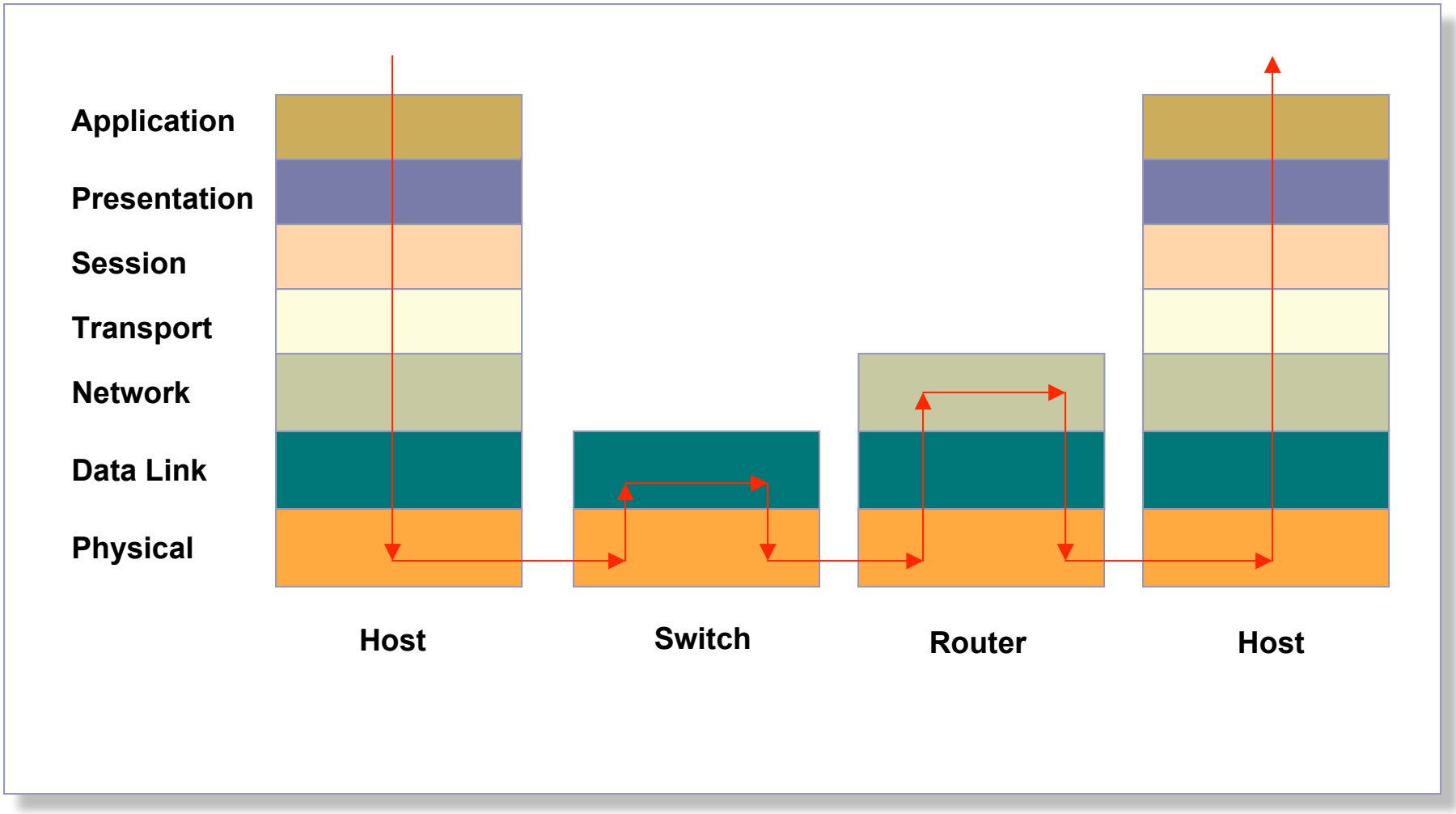
E.g.: OSI Model: 7 Protocol Layers



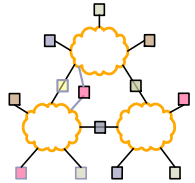
- Physical: how to transmit bits
- Data link: how to transmit frames
- Network: how to route packets
- Transport: how to send packets end2end
- Session: how to tie flows together
- Presentation: byte ordering, security
- Application: everything else

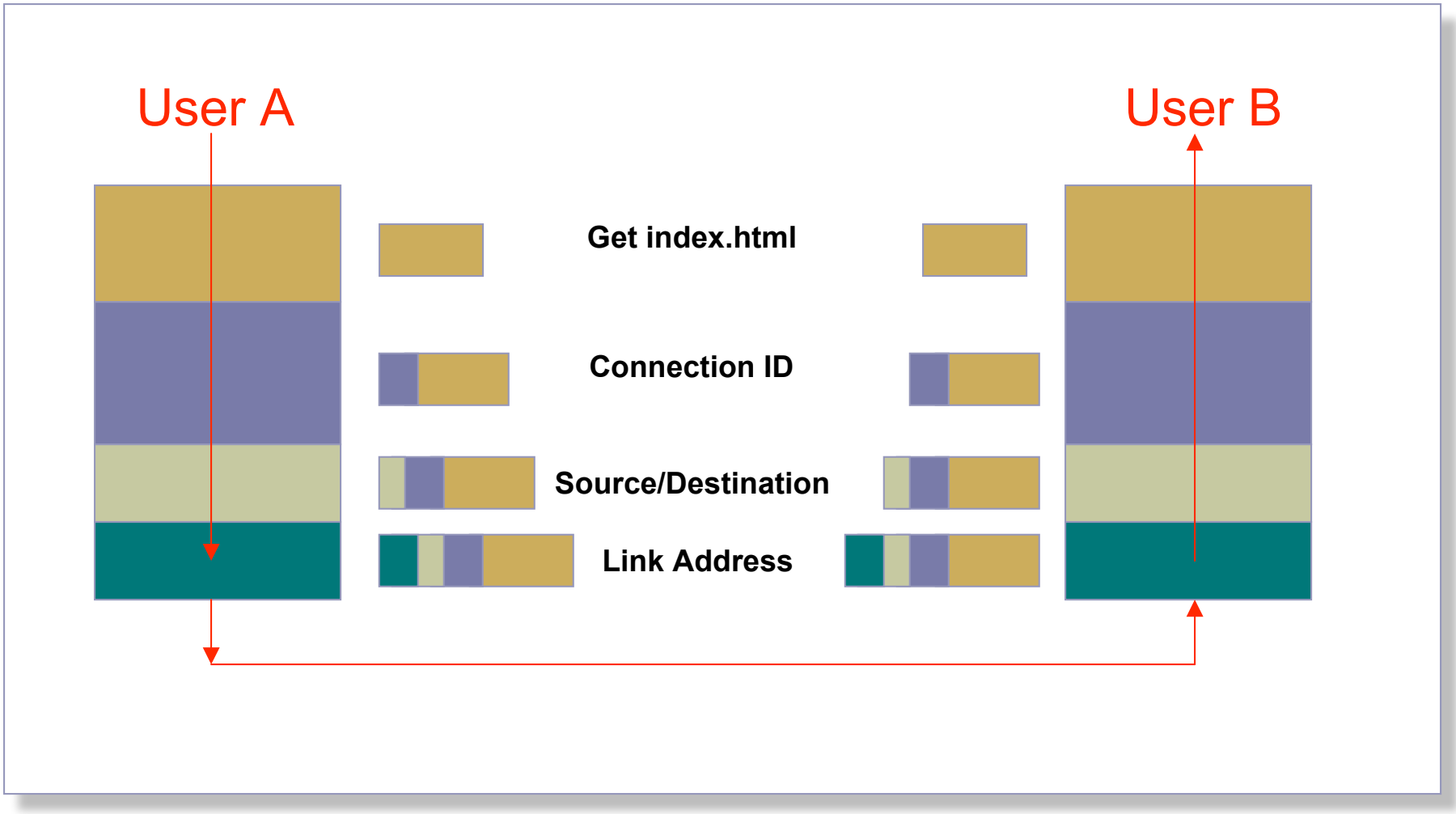
OSI Layers and Locations



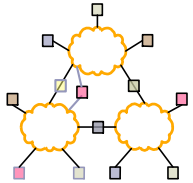


Layer Encapsulation

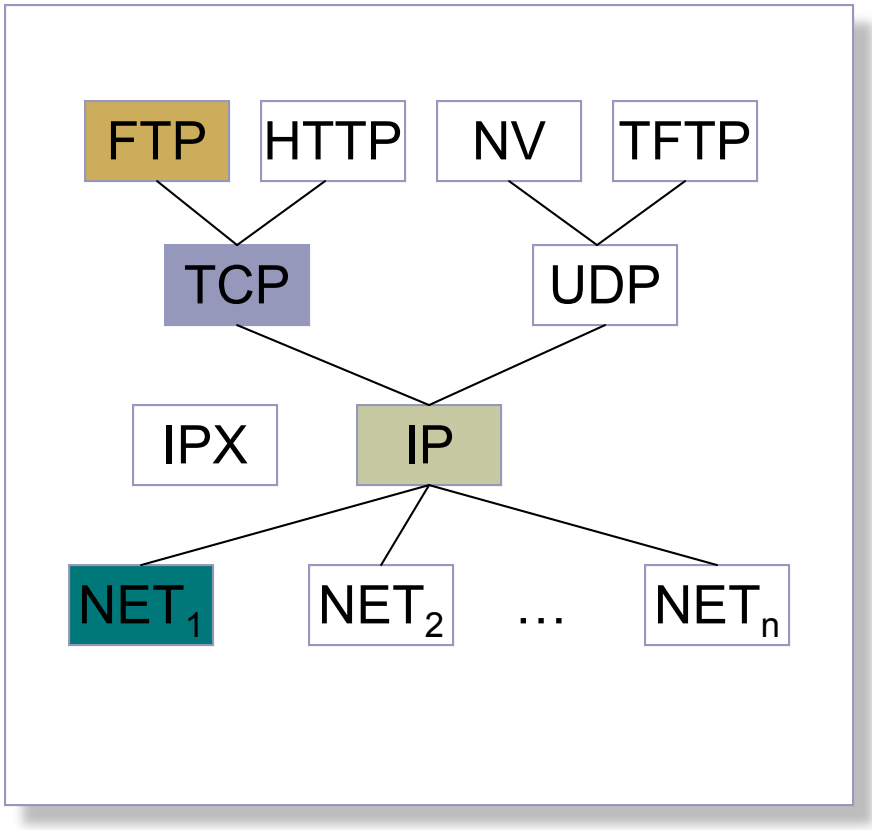


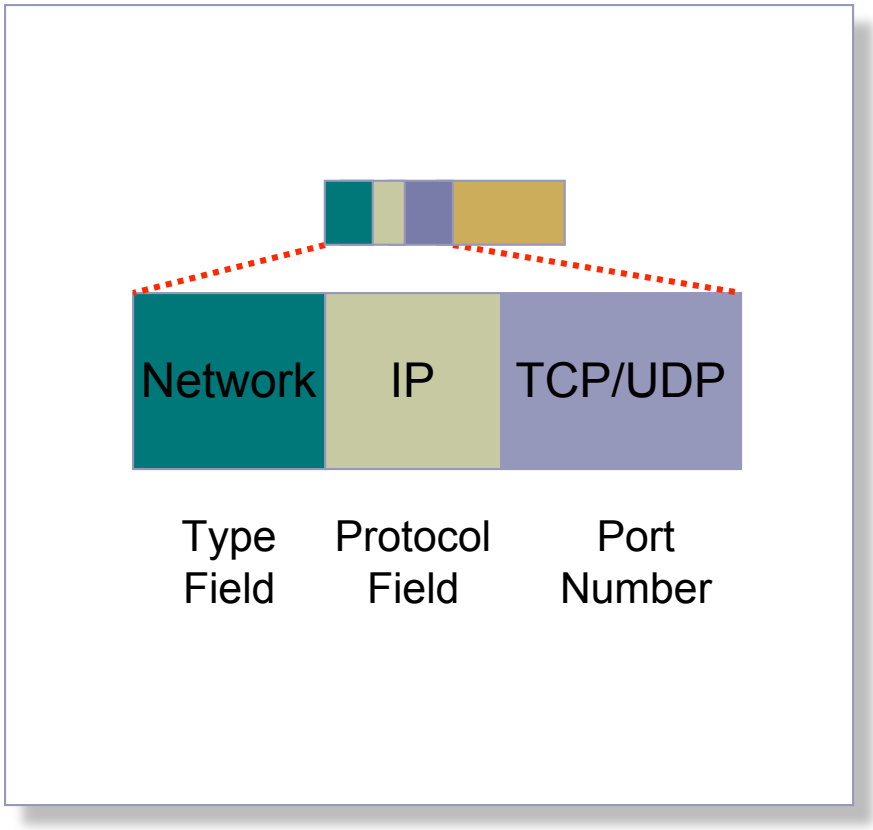


Protocol Demultiplexing

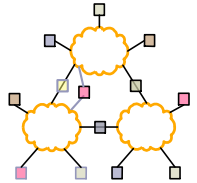


- Multiple choices at each layer



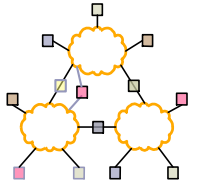


Is Layering Harmful?



- 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

Next Lecture: 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
- Optional Reading
  - [Cla02] Tussle in Cyberspace: Defining Tomorrow's Internet