

Measurement, App Layer

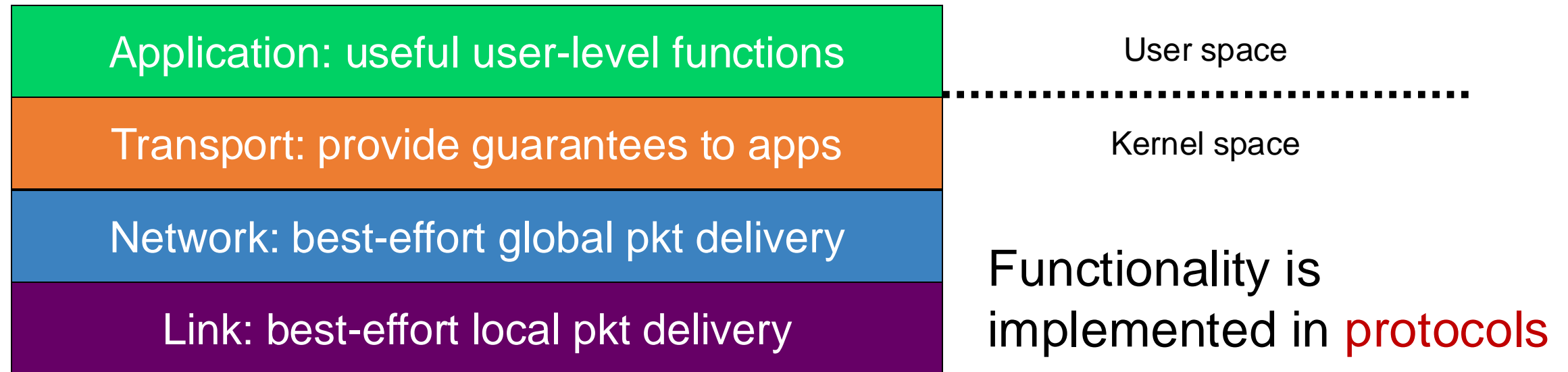
Lecture 3

<http://www.cs.rutgers.edu/~sn624/352-F24>

Srinivas Narayana

Review

- Switching: Circuit, Message, Packet
- Layering: Modularity



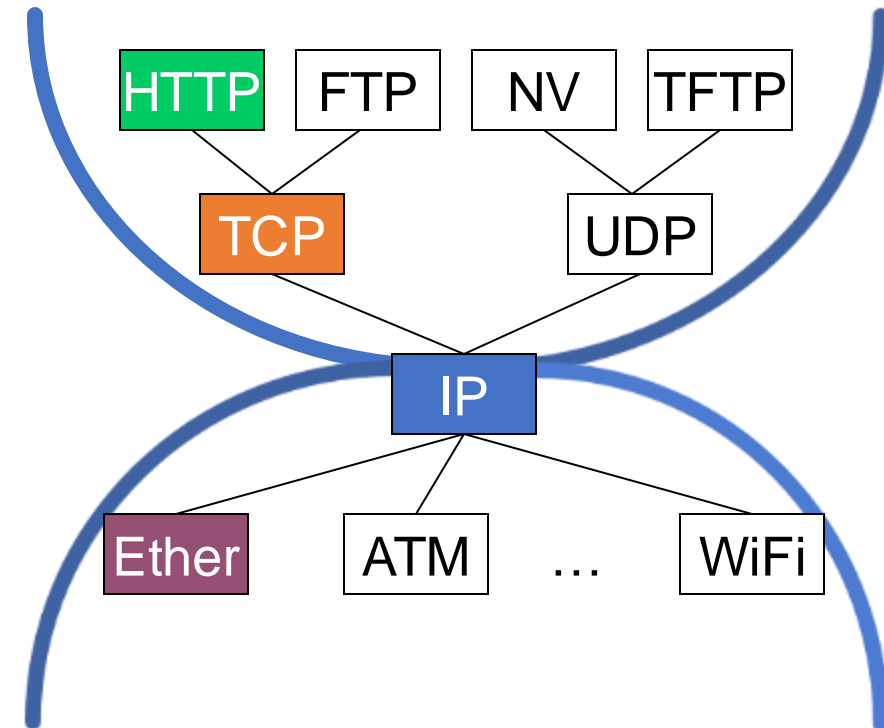
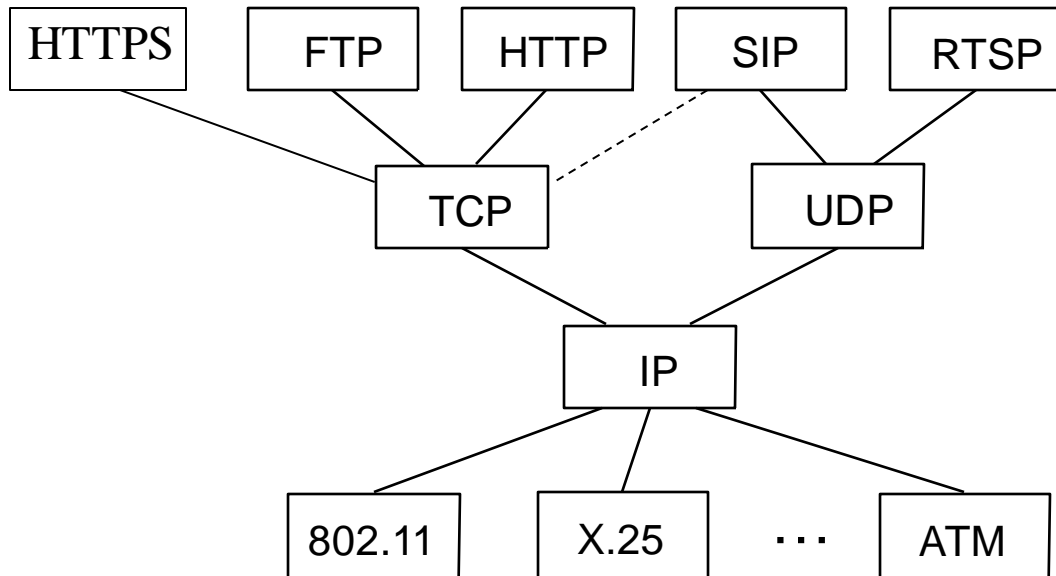
Protocols: The “rules” of networking

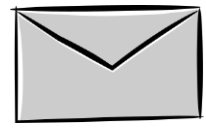
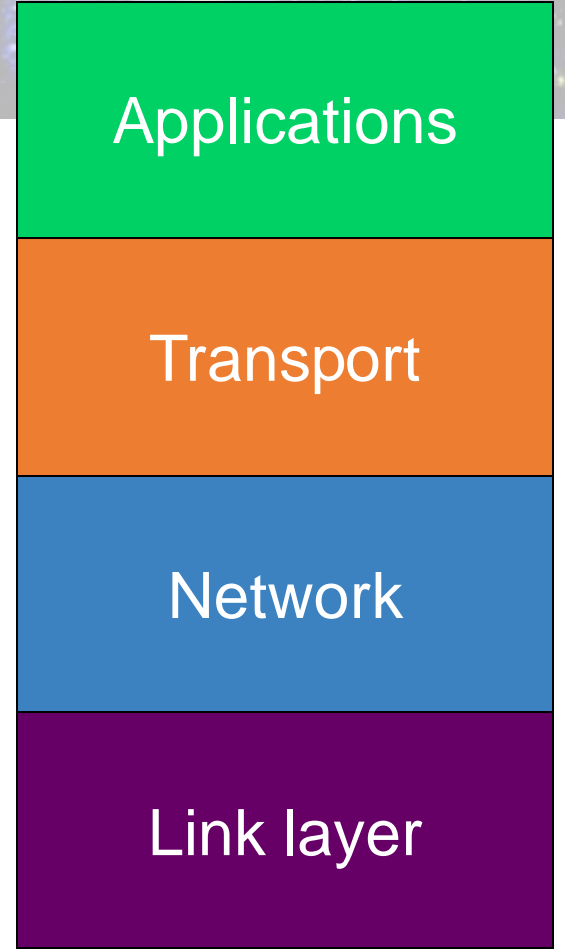
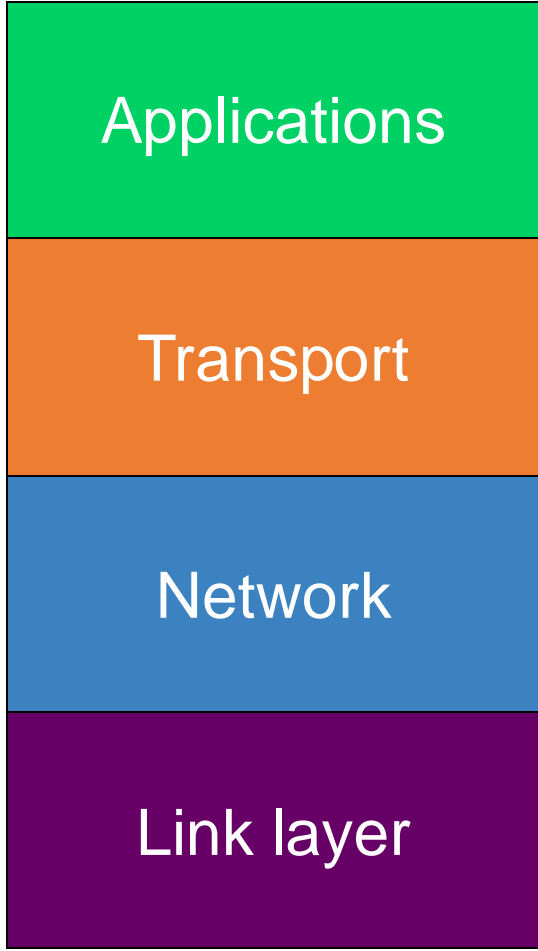
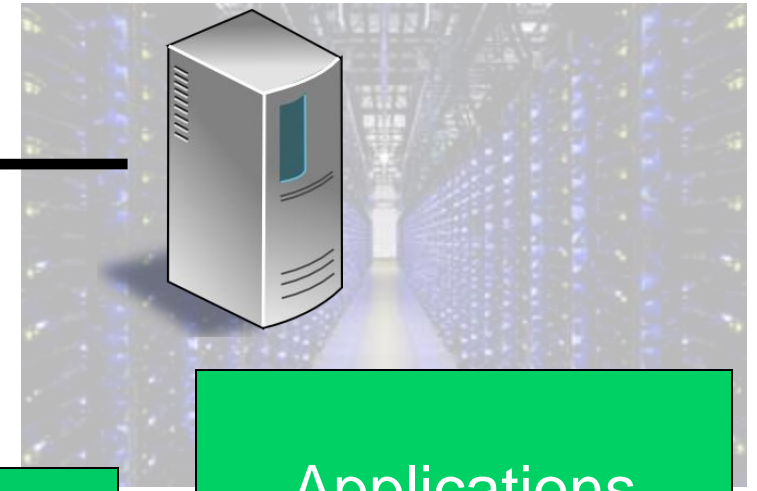
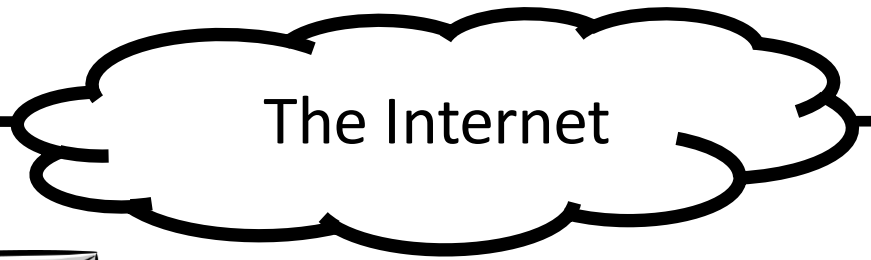
- Protocols consist of two things
- **Message format**
 - structure of messages exchanged with an endpoint
- **Actions**
 - operations upon receiving, or not receiving, messages
- Example of a Zoom conversation:
 - Message format: English words and sentences
 - Actions: when a word is heard, say “yes”; when nothing is heard for more than 3 seconds, say “can you hear me?”

The protocols of the Internet

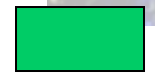
- Standardized by the Internet Engineering Task Force (IETF)
 - through documents called **RFCs** (“Request For Comments”)

- Layering of protocols

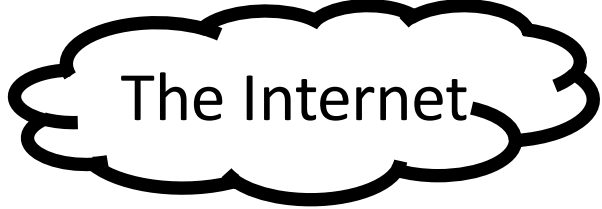
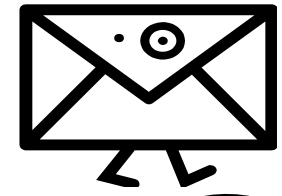


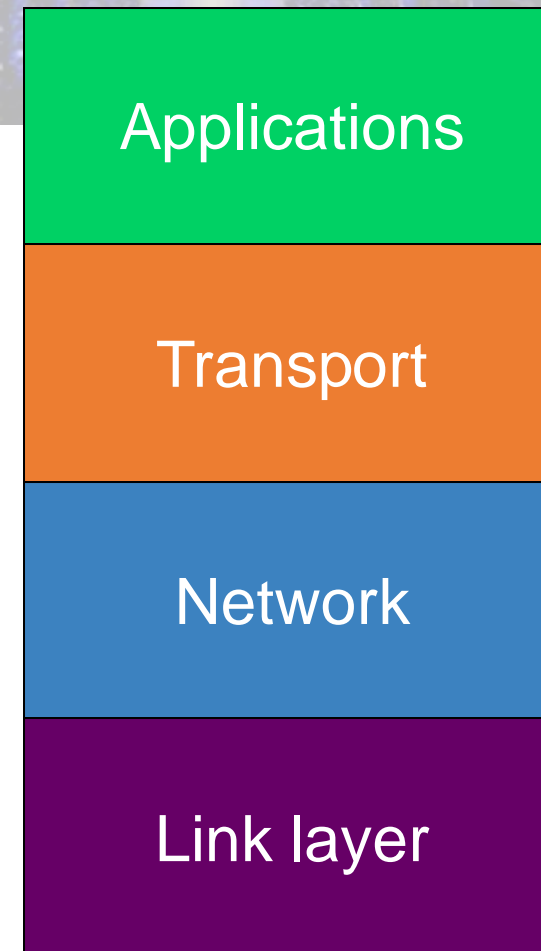
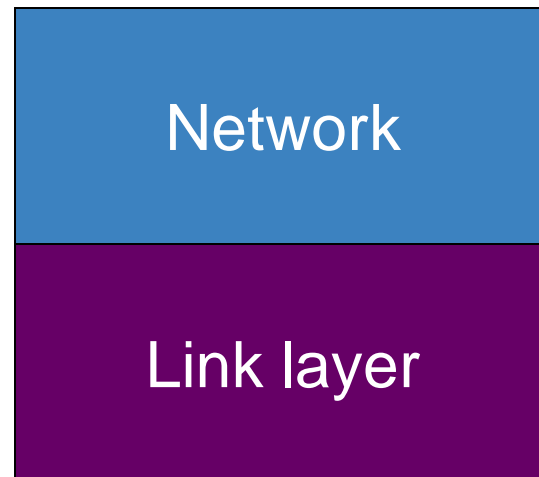
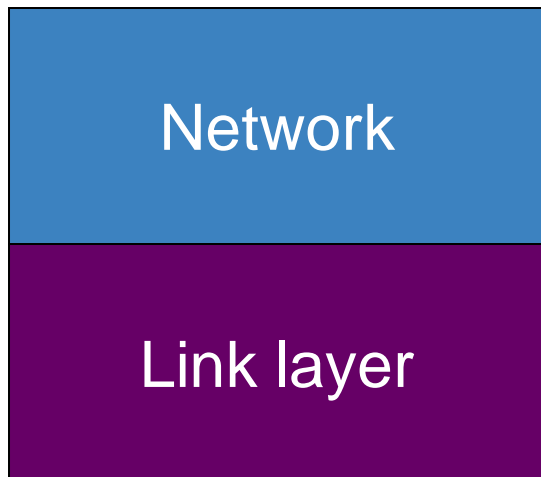
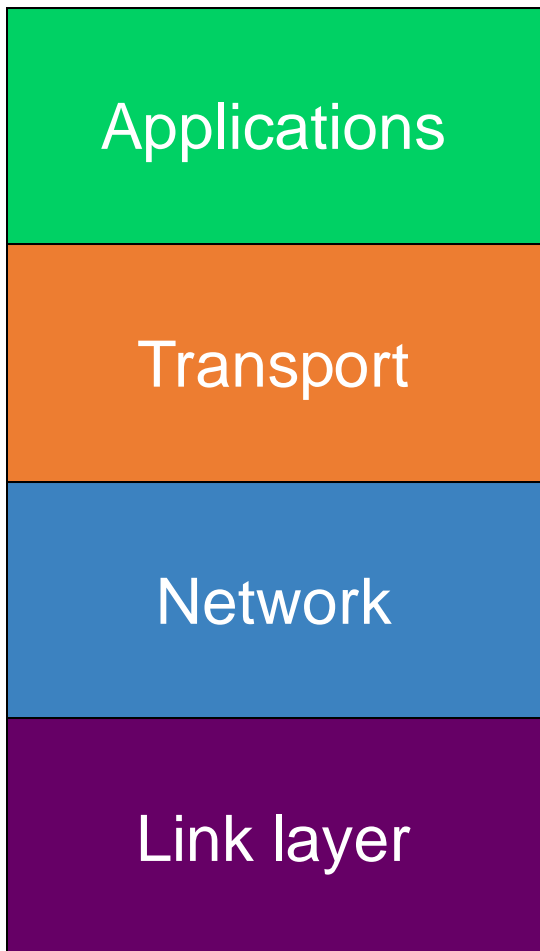
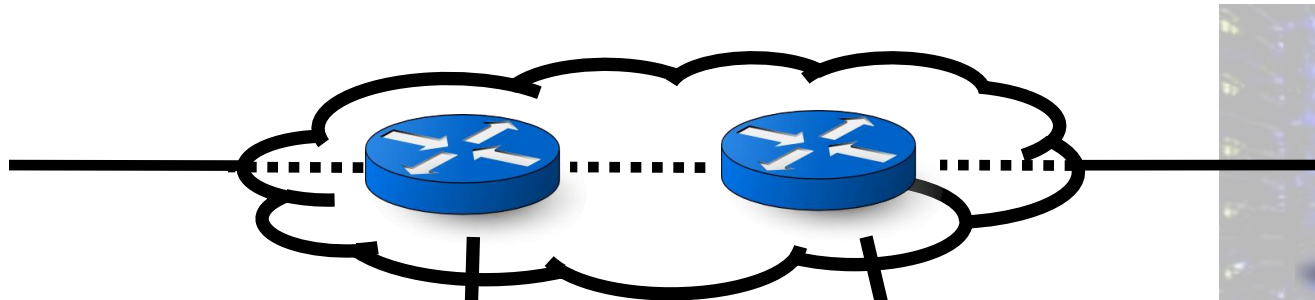


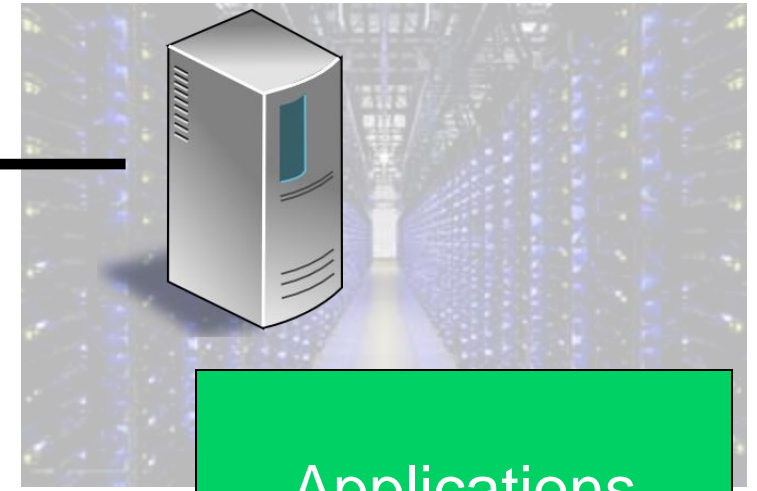
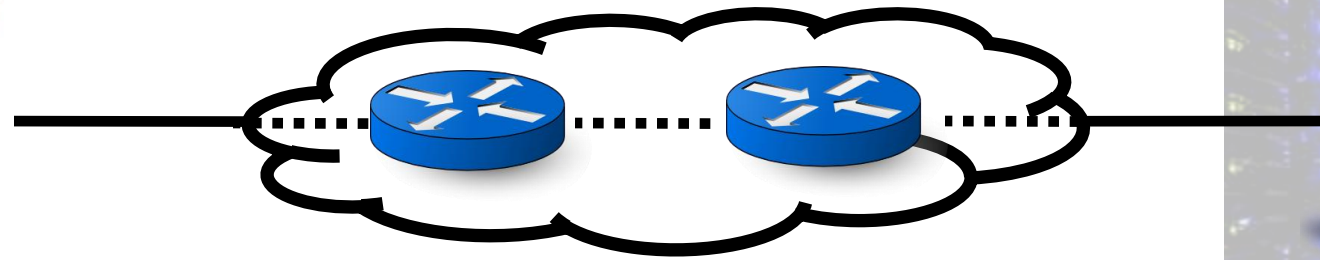
Packet starts as an app message



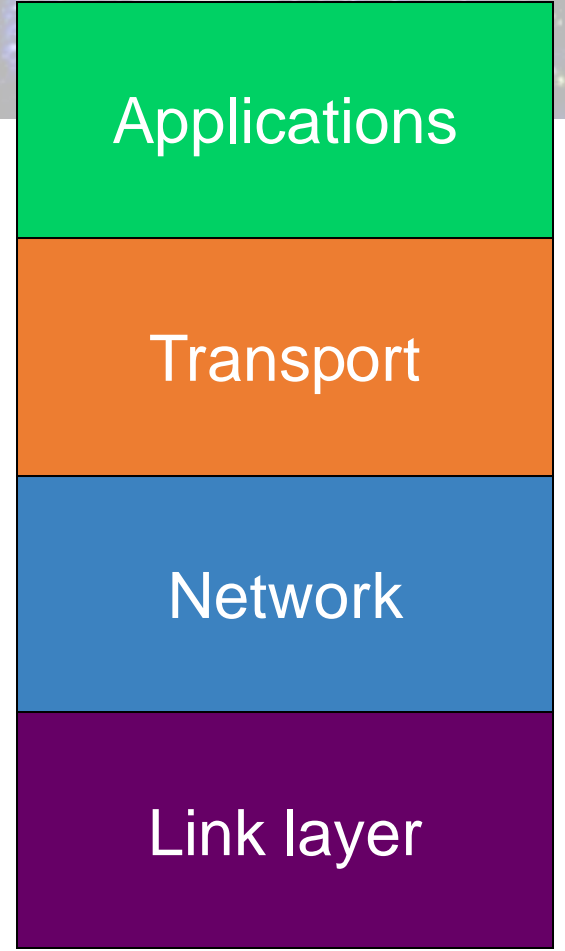
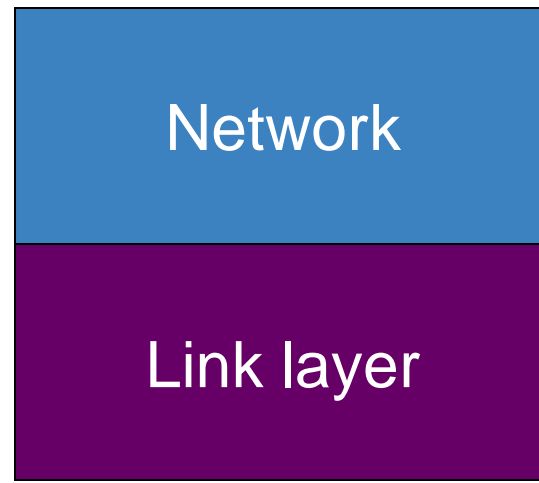
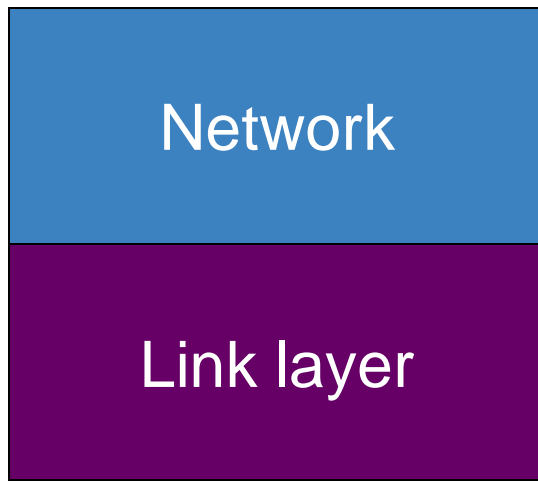
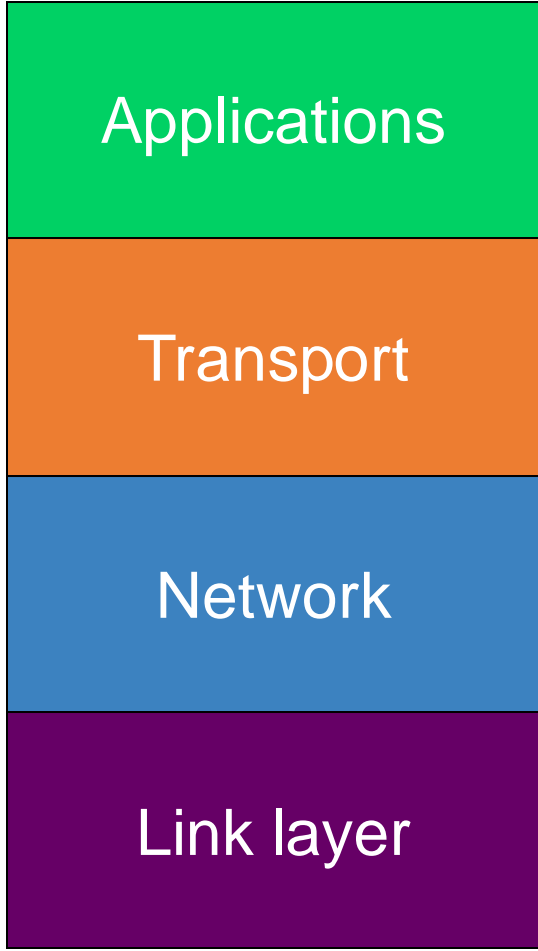
Packet takes on headers at each layer







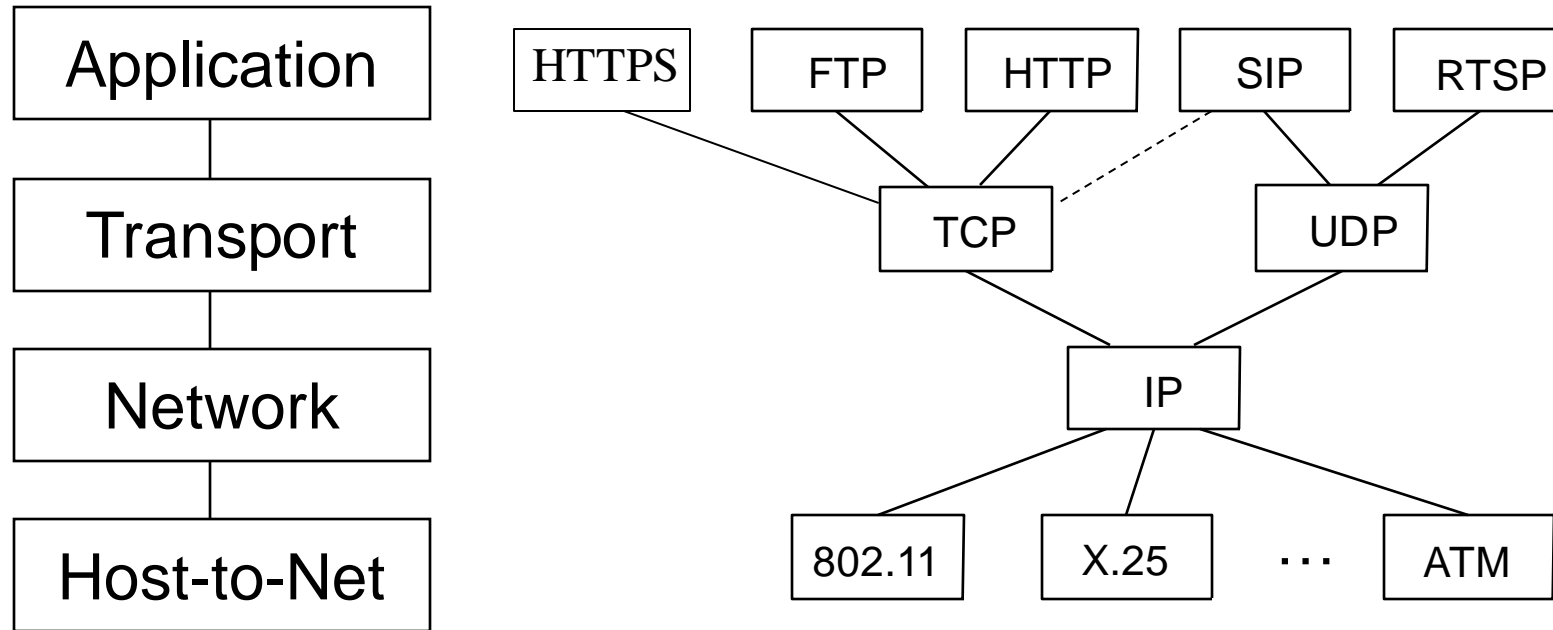
Routers have network and link layers too!



Layering

- Communication over the Internet is a complex problem.
- Layering simplifies understanding, testing, maintaining
- Easy to improve or replace protocol at one layer without affecting others

This course has layers



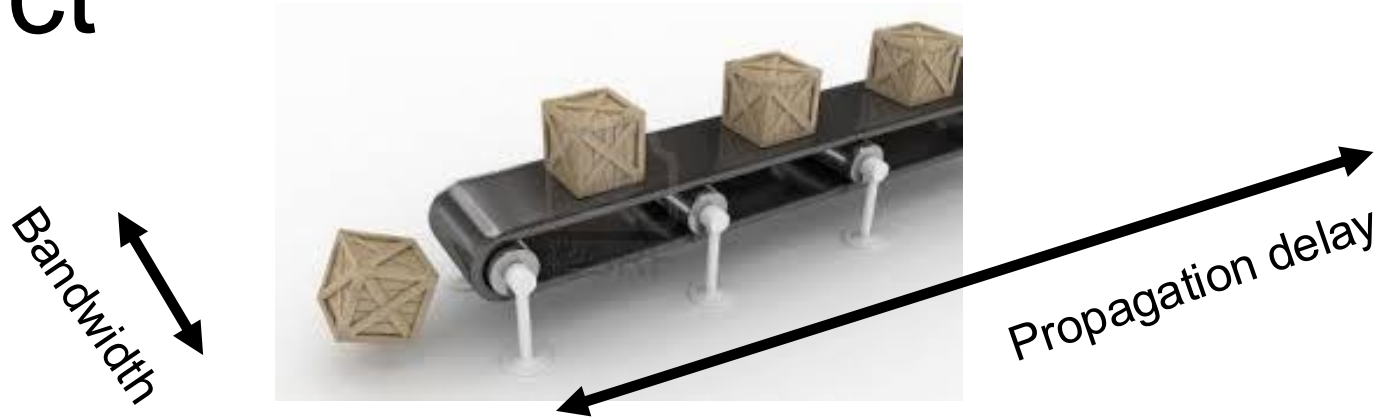
Measuring the Internet

Speed, by any other name

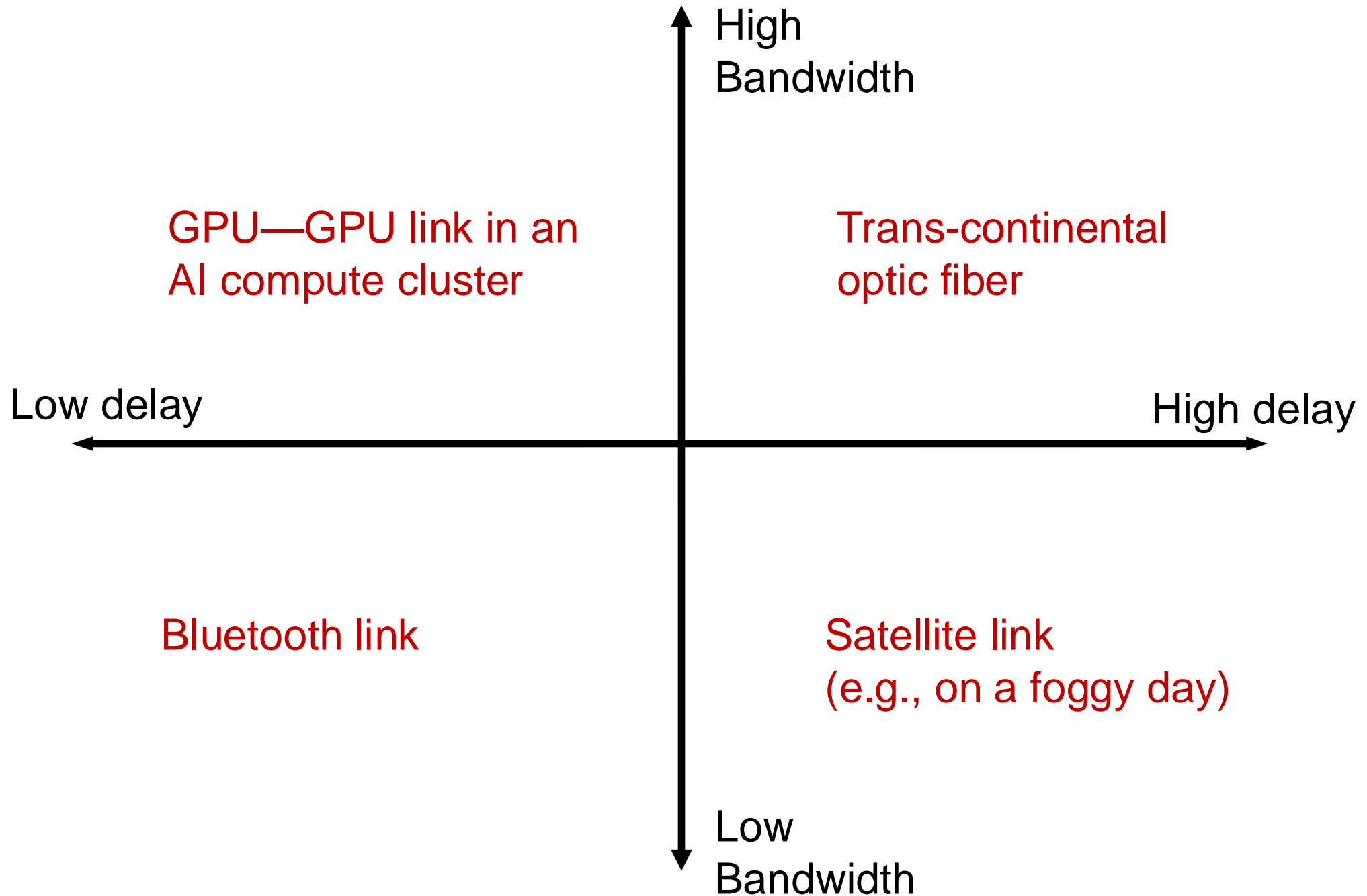
What exactly do we mean by speed?

- A packet consists of many bits, including header and data
 - **Packet size**: length of the packet (bits or bytes) incl. header and data
- **Bandwidth**: For a single link, amount of data it can transmit per unit time (bits/second or Bytes/second or packets/second)
- **Total packet delay**: time from the first bit@sender to the last bit@receiver

Bandwidth and delay are related but distinct



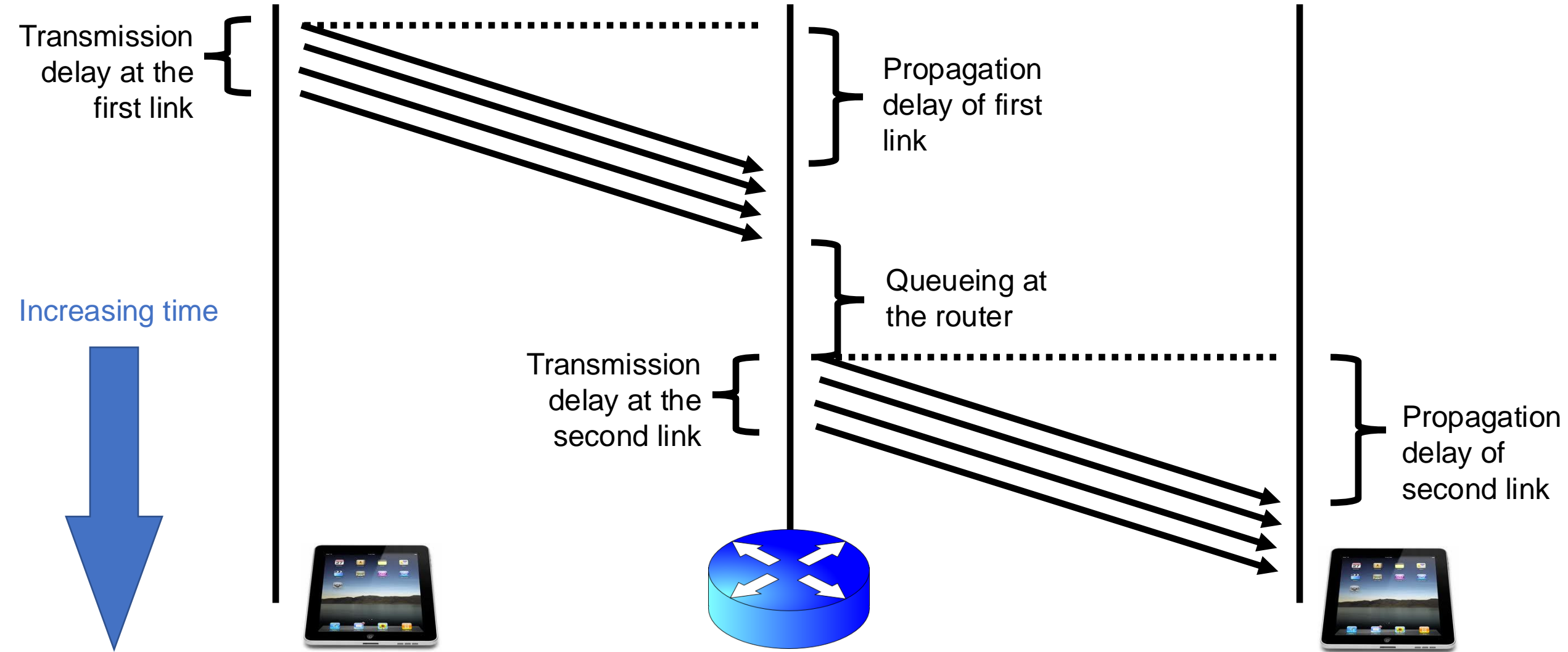
- Total packet delay = time for a box to travel the length of the belt
- Bandwidth = the number of boxes put on the belt per minute (“rate”)



Total Packet Delay has a few pieces

- **Propagation delay:** Time needed to move one bit across (second)
 - Imposed by the communication medium; depends on the link “length”
- **Transmission delay:** Time from first bit@sender to last bit@sender
 - Determined by link bandwidth and packet size
 - Packet size / link bandwidth
- **Queueing delay:** Time that a packet waits for transmission
 - Determined by contention for the link
- **Total packet delay** = propagation delay + queueing delay + transmission delay for a single packet

Visualizing the components of delay



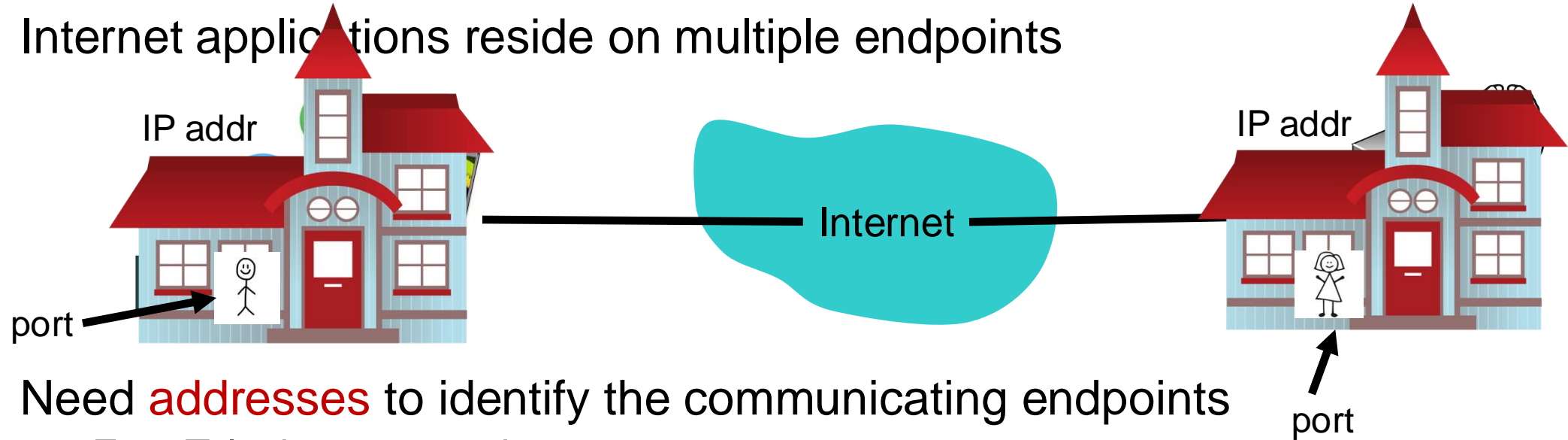
Bandwidth and delay demo

- Throughput (related to bandwidth)
 - `iperf -s #` at the destination
 - `iperf -c <destination> #` at the source,
 - e.g., `iperf -c localhost`
- (total) delay
 - `ping <destination>`
 - e.g., `ping google.com`
- (you can try it!)

Application Layer

App-layer communication

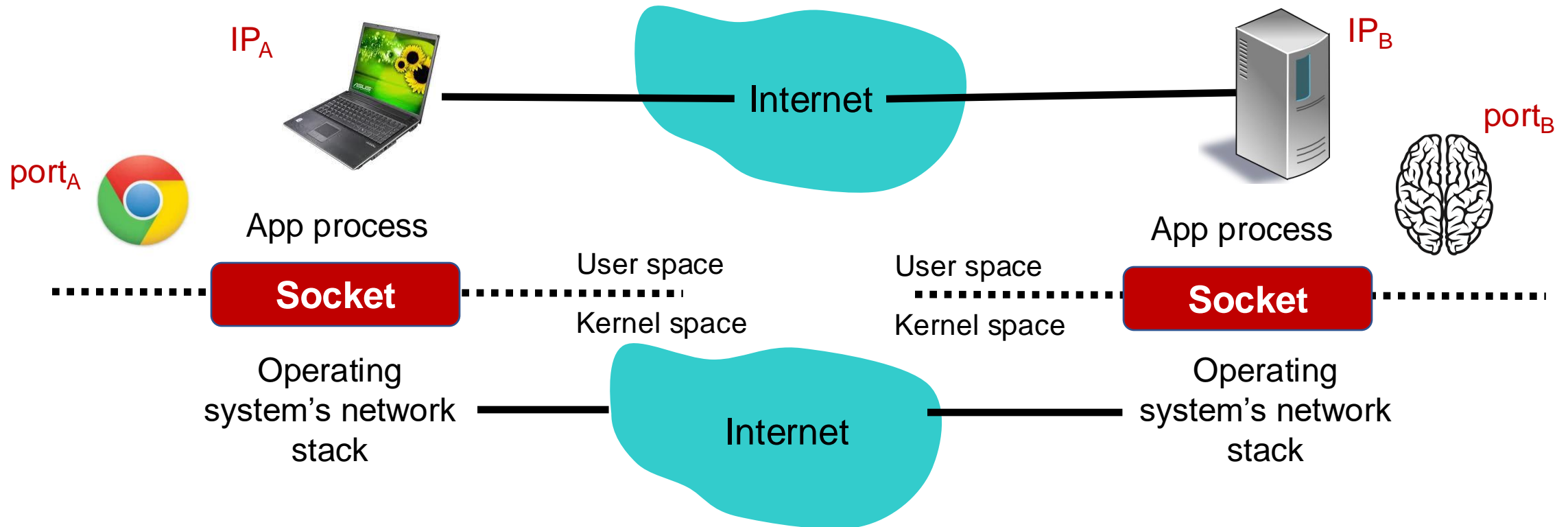
- Internet applications reside on multiple endpoints



- Need **addresses** to identify the communicating endpoints
 - E.g., Telephone network: xxx-yyy-zzzz
- Internet: **Internet Protocol (IP) addresses**
 - IPv4 (32 bits) 128.6.24.78
 - IPv6 (128 bits) 2001:4000:A000:C000:6000:B001:412A:8000
- Which app on each endpoint? **Port number**

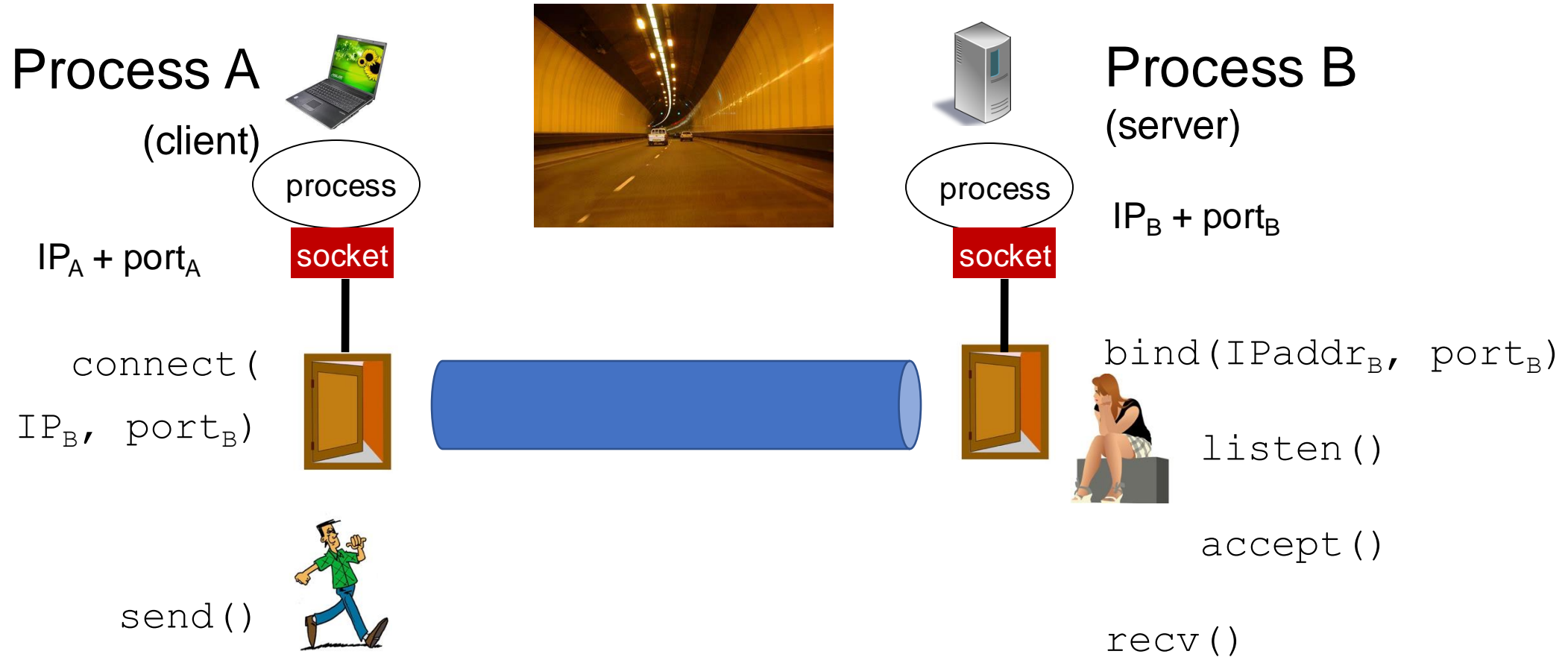
How are addresses used?

- **Socket**: abstraction (API) of the Internet for applications



App-layer connection is a 4-tuple: (IP_A , port_A, IP_B , port_B)

Socket system calls

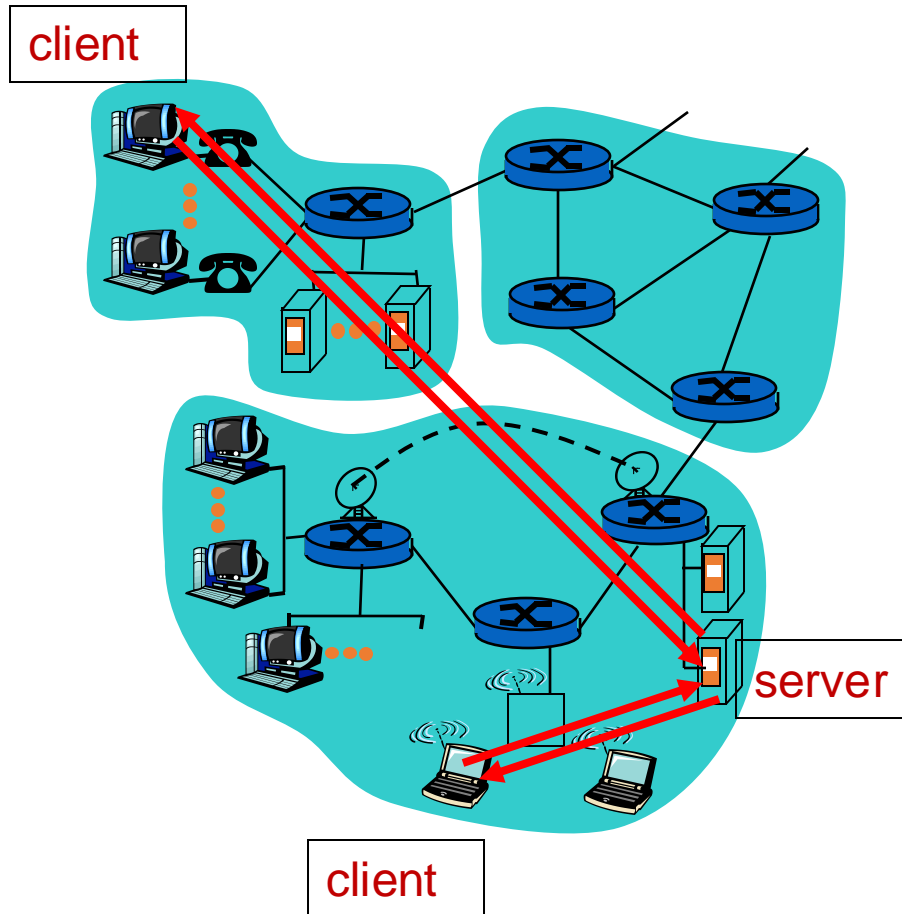


Seeing app-layer connections

- `netstat`
- `ss`

Common Architectures of Applications

Client-server architecture



Server:

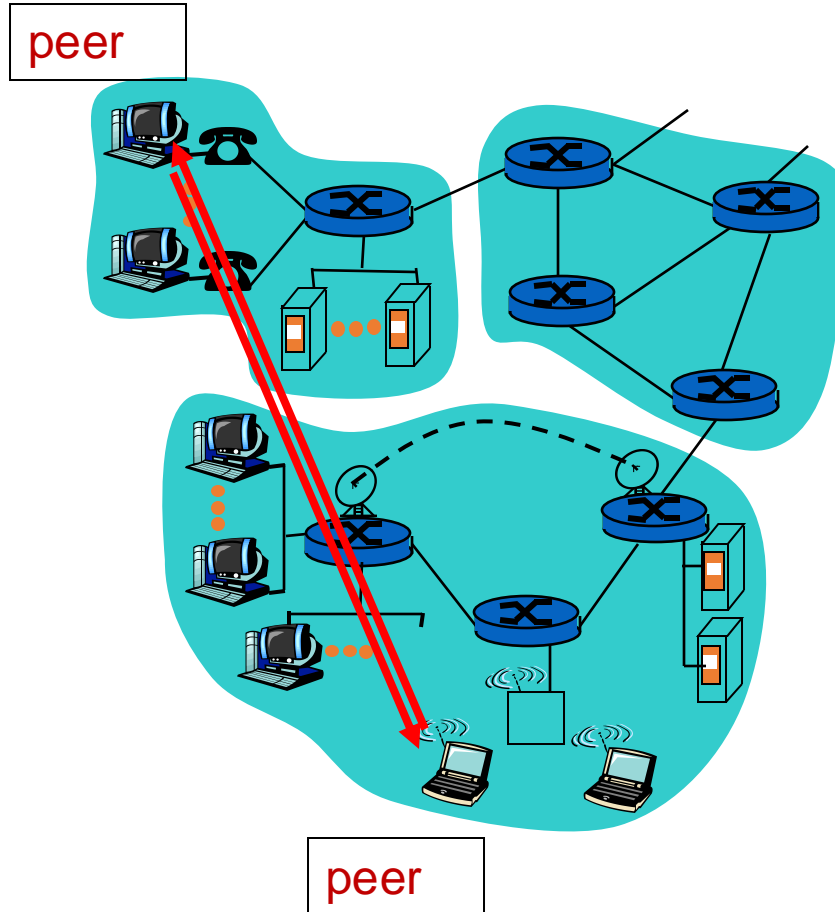
- Always-on endpoint
- Provides a “service” to the world
- Typically, a permanent IP address
- Compute clusters to scale to many users

Clients:

- A “customer” of the server
- May be intermittently connected
- May have dynamic IP addresses
- Typically, do not communicate directly with other clients

- The web and most mobile apps use a client-server architecture

Peer-to-peer (P2P) architecture



- **Peers:**
 - Intermittently connected hosts
 - Directly talking to each other
- Little to no reliance on always-up servers
 - Examples: BitTorrent, WhatsApp
- Today, many applications use a **hybrid** model
 - Example: (webRTC) Google meet, Facebook messenger, ...

Going forward: A few app-layer protocols

- Domain Name System
- The web
- Streaming video

Domain Name System

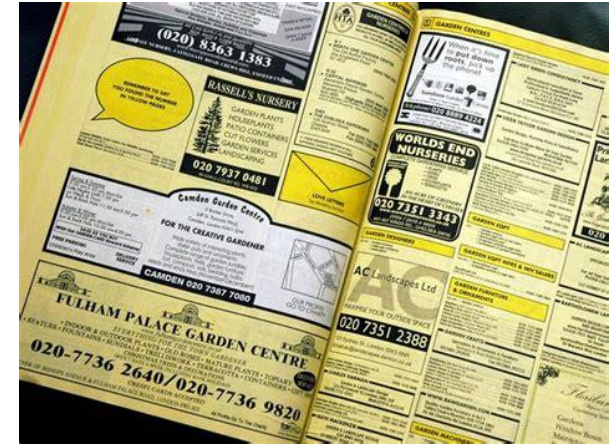
You have my name. Can you
lookup my address?

Domain Name System (DNS)

- Problem: We need an easier way to remember IP addresses
 - Average brain can easily remember 7 digits for a few names
 - On average, IP addresses have 12 digits
- Solution:
 - Use alphanumeric names to refer to hosts.
 - Called **host names** or **domain names** (e.g.: cs.rutgers.edu)
 - We need a **directory (address book)**
 - A service to map alphanumeric host names to binary IP addresses
 - We call this process **Address Resolution**

Types of Directories

- Directories map a *name* to an *address*
- Simplistic designs
 - Central directory
 - Ask everyone (e.g., flooding)
 - Tell everyone (e.g., push to a file like /etc/hosts)
- Scalable distributed designs
 - Hierarchical namespace (e.g., Domain Name System (DNS))
 - Flat name space (e.g., Distributed Hash Table)



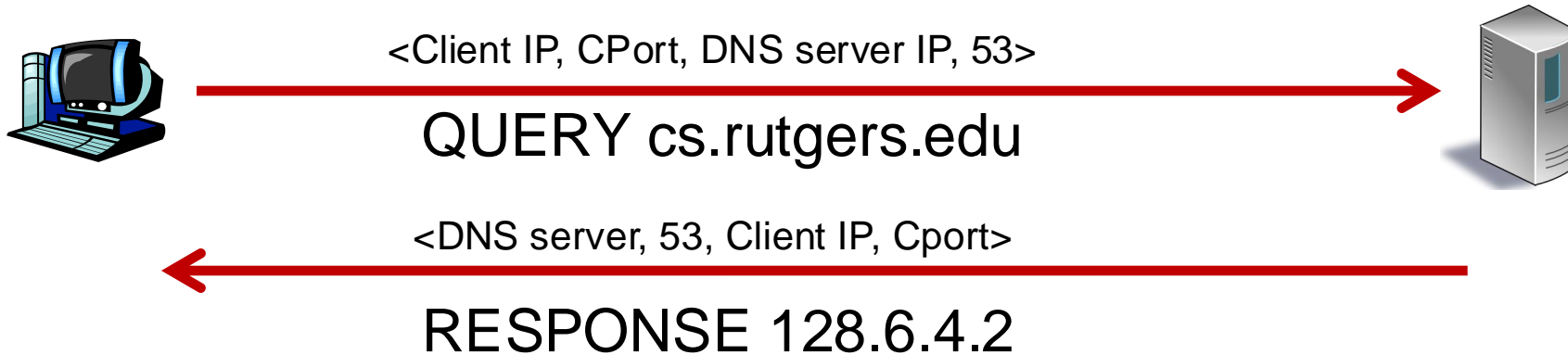
Simple DNS

- What if every endpoint has a local directory?
- `/etc/hosts.txt`
 - How things worked in the early days of the Internet!
- What if endpoints changed addresses? How do you keep this up to date?

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Simple DNS

DOMAIN NAME	IP ADDRESS
spotify.com	98.138.253.109
cs.rutgers.edu	128.6.4.2
www.google.com	74.125.225.243
www.princeton.edu	128.112.132.86



- Key idea: Implement a server that looks up a table.
- Will this scale?
 - Every new (changed) host needs to be entered in this table
 - Performance: can the server serve billions of Internet users
 - Failure: what if the server or the database crashes?
 - How to secure this server?