

Measurement, App Layer

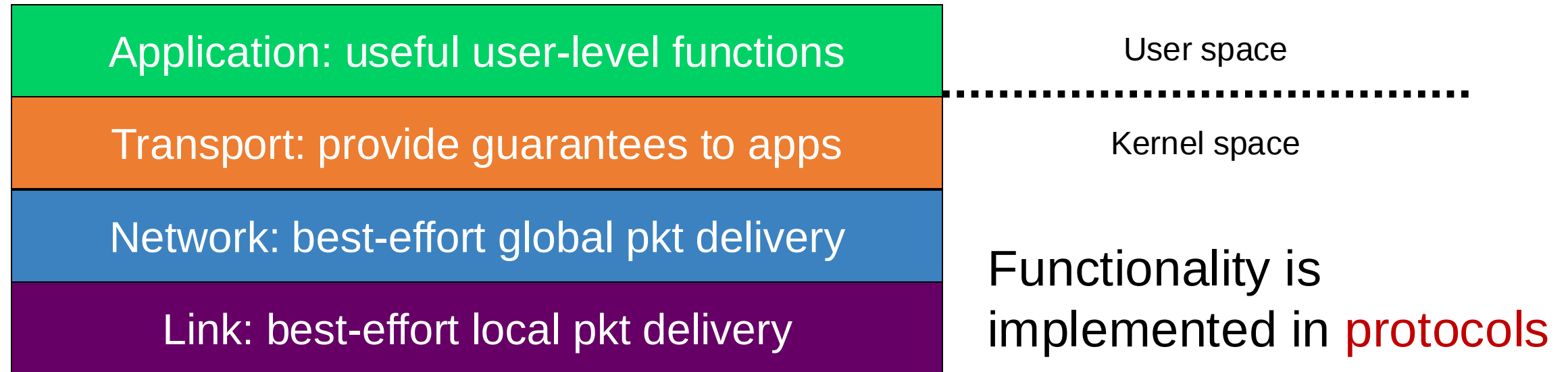
Lecture 3

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

Srinivas Narayana

Review

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



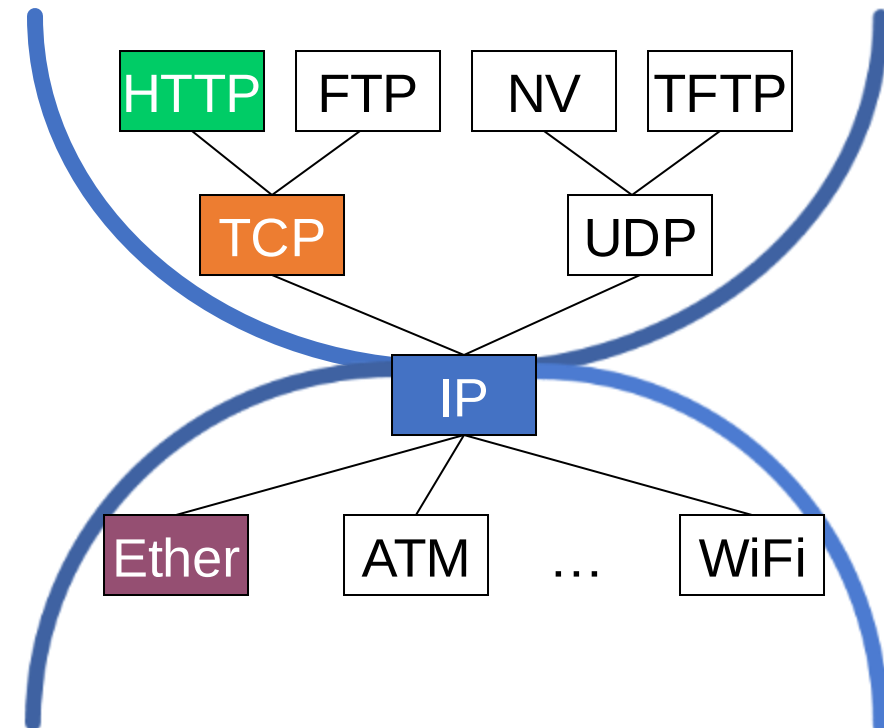
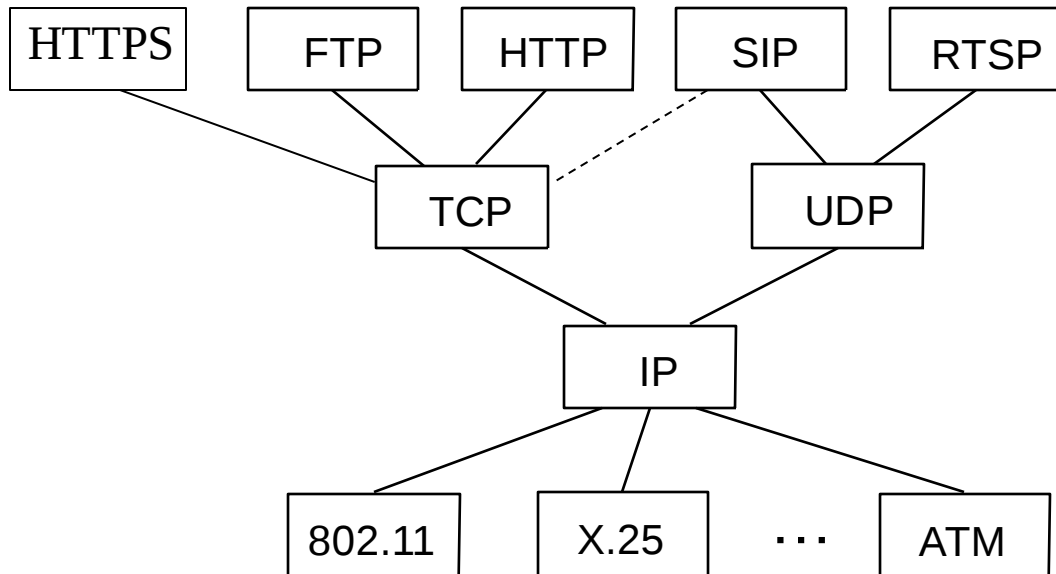
Protocols: The “rules” of networking

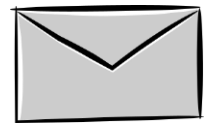
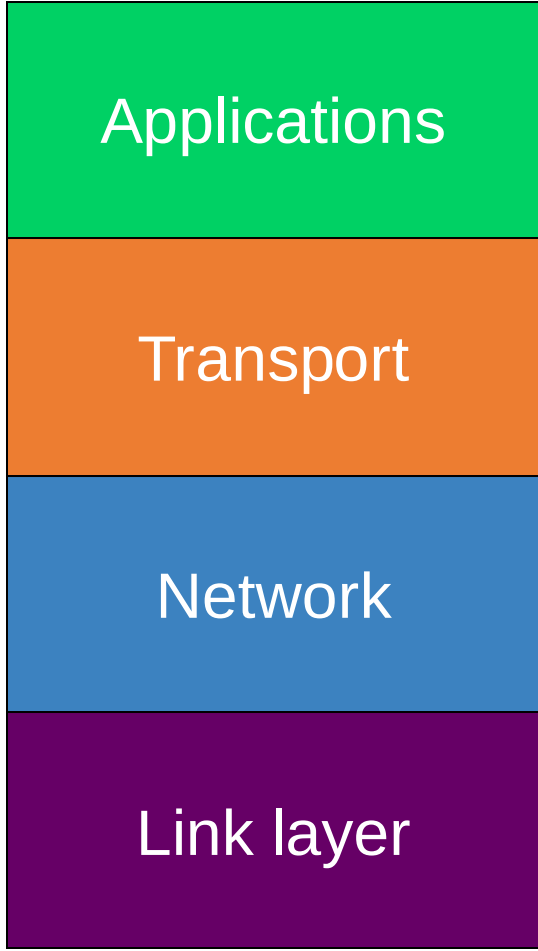
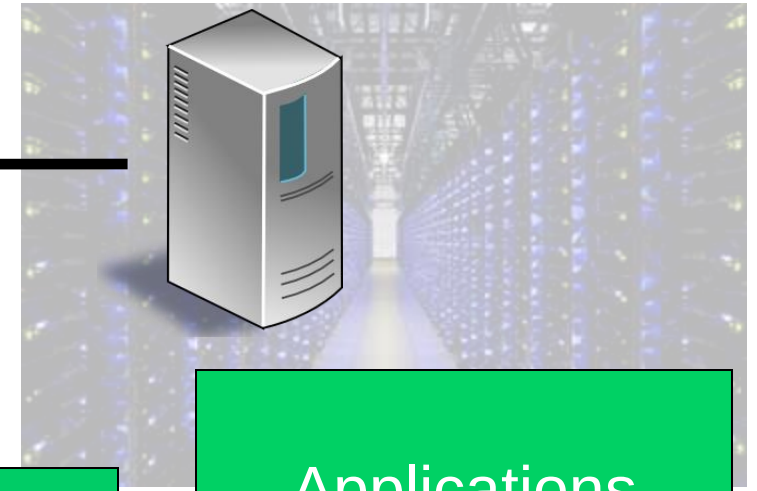
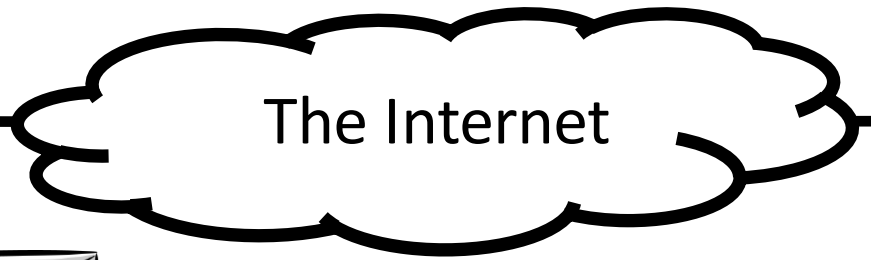
- Protocols consist of two things
- **Message format**
 - structure of messages exchanged with an endpoint
- **Actions**
 - operations upon receiving, or not receiving, messages
- Example of a Zoom conversation:
 - Message format: English words and sentences
 - Actions: when a word is heard, say “yes”; 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

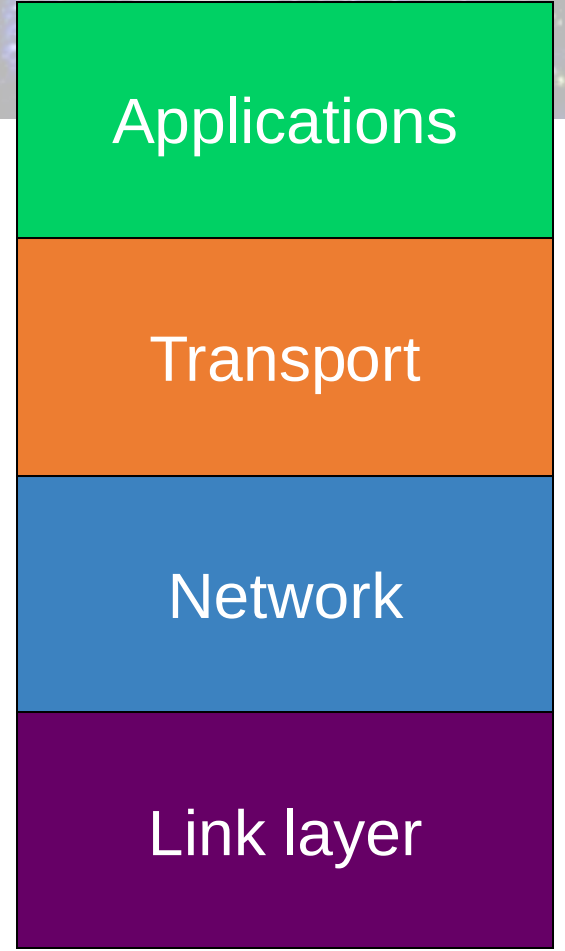
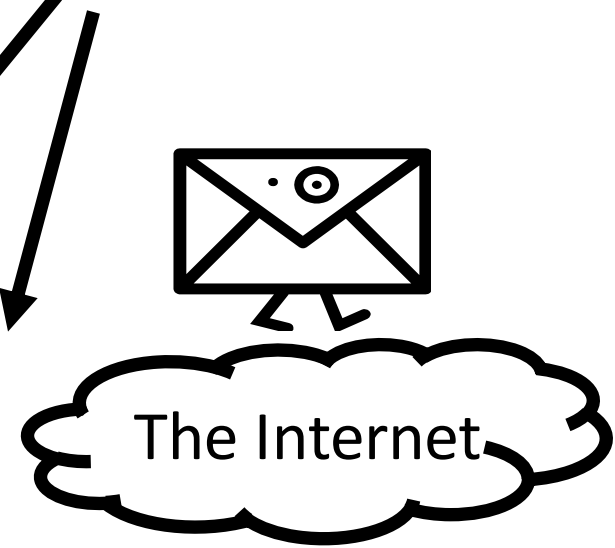


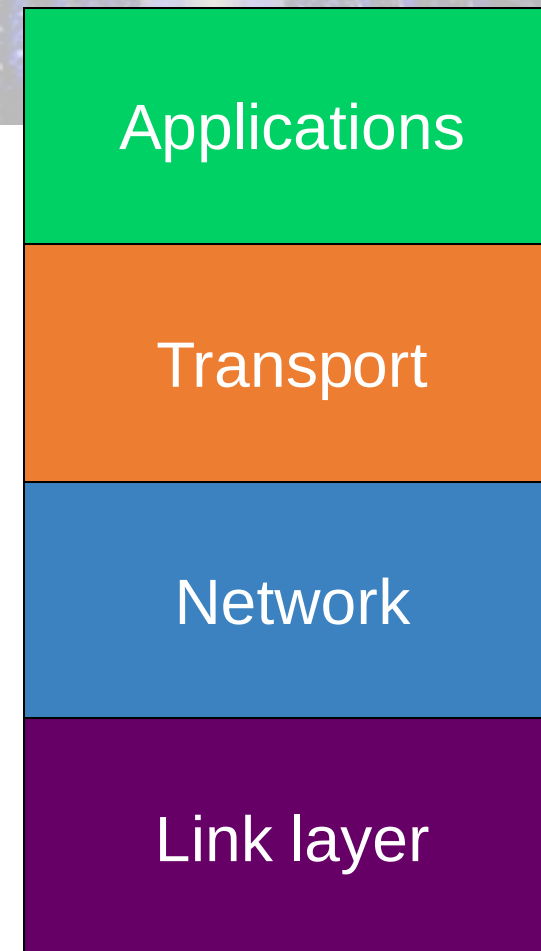
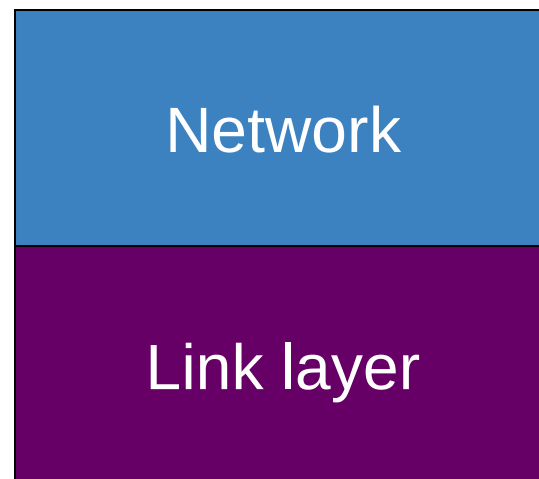
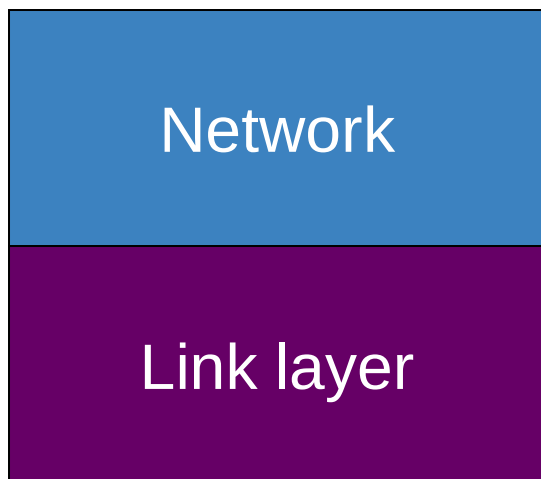
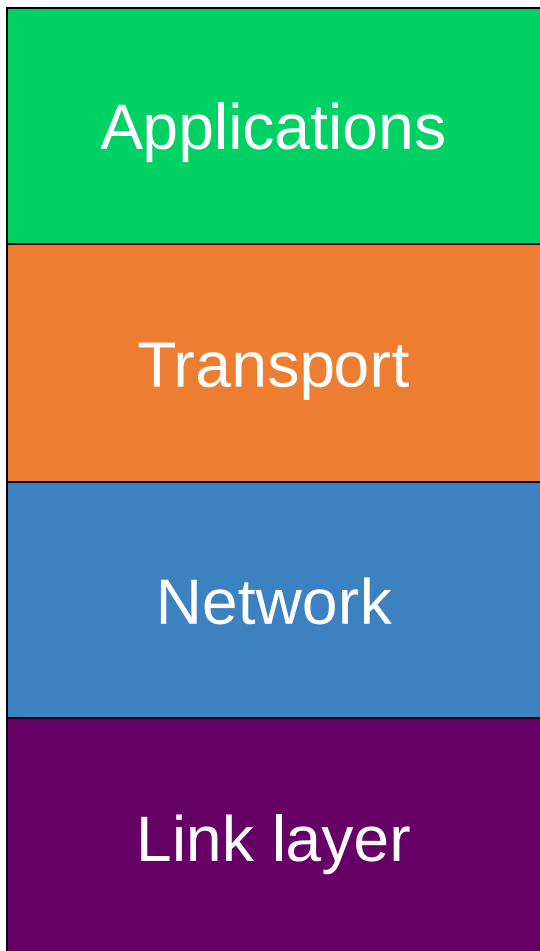
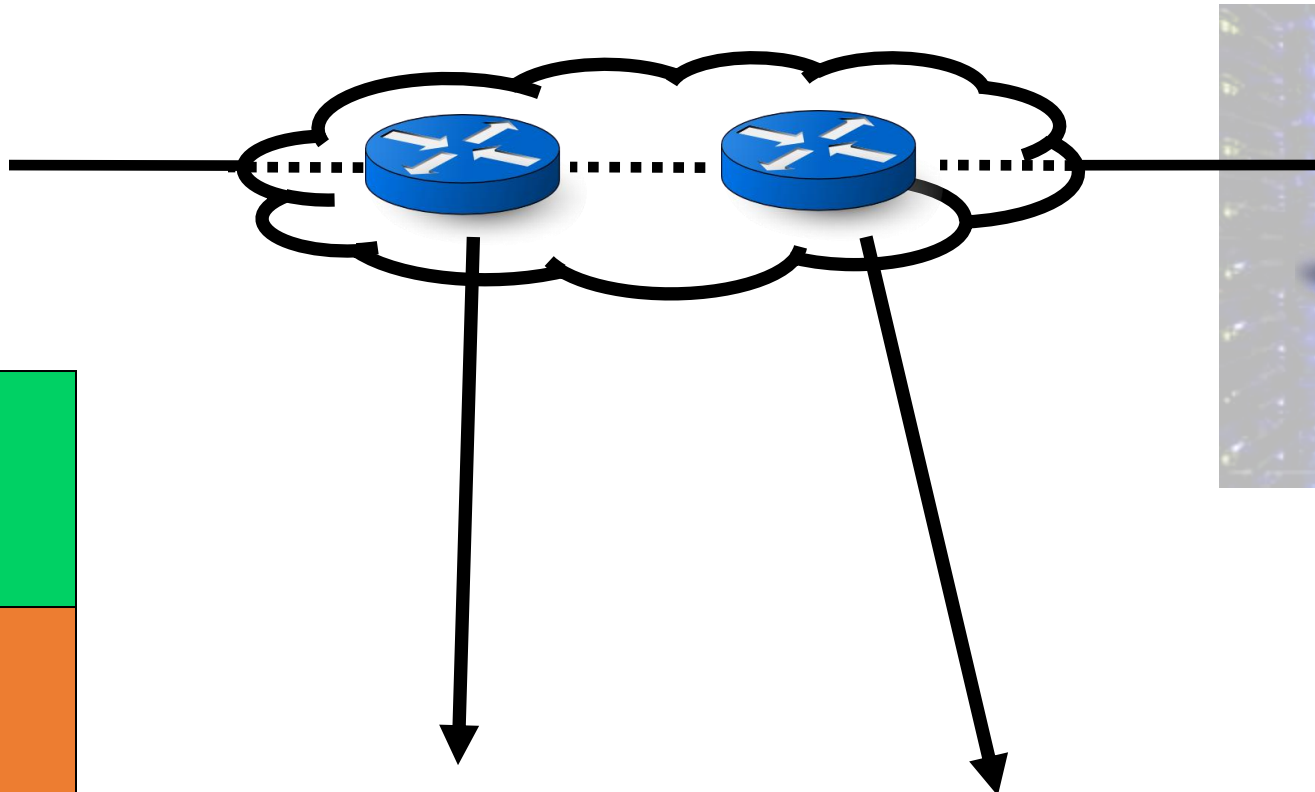


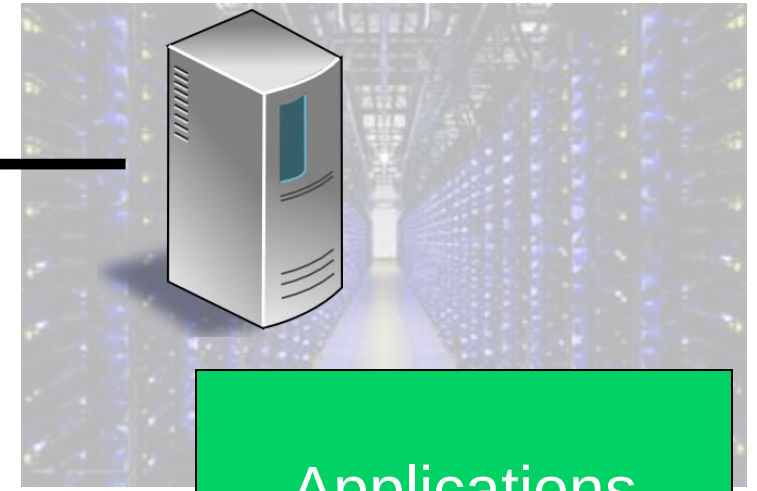
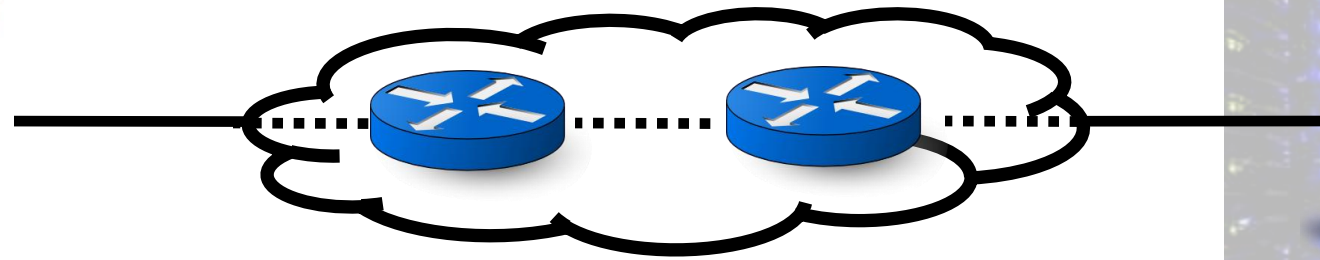
Packet starts as an app message



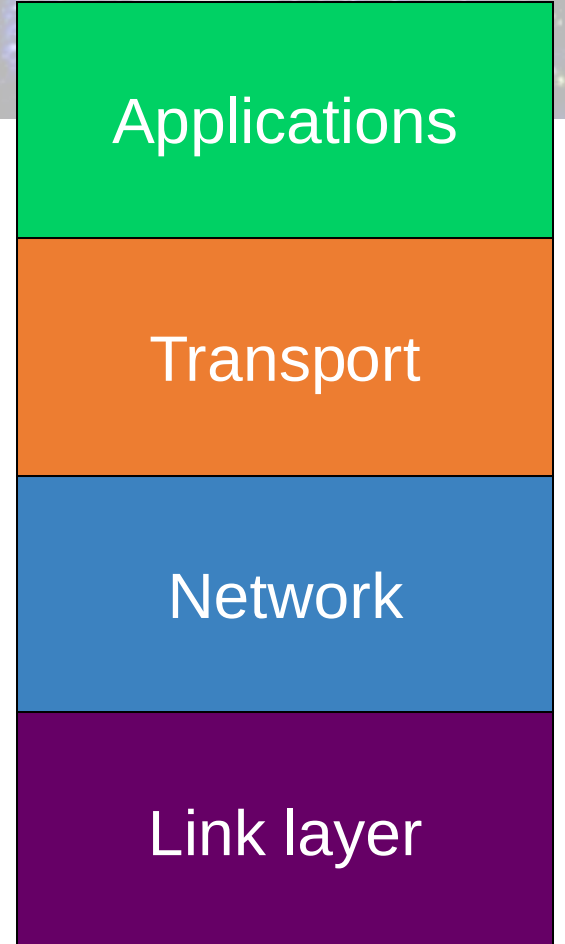
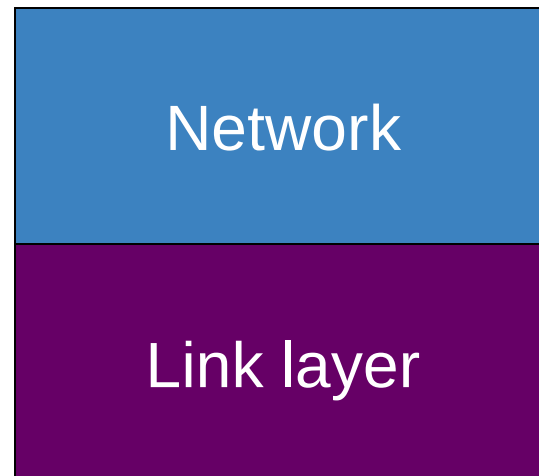
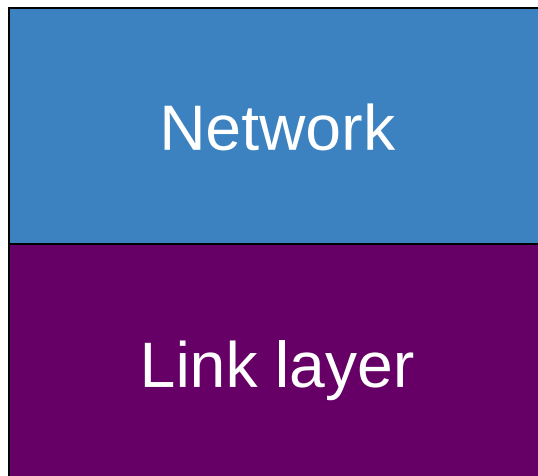
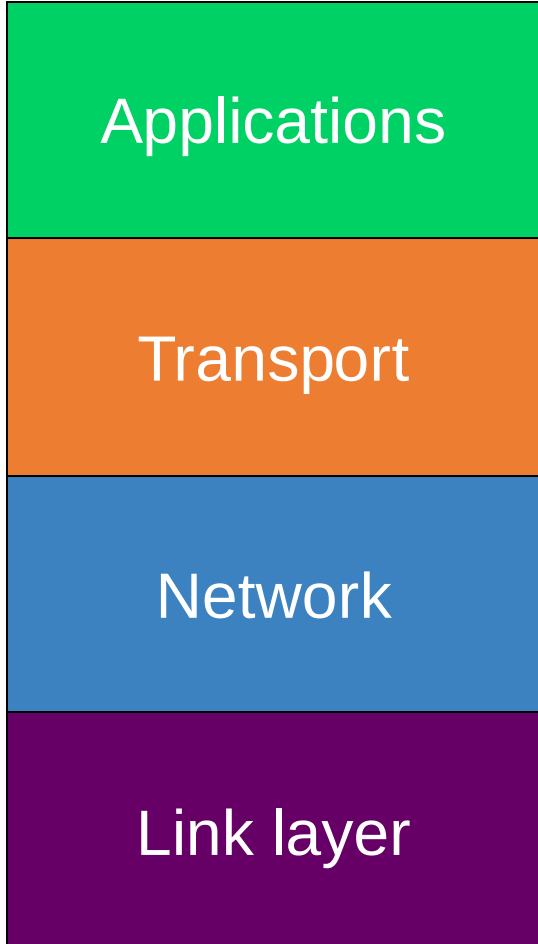
Packet takes on headers at each layer







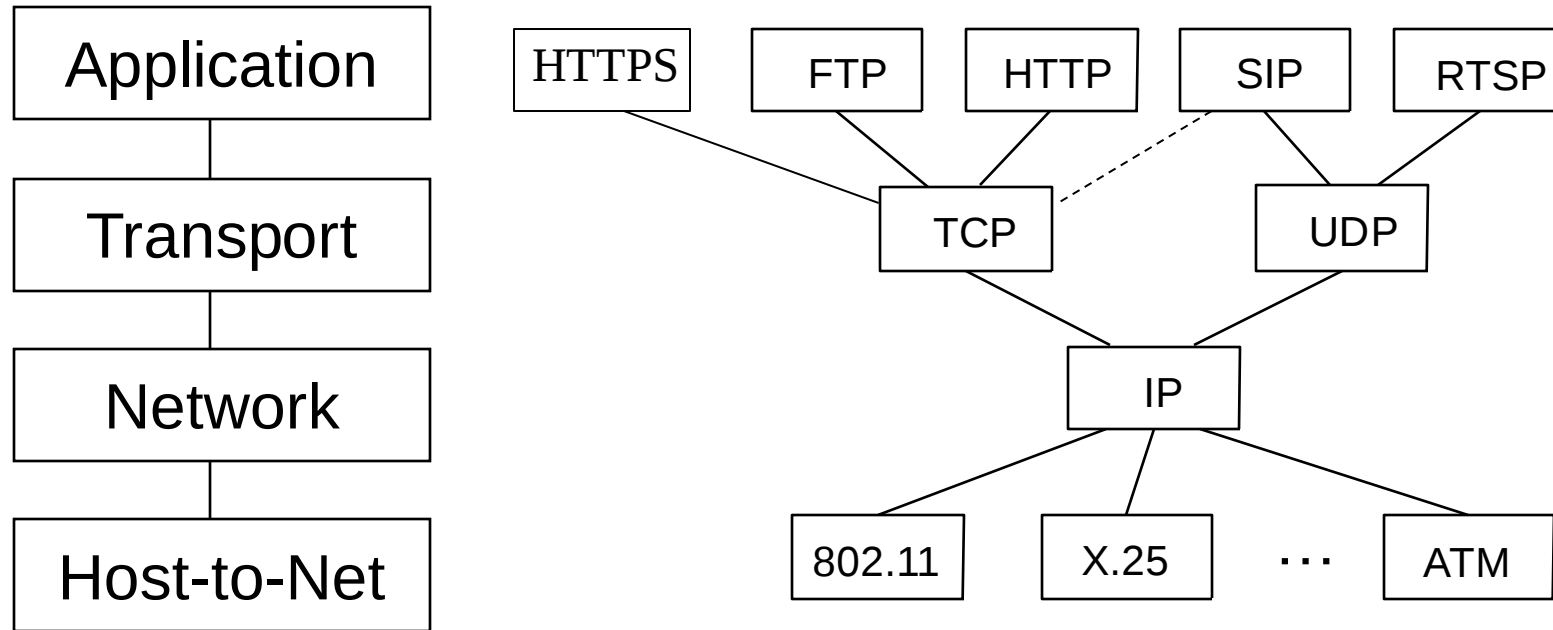
Routers have network and link layers too!



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



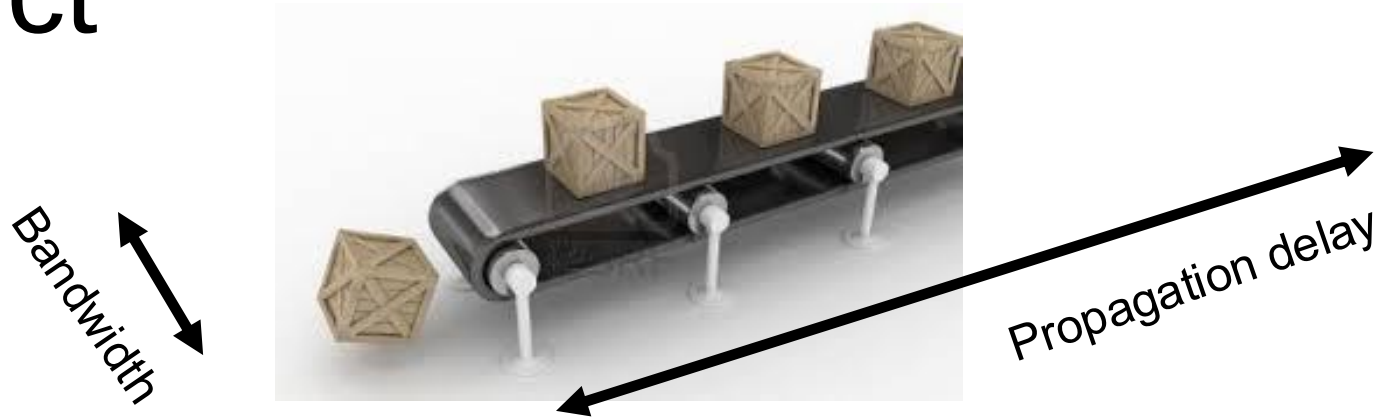
Measuring the Internet

Speed, by any other name

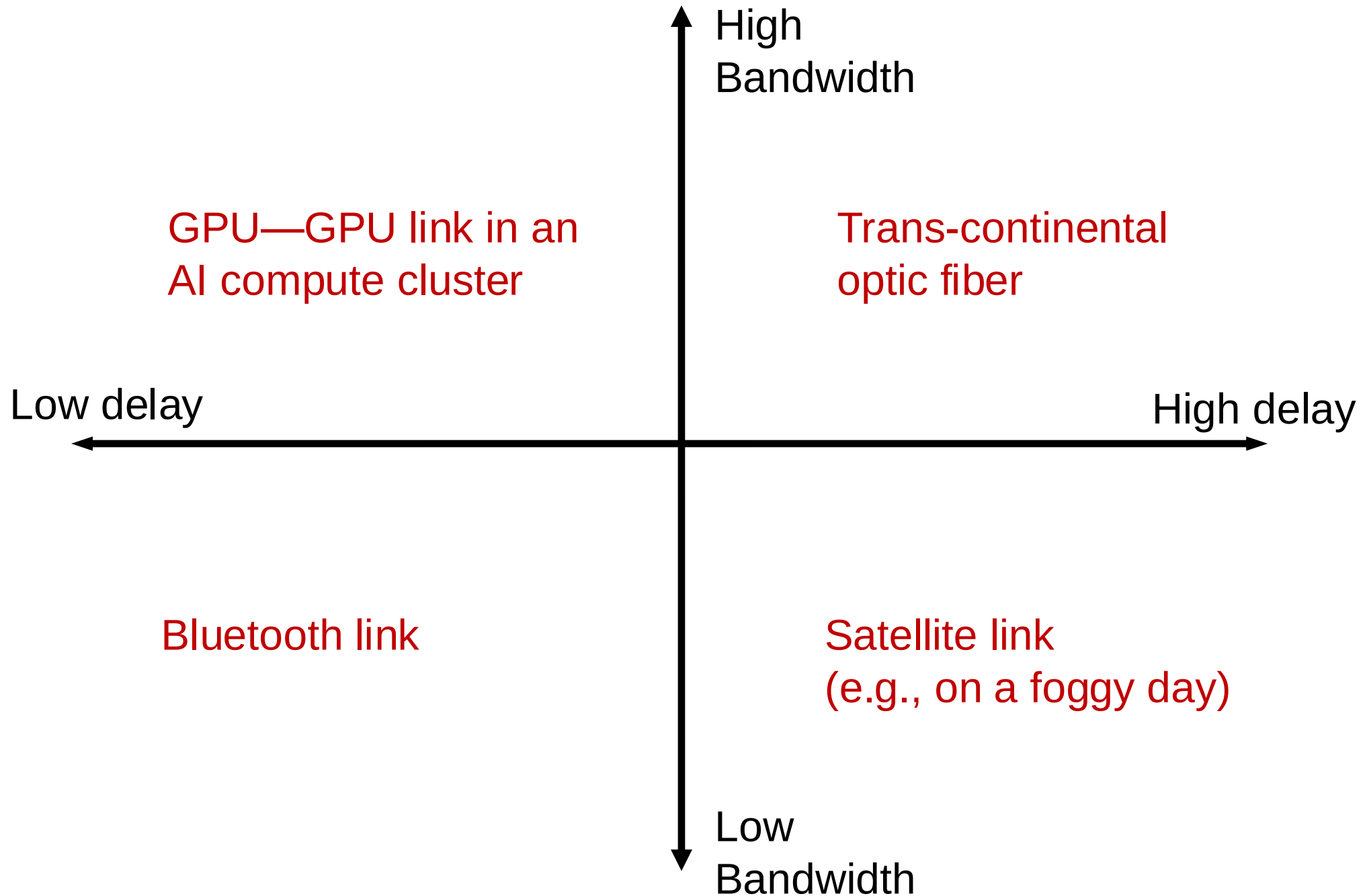
What exactly do we mean by speed?

- 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



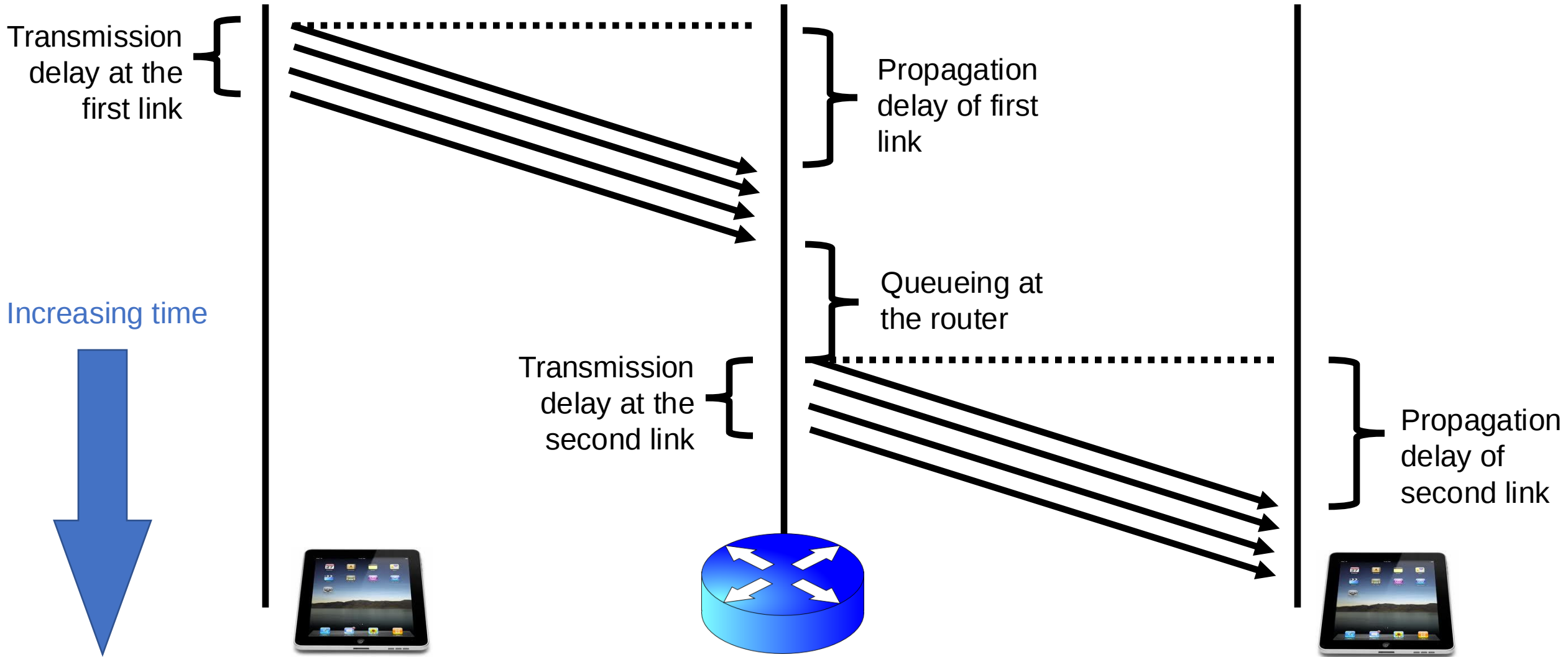
- Total packet delay = time for a box to travel the length of the belt
- Bandwidth = the number of boxes put on the belt per minute (“rate”)



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



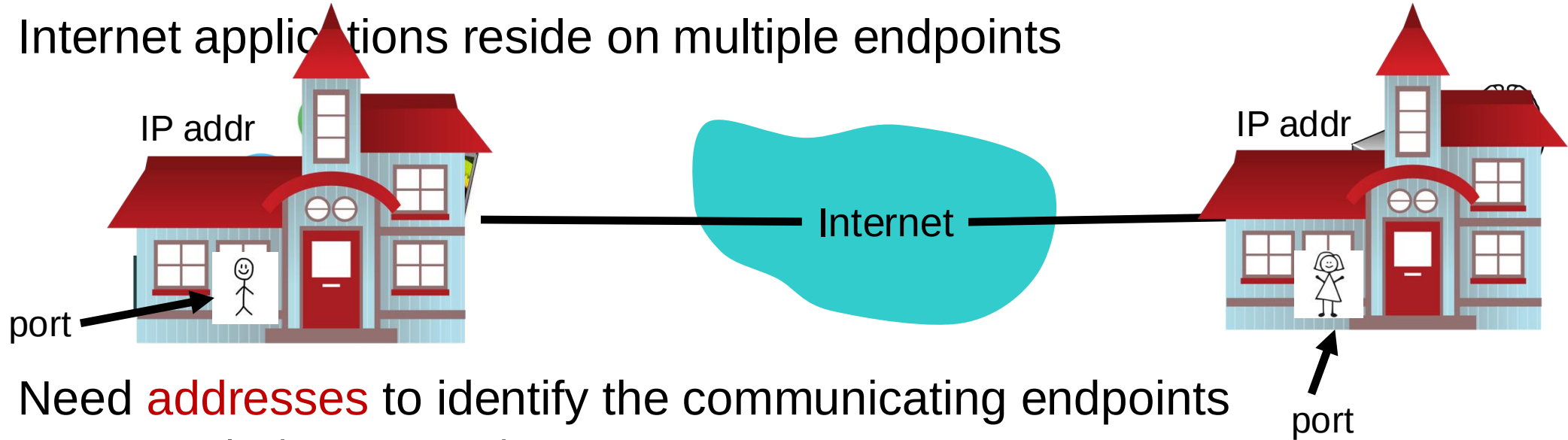
Bandwidth and delay demo

- 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

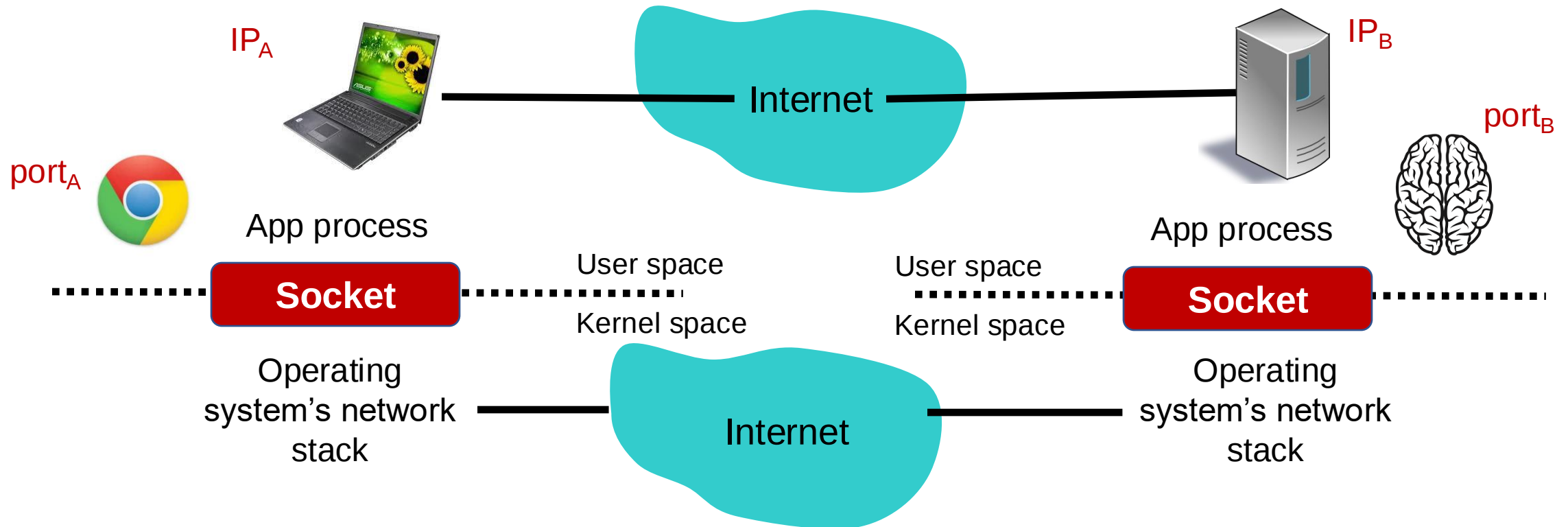
- Internet applications reside on multiple endpoints



- 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**

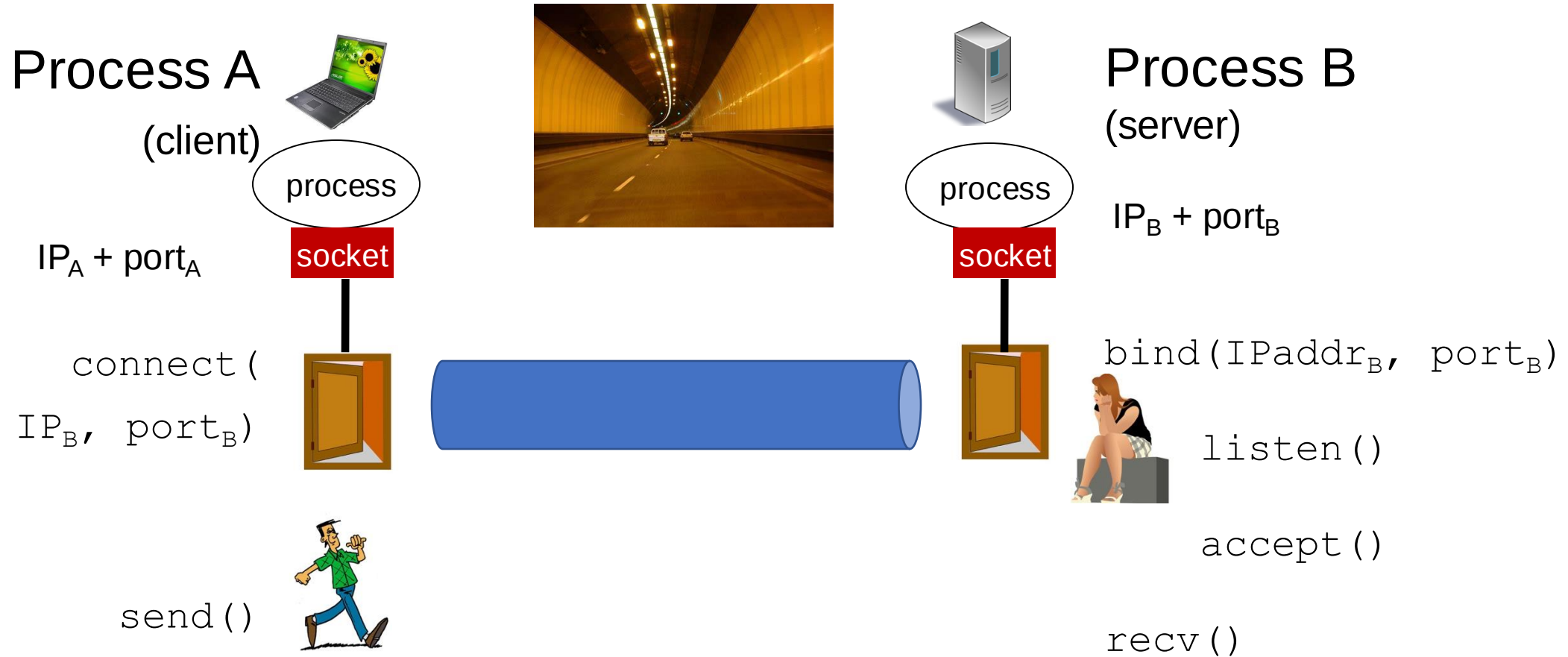
How are addresses used?

- **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`