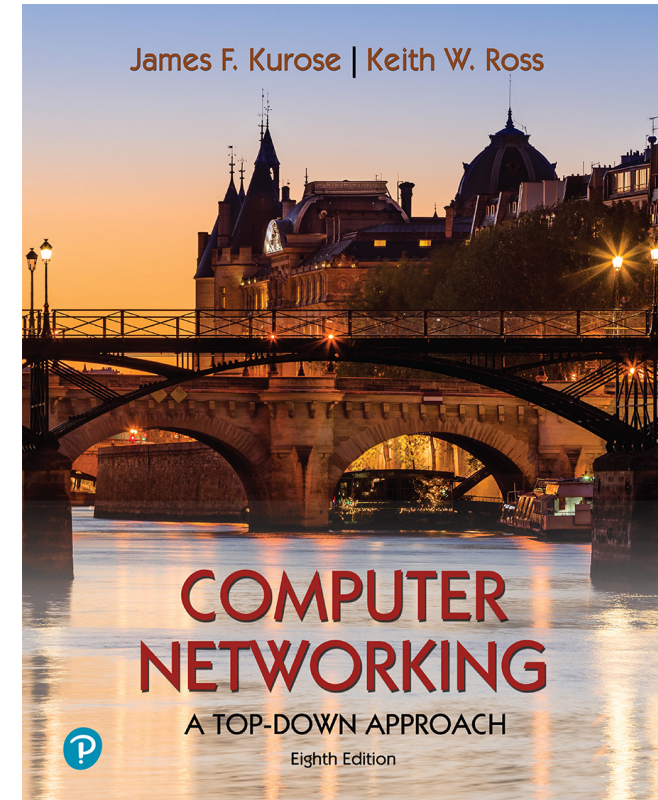


Chapter 3

Transport Layer



Computer Networking: A Top-Down Approach

8th edition

Jim Kurose, Keith Ross
Pearson, 2020

Acknowledgement: Based on the textbook's website:
https://gaia.cs.umass.edu/kurose_ross/index.php

Transport layer: overview

Our goal:

- understand principles behind transport layer services:
 - multiplexing, demultiplexing
 - reliable data transfer
 - flow control
 - congestion control
- learn about Internet transport layer protocols:
 - UDP: connectionless transport
 - TCP: connection-oriented reliable transport
 - TCP congestion control

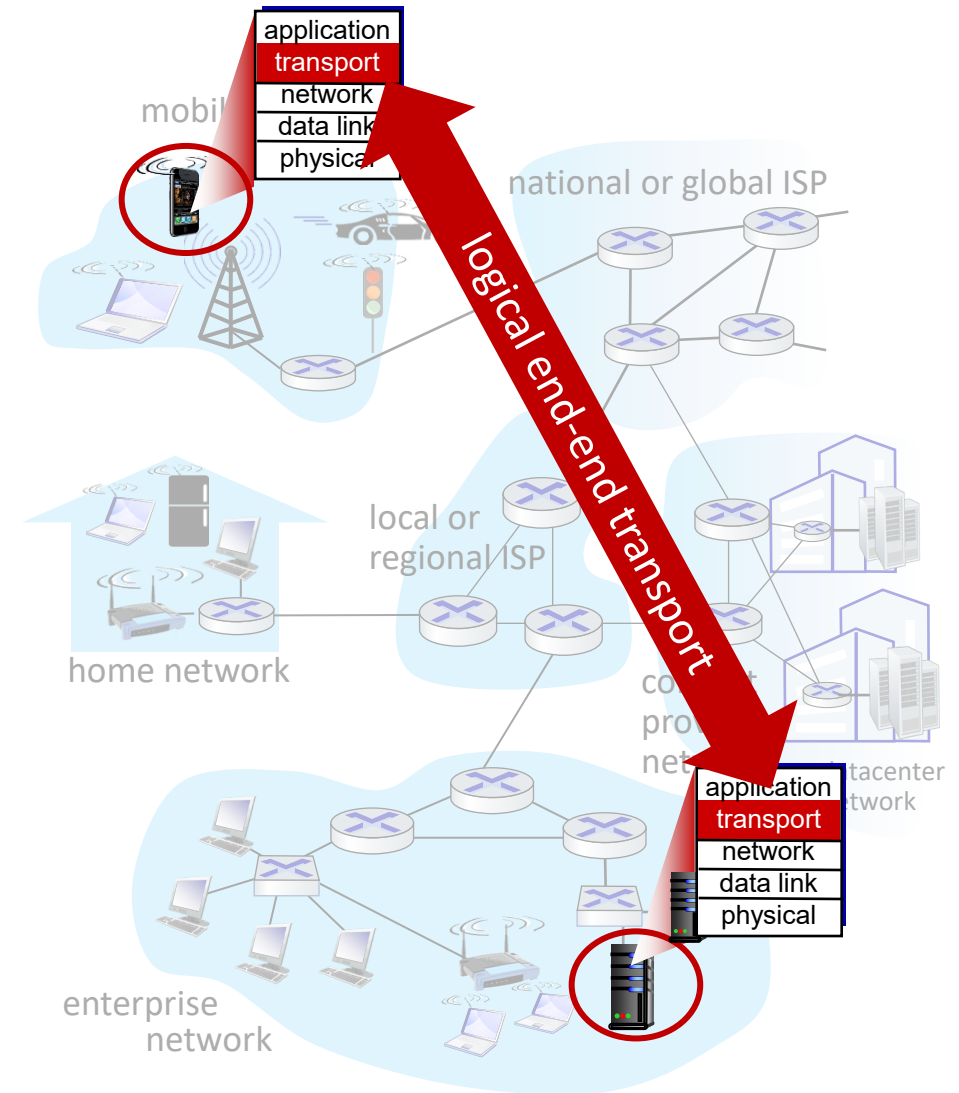
Transport layer: roadmap

- Transport-layer services
- Multiplexing and demultiplexing
- Connectionless transport: UDP
- Principles of reliable data transfer
- Connection-oriented transport: TCP
- Principles of congestion control
- TCP congestion control
- Evolution of transport-layer functionality



Transport services and protocols

- provide *logical communication* between application processes running on different hosts
- transport protocols actions in end systems:
 - sender: breaks application messages into *segments*, passes to network layer
 - receiver: reassembles segments into messages, passes to application layer
- two transport protocols available to Internet applications
 - TCP, UDP



Transport vs. network layer services and protocols



household analogy:

12 kids in Ann's house sending letters to 12 kids in Bill's house:

- hosts = houses
- processes = kids
- app messages = letters in envelopes

Transport vs. network layer services and protocols

- **transport layer:**
communication between *processes*
 - relies on, enhances, network layer services
- **network layer:**
communication between *hosts*

household analogy:

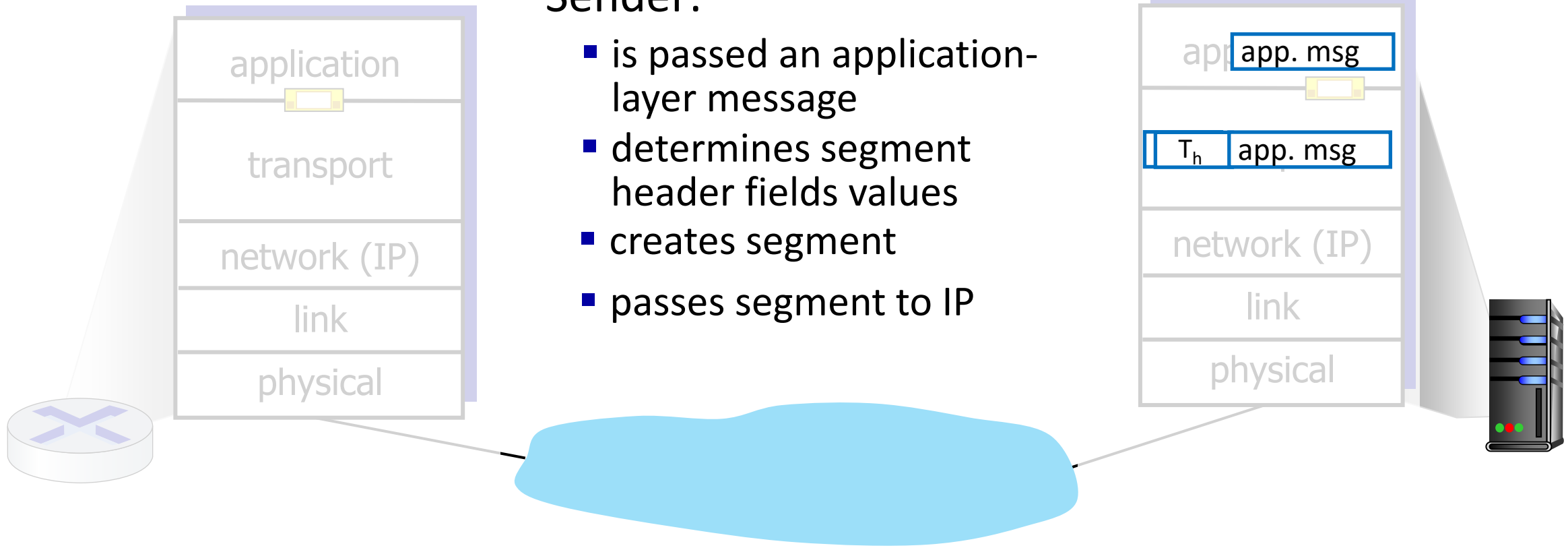
12 kids in Ann's house sending letters to 12 kids in Bill's house:

- hosts = houses
- processes = kids
- app messages = letters in envelopes

Transport Layer Actions

Sender:

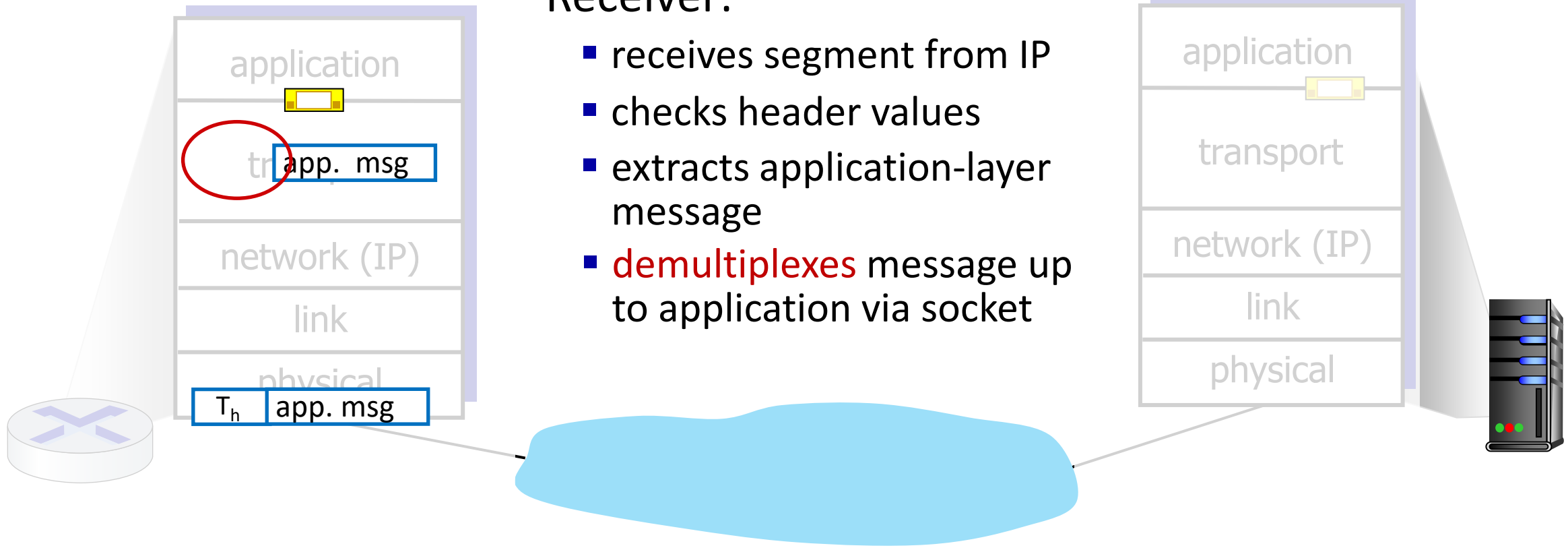
- is passed an application-layer message
- determines segment header fields values
- creates segment
- passes segment to IP



Transport Layer Actions

Receiver:

- receives segment from IP
- checks header values
- extracts application-layer message
- **demultiplexes** message up to application via socket



Two principal Internet transport protocols

■ **TCP:** Transmission Control Protocol

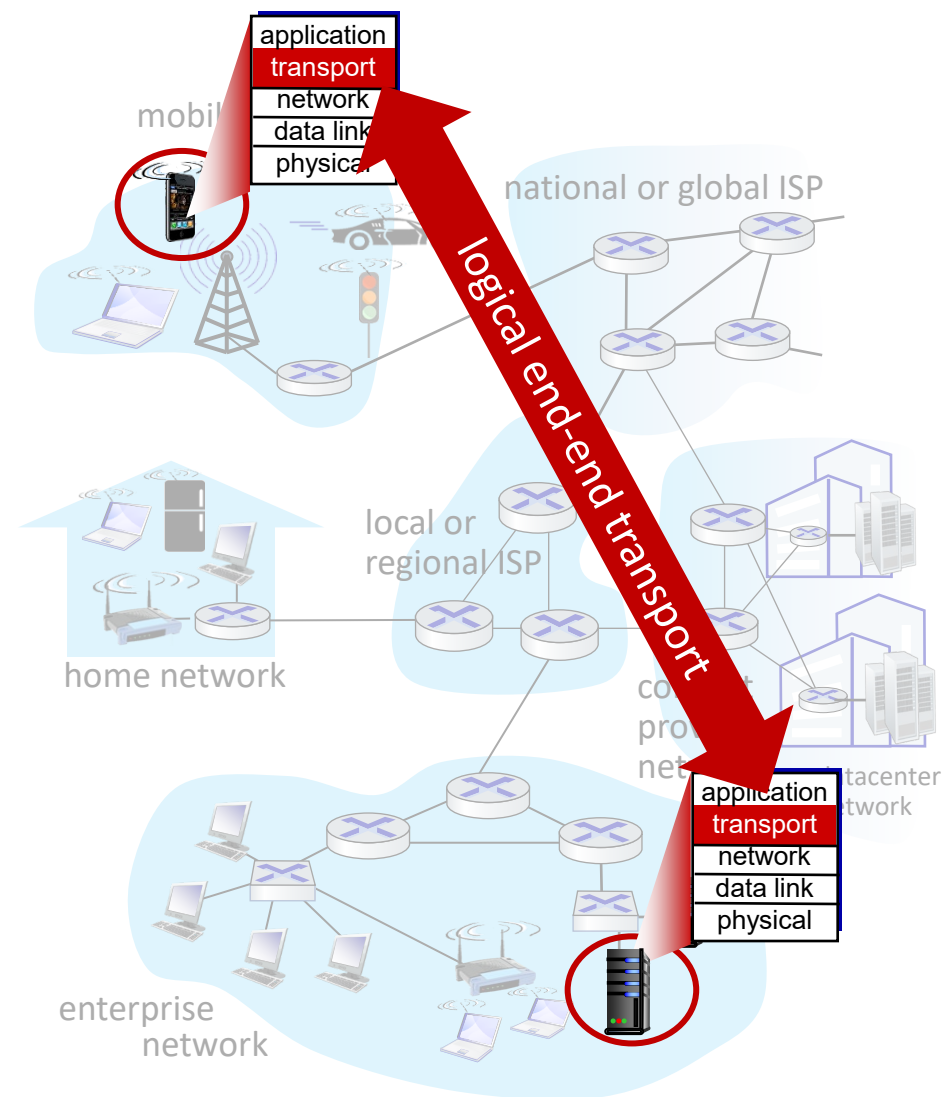
- reliable, in-order delivery
- congestion control
- flow control
- connection setup

■ **UDP:** User Datagram Protocol

- unreliable, unordered delivery
- no-frills extension of “best-effort” IP

■ services *not* available:

- delay guarantees
- bandwidth guarantees



Chapter 3: roadmap

- Transport-layer services
- **Multiplexing and demultiplexing**
- Connectionless transport: UDP
- Principles of reliable data transfer
- Connection-oriented transport: TCP
- Principles of congestion control
- TCP congestion control
- Evolution of transport-layer functionality



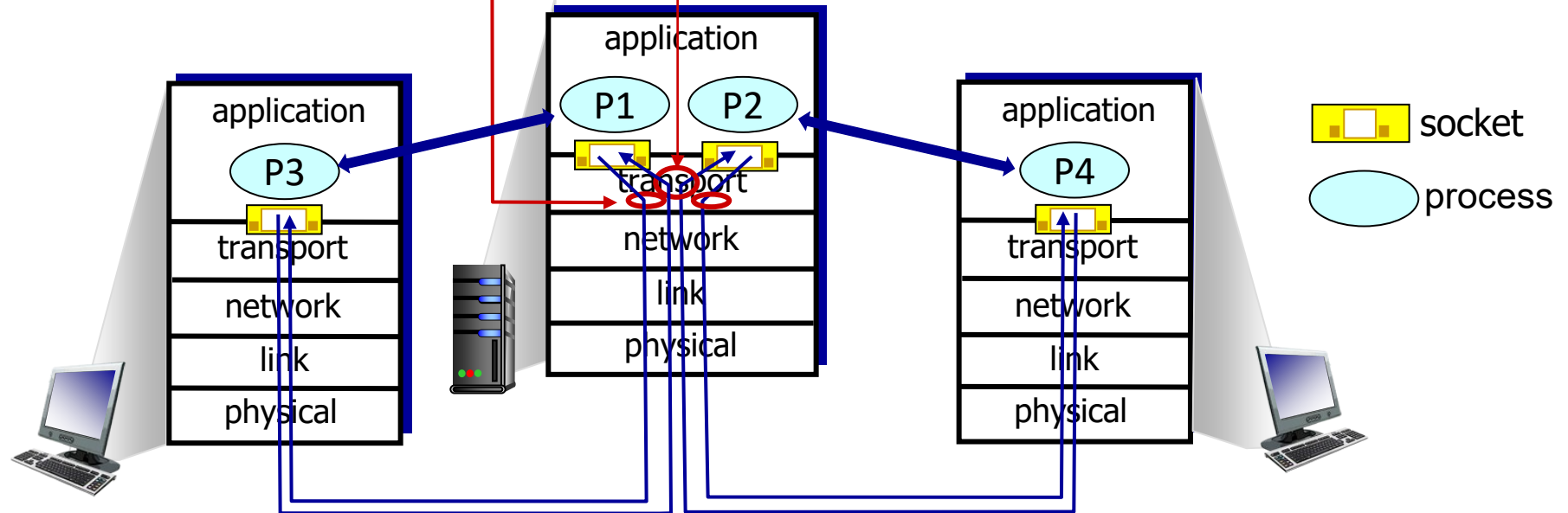
Multiplexing/demultiplexing

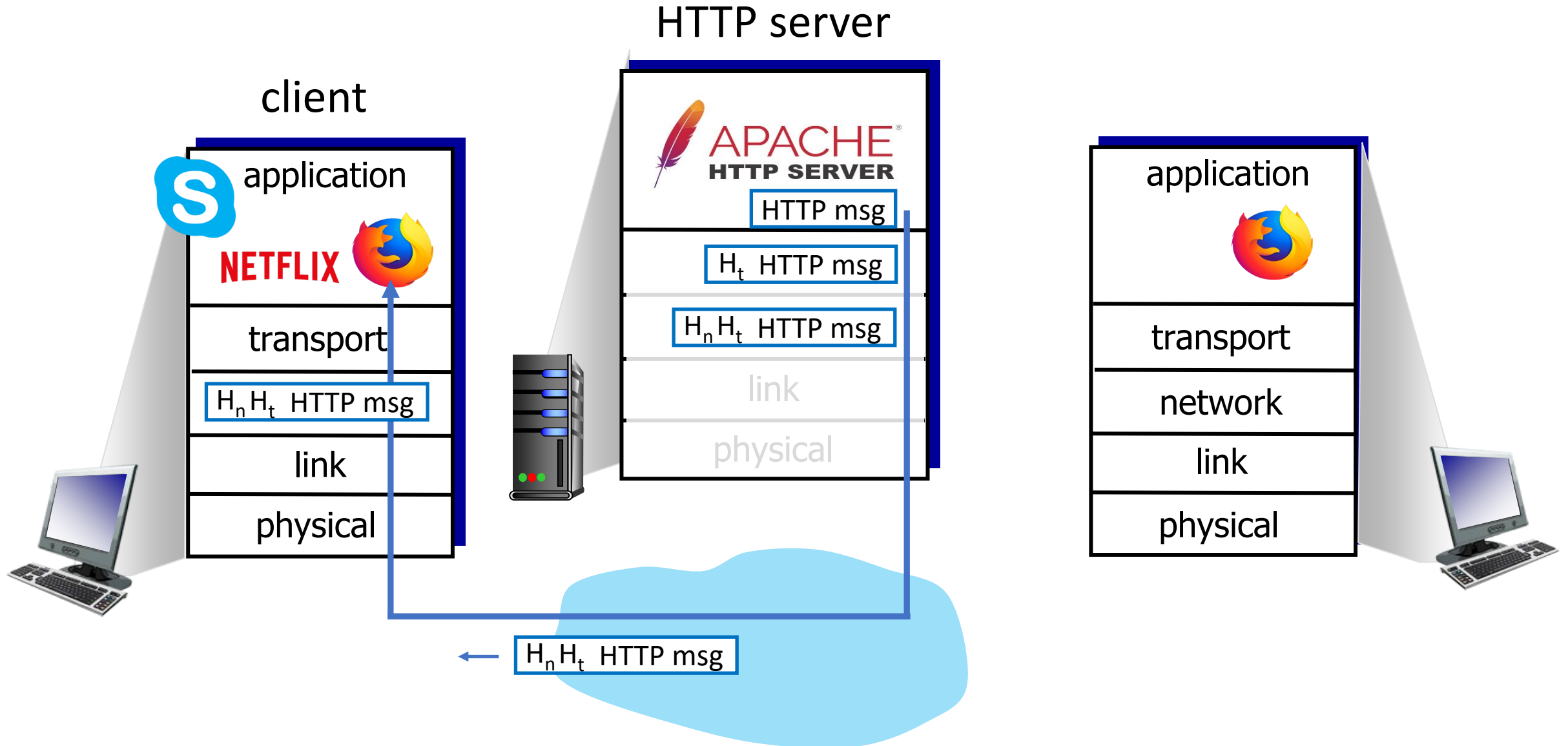
multiplexing as sender:

handle data from multiple sockets, add transport header (later used for demultiplexing)

demultiplexing as receiver:

use header info to deliver received segments to correct socket

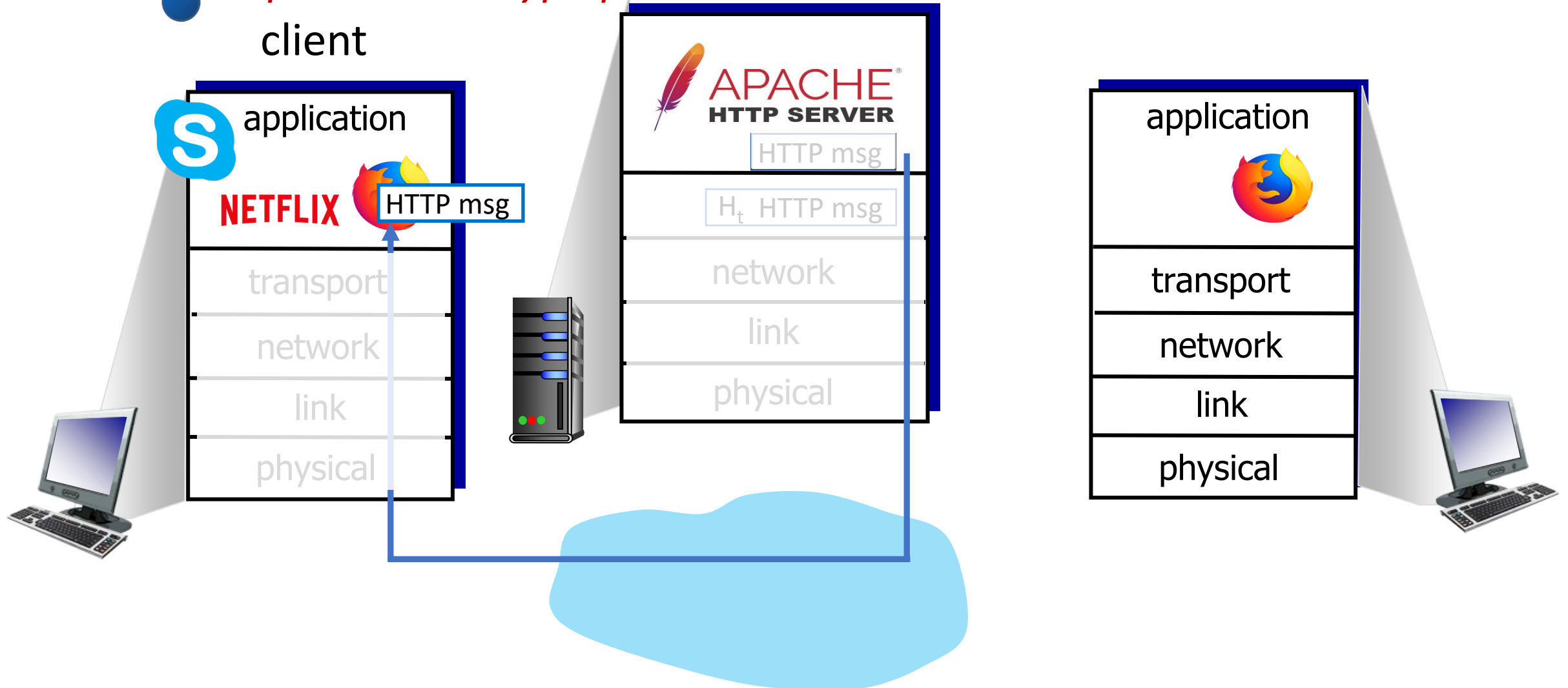


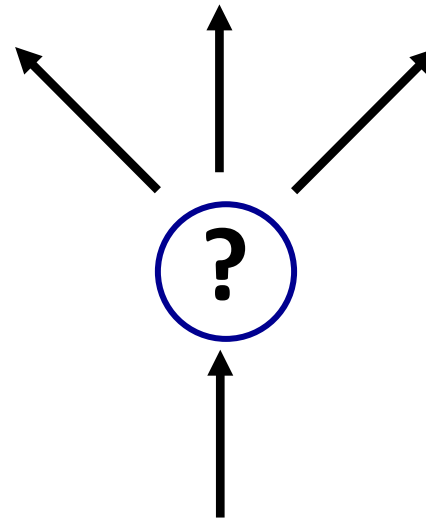




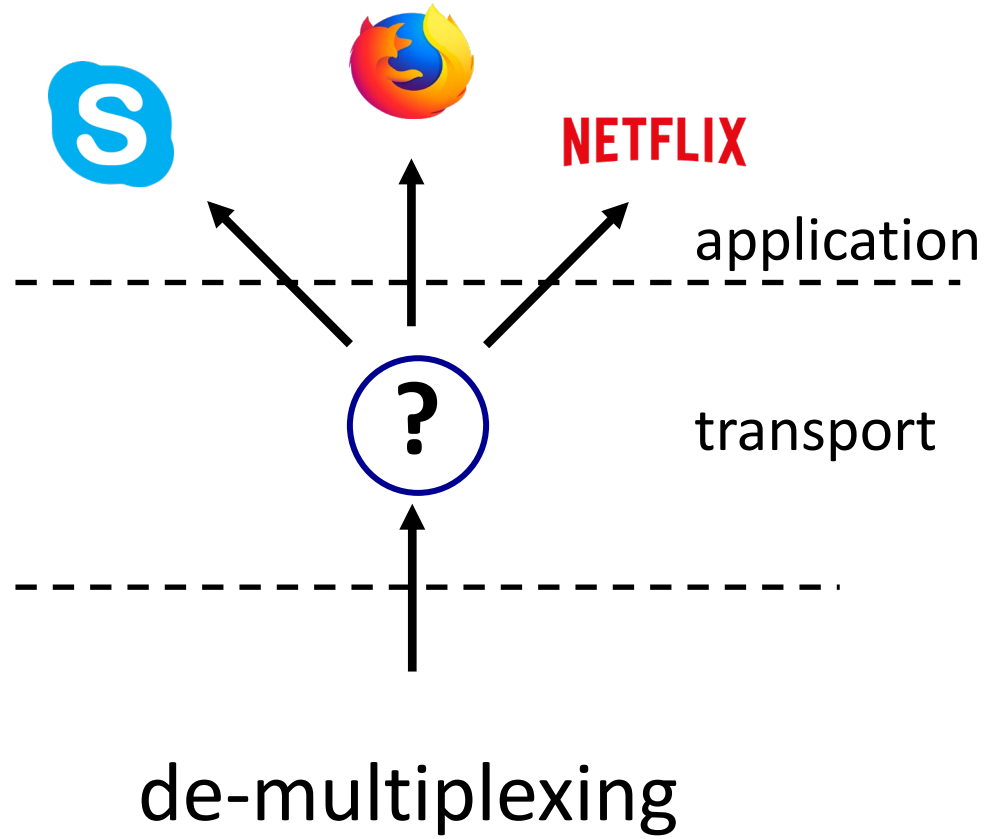
Q: how did transport layer know to deliver message to Firefox browser process rather than Netflix process or Skype process?

client





de-multiplexing





Demultiplexing



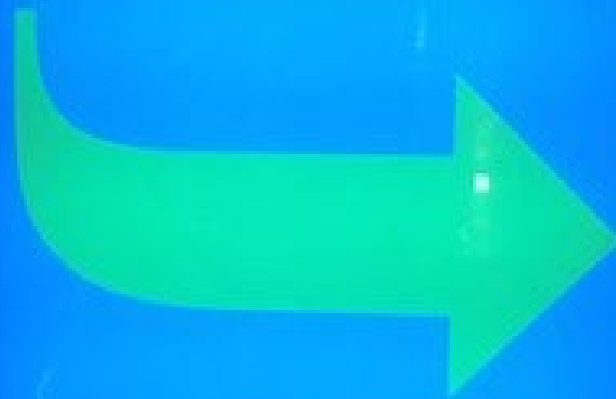
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Transportation
Security
Administration

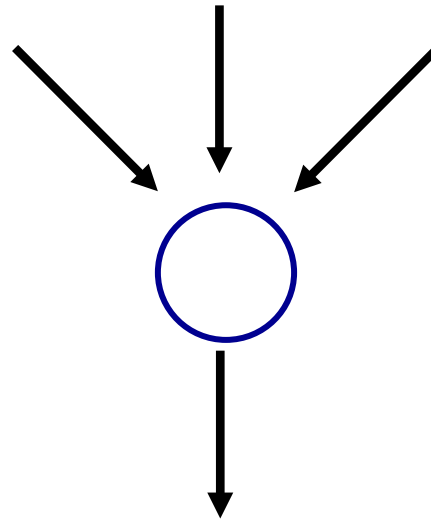
tsa.gov

Main
Checkpoint

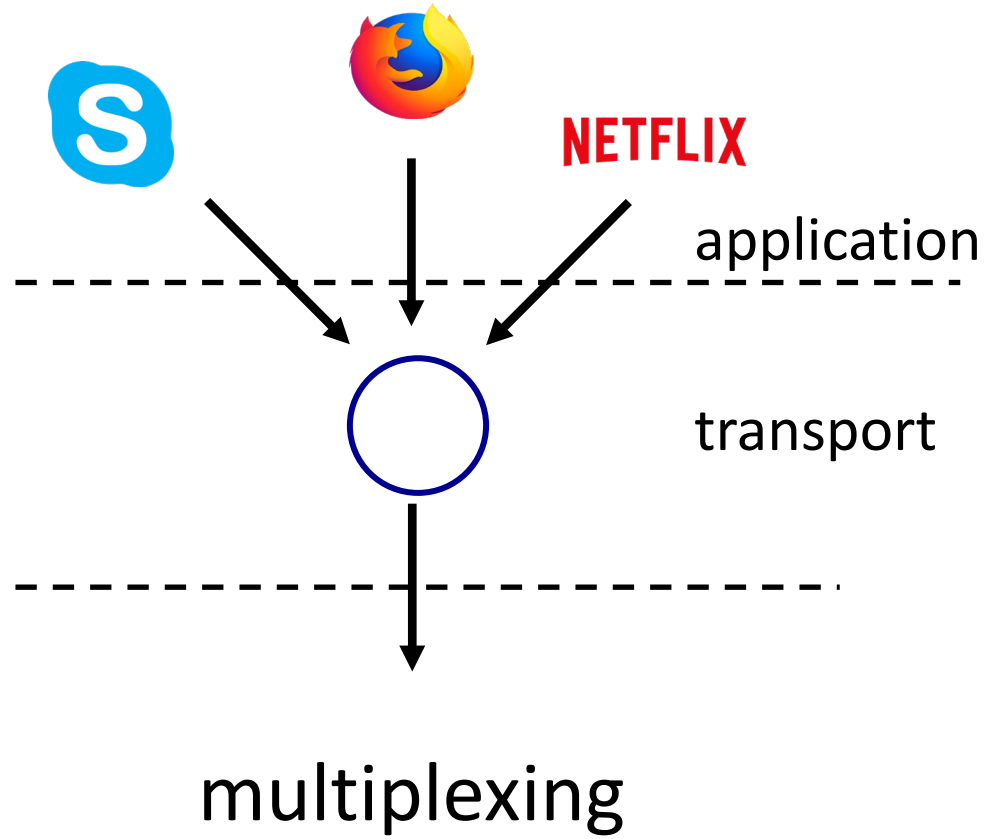


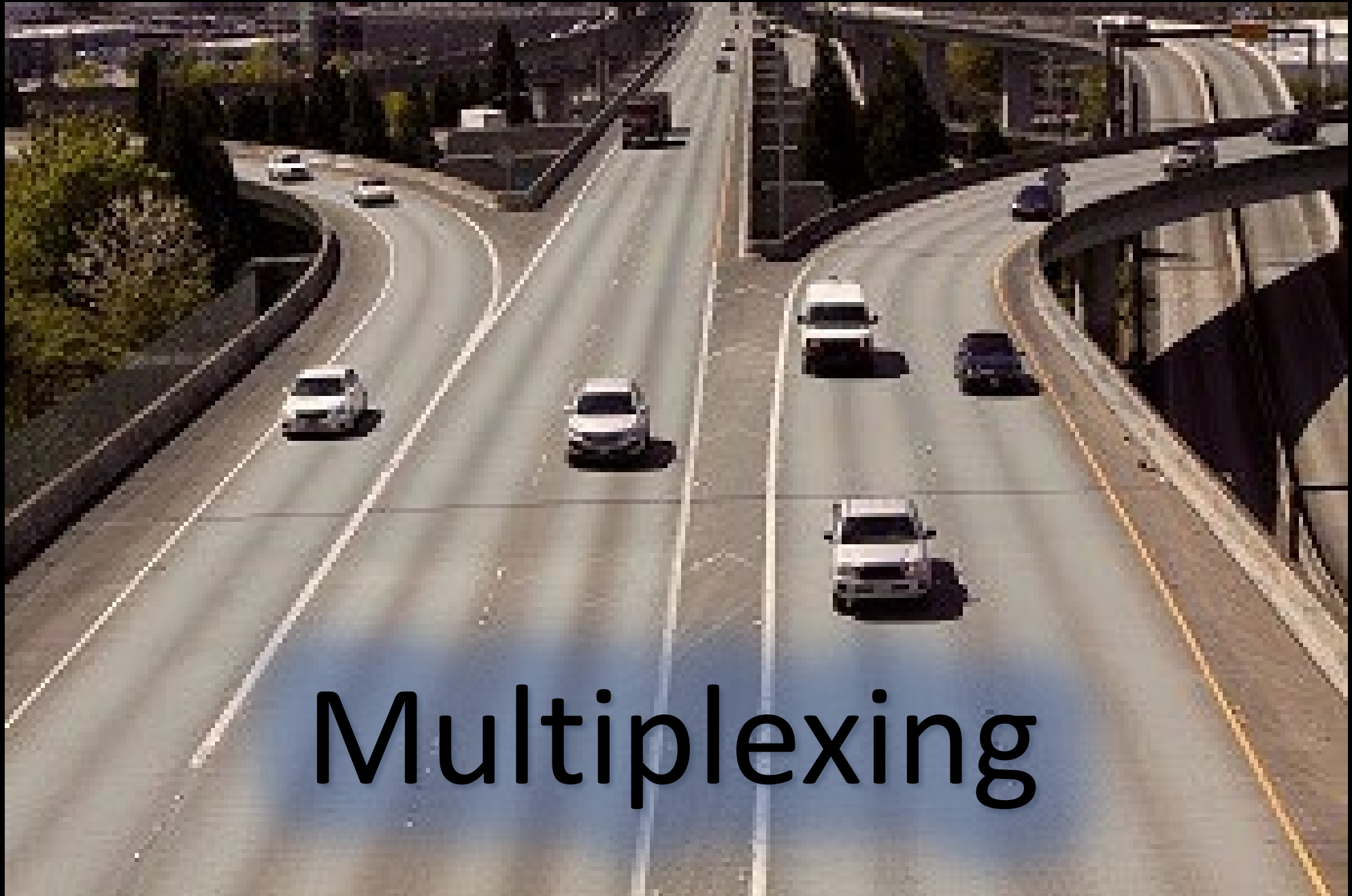
Transportation
Security
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multiplexing

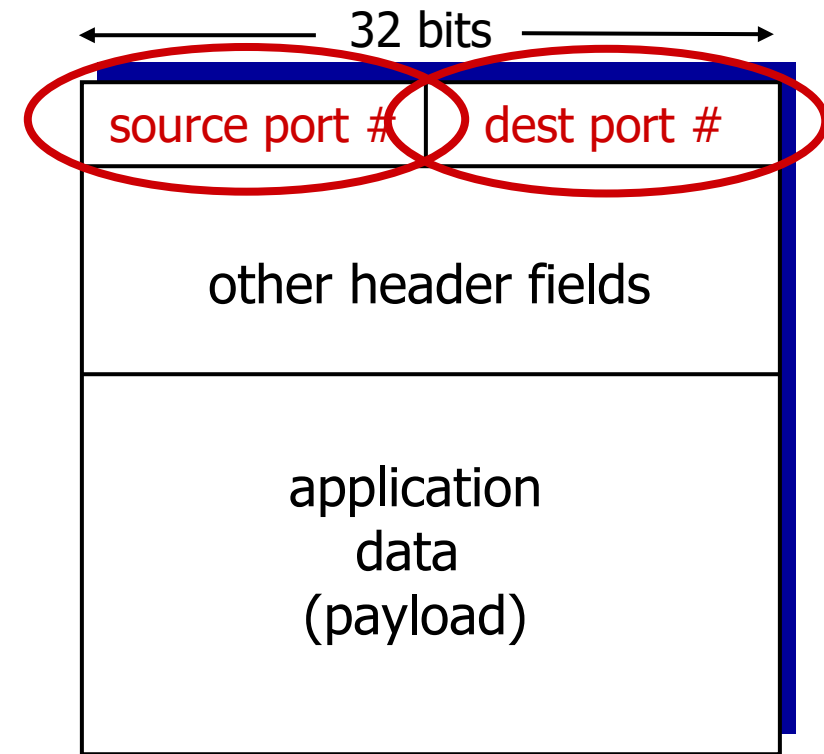




Multiplexing

How demultiplexing works

- host receives IP datagrams
 - each datagram has source IP address, destination IP address
 - each datagram carries one transport-layer segment
 - each segment has source, destination port number
- host uses *IP addresses & port numbers* to direct segment to appropriate socket



TCP/UDP segment format

Connectionless demultiplexing

Recall:

- when creating socket, must specify *host-local* port #:

```
DatagramSocket mySocket1  
= new DatagramSocket(12534);
```

- when creating datagram to send into UDP socket, must specify
 - destination IP address
 - destination port #

when receiving host receives *UDP* segment:

- checks destination port # in segment
- directs UDP segment to socket with that port #



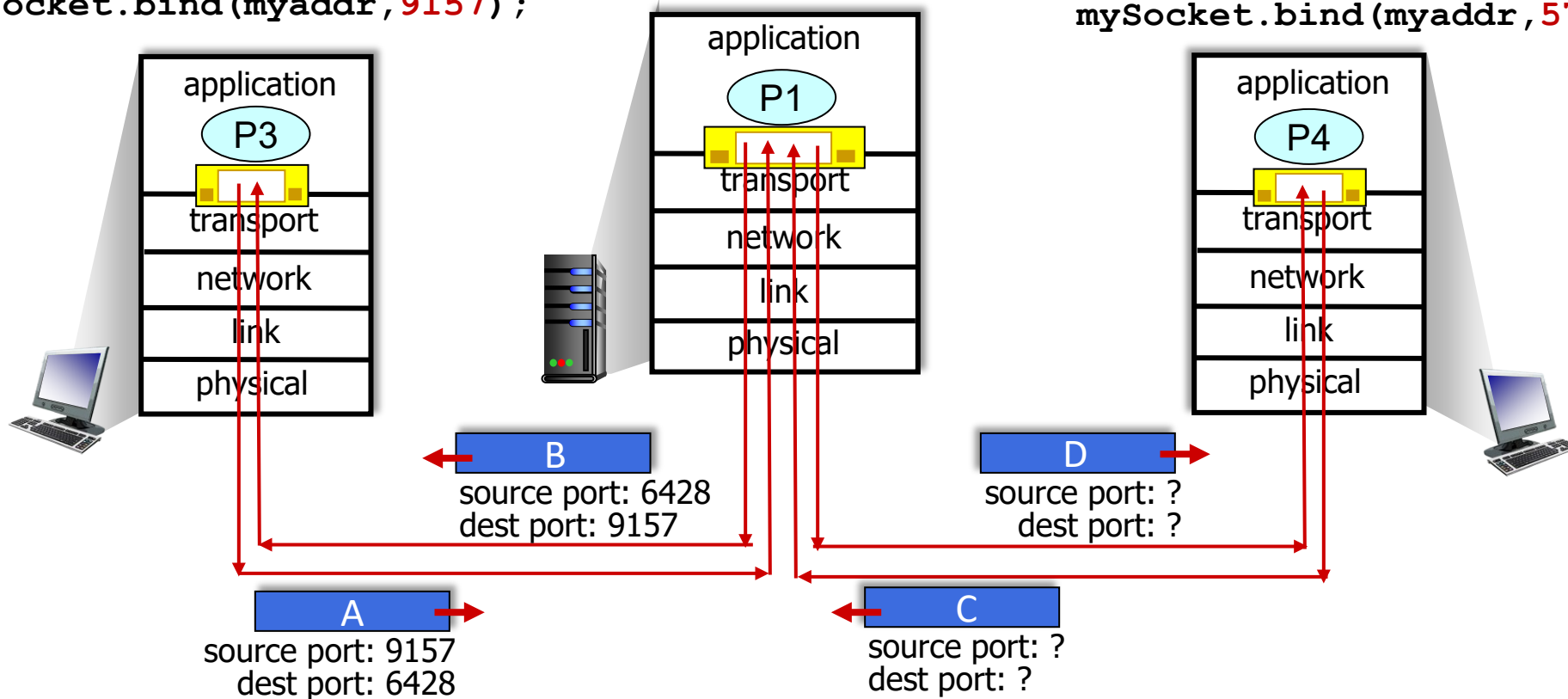
IP/UDP datagrams with *same dest. port #*, but different source IP addresses and/or source port numbers will be directed to *same socket* at receiving host

Connectionless demultiplexing: an example

```
mySocket =
    socket(AF_INET, SOCK_DGRAM)
mySocket.bind(myaddr, 6428);
```

```
mySocket =
    socket(AF_INET, SOCK_STREAM)
mySocket.bind(myaddr, 9157);
```

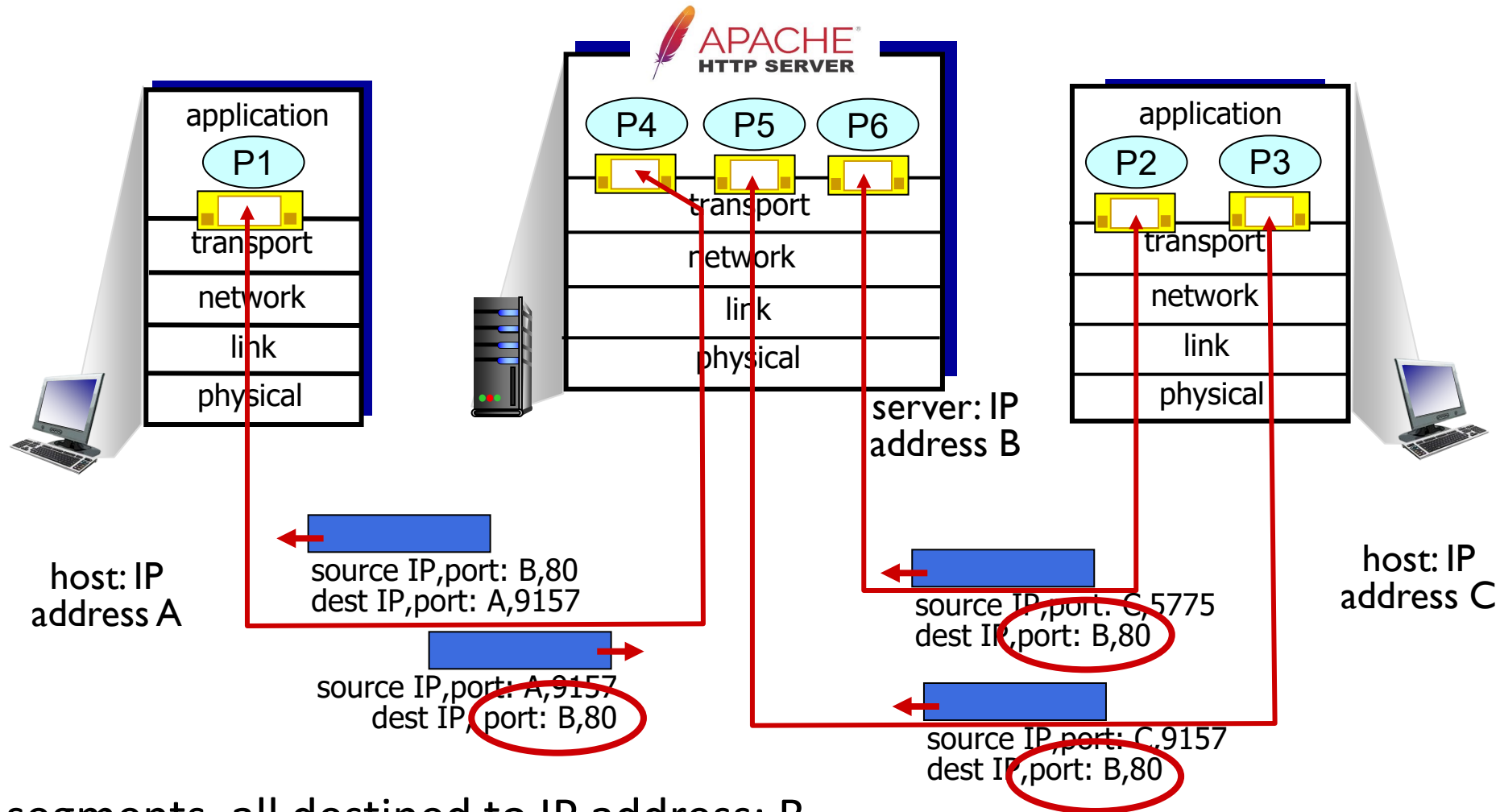
```
mySocket =
    socket(AF_INET, SOCK_STREAM)
mySocket.bind(myaddr, 5775);
```



Connection-oriented demultiplexing

- TCP socket identified by 4-tuple:
 - source IP address
 - source port number
 - dest IP address
 - dest port number
- demux: receiver uses *all four values (4-tuple)* to direct segment to appropriate socket
- server may support many simultaneous TCP sockets:
 - each socket identified by its own 4-tuple
 - each socket associated with a different connecting client

Connection-oriented demultiplexing: example



Three segments, all destined to IP address: B,
dest port: 80 are demultiplexed to *different* sockets

Summary

- Multiplexing, demultiplexing: based on segment, datagram header field values
- **UDP:** demultiplexing using destination port number (only)
- **TCP:** demultiplexing using 4-tuple: source and destination IP addresses, and port numbers
- Multiplexing/demultiplexing happen at *all* layers

Quiz

- https://gaia.cs.umass.edu/kurose_ross/interactive/UDP_Mux_Demux.php
- https://gaia.cs.umass.edu/kurose_ross/interactive/TCP_Mux_Demux.php