Introduction to Transport Layer

Lecture 6 | Part 1| CSE421 – Computer Networks

Department of Computer Science and Engineering
School of Data & Science

Objectives

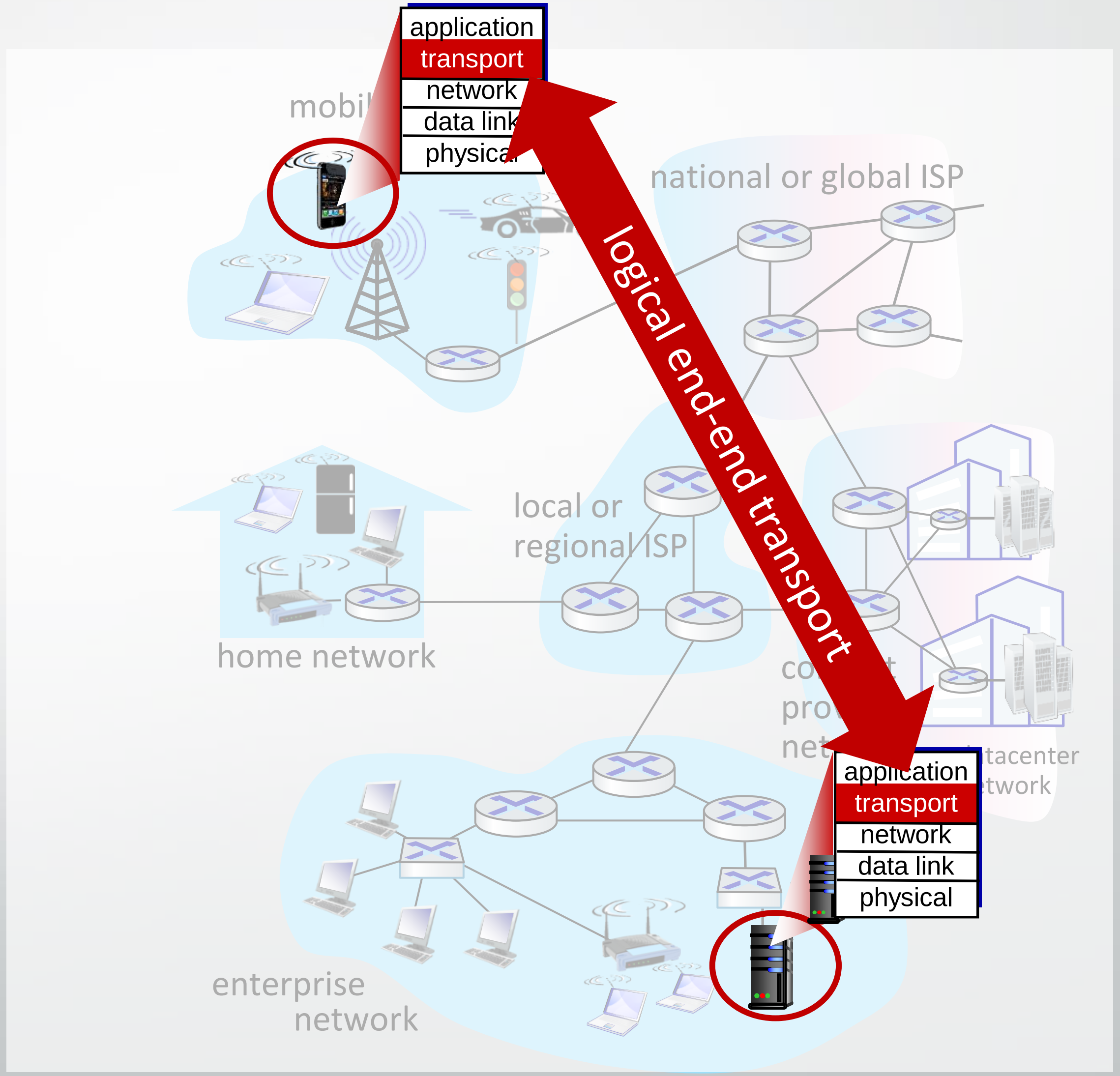
our goals:

- understand principles behind transport layer services:
  - reliable data transfer, segmentation, flow control etc..

- learn about Internet transport layer protocols:
  - UDP: connectionless transport
  - TCP: connection-oriented reliable transport

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

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

household analogy:

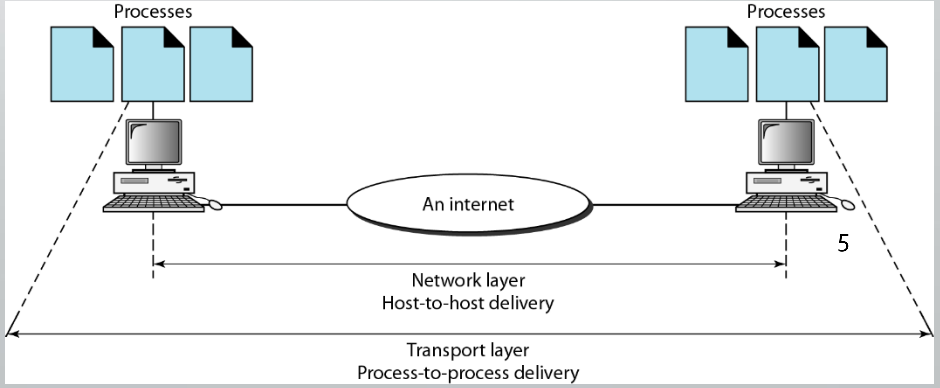
12 kids in Ann's house sending letters to 12 kids in Bill's house:

- hosts = houses
- processes = kids
- app messages = letters in envelopes
- transport protocol = Ann and Bill who demux to in-house siblings
- network-layer protocol = postal service

Transport Layer

- The transport layer is responsible for the delivery of a message from one process (sender) to another (receiver).
- Transport Layer PDU is called **Segments**
- Functions:
  - Segmentation and Reassembly
  - Adds Port Address to identify the application
  - Multiplexing
  - Connection establishment and termination
  - Flow and Error Control

- **PDU – Protocol Data Unit*



Purpose of the Transport Layer

- Primary responsibilities:
  - Segmenting the data and managing each piece.
  - Reassembling the segments into streams of application data.
  - Identifying the different applications.
  - Multiplexing
  - Initiating … ion.
  - Perform … n end users.
  - Enabling error recovery.

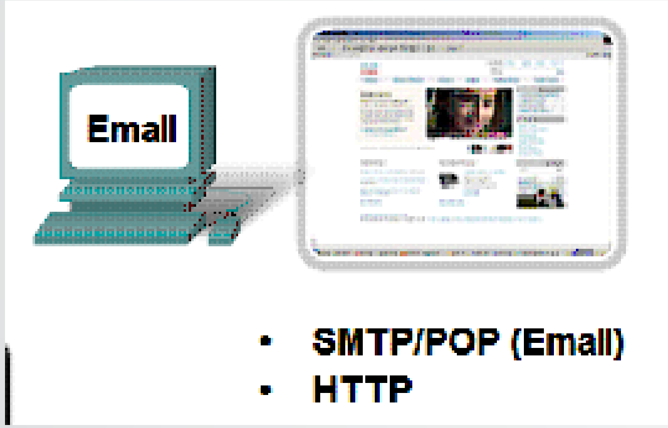
Reliability

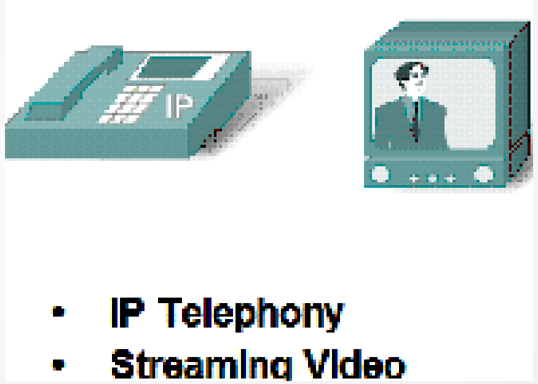
Reliability

- Three basic operations of reliability are:
  - Initiating sessions and tracking transmitted data
  - Acknowledging received data
  - Retransmitting any unacknowledged data
- To support these reliability operations, more control data is added in the Layer 4 header.

Different Applications

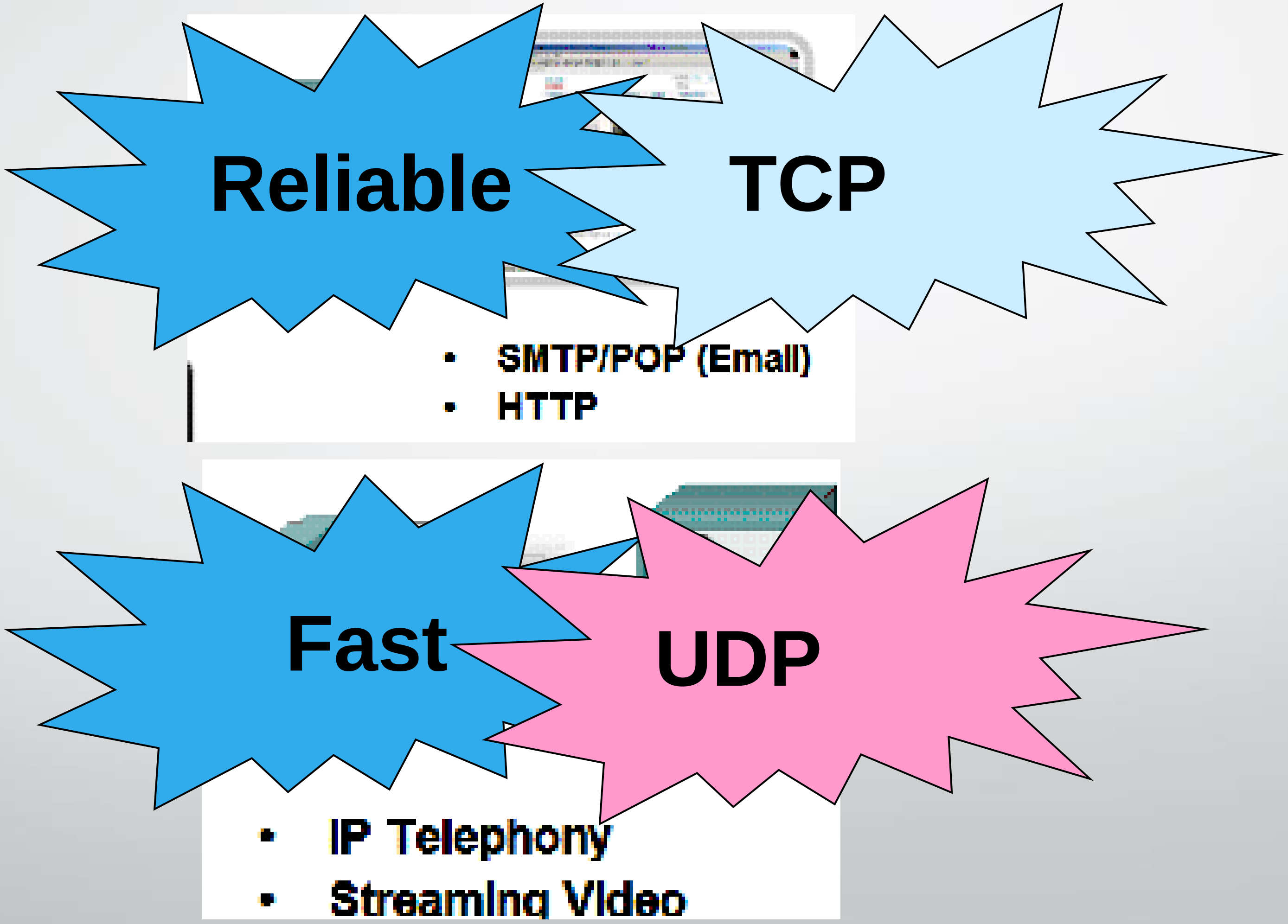
Different Requirements



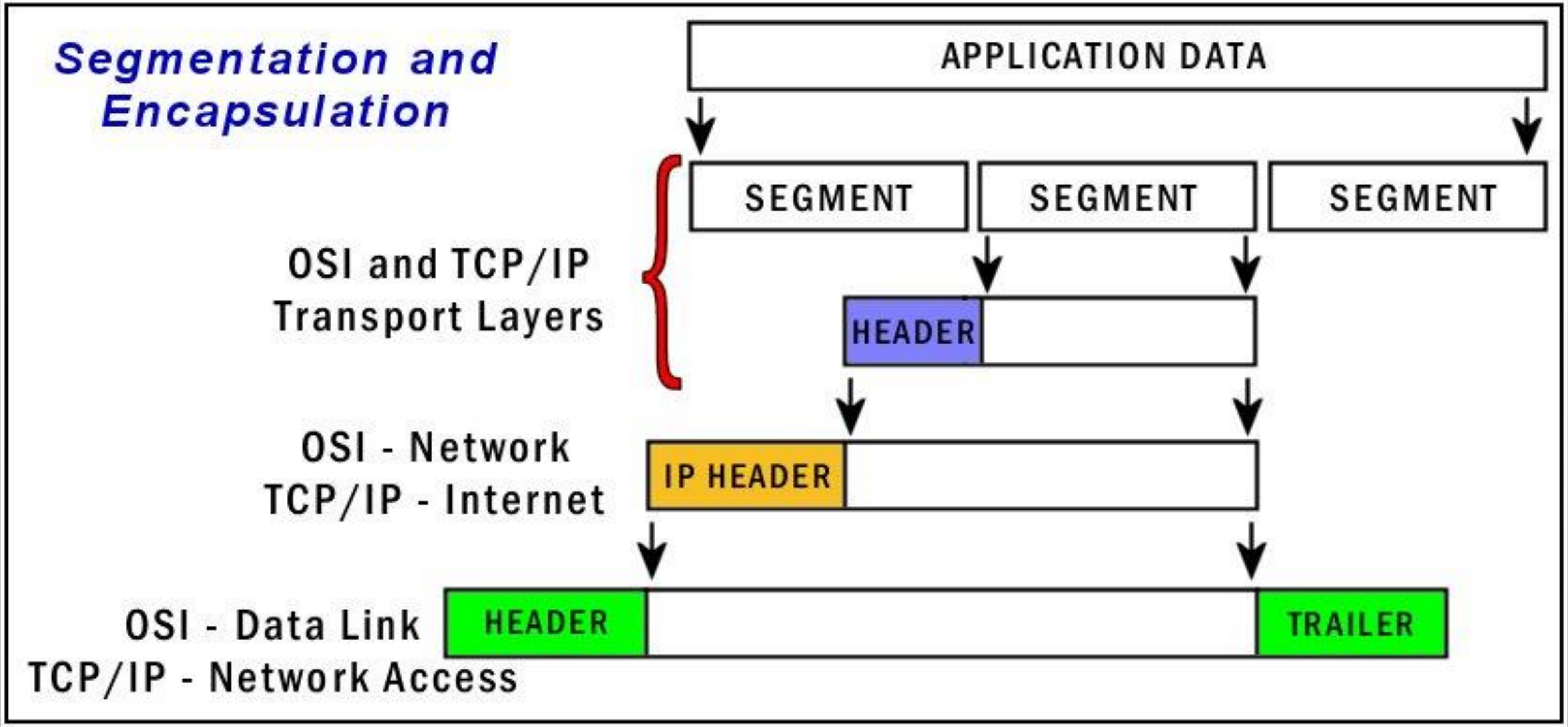


- Some applications need their data to be complete with no errors or gaps and they can accept a slight delay to ensure this.
- Some applications can accept occasional errors or gaps in the data but they cannot accept any delay.

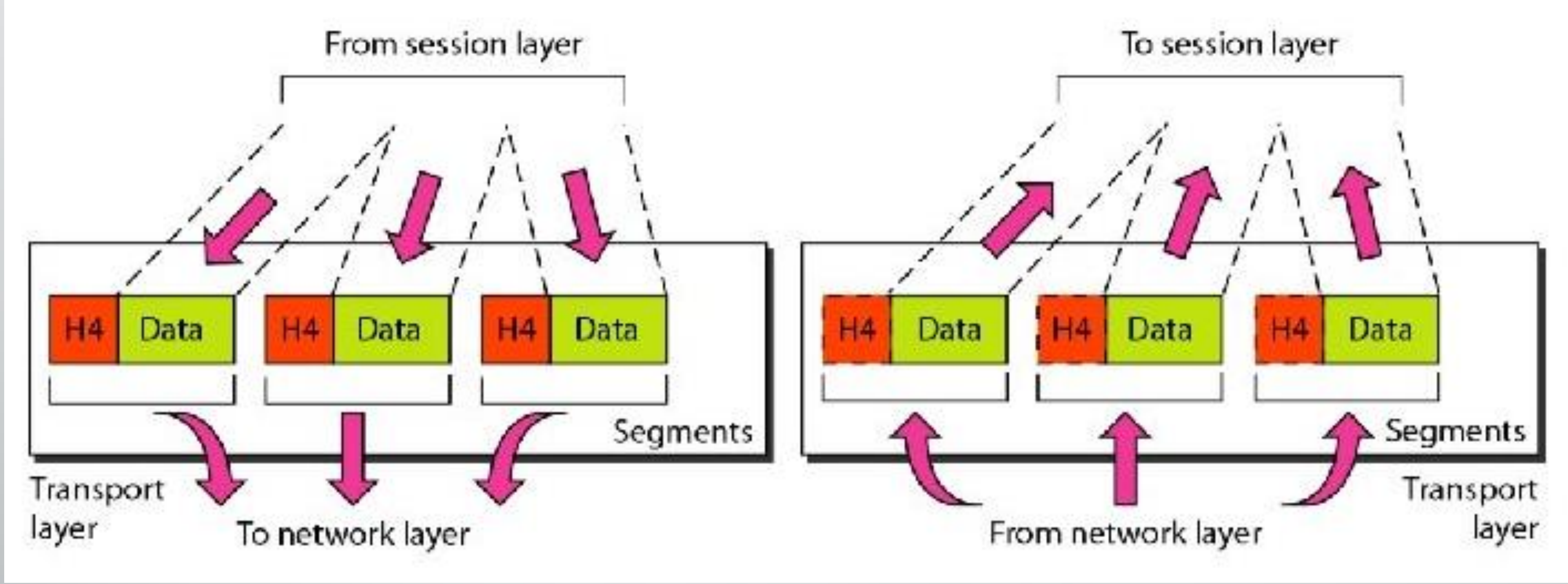
Solution : Two transport protocols?



Function 1 – Segmentation and Reassembly

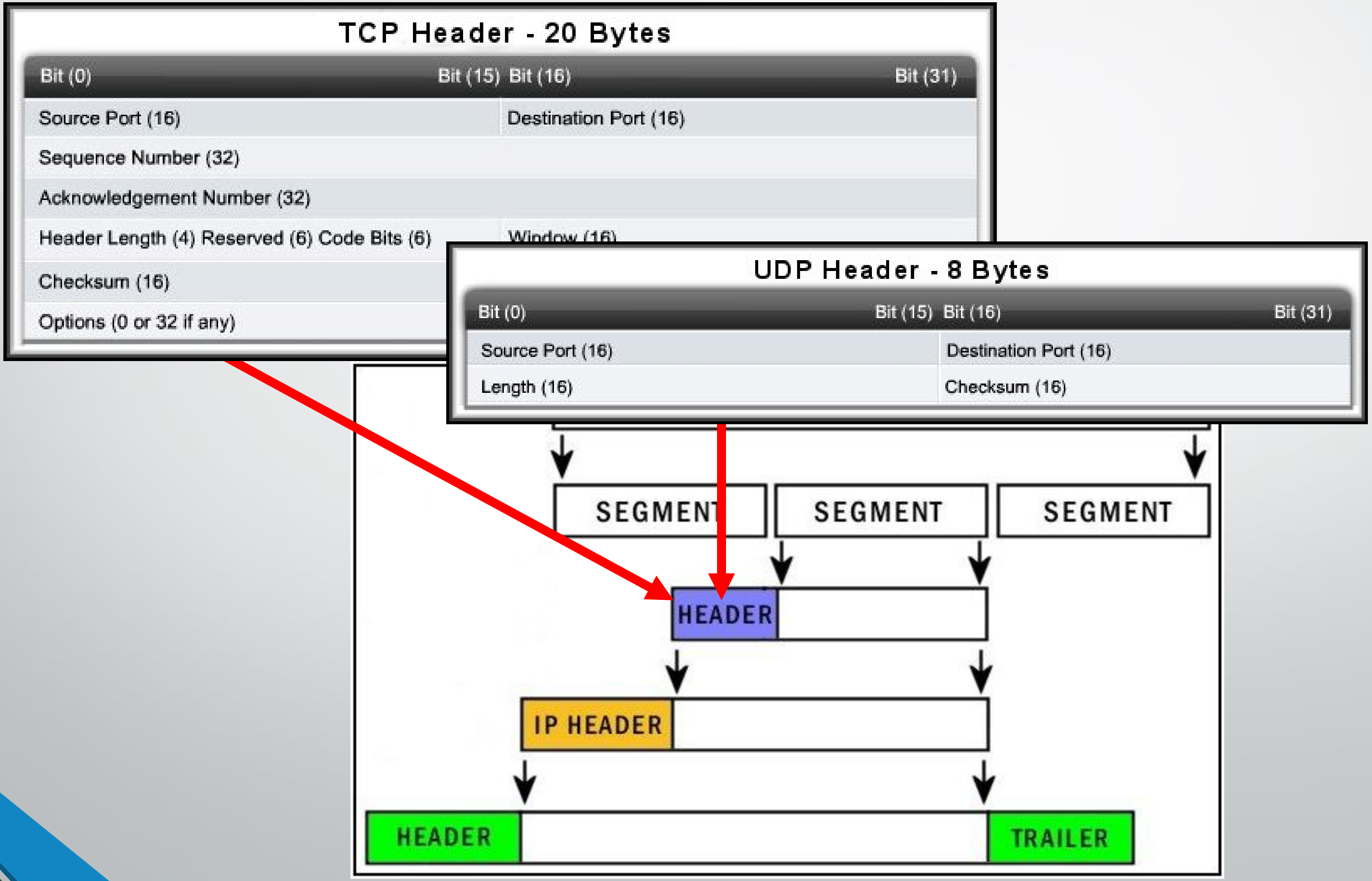


Function 1 – Segmentation and Reassembly

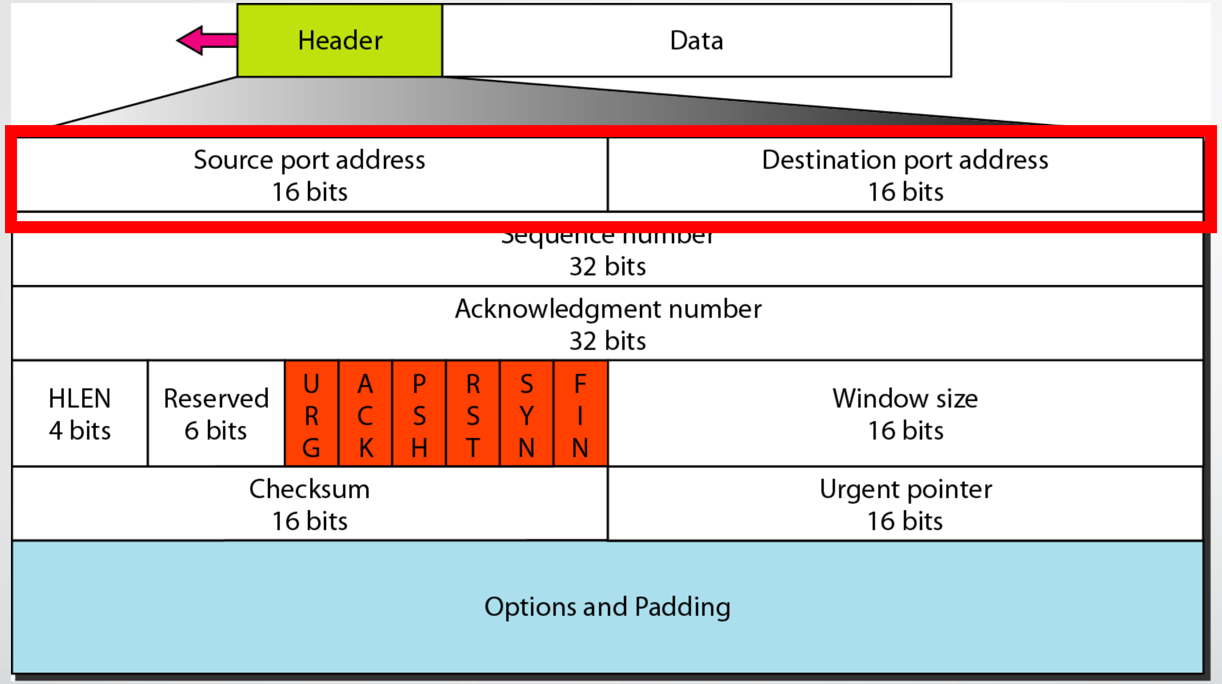


- Also known as encapsulation and de-capsulation.

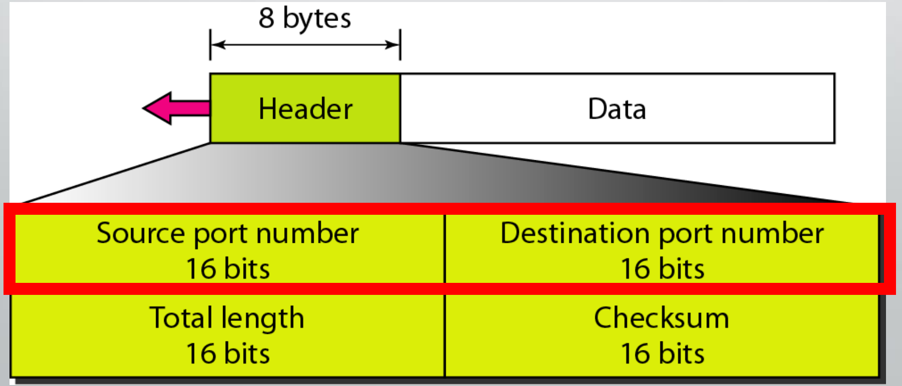
TCP and UDP Headers



TCP and UDP Headers



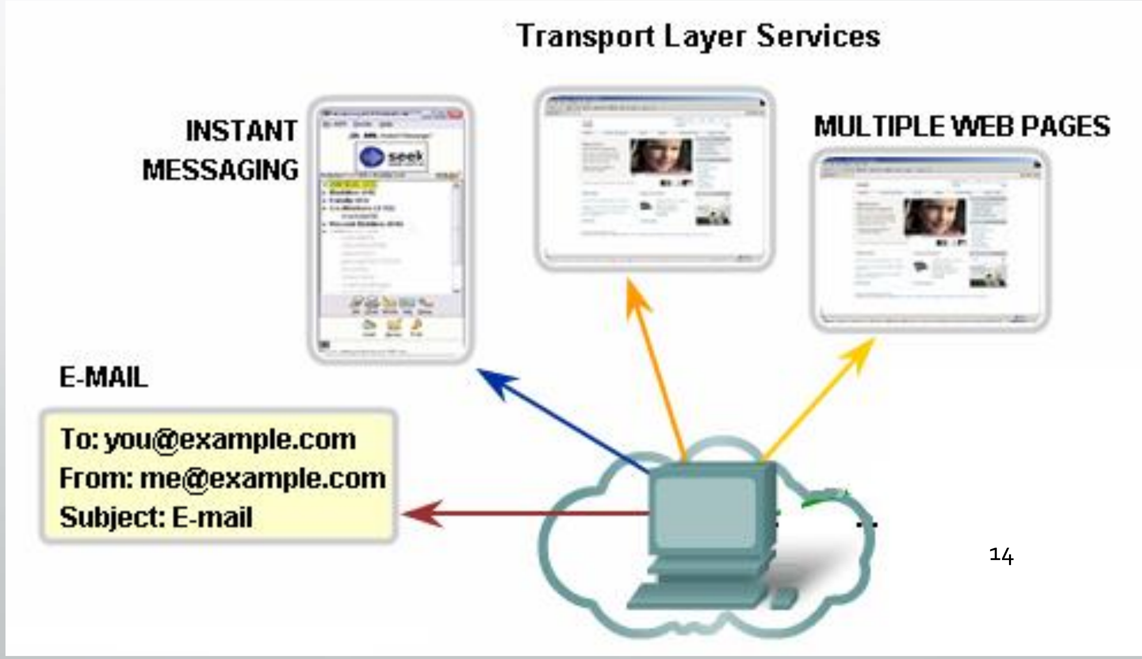
- TCP Header



- UDP Header

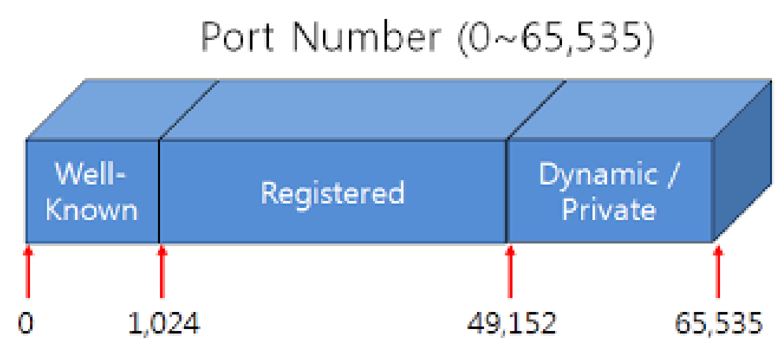
Function2 – Identification Applications Using Port Address

- Port Numbers/Addresses are used to identify different applications/processes running in a computer
- 16-bit in length
  - Represented as one single decimal number
  - Range **0 - 65535**
  - e.g. **80 – Web**; **25 – SMTP**
  - **110 – POP3**, **531 – Instant Messaging**



Port Numbers

- Internet Corporation for Assigned Names and Numbers (ICANN) assigns port numbers.
- **Three** categories:



Port Number Range	Port Group
0 to 1023	Well Known (Contact) Ports
1024 to 49151	Registered Ports
49152 to 65535	Private and/or Dynamic Ports

Port Addressing Types

- Well-Known Ports:
  - Reserved for common services and applications.
  - Pre-assigned by ICANN

Port Number Range	Port Group
0 to 1023	Well Known (Contact) Ports
1024 to 49151	Registered Ports
49152 to 65535	Private and/or Dynamic Ports

20 – FTP Data

21 – FTP Control

23 – Telnet

25 – SMTP

110 – POP3

520 – RIP

443 – HTTPS

69 – TFTP

Port Addressing Types

- Registered Ports:
  - Port numbers that companies and other users register with ICANN for use by the applications that communicate using any one of the transport layer protocols.

Port Number Range	Port Group
0 to 1023	Well Known (Contact) Ports
1024 to 49151	Registered Ports
49152 to 65535	Private and/or Dynamic Ports

8008 – Alternate HTTP

1863 – MSN Messenger

5004 – RTP

8080 – Alternate HTTP

5060 – SIP (VoIP)

Port Addressing Types

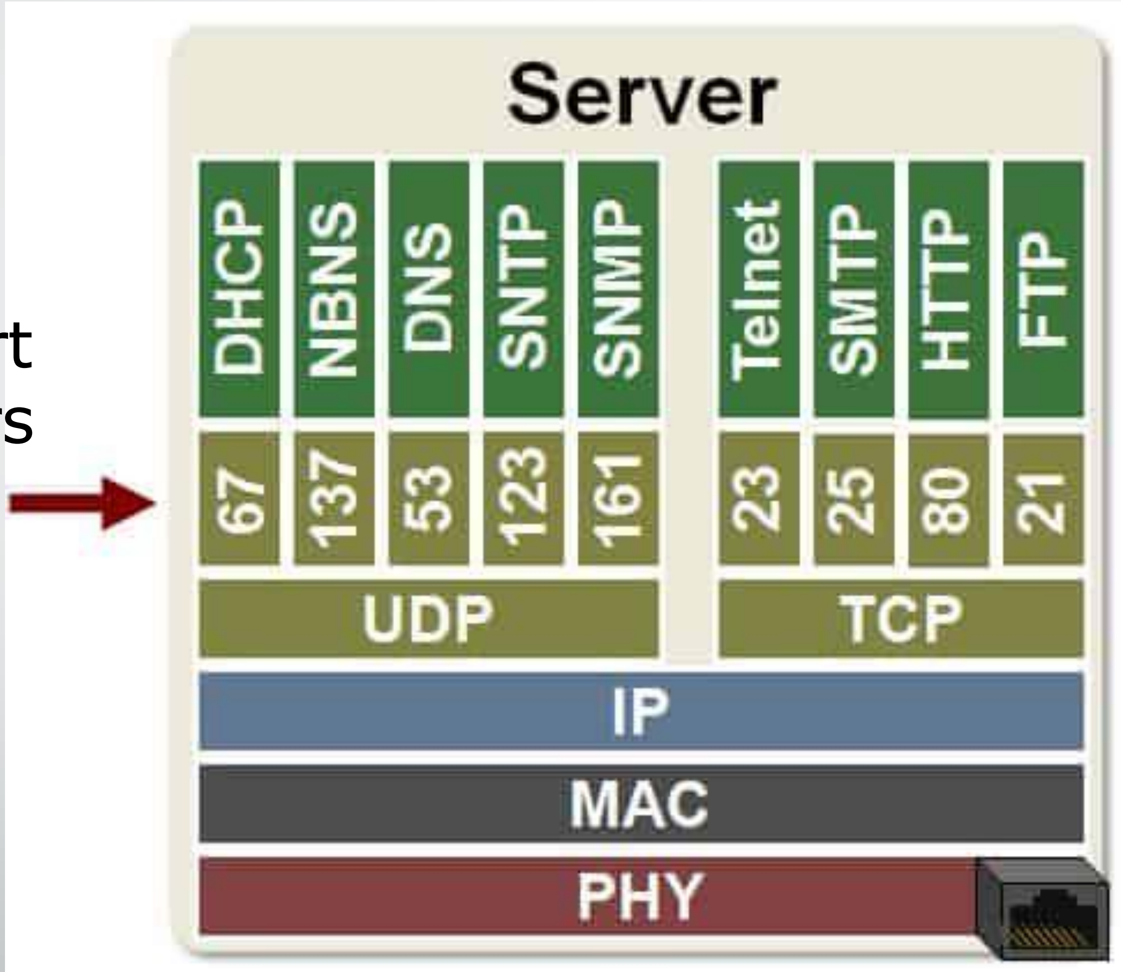
- Dynamic Ports:
  - Assigned to a user application at connect time.

Port Number Range	Port Group
0 to 1023	Well Known (Contact) Ports
1024 to 49151	Registered Ports
49152 to 65535	Private and/or Dynamic Ports

Dynamic port usage will become clearer as we move through the material.

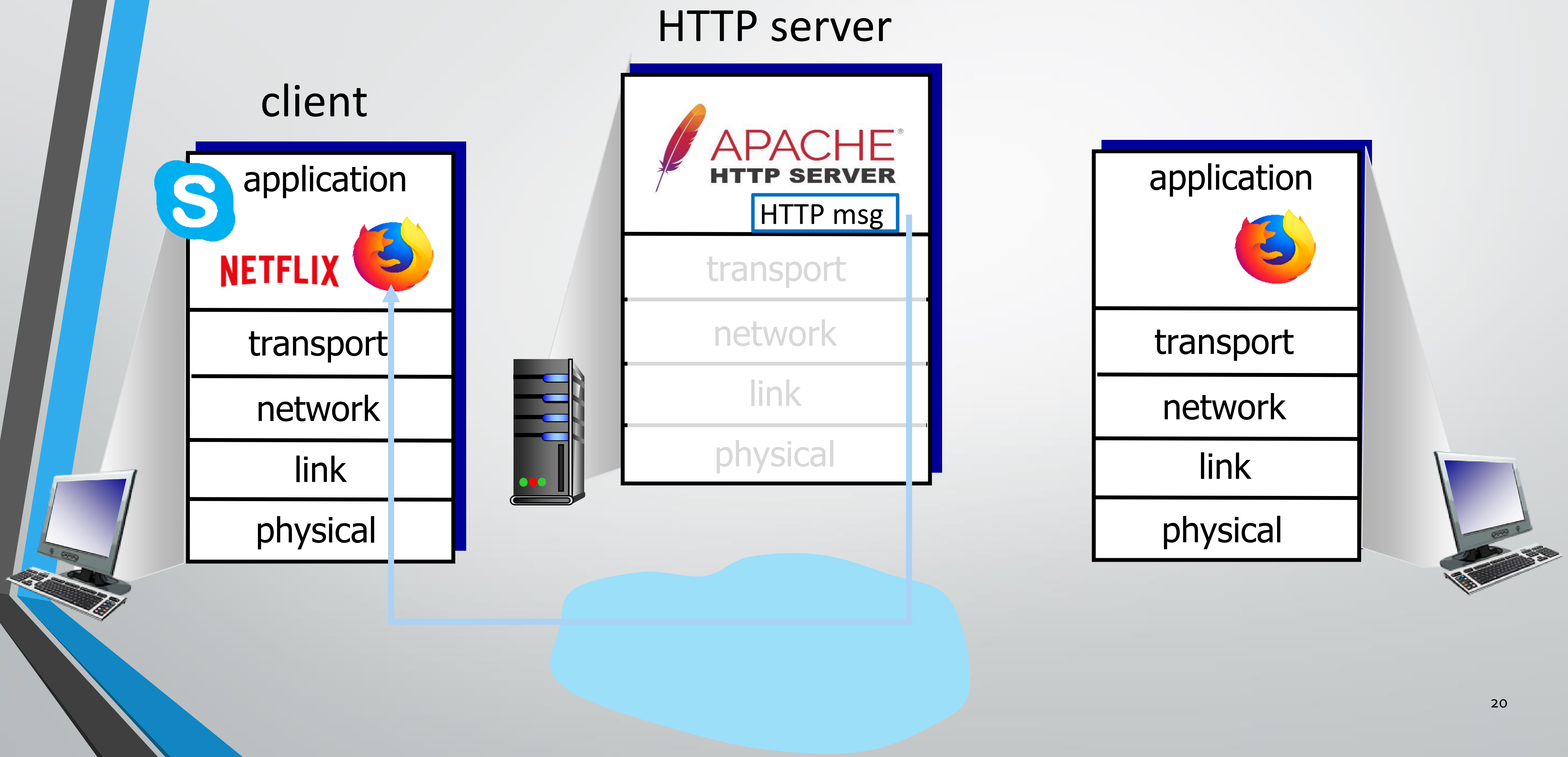
Port Numbers

- UDP Port Numbers

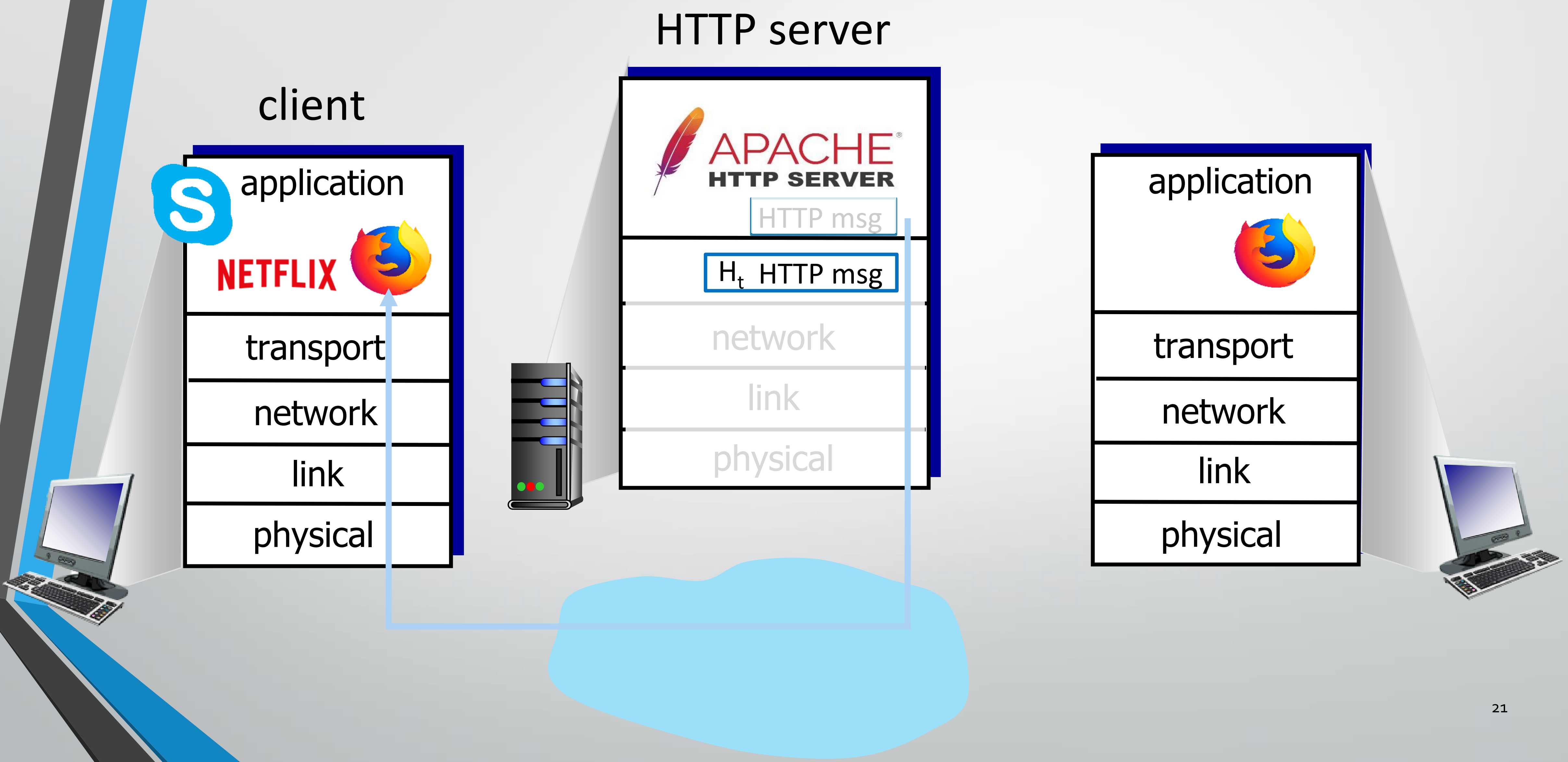


TCP Port Numbers

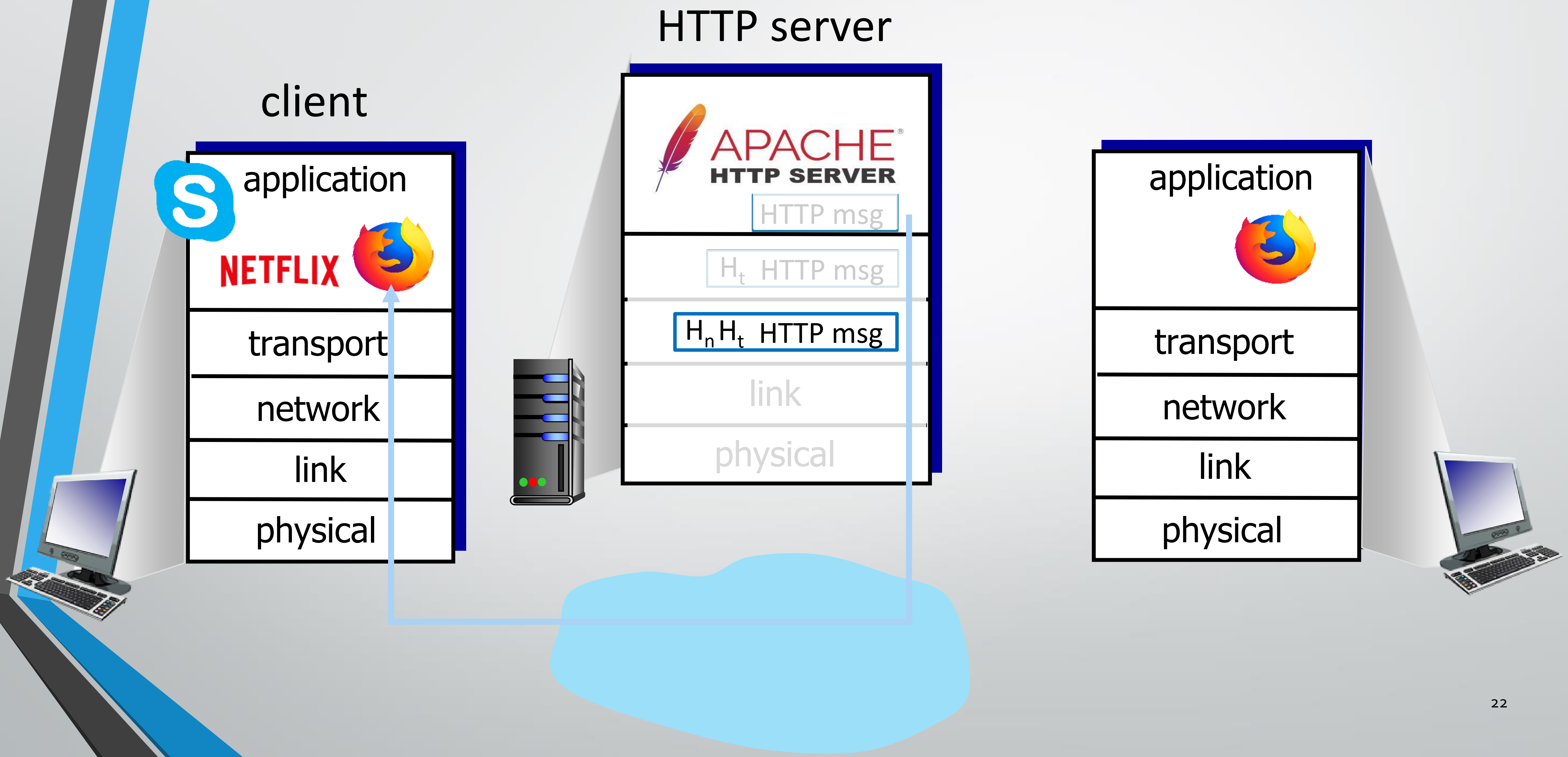
Function 3 -Multiplexing



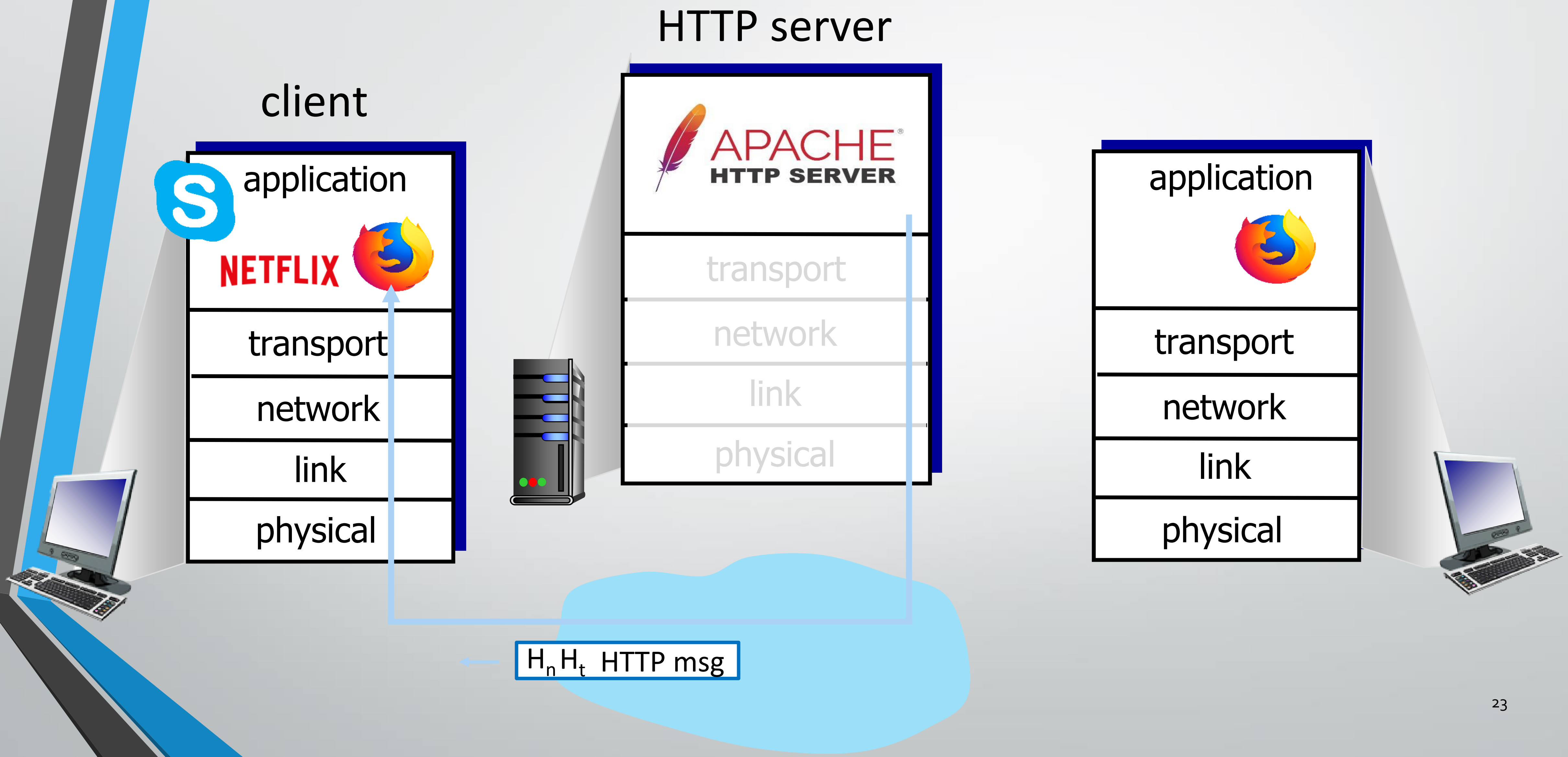
Multiplexing



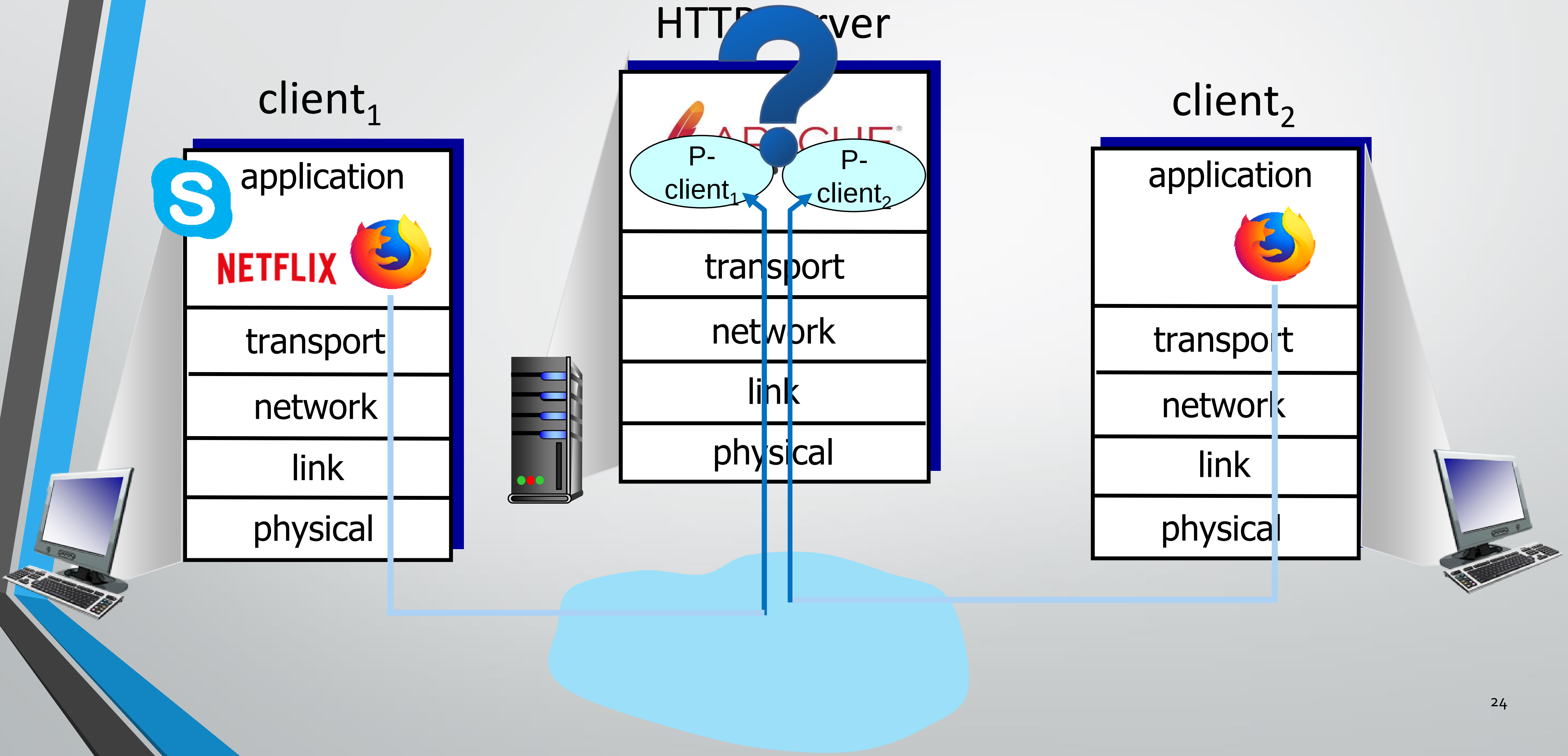
Multiplexing



Multiplexing



Multiplexing



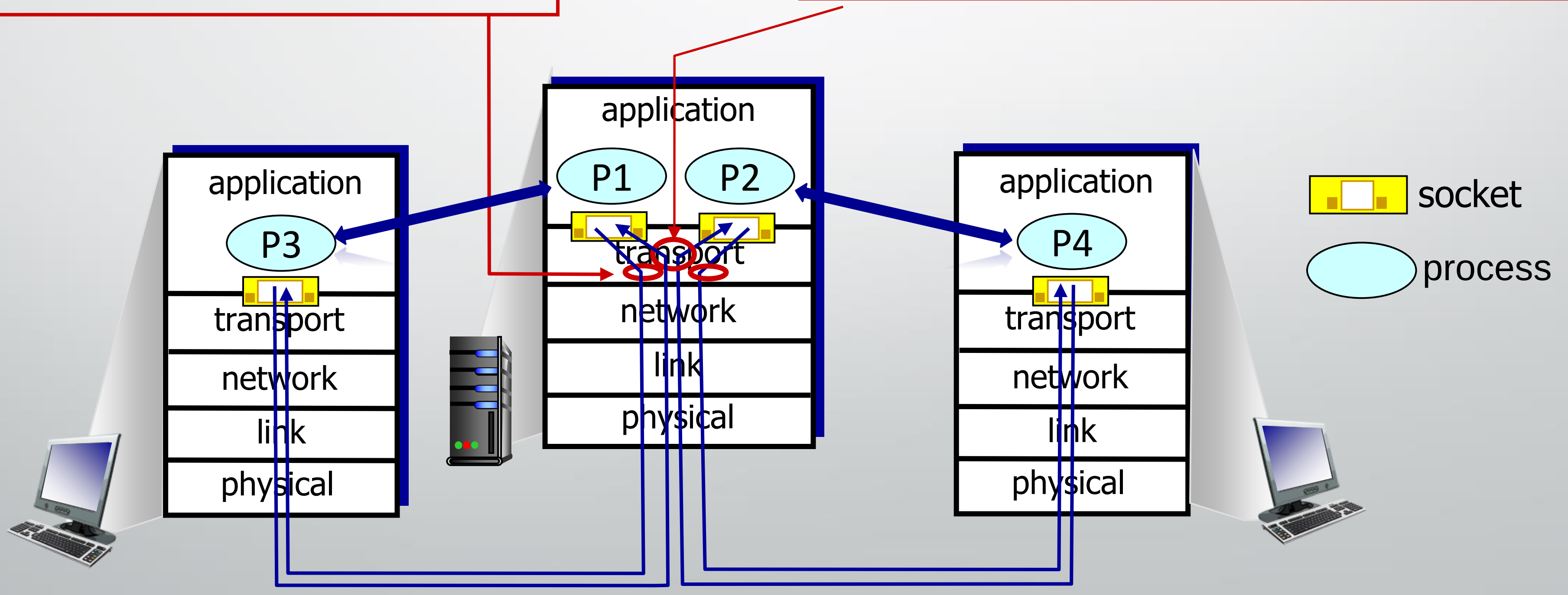
Multiplexing/demultiplexing

multiplexing at sender:

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

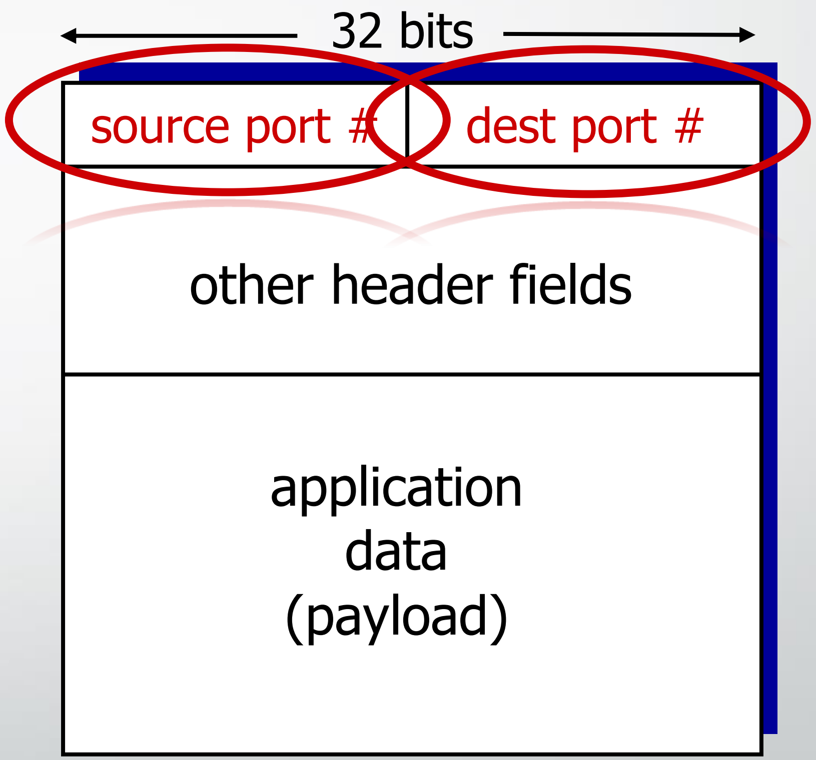
demultiplexing at receiver:

use header info to deliver received segments to correct socket



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

- 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 #

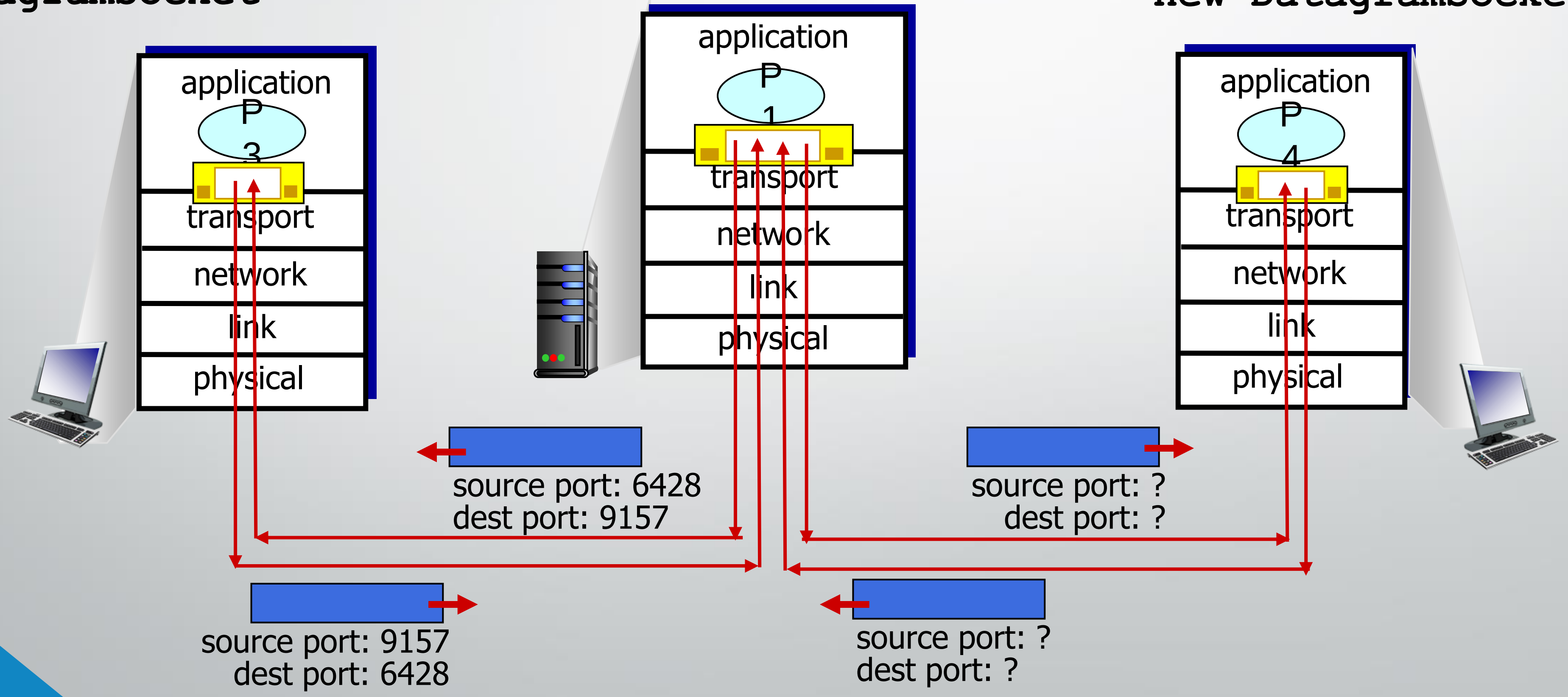
IP/UDP datagrams with *same dest. port #,* but different source IP addresses and/or source port numbers will be directed to *same socket* at receiving host

Connectionless demultiplexing: an example

```
DatagramSocket mySocket2 =
 new DatagramSocket
 (9157);
```

```
DatagramSocket
 serverSocket = new
 DatagramSocket
 (6428);
```

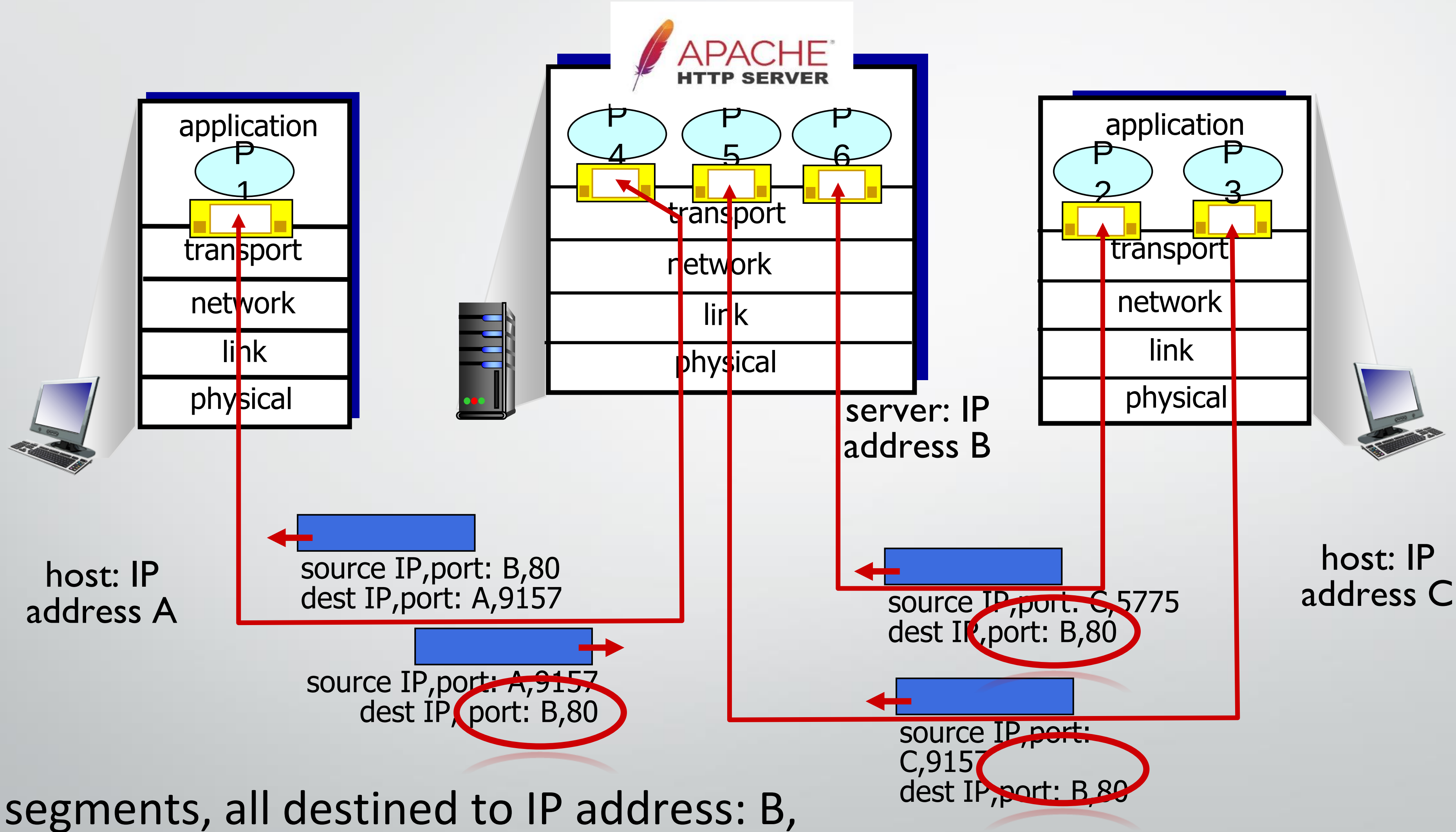
```
DatagramSocket mySocket1 =
 new DatagramSocket (5775);
```



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

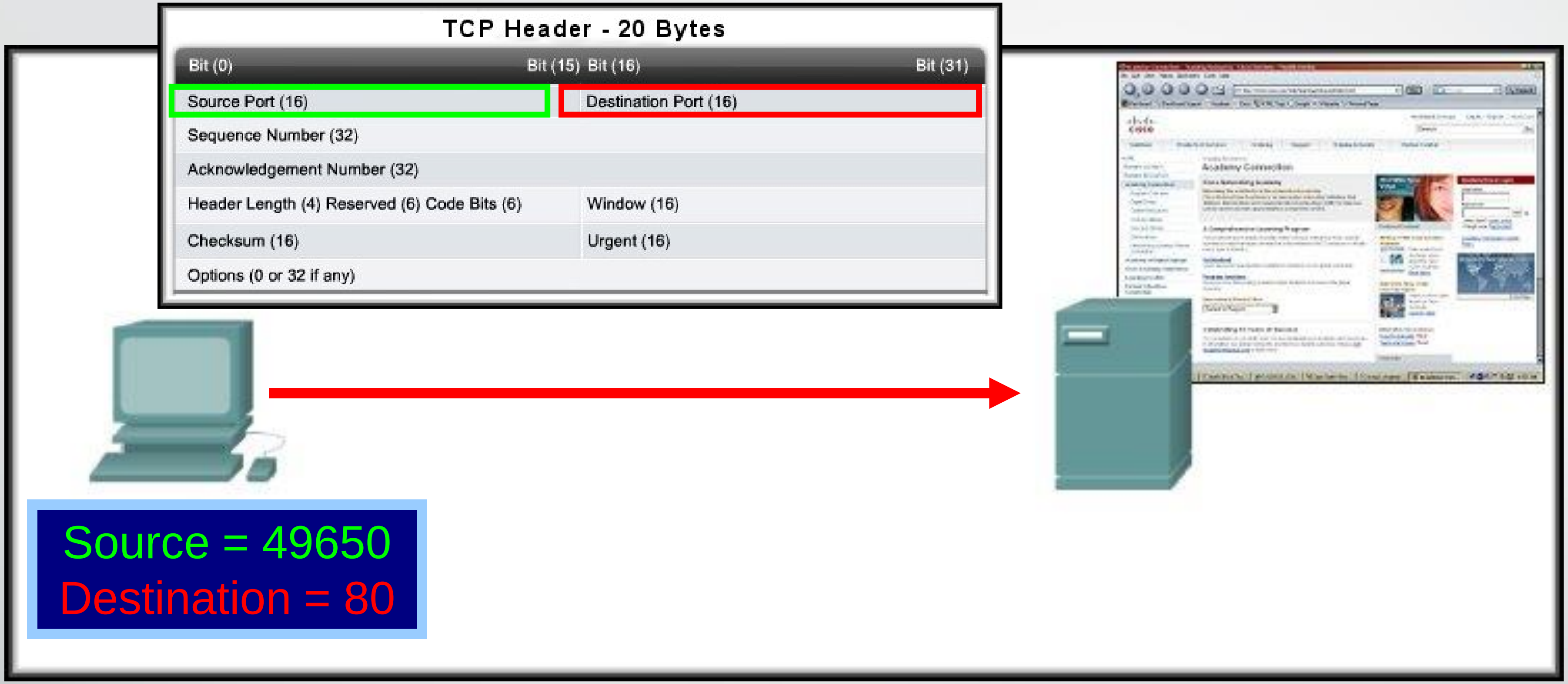


Three segments, all destined to IP address: B,
dest port: 80 are demultiplexed to *different* sockets

Summary

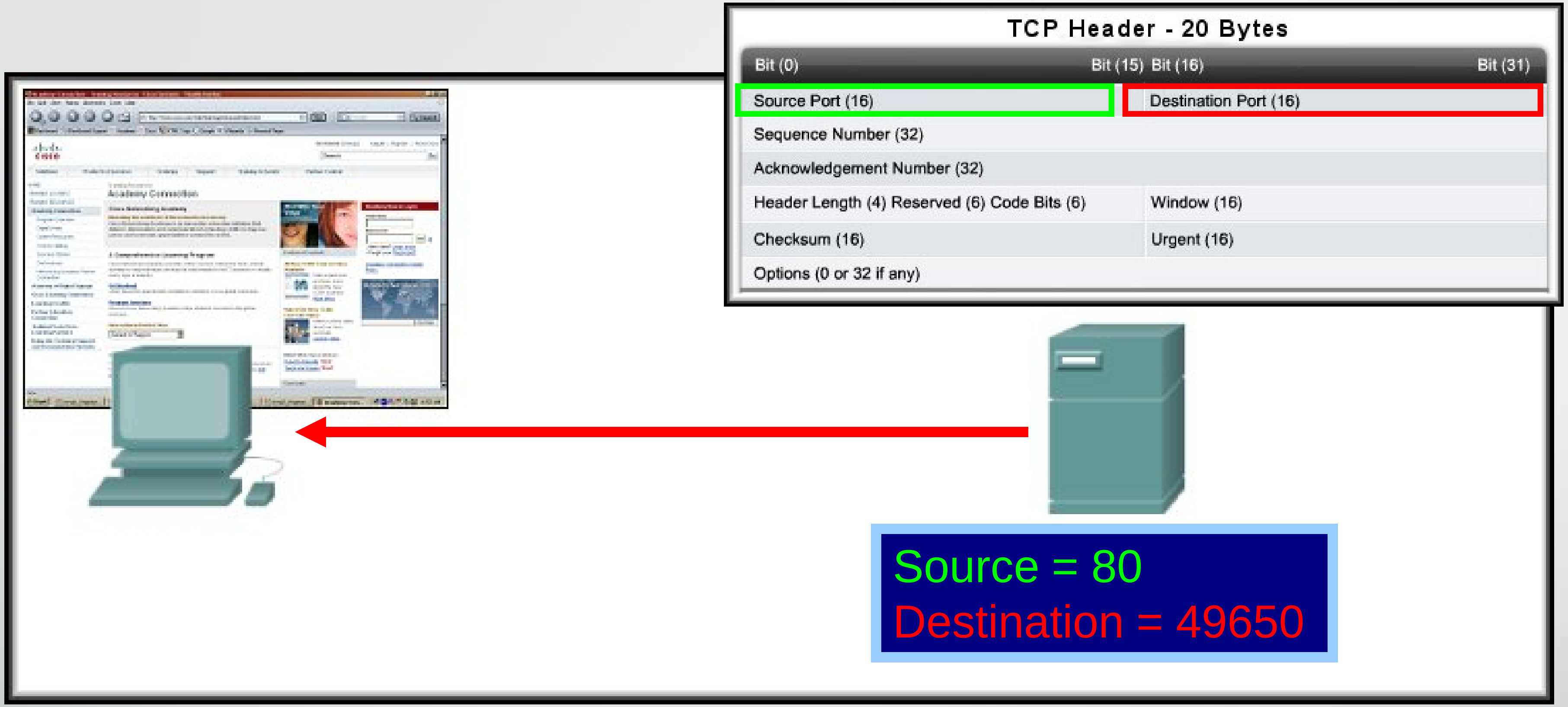
- Multiplexing, demultiplexing: based on segment, datagram header field values
- **UDP:** demultiplexing using destination port number (only)
- **TCP:** demultiplexing using 4-tuple: source and destination IP addresses, and port numbers
- Multiplexing/demultiplexing happen at *all* layers

More on Port Numbers



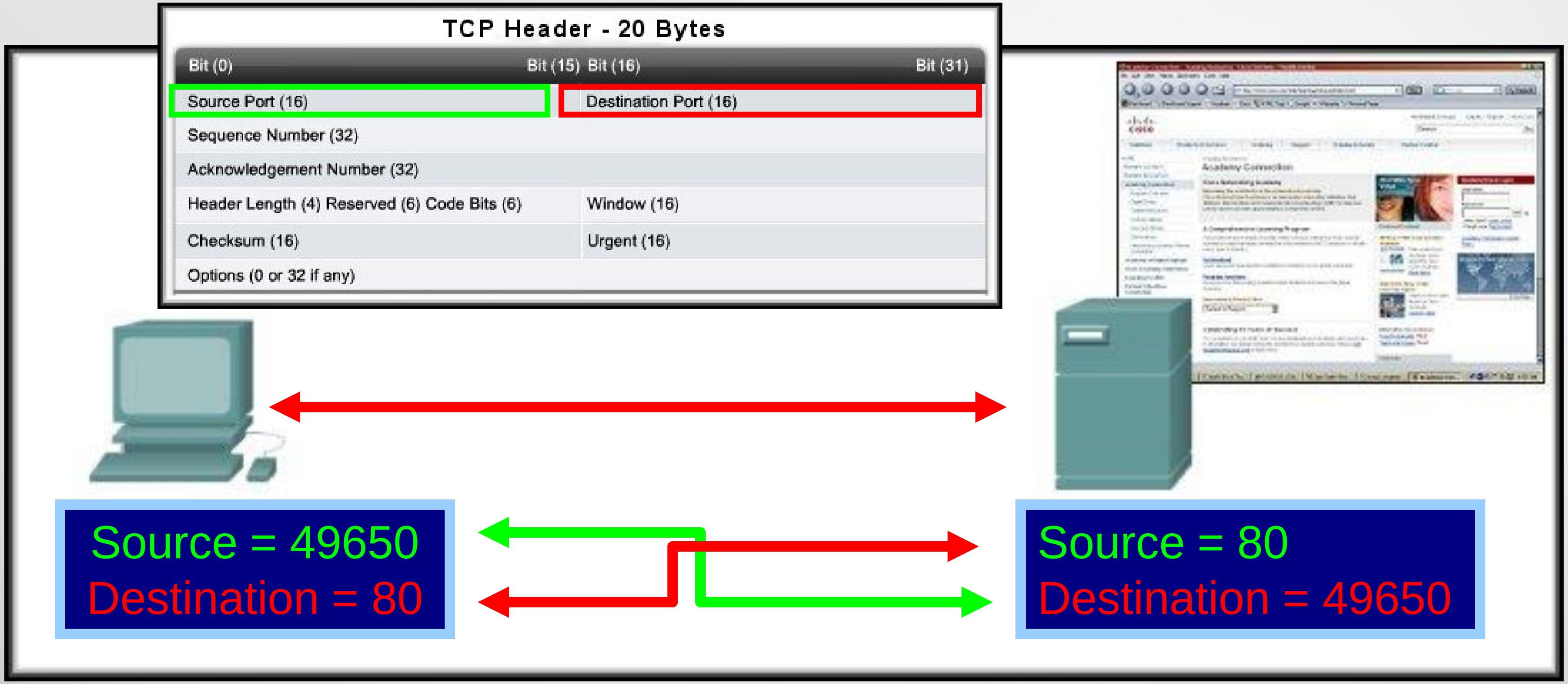
- Server is listening on Port 80 for HTTP connections.
- The client sets the destination port to 80 and uses a dynamic port as its source.

Port Numbers in Action



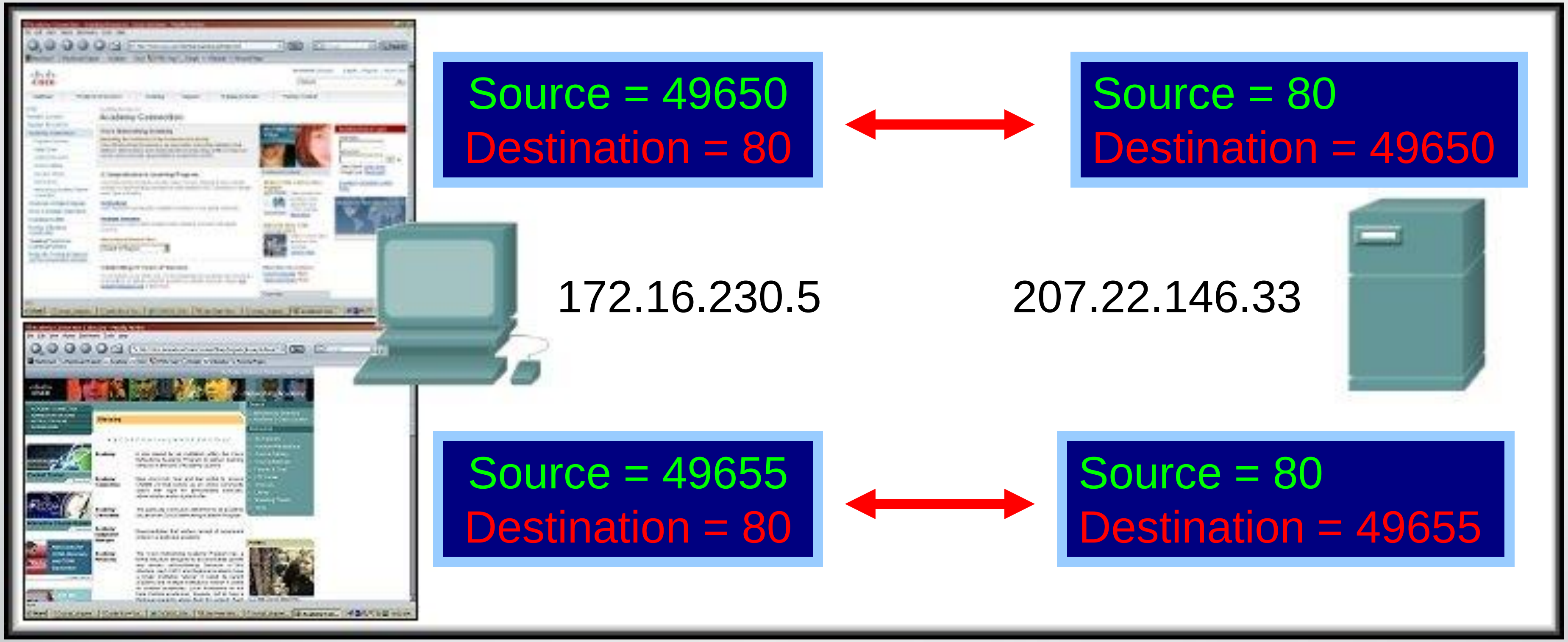
- Server replies with the web page.
  - Sets the source port to 80 and uses the client's source port as the destination.

Port Numbers in Action



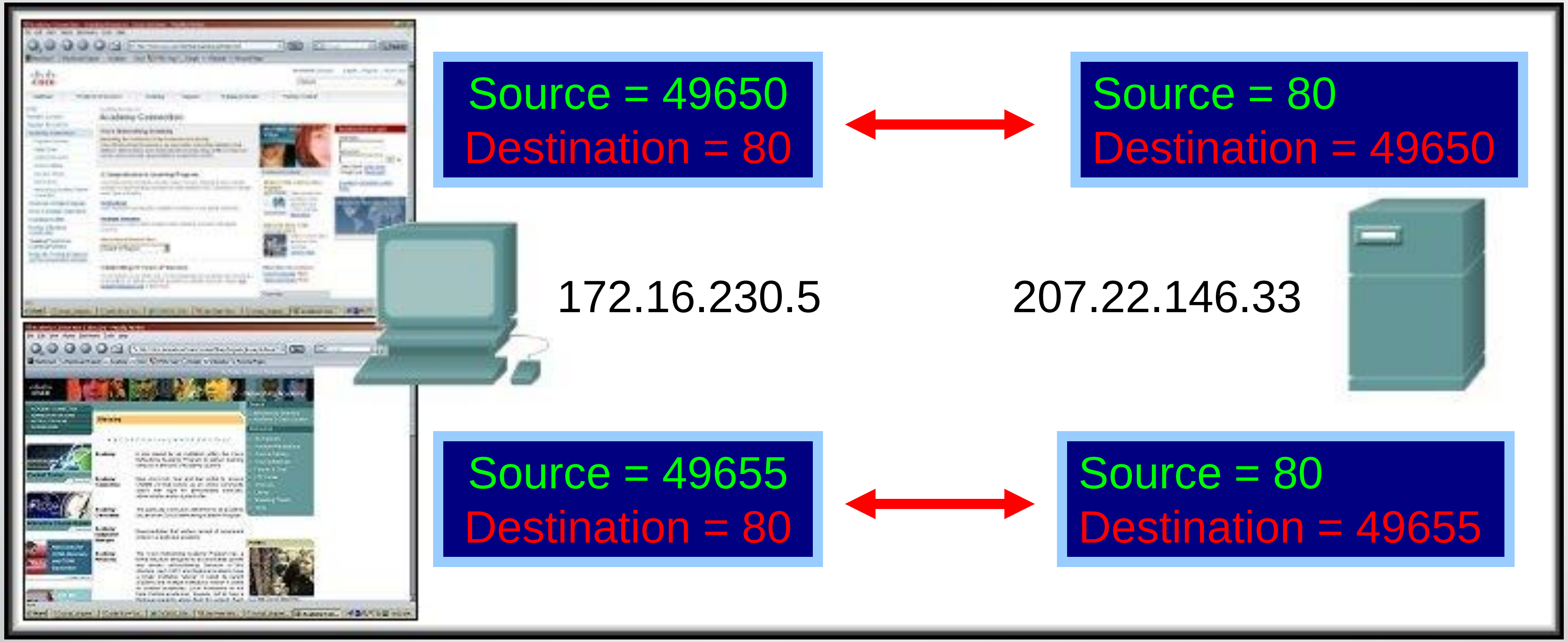
- Notice how the source and destination ports are used.
- Clients can use any random port number, servers can't.
  - Because clients won't be able to identify server process otherwise
- Servers, however, cannot use any random port number
  - Use of well-known port numbers!

Port Numbers in Action



- What if there are two sessions to the same server?
  - The client uses another dynamic port as its source and the destination is still port 80.
  - Different source ports keep the sessions unique on the server.

Port Numbers in Action

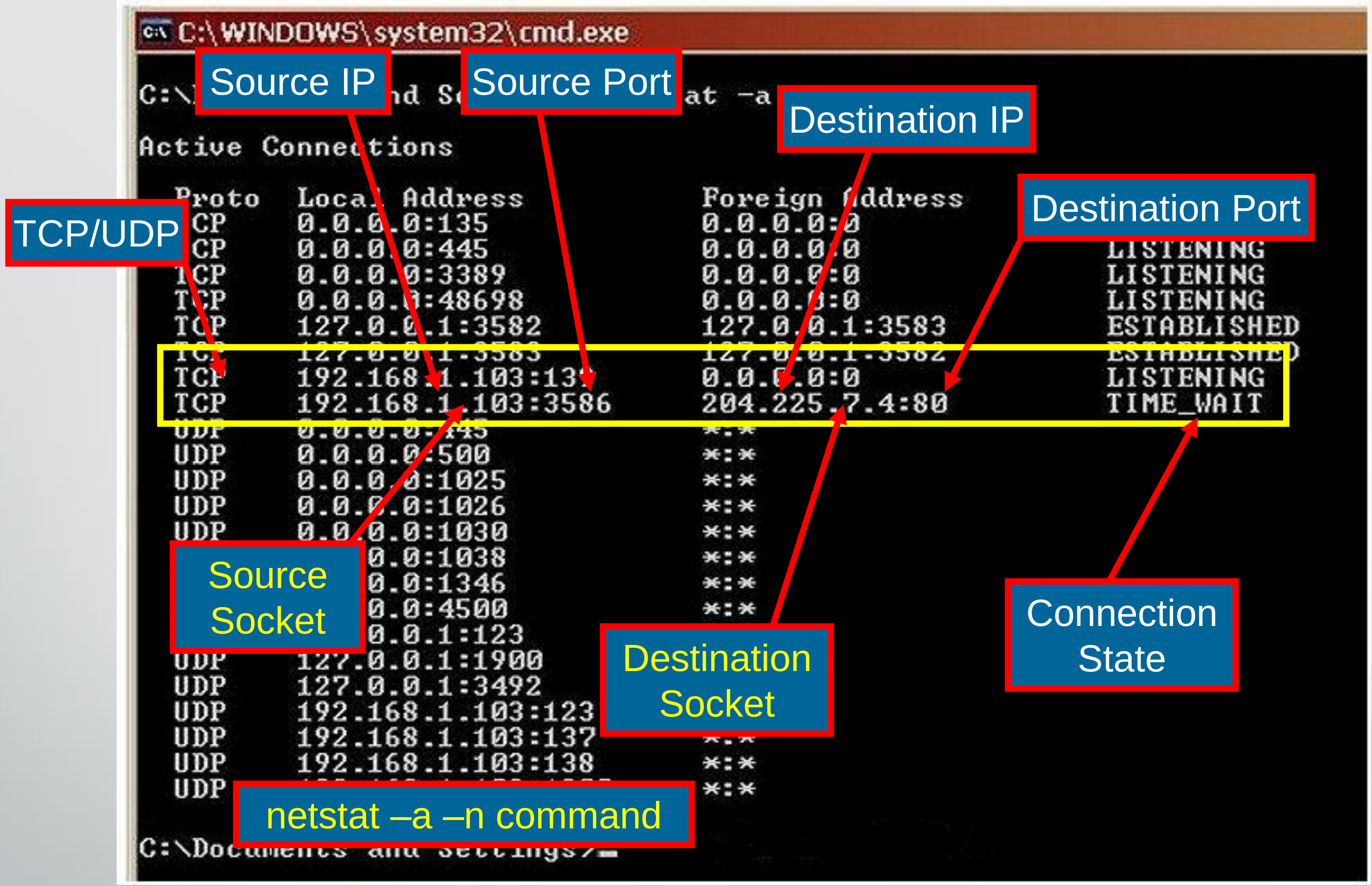


- How does the Transport Layer keep them separate?
  - The socket (IP Address:Port)

172.16.230.5:49650 ⟷ 207.22.146.33:49650

172.16.230.5:49655 ⟷ 207.22.146.33:49655

Netstat - Network Utility Tool



- Actually, when you open up a single web page, there are usually several TCP sessions created, not just one.

UDP: User Datagram Protocol [RFC 768]

UDP is a <u>connectionless</u>, unreliable protocol that has no flow and error control. It uses port numbers to track and multiplex data received from the application layer.

why is there a UDP?

- no connection establishment (which can add delay)
- simple: no connection state at sender, receiver
- small header size
- no congestion control: UDP can blast away as fast as desired

UDP

- UDP use:
  - streaming multimedia apps (loss tolerant, rate sensitive)
  - DNS
  - SNMP
  - HTTP/3

- reliable transfer over UDP:
  - add reliability at application layer
  - application-specific error recovery!

User Datagram Protocol (UDP)

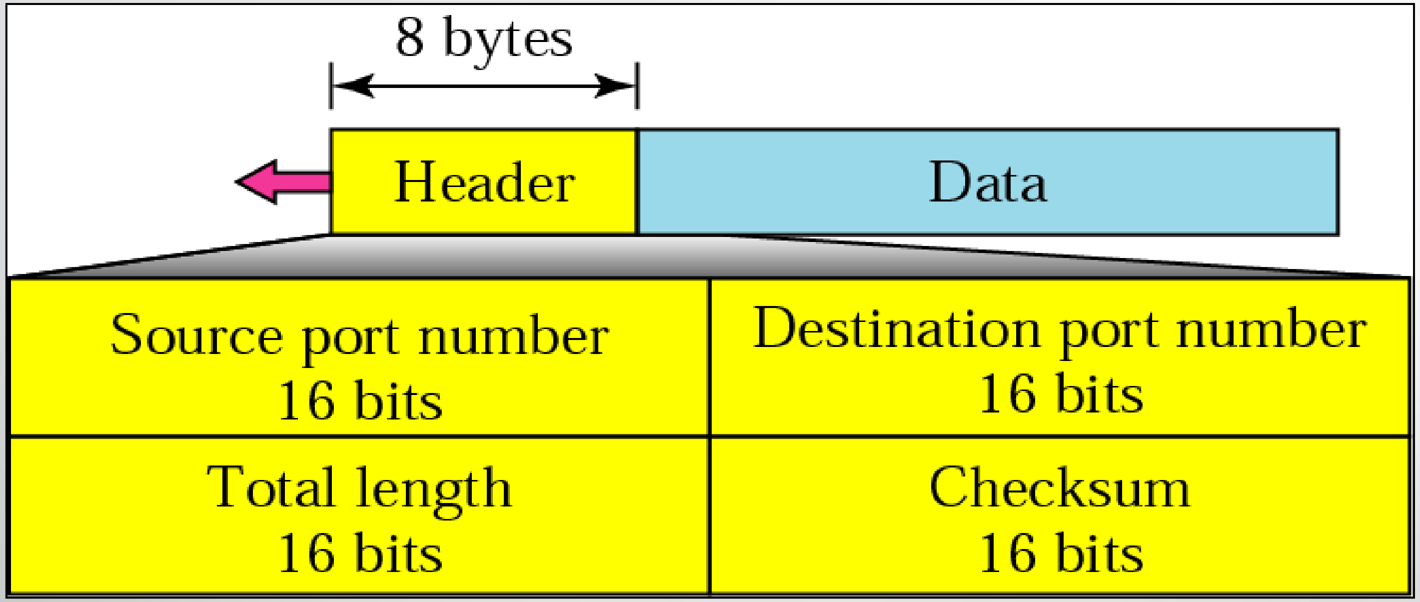


Figure 14: User Datagram Header format

- Connectionless
- No reassembly to order.
- No Error checking
- No Flow control

UDP checksum

Goal: detect errors (*i.e.*, flipped bits) in transmitted segment

	1st number	2nd number	sum
Transmitted:	5	6	11
Received:	4	6	11

receiver-computed checksum ≠ sender-computed checksum (as received)

UDP checksum

Goal: detect errors (*i.e.,* flipped bits) in transmitted segment

sender:

- treat contents of UDP segment (including UDP header fields and IP addresses) as sequence of 16-bit integers
- checksum: addition (one's complement sum) of segment content
- checksum value put into UDP checksum field

receiver:

- compute checksum of received segment
- check if computed checksum equals checksum field value:
  - Not equal - error detected
  - Equal - no error detected. *But maybe errors nonetheless?* More later ….

Internet checksum: an example

example: add two 16-bit integers

		1	1	1	0	0	1	1	0	0	1	1	0	0	1	1	0
		1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
wraparound	1	1	0	1	1	1	0	1	1	1	0	1	1	1	0	1	1
sum		1	0	1	1	1	0	1	1	1	0	1	1	1	1	0	0
checksum		0	1	0	0	0	1	0	0	0	1	0	0	0	0	1	1

Note: when adding numbers, a carryout from the most significant bit needs to be added to the result

* Check out the online interactive exercises for more examples: http://gaia.cs.umass.edu/kurose_ross/interactive/

Internet checksum: weak protection!

example: add two 16-bit integers

		1	1	1	0	0	1	1	0	0	1	1	0	0	1	1	0
		1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
wraparound	1	1	0	1	1	1	0	1	1	1	0	1	1	1	0	1	1
sum		1	0	1	1	1	0	1	1	1	0	1	1	1	1	0	0
checksum		0	1	0	0	0	1	0	0	0	1	0	0	0	0	1	1

0 1
1 0

Even though numbers have changed (bit flips), *no* change in checksum!

THE END