



Computer Networks

CS3611

Transport Layer-Part 1

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The slides are adapted from those provided by Prof. Romit Roy Choudhury.

Chapter 3: Transport Layer

Our goals:

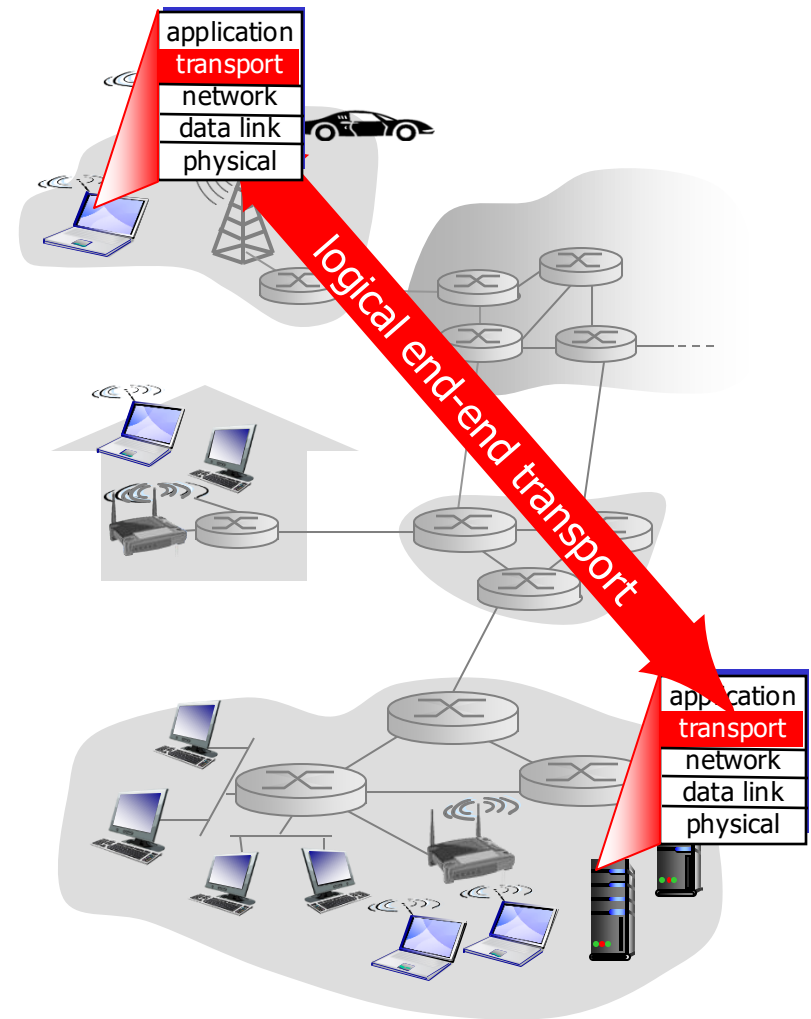
- ❑ understand principles behind transport layer services:
 - multiplexing/demultiplexing
 - reliable data transfer
 - flow control
 - congestion control
- ❑ learn about transport layer protocols in the Internet:
 - UDP: connectionless transport
 - TCP: connection-oriented transport
 - TCP congestion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

Chapter 3 outline

- ❑ 3.1 Transport-layer services
- ❑ 3.2 Multiplexing and demultiplexing
- ❑ 3.3 Connectionless transport: UDP
- ❑ 3.4 Principles of reliable data transfer
- ❑ 3.5 Connection-oriented transport: TCP
 - segment structure
 - reliable data transfer
 - flow control
 - connection management
- ❑ 3.6 Principles of congestion control
- ❑ 3.7 TCP congestion control

Transport services and protocols

- ❑ provide *logical communication* between app processes running on different hosts
- ❑ transport protocols run in end systems
 - sender: breaks app messages into *segments*, passes to network layer
 - receiver: reassembles segments into messages, passes to app layer
- ❑ more than one transport protocol available to apps
 - Internet: TCP and UDP



Transport vs. network layer

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

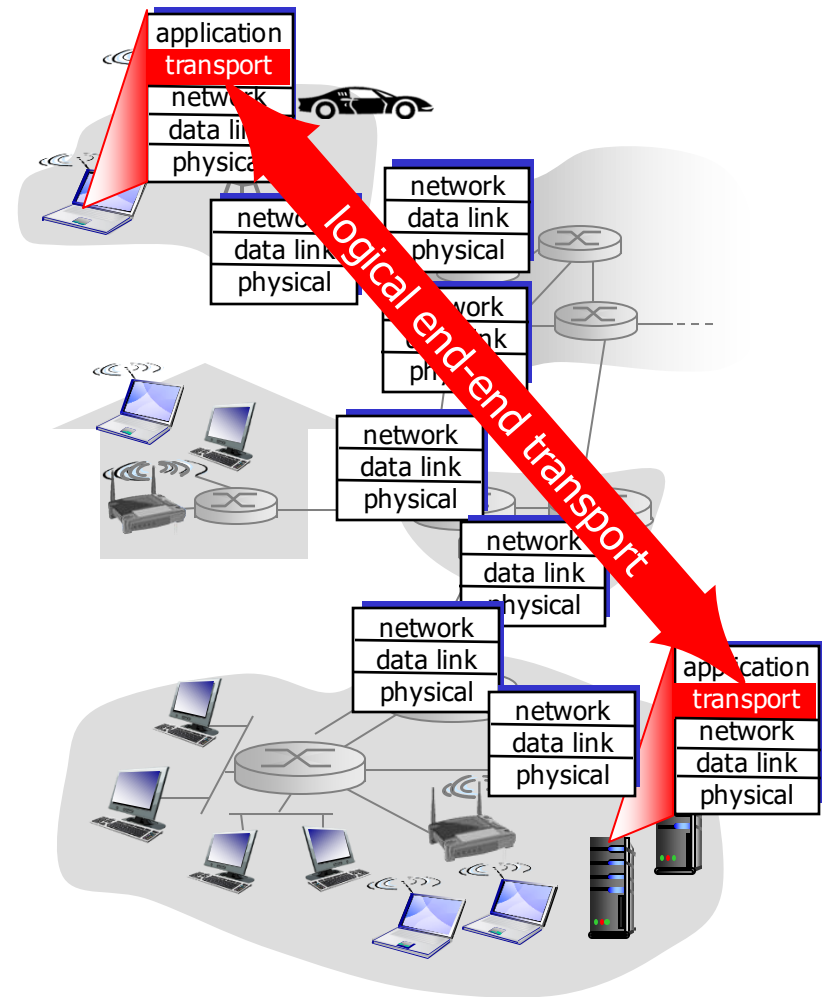
Household analogy:

12 kids sending letters to 12 kids

- ❑ processes = kids
- ❑ app messages = letters in envelopes
- ❑ hosts = houses
- ❑ transport protocol = Ann to Bill
- ❑ network-layer protocol = postal service

Internet transport-layer protocols

- ❑ reliable, in-order delivery (TCP)
 - congestion control
 - flow control
 - connection setup
- ❑ unreliable, unordered delivery: UDP
 - no-frills extension of “best-effort” IP
- ❑ services not available:
 - delay guarantees
 - bandwidth guarantees



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Multiplexing/demultiplexing

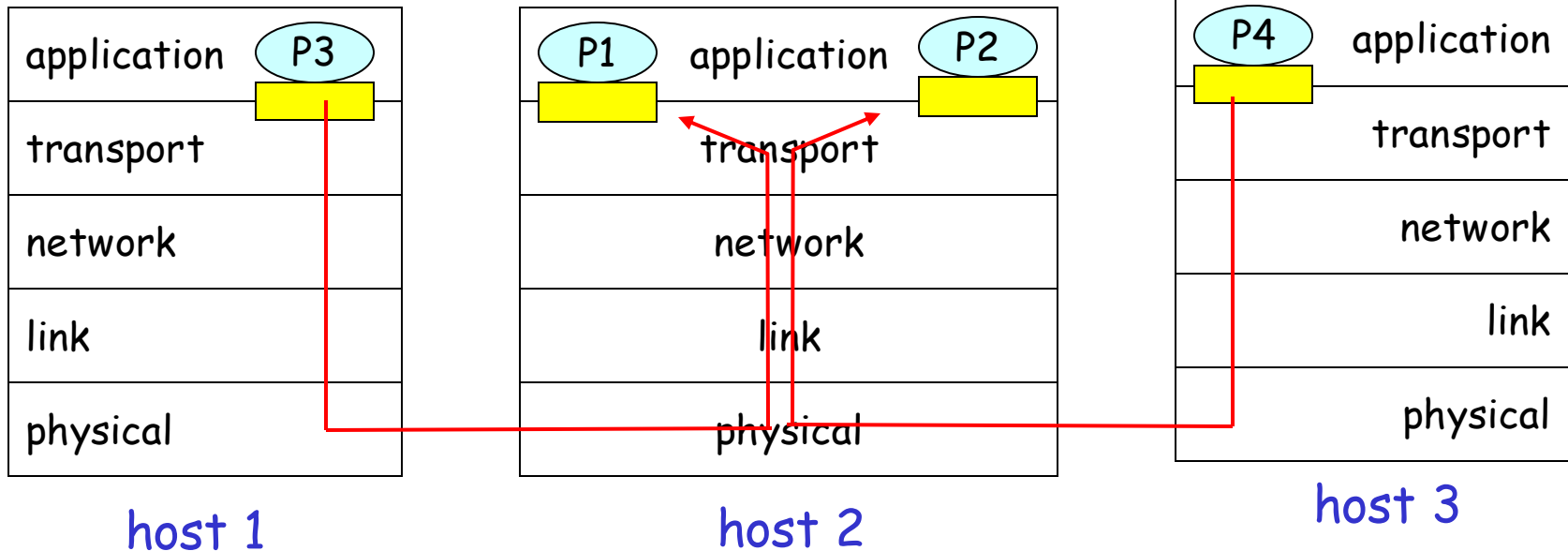
Demultiplexing at rcv host:

delivering received segments to correct socket

Multiplexing at send host:

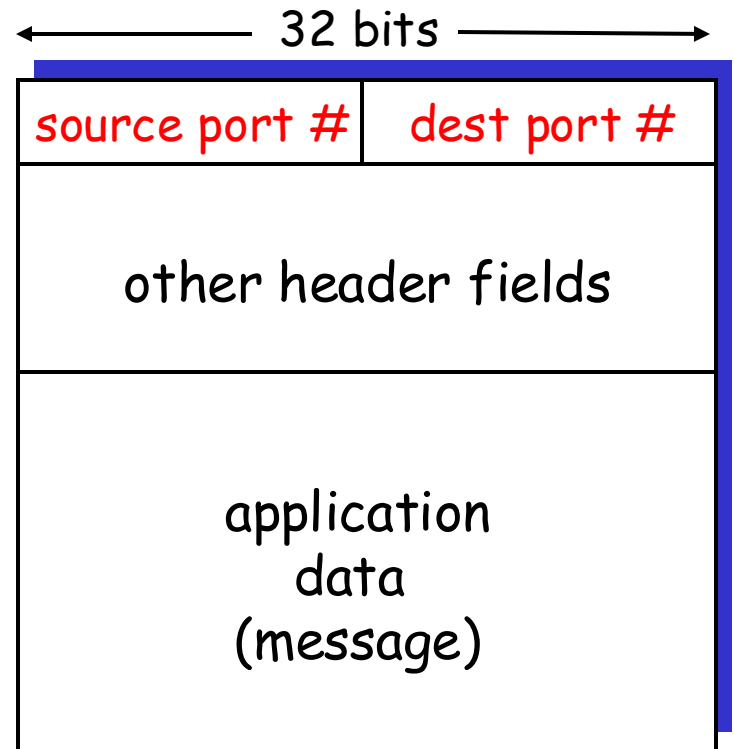
gathering data from multiple sockets, enveloping data with header (later used for demultiplexing)

■ = socket ○ = process



How demultiplexing works

- **host receives IP datagrams**
 - each datagram has source IP address, destination IP address
 - each datagram carries 1 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

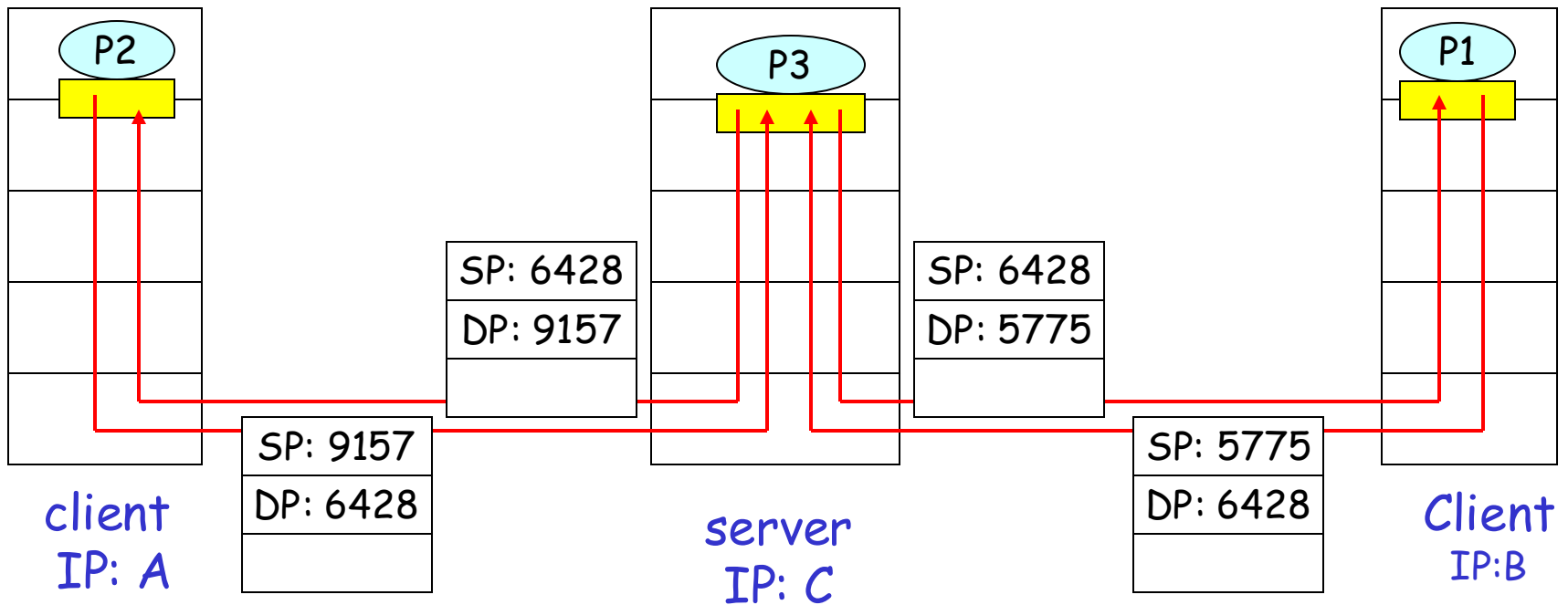
Connectionless demultiplexing

- ❑ UDP socket identified by two-tuple:

(dest IP address, dest port number)

- ❑ When host receives UDP segment:
 - checks destination port number in segment
 - directs UDP segment to socket with that port number
- ❑ IP datagrams with different source IP addresses and/or source port numbers directed to same socket

Connectionless demux (cont)



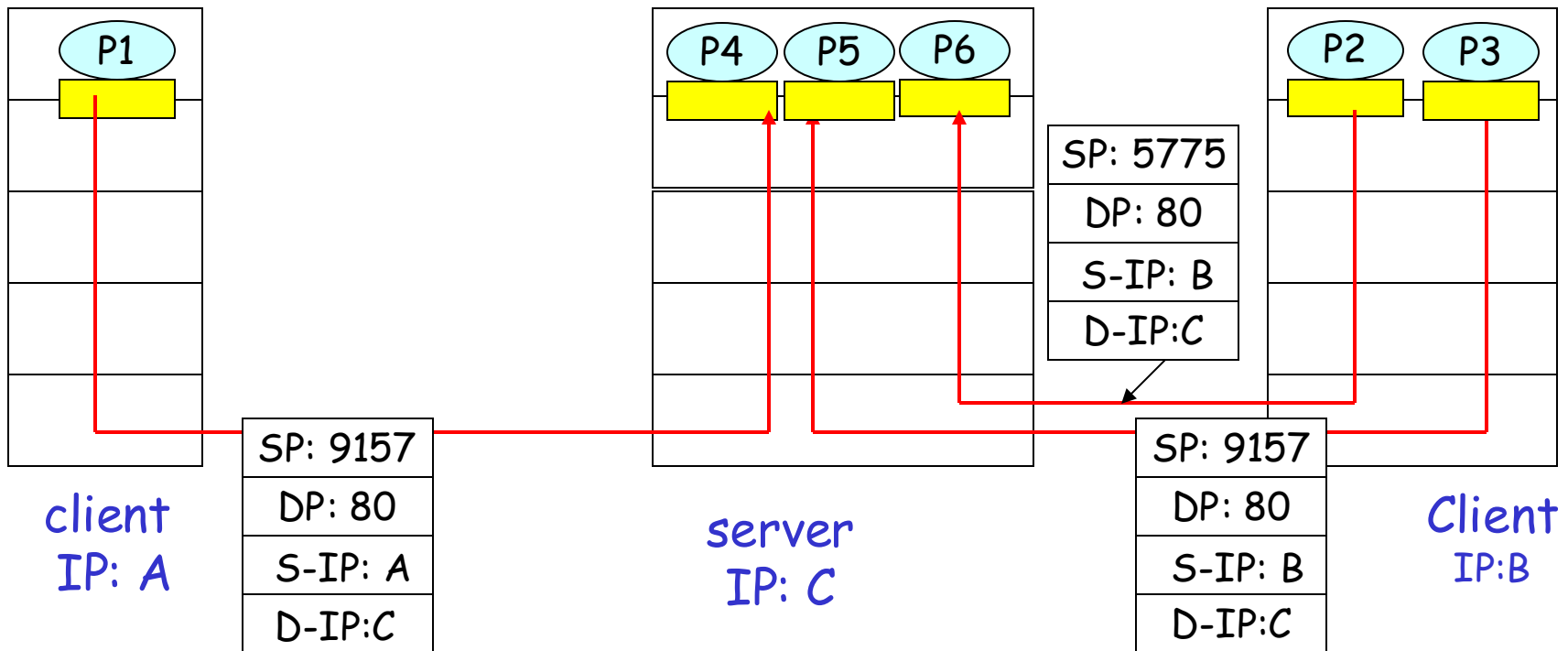
SP provides "return address"

Connection-oriented demux

- ❑ TCP socket identified by 4-tuple:
 - source IP address
 - source port number
 - dest IP address
 - dest port number
- ❑ recv host uses all four values to direct segment to appropriate socket
- ❑ Server host may support many simultaneous TCP sockets:
 - each socket identified by its own 4-tuple
- ❑ Web servers have different sockets for each connecting client
 - non-persistent HTTP will have different socket for each request

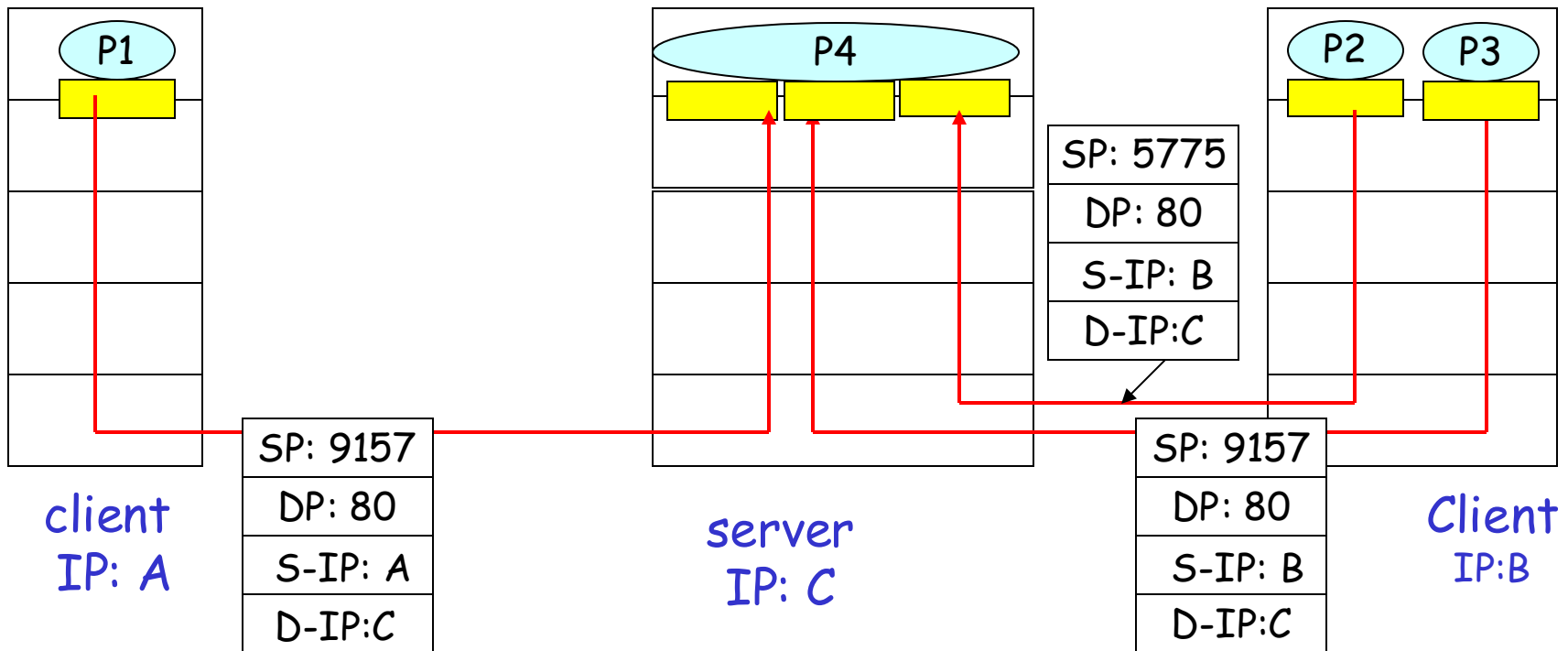
Connection-oriented demux (cont)

■ = socket ○ = process



Connection-oriented demux: Threaded Web Server

■ = socket ○ = process



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UDP: User Datagram Protocol [RFC 768]

- ❑ “no frills,” “bare bones”
Internet transport protocol
- ❑ “best effort” service, UDP segments may be:
 - lost
 - delivered out of order to app
- ❑ *connectionless*:
 - no handshaking between UDP sender, receiver
 - each UDP segment handled independently of others

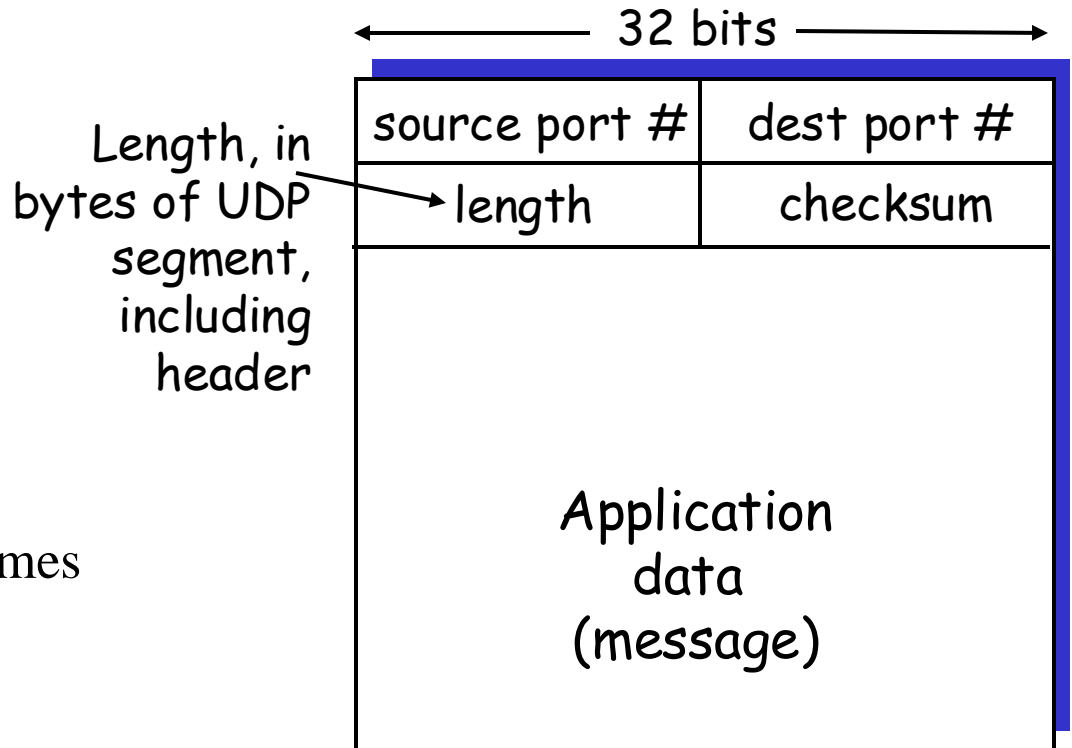
Why is there a UDP?

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

UDP: more

- ❑ often used for streaming multimedia apps
 - loss tolerant
 - rate sensitive

- ❑ other UDP uses
 - DNS
 - SNMP
 - Multi-player online games



UDP segment format

UDP checksum

Goal: detect “errors” (e.g., flipped bits) in transmitted segment

Sender:

- ❑ treat segment contents as sequence of 16-bit integers
- ❑ checksum: addition (1’s complement sum) of segment contents
- ❑ sender puts checksum value into UDP checksum field

Receiver:

- ❑ compute checksum of received segment
- ❑ check if computed checksum equals checksum field value:
 - NO - error detected
 - YES - no error detected. *But maybe errors nonetheless?* More later

UDP checksum

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	
	<hr/>																
wraparound	1	1	0	1	1	1	0	1	1	1	0	1	1	1	0	1	1
	<hr/>																
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

UDP 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	0
	1	1	0	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		

Diagram annotations: Red circles around the 15th and 16th bits of the two input numbers. Red arrows point from these circles to the 15th and 16th bits of the sum. A red arrow points from the 1st bit of the wraparound row to the 1st bit of the sum row. A red bracket on the right side groups the sum and checksum rows.

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