



Transport Layer



Chapter 3: Transport Layer

Our goals:

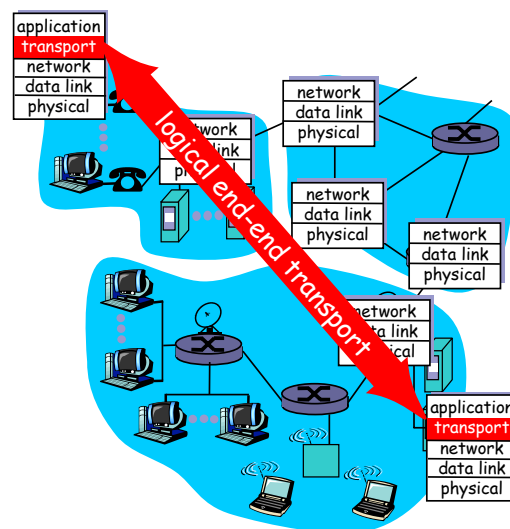
- understand principles behind transport layer services:
 - multiplexing/demultiplexing
 - reliable data transfer
 - flow control
 - congestion control
- learn about transport layer protocols in the Internet:
 - UDP: connectionless transport
 - TCP: connection-oriented transport
 - TCP congestion control

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
 - send side: breaks app messages into **segments**, passes to network layer
 - rcv side: reassembles segments into messages, passes to app layer
- more than one transport protocol available to apps
 - Internet: TCP and UDP

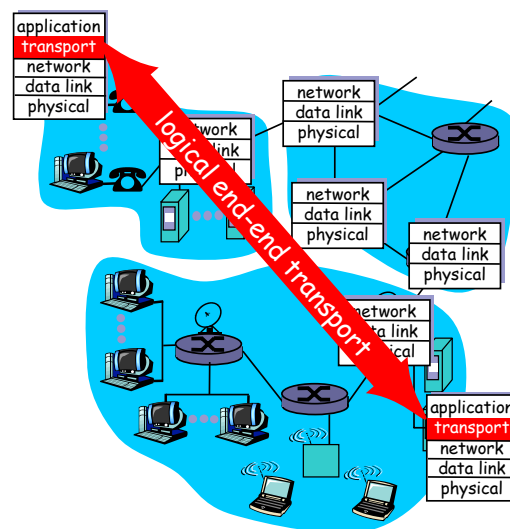


Transport vs. network layer

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

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

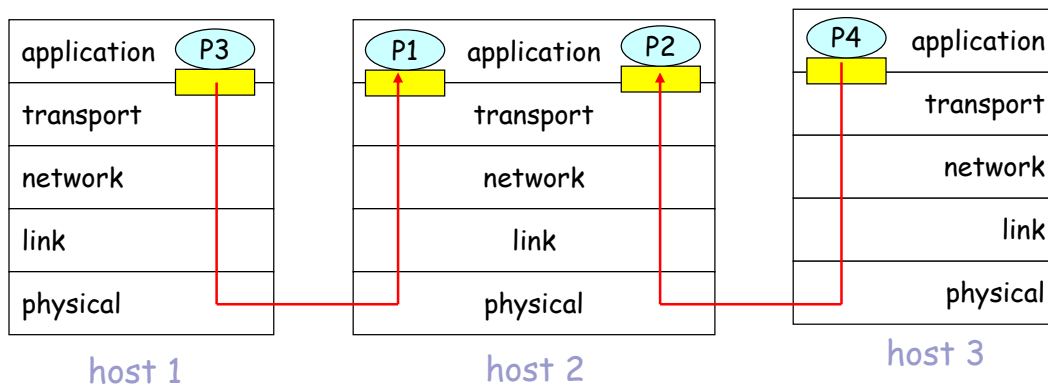
Demultiplexing at rcv host:

delivering received segments to correct socket

Multiplexing at send host:

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

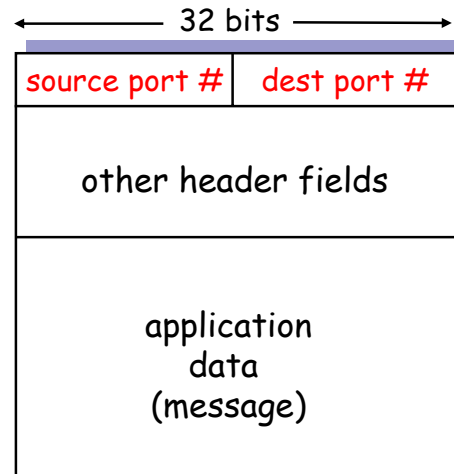
■ = socket ○ = process





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 (recall: well-known port numbers for specific applications)
- **host uses IP addresses & port numbers to direct segment to appropriate socket**



TCP/UDP segment format



Connectionless demultiplexing

- **Create sockets with port numbers:**

```
DatagramSocket mySocket1 = new  
    DatagramSocket(99111);
```

```
DatagramSocket mySocket2 = new  
    DatagramSocket(99222);
```

- **UDP socket identified by two-tuple:**

(dest IP address, dest port number)

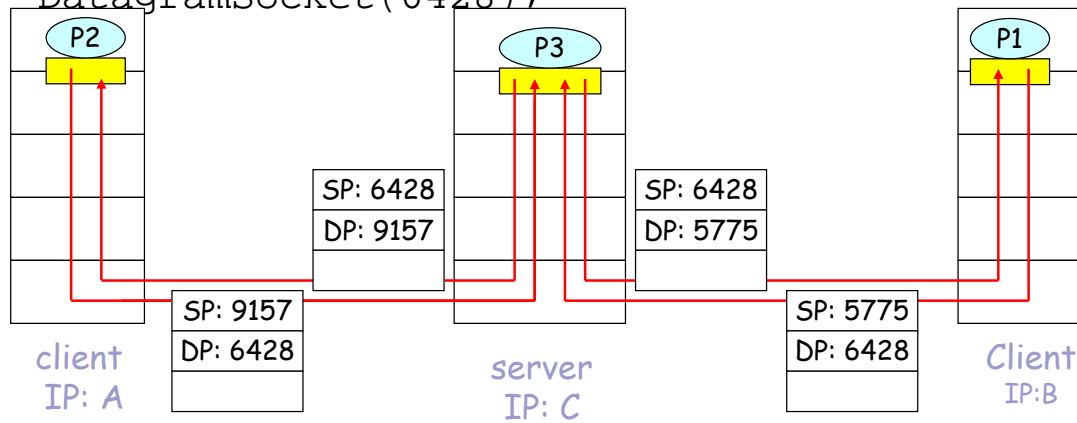
- **When host receives UDP segment:**

- 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)

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

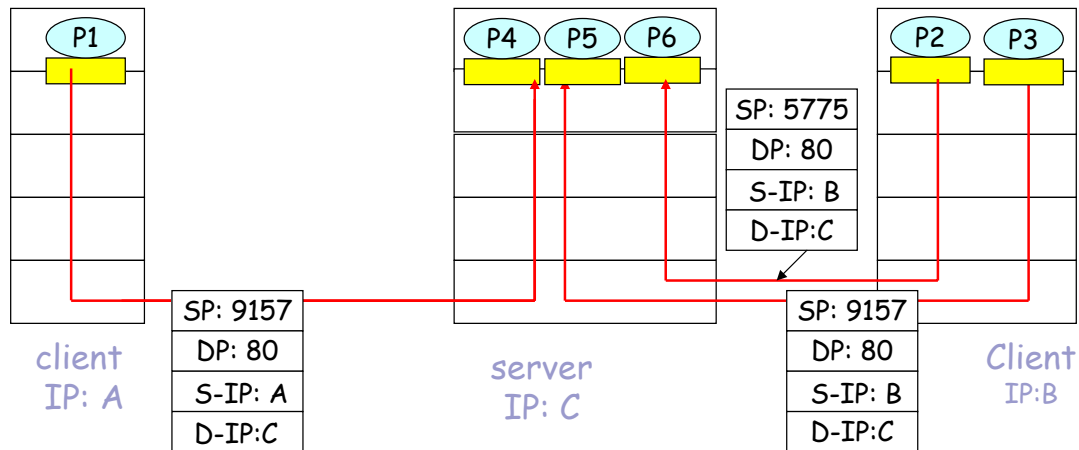


SP provides "return address"

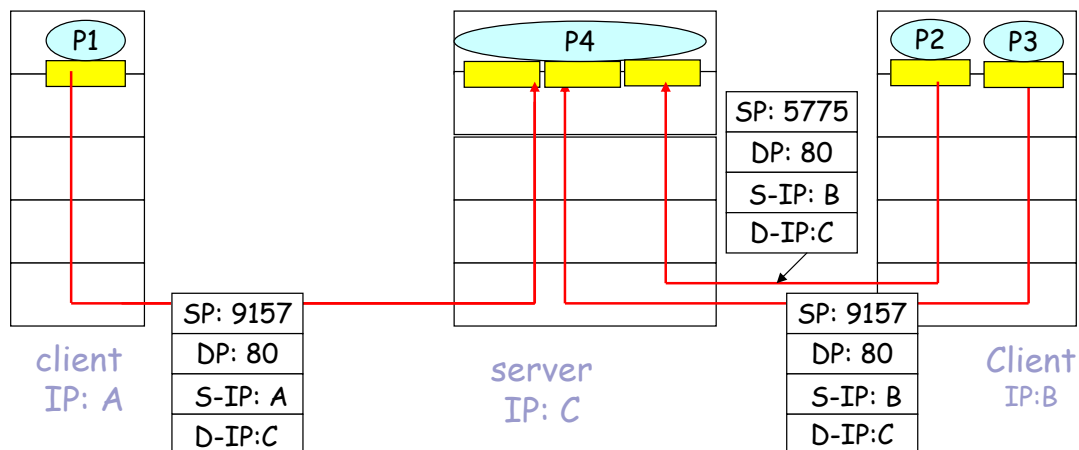
Connection-oriented demux

- 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)



Connection-oriented demux: Threaded Web Server





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UDP: User Datagram Protocol [RFC 768]

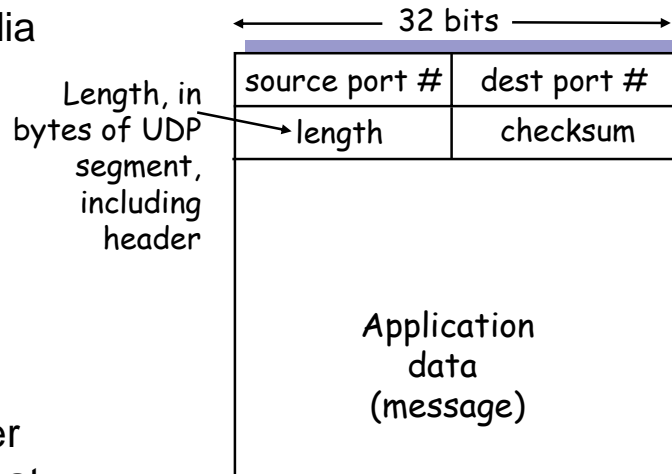
- “no frills,” “bare bones” Internet transport protocol
- “best effort” service, UDP segments may be:
 - lost
 - delivered out of order to app
- **connectionless:**
 - no handshaking between UDP sender, receiver
 - each UDP segment handled independently of others

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



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



Internet Checksum Example

- Note

- When adding numbers, a carryout from the most significant bit needs to be added to the result

- 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