

Chapter 3

Transport Layer

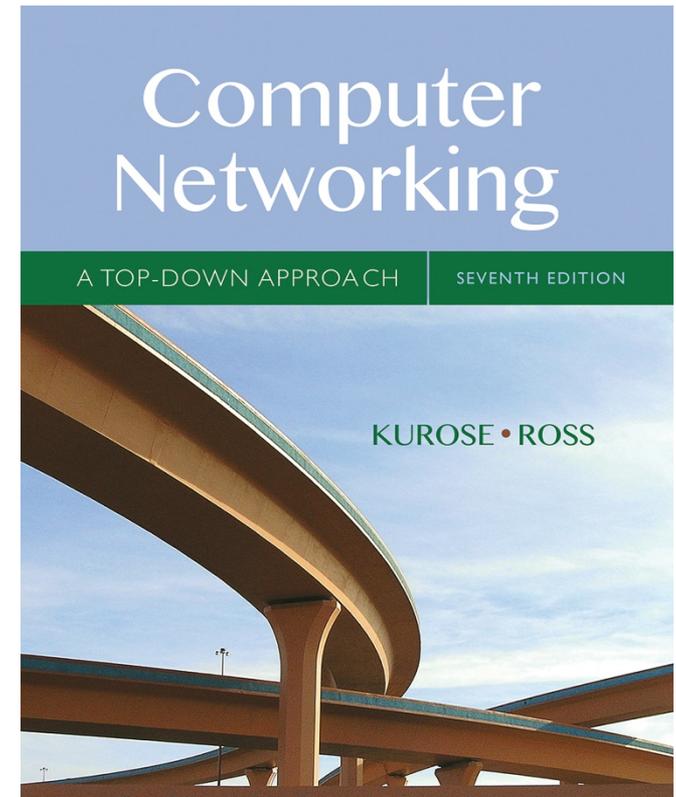
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Computer Networking: A Top Down Approach

7th edition

Jim Kurose, Keith Ross

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Chapter 3: Transport Layer

our goals:

- 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

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

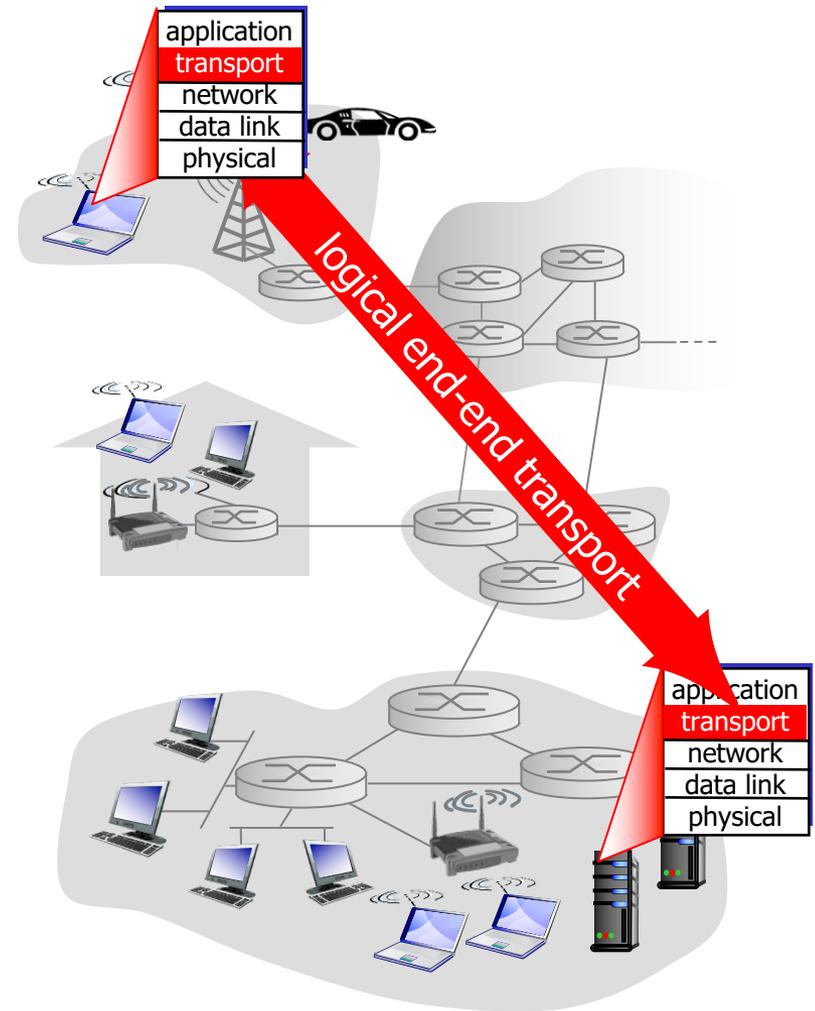
- segment structure
- reliable data transfer
- flow control
- connection management

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

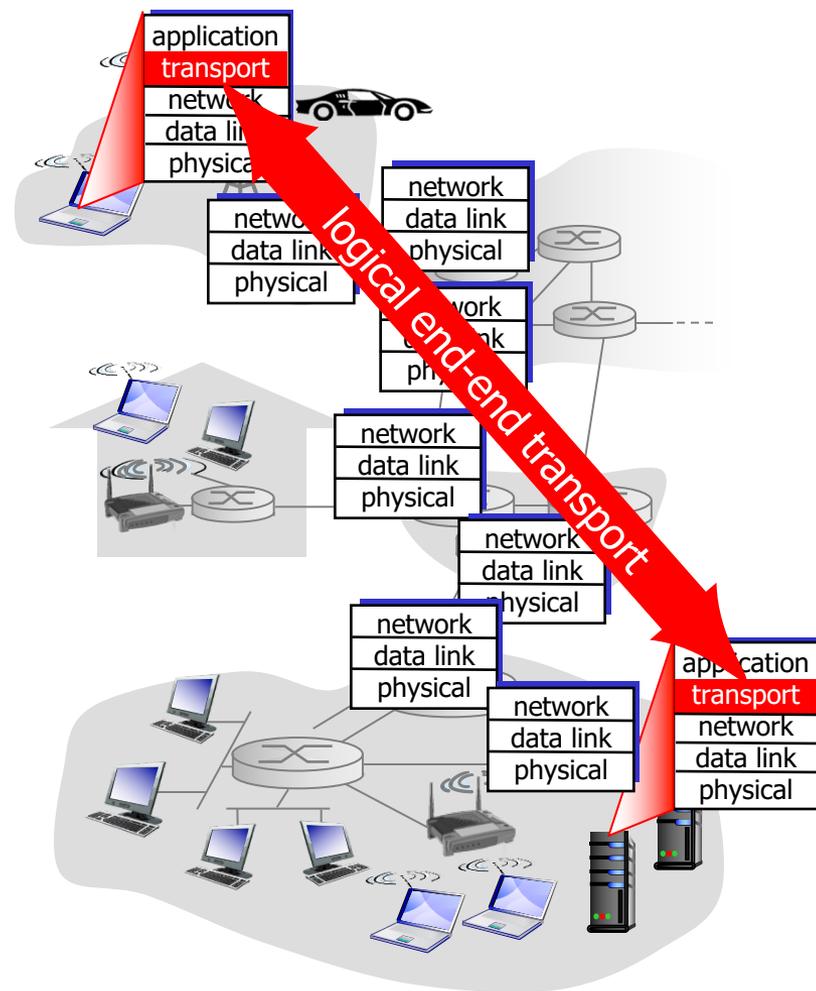
household analogy:

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

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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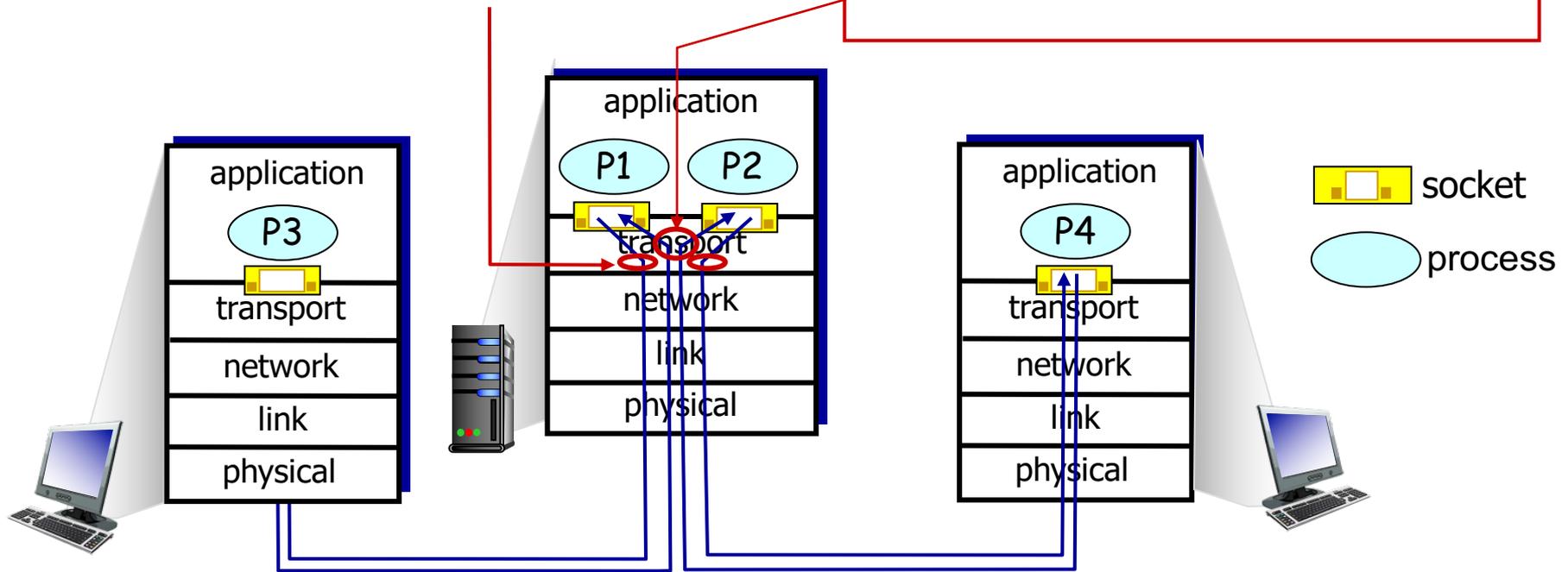
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Multiplexing/demultiplexing

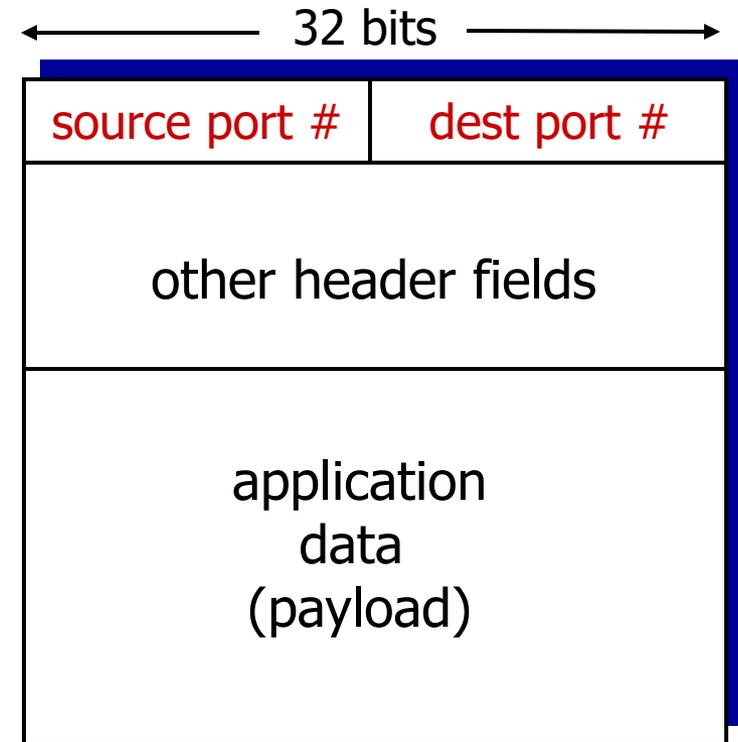
multiplexing at sender:
handle data from multiple sockets, add transport header (later used for demultiplexing)

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

- *recall*: created socket has host-local port #:

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

- *recall*: when creating datagram to send into UDP socket, must specify

- destination IP address
- destination port #

-
- when host receives UDP segment:

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



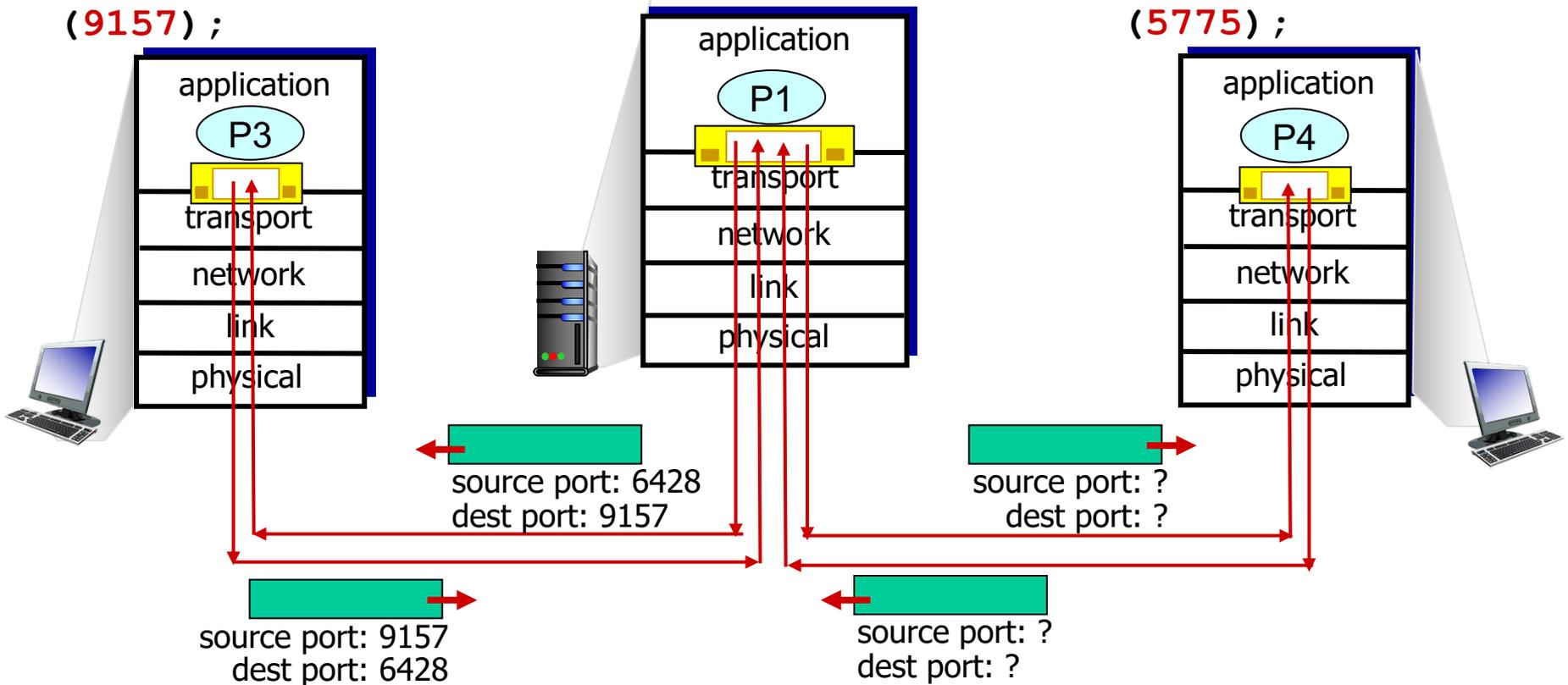
IP datagrams with *same dest. port #*, but different source IP addresses and/or source port numbers will be directed to *same socket* at dest

Connectionless demux: example

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

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

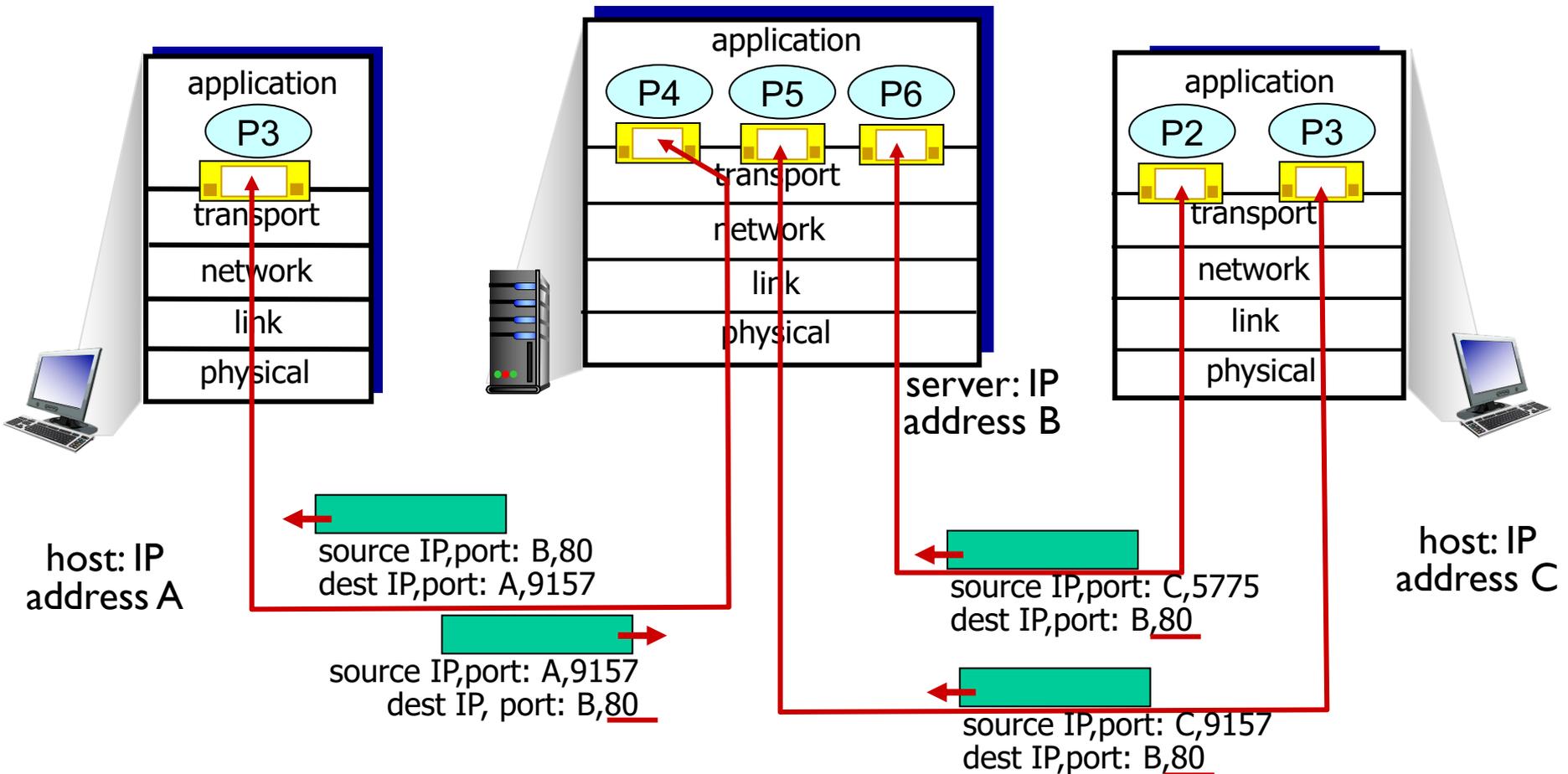
```
DatagramSocket  
mySocket1 = new  
DatagramSocket  
(5775);
```



Connection-oriented demux

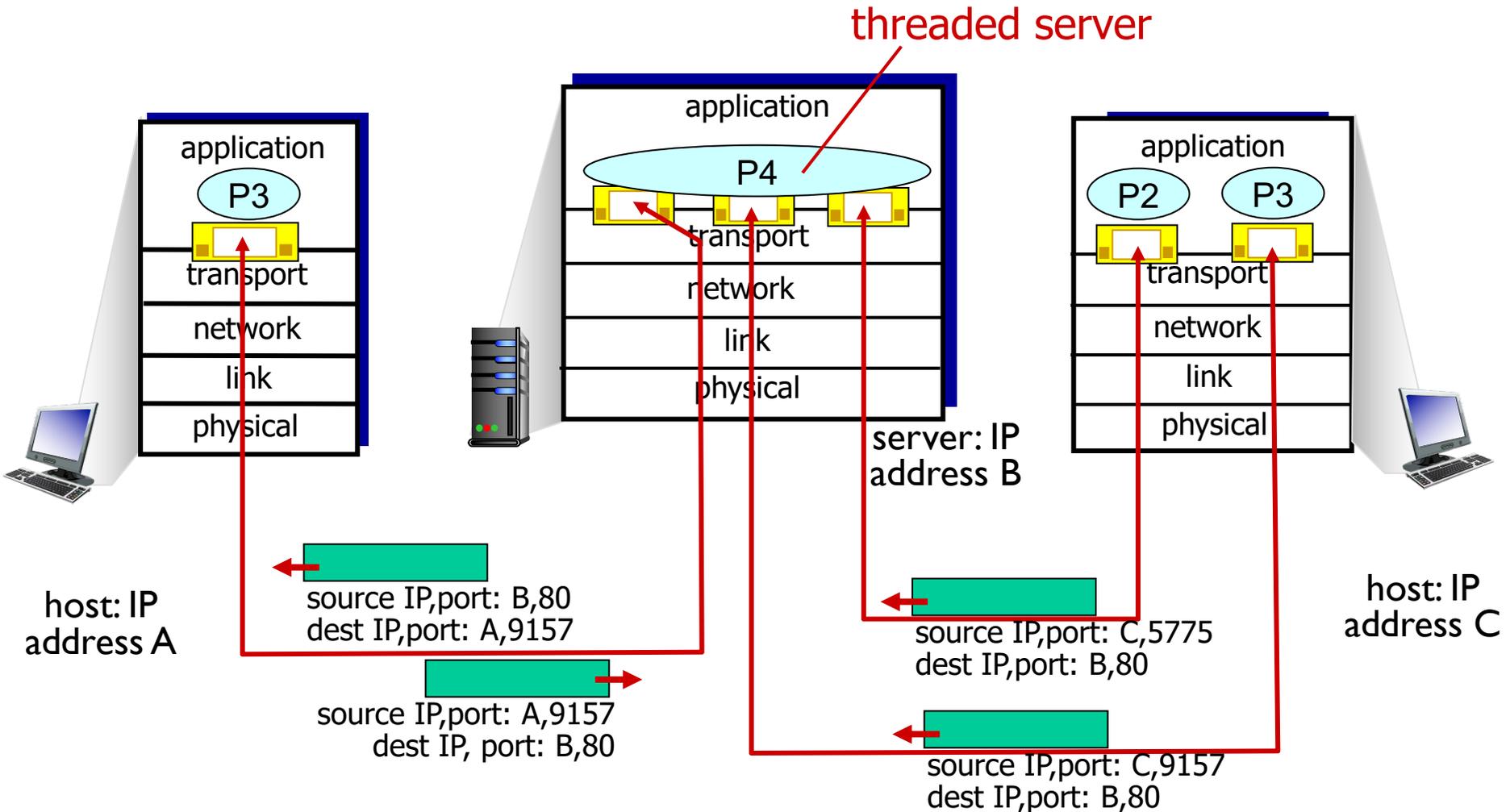
- TCP socket identified by 4-tuple:
 - source IP address
 - source port number
 - dest IP address
 - dest port number
- demux: receiver uses all four values to direct segment to appropriate socket
- server host may support many simultaneous TCP sockets:
 - each socket identified by its own 4-tuple
-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

Connection-oriented demux: example



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

Connection-oriented demux: example



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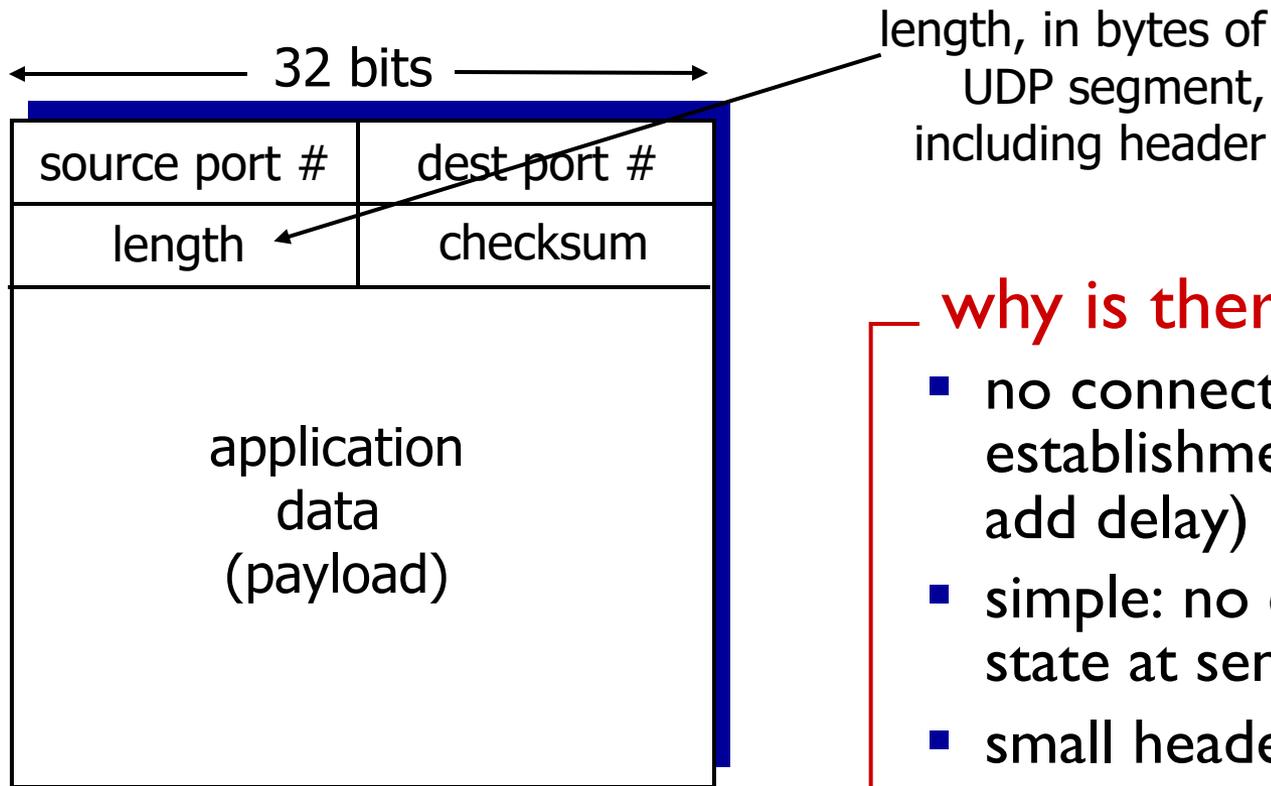
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UDP: User Datagram Protocol [RFC 768]

- “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
- UDP use:
 - streaming multimedia apps (loss tolerant, rate sensitive)
 - DNS
 - SNMP
- reliable transfer over UDP:
 - add reliability at application layer
 - application-specific error recovery!

UDP: segment header



UDP segment format

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 checksum

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

sender:

- treat segment contents, including header fields, as sequence of 16-bit integers
- checksum: addition (one’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

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

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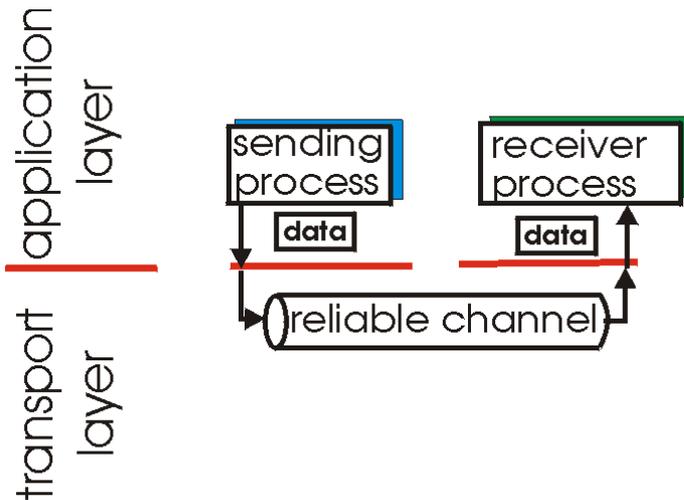
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Principles of reliable data transfer

- important in application, transport, link layers
 - top-10 list of important networking topics!

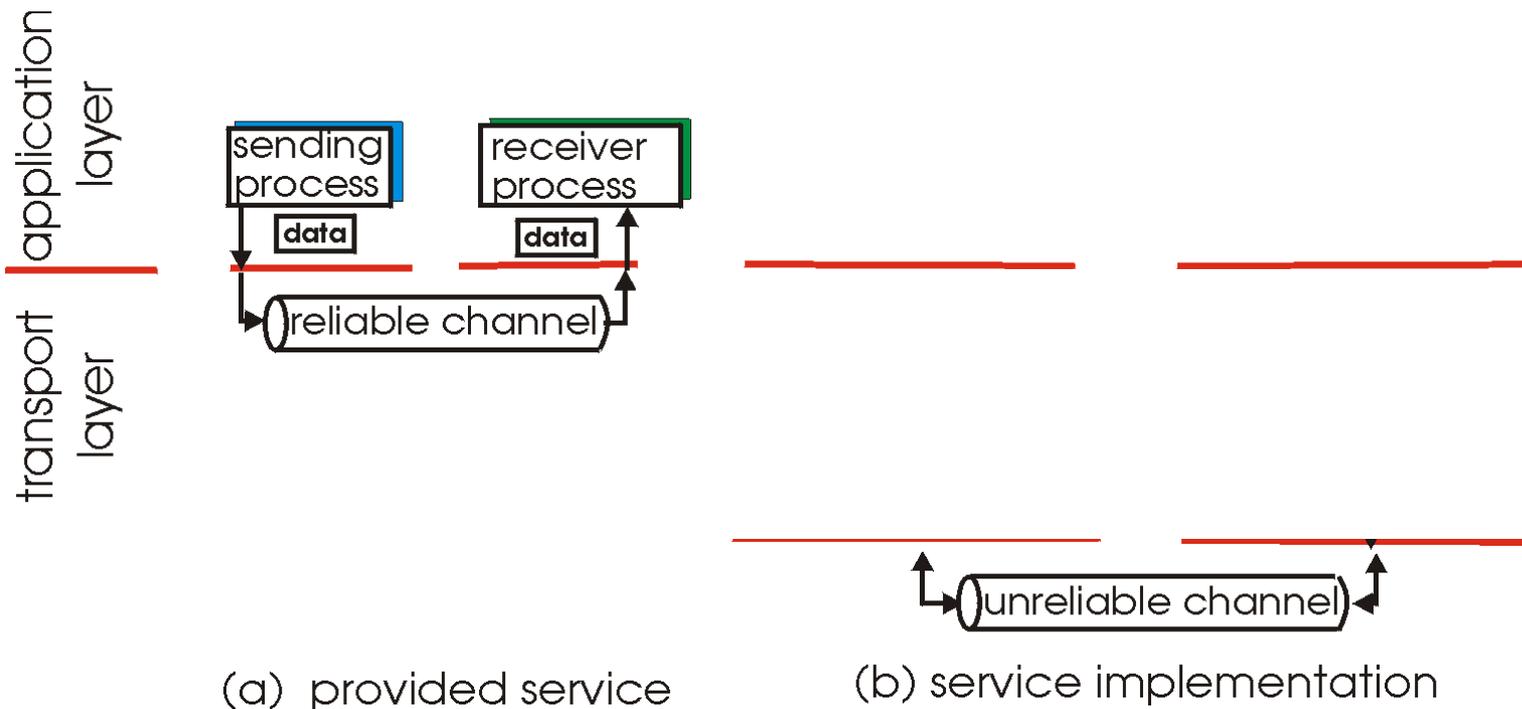


(a) provided service

- characteristics of unreliable channel will determine complexity of reliable data transfer protocol (rdt)

Principles of reliable data transfer

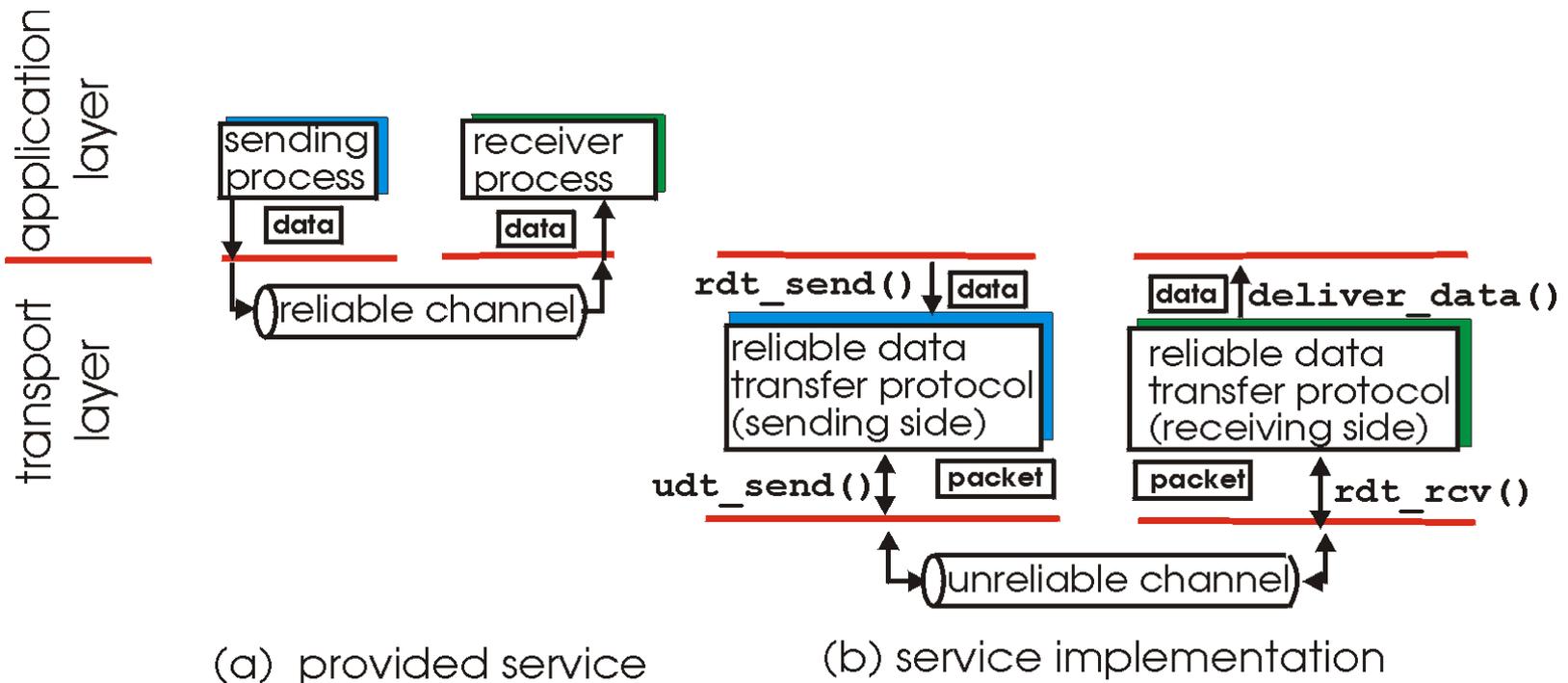
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Principles of reliable data transfer

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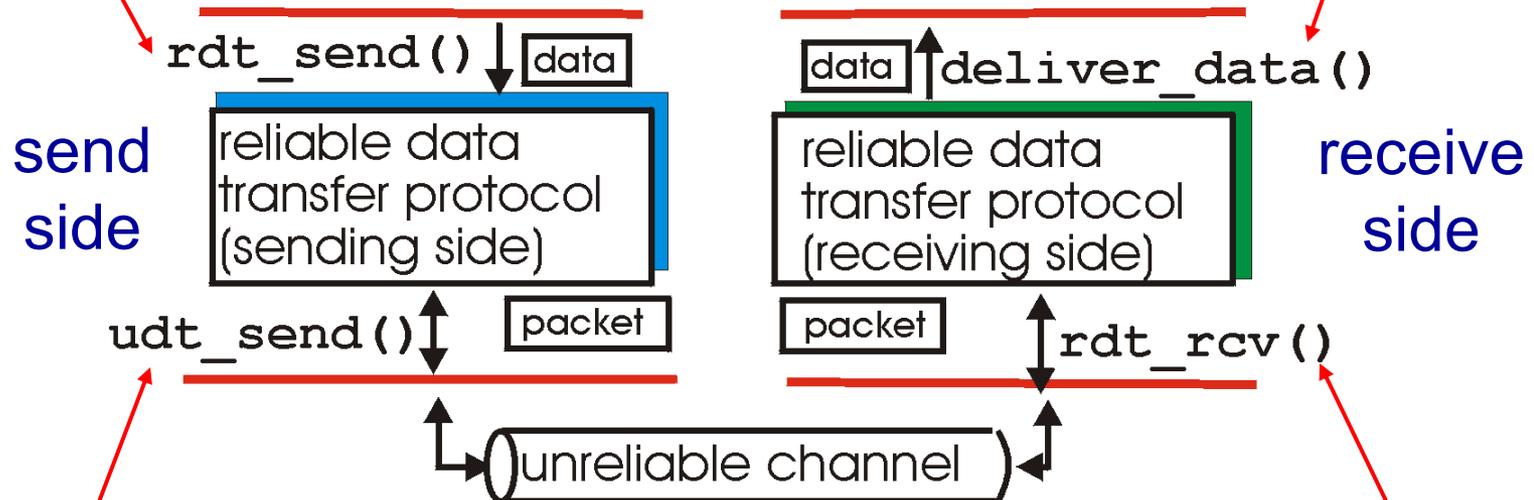


- characteristics of unreliable channel will determine complexity of reliable data transfer protocol (rdt)

Reliable data transfer: getting started

rdt_send() : called from above, (e.g., by app.). Passed data to deliver to receiver upper layer

deliver_data() : called by **rdt** to deliver data to upper



udt_send() : called by rdt, to transfer packet over unreliable channel to receiver

rdt_rcv() : called when packet arrives on rcv-side of channel

Reliable data transfer: getting started

we' ll:

- incrementally develop sender, receiver sides of reliable data transfer protocol (rdt)
- consider only unidirectional data transfer
 - but control info will flow on both directions!
- use finite state machines (FSM) to specify sender, receiver

state: when in this “state” next state uniquely determined by next event

