MAC0352 - Redes de Computadores e Sistemas Distribuídos

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IME - USP, 25 de Maio de 2021

Roteiro

Introdução à camada de transporte

UDP

Introdução à camada de transporte

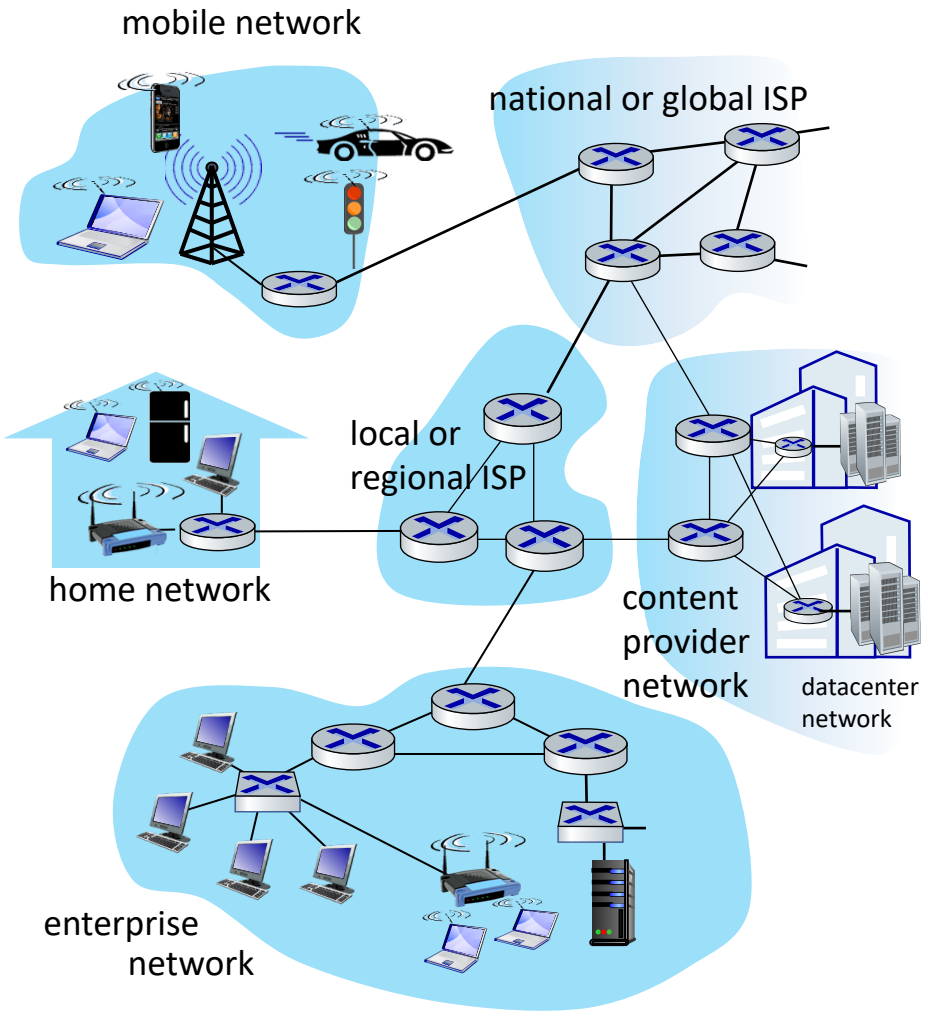
Transport layer: overview

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 services and protocols

- provide *logical communication* between application processes running on different hosts



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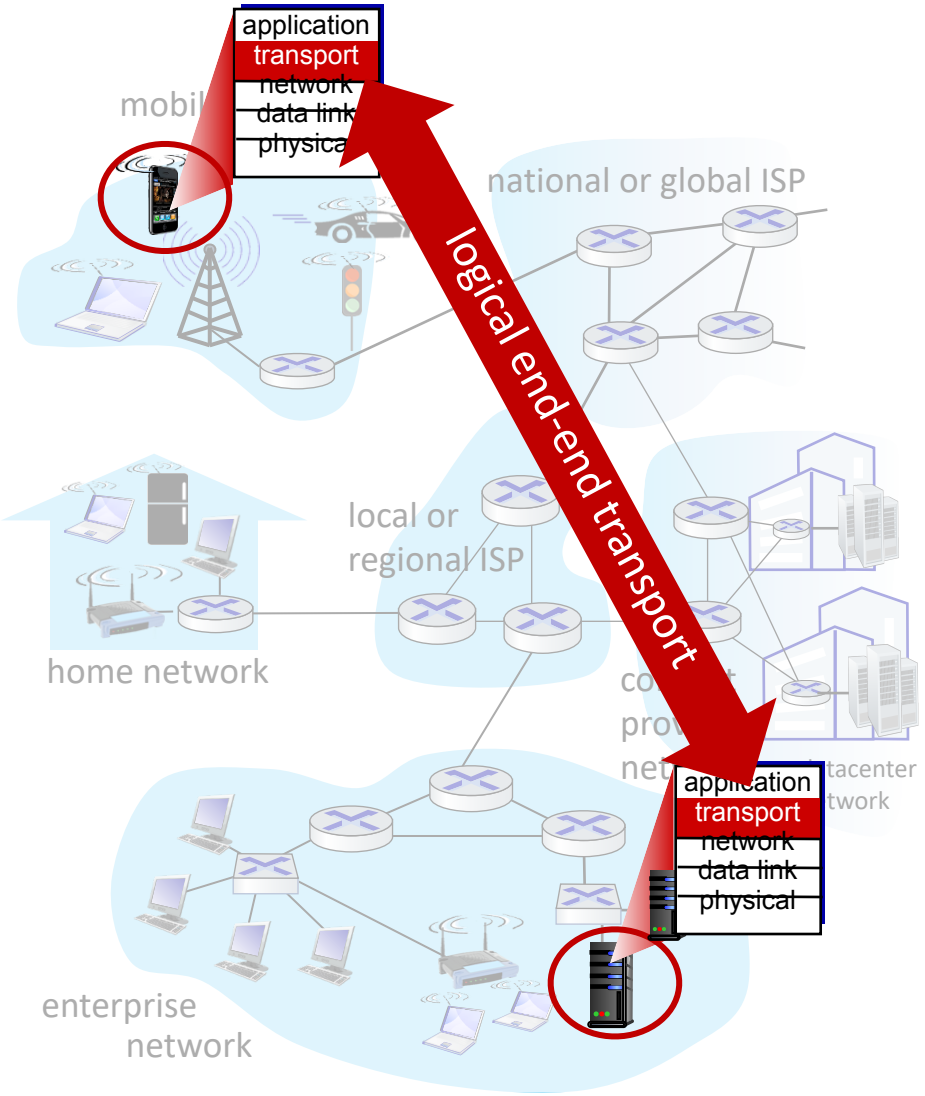

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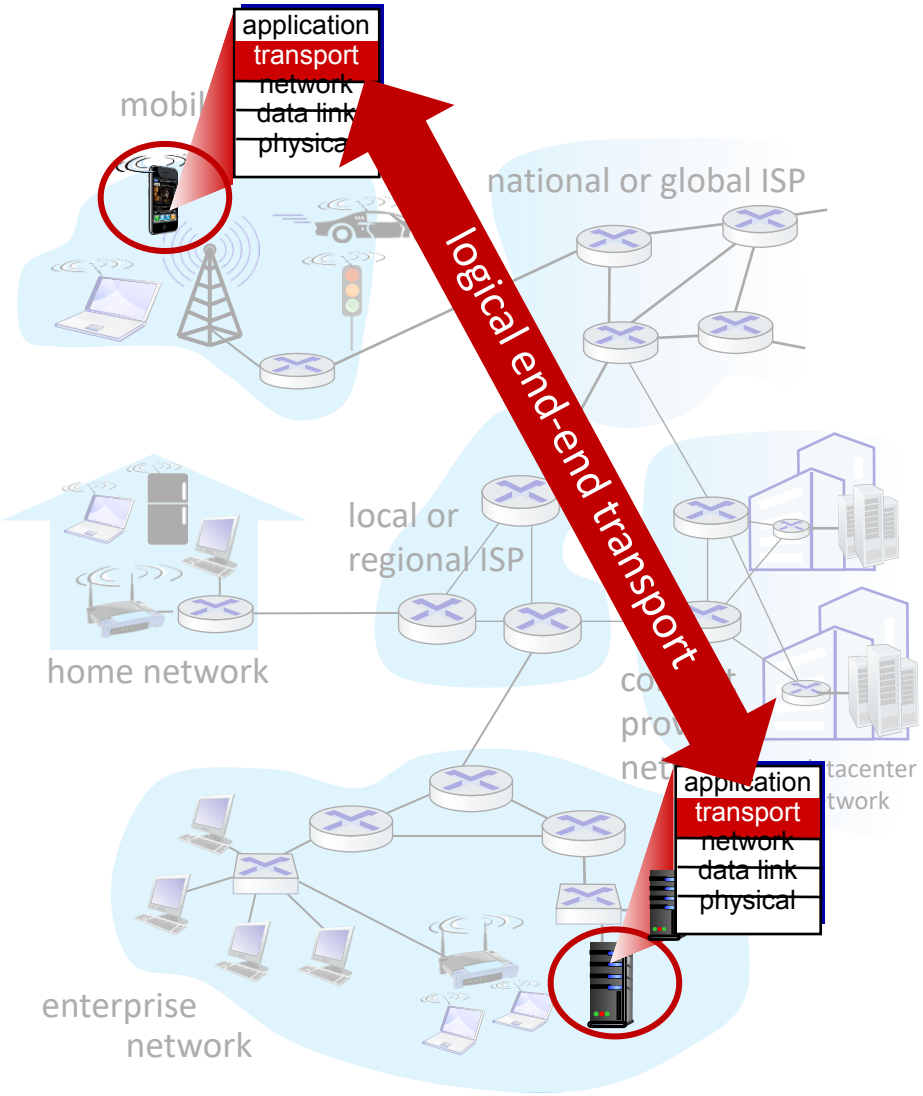
  - sender: breaks application messages into *segments*, passes to network layer
  - receiver: reassembles segments into messages, passes to application layer



Transport services and protocols

- provide *logical communication* between application processes running on different hosts
- transport protocols actions in end systems:
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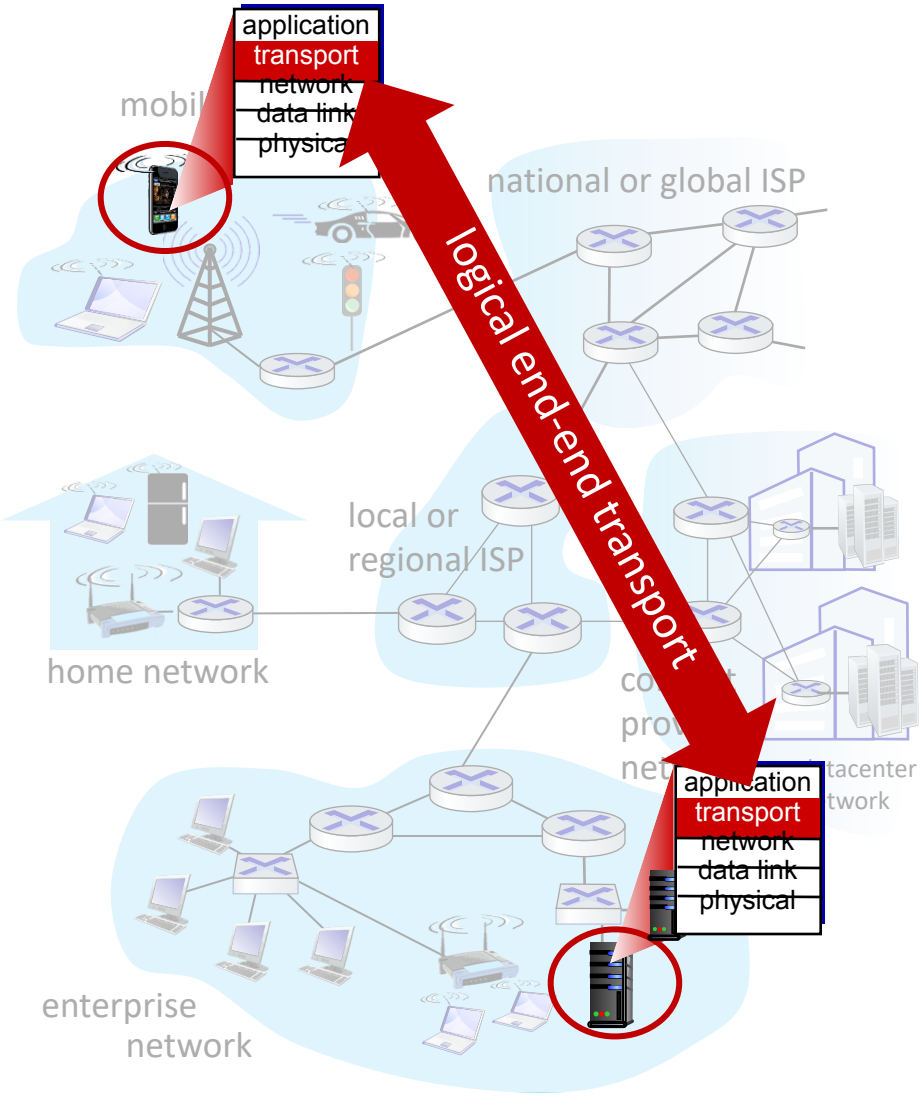
- two transport protocols available to Internet applications
  - TCP, UDP



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 protocol = Ann and Bill

Transport vs. network layer services and protocols

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

household analogy:

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- hosts = houses
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- transport protocol = Ann and Bill who demux to in-house siblings
- network-layer protocol = postal service

Transport Layer Actions

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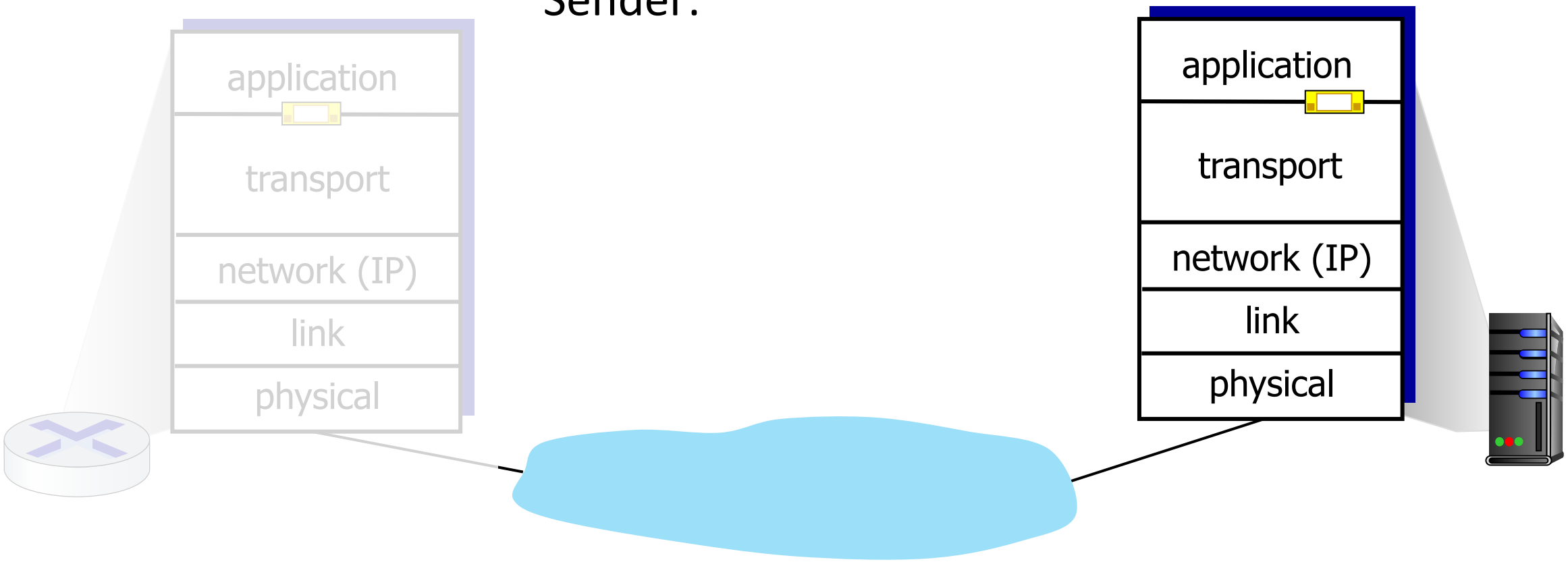

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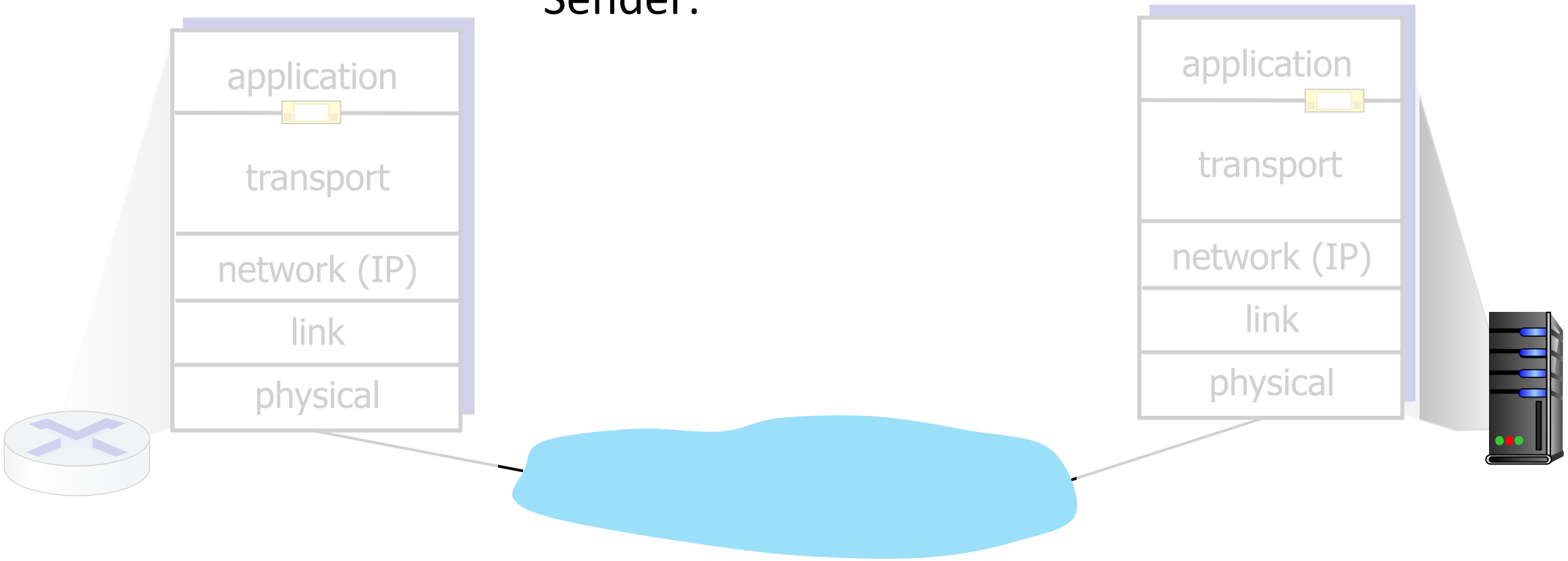

Transport Layer Actions

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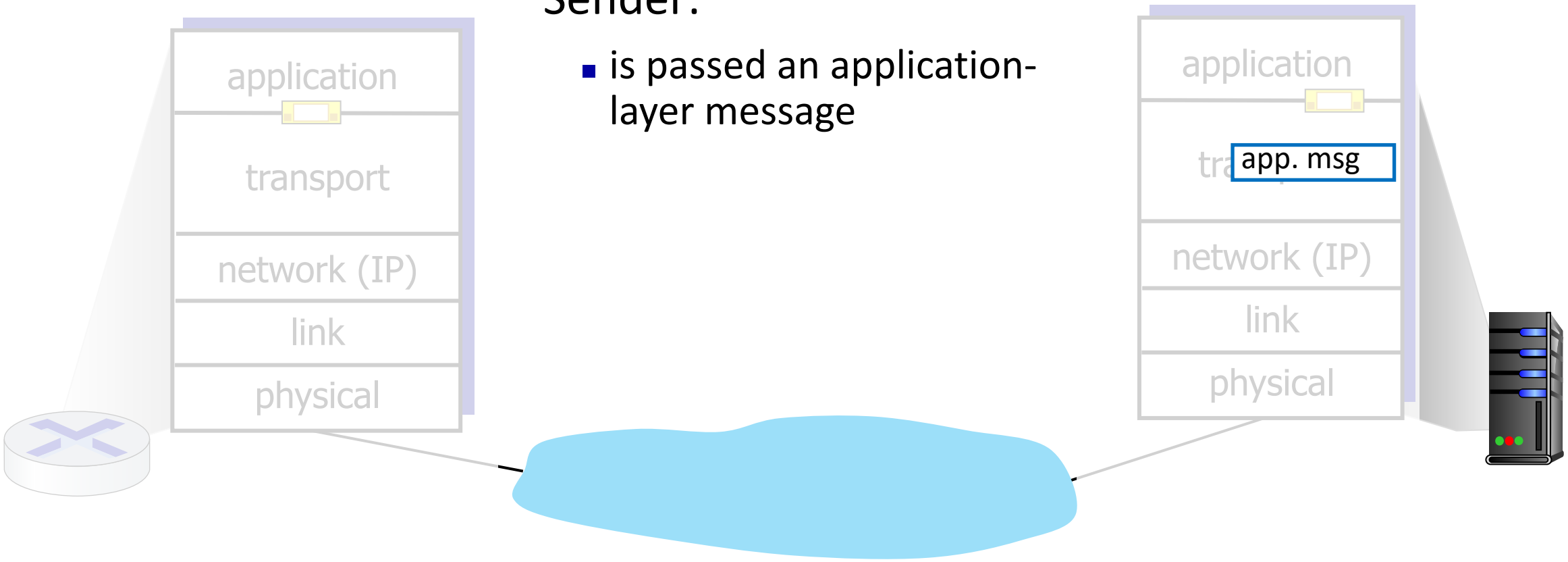

Transport Layer Actions

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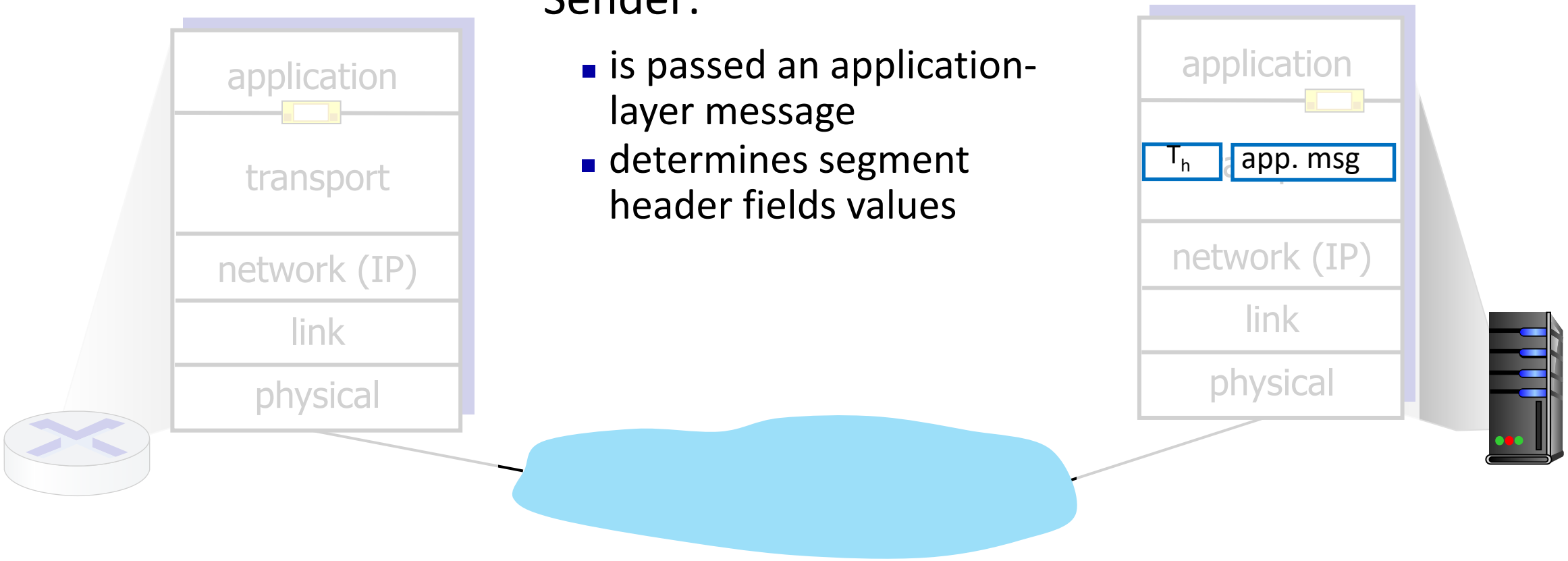
- determines segment header fields values



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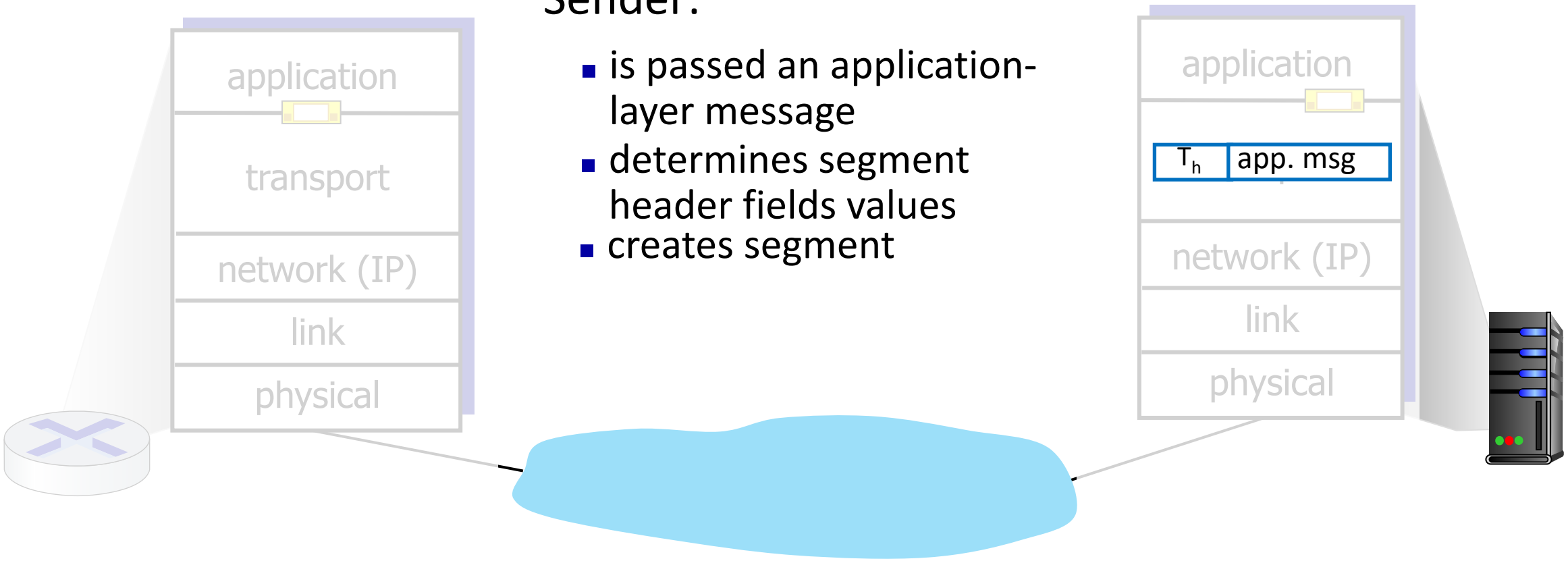

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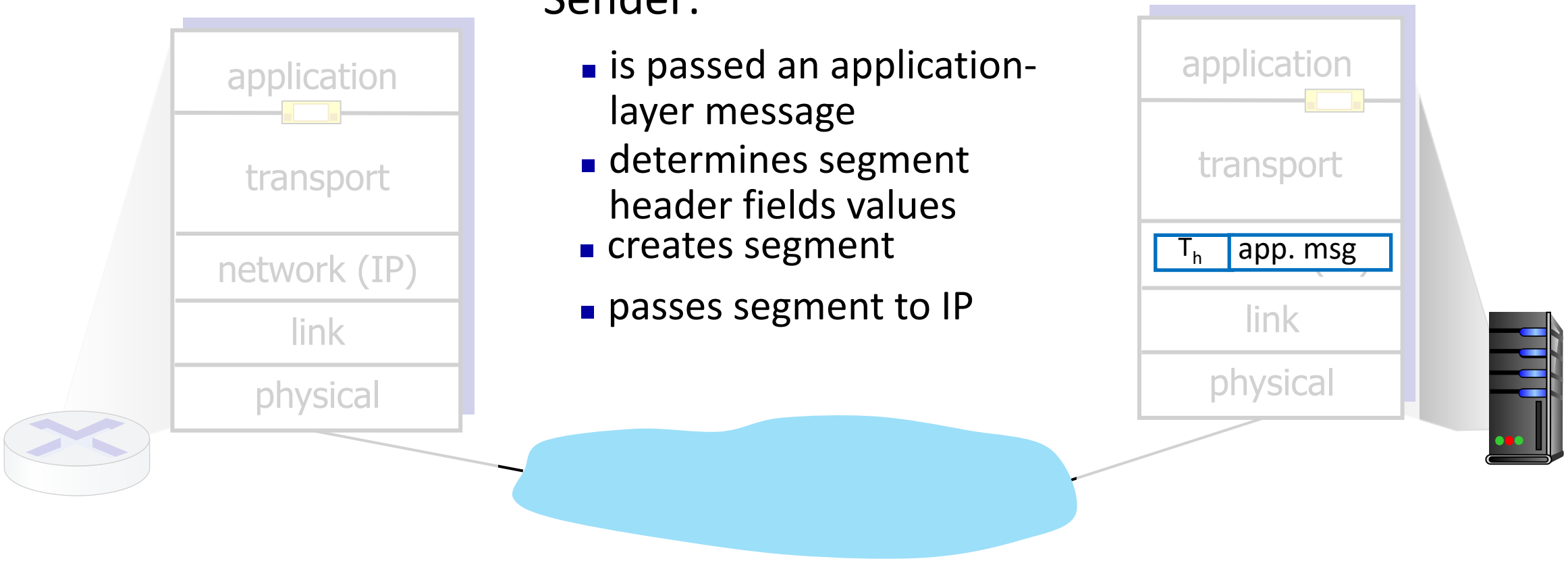

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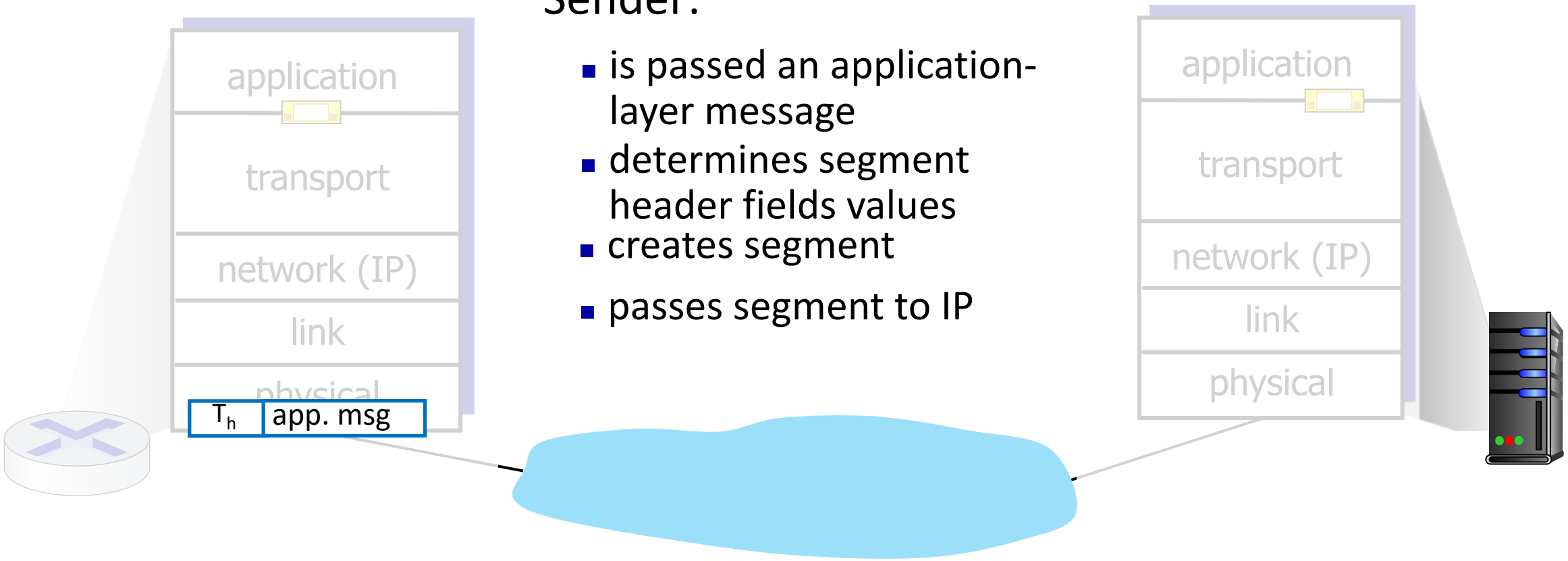

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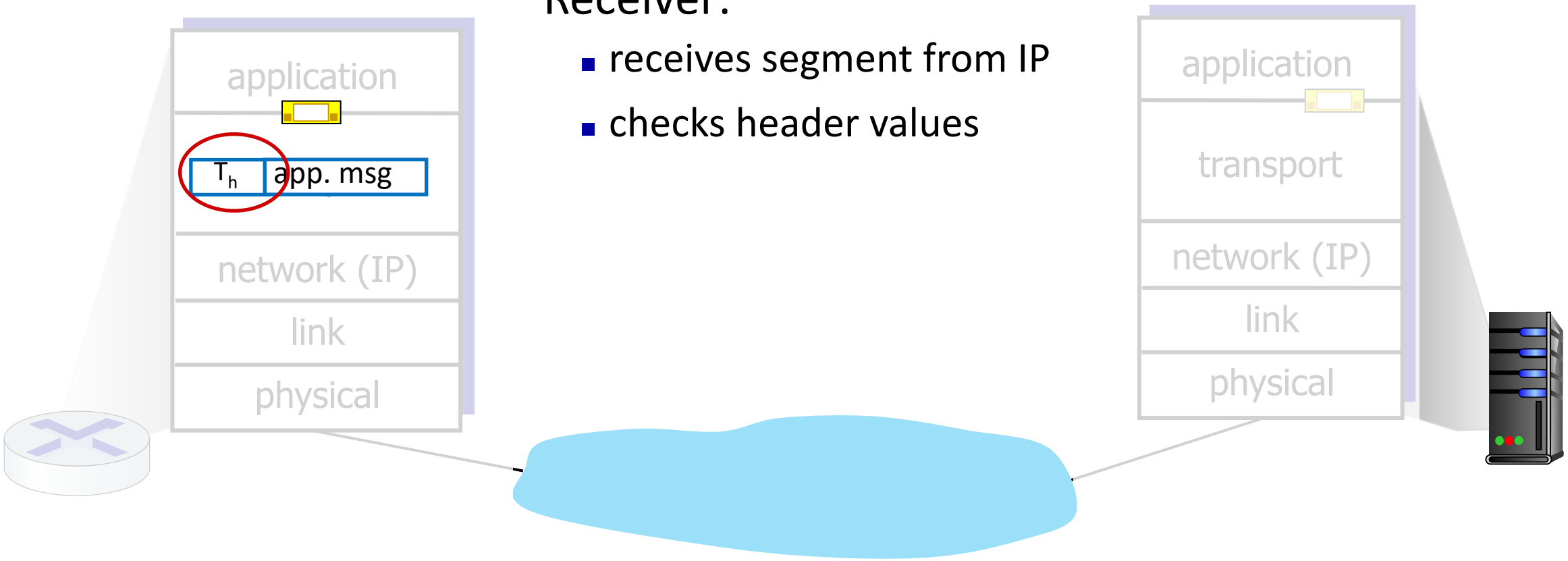

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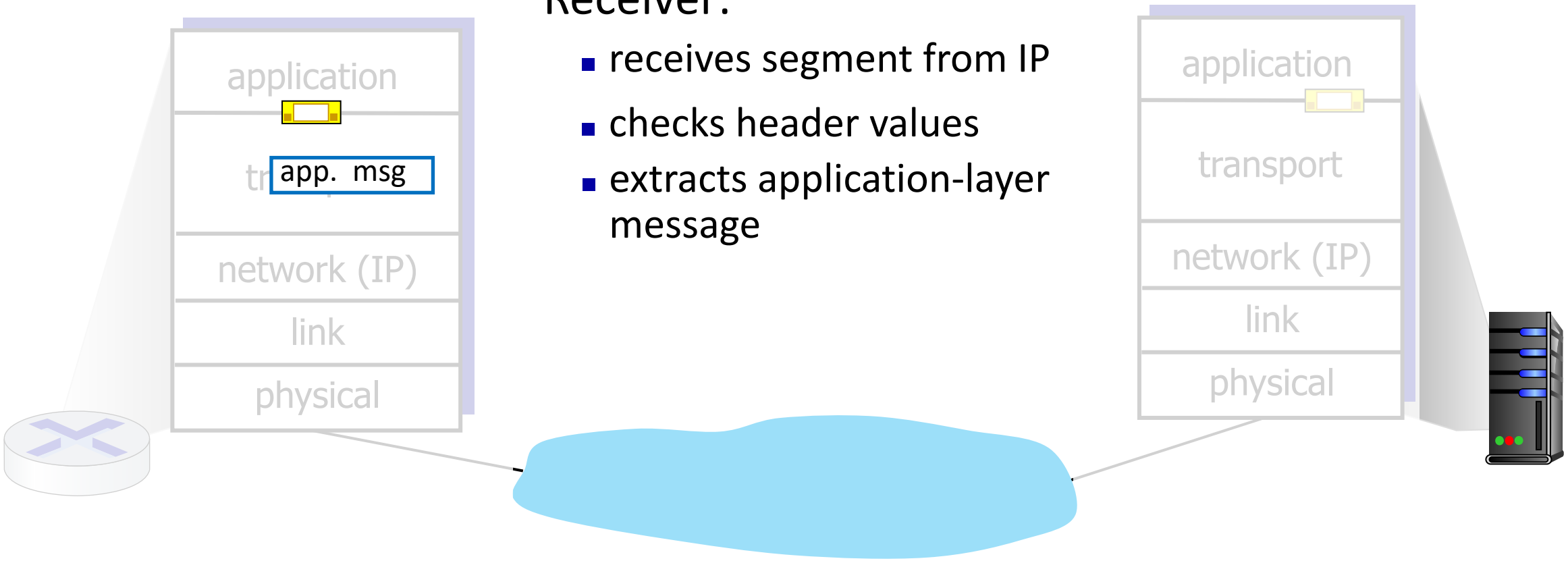

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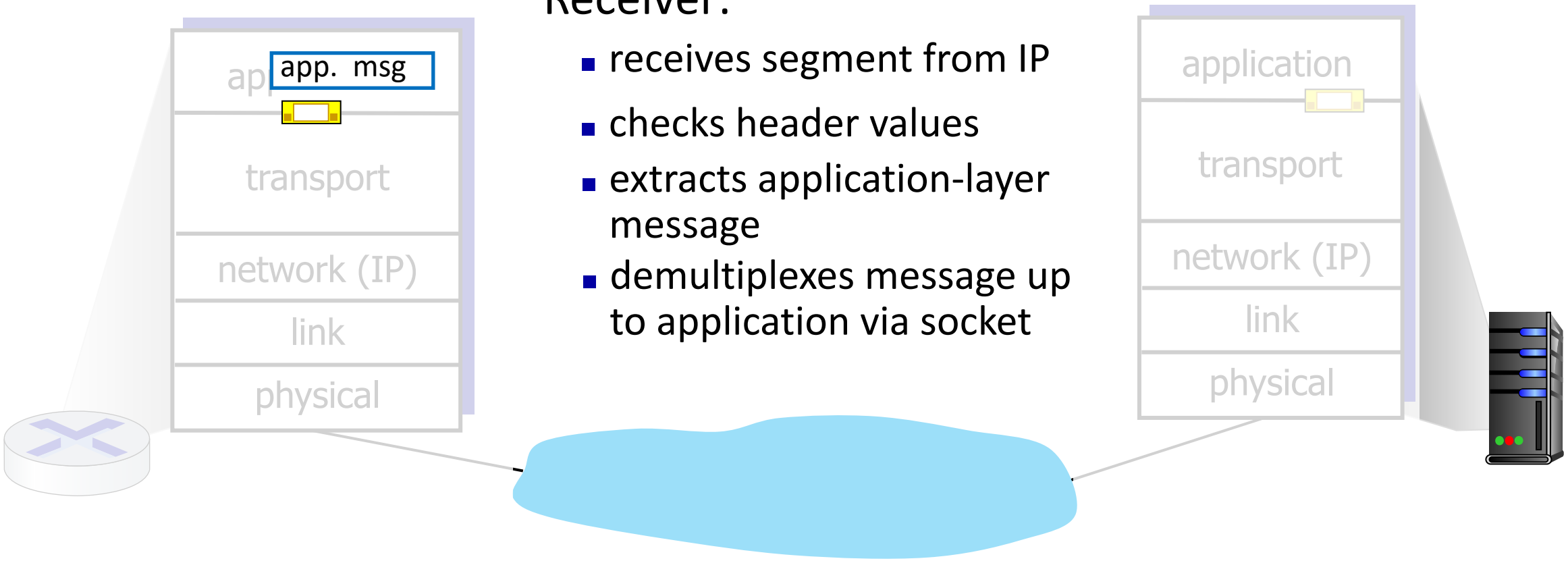

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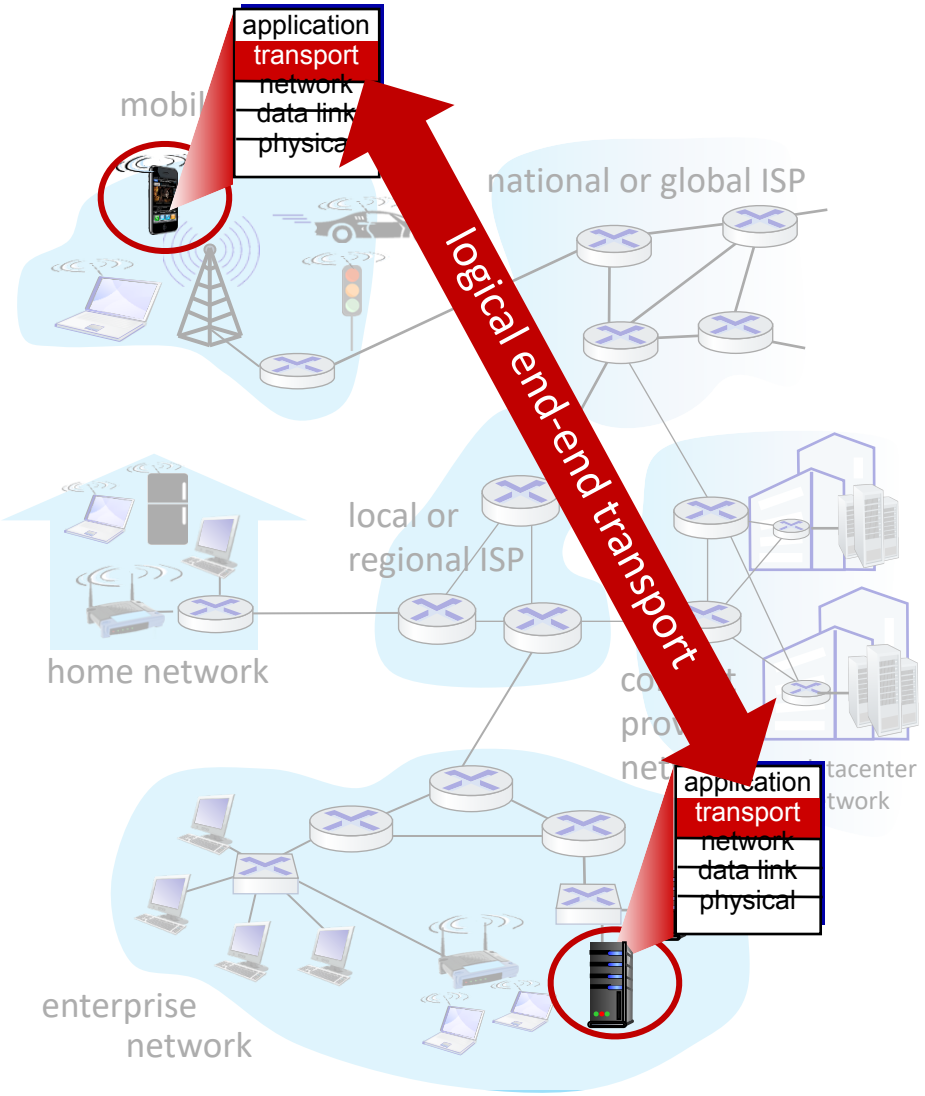
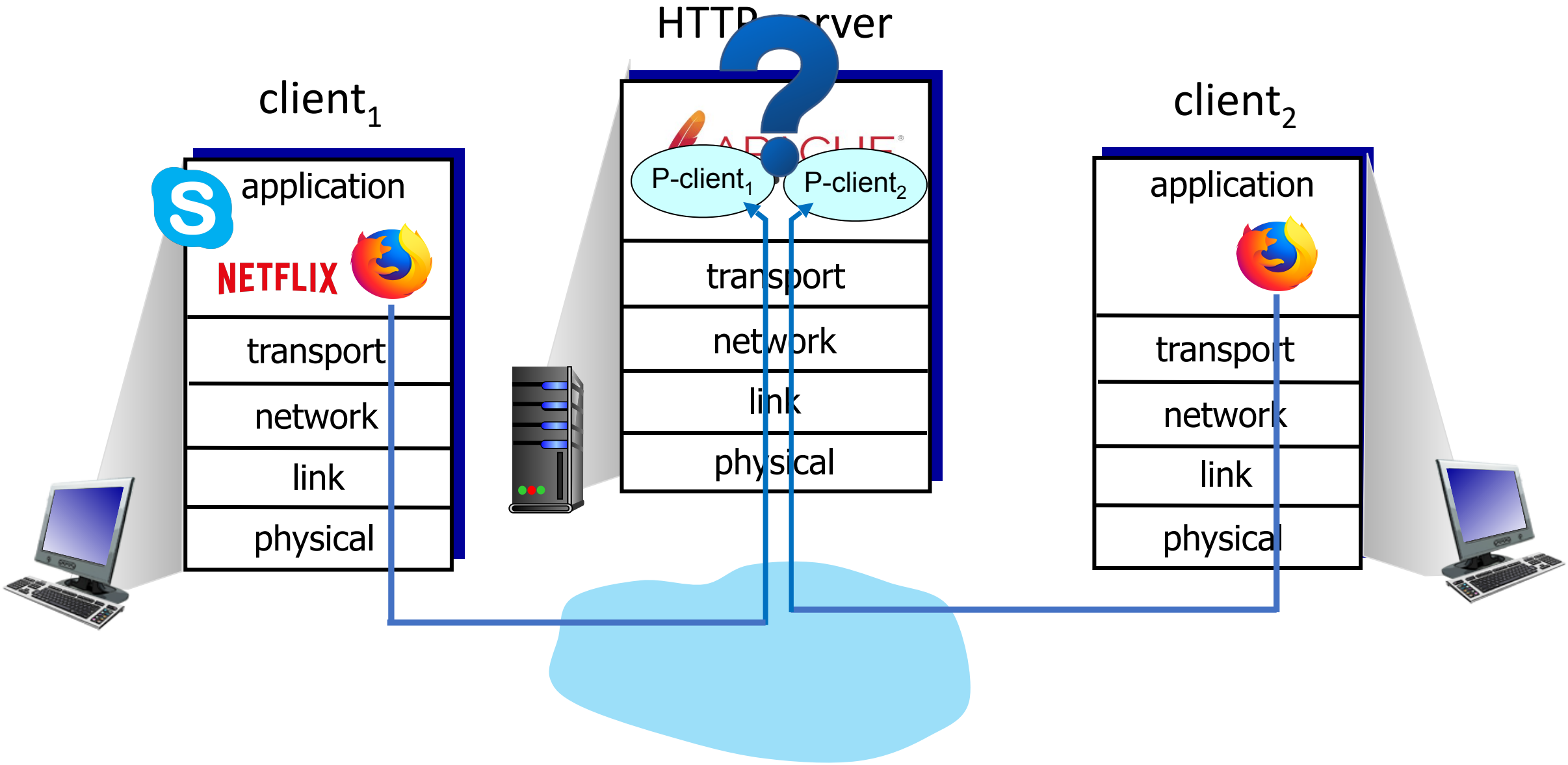
- demultiplexes message up to application via socket

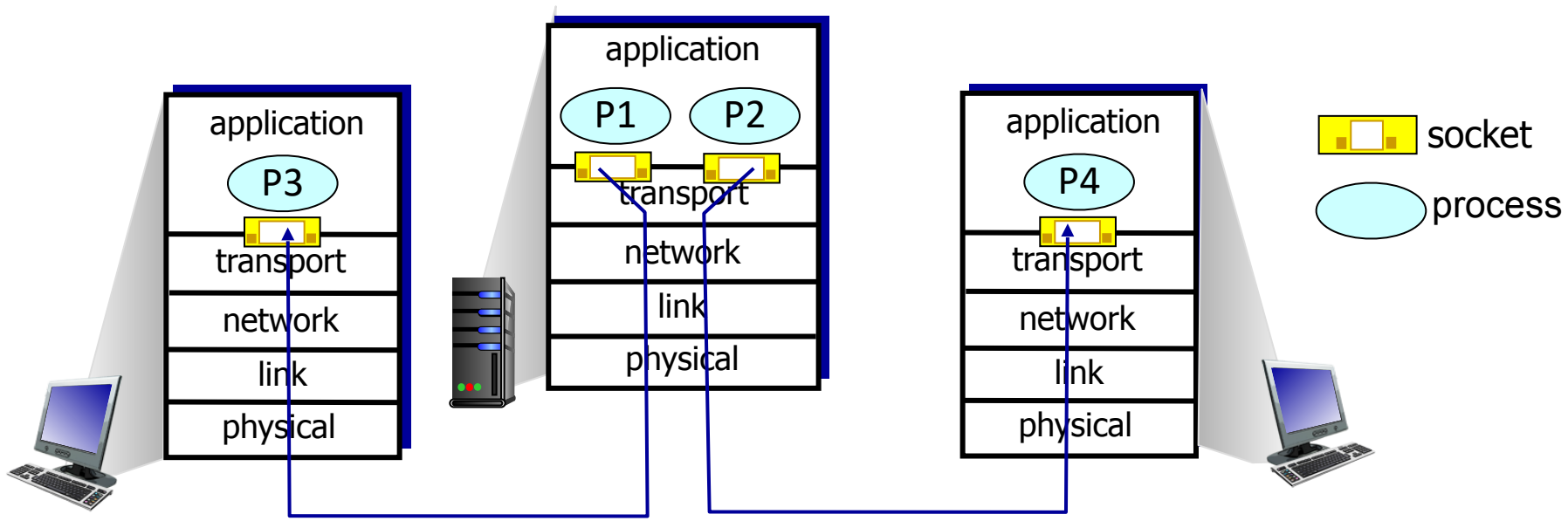
Two principal Internet transport protocols

- **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




client1
application
NETFLIX
transport
network
link
physical
HTTP server
P-client1
P-client2
transport
network
link
physical
client2
application
transport
network
link
physical

Multiplexing/demultiplexing



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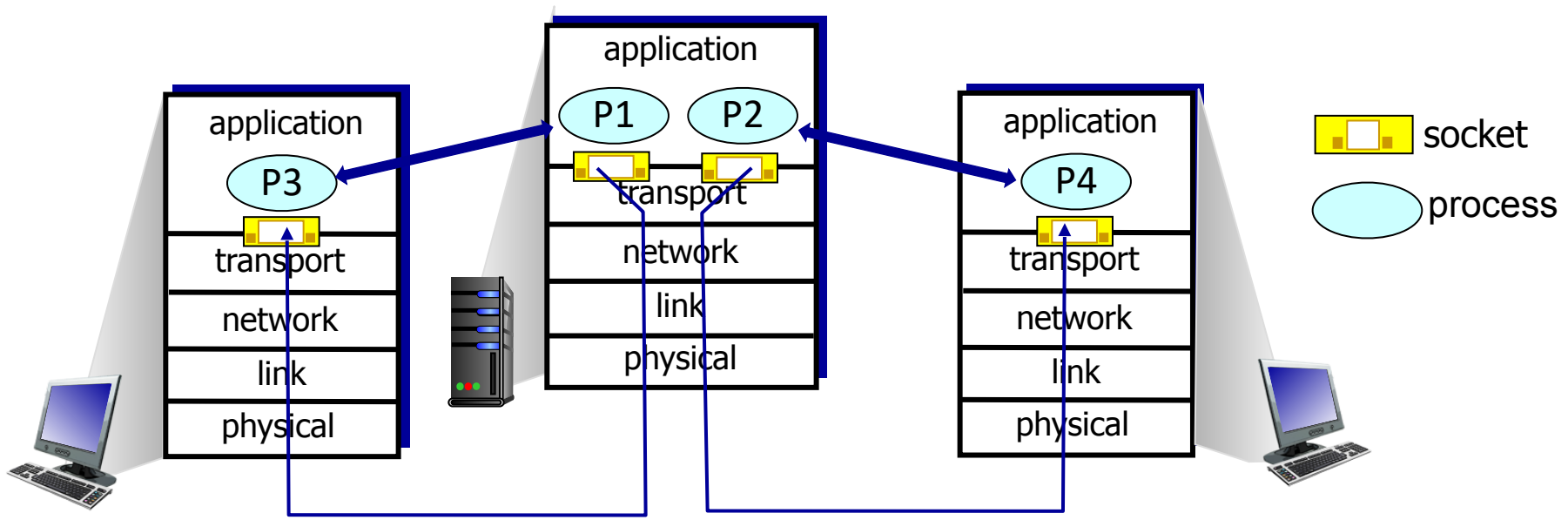
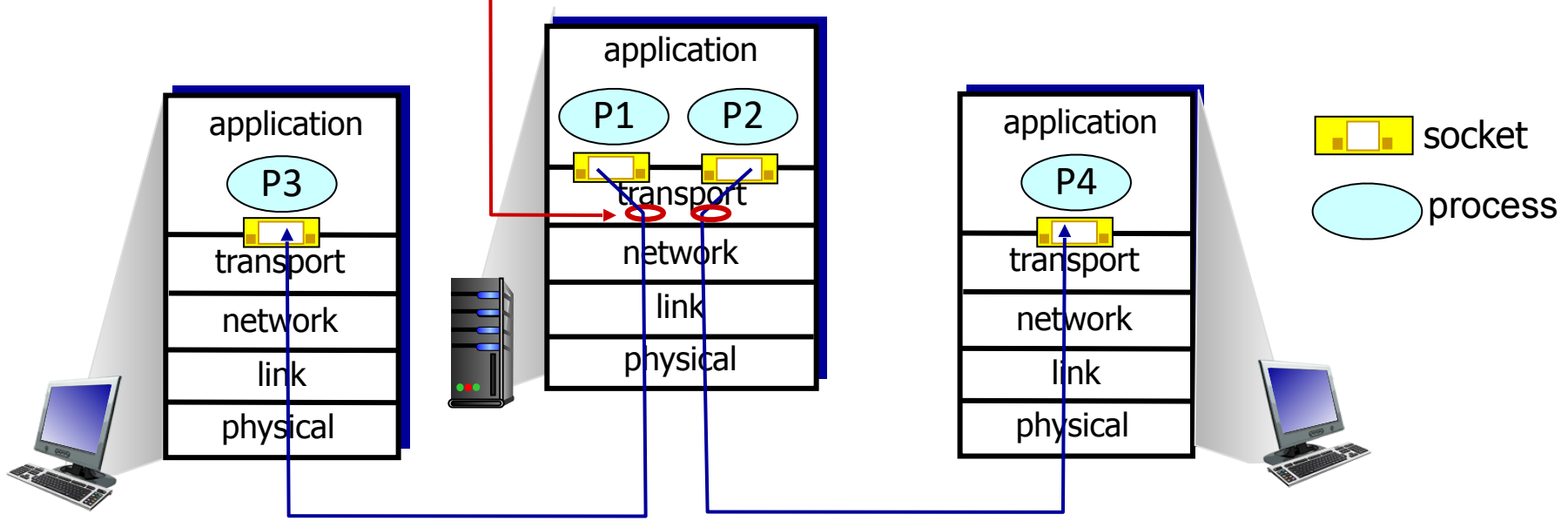


Multiplexing/demultiplexing

multiplexing at sender:

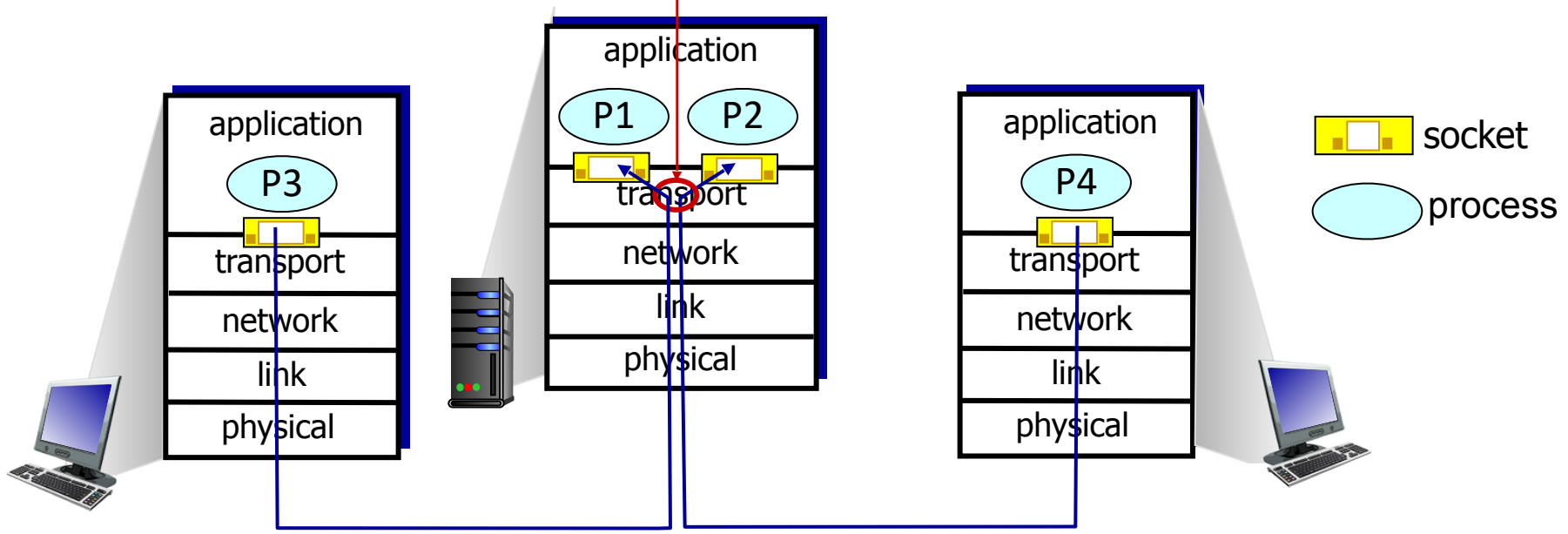
handle data from multiple sockets, add transport header (later used for demultiplexing)



Multiplexing/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
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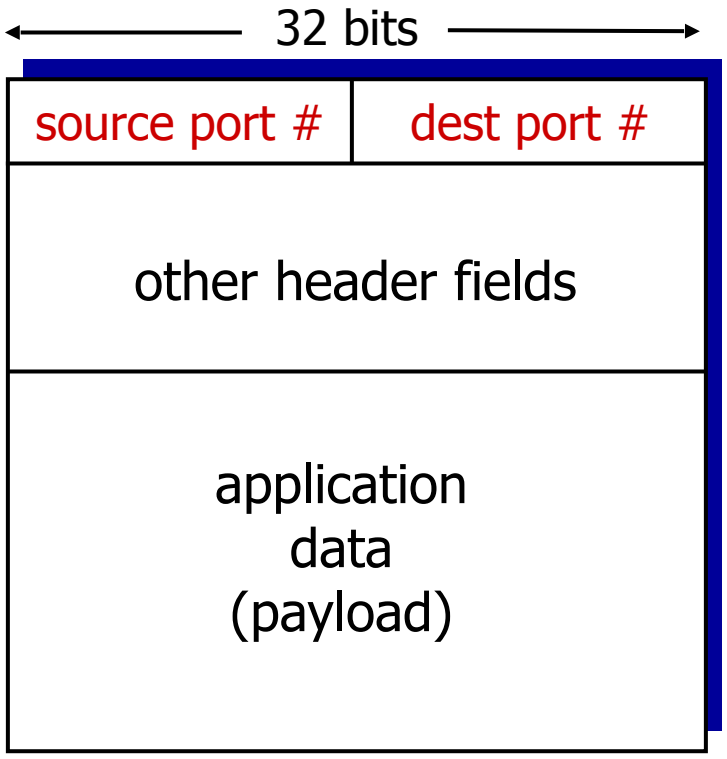

TCP/UDP segment format

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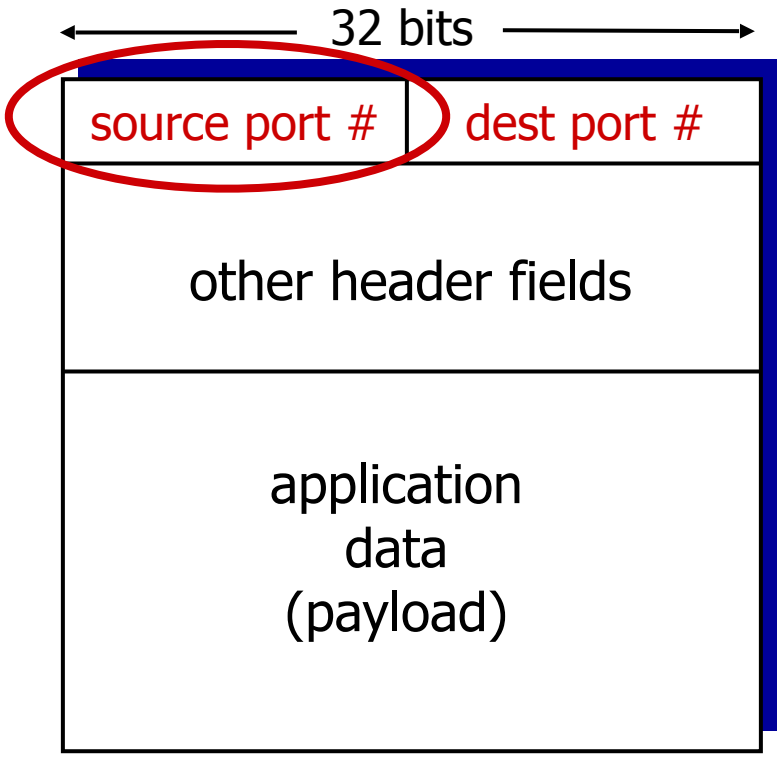

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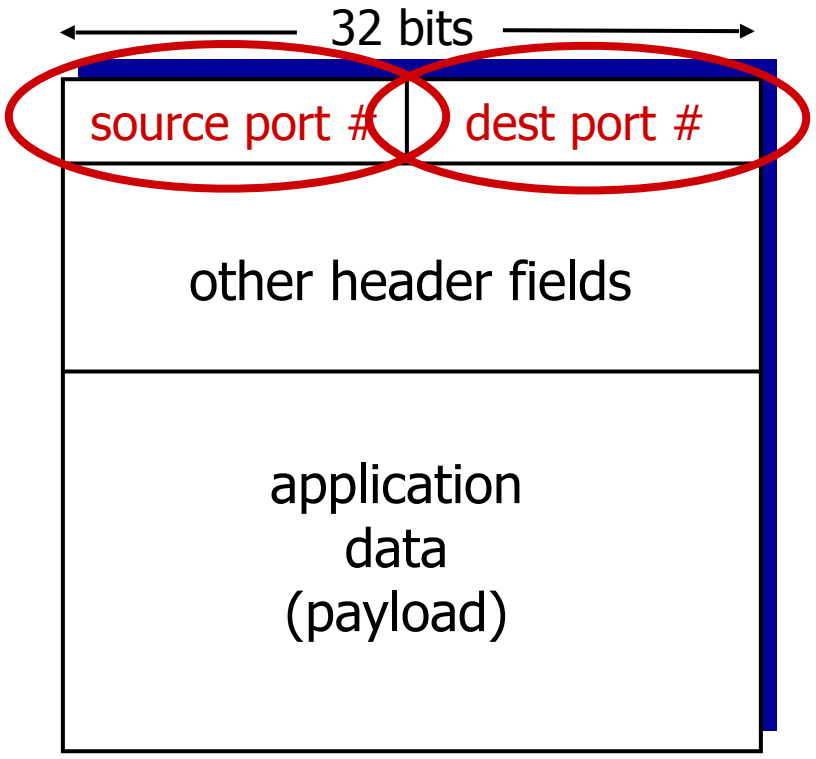


TCP/UDP segment format

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 #

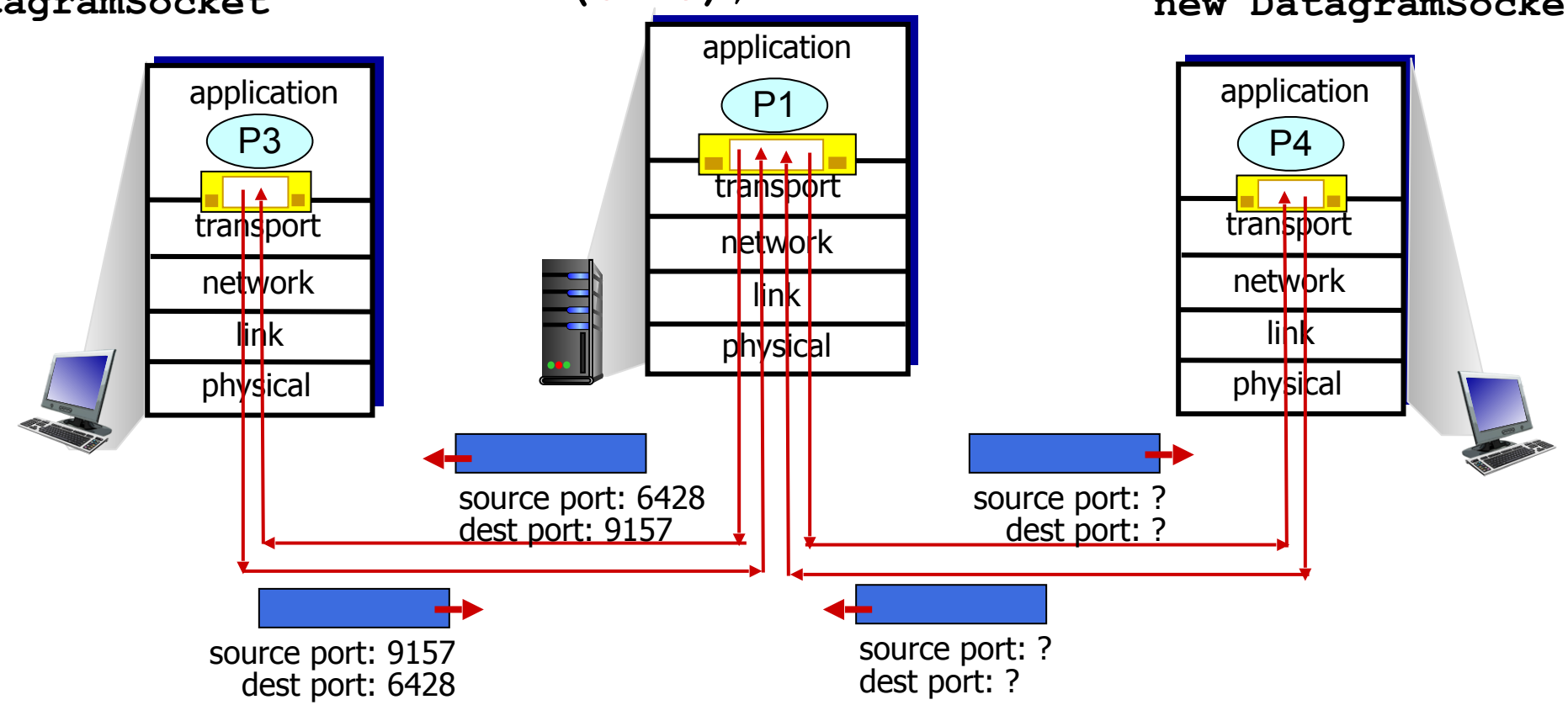
IP/UDP datagrams with *same dest. port #,* but different source IP addresses and/or source port numbers will be directed to *same socket* at receiving host

Connectionless demultiplexing: an example

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

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

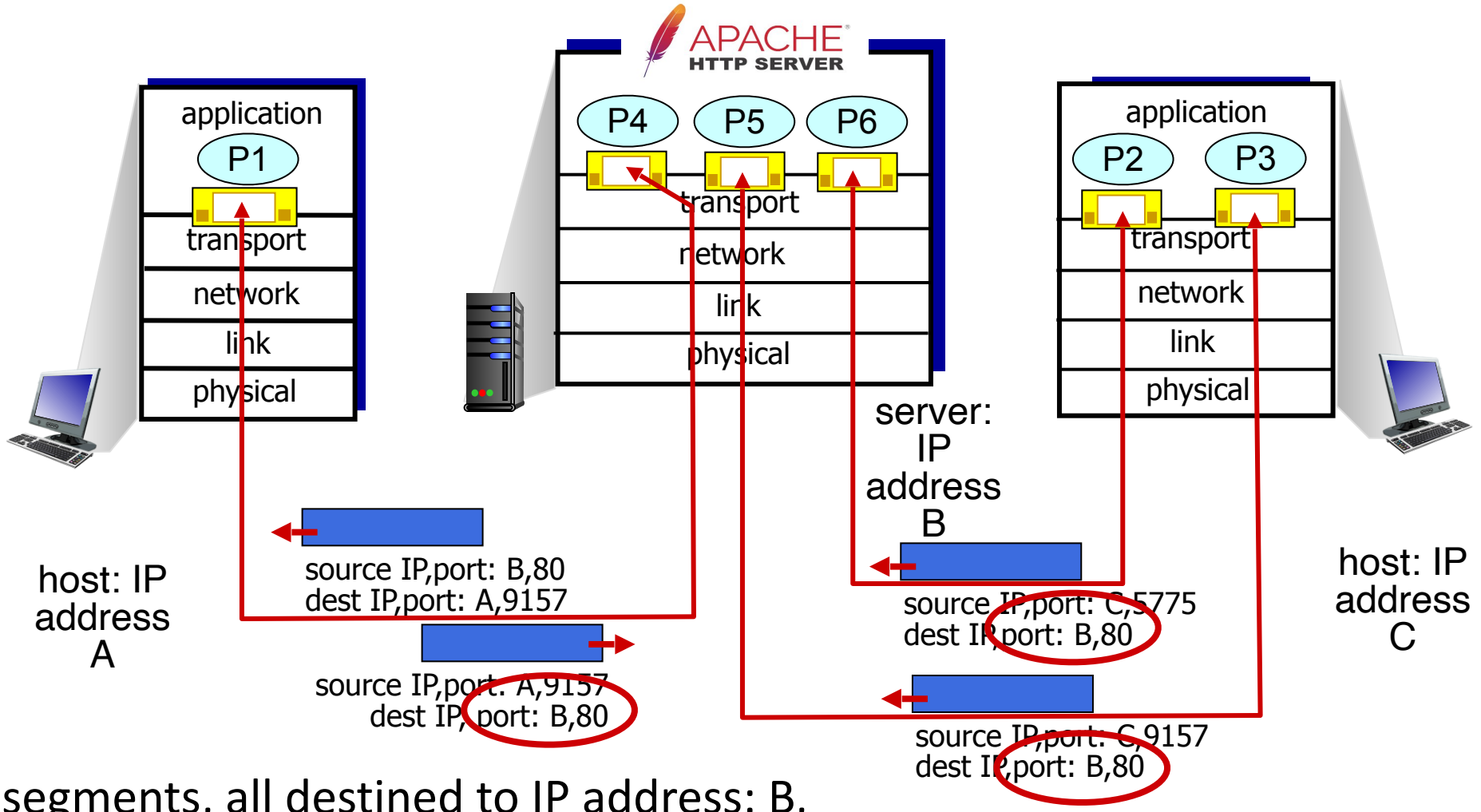
```
DatagramSocket mySocket1 =
 new DatagramSocket (5775);
```



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

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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

UDP

UDP: User Datagram Protocol

- “no frills,” “bare bones” Internet transport protocol
- “best effort” service, UDP segments may be:
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Why is there a UDP?

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

UDP: User Datagram Protocol

- UDP use:
  - streaming multimedia apps (loss tolerant, rate sensitive)
  - DNS
  - SNMP
  - HTTP/3
- if reliable transfer needed over UDP (e.g., HTTP/3):
  - add needed reliability at application layer
  - add congestion control at application layer

UDP: User Datagram Protocol [RFC 768]

INTERNET STANDARD

RFC 768

J. Postel
ISI
28 August 1980

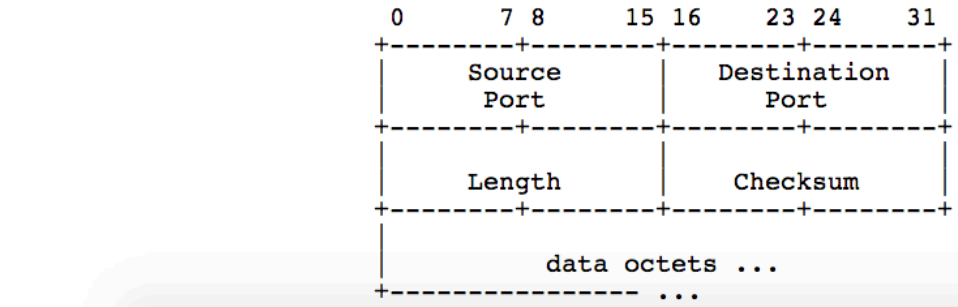
User Datagram Protocol

Introduction

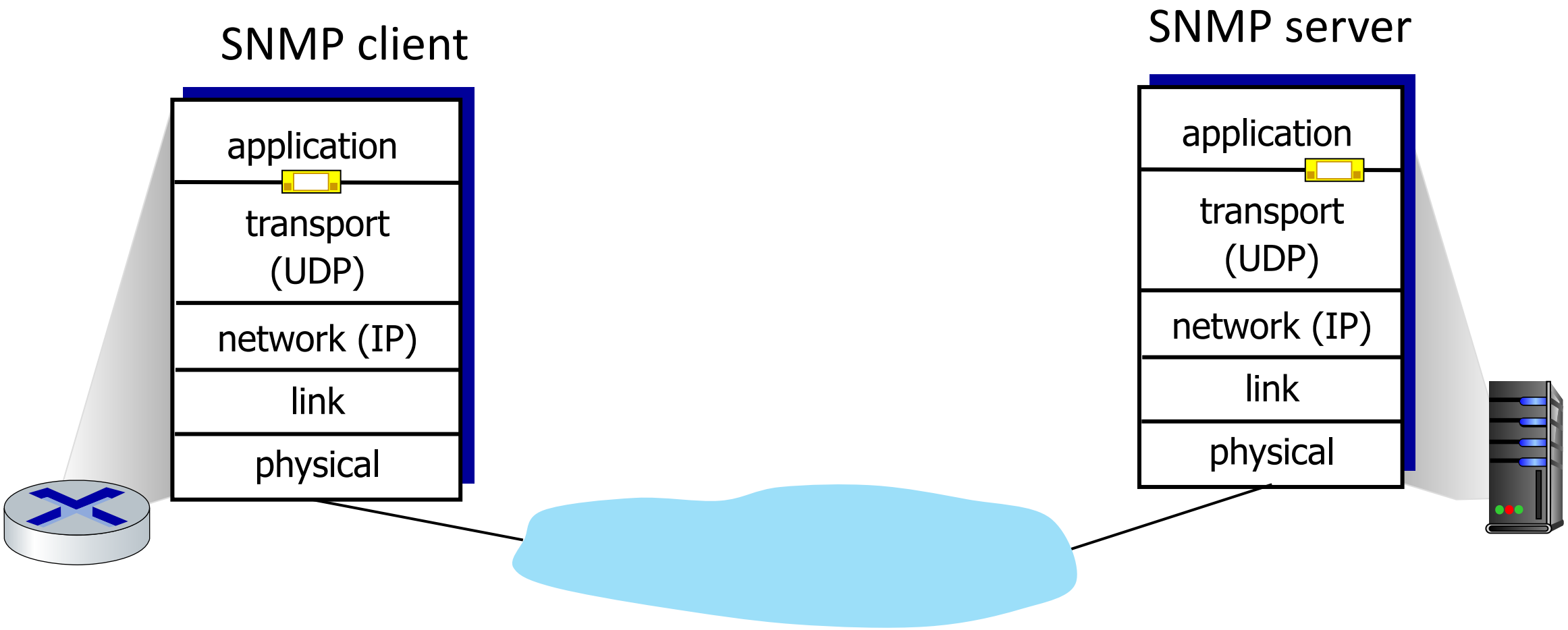
This User Datagram Protocol (UDP) is defined to make available a datagram mode of packet-switched computer communication in the environment of an interconnected set of computer networks. This protocol assumes that the Internet Protocol (IP) [1] is used as the underlying protocol.

This protocol provides a procedure for application programs to send messages to other programs with a minimum of protocol mechanism. The protocol is transaction oriented, and delivery and duplicate protection are not guaranteed. Applications requiring ordered reliable delivery of streams of data should use the Transmission Control Protocol (TCP) [2].

Format



UDP: Transport Layer Actions



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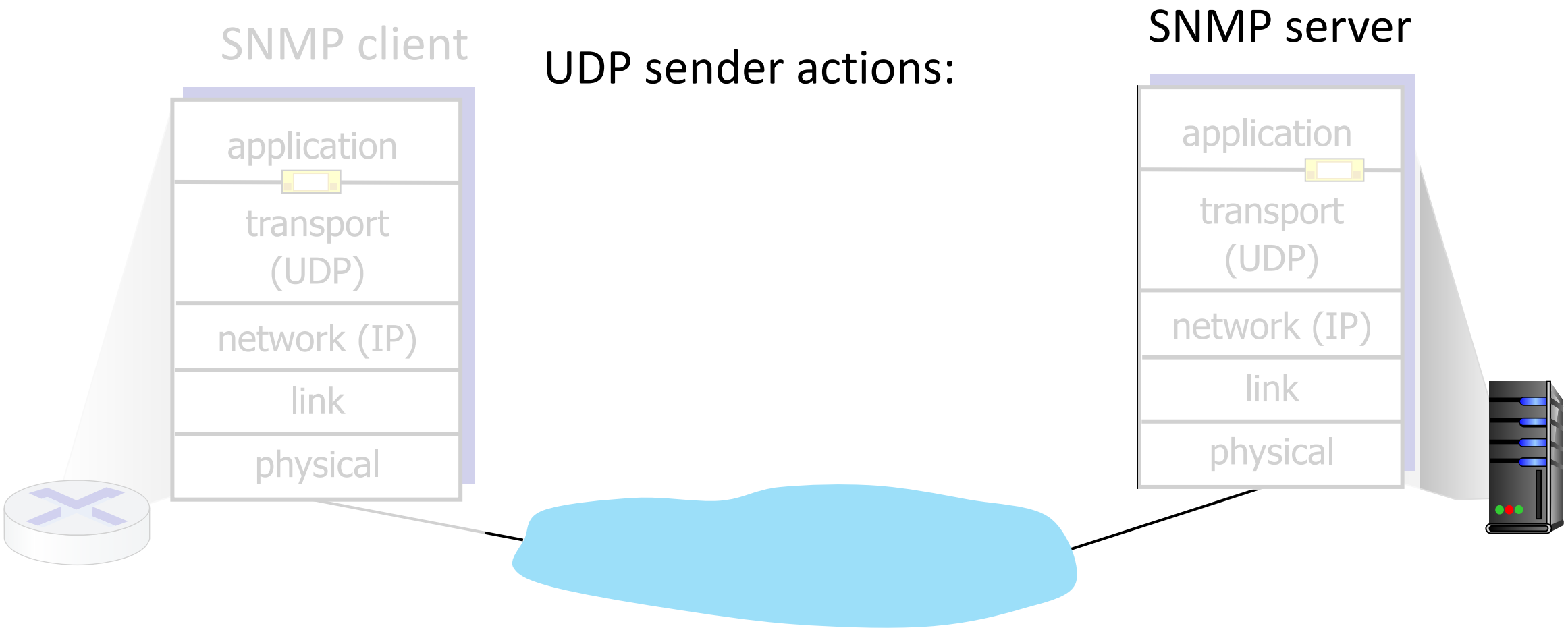

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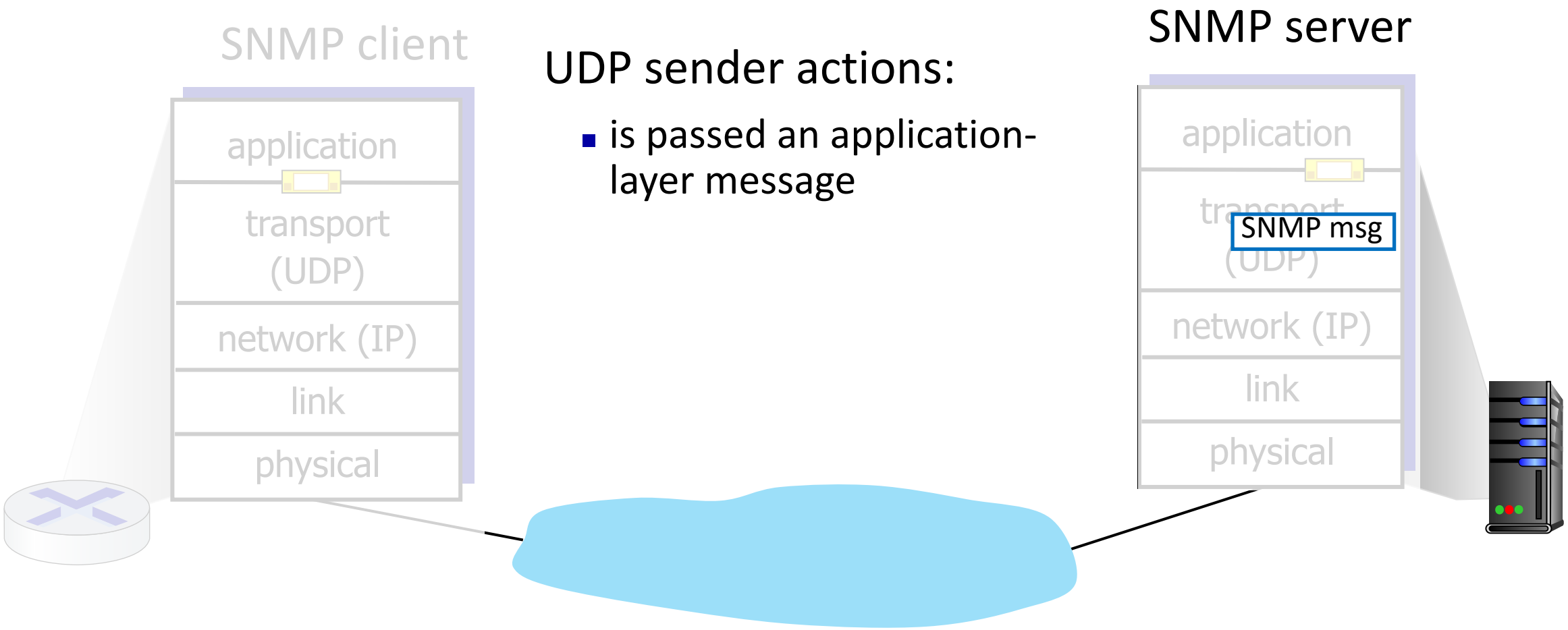

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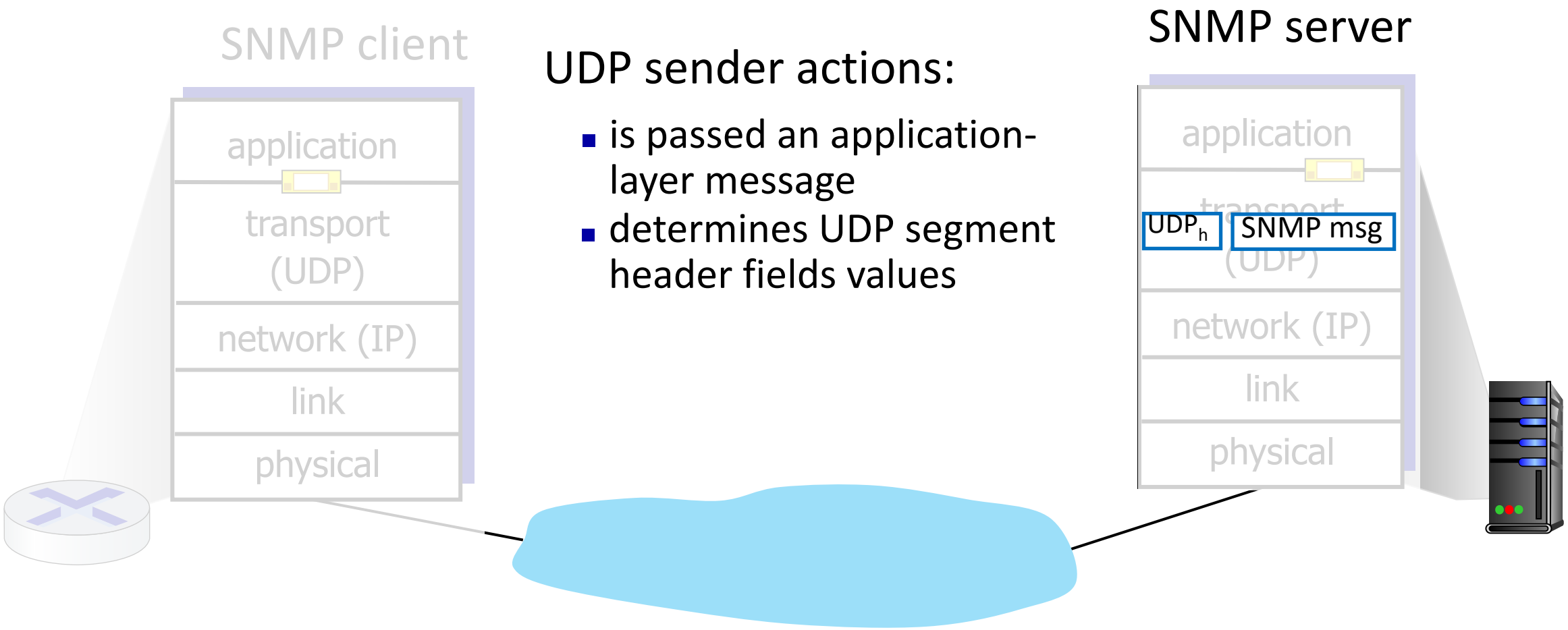

UDP sender actions:

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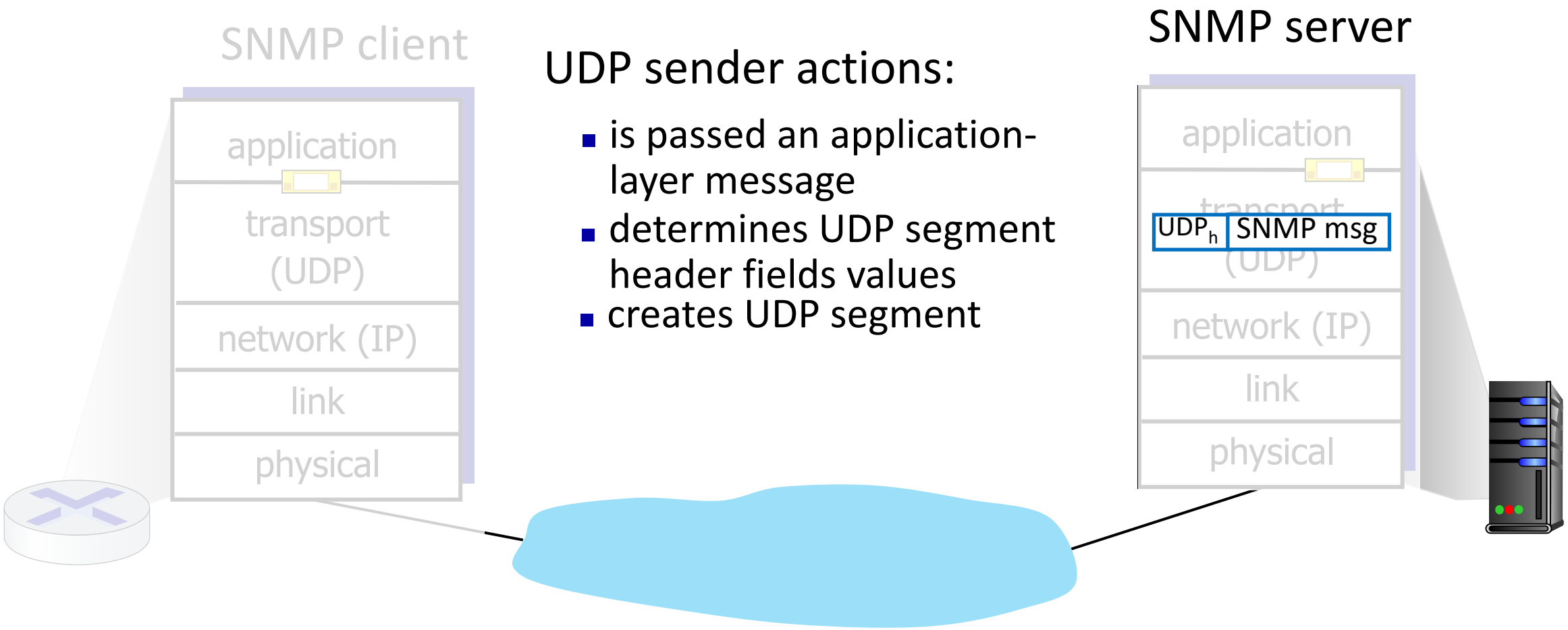

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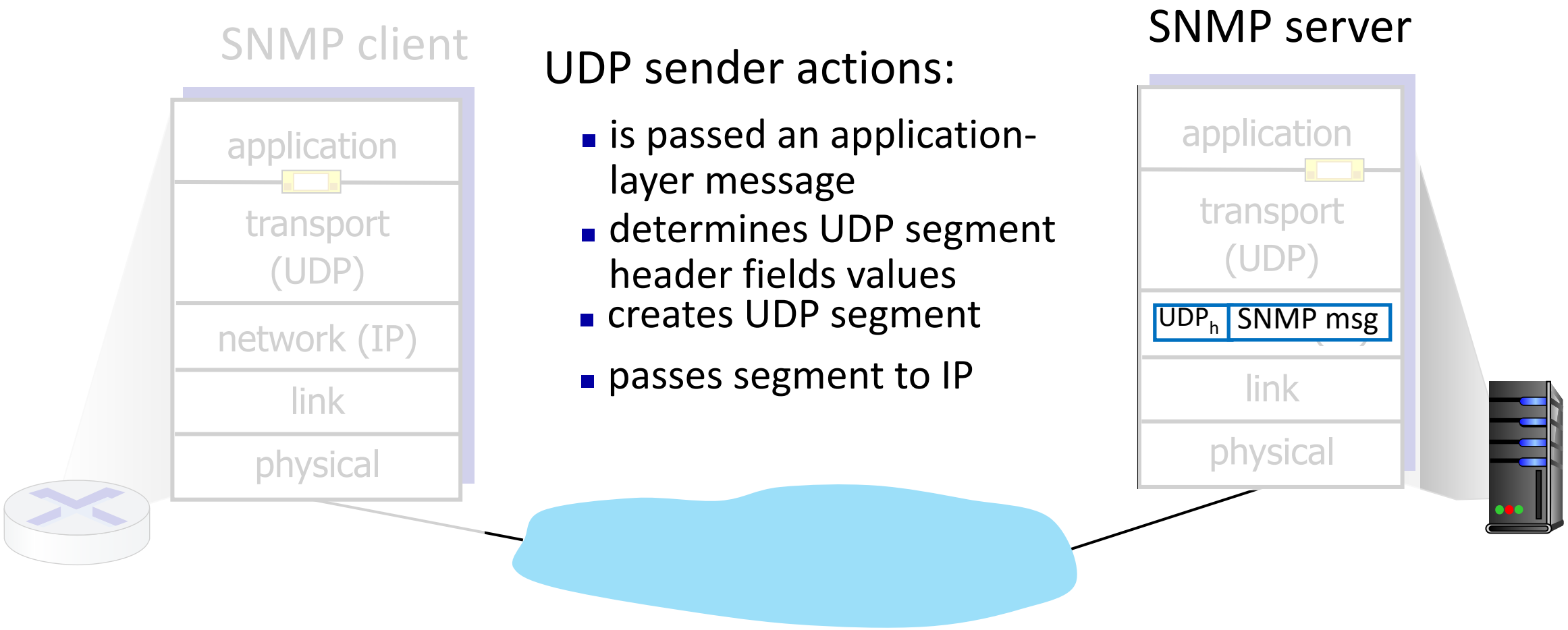

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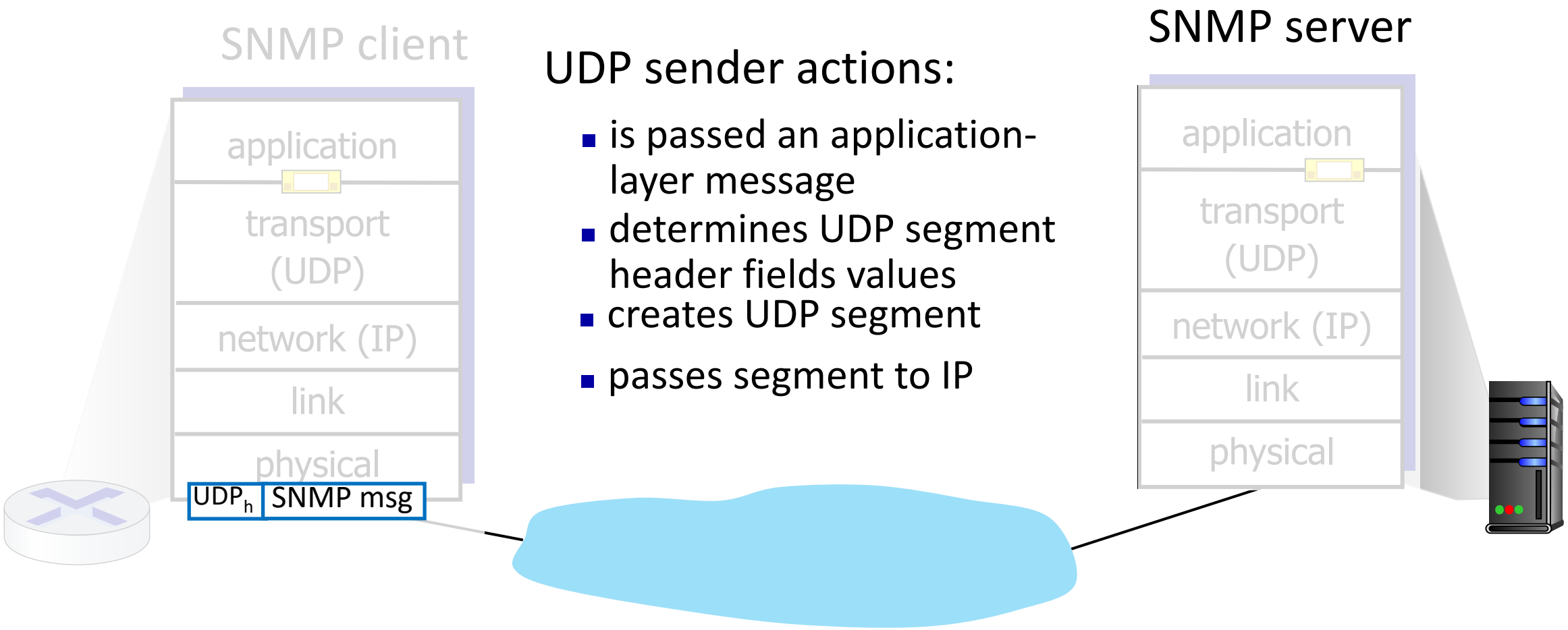

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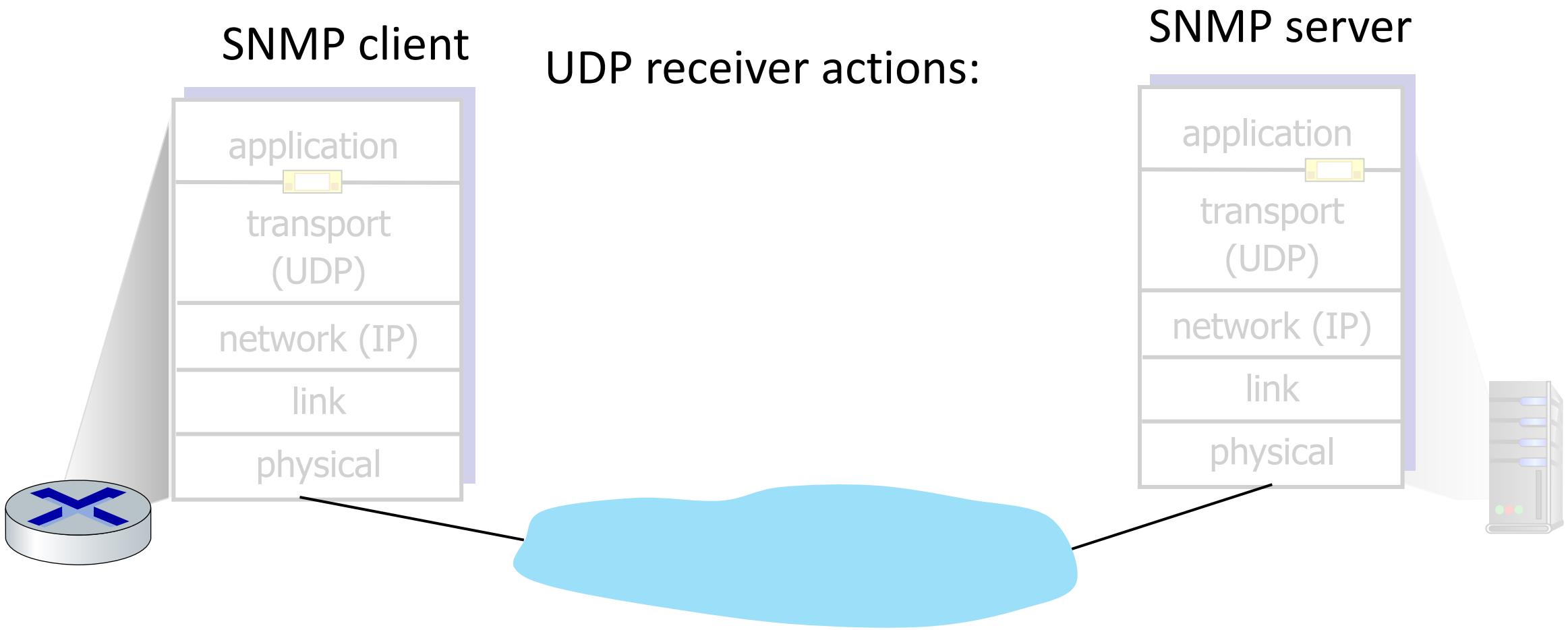

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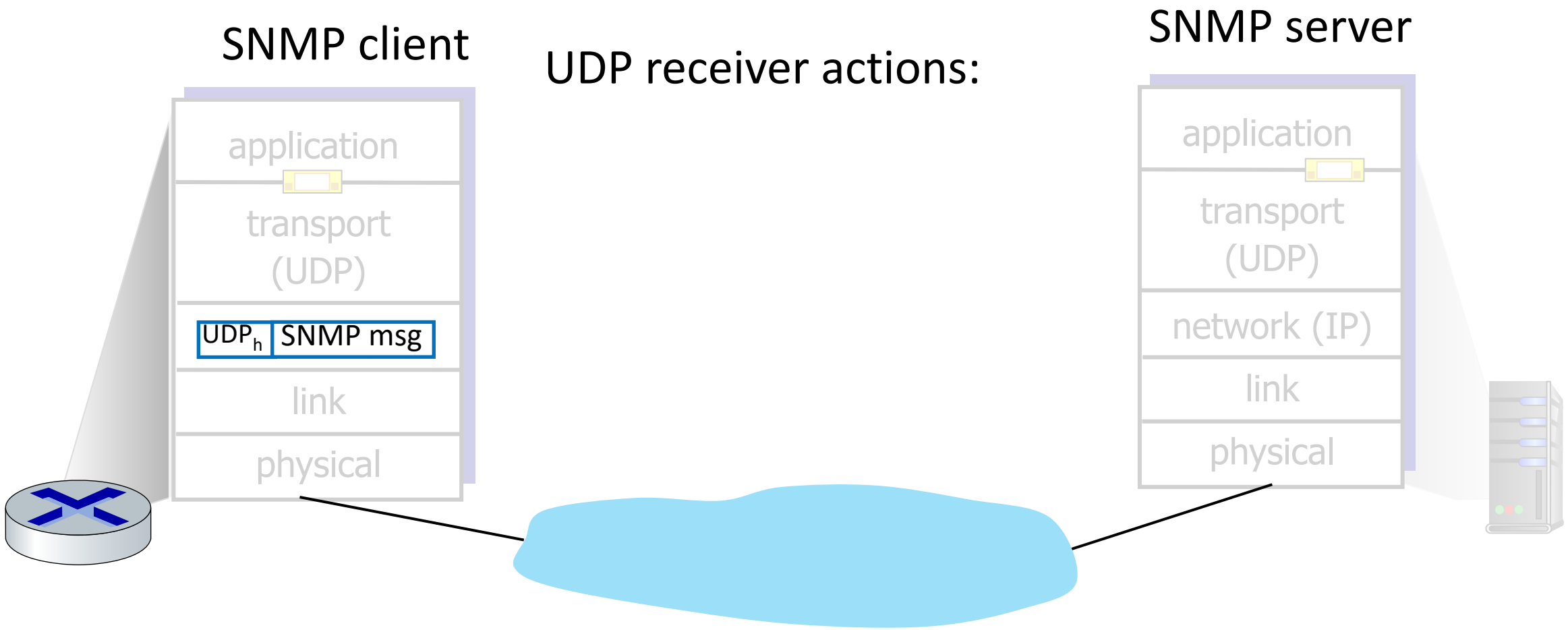

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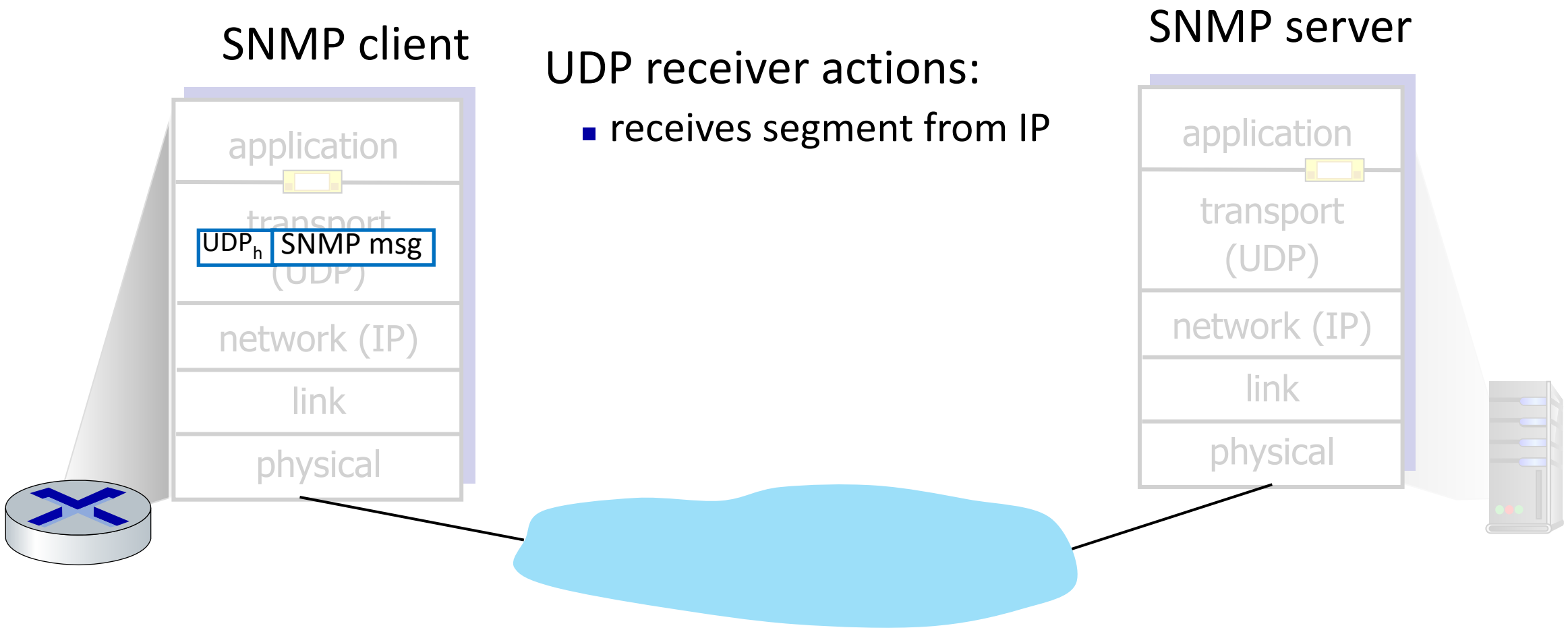

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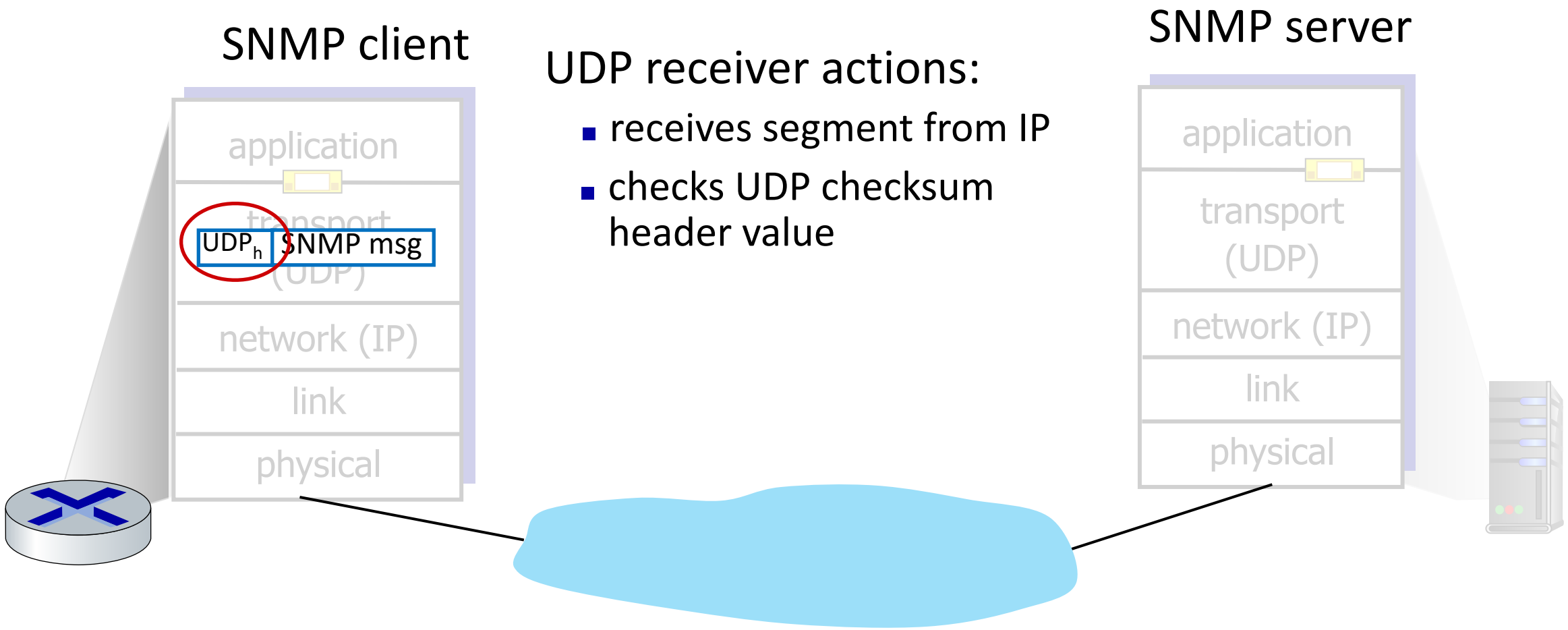

UDP receiver actions:

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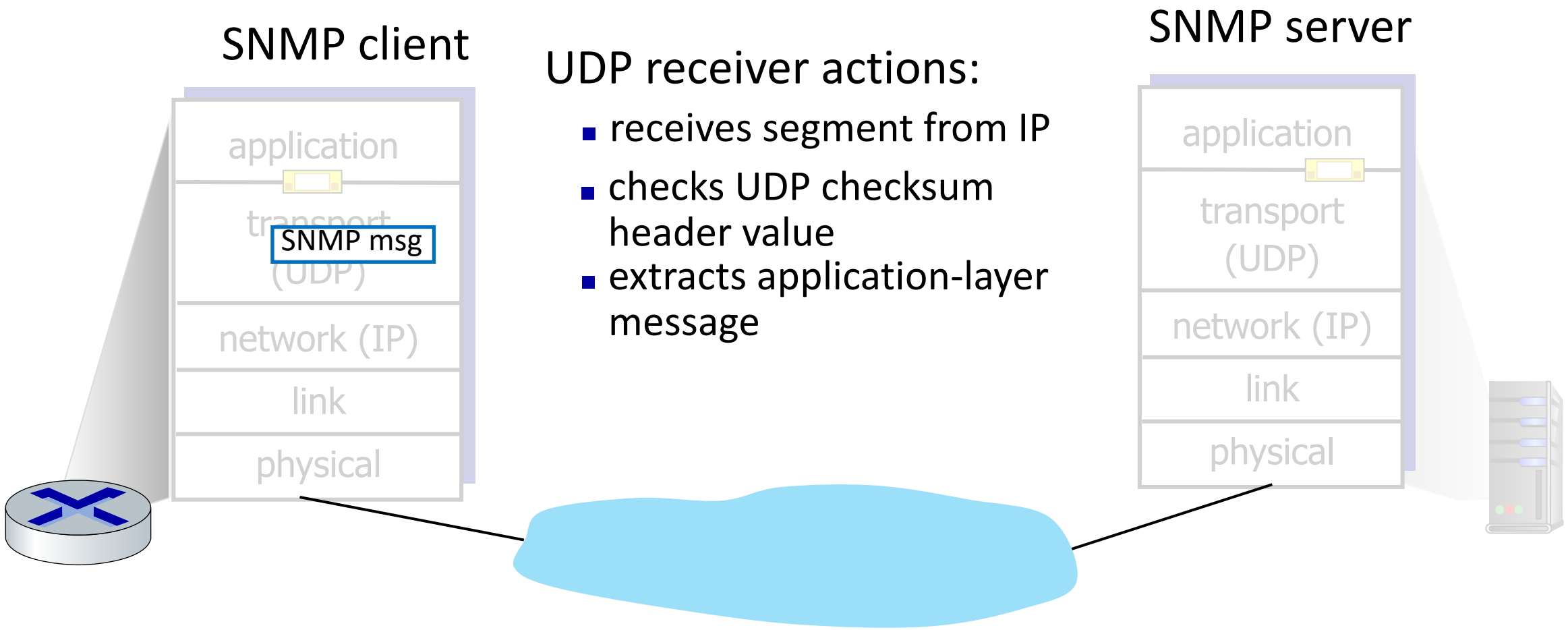

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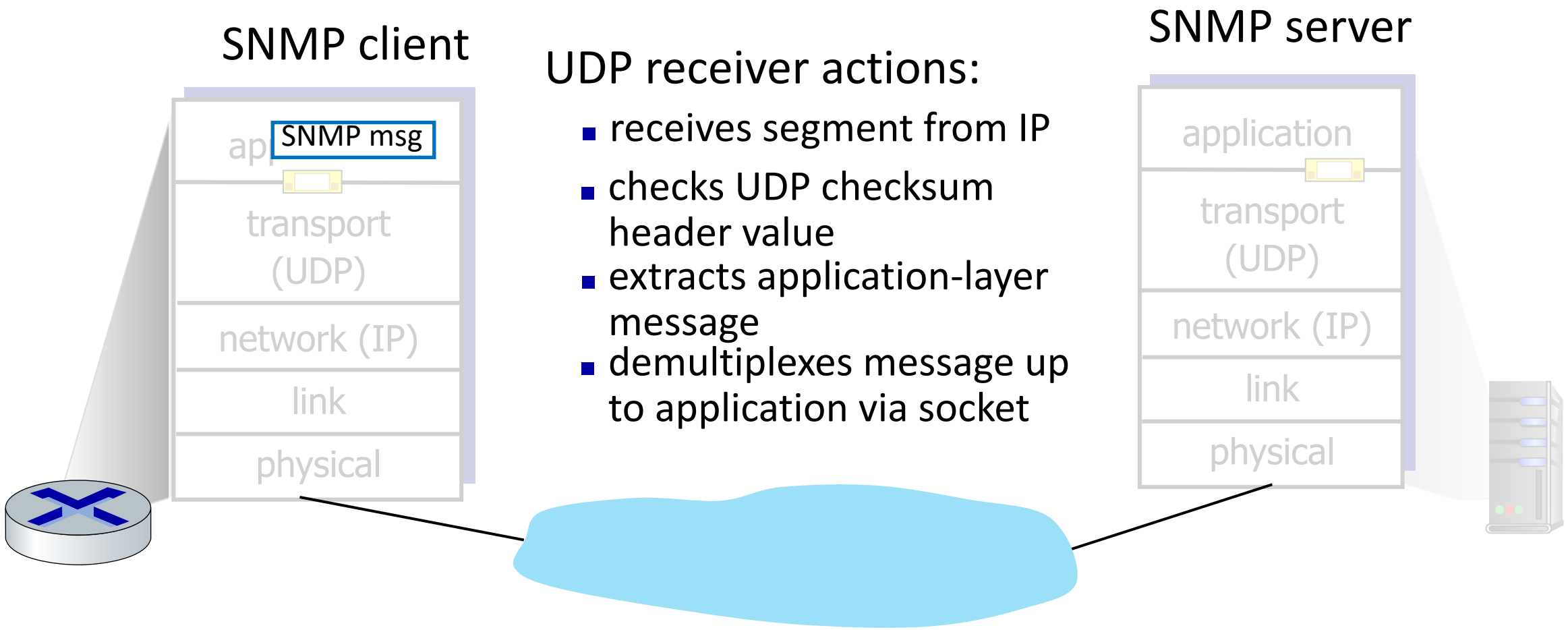

UDP receiver actions:

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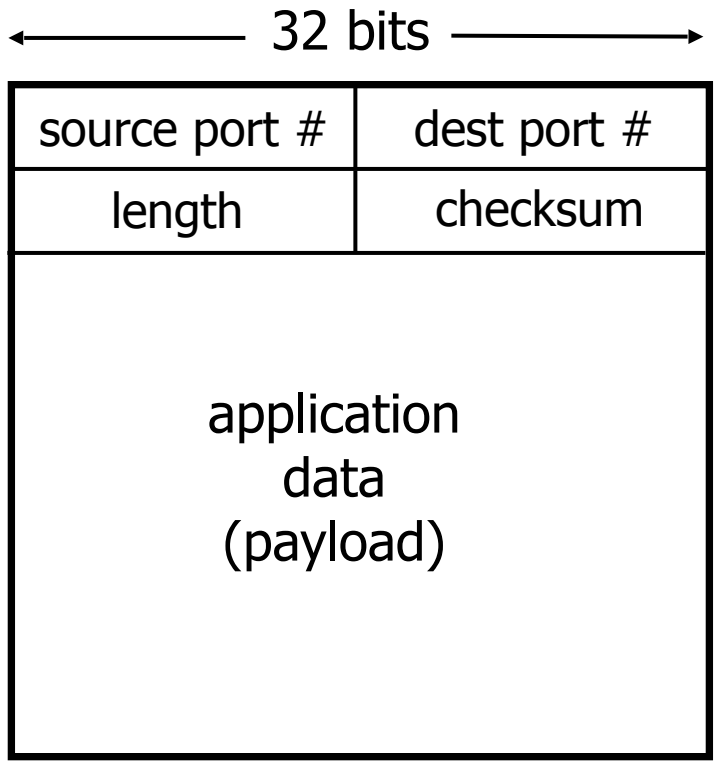
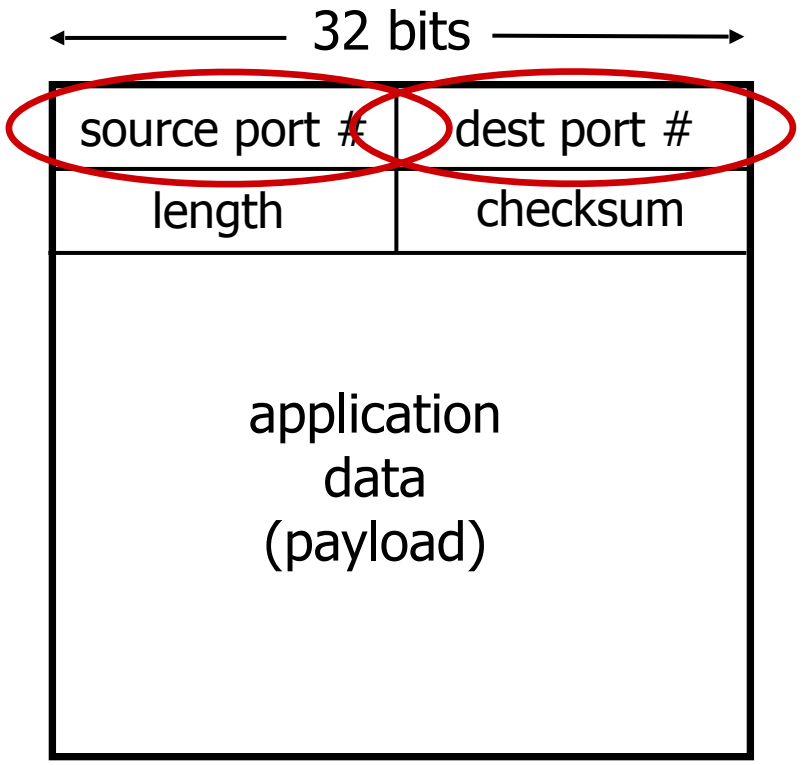
- demultiplexes message up to application via socket

UDP segment header



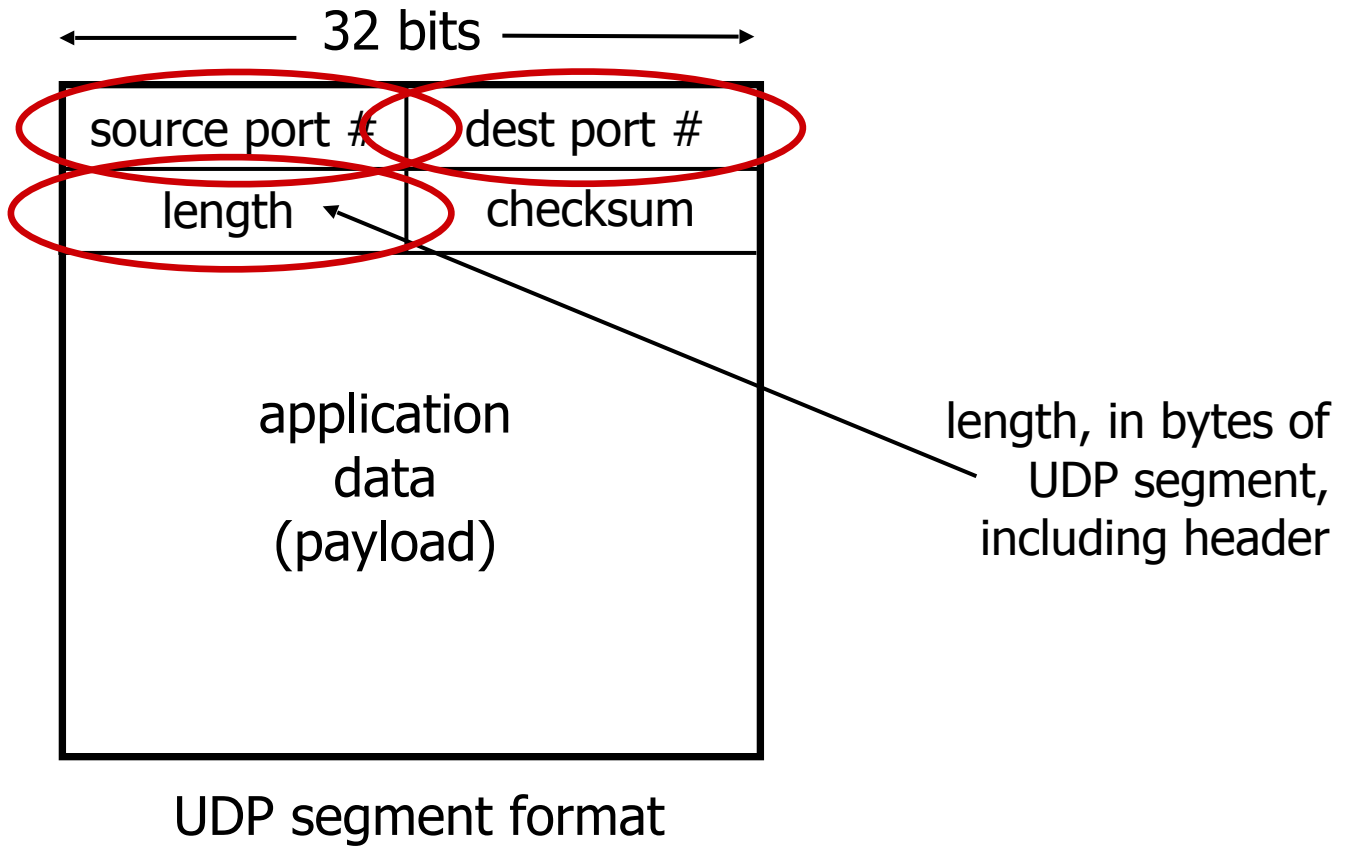
UDP segment format

UDP segment header



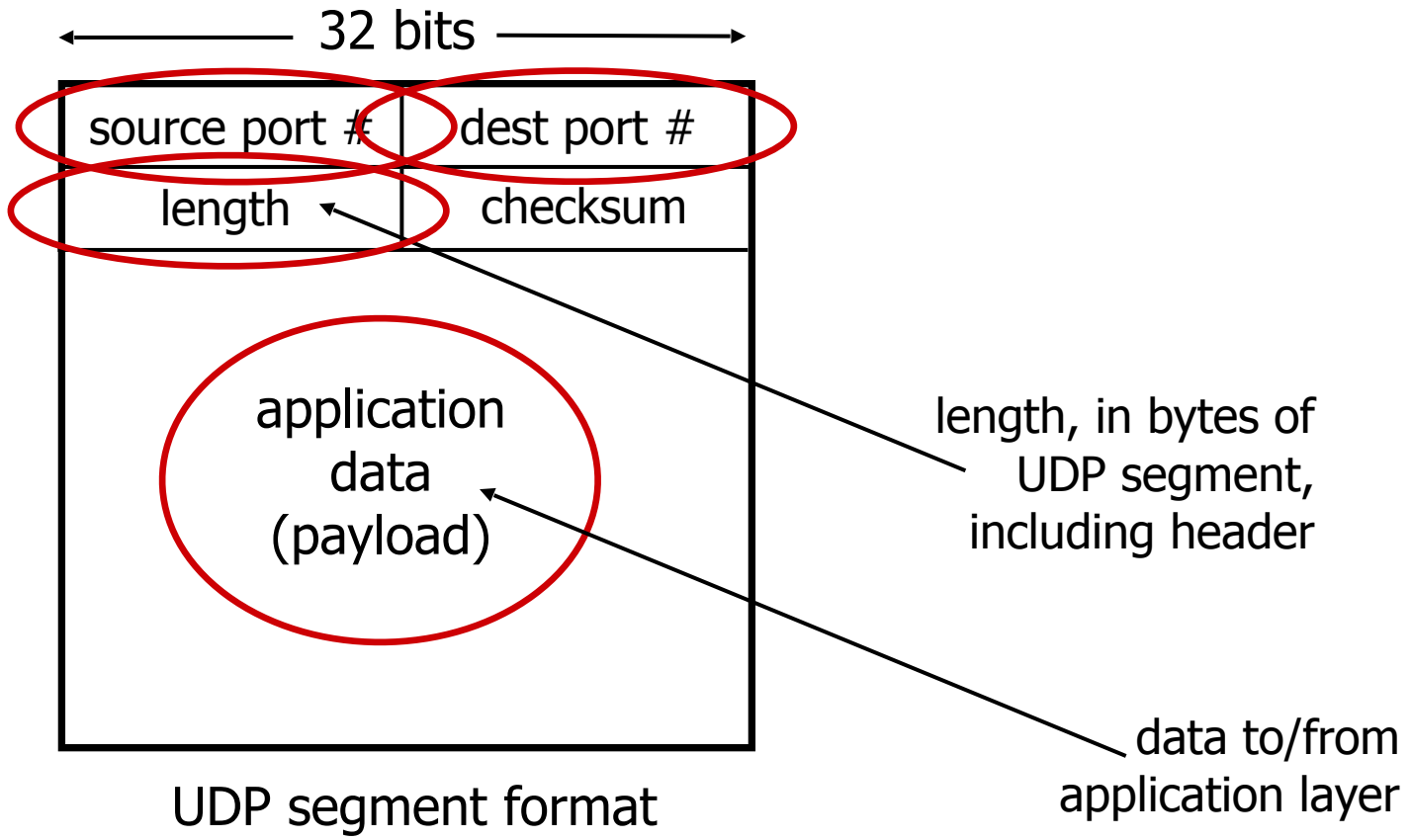
UDP segment format

UDP segment header

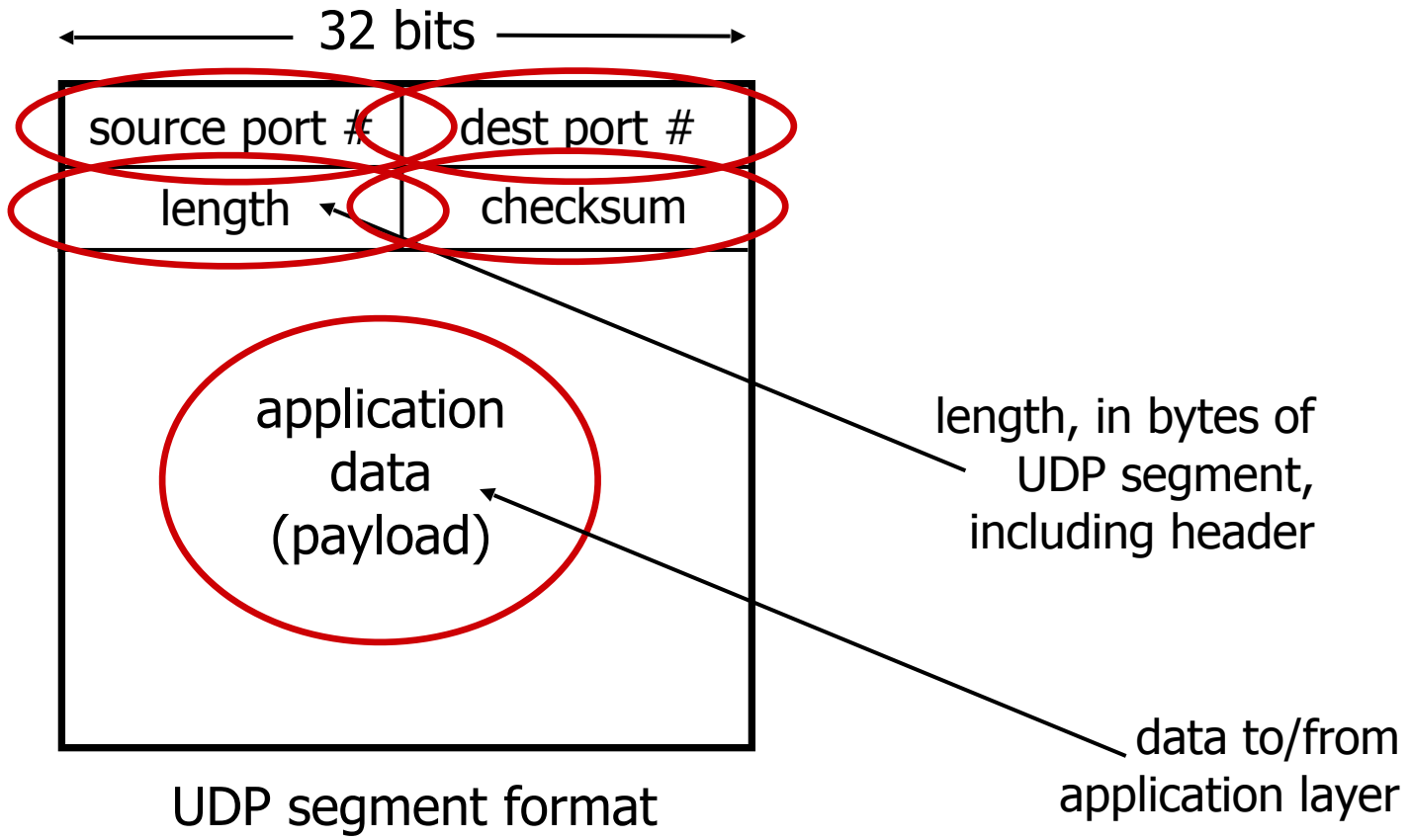


UDP segment format

UDP segment header



UDP segment header



UDP checksum

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

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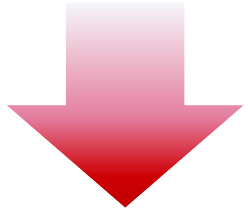
	1st number	2nd number	sum
Transmitted:	5	6	11

UDP checksum

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

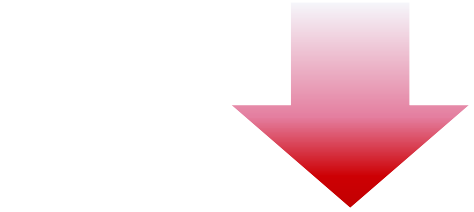
	1st number	2nd number	sum
Transmitted:	5	6	11
Received:	4	6	11



UDP checksum

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

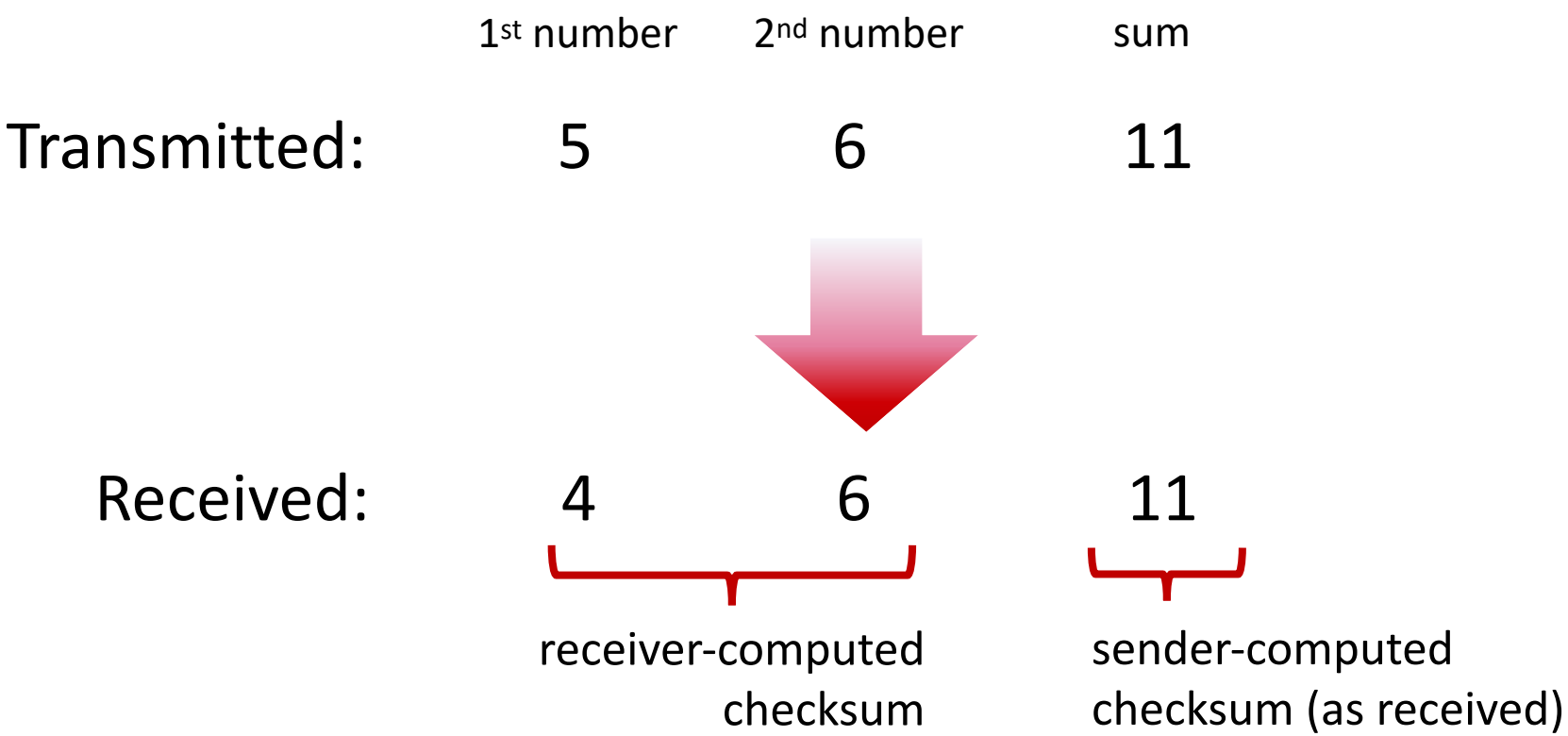
	1st number	2nd number	sum
Transmitted:	5	6	11
Received:	4	6	11



receiver-computed checksum

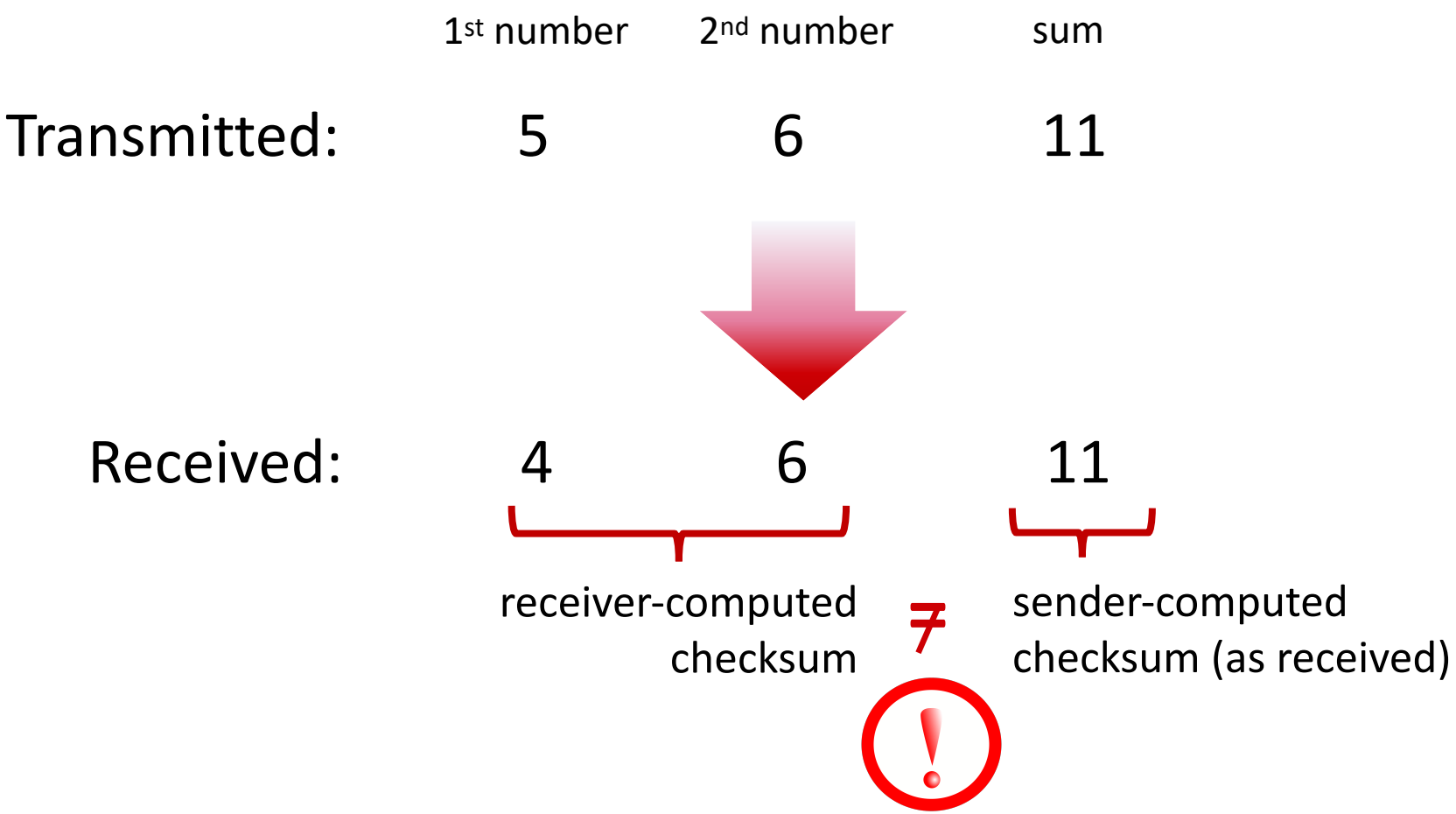
UDP checksum

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



UDP checksum

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



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

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**

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

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**
1	**1**	**0**	**1**	**1**	**1**	**0**	**1**	**1**	**1**	**0**	**1**	**1**	**1**	**0**	**1**	**1**

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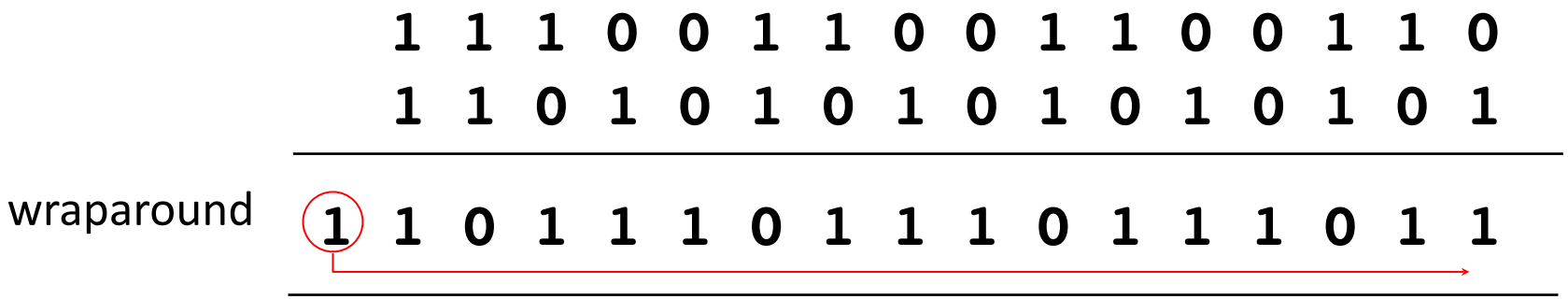
Internet checksum: an example

example: add two 16-bit integers



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

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Internet checksum: an example

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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

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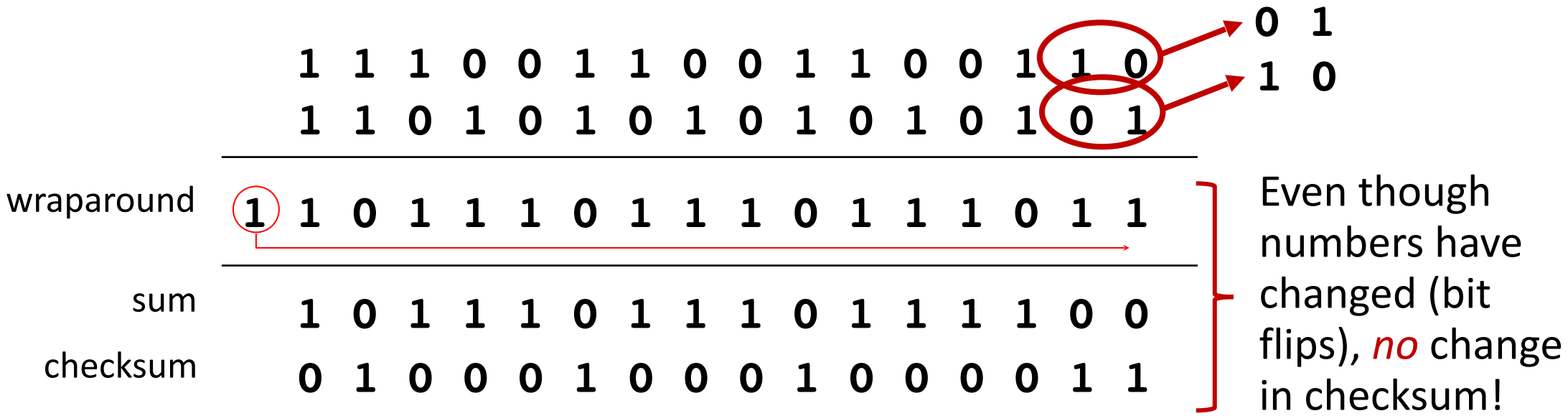
Internet checksum: weak protection!

example: add two 16-bit integers



Summary: UDP

- “no frills” protocol:
  - segments may be lost, delivered out of order
  - best effort service: “send and hope for the best”
- UDP has its plusses:
  - no setup/handshaking needed (no RTT incurred)
  - can function when network service is compromised
  - helps with reliability (checksum)
- build additional functionality on top of UDP in application layer (e.g., HTTP/3)

Estrutura do cabeçalho UDP com detalhes

Offsets	Octet	0								1								2								3							
Octet	Bit	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
0	0	Source port																Destination port															
4	32	Length																Checksum															

A UDP datagram consists of a datagram *header* and a *data* section. The UDP datagram header consists of 4 fields, each of which is 2 bytes (16 bits).[1] The data section follows the header and is the payload data carried for the application.

The use of the *checksum* and *source port* fields is optional in IPv4 (pink background in table). In IPv6 only the *source port* field is optional.

Source port number

This field identifies the sender's port, when used, and should be assumed to be the port to reply to if needed. If not used, it should be zero. If the source host is the client, the port number is likely to be an ephemeral port number. If the source host is the server, the port number is likely to be a well-known port number.[4]

Destination port number

This field identifies the receiver's port and is required. Similar to source port number, if the client is the destination host then the port number will likely be an ephemeral port number and if the destination host is the server then the port number will likely be a well-known port number.[4]

Length

This field specifies the length in bytes of the UDP header and UDP data. The minimum length is 8 bytes, the length of the header. The field size sets a theoretical limit of 65,535 bytes (8 byte header + 65,527 bytes of data) for a UDP datagram. However the actual limit for the data length, which is imposed by the underlying IPv4 protocol, is 65,508 bytes (2**16 = 65,536 – 8 byte UDP header – 20 byte IP header).[4]

Using IPv6 jumbograms it is possible to have UDP datagrams of size greater than 65,535 bytes.[5] RFC 2675 specifies that the length field is set to zero if the length of the UDP header plus UDP data is greater than 65,535.

Checksum

The checksum field may be used for error-checking of the header and data. This field is optional in IPv4, and mandatory in IPv6.[6] The field carries all-zeros if unused.[7]

https://en.wikipedia.org/wiki/User_Datagram_Protocol