NETWORK PROTOCOLS

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TRANSPORT LAYER
AND
TRANSPORT LAYER PROTOCOLS

LECTURE (4) PART A

2204 - 2025

14 October

Our goal

Our goal In this lecture is to:

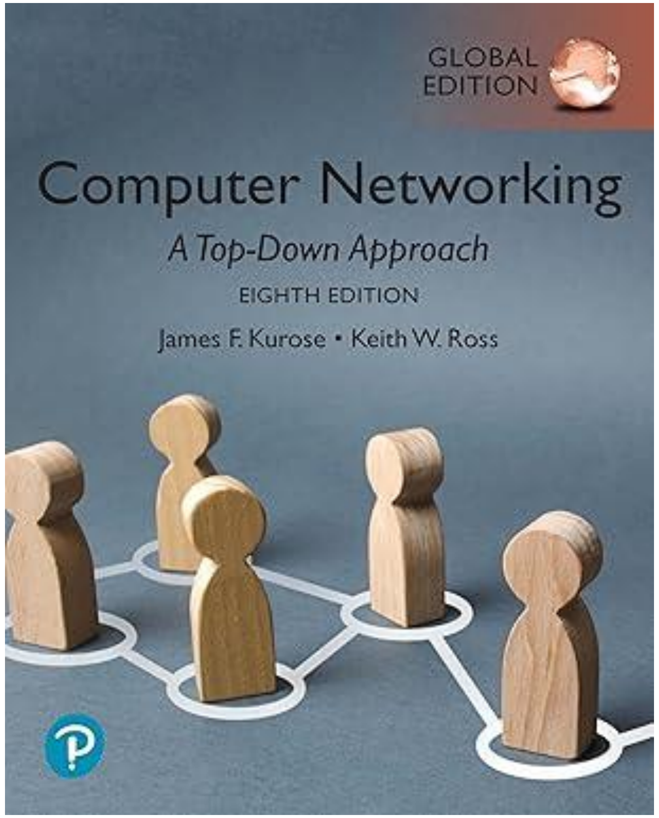
- **understand principles behind transport layer services:**
  - **multiplexing, demultiplexing**
  - reliable data transfer
  - flow control
  - congestion control

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

Transport layer: roadmap

In this lecture part A will talk about the following:

- **Transport-layer services**
- **Multiplexing and demultiplexing**
- Connectionless transport: UDP
- Principles of reliable data transfer
- Connection-oriented transport: TCP
- Principles of congestion control
- TCP congestion control
- Evolution of transport-layer functionality



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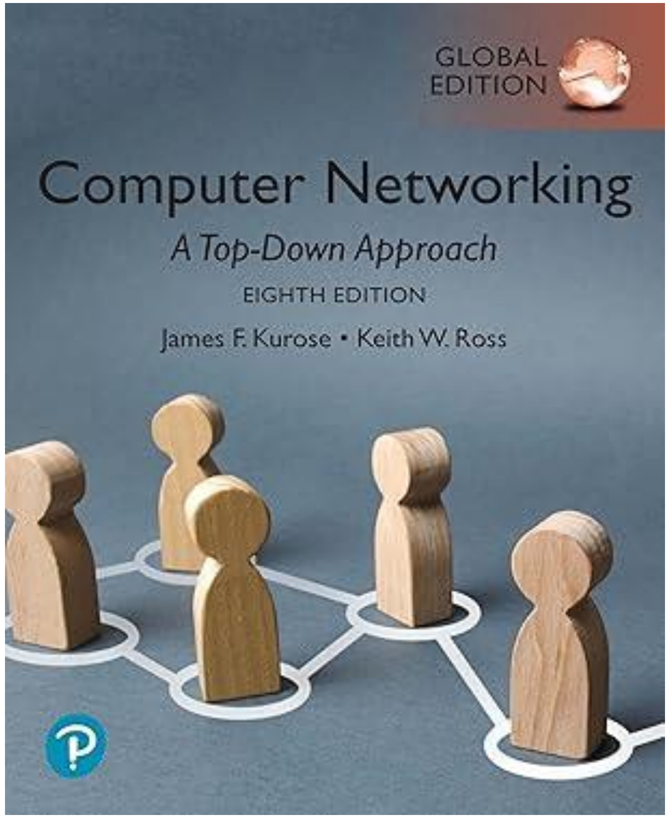
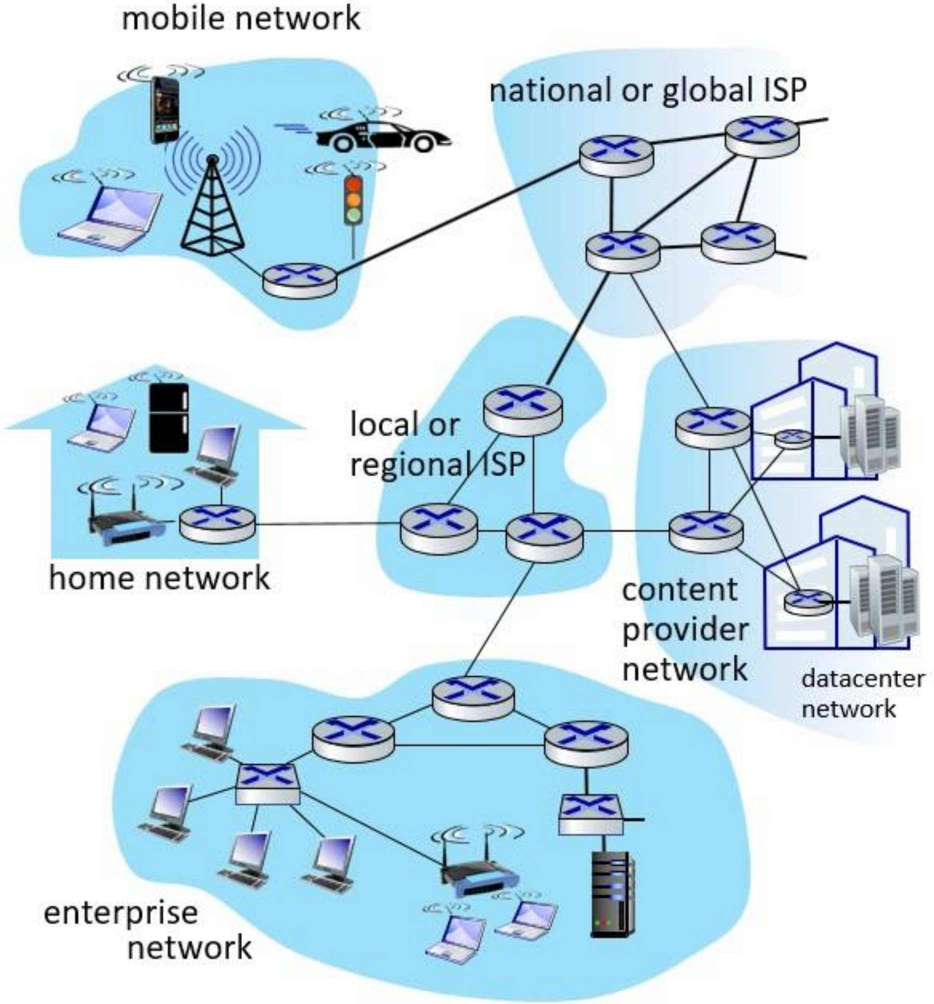


Transport services and protocols

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



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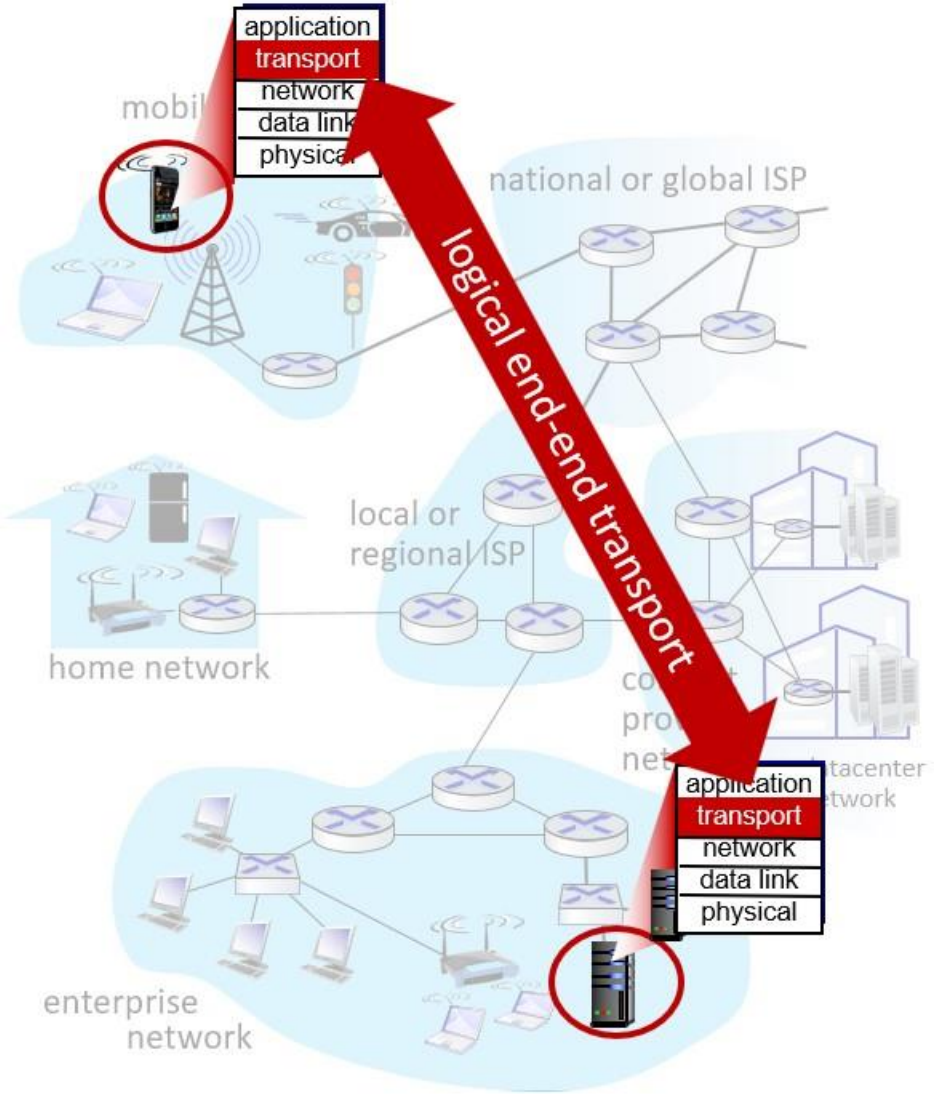
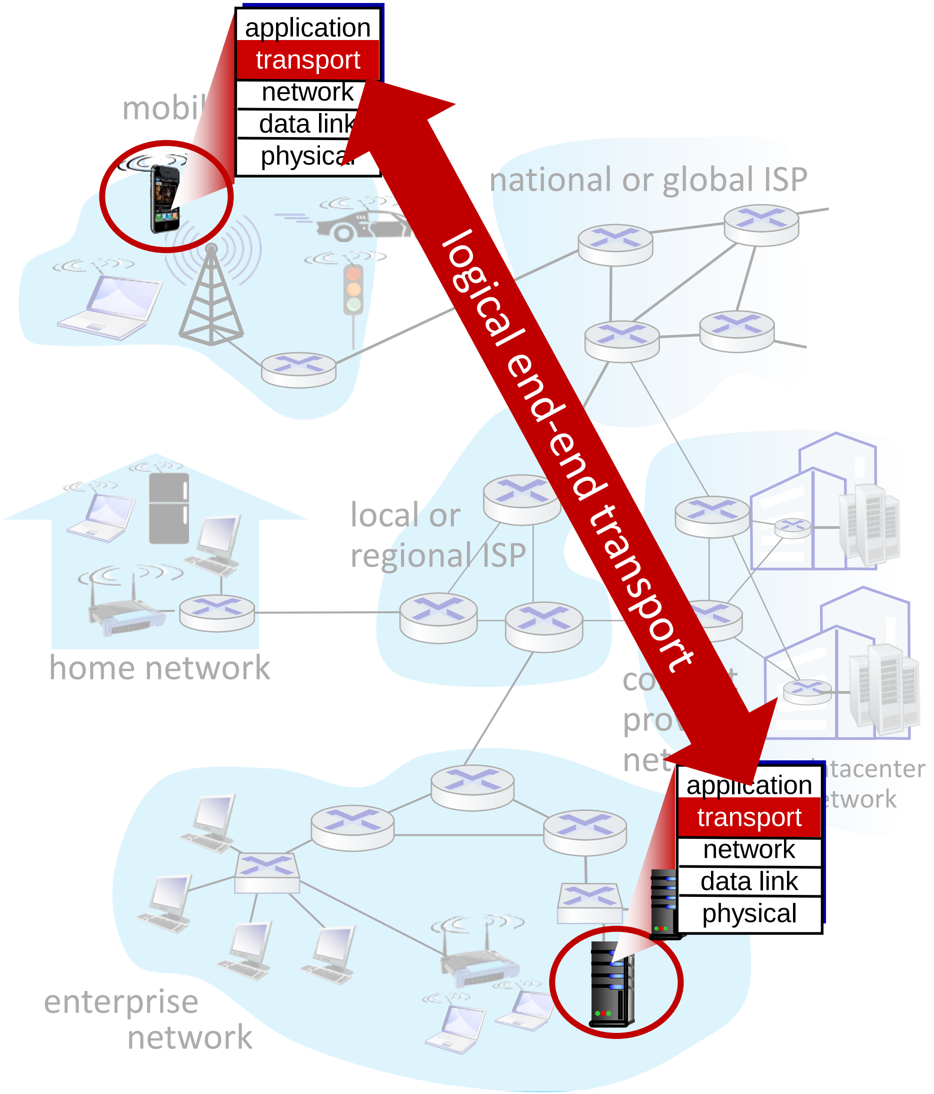


Transport services and protocols

- 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 services and protocols

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

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 vs. network layer services and protocols

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household analogy:

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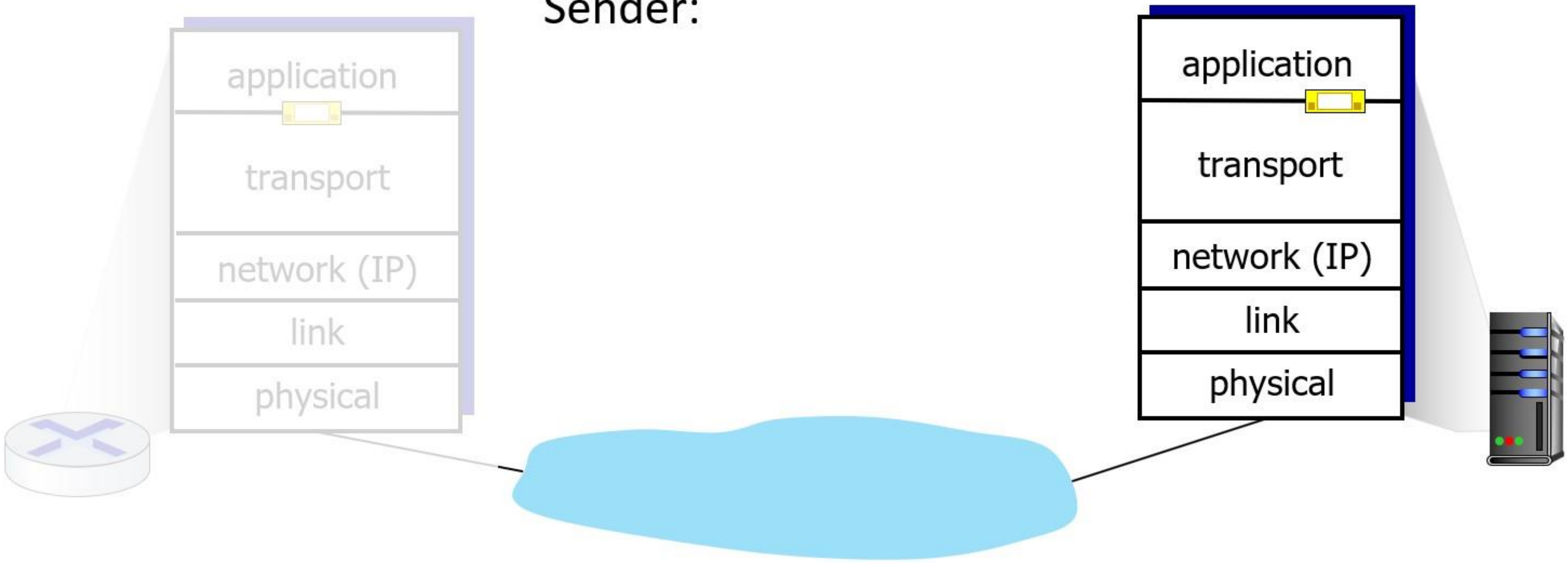
- hosts = houses
- processes = kids
- app messages = letters in envelopes
- transport protocol = Ann and Bill who demux to in-house siblings
- network-layer protocol = postal service

Transport Layer Actions

Sender:



Transport Layer Actions

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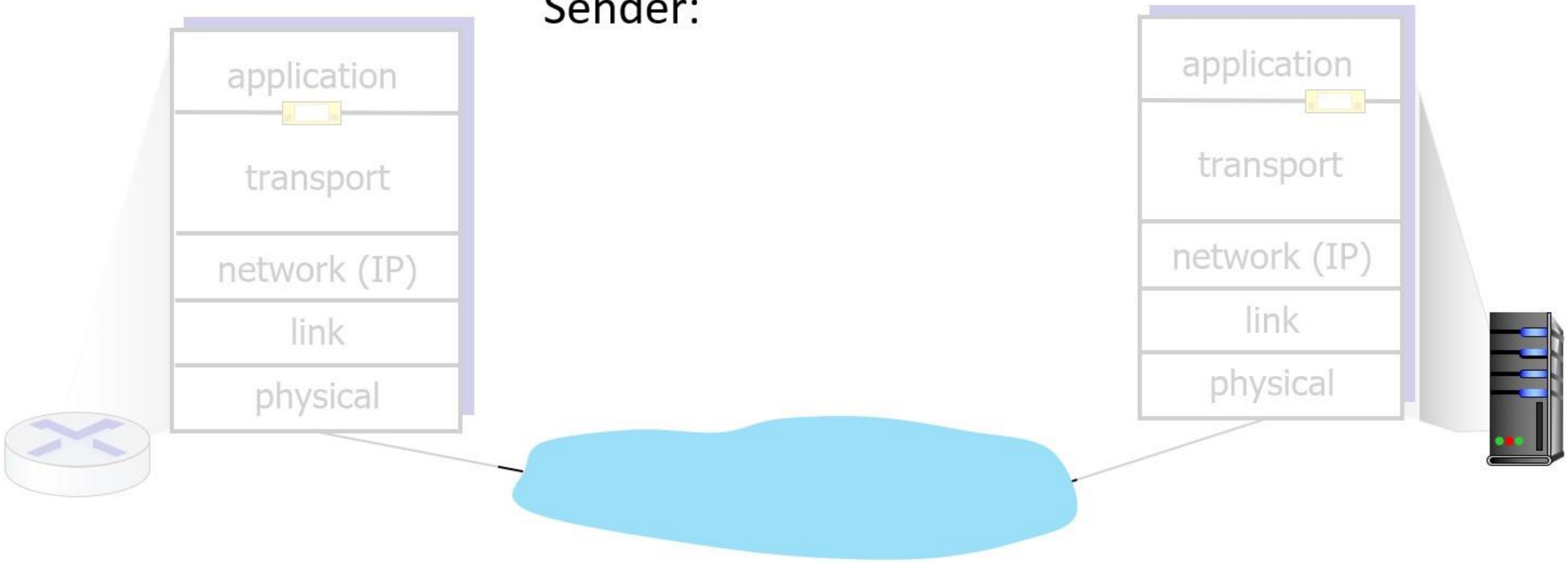
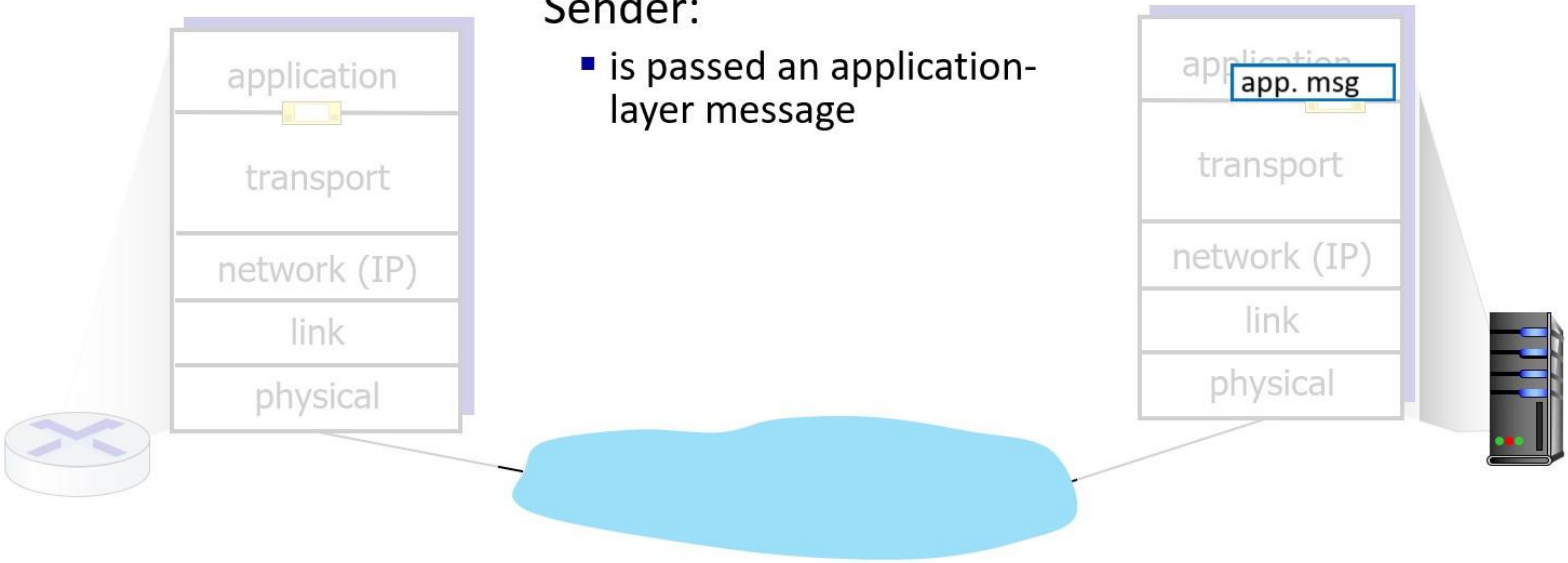


Transport Layer Actions

Sender:

- is passed an application-layer message



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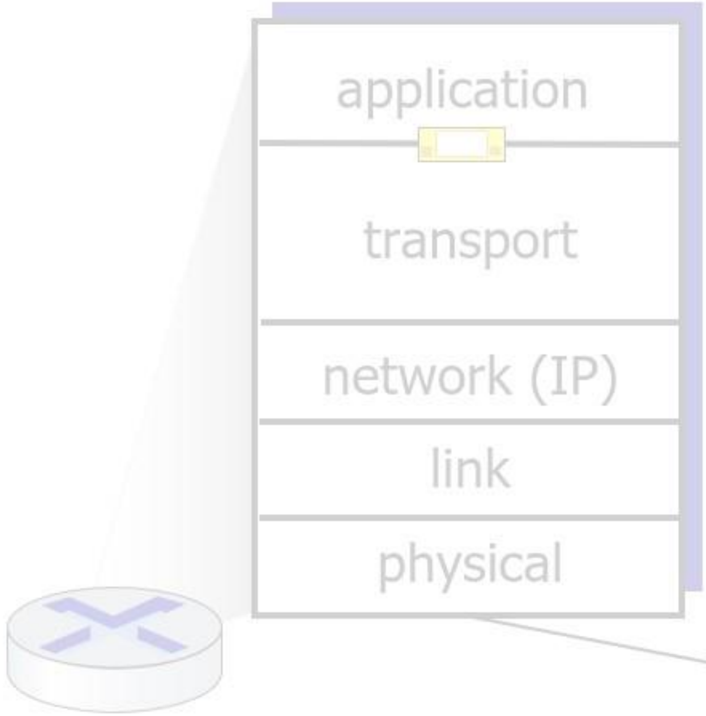

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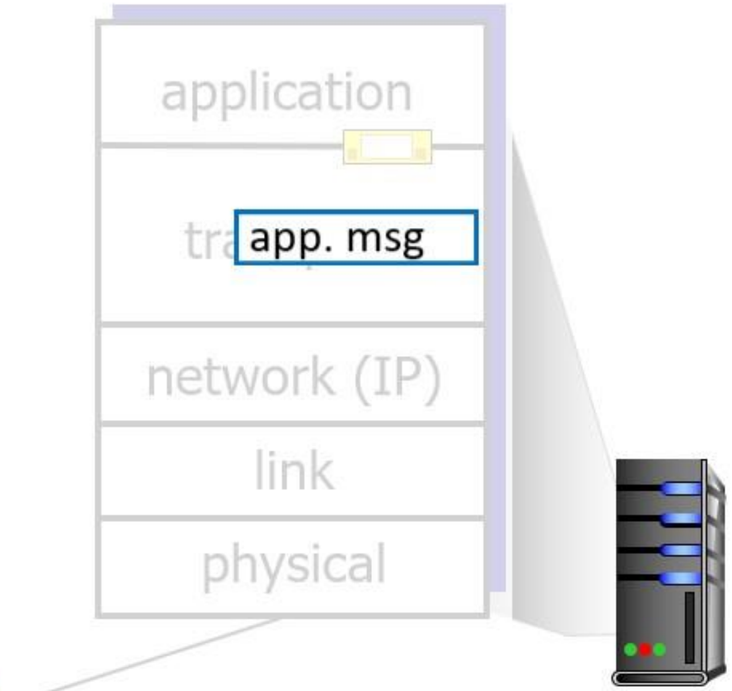

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Sender:

- is passed an application-layer message
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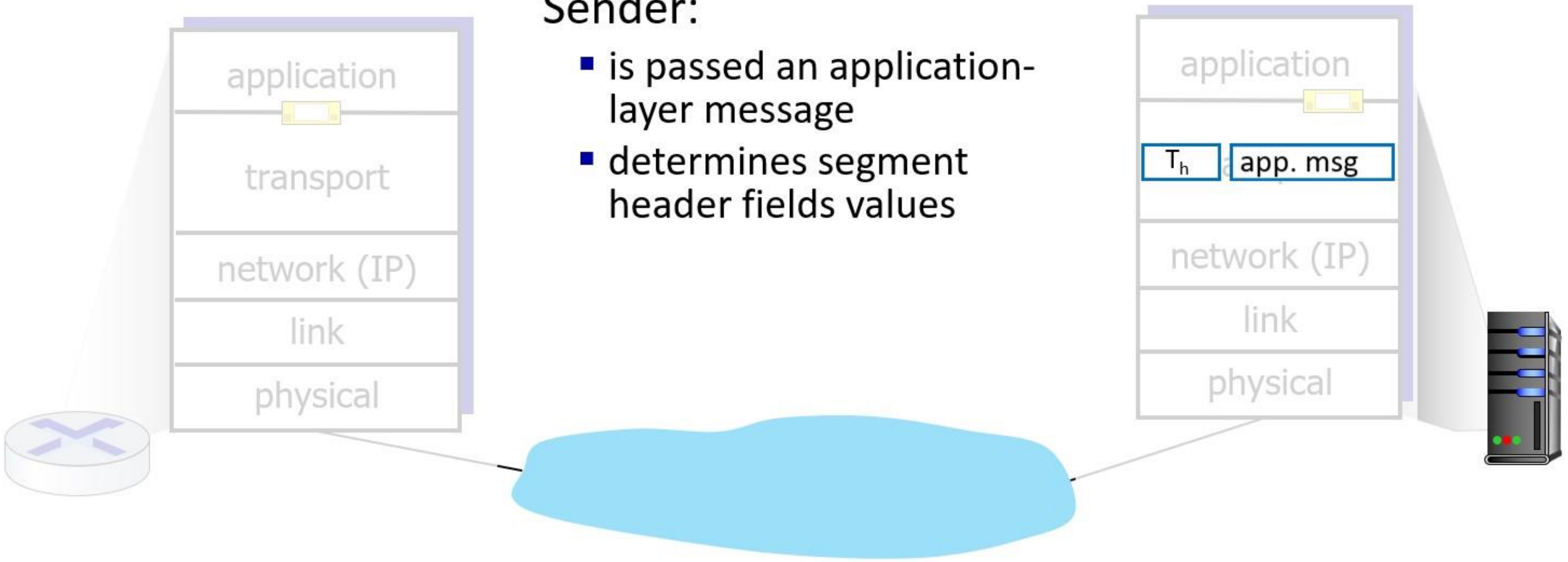

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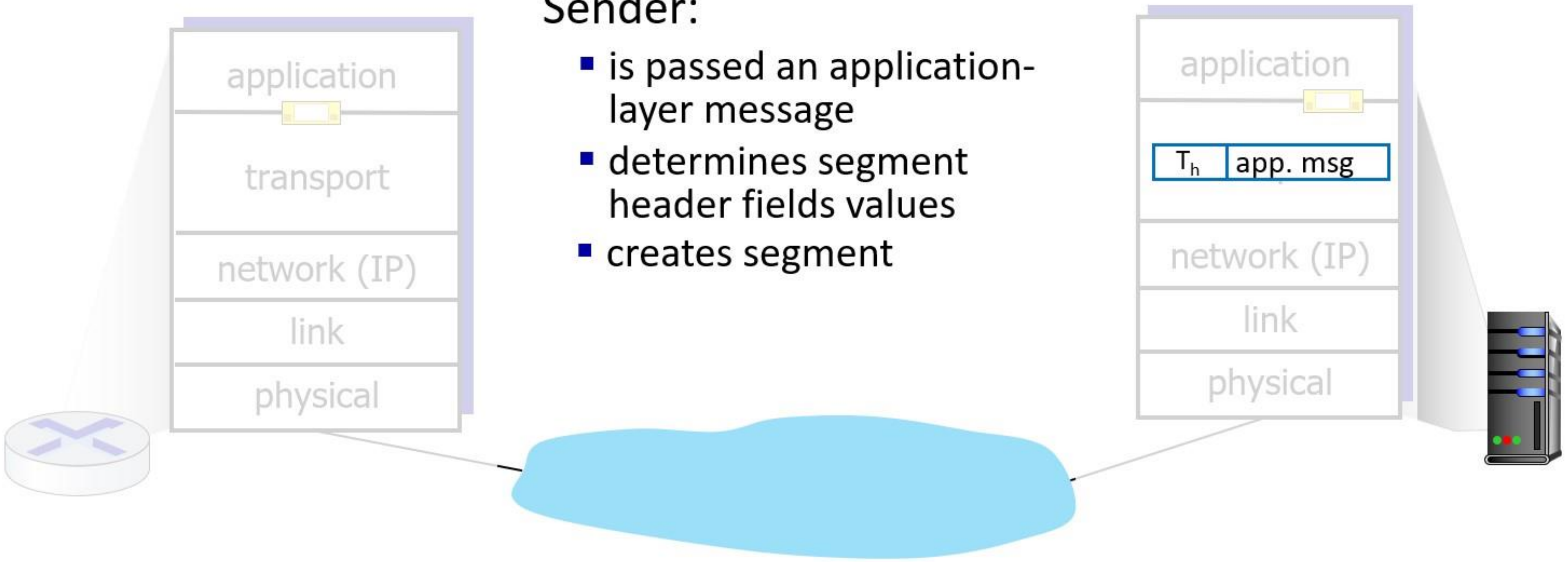

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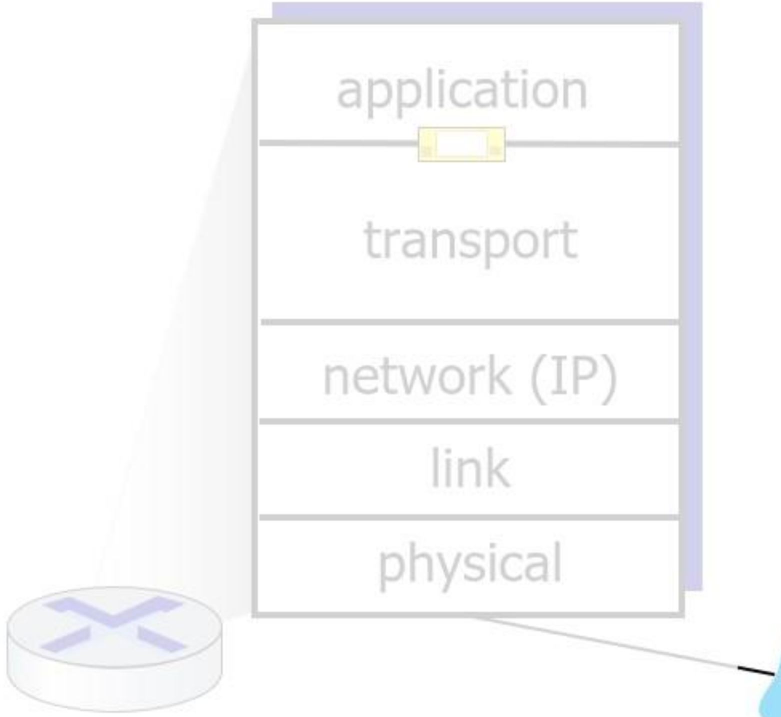

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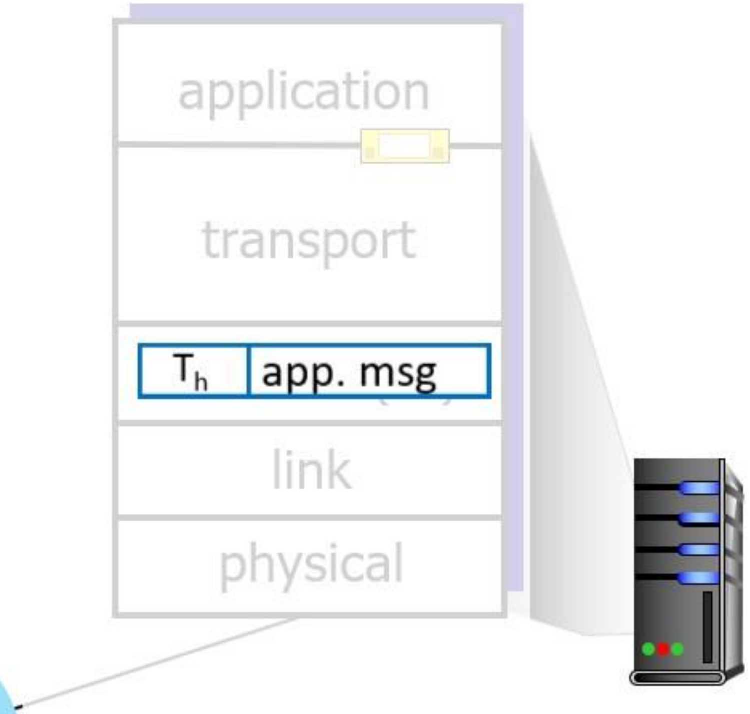

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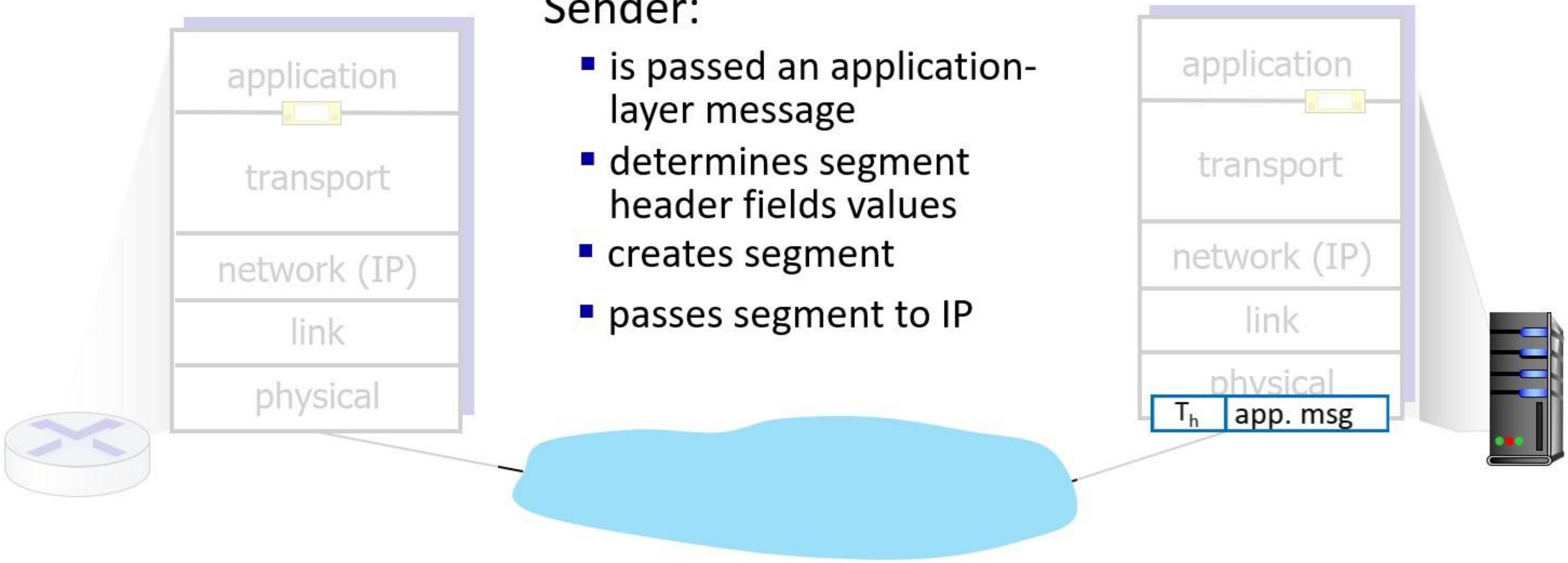

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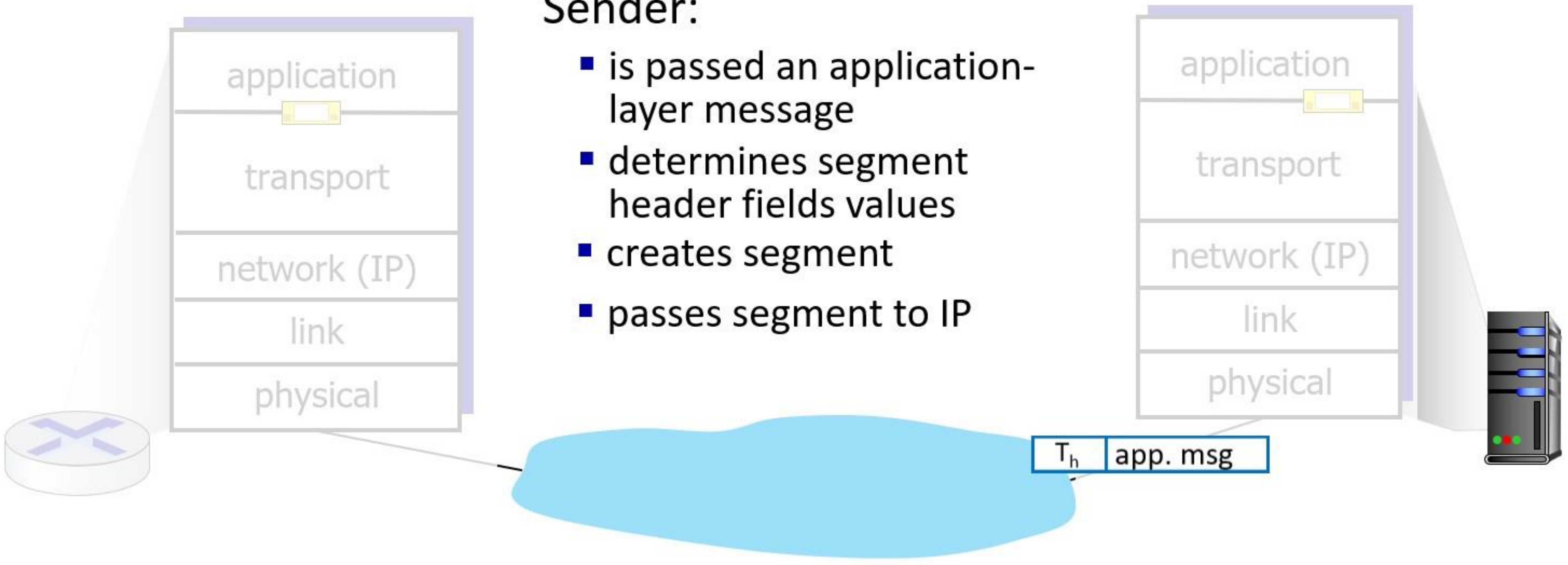

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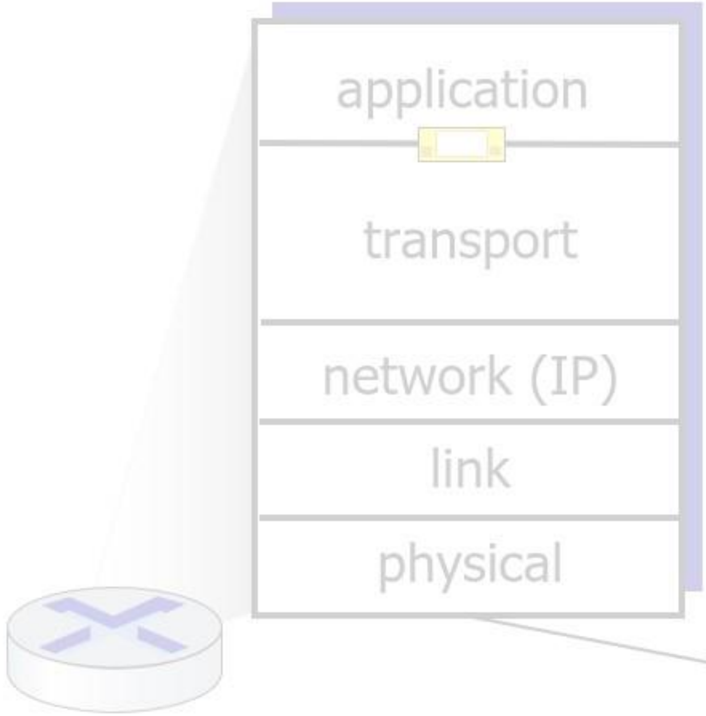

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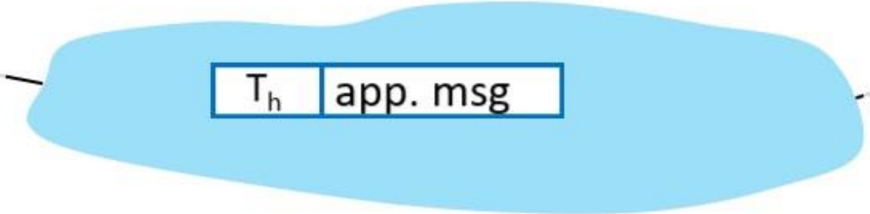

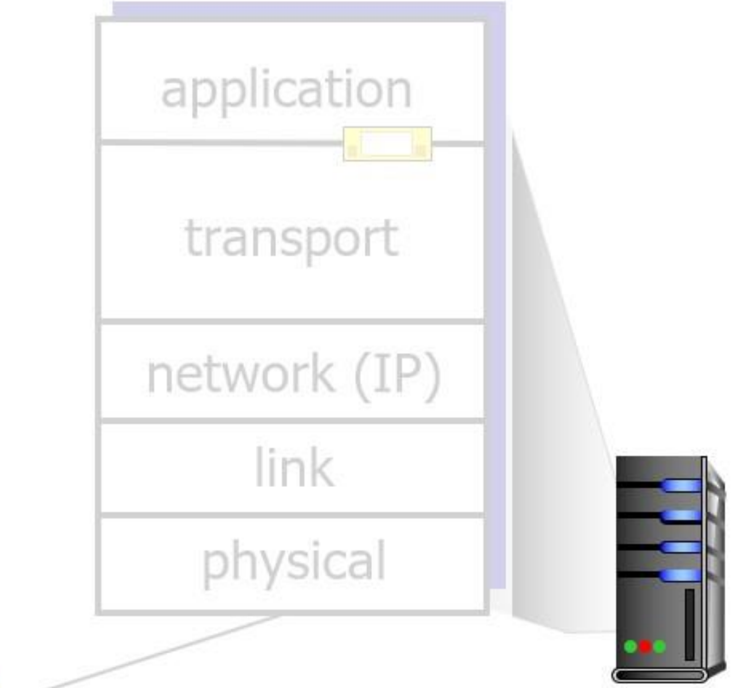

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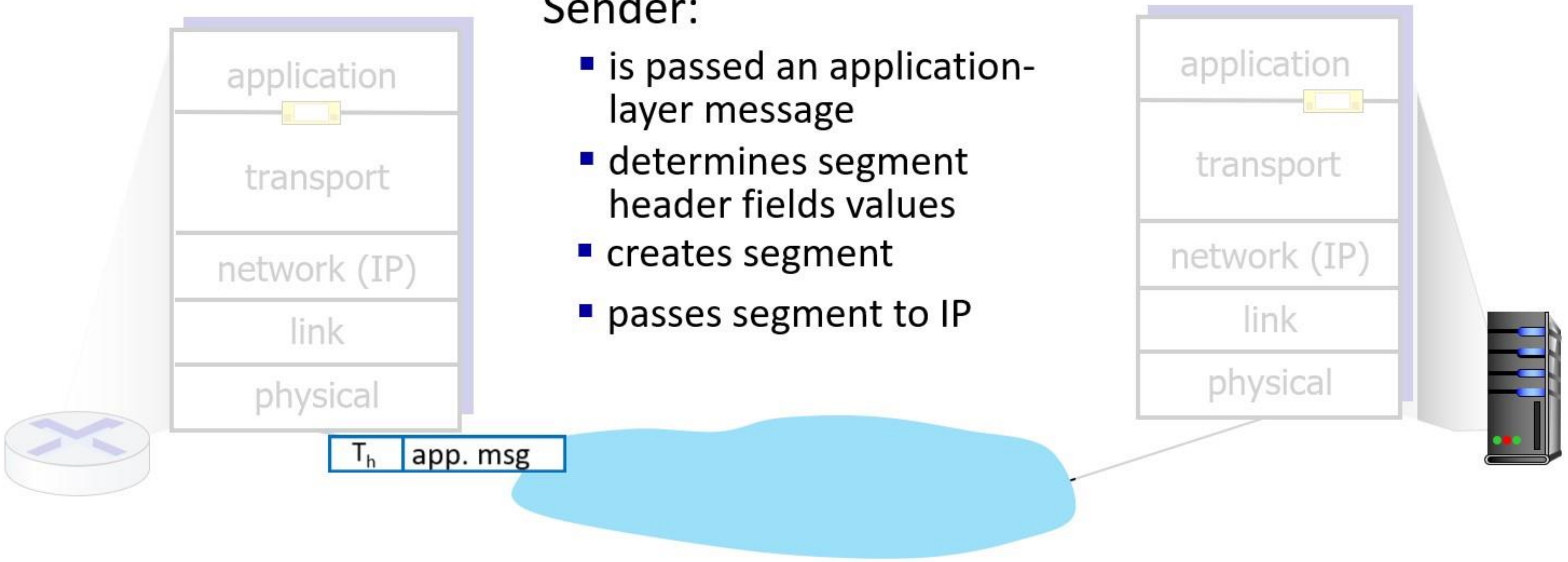

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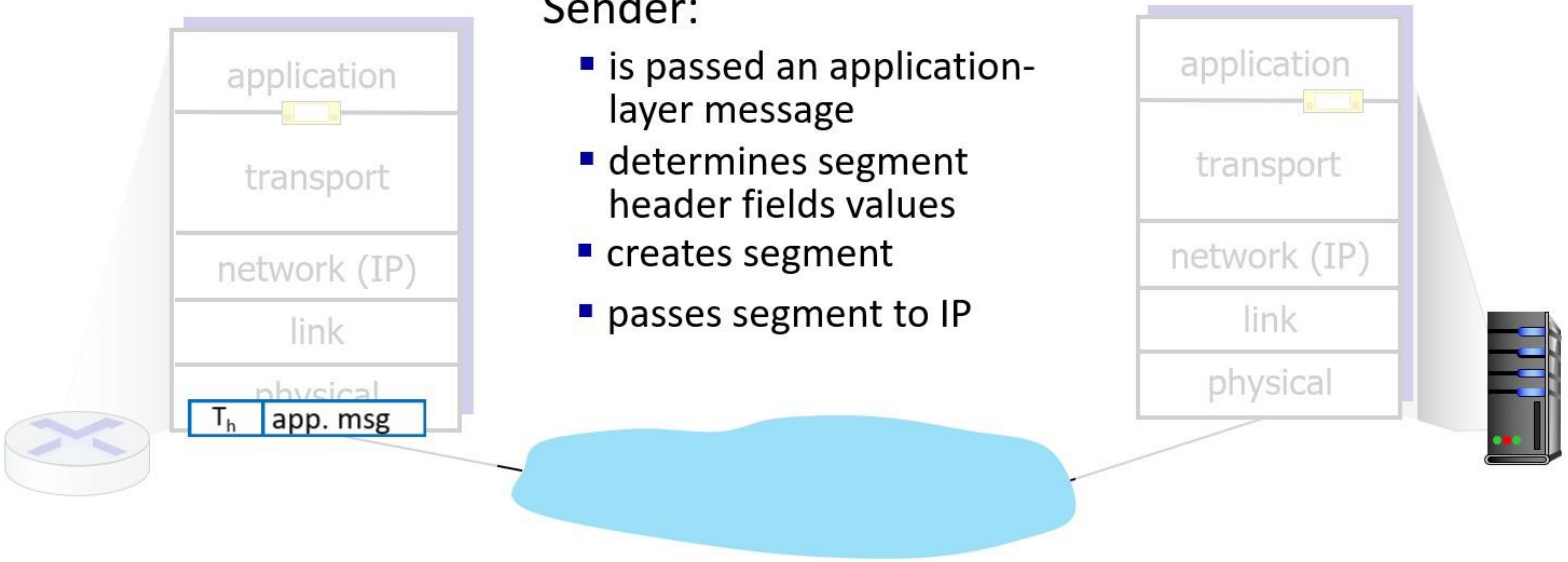

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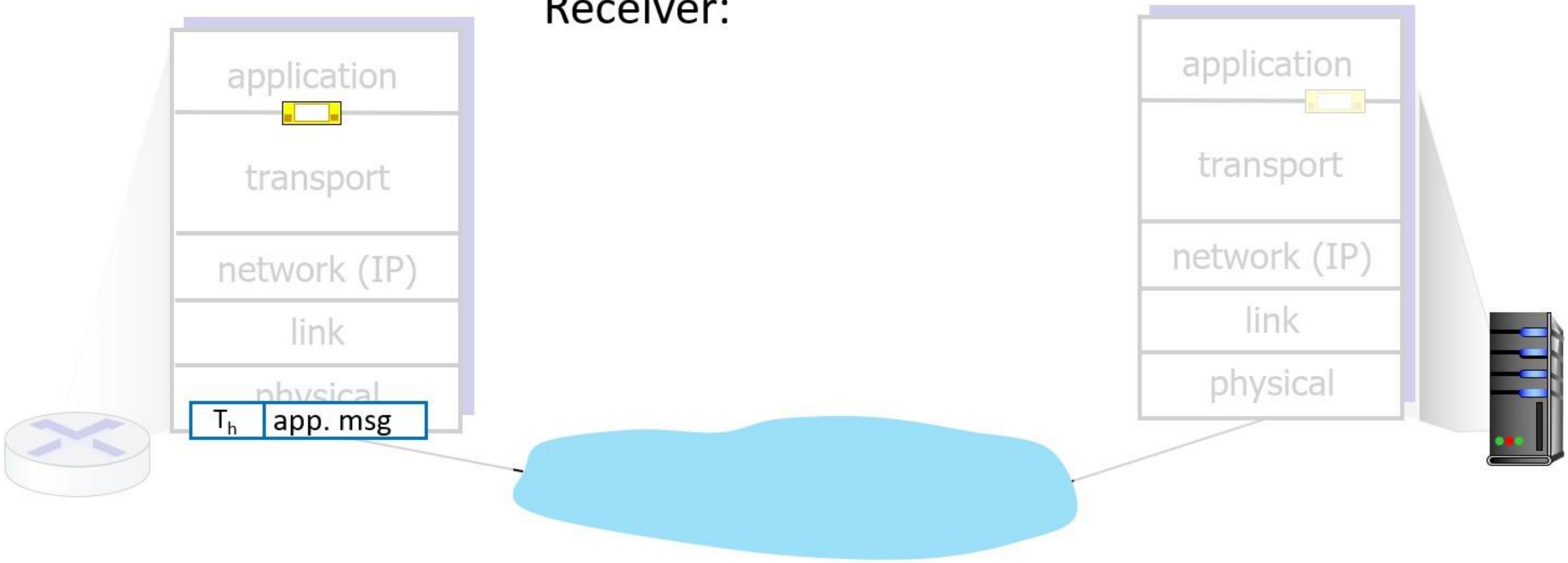

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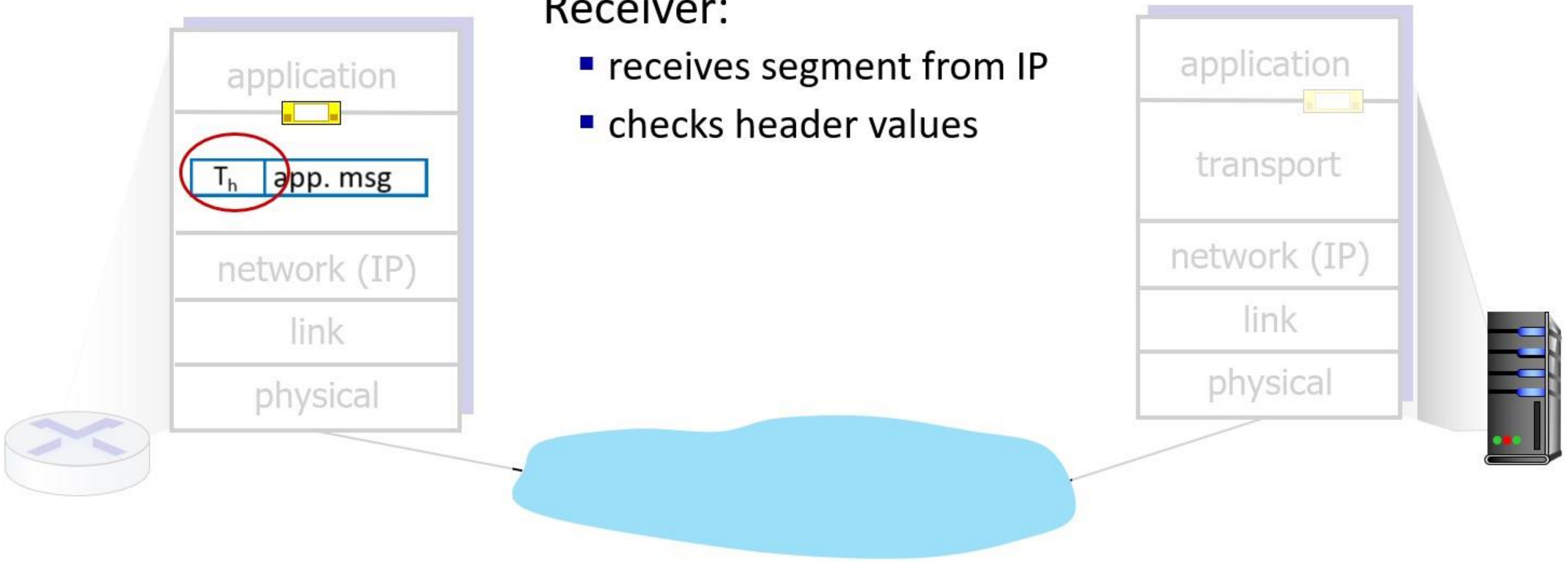

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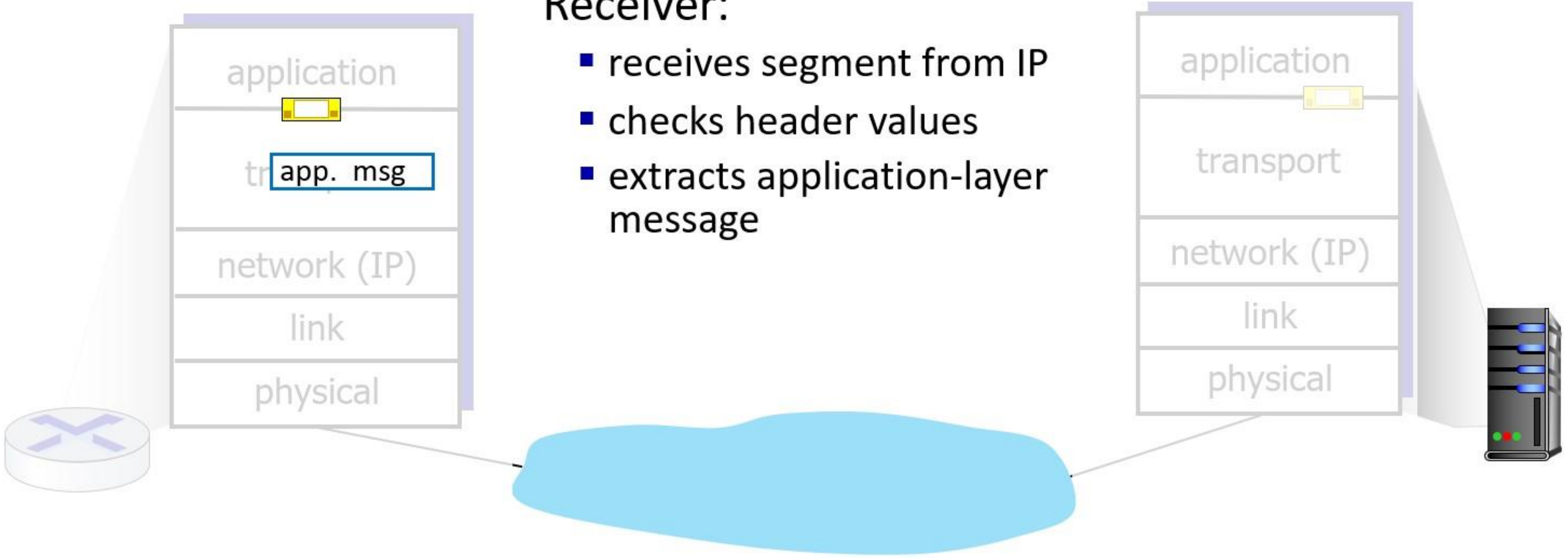

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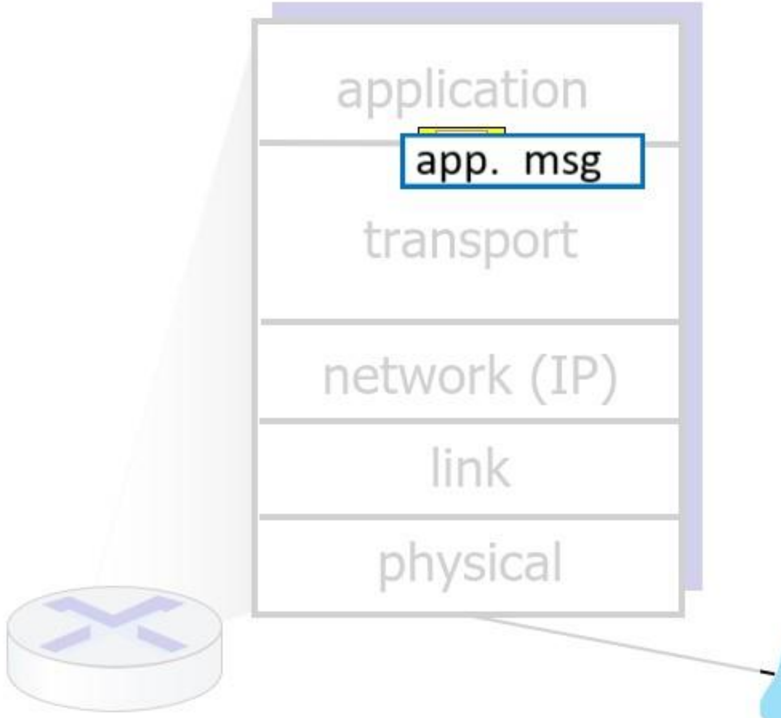

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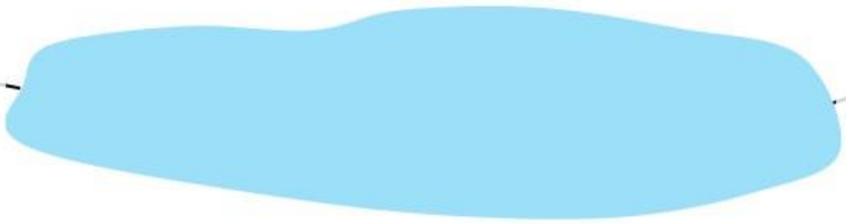
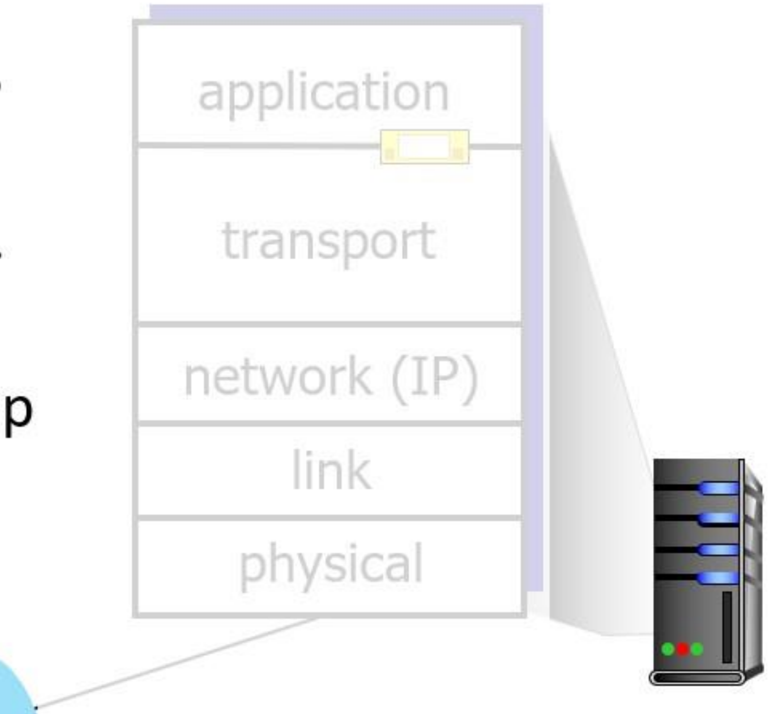
- demultiplexes message up to application via socket





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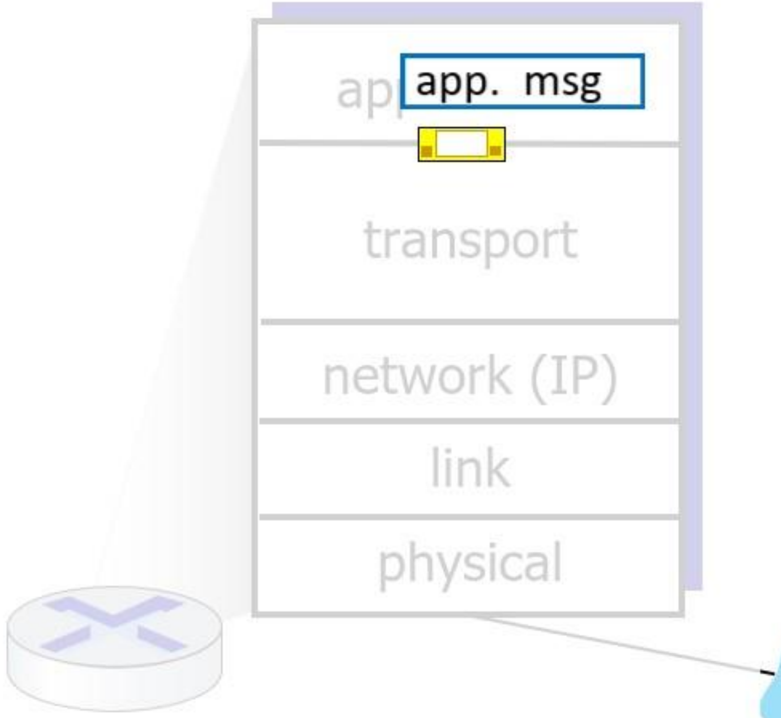

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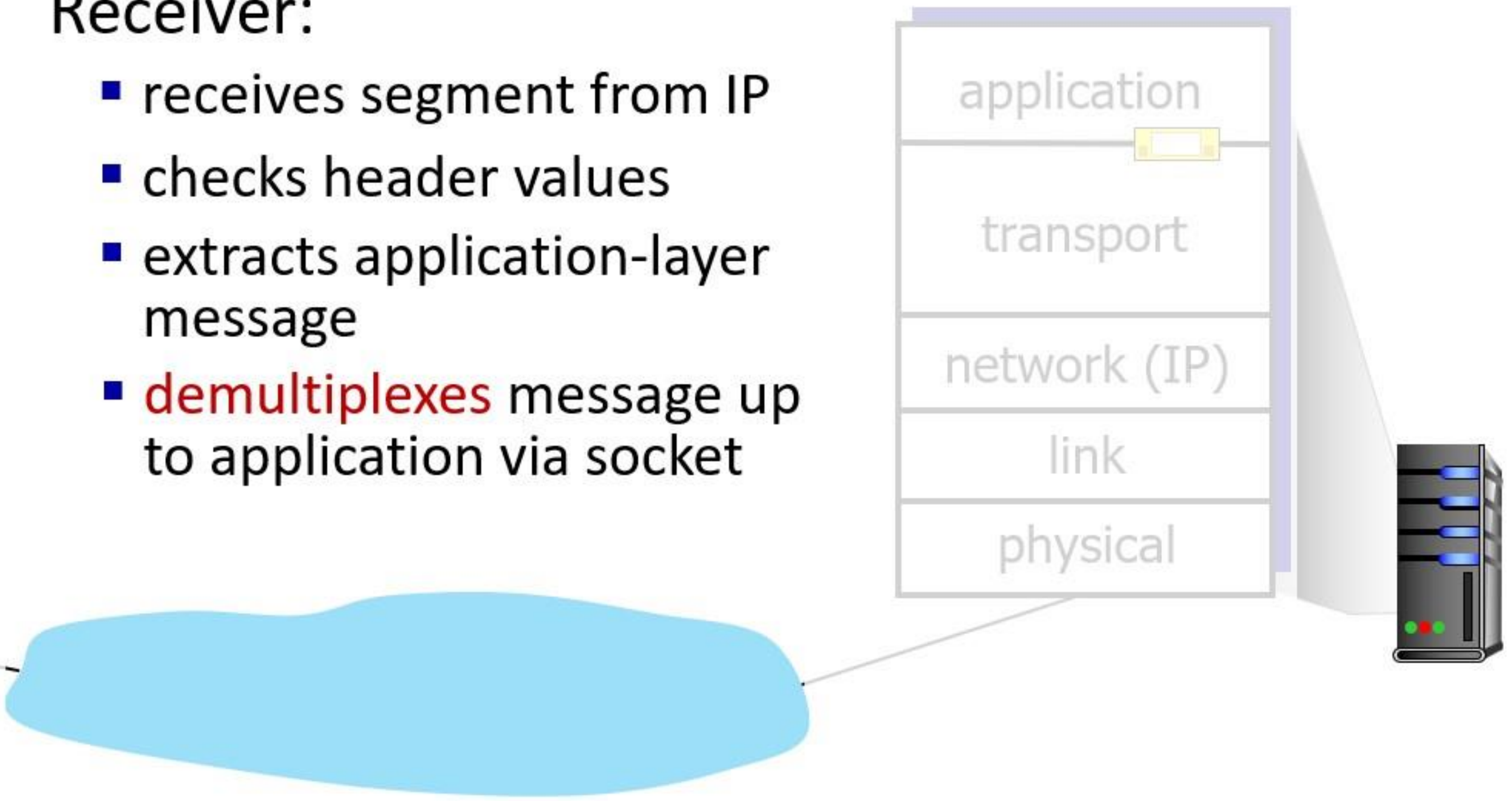
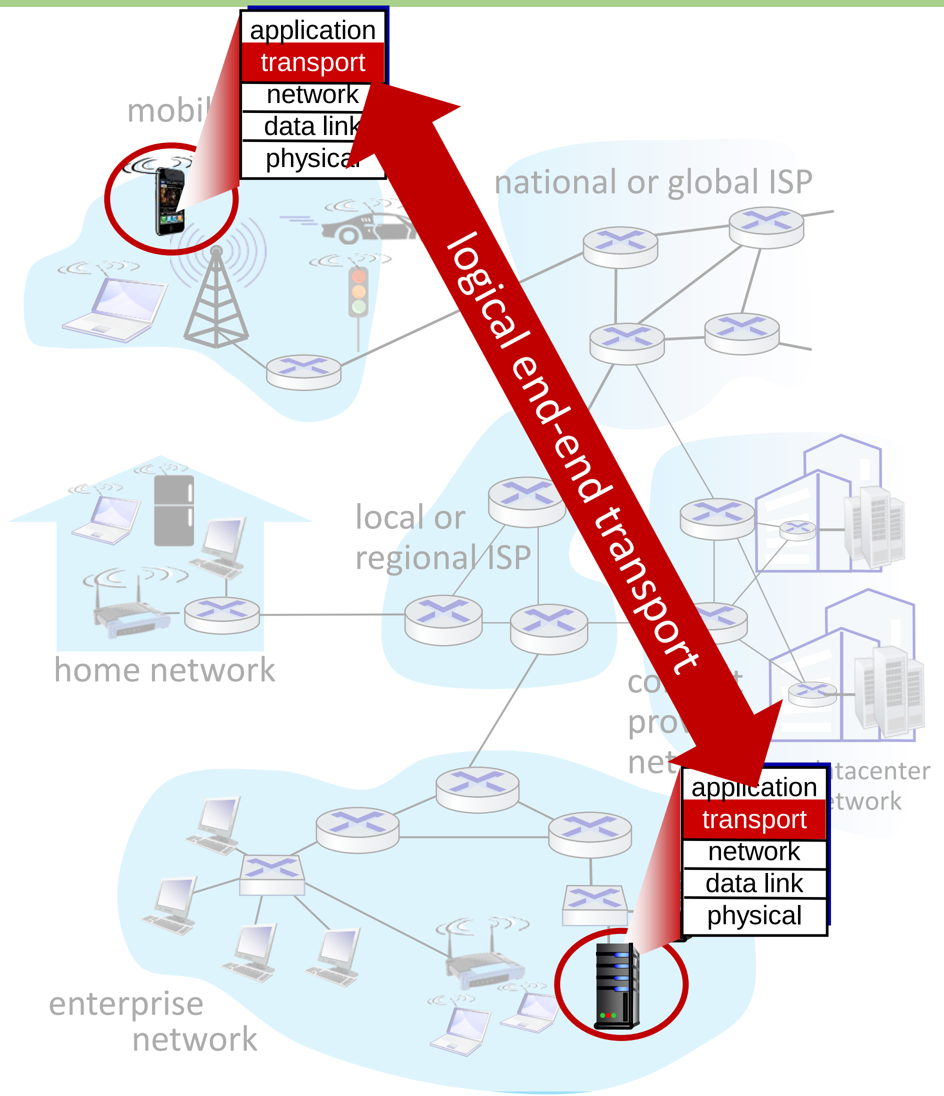


Two principal Internet transport protocols

- **TCP:** Transmission Control Protocol
  - reliable, in-order delivery
  - congestion control
  - flow control
  - connection setup
- **UDP:** User Datagram Protocol
  - unreliable, unordered delivery
  - no-frills بدون زخرفة extension of "best-effort" IP
- services *not* available:
  - delay guarantees
  - bandwidth guarantees



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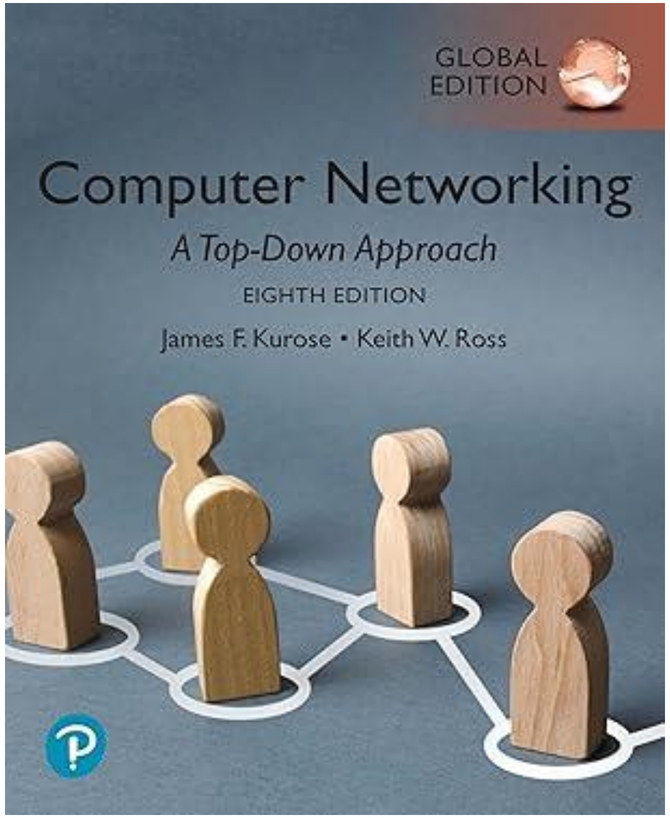

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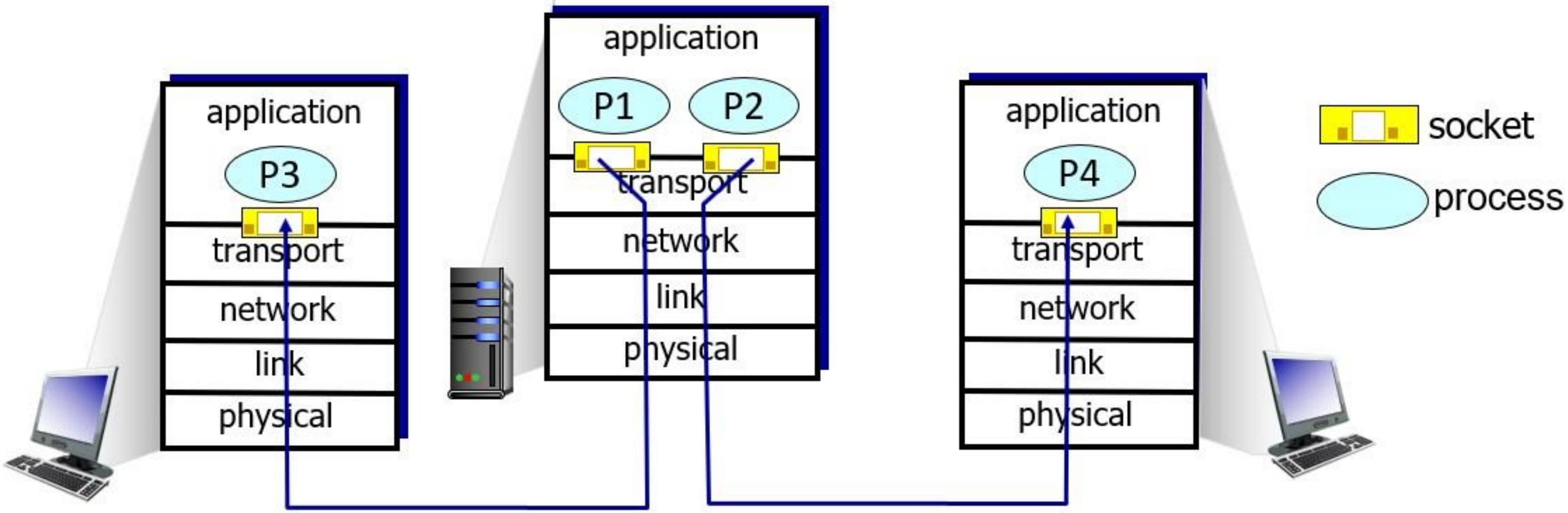

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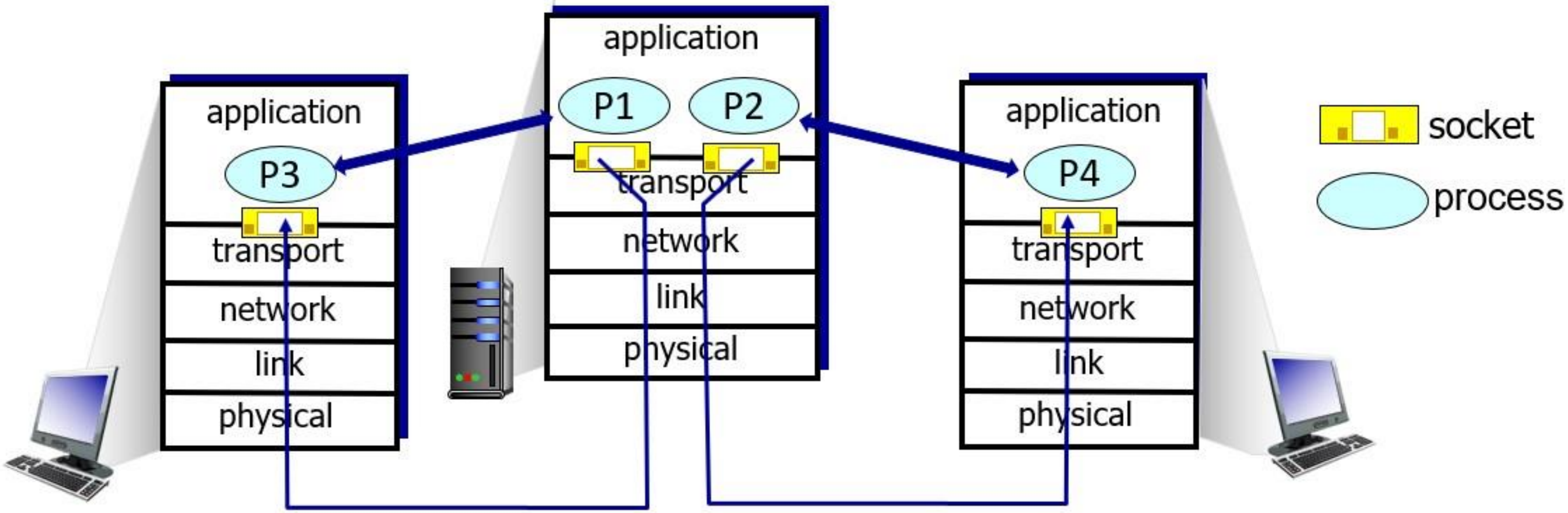
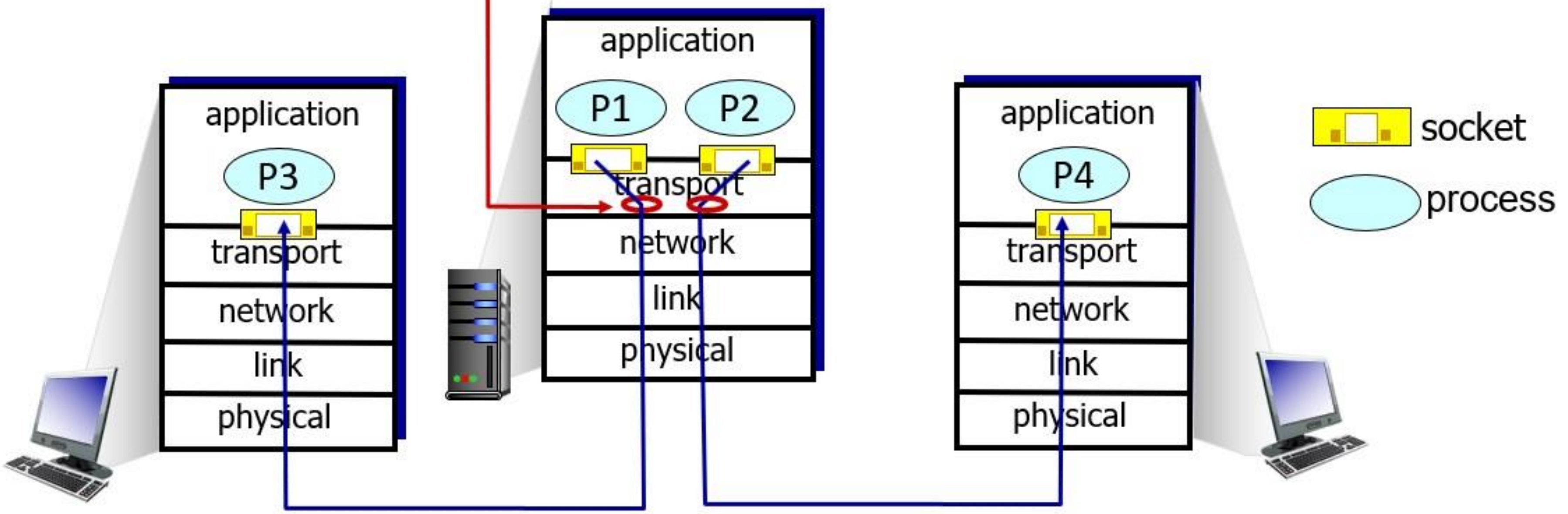


Multiplexing/demultiplexing

multiplexing as sender:

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



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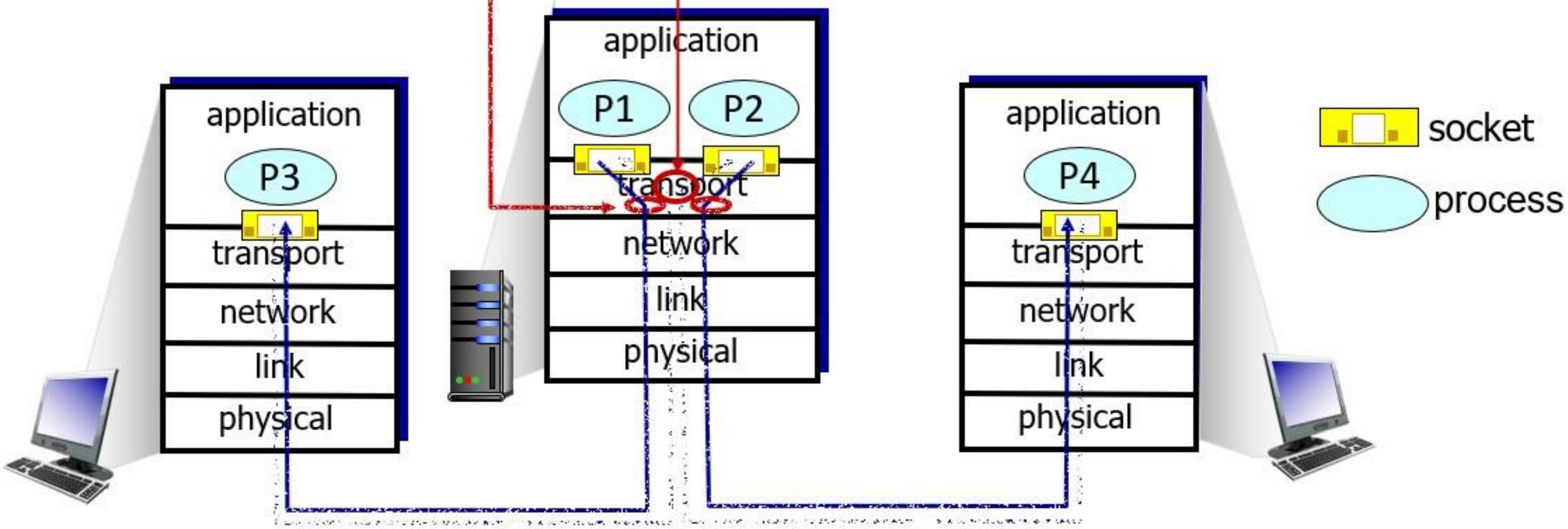

Multiplexing/demultiplexing

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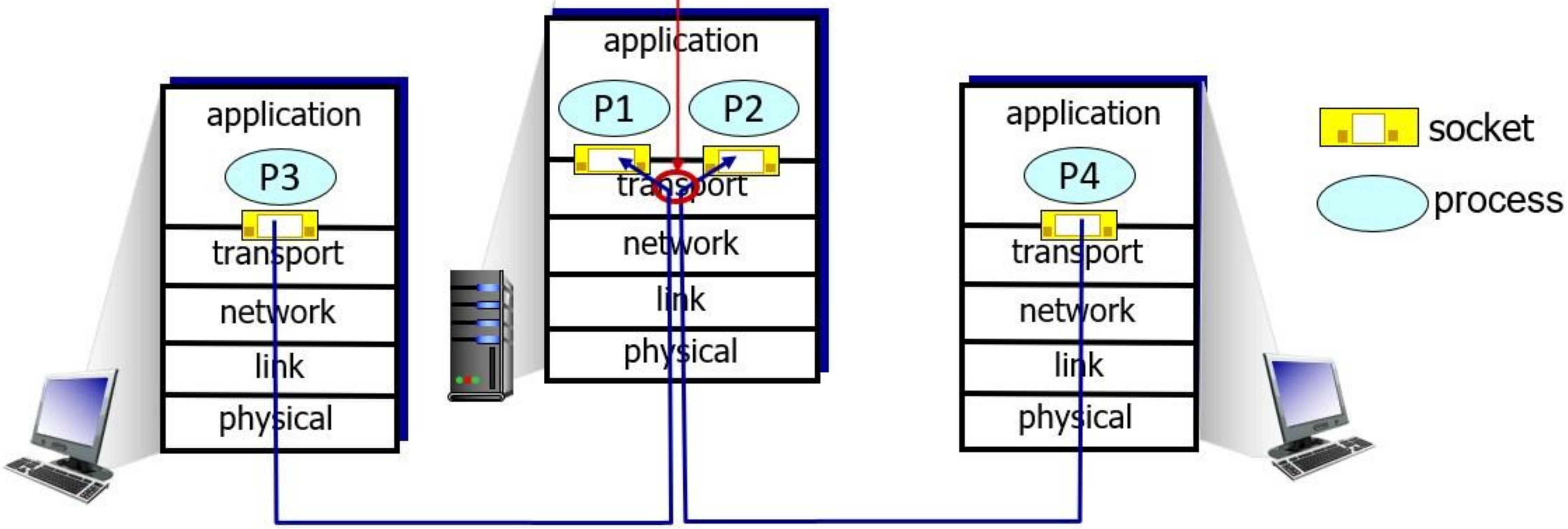

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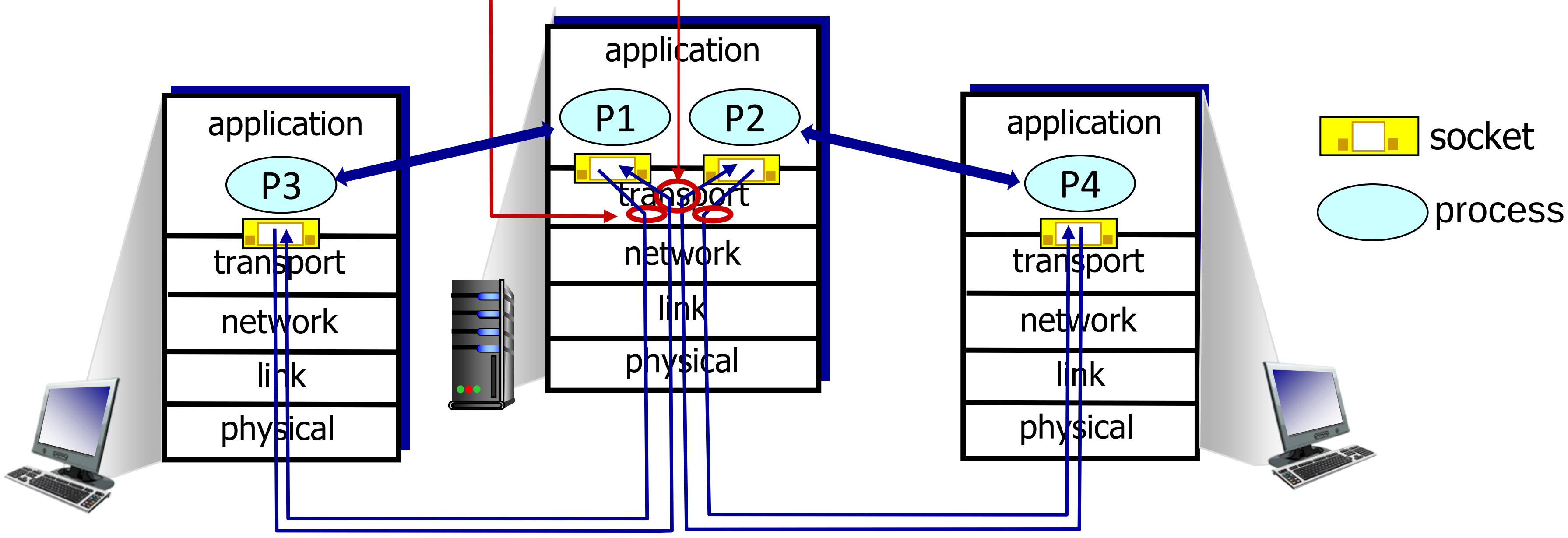

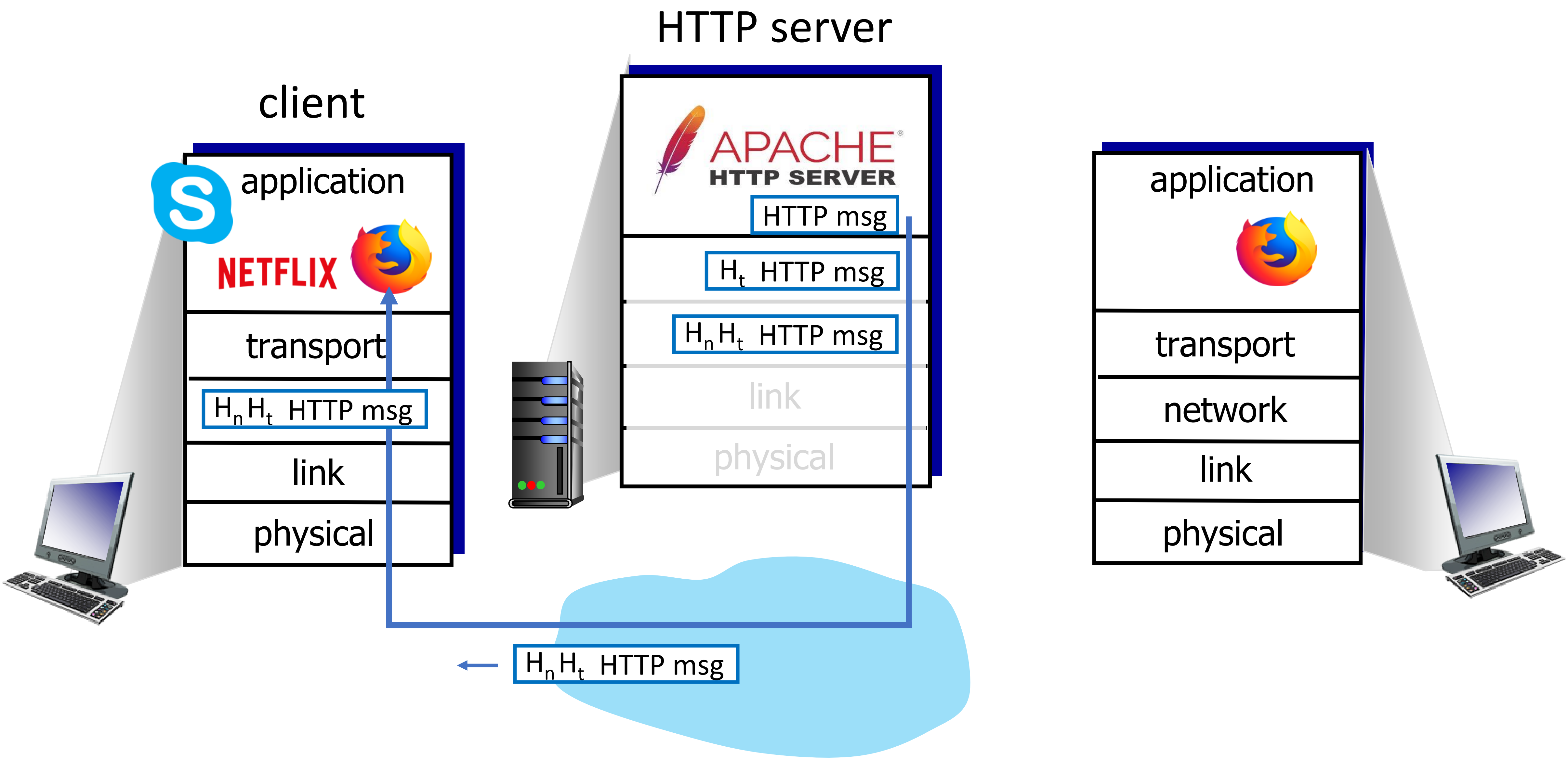
HTTP server
client
application
NETFLIX
transport
Hn Ht HTTP msg
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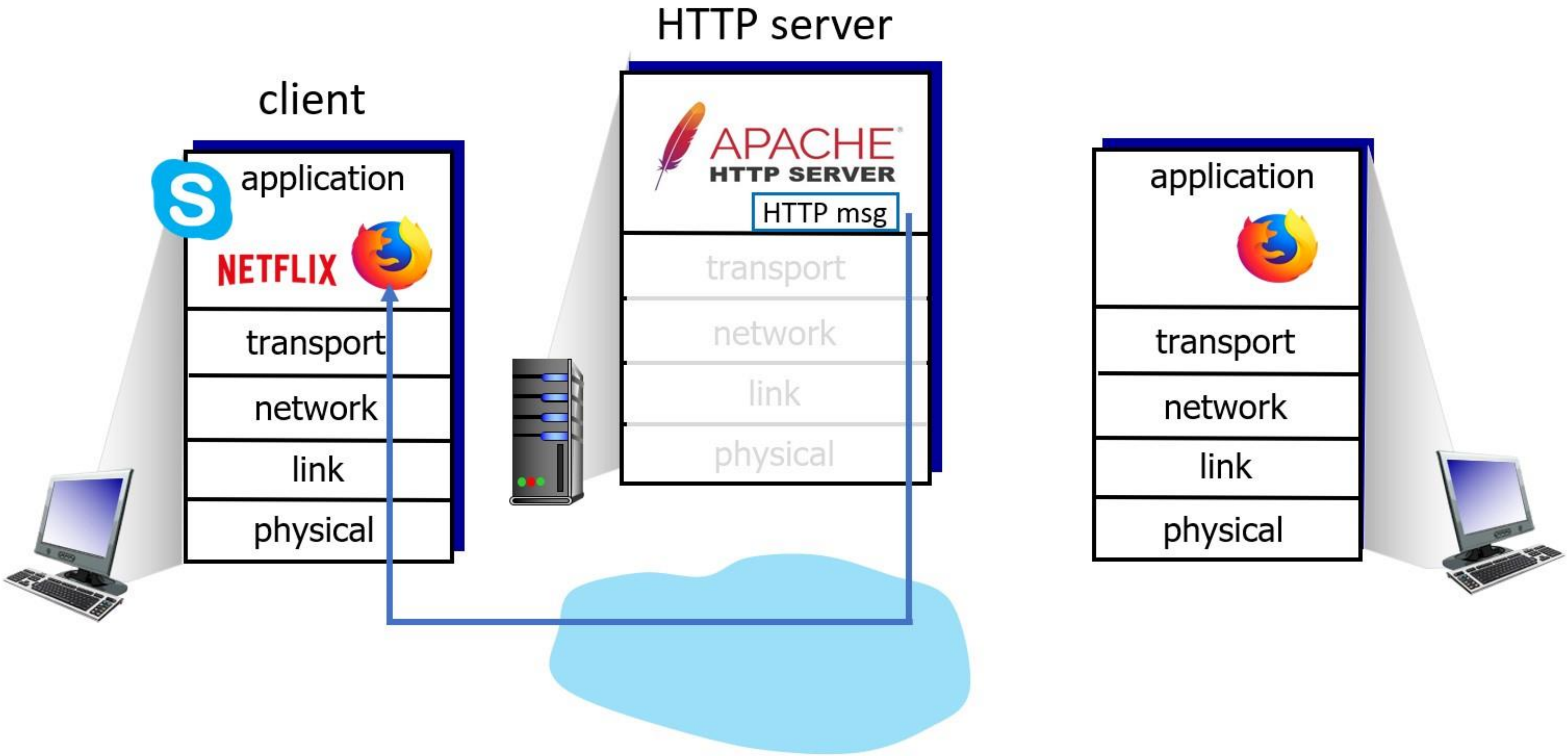

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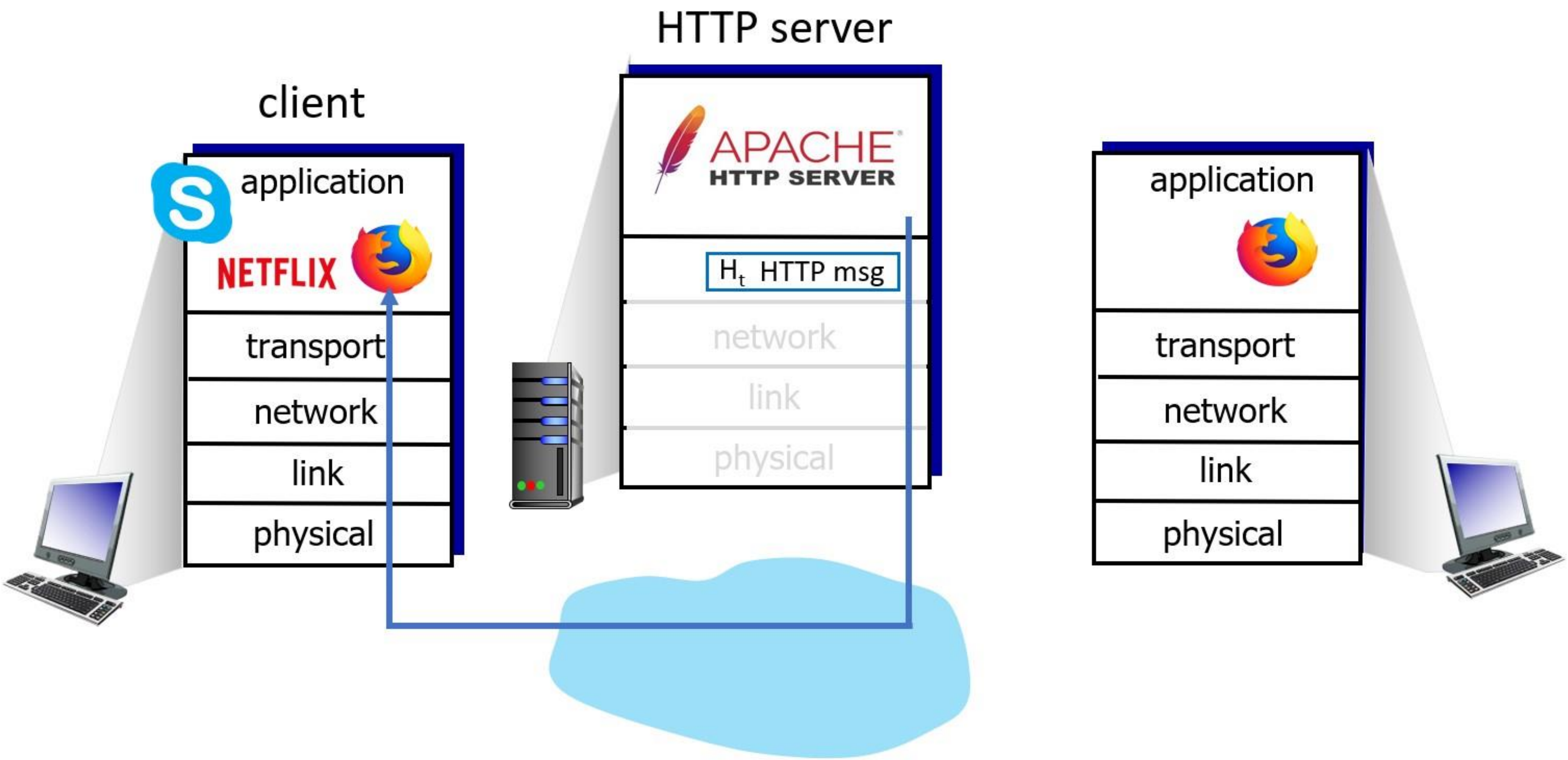
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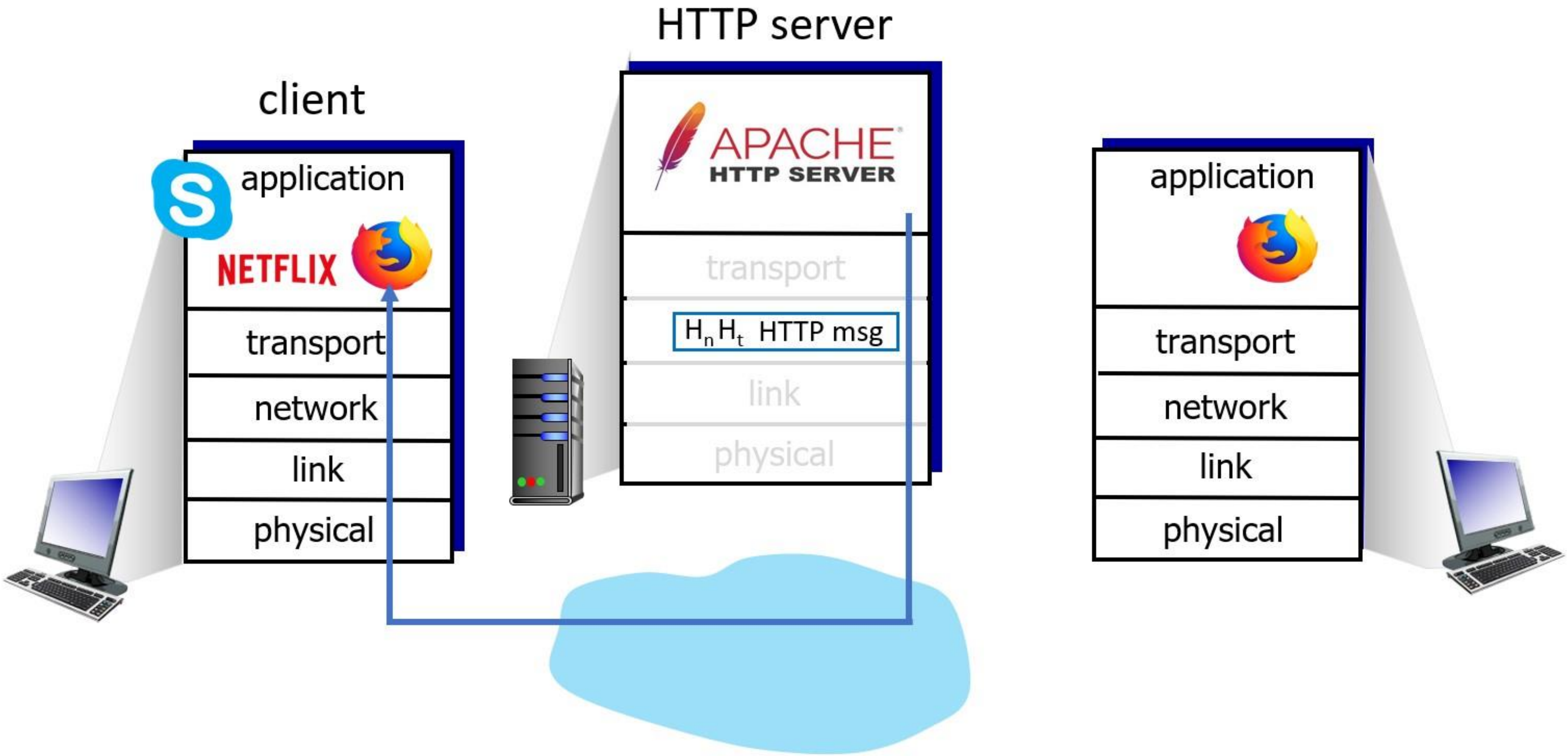

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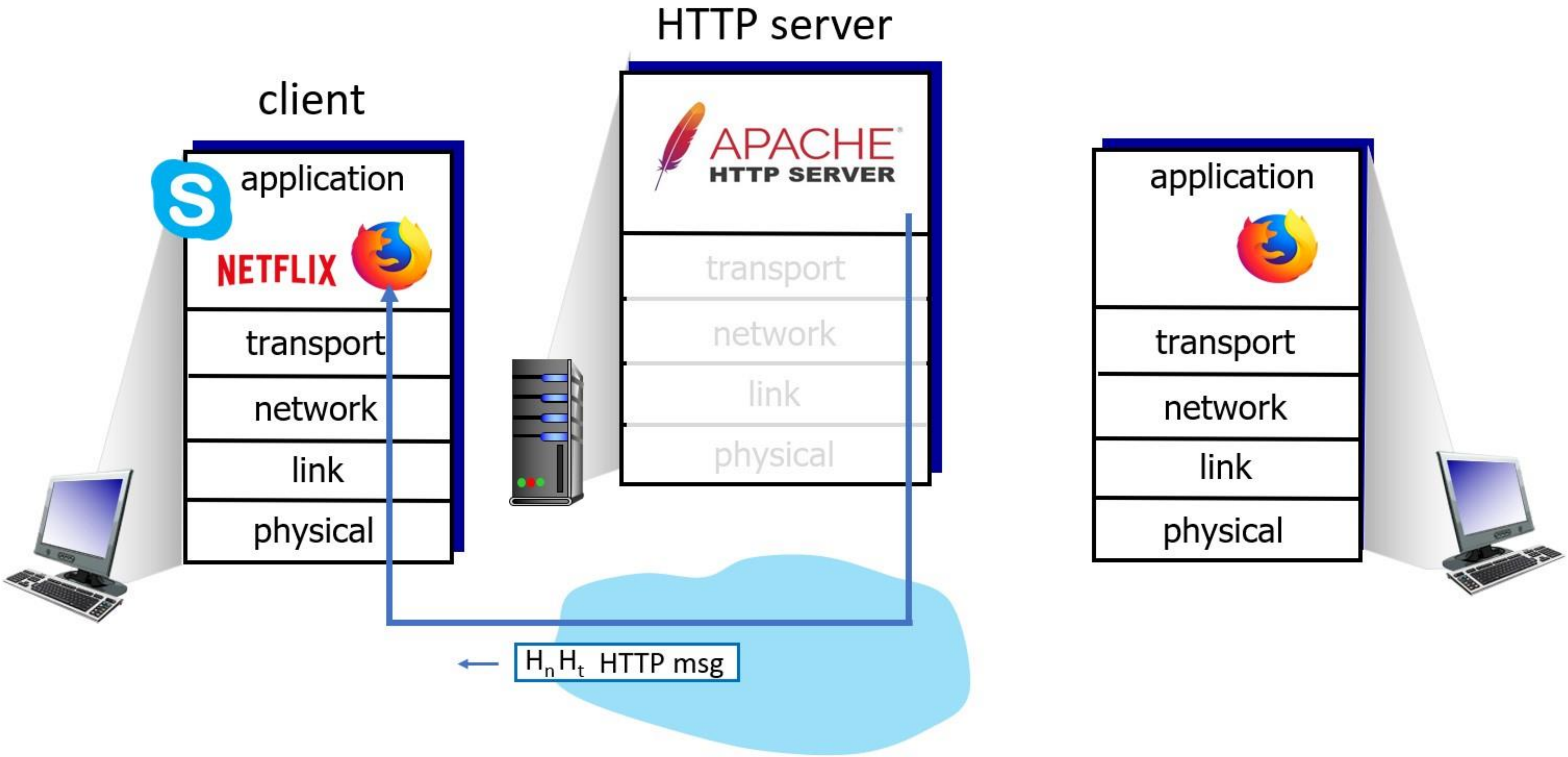
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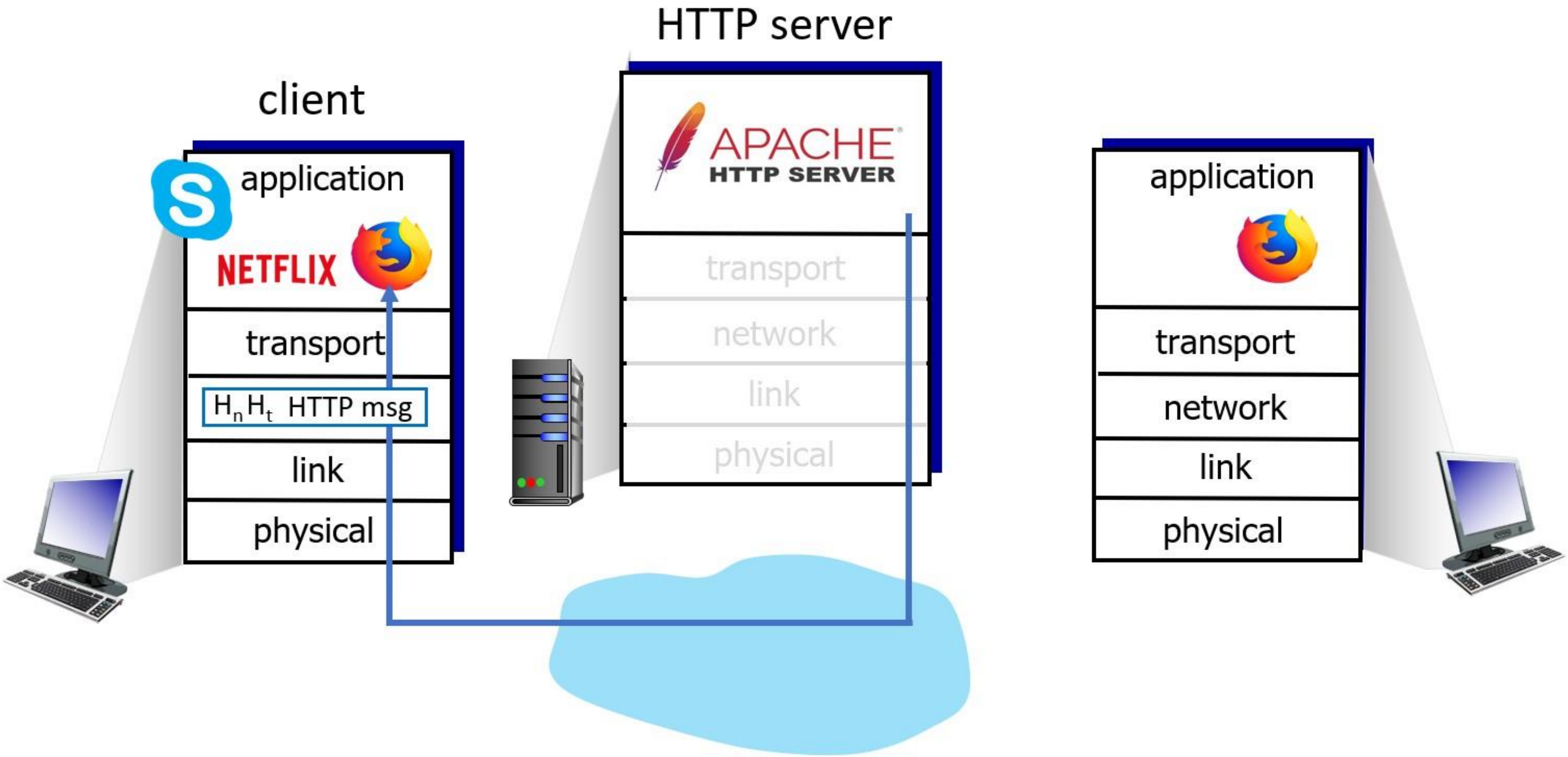

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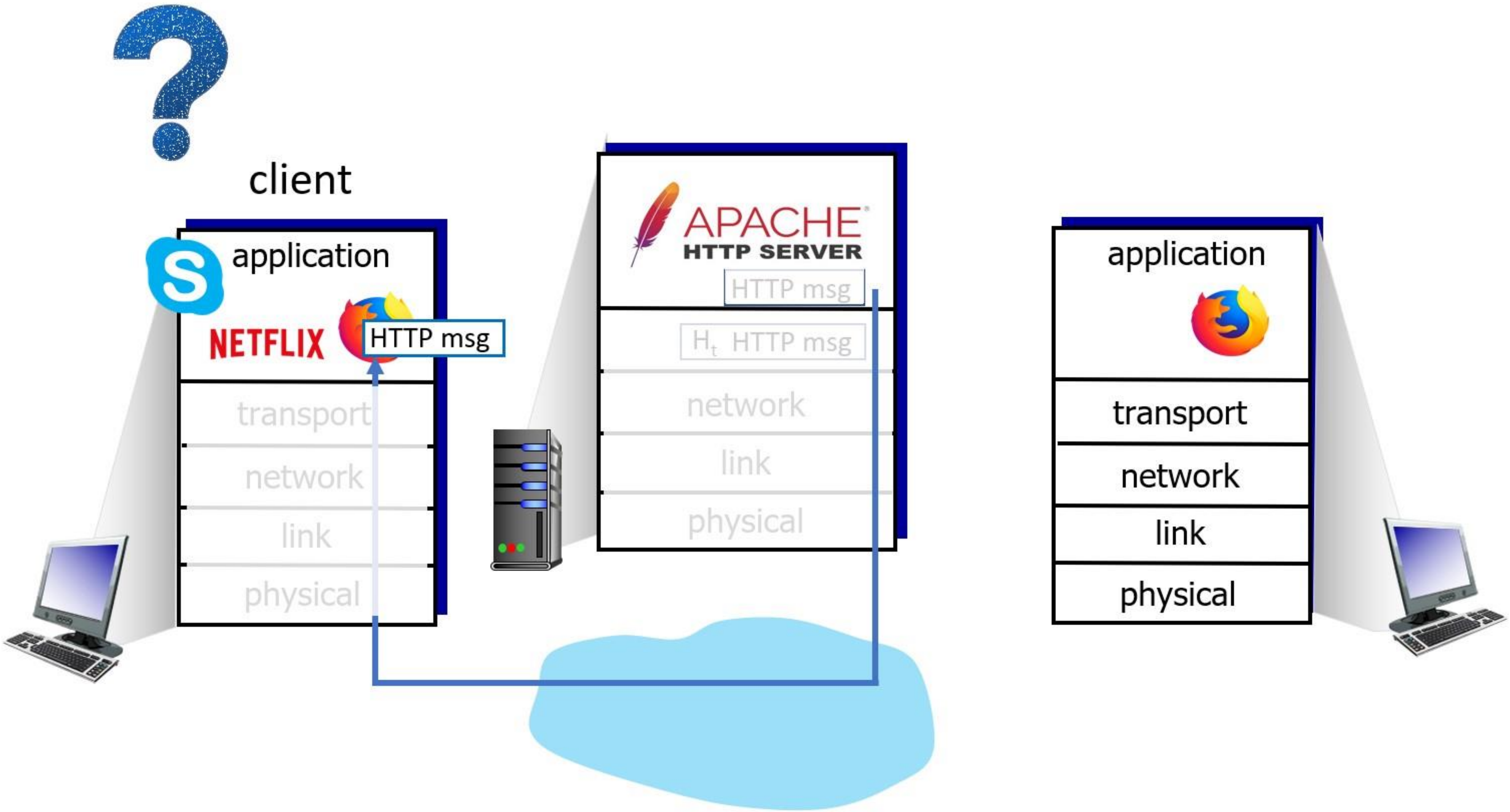

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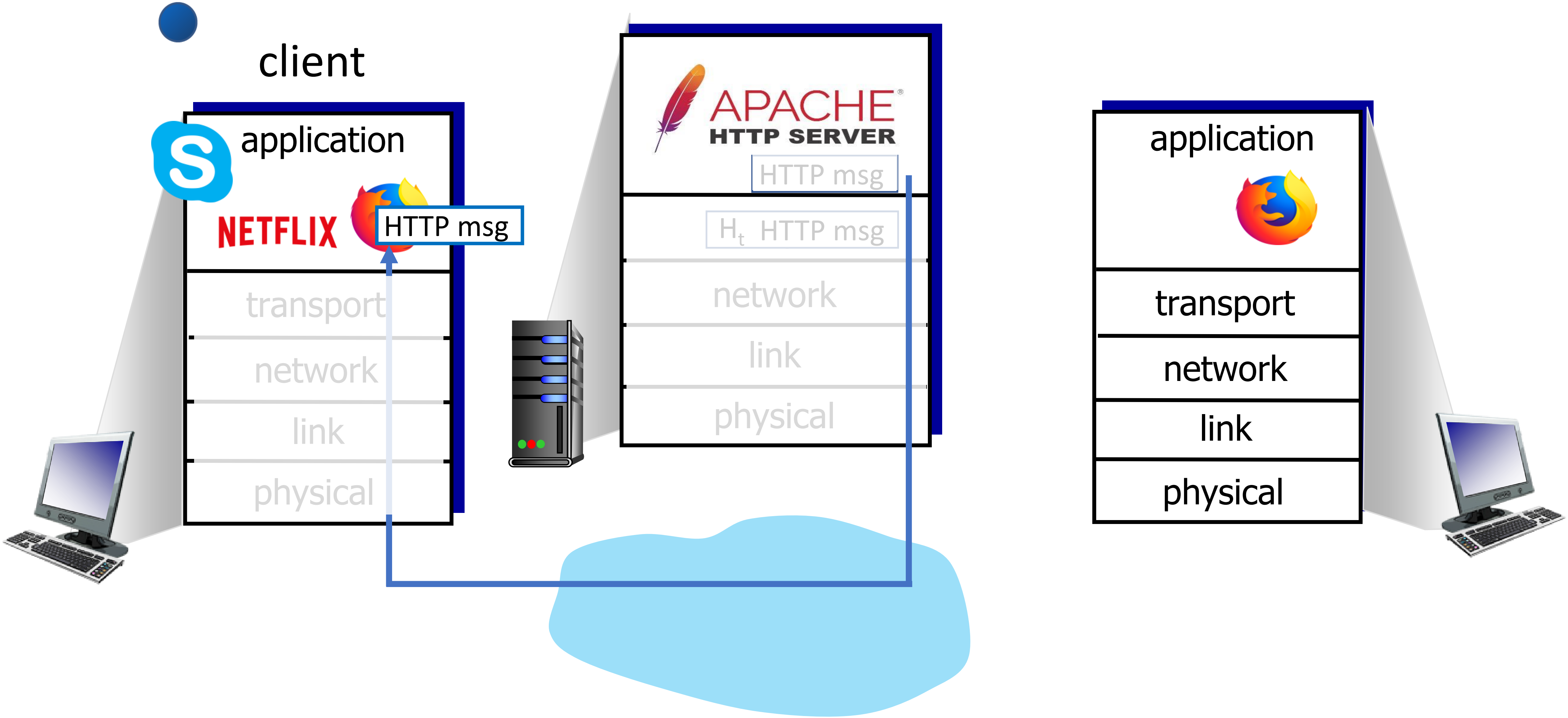
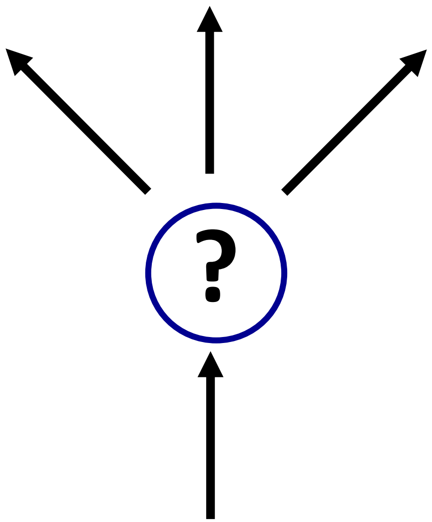
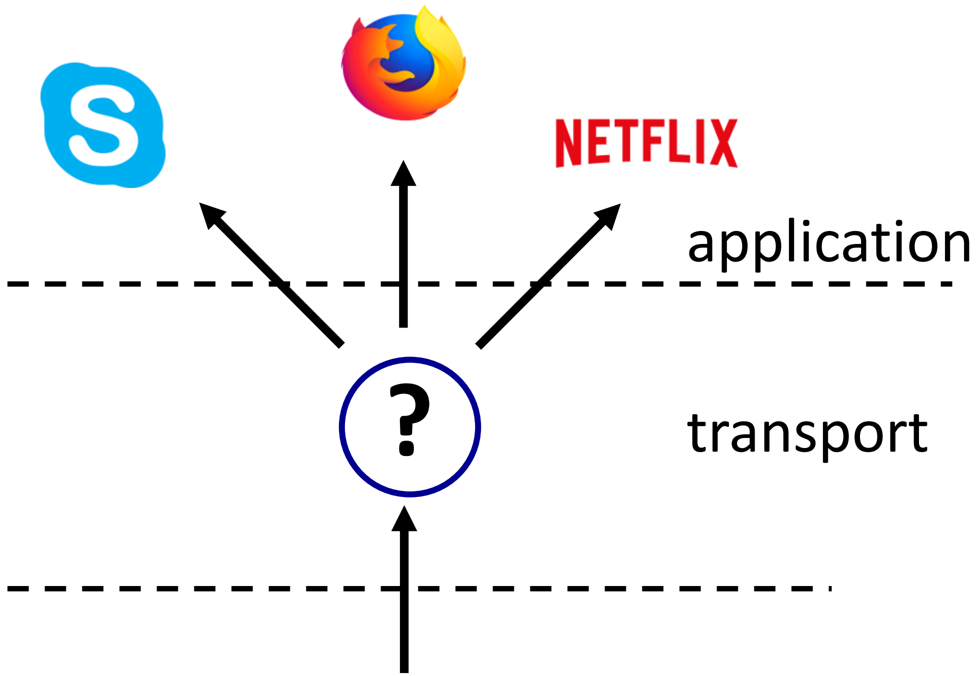
Q: how did transport layer know to deliver message to Firefox browser process rather then Netflix process or Skype process?





de-multiplexing



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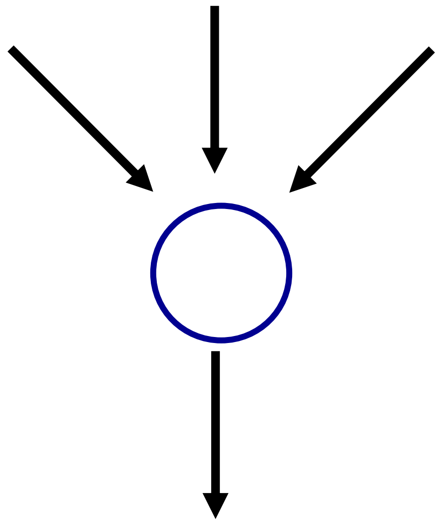
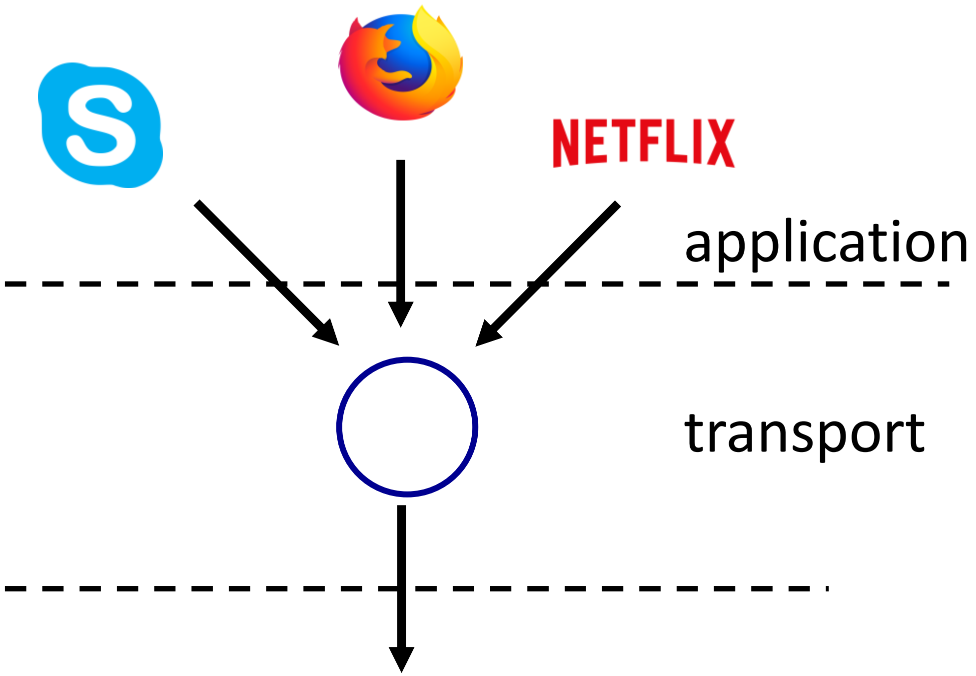


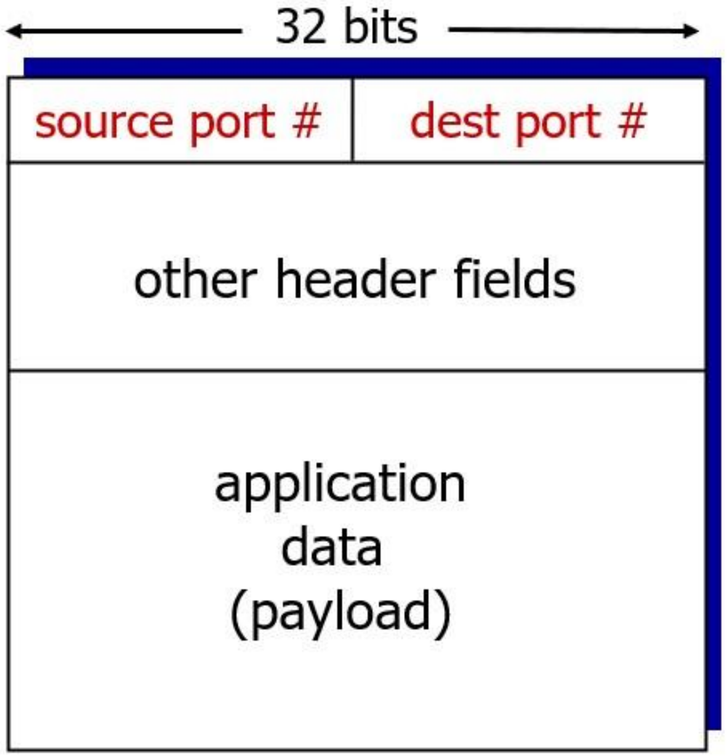
multiplexing



multiplexing

How demultiplexing works

- host <u>receives</u> 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

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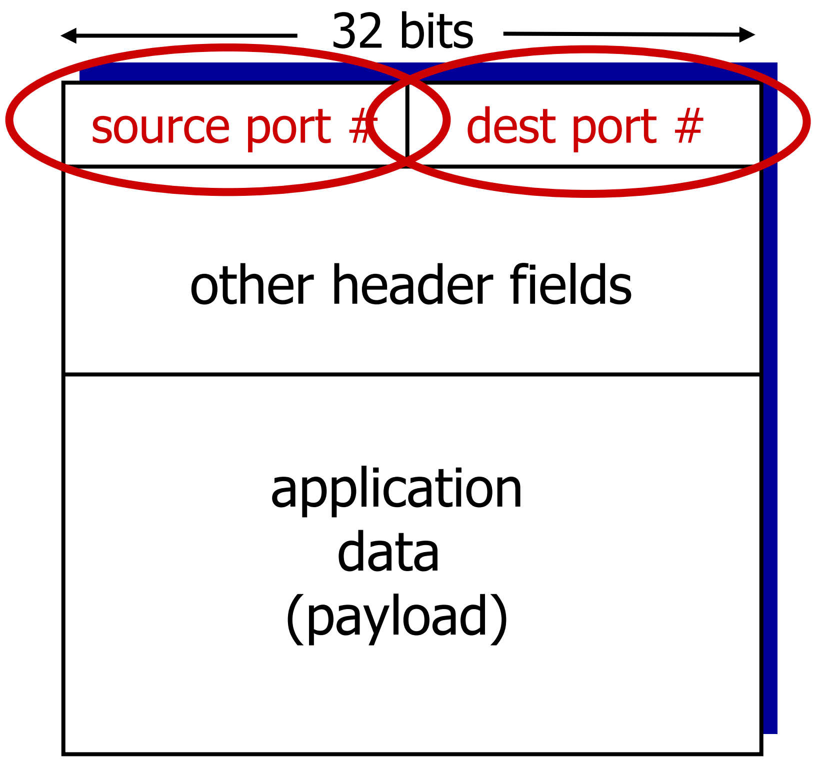

TCP/UDP segment format

Connectionless demultiplexing

- when creating socket, must specify *host-local* port #:

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DatagramSocket mySocket1
 = new DatagramSocket(12534);
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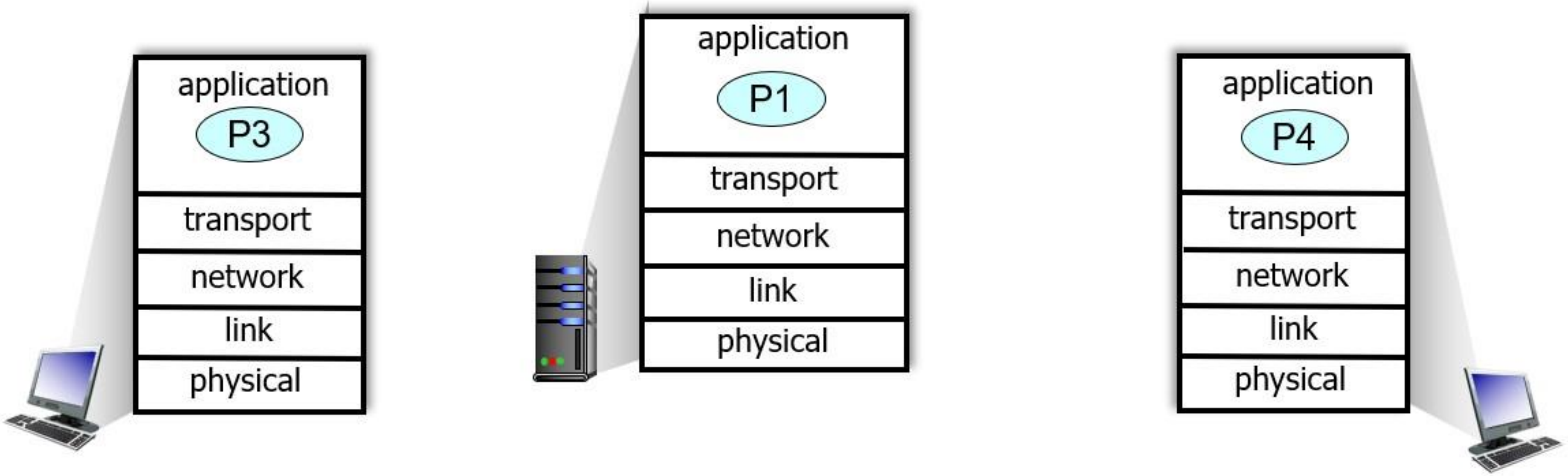
- when creating datagram to send into UDP socket, must specify
  - destination IP address
  - destination port #

when receiving host receives *UDP* segment:

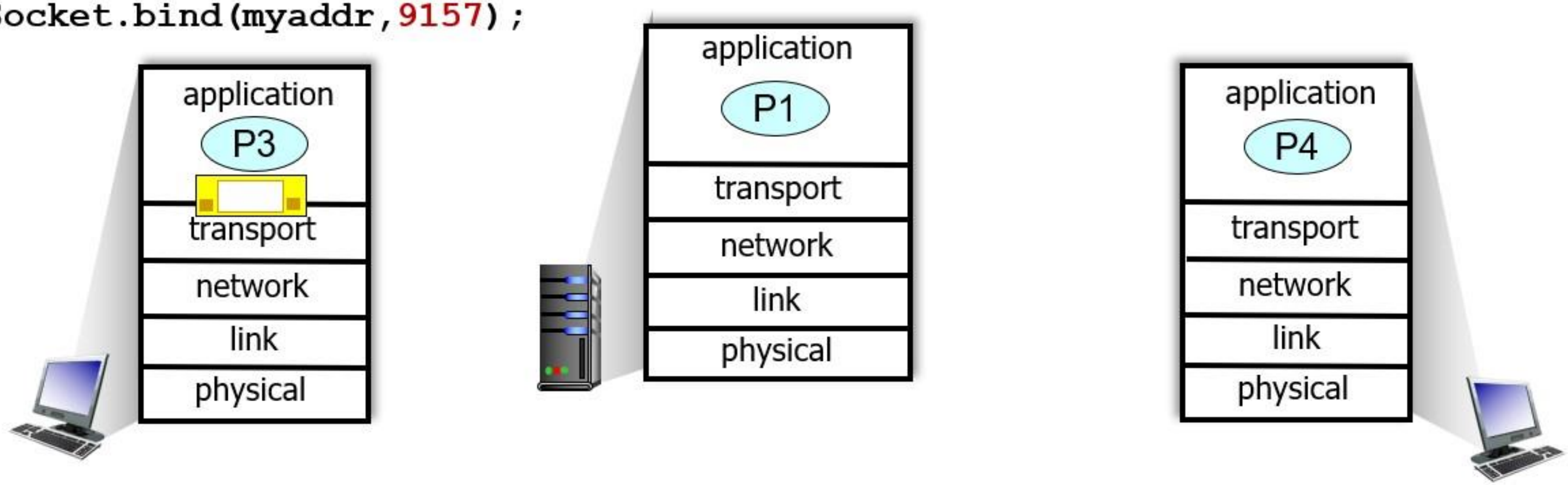
- checks destination port # in segment
- directs UDP segment to socket with that port #

Connectionless demultiplexing: an example



Connectionless demultiplexing: an example

```
mySocket =
 socket(AF_INET,SOCK_STREAM)
mySocket.bind(myaddr,9157);
```



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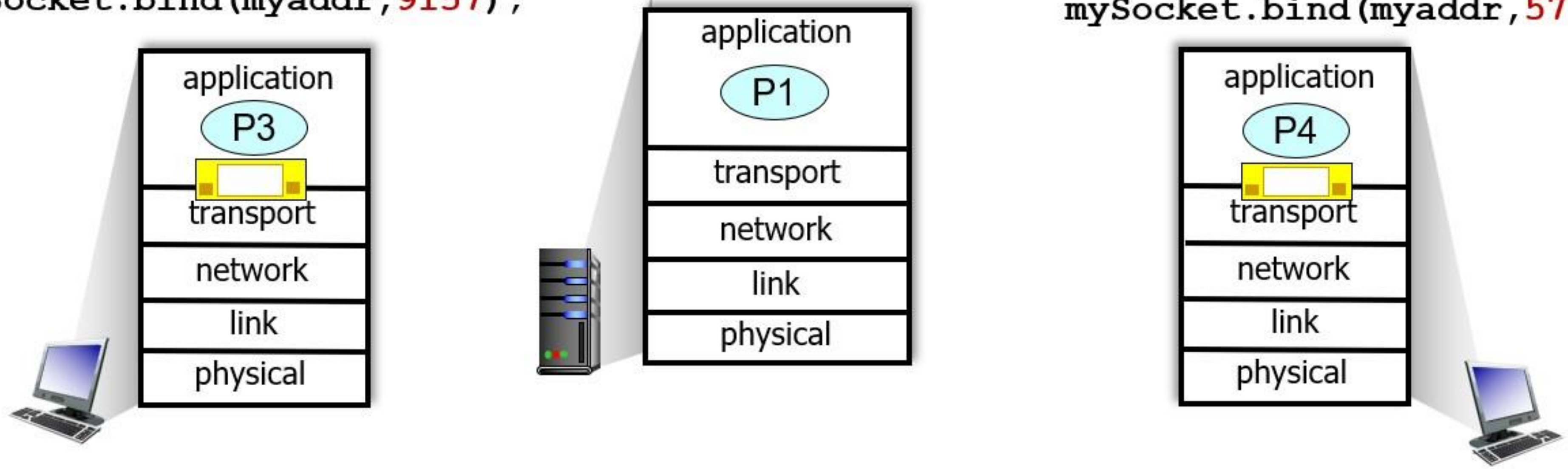
mySocket.bind(myaddr,9157);
```

```
mySocket =
 socket(AF_INET,SOCK_STREAM)
mySocket.bind(myaddr,5775);
```



Connectionless demultiplexing: an example

```
mySocket =
 socket(AF_INET,SOCK_DGRAM)
mySocket.bind(myaddr,6428);
```

```
mySocket =
 socket(AF_INET,SOCK_STREAM)
mySocket.bind(myaddr,9157);
```

```
mySocket =
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mySocket.bind(myaddr,5775);
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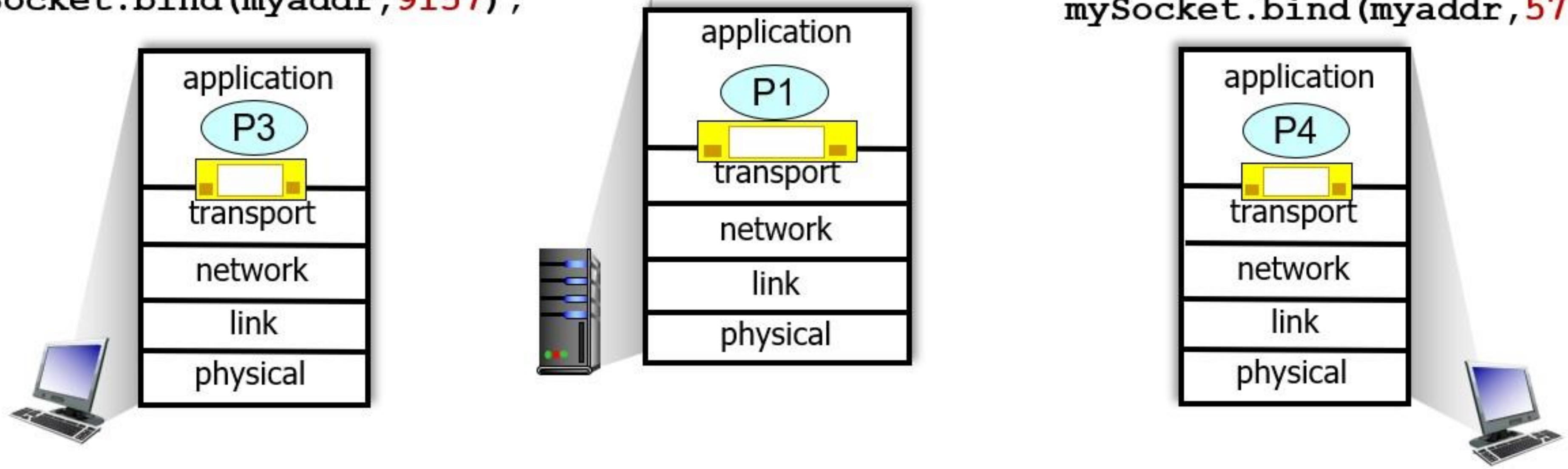
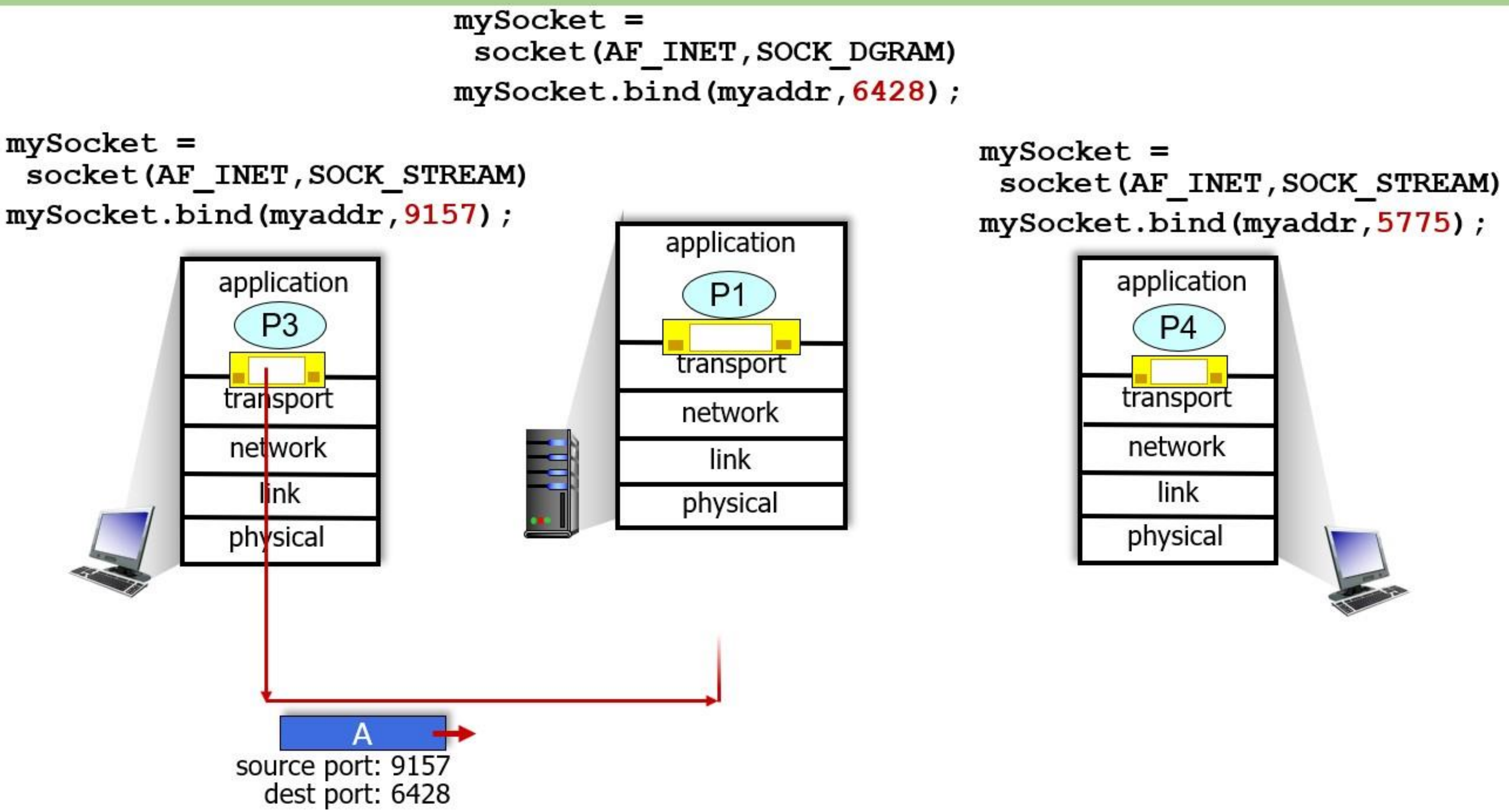


Connectionless demultiplexing: an example



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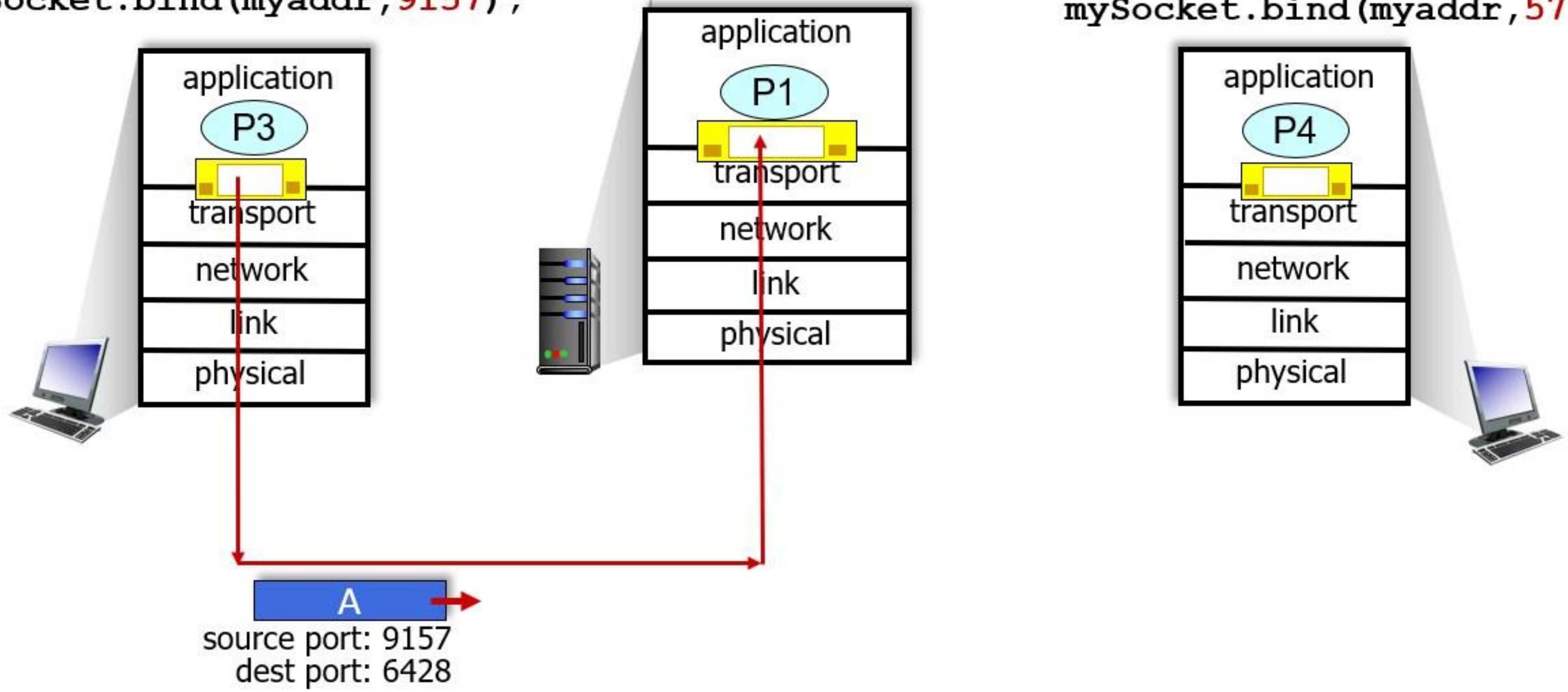

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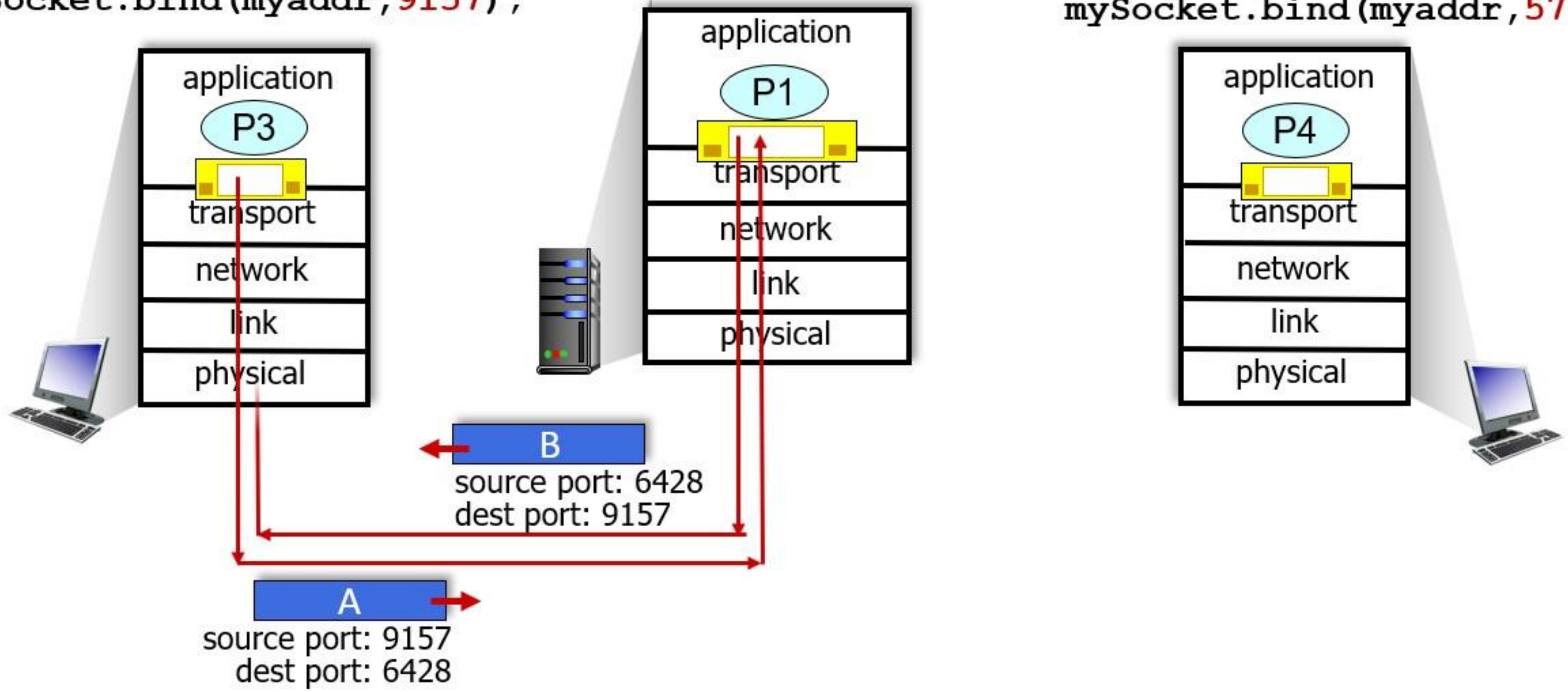
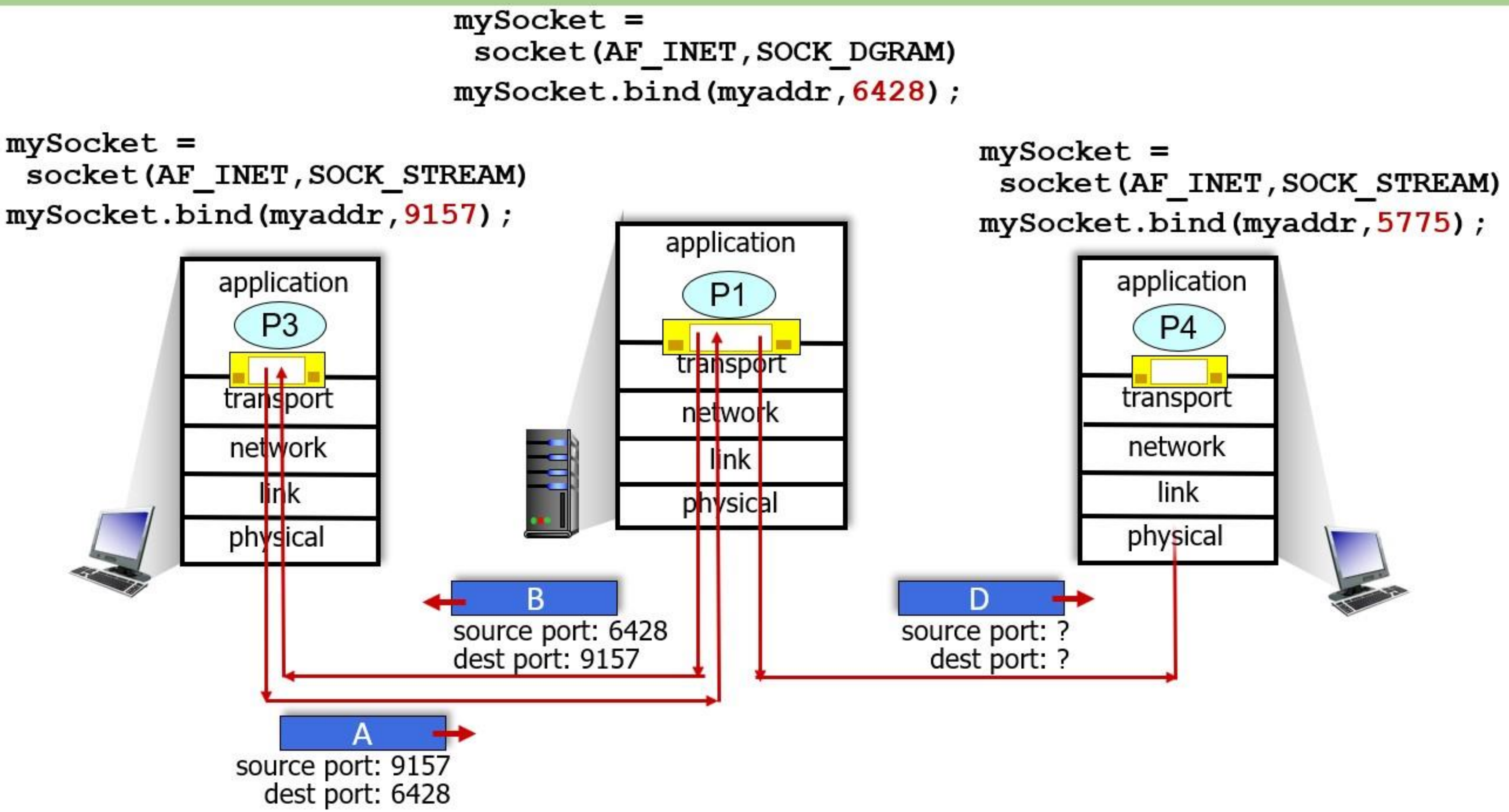
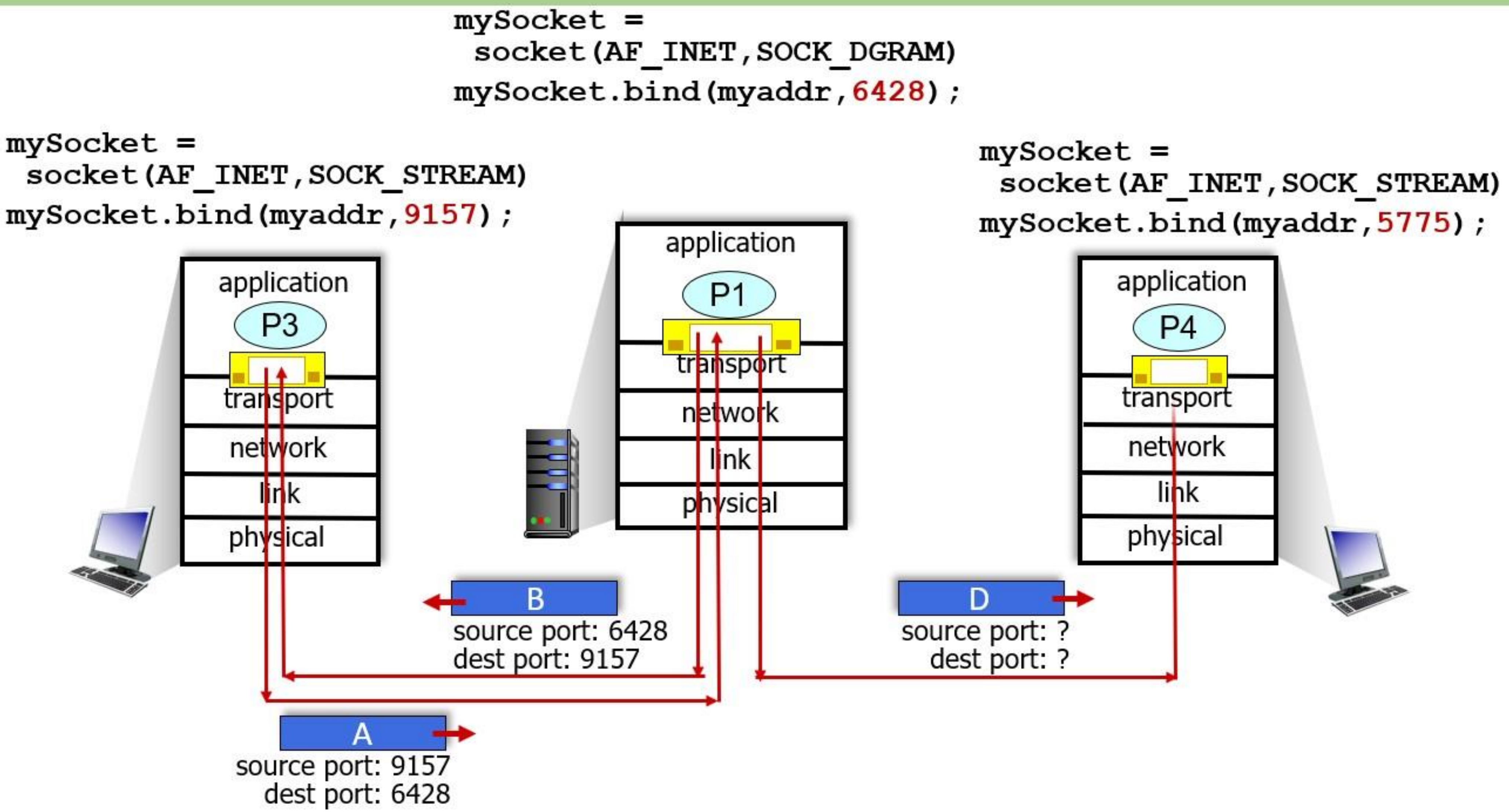


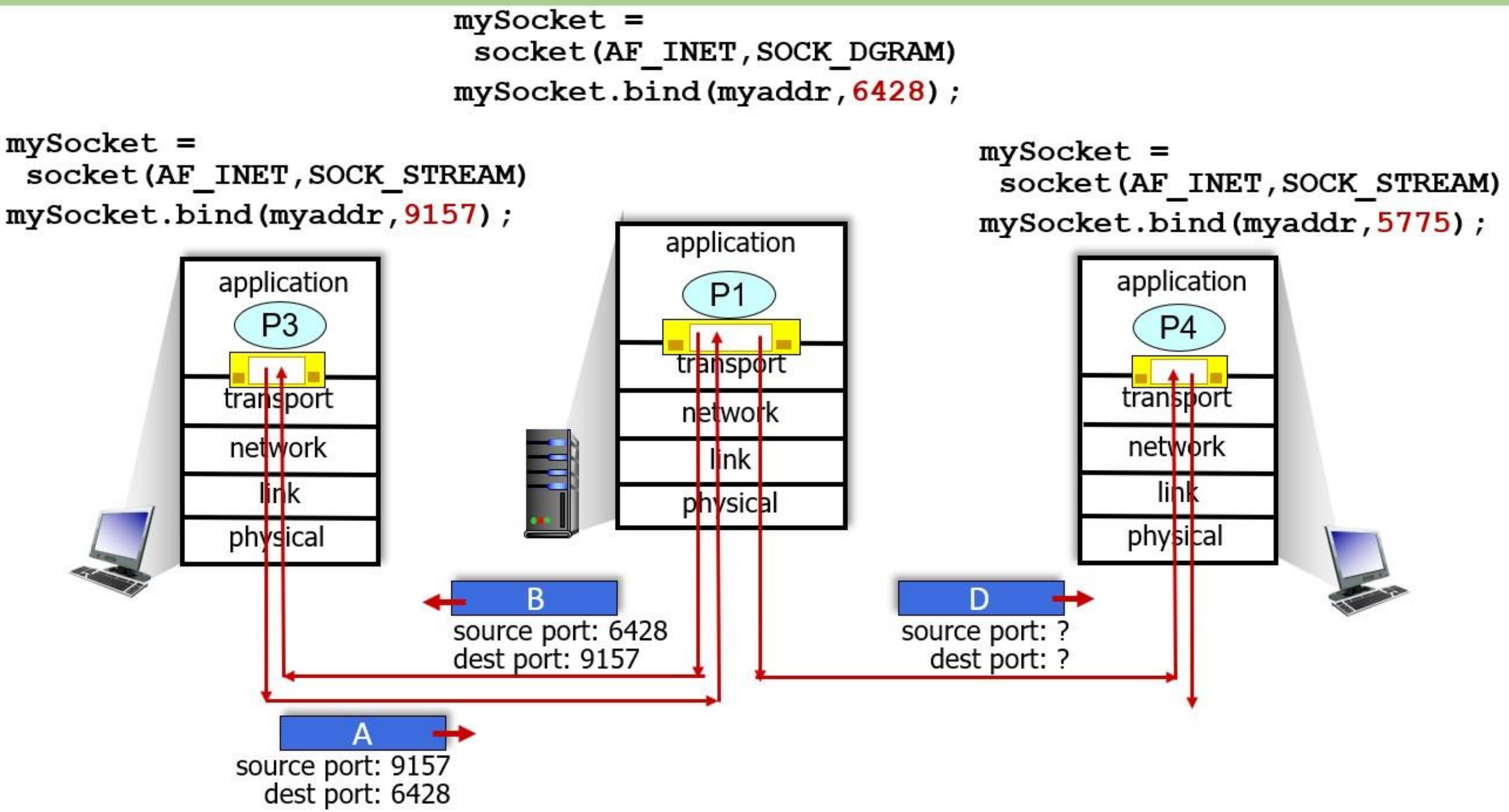
Connectionless demultiplexing: an example



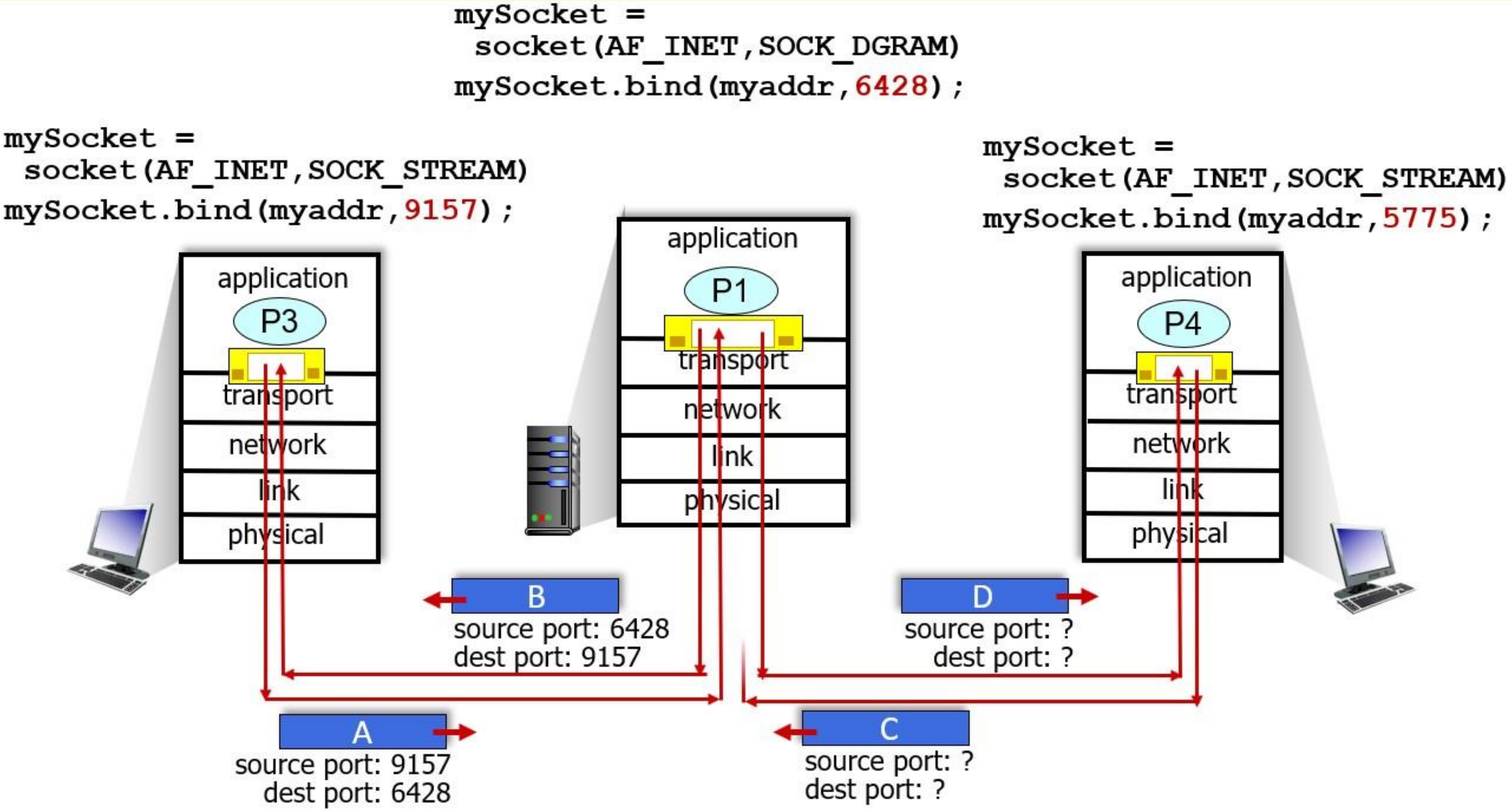
Connectionless demultiplexing: an example



Connectionless demultiplexing: an example



Connectionless demultiplexing: an example



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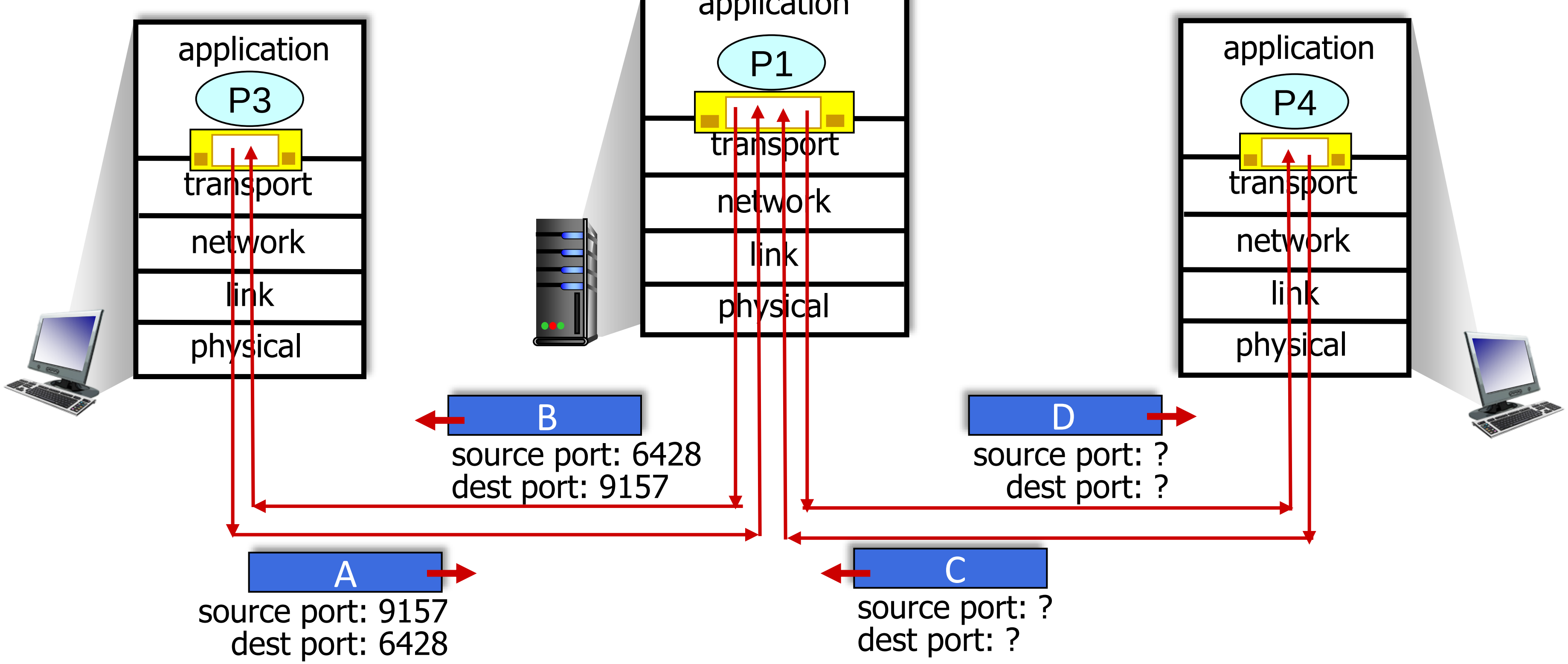
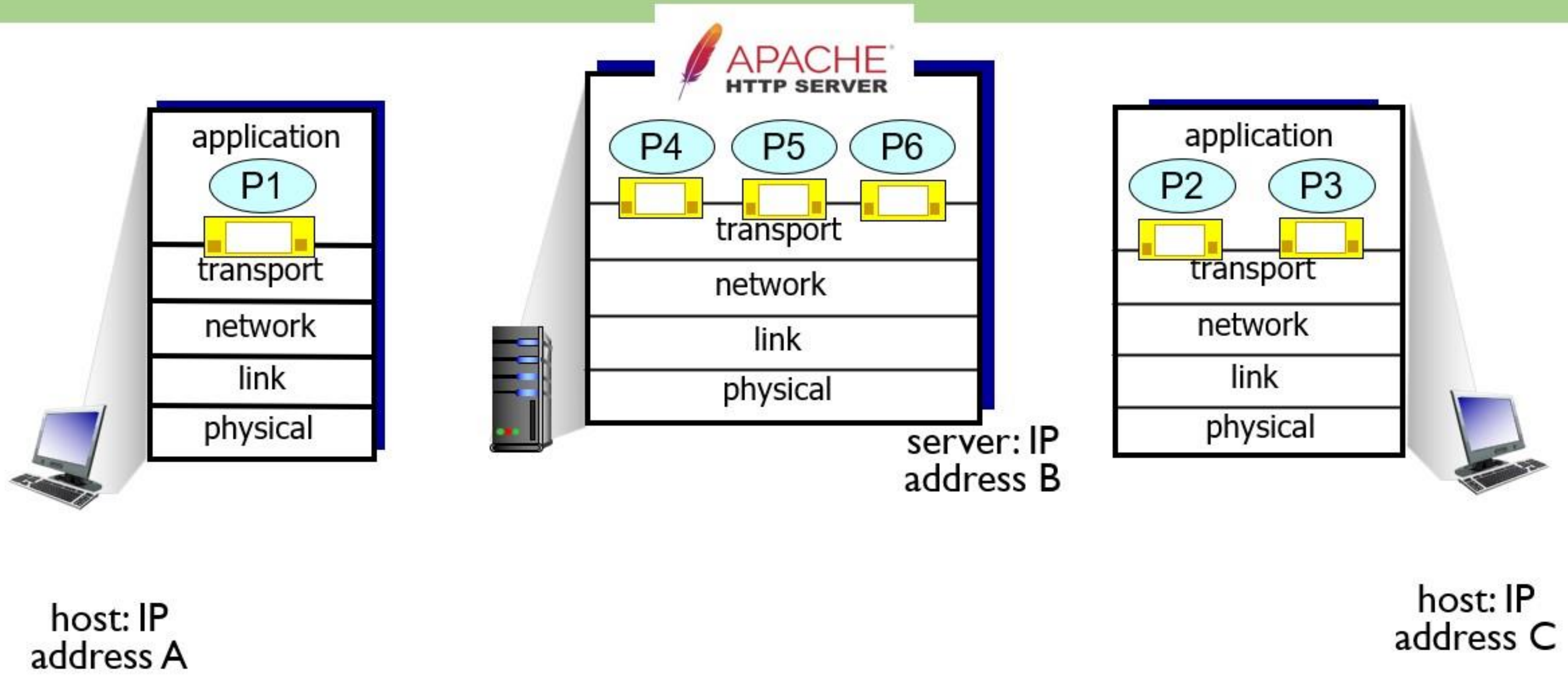


Connection-oriented demultiplexing

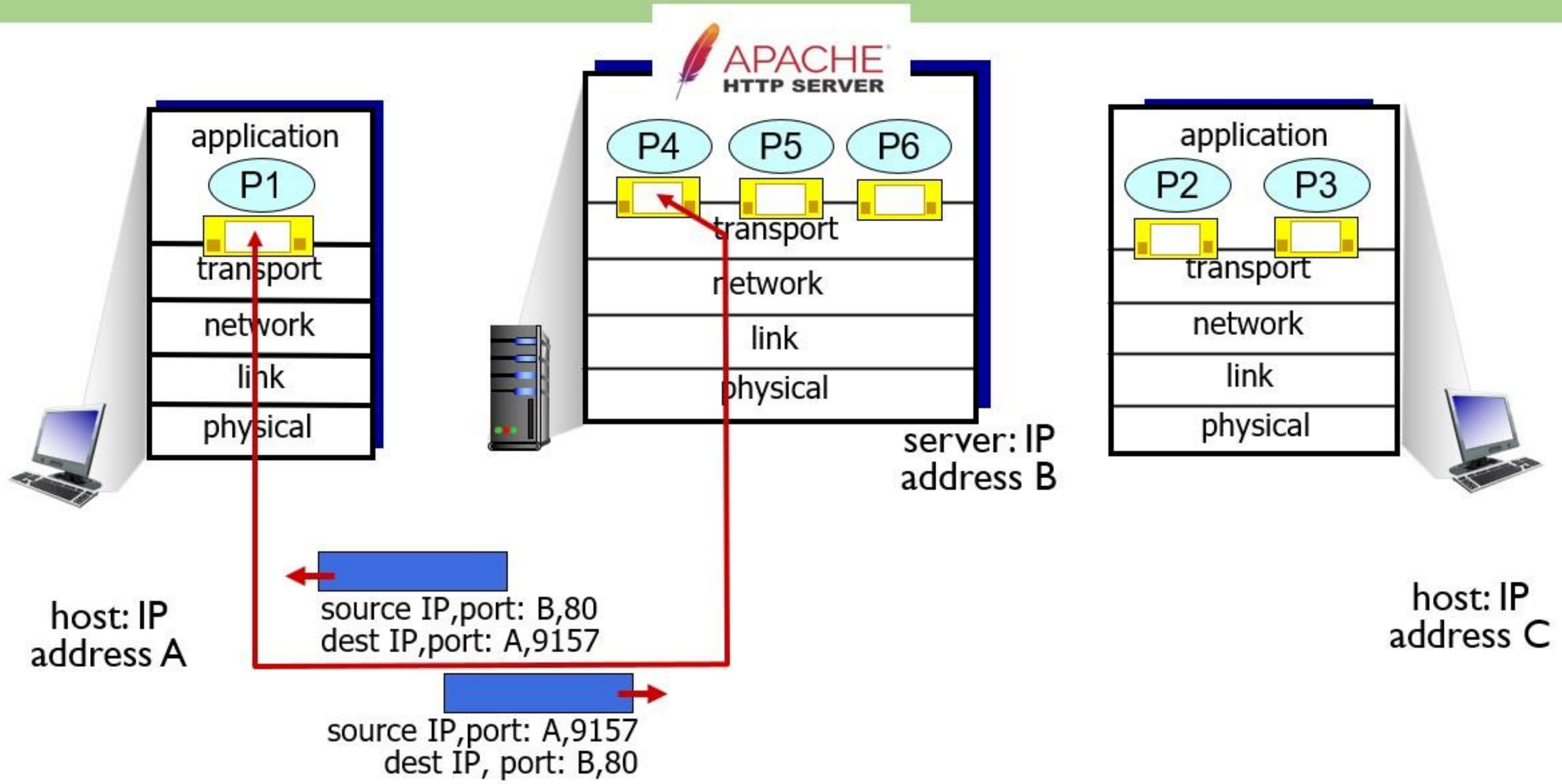
- TCP socket identified by 4-tuple:
  - **source IP address**
  - **source port number**
  - **dest IP address**
  - **dest port number**
- demux: receiver uses *all four values* *(4-tuple)* to direct segment to appropriate socket

- server may support many simultaneous TCP sockets:
  - each socket identified by its own 4-tuple
  - each socket associated with a different connecting client

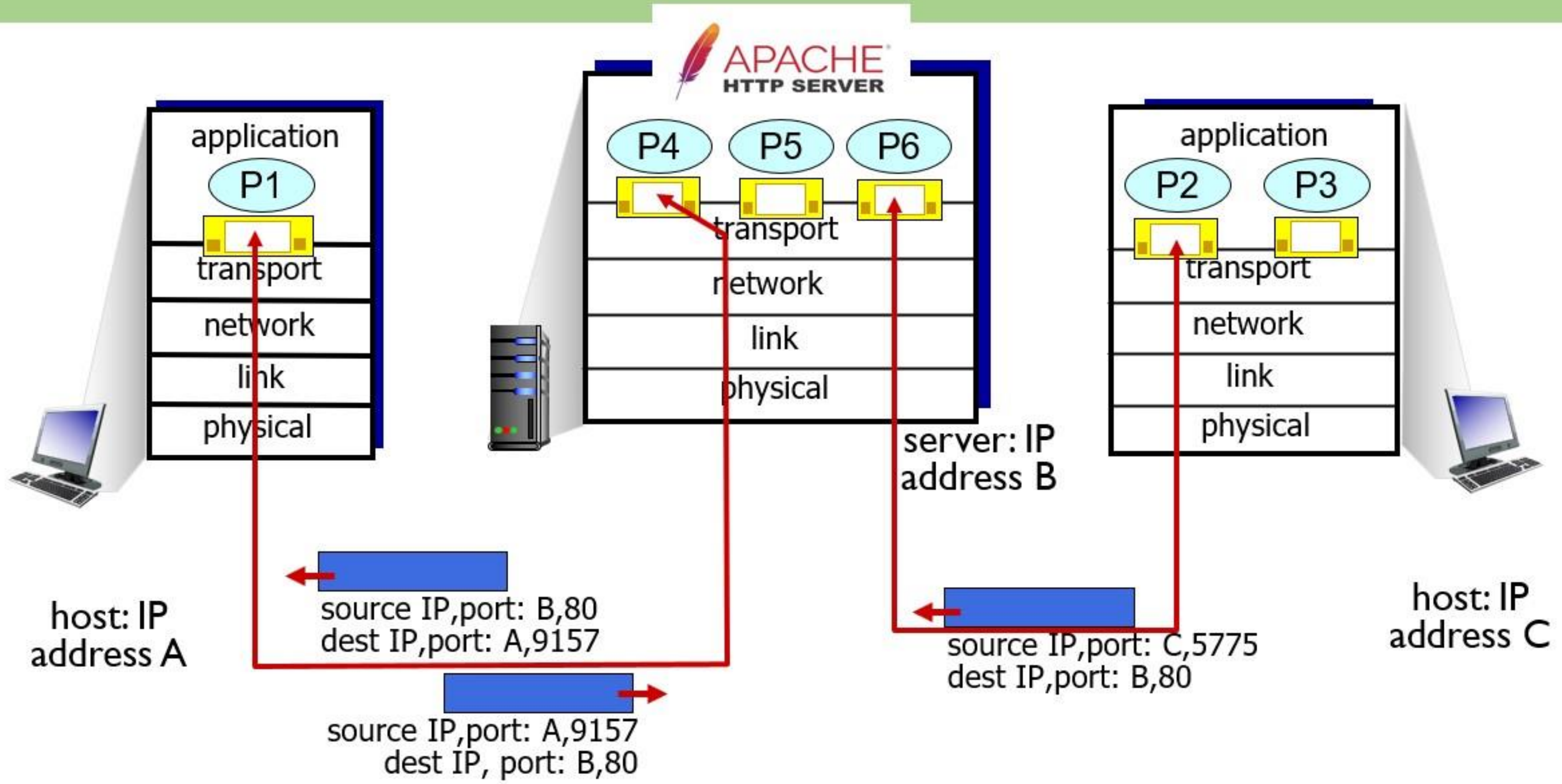
Connection-oriented demultiplexing: example



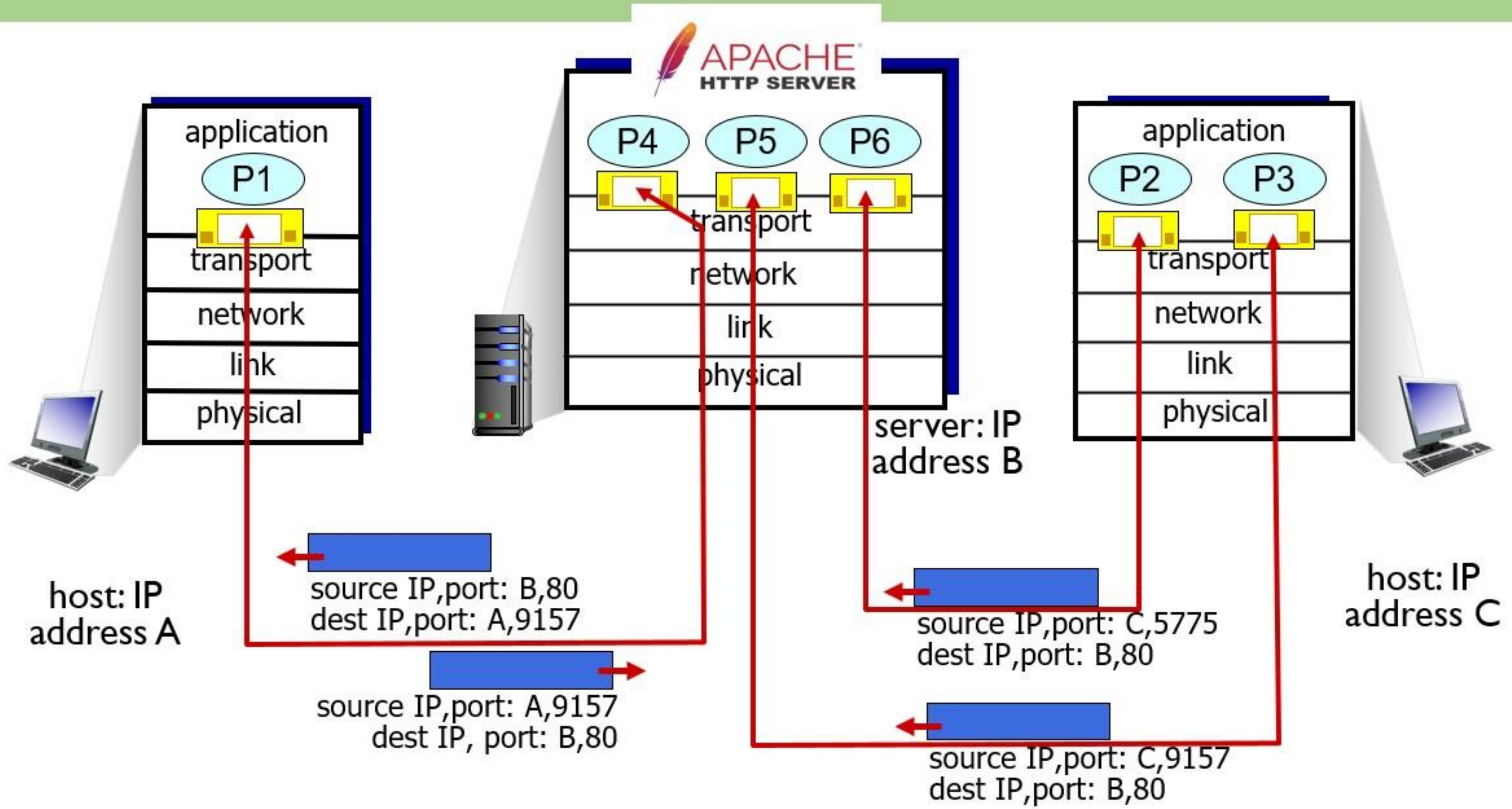
Connection-oriented demultiplexing: example



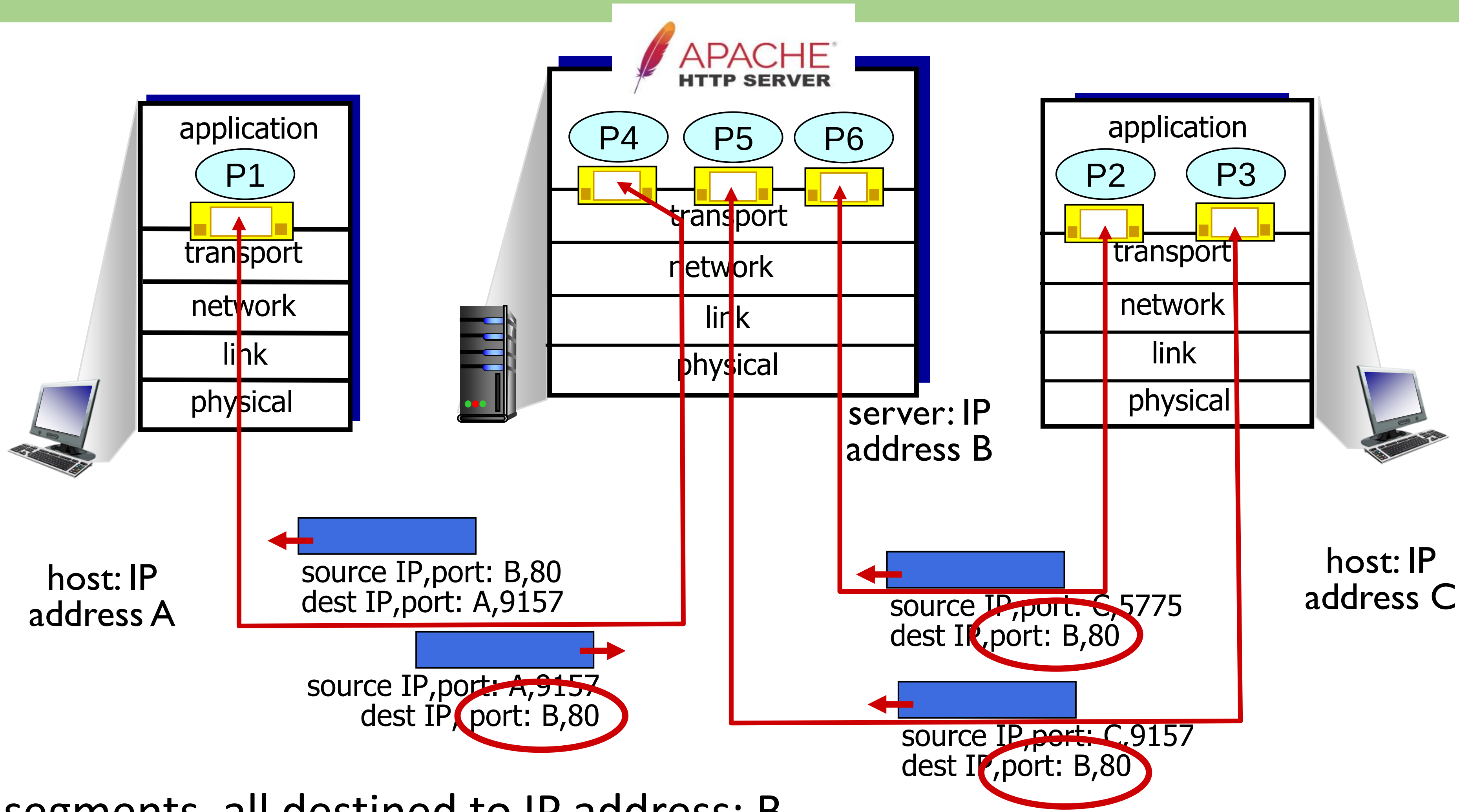
Connection-oriented demultiplexing: example



Connection-oriented demultiplexing: example



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

Acknowledgment

- **These lecture slides are based on:**

1) **Chapter 3 (P 211-224)** from the book "Computer Networking: A Top-Down Approach, Eighth Edition, Global Edition" by (James F. Kurose and Keith W. Ross's).

END OF LECTURE (4) Part A

Keep connected with the classroom

lmzcbsf

THANK YOU FOR YOUR ATTENTION