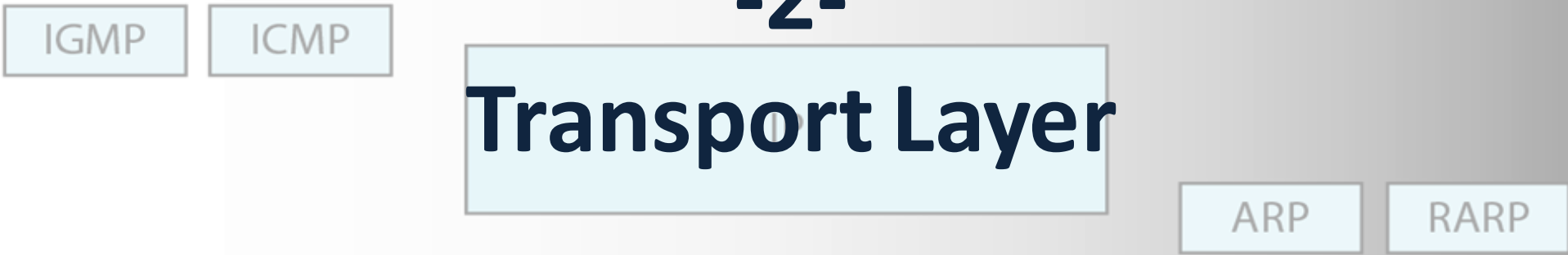


EITF25 – Internet: Technology and Applications



Internet Protocols

-2-



Transport Layer

2015, Lecture 06

Kaan Bür

Underlying LAN or WAN
technology

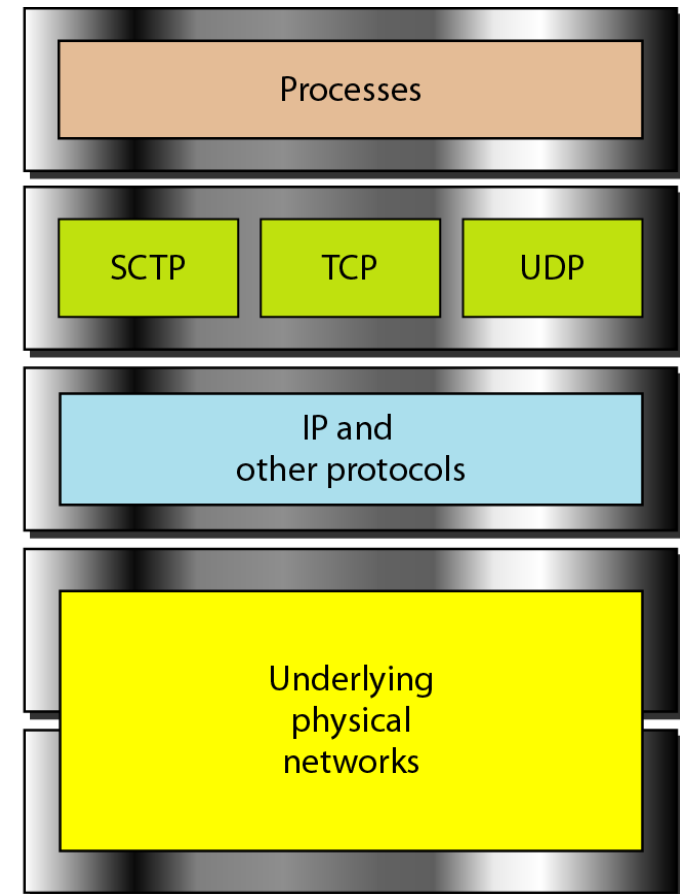


Previously on EITF25

Network Layer

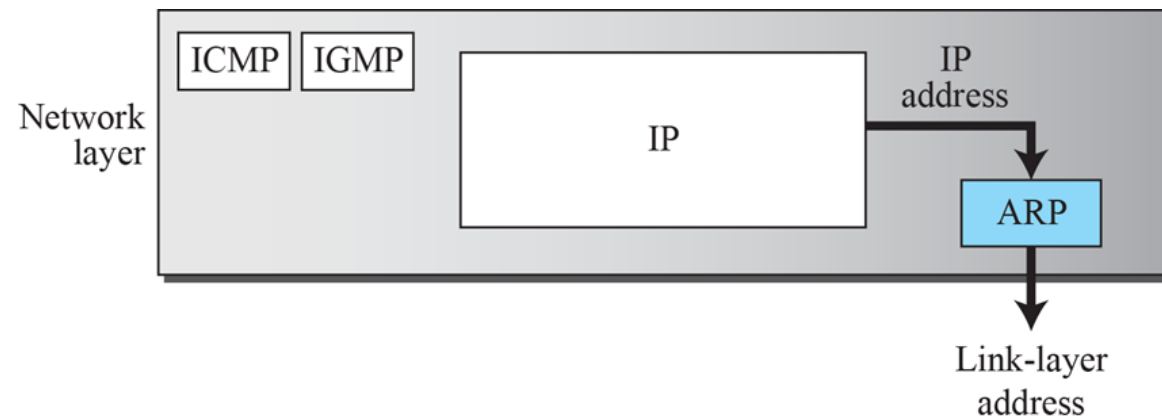
- Internet architecture
 - End-to-end principle, routing
- Internet Protocol (IPv4, IPv6)
 - Addressing, forwarding
 - Datagram format
 - Fragmentation
- Address Resolution Protocol

[S14.3 pp.473-474][F9.2]

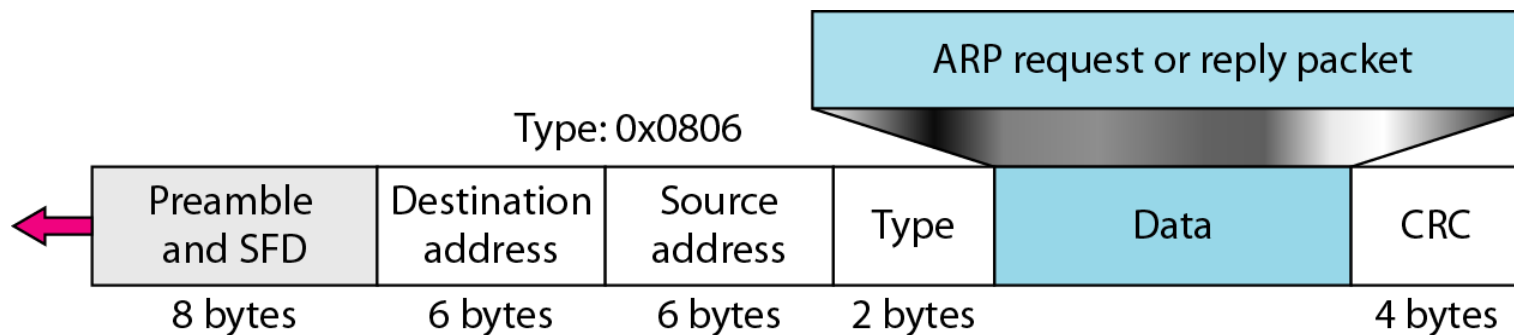
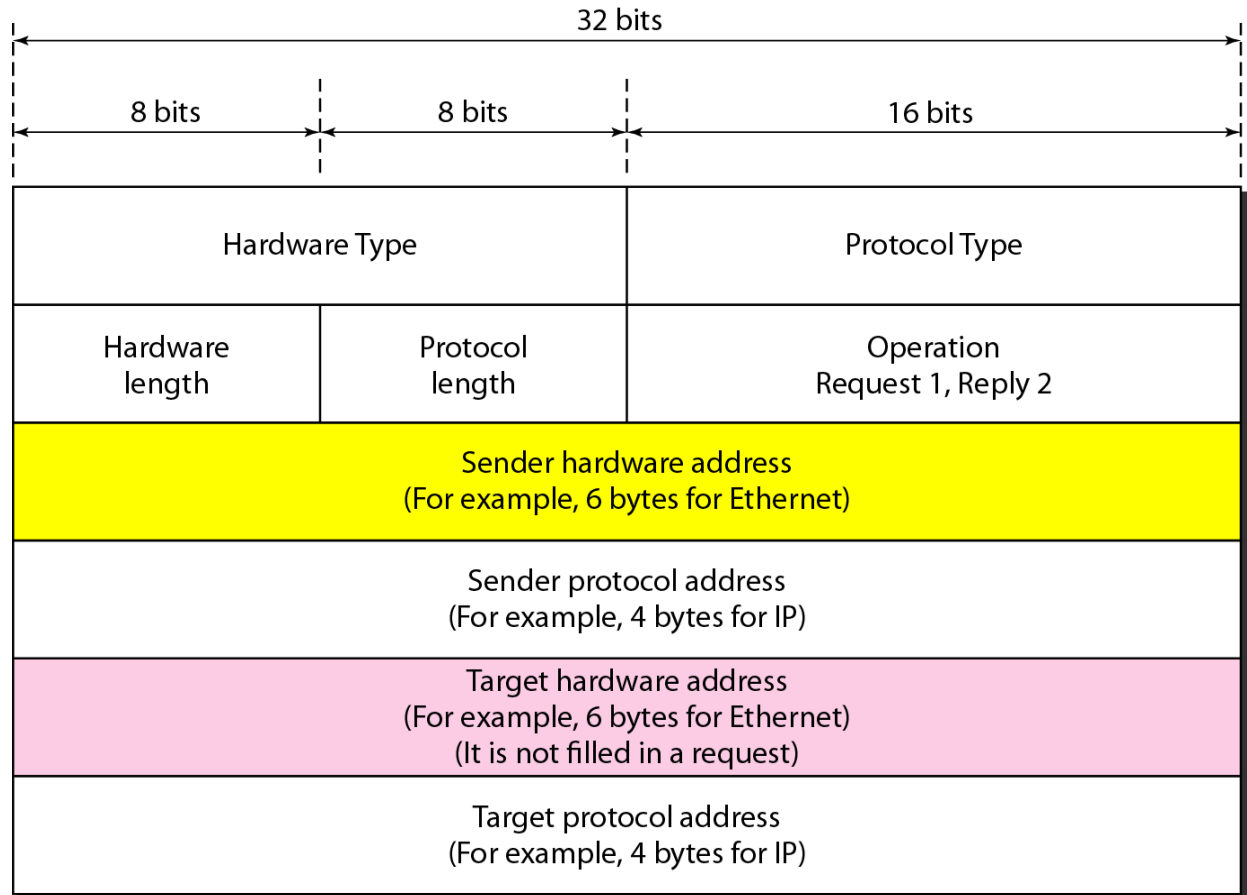


Address Resolution Protocol (ARP)

- Mapping of IP addresses to MAC addresses
- Internet
 - Network of networks connected by routers
- Routers/hosts need information
 - Logical (IP) → physical (MAC)



ARP packet

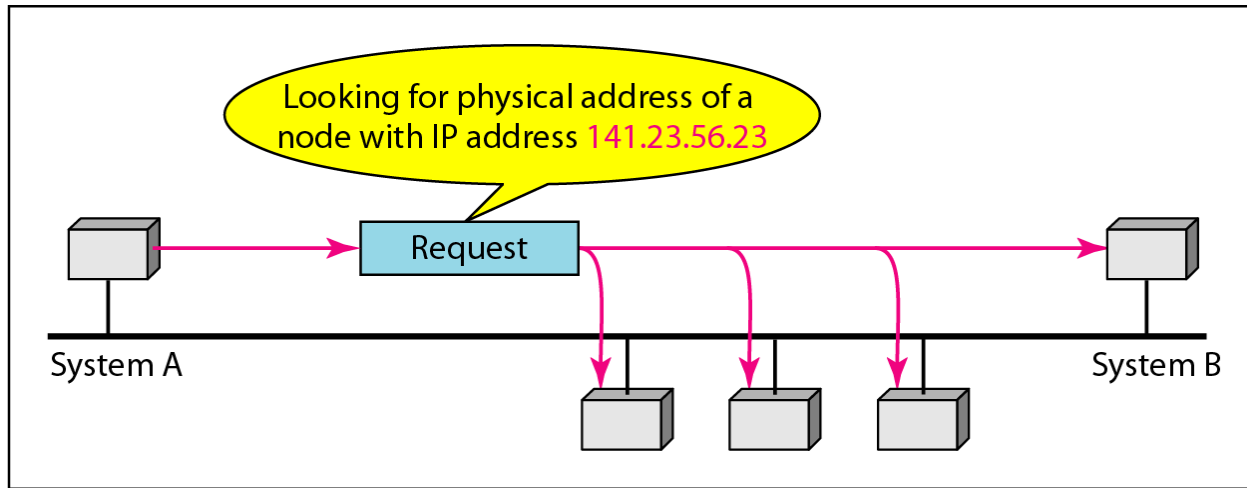


ARP operation

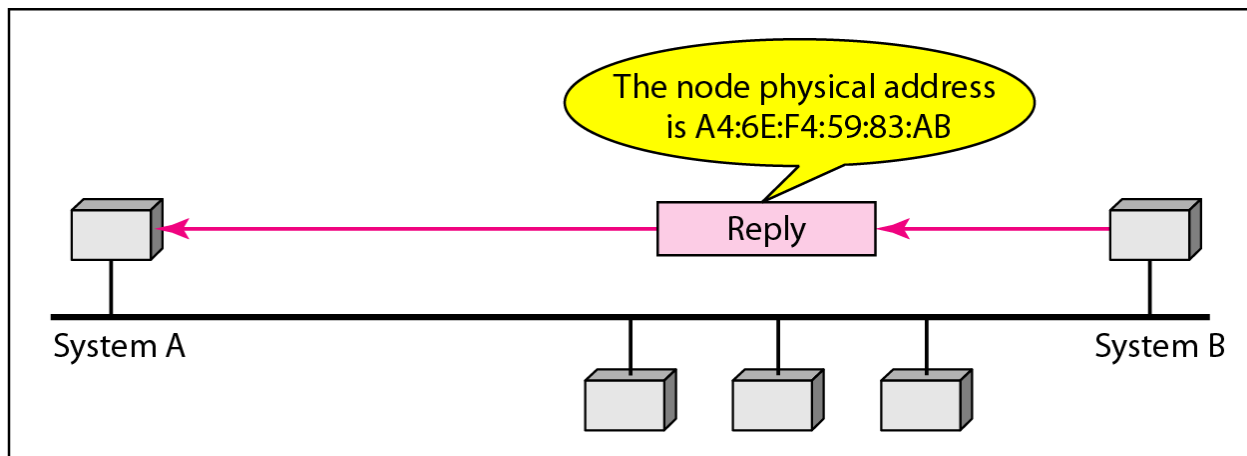
- ARP query broadcast every time a host/router needs a MAC address
- Intended host answers with an ARP response
- ARP cache (table) used to store MAC/IP pairs

- Some IP addresses known from start
 - Default gateway (router) → "rest of Internet"
 - DNS server

ARP request and reply

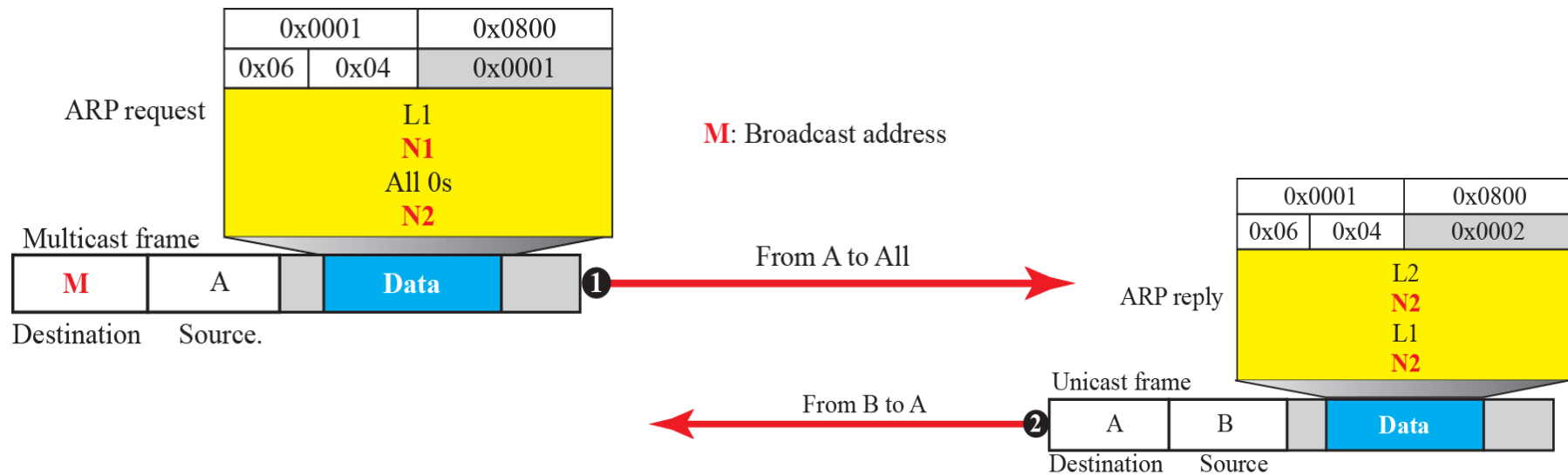
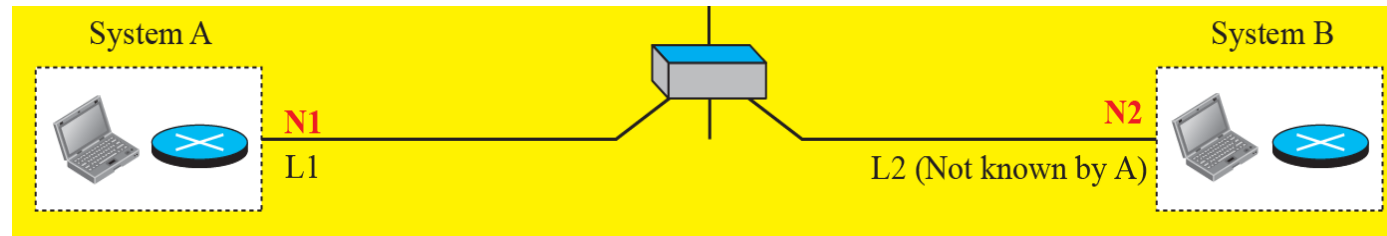


a. ARP request is broadcast

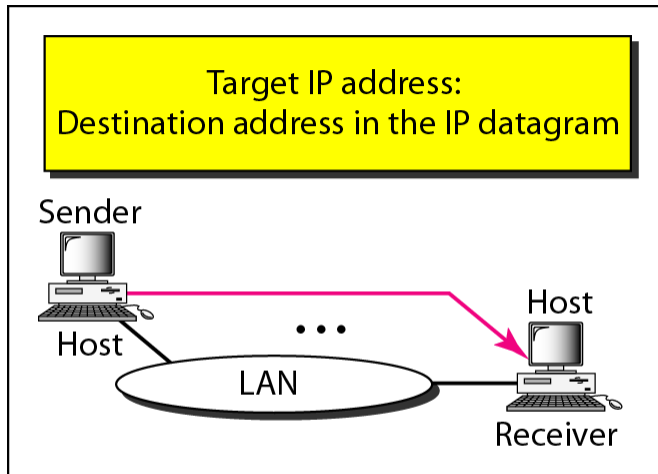


b. ARP reply is unicast

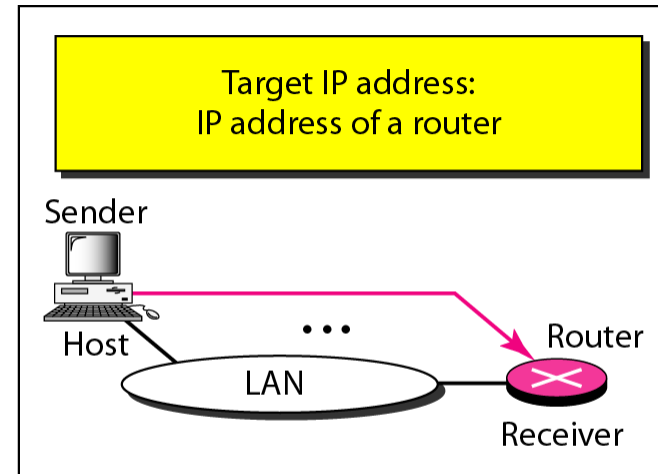
ARP example



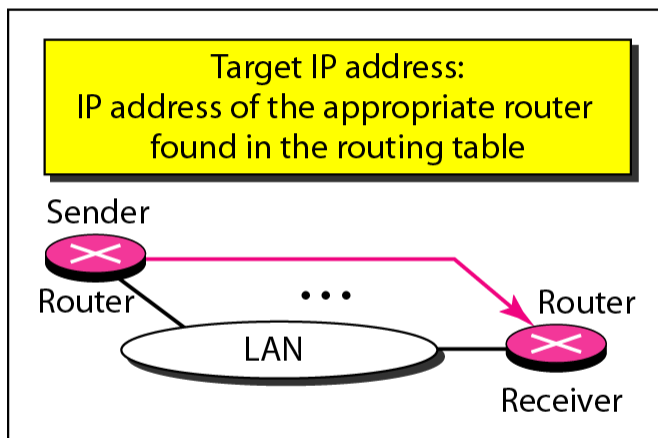
Four use cases for ARP



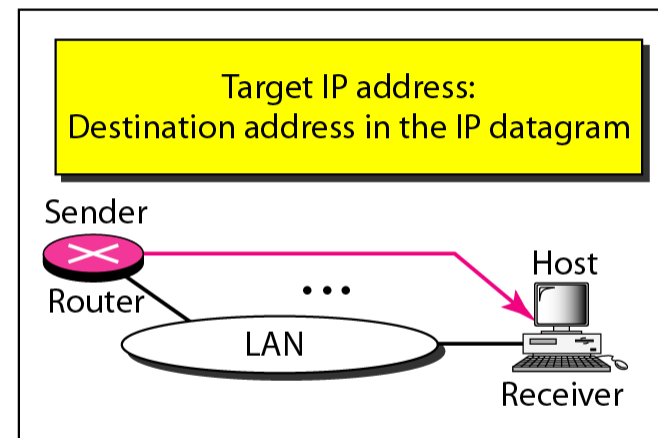
Case 1. A host has a packet to send to another host on the same network.



Case 2. A host wants to send a packet to another host on another network. It must first be delivered to a router.



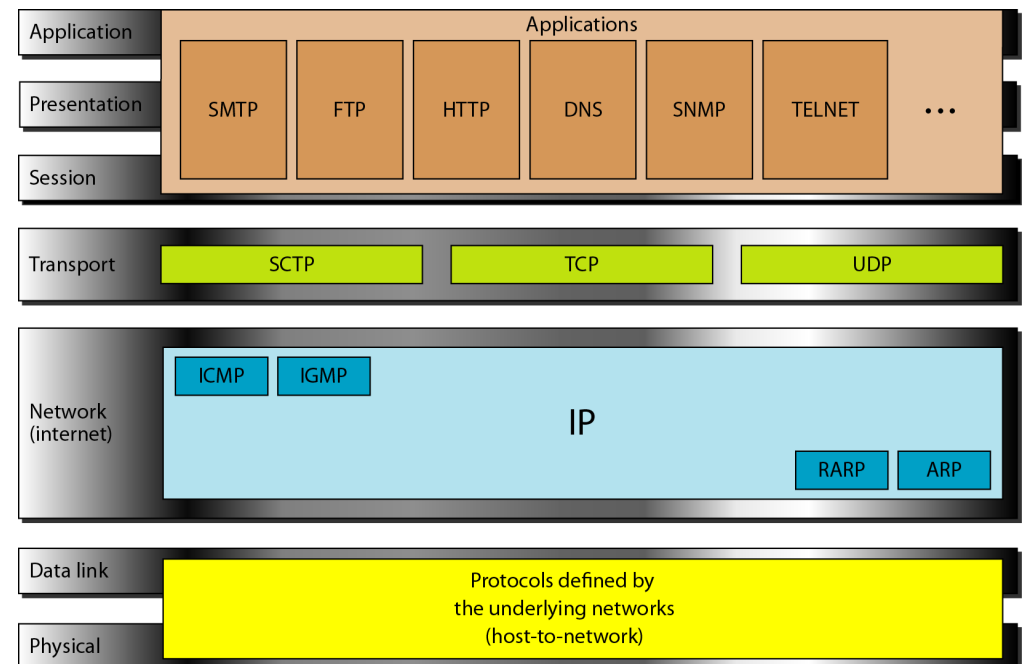
Case 3. A router receives a packet to be sent to a host on another network. It must first be delivered to the appropriate router.



Case 4. A router receives a packet to be sent to a host on the same network.

Transport layer

- Principles of digital communications
 - From electrical signals to bits to packets
- Using the physical infrastructure
 - Network access
- Finding your way
 - Addressing, routing
- Making use of it all
 - Applications



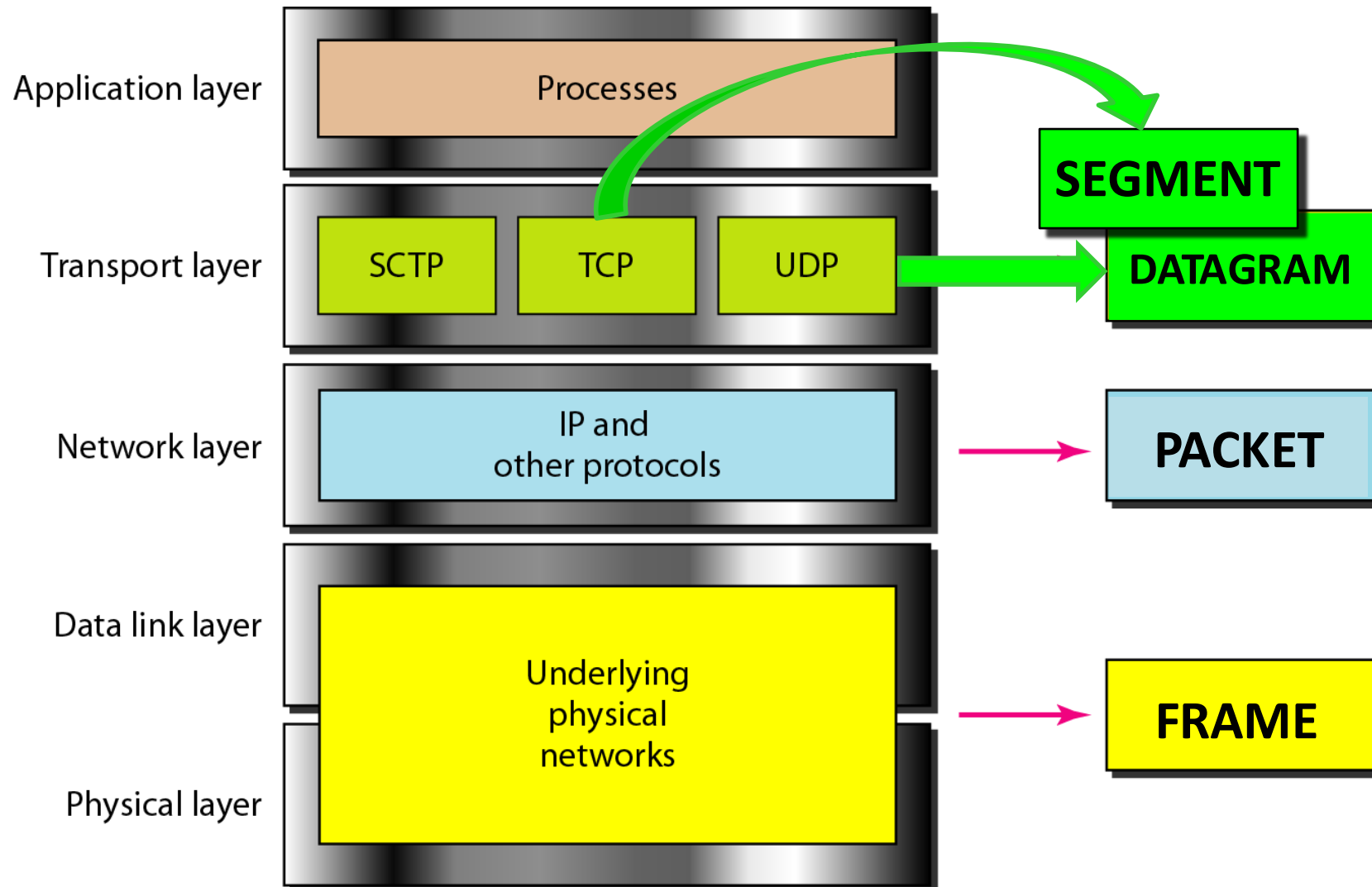
Today: Internet Protocols (2)

Transport Layer

- Introduction
[S15.1][F23.1]
- Transmission Control Protocol
[S15.2][F24.3]
- User Datagram Protocol
[S15.3][F24.2]

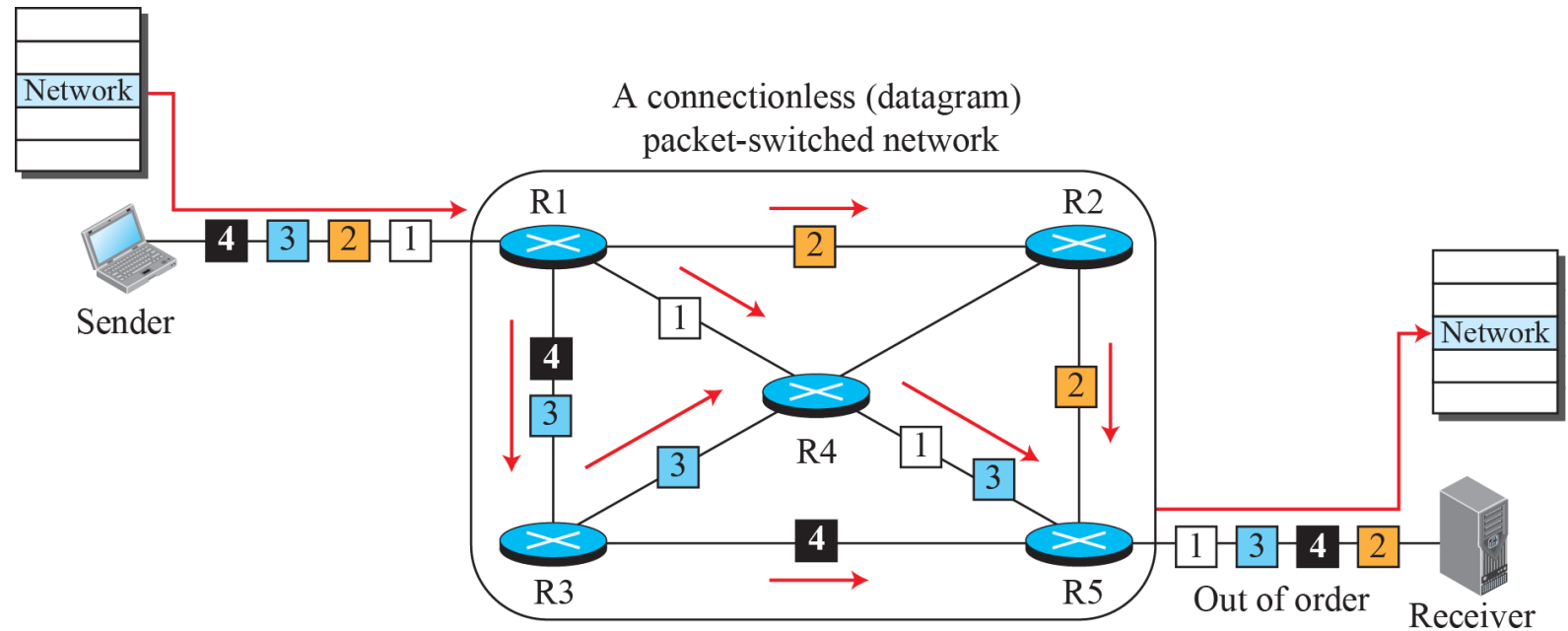
**[Kihl & Andersson: 10]*

TCP/IP model and data units ^{CORRECTION}

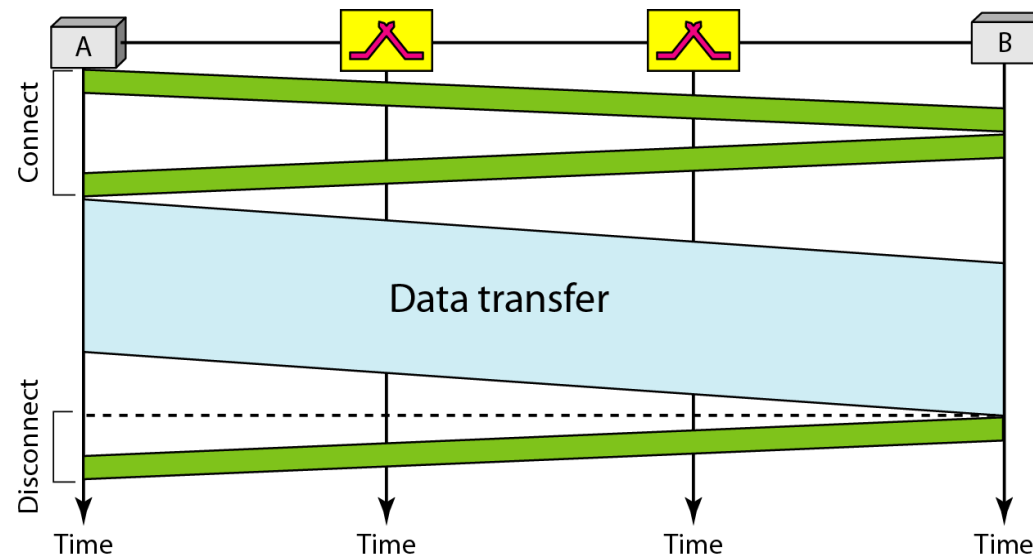


Network vs. Transport Layer

- L3



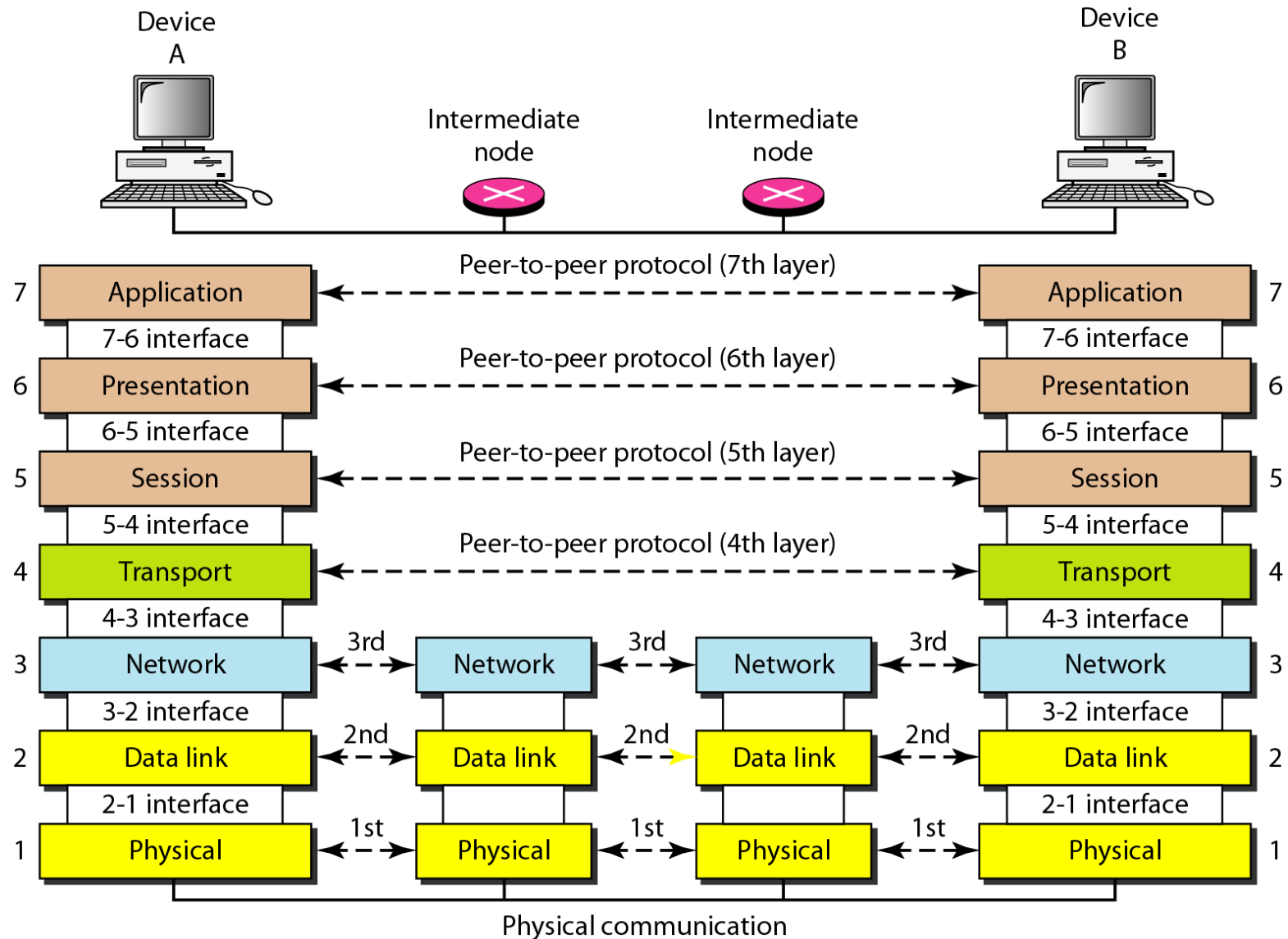
- L4?



Transport Layer

- Communication between applications
- Process-to-process delivery
- Client/server concept
 - Local host
 - Remote host
- Transport Protocol
 - Even more end-to-end

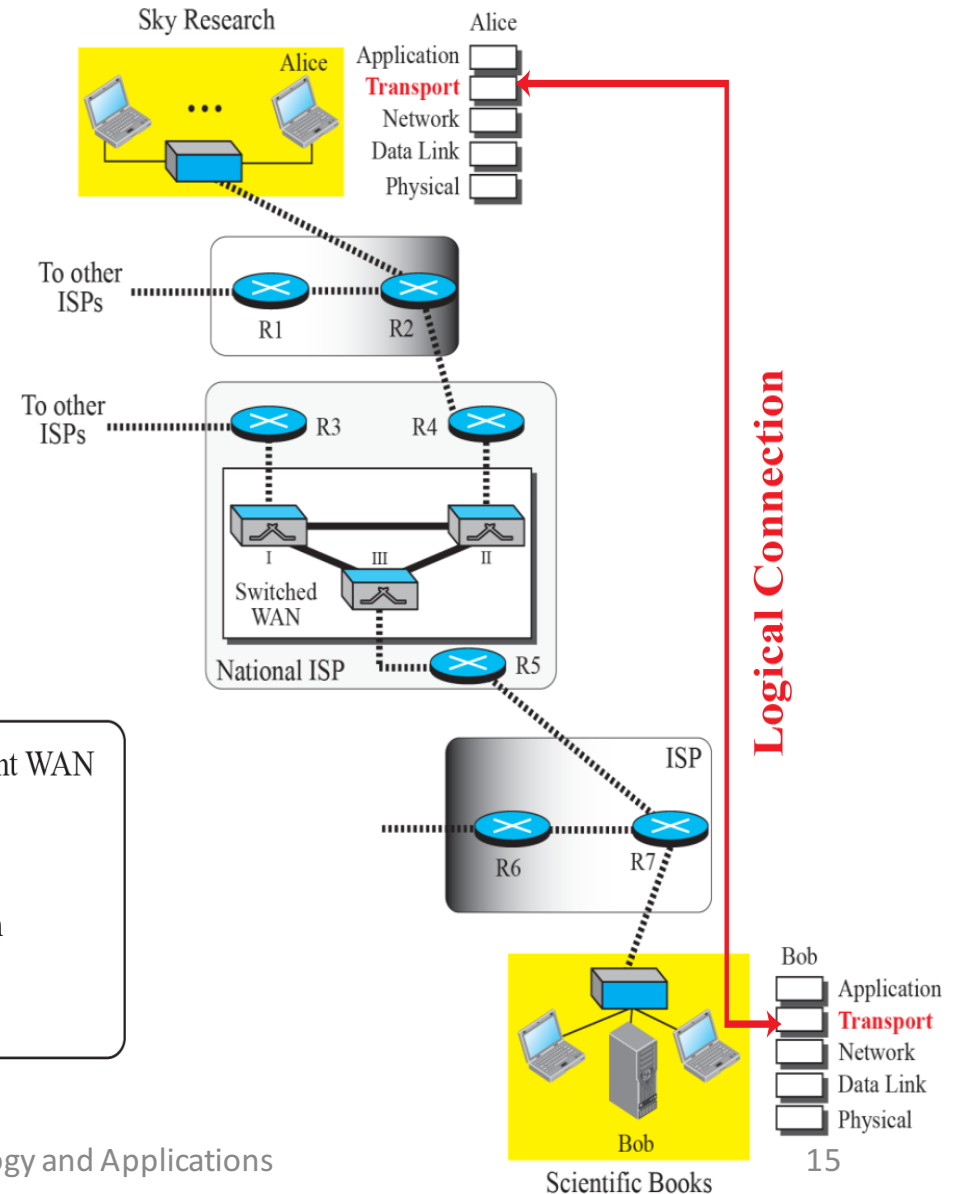
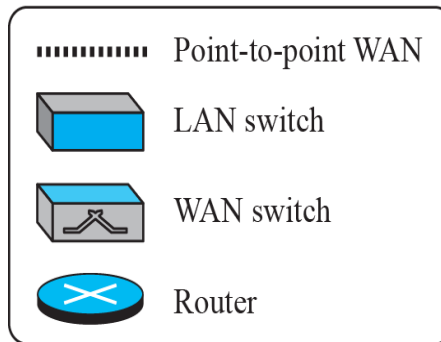
Transport Layer



Logical end-to-end connection

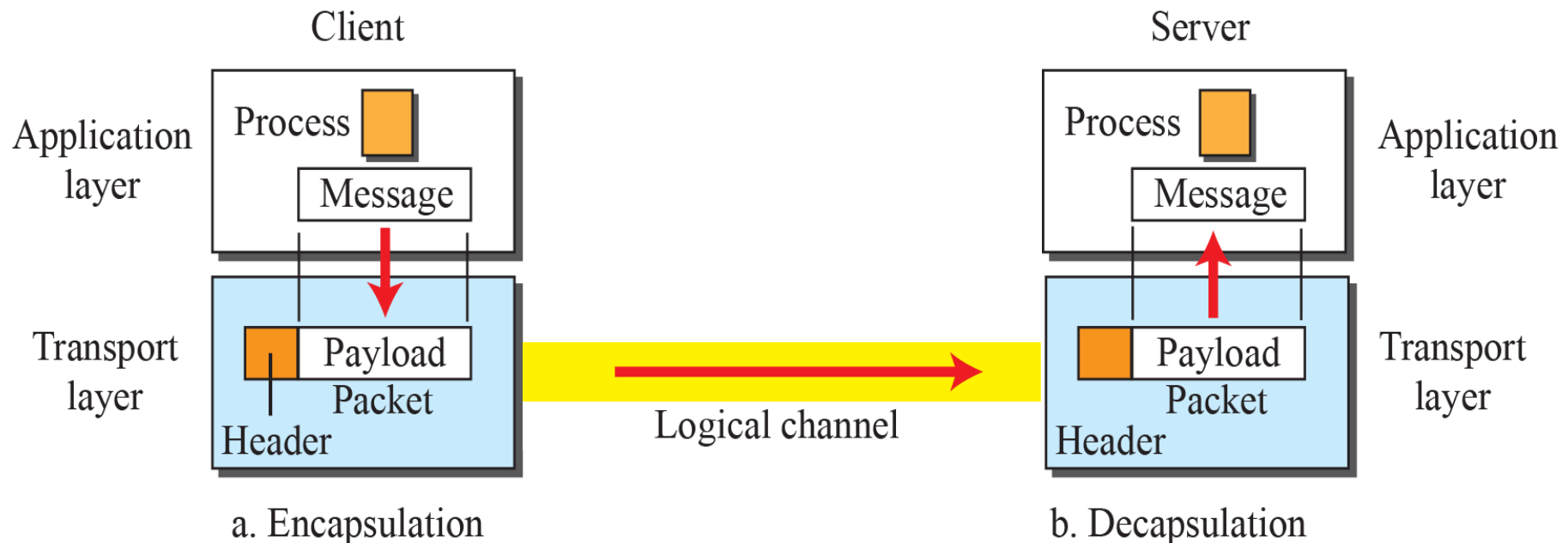
- Transport protocol creates a logical (virtual) connection between source and destination (application).

Legend



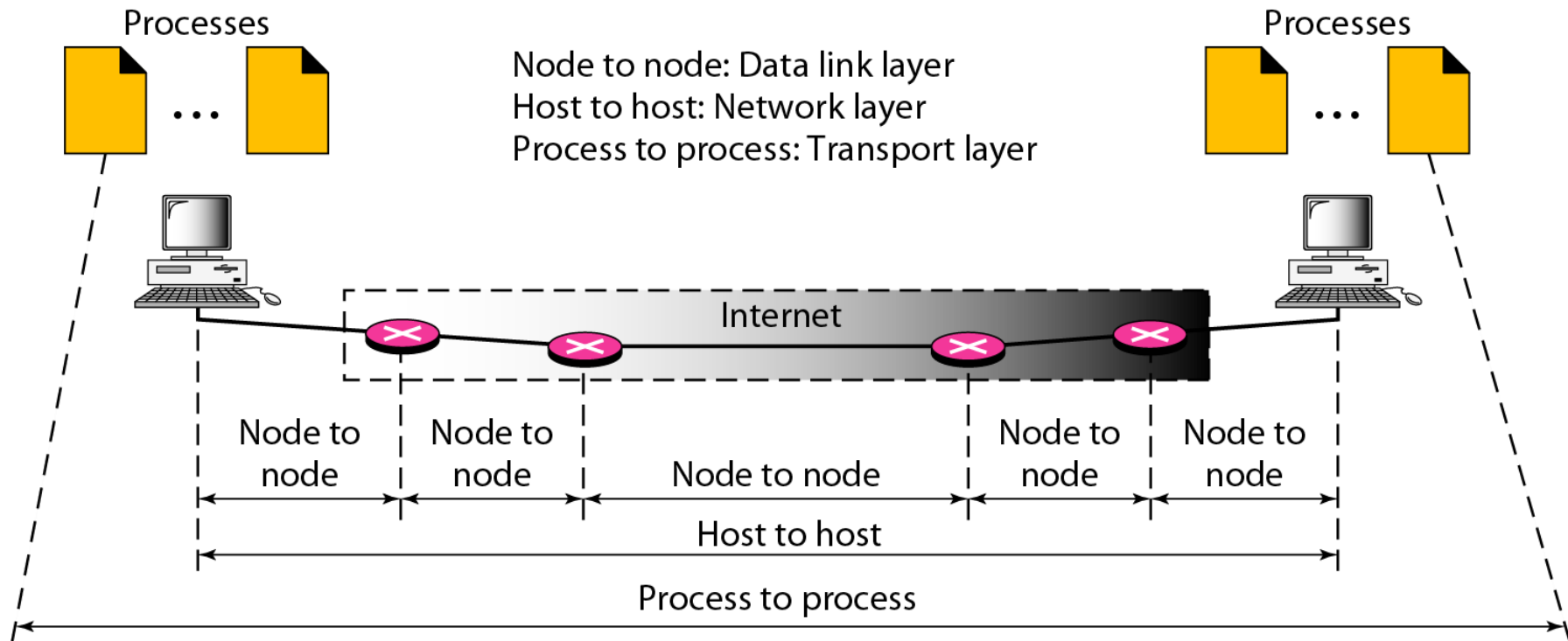
Transport protocol

- Encapsulates application data and ensures that it is sent to the correct receiving application to be decapsulated and used



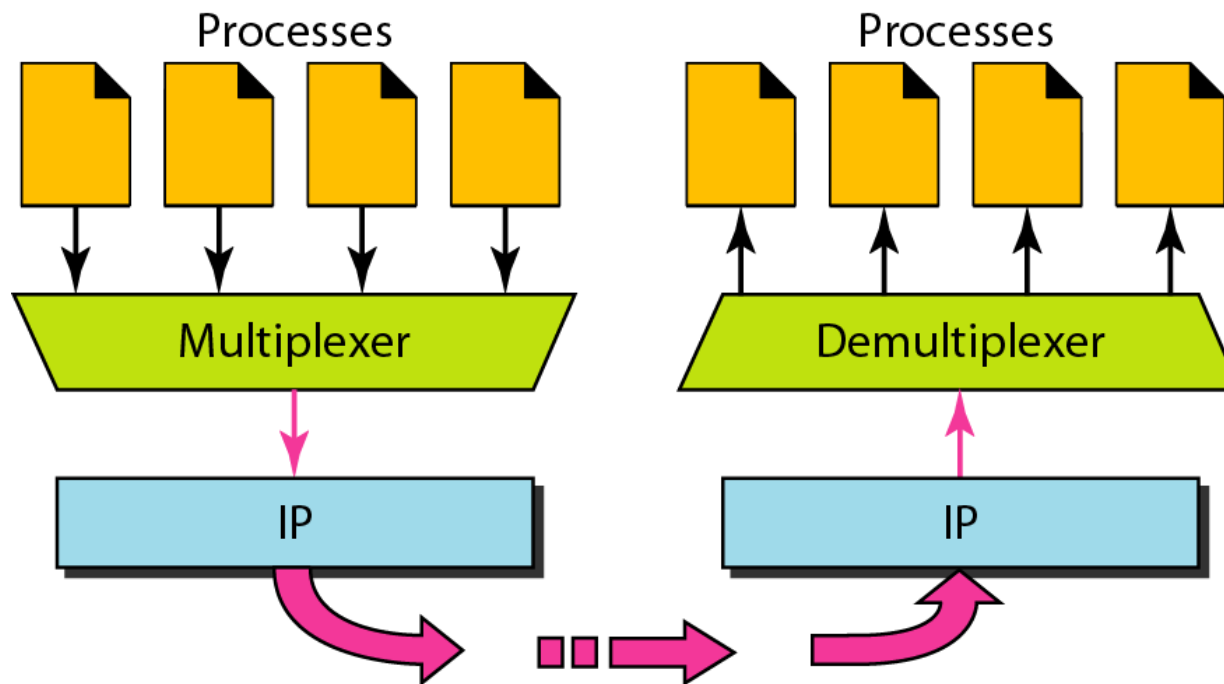
Process-to-Process Delivery

- Multiple applications even on the same host



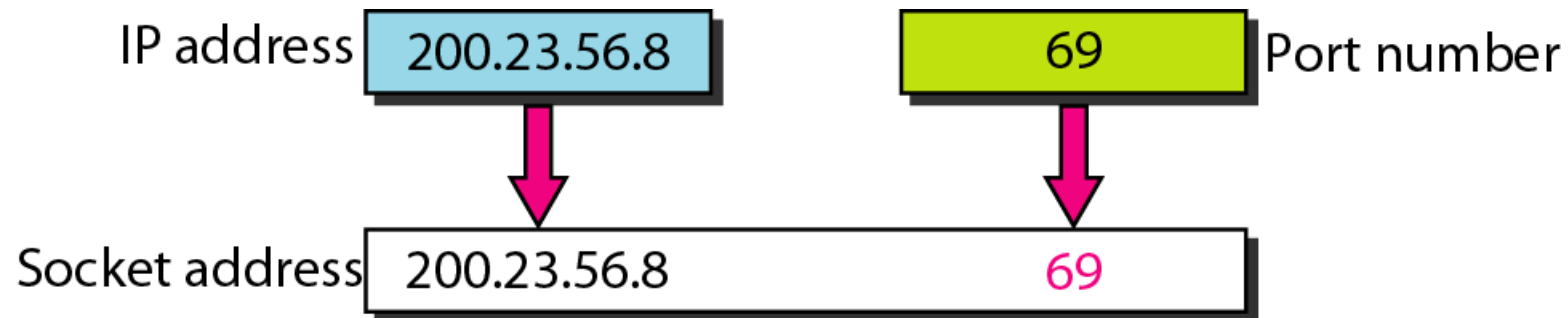
Multiplexing and demultiplexing

- **Socket addresses** allow multiplexing and demultiplexing multiple applications' data



Socket addresses

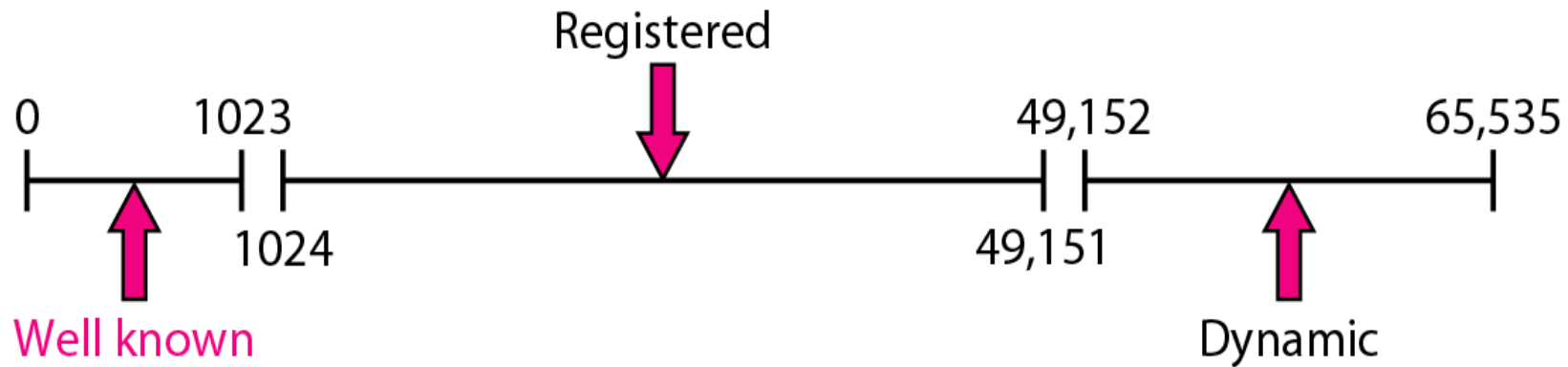
- Combination of IP address & port number
 - Unique for each process on the host



Port numbers

- Internet Cooperation for Assigned Names and Numbers Authority (ICANN) defines 3 types
 - **Well-known** ports, assigned and controlled by Internet Assigned Numbers Authority (IANA)
 - **Registered** ports, to be registered with IANA to prevent duplication
 - **Dynamic** (a.k.a. ephemeral) ports, neither controlled nor registered, to be used by any application

Port number ranges



TCP

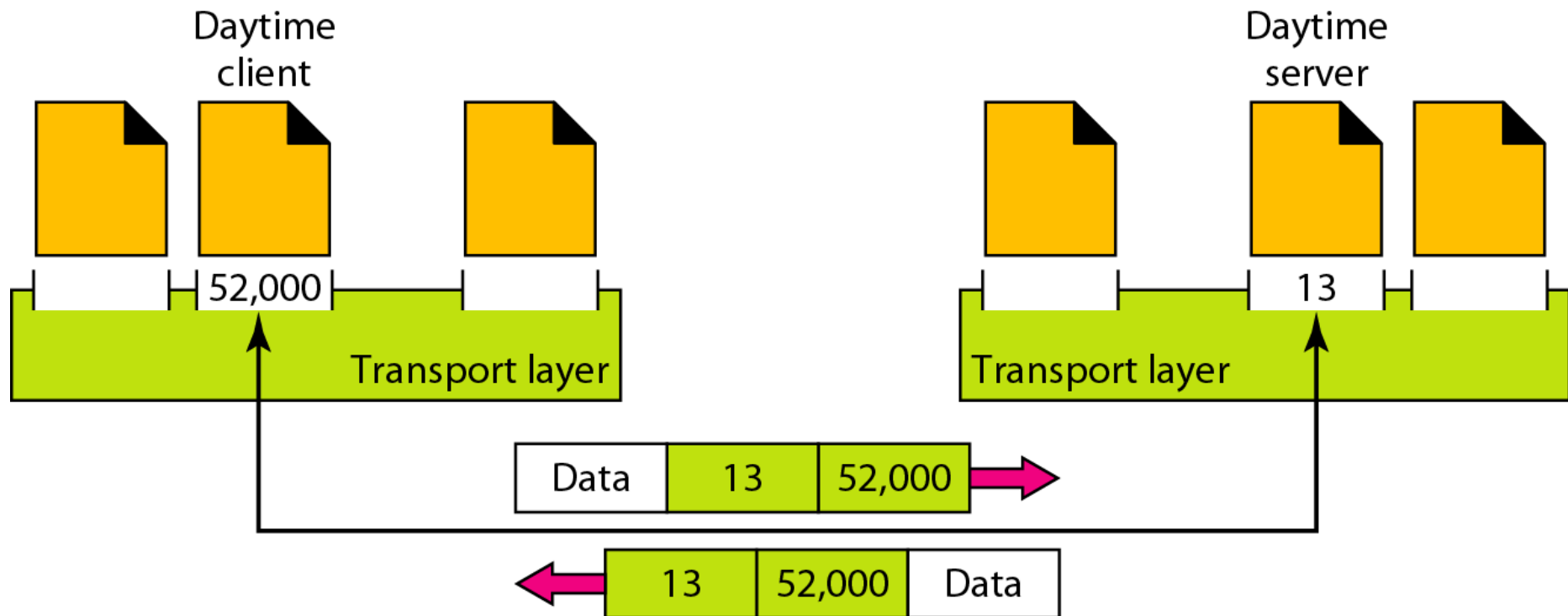
UDP

Port	Protocol	Description
7	Echo	Echoes a received datagram back to the sender
9	Discard	Discards any datagram that is received
11	Users	Active users
13	Daytime	Returns the date and the time
17	Quote	Returns a quote of the day
19	Chargen	Returns a string of characters
20	FTP, Data	File Transfer Protocol (data connection)
21	FTP, Control	File Transfer Protocol (control connection)
23	TELNET	Terminal Network
25	SMTP	Simple Mail Transfer Protocol
53	DNS	Domain Name Server
67	BOOTP	Bootstrap Protocol
79	Finger	Finger
80	HTTP	Hypertext Transfer Protocol
111	RPC	Remote Procedure Call

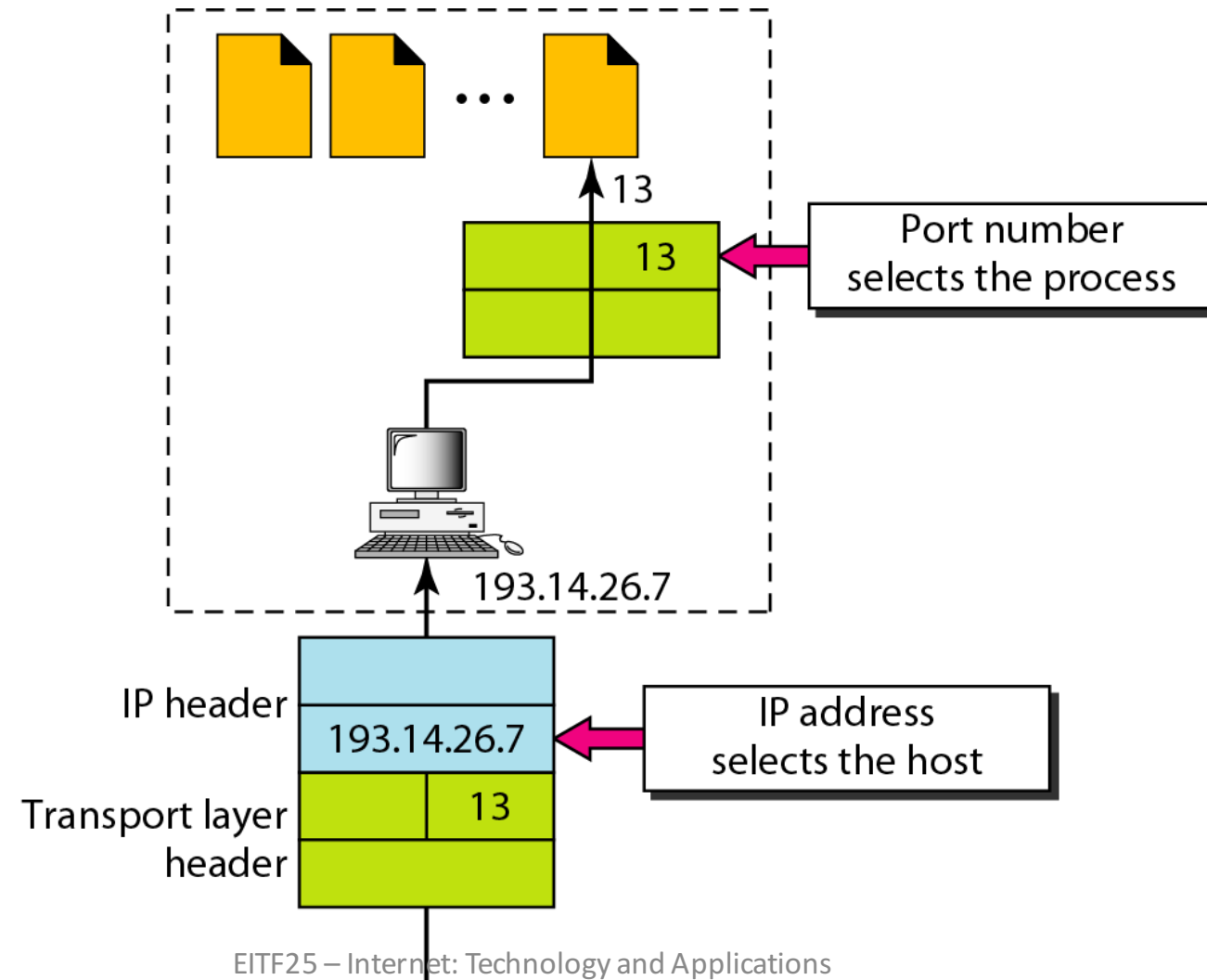
Port	Protocol	Description
7	Echo	Echoes a received datagram back to the sender
9	Discard	Discards any datagram that is received
11	Users	Active users
13	Daytime	Returns the date and the time
17	Quote	Returns a quote of the day
19	Chargen	Returns a string of characters
53	Nameserver	Domain Name Service
67	BOOTPs	Server port to download bootstrap information
68	BOOTPc	Client port to download bootstrap information
69	TFTP	Trivial File Transfer Protocol
111	RPC	Remote Procedure Call
123	NTP	Network Time Protocol
161	SNMP	Simple Network Management Protocol
162	SNMP	Simple Network Management Protocol (trap)

Addressing the processes

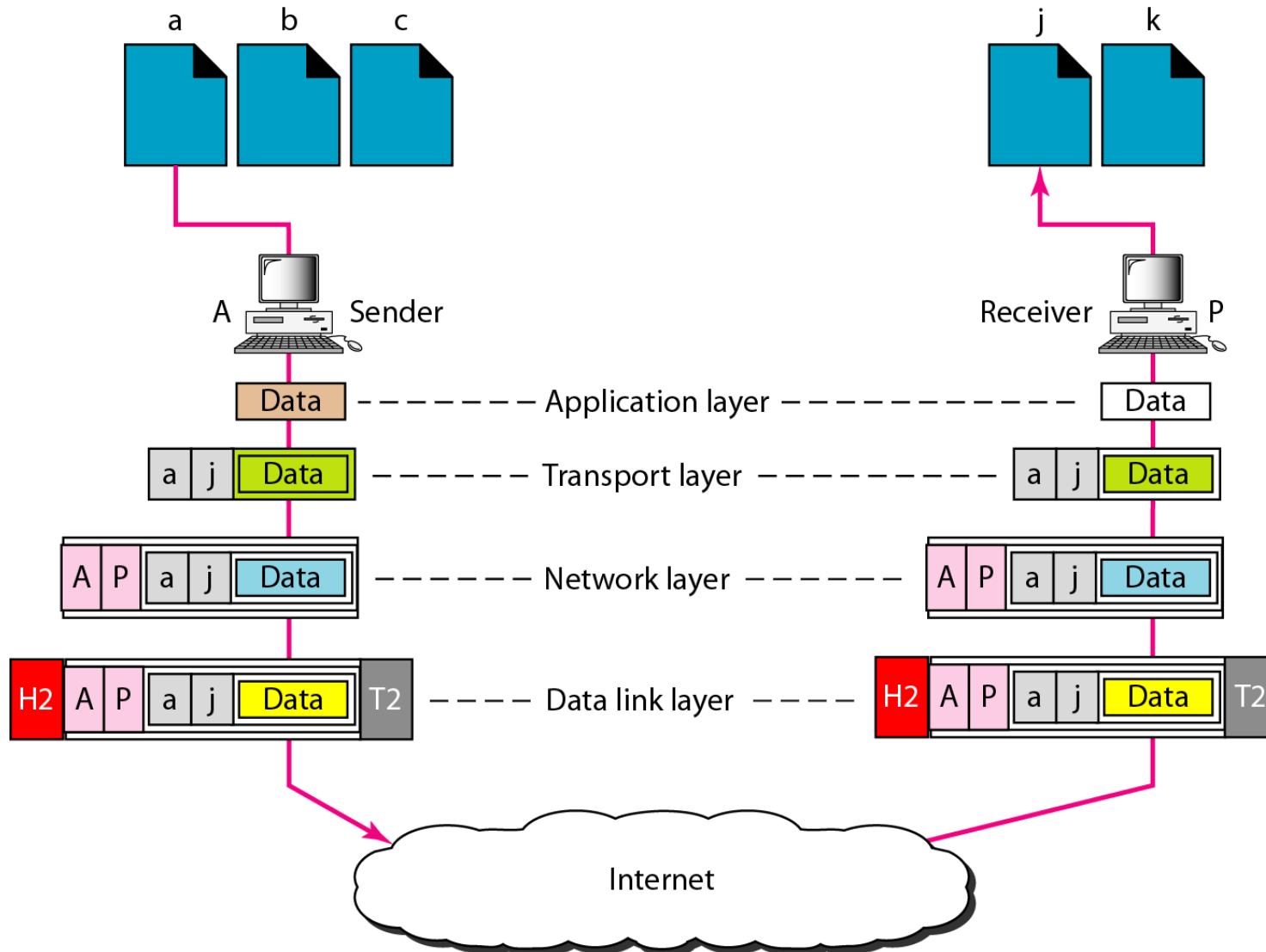
- Port numbers
 - Organised by IANA



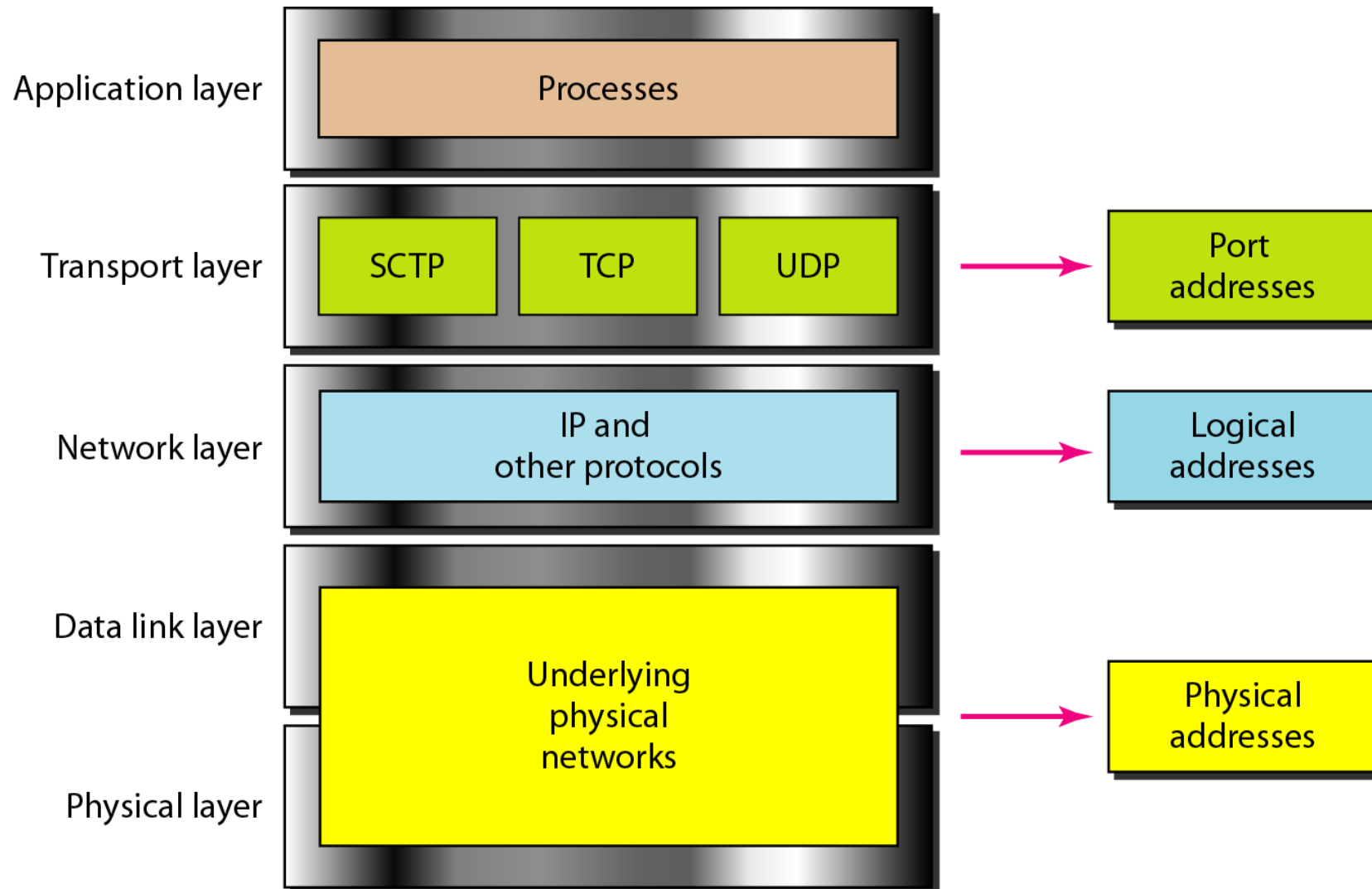
IP addresses and port numbers



Logical and port addresses



Addressing in TCP/IP



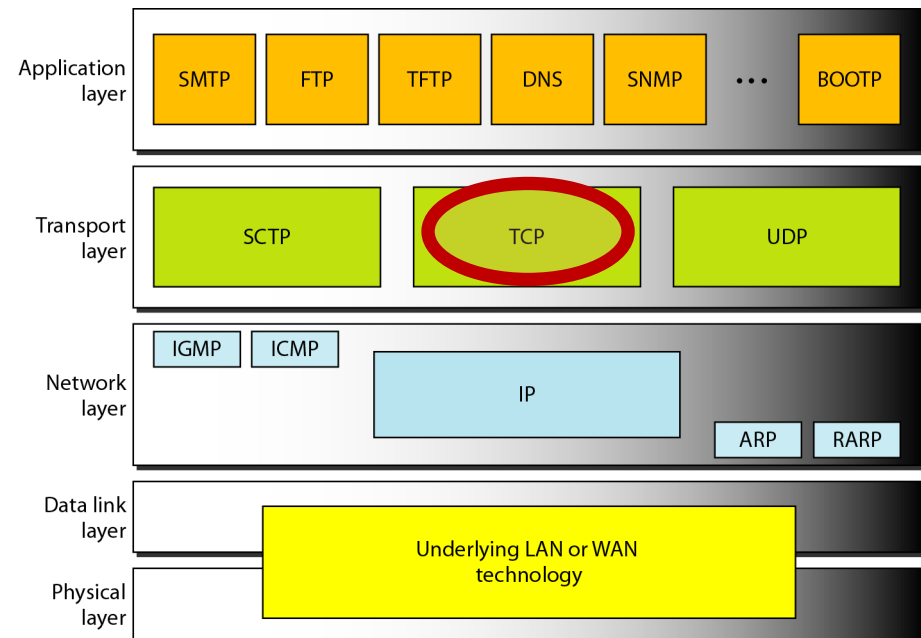
See you in 15' :)



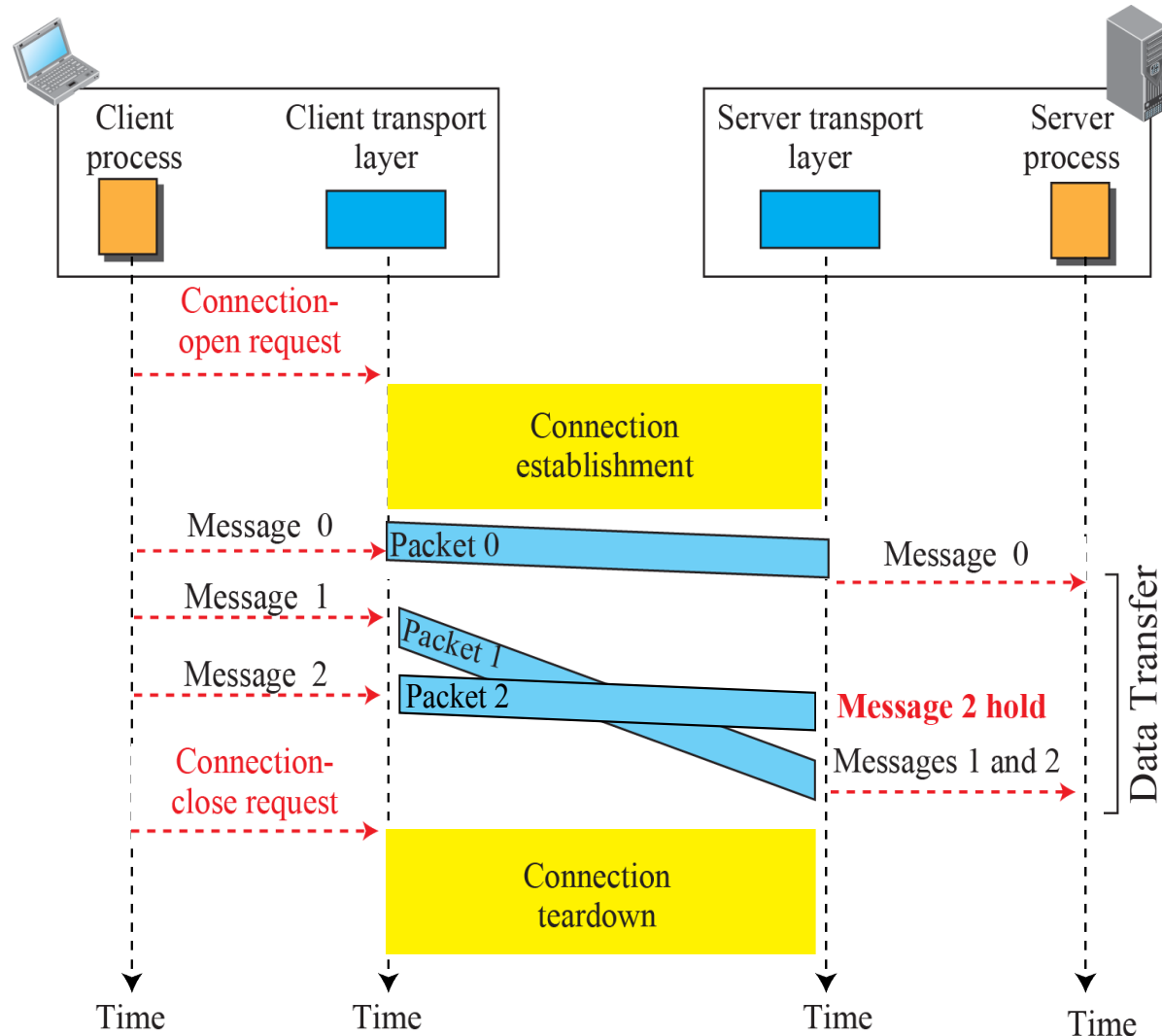
- After the break
 - TCP
 - QoS
 - UDP

Transmission Control Protocol (TCP)

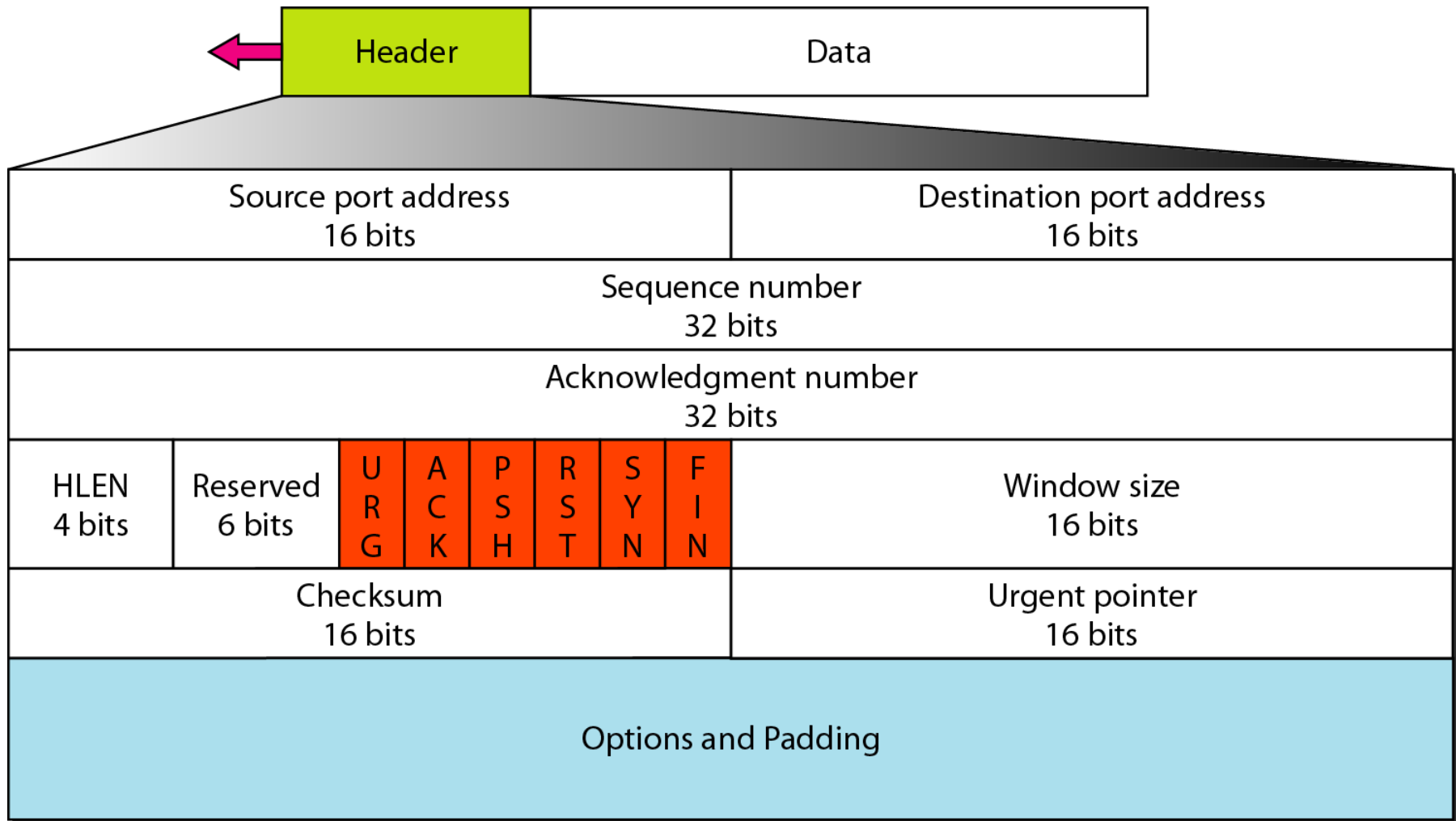
- Connection-oriented
 - Sessions
 - Byte stream service
 - Sequence numbers
- Reliable
 - Flow control
 - Error control
 - Retransmissions
 - Congestion control



Connection-oriented service



TCP header format

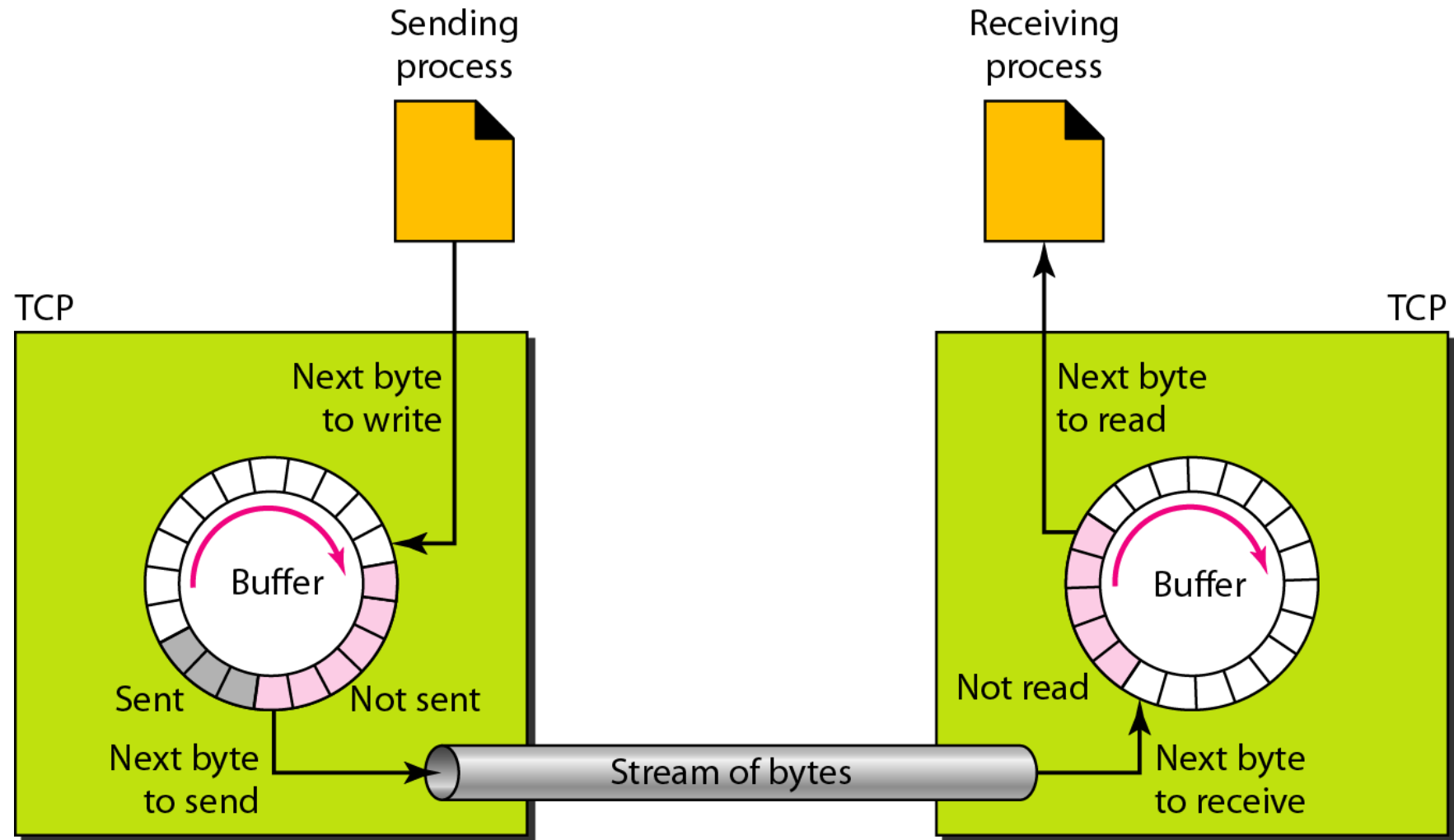


Exercise: Fill in the header.

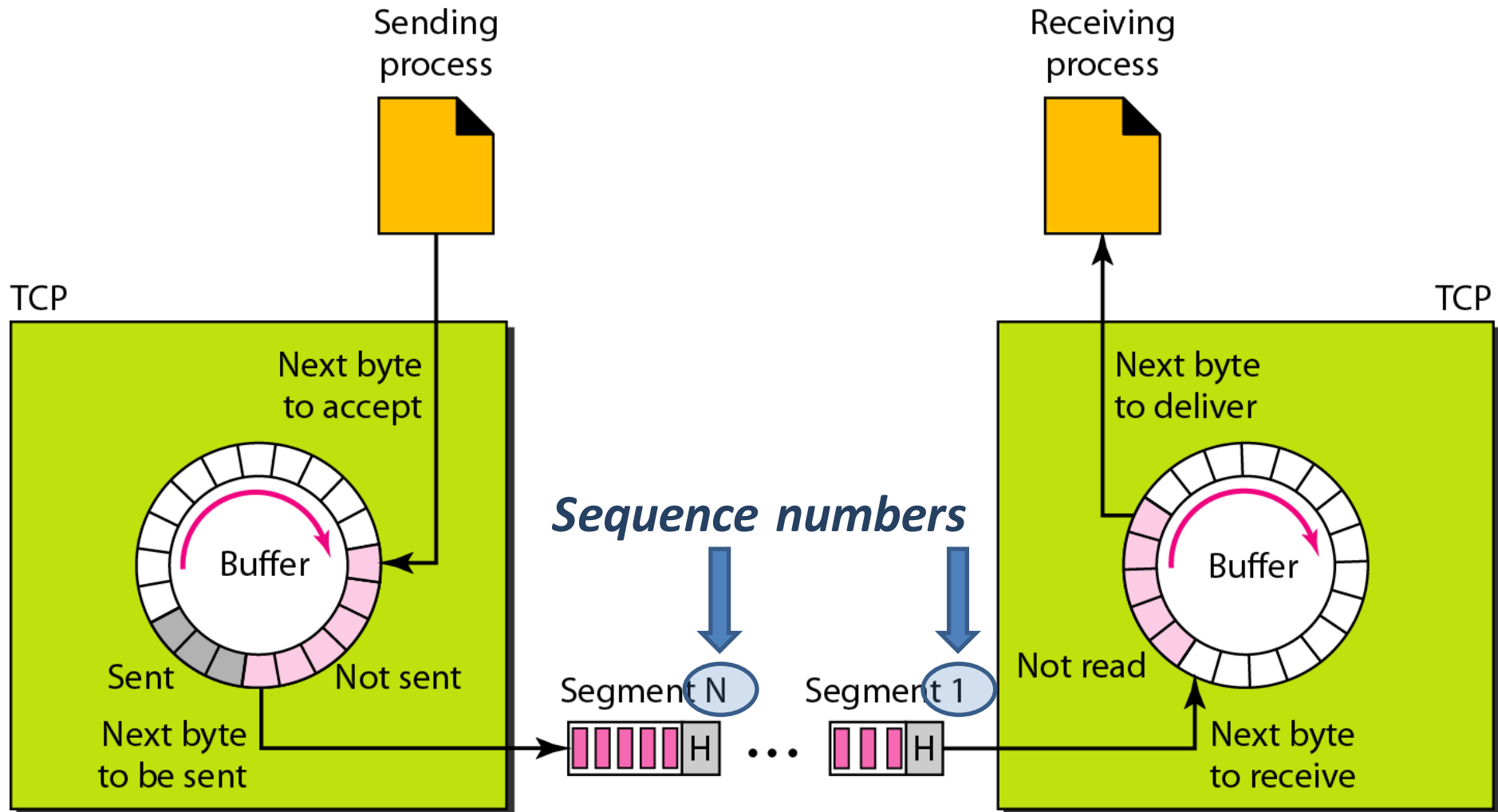
0532 0017 00001234 00004321 5 002 07FF

Source port address 16 bits	0532	Destination port address 16 bits	0017
Sequence number 32 bits		00001234	
Acknowledgment number 32 bits		00004321	
5	002	Window size 16 bits	07FF
Checksum 16 bits		Urgent pointer 16 bits	
Options and Padding			

Sending and receiving buffers...



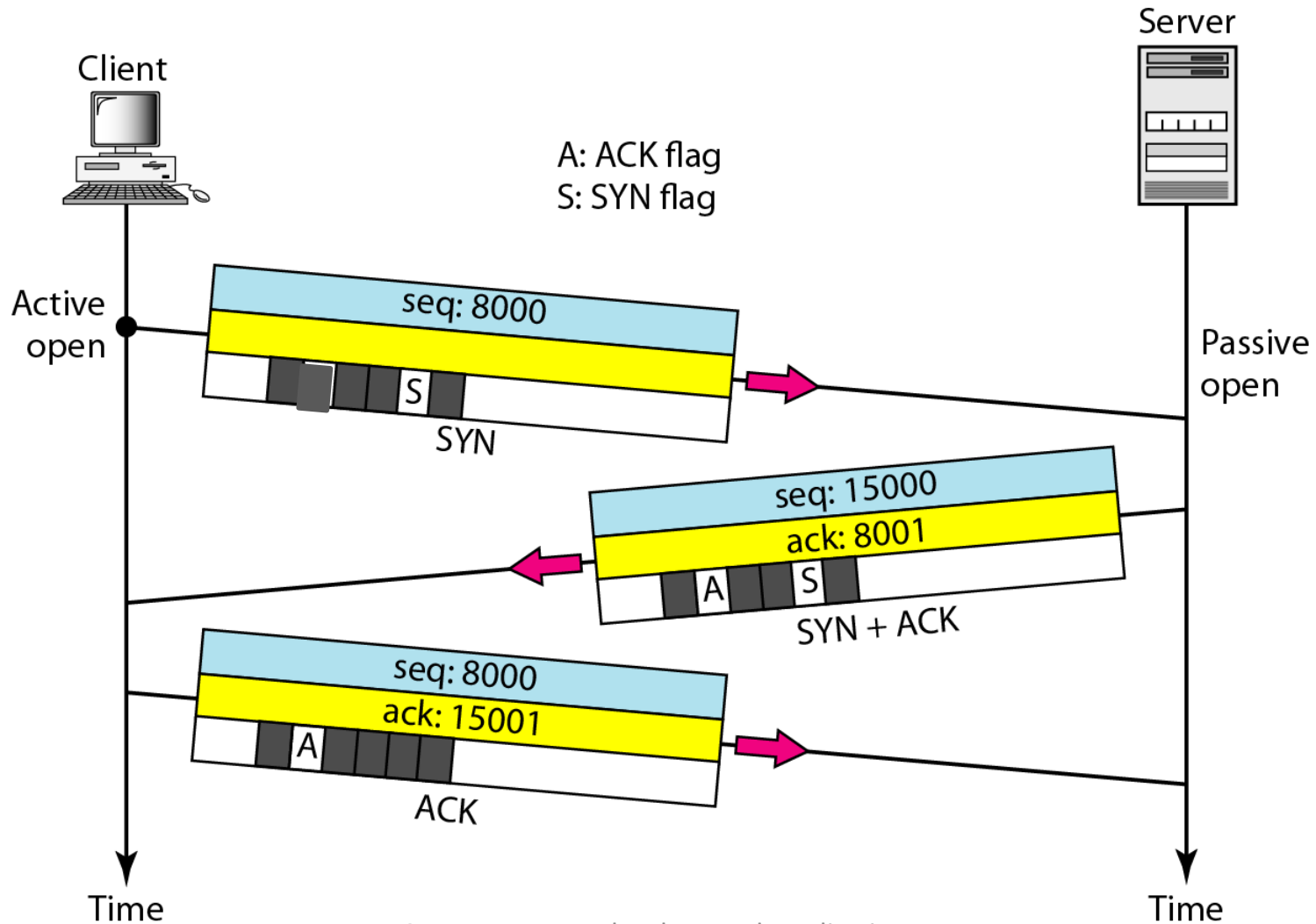
... turned into Segments



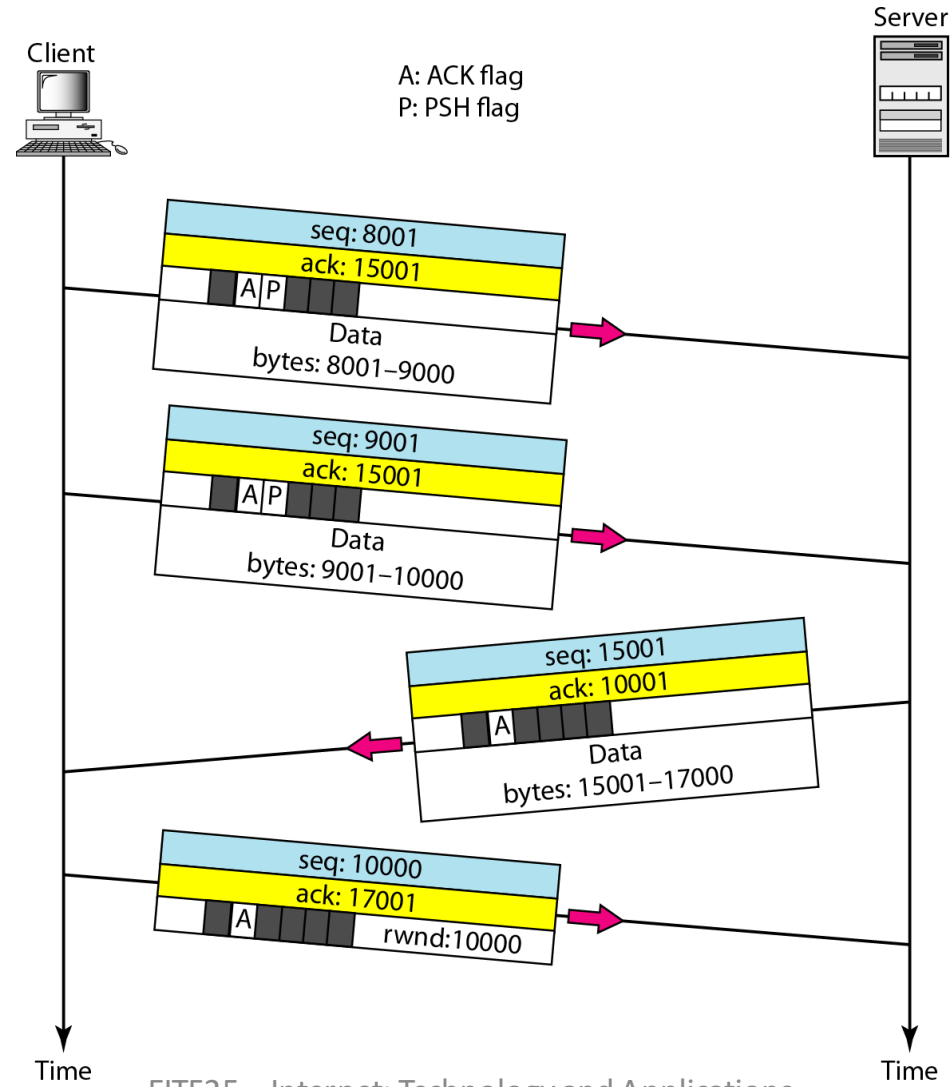
TCP operation

- Connection establishment
 - Three-way handshake
- Data transfer
 - Flow control (→ congestion control)
 - Error control (→ go back N with selective repeat)
- Connection termination
 - Three-way handshake
 - Half-close

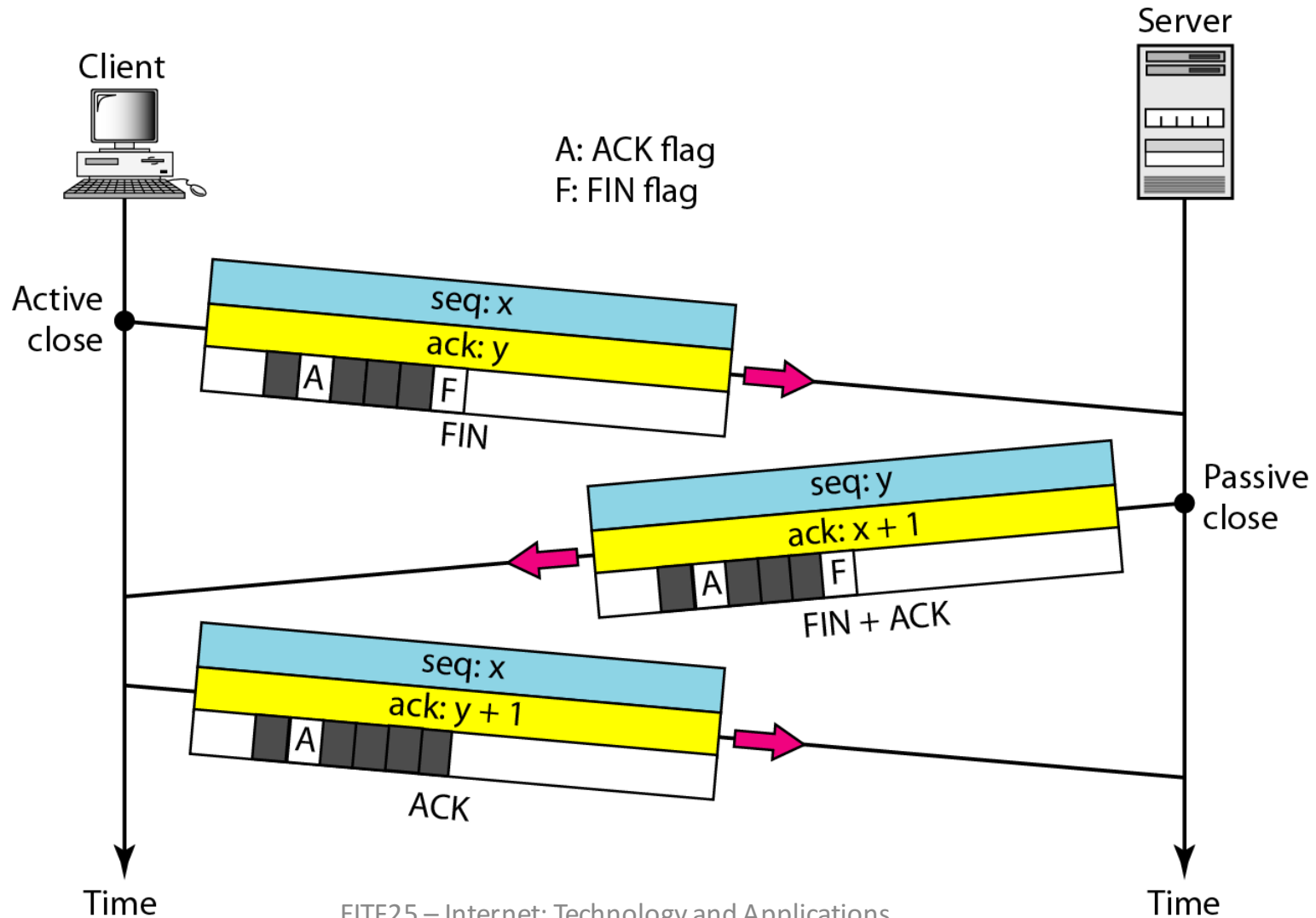
Connection establishment



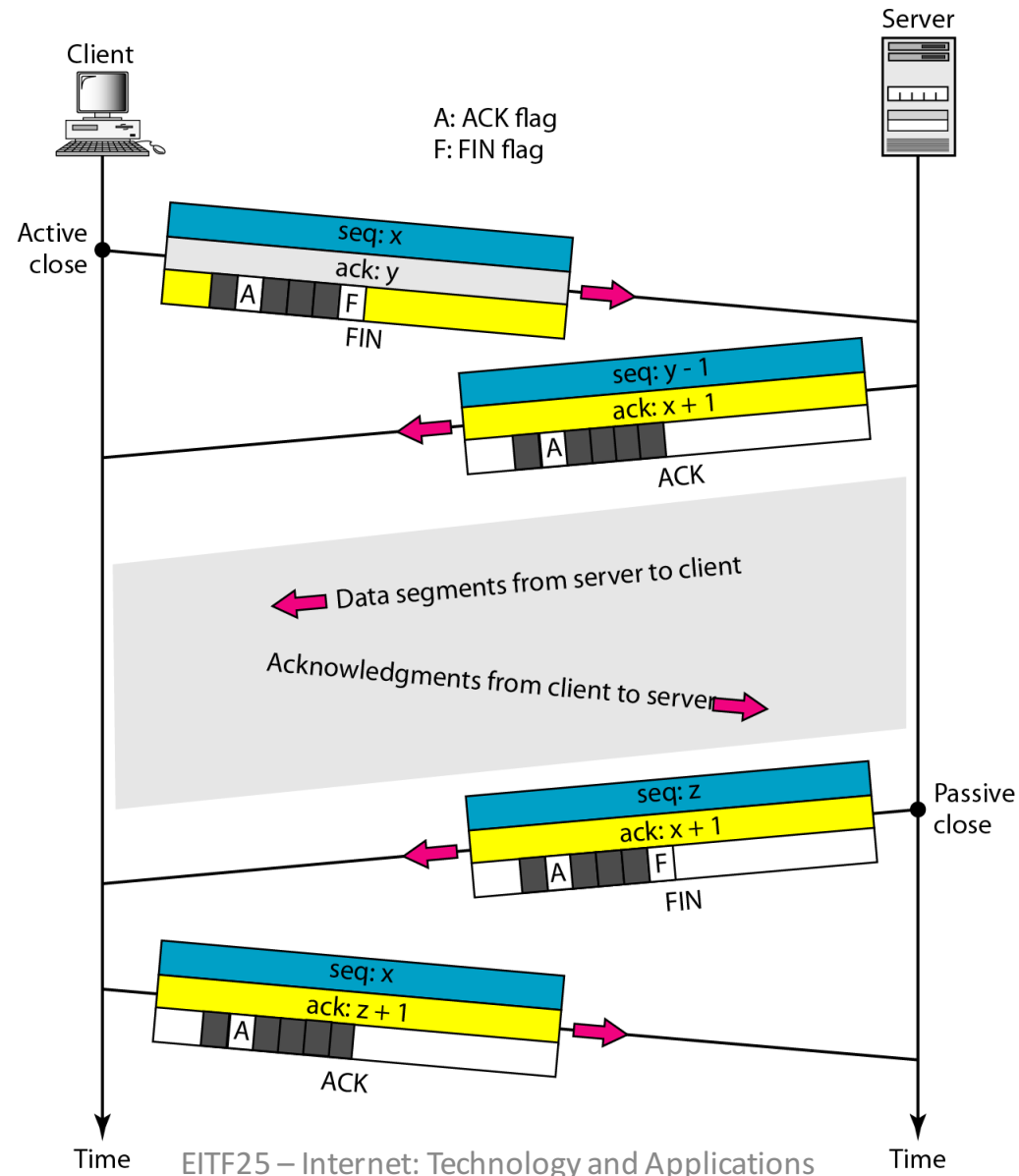
Data transfer



Connection termination



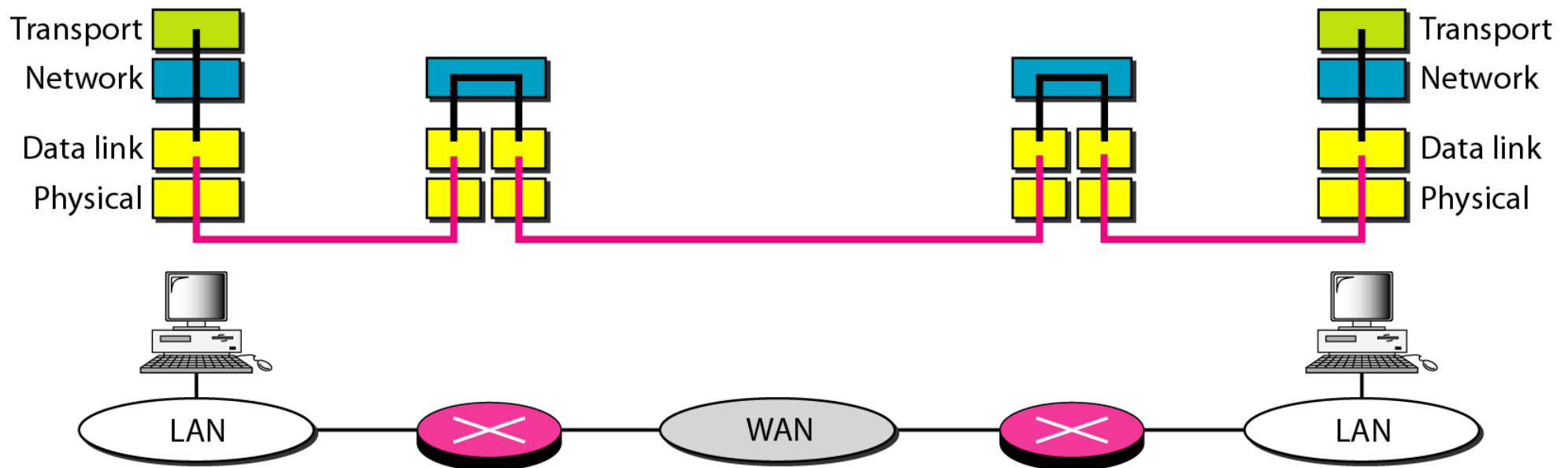
Half-close



Error control

- Reliable transport layer service: TCP
- Unreliable network layer service: IP

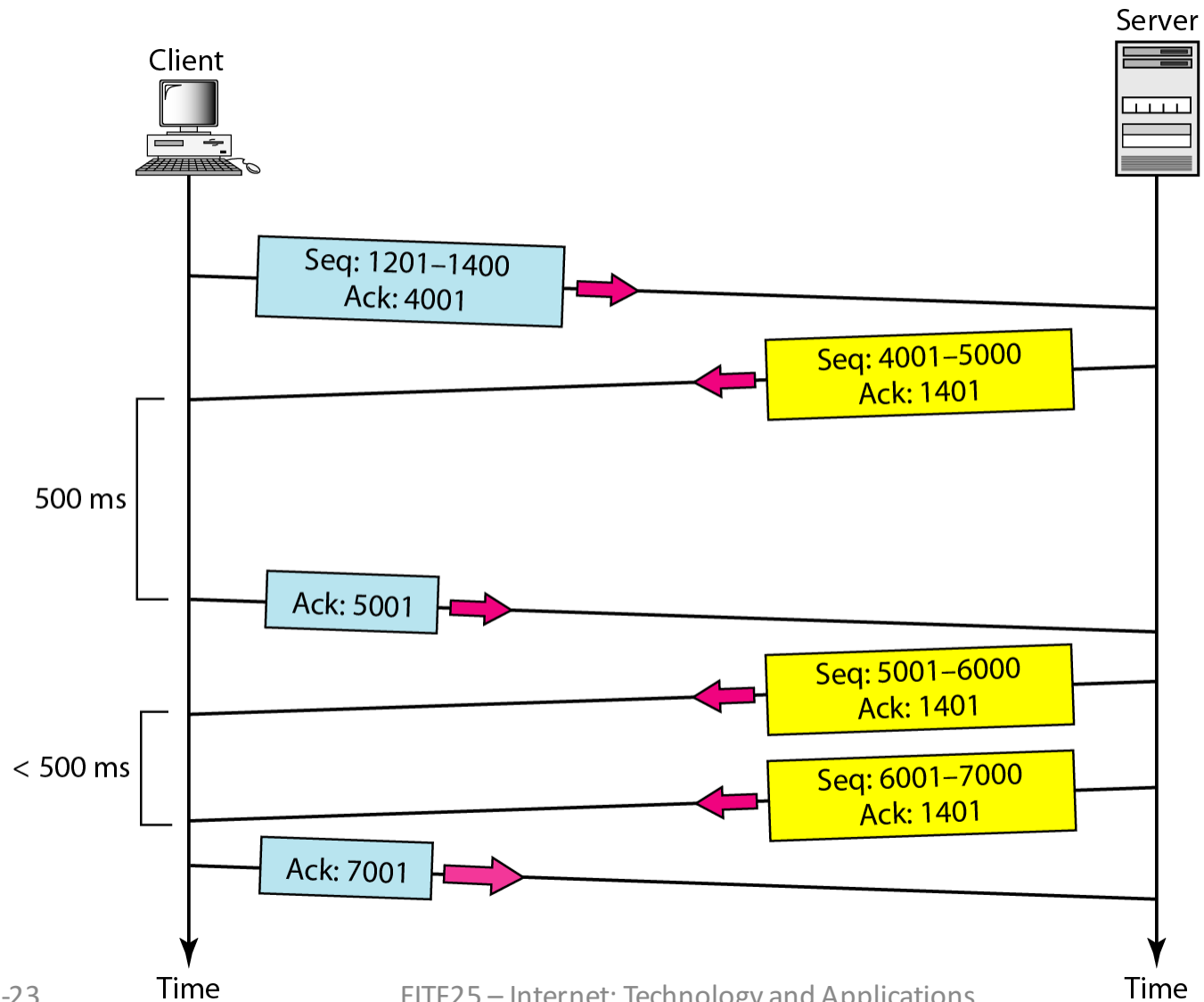
— Error is checked in these paths by the data link layer
— Error is not checked in these paths by the data link layer



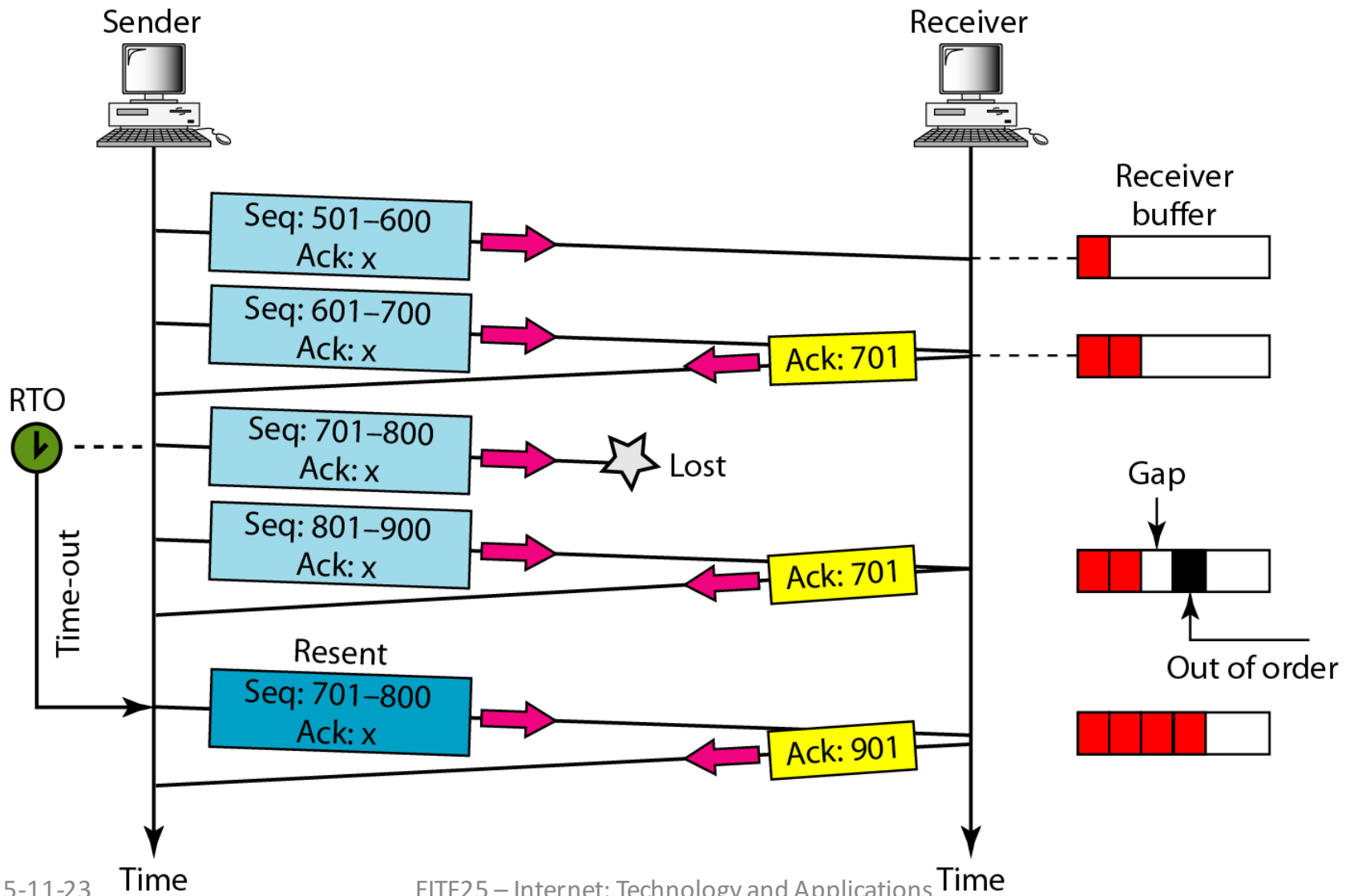
Error control in TCP

- Checksum
- Acknowledgement
 - ACK received data
- Retransmission
 - After time-out
 - After 3 duplicate ACK

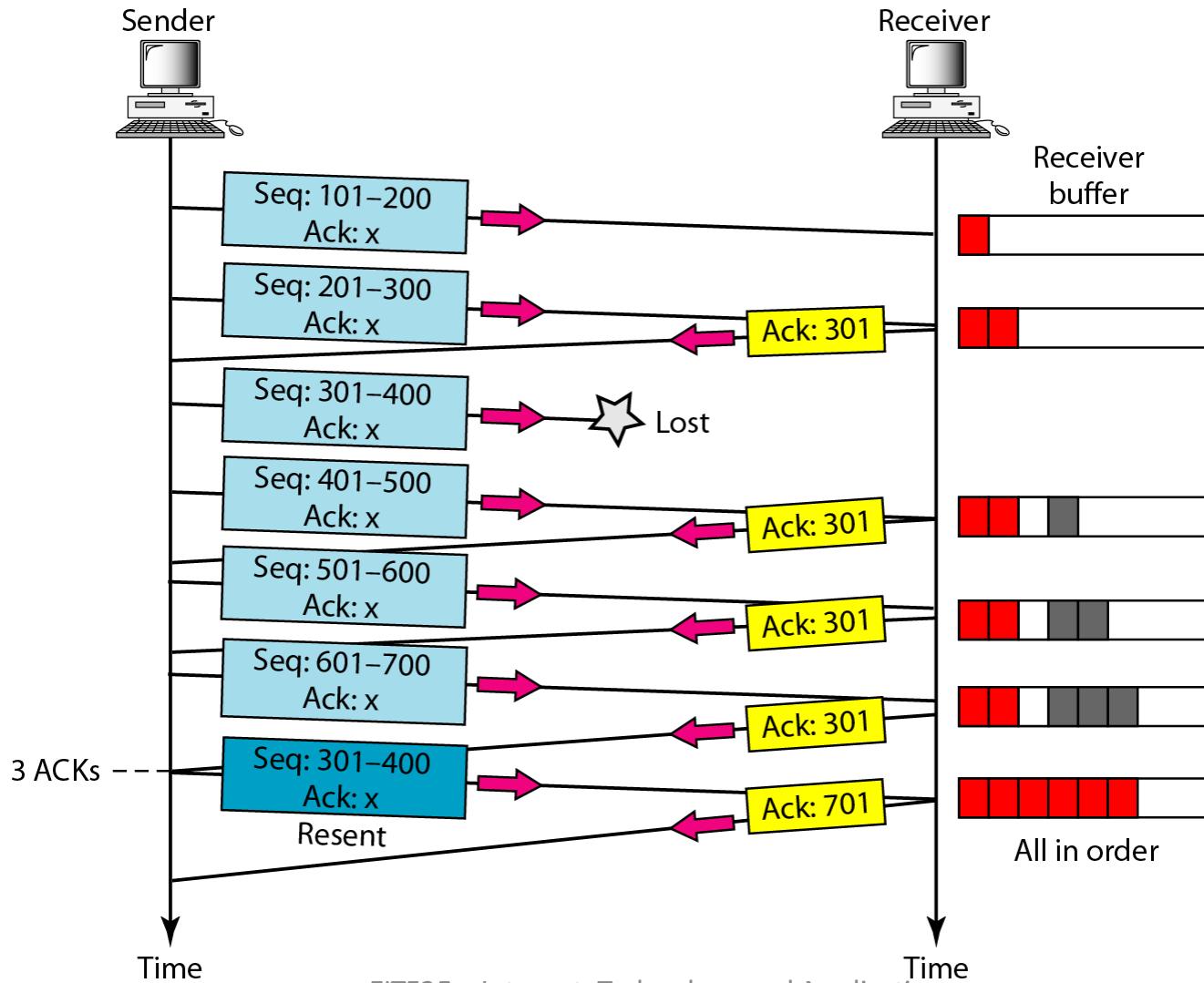
Normal operation



Lost segment

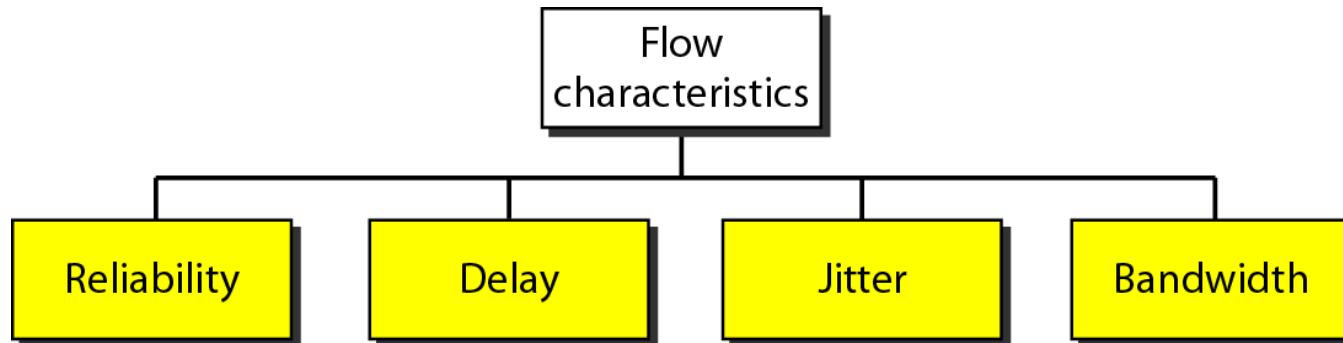


Fast retransmission



Quality of Service (QoS)

- Maintaining a functioning network
 - Meeting applications' demands
 - Dealing with flow characteristics
- Particularly important for real-time apps
 - Multimedia

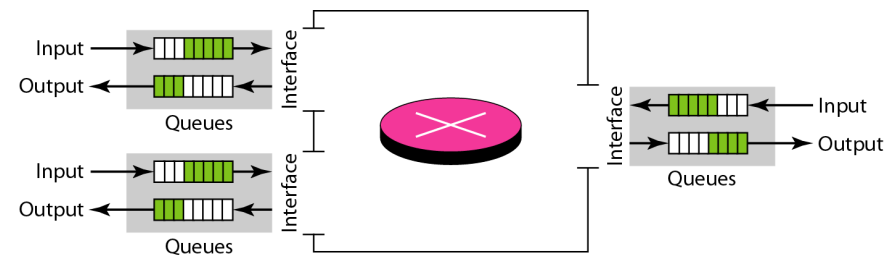
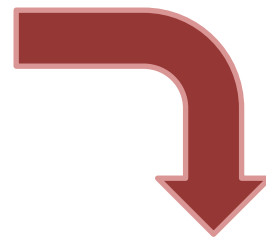


Where to improve QoS?

- Admission control
 - INTSERV, DIFFSERV
- Resource reservation
 - RSVP

+
underlying WAN technologies:
ATM

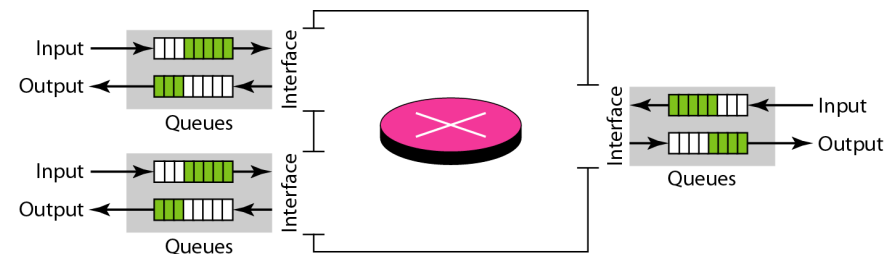
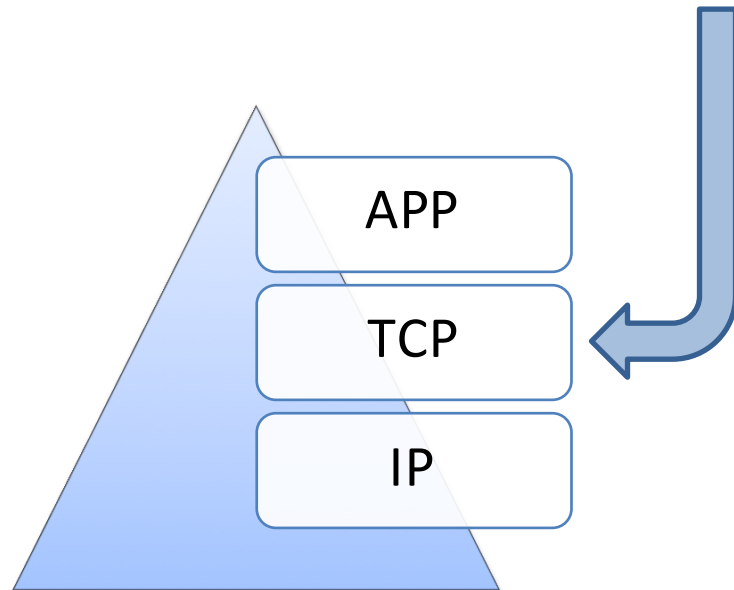
- Scheduling
- Traffic shaping



ANYWHERE YOU FIND QUEUES!

Congestion avoidance

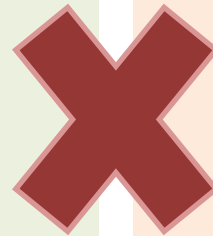
- Congestion = data load > network capacity
 - Arrival rate > processing rate
 - Processing rate > departure rate
- Congestion control



Summary and comparison: QoS

Multimedia Performance Requirements

- Sensitive to:
 - Delay
 - Jitter
- Not so sensitive to:
 - Packet loss
 - Corrupted packets



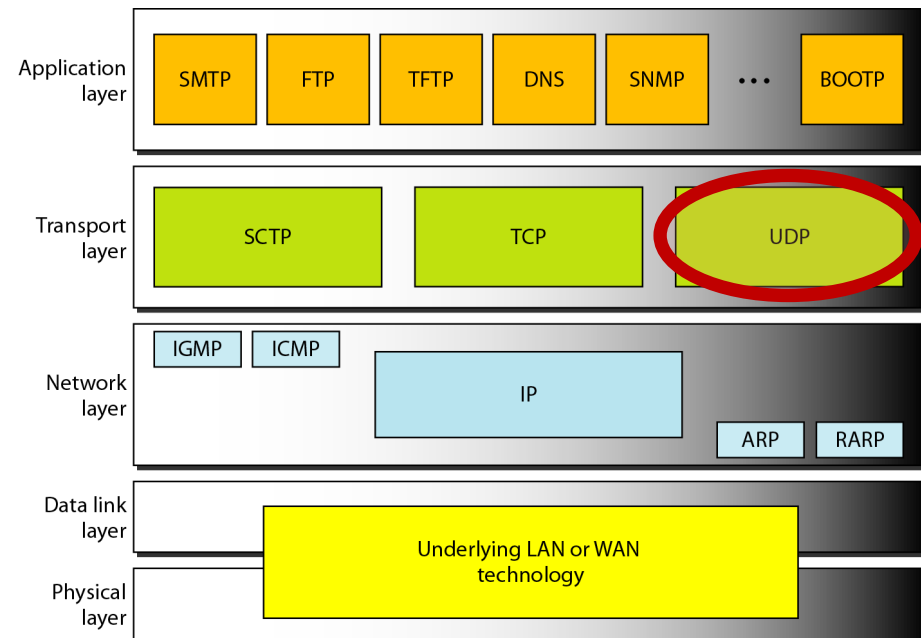
vs. Characteristics of TCP

- Sensitive to:
 - Lost or corrupted packets
- Not so sensitive to:
 - Delay
- No multicasting!

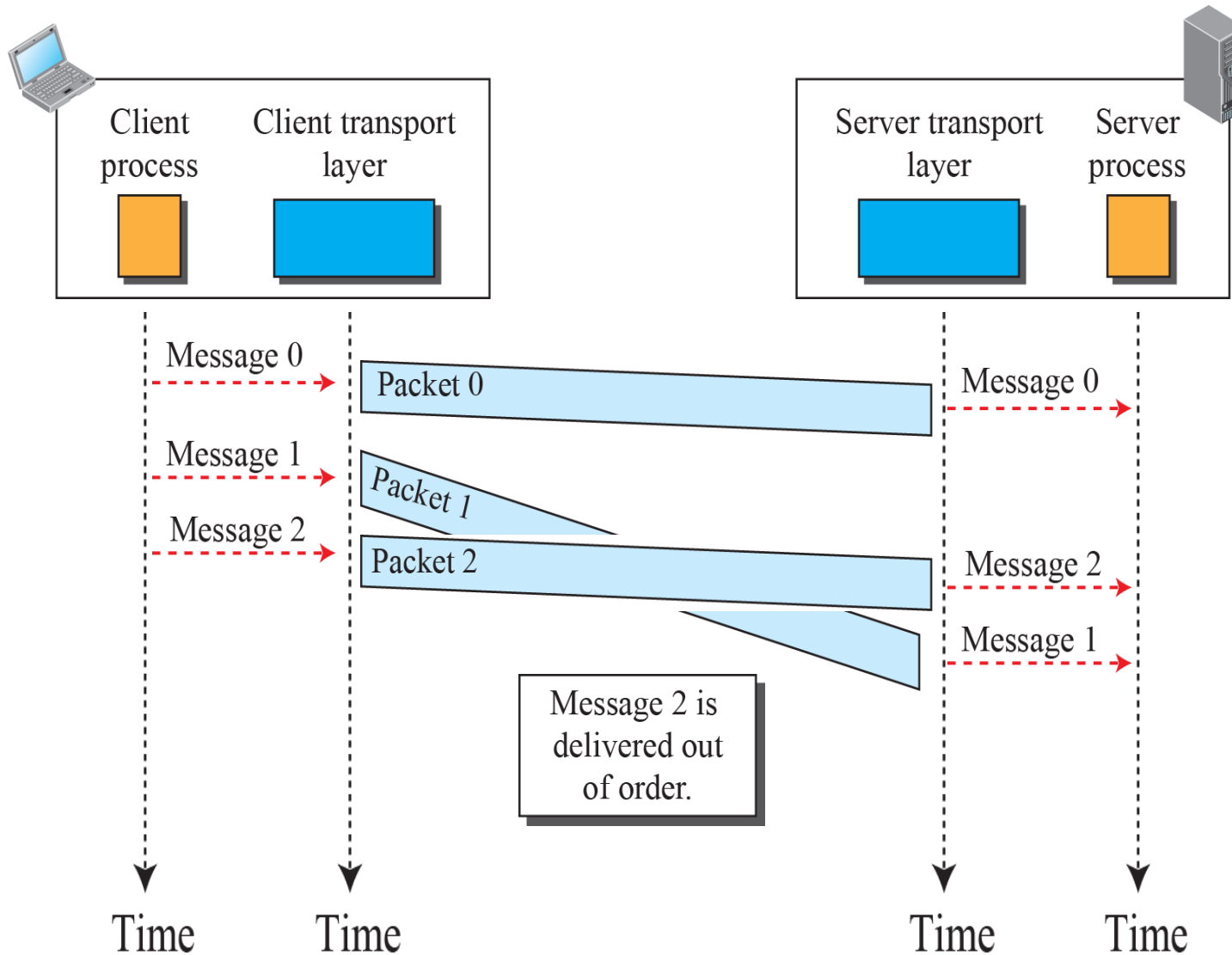
So, what about UDP?

User Datagram Protocol (UDP)

- Connectionless
 - Independent datagrams
 - No sessions
- Unreliable
 - No error control
 - No flow control
- Process-to-process

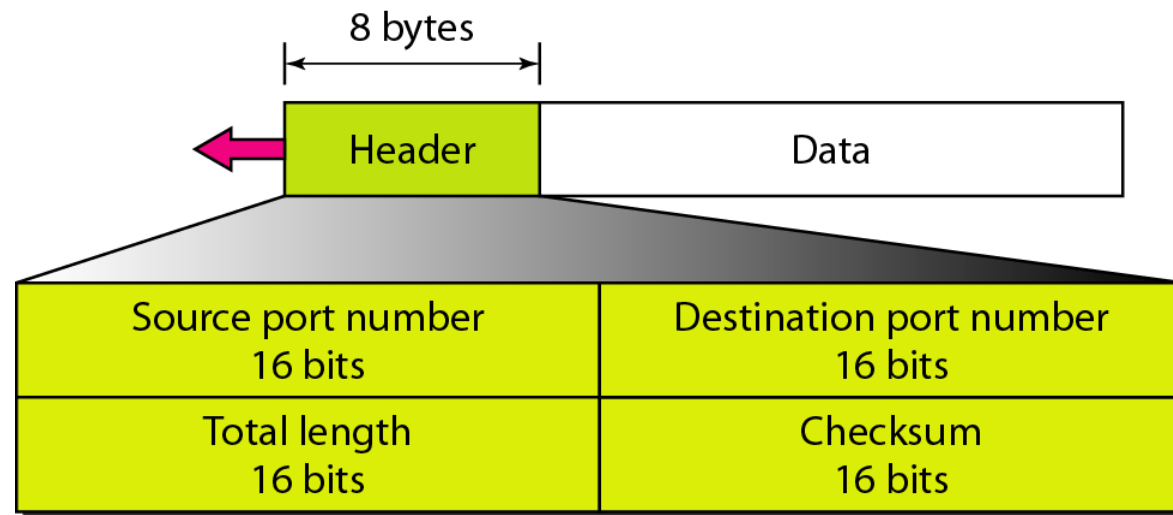


Connectionless service

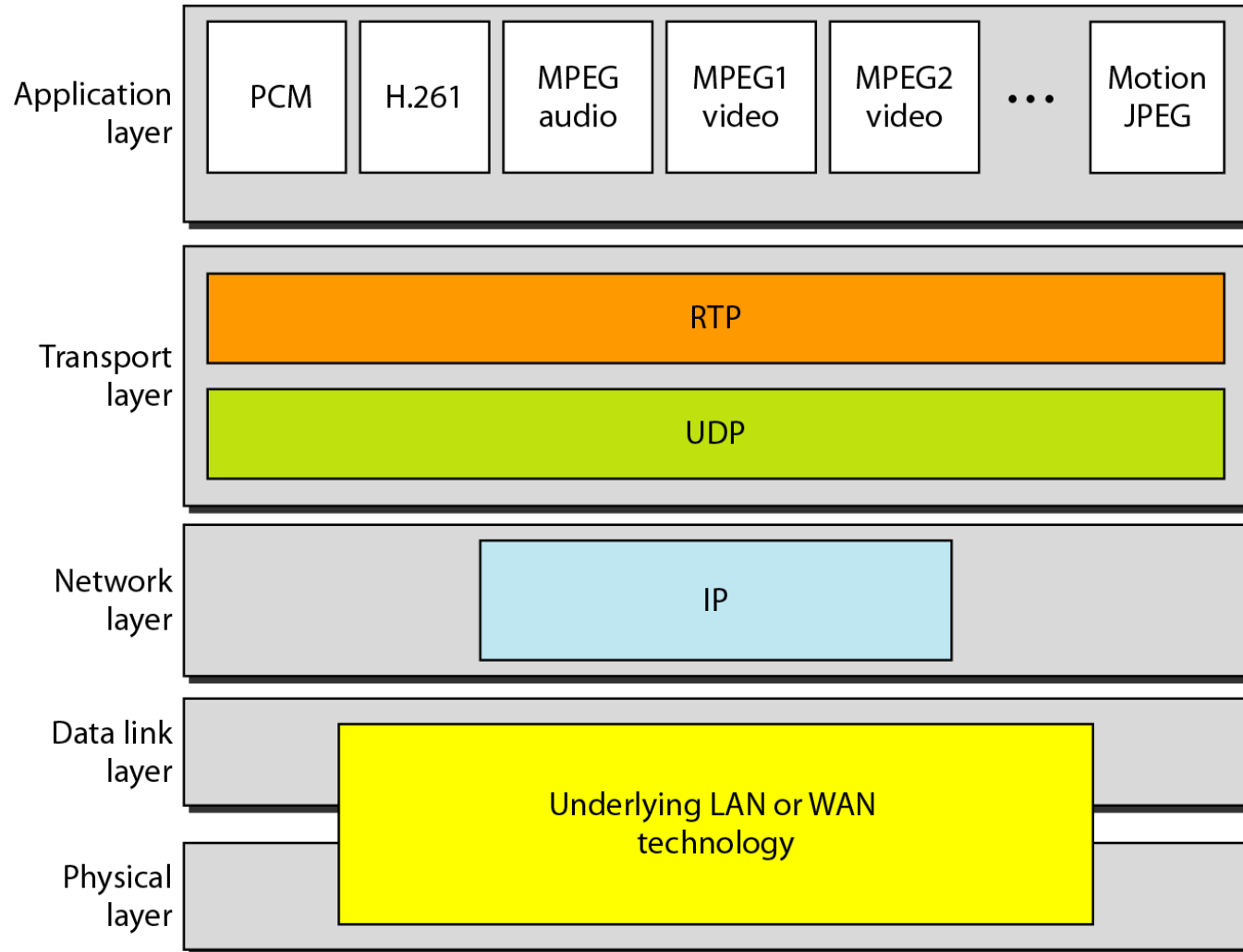


UDP header format

- Checksum optional
- No numbering
 - No relation between datagrams



Real-time Transport Protocol



Summary: Internet Protocols (2)

- Mapping IP addresses to MAC addresses
- Addressing beyond IP
 - Ports, sockets
- Process-to-process delivery
- Transport layer protocols
 - TCP: connection-oriented, reliable
 - UDP: connectionless, unreliable
- Quality of Service