

TCP Introduction

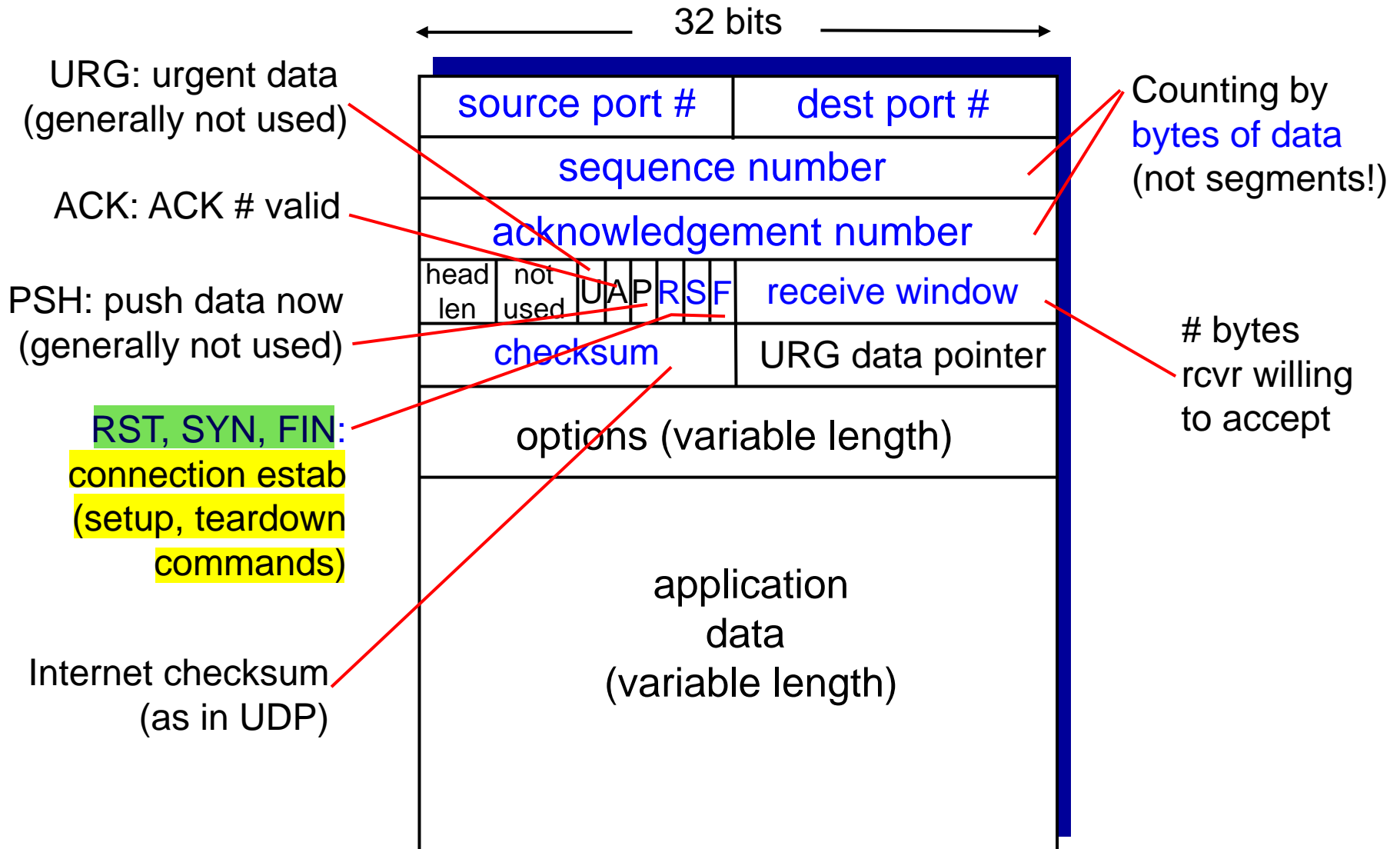
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TCP: Overview

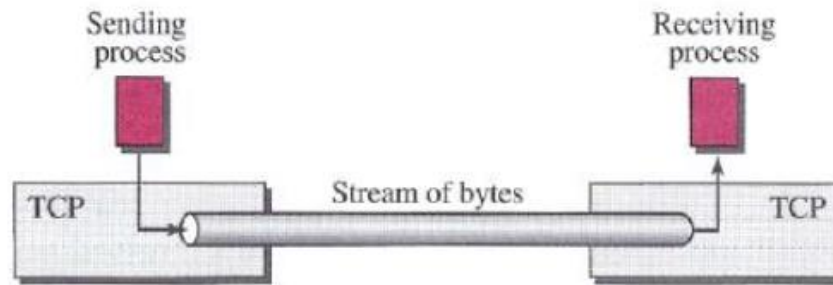


- **connection-oriented:**
 - **handshaking** (exchange of control msgs)
 - **initialize sender, receiver state before data exchange**
 - TCP connection **is not** end-to-end TDM/FDM **circuit** or virtual circuit (as **only end systems maintain connection state**)
- **point-to-point:**
 - one sender, one receiver
- **reliable, in-order, *byte stream*:**
 - error and loss control
 - **no “message boundaries”**
- **pipelined:**
 - **TCP congestion and flow control set **window size****
- **flow controlled:**
 - sender **will not overwhelm** the receiver
- **full duplex data:**
 - **bi-directional data flow in same connection**
 - **MSS: maximum segment size** (max amount of app. layer data in a segment)

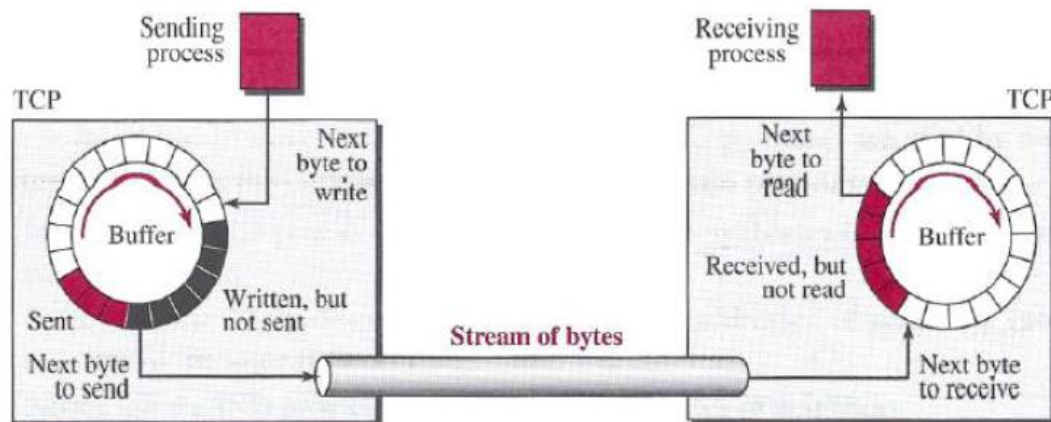
TCP segment structure



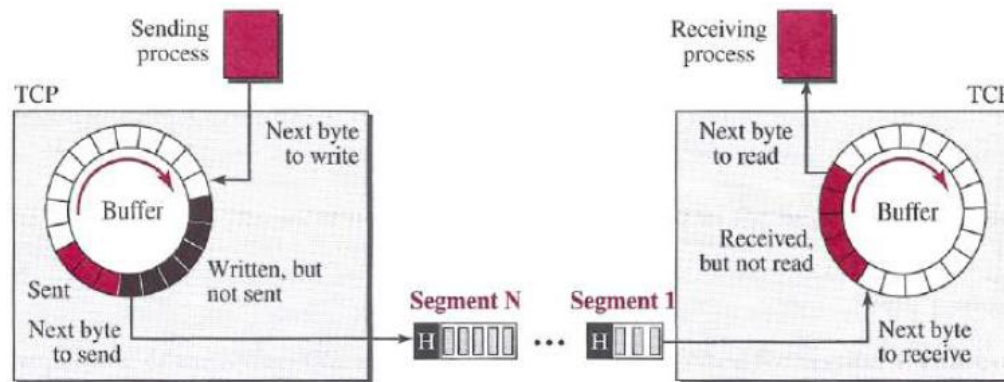
TCP - Stream Delivery Service



- Each TCP endpoint has its own **sending and receiving buffer**
- **Sending and Receiving buffer may not necessarily write / read data at the same rate**



Cont...



- Segmentation and Reassembly
 - TCP usually determines the **maximum segment size** (MSS) based on the MTU of Layer 3 (IP layer).
 - **Note**: for UDP, the assumption was that the UDP segments are small in size
- **No segment number in TCP**. But, TCP uses **SEQ** and **ACK** numbers
 - These are **byte numbers**, but not segment numbers
- Number is **independent in each direction**
- **For 1st byte**: arbitrary number in $[0, 2^{32} - 1]$, as TCP uses 32-bit seq#

TCP Seq #, ACK

sequence numbers:

- byte stream “number” of first byte in segment’s data

acknowledgements:

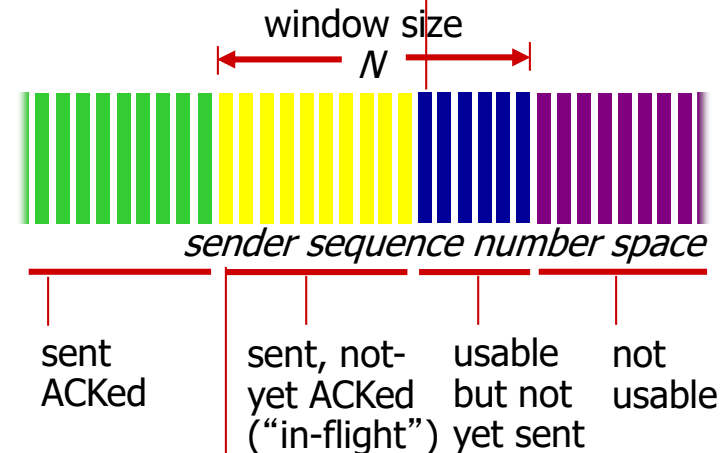
- seq # of next byte expected from other side
- cumulative ACK

Q: how receiver handles out-of-order segments

- Ans:** TCP spec doesn’t say!
-- up to implementer

outgoing segment from sender

source port #	dest port #
sequence number	
acknowledgement number	
	rwnd
checksum	urg pointer



incoming segment to sender

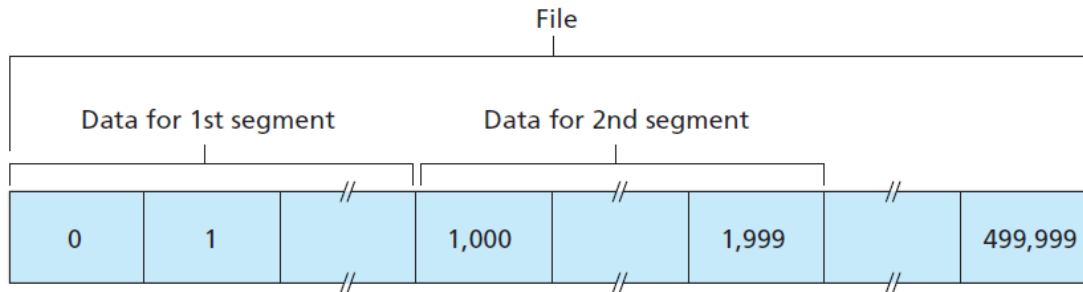
source port #	dest port #
sequence number	
acknowledgement number	
	A
checksum	urg pointer

Cont...



- **ACK in TCP** can be described as a **hybrid of GBN and SR**
- TCP is **similar to GBN** because both protocols have a **limit on the number of unACK'd packets** that the sender can send into the network.
- However, TCP is **different from GBN** because GBN requires the retransmission of every unACK'd packet when packets are lost, but **TCP only retransmits the oldest unACK'd one**.
- TCP is **similar to SR** because, when packets are lost due to congestion, the protocols do not require the sender to retransmit EVERY unACK'd packet sent by the sender. The sender **just retransmits the oldest unACK'd packet**.
- TCP is **different from SR** because SR requires individual acknowledgement of each packet that was sent by the receiver; but rather than selectively ACKing every packet, **TCP sends an ACK for the next packet that it is expecting and buffers the ones that it has received so far**, even if they're out of order

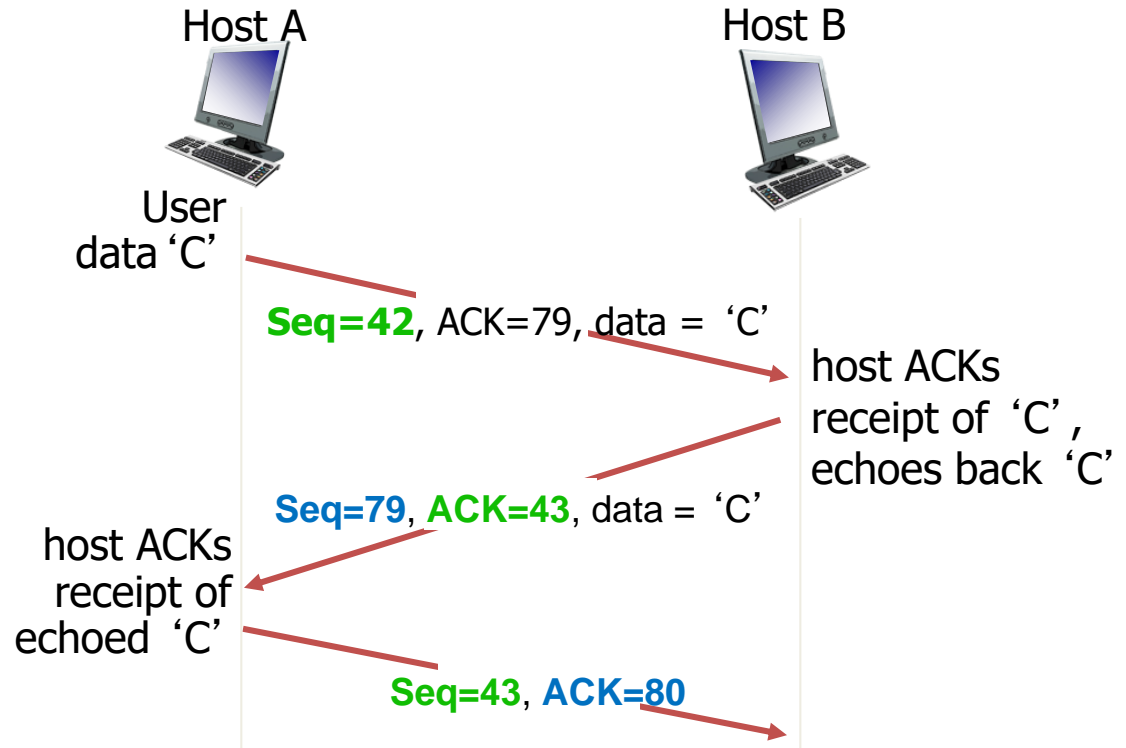
Cont...



- 1st seg. SEQ#=0
- 2nd seg. SEQ#=1000
- 3rd seg. SEQ#=2000
- So on.

Figure 3.30 ♦ Dividing file data into TCP segments

**simple
telnet
scenario**

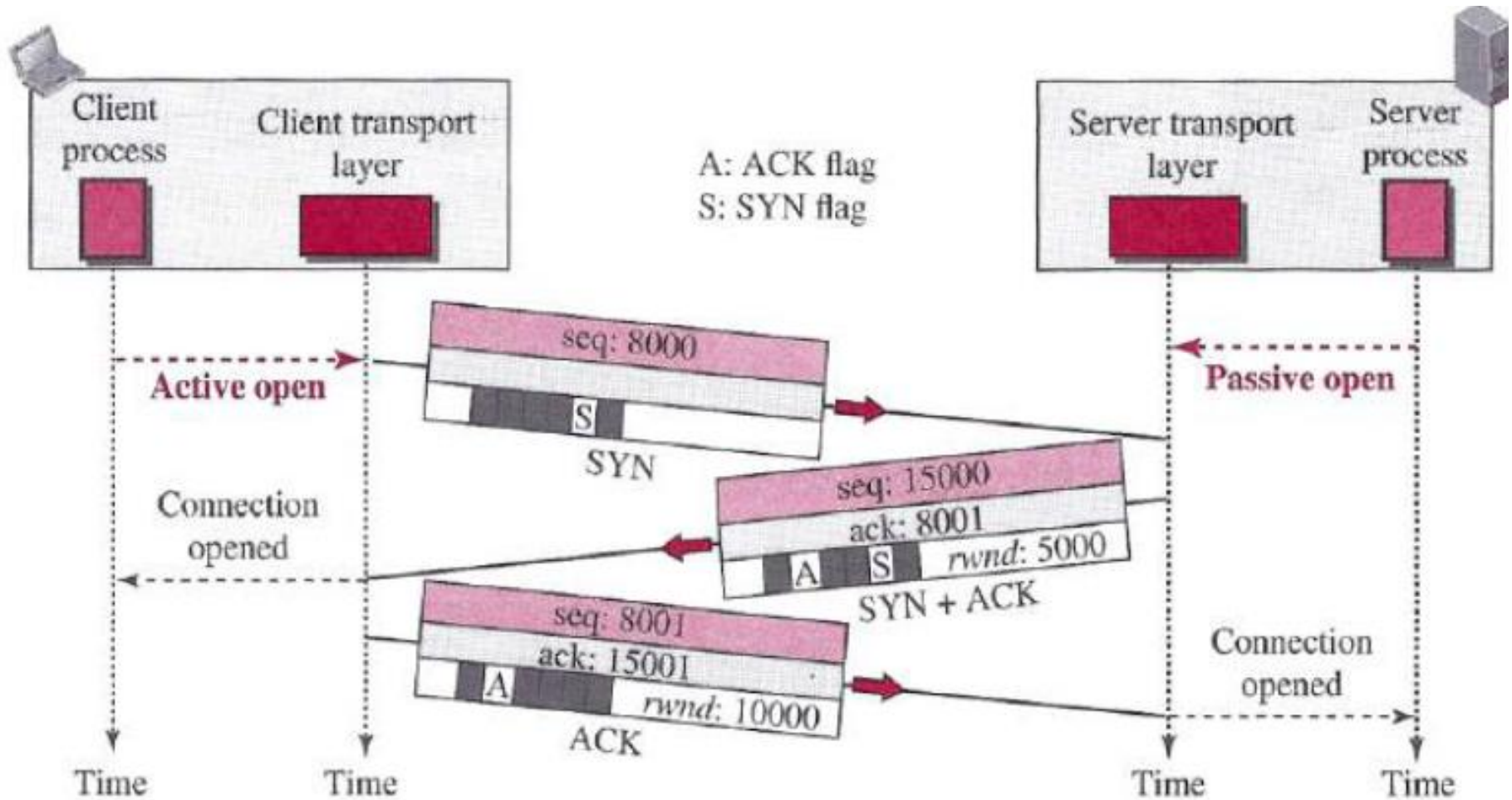


TCP Connection

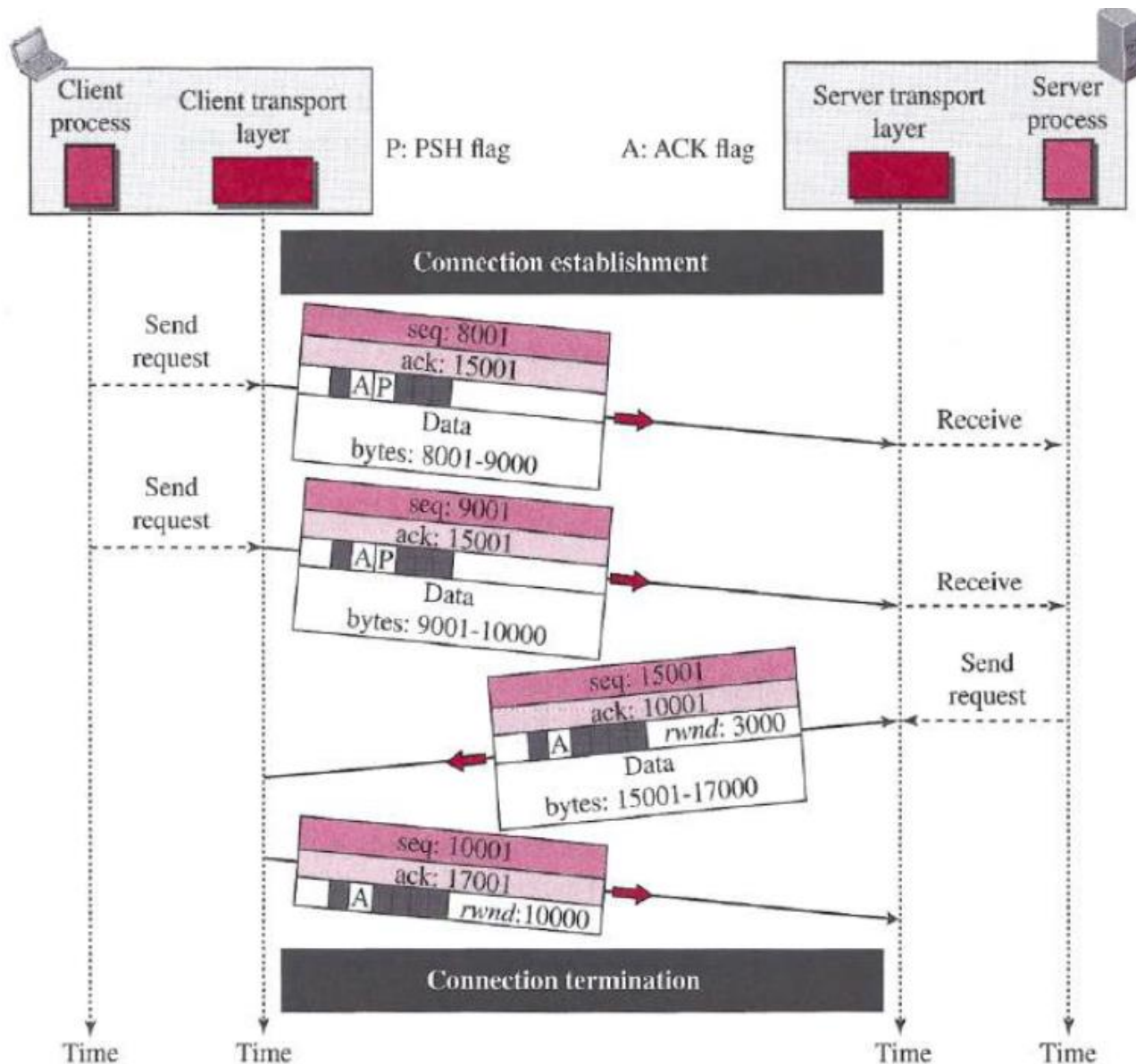
- TCP is **connection-oriented** (although IP is connectionless)
- TCP connection is **logical**, **not physical**.
- TCP operates in full-duplex mode
- TCP uses **three-way-handshaking**
 - **SYN**
 - **ACK+SYN**
 - **ACK**
- Let, an application program (i.e. **client**) wants to make a connection with another application program (i.e. **server**) using TCP
- The **process starts with the server**.
 - **Passive open** (server process informs transport layer of the server that it is ready)
 - **Active open** (client process issues request to client transport layer)
 - Now client transport layer starts **three-way-handshaking**

Connection Creation

- ACK and SYN flags are used



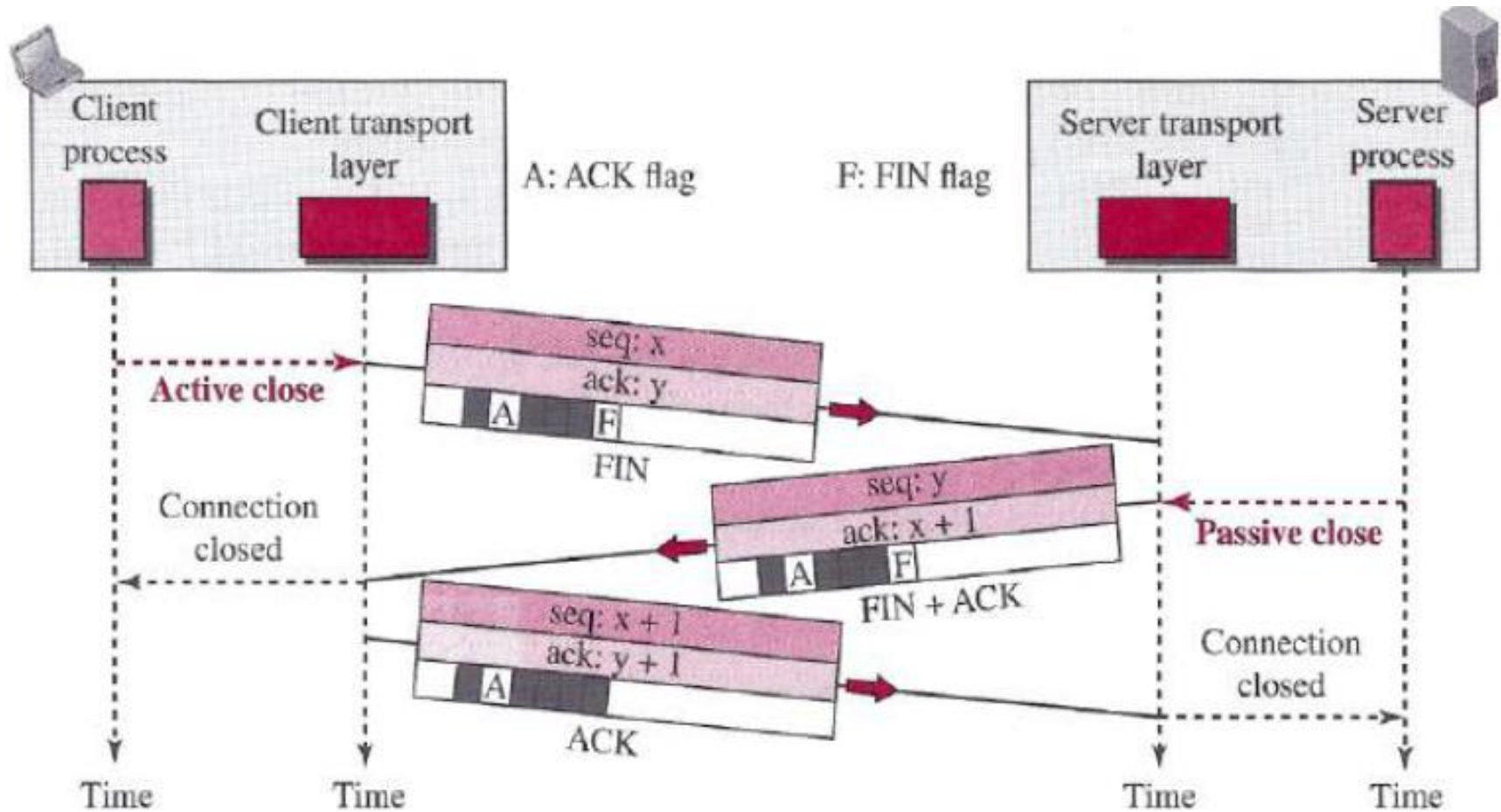
Data Transfer



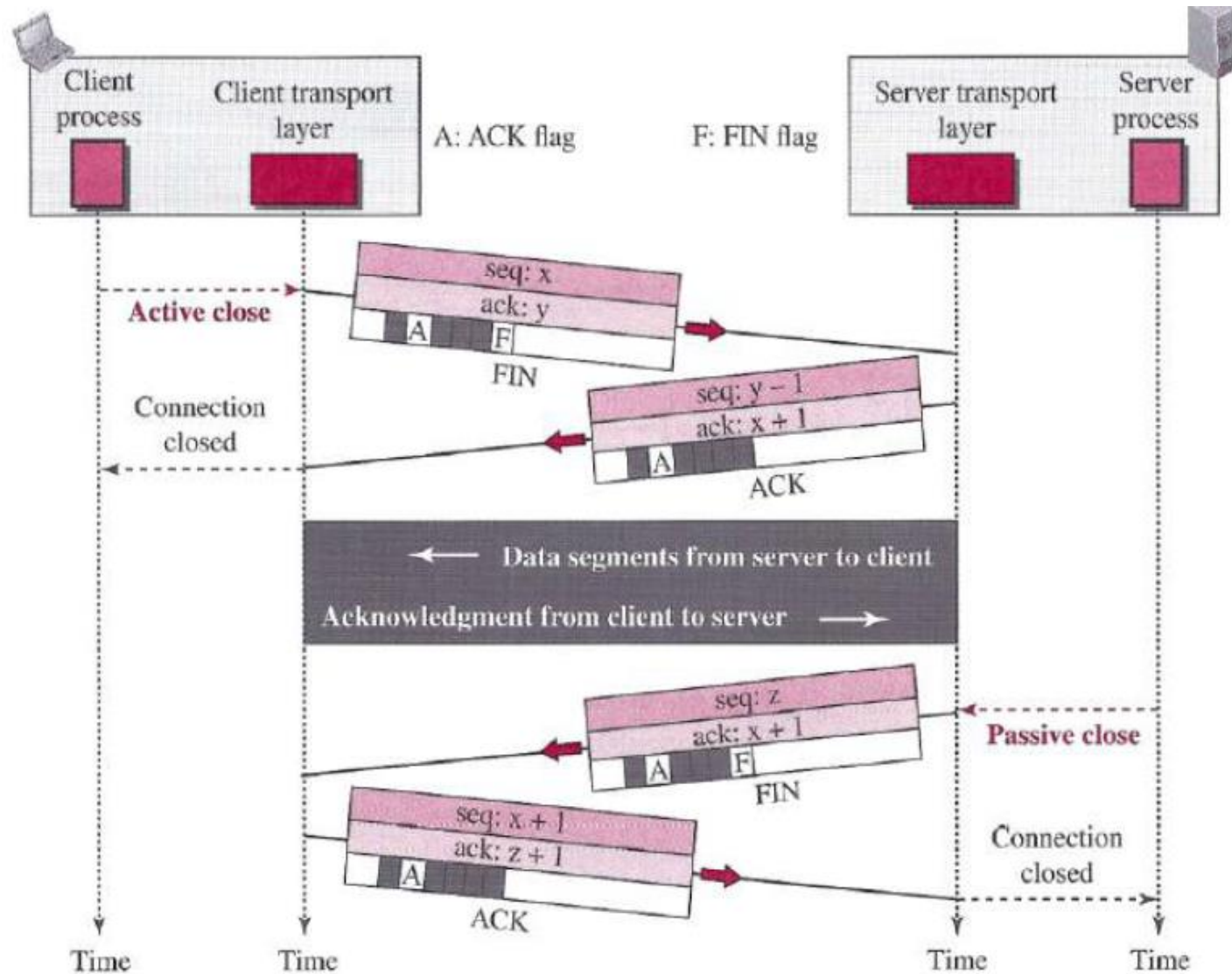
ACK and/or PSH flags are used

Connection Termination

- ACK and FIN flags are used



Half-close Connection



Example:
Sorting at server

Full Scenario

Create Connection

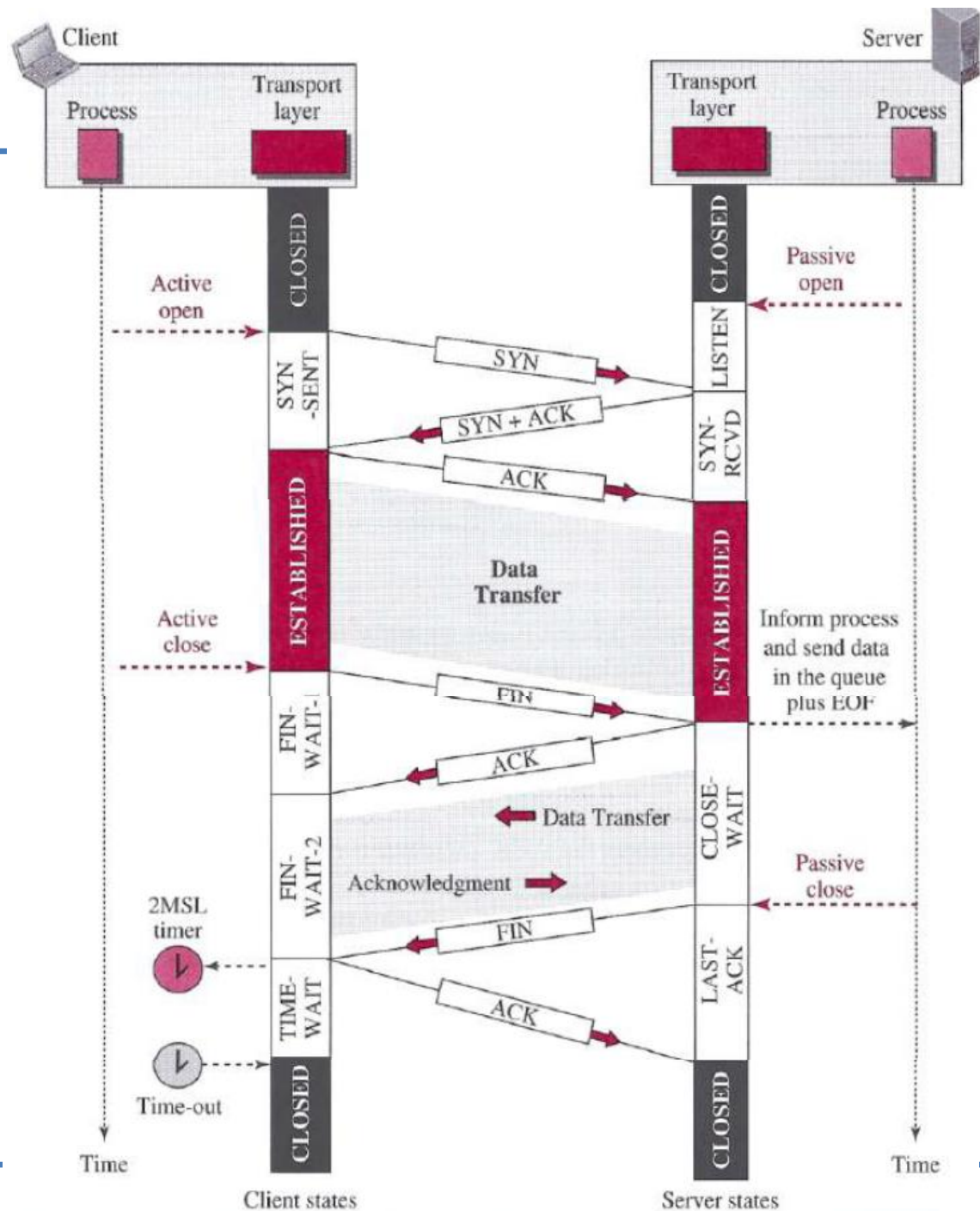
Data Transfer
in both direction

Half-close

Receive Response

Close other half

Closed status



PSH, RST, URG flags

- PUSH (**PSH**) flag
 - means **sending TCP must not wait for** the window to be **filled**, and then send the segment
 - informs the **receiving TCP to deliver** the received segment **immediately** to application program
- RESET (**RST**) flag
 - means it is telling the sender “**I don’t have socket for that segment. Please don’t resend the segment**”
 - It is required when a host receives TCP SYN segment with a destination port (say 80) but the destination is not accepting any connection on that port (may be Web server is not running at port 80)
- URGENT (**URG**) flag
 - when this bit is set, the **Urgent Pointer** is also set (in the TCP header Options field: 16 bit).
 - URG pointer tell **how many bytes of the data is urgent** in the segment that has arrived.
 - Example:
 - if the data size is 100 bytes and only first 50 bytes is urgent, the **urgent pointer** will have a value of 50

RTT Estimation & Timeout in TCP

- TCP uses a **timeout/retransmit mechanism** to **recover from lost segments**.
- The **timeout** should be larger than the connection's **round-trip time (RTT)**
- **Q:** How should the RTT be estimated in the first place?
- **Q:** Should a timer be associated with each and every unACKed segment?
- The base RTT (*SampleRTT*) for a segment is
 - the amount of time between the timestamps when the segment is sent and when an ACK for the segment is received.
- But, the *SampleRTT values will fluctuate* from segment to segment due to
 - congestion in the routers,
 - varying load on the end systems.
- **Solution:**
 - TCP maintains an **average of the SampleRTT values** (called *EstimatedRTT*)
 - Exponentially weighted moving average (EWMA)

$$\text{EstimatedRTT} = (1 - \alpha) \cdot \text{EstimatedRTT} + \alpha \cdot \text{SampleRTT}$$

The recommended value of α is $= 1/8$

Cont...



- It is also valuable to have a measure of the **variability of the RTT**.

$\text{DevRTT} = (1 - \beta) \cdot \text{DevRTT} + \beta \cdot | \text{SampleRTT} - \text{EstimatedRTT} |$ The recommended value of β is $1/4$.

- So, the DevRTT will be
 - **Small** for little fluctuation
 - **Large** for lot of fluctuation
- It is desirable to set, **Timeout** = *EstimatedRTT* + some margin.
- The margin should be
 - **large** when there is a lot of fluctuation in the *SampleRTT* values;
 - **small** when there is little fluctuation in the *SampleRTT* values

So, **Timeout_{Interval} = EstimatedRTT + 4 . DevRTT**

- **Question:** How long the receiver waits before sending a stand-alone ACK to acknowledge data?
 - **Delayed ACK** was invented to reduce the number of ACKs required to acknowledge the segments
 - A host may delay sending an ACK response by up to **500 ms**.
 - However, a stand-alone ACK is sent **if 2 packets** of data **arrive** before the **delayed ACK timer** expires.

TCP Applications



- Major Internet applications rely on TCP
 - World Wide Web (HTTP)
 - E-mail (SMTP, IMAP, POP)
 - File Transfer Protocol (FTP)
 - Secure Shell (SSH)
 - Telnet

Thanks!

Content of this PPT are taken from:

- 1) **Computer Networks: A Top Down Approach**, by J.F. Kurose and K.W. Ross, 6th Eds, 2013, Pearson Education.
- 2) **Data Communications and Networking**, by B. A. Forouzan , 5th Eds, 2012, McGraw-Hill.
- 3) **Chapter 3 : Transport Layer**, PowerPoint slides of “Computer Networking: A Top Down Approach”, 6th Eds, J.F. Kurose, K.W. Ross