CS 725/825 & IT 725
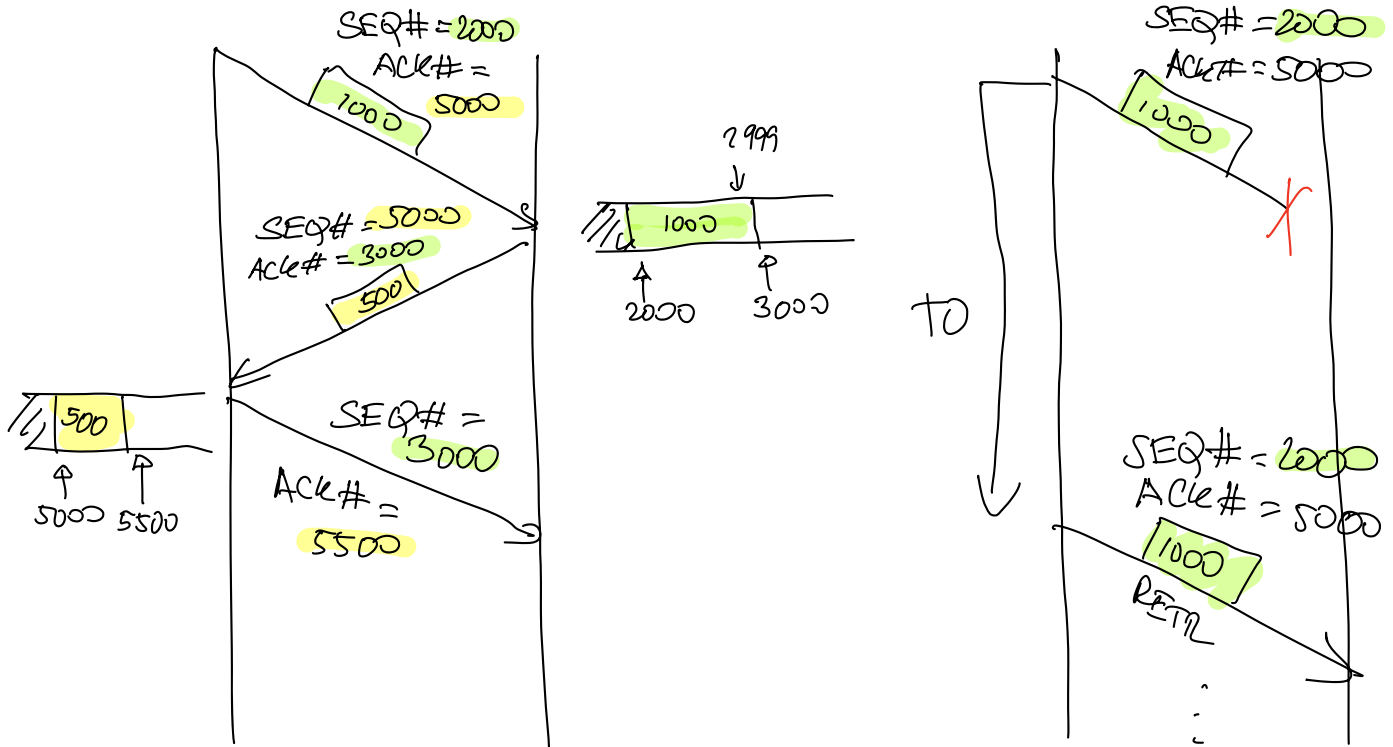# Lecture 15
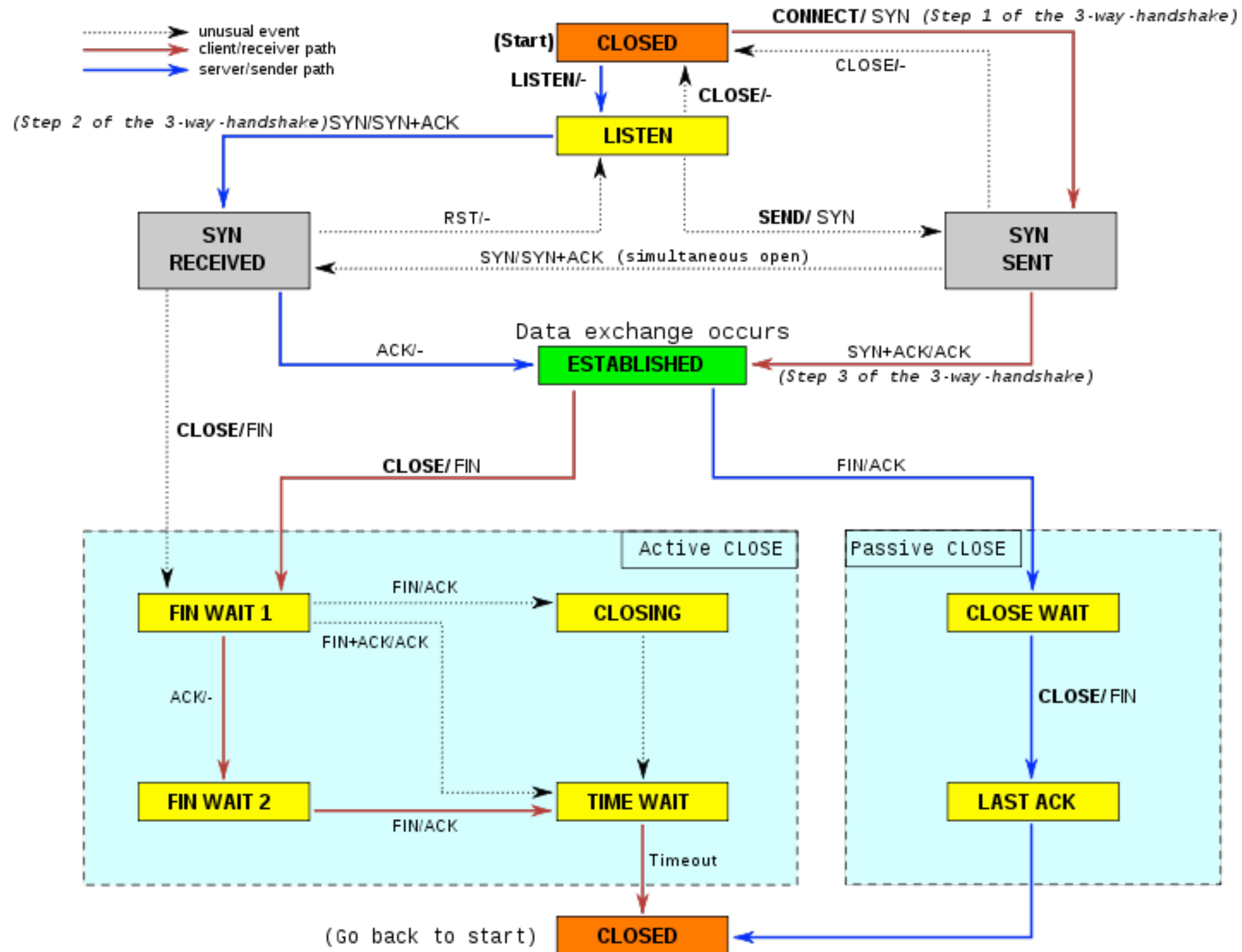# Transport Layer

October 21, 2024
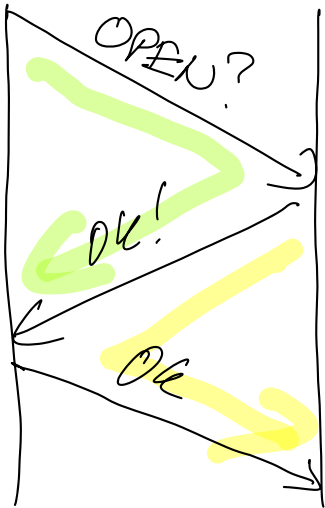
TCP SEQ & ACK #'S

SEQ# = 2000
ACK# = 5000

1000

SEQ# = 5000
ACK# = 3000

500

500

↑   ↑
5000   5500

SEQ# = 3000
ACK# = 5500

? 999
↓
1000

↑ |
2000   3000

TO

SEQ# = 2000
ACK# = 5000

1000

X

SEQ# = 2000
ACK# = 5000

1000

RETR

⋮

TCP State Diagram

CON. OPEN

RELIABILITY

OPEN?

OK!

OK

13-WAY HANDSHAKE

TO

OPEN? X

OPEN?

OK!

NEGATIVE RESP.

OPEN?

NO!

TCP CONNECTION OPEN

SYN = 1
SEQ # = X
ACK = 0
ACK# = UNSPEC.

SYN

SYN = 1
SEQ#   ACK = 1
= Y

SYN ACK

ACK# = X+1

SYN = 0
SEQ# =
ACK = 1   ACK   X+1
ACK# =
Y + 1

SYN =
0

ACK = 1
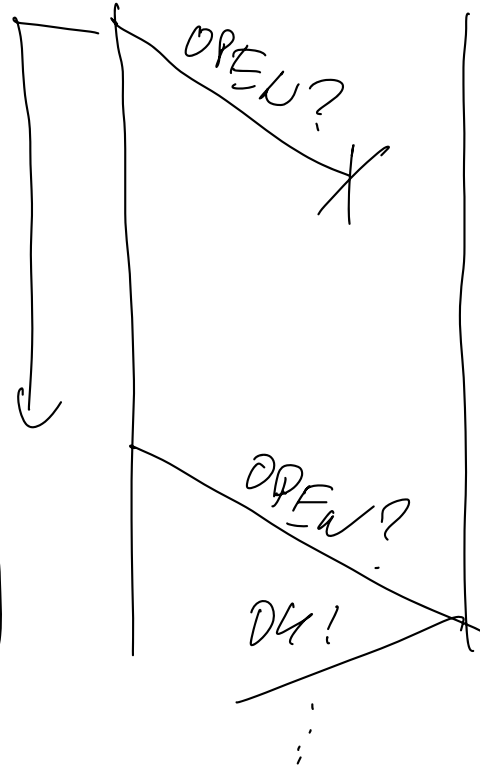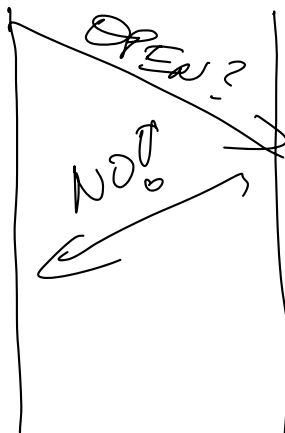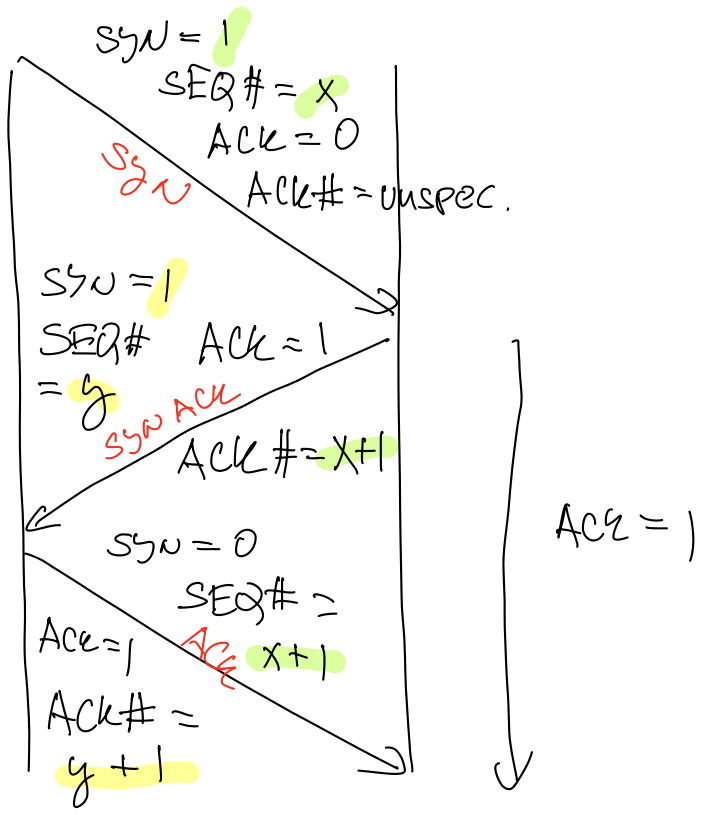
FLAGS

SYN = ssuc. SEQ#
ACK = ACK# CONT.
            VALID VALUE
RST = reset SEG#'s

SYN

RST = 1

COW. REJECTED

CONNECTION CLOSE

END?

END?

OK

SYM. RELEASE

END?

OK

DATA

ACK

END?

OK
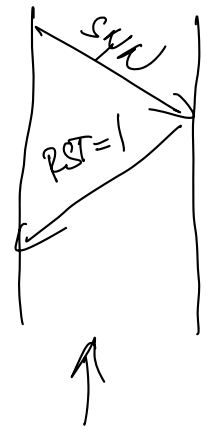
ASYM. RELEASE

CONNECTION CLOSE IN TCP

W

SEQ# = z
ACK # = w
FIN = 1

z

ACK# = z+1
FIN = 1   SEQ# = w

SEQ# = z+1
ACK# = w+1

FIN = 0

FLAGS

FIN — finish

REGULAR ACK

ACK# = z

FIN = 1
SEQ# = z

ACK# = z+1

MOTIVATION FOR ADDING
ONE TO SEQ/ACK#S FOR FIN
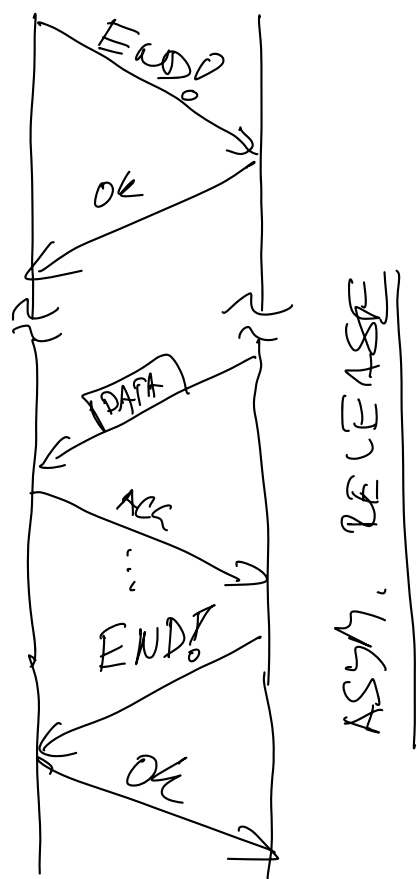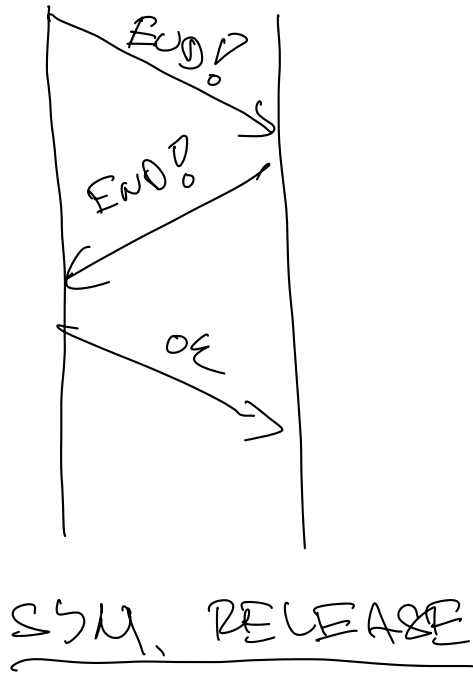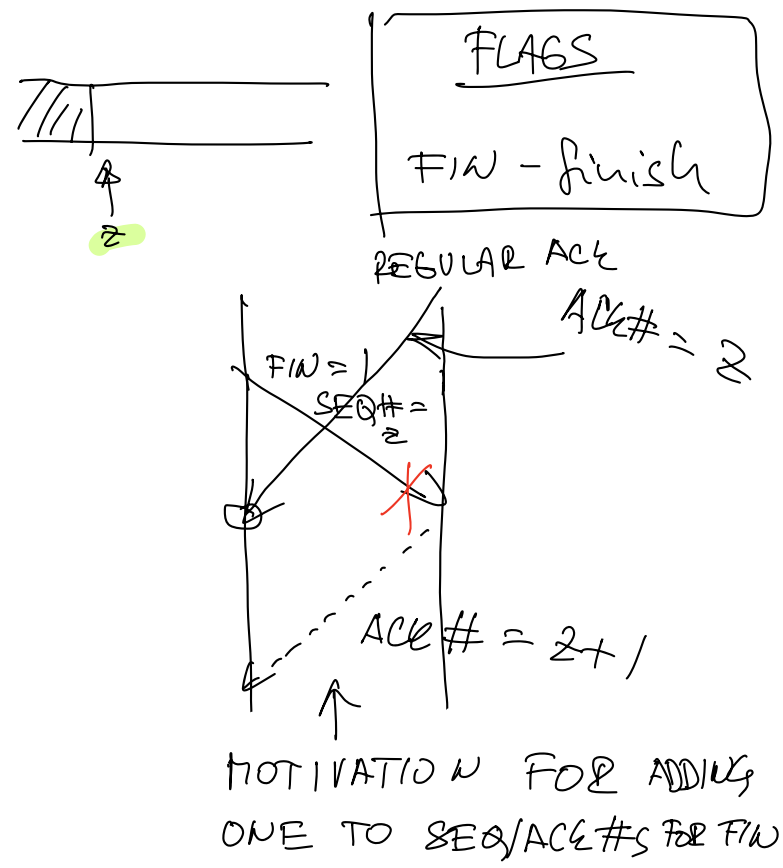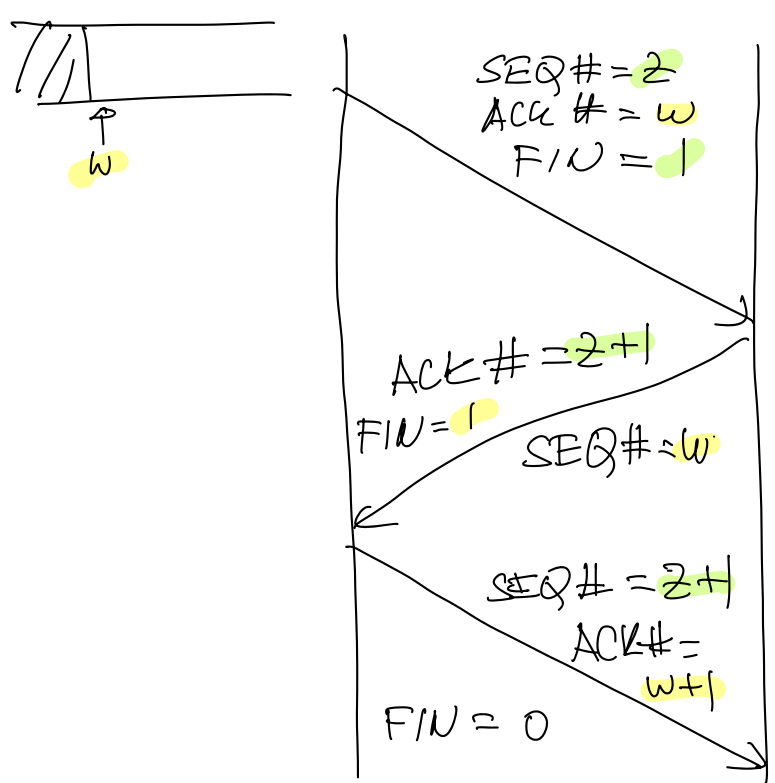
TCP Congestion Control

▸ Flow (receiver congestion) control

 – **Window Size field** - explicitly reported by the receiver

 – TCP Window Scale Option

▸ Network congestion control

 – **Retransmission timeout** - based on observed RTT

 – **Transmission window** - based on detected packet loss

Implicit Congestion Notification

▶ Round Trip Time (RTT)

   – time between data packet transmission and reception of it acknowledgement

   – increase in RTT could be interpreted as due to an increase in queue lengths in nodes (congestion)

   – … or it could be due to a route change…

▶ Packet Loss

   – packet loss due to queue overflow (congestion)

   – … or it could be packet loss due to random packet errors

Retransmission Timeout

Where:

R - first RTT measurement
R' - subsequent RTT measurement
RTTVAR - RTT variance
SRTT - smoothed RTT estimate
RTO - retransmission timeout
G - clock granularity

Recommended values:

alpha=1/8, beta=1/4, K=4

Initialization:

RTO ← 1 sec

After the first measurement:

SRTT ← R

RTTVAR ← R/2

RTO ← SRTT + max (G, K * RTTVAR)

After subsequent measurements:

RTTVAR ← (1 - beta) * RTTVAR + beta * |SRTT - R'|

SRTT ← (1 - alpha) * SRTT + alpha * R'

RTO ← SRTT + max (G, K * RTTVAR)