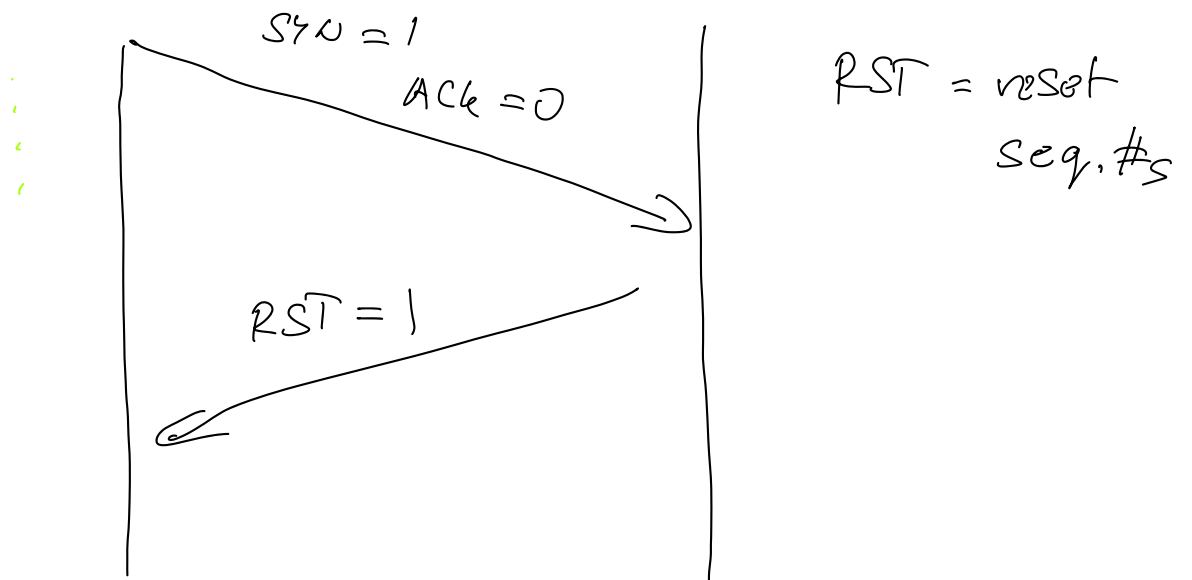
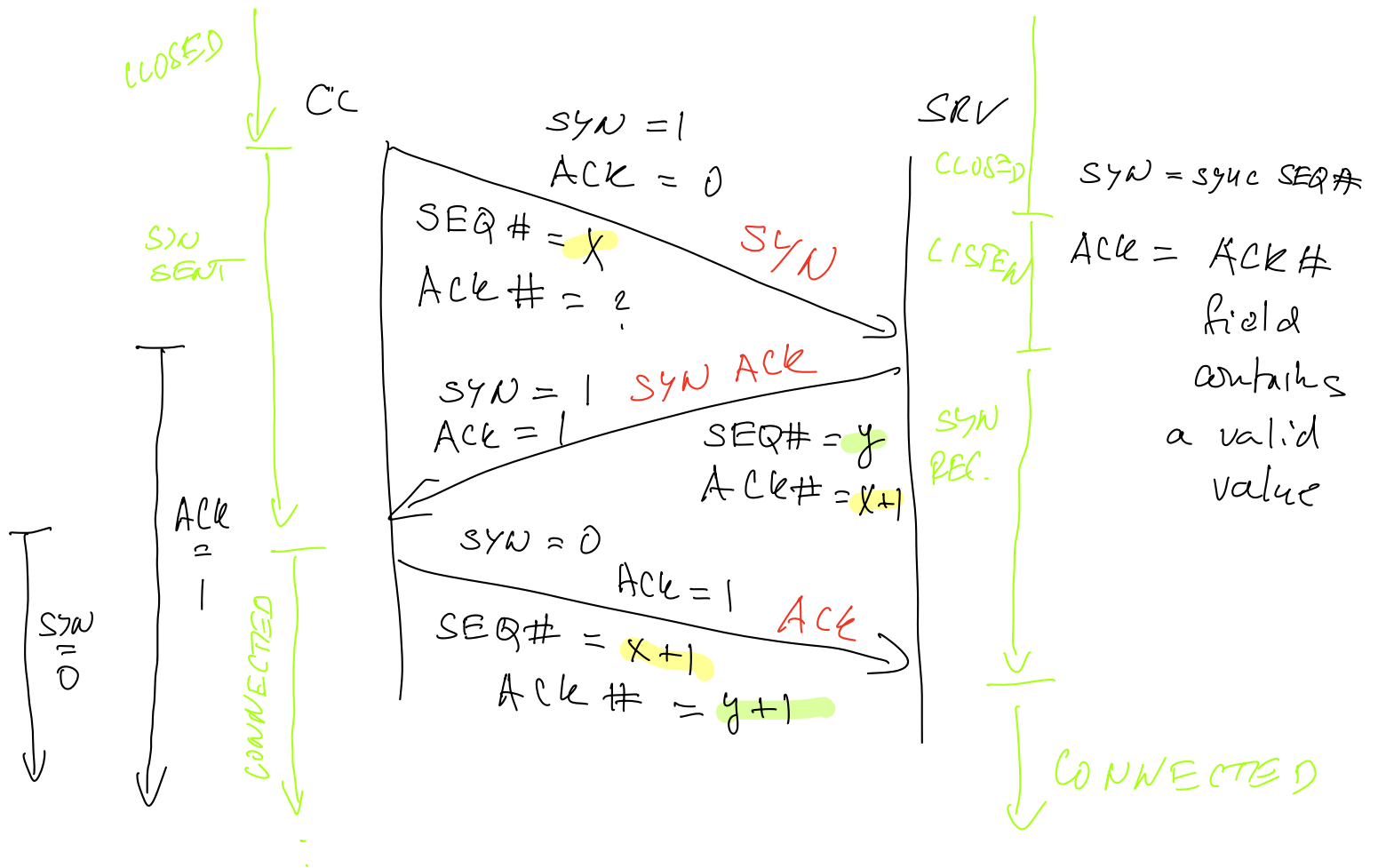


CS 725/825 & IT 725

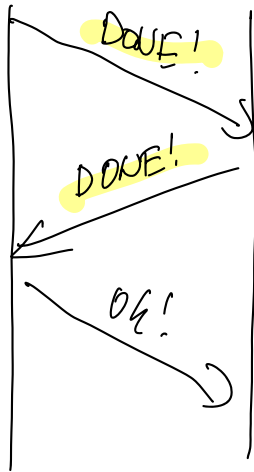
Lecture 16

Transport Layer

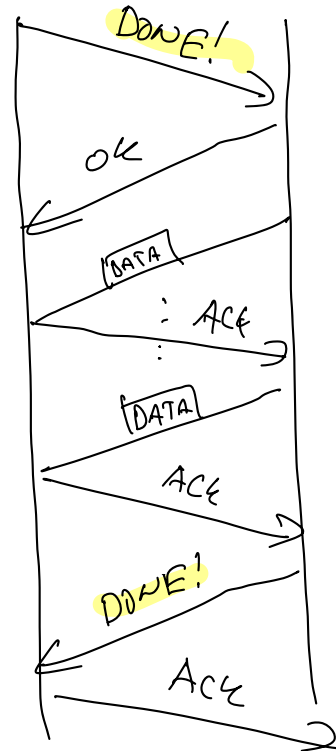
October 27, 2025



CONNECTION CLOSE

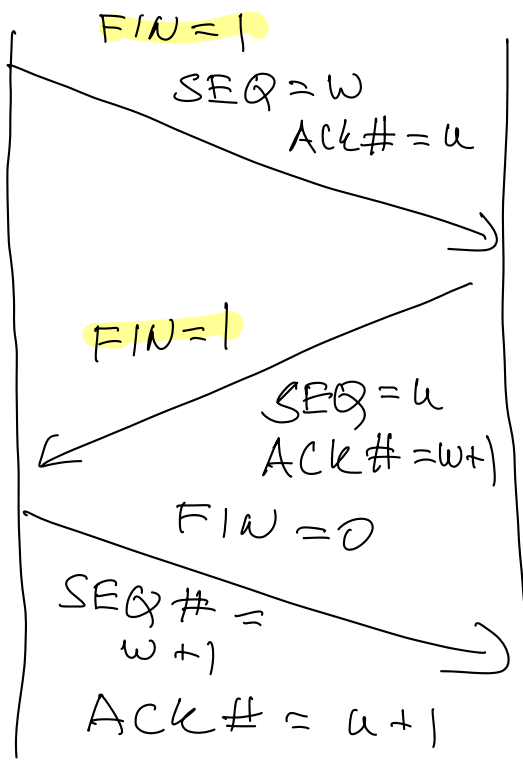


SYM, RELEASE



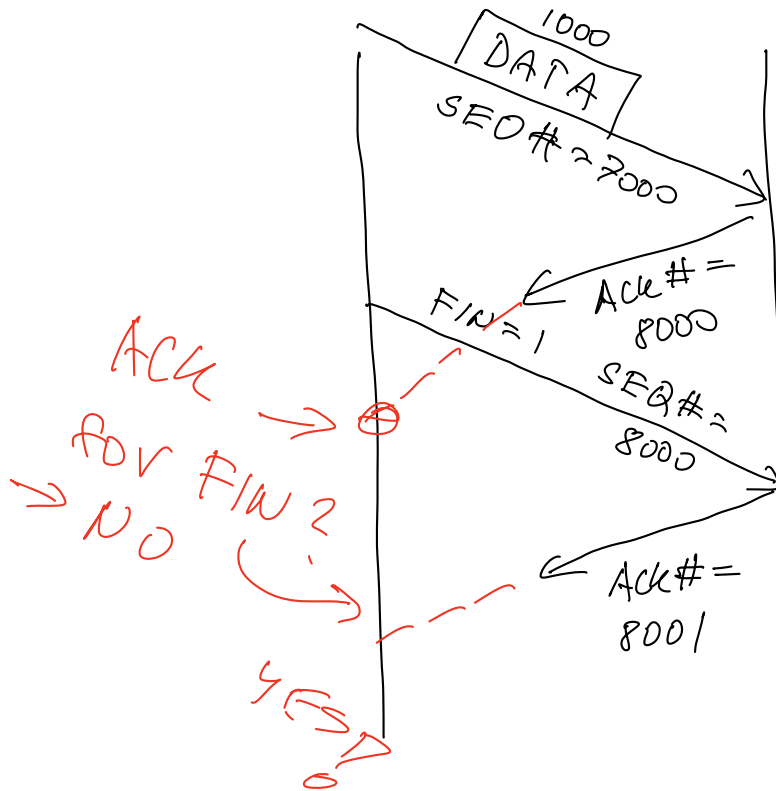
ASSYN. RELEASE

CON. CLOSE IN TCP

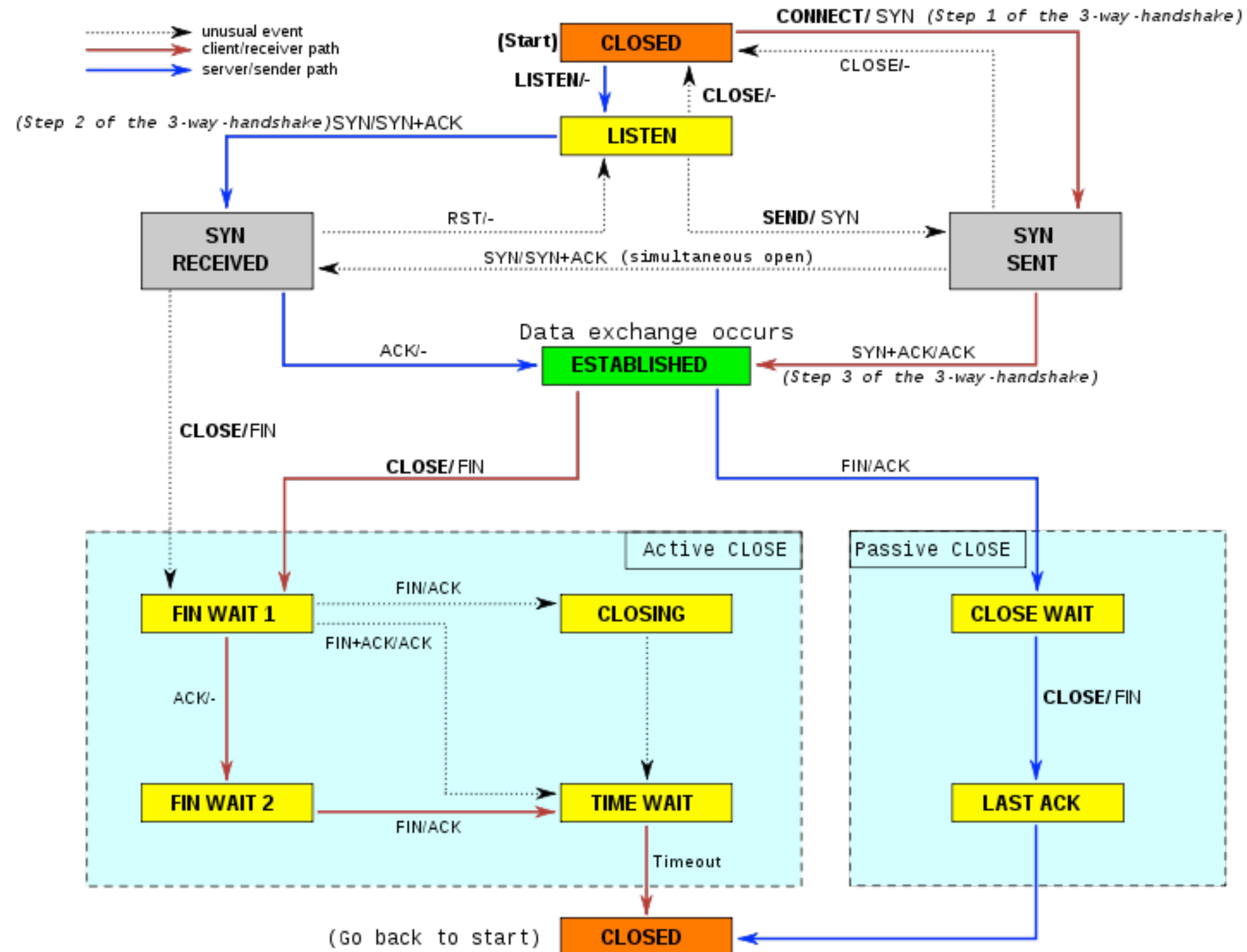


FIN = Finish

MOTIVATION FOR COUNTING FIN BIT IN SEQ# CALCULATION



TCP State Diagram



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 its 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

Initialization:

RFC 6298

$RTO \leftarrow 1 \text{ sec}$

After the first measurement:

$SRTT \leftarrow R$

$RTTVAR \leftarrow R/2$

$RTO \leftarrow SRTT + \max(G, K * RTTVAR)$

After subsequent measurements:

$RTTVAR \leftarrow (1 - \text{beta}) * RTTVAR + \text{beta} * |SRTT - R'|$

$SRTT \leftarrow (1 - \text{alpha}) * SRTT + \text{alpha} * R'$

$RTO \leftarrow SRTT + \max(G, K * RTTVAR)$

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

Exponential Back-off

RTO after a timeout:

Recommended value: $q = 2$

$$\text{RTO} \leftarrow q * \text{RTO}$$

This a **congestion control mechanism** since retransmissions are delayed after packet loss detected. The delay is increasing **exponentially** with more packet losses.

Transmission Window

- ▶ Network provides no explicit indication of congestion
- ▶ Source observes RTT and packet loss and adjusts transmission rate according to its estimate of the congestion state of the network
- ▶ Transmission window size is proportional to the maximum transmission rate
- ▶ Additive Increase Multiplicative Decrease (AIMD)
 - better safe than sorry