TCP State Diagram

TCP State Diagram
CON. CLOSE

CLOSE!

CLOSE!

OK

CLOSE!

OK

DATA

CLOSE!

ASYM. RELEASE

SYM. RELEASE

FIN - Finish

FIN = 1

SEQ# = w

ACK# = w+1

SEQ# = w+1

ACK# = 2

SAU = 0

FIN = 0

ACK# = 2+1

FIN = 1

SEQ# = 2
ASYMMETRIC
TCP
RELEASE

FIN = 1
ACK

FIN = 1
ACK

FIN = 1
ACK

FIN = 1
ACK

ACK OF
FIN = 1
ACK

FIN ?
NO

W + 1

YES
TCP Congestion Control

- **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
Retransmission Timeout

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)

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

RFC 6298
Exponential Back-off

RTO after a timeout:

\[ \text{RTO} \leftarrow q \times \text{RTO} \]

Recommended value: \( q = 2 \)

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

- 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
Network Congestion Control

- **Method:**
  \[
  \text{TransWind} = \min(\text{RecvWind}, \text{CongWind})
  \]

- **TransWind** - used in transmission
- **RecvWind** - from Window Size field
- **CongWind** - transmitter's estimate of how many unacknowledged packets can be pushed onto the network without causing congestion