TCP 3: Oct 13

- Fast Recovery
- TCP state diagram
- Saw tooth, rough tput
- Single timer
- RTO estimation
- Packets to Bytes
- TCP Flow control
- TCP fairness
- TCP over wireless

**TCP State Diagram**

- SST = 10
- CW = 4
- Fast Recovery mode ON
  - SST = 2
  - CW = SST + 3 = 5
- DUPACK++
  - CW = CW + 1 = 6
- Timeout for P5
  - CW = 1
  - SST = 3
- CW = 10

Action:
- Event: alarm rings
  - Wake up
- State: check email
  - Class cancelled
  - Go back to sleep

**TCP Flow Control**

- CW = 1
- SST = 3
- CW = 10
TCP Protocol: State Diagram

Socket connection, TCP handshake:
- CW = 1
- SST = 64
- dupACK = 0

Slow Start:
- new Ack
  - CW = CW+1
  - Send pkts based on CW
  - dupACK = 0

DupACK:
- dupACK++
- CW ≥ SST

Fast Recovery:
- new Ack
  - CW = CW + \( \frac{1}{L_{cw}} \)
  - CW = 1
  - dupACK = 0

DupACK avoidance:
- CW = SST + 3
- Retx "hole" packet
- CW = CW + 1
- Retx new pkt as allowed by CW.

Timeout:
- SST = CW/2
- CW = 1
- dupACK = 0
- Retx the pkt that timed out

DupACK = 3:
- SST = CW/2
- CW = 1
- dupACK = 0
- Retx timed out pkt

Retx packet timed out:
- SST = CW/2
- CW = 1
- dupACK = 0
- Retx timeout pkt

Retx new pkt as allowed by CW.
- CW = SST + 3
- Retx "hole" packet
- CW = CW + 1
- Retx new packet as allowed.
TCP CW exhibits a "saw tooth" behavior

\[ \text{Avg TCP throughput} = \frac{N}{\text{RTT}} + \frac{N/2}{\text{RTT}} \]

\[ = 0.75 \frac{N}{\text{RTT}} \]
TCP uses a single timer for timeouts:

Doesn’t set up 64 timeouts.

Instead, notes down timestamp of each packet and sets timer for only first packet in CW.

\[
\begin{align*}
T/0 & = 255 \\
9:00 & \rightarrow P_1 \\
T/0 & \rightarrow 10s \rightarrow P_2 \\
& \rightarrow 20s \rightarrow P_3 \leftarrow \text{A1}
\end{align*}
\]

At this time:
- Cancel old timer for pkt \( P_1 \)
- Start new timer for \( \Delta t \) where

\[
\Delta t = (P_2 \text{'s time} + \text{timeout} - \text{current time})
\]
How much should timeout duration be? RTO (Retransmit timeout).

\[ \text{RTO} = f(\text{historical RTT}) \]

1. RTO = current RTT -> Really bad idea
2. RTO = max \{ last K RTT \} -> very conservative about RTO
   - means TCP reacts slowly to real congestion
3. RTO = mean \{ last K RTT \} -> half of pkts would timeout -> bad idea
RTO = Weighted avg. of historical RTTs + Safety factor

\[ \text{Estimated RTT} \left( \hat{R} \right) \downarrow \]

\[ \text{Deviation of RTT} \left( \hat{\Delta} \right) \]