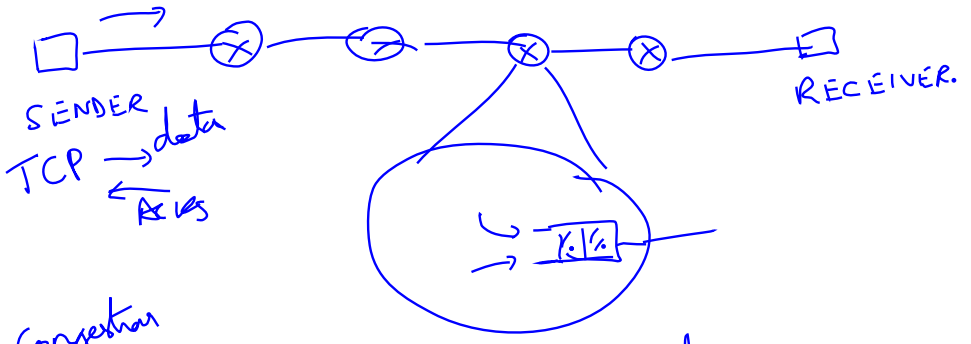
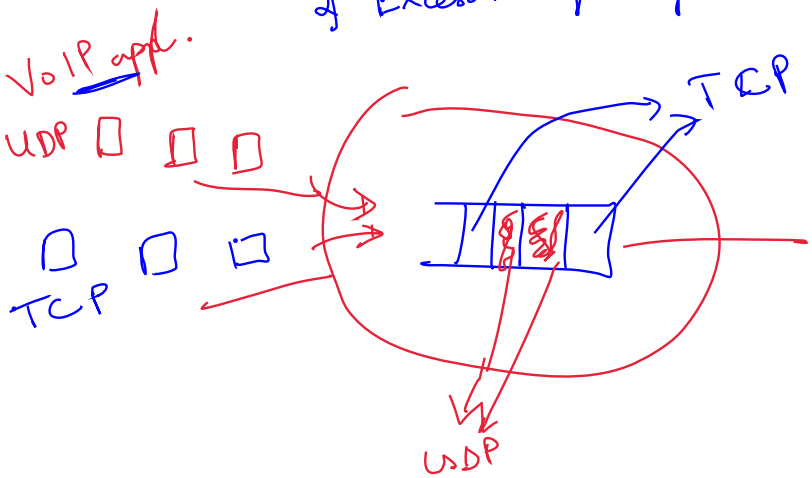
TCP Congestion Control



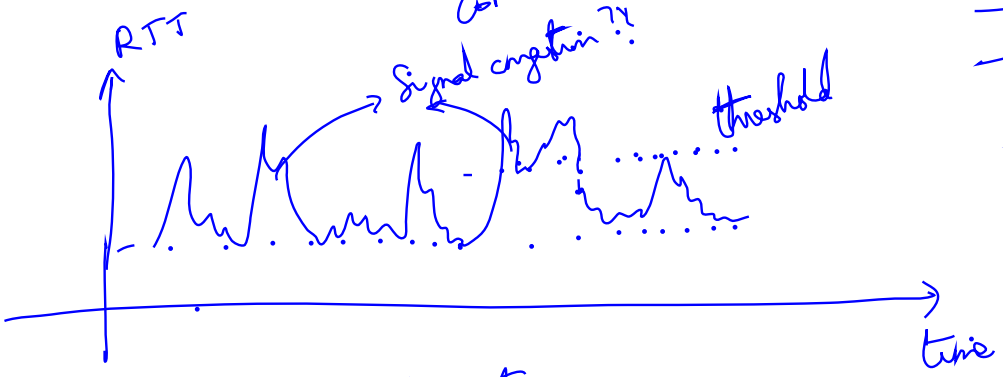
Congestion Problem: 1) Packets get dropped
2) Excessive queuing delays



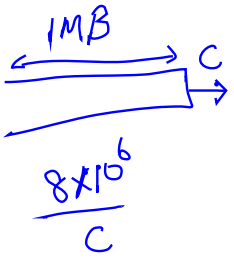
Window = min (Adv. Window , Cong. Window)

Adv. Window → Flow control

Cong. Window → Congestion control



Sending time of Data



Detect Packet loss

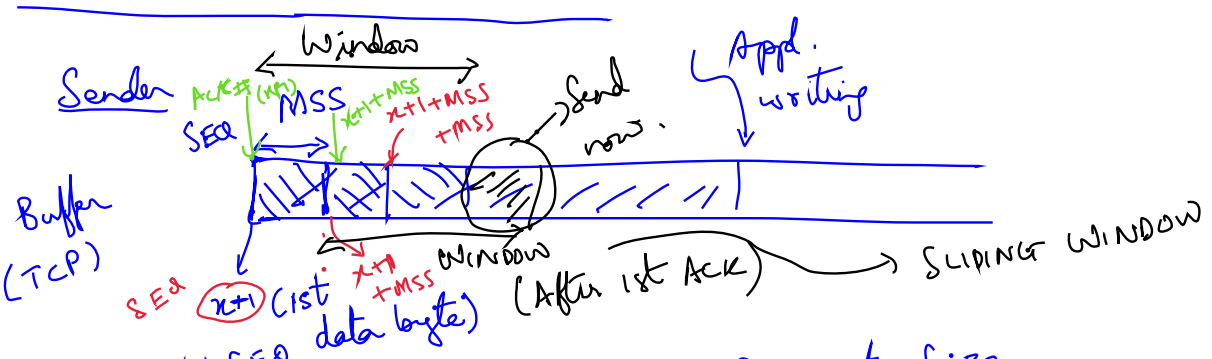
One idea: Timeout

Second idea: Use ACK feedback to infer losses

Pkt #: 1, 2, 3, 4, 5, 6 ...

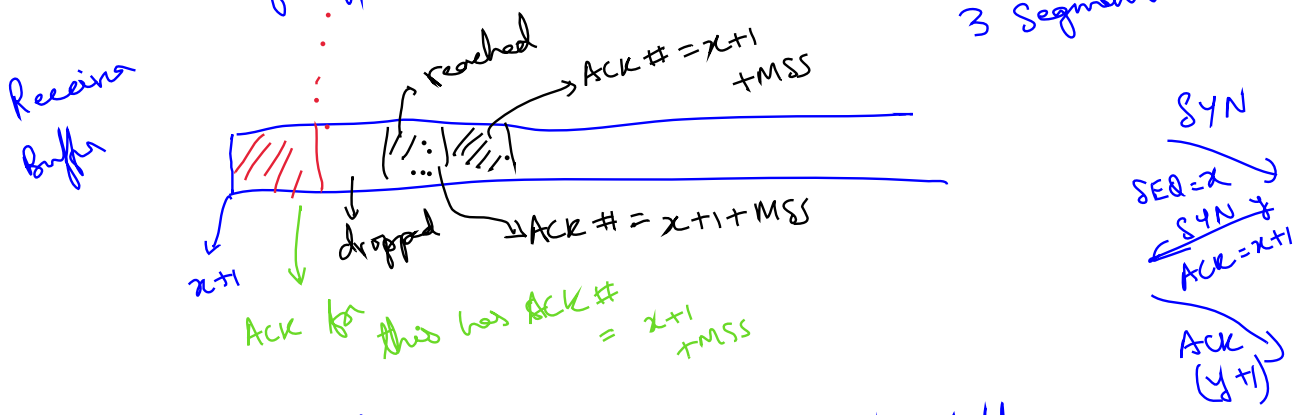
ACKs: ↓ ↓ ↑ ↓ ↓ ↓

dropped??



MSS = Max. Segment Size

If Initial Window = 3 MSS, we send out 3 Segments



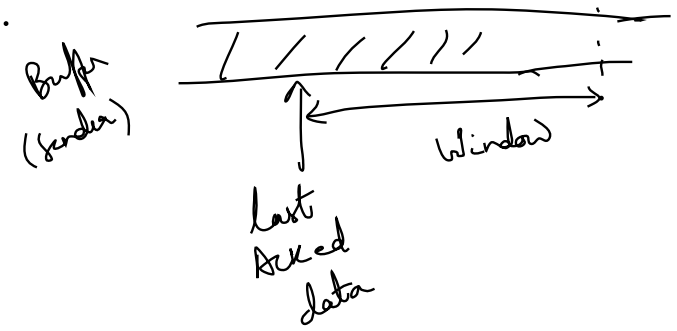
CUMULATIVE ACK

ACK #z (SENT) ⇒ Everything from start till byte (z-1) has been received.

DUPLICATE ACKS

↳ ACK # of some previous ACK sent out

↳ Each DUP ACK says one more segment received



PRICIPLES OF CONGESTION CONTROL

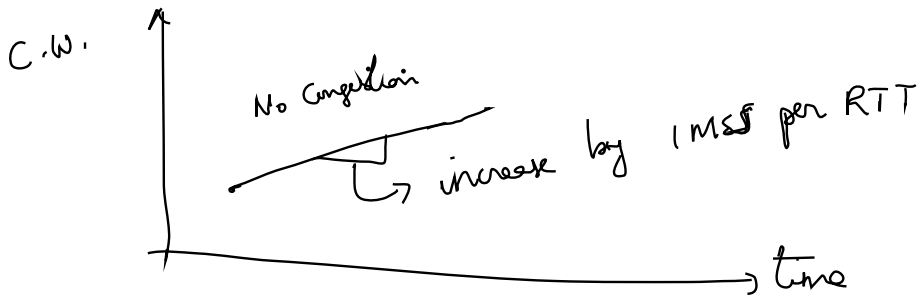
1. IF NO CONGESTION, INCREASE CW CONSERVATIVELY

$$\text{DataRate} \approx \frac{\text{Window}}{\text{RTT}}$$

[Window = min (Adv.Window, CW]
↙
Cong.Window

For now assume Window = CW

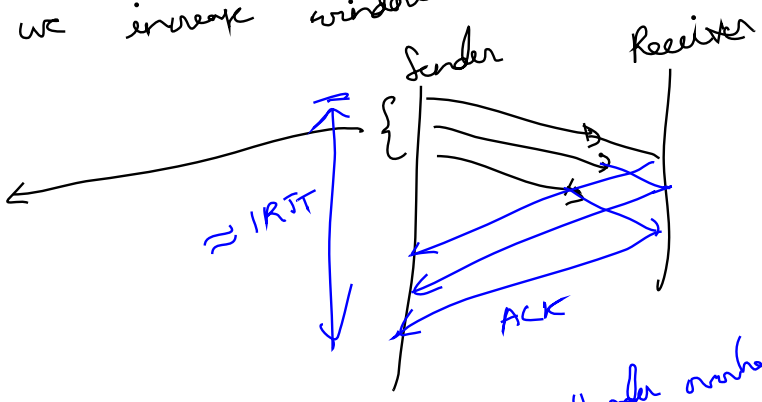
ADDITIVE INCREASE



TCP uses "self-clocking": Every time an ACK arrives, we increase window

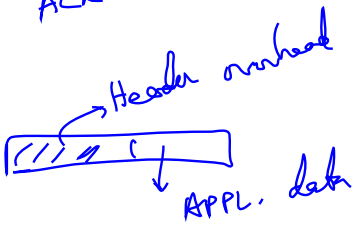
CW / MSS

$$\#\text{segments in Window} = \frac{CW}{MSS}$$



$$\#\text{ACKs (in Window)} = \frac{CW}{MSS}$$

$$\text{PER ACK Window increase} = \frac{MSS}{\#\text{ACKs}}$$



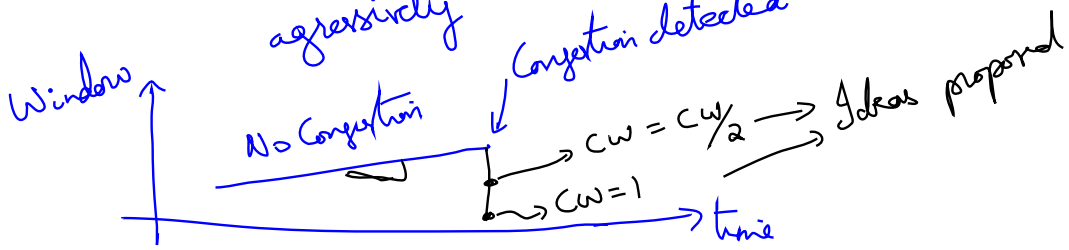
$$= \frac{MSS}{CW/MSS} = \frac{(MSS)^2}{CW}$$

Additive increase

On receiving an ACK (Assuming no congestion)

$$CW \mathrel{+}= \frac{(MSS)^2}{CW}$$

2) If congestion is detected, decrease window size aggressively

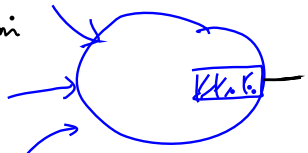


TCP Tahoe → CW = 1 on detecting congestion

TCP Reno → CW = CW/2

TCP Vegas → study later

TCP AFRICA → not study



Multiplicative decrease

AIMD: Add. Incr. Mult. Decrease

3) Initially set CW small, since we do not know the appropriate data rate

AI may be too slow

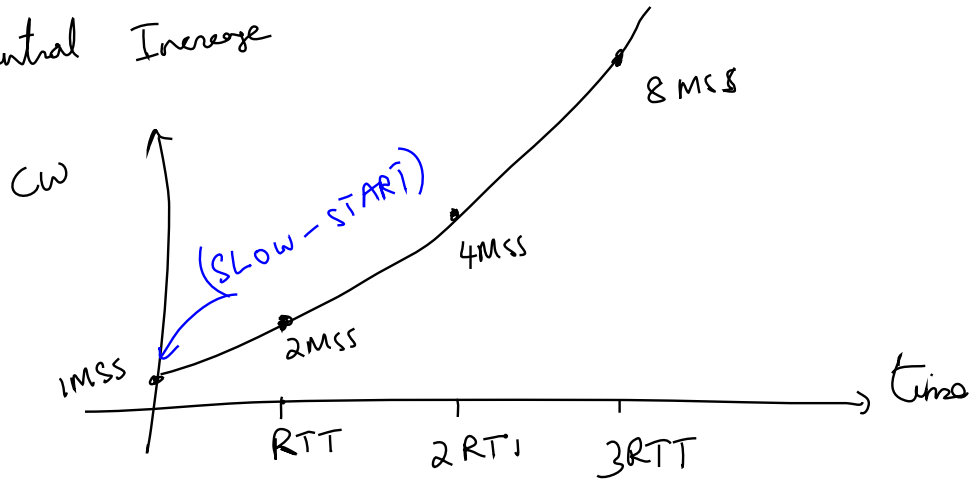
1GB file

Initial window = 1 MSS ≈ 10,000 bits

data rate ≈ $\frac{10^4}{1} = 10^4$ bits/sec

Be agressive to increase window (initially)

Exponential Increase

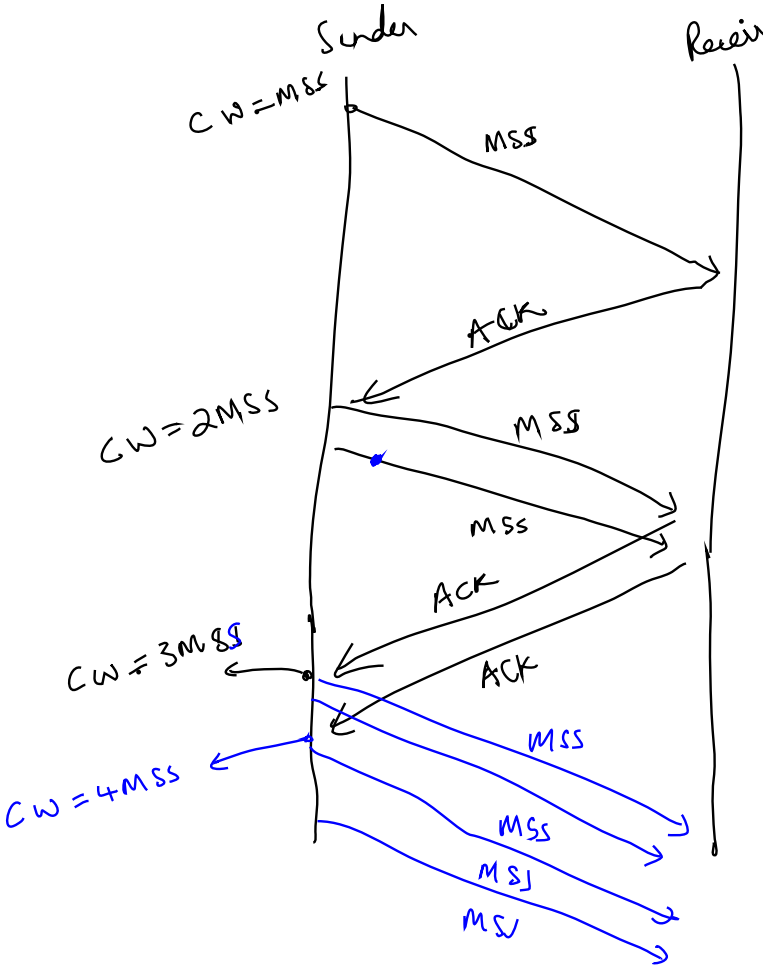


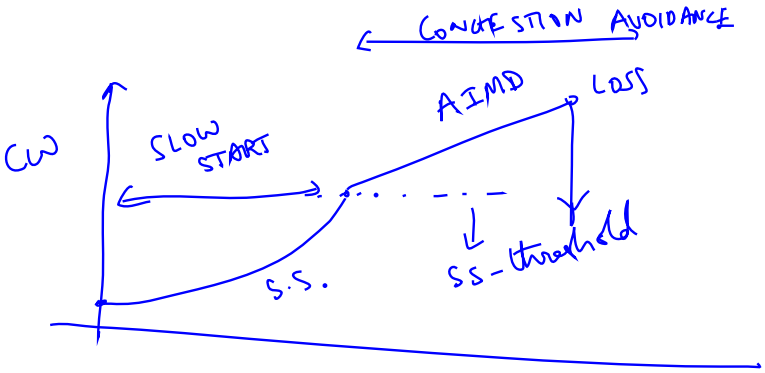
Implementation:

#Acks (in window) = $\frac{CW}{MSS}$

at sender

{ PER ACK CW += 1MSS (total increase for $\frac{CW}{MSS}$ Acks $\approx \frac{CW}{MSS} \cdot MSS \approx CW$)





Request For Comments

RFC

TCP CUBIC