Lecture 11: TCP congestion control

Mechanisms we've talked about so far

- checksums - corruption
- acknowledgments - packet losses
- timeout - handle packet losses
- sequence numbers - ordering guarantees

- pipelining - speedup technique
Flow Control

ACK: \{seqno, receiver window\}

On the sender side
\[
\min(\text{congestion window} - \text{outstanding packets}, \text{receiver window} - \text{outstanding packets})
\]
"Slow Start" - exponential increase

- every RTT - double the congestion window
- drop one packet - half the rate, go to congestion avoidance phase

Congestion avoidance phase - AIMD (additive increase, multiplicative decrease)
- every RTT - increase congestion window by one packet
- drop a packet - half the rate

![Graph showing congestion window over time]
32-bits of address + 16 port

MSL = maximum segment lifetime

Exponentially Weighted Moving Average (EWMA)

\[
\overline{rtt_{i+1}} = (1 - \alpha)\overline{rtt_i} + \alpha\overline{rtt_{i+1}}
\]

\[
\overline{dev_{i+1}} = (1 - \beta)\overline{dev_i} + \beta|\overline{rtt_{i+1}} - \overline{rtt_{i+1}}|
\]

TCP timeout = rtt + 4*dev