Congestion Avoidance and Control

Van Jacobson
Michael J. Karles

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Outline:

- INTRODUCTION: Conservation of packets principle in TCP

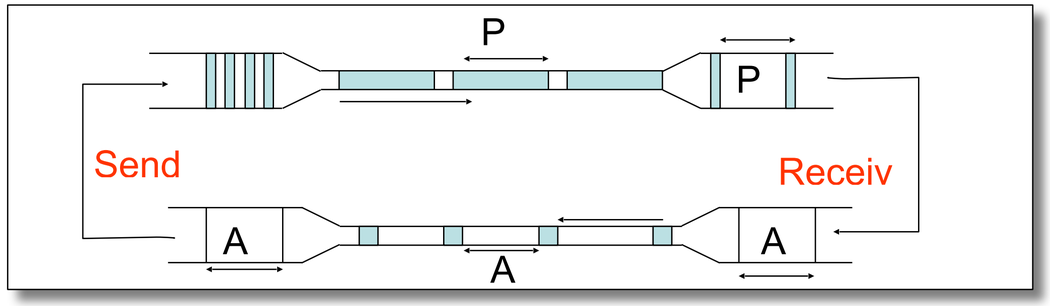
PROBLEM	SOLUTION
Connection doesn't get to equilibrium	Getting to equilibrium: Slow-start
Injecting a new packet before an old packet has exited	Conservation at equilibrium: Round-trip timing
Equilibrium can't be reached due to resource limits along the path	Adapting to the path: Congestion avoidance

Conservation of packets in TCP

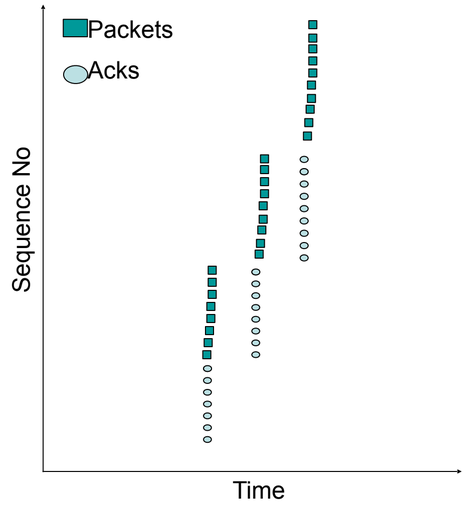
At equilibrium: inject packet into network only when one is removed

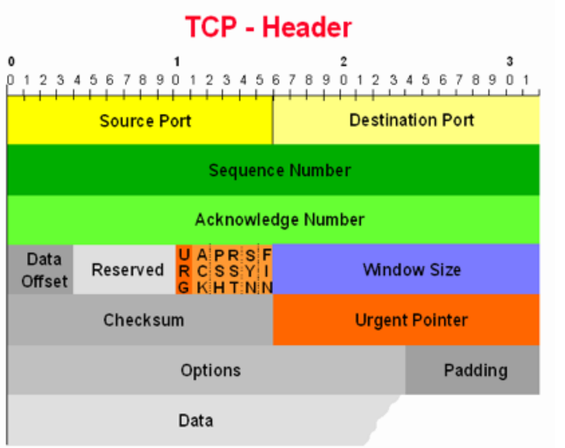
- Rate control by sliding window:
- self clocking, adjusted to bandwidth
- wide dynamic range
- transmission is smooth, once it is smooth

- Issues:
  - Needs to get to equilibrium, while:
  - avoiding sending burst of packets
  - avoiding retransmissions



window size = # of packets in flight

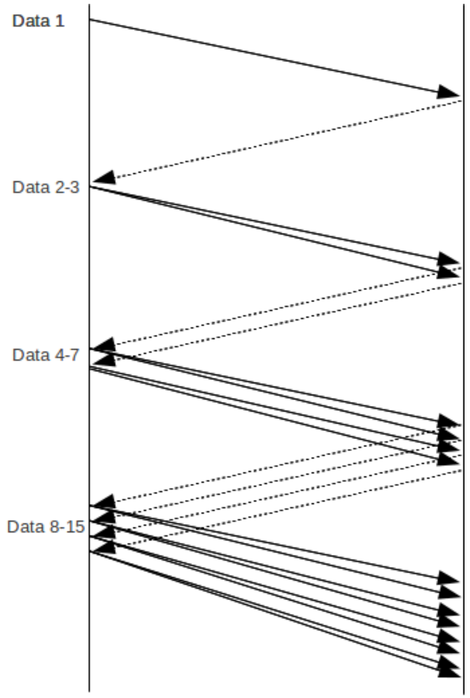




Problem 1: getting to equilibrium

Slow-Start:

- Add a congestion window cwnd
- when restarting, set cwnd=1
- send min(cwnd,window size) packets
- Increase cwnd by 1 for each ACK received



Slow Start with discrete packet flights

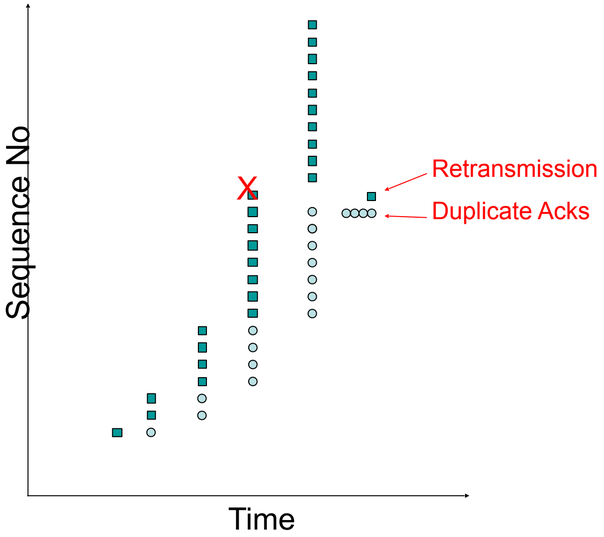


Figure 3: Startup behavior of TCP without Slow-start

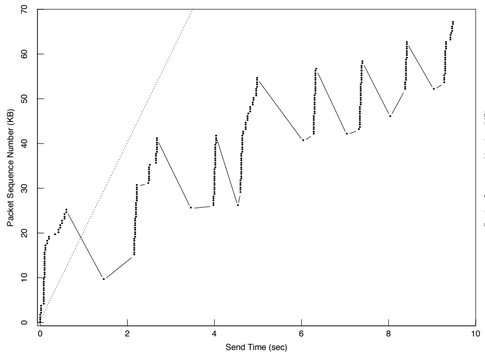
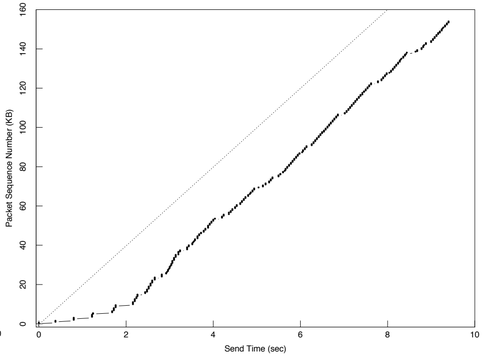


Figure 4: Startup behavior of TCP with Slow-start



Conservation at equilibrium

Problem: Injecting a new packet before an old packet has exited

Solution: estimate β, consider the variance of RTT

- Retransmission timeout (RTO):
  - wait βRTT before retransmitting
  - Needs RTT estimate $R_{n+1} \leftarrow \alpha R_n + (1-\alpha)M_n$
  - Not estimating variance $(\beta = 2)$

Result: poor RTT estimate

(become critical under heavy load)

Figure 5: Performance of an RFC793 retransmit timer

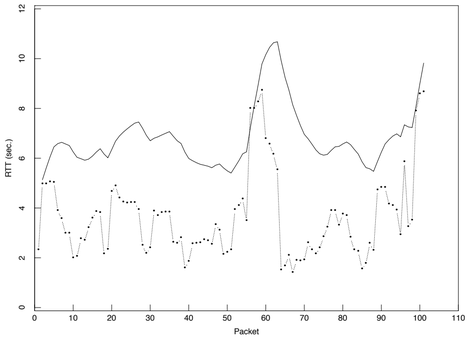
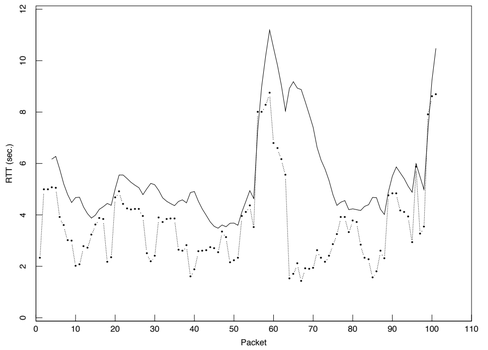


Figure 6: Performance of a Mean+Variance retransmit timer



Congestion avoidance

Main Problem: equilibrium cannot be reached

- Packet lost
  - usually due to insufficient buffer capacity in a congested network

Droped packet = congested network

- **Problem 1**: In a congested network queue length increases exponentially

Solution: multiplicative window size decrease on congestion

- **Problem 2:** The network does not tell us if the connection using less bandwidth than it can
  - Need to gradually increase bandwidth
  - Overestimating bandwidth is costly

Solution: additive widow size increase (by one packet per RTT)

1. On timeout set cwnd = cwnd/2
2. on each ACK set cwnd=cwnd+1/cwnd
3. send min(receiver_wnd,cwnd)