Introduction to Computer Networks
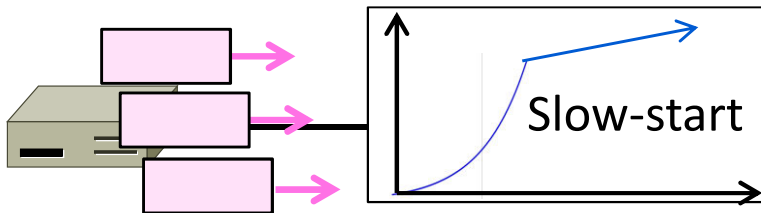
TCP Slow Start (§6.5.10)

David Wetherall (djw@uw.edu)

Professor of Computer Science & Engineering

UNIVERSITY *of* WASHINGTON

Topic

- How TCP implements AIMD, part 1
  - "Slow start" is a component of the AI portion of AIMD
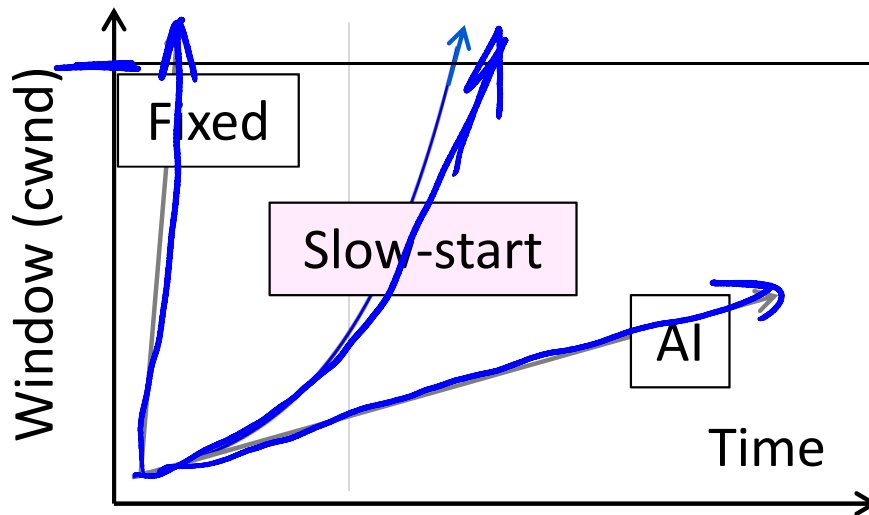

Slow-start

Recall

- We want TCP to follow an AIMD control law for a good allocation

- Sender uses a <u>congestion window</u> or <u>cwnd</u> to set its rate ($\approx$cwnd/RTT)

- Sender uses packet loss as the network congestion signal

- Need TCP to work across a very large range of rates and RTTs

TCP Startup Problem

- We want to quickly near the right rate, $cwnd_{IDEAL}$, but it varies greatly
  - Fixed sliding window doesn't adapt and is rough on the network (loss!)
  - AI with small bursts adapts cwnd gently to the network, but might take a long time to become efficient

Slow-Start Solution

- Start by doubling cwnd every RTT
  - Exponential growth (1, 2, 4, 8, 16, …)
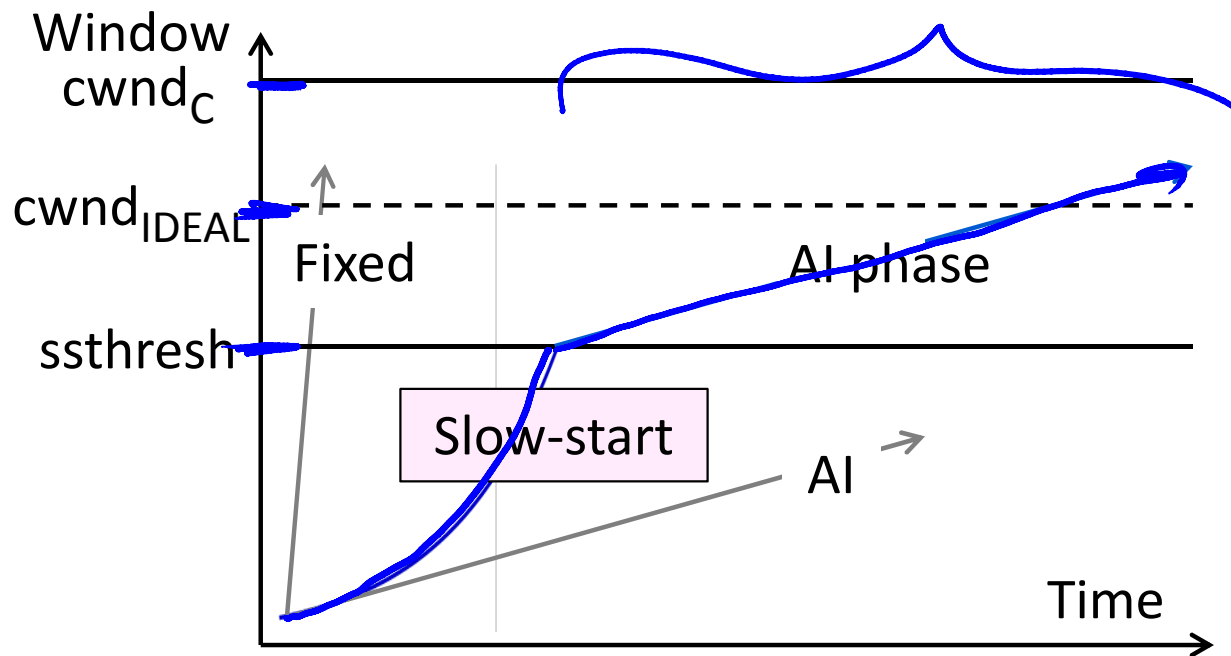 - Start slow, quickly reach large values

Slow-Start Solution (2)

- Eventually packet loss will occur when the network is congested
  - Loss timeout tells us cwnd is too large
  - Next time, switch to AI beforehand
    - Slowly adapt cwnd near right value

- In terms of cwnd:
  - Expect loss for $cwnd_C \approx 2BD+queue$
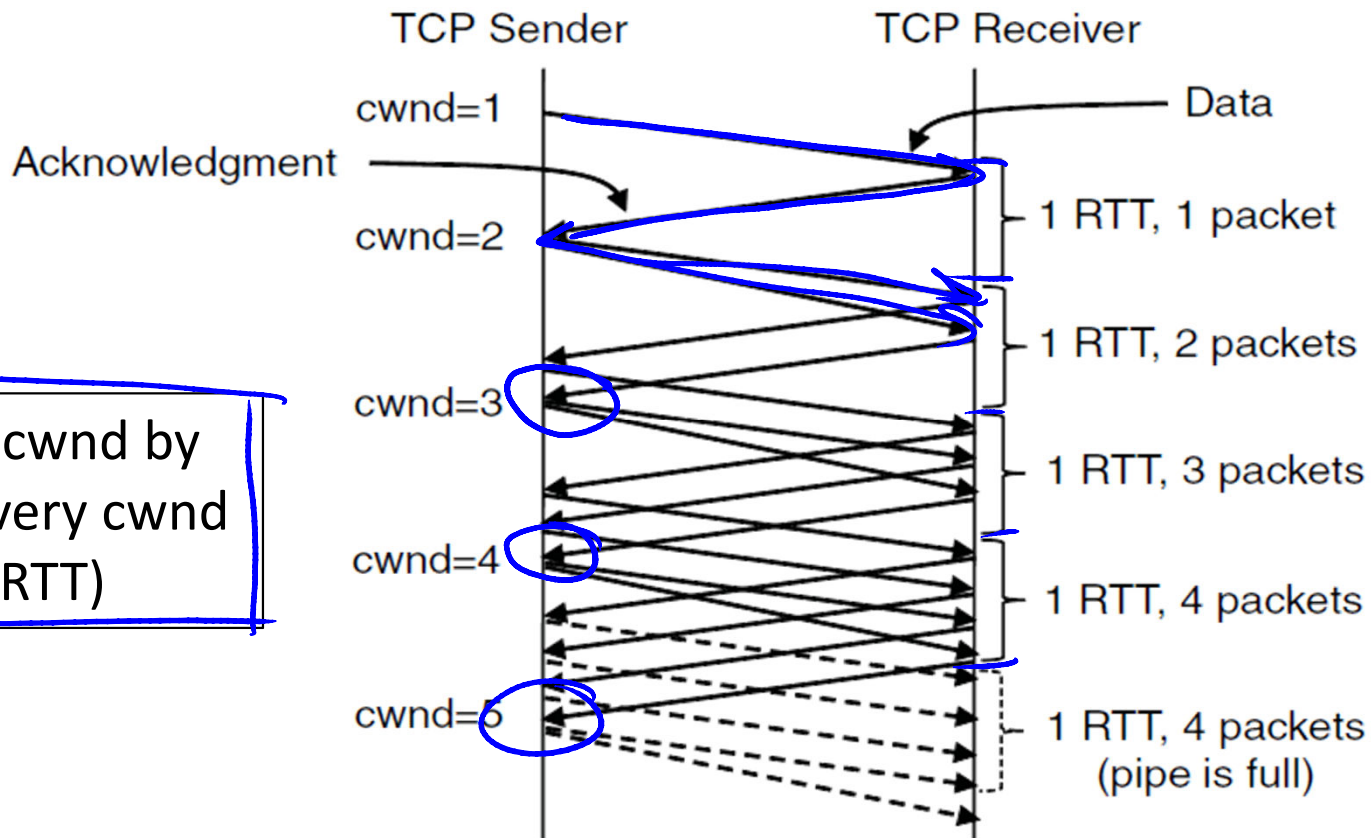 - Use ssthresh = $cwnd_C/2$ to switch to AI

Slow-Start Solution (3)

- Combined behavior, after first time
  - Most time spend near right value

Slow-Start (Doubling) Timeline

Increment cwnd by 1 packet for each ACK
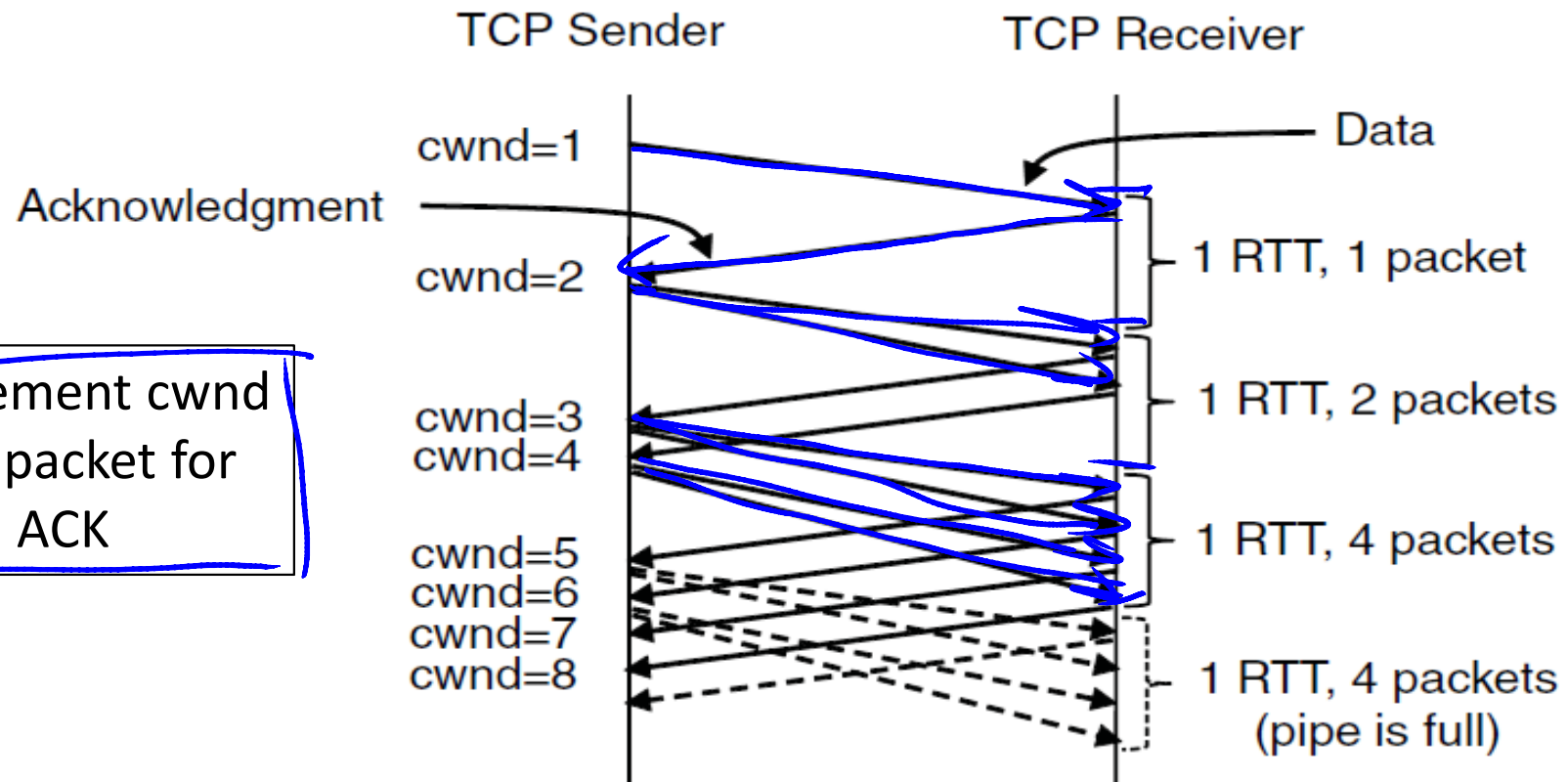
Additive Increase Timeline
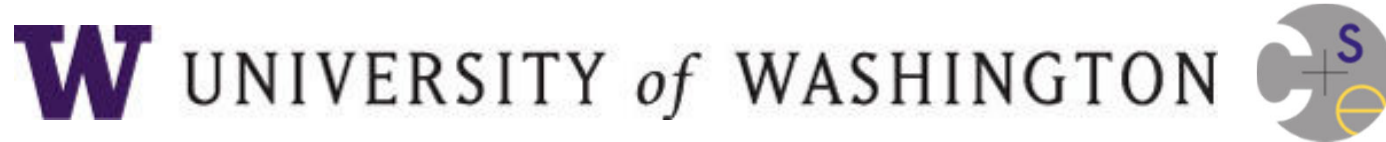

Increment cwnd by 1 packet every cwnd ACKs (or 1 RTT)

TCP Tahoe (Implementation)

- Initial slow-start (doubling) phase
  - Start with cwnd = 1 (or small value)
  - cwnd += 1 packet per ACK

- Later Additive Increase phase
  - cwnd += 1/cwnd packets per ACK
  - Roughly adds 1 packet per RTT

- Switching threshold (initially infinity)
  - Switch to AI when cwnd > ssthresh
  - Set ssthresh = cwnd/2 after loss
  - Begin with slow-start after timeout

Timeout Misfortunes

- Why do a slow-start after timeout?
  - Instead of MD cwnd (for AIMD)

- Timeouts are sufficiently long that the ACK clock will have run down
  - Slow-start ramps up the ACK clock

- We need to detect loss before a timeout to get to full AIMD
  - Done in TCP Reno (next time)

END

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