TCP Congestion Control Mechanisms

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Seminal Paper: Congestion Avoidance and Control
by Van Jacobson and Michael J. Karels

Exponential Damping

- From control theory: An unstable system can be stabilized by adding exponential damping
- “A network subject to random load shocks and prone to congestive collapse can be stabilized by adding exponential damping to its primary excitation (Traffic sources)”

Adapting to Path

- Estimating process can over or underestimate W; need to correct this
- Available bandwidth also changes over time; need to adapt to this
- Need a feedback mechanism from the network that the estimate is wrong

Overestimation

- Overestimation leads to congestion
- Feedback: If losses are due to congestion and timers are working correctly → Timeout indicates congestion

TO

- How to change the congestion window? $\boxed{w} - c$ $\boxed{TO} \rightarrow$
  - Additive decrease or multiplicative decrease? w/c
  - Multiplicative decrease yields better stability
    - $W_i = dW_{i-1}$ (d<1, typically 0.5)

$w = 10$

$w = 5$

Underestimation

$w = 5 \longrightarrow \underline{15}$

- Underestimation leads to lower utilization

$w + c$

$c \times \underline{\underline{w}}$

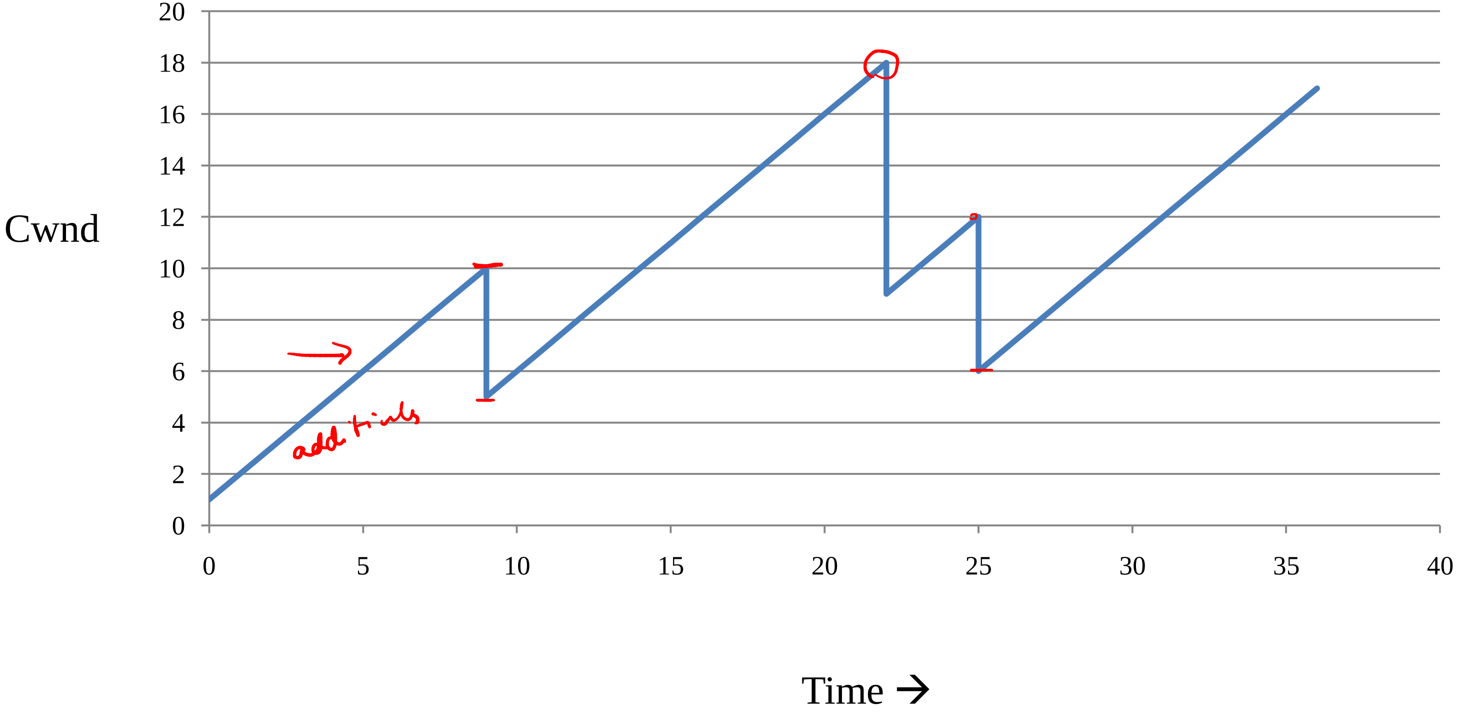
- Additive increase or multiplicative increase?
  - Exponential increase leads to instability; overestimation is inevitable
  - Additive increase
    - $W_i = W_{i-1} + u$ ($u \ll W_{max}$; typical u is 1)
    - Increase window by 1 segment every RTT

Congestion Avoidance

- Additive Increase, Multiplicative Decrease
- On detecting congestion, set cwnd to half the window size (multiplicative decrease)
- On each ack of new data, increase cwnd by 1/cwnd (additive increase)

self clocking

RTT → cwnd by 1 segment ✓


Cwnd
20
18
16
14
12
10
8
6
4
2
0
0
5
10
15
20
25
30
35
40
Time →
additive

Summary

- Congestion control is a difficult task
  - Prevent underutilization; ensure no congestion; ensure fairness
- TCP relies on a variety of techniques to achieve this
  - Slow start, RTT estimation, Congestion avoidance (AIMD)
- Ahead: Putting it all together in TCP versions