Computer Networks
COL 334/672

Congestion Control

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Slides adapted from KR

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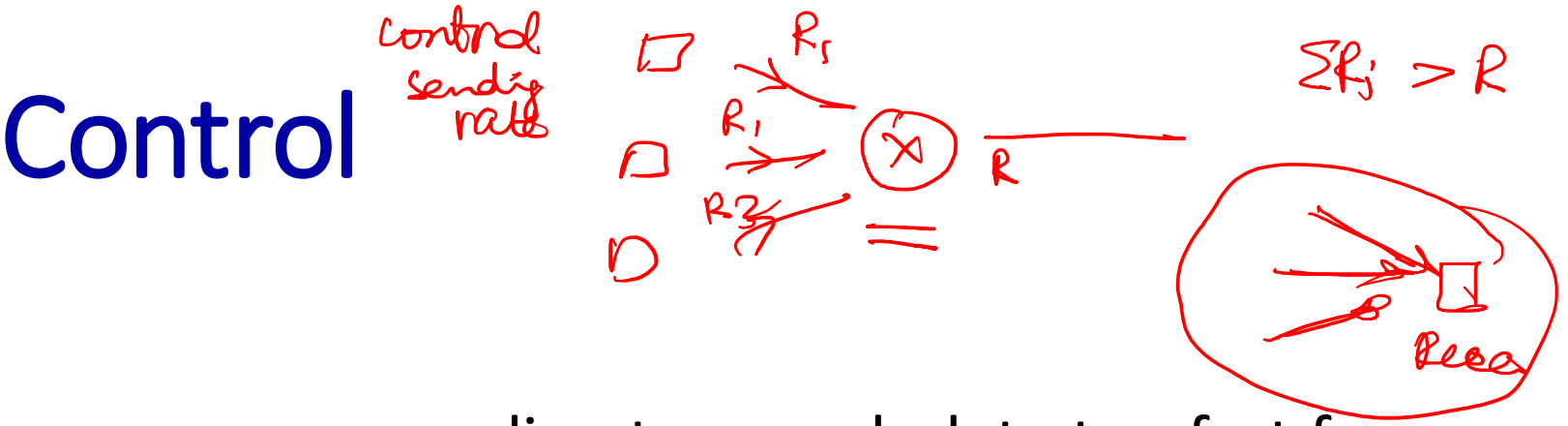
Quiz: Moodle

Password: tcp

Recap

- Transport Congestion Protocol
  - Connection establishment
  - Reliability
  - Flow control
  - **Congestion control**

Congestion Control



Congestion:

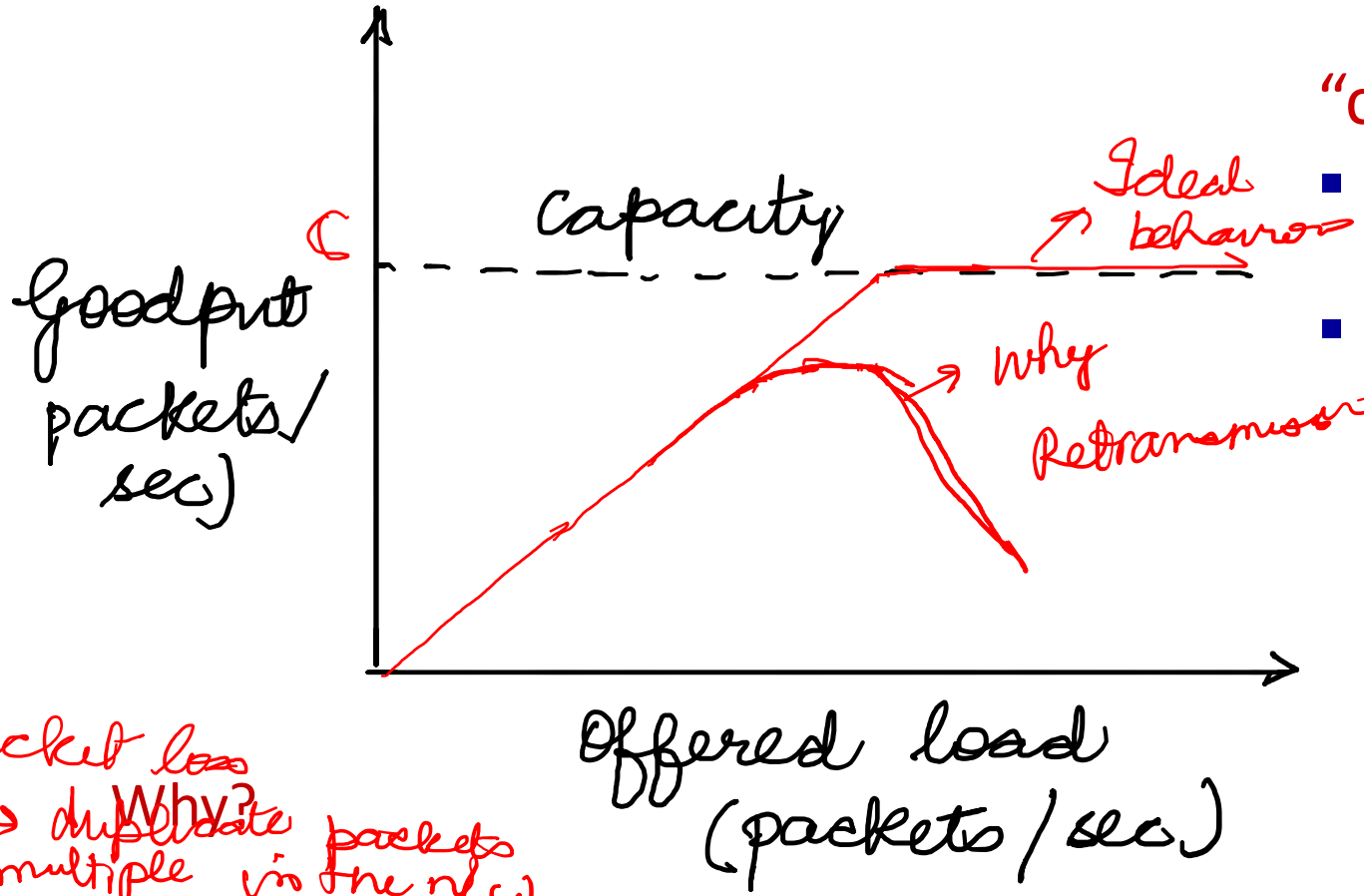
- informally: "too many sources sending too much data too fast for *network* to handle"
- manifestations:
  - long delays (queueing in router buffers)
  - packet loss (buffer overflow at routers)
- different from flow control!
- a top-10 problem!

congestion control:
too many senders,
sending too fast

flow control: one sender
too fast for one receiver

The Case of Congestion Collapse

- Early TCP protocol in 1980s used fixed size window
  - The focus was mainly on providing reliability
- As network load grew, goodput reduced

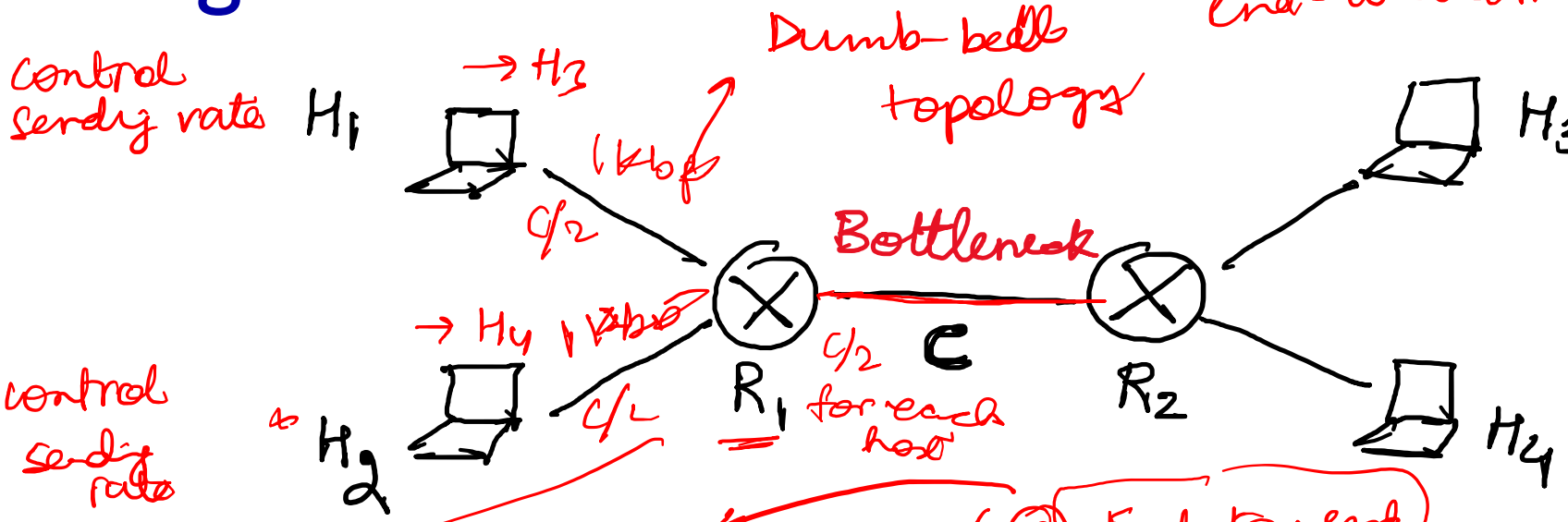


"costs" of congestion:

- more work (retransmission) for given receiver throughput
- unneeded retransmissions: link carries multiple copies of a packet
  - decreasing maximum achievable goodput

Need mechanisms for congestion control

How Would You Design a Congestion Control Algorithm?



Distributed, end-to-end manner

Metrics

④ Minimize latency

① Decrease packet loss

② Maximize link utilization → tput

③ Fairness

: Equal share of b/w

Jain's fairness index

$\frac{(\sum x_i)^2}{n\sum x_i}$ → 1 → fair, 1/n → highly unfair

① Routers implement or assist in CC / Network assisted

② End-to-end manner

② Centralized controller is Distributed

Max-min fairness

① Each host get no more than its need

② Maximize the minimum allocation

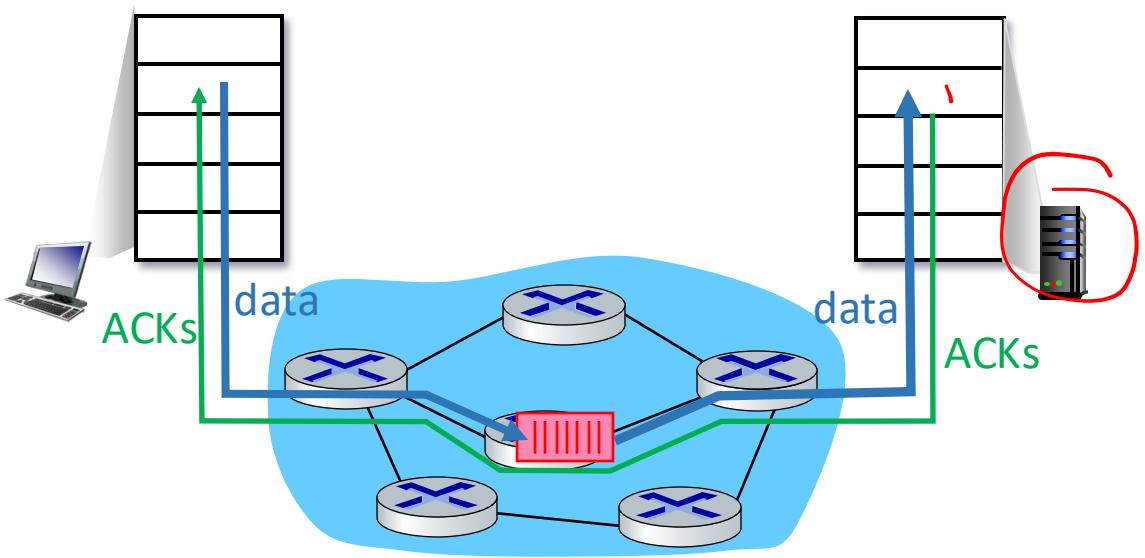
③ This is true even if you remove that min and adjust the resource

harm: CBR does not harm existing CC-A any more than A already harms itself

Approaches towards congestion control

End-end congestion control:

- no explicit feedback from network
- congestion *inferred*
- **approach taken by TCP**



Network-assisted congestion control:

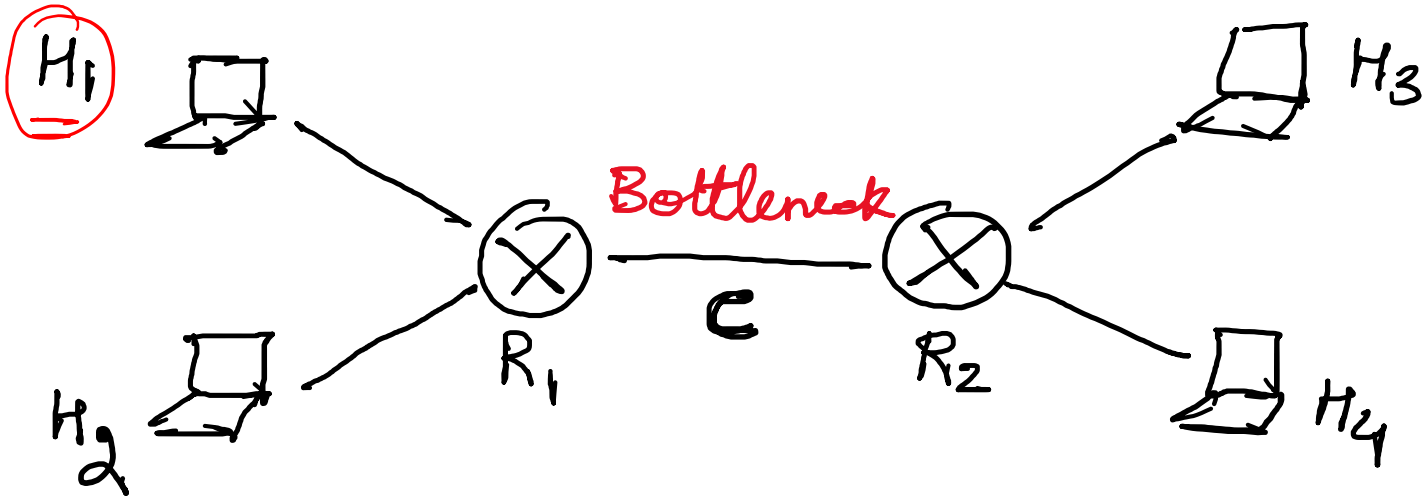
- routers provide *direct* feedback to sending/receiving hosts with flows passing through congested router
- may indicate congestion level or explicitly set sending rate
- E.g., TCP ECN, ATM, DECbit protocols

Metrics for evaluation of a Congestion Control Algorithm?

- Maximize the throughput
- Minimize the end-to-end delay
- Stability across a range of operating scenarios
- Flows should receive fair-share of bandwidth

common requirement

End-to-end congestion control



Fundamental questions

- How to determine the available capacity for a flow at any time?
- How to detect congestion?
- How to react to congestion once detected?

TCP congestion control:

- *approach:* senders can increase sending rate until packet loss (congestion) occurs, then decrease sending rate on loss event
- Many functions possible
- *Class of linear* control algorithms:
  - $w_{i+1} = aw_i + b$
  - a and b are different in case of increase and decrease
- Additive increase, multiplicative decrease (AIMD)
  - $w_{i+1} = w_i + b$
  - $w_{i+1} = aw_i$

TCP congestion control: AIMD

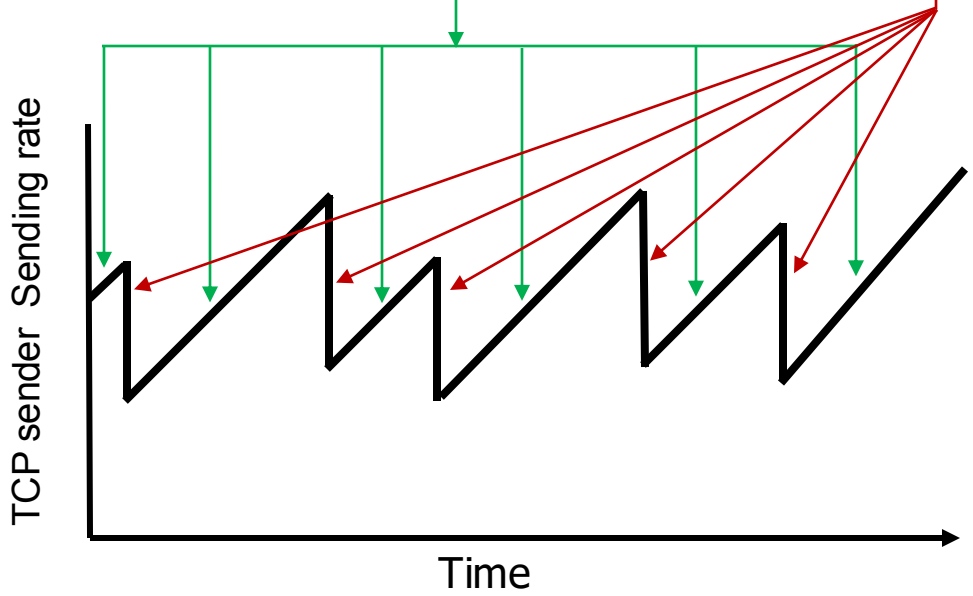
- Additive increase, multiplicative decrease (AIMD)
  - *Increase:* $w_{i+1} = w_i + b$, *Decrease:* $w_{i+1} = aw_i$

Additive Increase

increase sending rate by 1 maximum segment size every RTT until loss detected

Multiplicative Decrease

cut sending rate in half at each loss event



AIMD sawtooth behavior: *probing* for bandwidth

Why was AIMD chosen?

TCP fairness

Fairness goal: if *K* TCP sessions share same bottleneck link of bandwidth *R*, each should have average rate of *R/K*