Read 7.E & 7.F

Flow & Congestion Control

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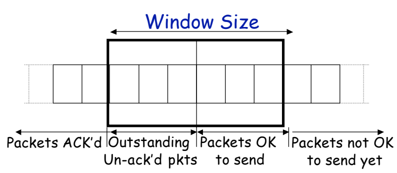
Some slides are from lectures by Nick Mckeown, Ion Stoica, Frans Kaashoek, Hari Balakrishnan, and Sam Madden

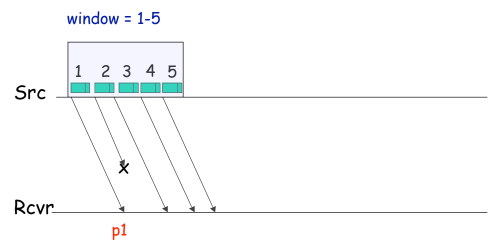
This Lecture

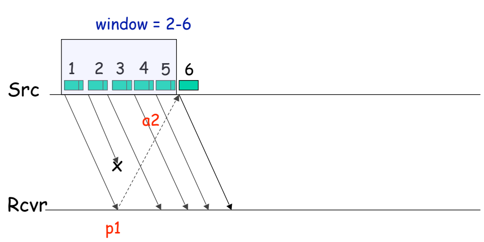
- More about Sliding Window
- Flow Control
- Congestion Control

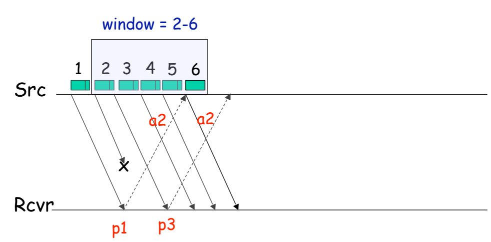
Sliding Window

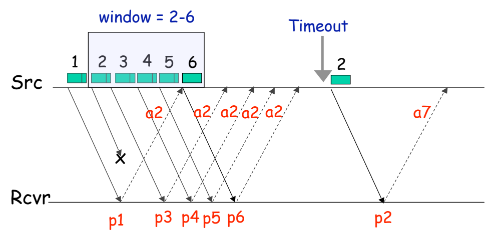


- The window advances/slides upon the arrival of an ack
- The sender sends only packets in the window
- Receiver usually sends *cumulative acks*
  - i.e., receiver acks the next expected in-order packet

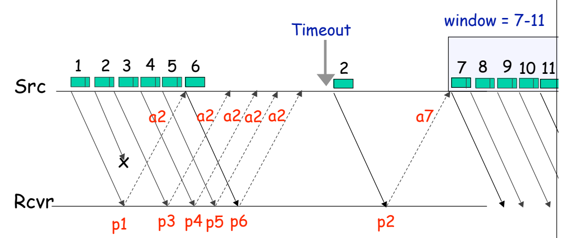








7



In this example, the receiver sent cumulative acks, but the same behavior happens if the receiver acks the received sequence number

8

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9

What is the right window size?

- The window limits how fast the sender sends
- Two mechanisms control the window:
  - Flow control
  - Congestion control

10

Flow Control

- The receiver may be slow in processing the packets → receiver is a bottleneck
- To prevent the sender form overwhelming the receiver, the receiver tells the sender the maximum number of packets it can buffer fwnd
- Sender sets W ≤ fwnd

But, what if the bottleneck is a slow link inside the network → Need Congestion Control

11

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12

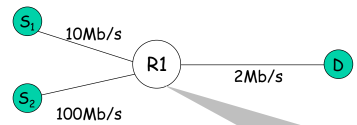
Sharing the Internet

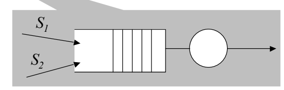
How do you manage the resources in a huge system like the Internet, where users with different interests share the same resources?

Difficult because of:

- Size
  - Millions of users, links, routers
- Heterogeneity
  - bandwidth: 9.6Kb/s (then modem, now cellular), 10 Tb/s
  - latency: 50us (LAN), 133ms (wired), 1s (satellite), 260s (Mars)

Congestion

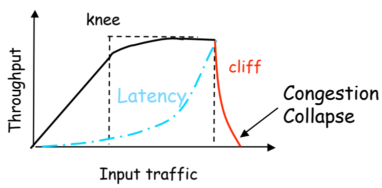




- Sources share links, and buffer space
- Why a problem?
  - Sources are unaware of current state of resource
  - Sources are unaware of each other
- Manifestations:
  - Lost packets (buffer overflow at routers)
  - Long delays (queuing in router buffers)

Congestion Collapse

Increase in input traffic leads to decrease in useful work



- Causes of Congestion Collapse
  - Spurious retransmissions of packets that are still in flight
  - Packet consume resources and then they are dropped downstream

What can be done?

- Increase network resources
  - But demands will increase too!
- Admission Control & Scheduling
  - Used in telephone networks
  - Hard in the Internet because can't model traffic well
- Pricing
  - senders pay more in times of congestion
- Congestion control: ask the sources to slow down
  - But how?
    - How do the sources learn of congestion?
    - What is the correct window?
    - How to adapt the window as the level of congestion changes?

How do senders learn of congestion?

Potential options:

- Router sends a Source Quench to the sender
- Router flags the packets indicating congestion
- Router drops packets when congestion occurs
  - Sender learns about the drop because it notices the lack of ack
  - Drops are the solution currently used in the Internet

How do senders learn how much to send?

- Define a congestion control window cwnd
- Sender's window is set to W = min (fwnd, cwnd)
- Simple heuristic to find cwnd:
  - Sender increases its cwnd slowly until it sees a drop
  - Upon a drop, sender decreases its cwnd quickly to react to congestion
  - Sender increases again slowly

TCP Increase/decrease algorithm

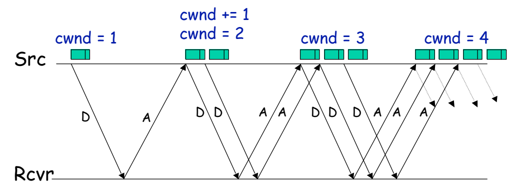
- Additive Increase / Multiplicative Decrease (AIMD)
  - Every RTT:

    No drop: cwnd = cwnd + 1

    drop: cwnd = cwnd /2

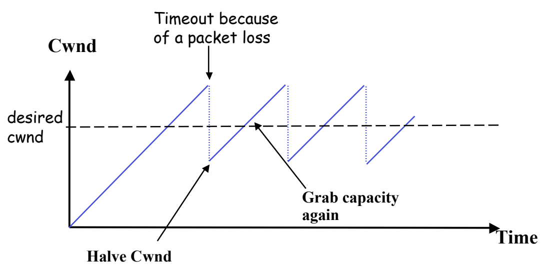
19

Additive Increase



20

TCP AIMD

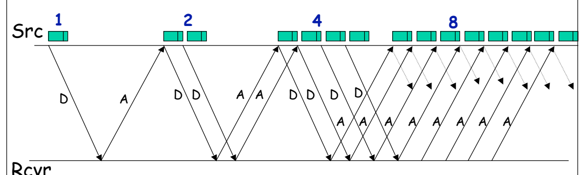


Need the queue to absorb these saw-tooth oscillations

21

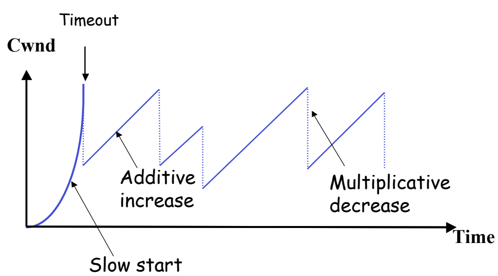
TCP "Slow Start"

- How to set the initial cwnd?
- At the beginning of a connection, increase exponentially
  - Every RTT, double cwnd



22

Slow Start + AIMD



23