L13: Sharing in network systems

6.033 Spring 2007

http://web.mit.edu/6.033

Slides from many folks

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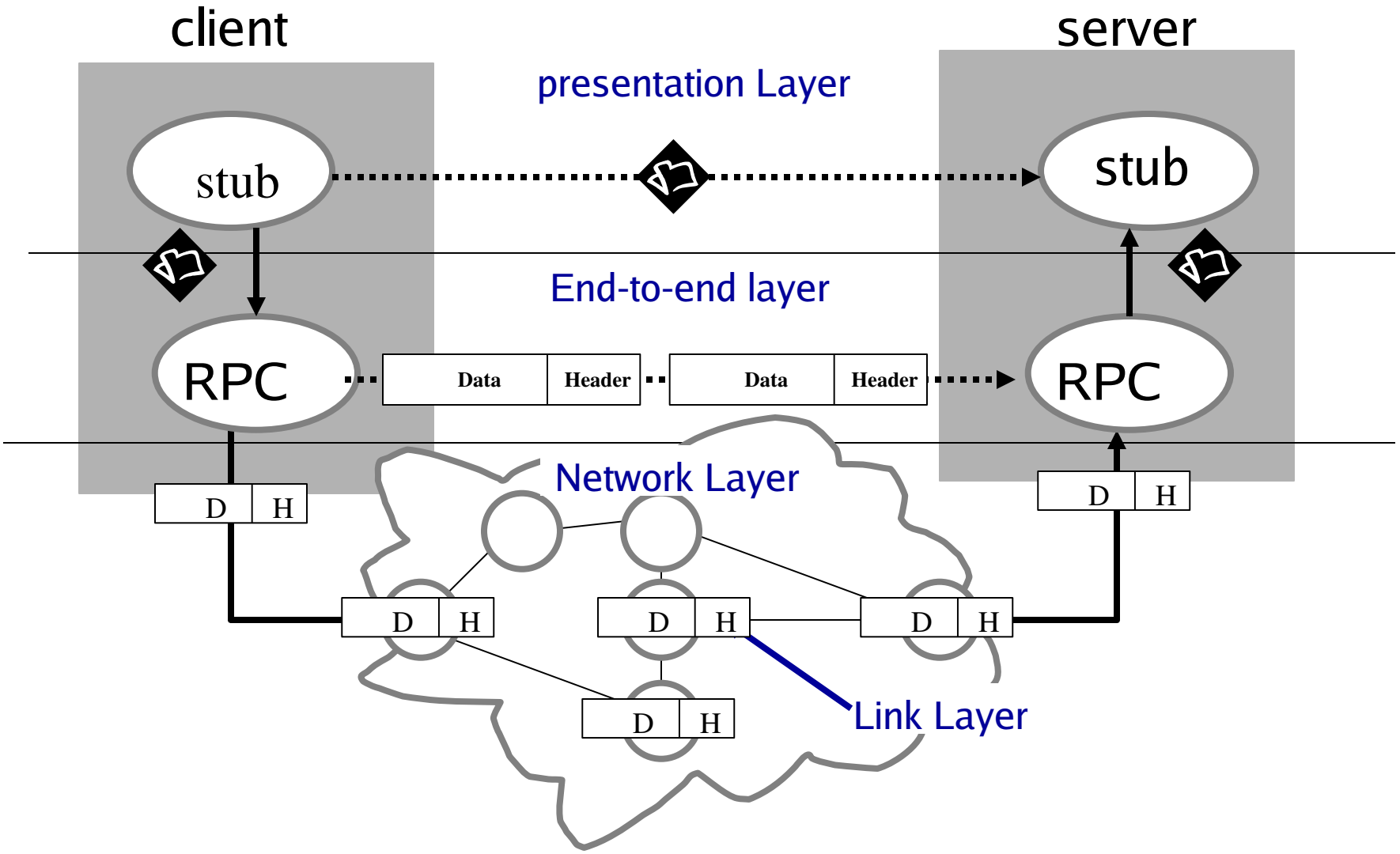
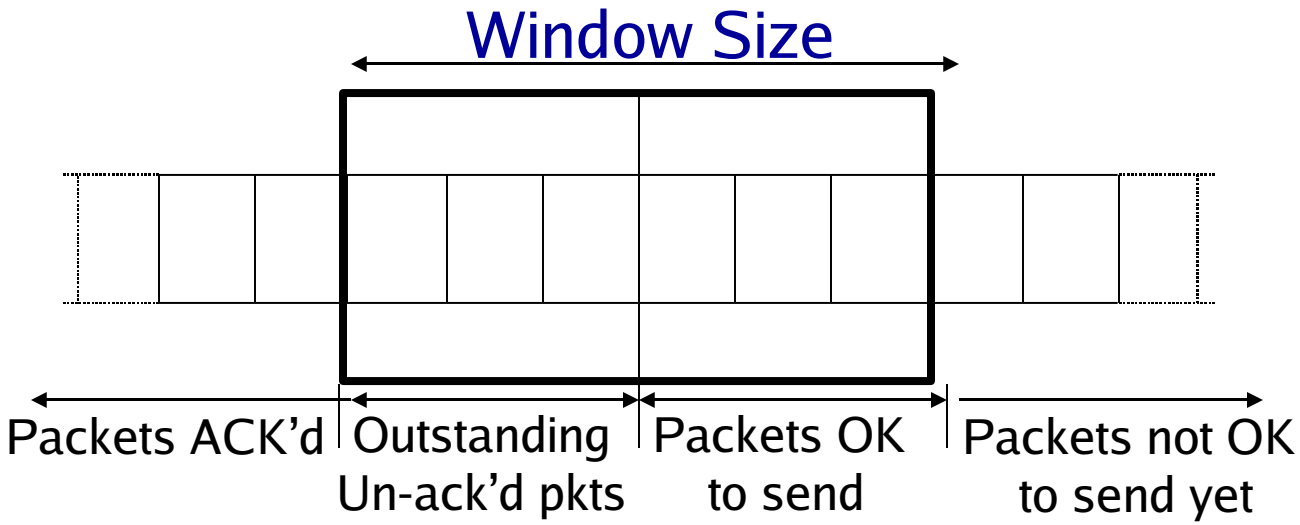
Where is sharing happening?



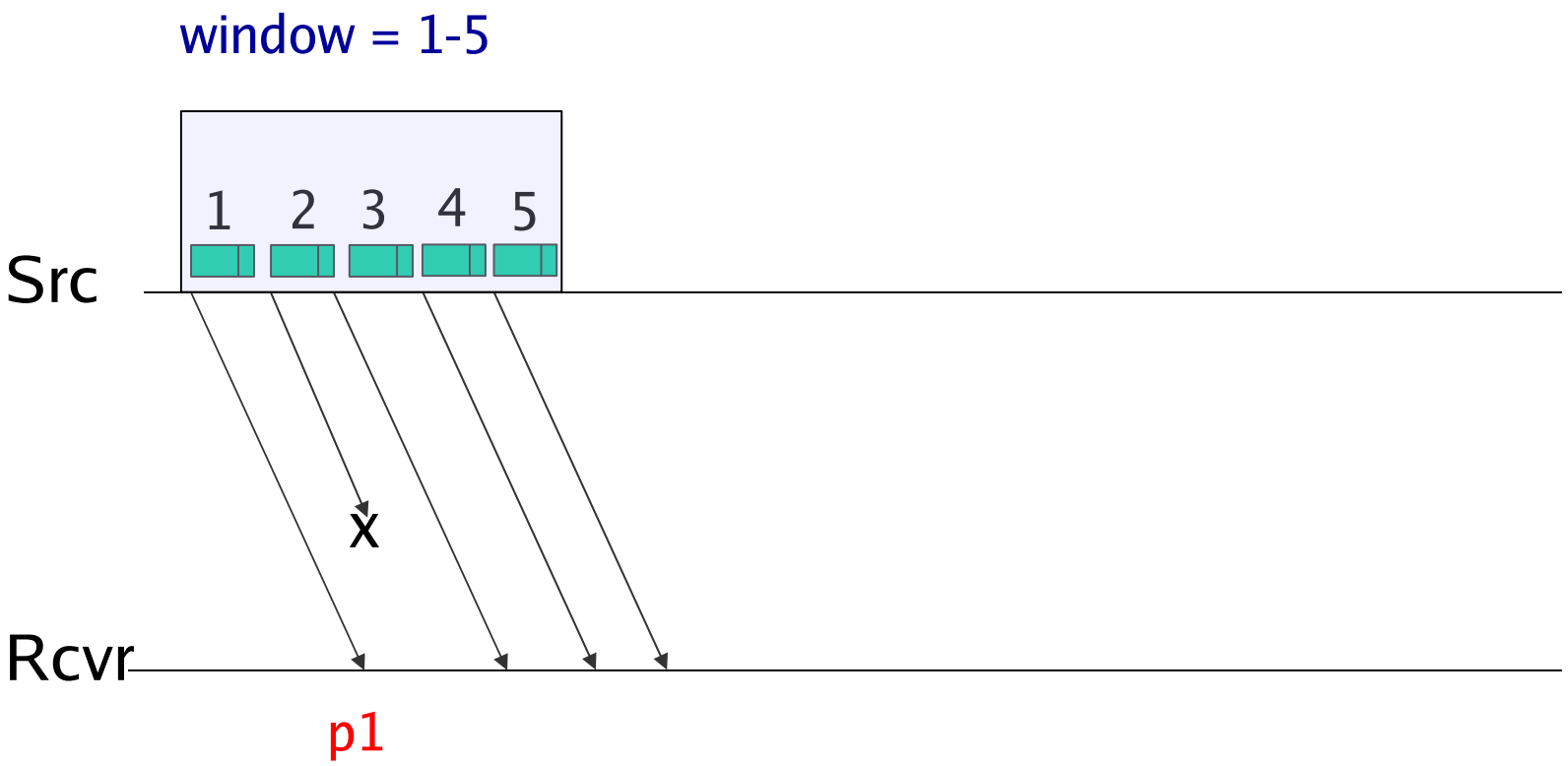
This Lecture

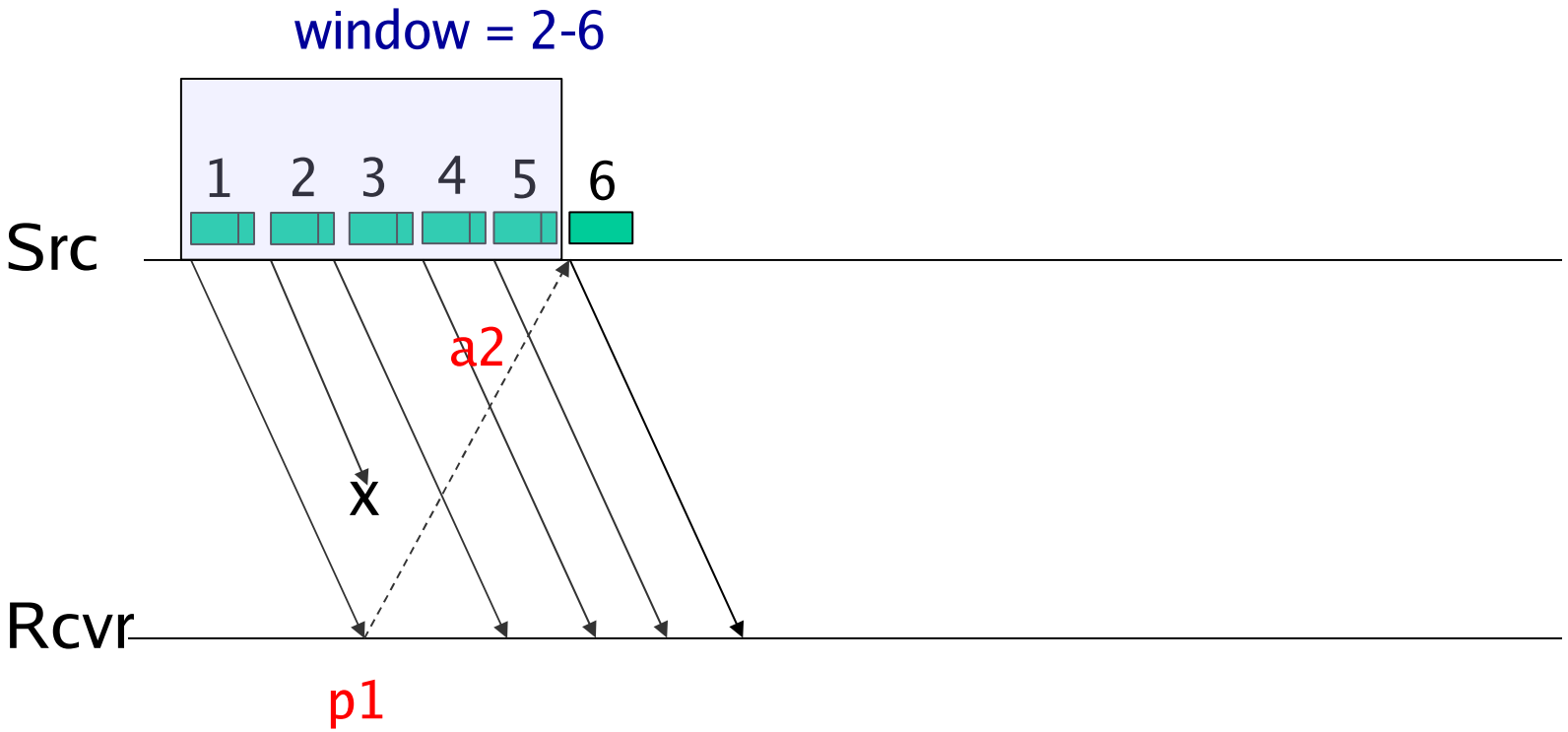
- Problems:
  - Sharing server
  - Sharing network
- Solution:
  - Set the window size carefully
  - Sharing server: flow control
  - Sharing the network: congestin control

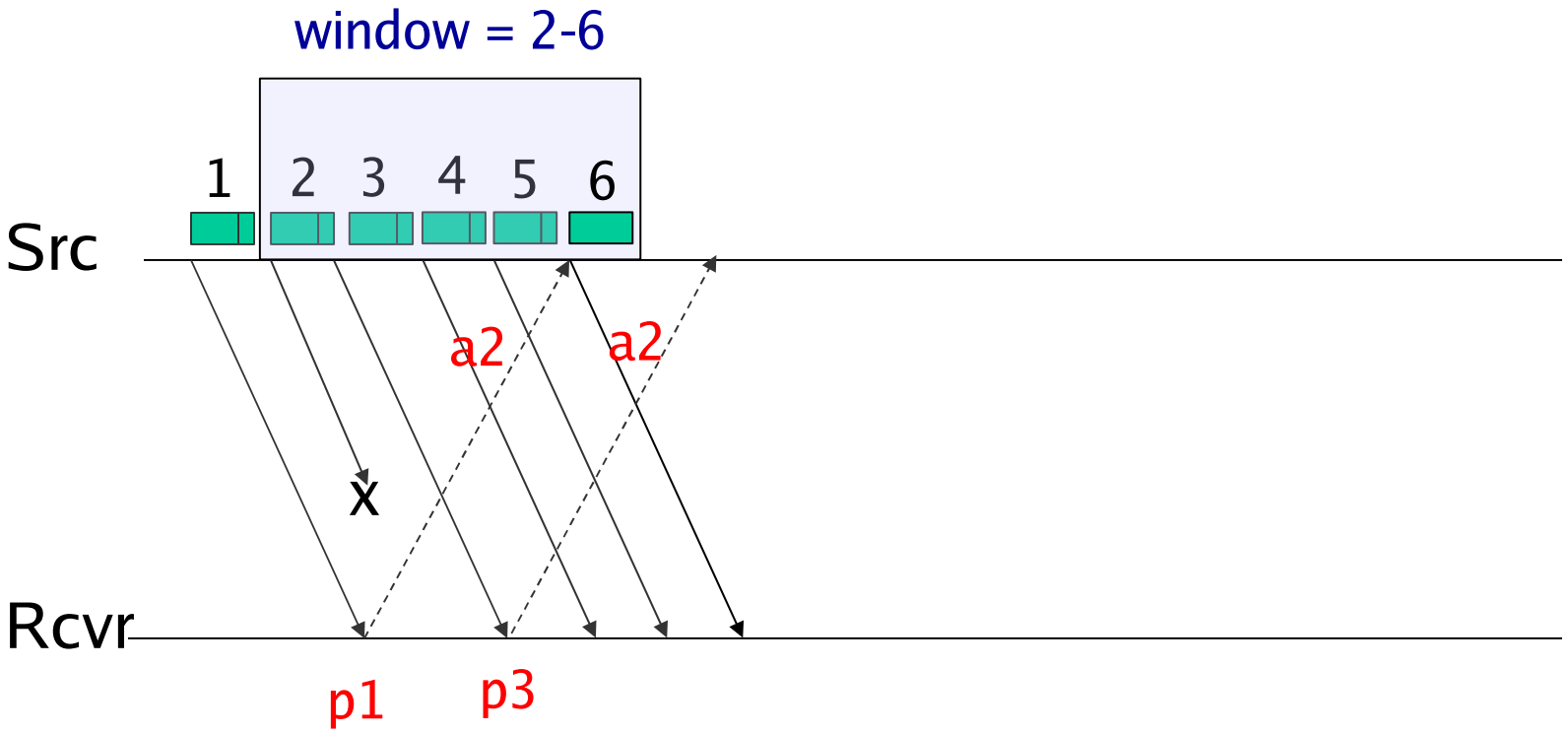
Sliding Window

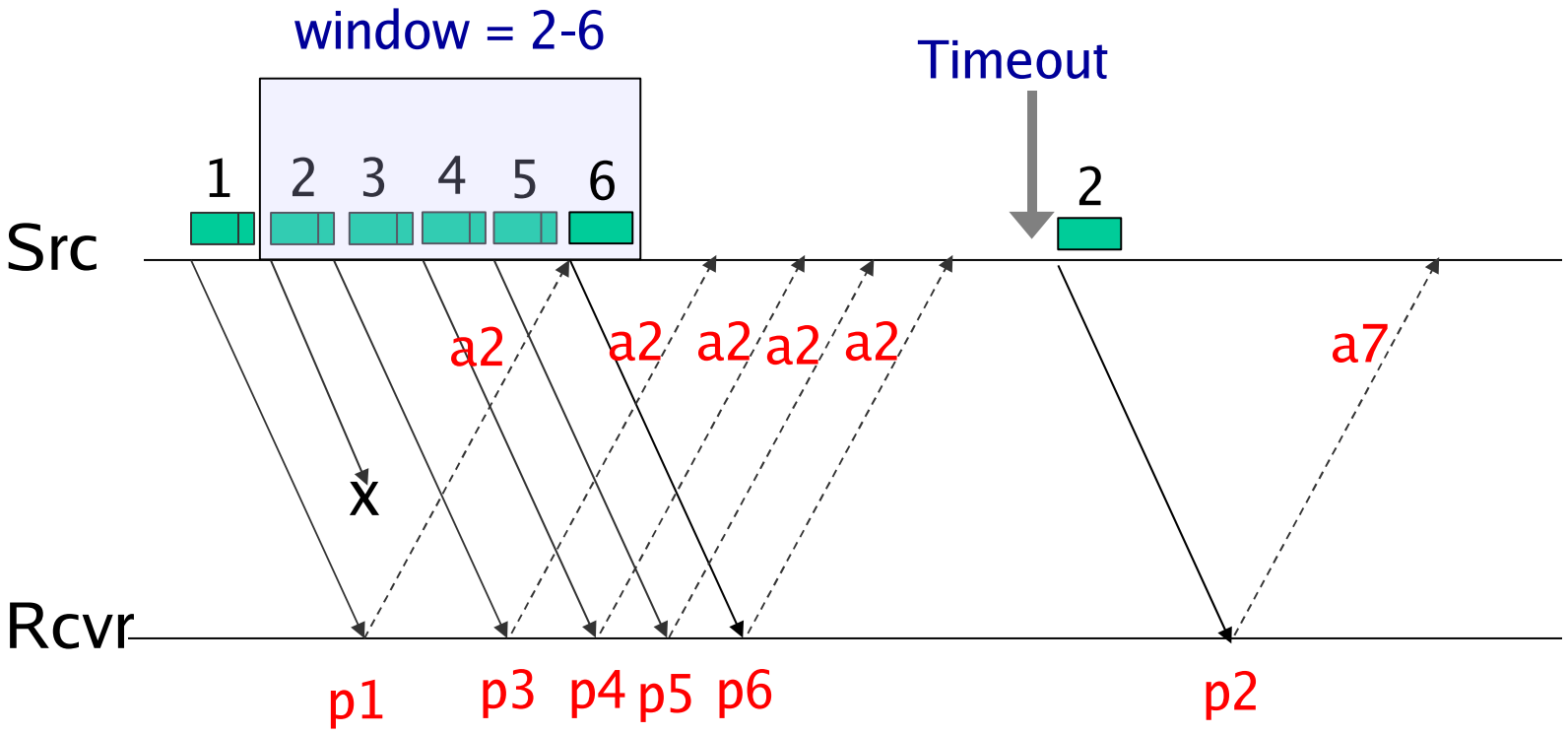


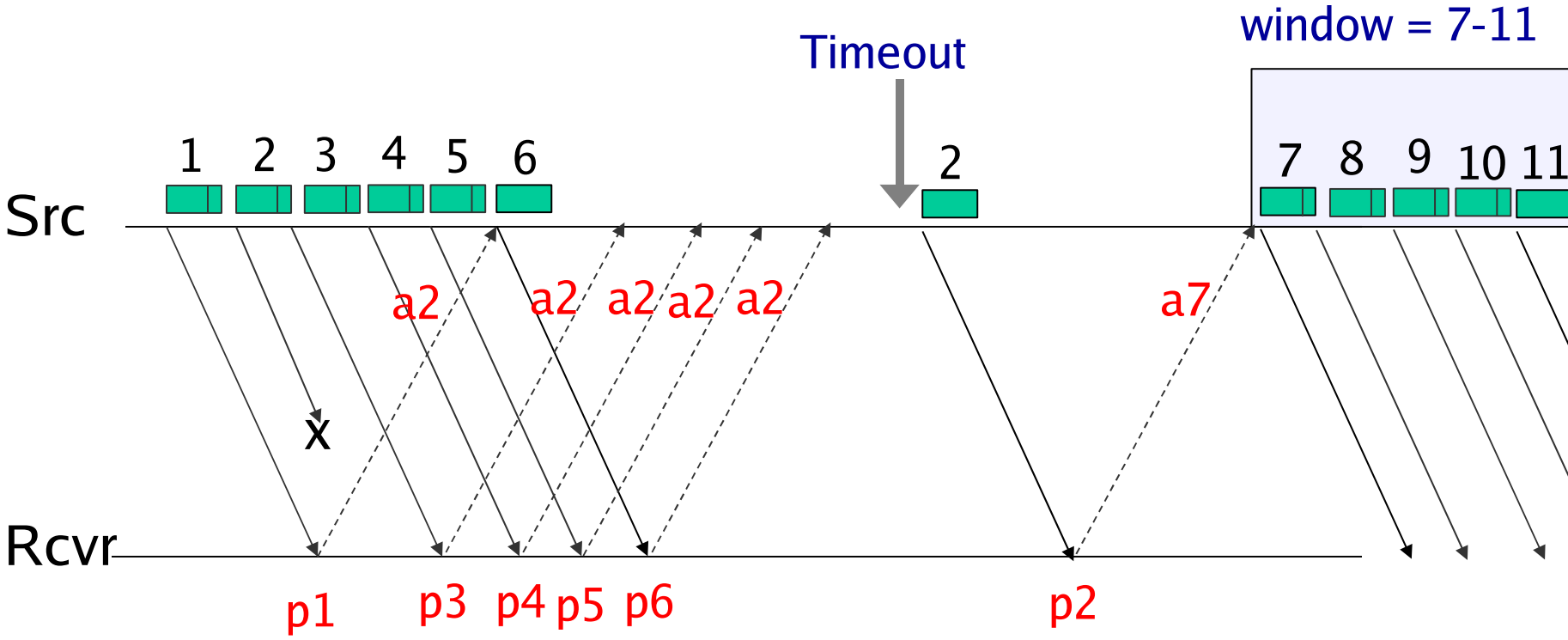
- The window advances/slides upon the arrival of an ack
- The sender sends only packets in the window
- Receiver usually sends *cumulative acks*
  - i.e., receiver acks the next expected in-order packet


window = 1-5
1
2
3
4
5
Src
X
Rcvr
p1


window = 2-6
1
2
3
4
5
6
Src
a2
x
Rcvr
p1


window = 2-6
1
2
3
4
5
6
Src
a2
a2
x
Rcvr
p1
p3


window = 2-6
Timeout
1
2
3
4
5
6
2
Src
a2
a2
a2
a2
a2
a7
X
Rcvr
p1
p3
p4
p5
p6
p2



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

What is the right window size?

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

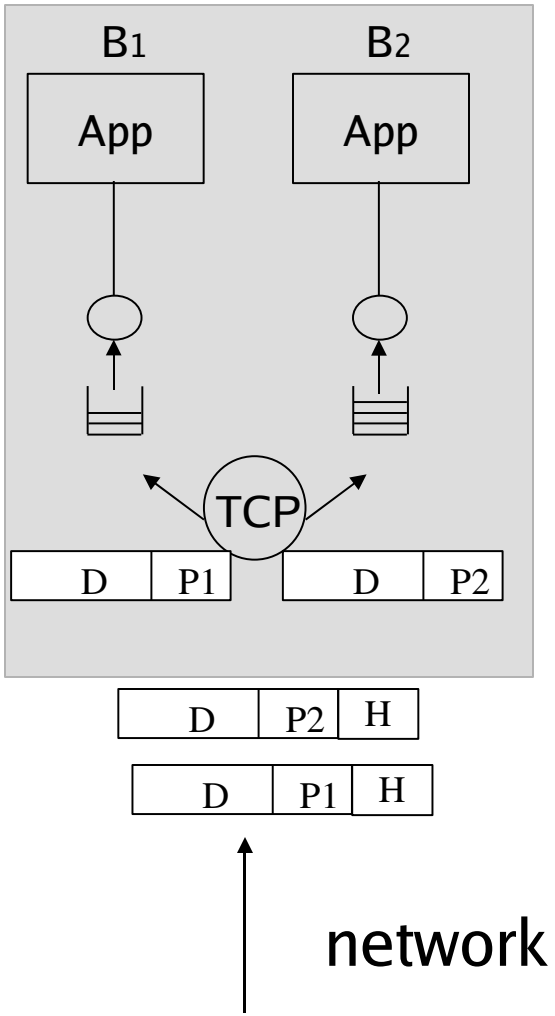
Flow Control

- 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 $W \leq fwnd$

How to set fwnd?

Multiple applications run on the same machine but use different ports

- Fwnd = B x RTT
  - Size of queue substitute for B
- Adapts to
  - RTT changes
  - B changes
- “self-pacing”



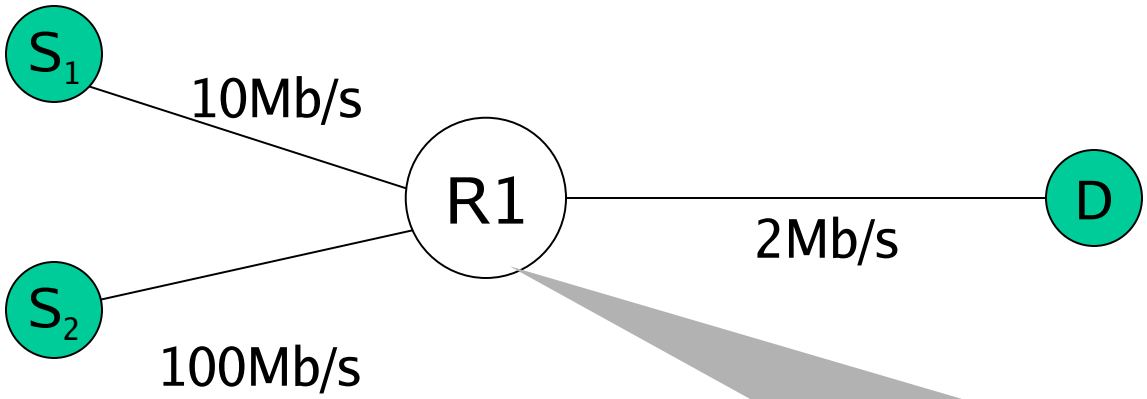
Sharing the network

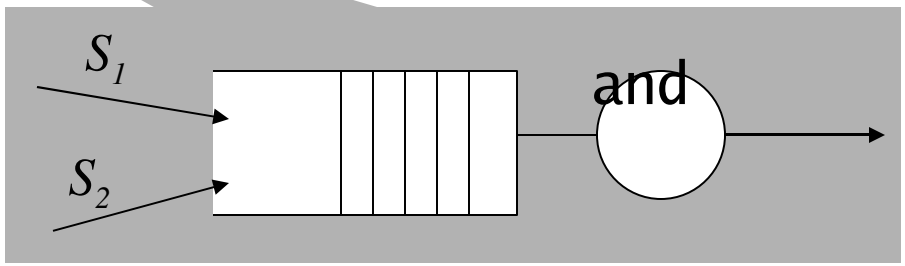
How do you manage the resources in a huge system like the Internet, where users with different interests share the same resources?

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

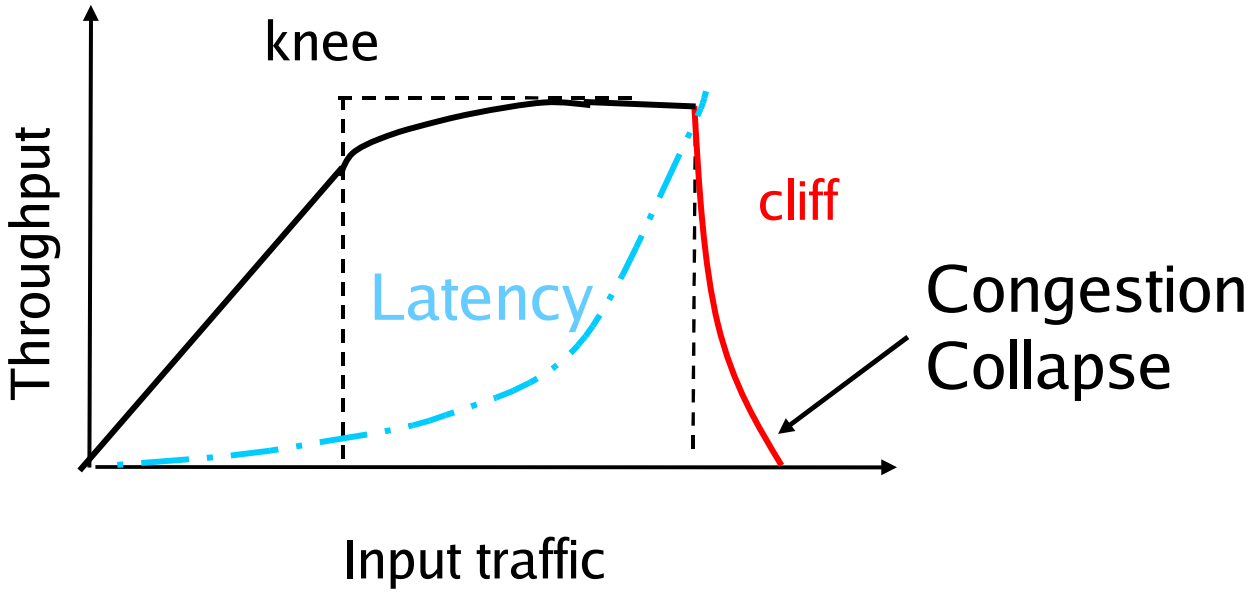




- Sources share links, buffer space
- Why a problem?
  - Sources are unaware of current state of resource
  - Sources are unaware of each other
- Manifestations:
  - Lost packets (buffer overflow at routers)
  - Long delays (queuing in router buffers)
  - Long delays may lead to retransmissions, which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

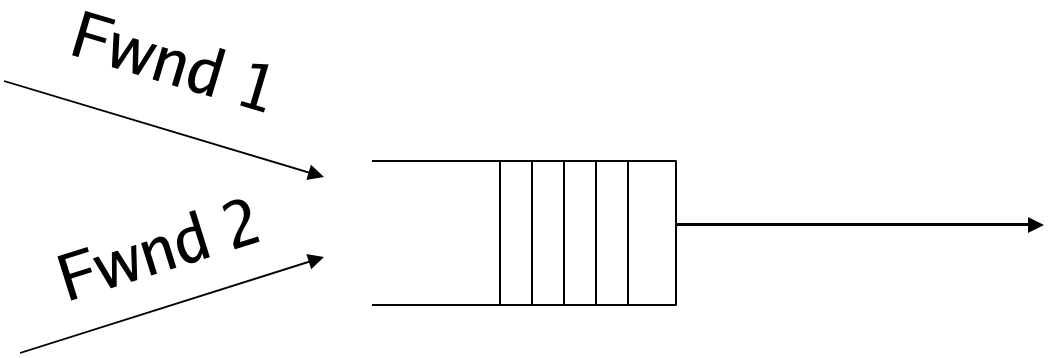
Danger: Congestion Collapse

Increase in input traffic leads to decrease in useful work



- Causes of Congestion Collapse
  - Retransmissions introduce duplicate packets
  - Duplicate packets consume resources wasting link capacity

Example: old TCP implementations



- Long haul network (i.e., large RTT)
- Router drops some of TCP 2's fwnd packets
  - Each discard packet will result in timeout
- At timeout TCP 2 resends complete window
  - Cumulative ACK, timeouts fire off at "same" time
- Blizzard of retransmissions can result in congestion collapse
  - Insufficiently adaptive timeout algorithm made things worse

What can be done in general?

- Avoid congestion:
  - 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
  - Perhaps combined with 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
  - Sender adjusts window

Case study: current TCP

- 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
- No changes to protocol necessary!

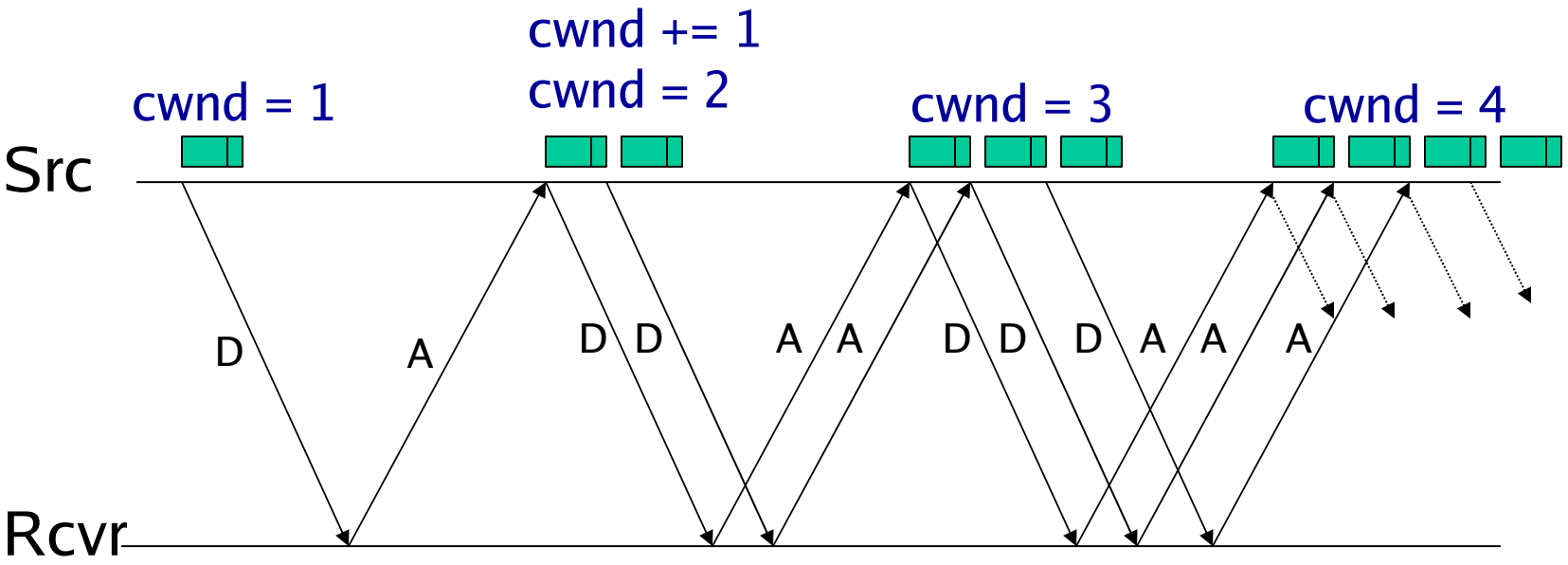
TCP Increase/decrease algorithm

- AIMD:
  - Additive Increase Multiplicative Decrease
- Every RTT:

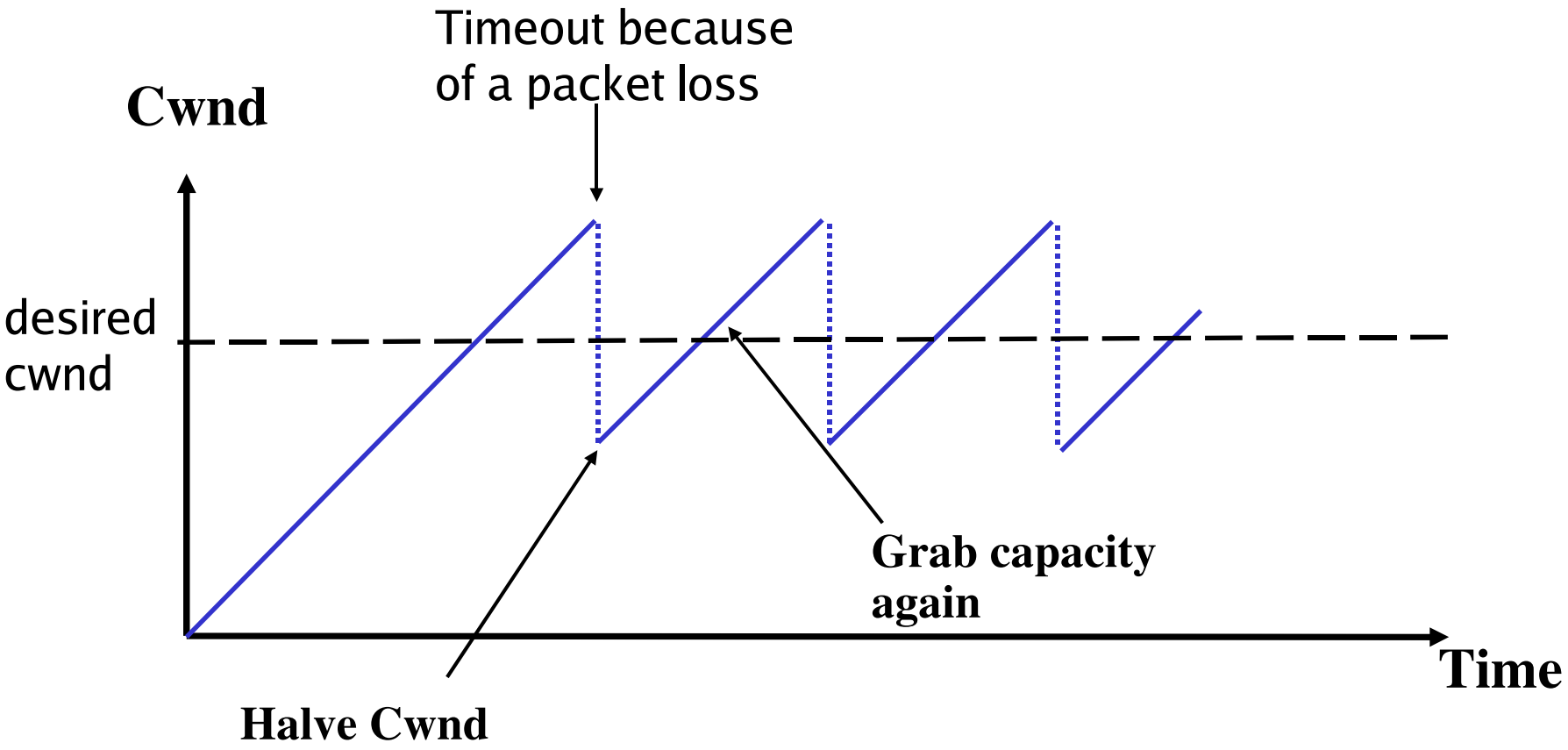
  No drop: cwnd = cwnd + 1

  drop: cwnd = cwnd /2

Additive Increase



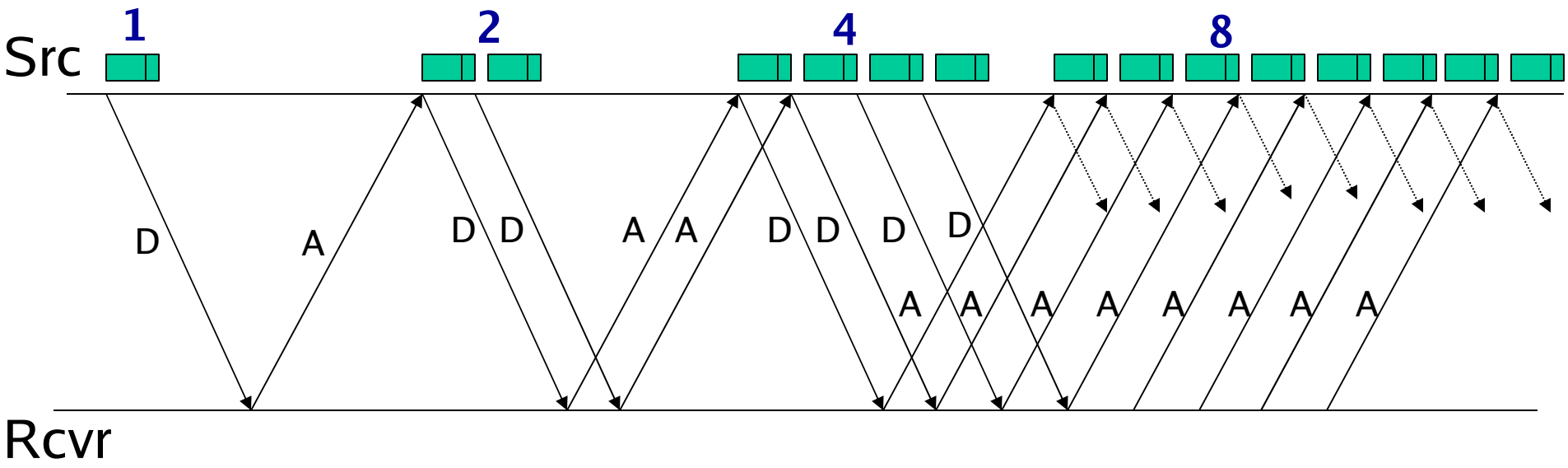
TCP AIMD



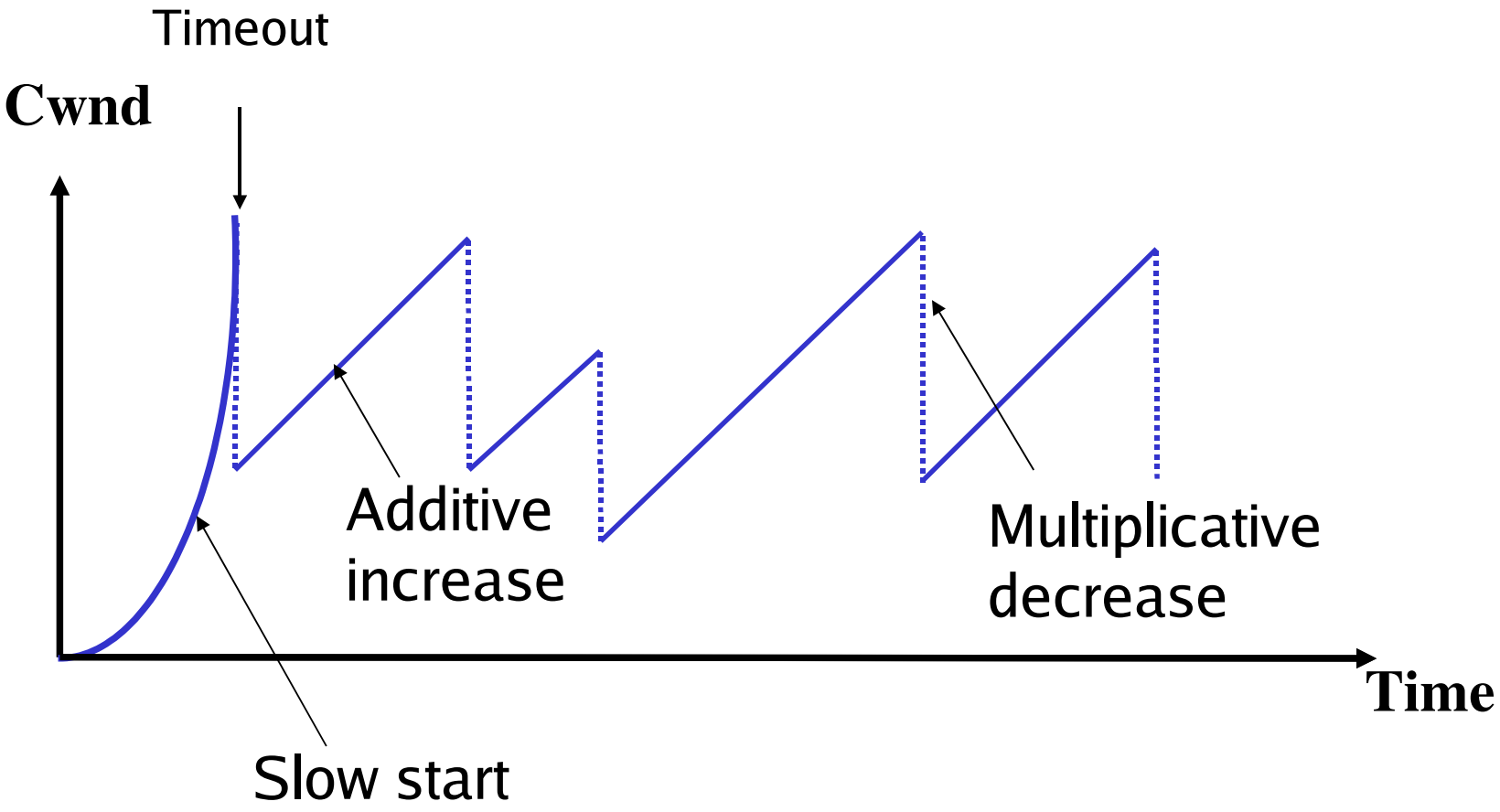
Need the queue to absorb these saw-tooth oscillations

TCP "Slow Start"

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



Slow Start + AIMD



Fairness?

- No!
  - Applications don’t have to use TCP
  - Use multiple TCP connections

Summary

- Controlling complexity in network systems
  - Layering
  - Interesting division of labors based on E2E principle
  - Case study: Internet
- Interesting problems and techniques
  - Packets
  - Protocols
  - …
- Client-server implementation

- Next: Application-level reliability and security