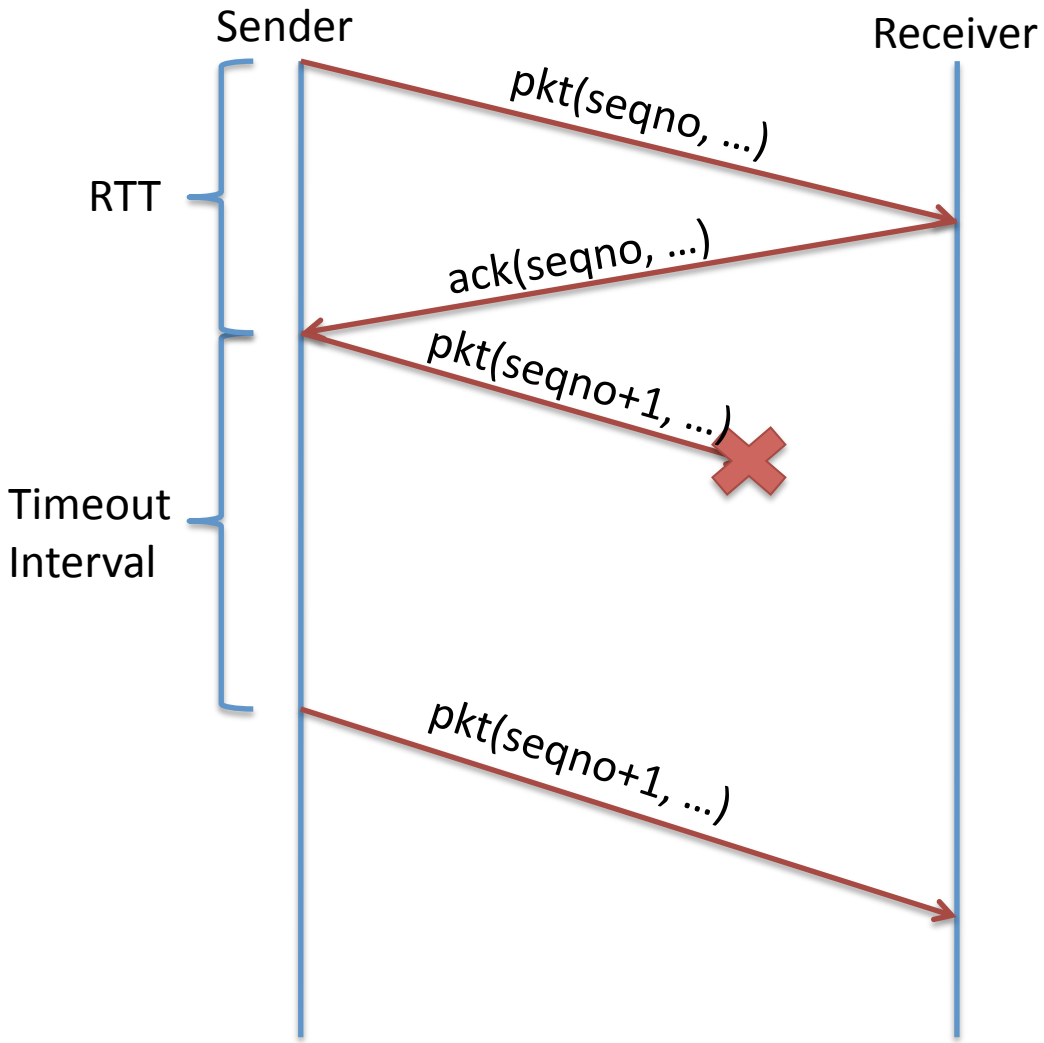
6.033 Lecture 11
Congestion Control

March 10, 2010

slides: http://mit.edu/6.033/www/assignments/lec11.pdf
http://mit.edu/6.033/www/assignments/lec11.pptx

Key Ideas:
- Sliding window protocol
- Congestion control

Recap: At Least Once Delivery



How long to set timeout?

Too long: net underutilized

Too short: rexmit all the time

Proper setting depends on packet round trip time (RTT)

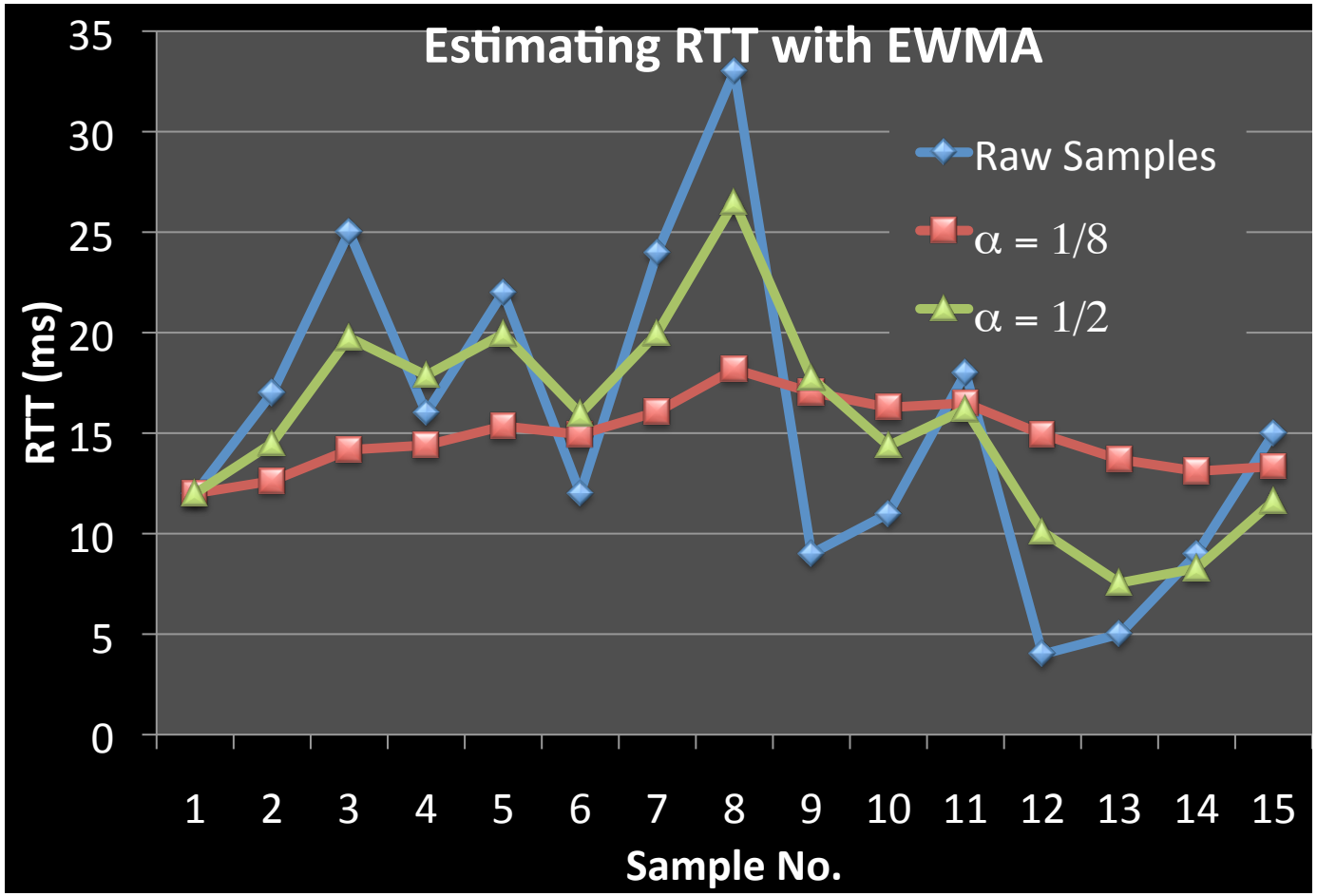
Can measure

Exponentially Weighted Moving Average (EWMA)

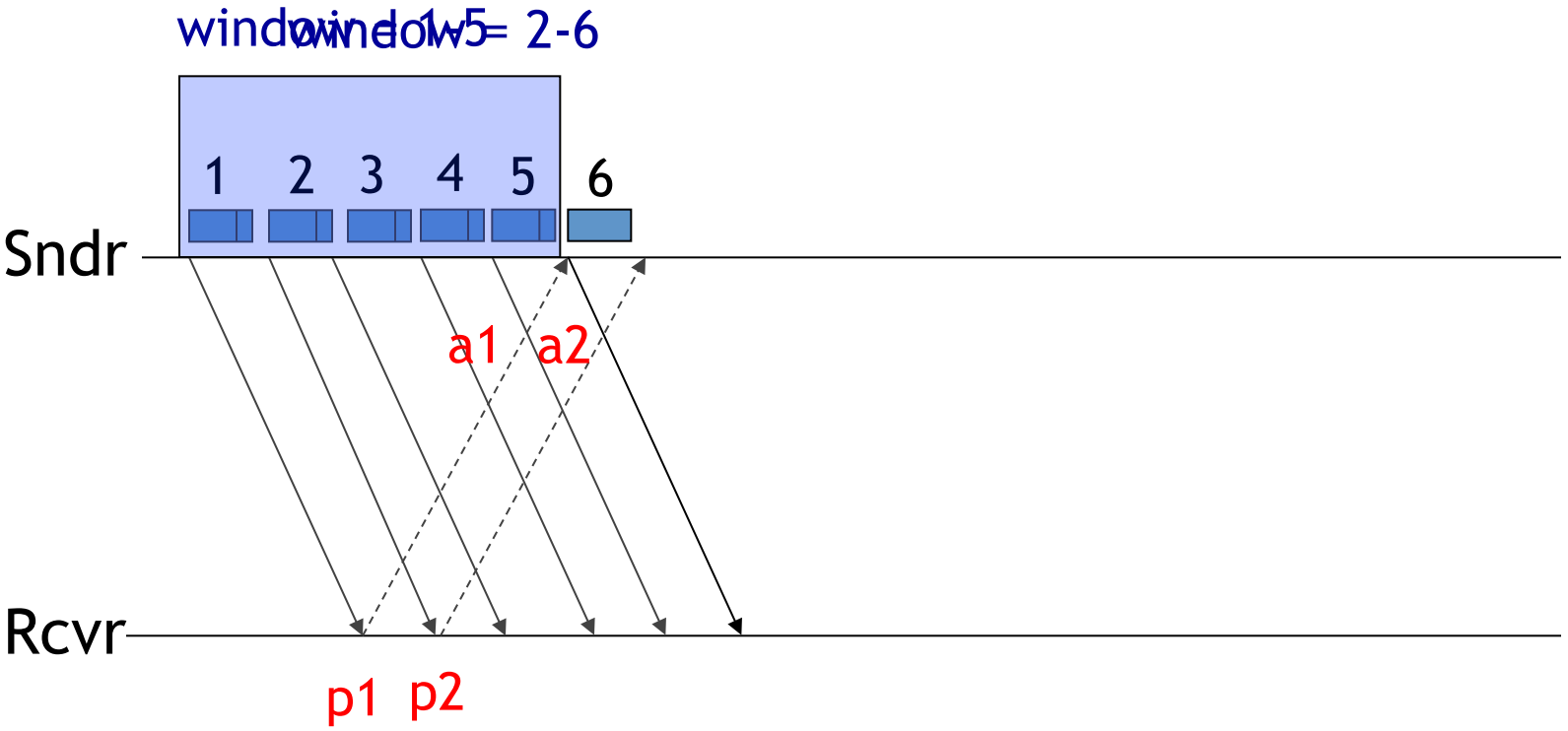
measure = new RTT measurement

rtt = α(measure) + (1-α)(rtt) ; α = 1/8

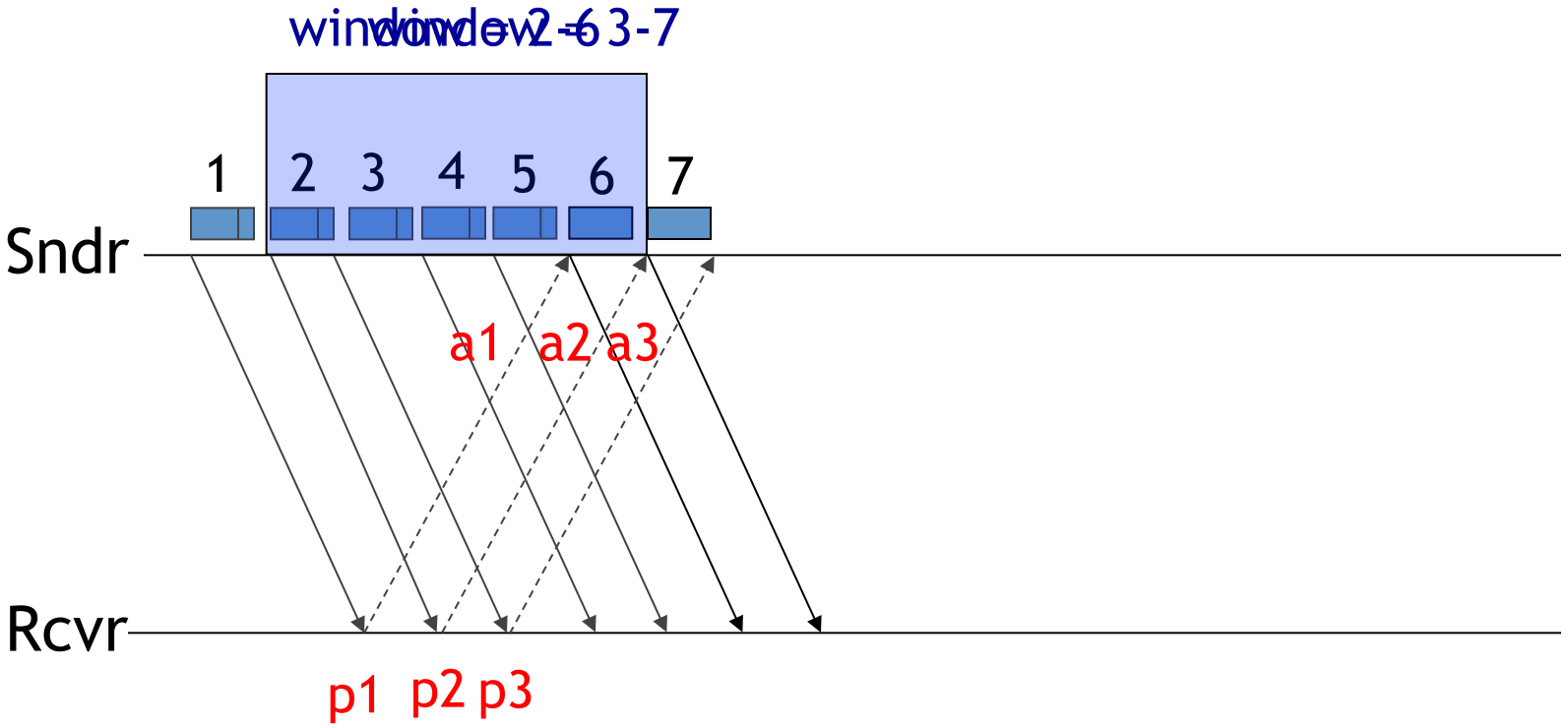
timeout = β * rtt ; β = 2



Sliding Window in Action

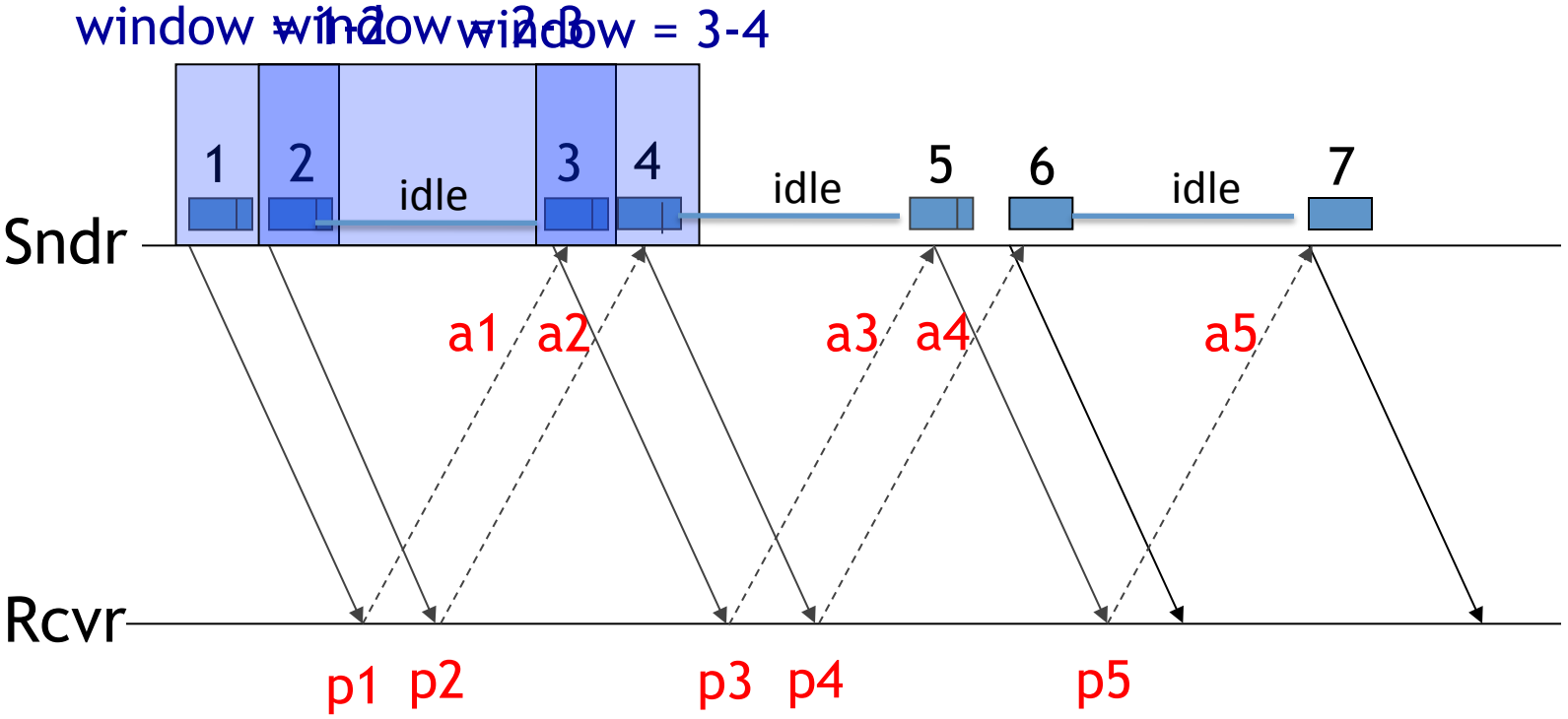


Sliding Window in Action



Send next packet as acks arrive, rather than waiting for all acks in window

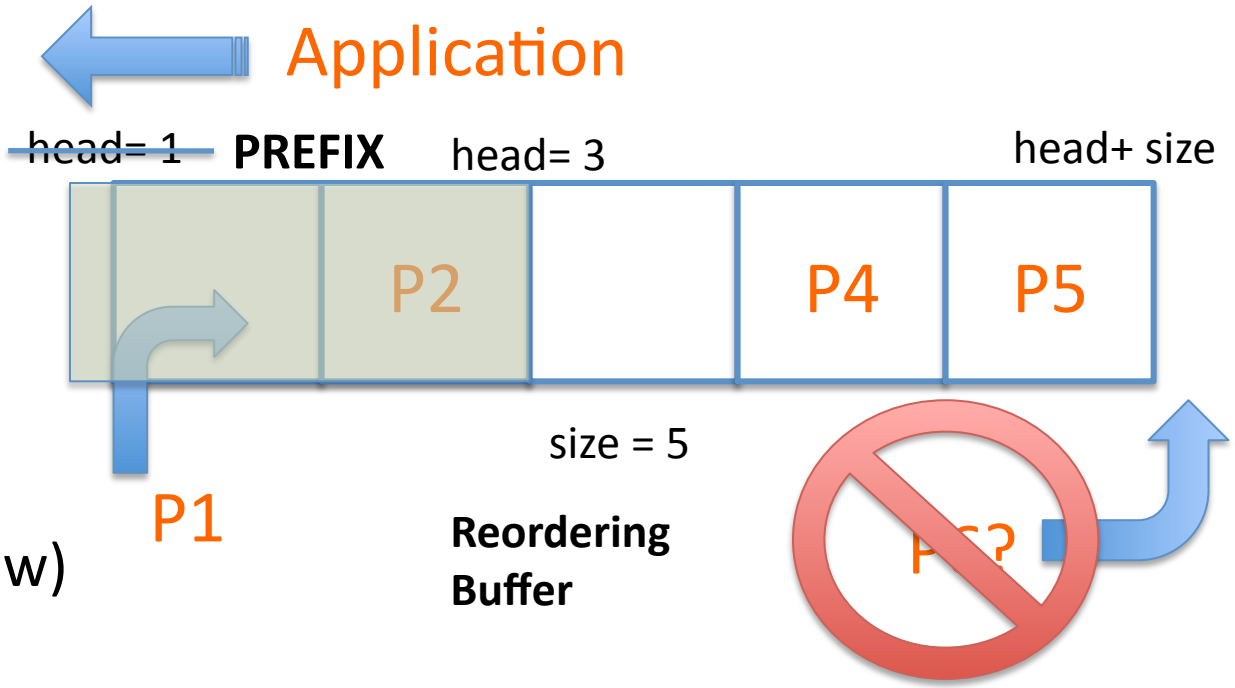
Still may wait



Reordering

```
recv(p):
    slot = p.sno – head
    if (slot > head + size):
     drop
    else:
     new = isempty(slot)
     if (new) add p to slot
     ack p
    if (slot == head and new)
     deliver prefix to app
     head = head+ len(prefix)
```

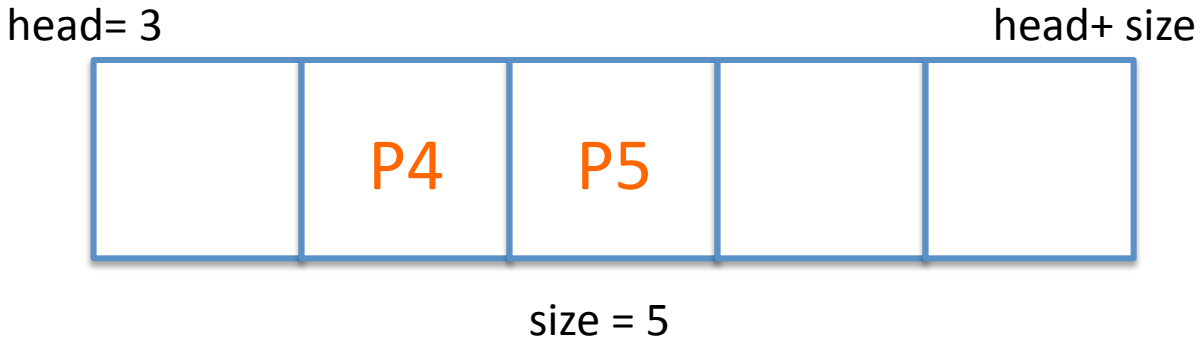
head : sno of last delivered packet
size: length of reordering queue
slot: position to insert new packet



Reordering

```
recv(p):
    slot = p.sno – head
    if (slot > head + size):
     drop
    else:
     new = isempty(slot)
     if (new) add p to slot
     ack p
    if (slot == head and new)
     deliver prefix to app
     head = head+ len(prefix)
```

head : sno of last delivered packet
size: length of reordering queue
slot: position to insert new packet



Reordering Buffer

T=0-1

Router Queue

Pkt
1
2
3

Head

Sender

Window

Pkt	Ack'd	Timeout
1		2
2		2.33
3		2.66
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		

T=1-2

Router Queue

Pkt
1
2
3

Head

Sender

Window

Pkt	Ack'd	Timeout
1		2
2		2.33
3		2.66
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		

T=1-2

Router Queue

Pkt
1
2
3

Head

Sender

Window

Pkt	Ack'd	Timeout
1	1	2
2		2.33
3		2.66
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		

T=1-2

Router Queue

Pkt
1
2
3

Head

Window

Sender

Pkt	Ack'd	Timeout
1	1	2
2		2.33
3		2.66
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		

T=1-2

Router Queue

Pkt
1
2
3
4
5
6

Head

Window

Sender

Pkt	Ack'd	Timeout
1	1	2
2		2.33
3		2.66
4		3
5		3.33
6		3.66
7		
8		
9		
10		
11		
12		
13		
14		

T=2-3

Router Queue

Pkt
1
2
3
4
5
6

Head

Window

Sender

Pkt	Ack'd	Timeout
1	1	2
2	2	2.33
3		2.66
4		3
5		3.33
6		3.66
7		
8		
9		
10		
11		
12		
13		
14		

T=2-3

Router Queue

Pkt
1
2
3
4
5
6
3
7
8

Head

Window

Sender

Pkt	Ack'd	Timeout
1	1	2
2	2	2.33
3		4.66
4		3
5		3.33
6		3.66
7		4
8		4.33
9		
10		
11		
12		
13		
14		

T=3-4

Router Queue

Pkt
1
2
3
4
5
6
3
7
8

Head

Sender

Window

Pkt	Ack'd	Timeout
1	1	2
2	2	2.33
3	3	4.66
4		3
5		3.33
6		3.66
7		4
8		4.33
9		
10		
11		
12		
13		
14		

T=3-4

Router Queue

Pkt
1
2
3
4
5
6
3
7
8
4
5
6

Head

Sender

Window

Pkt	Ack'd	Timeout
1	1	2
2	2	2.33
3	3	4.66
4		5
5		5.33
6		5.66
7		4
8		4.33
9		
10		
11		
12		
13		
14		

Sender is spending all of its time retransmitting
Queue is filling with duplicate packets
No new transmissions are getting through!

Congestion collapse

Ro

3			3	3	4.66
4		Head	4		5
5			5		5.33
6			6		5.66
3			7		4
7			8		4.33
8			9		
4			10		
5			11		
6			12		
			13		
			14		

Window

T=4-5

Router Queue

Pkt
1
2
3
4
5
6
3
7
8
4
5
6
7
8, 9

Head

Sender

Window

Pkt	Ack'd	Timeout
1	1	2
2	2	2.33
3	3	4.66
4	4	5
5		5.33
6		5.66
7		6
8		6.33
9		6.66
10		
11		
12		
13		
14		

T=5-6

Router Queue

Pkt
1
2
3
4
5
6
3
7
8
4
5
6
7
8, 9, 10,11,6

Head

Sender

Window

Pkt	Ack'd	Timeout
1	1	2
2	2	2.33
3	3	4.66
4	4	5
5	5	5.33
6		7.66
7		6
8		6.33
9		6.66
10		7
11		7.33
12		
13		
14		

T=6-7

Router Queue

Pkt
1
2
3
4
5
6
3
7
8
4
5
6
7
8, 9, 10,11,6, 7, 8,9

Head

Sender

Pkt	Ack'd	Timeout
1	1	2
2	2	2.33
3	3	4.66
4	4	5
5	5	5.33
6	6	7.66
7		8
8		8.33
9		8.66
10		7
11		7.33
12		
13		
14		

Window