

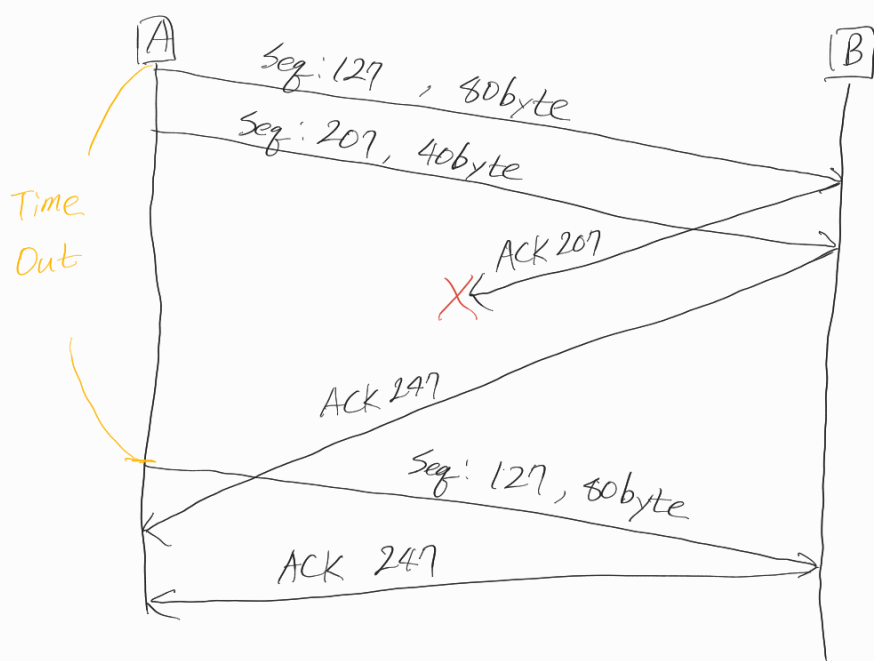
- 1.
- (a) (i) $[k-4, k-3, k-2, k-1]$ (iii) $[k-2, k-1, k, k+1]$ (iv) $[k, k+1, k+2, k+3]$
 (ii) $[k-3, k-2, k-1, k]$ (iv) $[k-1, k, k+1, k+2]$

- (b)
- (i) $[k-4, k-3, k-2, k-1]$ (iii) $[k-2, k-1]$ (iv) \emptyset
 (ii) $[k-3, k-2, k-1]$ (iv) $[k-1]$

\therefore All possible value of ACK = $[k-4, k-3, k-2, k-1]$

2.

- (a) Sequence Number: 207, Source Port: 302, Destination Port: 80
 (b) ACK Number: 207, Source Port: 80, Destination Port: 302
 (c) ACK Number: 127
 (d)



3.

- (a) Assume there is initial Estimated RTT, Estimated RTT₅.

$$\text{Estimated RTT}_4 = (1-\alpha)\text{Estimated RTT}_5 + \alpha \text{SampleRTT}_4$$

$$\begin{aligned} \text{Estimated RTT}_3 &= (1-\alpha)\text{Estimated RTT}_4 + \alpha \text{SampleRTT}_3 \\ &= (1-\alpha)^2\text{Estimated RTT}_5 + \alpha(1-\alpha)\text{SampleRTT}_4 + \alpha \text{SampleRTT}_3 \end{aligned}$$

$$\text{Estimated RTT}_2 = (1-\alpha)\text{Estimated RTT}_3 + \alpha \text{SampleRTT}_2$$

$$= (1-\alpha)^3\text{Estimated RTT}_5 + \alpha(1-\alpha)^2\text{SampleRTT}_4 + \alpha(1-\alpha)\text{SampleRTT}_3 + \alpha \text{SampleRTT}_2$$

$$\text{Estimated RTT}_1 = (1-\alpha) \text{Estimated RTT}_2 + \alpha \text{Sample RTT}_1$$

$$= (1-\alpha)^4 \text{Estimated RTT}_5 + \alpha (1-\alpha)^3 \text{Sample RTT}_4 + \alpha (1-\alpha)^2 \text{Sample RTT}_3 + \alpha (1-\alpha) \text{Sample RTT}_2 + \alpha \text{Sample RTT}_1$$

$$\therefore \text{Estimated RTT}_1 = 0.9^4 \text{Estimated RTT}_5 + 0.1 \cdot 0.9^3 \text{Sample RTT}_4 + 0.1 \cdot 0.9^2 \text{Sample RTT}_3 + 0.1 \cdot 0.9 \text{Sample RTT}_2 + 0.1 \text{Sample RTT}_1$$

(Estimated RTT₅ is a constant)

(b)

$$\text{Estimated RTT}_1 = 0.9^n \text{Estimated RTT}_{n+1} + 0.1 \sum_{k=1}^n (0.9)^{k-1} \text{Sample RTT}_k$$

(c)

$$\lim_{n \rightarrow \infty} \text{Estimated RTT}_1 = 0 \cdot \text{Estimated RTT}_{n+1} + 0.1 \sum_{k=1}^{\infty} (0.9)^{k-1} \text{Sample RTT}_k$$

In each movement, 0.9 is multiplied to the old sample RTT so that this movement is exponential moving average.

4.

(a) [0, 6], [23, 26]

(h) 7th round

(b) [6, 22] (AIMD Used)

(i) Window size = 4, ssthresh = 4

(c) Triple Duplicate ACK

(f) ssthresh = 21

(d) Time out

Window size = 4

(e) 32

(k)

(f) 21

Round 17 18 19 20 21 22

(g) 13

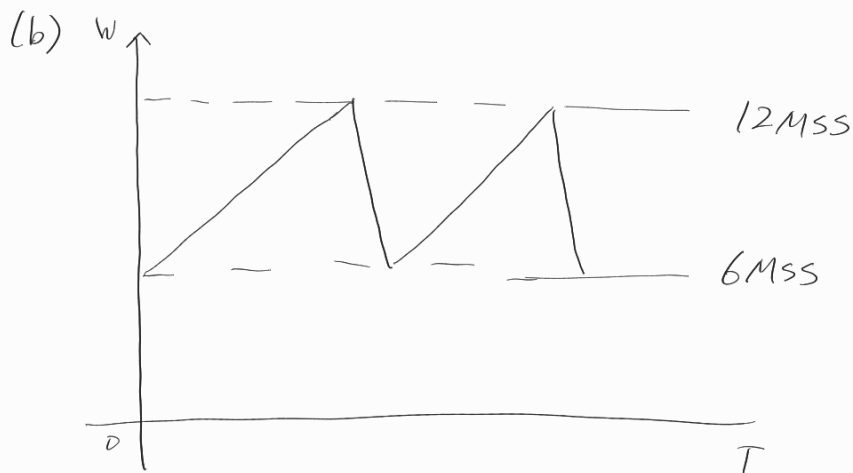
W 1 2 4 8 16 21

\therefore 52 packets

5.

(a) MSS increase / RTT

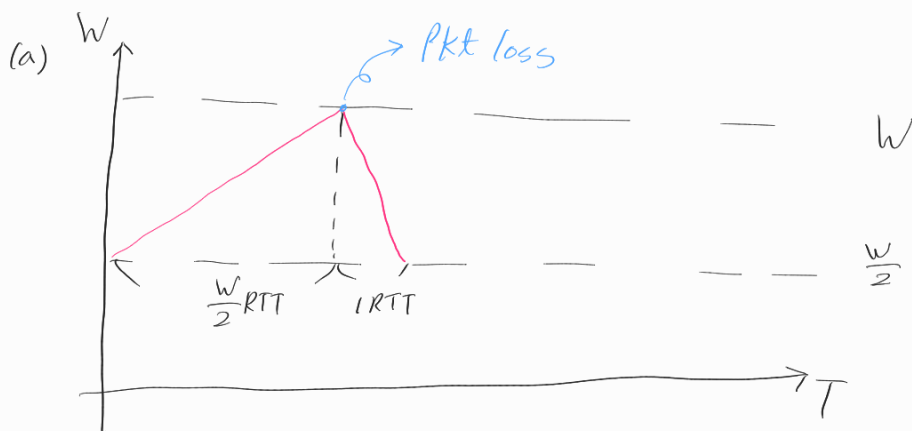
$$6MSS \sim 12MSS \Rightarrow 6RTT \quad \therefore 6RTT$$



$$\left(\frac{3}{4} \cdot \frac{12MSS}{RTT} = \frac{9MSS}{RTT} \right)$$

$$\therefore \frac{9MSS}{RTT}$$

6.



Avg Throughput

$$= \frac{3}{4} \frac{W MSS}{RTT}$$

$$\frac{3}{4} W \left(\frac{W}{2} + 1 \right) = \frac{3}{8} W^2 + \frac{3}{4} W \Rightarrow \# \text{ of pkt.}$$

There was only one loss.

$$\therefore L = \frac{1}{\frac{3}{8} W^2 + \frac{3}{4} W}$$

$$(b) \quad \frac{3}{8} W^2 \gg \frac{3}{4} W \rightarrow L \approx \frac{1}{\frac{3}{8} W^2} = \frac{8}{3W^2}$$

$$\sqrt{L} = \frac{1}{W} \sqrt{\frac{8}{3}} \Rightarrow W = \sqrt{\frac{8}{3L}}$$

$$\text{Avg throughput} = \frac{3W \cdot MSS}{4RTT} = \frac{3 \cdot \sqrt{8} \cdot MSS}{4\sqrt{3L} \cdot RTT} = \frac{1 \cdot MSS}{RTT\sqrt{L}} \times \frac{3\sqrt{8}}{4\sqrt{3}}$$

$$\left(\because \frac{3\sqrt{8}}{4\sqrt{3}} \approx 1.22 \right)$$

$$\approx \frac{1.22 \cdot MSS}{RTT\sqrt{L}}$$

7.

$$2\text{-way } d_{\text{prop}} = RTT = 150\text{ms} = 0.15\text{s}$$

$$MSS = 1500\text{byte}$$

$$\text{Throughput}_{\text{max}} = 10\text{Mbps}$$

(a)

$$\frac{W_{\text{max}} \cdot MSS}{RTT} = 10^7\text{bps} \Rightarrow W_{\text{max}} = 10^7\text{bps} \times \frac{0.15\text{s}}{1500 \cdot 8\text{bit}} = 125$$

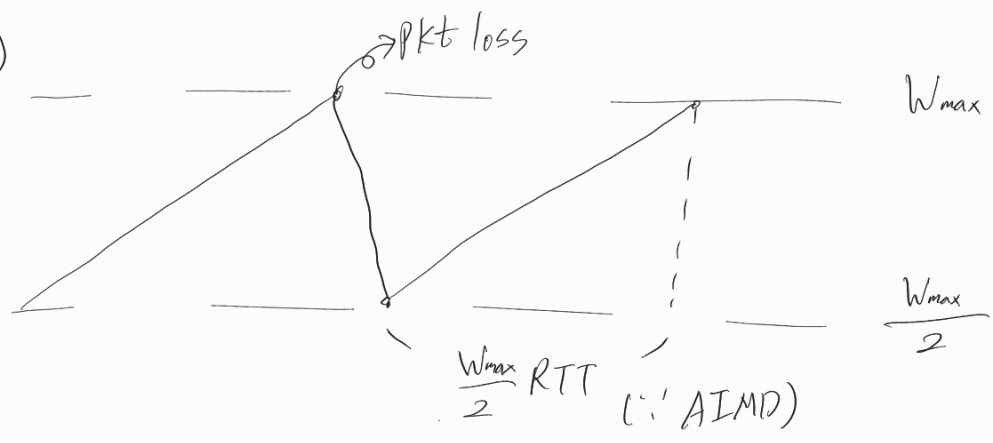
\therefore 125 segments

(b)

$$\text{Avg Throughput} = \frac{3}{4} \frac{W_{\text{max}} \cdot MSS}{RTT} = \frac{3}{4} \times 10\text{Mbps} = 7.5\text{Mbps}$$

$$\text{Avg Window size} = \frac{3}{4} \times W_{\text{max}} = \frac{3}{4} \times 125 = 93.75\text{ segments}$$

(c)



$$\frac{125}{2} \times 0.15\text{s} = 9.375\text{s}$$

$$\therefore 9.375\text{s}$$