1) sequence number is 32 bits in TCP
Why is it possible to wrap around from $2^{32}-1$ to 0
if less than 2^{32} bytes of data are sent?

The sequence number in TCP is chosen Randomly, so it is possible that the sequence number chosen for the start is close to 2^{32}. In that case a regular message could be long enough to cause the sequence number to wrap

Hw #8 Solutions

P2) $1\,Gbps = 1\times10^9\,bps$

RTT = 100 ms   MSL = 30 seconds

a) advertised window needs to keep the pipe full. Use RTT of 100 ms since sender transmitts that long before receiving an Ack for the first byte of data sent.

$\frac{1}{8}\times10^9$ Bytes per second $(100\,ms) = 12.5\times10^6$ bytes

$$2^n \geq 12.5\times10^6 \text{ Bytes}$$

$$n \geq \frac{\ln(12.5\times10^6)}{\ln 2} = 23.575$$

$\therefore \boxed{n = 24 \text{ bits}}$ for advertisedwindow

for sequence number, no wrap around in 30 seconds

$$\frac{1}{8}\times10^9 \frac{\text{Bytes}}{\text{sec}}(30\text{ sec}) = 3.75\times10^9 \text{ Bytes}$$

So $2^n \geq 3.75\times10^9 \Rightarrow n \geq \frac{\ln 3.75\times10^9}{\ln 2} = 31.8$

$\therefore \boxed{n = 32 \text{ bits (or more)}}$

b) BW comes from the network - hardware connecting to the network or the network itself will limit transmission rate

RTT - is measured (sampled) for Dynamic Networks or known for static networks

MSL - depends on Network topology - size of the network and the connections.

3) 1 Gbps $= 1 \times 10^9$ bps TCP being used

a) how long for sequence numbers to wrap

2^{32} bytes $= 2^{35}$ bits have to be sent

$$\text{time} = \frac{2^{35} \text{ bits}}{1 \times 10^9 \text{ bits/sec}} = \boxed{34.3597 \text{ seconds}}$$

b) 32 bit time stamp field

increments by 1000 every time sequence #'s wrap.

how long for the time stamp to wrap around

$$\frac{2^{32}}{1000} = \text{Number of } 34.3597 \text{ second intervals for wraparound to occur}$$

$$\therefore \text{ time} = 34.3597\left(\frac{2^{32}}{1000}\right) = \boxed{147.573788 \times 10^6 \text{ seconds}}$$

$= 40.99272 \times 10^3$ hours

$= 1708.03$ days

$= 4.6795$ years

4) a) Fair queueing $A_i = 0$ for all packets
all packets queued at same time

$F_i = \text{MAX}(A_i, F_{i-1}) + P_i = F_{i-1} + P_i$ for this problem since $A_i = 0$ for all packets

Packet #	Size	Flow	$F_i = F_{i-1} + P_i$
1	100	1	100
2	100	1	200
3	100	1	300
4	100	1	400
5	190	2	190
6	200	2	390
7	110	3	110
8	50	3	160

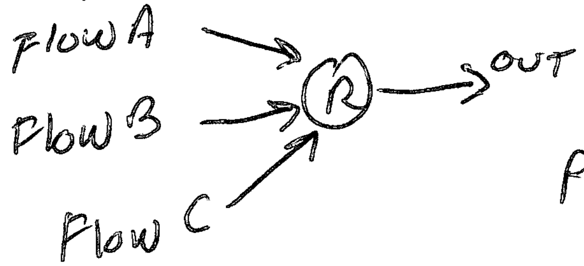
Packet order: 1, 7, 8, 5, 2, 3, 6, 4

b) weighted fair queue

Packet #	Size	Flow	wt	$F_i = F_{i-1} + \frac{P_i}{wt}$
1	100	1	1	100
2	100	1	1	200
3	100	1	1	300
4	100	1	1	400
5	190	2	4	47.5
6	200	2	4	97.5
7	110	3	1	110
8	50	3	1	160

Packet order: 5, 6, 1, 7, 8, 2, 3, 4

5) packets are constant size



one packet / wall time unit out

Packets are received & transmitted on wall clock time units

$P_i = 1$ (all packets same size)

tie resolution Flow A, B, C

a) Fair queue: $F_i = \max(F_{i-1}, A_i) + P_i$

Flow A: 1, 2, 4, 7, 9

Flow B: 2, 3, 5, 6

Flow C: 1, 3, 4, 5, 7, 8, 9

See next page for excel table (page 6)

b) Weighted Fair Queue. Flow C has weight 2

for Flow C $F_i = \max(F_{i-1}, A_i) + \frac{P_i}{2}$

See Page 7 for results

Fair Queue

					Queues		
wall clock	Ai	Arrivals	Fi	Sent	Flow A	Flow B	Flow C
1	1.000	A1 C1	2.000 2.000	A1	A1		C1
2	1.500	A2 B2	3.000 2.500	C1	A2	B2	C1
3	1.833	B3 C3	3.500 3.000	B2	A2	B2,B3	C3
4	2.166	A4 C4	4.000 4.000	A2	A2, A4	B3	C3, C4
5	2.500	B5 C5	4.500 5.000	C3	A4	B3.B5	C3, C4, C5
6	2.833	B6	5.500	B3	A4	B3.B5, B6	C4, C5
7	3.166	A7 C7	5.000 6.000	A4	A4, A7	B5, B6	C4, C5, C7
8	3.500	C8	7.000	C4	A7	B5, B6	C4, C5, C7, C8
9	3.833	A9 C9	6.000 8.000	B5	A7, A9	B5, B6	C5, C7, C8, C9
10	4.166			A7	A7, A9	B6	C5, C7, C8, C9
11	4.500			C5	A9	B6	C5, C7, C8, C9
12	4.833			B6	A9	B6	C7, C8, C9
13	5.166			A9	A9		C7, C8, C9
14	5.666			C7			C7, C8, C9
15	6.666			C8			C8, C9
16	7.666			C9			C9

Sending Queue		
Packet	Fi	Order
A1	2.000	1
C1	2.000	2
A2	3.000	4
B2	2.500	3
B3	3.500	6
C3	3.000	5
A4	4.000	7
C4	4.000	8
B5	4.500	9
C5	5.000	11
B6	5.500	12
A7	5.000	10
C7	6.000	14
C8	7.000	15
A9	6.000	13
C9	8.000	16

Weighted Fair Queue

					Queues		
wall clock	Ai	Arrivals	Fi	Sent	Flow A	Flow B	Flow C
1	1.000	A1 C1	2.000 1.500	C1	A1		C1
2	1.500	A2 B2	3.000 2.500	A1	A1, A2	B2	
3	2.000	B3 C3	3.500 2.500	B2	A2	B2,B3	C3
4	2.333	A4 C4	4.000 3.000	C3	A2, A4	B3	C3, C4
5	2.666	B5 C5	4.500 3.500	A2	A2, A4	B3.B5	C4, C5
6	3.000	B6	5.500	C4	A4	B3.B5, B6	C4, C5
7	3.333	A7 C7	5.000 4.000	B3	A4, A7	B3, B5, B6	C5, C7
8	3.666	C8	4.500	C5	A4, A7	B5, B6	C5, C7, C8
9	4.000	A9 C9	6.000 5.000	A4	A4, A7, A9	B5, B6	C7, C8, C9
10	4.333			C7	A7, A9	B5, B6	C7, C8, C9
11	4.666			B5	A7, A9	B5, B6	C8, C9
12	5.000			C8	A7, A9	B6	C8, C9
13	5.333			A7	A7, A9	B6	C9
14	5.666			C9	A9	B6	C9
15	6.000			B6	A9	B6	
16	6.500			A9	A9		

Sending Queue		
Packet	Fi	Order
A1	2.000	2
C1	1.500	1
A2	3.000	5
B2	2.500	3
B3	3.500	7
C3	2.500	4
A4	4.000	9
C4	3.000	6
B5	4.500	11
C5	3.500	8
B6	5.500	15
A7	5.000	13
C7	4.000	10
C8	4.500	12
A9	6.000	16
C9	5.000	14