1. Sequence numbers are implemented to detect segment duplicates. Once an ACK packet is received, the receiver moves to the next state, therefore do not require sequence numbers since this would inherently ignore duplicate ACK packets.
2. For each sample we will use the following equations:

EstimatedRTT = α \* SampleRTT + (1-α) \* EstimatedRTT

DevRTT = β \* |SampleRTT – EstimatedRTT| + (1-β) \* DevRTT

TimeoutInterval = EstimatedRTT + 4 \* DevRTT

# Sample: 85ms

EstimatedRTT = 0.2 \* 85ms + (1 - 0.2) \* 110 = **105ms**

DevRTT = 0.25 \* |85 – 105| + (1 – 0.25) \* 10 = **12.5ms**

TimeoutInterval = 105 + 4 \* 12.5 = **155ms**

# Sample: 130ms

EstimatedRTT = 0.2 \* 130 + (1 - 0.2) \* 105 = **110ms**

DevRTT = 0.25 \* |130 –110| + (1 – 0.25) \* 12.5 = **14.38ms**

TimeoutInterval = 110 + 4 \* 14.38 = **167.5ms**

# Sample: 108ms

EstimatedRTT = 0.2 \* 108 + (1 - 0.2) \* 110 = **109.6ms**

DevRTT = 0.25 \* |108 – 109.6| + (1 – 0.25) \* 14.38 = **11.18ms**

TimeoutInterval = 109.6 + 4 \* 11.18 = **154.33ms**

# After 72ms

EstimatedRTT = 0.2 \* 72 + (1 - 0.2) \* 109.6 = **102.08**

DevRTT = 0.25 \* |72 – 102.08| + (1 – 0.25) \* 11.18 = **15.91ms**

TimeoutInterval = 102.08 + 4 \* 15.91 = **165.70ms**

# After 142 ms

EstimatedRTT = 0.2 \* 142 + (1 - 0.2) \* 102.08= **110.06ms**

DevRTT = 0.25 \* |142 – 110.06| + (1 – 0.25) \* 15.91 = **19.91ms**

TimeoutInterval = 110.06 + 4 \* 19.91 = **189.72ms**

# After 64 ms

EstimatedRTT = 0.2 \* 64 + (1 - 0.2) \* 110.06 = **100.85ms**

DevRTT = 0.25 \* |64 – 100.85| + (1 – 0.25) \* 19.91 = **24.15ms**

TimeoutInterval = 100.85 + 4 \* 24.15 = **197.44ms**

# After 153 ms

EstimatedRTT = 0.2 \* 153 + (1 - 0.2) \* 100.85 = **111.28ms**

DevRTT = 0.25 \* |153 – 111.28| + (1 – 0.25) \* 24.15 = **28.54ms**

TimeoutInterval = 111.28 + 4 \* 28.54 = **225.44ms**

1. Sequence Number: 347

Source Port Num: 3120

Destination Port Num: 5470

1. Ack Num: 257
2. Ack Num: 347

Chart, line chart

Description automatically generatedSource Port Num: 5470  
Destination Port Num: 3120



1. Letting X be the sequence number space and N be the window size:   
     
   a. For GBN,   
    X >= N + 1

X – 1 >= N  
The largest window size (N) would be X - 1

b. For SR,   
 X >= 2(N)

X/2 >= N

The window cannot exceed half the sequence space.

1. See table:

|  |  |  |
| --- | --- | --- |
| **Tx Number** | **Tx Window** | **Threshold** |
| 0 | 06 | 32 |
| 1 | 12 | 32 |
| 2 | 24 | 32 |
| 3 | 30 | 32 |
| 4 | 36 | 32 |
| 5 | 42 | 32 |
| 6 | 48 | 32 |
| TIMEOUT OCCURS | | |
| 7 | 06 | 24 |
| 8 | 12 | 24 |
| 9 | 24 | 24 |
| 10 | 30 | 24 |
| 11 | 36 | 24 |
| 12 | 42 | 24 |
| TRIPLE DUPLICATE ACK OCCURS | | |
| 13 | 18 | 18 |
| 14 | 24 | 18 |
| 15 | 30 | 18 |
| 16 | 36 | 18 |
| 17 | 42 | 18 |

1. a.   
    GBN: 12 segments, 11 ACKS

SR: 8 segments, 7 ACKS

TCP: 12 segments, 11 ACKS  
  
b. TCP will reliably deliver all data segments in the least amount of time since it implements triple duplicate ACK retransmit without waiting for timeout.