

ECE 461 – Internetworking

Problem Sheet 6

Problem 1. Consider the state of a sliding window at the sending side of a TCP connections as shown in Figure 1. (Each number corresponds to one byte).

- Explain the difference between the advertised window and the usable window.
- Start with the state shown in Figure 2. How many bytes can be transmitted in the shown state? What are the sequence numbers of the bytes that can be transmitted?
- Start with the state shown in Figure 2. Show how the advertised and usable windows change when the sender transmits a 2-byte long segment.
- Start with the state shown in Figure 2. Show how the advertised and usable windows change when a segment with ($AckNo=5$, $Window\ size = 5$) is received.
- Start with the state shown in Figure 2. Show how the advertised and usable windows change when a segment with ($AckNo=3$, $Window\ size = 5$) is received.

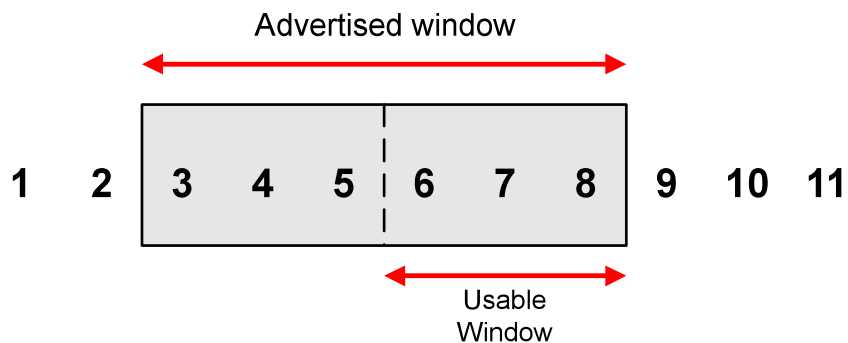
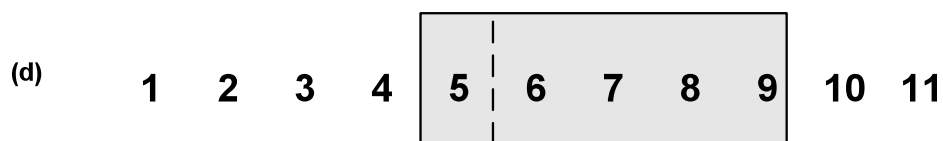
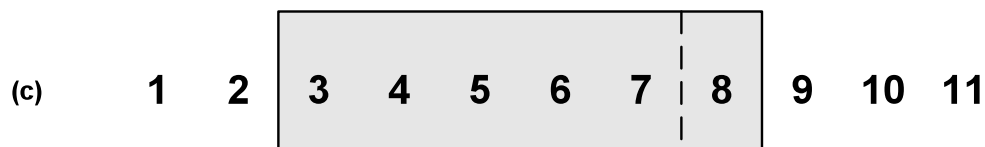
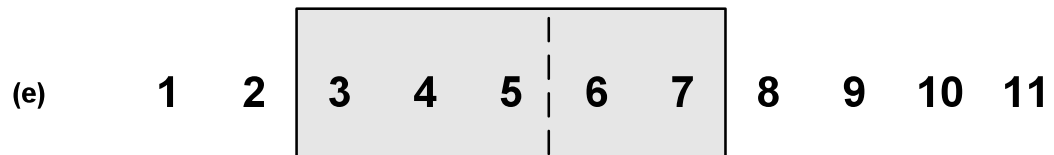


Figure 1.

- The advertised windows is the maximum number of unacknowledged bytes that the sender can transmit. The advertised window is set (=advertised) by the receiver. The usable windows is the advertised window minus the number of bytes which have been transmitted but have not been acknowledged.
- The sender can transmit 3 bytes with sequence number 6,7,8.

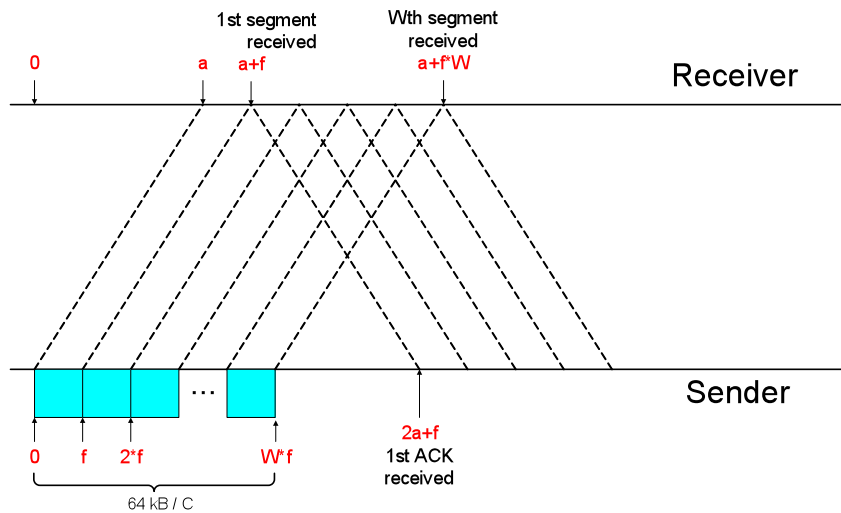




Problem 2. Consider a TCP connection with a roundtrip delay of 10 milliseconds. What is the maximum achievable throughput of the TCP connection? How does the throughput change if the roundtrip time increases to 40 milliseconds?

Solution:

- We ignore the transmission time of an ACK.
- The maximum size of the congestion window is approximately 64 KB ($2^{16}-1$).
- Let us consider a “round of transmission” of the maximum congestion window:
 - 64 KB are sent as segments to the receiver, sent as W segments/
 - Assume segment size is 1kB (MSS = 1kB)
 - At the receiver, each (or every second) segment is acknowledged.
- The transmission occurs a “round of transmission” of the maximum congestion window:



C = capacity of network (in bit/sec)
 f = transmission time of a segment ($f = 1\text{ kB} / C$)
 a = propagation delay between sender and receiver (roundtrip delay = $2a$)
 W = maximum window size (= 64 segments)

Note: 1 B = 1Byte = 8 bits !

There are two scenarios:

Scenario 1: $2a + f \leq Wf$

In this case, the first acknowledgement arrives before the entire congestion window (with W segments) has been transmitted. Then, the sender can continuously transmit. Here the throughput (TPut) is equal to the capacity C .

Plugging in the values in the condition:

$$10 \text{ ms} + 1\text{ kB} / C \leq 64 \text{ kB} / C$$

Solving for C :

$$C \leq 63 \text{ kB} / 10 \text{ ms}$$

$$C \leq 50.4 \text{ Mbit/sec}$$

Scenario 2: $2a + f > Wf$

In this case, the entire window (of 64 kB) has been transmitted before an acknowledgement has arrived. Here, the sender has to wait for the acknowledgment to arrive.

Thus, the sender can transmit at most 64 kB of data in each a time interval of $2a + f$. So, the throughput (TPut) is

$$64 \text{ kB} / (2a + f) = 64 \text{ kB} / (10 \text{ ms} + 1\text{ kB} / C)$$

This gives:

$$C = 60 \text{ Mbit/sec} \quad \text{TPut} \sim 50.54 \text{ Mbit/sec}$$

C = 100 Mbit/sec	TPut ~ 50.79 Mbit/sec
C = 1 Gbit/sec	TPut ~ 51.15 Mbit/sec
C = infinite	TPut ~ 51.2 Mbit/sec

Result:

- Throughput increases with capacity C.
- Maximum throughput $TPut_{max}$ is given by:

$$TPut_{max} = \text{max. window size} / (\text{round trip delay})$$
- Increase roundtrip delay from 10ms to 40 ms
 → decreases maximum throughput by a factor of four

Problem 3. Assume that we have a TCP connection between A and B. Assume that A uses slow start and congestion avoidance with the following initial values:

Congestion window (at time=0): $cwnd=12$ segment.

Slow-start threshold: $ssthresh=5$ segments.

For the purposes of this problem, assume that $MSS=100$ Bytes.

Assume that the following events occur at A:

Time t = 0: A sends segment with 100 bytes to B, starting with SeqNo=0.

Time t = 1: A receives an ACK with AckNo=100

Time t = 2: A sends segment with 100 bytes to B, starting with SeqNo=100.

Time t = 3: A sends segment with 100 bytes to B, starting with SeqNo=200.

Time t = 4: A receives an ACK with AckNo=100.

Time t = 5: A sends segment with 100 bytes to B, starting with SeqNo=300.

Time t = 6: A receives an ACK with AckNo=100.

Time t = 7: A sends segment with 100 bytes to B, starting with SeqNo=400.

Time t = 8: A receives an ACK with AckNo=100.

- Describe the actions performed by TCP Tahoe at time t=8, and describe the values of $cwnd$ and $ssthresh$ after the actions are performed.
- Describe the actions performed by TCP Reno at time t=8, and describe the values of $cwnd$ and $ssthresh$ after the actions are performed.
- For both TCP Tahoe and TCP Reno, describe the actions performed when a timeout occurs between times t=5 and t=6.

