I Stop-n-Wait-n-Answer

1. **[10 points]:**

An application needs to send 100KB of data using a stop-and-wait reliable protocol. The protocol splits the data into segments that have a 1KB application data payload. Each segment fits in a single IP packet. The RTT is 50ms, there is no packetization delay, and no queueing delay. The protocol uses a fixed retransmission timeout of 200ms and has no retransmission limit.

(i) How long will the transmission take, in seconds, if the network does not drop, duplicate or corrupt any packets? You may assume the connection is established when you start your measurement, so there is no additional latency from connection setup and consists only of data transmissions. Your answer must be accurate to two decimal points (10ms).

50ms for one packet

⇒ 50ms × 100 = 5000 ms

⇒ 5 seconds

5 seconds

(ii) Let us now suppose that the network drops each segment with a probability of 10%, independently from segment to segment. The network drops both data and acknowledgements. What is the *expected* duration of the transmission? Show your calculations. Your answer must be accurate to two decimal points (10ms).

(9.6s if retransmits can be dropped too). 8

8.8 seconds

100 packets ⇒ ~~10 packets dropped~~

~~100 acks~~ ⇒ 10 acks dropped.

On average, 10 packets will be dropped

⇒ 90 packets won't be dropped but 10% acks will

⇒ we won't get acks for 9 of these 90 packets.

$$\Rightarrow 50ms \times 81 + \underbrace{200ms \times 19}_{19 \text{ timeouts}} + \underbrace{50ms \times 19}_{\text{retransmit}}$$

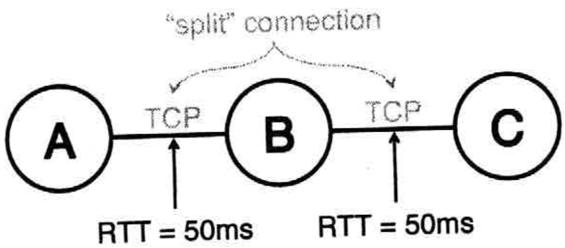
= 5s + 3800 ms

= 8.8 seconds

[I assumed retransmitted packets won't be dropped. If they are also dropped, look on left]

II Without TCP The Internet Ain't Nuthin'

There are devices and services in the Internet, such as proxy servers, that "split" TCP connections. Suppose a host A wants to open a connection to a host C. A device somewhere along the path, B, can terminate A's connection at itself, and open a connection to C. So in this case there are now two TCP connections, A to B and B to C. A thinks it's sending data to C, but B is processing the TCP segments itself and sending acknowledgments back to A, spoofed from B's IP address. Simultaneously, B opens a TCP connection to C, pretending to be A.



Suppose you have the network above, where the RTT from A to B is 50ms, the RTT from B to C is 50ms, and there is no packetization, queueing, or processing delay, such that the RTT from A to C is 100ms. The maximum segment size is 1400 bytes. A is sending an infinite stream of bytes, such that every segment is the maximum segment size. Recall that a TCP flow's throughput can be approximated as

$$\text{MSS} \cdot \sqrt{\frac{3}{2}} \cdot \frac{1}{\text{RTT}\sqrt{p}}$$

where p is the packet drop rate.

Please write out answers numerically and do not leave radicals or variables in your solutions. You may leave fractions. If you do not have a calculator, you may approximate with the following values:

$$MSS \cdot \sqrt{\tfrac{3}{2}} = 13,717 \text{ bits}$$

$$\sqrt{0.1} = 0.32$$

$$\sqrt{0.19} = 0.44$$

$$\sqrt{0.2} = 0.45$$

$$\sqrt{0.21} = 0.46$$

MSS $\sqrt{\frac{3}{2}} \cdot \frac{1}{RTT\sqrt{p}}$

2. [5 points]:

Suppose that B does not split the TCP connection, such that packets flow directly from A to C, through B. The route between A and B drops 10% of data segments and does not drop acknowledgments, while the route between B and C does not drop any packet. What will the TCP throughput from A to C be?

857.3

$16 \overline{)13717}$ 128 91 80 117 112 50

~~0.43 kbps~~ ~~43.49 kbps~~ $\boxed{428.7 \text{ kbps}}$

~~42.87 kbps~~

~~0.86 kbps~~ kbps

$1\cancel{40}28 \times 8 \text{ bits} \times \sqrt{\frac{3}{2}} \cdot \frac{1}{100 \cdot \sqrt{0.1}}$ + min(∞, prev throughput)

$= 13717 \times \frac{1}{\cancel{50 \times 0.32}\ 32} = \frac{13717}{16} = 857.3$ bps

$= 0.\frac{86}{2}$ kbps

$13717 \times \frac{1}{0.15 \times 0.32} = \frac{13717 \times 10^3}{32}$

$= 6.43$ kbps

$= 43.49 \times 10^3$ bits/s

$= 43.4$

43.49

$32 \overline{)13717}$ 128 91 96 157 128 290

3. [5 points]:

Suppose that B does split the connection, such that packets flow from A to B, terminate at B, then are forwarded in separate flow from B to C. The route between A and B drops 10% of data segements and drops no acknowledgments, while the route between B and C does not drop any packet. What will the throughput from A to C be?

42.87

$32 \overline{)13717}$ 128 91 64 277 256 210

~~0.86~~ kbps

2 × value of (2)

= 2 × 42.88

~~= 86.98 kbps~~

= $\boxed{\cancel{85.73 \text{ kbps}}}$

= $\boxed{857.3 \text{ kbps}}$

4. [5 points]:

Suppose that B does split the connection, such that packets flow from A to B, terminate at B, then are forwarded in separate flow from B to C. The route between A and B drops 10% of packets, and the route between B and C also drops 10% of packets. What will the throughput from A to C be?

If initially, we had 100 packets
at B, we have 90 packets. and
at C we have 81 packets
⇒ 19% drop rate

~~311.7~~ kbps

$$M.SS \sqrt{\tfrac{3}{2}} \times \frac{1}{RTT} \cdot \frac{1}{\sqrt{P}}$$

$$= 13717 \times \frac{1}{0.1s} \times \frac{1}{\sqrt{0.19}} = \frac{13717}{0.1 \times 0.44} = \frac{13717}{1 \times 44} \times \cancel{10^3\ \text{bits}}\ \text{kbps}$$

311.7

44) 13717

5. [5 points]:

Finally, suppose that B does not split the connection, such that packets flow from A to C passing through but not terminating at B. The route between A and B drops 10% of data segments, and the route between B and C also drops 10% of data segments. What will the throughput from A to C be?

311.7 kbps