(1) A channel has a data rate of R bps and a propagation delay of t sec/km. The distance between the sending and receiving node is L km. Nodes exchange fixed-size frames of B bits using sliding window protocol with Go-back-N ARQ. Assume that ACK frames are negligible in size and processing time at the node is also negligible.

(a) Find a formula that gives the required window size W (in terms of R, t, B and L) for maximum channel utilization.

(b) Find a formula that gives the minimum value of K (in terms of R, t, B and L) corresponding to the window size W obtained above, where K is the number of bits used for the representation of sequence number.

Solⁿ: Propagation time $= Lt$. Transmission time $= B/R$

~~RTT~~ Round-trip propagation time $= \frac{B}{R} + 2Lt$

$$\text{utilization} = \frac{W \cdot B/R}{\frac{B}{R} + 2Lt} = \frac{W}{1 + 2\frac{LtR}{B}}$$

Maximum utilization implies

$$W = 1 + \frac{2LtR}{B}$$

$$\Rightarrow 2^k - 1 = 1 + \frac{2LtR}{B}$$

$$\Rightarrow k = \left\lceil \log_2\left(2 + \frac{2LtR}{B}\right) \right\rceil$$

(P2)

(2)(a) A sliding-window protocol with selective repeat is using 7 bits to represent the sequence numbers. What is the size of the window.

Ans: $2^7/2 = 2^6 = 64$

(b) ~~For~~ For sliding window protocol with go-back-N, the size of the ~~sender~~ window would be 2^7-1.

(c) Frames are generated at node A and sent to C through B. Determine the minimum transmission rate (in kbps) required between B and C so that buffers at B are not flooded, based on the following;

(A) —— 4000km —— (B) —— 1000km —— (C) (full-duplex error free lines)

i) data rate between A & B is 100 kbps

ii) prop delay is 5 μsec/km for both lines.

iii) data frames are 1000 bits long. ACK frames are of negligible size.

iv) Between A & B: sliding window with window size 3.

v) Between B & C, stop-and-wait is used.

Sol: $A \to B$ Prop time $= 4000 \times 5\ \mu sec = 20$ msec

Tram time $= 1000 / 100\times10^3 = 10$ msec

(P3)

$B \to C$ Prop time $= 1000 \times 5\ \mu sec = 5$ msec

Trans time $= 1000/R$ (R = data rate between B and C)

Sliding-window with $w = 3$, A can transmit 3 frames before waiting for ack. $\left(\underset{10\ msec}{\overset{A}{\downarrow}} \underset{\leftarrow 20\ msec}{\xrightarrow{20\ msec}} B \right)$. A can transmit 3 frames in 50 msec. $\left(\underset{\frac{1000}{R} msec}{\overset{B}{\downarrow}} \underset{\leftarrow 5\ msec}{\xrightarrow{5\ msec}} C \right)$. B can transmit 1 frame in $\left(10 + \frac{1000}{R}\right)$ msec. So for 3 frames, $\left(30 + 3\frac{1000}{R}\right)$ msec.

To not flood, $30 + 3\frac{1000}{R} = 50 \Rightarrow R = 150$ kbps.

(3) Frames of 1000 bits are sent over a 1 Mbps channel using geostationary satellite whose propagation time from earth is 270 msec. Ack are piggybacked. 3-bit sequence numbers are used. What is the max channel utilization.

a) Stop-and-wait.
b) go-back-N
(c) Selective Repeat.

At $t=0$, frame start and at $t=1$ the frame fully transmitted. At $t=271$ msec the frame arrive at the receiver. At $t=272$ msec, the frame acking the frame is transmitted fully. At $t=272+270=542$ msec the ack bearing frame fully arrived at the sender. So the cycle is 542 msec. During 542 msec, let k frames are transmitted. So, efficiency $= \frac{k}{542}$.

Time to transmit 1000 bits @ 1 Mbps = 1 msec

(a) $k=1$ (stop-and-wait) $= \frac{1}{542}$

(b) $k=7$ ($2^3-1=7$, 3-bit sequence number) $= \frac{7}{542}$

(c) $k=4$ ($2^3/2 = 8/2 = 4$, 3-bit sequence number) $= \frac{4}{542}$.

Efficiency in Stop-and-wait protocol:

Let l = frame size, b = bit rate.

(P4) Time to transmit a frame = l/b

Let R be round-trip-propagation time.

Then efficiency = $\dfrac{l/b}{l/b + R}$.

No error

Let RTT = Round-trip time = packet transmission time + 2 propagation delay + ack transmission time (when no error is considered).

Let λ be the packet loss probability.

Let $1-\lambda$ be prob that no retransmission is required. that is, the packet reaches destination and the ack reaches the source. So with (λ) prob, retransmission is required. Let T = expected time to send a packet and get its ack back.

$$T = (1-\lambda)\,RTT + \lambda(RTO + T)$$

where RTO is time out interval.

$$T = RTT + \frac{\lambda}{1-\lambda} RTO.$$

Expected throughput = $\frac{1}{T}$ packet per second.

(B)

Suppose two nodes communicate with each other using a stop-and-wait protocol. The data packet size is 10000 bits. The total round-trip time (RTT) between the nodes is equal to 0.2 milliseconds (that includes the time to process the packet, transmit an ACK, and process the ACK at the sender) plus the transmission time of the 10000 bit packet over the link. Suppose you have two options to configure your connections with the following properties: 1) if you choose 10 Megabits/s, the bi-directional packet loss probability will be $1/11$, 2) if you choose 20 Megabits/s, the bi-directional packet loss probability will be $1/4$. For both bit rates, the retransmission timeout (RTO) is 2.4 milliseconds. For each bit rate, calculate the expected time, in milliseconds, to successfully deliver a packet and get an ACK for it. Show your work. Suppose your goal is to select the bit rate that provides the higher throughput for
a stream of packets that need to be delivered reliably between the nodes. Which bit rate would you choose to achieve your goal?

Sol:

Expected time $T = RTT + \frac{l}{1-l}RTO$. If you put the given values, RTT ($0.2 \;ms+\frac{10000}{10 \times 10^6}\time 10^3\;ms=0.2+1=1.2\;ms$ or $0.2 \;ms+\frac{10000}{20 \times 10^6}\time 10^3\;ms=0.2+0.5=0.7\;ms$) is found to be 1.2 ms for 10 Megabits/s and 0.7 ms for 20 Megabits/s. The expected times are 1.44 ms for 10 Megabits/s and 1.5 ms for 20 Megabits/s. We would choose the first rate, 10 Megabits/s, because it offers a better expected
throughput (1/T).

10 mbps

$$T = RTT + \frac{l}{1-l}\cdot RTO$$

$$= 1.2 + \frac{\frac{1}{11}}{1-\frac{1}{11}}\cdot 2.4 \text{ ms.}$$

$$= 1.2 + 0.1 \times 2.4 = 1.44 \text{ ms}$$

10 mbps

$$RTT = 0.2 + \frac{10000}{10\times10^6}\times10^3 \text{ ms}$$

$$= 0.2 + 1 = 1.2 \text{ ms}$$

20 mbps

$$RTT = 0.2 + \frac{10000}{20\times10}\times10^3 \text{ ms}$$

$$= 0.2 + 0.5 = 0.7 \text{ ms}$$

20 mbps

$$T = 0.7 + \frac{\frac{1}{4}}{1-\frac{1}{4}}\cdot 2.4 \text{ ms}$$

$$= 0.7 + 0.8 = 1.5 \text{ ms}$$

throughput $= \frac{1}{T} = \frac{1}{1.44}$ (10 mbps) $>$ $\frac{1}{1.5}$ (20 mbps)

We would choose 10 mbps.