ECE 358: Tutorial Set 3 Solution

Note: Stop-and-go protocol = Alternate bit protocol = Stop-and-wait protocol

Problem 2*.

a) Suppose the Stop-and-go protocol is used with 840 byte data frames and 40 byte ack frames on a link with a 8 ms propagation delay in each direction. In the absence of transmission errors, what are the throughput (in packets per second) and efficiency if the link data rate is 1 kbps? 100 kbps? 10 Mbps? 1 Gbps?

b) You must have found the above protocol to be very inefficient over links with very high data rates. Let's try replacing it by a sliding window protocol. At 1 Gbps, what would the throughput and efficiency be if the window size is 10 packets? 100? 1000? 10,000? What is the ideal window size?

DATA Packet size: 840bytes=6720bits
ACK packet size 40bytes=320bits
P = propagation delay = 8ms
C= link data rate

Assume no transmission errors, negligible framing overhead, and negligible processing time p.

a) With the Stop-and-go protocol:

T = d + 2P + a + p = d + 2P + a (p is the processing time, assumed negligible)

T: Time to send a data frame and receive the corresponding ACK
d: Time to transmit a data frame
P: Time for the frame to propagate from the sender to the receiver
a: Time for the receiver to transmit an ACK

$$\text{Throughput} = \frac{1}{T} \text{ (packet/second)}$$

$$\text{Efficiency} = \frac{d}{T} \text{ (no units)}$$

C	d	a	P	T	Throughput	Efficiency
1kbps	6.72sec	320msec	8ms	7.056 sec	0.142pkts/s	95%
100kbps	67.2 msec	3.2 msec	8ms	86.4 msec	11.6 pkts/s	77.8%
10Mbps	0.672 msec	0.032msec	8ms	16.7 msec	59.9 pkts/s	4.0%
1Gbps	6.72 μsec	0.3 μsec	8ms	16 msec	62.5 pkts/s	0.042%

b) With a sliding window protocol under the same assumptions

$$\text{Efficiency} = \min[(\frac{W \cdot d}{T}),1]$$

(the throughput cannot be larger than C (C and throughput should be in the same units).

C	Window size	T	Throughput	Efficiency
1Gbps	10	16 msec	625 pkts/s	0.42%
1Gbps	100	16 msec	6.25 kpkts/s	4.2%
1Gbps	1000	16 msec	62.5 kpkts/s	42%
1Gbps	10,000	16 msec	148.8 kpkts/s	100%

The ideal window is: $W_i = \frac{T}{d} = 2381$ frames

Problem 4*

Assume that the propagation speed in a coaxial cable is $2 \cdot 10^8 m/\sec$

a) Packets are transmitted using the ABP (alternate bit protocol) over a full-duplex 5-km coaxial cable with a 10-Mbps transmission rate. The packets and ACKs are 1500 bits long. The transmitter and receiver use a CRC chip and their processing time is negligible. How many packets are transmitted every second when there is no transmission error?

b) Five transmission lines identical to the one discussed in a) are connected in series. A buffer is used at each connection between the links to store packets as required. How many packets will go through the five lines every second when there is no transmission errors? Now assume that a packet or its acknowledgement is corrupted on any given link with probability p. What is the new packet transmission rate through the five links? Compare the rate when there are no errors with the transmission rate when a single 25-km link is used and when there is no transmission error. Comment.

Assume the processing delays and queuing delays for both ends are negligible.

Given: Propagation speed in coaxial cable is $2 \cdot 10^8 m/\sec$

a) The one way propagation delay, P is:

$$P = \frac{5Km}{2 \cdot 10^5 Km/\sec} = 25\mu\sec$$

The transmission delays for ACK, a and for PDU, d are the same:

$$a = d = \frac{1500 bits}{10 \cdot 10^6 bits/\sec} = 150\mu\sec$$

T = d + 2P + a = 0.35 ms

$$\text{Throughput} = \frac{1}{T} = 3077 \text{ packets/s}$$

b) With no errors on the links, the throughput for the 5 links in series (corresponding to 5 independent ABP protocols) is $\frac{1}{T} = 3077$ packets/s because the first packet will be completely received by the first router after P+L/C and could then be sent immediately to the second router that would receive it after 2P+2L/C. If we have 5 links, we have a sender, a receiver and 4 routers in the middle. Hence the first packet would be received at 5P+5L/C. The second packet could leave the sender at T (assuming that the first packet left at t=0) and would arrive at T+P+L/C just in time at the first router to be sent to the second router (since all the links are identical). Hence the second packet would arrive at the receiver exactly T seconds later. Hence the throughput is exactly 1 packet every T seconds…

When p = 0.01, each link's throughput will be multiplied with (1-p) which is the probability that no errors occur for a PDU and its ACK. Now the end-to-end throughput is just like before the same as the throughput on one link and hence:

Throughput$_{\text{end-to-end}}$ = $\dfrac{(1-p)}{T} \approx 3046\, packets/s$ when p = 0.01.

For a 25 Km link, the round trip delay for sending one PDU and receiving its ACK is:

$T_{25Km} = a + d + 2P_{25Km} = 150\mu\sec + 150\mu\sec + \dfrac{2 \cdot 25Km}{2 \cdot 10^5\, Km} = 550\mu\sec$

Hence if no error occurs:

Throughput$_{25Km}$ = $\dfrac{1}{T_{25Km}} \approx 1818\, Packets/s$.

Comparing Throughput$_{25Km}$ with Throughput$_{\text{end-to-end}}$, we can see that multiple ABP in series provides a better throughput than a long ABP as long as each segment is identical (i.e., same length and same C).

Problem 6*

a) TCP slow start is operating in the intervals [1,6] and [23,26]
b) TCP congestion avoidance is operating in the intervals [6,16] and [17,22]
c) After the 16th transmission round, packet loss is recognized by a triple duplicate ACK. If there was a timeout, the congestion window size would have dropped to 1.
d) After the 22nd transmission round, segment loss is detected due to timeout, and hence the congestion window size is set to 1.
e) The threshold is initially 32, since it is at this window size that slow start stops and congestion avoidance begins.

f) The threshold is set to half the value of the congestion window when packet loss is detected. When loss is detected during transmission round 16, the congestion windows size is 42. Hence the threshold is 21 during the 18th transmission round.
g) The threshold is set to half the value of the congestion window when packet loss is detected. When loss is detected during transmission round 22, the congestion windows size is 26. Hence the threshold is 13 during the 24th transmission round.
h) During the 1st transmission round, packet 1 is sent; packet 2-3 are sent in the 2nd transmission round; packets 4-7 are sent in the 3rd transmission round; packets 8-15 are sent in the 4th transmission round; packets15-31 are sent in the 5th transmission round; packets 32-63 are sent in the 6th transmission round; packets 64 – 96 are sent in the 7th transmission round. Thus packet 70 is sent in the 7th transmission round.
i) The congestion window and threshold will be set to half the current value of the congestion window (8) when the loss occurred. Thus the new values of the threshold and window will be 4.