Electrical and Computer Engineering
Memorial University of Newfoundland

ENGI 9876 - Advanced Data Networks
Fall 2018

Problem Set 1

(Due: Friday, Sept. 28, 2018)

Question 1

Consider a communications path through a packet switching network with bit errors that occur independently with a probability of $P_e = 10^{-6}$. Packets travelling through the network are a fixed length of 864 bits consisting of the following fields:

Destination Address	32 bits
Information Field	800 bits
CRC	32 bits

(a) What is the probability that a packet is lost before arriving at the destination? (Assume that a packet is lost if the destination address is corrupted during transit. You may assume that the probability that a packet is lost due to queue overflow at switches is negligible.) What is the probability that a packet arriving at the destination is detected as having errors, assuming that the CRC is capable of detecting all errors?

(b) How many packets are expected to be sent before a packet needs to be retransmitted?

(c) Assume that 1000 packets are to be sent. What is the probability that three or more packets need to be retransmitted?

(d) Assuming that the CRC is capable of detecting one, two, or three bit error patterns, what is the probability that a received packet has errors that are detected? What is the probability that errors are not detected? Comment.

Question 2

A communications protocol implements an error control scheme by sending the information and CRC fields of a packet 3 times and performing a majority vote on each bit of the fields. For example, at the receiver, bit *i* of the information field is determined by a majority vote on the 3 copies of bit *i*. For the protocol, each packet is 864 bits long, consisting of a 32-bit destination field (which is not triplicated, but is only sent once), an 800-bit information field and a 32-bit CRC. At the transmitter, the CRC scheme is applied to the packet information field before the bits are triplicated..

(a) Assuming that bit errors occur independently in the communications channel with a probability of $P_e = 10^{-6}$, determine the probability that a bit in the information field is in error after the majority vote is applied at the receiver.

(b) Under this scenario, repeat Question 1 (a) and (b).

Question 3

A CRC is constructed to generate a 5-bit FCS for a 12-bit message. The generator polynomial is $p(x) = x^5 + x^2 + x + 1$.

(a) Determine the FCS for the data sequence 110110001100 (left most bit = MSB) using the generator polynomial $p(x)$.

(b) Now assume that the following frame is received. Determine whether it is likely that an error has occurred in the received frame.

01010001110100010

(c) Draw the shift register circuit that could be used to generate the FCS and show that it produces the FCS calculated in part (a).

Question 4

A packet of size 2000 bits travels through a packet switched network along a path that includes 8 links and 7 switches. While traversing each link, the packet is susceptible to random, independent bit errors. The bit error rate on various links is given by the following: $P_e = 10^{-4}$ on three links, $P_e = 5 \times 10^{-5}$ on three links, and $P_e = 10^{-5}$ on two links. The probably of packet loss in a switch due to buffer overflow is 10^{-6} for all switches in the network. Determine the probability that the packet needs to be retransmitted.

Question 5

Consider the transmission of a file of data over an error-free link of length 2000 km. The data rate on the link is 1 Mbps and the velocity of signal propagation is 2×10^5 km/s. The file contains 10 Mbytes of information. Data is to be transmitted over the link in packets consisting of 48 header bits, 1000 data bits, and 32 CRC bits. You may assume that the time to process an incoming packet (of any type) is negligible and acknowledgment packets are 64 bits in length.

(a) If a stop-and-wait flow control is used on the link, how long will it take to send the entire file of data?

(b) If a sliding window flow control with a maximum window size of 8 is used on the link, how long will it take to send the entire file of data?

(c) Consider now a change in the maximum window size used by the protocol. Determine the window size needed to allow maximize utilization of the link. Determine how long it will take to send the entire file of data for this scenario.

(d) Consider now that the link is not error-free but has a bit error rate of 10^{-4}. Bit errors occur randomly and independently. Repeat (a) for this new scenario assuming that all bit errors are detectable by the CRC scheme.

Question 6

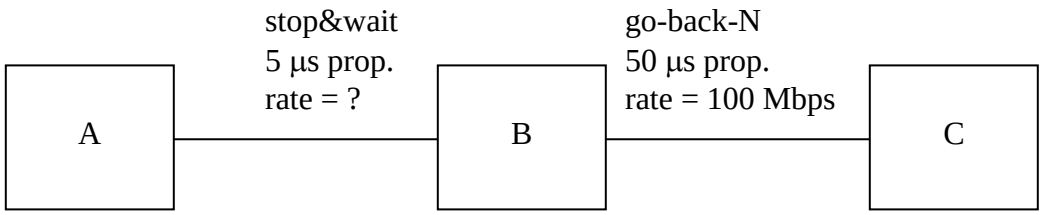
A communications link of length 50 km has a link rate of 10 Mbps. Data is to be transmitted in fixed-size packets of 500 bits, with acknowledgment packets of length 32 bits. The velocity of signal propagation is 2×10^5 km/s and the bit error rate is $P_e = 10^{-4}$. The processing time for any packet is negligible. The protocol to be used is a selective-reject ARQ protocol, with a CRC that detects all errors. What is the minimum size of the sequence number field to ensure the maximum possible utilization of the link. What is the maximum utilization? HINT: Consider a failed transmission as overhead in the calculation of the utilization.

Question 7

Consider the communications system below. Data is transmitted from A to B and then from B to C using fixed size packets of 1000 bits. The protocol used on link AB is a stop-and-wait ARQ. The packets arriving at B are forwarded onto C using a go-back-N ARQ protocol with the number of bits in the sequence number field given by $k = 3$. The one-way propagation delay on link AB is 5 μs and the one-way propagation delay on link BC is 50 μs. The link rate for link BC is 100 Mbps.

(a) Assuming that the bit error rate on both links AB and BC is zero, what is the maximum link rate on link AB to ensure that the buffers at B do not overflow? You may assume that acknowledgement packets are negligible in size and that there are no delays in a receiver sending an ACK after a data packet has been received. Be sure to state any other assumptions that you feel are reasonable to make in your analysis.

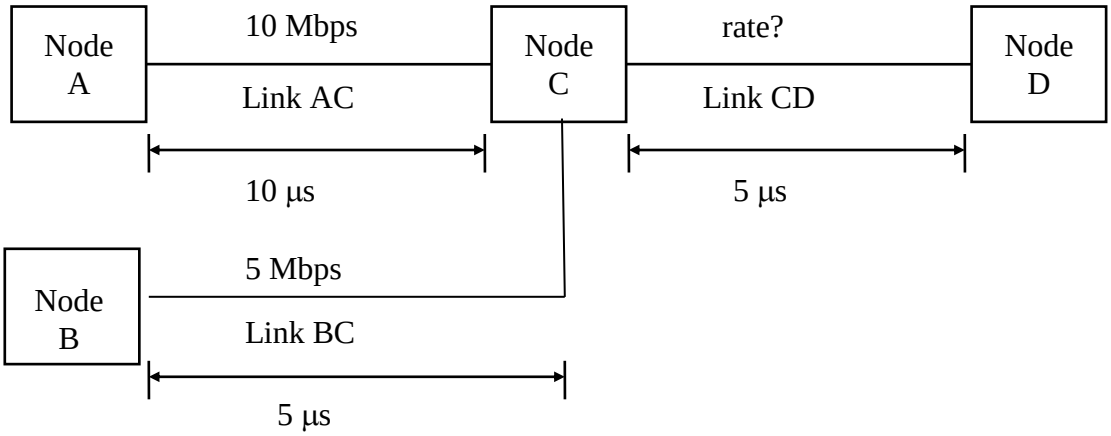
(b) Repeat (a) assuming that the bit error rate on link AB is $P_e = 10^{-4}$ and link BC is error-free. Assume that the CRC is able to detect all errors.



Question 8

Consider the communications system below. Data is transmitted from node A to node C in fixed-size packets of 1064 bits, of which 64 bits are control information such as a CRC frame check sequence, and data is transmitted from node B to node C in fixed-size packets of 264 bits, of which 64 bits are control information such as a CRC frame check sequence. At node C, the data field of each arriving packet from node A is divided into 5 blocks of data and each block has 64 bits of control information added and is then sent to node D as a 264 bit packet. Packets from node B are passed on to node D as 264 bit packets. The data rate and propagation delay for each link is shown on the diagram below, except that the rate on link CD is to be determined.

Assume that the links are error free. Given that stop-and-wait flow control is used on link AC and link CD and that sliding window flow control with maximum window size of $W = 7$ is used on link BC, determine the minimum rate required on link CD to ensure that the buffers at node C do not overflow. You may assume that the transmission time for an acknowledgement packet and the processing times for any packets are negligible.



Question 9

(a) Consider communication between two stations A and C which must communicate through node B and over two error-free links - AB and BC. The distances between the nodes and data rates on the links are: Link AB - 15 km, 5 Mbps Link BC - 10 km, 2 Mbps
Assuming that the packet sizes on both links are 1000 bits, determine the best case utilization of both links AB and BC for the following flow control protocols:
(i) stop-and-wait flow control
(ii) sliding window flow control with a maximum window size of $W = 8$
In your answer, assume that ACK packets are negligibly small and are sent immediately upon receipt of a data packet at station C. At node B it may be necessary to delay ACKs as a means of flow control. Use the velocity of signal propagation of 2×10^5 km/s.

(b) Assume that the links in (a) are not error free. Assume that on both links the probability that a packet is in error is 10^{-4}. Determine the best case utilization for
(i) stop-and-wait ARQ
(ii) selective reject ARQ with a maximum window size of $W = 8$

ANSWERS:

Q1. (a) P(lost packet) = 3.20×10^{-5}, P(damaged packet) = 8.32×10^{-4}
(b) 1157.9 packets
(c) 0.05692
(d) P(errors detected) = 8.32×10^{-4} (although not identical to the answer in part (a)),
P(errors not detected) = 3.6×10^{-12}

Q2. (a) 3.0×10^{-12}
(b) (a) P(lost packet) = 3.20×10^{-5}, P(damaged packet) = 2.5×10^{-9}
(b) 31248 packets

Q3. (a) 01100
(b) remainder = 1110, therefore error has probably occurred
(c) answer not available

Q4. 0.1307

Q5. (a) 1774 seconds
(b) 222 seconds
(c) window size must be 20 or greater, 90.6 seconds
(d) 1976 seconds

Q6. ≥ 5 bits, 90.48%

Q7. (a) ≤ 175 Mbps
(b) ≤ 237 Mbps

Q8. ≥ 37.2 Mbps

Q9. (a) (i) U_{AB} = 33.33%, U_{BC} = 83.33%
(ii) U_{AB} = 40%, U_{BC} = 100%
(b) (i) U_{AB} = 30.2%, U_{BC} = 75.4%
(ii) U_{AB} = 36.2%, U_{BC} = 90.5%