COMP 445 – Winter 2022
Data Communications & Computer Networks
Theoretical Assignment 4

1.

Let P_n denote the probability that a frame arrives with n bits in error.

a) With no error detection.

$$P_0 = \text{probability that a frame arrives with no bits in error} = (1 - BER)^L$$

A frame arrives with undetected errors as soon as there is an error (since there is no detection method). Hence the probability of undetected error is

$$P_{Error} = (1 - P_0) = (1 - (1 - BER)^L)$$

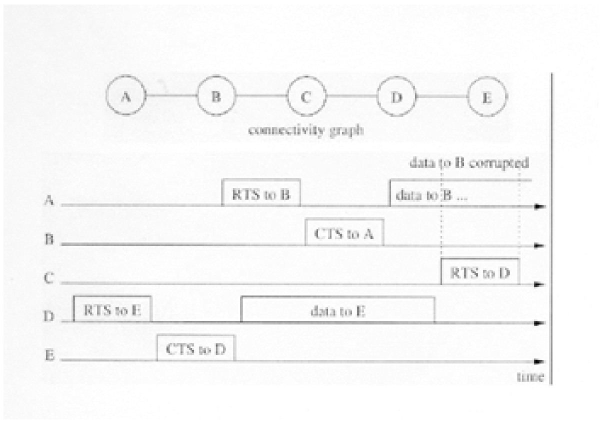
b) With 1-bit parity

Let us assume that we only detect single error with 1-bit parity (theoretically we could detect all odd number errors). Then a frame **(of size now L+1)** with errors will go undetected if it contains more than one error. Hence the probability of undetected errors is one minus the probability of no error, minus the probability of one error (if we detect all odd number of errors then we have to minus all probabilities of odd number of errors):

$$P_{Error} = 1 - P_0 - P_1 = 1 - (1-BER)^{L+1} - (L+1)BER(1-BER)^L$$

(if all odd number of errors are detected then: $P_{Error} = 1 - P_0 - P_1 - P_3 - \dots - P_{2n+1}$, where $2n+1 <= L+1$)

2.



The figure above presents a scenario where the hidden-terminal problem is not solved by the RTS/CTS mechanism. The upper part of the figure shows the connectivity graph: there are 5 stations: A, B, C, D, and E. In the lower part of the figure, the transmissions of each station are shown. The problem starts when station C cannot "hear" the CTS from B to A: this is because C is within range of both B and D, and is "drowned" by the data transmission of D and the CTS transmission of B, so that it doesn't receive anything at all. Also, C cannot hear the data sent from A to B, since A and C are not in range. Therefore, when C "wakes up" (C heard the RTS from D to E, so decided to wait for the whole transmission from D to E) and wants to send a packet, say to D (it could be any other station), it "drowns" B when it sends an RTS to D. So, A's data to B gets corrupted, although their RTS/CTS handshake got through without problems.

Because of situations like the above, RTS/CTS is usually accompanied by an ACK from the receiver to the sender, after data has been transmitted. In the above case, B will not send an ACK back to A, so A will know that its data didn't get through and try again.

3.

a. A can choose k_A=0 or 1; B can choose k_B=0,1,2,3. A wins outright if (k_A, k_B) is among (0,1), (0,2), (0,3), (1,2), (1,3); there is a 5/8 chance of this.

b. Now we have k_B among 0…7. If k_A =0, there are 7 choices for k_B that have A win; if k_A =1 then there are 6 choices. All told, the probability of A's winning outright is 13/16.

4. a.

$$E(p) = Np(1-p)^{N-1}$$
$$E'(p) = N(1-p)^{N-1} - Np(N-1)(1-p)^{N-2}$$
$$= N(1-p)^{N-2}((1-p) - p(N-1))$$
$$E'(p) = 0 \Rightarrow p^* = 1/N$$

b.

$$E(p^*) = N\frac{1}{N}(1-\frac{1}{N})^{N-1} = (1-\frac{1}{N})^{N-1} = \frac{(1-\frac{1}{N})^N}{1-\frac{1}{N}}$$

$$\lim_{N\to\infty}(1-\frac{1}{N}) = 1 \qquad \lim_{N\to\infty}(1-\frac{1}{N})^N = \frac{1}{e}$$

Thus

$$\lim_{N\to\infty} E(p^*) = \frac{1}{e}$$

5.
   R is the remainder of $D \cdot 2^r/G$ where r=3 since G has 4 bits. Thus, we divide 1001 into 111010000 to get 111101 with remainder R=101. So, we send (data + CRC) 111010101.

6.
   First Host A does an ARP query-response exchange with the router, taking y. Then it sends the packet to the router, taking x. The router does an ARP query-response exchange with Host B, taking y. Then it sends the packet to Host B, taking y. So the total time is 2y + 2x.

7. Node A creates a TCP SYN packet, which (after encapsulation in an IP datagram) gets encapsulated into an Ethernet frame. This Ethernet frame will have B's MAC address for its destination address. Node A transmits the frame. When the frame arrives at the switch, the switch will take note of A's location and then transmit the frame onto the other N-1 links, giving a total of N transmissions so far. When B receives the frame, it will send a SYNACK, encapsulated in an Ethernet frame with A's MAC address for the destination address. Thus, there are N+1 frames so far. When the switch receives the frame, it will take note of B's location; it will already have an entry in its table for A and thus will only transmit the frame onto one link. Thus, there are N+2 frames so far. When A receives the SYNACK it will send an ACK. Two more transmissions are required for this ACK, giving a total of N+4 transmitted frames.