1) A message $M = 11001$ is transmitted from node A to node B using the CRC code. The CRC generator polynomial is $C(x) = x^3 + x + 1$

a) What is the transmitted code word – perform the polynomial long division to find this result

b) If a bit error pattern of $10101000$ is introduced by the link. What is the received code word for the transmitted word determined in part a?

c) Assume node B receives the following code word: $11011001$. By using the CRC, does node B detect the bit errors introduced by the link?

2) Answer the following short answer questions.

a) What are the four lowest layers of the OSI Network architecture? Which layers are necessary for intermediate nodes (nodes that forward packets) in a network?

b) What are the differences between datagram packet switching (DPS) and virtual circuit packet switching (VCPS)?

c) What is the hidden node problem in a wireless network?

d) What is the main difference of framing using the BISYNC protocol framing and the SONET protocol framing?

3) A network has an end to end length of 5000 meters with a propagation speed of $2.5 \times 10^8$ m/s. The bandwidth of the link is 100 Mbps. The maximum frame size for transmission on this network is 5000 bits.

a) What is the transmission time for a maximum sized frame on the network?

b) What is the one way propagation delay for the network?

c) Which delay (from parts a and b) dominates for this link?

d) If the bandwidth of the link increases to 1 Gbps, which delay dominates for this link?
4) Consider the following virtual circuit network and the virtual circuit table entries for the switches. Complete the tables for a virtual circuit for a transmission from node A to node Z. An interface is the same as port number, and the interfaces of interest for each switch are shown (i.e. switch 1 has interfaces 1 and 3 shown).

Note: the network does not show all of the ports available on all switches, and it does not show all of the other nodes in the network. Switches always pick the lowest available virtual circuit identifier, and each port has its own set of virtual circuit identifiers (i.e each port on a switch has its own VCI's 0, 1, 2, etc.)

![Virtual Circuit Network Diagram]

**Virtual Circuit Table for Switch 1 (S1)**

<table>
<thead>
<tr>
<th>Incoming Interface</th>
<th>Incoming VCI</th>
<th>Outgoing Interface</th>
<th>Outgoing VCI</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

**Virtual Circuit Table for Switch 2 (S2)**

<table>
<thead>
<tr>
<th>Incoming Interface</th>
<th>Incoming VCI</th>
<th>Outgoing Interface</th>
<th>Outgoing VCI</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>0</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>0</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

**Virtual Circuit Table for Switch 3 (S3)**

<table>
<thead>
<tr>
<th>Incoming Interface</th>
<th>Incoming VCI</th>
<th>Outgoing Interface</th>
<th>Outgoing VCI</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>5</td>
<td>0</td>
</tr>
</tbody>
</table>
5) Consider the 1Gpbs ethernet shown

![Diagram of ethernet setup involving nodes A, B, and switches S1, S2]

The propagation delay between any two hosts (A, B or a switch) is $10 \mu s$. The data to transmit from node A to node B consists of 2500 Bytes. Each switch is a store and forward switch that starts retransmission of a packet $10 \mu s$ after receiving the last bit of a packet.

a) What is the latency for transmitting the data as a single packet from A to B (time from the first bit of the packet transmitted by node A until last bit of the packet is received at node B)?

b) What is the effective data throughput rate in bits per second (bps) for the circuit analyzed in part a?

6) A sliding window protocol is being used with a SWS = RWS = 3 frames (send window size and receive window size). Frames are sequenced using numbers 0, 1, 2, 3, 4, 5, 6 and 7. Acknowledgments are sent based on the highest consecutively received frame sequence number. ACK 0 indicates frame 0 has been received, and an ACK 5 indicates frames with sequence numbers 0 through 5 have all been received. If frames are received in the order 0,1,3,4,2 then the ACKS sent are ACK 0, ACK 1, ACK 4 (sent after receiving frame 2).

Draw the timeline for this protocol given the following information:

- Sender needs to send 8 frames with sequence numbers 0 through 7
- Receiver sends ACKs as indicated above
- The timeout period is 2 Round Trip Times
- **During transmission, Frame 1 is lost, and ACK’s 4 and 5 are lost**
- A frame is completely received $\frac{1}{4}$ of a RTT after transmission starts (Frame 0 and ACK 0 are shown)
- A frame is sent every $\frac{1}{4}$ of a RTT if the sender is allowed to send

7) Consider a token ring LAN where all stations have frames queued to send. The parameters of the ring are as follows:

- The ring length is 2500 meters
- signal propagation is 4 nanoseconds per meter,
- There are 10 stations spaced equally around the ring.
- The frame length is 50 bytes and the data rate on the ring is 100-Mbps.

Your calculations are to **take into account the token propagation delay between stations**. You can assume that stations know that information being received is a packet or the token after 1 bit is received (if receiving a token, then can start transmitting a packet, if receiving the packet back, release the token).

a) What is the effective bit rate (in Mbps) on the ring if delayed token release is used?
All stations have packets to send. Therefore, a station transmits a packet, releases the token and the next station removes the token and starts transmitting its packet. With delayed release, the transmitting station waits until it starts receiving its packet before releasing the token.

**Propagation delay around ring is** \(2500 \times (4 \times 10^{-9}) = 10 \mu S\)

**Time between hosts is** \(10 \mu S/10 = 1 \mu S\)

**Transmit time =** \(50(8)/(100 \times 10^6) = 4 \mu S\)

First bit transmitted takes 10 \(\mu S\) to get back to the host when the token is released. 1 \(\mu S\) later, the next host starts receiving the token and starts transmitting its packet. This procedure continues for all of the hosts on the ring.

Therefore, 1 host transmits every 11 \(\mu S\), so

**The effective bit rate = 400 bits/(11 \(\mu S\)) = 36.36 Mbps (36.4% efficiency)**

b) What is the effective bit rate (in Mbps) if early token release is used?

With early token release, the host transmitting places the token on the ring at the end of the packet transmission.

Now the host transmits for 4 \(\mu S\) and 1 \(\mu S\) later the token arrives at the next host. The next host starts transmitting at that time and the procedure continues.

Therefore, 1 station transmits every 5 \(\mu S\), so

**The effective bit rate = 400 bits/(5 \(\mu S\)) = 80 Mbps (80% efficiency)**