Problem 1: Consider an application that transmits data at a steady rate (for example, the sender generates an N-bit unit of data every k time units, where k is fixed). Also, when such an application starts, it will stay on for a relatively long period of time. Answer the following questions, briefly justifying your answer:

a. Would a packet-switched network or a circuit-switched network be more appropriate for this application? Why?

A circuit-switched network would be well suited to the application described, because the application involves long sessions with predictable smooth bandwidth requirements. Since the transmission rate is known and not bursty, bandwidth can be reserved for each application session circuit with no significant waste. In addition, we need not worry greatly about the overhead costs of setting up and tearing down a circuit connection, which are amortized over the lengthy duration of a typical application session

b. b. Suppose that a packet-switching network is used and the only traffic in this network comes from such applications as described above. Furthermore, assume that the sum of the application data rates is less than the capacities of each and every link. Is some form of queuing needed? Why?

Given such generous link capacities, the network needs no congestion control mechanism. In the worst (most potentially congested) case, all the applications simultaneously transmit over one or more particular network links. However, since each link offers sufficient bandwidth to handle the sum of all of the applications' data rates, no congestion (very little queuing) will occur

Problem 2: Consider a network in which host *A* is connected to host *B*.

(a) Assume there are two links and one node between A and B. Neglect propagation delays and queuing delays. *A* segments the file into segments of S bits each and adds h bits of header to each segment forming packets of size h+S. Each link has a transmission rate of R bps. Find the end-to-end delay in sending the file.

A --------------------- n --------------------- B

Assume the file has F bits. Hence, there are F/S segments where each segment is h+S bits.

But A→n and n→B Segments can be sent simultaneously, so total delay (in seconds) is

2*(h+S)/R + ((F/S)-1)*(h+S)/R = (h+S)/R * ((F/S) +1)

(b) Now assume there is only one link between *A* and *B*; its transmission rate is 1 Mbps and its propagation delay is 2 ms. Consider sending voice from *A* to *B* over a packet-switched network. *A* uses a 64 Kbps bit stream on the fly and groups the bits into 48-byte packets. As soon as *A* gathers a packet, it sends it to *B*. As soon as *B* receives an entire packet, it converts the packet's bits to a voice signal. How much time elapses from the time a bit is created until the bit is decoded back to voice.

Before the first bit of a packet can be transmitted, all the other bits belonging to the same packet need to be generated. This requires: $48*8 / 64x10^3$ = 6 ms

The time to transmit this packet is: $48*8 / 10^6$ = .384 ms

The propagation delay is 2 ms

Therefore, the delay until decoding is: 6ms + 0.384ms + 2ms = 8.384 ms

Problem 3: Stations A and B are connected in a radio packet-switched network via a geo-synchronous satellite, 22,000 miles in orbit. The channel has a data transfer rate of 120 Kbps and frames are typically 1000 bits long.

(a) For what range of frame sizes does the channel yield utilization of at least 50% if the Stop-and-Wait protocol is used?

U = 1 / (1+2a) and a=dR/vL where v, d and R are known.

Let U >= 0.50 and solve for L.

(b) Repeat part (a) but assume the nodes use the sliding window protocol with W=3.

U = W / (1+2a) and a=dR/vL where W, v, d and R are known.

Let U >= 0.50 and solve for L.

Problem 4: Let P=11011 and M=11100101.

(a) Assume the transmitter computes the CRC and transmits the message without any errors. Show the transmitted message and explain in words how the receiver determines that the received message is error-free.

The transmitted message is 11100101**0100** and is divided by 11011 at the receiving end. The remainder can be shown to be zero using a division similar to the one show below to compute the CRC.

```
                10101100
11011       111001010000
            11011
              11110
              11011
                10110
                11011
                 11010
                 11011
                    0100
```

(b) Repeat part (a) but this time assume the transmitted message was affected by the error polynomial $X^3 + 1$. Show the received message and explain in words how the receiver determines that the received message is in error.

The received message is T(X) ⊕ E(X) = 111001010100 ⊕ 000000001001 = 111001011101 which is divided by 11011 at the receiving end. The remainder can be shown to be non-zero using a division similar to the one shown above to compute the CRC.

Problem 5: Suppose a file of 10,000 bytes is to be sent over a line at 2400 bps.

a. Calculate the overhead in bits and time in using asynchronous communication. Assume one start bit and a stop element of length of one bit, and 8 bits to send the byte itself for each character. The 8-bit character consists of all data bits, with no parity bit.

   Each character has 25% overhead. For 10,000 characters, there are 20,000 extra bits. This would take an extra 20,000/2400 = 8.33 seconds.

b. Calculate the overhead in bits and time using synchronous communication. Assume that the data are sent in frames. Each frame consists of 1000 characters = 8000 bits, and an overhead of 48 control bits per frame.

   The file takes 10 frames or 480 additional bits. The transmission time for the additional bits is 480/2400 = 0.2 seconds.

c. What would the answers to parts (a) and (b) be for the original file of 10,000 characters except at a rate of 9600 bps?

   The number of overhead bits would be the same, and the time would be decreased by a factor of 4 = 9600/2400.

Problem 6: A channel has a data rate of *R* bps and a propagation delay of *t* sec/km. The distance between the sending and receiving nodes is *L* km. Nodes exchange fixed-size frames of *B* bits. Find a formula that gives the minimum sequence field size in bits of the frame as a function of *R*, *t*, *B* and *L.* Assume that ACK frames are negligible in size, the processing at the nodes is instantaneous, and that maximum utilization is required.

Round trip propagation delay of the link = $2 \times L \times t$

Time to transmit a frame = B/R

To reach 100% utilization, the transmitter should be able to transmit frames continuously during a round trip propagation time. Thus, the total number of frames transmitted without an ACK is:

$$N = \left\lceil \frac{2 \times L \times t}{B/R} + 1 \right\rceil,$$

where $\lceil X \rceil$ is the smallest integer greater than or equal to X

This number can be accommodated by an M-bit sequence number with:

$$M = \lceil \log_2(N) \rceil$$