Problem 1. A communication link provides 1 Mbps for communications between the earth and the moon. The link sends color images from the moon. Each image consists of 10,000x10,000 pixels, and 16 bits are used for each of the three color components of each pixel.

(a) How many images/second can be transmitted over the link?

(b) If each image is transmitted as a single block, how long does it take to get an acknowledgement back from earth? The distance between earth and the moon is approximately 375,000 km.

(c) Suppose that the bit error rate is $10^{-5}$, compare Go-Back-N and Selective Repeat ARQ in terms of their ability to provide reliable transfer of these images from the moon to earth. Optimize the frame size for each case using trial and error. Assume a header overhead of 64 bits. Plot transmission efficiency as a function of frame size (matlab program will be posted on the website). Study the impact of the header overhead.

Problem 2. Find the optimum frame length $n_f$ that maximized transmission efficiency for a channel with random bit errors by taking the derivative and setting it to zero for the following protocols:

(a) Stop-and-Wait ARQ

(b) Go-Back-N ARQ

(c) Selective Repeat ARQ

(d) Find the optimum frame length for a 1 Mbps channel with 10 ms reaction time, 25-byte overhead, 25-byte ACK frame, and $p = 10^{-4}, 10^{-5}$ and $10^{-6}$.

Problem 3. A data-link layer protocol that uses ON/OFF control executes on a 1.5Mbps link. The sender emits data at this full data rate and uses frames of size 1000 bytes. One-way propagation delay is 20ms. The rate at which the receiver empties its buffer, $R_{rcv}$, is shown in the figure below.
for different time intervals. Assume the receiver buffer size is 10000 bytes.

1. Does the receiver send an OFF signal to avoid packet loss at any of these time instants?
   a. 1.025 sec
   b. 1.06 sec
   c. 2.06 sec
   d. 1.13 sec

2. How full is the receiver buffer at t=1sec?
   a. 4000 bytes
   b. 6000 bytes
   c. 10000 bytes
   d. 2 frames