1. Questions to ponder
a) What’s the tradeoffs between copper and optical?
b) Introduce two multiple access methods / protocols that weren’t covered in class. Discuss their advantages and disadvantages.
c) In a token ring network, describe a situation where delayed release is preferred to early release, and another situation where early release is preferred.

Key:
a) Copper:
less expensive, lower bandwidth, shorter distance, bend more than optical, gives moderate performance.

Optical:
expensive, higher bandwidth, longer distance, no electromagnetic inference, greatly reduces packet loss/interference and provides huge bandwidth, which are usually needed for inter-state/country network.

b) SDMA (Space-division multiple access)
This is a channel access method which aims at adding parallel spatial pipes to high capacity pipes, it offers superior performance in radio multiple access communication systems.
Advantage:
The bandwidth efficiency is proportional to the number of occupied space divisions.
Can increase throughput in a given period of time.
Disadvantage:
Bandwidth efficiency depends on the number of users. To be specific, the efficiency decreases as the number of users decreases.
Cost increases.

CDMA (Code division multiple access)
This is a multiple access method, which allows multiple signals to occupy and utilize a single transmission channel by assigning shared band of frequency to multi users.
Advantage:
Can send more data with same bandwidth.
The allocation of resources is in a flexible way.
No absolute upper bound for the number of users.
Disadvantage:
The overall quality of service decreases as the number of users increases.(even though no upper bound of user number)
Self-jamming may happen.

c) Early release can bring about better utilization of bandwidth and improves throughput more significantly on high-bandwidth/high-delay rings.
Delayed release is simpler and the earlier design, usually used in low bandwidth/low-delay rings.

As long as your described situation can reveal such features you can get points.
2. Noisy Channel Data Rates
The decibel is a measure of the ratio between two signal levels: $N_{db} = 10 \log_{10} \left( \frac{P_2}{P_1} \right)$, where $N_{db}$ = the number of decibels, $P_1$ = the input power level and $P_2$ = the output power level.
a. A telephone line is known to have a loss of 20db. The input signal power is measured as 0.50 watt and the output noise is measured as 8 μwatt. Using this information, calculate the output signal-to-noise ratio in dB.
b. What is the capacity of this phone line with a frequency range of 100 Hz – 1000 Hz?
c. If the attenuation rate of this phone line is 2db/km, and the minimum output signal is 0.00025 watt, given the input signal from part a), how long can the phone line be before requiring a repeater?

Key:
a. $P_1$ = the input power level = 0.50 watt, and $P_2$ = the output power level that we need to find.
$10 \log \left( \frac{P_2}{P_1} \right) = -20$ dB
$P_2 / P_1 = 0.01$
Since $P_1 = 0.50$ watt, $P_2 = 0.0050$ watt

$SNR = \frac{0.0050}{(8 \times 10^{-6})} = 625$
$SNR_{db} = 10 \log (625) = 27.95$ dB

b. Using Shannon’s law
$C = B \log_2 (1 + S/N)$
$C = (1000-100) \log_2 (1 + 625)$
$C = 900 \times 6.43935 = 8363.09$

c. $10 \log \left( \frac{P_2}{P_1} \right) = 10 \log \left( \frac{0.00025}{0.50} \right) = -33.01$ dB
Max length = 16.505km.

3. 4B/5B Encoding
a) Show the 4B/5B encoding, and the resulting NRZI signal, for the following bit sequence:
   1110 0101 0000 00011
b) Show the 4B/5B encoding, and the resulting NRZI signal, for the following bit sequence:
   1101 1110 1010 1101 1011 1101 1110 1111

Key:
a) 111000 01011 11110 10101
   ....
   b) 110111 11100 10110 11011 10111 11100 11100 11110

4. Two-Dimensional Parity Error Detection
a) Show (give an example) that two-dimensional parity checks can correct and detect a single bit error.
b) Show (give an example) that a double-bit error that can be detected but not corrected.

Key:
Suppose we begin with the initial two-dimensional parity matrix:

```
0 0 0 0
1 1 1 1
0 1 0 1
1 0 1 0
```

With a bit error in row 2, column 3, the parity of row 2 and column 3 is now wrong in the matrix below:

```
0 0 0 0
1 1 1 1
0 1 0 1
1 0 1 0
```

Now suppose there is a bit error in row 2, column 2 and column 3. The parity of row 2 is now correct! The parity of columns 2 and 3 is wrong, but we can't detect in which rows the error occurred!

```
0 0 0 0
1 0 0 1
0 1 0 1
1 0 1 0
```

The above example shows that a double bit error can be detected (if not corrected).

5. CRC Error Detection
In CRC approach, consider the 5-bit generator, G=10011, and suppose that D has the value
a. 1010101010.
b. 1001000101.
c. 1010001111.
d. 0101010101.

What is the value of R(remainder)?

Key:
a) If we divide 10011 into 1010101010 0000, we get 1011011100, with a remainder of R=0100. Note that, G=10011 is CRC-4-ITU standard.
b) we get 1000100011, with a remainder of R=0101.
c) we get 1011111111, with a remainder of R=0001.
d) we get 0101101110, with a remainder of R=0010.

6. Multiple Access
Suppose nodes A and B are ready to send a packet at the same time a third node ends transmission on a 10 Mbps Ethernet. In the ith round after i − 1 collisions have already occurred, the two nodes wait 0, 1, . . . , 2^{i−1} − 1 slots until the next attempt, all 2^{i−1} choices having equal probability.

(a) Find the probability q_i of a collision in the ith round, given that there are collisions in the previous i−1 rounds (i.e. q_1 =1, q_2 =1/2), for all i≥1.
(b) Find the probability p_i that exactly i rounds are needed for the first success, and compute
p_1, p_2, ..., p_4.

(c) Now assume that after the first collision, node A “wins” the backoff and transmits successfully. After it is finished, both nodes try to transmit again (A has an infinite amount of traffic to send), causing a collision. After this collision, the A’s collision counter is at 1 and B’s is at 2. Compute the probability that A wins again.

(d) Given that A “won” the first round, compute the probability that A captures the network for the next 5 frames.

Key:

(a) q_i = \frac{1}{2^{i-1}}

(b) 
\begin{align*}
p_i &= \left(\prod_{j=1}^{i-1} q_j\right) \cdot (1 - q_i) \\
p_1 &= 0 \\
p_2 &= 0.5 \\
p_3 &= 0.375 \\
p_4 &= 0.109
\end{align*}

(c) 
If A picks 0 (with probability 1/2), it wins if B does not pick 0, which happens with probability 3/4. If A picks 1, it wins if B picks 2 or 3, which happens with probability 1/2. So A wins with probability \(\frac{1}{2} \cdot \frac{3}{4} + \frac{1}{2} \cdot \frac{1}{2} = \frac{5}{8}\).

(d) In general, we can see that A wins after i collisions with probability:

\[
\frac{2^i - 1 + 2^i - 2}{2^{i+1}}
\]

The chance of winning all 5 frames is surprisingly high:

\[
\prod_{i=2}^{5} w_i \approx 0.43
\]

7. **Token Ring Networks**

In a token ring network, a station is allowed to hold the token for some period of time, the token holding time, THT. Let RingLatency denote the time it takes the token to make one complete rotation around the network when none of the stations have any data to send.

(a) In terms of THT and RingLatency, express the efficiency of the network when only one station is active. Assume early release for the next few questions.

(b) What setting of THT would be optimal for a network that only had one station active (with data to send) at a time?

(c) In the case where N stations are active, give an upper bound on the token rotation time, TRT, for the network.

(d) Let N = 100, THT = 1000 μs, and RingLatency = 200 μs. Compute the efficiency of this network if all N nodes are active and are using early release.

(e) Compute the efficiency of the above network if delayed release is used.

Key:

(a) The station sends data for THT time and then waits for RingLatency for the token to circle around, resulting in an efficiency of:

\[
\frac{THT}{THT + \text{RingLatency}}
\]

(b) Infinite (or as large as possible)
(c) $TRT \leq N \cdot THT + \text{RingLatency}$

(d) Using the above equation, $TRT$ is $100 \times 1000 + 200 = 100200 \mu s$. Out of this, $100000 \mu s$ is used for productive transmission, so the efficiency is $100000/100200 \approx 99.8\%$.

(e) With delayed release, each node transmits for $THT$, then waits $\text{RingLatency}$ before releasing the token. So in this case:

$TRT = N(THT + \text{RingLatency}) + \text{RingLatency} = 100 \cdot 1200 + 200 = 120200\mu s$

The useful transmission time is still $100000$ so the efficiency is $100000 / 120200 \approx 83\%$. 