1. (3 pts) Explain the function / purpose / use of a repeater in a communications link.

A **repeater** receives, decodes, and regenerates signals in both directions. Its purpose is to extend the network to reach devices that are further than the maximum cable length for the segment.

2. (3 pts) What is sent physically (as the signal or “carrier”) on the link to carry the data when the physical link is
   
   a. UTP
   b. Coax
   c. Fiber

   a. UTP: Electrical Signal
   b. Coax: Electrical Signal
   c. Fiber: Light Waves

3. (6 pts) Since Gigabit Ethernet can be implemented using UTP, under what circumstances would one install fiber if Gigabit Ethernet LANs were needed in an organization?

   - **Fiber is recommended if the distances between hosts or subnets are too long.** Fiber can connect devices that are up to 5km apart without using repeaters vs. only 100m for UTP.

   - **Fiber has a higher signal to noise ratio and is therefore very immune to noise.** It will be preferred to copper if the network is in a very high noise area

   - **Fiber is light compared with copper** – it will be preferred if the cables need to be carried over long distances to the destination network

4. (8 pts) For communication links using geo-synchronous satellites

   a. Give two **positive** attributes of these links that make them attractive for some applications or contexts.

   - Larger footprint – can connect several computers that are large distances apart and that are not normally reachable due to harsh terrain or other obstacles

   - **Wireless and suitable for mobile applications** – e.g. a mobile clinic can use satellite connection rather than cable
b. Give two **negative** attributes of these links.

- Security – Information is broadcast to all and needs to be protected
- Lower bandwidth when compared with Fiber
- Expensive to launch, difficult to repair

5. (10 pts) For the data sequence 101111 and with a CRC generator $x^4 + 1$

   a. What is the message sent – including the CRC bits?

   Message sent: 10111110

   b. If the fifth bit from the left (in the received bit string) is inverted during transmission, show how this error is detected at the receiver.

   Error is detected because there is a remainder
6. (10 pts) For flow control, what is achieved by using Selective Repeat flow control protocol (and NAKs) over that achieved by the Go Back N protocol?

Increased throughput since only failed frames are retransmitted instead of all frames that followed the failed one. Channel utilization will increase since it will used more for transmitting valuable data instead of unnecessary resends.

Is there any extra cost to sender and/or receiver to implement Go Back N?

No extra cost in implementation. There is no buffering required at the receiver to implement Go Back N and complex buffering and processing is not required at the sender. Selective Repeat requires more receiver frame buffering than Go back N. Go Back N requires less processing at sender than Selective Repeat.

NB: Go back and N costs too much in bandwidth when in use, though.

7. (10 pts) 802.11 LANS break a frame into fragments to improve the throughput.

a. Why?

Each small fragment is less likely to be damaged by random noise than is a long frame.

b. What limits the improvement of throughput as we decrease fragment size?

Each fragment has overhead, as they are individually numbered and have a check sum. The smaller they are, the more overhead vs. data sent.

Also fragments are sent using Stop-and-Wait, which means dead time on the channel while the acknowledgment is being sent. Shorter fragments means more fragments / frame, and thus poorer channel utilization. Tannenbaum, page 297

8. (10 pts) Is Switched Ethernet still CSMA/CD? If not, what has (or could be) removed from “standard” Ethernet in Switched Ethernet, why can these be removed, and what is the result?

Switched Ethernet -- if the input ports are buffered (I would not buy a switch that did not do this) there will be no collisions. So there is no need for to wait (listen – CS) the time equal to that required for data to go down the link and back before sending nor is collision detection (CD) needed as there is only one use. These Switched Ethernet links are full duplex -- so sending does not conflict with acknowledgments -- and achieve higher throughput.
9. (10 pts) A transparent LAN bridge doing backward learning builds a table of the addresses and the LAN to which each belong. What limits the ultimate size of this table (ignoring hashing) – if stations (users) come and go from the LANs connected by the bridge?

The LAN Bridge replaces the entry of each host each time it generates frames, and it periodically removes hosts from the table that have not reported activity during a given period of time. This limits the size of the lookup table.

10. (15 pts) Super audio (for those with superb hearing) would need to include frequencies up to 24 kHz. If this is to be sent over a LAN by sampling appropriately and quantizing using 12 bits / sample

   a. What sampling rate is required?

   According to Nyquist, sampling rate = \(2H = 2 \times 24000\). Sampling rate = 48000 samples per sec.

   b. What data rate will this “super audio” generate?

   Bit rate = \(2 \times 24000 \times \log_2 2^{12} = 2 \times 24000 \times 12 = 576\text{kbps}\)

   c. If you were to send four channels of this data on a 1 MHz bandwidth link, what number of levels would be required?

   4 channels of 576kbps \(\Rightarrow\) 2.304Mbps The number of signal levels needed is found using

   Nyquist’s theorem : \(2.304 \times 10^6 = 2 \times 1 \times 10^6 \log_2 V \implies \log_2 V = 1.152 \text{ or } V = 2.2 \text{ or 3 Levels}\)

   d. If the 1 MHz link had a signal noise ratio (S/N) of 31 (or \(\sim 15\, \text{db}\)) would it be possible to send this data over this link?

   Shanon’s theorem gives the relationship: bit rate = \(H \log_2 (1+S/N)\)

   \[ \Rightarrow \text{Bit rate} = 1 \times 10^6 \times \log_2 (1+31) = 5 \text{ Mbps}. \text{ The signal is } 2.3 \text{ Mbps so it will be possible since the link can support up to } 5 \text{ Mbps} \]
For the 10Mbps LAN:

Time to seize the channel = 2 x propagation delay of signal from source to destination.

 propagated delay for transmission (speed of signal : $2 \times 10^8$ m/s) : $2 \times \frac{1000}{2 \times 10^8} = 10 \mu s$

Time to transmit 512 bits : $512 / 10 \times 10^6 = 51.2 \mu s$

Propagation delay for transmission (speed of signal : $2 \times 10^8$ m/s) : $1000 / 2 \times 10^8 = 5 \mu s$

Time reserved for receiver to send ack : $32 / 100 \times 10^6 = 0.32 \mu s$

Propagation delay for transmission of ack (speed of signal : $2 \times 10^8$ m/s) : $1000 / 2 \times 10^8 = 5 \mu s$

Total time spent to transmit 480 bits (useful data) = $10 + 51.2 + 5 + 3.2 + 5 = 74.4 \mu s$

Effective bandwidth = $480 / (74.4 \times 10^{-6}) = 6.45$ Mbps

For the 100Mbps LAN:

Time to seize the channel = 2 x propagation delay of signal from source to destination.

 propagated delay for transmission (speed of signal : $2 \times 10^8$ m/s) : $2 \times \frac{1000}{2 \times 10^8} = 10 \mu s$

Time to transmit 512 bits : $512 / 100 \times 10^6 = 5.12 \mu s$

Propagation delay for transmission (speed of signal : $2 \times 10^8$ m/s) : $1000 / 2 \times 10^8 = 5 \mu s$

Time reserved for receiver to send ack : $32 / 100 \times 10^6 = 0.32 \mu s$

Propagation delay for transmission of ack (speed of signal : $2 \times 10^8$ m/s) : $1000 / 2 \times 10^8 = 5 \mu s$

Total time spent to transmit 480 bits (useful data) = $10 + 5.12 + 0.32 + 5 = 25.44 \mu s$

Effective bandwidth = $480 / (25.44 \times 10^{-6}) = 18.86$ Mbps

Extra credit: Does the frame length of 512 bits work for CSMA/CD at 100 Mbps for a LAN of this length?

Extra Credit The length of 1 Km at 100 Mbps means that the transmissions take only 5.2 \mu s, and this is too fast to meet the Ethernet requirement that the transmission not complete before the first bit can go all the way to the receiver and back, which is 10 \mu s. So with this combination of length and speed, we can't do CD.