15-441: Computer Networks
Homework 1

Assigned: January 29, 2008
Due: February 7, 2008

1. Suppose a 100-Mbps point-to-point link is being set up between Earth and a new lunar colony. The distance from the moon to Earth is approximately 385,000 km, and data travels over the link at the speed of light—$3 * 10^8$ m/s.
   (a) Calculate the minimum RTT for the link.
   (b) Suppose Mission Control on Earch wishes to download a 25MB image from a camera on the lunar base. What is the minimum amount of time that will elapse between when the request for the data goes out and the transfer is finished?
   (c) Using the RTT as the delay, calculate the delay*bandwidth product for the link.
   (d) Imagine that Mission Control requests one 25MB image and then waits until it starts receiving the file before sending another request (the size of the request is negligible). Use the delay*bandwidth product to determine what percentage of the link is utilized.

Solution:

(a) The time for data to travel from earth to the moon is:
$\frac{(385{,}000km*1000m/km)}{3*10^8 m/s} = 1.28333s$
So the minimum RTT is $1.2833 * 2 = 2.56666s$

(b) From (a), the request will take $1.28333s$ to reach the moon. The time to put the picture on the link is:
$\frac{25MB*1024kB/MB*1024byte/kB*8bits/byte}{100Mbps*1000kb/Mb*1000bits/kb} = \frac{209715200}{100000000} = 2.097152s$
Then it will take another $1.28333s$ to return to earth. The total time is:
$2 * 1.28333s + 2.097152s = 4.66382$

(c) $2.56666s * 100Mbps * 1000000bits/Mb = 256666000bits$

(d) The cycle time for this is 1 RTT. From (c) we see that the link would be fully utilized if 256666000 bits were transferred during this time. The total number of bits transferred is:
$25MB * 1024kB/MB * 1024bytes/kB * 8bits/byte = 209715200bits$
The link utilization is $209715200/256666000 = 81.707\%$

If you assume that the earth doesn't send a request until the entire picture has been received, then the time for a cycle is 4.66382 seconds from (b).
$4.66382s * 100Mbps * 1000000bits/Mb = 466382000bits$
$209715200/466382000 = 44.923\%$

2. Calculate the latency (from first bit sent to last bit received) for the following:
   (a) A 10-Mbps link with a single store-and-forward switch in the path, and a packet size of 5,000 bits. Assume that each section of the link introduces a propogation delay of 10 microseconds, and that the switch begins retransmitting immediately after it has finished receiving the packet.
   (b) Same as (a) but with three switches
   (c) Same as (a) but assume the switch implements cut-through switching: it is able to begin retransmitting the packet after the first 200 bits have been received.

Solution:

(a) To put the packet on the first link it will take:
$\frac{5000bits}{10-Mbps*1000000bits/Mb} = 0.0005s = 0.5ms$
Then it will take another .01 ms for the switch to finish receiving the packet for a total of .51 ms. It will take another .51 ms for the switch to send, and then for the destination to receive all of the packet. The total latency is:
$2 * 0.51ms = 1.02ms$

(b) From (a) we know that each link section will take .51 ms. The total time will be: $4 * 0.51ms = 2.04ms$

(c) To begin we can calculate the time it will take to send the first 200 bits: $\frac{200bits}{10-Mbps*1000000bits/Mb} = 0.00002s = 0.02ms$
Then .01 ms later the switch can start sending the packet. It will take .5 ms (from (a)) to put the entire packet on the wire (As the switch is sending out the packet, it will continue receiving the rest of the packet). Then it will take .01 ms for the destination to finish receiving the entire packet:
$0.02ms + 0.01ms + 0.5ms + 0.01ms = .54ms$

3. Do Exercise 1 from Chapter 3 in the textbook (Computer Networks: A Systems Approach Edition 4).
   For each connection it is fine to write out only the new table entries that would be added for each router instead of rewriting the full table each time.

Solution:

	Switch	In Port	In VCI	Out Port	Out VCI
(a)	1	2	0	1	0
	2	3	0	0	0
	3	0	0	3	0
(b)	1	3	0	1	1
	2	3	1	1	0
	4	3	0	1	0
(c)	2	2	0	0	1
	3	0	1	2	0
(d)	1	0	0	1	2
	2	3	2	0	2
	3	0	2	3	1
(e)	4	2	0	3	1
	2	1	1	0	3
	3	0	3	1	0
(f)	4	0	0	3	2
	2	1	2	3	3
	1	1	3	2	1

4. Look in the book at section 2.3.2 to learn about HDLC
   (a) Assuming that we are using the HDLC protocol for bit stuffing, show the bit sequence transmitted over the link when the frame contains the following bit sequence:
   110100011011111100110100111110011000000111111000100011
   Mark the stuffed bits
   (b) Supposed the following sequence of bits arrives over a link:
   11011000101111101001000001101111100001011011111110010
   Show the resulting frame after any stuffed bits have been removed. Indicate any errors that might have been introduced into the frame.
   (c) Given an original data size of 64 bits, what is the largest number of bits that may need to be transmitted (using HDLC)? What is the smallest number of bits? Remember to include both begin and end HDLC frame markers.

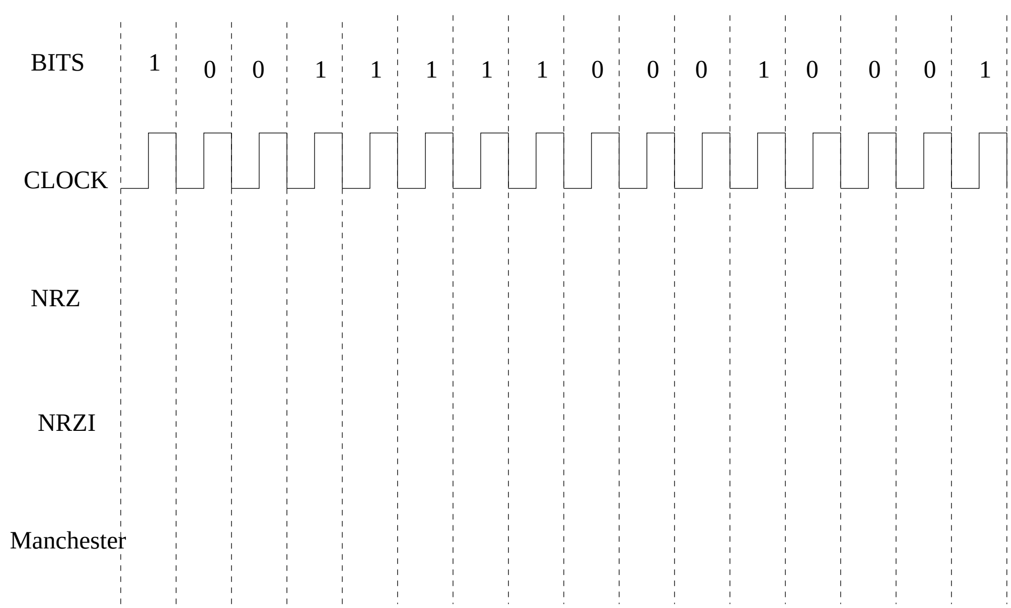
Solution:

(a) ∗01111110∗ 110100011011111*0*10011010011111*0*001100000011111*0*11000100011 *01111110*

(b) 1101100010111111001000001101111110001011 * 01111110010
There may be an error in the last few bits of the message because there is a sequence of 6 1's, or it may just be an end of frame marker. The receiver will treat it as an end of frame marker either way.

(c) 8 bits for start frame + 8 bits for end frame. If every bit is a 1, we will need to stuff every 5 bits. This adds another $64/5 = 12$ bits for a maximum of 12 bits + 16 bits + 64 bits = 92 bits. If there are no sequences of 5 1's, we don't have to stuff at all so the minimum number of bits is 16 (+32 bits)+ 64 = 80 bits (96 bits). If you included the header and CRC sections then there are a total of 96 bits that might need to be stuffed. Then the minimum is $8 + 8 + 96 = 112$ and the maximum is $8 + 8 + 96 + 96/5 = 131$

5. Show the NRZ, Manchester, and NRZI encodings for the bit pattern shown in the figure below. Assume that the NRZI signal starts out low (Exercise 1, Chapter 2, Peterson and Davie)



Charles, an ex-441 student, is given the task of building a new network link technology. Unfortunately, many of his beta-testers complain that their packets get corrupted when using his technology! He tracks the problem down to time synchronization problems between the sender and receiver on the link. Perhaps you can help Charles solve his problems by telling him a little about different encoding methods. Identify the problem and give a 1-2 sentence explanation about why this occurs.

For each of these sub-parts, identify whether the encoding can have problems with:

A. Long strings of 0s

B. Long strings of 1s

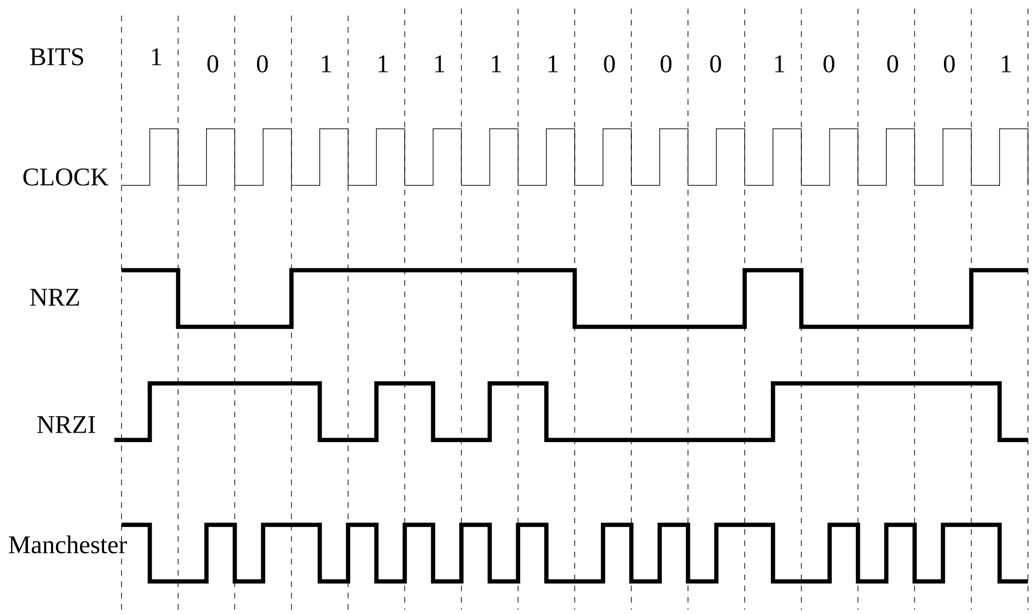
C. Both long strings of 1s or long strings of 0s

D. None of the above

(a) Manchester encoding

(b) NRZ

(c) NRZI



Solution:

(a) Manchester encoding: (D) Non-of the above. Manchester encoding will provide a signal change on every bit of data transferred, but has the down-side of making the data-rate only have the baud rate (i.e., rate at which the signal can change on the wire).

(b) NRZ: (C) For non-return to zero, the signal only changes when the data on the wire changes. Thus, it can lose clock synchronization with a sequence of either 1's or 0's.

(c) NRZI: (A) Non-return to zero inverted signals a 1 by making a transition, but signals a 0 by staying at the same signal. Thus, it has problems with long sequences of zeros.

Common errors: Most people got this right

6. You are working for a company that delivers digital pictures to users over different types of networks. You are developing a new product that will use a network link that has a bandwidth of 1MHz. Your boss asks two of your colleagues, Bob and Jane, to estimate how long it will take to transfer 1 MByte images over the channel.

   (a) Jane took a networking course and vaguely remembers something about Nyquist. She uses the Nyquist limit - what answer does she get?

   (b) Bob took the same course but was more impressed by the slide on Shannon. He applies the Shannon formula. He assumes that the signal-to-noise-ratio is 30 dB (that is after all, what was on the slide in class). What answer does he get?

   (c) Your boss is unhappy. He did not expect to get two different answers and he calls you in to explain the difference. What do you say?

Solution:

(a) 2 * 1MHz = 2Mbps

(b) 30 dB = 10 * log(S/N) ; S/N = 1000.
C = 1 MHz * $log_2(1 + 1000)$ = 9.967 Mbps

(c) The Nyquist limit assumes a binary amplitude encoding. Shannon's theorem allows for more aggresive encodings. This explains why that formula results in a higher bandwidth. Shannon's theorem also takes noise into consideration.