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Computer Networks and Distributed Systems

Reference solution to Questionnaire no. 4

Context

- Based on this lecture presentation: http://paloalto.unileon.es/cn/ch2-2017.pdf
  - Brief intro to Communication and Information Theory: Nyquist, Shannon-Hartley
  - Links, wavelength
  - PCM Line Encoding (NRZ, NRZ-i and Manchester)

1. Which Internet Architecture layer is this chapter focused on? Briefly list the functions of this layer and the name and the structure of its PDU (Protocol Data Unit) in the case of the Ethernet technology.
   The focus of this chapter is on the Subnetwork layer.

   The functions of this layer include the following:
   - Building frames that will encapsulate a specific type of upper-layer payload
   - Properly delimiting the standard fields that comprise a frame
   - Turning the frame's bits into signals appropriate for transmission (Line encoding)
   - Adding redundancy to the frame that allows the receiver to establish whether or not some error took place
   - Accessing the physical medium in an orderly manner that create no problems to the rest of network elements connected to it, etc.

   Ethernet is concrete subnetwork-layer technology, its PDU is known as Ethernet frame and its structure follows (Recall Lab 2 in which we received Ethernet frames and printed out their fields):

   |Destination MAC(48) | Source MAC(48) | Ethertype(16) | Payload(-)|CRC(32)|

2. Observe the network diagram of slide no. 6, then, respond to the following questions related to it:

   a. Is the physical layer implemented in all the network elements? Explain why it is
   All network elements must implement a physical layer protocol which will allow it to line-encode the bits so they get transmitted over the physical medium(Copper wire, Optical Fiber, etc.)

   b. Switches have no IP, try to justify this on the basis of the board discussions we held in the labs as we were evolving the lab practicals
   Switches operate on Ethernet frames, consequently they are oblivious about a frame's payload, whatever its type (IP packet, ARP packet, for example), all in all, switches don't run the IP protocol

   c. Why do routers have IP? By contrast to the preceding question, routers (IP routers) do run IP, actually, running IP is one of their main concerns.

   d. Try to justify the great variety of link layer protocols that appear on the net diagram

Today, there exist a large number of Ethernet technologies which Physical layer protocol is capable of dealing with speeds that range from 10Mbps to 10Gbps. Each of these technologies may use a certain frame format that abstracts the details of the specific physical layer selected.

3. We can digitize the variables that represent a real-world process like the surrounding sound by turning time, which is considered continuous, into a discrete variable, then, at each discrete-time value we must quantize the sound which consists of assigning the correct discrete value to its sound power (Air pressure). Nyquist established an important result known as the Nyquist rate or criterion:

   a. We want to find out whether Nyquist rate applies to the discretization process (continuous time to discrete time) or the quantization process (Continuous air-pressure to discrete air-pressure)

   The Nyquist rate applies to time-discretization

   b. Is the Nyquist rate a sufficient condition or a necessary condition for obtaining the original signal from the digitized samples?

   c. The Nyquist rate is a necessary condition and it never results sufficient, for example, the vertical quantization's accuracy is an essential consideration when converting the digital samples back into their continuous form

   d. We are digitizing music at a 8Ksamples/sec, then, when converting the samples back into real sound, what will that sound bandwidth be?

   According to the Nyquist's rate, the resulting analog signal's bandwidth will be half the sampling frequency or 4KHz

4. Over a communication channel, can we transmit at a speed as high as we wish? Carefully discuss this question according to Shannon-Hartley theorem.

   We can transmit at any speed of our choosing, however, if the speed chosen is higher than C, the Shannon's limit (Shannon's Channel Capacity Theorem), then the probability of error in the receiver will fast grow towards 1

5. Compute the Shannon capacity of a channel with a 2MHz bandwidth whose SNR=500. In order to increase the channel capacity in this case, you can choose to double either the bandwidth or the SNR: which one would you choose? Explain why.

   $C = 2 \cdot 10^6 \log_2(1+500)$ bps $= 17{,}93 \cdot 10^6$ bps

6. In slide 8 on the presentation mentioned above, you can observe that the different transmission media offer different bandwidths. Why is it good to have transmission media with high bandwidth? Does a higher bandwidth mean a higher propagation speed?
   Transmission media with high bandwidth allow transmission at high speeds

   No, a higher bandwidth allows transmission at a higher speed, but, propagation speed, in principle, is not related to a higher bandwidth. Copper wires propagate electromagnetic waves at a higher –propagation- speed than that of Optical Fibers, however, Copper wires have a much smaller bandwidth than that offered by Optical Fibers.

7. The following URL gives us a listing of the frequency bands used by European LTE mobile operators, among them, Movistar uses these frequencies: 800 MHz, 1800MHz and 2600MHz:

   https://en.wikipedia.org/wiki/List_of_LTE_networks_in_Europe

   a. Calculate the electromagnetic signals' resulting wavelengths and briefly discuss the advantage to using the highest frequency (Recall the lectures when I explained the efficiency of an antenna).

      The highest frequency results in the least wavelength; since the smallest efficient antenna is the one whose size is about the same as the wavelength, then, selecting the highest frequency will result in the smallest, efficient antenna

   b. Calculate the wavelength resulting when transmitting at 2600MHz

      Transmission speed (frequency, f) and the resulting electromagnetic wave's wavelength (λ) are related according to the following formula: $\lambda = v/f$ where v represents the light propagation speed in the considered medium. In the present case: $\lambda = 3 \cdot 10^8$ m/s / $2600 \cdot 10^6$ 1/s, the final result is:

      $\lambda = 11{,}54$ cm

8. There exist a number of PCM line encoding techniques, among them, we note the importance of NRZ, which you used in the Digital Electronics lab, however, in this course on Computer Networks, we are only interested in PCM signals such as NRZ-i and Manchester. Provide a brief explanation about why we don't use NRZ in Computer Networks.
   When transmitting long sequences of like-bits (1's or 0s), NRZ will remain in the same level, that situation will hinder the receiver from accurately set the bit sampling times. Also, NRZ contains a lot of power in the baseband which gets filtered (Suppressed) by some transmission media (Telephone lines, for example).

9. Briefly explain the voltage levels used at the output of a CMOS NOT gate for representing a 0 and a 1. Observe that all CMOS NOT gates must follow these specifications, in particular, we want to note that each binary value is represented by a continuous range of voltages and that in between them, there exists a region in which no signal should remain for a long time.

   Typically, a CMOS gate will decode a 1 when the input voltage is in the range [3.5 v, 5.0 v] and a 0 when the input voltage is in the range [0 v, 1.5 v]. If a signal lays in a region other than these, the gate provides no guarantee regarding the decode bit value.

10. By contrast to logic gates, line encoders (NRZi, Manchester, etc.) don't have such a stringent specification but the receiver keeps the average value of the input signals it has seen so far and decodes a 1 when the input signal's value is greater than the average voltage and 0 otherwise. What adverse effect is derived when a signal stays on the same level for a long number of bit times? What's the name of this effect?

    A signal that stays at the same level for a long number of bit times, will cause the input signal average value kept by the receiver to wander off the baseline, thereby hindering the receiver from accurately determining whether a newly received signal level should be decoded as a bit value 1 or as a bit value 0. This is known as *baseline wandering*.

11. Assume a 4B/5B + NRZ-I encoder for this exercise. We want to transmit the following sequence of 20 binary symbols: 0100 0000 0000 0000 0001

a. What's the length of the longest string of bits 0 present in the sequence?

17 bits

b. What's the length of the longest string of bits 0 present in the output of the 4B/5B encoder? Is this result consistent with the 4B/5B encoder's mission?

First, we will carry out the 4B/5B channel encoding operation, to that purpose, first, we will group the input bit string into a number of 4-bit groups and, then, input each 4-bit block into the 4B/5B table which will yield the corresponding 5-bit block:

0100 -> 01010
0000 -> 11110
0000 -> 11110
0000 -> 11110
0001 -> 01001

Concatenating the result 5-bit blocks, yields the following output bit string:
01010 11110 11110 11110 01001

By inspection, we confirm that no string of bit values 0 is longer than 3, which is consistent with the goal of 4B/5B encoding of avoiding long sequences of bit values 0

c. What's the length of the longest string of bits 1 present in the output of the 4B/5B encoder? Now, carry out the NRZ-I line encoding, then, count the longest string of bit times in which the signal stays on the high level and also count the longest string of bit times in which the signal stays on the low level. Contrast each of the results obtained with the results obtained in a) and in b).

Inspecting the output above we conclude that the longest string of 1's is 4. NRZi encoding is included in the handwritten diagram below (.e).

d. Assume the encoder is using a bit time τ=0.1μs. Calculate the ~~transmitting~~ transmission clock frequency corresponding to this value of τ.

The transmission frequency is **$f = 1/\tau$** $= 10 \cdot 10^6$ Hz = 10MHz

The transmission clock signal is comprised of a train of periodic pulses of fundamental frequency f. The resulting *fundamental period, T will be such that* $T = \frac{1}{f}$. We assume in any single period T, 1 bit can be sent; if we define τ as the *bit time,* we conclude that $T = \tau$. Consequently, the transmission frequency is $f = \frac{1}{\tau} = \frac{1}{0{,}1\mu s} = 1 \cdot 10 \cdot 10^6$ Hz = 10 MHz.

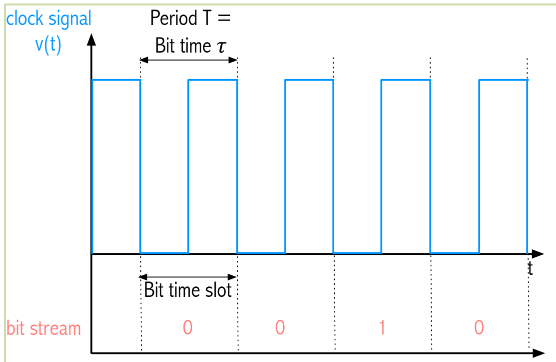


Fig. 1: Clock signal period and bit time

e. Estimate the sampling clock derived by the receiver by calculating the average distance between signal level changes. (See the handwritten diagram in Fig. 2, below)

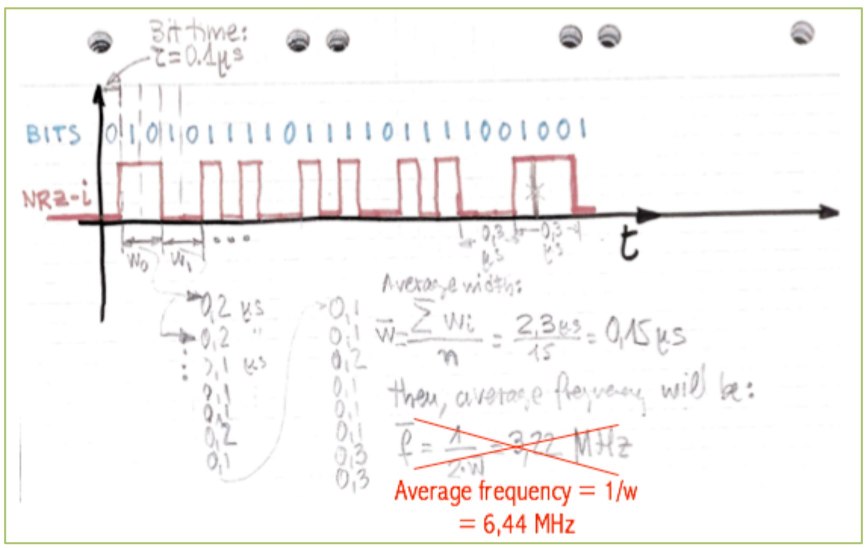


Fig. 2: NRZi data signal: Estimation of transmission frequency

12. Assume, now a Manchester encoder:
    a. Encode the same bit sequence used in the preceding exercise

       Recall a 1 is encoded by a low-to-high transition centered within the bit time and that a bit 0 is encoded with a high-to-low transition centered within the bit time

    b. Assume the encoder is using a bit time τ=0.1μs. Calculate the transmitting clock frequency corresponding to this value of τ.

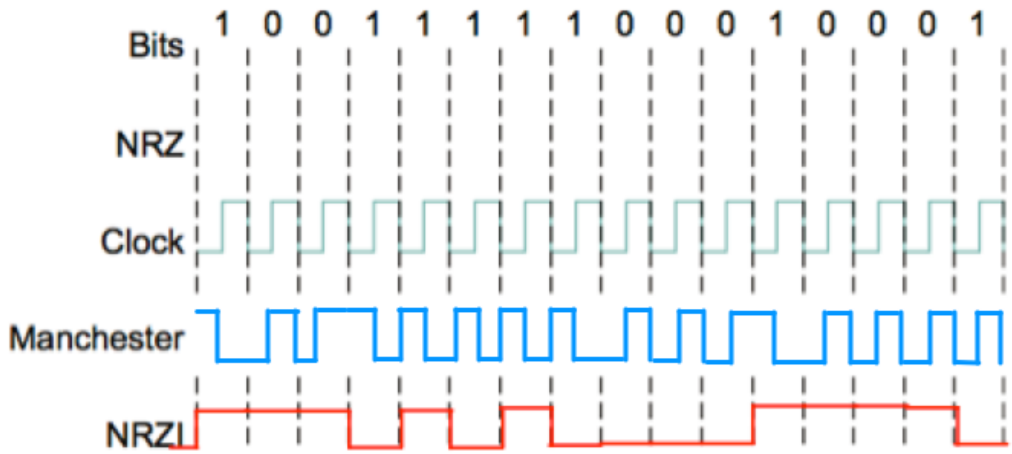
       Solved above (12.d)

    c. Estimate the sampling clock derived by the receiver by calculating the average distance between signal level changes.

       Manchester always has a transition amid the bit time, you should see a frequency higher than that of the case above.

13. Practice line and channel encoding by solving exercises 1 and 3 of chapter 2.

Ex 1:



Consult the solution to Ex 3 in the textbook solutions section