Data Networks: Homework #1

1. Bandwidth and Delay

On a generic multi-hop network, explain the potential causes of delay for a packet:

a. Propagation delay

b. Transmission delay

c. Queueing delay

d. Processing delay

e. For a fixed network path, which of these delays are constant over time, and which ones vary with load? Explain why.

f. What is the total delay (latency) for a frame of size 5 million bits that is being sent on a link with 10 routers each having a queuing time of $2\mu s$ and a processing time of $1\mu s$. The length of the link is 2000 Km. The speed of light inside the link is $2 \times 10^8 \frac{m}{s}$. The link has a bandwidth of 5 Mbps. Which component of the total delay is dominant? Which one is negligible?

2. WAN Technologies

The T-carrier is a member of the series of carrier systems developed by AT&T Bell Laboratories for digital transmission of multiplexed telephone calls. The first version, the Transmission System 1 (T1), was introduced in 1962 in the Bell System, and could transmit up to 24 telephone calls simultaneously over a single transmission line of copper wire. Subsequent specifications carried multiples of the basic T1 (1.544 Mbit/s) data rates, such as T2 (6.312 Mbit/s) with 96 channels, T3 (44.736 Mbit/s) with 672 channels, and others.

a. A T1 line employs what type of multiplexing?

b. With what type of media does a T1 line most likely use when it enters a building?

c. With what type of media would a T3 likely use when it enters a building?

As demand for faster, better, more efficient internet connection increases, so does the number of connection options developed to meet these needs. If you need a link to the Internet, you're probably going to use one of the more common Internet options: Satellite, IDSN, Cable, DSK, and Dialup

d. How does the cost of non-terrestrial communications compare with conventional terrestrial networking?

e. Other than cost, what is the significant disadvantage of satellite communications?

In circuit switching, each data unit know the entire path address which is provided by the source. In Packet switching, each data unit just know the final destination address intermediate path is decided by the routers.

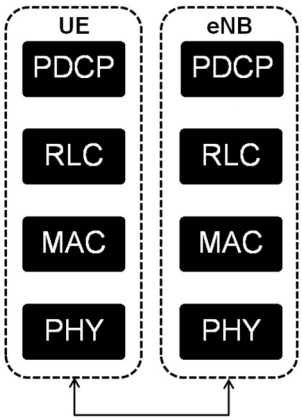
f. Which technology, circuit switching or packet switching is most like the technology utilized by POTS?

g. What is the major criticism of circuit switching?

h. Why is packet switching considered more efficient than circuit switching?

3. LTE and beyond

In class lectures, we talked about OSI model and the layers of a typical network. These layers are implemented differently in each wireless protocol. The state-of-the-art LTE protocol design is the result of a careful cross-layer approach where the protocols interact with each other efficiently. The following diagram describes a general view of the protocol stack between a UE (User equipment such as Cellphones, TD-LTE modems, …) and an eNB.



The wireless technology deployed in the PHY layer of LTE for multiplexing and multiple access is called OFDM (Orthogonal Frequency Division Multiplexing). OFDM is a method of digital signal modulation in which a single data stream is split across several separate narrowband channels at different frequencies to reduce interference and crosstalk. In the following questions we are going to gain a general understanding of OFDM and how it works with the basic knowledge of Communication Systems course which you all probably passed.

Note: In the following questions we use the BPSK digital modulation scheme.

a. Suppose we have a frequency band of BW = 15.36MHz available. What is the minimum pulse width to be transmitted over this communication system?

b. Now suppose we divide the whole band into N=1024 subcarriers providing each subcarrier $\frac{BW}{N}\ Hz$ bandwidth. Calculate the minimum pulse width to be transmitted over the new communication system.

c. Compare the bit rates of the above mentioned systems. Is there any enhancement in the performance?

d. Now explain why we use OFDM in the modern mobile communication systems.

4. Error Correcting Code

For each of the following sets of codewords, please give the appropriate (n,k,d) designation where n is number of bits in each codeword, k is the number of message bits transmitted by each code word and d is the minimum Hamming distance between codewords. Also give the code rate.

a. {111, 100, 001, 010}

b. {111, 100, 001, 010}

c. $\{00000\}$

d. Suppose management has decided to use 20-bit data blocks in the company's new (n,20,3) error correcting code. What's the minimum value of n that will permit the code to be used for single bit error correction?

e. The Registrar has asked for an encoding of class year ("Freshman", "Sophomore", "Junior", "Senior") that will allow single error correction. Please give an appropriate 5-bit binary encoding for each of the four years.

5. Digital Transmission

A CDMA receiver gets the following chips: (-1 +1 -3 +1 -1 -3 +1 +1), and the chip sequence assignment for each station:

A: -1 -1 -1 +1 +1 -1 +1 +1

B: -1 -1 +1 -1 +1 +1 +1 -1

C: -1 +1 -1 +1 +1 +1 -1 -1

D: -1 +1 -1 -1 -1 -1 +1 -1

a. which stations transmitted, and which bits did each one send?

b. We have a baseband channel with a 1-MHz bandwidth. What is the data rate for this channel if we use one of the following line coding schemes? If any of the following schemes was not mentioned in the class lecture, use google :)

a. NRZ-L

b. Manchester

c. MLT-3

d. 2B1Q