# CSC/ECE 570 Section 002

# Spring 2021

# Homework #2

**Keywords:** Physical layer, packet vs circuit switching, transmission media, signal modulation, multiplexing, Systems, signal carriers, satellites, phone networks, cable systems.

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## Instructions

* You can do this homework in groups of two (at most). Only one submission per group.
* The total number of points is 50.
* You must answer all questions for full credit.
* Use only this paper for your answers, in the space provided.
* The due date is as posted on the web page (please submit your answers through Moodle).

# Questions: Answer the following questions. Justify your answers and be as precise as possible. Do not make unnecessary assumptions.

**[1] [4 points]** What is the difference if any between the demodulator part of a modem and the coder part of a codec? After all, both convert analog signals to digital ones.

**Ans** – A coder accepts an arbitrary analog signal and generates a digital signal from it. A demodulator accepts a modulated sine wave only and generates a digital signal.

**[2] [4 points]** Three packet switching networks each contain *n* nodes. The first network has a star topology with a central switch, the second is a bidirectional ring, and the third is fully interconnected, with a wire from every node to every other node. What are the best-, average-, and worst-case transmission paths in hops?

**Ans** – The first network will always have a path equal to 2. The packet goes from the originating computer to the switch, then from the switch to the destination computer (2 hops).

The second would have a best path equal to 1, a worst path equal to n/2 and an average of (n/2)/2. The worst path is equal to n/2 because the farthest a packet will have to travel is equal to half the total nodes since it is bidirectional ring. The average is just a guess and you should be able to figure out why I chose it.

The third (interconnected) network would have a best, average and worst case of 1. Since all machines are connected to each other, there is no hopping at all. Each computer can directly connect to any other computer directly.

**[3] [6 points]** Suppose that *x* bits of user data are to be transmitted over a *k*-hop path in a packet-switched network as a series of packets, each containing *p* data bits and *h* header bits, with *x >> p*+*h*. The bit rate of the lines is *b* bps and the propagation delay is negligible. What value of *p* minimizes the total delay? What is the value of *p* that maximizes the total delay?

**Ans** – There can be multiple ways to find the total delay. We can start by considering the delay of the first packet. Each packet undergoes a transmission delay of p+h/b. The first packet will take k\*(p+h/b) to reach the destination. By this time, the later packets have already reached a certain part of the network.

Eg – The second packet has covered k-1 hops, and it takes (k+1)\*(p+h/b) to reach the destination.

* For the last packet to reach the destination, it will take (x/p – 1)\*(p+h/b) additional time after the first packet.

So, the total delay becomes,

(x/p – 1)\*(p+h/b) + k\*(p+h/b)

The total number of packets needed is x / p,

Size of each packet = (p+h)

Total number of bits to transfer = number of packets \* size of each packet = (x / p) \* (p + h )

The source requires (p + h )x / pb sec to transmit these bits.

Retransmissions of the last packet by the intermediate routers take up a total of (k − 1)\*(p + h)/b sec.

Total delay = Time for the source to send all the bits + Time for the routers to carry the last packet to the destination= (p + h)x /pb + (k − 1) (p + h ) / b

Minimizing this quantity with respect to p, we find p = +-√(hx)/(k−1).

We get minimum delay = √(hx)/(k−1).

We get maximum delay = -√(hx)/(k−1). A negative value of p is not possible. Hence we can assume the graph of p vs delay to be an increasing graph.

[4] [4 points] A CDMA receiver gets the following chips (-1 +1 +1 -1 +1 +3 -1 -3). Assuming the chip sequences used on the lecture slides, which stations transmitted, and which bit did each one send?

**Ans** – Taking the dot product of the signal with each station –

S.A = (-1 +1 +1 -1 +1 +3 -1 -3) . (-1 -1 -1 +1 +1 -1 +1 +1)

* [1 + (-1) + (-1) + (-1) + 1 + (-3) + (-1) + (-3)]/8
* -1

This implies that A transmitted with its negation signal (-1).

S.B = (-1 +1 +1 -1 +1 +3 -1 -3) . (-1 -1 +1 -1 +1 +1 +1 -1)

* [1 + (-1) + 1 + 1 + 1 + 3 + (-1) + 3]/8
* 1

This implies that B transmitted with its positive signal (+1).

S.C = (-1 +1 +1 -1 +1 +3 -1 -3) . (-1 +1 -1 +1 +1 +1 -1 -1)

* [1 + 1 + (-1) + (-1) + 1 + 3 + 1 +3]/8
* 1

This implies that C transmitted with its positive signal (+1).

S.D = (-1 +1 +1 -1 +1 +3 -1 -3) . (-1 +1 -1 -1 -1 -1 +1 -1)

=> [1 + 1 + (-1) + 1 + (-1) + (-3) + (-1) + 3]/8

=> 0

This implies that D was not transmitted.

The signal was made in this way – A bar + B + C.

[5] [4 points] The 66 low-orbit satellites in the Irdium project are divided into 6 necklaces around the earth. At the altitude they are using, the period is 90 minutes. What is the average interval for handoffs for a stationary transmitter?

**Ans** – There are 11 satellites in each necklace. For a stationary transmitter, there are 11 satellites crossing every 90 minutes.

Therefore, the handoff interval = 90 \* 60 / 11 = 491 seconds.

[6] [4 points] Calculate the end-to-end transit time for a packet for both GEO (altitude:35,000 km), MEO (altitude: 18,000 km) and LEO (altitude: 750 km) satellites.

**Ans** – We can use the formula Speed = Distance/Time, where

Distance = Altitude

Speed = Speed of light.

But this distance is travelled twice, so we need to multiply by two to get the time.

Time for GEO satellite = 2 \* [35000 \* 103 / 3 \* 108] = 0.233 sec = 233 msec.

Time for MEO satellite = 2 \* [18000 \* 103 / 3 \* 108] = 0.12 s = 120 msec.

Time for LEO satellite = 2 \* [750 \* 103 / 3 \* 108] = 0.0025 s = 5 msec.

[7] [4 points] A simple telephone system consists of two end offices and a single toll office to which each end office is connected by a 1-MHz full-duplex trunk. The average telephone is used to make 4 calls per 8-hour workday. The mean call duration is 5 min. Ten percent of the calls are long distance (i.e.; pass through the toll office). What is the maximum number of telephones an end office can support? Assume 4-KHz per circuit. Explain why a telephone company may decide to support a lesser number of telephones than this maximum number at the end office.

**Ans** – Each user makes 4 calls, 5 minutes each (20 minutes). 10% calls (2 minutes) are long distance. Each user has a 4KHz connection. This means that 1MHz /4 KHZ = 256 simultaneous calls can be made. The maximum number of telephones are supported if the long-distance calls are distributed uniformly during the 8-hour workdays.

Maximum number of supported telephones is 256 \* 8 \* 60 / 2

* 61440.

[8] [4 points] How long will it take to transmit a 1-GB file from one VSAT to another using a hub? Assume that the uplink is 1 Mbps, the downlink is 6 Mbps, and circuit switching is used with 1 sec circuit setup time.

**Ans** – Time taken to transmit 1 GB file = Transmission time + One way latency + Circuit setup time.

Transmission time = Number of megabytes in a file for 1 GB \* Number of bits per byte.

The lowest bandwidth link (1 Mbps) is the bottleneck.

The transmission time to send 1 GB at 1 Mbps is 1024 × 8 seconds.

The one-way latency= 4 × (35000 / 300000) = 467 msec.

Thus, the total time is 1 + 1024 × 8 + 0. 48 = 8193. 467 seconds.

[9][4 points] Calculate the transmit time in the previous problem if packet switching is used instead. Assume that the packet size is 64 KB, the switching delay in the satellite and hub is 14 microseconds, and the packet header size is 32 bytes.

**Ans** – The lowest bandwidth link (1 Mbps) is the bottleneck.

With 64 KB packets there are 16 packets in a 1 GB file.

This adds 16 × 32 = 512 bytes of headers to transmit.

The transmission time is thus 1024.5 × 8 seconds.

The one-way latency is the propagation delay of 4 × (35000 / 300000) = 467 msec plus three switching times of 0.01 msec.

Thus, the total time is 1024. 5 × 8 + 0. 467 + 3 × 0. 000014 = 8196. 4670014 seconds.

[10][4 points] In a typical mobile phone system with hexagonal cells, it is forbidden to reuse a frequency band in an adjacent cell. If 840 frequencies are available, how many can be used in a given cell?

**Ans** – Each cell has six other adjacent cells, in a hexagonal grid. So, it has to avoid any frequency that any of these cells use. This pattern can repeat, and cover the plane endlessly, so each of these six other cells have to avoid each of the others, but no more. For each cell to have the same number of frequencies (so that a user has the same sort of experience no matter what cell they are in), they all have to have the same number of frequencies, which is thus 840/7 = 120.

This is the answer assuming that you hold to Tanenbaum’s assumption that no two cells which are adjacent to the same cell may re-use frequencies.

However, it is also possible to answer the question by repeating a 3-cell pattern without violating the conditions of the question, and this is also acceptable. In that case, the answer is 840/3 = 280.

The second one saves frequencies, but the first one has the advantage that every frequency is unique to a unique neighbor, as far as a particular tower is concerned. This can facilitate handoff in some situations when two phones are moving into the same cell, and they can be depended upon to have been using different frequencies in their old cells.

[11][4 points] A cable company decides to provide Internet access over cable in a neighborhood consisting of 5000 houses. The company uses a coaxial cable and a spectrum allocation allowing 100 Mbps downstream bandwidth per cable. To attract customers, the company decides to guarantee at least 4 Mbps downstream bandwidth to each house at any time. Describe what the cable company needs to do to provide this guarantee.

**Ans** – A 4-Mbps downstream bandwidth guarantee to each house implies at most 25 houses per coaxial cable.

* To cover 5000 houses, we would need 5000/25 = 200 coaxial cables.

Thus, the cable company will need to split up the existing cable into 200 coaxial cables and connect each of them directly to a fiber node.

[12][4 points] How fast can a cable user receive data if the network is otherwise idle? Assume that the user interface is:

(a) 10 Mbps Ethernet

(b) 100 Mbps Ethernet

(c) 54 Mbps Wireless

**Ans** – The downstream data rate of a cable user is the smaller of the downstream cable bandwidth and the bandwidth of the communication medium between the cable modem and the user’s PC. If the downstream cable channel works at 25 Mbps, the downstream data rate of the cable user will be -

1. 10 Mbps. (b) 25 Mbps. (c) 25 Mbps.

This is assuming that the communication medium between cable modem and the user’s PC is not shared with any other user. Usually, cable operators specify 10-Mbps Ethernet because they do not want one user sucking up the entire bandwidth.