CS/ECE 438: Communication Networks for Computers — Spring 2018

Problem Set 1 — Due: start of class, Wednesday, Jan 31st

Network Overview, Physical Layer, Basic Probability and Network Utilities

Assigned reading: Peterson and Davie: Chapter 1. All problems carry equal weight. To receive full credit, show all of your work. All homework must be turned in via svn. No handwritten solutions accepted.

Network Overview

1. Your company has a large data store that needs to backed up to a new site every week. You have two choices:
   a. Use your high-speed Internet connection and transfer all of the data over the Internet;
   b. Copy your data to a number of portable hard disks, drive them over in your van, then read data from the hard disks at the new site.

   Your Internet connection is 200 Mbps. The one-way latency to the remote site is 10ms. The read/write speed of your portable hard disks is 700 Mbps. Each disk can hold 2 TB. You can only copy to or read data from one disk at a time. You need to drive 2 hours to the new site. You have 15 TB of data to backup every week. Compute and compare the data rate for the two choices, from the moment you start moving the first byte, to the moment the last byte is online at its new location. Which one is faster?

   For choice (1), we only need to transfer data over the Internet (no copying needed) with a latency of 10ms. The data rate is 200 Mbps (the effect of the latency is negligible). Total transfer time is $(15*2^{40}*8)/(200*10^6)$ + 10ms = 659707 s.

   For choice (2), the time of transferring all data to hard disks is $(15*2^{40}*8)/(700*10^6)$ = 188488 s . The time of reading data from hard disks at new site is also 188488 s. Travel time is 2 hours, i.e. 7200 s. Therefore, total transfer time is 384176 s. The data rate is $(15*2^{40}*8)/(384176*10^6)$ = 343.44 Mbps.

   Choice (2) is faster.

2. Consider two machines, A and B, connected by a 200 Mbps Ethernet with four store-and-forward relay switches on the path between them. Suppose that no other machines are using the Ethernet, that each of the links between the machines and switches, as well as between each adjacent switch, introduces a propagation delay of 5µs, and that a switch begins transmitting a packet immediately after receiving the last bit of the packet.
   a. What is the total transfer time for a 512B packet, as measured from transmission of the first bit at A to receipt of the last bit at B?

      The transmission time necessary for station A to put the first packet onto the Ethernet, is (512 x 8) / 200 x 10^6 = 0.00002048, or 20.48µs. The time needed for the last bit of the packet to propagate to the first switch is 5µs. The time needed for the first switch to transmit the packet to the second switch on the second Ethernet is again 48µs, and the time needed for the last bit to propagate over the second Ethernet is 5µs. The time needed for the second switch to transmit the packet to the third switch on the third Ethernet is again 48µs, and the time needed for the last bit to propagate over the third Ethernet is 5µs. The time needed for the third switch to transmit the packet to the fourth switch on the fourth Ethernet is again 48µs, and the time needed for the last bit to propagate over the fourth Ethernet is 5µs. Finally, the time needed for the fourth switch to transmit the packet to B on the fifth Ethernet is again 48µs, and the time needed for the last bit to propagate over the third Ethernet is 5µs. Thus, the total latency is (48µs + 5µs) x 5 = 265µs, with the propagation time accounting for about 9% of the total latency.

   b. What is the effective bandwidth for transmission of a large file from A to B, assuming that packets of size 512B are used and that packet headers use 100B of the 512B? Assume that the nodes can send constantly, and in particular that the switches can simultaneously receive a packet from one side while transmitting a previous packet out the other side, and that A is not slowed down waiting for acknowledgements.

The intermediate switches do not decrease the long term effective data rate, since they transmit and receive simultaneously after receipt of the first packet. The data rate (end-to-end bandwidth) is therefore the link speed times a factor (512 – 100) / 512 = 0.805 due to packet headers, yielding an effective bandwidth of 160.94 Mbps.

c. What is the effective bandwidth if, after each transmission of a 512B packet, node A must wait for an 100-byte acknowledgement from B?

As found in part (a), the latency for a single 512B packet is 265µs. Similarly, the latency for a 100-byte acknowledgment is $5 \times ((100 \times 8)/(200 \times 10^6 s) + 5\mu s) = 5 \times 4\ \mu s = 20\mu s$. Thus, the total time to send a packet and receive an acknowledgment is 285µs. Therefore, 512B – 100B = 412B = 3296 bits of data can be sent every 285µs, and the effective bandwidth is 3296 / 0.000285 = 11.6 Mbps.

3. Suppose users share a 100 Gbps link. Also suppose each user requires 700 Mbps when transmitting, but each user only transmits 8 percent of the time. Whether a user is transmitting or not is an independent random variable with uniform distribution.

a. When circuit switching is used, how many users can be supported?

Up to 142 circuits can be established, independently from their actual usage. So **at most 142 users** are supported in this case.

b. For the remainder of this problem, suppose packet switching is used. Suppose there are 1500 users. First, find an equation for the probability that at any given time, n users are transmitting simultaneously. (You only need to set up the equations)

The probability that a specific group of n users are transmitting is:

$p^n \times (1 - p)^{(1500-n)}$

And in a group of 1500 users, there are (1500 choose n) different groups of n users. So the probability that n users are transmitting simultaneously is:

$(1500 \text{ choose } n) \times 0.08^n \times (1-0.08)^{(1500-n)}$

c. What is the probability that the link will get overloaded?

The link is overloaded if more than 142 users are transmitting at the same time. This can be computed as one minus the probability that 0,1,2…142 users are transmitting. Following from part (b), the probability is:

$P_{overload} = 1- \Sigma_{i=0}^{142} P_i$

4. For each of the following links, calculate the bandwidth x delay product in bits using one-way delay.

a. 15 Gbps Ethernet with a delay of 60 µs.

Bandwidth x delay = $(15 \text{ Gbps})(60 \times 10^{-6} \text{ sec})$ = 900,000 bits

b. 450 Mbps wireless link, with a one-way delay of 0.15 µs.

Bandwidth x delay = $(450 \times 10^6)(0.15 \times 10^{-6} \text{ sec})$ = 67.5 bits

c. 500 Mbps link through a satellite in geosynchronous orbit, 35,786 km high. The only delay is speed-of-light propagation delay.

This link went through a satellite so we have to account for both the delays involved in going both up to the satellite and back down (these delays are, of course, the same). Given that the speed of light = c = $3*10^8$, the propagation delay is then 2 x 35,786,000/c = .24 sec. The bandwidth x delay product is thus (500 x 10^6 bits/sec)(.24 sec) = 120,000,000 bits.

5. Every year, an industrious computer science student heads to Las Vegas to play in a poker tournament. There are seven rounds in the tournament, and the student must win each round to advance to the next. The student wins (50*n) chips in the nth round, if the student makes it that far, and has a 65% chance of winning each round they play.

Let m be the (statistical) mean number of chips earned by the student in a tournament, and let n be the mean number of rounds played per tournament. Use cycle analysis to find:

a. What fraction of years does the student make it to the final round?
b. m
c. n
d. m/n. Note that this ratio is the student's long-term rate of chips per round.

Cycles	Probability (p)	Rounds	Chips Earned
L	.35	1	0
WL	.65 x .35	2	50
WWL	.65 x .65 x .35	3	50 + 100
WWWL	.65 x .65 x .65 x .35	4	50 + 100 + 150
WWWWL	.65 x .65 x .65 x .65 x .35	5	50 + 100 + 150 + 200
WWWWWL	.65 x .65 x .65 x .65 x .65 x .35	6	50 + 100 + 150 + 200 + 250
WWWWWWL	.65 x .65 x .65 x .65 x .65 x .65 x .35	7	50 + 100 + 150 + 200 + 250 + 300
WWWWWWW	.65 x .65 x .65 x .65 x .65 x .65 x .65	7	50 + 100 + 150 + 200 + 250 + 300 + 350

a. What fraction of years does the student make it to the final round?

The probability of playing in round 7 is the probability of being either in cycle WWWWWWL is or WWWWWWW. The actual value is:

$$0.65^6 \text{ x } 0.35 + 0.65^7 = 0.00129$$

a. *m* = The expected amount of chips earned

m = (0) * P[cycle (L)
+ (50) * P[cycle (WL)
+ (50 + 100) * P[cycle (WWL)
+ (50 + 100 + 150) * P[cycle (WWWL)
+ (50 + 100 + 150 + 200) * P[cycle (WWWWL)
+ (50 + 100 + 150 + 200 + 250) * P[cycle (WWWWWL)
+ (50 + 100 + 150 + 200 + 250 + 300) * P[cycle (WWWWWWL)
+ (50 + 100 + 150 + 200 + 250 + 300 + 350) * P[cycle (WWWWWWW)

m = (0) * 0.35
+ (50) * 0.2275
+ (150) * 0.147875
+ (300) * 0.09611875
+ (500) * 0.0624771875
+ (750) * 0.040610171875
+ (1050) * 0.02639661171875
+ (1400) * P 0.04902227890625

m = 220.4357304 coins

b. *n* = the expected amount of rounds played

n = 1*P[1 round] + 2*P[2 rounds] + 3*P[3 rounds] + 4*P[4 rounds] + 5*P[5 rounds] + 6*P[6 rounds] + 7*P[7 rounds]

n = (1) * P[cycle (L)]
+ (2) * P[cycle (WL)]
+ (3) * P[cycle (WWL)]
+ (4) * P[cycle (WWWL)]
+ (5) * P[cycle (WWWWL)]
+ (6) * P[cycle (WWWWWL)]
+ (7) * P[cycle (WWWWWWL)]
+ (8) * P[cycle (WWWWWWW)]

n = (1) * 0.35
+ (2) * 0.2275
+ (3) * 0.147875
+ (4) * 0.09611875
+ (5) * 0.0624771875
+ (6) * 0.040610171875
+ (7) * 0.02639661171875
+ (8) * P 0.04902227890625

n = 2.717 rounds

c. *m/n*. Note that this ratio is the Illini's long-term rate of points per game.
m/n = 220.4357304 coins /2.717 rounds = 81.132 coins/round

Networking Utilities

6. The Unix utility `whois` can be used to find the domain name corresponding to an organization, or vice versa. The information is provided by a *domain name registration* service provider. This utility is commonly shipped with linux, but it is not available on the ews machines. If you try it on your own linux machine with high probability you will find it available. Read the online man page for `whois` and experiment with it. For example, try `whois twitter.com`.

Now, do a whois query for the following domains:

`microsoft.com`
`microsoot.com`
`illinois.edu`
`npr.org`
`chelseafc.com`

For each, turn in the registar and the date in which this record was created and/or activated and the expiration date, if present.

Domain Name: MICROSOFT.COM
Updated Date: 2014-10-09T16:28:25Z
Creation Date: 1991-05-02T04:00:00Z
Registry Expiry Date: 2021-05-03T04:00:00Z
Registrar: MarkMonitor Inc.

Domain Name: MICROSOOT.COM

Updated Date: 2017-04-20T09:24:49Z
Creation Date: 1999-05-22T10:29:58Z
Registry Expiry Date: 2018-05-22T10:29:26Z
Registrar: MarkMonitor Inc.

Domain Name: ILLINOIS.EDU
Domain record activated: 13-Jan-1997
Domain record last updated: 10-Apr-2017
Domain expires: 31-Jul-2018

Domain Name: NPR.ORG
Updated Date: 2018-01-13T20:23:41Z
Creation Date: 1993-12-13T05:00:00Z
Registry Expiry Date: 2018-12-12T05:00:00Z
Registrar: NETWORK SOLUTIONS, LLC.

Domain Name: CHELSEAFC.COM
Updated Date: 2016-07-11T14:43:21Z
Creation Date: 1998-09-12T04:00:00Z
Registry Expiry Date: 2021-09-11T04:00:00Z
Registrar: GoDaddy.com, LLC

Note: These are all domains that belong to an organization, which takes care of managing the various subdomains such as **www**.*company.com* or **mail**.*company.com.* But someone must have registered simply **com, edu, net, gov,** and all the other root domains, first! Do some more digging if this topic finds you interested, and have fun!