CS/ECE 438: Communication Networks Spring 2010
Problem Set 1 Due: start of class, Wednesday, February 3rd

Network Overview, Utilities and Basic Probability

Assigned reading: Peterson and Davie: Chapter 1

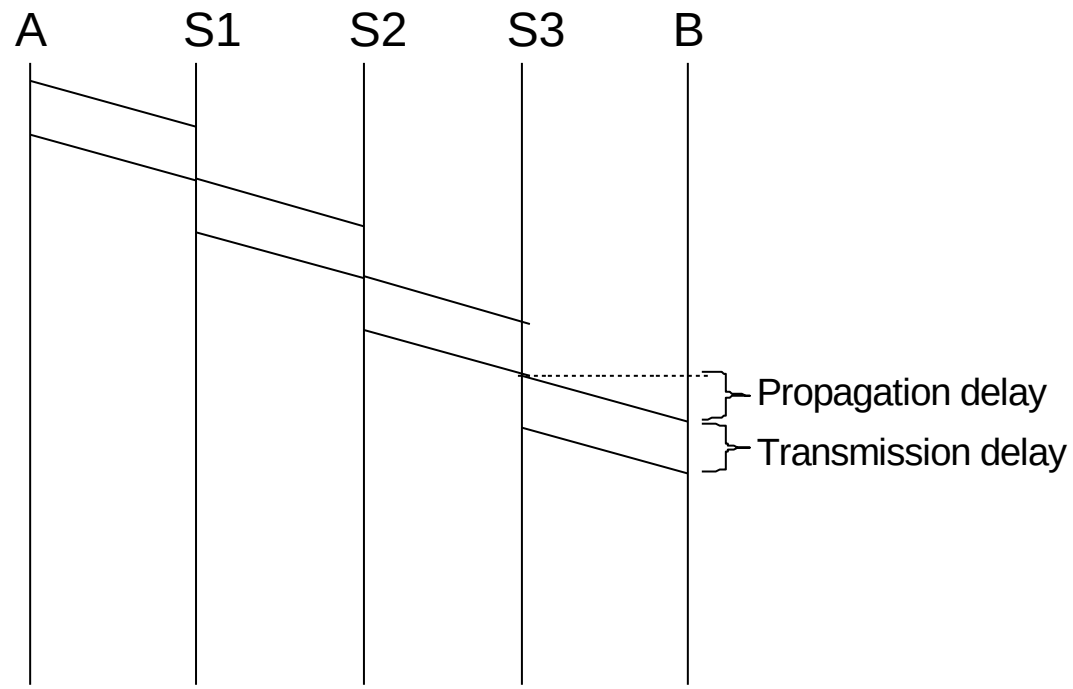
All problems carry equal weight. To receive full credit, show all of your work.

1. Your company has a large data store to back up every week and you want to find the quickest possible way to get your backup off site. You have two choices: (1) use your high-speed internet connection and transfer all of the data over the internet or (2) copy your data to a flash drive and drive it over in your car. Your internet connection is over an OC3 line (155.52Mbps), and you copy to your flash drive via high-speed USB (480Mbps), each flash drive holds 32 GB and you live two hours away from your storage location. If you have 4TB of data to back up every week. Answer these two questions (a) How many flash drives would you need with option #1? (b) Which transmission method has the higher data rate?

   *You need 4TB / 32 GB = 125 flash drives. It will take you 125 * 256 Gb / 480 Mbps = 66666 sec to fill 125 drive and then another 66666 sec to copy the data to your storage site (a flash drive contains 32 GB = 256 Gb). Carrying 125 drives and given a copy time of 2 x 66666 sec and a travel time of 120 min = 7200 sec, we have a data rate of 125 * 256 Gb / 140533 sec ~= 228 Mbps.*

2. Consider two machines, A and B, connected by a 1 Gbps Ethernet with five store-and-forward relay switches on the path between them. Suppose that no other machines are using the Ethernet, that each of the five links introduces a propagation delay of 3μs, 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 1500B 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 1500 x 8 / 10^8 = 0.000012 seconds, or 12μs. The time needed for the last bit of the packet to propagate to the switch is 3μs. The time needed for the first switch to transmit the packet on the second Ethernet is again 12μs, and the time needed for the last bit to propagate over the second Ethernet is 3μs. The time needed for the second switch to transmit the packet on the third Ethernet is again 12μs, and the time needed for the last bit to propagate over the third Ethernet is 3μs. The same is true for the fourth and fifth link in the system. Thus, the total latency is (12μs/link + 3μs/link) *(5 links)s = 75us, with the propagation time accounting for only about 20% of the total latency. This problem may be visualized as follows:*



b. What is the effective bandwidth for transmission of a large file from A to B, assuming that packets of size 1500B are used and that packet headers are 120B long? 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 (1500 – 120) / 1500 = 0.92 due to packet headers, yielding an effective bandwidth of 920 Mbps.

c. What is the effective bandwidth if, after each transmission of a 1500B packet, node A must wait for a 40-byte acknowledgement from B? For simplicity, you can assume there are no packet headers.

As found in part (a), the latency for a single 1500B packet is 75 μs. Similarly, the latency for a 40-byte acknowledgment is 5 x ((40 x 8/10^9)s + 3μs) = 16.6 μs. Thus, the total time to send a packet and receive an acknowledgment is 91.6 μs. Therefore,
*1500*8 bits of data can be sent every 91.6μs and the effective bandwidth is 131 Mbps.*

3. Suppose users share a 1 Gbps link. Also suppose each user requires 180 Mbps when transmitting, but each user only transmits 8 percent of the time.
   a. When circuit switching is used, how many users can be supported?

   ⌊ 1 Gbps / 180 Mbps ⌋ = 5 users

   b. For the remainder of this problem, suppose packet switching is used. Suppose there are 30 users, and each user is equally likely to transmit at any point in time (e.g., there are no correlations in sending times across users). Find an equation for the probability that at any given time, n users are transmitting simultaneously.

   (30 choose n) x 0.08^n x $0.92^{(30-n)}$

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

Find the probability that there are 6 or more users transmitting simultaneously.

P[6 or more transmitting] = $1 - P[5 \text{ or fewer transmitting}]$

= $1 - \Sigma_{i=0}^{5} (30 \text{ choose } i) \times 0.08^{i} \times 0.92^{(30-i)}$

4. For each of the following links, compute how many bits can be "in flight" at any point in time (i.e., how many bits are within the link itself, as opposed to being stored in queues at the link endpoints). Use one-way delay, measured from first bit sent to first bit received.

a. 1 Gbps Ethernet with a delay of 4 μs.

Bandwidth x delay = (1 Gbps)(4 x 10^{-6} sec) = 4000 bits

b. 1.5-Mbps T1 link, with a one-way delay of 30 ms.

Bandwidth x delay = (1.5 x 10^{6})(30 x 10^{-3} sec) = 45000 bits

c. 10 Mbps link through a satellite in geosynchronous orbit, 35,000 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 35,000,000/c = .23 sec. The bandwidth x delay product is thus (10 x 10^{6} bits/sec)(.23 sec) = 2,333,333 bits.*

5. Networking utilities `whois`, `ping` and `traceroute`

a. 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. Read the man page for `whois` and experiment with it. For example, try `whois facebook.com`. The response should tell you that `facebook.com` is registered on the server `whois.tucows.com` owned by TUCOWS INC. Try `whois myspace.com`. Now try `whois -h <whois server for myspace.com> myspace.com`. You will find out a lot more information. Here is what you need to turn in: (i) Give the phone # of the technical contact, (ii) Give both the English language names, and the internet addresses of all nameservers, and (iii) Give the date and time this record was last updated.

```
> whois myspace.com
[Querying whois.verisign-grs.com]
[whois.verisign-grs.com]

Whois Server Version 2.0

   Domain Name: MYSPACE.COM
   Registrar: NETWORK SOLUTIONS, LLC.
   Whois Server: whois.networksolutions.com
   Referral URL: http://www.networksolutions.com
   Name Server: NS1.MYSPACE.COM
   Name Server: NS2.MYSPACE.COM
   Status: clientDeleteProhibited
   Status: clientTransferProhibited
   Status: clientUpdateProhibited
   Updated Date: 02-jul-2008
   Creation Date: 22-feb-1996
   Expiration Date: 23-feb-2013

> whois -h whois.networksolutions.com myspace.com
[Querying whois.networksolutions.com]
[whois.networksolutions.com]

Registrant:
MySpace, Inc.
```

```
   ATTN: MYSPACE.COM
   c/o Network Solutions
   P.O. Box 447
   Herndon, VA.  20172-0447

   Domain Name: MYSPACE.COM

   Administrative Contact, Technical Contact:
      DNS                                Admin,                                Myspace
fw4fn5h486w@networksolutionsprivateregistration.com
      Fox Group Legal
      ATTN: MYSPACE.COM
      c/o Network Solutions
      P.O. Box 447
      Herndon, VA 20172-0447
      570-708-8780

   Record expires on 23-Feb-2013.
   Record created on 22-Feb-1996.
   Database last updated on 22-Jan-2009 22:48:24 EST.

   Domain servers in listed order:

   NS1.MYSPACE.COM             204.74.66.247
   NS2.MYSPACE.COM             204.74.67.247
```

i. 570-708-8780
ii. NS1.MYSPACE.COM 204.74.66.247
NS2.MYSPACE.COM 204.74.67.247
iii. 22-Jan-2009

b. The Unix utility `ping` can be used to find the round trip time (RTT) to various Internet hosts. See the man page for `ping` to see how to use `ping` and the `-s` option with other options to see how you can control the time between ping packet transmissions, and to display the resulting round trip times. Upon interrupting execution of `ping`, the min, average and maximum RTT will also be displayed. Here is what you turn in: Report the average (average over five pings) round trip times for pings to the nameservers for `facebook.com`, for `myspace.com` and for `linkedin.com`. If there are multiple nameservers for a domain, use the first one listed.

```
>  whois facebook.com
[Querying whois.verisign-grs.com]
[whois.verisign-grs.com]

   Domain Name: FACEBOOK.COM
   Name Server: DNS04.SF2P.TFBNW.NET
   Name Server: DNS05.SF2P.TFBNW.NET
   Name Server: NS1.FACEBOOK.COM
   Name Server: NS2.FACEBOOK.COM

> ping DNS04.SF2P.TFBNW.NET
PING DNS04.SF2P.TFBNW.NET (69.63.176.8) 56(84) bytes of data.
64 bytes from dns04.sf2p.tfbnw.net (69.63.176.8): icmp_seq=1 ttl=48 time=72.5 ms
64 bytes from dns04.sf2p.tfbnw.net (69.63.176.8): icmp_seq=2 ttl=48 time=72.0 ms
64 bytes from dns04.sf2p.tfbnw.net (69.63.176.8): icmp_seq=3 ttl=48 time=72.8 ms
64 bytes from dns04.sf2p.tfbnw.net (69.63.176.8): icmp_seq=4 ttl=48 time=72.7 ms
64 bytes from dns04.sf2p.tfbnw.net (69.63.176.8): icmp_seq=5 ttl=48 time=72.4 ms

--- DNS04.SF2P.TFBNW.NET ping statistics ---
5 packets transmitted, 5 received, 0% packet loss, time 4003ms
rtt min/avg/max/mdev = 72.063/72.522/72.877/0.367 ms

> whois myspace.com
[Querying whois.verisign-grs.com]
[whois.verisign-grs.com]

   Domain Name: MYSPACE.COM
```

```
   Name Server: NS1.MYSPACE.COM
   Name Server: NS2.MYSPACE.COM


> ping NS1.MYSPACE.COM
PING NS1.MYSPACE.COM (204.74.66.247) 56(84) bytes of data.
64 bytes from ns1.myspace.com (204.74.66.247): icmp_seq=1 ttl=51 time=13.5 ms
64 bytes from ns1.myspace.com (204.74.66.247): icmp_seq=2 ttl=51 time=5.33 ms
64 bytes from ns1.myspace.com (204.74.66.247): icmp_seq=3 ttl=51 time=5.63 ms
64 bytes from ns1.myspace.com (204.74.66.247): icmp_seq=4 ttl=51 time=5.97 ms
64 bytes from ns1.myspace.com (204.74.66.247): icmp_seq=5 ttl=51 time=34.0 ms

--- NS1.MYSPACE.COM ping statistics ---
5 packets transmitted, 5 received, 0% packet loss, time 4001ms
rtt min/avg/max/mdev = 5.335/12.908/34.047/11.006 ms

> whois linkedin.com
[Querying whois.verisign-grs.com]
[whois.verisign-grs.com]

   Domain Name: LINKEDIN.COM
   Name Server: PDNS1.ULTRADNS.NET
   Name Server: PDNS2.ULTRADNS.NET
   Name Server: PDNS3.ULTRADNS.ORG
   Name Server: PDNS4.ULTRADNS.ORG
   Name Server: PDNS5.ULTRADNS.INFO
   Name Server: PDNS6.ULTRADNS.CO.UK

> ping PDNS1.ULTRADNS.NET
PING PDNS1.ULTRADNS.NET (204.74.108.1) 56(84) bytes of data.
64 bytes from pdns1.ultradns.net (204.74.108.1): icmp_seq=1 ttl=51 time=6.29 ms
64 bytes from pdns1.ultradns.net (204.74.108.1): icmp_seq=2 ttl=51 time=5.97 ms
64 bytes from pdns1.ultradns.net (204.74.108.1): icmp_seq=3 ttl=51 time=6.31 ms
64 bytes from pdns1.ultradns.net (204.74.108.1): icmp_seq=4 ttl=51 time=6.31 ms
64 bytes from pdns1.ultradns.net (204.74.108.1): icmp_seq=5 ttl=51 time=7.12 ms
64 bytes from pdns1.ultradns.net (204.74.108.1): icmp_seq=6 ttl=51 time=6.63 ms

--- PDNS1.ULTRADNS.NET ping statistics ---
6 packets transmitted, 6 received, 0% packet loss, time 5000ms
rtt min/avg/max/mdev = 5.973/6.441/7.122/0.371 ms
```

c. The Unix utility `traceroute` is like ping, but it sends packets that are limited to go one hop, then two hops, then three hops, and so on, towards a given destination, and the intermediate routers are reported. Read the man page for `traceroute` and experiment with it. Try `traceroute www.google.com`, or equivalently `traceroute 64.233.189.99`. How many routers are encountered along the way? You can try identifying the intermediate routers further using `ping`. Here is what you need to turn in: (i) Give the internet address of the ninth router encountered for the `traceroute` to `www.google.com`. (ii) Also, `ping` that router and report whether `ping` and `traceroute` report the same round trip times to that router. (iii) Which states of the USA does your packet traverse through?

```
traceroute www.google.com
traceroute to www.google.com (64.233.189.99), 30 hops max, 40 byte packets
 1  dcsgw-csil.cs.uiuc.edu (128.174.242.1)  0.457 ms  0.753 ms  1.064 ms
 2  uiuc-node1siebel-net.gw.uiuc.edu (128.174.1.185)  0.257 ms  0.273 ms  0.357 ms
 3  172.20.20.5 (172.20.20.5)  0.216 ms  0.316 ms  0.368 ms
 4  t-exitio.gw.uiuc.edu (130.126.0.162)  0.192 ms  0.220 ms  0.257 ms
 5  130.126.0.14 (130.126.0.14)  0.340 ms  0.502 ms  0.656 ms
 6  uiuc-exite-fw-net.gw.uiuc.edu (130.126.0.30)  1.509 ms  1.425 ms  1.435 ms
 7  t-dmzo.gw.uiuc.edu (130.126.0.70)  1.940 ms  1.985 ms  4.145 ms
 8  ur1rtr-uiuc.ex.ui-iccn.org (72.36.127.1)  2.017 ms  2.413 ms  2.597 ms
 9  t-710rtr.ix.ui-iccn.org (72.36.126.110)  6.968 ms  7.023 ms  7.070 ms
10  i2-cps.ex.ui-iccn.org (72.36.127.138)  205.443 ms  205.531 ms  205.999 ms
11  74.125.48.105 (74.125.48.105)  7.750 ms  7.632 ms  7.636 ms
12  216.239.46.245 (216.239.46.245)  7.671 ms 209.85.251.38 (209.85.251.38)  8.116 ms
8.136 ms
13  72.14.232.141 (72.14.232.141)  19.442 ms  19.649 ms  19.263 ms
```

```
14  209.85.243.117 (209.85.243.117)  63.537 ms  60.750 ms  60.744 ms
15  209.85.248.129 (209.85.248.129)  56.441 ms  56.745 ms  56.736 ms
16  209.85.248.130 (209.85.248.130)  139.533 ms  139.849 ms  139.198 ms
17  209.85.252.104 (209.85.252.104)  192.412 ms  191.309 ms  191.071 ms
18   66.249.94.6 (66.249.94.6)   202.718 ms   197.039 ms  66.249.94.34 (66.249.94.34)
190.744 ms
19  hk-in-f99.google.com (64.233.189.99)  190.769 ms  191.687 ms  191.668 ms

> ping 72.36.126.110
PING 72.36.126.110 (72.36.126.110) 56(84) bytes of data.
64 bytes from 72.36.126.110: icmp_seq=1 ttl=56 time=4.48 ms
64 bytes from 72.36.126.110: icmp_seq=2 ttl=56 time=3.68 ms
64 bytes from 72.36.126.110: icmp_seq=3 ttl=56 time=3.82 ms
64 bytes from 72.36.126.110: icmp_seq=4 ttl=56 time=4.40 ms
64 bytes from 72.36.126.110: icmp_seq=5 ttl=56 time=3.84 ms

--- 72.36.126.110 ping statistics ---
5 packets transmitted, 5 received, 0% packet loss, time 4001ms
rtt min/avg/max/mdev = 3.689/4.049/4.488/0.337 ms
```