| ECE/CS 438: Communication Networks	Fall 2017

Homework 1

Handed Out: September 6th, 2017   *Due: 11:59pm, September 20th, 2017*

TA: Suraj Jog

- Feel free to talk to other members of the class in doing the homework. I am more concerned that you learn how to solve the problem than that you demonstrate that you solved it entirely on your own. You should, however, write down your solution yourself. Please try to keep the solution brief and clear.

- Please use Piazza first if you have questions about the homework. Also feel free to send us e-mails and come to office hours.

- While we encourage discussion within and outside of the class, cheating and copying is strictly prohibited. Copied solutions will result in the entire assignment being discarded from grading at the very least. Please note that you must explicitly state at the top of your solutions the names of students you discussed your solution with.

- The homework is due at 11:59 PM on the due date. We will be using Compass2g for collecting the homework assignments. Please submit an electronic copy via Compass (`http://compass2g.illinois.edu`). If you plan to submit a hand-written copy, you must upload a **legible** scanned copy on compass. Failure to understand written assignments will be the student's fault. Contact the TAs if you face technical difficulties in submitting the assignment.

- The TA in charge for HW 1 is Suraj Sanjay Jog, and all questions should be directed to him.

1. Circuit Switching - 12 points

The diagram below shows a network of routers and the capacity of links (in Mbps) that are attached to each router.
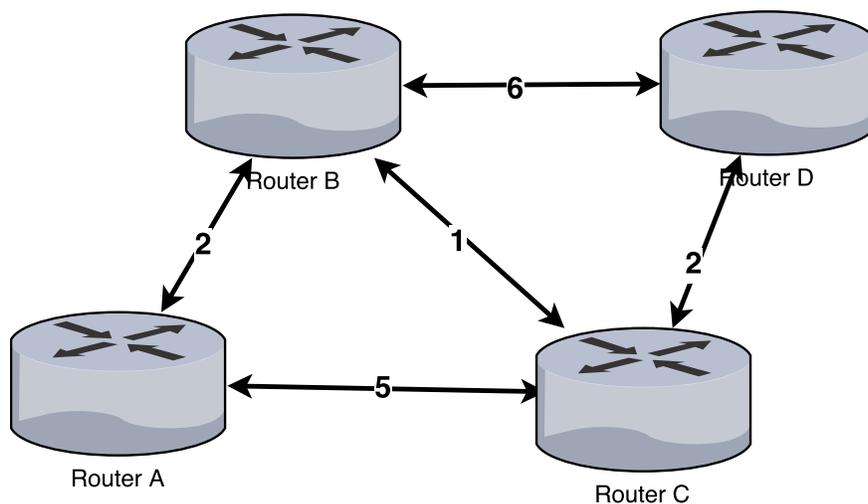
1. If each circuit uses 0.25 Mbps, how many circuits can we simultaneously support between routers A and D? Which links would they use?

2. How many circuits can we simultaneously support between B and C? Which links would they use? For this part, assume that no other circuits are active.

3. For this part, consider establishing circuits simultaneously A↔D and B↔C. What is the maximum total number of circuits that this network configuration would support?

2. Packet Switching - 12 points

Suppose that you share your 20 Mbps connection with two roommates. The first roommate uses the link 30% of the time, and the second one uses the link 40% of the time.

1. What is the fraction of the time that you have the connection all to yourself?

2. What is the fraction of the time that you have to share the connection with both roommates simultaneously?

3. Assume that when two or more people use the connection, the bandwidth is divided fairly among them. What is the average bandwidth you will receive from the link?

3. Layering - 10 points

Give a real-world example of a system / set of protocols that can be explained using layering. Explain what the layers are (there should be at least 3), and what the interface between each pair of adjacent layers looks like.

In the context of your example, what are some of the advantages of layering? What is a disadvantage?

4. Client-Server - 12 points

Consider distributing a file of F bits to N peers using a client-server architecture. Let the server have an maximum upload capacity μ_s, and each client c has a download capacity d_c. Let $d_{min} = \min_c d_c$ be the minimum download rate. Assume that the server can serve multiple clients simultaneously and fluidly set the rate for each client, r_c, as long as $\forall_c r_c \leq d_c$ and $\sum_c r_c \leq \mu_s$.

1. Suppose that $\mu_s/N \leq d_{min}$. How would you set the rates r_c so that the file is fully distributed to all clients in a minimum time? (i.e., you are minimizing the time that the slowest client receives the file.) What would the distribution time be?

2. Suppose now that $\mu_s/N > d_{min}$. How would you set the rates r_c now to fully distribute the file to the clients in a minimum time? And what would this time be?

3. Consider a concrete example with 4 clients with $d_c = \{10, 15, 20, 25\}$ and a server upload capacity of $\mu_s = 60$. How would you set the rates to get the smallest average download time *without* increasing the total distribution time from the previous part?

5. Delays - 20 points

For this part, consider two hosts, A and B, connected by a switch S. The link A↔S is 10 Mbps and has a propagation delay of 20 ms; the link B↔S is 5 Mbps and has a propagation delay of 150 ms.

1. Suppose A sends a 50 KB packet to B. What is the total (end-to-end) delay before the packet is received by B in its entirety? Assume that S operates in a "store-and-forward" manner and that the processing delay is 0.

2. Suppose A is sending a sequence of 50 KB packets. How many packets will it have sent when the first packet arrives (completely) at B?

3. Let S have a 500 KB buffer for packets. Suppose A sends a sequence of 50 KB packets as fast as possible; how long will it be until the buffer is full?

4. What will be the queueing delay encountered by the last packet to enter the buffer?

5. Assume now that the buffer is infinite. How long will it take (end-to-end) for a 10 MB file to be sent from A to B? What is the average throughput.

6. Suppose that, after B receives a packet, it sends a short (100 byte) acknowledgment packet to A. A waits for this acknowledgment before sending the next packet. How long will it take to send a 10 MB file in this setting? What is the average throughput?

6. DNS - 10 points

You have clicked a link to an html page in your web browser. In this problem, nothing is cached. Assume the network is lightly loaded (so, no queuing delay).

Name resolution phase: suppose n DNS servers will need to be visited to finish the resolution of the link's domain. You use a DNS resolver in the regular way. Your RTT to your DNS resolver is T_r, your RTT to all other DNS servers is T_d, and your resolver's RTT to all other DNS servers is T_o. The other DNS servers all have RTTs of T_o' to each other.

Starting from your click, how much time passes before your localhost gets a reply from your DNS resolver? Please explain all assumptions, along with the calculations.

7. Traceroute - 14 points

In the next figures, you will see a series of results from running `traceroute` (with the `-q 1` option to send one probe per hop). For each of the results, please answer the following questions:

1. Which hop (if any) is the transoceanic link?

2. Based on the RTT to the last hop, what's the furthest away the corresonding server could possibly be located?

3. How does this compare to the distance to where you think the server is actually located?

4. Sometimes the RTT of a subsequent hop is *lower* than the RTT of a previous one. Give one reason why this might happen. (You only need to answer this question once.)

```
traceroute to www.google.com (172.217.0.4), 30 hops max, 60 byte packets
 1  0148-cslgeneral-net.gw.uiuc.edu (192.17.100.1)  0.679 ms
 2  t-core1-1.gw.uiuc.edu (172.20.101.25)  712.760 ms
 3  t-exit1.gw.uiuc.edu (130.126.0.242)  0.479 ms
 4  t-fw1.gw.uiuc.edu (130.126.0.134)  1.297 ms
 5  t-exite1.gw.uiuc.edu (130.126.0.141)  2.035 ms
 6  t-dmzo.gw.uiuc.edu (130.126.0.202)  1.996 ms
 7  ur1rtr-uiuc.ex.ui-iccn.org (72.36.127.1)  2.551 ms
 8  t-710rtr.ix.ui-iccn.org (72.36.127.85)  4.633 ms
 9  r-equinix-isp-ae0-2244.wiscnet.net (216.56.50.49)  5.305 ms
10  r-equinix-isp-ae0-2244.wiscnet.net (216.56.50.49)  5.166 ms
11  108.170.243.193 (108.170.243.193)  5.306 ms
12  216.239.42.35 (216.239.42.35)  5.176 ms
13  ord38s04-in-f4.1e100.net (172.217.0.4)  5.285 ms
```

```
traceroute to www.auckland.ac.nz (130.216.159.127), 64 hops max, 52 byte packets
 1  0148-cslgeneral-net.gw.uiuc.edu (192.17.100.1)  0.967 ms
 2  t-core1-1.gw.uiuc.edu (172.20.101.25)  0.536 ms
 3  t-exit1.gw.uiuc.edu (130.126.0.242)  0.407 ms
 4  t-fw1.gw.uiuc.edu (130.126.0.134)  0.666 ms
 5  t-exite1.gw.uiuc.edu (130.126.0.141)  0.937 ms
 6  t-dmzo.gw.uiuc.edu (130.126.0.202)  12.626 ms
 7  ur1rtr-uiuc.ex.ui-iccn.org (72.36.127.1)  1.051 ms
 8  t-ur2rtr.ix.ui-iccn.org (72.36.126.66)  1.576 ms
 9  internet2-710rtr.ex.ui-iccn.org (72.36.127.158)  4.107 ms
10  et-7-1-0.4070.rtsw.kans.net.internet2.edu (198.71.45.15)  21.305 ms
11  et-4-1-0.4070.rtsw.salt.net.internet2.edu (198.71.45.19)  41.337 ms
12  et-4-1-0.4070.rtsw.salt.net.internet2.edu (198.71.45.19)  41.280 ms
13  aarnet-1-is-jmb-776.lsanca.pacificwave.net (207.231.241.149)  81.268 ms
14  et-1-2-1.pe1.a.koa.aarnet.net.au (113.197.15.86)  205.814 ms
15  et-1-2-1.pe1.a.koa.aarnet.net.au (113.197.15.86)  205.753 ms
16  et-1-0-0-202.and12-nsh.reannz.co.nz (182.255.119.201)  205.921 ms
17  br-cpf1-north.net.auckland.ac.nz (130.216.95.106)  206.111 ms
18  cxj-alfa-430.net.auckland.ac.nz (130.216.95.122)  208.200 ms
19  cxj-alfa-430.net.auckland.ac.nz (130.216.95.122)  207.881 ms
20  *
21  www.auckland.ac.nz (130.216.159.127)  206.567 ms
```

```
traceroute to www.w3.berkeley.edu (128.32.203.137), 30 hops max, 60 byte packets
 1  0148-cslgeneral-net.gw.uiuc.edu (192.17.100.1)  0.751 ms
 2  t-core1-2.gw.uiuc.edu (172.20.101.29)  0.426 ms
 3  t-exiti1.gw.uiuc.edu (130.126.0.162)  3.425 ms
 4  t-fw1.gw.uiuc.edu (130.126.0.134)  1.287 ms
 5  t-exite2.gw.uiuc.edu (130.126.0.189)  2.136 ms
 6  t-dmzb.gw.uiuc.edu (130.126.0.206)  2.125 ms
 7  ur2rtr-uiuc.ex.ui-iccn.org (72.36.127.5)  2.332 ms
 8  t-710rts.ix.ui-iccn.org (72.36.126.102)  6.955 ms
 9  internet2-710rtr.ex.ui-iccn.org (72.36.127.158)  4.855 ms
10  et-3-1-0.4070.rtsw.kans.net.internet2.edu (198.71.47.207)  16.165 ms
11  et-8-0-0.4079.sdn-sw.denv.net.internet2.edu (162.252.70.10)  26.594 ms
12  et-4-1-0.4079.rtsw.salt.net.internet2.edu (162.252.70.9)  36.264 ms
13  et-7-0-0.4079.sdn-sw.lasv.net.internet2.edu (162.252.70.30)  43.606 ms
14  et-4-1-0.4079.rtsw.losa.net.internet2.edu (162.252.70.29)  48.790 ms
15  137.164.26.200 (137.164.26.200)  48.568 ms
16  hpr-svl-hpr3--lax-hpr3-100ge.cenic.net (137.164.25.74)  60.139 ms
17  hpr-ucb--svl-hpr-10g.cenic.net (137.164.27.133)  62.596 ms
18  t1-3.inr-202-reccev.berkeley.edu (128.32.0.67)  62.122 ms
19  calweb-farm-prod.ist.berkeley.edu (128.32.203.137)  62.233 ms
```

8. Wireshark - 10 points

Install Wireshark on your laptop and use it to monitor your Internet traffic. Record a session that includes you opening YouTube in your browser and watching a 30 second video. Answer the questions below.

1. How much data in total was received by your computer during this time?

2. What are the top 2 IPs that sent traffic to your computer (by number of bytes sent)

3. What ports were used to communicate with these two IPs? Was TCP or UDP used?

4. Try to find out a bit about where these IPs are located and who owns them

5. Suppose that the campus tried to block YouTube by blocking all connections to YouTube.com. Can you think of a way you could still watch videos?