CS244a: An Introduction to Computer Networks

Problem Set #2: Due 12noon, Friday 15th February 2008.

Your solution should be handed to Ann Coulthard in Gates 351, or posted under her door.

Show your reasoning clearly. If your reasoning is correct, but your final answer is wrong, you will receive most of the credit. If you just show the answer without reasoning, and your answer is wrong, you may receive no points at all. Hand in your solution on separate paper.

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1. **(10 points) Subnetting.** In this question you'll use the tools `traceroute, host, route` and `ifconfig` to map a portion of the Stanford network. For routers inside of Stanford, you can use the site: `http://stanfordwhat.stanford.edu/` to get additional information about the routers. Note that this information may not always be up to date.

   (a.) Using `traceroute`, find and write down the sequence of routers followed by packets from myth18.stanford.edu (or myth19) to the main web-site of the University of Tokyo.

   (b.) Draw a graph representing the topology of the first **three** routers in your answer to part (a). Show the IP addresses of:
   - (i) The IP Address that the ICMP response is sent from
   - (ii) The DNS name, ip addresses and the subnet mask of the **incoming** and **outgoing** network interface. If you can't determine them accurately, make and educated guess. Explain how you figured it out.
   - (iii) Count how many interfaces this router approximately has

   (c.) It is often assumed that ICMP responses are sent out with the source IP address from the incoming network interface. For which of the three routers in (b) this the case?

   (d.) Find the names of three networks that your packets passed through after they left Stanford on their way to Tokyo. For each one, write a sentence or two about who owns the network and why it exists.

2. **(10 points) IP addresses.** Company X and Company Y both connect to the same ISP. Company X is assigned the prefix 121.77.80/26 and Company Y is assigned the prefix 121.77.64/18. The ISP has a single 3-port router: port 1 connects to Company X, port 2 connects to Company Y, and port 3 connects to the rest of the Internet.

   (a.) Draw and complete (as best you can) the contents of the forwarding table in the ISP's router.
   (b.) What aggregated prefix does the router advertise to the rest of the Internet so that packets can reach Company X and Company Y?

(c.) Find out who, in real-life, owns the addresses represented above.

3. **(5 points)** Kurose and Ross Question R4 (page 417)
4. **(5 points)** Kurose and Ross Question R6 (page 417)
5. **(2 points)** Kurose and Ross Question R34 (page 419)

6. (15 points) The Bellman-Ford Distributed Routing Algorithm.

Consider the network topology shown in Figure 1

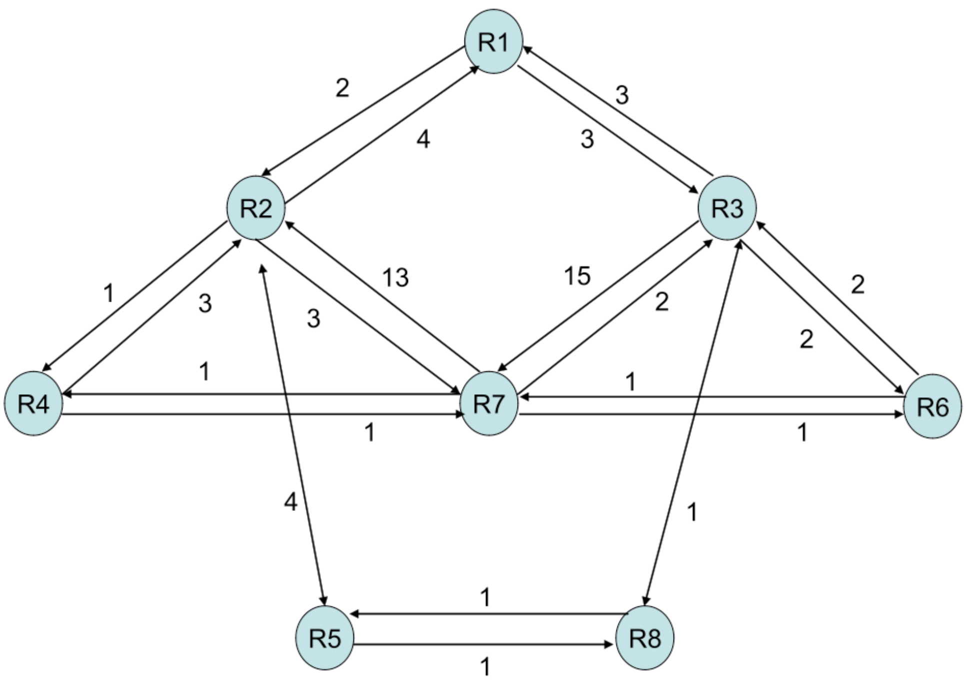

Figure 1.

Using the Bellman-Ford algorithm, find the shortest-path spanning-tree for routing packets *to* router R_8 *from* every other router. Clearly show each step of the algorithm in a table like the ones shown in class.

7. **(15 points) Estimating the data rate of the slowest link along a path.** If we measure the round-trip time using `traceroute` multiple times, we seem to get a different answer each time (try for example: `elaine> traceroute -q 10 www.mit.edu`). This is because, as we saw in class, the delay is made up of three components: the *fixed* transmission time of the packet on each link, the *fixed* propagation delay along each link, and the *variable* queueing delay in the router buffers due to congestion. (We'll assume throughout this question that the routers are store-and-forward devices, but process each packet in zero time). Because the router buffers contain a different number of packets each time `traceroute` sends a probe, it will get a different answer. However, if by chance a probe arrives and finds the router buffers empty, there

will be no queuing delay, and the round-trip time will correspond to the fixed component of delay.

(a) Using `traceroute` send 100 probes to www.mit.edu. Determine which options you need so that there is a 1 second pause between each probe, and the round-trip time is not calculated for any of the intermediate routers.
   (i) Write down the `traceroute` command line that you used.
   (ii) Plot a graph that shows the measured round-trip time for each probe. Show the probe number on the x-axis, and the measured round-trip time on the y axis. You might like to use `gnuplot`, or a similar graphing program.
   (iii) What is your estimate of the fixed component of delay between here and MIT?
   (iv) What confidence do you have in your estimate, and why?

(b) How many hops is it from `myth22.stanford.edu` to University College London? Estimate how far it is across the Atlantic Ocean. Is this is a good way to estimate geographic distance?

(c) Repeat (d) between `myth22` and `www.georgetown.edu` to estimate how far it is across the USA. (Georgetown University is in Washington D.C.). Why does www.whitehouse.gov seem so close? Find out how this works (Chapter 7 of the book will help) and write 3-4 sentences explaining who the company is providing the service and how it works.

(d) Your answer in part (a) is an estimate of the fixed component of delay. We know the fixed component consists of two sub-components: the transmission time and the propagation delay over each link along the path. The method in (a) can't distinguish between, or measure, these two sub-components. And so we'll consider a technique, called *packet-pair*, that allows us to estimate the rate of the slowest link along the path. (This is sometimes called the "bottleneck" link). Packet-pair sends probes in pairs. For example, consider a source that sends two packets P_1 and P_2 through the network to some destination. Both packets are P bits long. The time between when it starts sending P_1 and when it starts sending P_2 is T seconds. Assume that the packets arrive to empty queues in all the routers along the path.

   (i) If the data rate of the first link, R_1 is lower than the data rate of all the successive links along the path (i.e. the first link is the slowest), what is time between when P_1 and P_2 start arriving at the destination?
   (ii) If the data rate of the second link, R_2 is the slowest link, write down an expression for the maximum value of T that will cause the packets to arrive back-to-back (i.e. without a gap between them) at the destination.
   (iii) Describe a technique in which we vary T to find the data rate of the bottleneck link.

8. **(10 points) Network Address Port Translation.** Residential Network connections via Cable or DSL usually are allocated only a single IP Address. As end users often want to operate multiple internet enabled devices at home, people often use small routers to map an internal network with multiple IP addresses, to the single IP address provided by the ISP. This is referred to as Network Address Port Translation (NAPT) or just Network Address Translation (NAT).

Assume we have a home network that is connected by a wireless router that includes NAT capabilities as well as a DHCP server. On the wireless network we have a Desktop, a Laptop and a Video Game Console that are switched on and used in this order. The external IP address of the router is 71.204.145.120, the internal IP address is 192.168.1.1. The DHCP server on the router is programmed to give out IP addresses on the nework 192.168.1.1, netmask FF:FF:00:00.

(a.) Draw the topology of the network with the router after all devices are switched on (you can omit any hosts between the wireless router and myth18). The topology should include IP addresses and netmasks where known.
(b.) After all three hosts on the wireless network are switched on they connect to a web server running on myth18.stanford.edu. What IP addresses will the web server on myth18 record for the web requests coming from the Laptop, Desktop and Video Game Console?
(c.) Both the Laptop and Desktop have an SSH server running on port 22. Is it possible to connect from myth18 to the SSH servers? If yes, explain the steps involved in setting up the connection. If no explain why it is not possible.
(d.) Is there an upper limit for the maximum number of parallel UDP connections from hosts on the local network of the router to servers on the internet? If yes, what is this maximum?

9. **(No points) Optional bonus question.** Using `traceroute` on the myth cluster, what is the longest path (most hops) that you can find in the Internet? I'll give a prize to the person who finds the largest hop count from myth to a (real) remote host. The experiment must be repeatable by the TA's on the myth cluster, and the `traceroute` must complete.