COSC 328 – LAB 1
Introduction to Networks
2021 Winter Term 1

Deadline: September 20, 2021 at 11:59 PM (Sharp). Delayed assignments will receive penalty as described in the course outline.

Introduction

In this lab, we will do some practice questions on calculating delays and transmission times in packet and circuit switched networks. We will also use Traceroute to investigate the paths packets take in the network from source to destination.

For this lab, some of the problems come from the review and problems at the end of chapter 1. Please ensure that you have reviewed chapter 1 for this lab. <u>All work must be shown for marks</u>. This lab should be electronically submitted on Canvas.

Warm-up Problems: The authors of the text have provided interactive problems to help you with understanding the concepts presented in chapter 1. Please take the time to review these problems before attempting the questions. These problems are for your own learning and practice (no marks) but will allow you to review solutions.

a. One-hop transmission delay: http://www-net.cs.umass.edu/kurose_ross/interactive/one-hop-delay.php
b. End-to-end propagation delay: http://www-net.cs.umass.edu/kurose_ross/interactive/end-end-delay.php
c. Throughput: http://www-net.cs.umass.edu/kurose_ross/interactive/end-end-throughput.php

Transmission (20 marks)

Complete the following review questions from the text:

1. R18. How long does it take a packet of length 1,000 bytes to propagate over a link of distance 2,500 km, propagation speed 2.5×10^8 m/s, and transmission rate 2 Mbps? More generally, how long does it take a packet of length L to propagate over a link of distance d, propagation speed s, and transmission rate R bps? Does this delay depend on packet length? Does this delay depend on transmission rate? (10 marks)
2. R19. Suppose Host A wants to send a large file to Host B. The path from Host A to Host B has three links, of rates R1 = 500 kbps, R2 = 2 Mbps, and R3 = 1 Mbps. (10 marks)
    a. Assuming no other traffic in the network, what is the throughput for the file transfer?
    b. Suppose the file is 4 million bytes. Dividing the file size by the throughput, roughly how long will it take to transfer the file to Host B?
    c. Repeat (a) and (b), but now with R2 reduced to 100 kbps.

Packet Switching (10 marks)

3. For this question, let the packet size L = 1000 bytes, the propagation speed s = 2.5×10^8 m/s, the link distance d = 2000 km, and the transmission rate R = 10 Mbps (megabits per second). Assume that 1 Mbyte (megabyte) = 1×10^6 bytes (SI definition). Be mindful of units. Answer these questions:

a. Write the formula and calculate the propagation delay for a packet on the link.
b. Write the formula and calculate the transmission delay for a packet on the link.
c. Ignoring queuing and processing delays, what is the total end-to-end delay if two hosts are connected by 3 links (2 routers) of this type. Assume all links have the same transmission rate and propagation speed, but the links have lengths of 10 m, 1000 km, and 5000 km respectively.

Packet vs. Circuit Switching (20 marks)

4. P8. Suppose users share a 3 Mbps link. Also suppose each user requires 150 kbps when transmitting, but each user transmits only 10 percent of the time. (See the discussion of packet switching versus circuit switching in Section 1.3.)
   a. When circuit switching is used, how many users can be supported? (2.5marks)
   b. For the remainder of this problem, suppose packet switching is used. Find the probability that a given user is transmitting. (2.5 marks)
   c. Suppose there are 120 users. Find the probability that at any given time, exactly n users are transmitting simultaneously. (Hint : Use the binomial distribution.) **(optional)**
   d. Find the probability that there are 21 or more users transmitting simultaneously. **(optional)**

5. For this question, let the packet size L = 1000 bytes, the propagation speed s = 2.5 x 10^8 m/s, the link distance d = 2000 km, and the transmission rate R = 10 Mbps. For circuit switching, the setup time is 5 ms, and each link supports 10 circuits. One of the factors that needs to be considered is the setup time for the circuit (being the time for each switch to connect the correct inbound and outbound circuits). In this case the setup time provided is for the complete circuit to be formed and can be included in the total delay as a single factor. Assume that 1 Mbyte (megabyte) = 1 x 10^6 bytes (SI definition). Be mindful of units. Answer these questions: (10 marks)
   a. How many simultaneous users can be on one link in a circuit switched network?
   b. Assume we have 3 switches connected in a triangle. What is the maximum number of connections supported on this network with circuit-switching (keeping in mind that that each link supports a limited number of circuits, whereas the switches are limited only by the total number of available links)?
   c. Given a file size of 1 MB, how long does it take to send it from one host to another over 4 circuit switched links?
   d. Given the same file of 1 MB, how long does it take to send it between two hosts that are connected with 4 datagram, packet switched links where the switches use store-and-forward? In a packet switched network, data needs to be encapsulated (information regarding addressing) needs to be added. Assume each packet has a header size of 50 bytes in addition to its data payload of 1000 bytes.
   e. How long does it take to transfer the 1 MB file if store-and-forward is not used (assume that packet can flow through the switch without delay)?

Queuing Delay (10 marks)

6. For this question, let the packet size L = 1000 bytes, the propagation speed s = 2.5 x 10^8 m/s, the link distance d = 2000 km, and the transmission rate R = 10 Mbps. Assume that 1 Mbyte (megabyte) = 1 x 10^6 bytes (SI definition). Answer these questions:
    a. If 5 packets arrive simultaneously and the queue is initially empty, what is the average queuing delay for all 5 packets.

Transmission Times (10 marks)

Complete the following problems from the text:

7. P24. Suppose you would like to urgently deliver 40 terabytes data from Boston to Los Angeles. You have available a 100 Mbps dedicated link for data transfer. Would you prefer to transmit the data via this link or instead use FedEx overnight delivery? Explain.

Layers and services (20 marks)

Answer the following questions from the textbook:

8. R22. List five tasks that a layer can perform. Is it possible that one (or more) of these tasks could be performed by two (or more) layers? (10 marks)
9. R25. Which layers in the Internet protocol stack does a router process? Which layers does a link-layer switch process? Which layers does a host process? (10 marks)

Traceroute (10 marks)

One of the challenges often encountered with networking is gaining an understanding of how packets are flowing between different routers in the network one the way from the source to destination address. Packets are not guaranteed to take the same route, experience the same delays or latencies due to multiple factors within the network itself. One tool that needs to the in your networking toolkit is Traceroute which is an application that sends multiple special packets from the source host towards the destination host. The special packets are constructed such that when they pass through router (considered a node or a hop) on the way to the destination, the router in the path will respond with the address of the device (how this works we will be examining in a few weeks). The system then calculates the round-trip time based on the time difference between the transmission of the original packet and the response from the router. RFC 1393 details the mechanics of Traceroute and an overview can be found on p.42 of the text (and a good summary: https://en.wikipedia.org/wiki/Traceroute).

To run a Traceroute to a destination address, you will need to open up a terminal window or command prompt from which you can instruct the system to trace a route from your local computer to the target IP address. Note: the commands are different if you are on Windows, OS X or Linux. For a Windows machine, to trace a route to example.com, enter the following command:

C:\Users\RobertPaulson> tracert example.com

and on OS X/Linux:

RobertPaulson$ traceroute example.com

This will send a number of packets into the network (it will send three to each hop in the route). The output from this trace is (and this will depend on where it originated from and network conditions):

```
RobertPaulson$ traceroute example.com
traceroute to example.com (93.184.216.34), 64 hops max, 52 byte packets
1  192.168.1.254 (192.168.1.254)  5.413 ms  1.485 ms  1.943 ms
2  10.29.156.1 (10.29.156.1)  3.057 ms  2.532 ms  3.045 ms
3  * * *
4  154.11.3.52 (154.11.3.52)  136.299 ms  18.077 ms  17.446 ms
5  152.195.92.129 (152.195.92.129)  140.575 ms  28.809 ms  22.438 ms
6  93.184.216.34 (93.184.216.34)  16.643 ms  20.513 ms  20.716 ms
```

The response from each hop in the route is represented by a different line (depending on your OS, the order of information on each line may be reversed - time info followed by IP address). Each single hop is numbered and represents responses from a router in the path. This trace took 6 hops to reach the destination server, example.com (who is assigned the IP address 93.184.216.34).

Each row is displayed in 5 columns. The first column is simply the number of the hop.

```
1  192.168.1.254 (192.168.1.254)  5.413 ms  1.485 ms  1.943 ms
```

Traceroute sends three packets of data, and measures the round-trip time taken for each packet. You can also see the IP address and potentially the domain name associated with the hop along with the round-trip travel time for each packet.

From these results you can see that it took between 16 and 20 milliseconds to retrieve data from the destination server, as shown in the last hop.

```
6  93.184.216.34 (93.184.216.34)  16.643 ms  20.513 ms  20.716 ms
```

One thing that you will notice is that the times are different for each hop with some of the middle hops having longer round-trip times as compared to the destination. This is a excellent example of the impacts and variability of the different types of delay that can be experienced in a network between different packets sent into the network.

Hop number 3 in the results shows no time data and just a series of *'s. Whenever Traceroute does not receive a response for a given packet, it will place an * in place of the time (Request timed out error). This is commonly seen when encountering a server at hop that is not accepting Internet Control Message Protocol (ICMP) traffic (which is the protocol used with Traceroute). As a result, it ignores Traceroute's request for information, but it will still allow the data to pass to the next hop. The Request timed out error message may be commonly encountered, as many network providers disable ICMP response-request traffic if their network is under heavy load (or for other reasons which we will discuss in the future). The output from this tool can be exceptionally useful to understand what is going on in the network.

One thing that can be done with the IP addresses of each router, is to attempt to physically locate the router using a geoIP location tool such as https://www.melissa.com/lookups/iplocation.asp. This will give you the approximate location (latitude and longitude/postal code) of a router that can then be mapped using a tool like Google map.

Information:
As we will see in a few weeks, there are certain classes of IP addresses that are considered to be private, preventing them from being geolocated. Addresses from the IP block of 10.0.0.0 to 10.255.255.255, 17.16.0.0 to 17.31.255.255, and 192.168.0.0 to 192.168.255.255 are considered to be private and therefore cannot be geolocated.

10. From your computer (either a lab machine or your own), open up a terminal (Command prompt on Windows, or terminal on Linux/OS X) and perform a Traceroute to google.ca. Answer the following questions: (10 marks)
    a. Copy and paste the output of your Traceroute into your assignment.
    b. Using the provided URL for the geolocation tool, determine the postal code/zip code for each hop in the route as well as the ISP responsible for the router and list in a table in proper order.
    c. Using Google Maps (or equivalent), plot and number the hops based on postal codes/zip codes for each router in the path. Submit a copy of your map with your assignment.
    d. Once your map is complete, consider the complexity of the route taken to reach this destination. Considering the approximate length of the route (which can be done with a straight-line approximation of the distance measure between points and using the propagation speed $s = 2.5 \times 10^8$ m/s), does the round-trip time seem reasonable and what are the other factors that can impact this time? Remember that this is a round-trip time, so to consider the time is takes to go from source to destination, divide the time in half.