Elizabeth Dayton
Ead0044

COMP 4320
Introduction to Computer Networks
2021 Summer Mini-Semester II

Homework 2
Due in Canvas: 11:55 pm July 22, 2021

Reference textbook: Computer Networking: A Top-Down Approach, 7th Edition, by James F. Kurose and Keith W. Ross, published by Addison-Wesley, 2017, ISBN 0-13-359414-9.

All homework assignments must be completed by each student individually. Any copying of someone else's work, or misrepresentation of other work as your own, will be grounds for failing this assignment or the course.

Penalty for late work is 20 points per day late.
All homework must be submitted in Canvas.

There are 6 questions; make sure you answer all the questions.

1. Consider an HTTP client that wants to retrieve a Web document at a given URL. The IP address of the HTTP server is initially unknown. What transport and application-layer protocols besides HTTP are needed in this scenario?

   Application layer protocols: DNS and HTTP
   Transport layer protocols: UDP for DNS; TCP for HTTP

2. Suppose within your Web browser you click on a link to obtain a Web page. The IP address for the associated URL is not cached in your local host, so a DNS lookup is necessary to obtain the IP address. Suppose that *N* DNS servers are visited before your host receives the IP address from DNS; the successive visits incur an RTT of $RTT_1, \ldots, RTT_N$. Further suppose that the Web page associated with the link contains exactly one object, consisting of a small amount of HTML text. Let RTT_s denote the *RTT* between the local host and the server containing the object. Assume that the transmission time of the object is T_i. How much time elapses from when the client clicks on the link until the client receives the object.

   The total amount of time to get the IP Address is $RTT_1 + RTT_2 + \ldots + RTT_N$
   After this, RTT_s elapses to set up the TCP connection, then another RTT_s elapses to request the small object, and then T_i to receive the small object.
   The total elapsed time is $2RTT_s + T_i + RTT_1 + RTT_2 + \ldots + RTT_N$

3. Referring to Problem 2 above, suppose the HTML file references eight very small objects on the same server. Neglecting transmission time, how much time elapses with

   a. Non-persistent HTTP with no parallel TCP connections?

   The total elapsed time is $2RTT_s + 8T_i + RTT_1 + RTT_2 + ... + RTT_N$

   b. Non-persistent HTTP with the browser configured for 6 parallel connections?

   The total elapsed time is $2RTT_s + 3T_i + RTT_1 + RTT_2 + ... + RTT_N$

   c. Persistent HTTP? (Assume that pipelining is used.)

   The total elapsed time is $2RTT_s + T_i + RTT_1 + RTT_2 + ... + RTT_N$

4. Consider a short, 90-meter link, over which a sender can transmit at a rate of 420 bits/sec in both directions. Suppose that packets containing data are 320,000 bits long, and packets containing only control (e.g. ACK or handshaking) are 240 bits long. Assume that *N* parallel connections each get 1/*N* of the link bandwidth. Now consider the HTTP protocol, and assume that each downloaded object is 320 Kbit long, and the initial downloaded object contains 6 referenced objects from the same sender. Would parallel download via parallel instances of nonpersistent HTTP make sense in this case? Now consider persistent HTTP. Do you expect significant gains over the non-persistent case? Justify and explain your answer.

   Let Tp denote the propagation delay between client and server.

   Parallel download via parallel instances of nonpersistent HTTP is given by:

$$\left(\frac{240}{420} + T_p + \frac{240}{420} + T_p + \frac{240}{420} + T_p + \frac{320,000}{420} + T_p\right) + \left(\frac{240}{\frac{420}{6}} + T_p + \frac{240}{\frac{420}{6}} + T_p + \frac{240}{\frac{420}{6}} + T_p + \frac{320,000}{\frac{420}{6}} + T_p\right)$$
$$= 5345.33 + 8T_p\ seconds$$

   Persistent HTTP is given by:

$$\left(\frac{240}{420} + T_p + \frac{240}{420} + T_p + \frac{240}{420} + T_p + \frac{320,000}{420} + T_p\right) + 6 * \left(\frac{240}{420} + T_p + \frac{320,000}{420} + T_p\right) = 5338.48 + 16T_p\ seconds$$

Assuming the speed of light is $300 * 10^6$, $T_p = \frac{9}{300*10^6} = 0.03\ microseconds$, thus T_p is negligible. Thus, we can see persistent HTTP is not significantly faster than parallel download via parallel instances of nonpersistent HTTP.

5. Consider the scenario introduced in Question (4) above. Now suppose that the link is shared by Tom with seven other users. Tom uses parallel instances of non-persistent HTTP, and the other seven users use non-persistent HTTP without parallel downloads.
   a. Do Tom's parallel connections help him get Web pages more quickly? Why or why not?

   Yes, because Tom has more connections, and therefore can get a larger share of the bandwidth.

   b. If all eight users open parallel instances of non-persistent HTTP, then would Tom's parallel connections still be beneficial? Why or why not?

   Yes, Tom would still have to use parallel connections, or he'll get less bandwidth than the other 7 users.

6. Consider Figure 1 in which there is an institutional network connected to the Internet. Suppose that the average object size is 675,000 bits and that the average request rate from the institution's browser to the origin server is 20 requests per second. Also suppose that the amount of time it takes from when the router on the Internet side of the access link forwards an HTTP request until it receives the response is 2.0 seconds on average. Model the total average response time as the sum of the average access delay (that is, the delay from Internet router to institution router) and the average Internet delay.

   The average access delay is related to the traffic intensity as given in the following table.

Traffic Intensity	0.50	0.55	0.60	0.65	0.70	0.75	0.80	0.85	0.90	0.95
Average access delay (msec)	26	33	41	52	64	80	100	137	250	1000

   Traffic intensity is calculated as follows: Traffic intensity = *aL/R,* where *a* is the arrival rate, *L* is the packet size and *R* is the transmission rate.

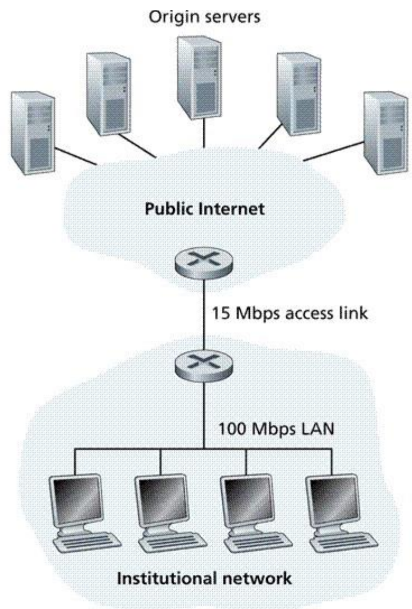

Figure 1. Access Link Connecting an Institutional Network to the Internet

a. Find the total average response time.

The time transmit an object of size L over a link of rate R is L/R, which is

$$\frac{675{,}000\ bits}{15{,}000{,}000\ bits/sec} = 0.045\ seconds$$

Traffic Intensity = $20\ requests/\sec * 0.045 \frac{seconds}{request} = 0.9$

Thus, the average access delay is $\frac{0.05}{1-0.9} = 0.5\ seconds$

The total average response time is thus 2.0 seconds + 0.5 seconds = 2.5 seconds

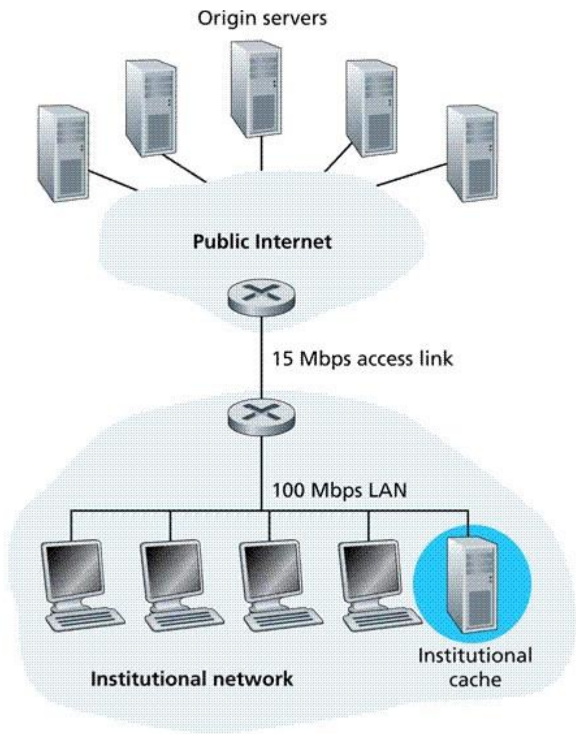

Figure 2. Adding a Cache to the Institutional Network

b. Now suppose a cache is installed in the institutional LAN as shown in Fig. 2. Suppose the hit rate is 0.333. Find the total average response time.

The traffic intensity is reduced by 33% since that is the percent of requests that are handled within in the institutional network.

The average access delay is $\frac{0.045}{1-(0.66)(0.9)} = 0.1123\ seconds$

The response time is approximately 0 when the request is handled by the cache (which happens with a probability of 0.33).

The average response time for cache misses is 2 + 0.1123 = 2.1123 seconds (which happens with a probability of 0.66).

So, the average response time is $(0.33)(0\ secs) + (0.66)(2.1123) = 1.39\ seconds$

Average response time has dropped from 2.5 seconds to 1.39 seconds.