CSEE 4119 Fall 2019
Homework 2

Assigned: 2019-09-30. **Due: 11pm, 2019-10-15**

Corrections:
2019-09-30: fixed typo for propagation speed
2019-10-02: fixed question order
2019-10-08: added Question 4

You are welcome to discuss your homework with other students, but each student is expected to write his or her final answer independently and in his or her own words. Students are expected to consult whatever resources are necessary to answer homework questions, including things like class papers, textbooks, other papers or RFCs, and the web. However, as above, all answers are expected to be formulated independently in your own words. If you find you must use materials from other sources, standard academic policies apply---you need to cite what material you use and clearly indicate (such as by quotes) what material was yours and what is theirs. You are welcome to use calculators to solve equations, but for full credit, your answer must include the equation you entered in the calculator.

You will submit the homework as a PDF file to the class CourseWorks under Assignments. The homework can be either typeset and converted to pdf, or it can be handwritten and scanned to pdf. For scanned or photographed handwritten homeworks, you need to make sure the images are clear enough to read and that the file is small (the final pdf shouldn't take up more than 5MB). You may find helpful tools online to compress or binarize the original images. Simple text should be sufficient for most questions and is recommended as it is generally easier to mark up and give feedback about. Please identify yourself at the top of the first page. Write your full name and your UNI. This will make it easier for the TAs to grade the homeworks and ensure that everything gets recorded properly.

Homeworks are due on the specified due date and time. Any submission past the deadline (even 1 minute late) will be subject to the late policy described in the syllabus. To avoid last-minute problems (with a scanner, network, etc), please submit your homework well in advance.

Please refer to the course information in the syllabus for further information and policies regarding late homeworks and collaboration, and the academic honesty policies. Make sure that you observe these policies.

Please make sure you label the parts of your answer 1, 2, 3a, 3b, etc. Answers that don't clearly identify what part of the question they are answering, or that are overly long, may not get full

credit. If you choose to handwrite your answers, please make sure your writing is clear. Make sure any mathematical notation is clearly explained. Further, unless we derived a formula in class, for full credit you must derive it in your homework in order to use it, including explaining what each term represents and WHY your equations correctly capture the problem. For example, in class, we used an equation to get the probability of collisions under packet switching, but we only briefly discussed the derivation. If you use this equation in your homework answers, you must derive it to get full credit.

Unless otherwise specified, we use 10^3 for "K", 10^6 for "M", and so on to simplify calculations. Please do the same in your answers.

Questions:

Network Applications & Socket Programming [25 points, part a - f]

The Web and HTTP [22 points, parts a - j]

Developer Tools and the Web [12 points, parts a - h]

Video Streaming and CDN [34 points, parts a - o]

Bonjour, Le Monde! [13 points, parts a - k]

Network Applications & Socket Programming [25 points, part a - f]

a) [1 point] What are the two predominant modern application architectures?

b) [2 points] For the architectures in problem 1, what is the main difference between them?

c) [3 points] Alice downloads a movie from Bob on a P2P file-sharing application. Are there client and server processes running on their machines? If so, please answer which one is client and which one is server and explain why. If not, also explain why.

d) [3 points] Alice creates a web application for fun and hosts it on her local machine. She wants Bob to use her application and gives him her IP address which his machine is able to send packets to.
   i) [2 points] Can Bob use her application successfully? Why or why not?
   ii) [2 points] Alice wants to add some security properties on her app such as encryption. One way to do it is using TLS/SSL. Which layer should Alice implement TLS/SSL in? What is the typical way that Alice can integrate TLS/SSL into her app?

e) [4 points] Answer the following questions on sockets:
   i) [2 points] Why does a TCP server need more than one socket?

ii) [1 point] How many sockets does a TCP server need for n simultaneous connections, each coming from different users?
iii) [1 point] Why is only one socket enough for a UDP server?

f) [12 points] Download the Python programs TCPClient, UDPClient, TCPServer and UDPServer on your local machine.
   i) [2 points] Run TCPClient, input a sentence and then run TCPServer. What happens? Why?
   ii) [2 points] Run TCPClient, then run TCPServer and then input a sentence on the client. What happens? Why?
   iii) [2 points] Repeat part i using UDP. What happens? Why?
   iv) [2 points] Repeat part ii using UDP. What happens? Why?
   v) [2 points] For TCP, what happens if you run the server on port N and the client tries to send a message to port M? Why?
   vi) [2 points] For UDP, what happens if you run the server on port N and the client tries to send a message to port M? Why?

The Web and HTTP [22 points, parts a - j]

Consider a 3×10^7 -meter link connecting a client to a server, over which a sender can transmit at a rate of 1,000,000 bits/sec in both directions. Suppose that packets containing data are 100,000 bits long, and packets containing only control messages (e.g., ACK, SYN) and/or requests are 2000 bits long. To set up a TCP connection, a three-way handshake is a needed method that requires both the client and server to exchange SYN and ACK packets before actual data communication. (Don't worry about this if you don't know it, we will cover this later in class. Just assume that, before sending any data, the client sends the server a control packet, the server replies with a second control packet, and the client replies to that with a third control packet that also includes the request.) If the client/server use N parallel connections, assume each gets 1/N of the link bandwidth. Now consider the HTTP protocol, and suppose that each downloaded object is 100 Kbits long (so each can be perfectly fit into a data packet), and that the initial downloaded page(100 Kbits) contains references to 10 referenced objects. Assuming the signal propagation speed is 3×10^8 m/s, the RTT between client and server only depends on propagation delay, and connections can transmit at their share of the link bandwidth (without worrying about flow control or congestion control). Answer question a - e.

a) [3 points] How long will it take for the client to get the whole 11 objects from the server if using non-persistent HTTP with a single TCP connection? Please show your calculation and the final answer.

b) [3 points] How long will it take for the client to get the whole 11 objects from the server if using non-persistent HTTP with enough parallel TCP connections to allow all requests in parallel? Please show your calculation and the final answer.

c) [3 points] How long will it take for the client to get the whole 11 objects from the server if using persistent HTTP and a single TCP connection? Please show your calculation and the final answer.

d) [1 points] In this question, is there significant gains for persistent HTTP over the non-persistent case?

e) [2 points] What if the link length is 3×10^{10} meter ? Is there any significant gains using persistent HTTP with a single TCP connection? Prove your answer either by calculation or explanation.

Jeff is shopping on Amazon (www.amazon.com) on his laptop. Answer question f - j.

f) [3 points] When the first time Jeff logged into his account, he permitted Amazon to remember him on his laptop. So next time when Jeff visits Amazon on his laptop, he is still logged in. How does Amazon remember Jeff's login status? Please briefly describe the procedure.

g) [1 point] Why does Jeff need to log in again if he uses another browser or switches his device?

h) [1 points] Jeff watched an advertising video on Amazon about a robot and closed the tab. About 1 minute later he wants to show this video again to his friend Adriana and he reopens the tab, and he notices that the video is downloaded much faster than 1 minute ago. Why is it faster this time?

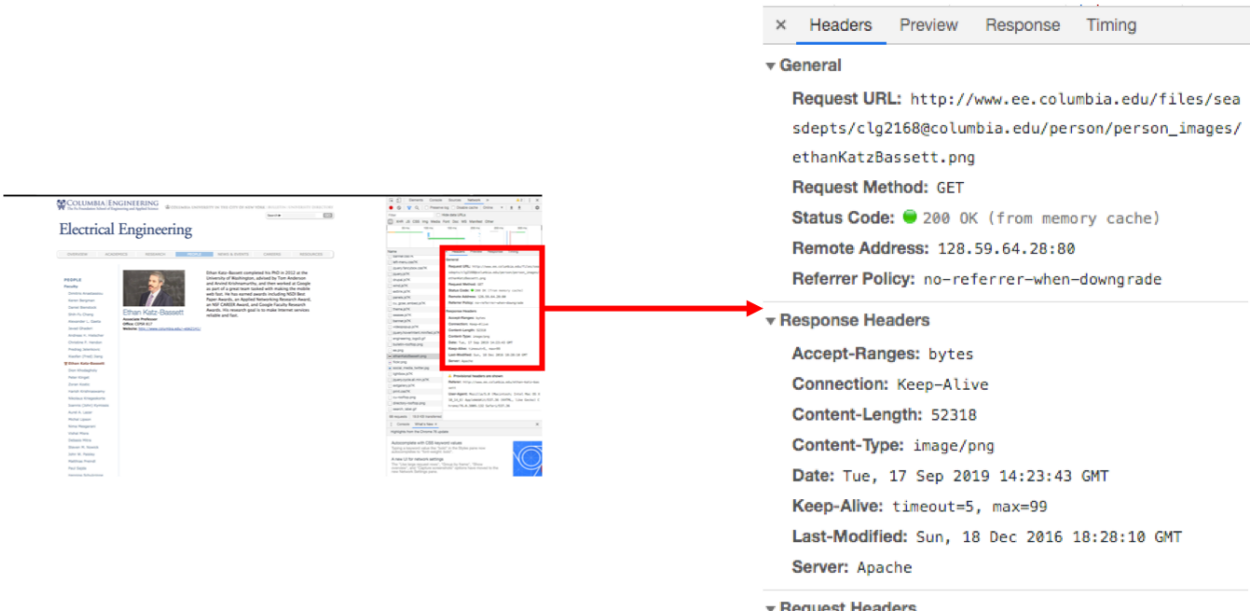
Suppose transmission rate within the local area network (LAN) is 1 Gbps, and the transmission rate on access link to public Internet is 100 Mbps. Suppose average packet size is 1.5 KB and average request rate from all browsers across the LAN is 10000/s. RTT from LAN router to any origin server is 1 s.

i) [3 points] Given the access link utilization is 45%, what's the cache hit rate?

j) [2 points] Following question i, assess the expected delay when Jeff is loading a single request (hint: neglect insignificant parts).

Developer Tools and the Web [12 points, parts a - h]

One good way to inspect networks is to use developer tools provided by browsers. Below is a screenshot of Google Chrome's developer tool capturing HTTP messages. Let's look at one specific request asking for Prof. Katz-Bassett's photo. Answer questions a - e.



a) [1 point] What is the host name of this request?

b) [1 point] What is the path name of this request?

c) [2 points] Does the browser request a persistent connection or non-persistent connection? How do you know it?

d) [1 point] If someone pings ee.columbia.edu, what IP address is going to response?

e) [2 points] Explain what “Keep-Alive: timeout=5, max=99” means in response header.

Now it’s your turn to play with developer tools. A good tutorial on how to get started using Google Chrome: https://developers.google.com/web/tools/chrome-devtools/network. If you are using other browsers (e.g. FireFox, Safari, Edge, IE, etc.) you can also easily find tutorials pretty much alike.

(**Important**) Different browsers may have different behaviors, so please use **the latest version of Google Chrome** to complete this problem. Open the homepage of Columbia University (www.columbia.edu) in your browser. Answer question f - h.

f) [1 point] What is the server’s IP address?

g) [2 points] Which request asks for the HTML file (answer the request URL)? How do you know it?

h) [2 points] Click on the reload (refresh) button twice in a short time (say in 10 seconds). What is the HTTP response status code for the HTML file after the second reloading? Explain why the server responds with this code.

Video Streaming and CDN [34 points, parts a - o]

a) [2 points] Why do many popular stored-video streaming services use TCP or other transports with reliable delivery?

b) [2 points] Increasingly, YouTube and other streaming services use QUIC, which is UDP-based but adds TCP features like reliable delivery, connection-oriented, and congestion control. What is a primary advantage of providing TCP-like features on top of UDP, rather than using TCP directly? (Note: We expect that you will have to look up QUIC to learn about it for the answer. Please feel free to do so, but remember to cite your sources appropriately)

c) [1 point] Consider a video stored in the server has a length of 60s. This video is divided into 30 video chunks, and each chunk has a size of 0.5MB, 1MB, or 2MB, depending on the selected resolution. No other compression methods are used. A user wants to stream this video on a browser. How does the browser learn how this video is divided, if it has no cache records of this website?

d) [2 points] Following c), if DASH is used, what is an advantage of dividing the video into a fixed number of chunks (30), rather than chunks of a fixed size (say, 60 1s chunks at the highest resolution, 30 2s chunks at the medium resolution, and 15 4s chunks at the lowest resolution)?

e) [2 points] Following c), if this webpage only has an HTML page plus the video, starting from entering the website's URL, how many HTTP GET requests are needed to fully load this video?

f) [1 point] Describe the role of DNS in Content Distribution Networks.

g) [2 points] Suppose Bob is running a ping test to www.youtube.com from a different continent. The minimal total length of physical links connecting Bob's city to North America is 10,000km. If the ping results show that the RTT to www.youtube.com from Bob's computer is 50ms, can you tell whether the youtube server Bob connected to is in North America?[can tell, yes/can tell, no/can't tell] Explain why.

h) [2 points] How will you change your answer for g) if the RTT is 110ms? Briefly explain your answer.

i) [3 points] Ethan used the Chrome Developer tools while watching Netflix. He saw content fetched from multiple hosts, including:
- `www.netflix.com` (the home page HTML)

- `ipv4-c001-lga001-nysernet-isp.1.oca.nflxvideo.net` (chunks of video)
- `ae.nflximg.net` (icons and other small images)

Conduct research on how to use a network administration command-line tool called **nslookup** (https://en.wikipedia.org/wiki/Nslookup). Then use what you learn to obtain the A records of each of the three domains that Ethan found from Columbia's default local DNS server (i.e., when connected to a network at Columbia). Please include both command and query result in your answer.

j) [2 points] **nslookup** can also be used to do a reverse DNS lookup, i.e. find out the hostname of an IP address. What is the hostname of 128.59.64.28? Please include both command and query result in your answer.

k) [2 points] Use **nslookup** to do reverse DNS lookups on the IP addresses you found in A records for the three Netflix hosts that Ethan discovered (if nslookup returned multiple IP addresses in A records for a host, choose the first). For the first IP address, does **nslookup** return `www.netflix.com`? If not, explain why it returns what it does. Please include both command and query result in your answer.

l) [2 points] For the second IP address, does **nslookup** return `ipv4-c001-lga001-nysernet-isp.1.oca.nflxvideo.net`? If not, explain why it returns what it does. Please include both command and query result in your answer.

m) [2 points] For the third IP address, does **nslookup** return `ae.nflximg.net`? If not, explain why it returns what it does. Please include both command and query result in your answer.

https://www.cdnperf.com/tools/cdn-latency-benchmark is a web interface that allows you to run ping tests on a hostname or IP address from various global locations in parallel. Run a ping test on `www.amazon.com` in United States (under 'country' dropdown menu, select United States).

n) [5 points] Paste the screenshot of your ping result (map with latency measurements). What is the IP address of `www.amazon.com` when ping is issued from New York and Seattle respectively? (If the webpage gives you results from multiple New York (or Seattle) locations, pick the one with the lowest latency out of all the New York (Seattle) results. If it doesn't give you any locations from that city, pick the one from the location nearest to New York (or Seattle) on the map.) In most cases, these two IP addresses will be different. Explain why they are different.

o) [4 points] Which city is `www.amazon.com`'s New York IP address located in? Which city is `www.amazon.com`'s Seattle IP address located in? How do you get your answers?

Note: You can only use tools we present in this question(nslookup, cdnperf's ping, etc) to explain your answer.

Bonjour, Le Monde! [13 points, parts a - k]

You are using a workstation in the Columbia network and want to browse content from Le Monde (French daily newspaper). You want to browse https://www.lemonde.fr

a) [1 point] You enter the URL on the search bar of your browser. Your browser has an empty cache. What server should the workstation contact to get the IP address corresponding to https://www.lemonde.fr ?

b) [0.5 points] When contacting the server from your previous answer, what application protocol is used?

c) [0.5 points] When contacting the server, what transport protocol is used?

d) [0.5 points] When contacting the server, what destination port is used?

e) [1 point] What is one reason why that transport protocol has been used instead of the other main one we've seen in class?

f) [1 point] What is another reason?

g) [2 points] If the server you mention in a) performs caching, you should receive an immediate response. Does this application protocol use conditional requests to check for possible IP updates? If so, why are conditional requests a good solution (what benefit do they provide)? If not, mention the correct mechanism for caching and explain why it is better than conditional requests.

h) [1.5 points] If no results are cached, what would be the chain of servers that are contacted to get the IP address corresponding to https://www.lemonde.fr?

i) [2 points] Can these servers be deployed geographically such that a recursive resolution of the IP address results in a faster response compared to an iterative resolution? Describe the deployment.

j) [2 points] You land on a page that looks a lot like lemonde.fr, except that you are immediately prompted to enter your credit card information to access the page. That is

fishy and very unusual. Further investigation with Columbia's IT department shows that a phishing IP address was returned by the server you mentioned in question a). Name one attack that might have caused this to happen.

k) [1 point] Explain why DNS is vulnerable to the attack that you mentioned in j) is possible.