CS 655: Introduction to Computer Networks
Fall 2020

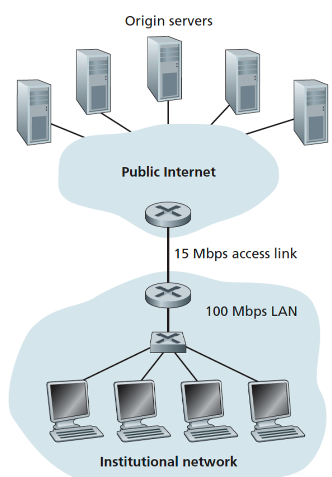
Homework 2

<u>To be completed individually. Please review the academic conduct rules mentioned in the syllabus.</u>

<u>Answer all questions. Submit on Gradescope.</u>

This assignment is part of BU CS 655 material and is provided for educational purposes. Please do NOT share or post this assignment handout or your solution, on any public site, *e.g.* github. Of course, you are not allowed to share your solution with classmates.

1. (15 pts) Consider the figure below, for which there is an institutional network connected to the Internet. Suppose that the average object size is 850,000 bits and that the average request rate from the institution's browsers to the origin servers is 16 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 three 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. For the average access delay, use $\Delta/(1 - \Delta b)$, where Δ is the average time required to send an object over the access link and b is the arrival rate of objects to the access link.



Bottleneck between an institutional network and the Internet

a. Find the total average response time.

b. Now suppose a cache is installed in the institutional LAN. Suppose the miss rate is 0.4. Find the total response time.

2. (15 pts) Consider a short, 10-meter link, over which a sender can transmit at a rate of 150 bits/sec in both directions. Suppose that packets containing data are 100,000 bits long,

and packets containing only control (e.g., ACK or handshaking) are 200 bits long. Assume that N parallel connections each get 1/N of the link bandwidth. Now consider the HTTP protocol and suppose that each downloaded object is 100 Kbits long, and that the initial downloaded object contains 10 referenced objects from the same sender. Would parallel downloads via parallel instances of non-persistent 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.

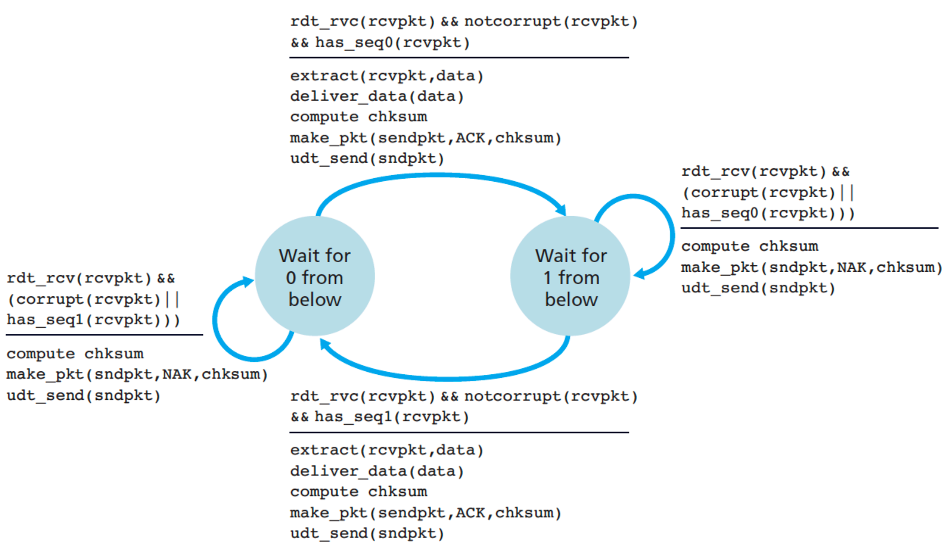
3. (10 pts) Consider distributing a file of F = 15 Gbits to N peers. The server has an upload rate of u_s = 30 Mbps, and each peer has a download rate of d_i = 2 Mbps and an upload rate of u. For N = 10, 100, and 1,000 and u = 300 Kbps, 700 Kbps, and 2 Mbps, prepare a chart giving the minimum distribution time for each of the combinations of N and u for both client-server distribution and P2P distribution.

4. (10 pts) Suppose Bob joins a BitTorrent torrent, but he does not want to upload any data to any other peers (so called free-riding).

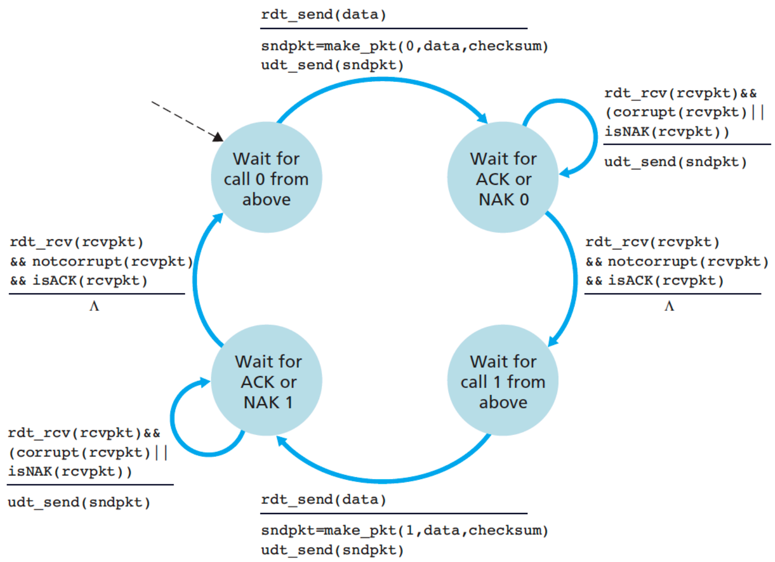
   a. Bob claims that he can receive a complete copy of the file that is shared by the swarm. Is Bob's claim possible? Why or why not?

   b. Bob further claims that he can further make his "free-riding" more efficient by using a collection of multiple computers (with distinct IP addresses) in the computer lab in his department. How can he do that?

5. (10 pts) Show that the (incorrect) receiver, shown in figure below, when operating with the sender shown, can lead the sender and receiver to enter into a deadlock state, where each is waiting for an event that will never occur.



An incorrect receiver



Sender

6. (10 pts) Consider the alternating-bit (stop-and-wait) protocol. Draw a diagram showing that if the network connection between the sender and receiver can reorder messages (that is, that two messages propagating in the medium between the sender and receiver can be reordered), then the alternating-bit protocol will not work correctly (make sure you clearly identify the sense in which it will not work correctly). Your diagram should have the sender on the left and the receiver on the right, with the time axis running down the page, showing data (D) and acknowledgment (A) message exchange. Make sure you indicate the sequence number associated with any data or acknowledgment segment.

7. (15 pts) Consider a scenario in which Host A wants to simultaneously send packets to Hosts B and C. A is connected to B and C via a broadcast channel—a packet sent by A is carried by the channel to both B and C. Suppose that the broadcast channel connecting A, B, and C can independently lose and corrupt packets (and so, for example, a packet sent from A might be correctly received by B, but not by C). Design a stop-and-wait-like error-control protocol for reliably transferring packets from A to B and C, such that A will not get new data from the upper layer until it knows that both B and C have correctly received the current packet. Give FSM descriptions of A and C. (Hint: The FSM for B should be essentially the same as for C.) Also, give a description of the packet format(s) used.

8. (15 pts) Suppose we have two network entities, A and B. B has a supply of data messages that will be sent to A according to the following conventions. When A gets a request from the layer above to get the next data (D) message from B, A must send a request (R) message to B on the A-to-B channel. Only when B receives an R message can it send a data (D) message back to A on the B-to-A channel. A should deliver exactly one copy of each D message to the layer above. R messages can be lost (but not corrupted) in the A-to-B channel; D messages, once sent, are always delivered correctly. The delay along both channels is unknown and variable. Design (give an FSM description of) a protocol that incorporates the appropriate mechanisms to compensate for the loss-prone A-to-B

channel and implements message passing to the layer above at entity A, as discussed above. Use only those mechanisms that are absolutely necessary.

9. (50 pts) This exercise relates to the GENI lab "Two queues or not two queues? The benefit of statistical multiplexing" (https://witestlab.poly.edu/blog/two-queues-or-not-two-queues-the-benefit-of-statistical-multiplexing). You are asked to compare the M/M/1 results to the M/D/1 results where "D" stands for deterministic (i.e., constant) service times. To produce constant service times, you should use the –c option when you run the traffic generation sender, for example:

   ITGSend -a receiver-1 -E 110 **-c 512** -T UDP -t 600000

   generates a Poisson traffic stream to receiver-1 with a mean packet rate of 110 packets per second, and constant packet sizes of 512 B. You should also compare your experimental results to those obtained analytically for the M/D/1 queuing system, where the average packet delay is given by:

$$\frac{1}{2\mu} \cdot \frac{2-\rho}{1-\rho}$$

   Submit the CDF of delay results for the percentile values (0.25, 0.5, 0.75, 1) produced by the R script, one for M/M/1 and another for M/D/1, along with your observations and brief analysis of how the two systems compare and why. You only need to include the CDF data and not the plots. In your analysis, you may want to try different parameters, for example, packet rate of 220 packets per second and average packet size of 256. (*Hint:* each link/network supports a maximum packet size, referred to as MTU. Any packet larger than MTU is either dropped or fragmented.)