Q1. Assume that you have a base html file with 30 embedded images that is requested by a client. Assume that the base file and all of the images are small enough to fit within one TCP segment. How many round trips are required to retrieve the base file and the images under the following settings? Assume that the round trip times dominate all other times.

a. HTTP 1.0 with no parallel connections

b. HTTP 1.0 with up to 10 parallel connections

c. HTTP 1.1. with no pipelining

d. HTTP 1.1. with pipelining

Q2. Using a Web browser, you visit the web site for www.hamburger.com. The base HTML page for the main page www.hamburger.com is 30,000 bits. Once the base HTML page is fetched, it contains URL references for the following embedded images:

http://www.hamburger.com/burger banner.jpg 15,000 bits
http://www.hamburger.com/lettuce.jpg 5,000 bits
http://www.hamburger.com/mmm bacon.jpg 10,000 bits
http://www.hamburger.com/veggie.jpg 10,000 bits
http://www.hamburger.com/disclaimer.txt 5,000 bits
http://www.hamburger.com/royale with cheese.jpg 35,000 bits

Your Web browser uses the HTTP protocol to download the base page and the embedded objects. Make the following assumptions:

- At most 10,000 bits of data fits into a single packet. You can ignore the overhead of any headers or framing.
- You must first download the entire base page before you can start fetching the embedded images.
- HTTP requests are 1,000 bits in size.
- Any new connection to a machine requires a connection-establishment handshake.

- For this problem, you do not need to worry about closing connections, and you can ignore the delay introduced in acknowledging the final data packet sent by the server to your browser.
- All senders use windows of 20,000 bits.
- No packets are lost.

a. For the initial transfer of the home page, how many RTTs are required, and what occurs during each of them?

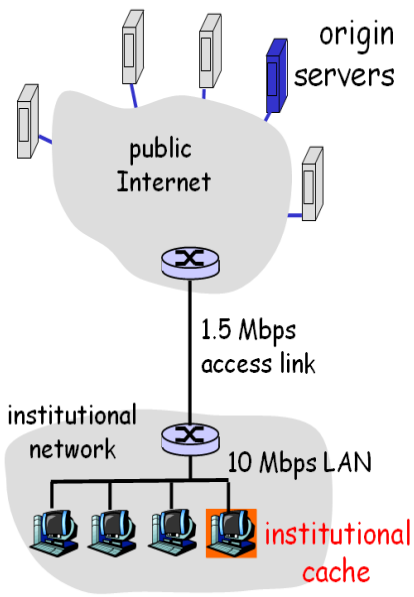
b. How quickly (in terms of RTTs) can your browser download the base page for www.hamburger.com and all embedded objects if the browser uses:

i. One connection per item, with up to 4 concurrent connections.

ii. A single persistent, non-pipelined connection.

iii. A single pipelined connection.

Q3. Consider the networks shown in the figure below. Assume computers in the institution send out 14 requests per second. Each object average size is 100,000 bits. Also assume the internet side delay of a request is 2 seconds. Using M/M/1 queue to model the access delay in the 1.5Mbps access link. The formula for the average response time is E[T]=1/(), where is the arrival rate of objects to the access link and is the service rate of the access link.



a. Find the total average response time when no institutional cache is used. [Note: you should also use the M/M/1 queue formula to calculate the delay in internal Ethernet LAN.]

b. Now suppose the institutional cache is used. The hit rate for the cache is 0.75. Find the total average response time.