Problem 1

Two hosts, A and B are separated by 5,000 kilometers and are connected by a direct link of $R = 2.5Mbps$. Suppose the propagation speed over the link is $2.5 * 10^8 meters/sec$.

1. Consider sending a file of 80,000 bits from Host A to Host B. Suppose the file is sent continuously as one large message. What is the maximum number of bits that will be in the link at any given time?
2. How long it takes for B to receive the last bit of the file, assuming it is sent continuously?
3. Suppose now the file is broken up into 10 packets with each packet containing 8,000 bits. Suppose that each packet is acknowledged by the receiver and the transmission time of an acknowledgment packet is negligible. Finally, assume that the sender cannot send a packet until the preceding one is acknowledged. How long it takes for B to receive the last bit of the file?

1. $T_p = \frac{d}{S} = \frac{5,000,000 m}{2.5 \cdot 10^8 m/s} = 0.02S$

$\text{Max bits} = R \cdot T_p$

$= 2.5 \cdot 10^6 m/s \cdot 0.02S$

max bits = 50,000 bits

2. $T_t = \frac{L}{R} = \frac{80,000 m}{2.5 \cdot 10^6 m/s} = 0.032 s$

$T = T_R + T_P = 0.032 + 0.02 = 0.052$

$T = 0.052$ sec

3. $RTT = 10(2 \cdot T_p + T_t)$ $T_t = \frac{L}{R} = \frac{8,000}{2.5 \cdot 10^6} = 0.0032s$

$= 10 \cdot ((0.04) + 0.0032)$

$= 0.432$

$RTT = 0.432S$

Problem 2

Suppose within your Web browser you click on a link to obtain a Web page from Server S, and the browser already obtained S's IP address. Suppose that the Web page associated with the link is a small HTML file, consisting only of references to 30 very small objects on the same server. Let RTT_0 denote the RTT between the local host and the server containing the object. How much time elapses (in terms of RTT_0) from when you click on the link until your host receives all of the objects, if you are using:

1. HTTP/1.0 without parallel TCP connections?
2. HTTP/1.0 with parallel TCP connections? The maximum number of parallel connections is 15.
3. HTTP/1.1 without parallel connections, but with pipelining?

Ignore any processing, transmission, or queuing delays in your calculation.

1. # objects = 1(HTML) + 30 = 31

Connection + response = $2RTT_0$

For 31 objects, $2RTT_0 \Rightarrow 2 \cdot 31 = 62\ RTT_0$

2. 2 rounds for 30, + additional for HTML

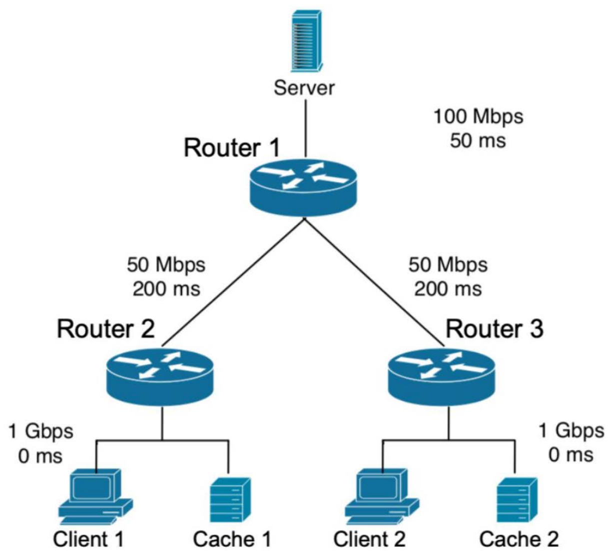
$2(\text{HTML}) + 2(2\text{ rounds}) = 6RTT_0$

3. 1 round for HTML because HTTP 1.1, 2 rounds for pipeling 30 objects

$\Rightarrow 1(RTT_0) + 2(RTT_0) = 3RTT_0$

Problem 3

Consider the scenario shown in Figure below in which a server is connected to the Router 1 by a 100Mbps link with a 50ms propagation delay. Initially Router 1 is also connected to two routers (Router 2 and Router 3), each over a 50Mbps link with a 200ms propagation delay. 1Gbps links connect a host and a cache to each of these routers and we assume that the links between Router 2 - Client1, Router 2 - Cache 1, and Client 1 - Cache 1 have 0 propagation delay. All packets in the network are 20,000 bits long.



1. What is the end-to-end delay from when a packet is transmitted by the server to when it is received by Client 1? In this case, we assume there's no queuing delay at the routers, and the packet processing delays at routers and nodes are all 0.
2. Here we assume that client hosts send requests for files directly to the server (caches are not used or off in this case). What is the maximum data rate at which Client 1 can receive data from the server if we assume Client 2 is not making requests?
3. Now we assume that the caches are ON and behave like HTTP caches. Again, Client2 is not active in this problem. Client1's HTTP GET is always first directed to its local cache. 80% of the requests can be satisfied by the local cache. What is the average data rate at which Client 1 can receive a HTTP object in this case?

1. Total end delay $= T_{t_{server-R_1}} + T_{t_{R_1-R_2}} + T_{t_{R_2-Client_1}} + T_{p_{S-R_1}} + T_{p_{R_1-R_2}} + T_{p_{R_2-client}}$

$$= \frac{L}{R_0} + \frac{L}{R_1} + \frac{L}{R_2} + 50ms + 200ms + 0ms$$

$$= \frac{20,000}{100 \cdot 10^6} + \frac{20,000}{50 \cdot 10^6} + \frac{20,000}{1 \cdot 10^9} + 250ms$$

$$= 0.0002 + 0.0004 + 0.00002 + 250ms$$

$$T = 250.62 \text{ ms}$$

2. Propagation delay is irrelevant because the bottleneck link capacity capacity between Router 1 and Router 2 is 50Mbps

Problem 3 continued on next page. . .

3.

80% of requests by local cache | to client 1 = 1 Gbps link capacity

20 % of requests by Router 1 to Router 2 = 50 Mbps

average data rate = 80% · 1Gbps + 20% · 50 Mbps

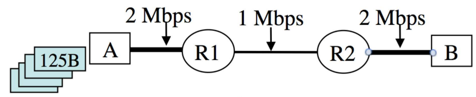
= 800 Mbps + 10 Mbps

= 810 Mbps

Problem 4

Consider sending 4 packets from Node A to Node B via 2 routers R1 and R2 (see the figure to the right). The packet length is 125 bytes each (i. e. 1000 bits). The propagation delay of all the 3 Links is 5ms. Links A-R1 and R2-B's bandwidth is 2 Mbps, and link R1-R2's bandwidth is 1 Mbps.

Assume A starts transmitting the first packet at time T = 0,



1. What is the time gap between the first and second packets when they arrive at R2 ? (i. e. , the time gap between receiving the last bit of the first packet and the last bit of 2nd packet)
2. What is the time gap between the first and second packets when they arrive at B ?
3. When will B receive all the 4 packets?

1.

$L = 1000$ bits

$R_{A-R1} = 2$ Mbps

$R_{R1-R2} = 1$ Mbps

$S = 5$ms

$\Rightarrow$ $T_{A-R1} = \frac{1000}{2} = 500s = .5ms$

$T_{R1-R_2} = \frac{1000}{1} = 1000s = 1ms$

time until when first packet reaches R2:

$T_{A-R1} + S_{A-R1} + T_{R1-R2} + S_{R1-R2} = .5 + 5 + 1 + 5 = 11.5$

time until second packet reaches R2:

$T_{A-R1} + T_{A-R1} + S_{A-R1} + T_{R_1-R_2} + S_{R1-R2} = 1 + 5 + 1 + 5 = 12$

time gap between recieving last bit of first packet and second packet when reaching R2:

$12 - 11.5 = 0.5ms$

2.

$T_{R_2-B} = \frac{1000}{2} = 0.5ms$

Time first packet at B = $11.5 + 0.5 + 5 = 17ms$

Time second packet at B = $12 + 0.5 + 5 = 17.5$

time difference = $17.5ms - 17ms = 0.5ms$

3.

Packet 1 = $T_{A-R1} + 5 + T_{R_1-R_2} + 5 + T_{R2-B} + 5$

$= 0.5 + 5 + 1 + 5 + 0.5 + 5$

$= 17$

Packet 2 = $0.5 +$ Packet 1 $= 17.5$

Packet 3 = $0.5 +$ Packet 2

$= 18$

Packet 4 = $0.5 +$ Packet 3

$= 18.5$

Packet 4 reaches B in 18.5ms