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CS453
Written HW 1

1.

If $LP/R \sim 0$:

$d_{backback} = PN\frac{L}{R}$

If $LP/R \le 1$:

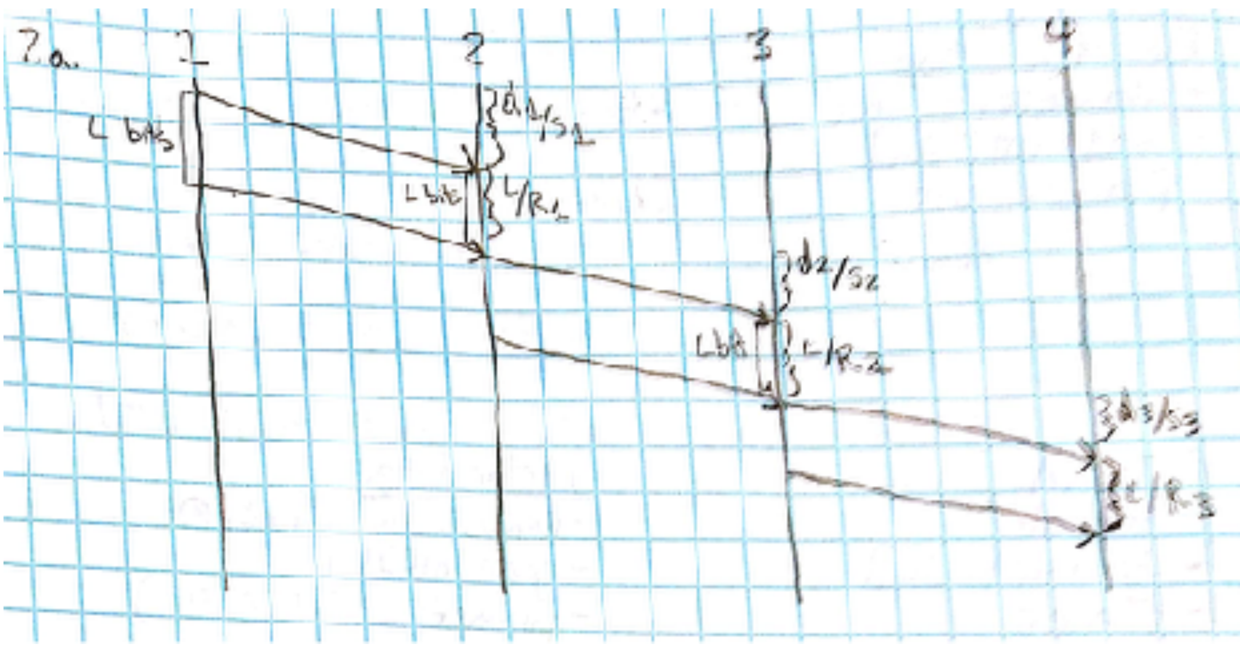
$d_{backback} = \sum_{n=1}^{P}(n-1)\frac{L}{R} + PN\frac{L}{R}$

If $LP/R > 1$:

$d_{backback}$ approaches infinity

2.

a)



b)

$$d_{endtoend} = \sum_{i=1}^{3}\left(\frac{d_i}{s_i} + \frac{L}{R_i}\right) + \sum_{i=2}^{3} d_{proc,i}$$

c)

$L = 3500B = 30400b$

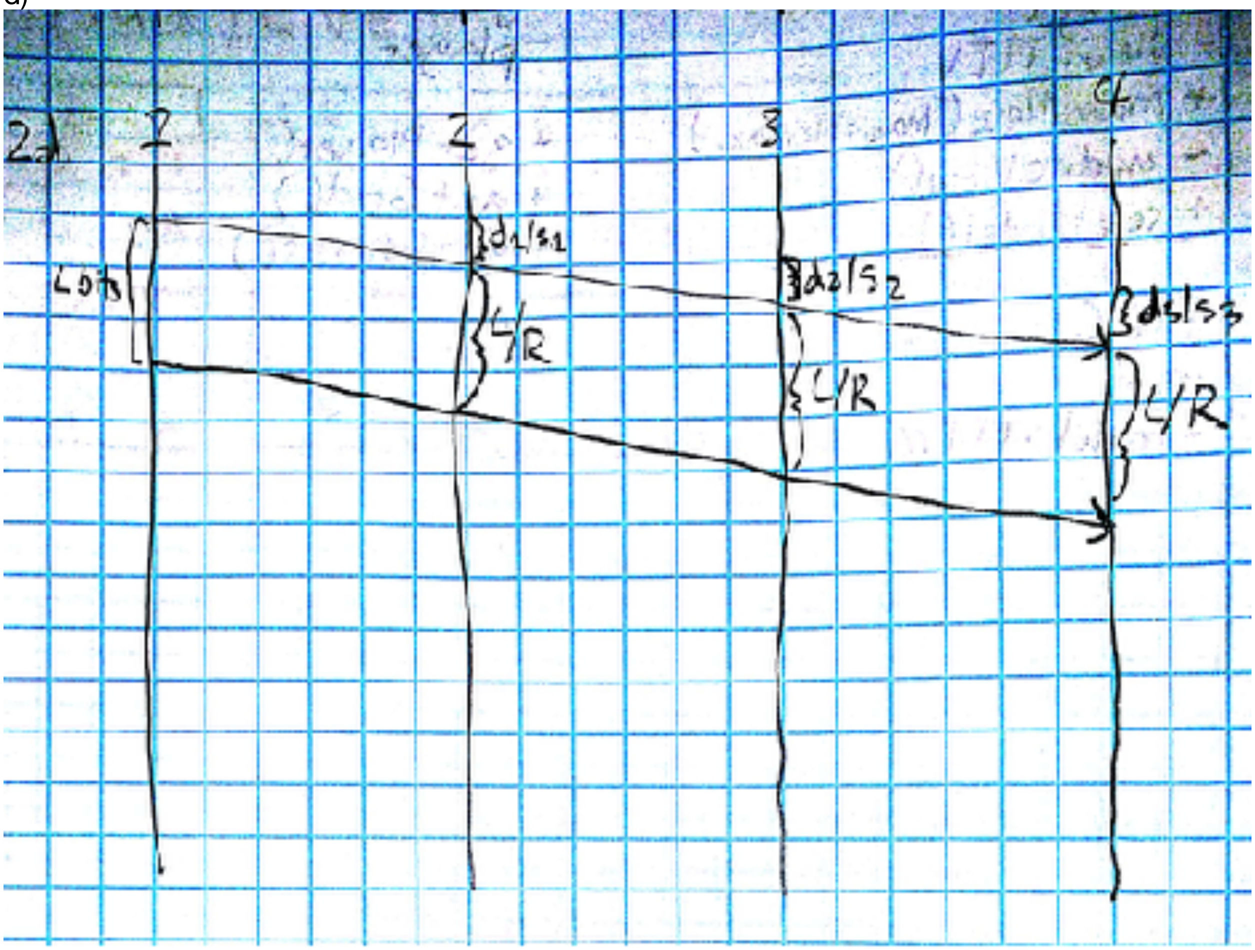
$R = 2\,Mbps = 2000\,Kbps = 2000000bps$

d_{proc} for 2,3=$2ms = .002s$

$$d_{endtoend} = (\frac{15000}{250000}s + \frac{30400b}{2000000b/s}) + (\frac{12000}{250000}s + \frac{30400b}{2000000b/s} + .002s) + (\frac{3000}{250000}s + \frac{30400b}{2000000b/s} + .002s)$$

$= .1696s$

d)



e)

$$d_{endtoend} = 3\frac{L}{R} + \sum_{i=1}^{3}\frac{d_i}{s_i}$$

3.

a)

The maximum throughput is the minimum of the $R^k_{1..N}$ transmission rates.

$\min(R^k)$

b)

$$\sum_{k=1}^{M} \min(R^k)$$

4.

1)

$$KR_s = 1876\,Mbps < R$$

Since the total throughput through R is 1876Mbps, the bottleneck links are at the source nodes. Thus, the throughput between each pair is 14Mbps

2)

$$KR_s = 2010\,Mbps > R$$

$$RR_D = 1990\,Mbps < R$$

Since the total amount of data the destination can receive is less than the total data that the source can send, the bottleneck links are at the destination. The throughput between each pair is 199Mbps.

3)

This change would increase the throughput between the sources and destination. It would also change the bottleneck link to R. Assuming each source/destination pair has completely fair usage of link R, the total throughput would be 200Mbps between each pair.

4)

The throughput between S_1 and D_1 would now be 2Mbps. The throughput between $S_{2..10}$ and $D_{2..10}$ would now be 201Mbps. This is because 9 * 201 + 2 < 2000. The total throughput from the sources is below the capacity of link R, so each source operates at full capacity since the max throughput of the destination is greater than or equal to the max throughput of the source.

5.

Time of day 1:

9 lsldc-rt-106-0-et-0-2-0.gw.umass.edu (128.119.0.76) 19.015 ms 20.554 ms 35.222 ms
9 lsldc-rt-106-0-et-0-2-0.gw.umass.edu (128.119.0.76) 20.582 ms 23.089 ms 19.551 ms
9 lsldc-rt-106-0-et-0-2-0.gw.umass.edu (128.119.0.76) 18.772 ms 18.964 ms 19.676 ms
9 lsldc-rt-106-0-et-0-2-0.gw.umass.edu (128.119.0.76) 19.948 ms 19.664 ms 20.420 ms
9 lsldc-rt-106-0-et-0-2-0.gw.umass.edu (128.119.0.76) 18.480 ms 20.621 ms 19.003 ms

19.015	20.554	35.222	Average	20.9040667
20.582	23.089	19.551	Std Dev	4.1185723
18.772	18.964	19.676		
19.948	19.664	20.42		
18.48	20.621	19.003		

Time of day 2:

9 lsldc-rt-106-0-et-0-2-0.gw.umass.edu (128.119.0.76) 20.474 ms 18.429 ms 21.707 ms
9 lsldc-rt-106-0-et-0-2-0.gw.umass.edu (128.119.0.76) 47.278 ms 24.201 ms 20.209 ms
9 lsldc-rt-106-0-et-0-2-0.gw.umass.edu (128.119.0.76) 19.228 ms 18.933 ms 19.756 ms
9 lsldc-rt-106-0-et-0-2-0.gw.umass.edu (128.119.0.76) 26.992 ms 20.797 ms 19.162 ms
9 lsldc-rt-106-0-et-0-2-0.gw.umass.edu (128.119.0.76) 19.598 ms 19.458 ms 19.573 ms

20.474	18.429	21.707	Average	22.3863333
47.278	24.201	20.209	Std Dev	7.24384642
19.228	18.933	19.756		
26.992	20.797	19.162		
19.598	19.458	19.573		

Time of day 3:

9 lsldc-rt-106-0-et-0-2-0.gw.umass.edu (128.119.0.76) 20.364 ms 37.023 ms 19.445 ms
9 lsldc-rt-106-0-et-0-2-0.gw.umass.edu (128.119.0.76) 20.010 ms 19.932 ms 20.571 ms
9 lsldc-rt-106-0-et-0-2-0.gw.umass.edu (128.119.0.76) 18.789 ms 22.112 ms 20.918 ms
9 lsldc-rt-106-0-et-0-2-0.gw.umass.edu (128.119.0.76) 25.618 ms 23.462 ms 49.979 ms
9 lsldc-rt-106-0-et-0-2-0.gw.umass.edu (128.119.0.76) 20.542 ms 20.725 ms 21.216 ms

20.364	37.023	19.445	Average	24.0470667
20.01	19.932	20.571	Std Dev	8.43558885
18.789	22.112	20.918		
25.618	23.462	49.979		
20.542	20.725	21.216		

2)

The total number of routers that responded before timeout in the path changed throughout the traceroute attempts. The number of routers is the count of the last line given in the response to question 5.1. On the 4th trial on the first time of day, I saw lag-9.bear1.boston1.level3.net again, which timed out on the 2nd and 3rd trials. The total number of hops was 9 at all times.

6.

a)

The inter-arrival time is equal to the total time it takes to send the second packet.

$$2d_{prop} + \frac{L}{R_s} + \frac{L}{R_C}$$

b)

Yes, it is possible because the server will finish sending the first packet and begin to send the second packet while the router is still sending the client the first packet. Since both links have the same propagation delay, there is no chance that the propagation delay on the first link would be long enough for the router to complete sending of the first packet before the second packet arrives.

c)

The delay must be $T \geq d_{prop} + \frac{L}{R_c}$. This is the amount of time that it takes for the router to finish sending the first packet to the client. The delay must exceed the time it takes to finish sending the first packet from the server to the client.

7.

a)

$$F = 288kB = 2304kb$$
$$h = 80B = 640b = .64kb$$
$$R = 4Mbps = 4000kbps$$
$$L = F + h = 2304.64kb$$
$$d_{endtoend} = \frac{2L}{R} = 1.15232\sec$$

b)

$$F = 288kB = 2304kb$$
$$h = 80B = 640b = .64kb$$
$$R = 4Mbps = 4000kbps$$
$$L = \frac{F}{n} + h = 1152.64\text{kb}$$
$$\text{d}_{endtoend} = \frac{4L}{R} = 1.15264 \text{ sec}$$

c)

The optimal n appears to be 1. For n > 1, a greater total transmission size results due to the extra 80B header that is appended to each additional packet. These packets must still travel through the links, which operate at the same speeds, leading to a slower end to end delay. The end to end delay for n = 1 is 1.15232 seconds.

However smaller packets (greater n) could be favorable if the link utilization was significant, since smaller packets will reach the endpoint sooner, the queue will have a lower probability of completely filling up and causing packet loss or high queueing delays.

8. The answer to this problem depends on the number of circuits that exist on the 200 Mbps link. This is because a direct connection from user to host is made in circuit switching, which gives that user exclusive access to the established link. Given that an arbitrary number of circuits exist on the link, the maximum number of circuit switched users is 6, which would lead to a link utilization of 180Mbps. More users could be supported at

reduced bandwidth, given chunks of the rest of the 20Mbps available on the link as well, but they would not be able to attain the required 30Mbps speeds.