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CSE 353
HW1
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P6. This elementary problem begins to explore propagation delay and transmission delay, two central concepts in data networking. Consider two hosts, A and B, connected by a single link of rate R bps. Suppose that the two hosts are separated by m meters, and suppose the propagation speed along the link is s meters/sec. Host A is to send a packet of size L bits to Host B.

a. Express the propagation delay, d_{prop}, in terms of m and s.

b. Determine the transmission time of the packet, d_{trans}, in terms of L and R.

c. Ignoring processing and queuing delays, obtain an expression for the end-to-end delay.

d. Suppose Host A begins to transmit the packet at time $t = 0$. At time $t = d_{trans}$, where is the last bit of the packet?

e. Suppose d_{prop} is greater than d_{trans}. At time $t = d_{trans}$, where is the first bit of the packet?

f. Suppose d_{prop} is less than d_{trans}. At time $t = d_{trans}$, where is the first bit of the packet?

g. Suppose $s = 2.5 \cdot 10^8$, $L = 120$ bits, and $R = 56$ kbps. Find the distance m so that d_{prop} equals d_{trans}.

A. $d_{prop} = m / s$
B. $d_{trans} = L / R$
C. $d_{total} = d_{prop} + d_{trans} = (m / s) + (L / R)$
D. The last bit of the packet has been transmitted and is ready to propagate to the destination.
E. The first bit has finished transmitting and is propagating to the destination but hasn't finished propagating to Host B
F. The first bit has finished propagating to the destination B.
G. $m/s = L/R \rightarrow m / 2.5*10^8 = 120_{bits} / 56_{kb/sec}$
$m = (0.12_{kb} / 56_{kb/sec}) * (2.5 * 10^8)_{m/s}$
$m = \mathit{535714.28}_{meters}$

P8. Suppose users share a 3 Mbps link. Also suppose each user requires 150 kbps when transmitting, but each user transmits only 10 percent of the time. (See the discussion of packet switching versus circuit switching in Section 1.3.)

a. When circuit switching is used, how many users can be supported?

b. For the remainder of this problem, suppose packet switching is used. Find the probability that a given user is transmitting.

c. Suppose there are 120 users. Find the probability that at any given time, exactly n users are transmitting simultaneously. (*Hint*: Use the binomial distribution.)

d. Find the probability that there are 21 or more users transmitting simultaneously.

A. $3000_{kb} / 150_{kbps} = 20$, so 20 users can be supported using circuit switching.

B. Probability of a given user being active:
P = 0.1
Probability of a given user being not active:
1 - P = 0.9

C. $\binom{120}{n} p^n (1-P)^{120-n}$

D. $\sum_{n=21}^{120} \binom{120}{n} p^n (1-P)^{120-n} = 0.007941$

P10. Consider a packet of length L which begins at end system A and travels over three links to a destination end system. These three links are connected by two packet switches. Let d_i, s_i, and R_i denote the length, propagation speed, and the transmission rate of link i, for $i = 1, 2, 3$. The packet switch delays each packet by d_{proc}. Assuming no queuing delays, in terms of d_i, s_i, R_i, ($i = 1,2,3$), and L, what is the total end-to-end delay for the packet? Suppose now the packet is 1,500 bytes, the propagation speed on all three links is $2.5 \cdot 10^8$ m/s, the transmission rates of all three links are 2 Mbps, the packet switch processing delay is 3 msec, the length of the first link is 5,000 km, the length of the second link is 4,000 km, and the length of the last link is 1,000 km. For these values, what is the end-to-end delay?

Delay = $L/R_1 + d_1/s_1 + L/R_2 + d_2/s_2 + L/R_3 + d_3/s_3 + d_{proc} + d_{proc}$

Delay = $\frac{1500 \times 8}{2 \times 10^6} + \frac{5000 \times 10^3}{2.5 \times 10^8} + \frac{1500 \times 8}{2 \times 10^6} + \frac{4000 \times 10^3}{2.5 \times 10^8} + \frac{1500 \times 8}{2 \times 10^8} + \frac{1000 \times 10^3}{2.5 \times 10^8} +$
0.003 + 0.003

Delay = 0.064sec

P18. Perform a Traceroute between source and destination on the same continent at three different hours of the day.

a. Find the average and standard deviation of the round-trip delays at each of the three hours.

b. Find the number of routers in the path at each of the three hours. Did the paths change during any of the hours?

c. Try to identify the number of ISP networks that the Traceroute packets pass through from source to destination. Routers with similar names and/or similar IP addresses should be considered as part of the same ISP. In your experiments, do the largest delays occur at the peering interfaces between adjacent ISPs?

d. Repeat the above for a source and destination on different continents. Compare the intra-continent and inter-continent results.

(Note: please include screenshots of Traceroute results to support your answer)

To perform traceroutes https://www.ip2location.com/free/traceroute was used
Traceroute 1 to American Server:

Hop	IP Address	Hostname	Location	Time
1	50.97.82.1	fcr03a.dal05.v797.uk2group.com	United States of America, Texas, Dallas	3.018 ms
2	173.192.118.144	ae13.dar02.dal05.networklayer.com	United States of America, Texas, Dallas	9.916 ms
3	173.192.18.214	d6.12.c0ad.ip4.static.sl-reverse.com	United States of America, Texas, Dallas	1.046 ms
4	206.223.118.32	equinix-dallas.transitrail.net	United States of America, Texas, Dallas	1.550 ms
6	64.57.20.116	lo-0.8.rtsw.denv.net.internet2.edu	United States of America, Washington, Seattle	21.369 ms
7	64.57.20.7	64.57.20.7	United States of America, Washington, Seattle	29.156 ms
8	208.77.78.102	208.77.78.102	United States of America, New Mexico, Albuquerque	29.318 ms
9	129.138.252.90	129.138.252.90	United States of America, New Mexico, Socorro	30.534 ms

Traceroute 2 to American Server:

Hop	IP Address	Hostname	Location	Time
1	50.97.82.1	fcr03a.dal05.v797.uk2group.com	United States of America, Texas, Dallas	0.588 ms
2	173.192.118.144	ae13.dar02.dal05.networklayer.com	United States of America, Texas, Dallas	0.395 ms
3	173.192.18.214	d6.12.c0ad.ip4.static.sl-reverse.com	United States of America, Texas, Dallas	1.030 ms
4	206.223.118.32	equinix-dallas.transitrail.net	United States of America, Texas, Dallas	1.459 ms
6	64.57.20.116	lo-0.8.rtsw.denv.net.internet2.edu	United States of America, Washington, Seattle	21.316 ms
7	64.57.20.7	64.57.20.7	United States of America, Washington, Seattle	30.769 ms
8	208.77.78.102	208.77.78.102	United States of America, New Mexico, Albuquerque	29.390 ms
9	129.138.252.90	129.138.252.90	United States of America, New Mexico, Socorro	30.582 ms

Traceroute 3 to American server:

Hop	IP Address	Hostname	Location	Time
1	50.97.82.1	fcr03a.dal05.v797.uk2group.com	United States of America, Texas, Dallas	0.515 ms
2	173.192.118.144	ae13.dar02.dal05.networklayer.com	United States of America, Texas, Dallas	0.339 ms
3	173.192.18.214	d6.12.c0ad.ip4.static.sl-reverse.com	United States of America, Texas, Dallas	1.053 ms
4	206.223.118.32	equinix-dallas.transitrail.net	United States of America, Texas, Dallas	1.533 ms
6	64.57.20.116	lo-0.8.rtsw.denv.net.internet2.edu	United States of America, Washington, Seattle	21.502 ms
7	64.57.20.7	64.57.20.7	United States of America, Washington, Seattle	29.404 ms
8	208.77.78.102	208.77.78.102	United States of America, New Mexico, Albuquerque	29.327 ms
9	129.138.252.90	129.138.252.90	United States of America, New Mexico, Socorro	30.578 ms

A. Sum of Delays Trial 1: 125.907 ms
   Sum of Delays Trial 2: 115.529 ms
   Sum of Delays Trial 3: 114.251 ms
   Total Average: 118.562
   Standard Deviation =
   $$\sqrt{1/3 \ * \ (125.907 - 118.562)^2 + (115.529 - 118.562)^2 + (114.251 - 118.562)^2}$$
   Standard deviation = 5.2196ms
B. There were 9 routers during each of the three hours. The paths didn't change though it's possible for them to change depending on the time of day.
C. It's pretty clear, especially by the ISPs in Dallas, that the largest delays occur at the peering interfaces between adjacent ISPs.

Traceroute 1 to Japanese Server:

Hop	IP Address	Hostname	Location	Time
1	50.31.252.1	50.31.252.1.static.vps.net	Japan, Tokyo	0.584 ms
2	75.102.60.21	0.ge-1-1-3.cr2.tko1.scnet.net	Japan, Tokyo	0.856 ms
3	203.105.72.213	xe-0-0-7-1.a00.tokyjp03.jp.bb.gin.ntt.net	Japan, Tokyo	1.188 ms
4	129.250.5.54	ae-9.r01.tokyjp08.jp.bb.gin.ntt.net	Japan, Tokyo	1.510 ms
5	129.250.6.126	ae-16.r30.tokyjp05.jp.bb.gin.ntt.net	Japan, Tokyo	3.412 ms
6	129.250.4.142	ae-5.r24.sttlwa01.us.bb.gin.ntt.net	United States of America, Washington, Seattle	94.794 ms
7	129.250.3.238	ae-2.r00.lsanca07.us.bb.gin.ntt.net	United States of America, California, Los Angeles	105.689 ms
10	4.14.121.50	CENIC.ear3.Denver1.Level3.net	United States of America, Colorado, Denver	149.507 ms
11	208.77.78.102	208.77.78.102	United States of America, New Mexico, Albuquerque	127.820 ms
12	129.138.252.90	129.138.252.90	United States of America, New Mexico, Socorro	158.027 ms

Traceroute 2 to Japanese Server:

Hop	IP Address	Hostname	Location	Time
1	50.31.252.1	50.31.252.1.static.vps.net	Japan, Tokyo	0.525 ms
2	75.102.60.21	0.ge-1-1-3.cr2.tko1.scnet.net	Japan, Tokyo	0.457 ms
3	203.105.72.213	xe-0-0-7-1.a00.tokyjp03.jp.bb.gin.ntt.net	Japan, Tokyo	0.760 ms
4	129.250.5.50	ae-10.r00.tokyjp08.jp.bb.gin.ntt.net	Japan, Tokyo	1.615 ms
5	129.250.6.132	ae-19.r31.tokyjp05.jp.bb.gin.ntt.net	Japan, Tokyo	1.132 ms
6	129.250.5.78	ae-4.r25.snjsca04.us.bb.gin.ntt.net	United States of America, California, San Jose	114.465 ms
7	129.250.2.99	ae-0.a03.sttlwa01.us.bb.gin.ntt.net	United States of America, Washington, Seattle	97.854 ms
10	4.14.121.50	CENIC.ear3.Denver1.Level3.net	United States of America, Colorado, Denver	148.192 ms
11	208.77.78.102	208.77.78.102	United States of America, New Mexico, Albuquerque	139.314 ms
12	129.138.252.90	129.138.252.90	United States of America, New Mexico, Socorro	133.183 ms

Traceroute 3 to Japanese server:

Hop	IP Address	Hostname	Location	Time
1	50.31.252.1	50.31.252.1.static.vps.net	Japan, Tokyo	0.585 ms
2	75.102.60.21	0.ge-1-1-3.cr2.tko1.scnet.net	Japan, Tokyo	1.521 ms
3	203.105.72.213	xe-0-0-7-1.a00.tokyjp03.jp.bb.gin.ntt.net	Japan, Tokyo	0.884 ms
4	129.250.5.54	ae-9.r01.tokyjp08.jp.bb.gin.ntt.net	Japan, Tokyo	1.322 ms
5	129.250.6.128	ae-18.r31.tokyjp05.jp.bb.gin.ntt.net	Japan, Tokyo	1.451 ms
7	129.250.3.238	ae-2.r00.lsanca07.us.bb.gin.ntt.net	United States of America, California, Los Angeles	99.637 ms
8	129.250.9.94	ae-0.lumen.lsanca07.us.bb.gin.ntt.net	United States of America, California, Los Angeles	112.037 ms
10	4.14.121.50	CENIC.ear3.Denver1.Level3.net	United States of America, Colorado, Denver	144.276 ms
11	208.77.78.102	208.77.78.102	United States of America, New Mexico, Albuquerque	123.325 ms
12	129.138.252.90	129.138.252.90	United States of America, New Mexico, Socorro	145.672 ms

A. Delay Trial 1: 643.387 ms
   Delay Trial 2: 637.497 ms
   Delay Trial 3: 630.71 ms
   Total Average: 637.198
   Standard Deviation =
   $$\sqrt{1/3 * (643.387 - 637.198)^2 + (637.497 - 637.198)^2 + (630.71 - 637.198)^2}$$
   Standard deviation = 5.17968ms
B. There were 12 routers in each test, the route actually did differentiate in between tests on these trials.
C. This data also supports that the biggest delays come at the peering interfaces between adjacent ISPs.
D. The main difference between the inter-continental and intra-continental results were that the out of country trials took far longer to reach the destination. Another difference was that we saw the routes actually change in the out of country trials. Surprisingly, the standard deviation between both trials were very similar.

P25. Suppose two hosts, A and B, are separated by 20,000 kilometers and are connected by a direct link of $R = 2$ Mbps. Suppose the propagation speed over the link is $2.5 \cdot 10^8$ meters/sec.

a. Calculate the bandwidth-delay product, $R \cdot d_{prop}$.

b. Consider sending a file of 800,000 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?

c. Provide an interpretation of the bandwidth-delay product.

d. What is the width (in meters) of a bit in the link? Is it longer than a football field?

e. Derive a general expression for the width of a bit in terms of the propagation speed *s*, the transmission rate *R*, and the length of the link *m*.

A. $d_{prop} = 20{,}000_{kilometers} / 2.5*10^{8}{}_{meters/sec} = 0.08_{sec}$
$R * d_{prop} = 2*10^{6}{}_{mpbs} * 0.08_{sec} = 16*10^{4}{}_{bits}$

B. R = 2,000,000bits
File = 800,000bits
$R*d_{prop}$ = 160,000bits
Therefore, the bandwidth-delay product is the cap, and so the max number of bits at any given time is 160,000bits

C. The bandwidth-delay product can be viewed as the maximum number of bits on the line at a time.

D. $20{,}000_{kilometer} / 160{,}000_{bit} = 0.125_{kilometer/bit} = 410_{feet/bit}$
One football field is 360 feet in length, so the width of a single bit in the link is longer than one football field.

E. Width = $\frac{R*s}{m}$

P31. In modern packet-switched networks, including the Internet, the source host segments long, application-layer messages (for example, an image or a music file) into smaller packets and sends the packets into the network. The receiver then reassembles the packets back into the original message. We refer to this process as *message segmentation*. Figure 1.27 illustrates the end-to-end transport of a message with and without message segmentation. Consider a message that is $8 \cdot 10^6$ bits long that is to be sent from source to destination in Figure 1.27. Suppose each link in the figure is 2 Mbps. Ignore propagation, queuing, and processing delays.

a. Consider sending the message from source to destination *without* message segmentation. How long does it take to move the message from the source host to the first packet switch? Keeping in mind that each switch uses store-and-forward packet switching, what is the total time to move the message from source host to destination host?

b. Now suppose that the message is segmented into 800 packets, with each packet being 10,000 bits long. How long does it take to move the first packet from source host to the first switch? When the first packet is being sent from the first switch to the second switch, the second packet is being sent from the source host to the first switch. At what time will the second packet be fully received at the first switch?

c. How long does it take to move the file from source host to destination host when message segmentation is used? Compare this result with your answer in part (a) and comment.

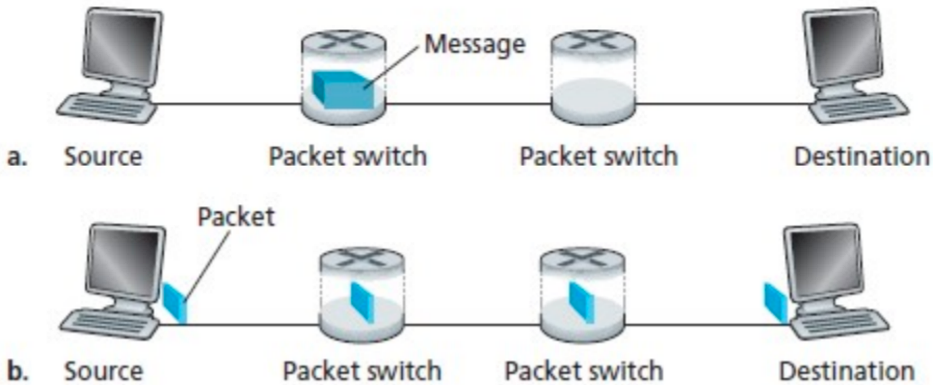

Figure 1.27 ♦ End-to-end message transport: (a) without message segmentation; (b) with message segmentation

d. In addition to reducing delay, what are reasons to use message segmentation?

e. Discuss the drawbacks of message segmentation.

A. 2Mbps = $2*10^6_{bits/sec}$
   Message = $8*10^6_{bits}$
   Source to first packet switch = $8*10^6_{bits}$ / $2*10^6_{bits/sec}$ = 4_{sec}
   Total time = 4_{sec} + 4_{sec} + 4_{sec} = 12_{sec}
B. First packet = $1*10^4_{bits}$
   First packet to first switch = $1*10^4_{bits}$ / $2*10^6_{bits/sec}$ = 0.005_{sec}
   Second packet to first switch = 0.005_{sec} * 2 = 0.010_{sec}
   Second packet will arrive at first switch at 0.0010_{sec}
C. Total time = 800 * 0.005_{sec} = 4_{sec}
   The total time for the message to be sent without message segmentation in part A was 12_{sec}, so with message segmentation <u>it took 1/3rd of the time</u> which is far faster.
D. Message segmentation also reduces the total space taken up by each switch at any time, which is helpful as each switch only has a finite amount of resources that could be filled up without message segmentation, messages could also end up stuck in a long queue waiting for a big message without message segmentation. Also, without message segmentation, if one bit of the message ends up wrong the whole message has to be re-sent instead of one individual packet needing to be re-sent.
E. Header bytes add up with multiple individual packets which is a drawback of message segmentation. Another drawback of message segmentation is

that all the bits have to be put into the proper sequence at the destination to be usable.