Homework 01

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Question 01

Consider an application that transmits data at a steady rate (for example, the sender generates an N-bit unit of data every k time units, where k is small and fixed). Also, when such an application starts, it will continue running for a relatively long period of time. Answer the following questions, briefly justifying your answer:

A. Would a packet–switched network or a circuit-switched network be more appropriate for this application? Why?

A circuit-switched network could be a more optimal selection for the application outlined in the statement. The application's sessions will have a lengthy duration, and the data transmission needs may be anticipated and are likely to be consistent over time. If we utilize a circuit-switched network, we can allocate each session with little bandwidth waste, as the transmission rate for each session can be accurately estimated without the need to account for abrupt fluctuations. The use of a packet-switched network is not optimal for applications that require continual and high-volume usage, as the network's performance deteriorates as the number of sessions increases. Additionally, packet-switched networks may incur greater installation expenses and include more intricate delivery protocols.

B. Suppose that a packet-switched network is used and the only traffic in this network comes from such applications as described above. Furthermore, assume that the sum of the application data rates is less than the capacities of each and every link. Is some form of congestion control needed? Why?

No, there is no need for congestion control as the capacity of the network is larger than the overall bandwidth required by all sessions of the application. There is simply no congestion with almost no queuing happening throughout the transmission.

Question 02

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.

1. **Express the propagation delay, *dprop*, in terms of *m* and *s*.**

   $dprop = \frac{m}{s}(seconds)$

2. **Determine the transmission time of the packet, *dtrans*, in terms of *L* and *R*.**

   $dtrans = \frac{L}{R}\ (seconds)$

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

   If we ignore the the potential delays, the end to end delay would be $de - t - e = dprop + dtrans = \frac{m}{s} + \frac{L}{R}\ (seconds)$

4. **Suppose Host A begins to transmit the packet at time *t=0*. At time *t=dtrans*, where is the last bit of the packet?**

   At $t = dtrans$, the last bit of the packet just got pushed out from Host A.

5. **Suppose *dprop* is greater than *dtrans*. At time *t=dtrans*, where is the first bit of the packet?**

   If $dprop > dtrans$, then although the first bit of the packet left Host A, it has not yet reach to Host B.

6. **Suppose *dprop* is less than *dtrans*. At time *t=dtrans*, where is the first bit of the packet?**

   If $dprop < dtrans$, then the first bit of the packet has already been received by Host B.

7. **Suppose $s = 2.5 \times 10^8 m/s$, L=500 bits, and *R=128* kbps. Find the distance *m* so that *dprop* equals *dtrans*.**

   In this case, assume $s = 2.5 \times 10^8 m/s$ (cuz it was printed as 108 m/s on canvas, which does not make sense), we have

   $m = \frac{S \times L}{R} = \frac{2.8 \times 10^8 \times 500}{128 \times 10^3} = 976,000(meters)$

Question 03

A packet switch receives a packet and determines the outbound link to which the packet should be forwarded. When the packet arrives, one other packet is halfway done being transmitted on this outbound link and four other packets are waiting to be transmitted. Packets are transmitted in order of arrival. Suppose all packets are 2,400 bytes and the link rate is 2 Mbps. What is the queuing delay for the packet? More generally, what is the queuing delay when all packets have length *L*, the transmission rate is *R*, *x* bits of the currently-being-transmitted packet have been transmitted, and *n* packets are already in the queue?

The size of the packet $L = 2400$, the transmitted bits $x = \frac{2400}{2} = 1200$, then the remaining bits would be $L - x = 1200$. Then the queuing delay can be calculated as $Tq = \frac{4.5 \times 2400 \times 8}{2 \times 10^6} = 4.32 \times 10^-2(seconds) = 43.2(ms)$.

However, generally speaking, the queuing delay shall be computed as $Tq = \frac{n \times L + (L - x)}{R}$.

Question 04

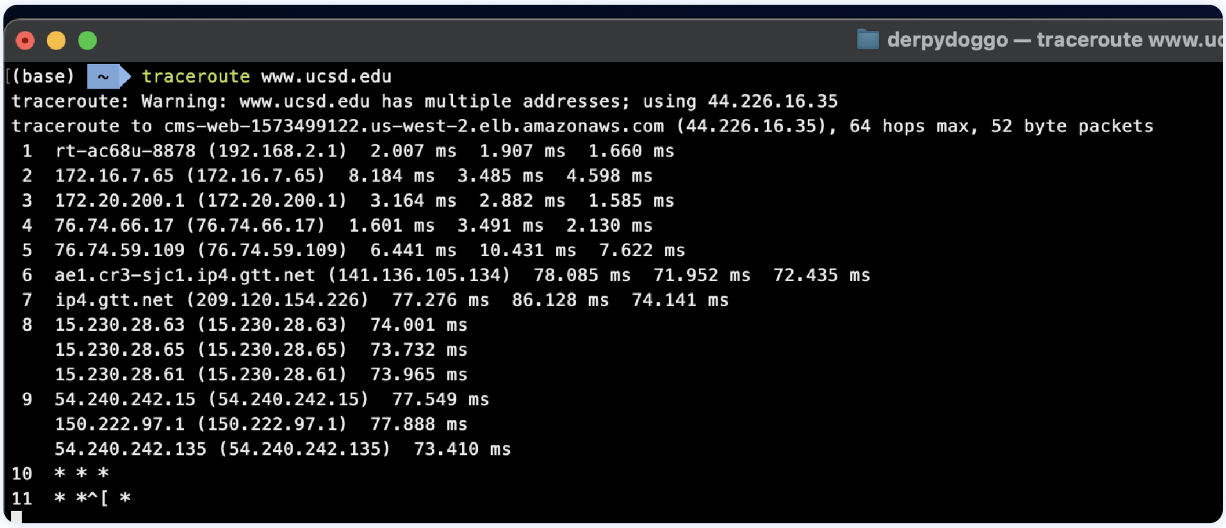
Perform a Traceroute (command "traceroute" on Unix systems and "tracert" on Windows systems) between your computer and *www.ucsd.edu* at three different hours of the day. (Add screenshots of the three Traceroutes to your answer!). Note, the traceroute might not go all the way through to the web server. In that case you can abort at a router that partly matches the following name

> *uwcr-atg-1.infra.washington.edu* .

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

#	RTT_1	RTT_2	RTT_3	Average	Std.
1	77.549 ms	77.888 ms	73.410 ms	0.076282	0.0024933
2	75.862 ms	74.117 ms	78.185 ms	0.076055	0.0020408
3	73.297 ms	74.279 ms	72.971 ms	0.073516	0.0006809

The results can be found in the table above. But we do need to notice that since the site is hosted by AWS, the destination we can arrive at is no longer a webserver described in the statement.



```
derpydoggo — traceroute www.uc
(base) ~ traceroute www.ucsd.edu
traceroute: Warning: www.ucsd.edu has multiple addresses; using 44.226.16.35
traceroute to cms-web-1573499122.us-west-2.elb.amazonaws.com (44.226.16.35), 64 hops max, 52 byte packets
 1  rt-ac68u-8878 (192.168.2.1)  2.007 ms  1.907 ms  1.660 ms
 2  172.16.7.65 (172.16.7.65)  8.184 ms  3.485 ms  4.598 ms
 3  172.20.200.1 (172.20.200.1)  3.164 ms  2.882 ms  1.585 ms
 4  76.74.66.17 (76.74.66.17)  1.601 ms  3.491 ms  2.130 ms
 5  76.74.59.109 (76.74.59.109)  6.441 ms  10.431 ms  7.622 ms
 6  ae1.cr3-sjc1.ip4.gtt.net (141.136.105.134)  78.085 ms  71.952 ms  72.435 ms
 7  ip4.gtt.net (209.120.154.226)  77.276 ms  86.128 ms  74.141 ms
 8  15.230.28.63 (15.230.28.63)  74.001 ms
    15.230.28.65 (15.230.28.65)  73.732 ms
    15.230.28.61 (15.230.28.61)  73.965 ms
 9  54.240.242.15 (54.240.242.15)  77.549 ms
    150.222.97.1 (150.222.97.1)  77.888 ms
    54.240.242.135 (54.240.242.135)  73.410 ms
10  * * *
11  * *^[ *
```

```
derpydoggo — traceroute
(base) ~ traceroute www.ucsd.edu
traceroute: Warning: www.ucsd.edu has multiple addresses; using 44.233.103.84
traceroute to cms-web-1573499122.us-west-2.elb.amazonaws.com (44.233.103.84), 64 hops max, 52 byte packe
 1  rt-ac68u-8878 (192.168.2.1)  4.149 ms  1.364 ms  1.343 ms
 2  172.16.7.65 (172.16.7.65)  2.823 ms  7.904 ms  5.049 ms
 3  172.20.200.1 (172.20.200.1)  2.047 ms  2.510 ms  8.640 ms
 4  76.74.66.17 (76.74.66.17)  1.790 ms  2.124 ms  2.051 ms
 5  76.74.59.109 (76.74.59.109)  7.467 ms  7.284 ms  9.069 ms
 6  ae1.cr3-sjc1.ip4.gtt.net (141.136.105.134)  71.992 ms  72.847 ms  72.766 ms
 7  ip4.gtt.net (209.120.154.226)  72.546 ms  73.386 ms  72.840 ms
 8  15.230.28.67 (15.230.28.67)  75.690 ms
    15.230.28.61 (15.230.28.61)  75.581 ms  79.180 ms
 9  150.222.97.51 (150.222.97.51)  75.862 ms
    54.240.242.35 (54.240.242.35)  74.117 ms
    54.240.242.81 (54.240.242.81)  78.185 ms
10  * * *
11  * * *
12  * * *
13  * 108.166.236.46 (108.166.236.46)  91.779 ms
    108.166.228.70 (108.166.228.70)  87.322 ms
14  * 108.166.236.20 (108.166.236.20)  88.313 ms *
15  * * *
16  * * *
```

```
(base) ✗ ~ traceroute www.ucsd.edu
traceroute: Warning: www.ucsd.edu has multiple addresses; using 44.233.103.84
traceroute to cms-web-1573499122.us-west-2.elb.amazonaws.com (44.233.103.84), 64 hops max, 52 byte packets
 1  rt-ax86u-9e48 (192.168.50.1)  9.521 ms  2.282 ms  4.949 ms
 2  172.16.7.65 (172.16.7.65)  14.082 ms  8.022 ms  3.725 ms
 3  172.20.200.1 (172.20.200.1)  3.308 ms  2.024 ms  2.440 ms
 4  76.74.66.17 (76.74.66.17)  2.310 ms  2.267 ms  2.653 ms
 5  76.74.59.109 (76.74.59.109)  10.062 ms  8.799 ms  11.768 ms
 6  ae1.cr3-sjc1.ip4.gtt.net (141.136.105.134)  98.809 ms  77.822 ms  73.362 ms
 7  ip4.gtt.net (209.120.154.226)  73.453 ms  74.367 ms  74.779 ms
 8  15.230.28.67 (15.230.28.67)  74.680 ms
    15.230.28.63 (15.230.28.63)  77.499 ms
    15.230.28.57 (15.230.28.57)  73.880 ms
 9  54.240.242.101 (54.240.242.101)  73.297 ms
    54.240.242.61 (54.240.242.61)  74.279 ms
    150.222.97.127 (150.222.97.127)  72.971 ms
10  * * *
11  * *
```

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

#	Hop$_1$	Hop$_2$	Hop$_3$
1	9	9	9
2	9	9	9
3	9	9	9

The paths are indeed changing over time. Although, we need to notice that the site is now hosted on AWS. And sometimes, AWS does have weird behaviors to reroute packets to somewhere else, see in screenshot for trial 02.

3. **Try to identify the number of ISP networks 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 peering interfaces between adjacent ISPs?**

After the 3^{rd} hop, our packet leaves the wifi router, and from 4^{th} to 5^{th}, it is traversing through the ISP provider called SingleDigit, and then it enters Tier 1 Network from gtt.net from 6^{th} to 7^{th}. Then, from 8^{th} to 9^{th}, the packet enters AWS cloud.

4. **Repeat the above for a destination on a continent different then the source. Compare the intra- and inter-continent results.**

And for this one, I attempted to visit

> www.docomo.ne.jp

which is the telecom provider from Japan.

```
derpydoggo — traceroute www.docomo
(base) ~ traceroute www.docomo.ne.jp
traceroute to www.docomo.ne.jp (160.13.90.208), 64 hops max, 52 byte packets
 1  rt-ax86u-9e48 (192.168.50.1)  2.715 ms  2.282 ms  2.141 ms
 2  172.16.7.65 (172.16.7.65)  3.570 ms  3.500 ms  4.126 ms
 3  172.20.200.1 (172.20.200.1)  2.240 ms  2.715 ms  2.634 ms
 4  76.74.66.17 (76.74.66.17)  2.840 ms  2.773 ms  2.815 ms
 5  76.74.59.109 (76.74.59.109)  7.573 ms  34.013 ms  7.567 ms
 6  ae36.cr5-was1.ip4.gtt.net (89.149.181.50)  17.469 ms  17.142 ms  17.913 ms
 7  202.232.1.113 (202.232.1.113)  18.038 ms  18.250 ms  17.852 ms
 8  sjc002bb01.iij.net (58.138.81.237)  114.782 ms
    sjc002bb00.iij.net (58.138.81.229)  78.061 ms
    sjc002bb01.iij.net (58.138.81.237)  246.550 ms
 9  tky009bb01.iij.net (58.138.88.237)  176.881 ms
    tky009bb01.iij.net (58.138.88.245)  211.465 ms
    tky008bb00.iij.net (58.138.88.97)  176.755 ms
10  ykh002bb01.iij.net (58.138.89.149)  187.736 ms
    ykh002bb00.iij.net (58.138.89.145)  177.259 ms  243.870 ms
11  ykh002ip61.iij.net (58.138.120.14)  524.847 ms
    ykh002ip61.iij.net (58.138.120.230)  214.077 ms
    ykh002ip61.iij.net (58.138.120.10)  213.184 ms
12  210.130.152.218 (210.130.152.218)  178.008 ms
    210.130.163.98 (210.130.163.98)  176.846 ms  177.404 ms
13  * * *
14  * * *
```

```
derpydoggo — traceroute
(base) ~ traceroute www.docomo.ne.jp
traceroute to www.docomo.ne.jp (160.13.90.210), 64 hops max, 52 byte packets
 1  rt-ac68u-8878 (192.168.2.1)  3.518 ms  1.657 ms  1.324 ms
 2  172.16.7.65 (172.16.7.65)  2.847 ms  3.568 ms  2.571 ms
 3  172.20.200.1 (172.20.200.1)  2.050 ms  1.968 ms  1.633 ms
 4  76.74.66.17 (76.74.66.17)  2.338 ms  9.234 ms  3.174 ms
 5  76.74.59.109 (76.74.59.109)  6.871 ms  24.477 ms  21.742 ms
 6  ae36.cr5-was1.ip4.gtt.net (89.149.181.50)  26.352 ms  20.990 ms  47.556 ms
 7  202.232.1.113 (202.232.1.113)  23.549 ms  18.243 ms  19.392 ms
 8  sjc002bb01.iij.net (58.138.81.237)  117.301 ms
    sjc002bb00.iij.net (58.138.81.229)  77.168 ms
    sjc002bb01.iij.net (58.138.81.237)  202.680 ms
 9  tky008bb00.iij.net (58.138.88.97)  232.218 ms
    tky009bb01.iij.net (58.138.88.237)  307.180 ms
    tky009bb01.iij.net (58.138.88.245)  336.506 ms
10  ykh002bb01.iij.net (58.138.89.149)  334.152 ms  177.695 ms  178.352 ms
11  ykh002ip61.iij.net (58.138.120.238)  337.242 ms
    ykh002ip61.iij.net (58.138.120.254)  182.091 ms
    ykh002ip61.iij.net (58.138.120.230)  236.238 ms
12  210.130.152.218 (210.130.152.218)  247.676 ms  179.575 ms  231.135 ms
13  * * *
```

```
derpydoggo — tracerou
(base) ~ traceroute www.docomo.ne.jp
traceroute to www.docomo.ne.jp (160.13.90.213), 64 hops max, 52 byte packets
 1  rt-ac68u-8878 (192.168.2.1)  2.286 ms  2.018 ms  1.771 ms
 2  172.16.7.65 (172.16.7.65)  34.626 ms  12.793 ms  2.964 ms
 3  172.20.200.1 (172.20.200.1)  1.884 ms  2.610 ms  2.998 ms
 4  76.74.66.17 (76.74.66.17)  2.798 ms  2.429 ms  2.116 ms
 5  76.74.59.109 (76.74.59.109)  10.046 ms  12.379 ms  12.141 ms
 6  ae36.cr5-was1.ip4.gtt.net (89.149.181.50)  17.224 ms  19.009 ms  19.092 ms
 7  202.232.1.113 (202.232.1.113)  17.548 ms  20.020 ms  17.762 ms
 8  sjc002bb00.iij.net (58.138.81.229)  78.285 ms
    sjc002bb01.iij.net (58.138.81.237)  112.040 ms
    sjc002bb00.iij.net (58.138.81.229)  78.370 ms
 9  tky008bb00.iij.net (58.138.88.97)  175.893 ms
    tky009bb01.iij.net (58.138.88.237)  176.883 ms
    tky008bb00.iij.net (58.138.88.105)  296.625 ms
10  ykh002bb00.iij.net (58.138.89.145)  176.720 ms  240.031 ms
    ykh002bb01.iij.net (58.138.89.149)  177.581 ms
11  ykh002ip61.iij.net (58.138.120.10)  177.011 ms
    ykh002ip61.iij.net (58.138.120.230)  177.806 ms
    ykh002ip61.iij.net (58.138.120.10)  177.135 ms
12  210.130.152.218 (210.130.152.218)  289.046 ms
    210.130.163.98 (210.130.163.98)  211.871 ms  176.778 ms
13  * * *
14  *
```

The results can be seen as:

#	RTT_1	RTT_2	RTT_3	Average	Std.
1	178.008 ms	176.846 ms	177.404 ms	0.177419	0.0005811
2	247.676 ms	179.575 ms	231.135 ms	0.219462	0.0355194
3	289.046 ms	211.871 ms	176.778 ms	0.225898	0.0574334

#	Hop_1	Hop_2	Hop_3
1	12	12	12
2	12	12	12
3	12	12	12

We can tell that the paths were changing as well. And compared to intra-continent destination, the number of hops does increase, and RTT also increases. And during busy time of the day, the variation in RTT is greater than non-busy time. However, thanks to the awesome ISP I have, it is much more stable than other providers such as UMass and Xfinity.

Question 05

Suppose you would like to urgently deliver 30 terabytes of data from Boston to Los Angeles. You have a 500 Mbps dedicated link for data transfer available. Would you prefer to transmit the data via this link or instead use FedEx overnight delivery? Explain.

FedEx Overnight Delivery might be a better option, if there is no damages happening during the transportation.

First, we calculate the amount of time for us to use the 500 Mbps dedicated link to transfer such a large amount of data.

$T_{transfer} = \frac{30 \times 10^1 2 \times 8}{500 \times 10^6} = 480,000(seconds)$, which is roughly 5.6 days. Therefore, FedEx Overnight Delivery option can be desirable if the costs are cheaper than the dedicated link, and there is no damage to the hardware during the transportation.

Question 06

Answer the following question about the paper "A Protocol for Packet Network Intercomunication" by Cerf and Kahn.

1. **Explain why fragments of an original datagram are reassembled at the receiving host and not an intermediary gateway?**

   There are multiple benefits to reassembling packets at end hosts. Gateways are primarily designed to expediently transmit packets to the subsequent hop. Reassembling packets from upstream routes would require a substantial amount of resources, resulting in a slowdown of packet forwarding and significant processing delays. Furthermore, if a gateway were to reconstruct packets only for the purpose of transmitting them to another gateway that requires smaller datagrams, the reconstructed packets would then have to be divided again by the downstream gateway, making the initial reconstruction effort pointless. Furthermore, gateways are required to handle the processing of all packets that pass through them while reassembling them, resulting in a significant amount of labor. On the other hand, end hosts only reconstruct packets that they receive directly, so greatly lowering the workload of processing.

2. **What is the purpose of the "process header" in TCP?**

   The process header indicates the specific application layer process responsible for managing/processing the data.

3. **What are the ES and EM bit for?**

   The End Segment (ES) marker indicates the termination of a segment inside a partitioned data stream. Similarly, the End Message (EM) marker is used to indicate that a segment is the last part of a data flow.

4. **Explain how the flow control mechanism in this early version of TCP is specified!**

   The receiver utilizes the 'Suggested Window' to control the transmission of data from the sender.

5. **What mechanisms does the TCP protocol apply to recover from packet losses?**

   The TCP protocol employs retransmission as a means to compensate for packet losses. It utilizes timeouts and acknowledgements (ACKs) to notify the sender about lost packets and trigger their resend.