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Homework 1

CNT5106C : Fall 2020 : Dr. Ye Xia
Due Tue, Sept 15, 2020

Contents

Problem 1

(a)

Answer

The transmission delay is L/R and is the amount of time required to push all of the packet's bit into the link.

$$d_{trans} = \frac{1KB \times 8 \text{ bits/byte}}{1\text{Mbps}} = 8ms \tag{1}$$

The amount of required to propagate from one link to another is using propagation delay

$$d_{prop} = \frac{100Km}{20000Km/s} = 5ms \tag{2}$$

The processing time at each router is $5\mu s$
In order to calculate total end to end delay is given using

$$\begin{aligned} d_{end-to-end} &= 3 * d_{trans} + 3 * d_{prop} + 2 * d_{proc} \\ &= 3 * 8 + 3 * 5 + 2 * 0.005 \\ &= 39.01ms \end{aligned}$$

(b)

Answer

In case of cut-through, router does not wait for the entire packet to arrive. Therefore there would no transmission delay. In order to solve this, the equation in (a) could be transformed as

$$\begin{aligned} d_{end-to-end} &= d_{trans} + 3 * d_{prop} + 2 * d_{proc} \\ &= 8 + 3 * 5 + 2 * 0.005 \\ &= 23.01ms \end{aligned}$$

(c)

Answer

Since $R_1 = R_2 = R_3 = 1Gbps$, the new transmission delay is

$$d_{trans} = \frac{1KB \times 8 \text{ bits/byte}}{1\text{Gbps}} = 8\mu s \tag{3}$$

In case of store and forward,

$$\begin{aligned} d_{end-to-end} &= d_{trans} + 3 * d_{prop} + 2 * d_{proc} \\ &= 3 * 0.008 + 3 * 5 + 2 * 0.005 \\ &= 15.034ms \end{aligned}$$

In case of cut through,

$$\begin{aligned}d_{end-to-end} &= d_{trans} + 3 * d_{prop} + 2 * d_{proc}\\&= 0.008 + 3 * 5 + 2 * 0.005\\&= 15.018ms\end{aligned}$$

(d)

Answer

$$d_{trans}^{R_1,R_2} = \frac{1KB \times 8 \text{ bits/byte}}{2\text{Mbps}} = 4ms$$

$$d_{trans}^{R_3} = \frac{1KB \times 8 \text{ bits/byte}}{1\text{Mbps}} = 8ms$$

In case of **store and forward**,
For packet 1:

$$d_{end-to-end} = 2 * 4 + 8 + 3 * 5 = 31ms$$

In case of packet 2, packet 1 is still being served

$$d_{end-to-end} = 31 + 4 = 35ms$$

In case of packet 3, packet 2 is still being served

$$d_{end-to-end} = 31 + 8 = 39ms$$

In case of **cut through**,
For packet 1:

$$d_{end-to-end} = 3 * 5 + 8 = 23ms$$

In case of packet 2,

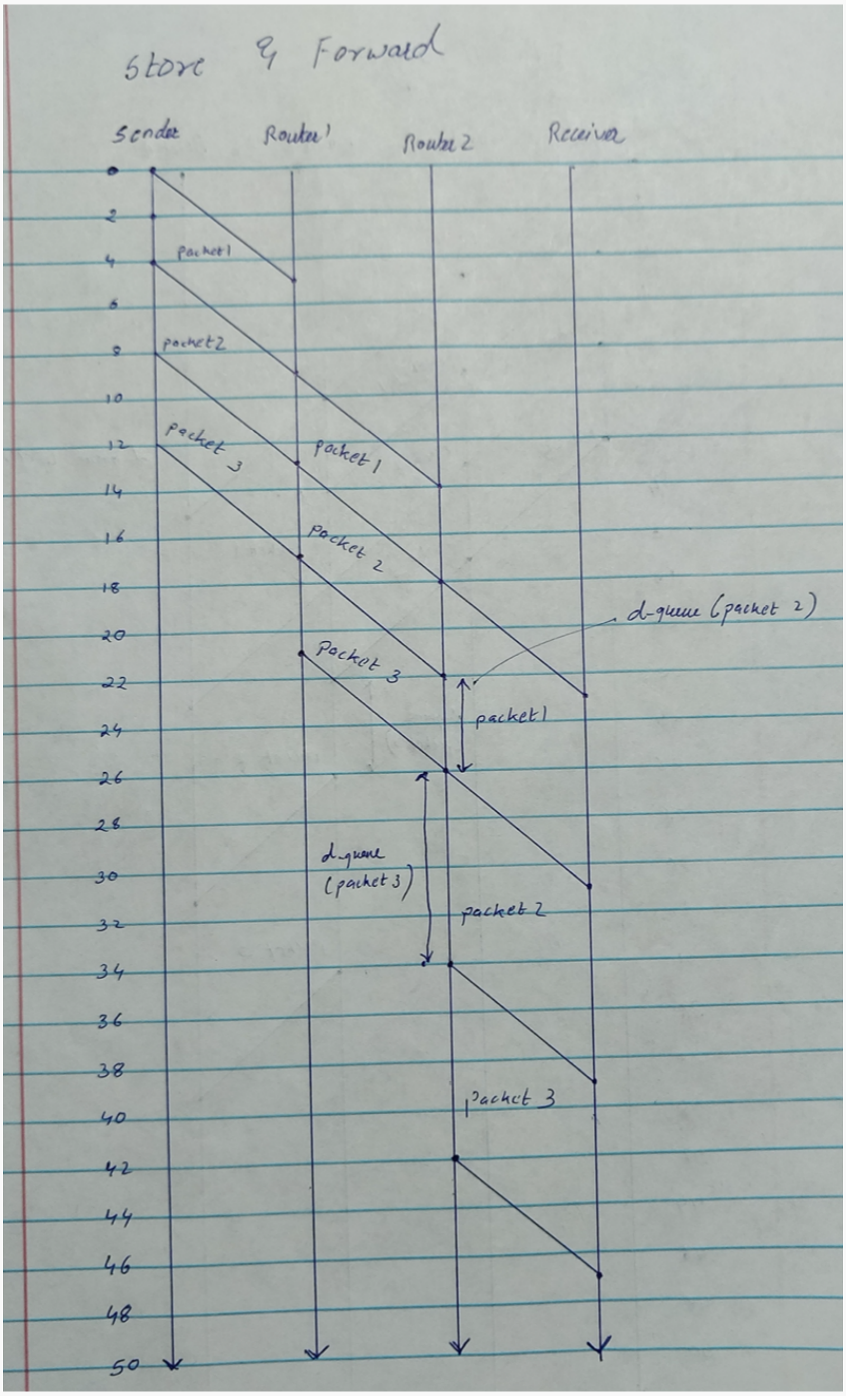
$$d_{end-to-end} = 23 + 4 = 27ms$$

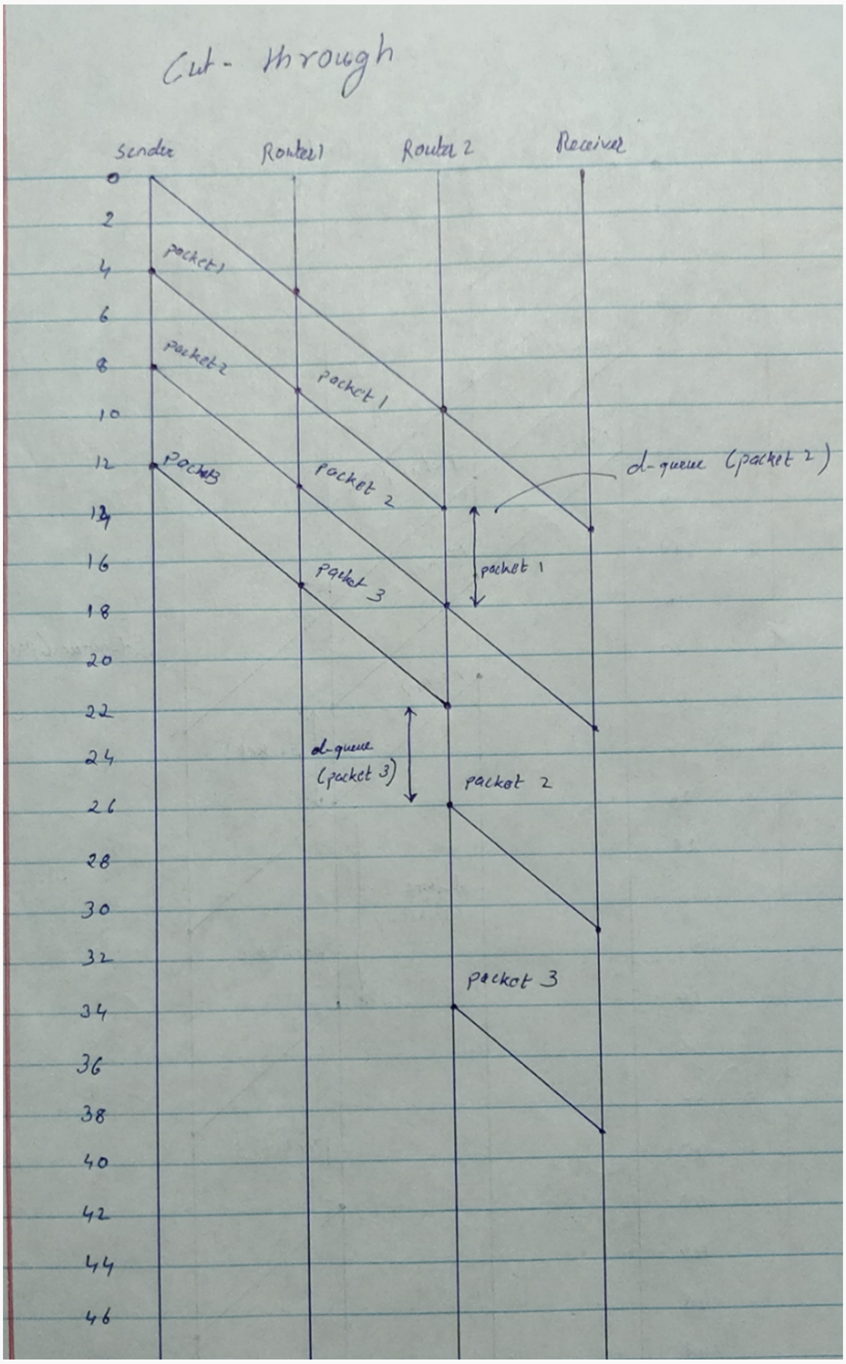
In case of packet 3,

$$d_{end-to-end} = 27 + 4 = 31ms$$

(e)

Answer

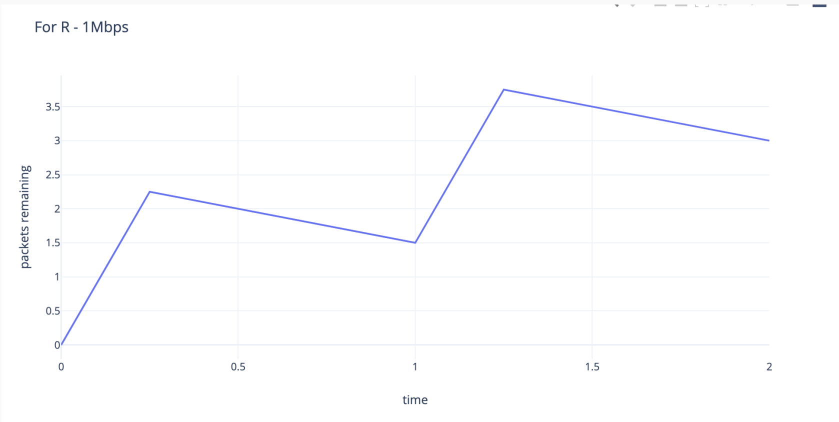

Store & Forward
Sender
Router 1
Router 2
Receiver
packet 1
packet 2
packet 3
packet 1
packet 2
packet 3
d-queue (packet 2)
packet 1
d-queue (packet 3)
packet 2
packet 3
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40
42
44
46
48
50

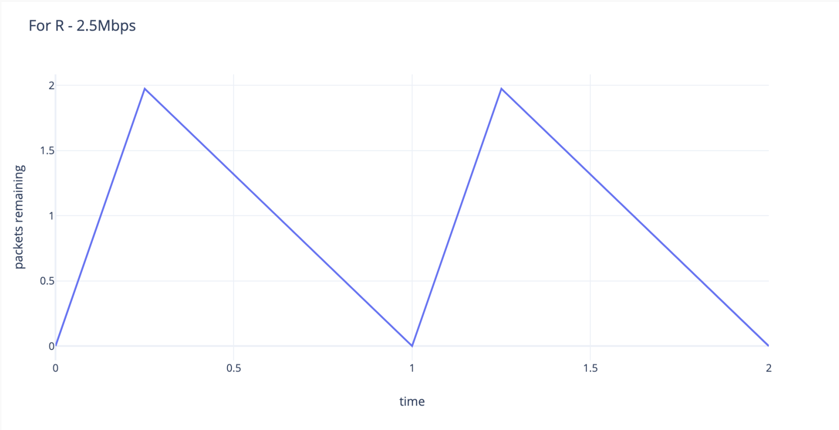

Cut-through
Sender
Router1
Router 2
Receiver
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40
42
44
46
packet1
packet2
packet 1
packet 2
packet 3
d-queue (packet 2)
packet 1
d-queue (packet 3)
packet 2
packet 3

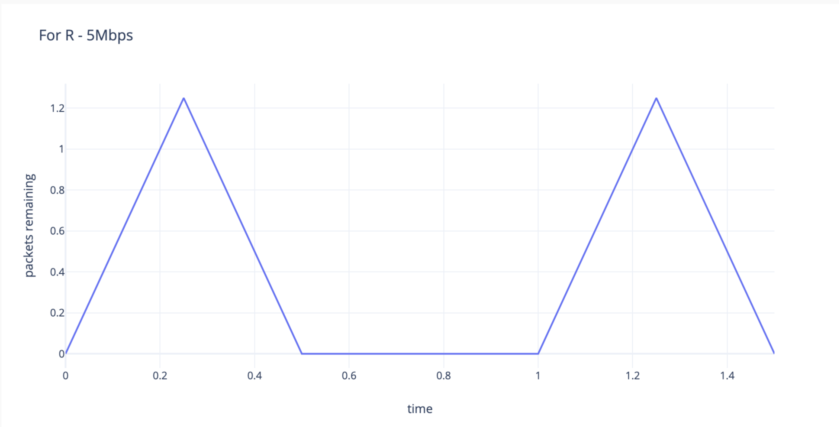
Problem 2

(a)

Answer







(b)

Answer

We could avoid buffer from growing by passing the incoming traffic received at the end of the period.
As T=1s,

From 0 to T/4s, $\frac{1}{4} * 10 = 2.5 MBits$ is received. In order to avoid queuing, we must use a bandwidth of 2.5Mbps or above to transfer all the data received.

(c)

Answer

At any given time, the remaining queue size is

$$Q = \begin{cases} (10 - R)t & t \in [0, 1/4] \\ max(2.5 - Rt, 0) & t \in (1/4, 1) \end{cases}$$

Average delay of all bits is given using,

$$\begin{aligned} D(R) &= \frac{1}{4} \int_0^{\frac{1}{4}} \frac{(10 - R)t}{R} dt \\ &= \frac{10 - R}{8R} \end{aligned}$$

(d)

Answer

The time required for the queue to be empty is

$$\begin{aligned} \frac{1}{4}(10) - Rt_0 &= 0 \\ 2.5 - Rt_0 &= 0 \\ t_0 &= \frac{2.5}{R} \end{aligned}$$

Average buffer occupancy L(R) as a function of R is given using

$$\begin{aligned} L(R) &= \int_0^{t_0} q(t) dt \\ &= \int_0^{\frac{1}{4}} (10 - R)t dt + \int_{\frac{1}{4}}^{t_0} (2.5 - Rt) dt \\ &= \frac{2.5}{R} \left(\frac{10 - R}{8} \right) \end{aligned}$$

(e)

Answer

As $\lambda = 2.5 Mbps$

$$\begin{aligned} \text{As } L(R) &= \frac{2.5}{R} \left(\frac{10 - R}{8} \right) \\ &= \lambda D(R) \end{aligned}$$

Problem 3

(a)

Answer

A Circuit-switched network would be more suitable in this since the data transmitted is small, fixed and does not occur in burst. Also, the data would be transmitted for longer session hence a steady connection is needed.

(b)

Answer

Since the total sum of application data rates is less than the capacities of each and every link, no congestion control is needed as there would be little to no queuing. Hence no congestion is required as the link capacities are more than the data transferred.

Problem 4

(a)

Answer

$$\begin{aligned}\text{Total user} &= \frac{\text{Transmission rate of link}}{\text{Transmission rate required by the user}} \\ &= \frac{3000Kbps}{150Kbps} \\ &= 20 \text{ users}\end{aligned}$$

(b)

Answer

Probability that the user is transmitting is 10/100 (since 10% are active at a time) = 0.1

(c)

Answer

$$\begin{aligned}P(n) &= C_n^N \left(P\right)^n \left(1-P\right)^{N-n} \\ &= C_n^{120} \left(0.1\right)^n \left(0.9\right)^{120-n}\end{aligned}$$

(d)

Answer

Probability that 21 or more user are transmitting is given using

$$\begin{aligned}P(>=21) &= 1 - P(<21) \\ &= 1 - [P(0) + P(1) + P(2) + P(3)...P(20)] \\ &= 1 - \sum_{n=0}^{20} C_n^{120} \left(0.1\right)^n \left(0.9\right)^{120-n}\end{aligned}$$

Problem 5

(a)

Answer

Total delay = Queuing delay + transmission delay

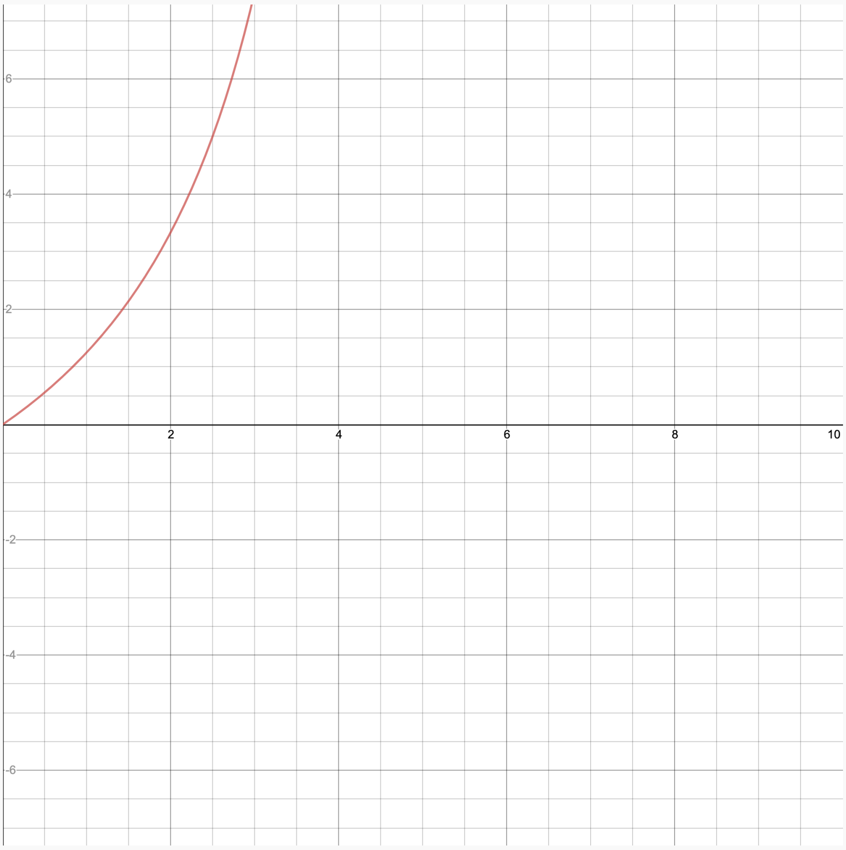
$$= \frac{IL}{R(1-L)} + \frac{L}{R}$$
$$= \frac{L}{R}\frac{1}{1-I}$$

(b)

Answer

Let $x = \frac{L}{R}$
Therefore total delay $F(x)$ is given by the following equation

$$= \frac{L}{R}\frac{1}{1-I}$$
$$= \frac{L}{R}\frac{1}{1-a\frac{L}{R}}$$
$$= \frac{x}{1-ax}$$



It is clear that as x $\rightarrow \frac{1}{a}$, delay goes to infinity and when x $\rightarrow 0$, delay goes to 0

Problem 6

Answer

As per Wikipedia,
Total packets = Buffer packets + transmitted packet
N = 10

As,

$$
\begin{aligned}
N &= a * d \\
10 &= a * (d_{queue} + d_{trans}) \\
11 &= a * (0.01 + 0.01) \\
a &= 500 \text{ packets/sec}
\end{aligned}
$$

As per textbook,
Total packets = Buffer packets + transmitted packet
N = 10 + 1

As,

$$
\begin{aligned}
N &= a * d \\
10 + 1 &= a * (d_{queue} + d_{trans}) \\
11 &= a * (0.01 + 0.01) \\
a &= 550 \text{ packets/sec}
\end{aligned}
$$

The real ambiguity lies with respect to value of N

Problem 7

(a)

Answer

The average of round trip delay is 15.138 ms, 12.673 ms, 11.881 ms and standard deviation is 3.982 ms, 0.888 ms, 1.351 ms.

(b)

Answer

The traceroute between my laptop and thunder.cise.ufl.edu has 12 routers. There was no change in path.

(c)

Answer

There were a total of 3 ISP in traceroute between my laptop and thunder.cise.ufl.edu. There is a spike whenever there is change of ISP i.e at the peering interfaces

(d)

Answer

The average of round trip delay is 111.765 ms and 111.858 ms and standard deviation is 7.282 ms and 7.174 ms.

The traceroute from france and thunder.cise.ufl.edu had varying amount of routers (12-19). There was change in path. There were a varying amount of ISP(4-6) in traceroute between france and thunder.cise.ufl.edu. There is a spike whenever there is change of ISP i.e at the peering interfaces

```
meanmachin3@Manishs-MacBook-Pro: ~/github/manishyadav.dev
(base)
manishyadav.dev on master is v1.0.0 via • v10.13.0 via base
→ clear
(base)
manishyadav.dev on master is v1.0.0 via • v10.13.0 via base
→ traceroute thunder.cise.ufl.edu
traceroute to thunder.cise.ufl.edu (128.227.205.239), 64 hops max, 52 byte packets
 1  192.168.0.1 (192.168.0.1)  2.418 ms  3.743 ms  2.044 ms
 2  10.4.0.1 (10.4.0.1)  9.554 ms  9.314 ms  9.992 ms
 3  100.122.94.78 (100.122.94.78)  11.651 ms  11.179 ms  11.397 ms
 4  ip72-214-194-5.ga.at.cox.net (72.214.194.5)  16.718 ms  10.723 ms  9.138 ms
 5  * * *
 6  ctx36-pel-asr9001-1-v18-1.ns.ufl.edu (128.227.236.208)  60.244 ms  11.669 ms  11.610 ms
 7  * * *
 8  ctx36-nexus-msfc-1-v17-1.ns.ufl.edu (128.227.236.206)  20.887 ms  10.407 ms  11.760 ms
 9  csev1-core-msfc-1-v41-1.ns.ufl.edu (128.227.236.14)  11.459 ms  11.592 ms  11.327 ms
10  128.227.254.74 (128.227.254.74)  10.626 ms  10.885 ms  11.446 ms
11  thunder.cise.ufl.edu (128.227.205.239)  20.743 ms  12.230 ms  10.720 ms
(base)
manishyadav.dev on master is v1.0.0 via • v10.13.0 via base took 31s
→
```

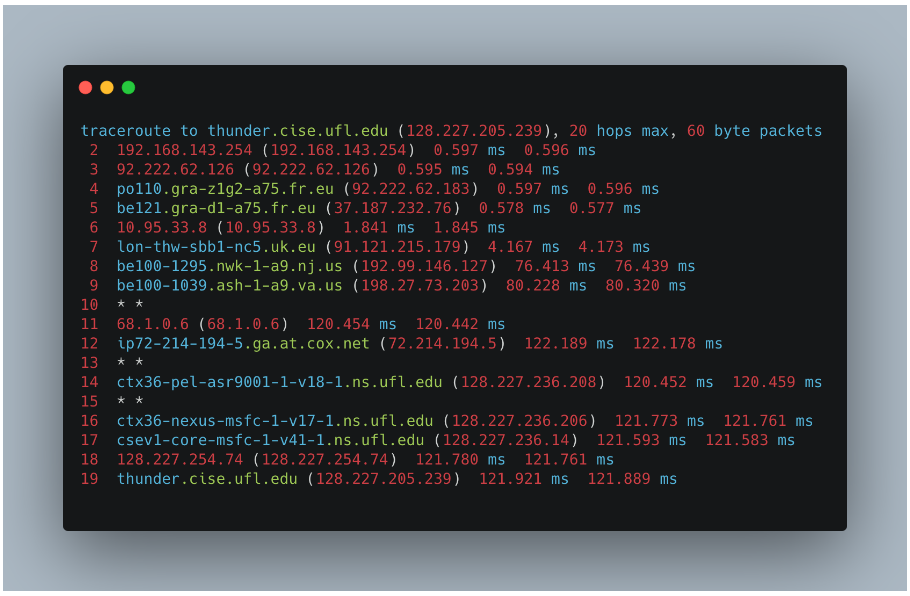
Figure 1: traceroute from desktop to thunder.cise.ufl.edu 4 am

```
meanmachin3@Manishs-MacBook-Pro: ~
Last login: Tue Sep 15 11:13:07 on ttys005
(base)
~ via base
→ traceroute thunder.cise.ufl.edu
traceroute to thunder.cise.ufl.edu (128.227.205.239), 64 hops max, 52 byte packets
 1  192.168.0.1 (192.168.0.1)  2.911 ms  4.713 ms  2.134 ms
 2  10.4.0.1 (10.4.0.1)  11.407 ms  11.678 ms  12.147 ms
 3  100.122.94.78 (100.122.94.78)  13.416 ms  11.781 ms  11.143 ms
 4  ip72-214-194-5.ga.at.cox.net (72.214.194.5)  9.995 ms  11.277 ms  9.860 ms
 5  * * *
 6  ctx36-pel-asr9001-1-v18-1.ns.ufl.edu (128.227.236.208)  11.491 ms  14.550 ms  14.407 ms
 7  * * *
 8  ctx36-nexus-msfc-1-v17-1.ns.ufl.edu (128.227.236.206)  17.976 ms  11.044 ms  11.068 ms
 9  csev1-core-msfc-1-v41-1.ns.ufl.edu (128.227.236.14)  44.511 ms  98.735 ms  11.710 ms
10  128.227.254.74 (128.227.254.74)  12.038 ms  12.287 ms  11.607 ms
11  thunder.cise.ufl.edu (128.227.205.239)  11.852 ms  13.913 ms  11.147 ms
(base)
~ via base took 30s
→
```

Figure 2: traceroute from desktop to thunder.cise.ufl.edu 11 am

```
meanmachin3@Manishs-MacBook-Pro: ~
(base)
~ via base
→ traceroute thunder.cise.ufl.edu
traceroute to thunder.cise.ufl.edu (128.227.205.239), 64 hops max, 52 byte packe
ts
 1  192.168.0.1 (192.168.0.1)  9.513 ms  2.007 ms  3.238 ms
 2  10.4.0.1 (10.4.0.1)  13.897 ms  11.815 ms  11.032 ms
 3  100.122.94.78 (100.122.94.78)  12.270 ms  12.949 ms  10.637 ms
 4  ip72-214-194-5.ga.at.cox.net (72.214.194.5)  11.144 ms  17.263 ms  18.754 ms
 5  * * *
 6  ctx36-pel-asr9001-1-v18-1.ns.ufl.edu (128.227.236.208)  17.136 ms  14.626 ms
 13.875 ms
 7  * * *
 8  ctx36-nexus-msfc-1-v17-1.ns.ufl.edu (128.227.236.206)  10.698 ms  9.676 ms
9.956 ms
 9  csev1-core-msfc-1-v41-1.ns.ufl.edu (128.227.236.14)  14.120 ms  11.694 ms  1
1.921 ms
10  128.227.254.74 (128.227.254.74)  12.924 ms  11.874 ms  10.334 ms
11  thunder.cise.ufl.edu (128.227.205.239)  12.820 ms  11.878 ms  13.776 ms
(base)
~ via base took 31s
→
```

Figure 3: traceroute from desktop to thunder.cise.ufl.edu 2 pm

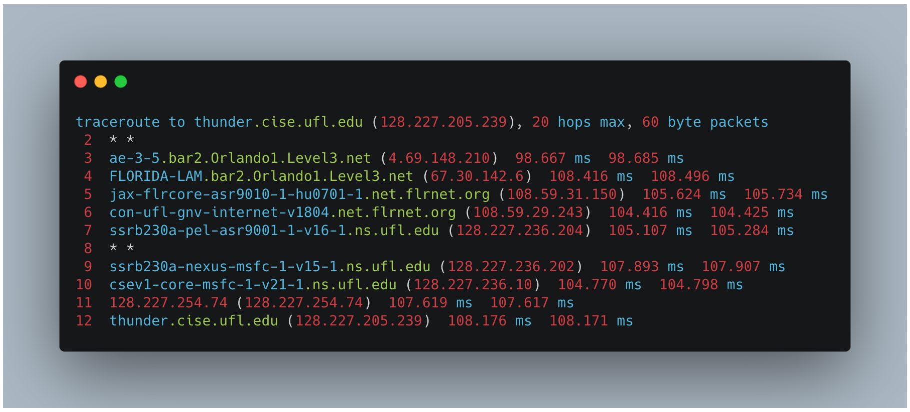


```
traceroute to thunder.cise.ufl.edu (128.227.205.239), 20 hops max, 60 byte packets
 2  192.168.143.254 (192.168.143.254)  0.597 ms  0.596 ms
 3  92.222.62.126 (92.222.62.126)  0.595 ms  0.594 ms
 4  po110.gra-z1g2-a75.fr.eu (92.222.62.183)  0.597 ms  0.596 ms
 5  be121.gra-d1-a75.fr.eu (37.187.232.76)  0.578 ms  0.577 ms
 6  10.95.33.8 (10.95.33.8)  1.841 ms  1.845 ms
 7  lon-thw-sbb1-nc5.uk.eu (91.121.215.179)  4.167 ms  4.173 ms
 8  be100-1295.nwk-1-a9.nj.us (192.99.146.127)  76.413 ms  76.439 ms
 9  be100-1039.ash-1-a9.va.us (198.27.73.203)  80.228 ms  80.320 ms
10  * *
11  68.1.0.6 (68.1.0.6)  120.454 ms  120.442 ms
12  ip72-214-194-5.ga.at.cox.net (72.214.194.5)  122.189 ms  122.178 ms
13  * *
14  ctx36-pel-asr9001-1-v18-1.ns.ufl.edu (128.227.236.208)  120.452 ms  120.459 ms
15  * *
16  ctx36-nexus-msfc-1-v17-1.ns.ufl.edu (128.227.236.206)  121.773 ms  121.761 ms
17  csev1-core-msfc-1-v41-1.ns.ufl.edu (128.227.236.14)  121.593 ms  121.583 ms
18  128.227.254.74 (128.227.254.74)  121.780 ms  121.761 ms
19  thunder.cise.ufl.edu (128.227.205.239)  121.921 ms  121.889 ms
```

Figure 4: traceroute from france to thunder.cise.ufl.edu 8 am

```
traceroute to thunder.cise.ufl.edu (128.227.205.239), 20 hops max, 60 byte packets
 2  vl199-ds1-b5-RAB01.par3.choopa.net (45.63.112.65)  3.453 ms  6.451 ms
 3  * *
 4  * *
 5  he.par.franceix.net (37.49.236.10)  0.530 ms  0.545 ms
 6  100ge10-2.core1.ash1.he.net (184.105.213.173)  99.279 ms  99.385 ms
 7  100ge13-1.core1.atl1.he.net (184.105.80.162)  92.876 ms  92.908 ms
 8  e0-36.core2.jax1.he.net (184.105.213.186)  102.213 ms  102.220 ms
 9  florida-lambdarail.10gigabitethernet3-2.core1.jax1.he.net (64.71.158.82)  103.034 ms  103.078 ms
10  con-ufl-gnv-internet-v1804.net.flrnet.org (108.59.29.243)  104.716 ms  104.725 ms
11  ssrb230a-pel-asr9001-1-v16-1.ns.ufl.edu (128.227.236.204)  104.422 ms  104.657 ms
12  * *
13  ssrb230a-nexus-msfc-1-v15-1.ns.ufl.edu (128.227.236.202)  104.928 ms  104.928 ms
14  csev1-core-msfc-1-v21-1.ns.ufl.edu (128.227.236.10)  104.300 ms  104.230 ms
15  128.227.254.74 (128.227.254.74)  104.491 ms  104.489 ms
16  thunder.cise.ufl.edu (128.227.205.239)  105.200 ms  105.516 ms
```

Figure 5: traceroute from france to thunder.cise.ufl.edu 12 pm



```
traceroute to thunder.cise.ufl.edu (128.227.205.239), 20 hops max, 60 byte packets
 2  * *
 3  ae-3-5.bar2.Orlando1.Level3.net (4.69.148.210)  98.667 ms  98.685 ms
 4  FLORIDA-LAM.bar2.Orlando1.Level3.net (67.30.142.6)  108.416 ms  108.496 ms
 5  jax-flrcore-asr9010-1-hu0701-1.net.flrnet.org (108.59.31.150)  105.624 ms  105.734 ms
 6  con-ufl-gnv-internet-v1804.net.flrnet.org (108.59.29.243)  104.416 ms  104.425 ms
 7  ssrb230a-pel-asr9001-1-v16-1.ns.ufl.edu (128.227.236.204)  105.107 ms  105.284 ms
 8  * *
 9  ssrb230a-nexus-msfc-1-v15-1.ns.ufl.edu (128.227.236.202)  107.893 ms  107.907 ms
10  csev1-core-msfc-1-v21-1.ns.ufl.edu (128.227.236.10)  104.770 ms  104.798 ms
11  128.227.254.74 (128.227.254.74)  107.619 ms  107.617 ms
12  thunder.cise.ufl.edu (128.227.205.239)  108.176 ms  108.171 ms
```

Figure 6: traceroute from france to thunder.cise.ufl.edu 6 pm

Problem 8

(a)

Answer

$$d_{prop} = \frac{20000 * 1000}{2.5 * 10^8} = 0.08s$$

Bandwidth-delay product $= R * d_{prop}$
$= 2 * 10^6 * 0.08$
$= 16 * 10^4$

(b)

Answer

The bandwidth delay product is the maximum number of bit that can be in the link. Since we are transmitting $80 * 10^4$ and the bandwidth delay product is $16 * 10^4$. Therefore at given time the maximum bit in the link would be $16 * 10^4$

(c)

Answer

The bandwidth delay product is the maximum number of bit that can be in the link.

(d)

Answer

The width of the bit in the link is given using

$$\frac{20000 * 1000}{16 * 10^4} = 125m$$

It is indeed larger than football field of 100 yards (91.44 m)

(e)

Answer

Width of bit is given using the following

$$= \frac{m}{R * d_{prop}}$$
$$= \frac{m}{R * \frac{m}{s}}$$
$$= \frac{s}{R}$$