Problem Set # 1

1) Problem 1

(a) BW = 2Gbps

d = 385,000 km

s = 3×10^8 m/s

RTT = forward propagation delay + forward transfer time + reverse transfer time + reverse propagation delay

RTT =

we don't know which kind of protocol is used. So as we need to find the minimum RTT: we can think of the protocol as UDP then there will be no reverse transfer time and reverse propagation delay

~~RTT~~ forward propagation delay = $\frac{385{,}000 \text{ km}}{3 \times 10^8 \text{ m/s}}$

$= \frac{385{,}000 \times 10^3}{3 \times 10^{8\,2}}$

$= \frac{385}{300}$

$= 1.283$ sec $\times 2 = 2.566$ sec

forward transfer time = $\frac{\text{width of packet}}{\text{Band width}}$

as it is minimum consider width of packet = 1.

$= \frac{1}{2\text{Gbps}} \simeq 0$

minimum RTT = 1.283 sec + 0 + 0 + 0

= 1.283 sec X2

= 2.566 sec

Scanned by CamScanner

(b) Bandwidth Delay product = BW × Delay

= BW × RTT

BW = 2Gbps

BDP = 2Gbps × 1.283 sec × 2

= (2 × 1024 × 1.283) kb × 2

= 2627.584 kb / 328.448 kB × 2

= 5255.168 kb / 656.896 kB

(c) Significance of bandwidth delay product

Bandwidth delay product means that amount of data that can fit in a link.

Even though the link says it can transmit 1Mbps we should'nt/can't transfer 1Mb per second. we can transmit BDP of the link.

(d) Image size = 30MB

transfer time = transmit time + propagation delay

$$= \frac{30MB}{2Gbps} + 2.566 sec$$

$$= \frac{240Mb}{2 \times 1024 Mbps} + 2.566 sec$$

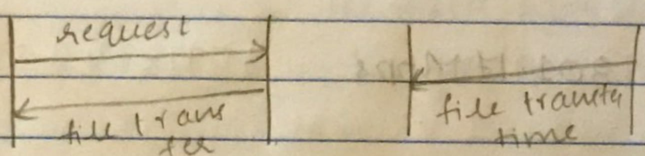
$$= \frac{240Mb}{2048 Mbps} + 2.566 sec$$

$$= 0.11718 sec + 2.566$$

$$= 0.26 \ 2.68318 sec$$

Problem-2

(a) Throughput = The rate at which the file is transfered



$$\text{Throughput} = \frac{4MB}{\underbrace{\frac{1}{2}RTT}_{\text{request}} + \text{transfer time of packet} + \text{propagation delay}}$$

$$= \frac{4MB}{\frac{1}{2}RTT + \frac{1}{2}RTT + \frac{Packet}{BW}}$$

$$= \frac{4MB}{\frac{1}{2}RTT + \frac{1}{2}RTT + \frac{4MB}{1Gbps}}$$

$$= \frac{4MB}{150msec + 31.25 msec} = \frac{4MB}{181.25 msec}$$

$$= \frac{4 \times 8 \text{ Mbit}}{0.18125 \text{ sec}}$$

$$= 176.55 \text{ Mbps.}$$

(b) if there is no ACK then the time it takes is less

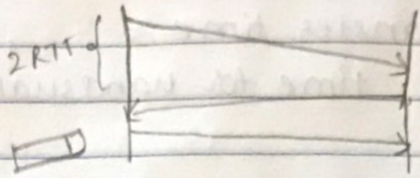
$$\text{Throughput} = \frac{4\text{MB}}{75\text{ms} + \frac{4\text{MB}}{1\text{Gbps}}}$$

$$= \frac{4\text{MB}}{75\text{ms} + 31.25\text{ms}}$$

$$= \frac{32\text{Mb}}{106.25\text{ms}} = \frac{32\text{Mb}}{0.10625\text{s}}$$

$$= 301.17 \text{ Mbps}$$

Problem - 3



(a) Total Packet ~~size~~ = 2000KB

RTT = 100ms

Packet size = 1KB

Initial handshaking = 2×RTT

= 2×100ms = 200ms

BW = 1Mbps

Total time for transfer =

= forward propagation delay (1st bit) + forward transfer time + 2RTT

$$= \frac{1}{2}RTT + \frac{2000 \times (1KB)}{1Mbps} + 2RTT$$

as data packets can be sent continously

so for 1 packet (1KB) $= \frac{1KB}{1Mbps}$

2000 packets $= \frac{2000}{1Mbps}$

$$= \frac{5RTT}{2} + \frac{2000 \times (1KB)}{1Mbps}$$

$$= 2.5(100ms) + \frac{2000 \times 8 \times 1024 (bits)}{1024 \times 1024 (bits/sec)}$$

= 2.5(100ms) + 15.625 sec

= 0.25 + 15.625 sec

= 15.875 sec

(b) BW = 1.5Mbps

transfer time =

time for handshake + data transfer time

transfer time for file for a frame $= \frac{2}{2} RTT + \frac{1KB}{1.5Mbps}$

so there are 1999 frames for which we should wait for ACK

The last 2000^{th} frame ~~can~~ doesn't have ACK to send

$= 1KB / 1.5Mbps$

$= \text{time for handshake} + 1999\left(\frac{2}{2} RTT + \frac{1KB}{1.5Mbps}\right) + \frac{1KB}{1.5Mbps}$

$= 2RTT + 1999\left(\frac{2}{2} RTT + \frac{1KB}{1.5Mbps}\right) + \frac{1KB}{1.5Mbps}$

$= 200ms + 1999(100ms) + \frac{1999 \times 8Kb}{1.5 \times 1024 \times Kb} + \frac{8Kb}{1.5 \times 1024 \times Kb}$

$= 200ms + 199900ms + 10.4114 sec + 0.00927$

$= 0.2s + 199.900 + 10.4114 sec + 0.00927$

$= 210.520 sec$

(C) BW = ∞ tranmit time = 0.
1 packet = 1KB
40 packets per RTT

40KB (+RTT)

transfer time = handshake +
40 packets - RTT
number of times is 2000/40 = 50RTT
= 50 x 100ms
= 5 sec

total transfer time
= handshake + transfer time

(a)

= 2 RTT + 5 sec
= 0.2 + 5 = 5.2 sec

(d) 1st packet = 100
2
3
4
⋮
2000 = 100
how many times should data to be transmitted
for 2000KB ?

$\frac{n(n+1)}{2} = 2000$

$n(n+1) = 4000$

$2^{n-1} = 2000$

$n = \log_2 (4000)$

$n = 1204.11998$ 11.96

$n = 1205$ times 12

$1 + 2 + 3 + 4 + \cdots = 2000$

$2^{1-1} + 2^{2-1} + 2^{3-1} + 2^{4-1} + \cdots = 2000$

$n+1 = 12$ $n = 11$

Total transfer time = 2RTT + 11RTT
= 13RTT
= 13 × 100ms
= 1.3 sec

4) Problem-4

BDP = BW × Propagation delay

$$= 20\text{Gbps} \times \left(\frac{l}{2.3\times10^8}\right)$$

$$\text{width} = \frac{\text{length of link}}{\text{BDP}}$$

$$= \frac{l}{20\text{Gbps} \times \frac{l}{2.3\times10^8}}$$

$$= \frac{2.3\times10^8}{20\text{ Gbps}}$$

$$= \frac{2.3\times10^8}{20\times1024\times1024\times1024}$$

$$= \frac{2.3}{20} \times 0.09313 = \cancel{10.966\text{kB}}$$

= 0.0107 bit

Problem-5

5. To maximize the successful transmission rate is to maximize the probability of successful transmission

Pr (success) = (# stations) x Pr (one station transmits on one bus and at next slot) x Pr (no other stations transmit on the same bus and at next slot)

$$= 4\left(\frac{1}{2}p\right)\left(1-\frac{1}{2}p\right)^3$$

to maximise $\frac{d}{dp} = 0$

$$2\left(1-\frac{1}{2}p\right)^3 - 3p\left(1-\frac{1}{2}p\right)^2 = 0$$

$$\left(1-\frac{1}{2}p\right)^2\left(2-p-3p\right) = 0.$$

$$\left(1-\frac{1}{2}p\right)^2\left(2-4p\right) = 0.$$

$1 = \frac{1}{2}p$ | $2 = 4p$

$p = 2$ | $2/4 = p$ $\boxed{p = 1/2}$

p can't be greater than 1

Problem-6

BW = 10Mbps

s = 2.4×10^8 m/sec

d = 36000 km

(a) propagation delay = $\frac{d}{s}$

$= \frac{36000 \times 10^3}{2.4 \times 10^8}$

$= \frac{36}{240}$

= 0.15 sec

(b) BDP = Bandwidth x delay

= 10Mbps x 0.15 sec

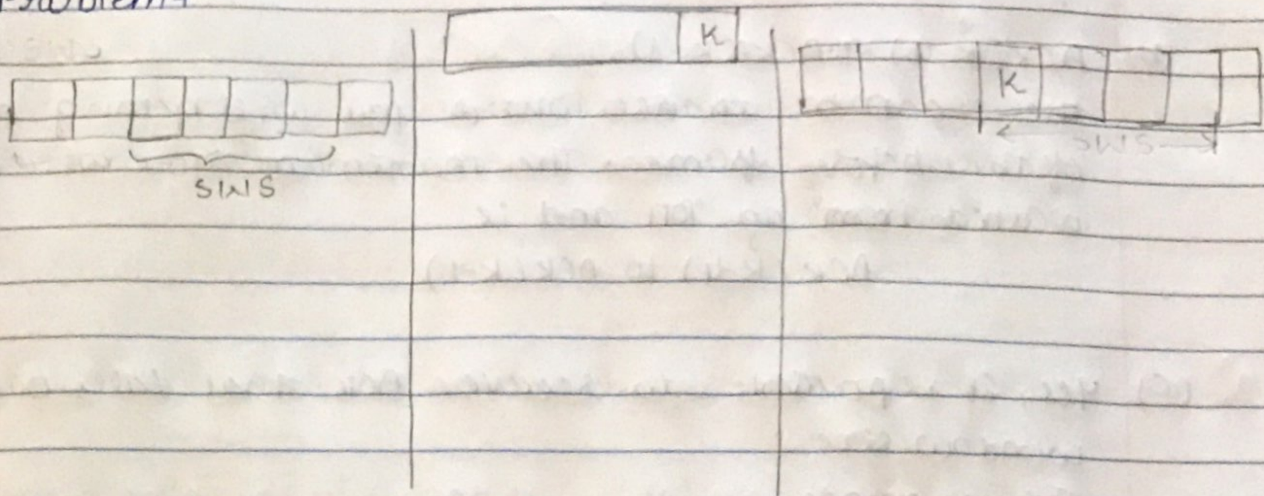
= 1.5 Mb

(c) transfer time = $\frac{\text{message size}}{BW}$

60 x 10Mb = size of message

x = 600 Mb

Problem 7.



Here the BDP is a variable we don't know how much the pipe will be able to fit

It can have a pipe which is greater, less, equal to SWS

SWS > BDP , SWS ≤ BDP

SWS > BDP - then the Gobackn protocol is not efficient
so it is just not implemented

SWS ≤ BDP

So BDP can be either 4 or a multiple of 4

When SWS = 4

there can be 2 cases

when k is in flight ~~the~~ and it has ACK's from all the frames before then

SWS will have - K, K+1, K+2, K+3

When K is in flight and it didn't recieve ACK's of previous frame then

SWS will have - K-4, K-3, K-2, K-1

(b) ACK(K-4) to ACK (K-1)
there can be chance where you will getting ACK's of the before frame. The maximum you would have waited from an RTT and is

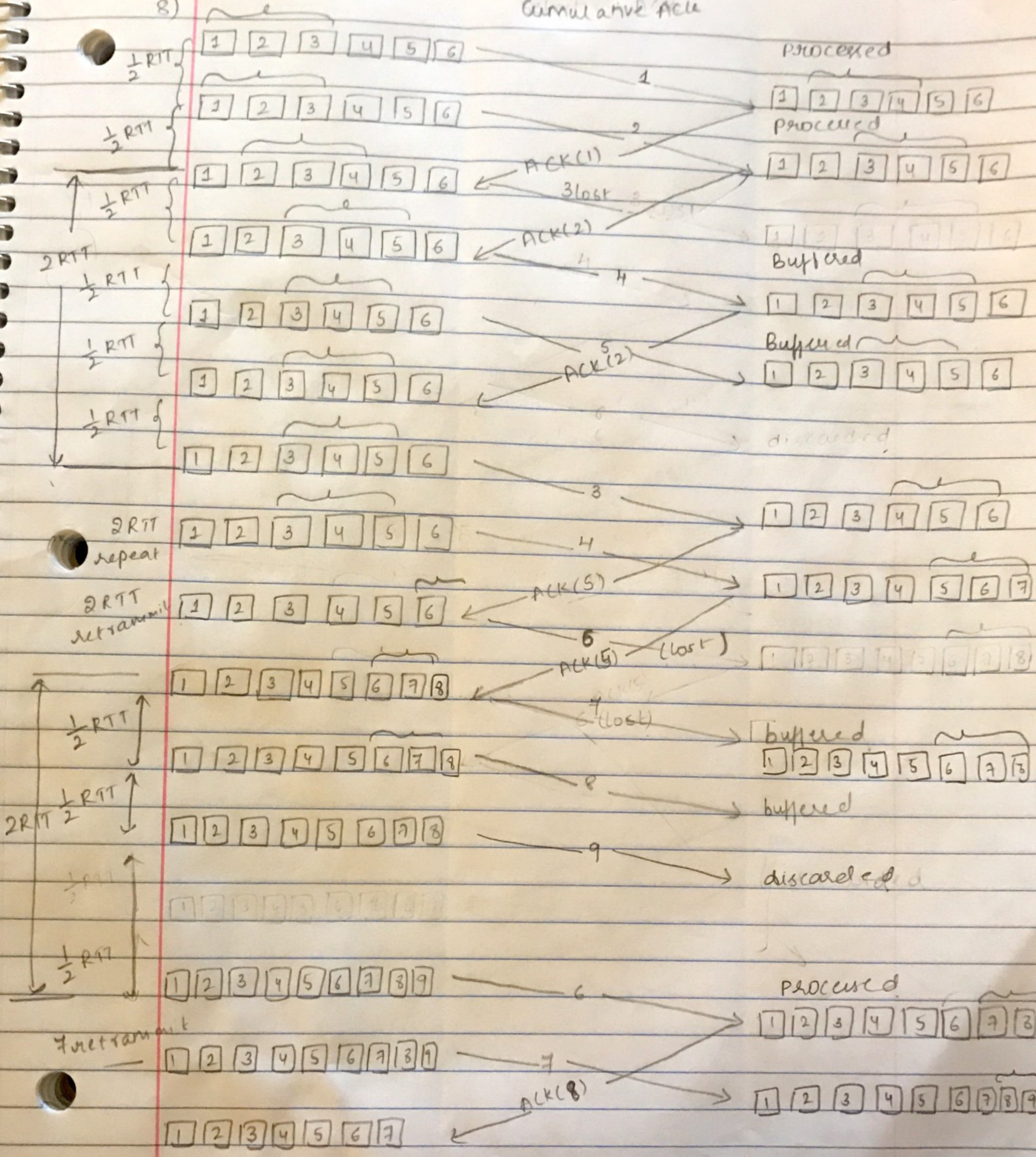
ACK (K-4) to ACK(K-1)

(C) Yes, it is possible to receive ACK that falls out of the window size.
For example
There might be a case where the ACK of transmission is in flight and time out of that ACK occurs and window is transmitted and window is moved forward and ACK from before which was in flight might be received that time.

8) SWS = RWS = 3
Time out = 2RTT
2 frames 1/2 RTT
So it can be Cumulative ACK / selective ACK.
Timing diagram for Cumulative ACK

07

8) Cumulative Ack

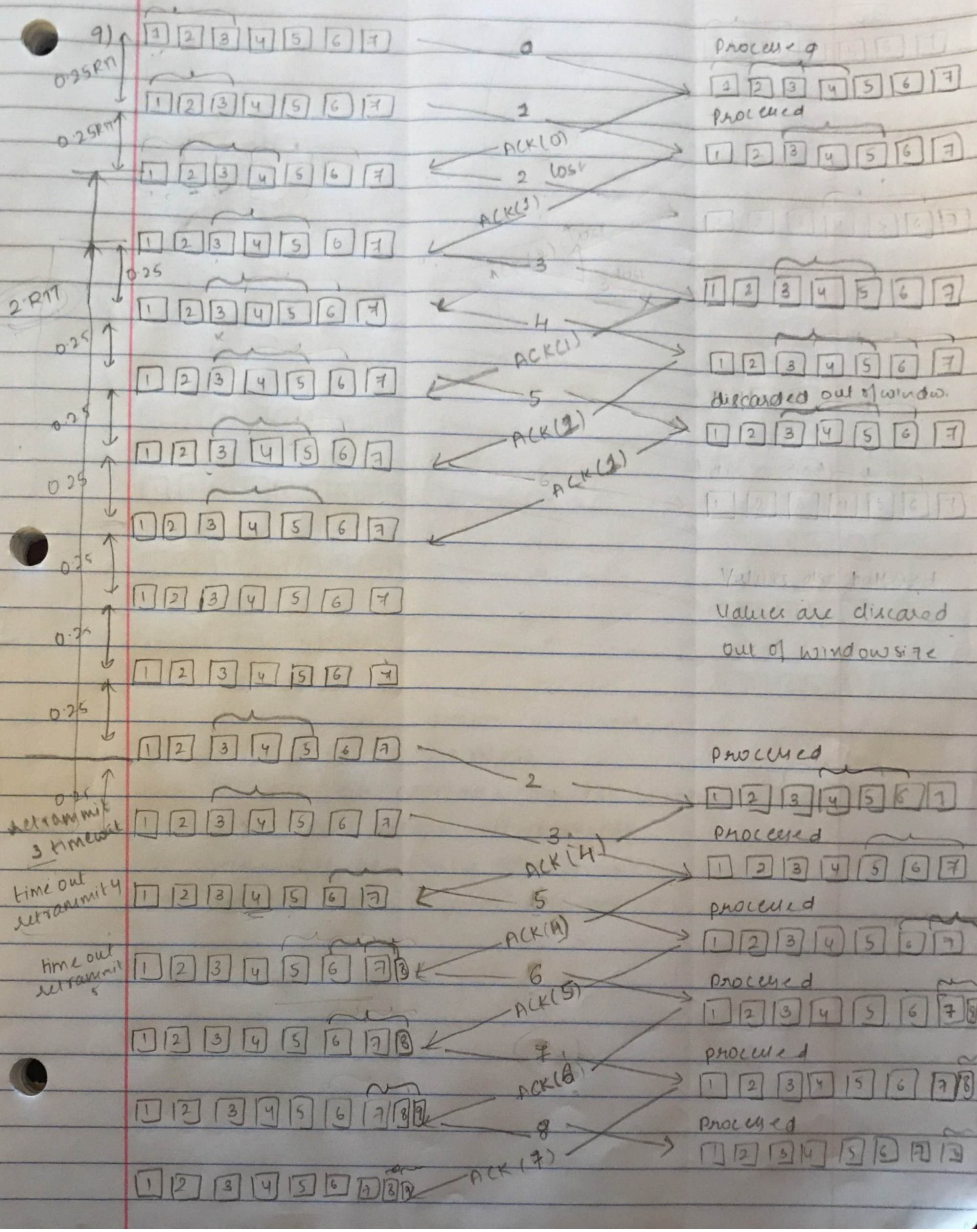


SWS=4 RWS=3 but still SWS=RWS=3

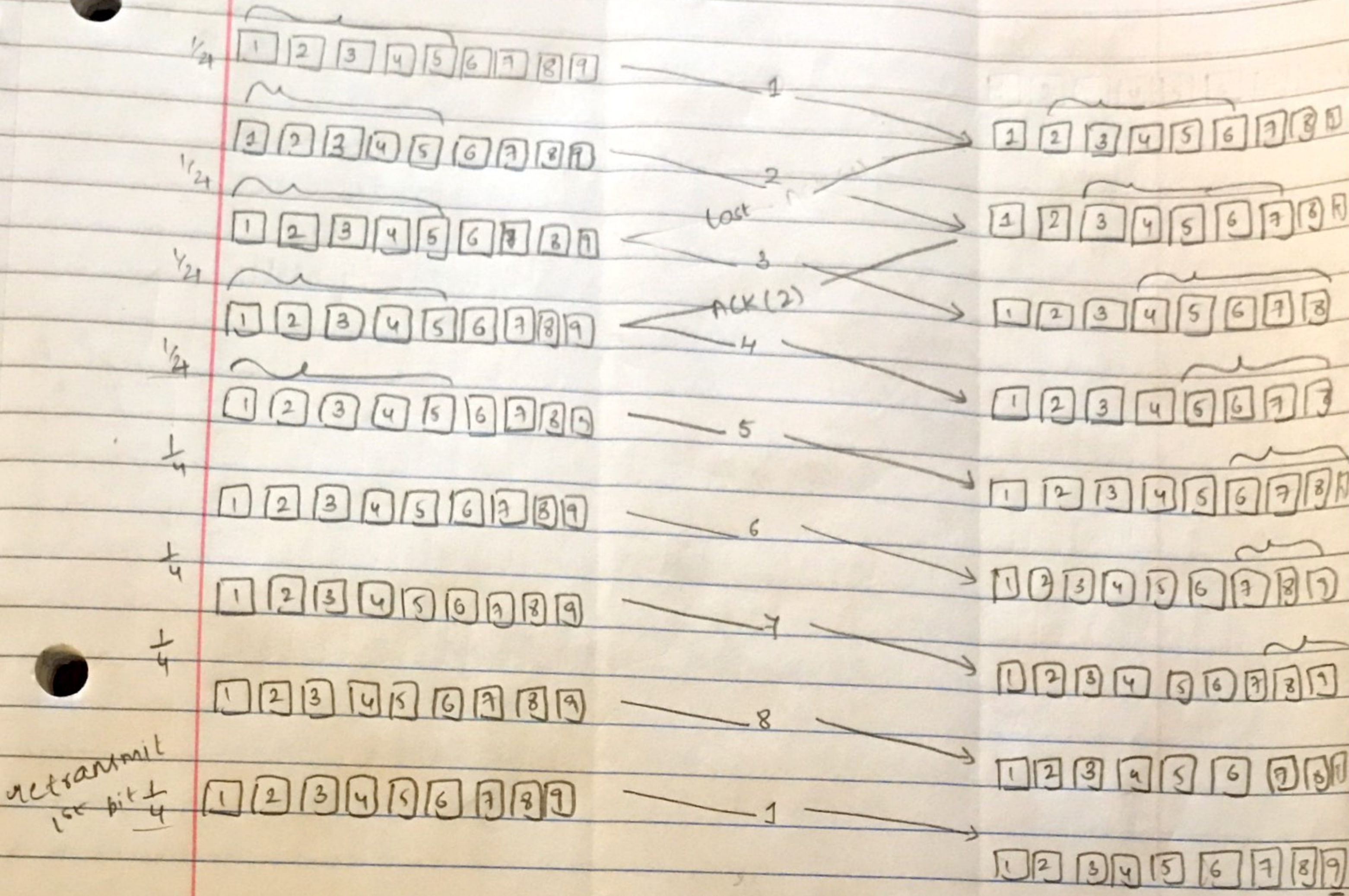
third frame is lost, cumulative ACK

08

9)



Problem-10



actually retransmitting the 1st bit

But the network considers the bit transmitted as next frame not the retransmitted 1st bit
So there will be data corruption
This implies that sequence Numbers > 9 is needed

Problem-11

BW = 1Mbps

d = 3×10^4 km

packet size = 1KB

optimal window size = BDP

BDP = BW x Delay

Delay = 3×10^4 km / 3×10^8 + 1KB / 1Mbps)

$$= 1\text{Mbps} \times \left(\frac{3\times10^4\times10^3}{3\times10^8} + \frac{8\times \cancel{1024}}{1\times1024\times1024 \cancel{\times1024}} \right) + \frac{3\times10^4\times10^3}{3\times10^8} \Big)$$

$\frac{P}{BW}$

$= \frac{d}{v}$

$\frac{d}{s}$

= 1Mbps (0.2 + 0.008001

= 1Mbps (0.208)

BDP = ~~110.592 kb~~ = 204.824 kb

25.628 KB

Each frame carries = 1KB

optimal window size = $\frac{25.628\text{KB}}{1\text{KB}}$

= 25.628

= 26

Optimal window size = BDP

For ~~full~~ efficient utilisation of link the number of bits that can fit into BDP should be considered.

So window size is BDP / frame size.

(c) BW: 3Mbps

$$Delay = \left(\frac{3\times10^4 km}{3\times10^8}\right)2 + \frac{1KB}{1Mbps}$$

$$BDP = 3 \times \left(\frac{\cancel{6}^{2}}{\cancel{3}}\times10^{-1} + \frac{1}{1Mbps}\right)$$

$$= 3 \times (0.2)$$

$$= 0.6\ Mbps$$

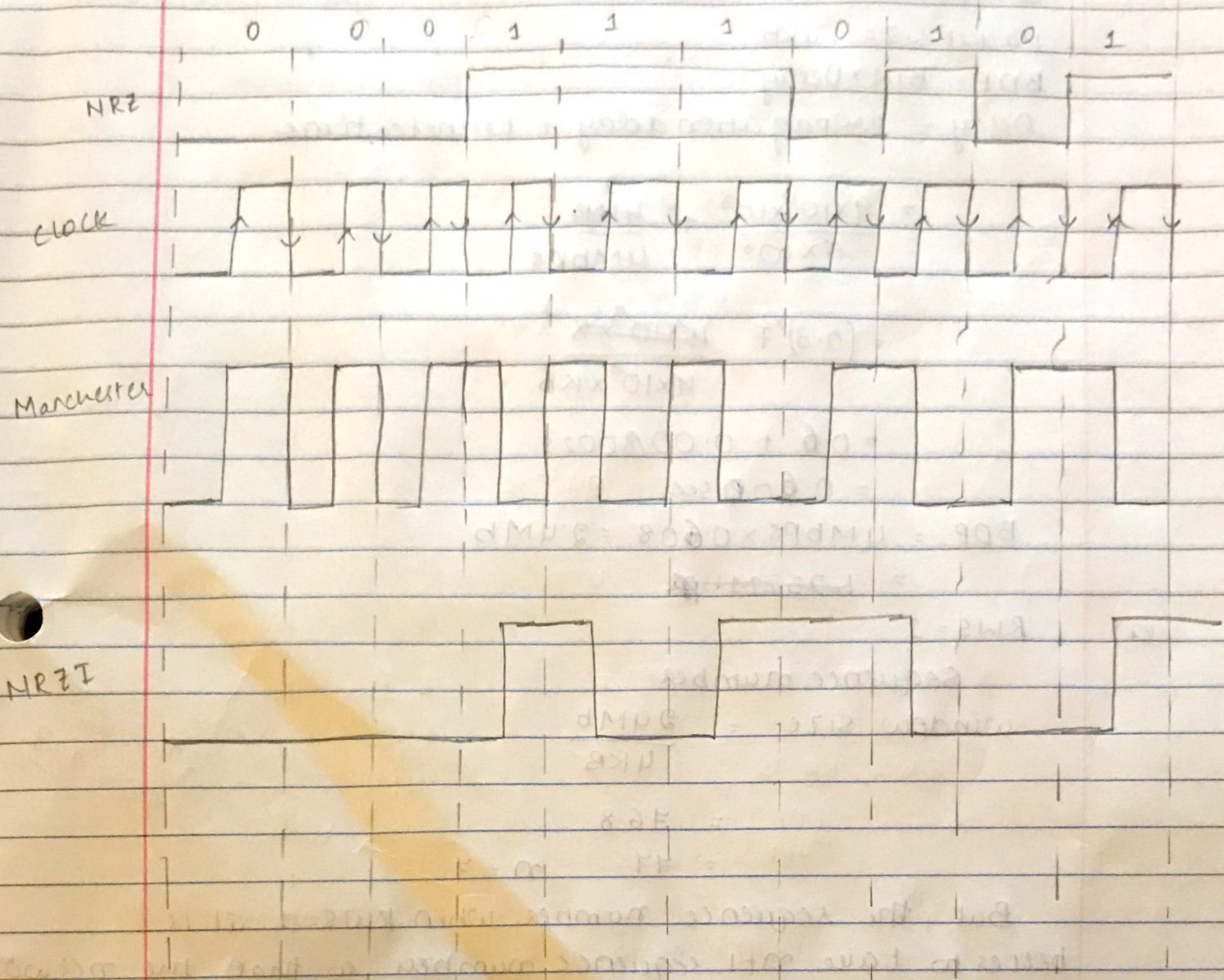
$$Window\ size = \frac{BDP}{frame\ size}$$

$$= \frac{0.6 \times 1024\ KB}{8 \times 1KB}$$

$$= 76.8$$

$$\cong 77$$

12) 000111 0101



13. BW = 4Mbps
d = 9×10^4 km
packet size = 4KB
BDP = BW × Delay
Delay = propagation delay + transfer time

$$= \frac{9 \times 10^4 \times 10^3}{3 \times 10^8} + \frac{4KB}{4Mbps}$$

$$= (0.3)^{\times 2} + \frac{\cancel{4 \times 10^3 \times 8}}{4 \times 10^6 \times Kb}$$

$= 0.6 + 0.008002s$
$= 0.608$ sec
BDP = 4Mbps × 0.608 = 2.4Mb
= ~~1.232Mbps~~

(a) RWS = 1
sequence number
window size $= \frac{2.4Mb}{4KB}$
$= 76.8$
$= 77$ $n = 7$

$2^6 = 64$
$2^7 = 128$

But the sequence number when RWS = 1 it is better to take n+1 sequence number so that the network will not get confused. The case where it confuses for nth bit and 1st bit.
So $n = 8$ when RWS = 1

(b) SWS = RWS
Here it is better to take the whole window seperated
$n = 14$ when RWS = SWS

Problem ~~4~~

(c) The efficiency of ARQ is

$$\text{maximum efficiency} = \frac{\text{frames in transit}}{\text{max possible frames}}$$

$$= \frac{1}{77}$$

$$= 0.0129$$

Scanned by CamScanner

Problem 14

RTT

	Average	STDDEV
Morning	24.277	9.995
Afternoon	35.784	16.30
Night	30.028	0.401
STDEV in morning, night, afternoon		5.7535

b) The number of routers in the path didn't change. The path is same during all hours

c)The ISP present in the path is comcast and then it is managed by a cloud managing company

But I didn't find any large delays in the peering interface of comcast and akamaitechechnologies

```
maunika@maunika-HP-Pavilion-Notebook:~$ tracepath www.aa.com
 1?: [LOCALHOST]                                          pmtu 1500
 1:  10.0.0.1                                              6.646ms
 1:  10.0.0.1                                              6.415ms
 2:  96.120.12.133                                        31.627ms
 3:  ae-205-sur03.boulder.co.denver.comcast.net           29.494ms
 4:  ae-10-sur02.boulder.co.denver.comcast.net            36.440ms asymm  3
 5:  ae-29-ar01.aurora.co.denver.comcast.net              24.305ms asymm  4
 6:  a184-25-206-18.deploy.static.akamaitechnologies.com  51.097ms reached
     Resume: pmtu 1500 hops 6 back 5
maunika@maunika-HP-Pavilion-Notebook:~$ traceroute www.aa.com
traceroute to www.aa.com (184.25.206.18), 30 hops max, 60 byte packets
 1  10.0.0.1 (10.0.0.1)  2.944 ms  3.707 ms  4.421 ms
 2  96.120.12.133 (96.120.12.133)  28.373 ms  33.874 ms  33.867 ms
 3  ae-205-sur03.boulder.co.denver.comcast.net (68.86.105.165)  33.852 ms  33.835 ms  33.825 ms
 4  ae-10-sur02.boulder.co.denver.comcast.net (162.151.51.34)  33.809 ms  33.799 ms  33.781 ms
 5  ae-29-ar01.aurora.co.denver.comcast.net (162.151.51.13)  33.769 ms  35.678 ms  35.668 ms
 6  a184-25-206-18.deploy.static.akamaitechnologies.com (184.25.206.18)  35.651 ms  20.480 ms  16.790 ms
maunika@maunika-HP-Pavilion-Notebook:~$
```

```
maunika@maunika-HP-Pavilion-Notebook:~$ traceroute www.aa.com
traceroute to www.aa.com (184.25.206.18), 30 hops max, 60 byte packets
 1  10.0.0.1 (10.0.0.1)  4.538 ms  6.442 ms  6.422 ms
 2  96.120.12.133 (96.120.12.133)  24.189 ms  25.438 ms  25.388 ms
 3  ae-205-sur03.boulder.co.denver.comcast.net (68.86.105.165)  26.152 ms  26.131 ms  26.101 ms
 4  ae-10-sur02.boulder.co.denver.comcast.net (162.151.51.34)  27.222 ms  27.929 ms  27.905 ms
 5  ae-29-ar01.aurora.co.denver.comcast.net (162.151.51.13)  33.580 ms  33.557 ms  33.925 ms
 6  a184-25-206-18.deploy.static.akamaitechnologies.com (184.25.206.18)  34.928 ms  19.924 ms  52.501 ms
maunika@maunika-HP-Pavilion-Notebook:~$ tracepath www.aa.com
 1?: [LOCALHOST]                                          pmtu 1500
 1:  10.0.0.1                                             11.108ms
 1:  10.0.0.1                                              3.974ms
 2:  96.120.12.133                                        14.598ms
 3:  ae-205-sur03.boulder.co.denver.comcast.net           18.893ms
 4:  ae-10-sur02.boulder.co.denver.comcast.net            18.122ms asymm  3
 5:  ae-29-ar01.aurora.co.denver.comcast.net             426.064ms asymm  4
 6:  a184-25-206-18.deploy.static.akamaitechnologies.com  37.961ms reached
     Resume: pmtu 1500 hops 6 back 5
```

```
maunika@maunika-HP-Pavilion-Notebook:~$ traceroute www.aa.com
traceroute to www.aa.com (184.25.206.18), 30 hops max, 60 byte packets
 1  10.0.0.1 (10.0.0.1)  3.098 ms  3.177 ms  3.895 ms
 2  96.120.12.133 (96.120.12.133)  12.851 ms  22.747 ms  23.129 ms
 3  ae-205-sur02.boulder.co.denver.comcast.net (68.85.220.237)  21.259 ms  21.603 ms  20.459 ms
 4  ae-29-ar01.aurora.co.denver.comcast.net (162.151.51.13)  20.514 ms  31.232 ms  30.826 ms
 5  a184-25-206-18.deploy.static.akamaitechnologies.com (184.25.206.18)  30.430 ms  30.027 ms  29.628 ms
maunika@maunika-HP-Pavilion-Notebook:~$
```

2.

Average RTT	Local(ms)	National(ms)	International(ms)
Morning	48.7805	69.442	301.91
Afternoon	84.7035	92.59	313.679
Late Night	37.819	90.325	315.619

Server of choice:

Local:www.cu.edu

National: www.uic.edu

International :www.jntuh.ac.in

a) There is significant variation in the RTT over the course of the day

The reasons can be network traffic can be high during the day times so the RTT during afternoon is the highest

During the night may be some of the servers will be down because of the manintaince

So the night has 2nd large RTT

In the morning the traffic is very less

b) 0,0
No

c) The RTT for international server is more as the propagation delay will be more
National will be 2

d) Propagation delay is 0.5RTT
Local -
Minimum RTT for local is 37.819 we should consider the minimum RTT because propagation delay = ½ RTT as we are ignoring the transfer time and processing data to be less
But the RTT is high in other phases because of increased transmit time as propagation delay will be constant
Propagation Delay = 37.819/2 =18.9095msec
National –
Propagtion delay = 69.442/2 = 34.721msec
International
Propagation delay = 301.91/2 = 150.95msec

National
Predicted propagation delay –
Distance = 1017*1.609 km(boulder -Illinois)
Delay = $(1017*1.609)/3*10^8$
Delay = 5.4545msec

Local
The traceroute for www.cu.edu shows the ping goes to Denver
Predicted propagation delay –
Distance = 29.3*1.609 km(boulder-denver)
Delay = $(29.3*1.609)/3*10^8$
Delay = 1.5micro sec

International
Predicted propagation delay –
Distance = 13612km (boulder -hyd)
Delay = $(13612km)/3*10^8$
Delay = 0.4537sec == 453.7 msec

	Local	National	international
Estimate	1.5us	5.45msec	45.37 msec
Predicted	18.9095ms	34.721msec	150.95 msec

The difference in between the estimated and predicted propagation delays is that Predicted propagation delays are according to ideal conditions like shortest path between sender and receiver but the estimated delay it is accurate as there might be delay due to transmit time even in the minimum RTT and also the packet might not take the shortest path due to traffic control. There can be losses in the packet due to buildings…
So for local and national the predicted is very less when compared with estimate.