Question 1

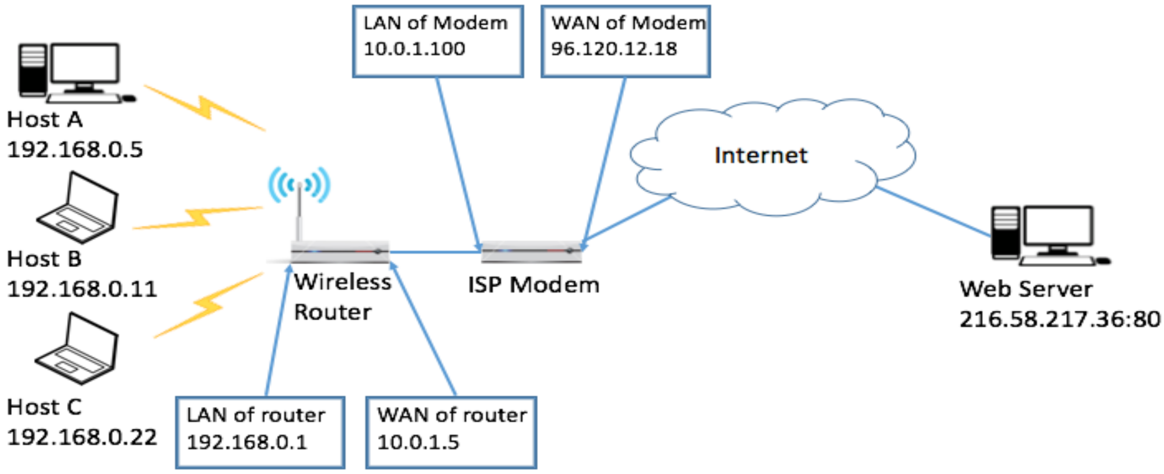

Figure 1. Network setup

The Figure 1 above is a typical home network setup. An ISP Modem provides internet service; a wireless router is connected to the ISP Modem via Ethernet. Hosts A, B and C are connected to the wireless router to access the Internet.

(a) (5 points) In order for the hosts A, B, and C to access the Web Server, Network Address Translation (NAT) with random port mapping needs to be enabled for both the Wireless Router and the ISP Modem. Assume Hosts will pick a random port number between 8000 and 9000, the Wireless Router can choose a random port number between 2000 and 2500, and the ISP Modem can choose a random port number between 3000 and 4000. Please fill in the NAT table for the Wireless Router and the ISP Modem below.

We can select random ports as far as it matches up

NAT Table of Wireless Router	
LAN side	WAN side
192.168.0.5:8001	10.0.1.5:2002
192.168.0.11:8002	10.0.1.5:2003
192.168.0.22:8003	10.0.1.5:2004

NAT Table of ISP Modem	
LAN side	WAN side
10.0.1.5:2002	96.120.12.18:3001
10.0.1.5:2003	96.120.12.18.3002
10.0.1.5:2004	96.120.12.18:3003

(b) (10 points) Now we look-into the details about how packets are exchanged between Host B and Web Server. Assume Host B sends a HTTP request packet to Web Server. And Web Server then sends HTTP content back to Host B. Please fill in the tables below to show how the packet's IP header changed along the route. (Please formulate your answer based on your answers for (a).)

Ports need to match answer in a

HTTP request Before entering router	
Src IP	192.168.0.11
Src Port	8002
Dst IP	216.52.217.36
Dst Port	80

HTTP request After exiting router	
Src IP	10.0.1.5
Src Port	2002
Dst IP	216.58.217.36
Dst Port	80

HTTP request After exiting modem	
Src IP	96.120.12.18
Src Port	3002
Dst IP	216.58.217.36
Dst Port	80

HTTP response Before entering modem	
Src IP	216.58.217.36
Src Port	80
Dst IP	96.120.12.18
Dst Port	3002

HTTP response After exiting modem	
Src IP	216.58.217.36
Src Port	80
Dst IP	10.0.1.5
Dst Port	2003

HTTP response After exiting router	
Src IP	216.58.217.36
Src Port	80
Dst IP	192.168.0.11
Dst Port	8002

(c) (10 points) Suppose now Host A also runs a webserver on port 8888, it is attached to a domain name http://www.mylocalhomeserver.com, explain **what NAT entries** should be added so that people from the internet can assess this webserver via URL. You can assume that the above domain name is registered properly.

Both the router and the modem should have the following entries added.
Port 8888 ought to be present at 192.168.0.5
Port number 10.0.1.5 can be chosen at random.
It is also accurate if 92.120.12.18 has port 80 open.

NAT table for wireless router	
LAN	WAN
192.168.0.5:8001	10.0.1.5:2002
192.168.0.5:8002	10.0.1.5:2003
192.168.0.5:8003	10.0.1.5:2004
192.168.0.5:8888	10.0.1.5:8888

NAT table for wireless router	
LAN	WAN
192.168.0.5 8001	96.120.12.18 3001
192.168.0.11 8002	96.120.12.18 3002

192.168.0.12 8003	96.120.12.18 3003
10.0.1.5:8888	96.120.12.18:8888(or 80)

(t) (10 points) The wireless link at the last mile is very error prone and you would like to improve the performance. What would you do in this case?

Performance of the wireless link at the last mile is error prone and we could improve the performance by

- Improving the transmittion power of sender.
  - Increasing transmittion power will however require more energy and will be more prone to interference.
- Providing strong error detection and recovery
  - Corrupted frames could be retransmitted in link layer
  - Powerful error detection would be needed along with power error

Question 2

Suppose a router has three input flows and one output flow. It receives the packets listed in the Table 1. below, all at about the same time, in the order listed, during a period in which the output port is busy, but all queues are otherwise empty. Give the order in which the packets are transmitted, assuming:

Packet	Size	Flow
1	200	1
2	200	1
3	160	2
4	200	2
5	160	2
6	210	3
7	120	3
8	90	3

Table 1.

(a) (5 points) Fair queuing

In order calculate the order in which packets will be transmitted we need to calculate finishing time F_i.

Packet	Size	Flow	Finishing Time (Fi)
1	200	1	200
2	200	1	400
3	160	2	160
4	200	2	360
5	160	2	520
6	210	3	210
7	120	3	330
8	90	3	420

Based on table above the order of packets transmission will be as follows:
P3 -> P1 -> P6 -> P7 -> P4 -> P2 -> P8 -> P5

(b) (5 points) Weighted fair queuing with flow 2 having twice as much share as flow 1, and flow 3 having 1.5 times as much share as flow 1. Note that ties are to be solved in the order of flow1, flow2 and flow3.

In order to calculate the order in which packets are calculated we need to calculate the weighted Fi.

Packet	Size	Flow	Weight	Weighted F_i
1	200	1	1	100
2	200	1	1	200
3	160	2	4	40
4	200	2	4	90
5	160	2	4	130
6	210	3	3	70
7	120	3	3	110
8	90	3	3	140

The order in which packets are transmitted will be
P3 -> P6 -> P4 -> P1 -> P7 -> P5 -> P8 -> P2

Question 3

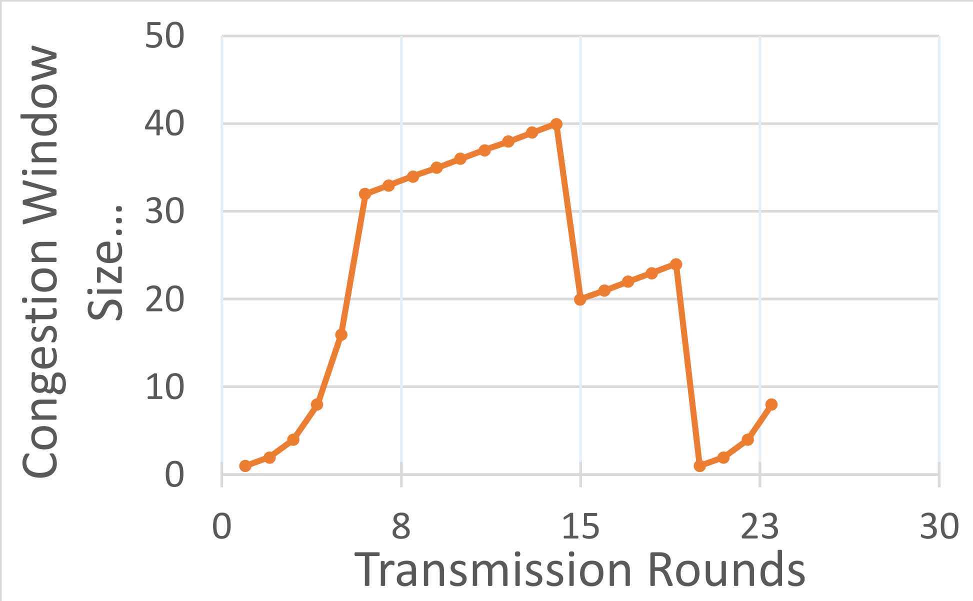

Figure 2. Congestion Window Size

Assuming TCP Reno is the protocol experiencing the behavior shown above, answer the following questions:

(a) Identify the RTT rounds when TCP runs Slow Start (e.g., from the 1th round to which round?)
Based on protocol experience shown above, TCP slow starts to operate for first 6 RTT and the last 4 RTT

(b) Identify the RTT rounds when TCP runs Congestion Avoidance
Based on protocol experience shown above, TCP congestion avoidance will be operating from 6th transmittion till the 19th transmittion

(c) After the 14th RTT round, is segment loss detected by a triple duplicate ACK or by a timeout and why?
Segment loss detected due to Triple Duplicate ACK otherwise window would have been dropped. It is now a triple duplicate ACK because it was halved, but if it had been a timeout, it would have dropped down to zero.

(d) During which RTT round the 170th segment is sent?
170th segment sent during 10th transmittion.

(e) Assuming a packet loss is detected after the 23rd RTT round by the receipt of triple duplicate ACKs, what will be the value of the congestion window?
By receiving the triple after the 23rd RTT, the value of the congestion window should be cut in half. Value of congestion window will be “4”

Question 4

Figure 3. below shows how 2 disconnected LAN are connected by IP tunnel (the dash line). For each interface the IP and MAC addresses are shown in the figure. (HW1-HW14 are used to represent hardware addresses)

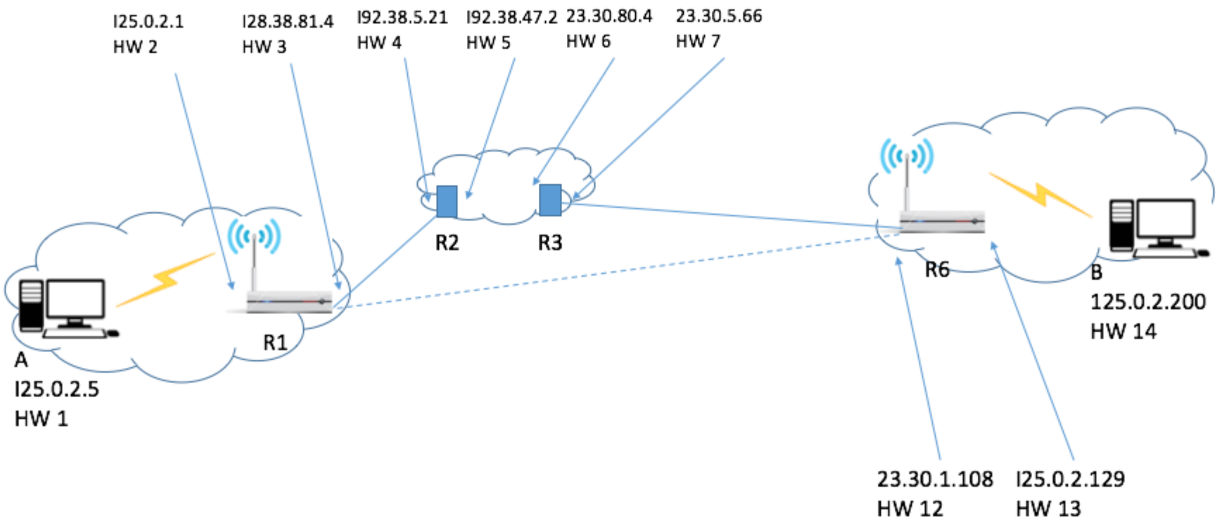

Figure 3. Network setup

Now Host B sends a packet to Host A. Please show how the packet travels along the route, please describe header information along the route (B->R6, R6-> R3, R3->R2, R2->R1, R1->A).

- **B -> R6**

Route : B - > R6	
Source IP	125.0.2.200
Source MAC	HW14
Dest IP	125.0.2.5
Dest MAC	HW13

- **R6 -> R3**

Outer IP header

Route : R6 -> R3	
Source IP	23.30.1.108
Source MAC	HW12
Dest IP	128.38.81.4
Dest MAC	HW7

Inner IP header
Same as Route : B to R6

- **R3 -> R2**

Outer IP Header

Route : R3 - > R2	
Source IP	23.30.1.108
Source MAC	HW6
Dest IP	128.38.81.4
Dest MAC	HW5

Inner IP header
Same as Route : A to R1

- **R2 -> R1**

  Outer IP Header

Route : R2 - > R1	
Source IP	23.30.1.108
Source MAC	HW4
Dest IP	128.38.81.4
Dest MAC	HW3

  Inner IP Header

  Same as Route : A to R1

- **R1 -> A**

  Outer IP Header

Route : R1 - > A	
Source IP	125.0.2.200
Source MAC	HW2
Dest IP	125.0.2.5
Dest MAC	HW1

Question 5

Derive the expected throughput of the following TCP congestion control algorithm: The additive increment factor is **α**. Multiplicative decrease factor **β**, which means after loss, the windows size will change from **W** to **(1-β)W**. Please order the throughput for each flow. AIMD(a,b) means the cwnd increases a per each round trip time and the cwnd set to (1-b)W from W when the loss happens.

Flow1: AIMD(a=1,b=0.5), RTT=10ms, loss rate = 10^{-6}
Flow2: AIMD(a=2,b=0.2), RTT=100ms, loss rate = 10^{-8}
Flow3: AIMD(a=5,b=0.8), RTT=300ms, loss rate = 10^{-9}
Flow4: AIMD(a=8,b=0.4), RTT=1000ms, loss rate = 10^{-4}
Flow5: AIMD(a=6,b=0.5), RTT=100ms, loss rate = 10^{-10}

Flow 1:

$$E(W_{aimd}) = \frac{\sqrt{2-\beta}\sqrt{\alpha}}{\sqrt{2\beta}*RTT*\sqrt{p}}$$

Given, $\alpha = 1$ and $\beta = 0.5$ $RTT = 10\ ms$ and $p = 10^{-6}$

$$= \frac{\sqrt{2-0.5}\sqrt{1}}{\sqrt{20.5}*10*10^{-3}*\sqrt{10^{-6}}}$$

$E(W_{aimd})$ = 122474.4871 MSS/Sec

Flow 2:

$$E(W_{aimd}) = \frac{\sqrt{2-\beta}\sqrt{\alpha}}{\sqrt{2\beta}*RTT*\sqrt{p}}$$

Given, $\alpha = 2$ and $\beta = 0.2$ $RTT = 100\ ms$ and $p = 10^{-8}$

$$= \frac{\sqrt{2-0.2}\sqrt{2}}{\sqrt{2*0.2}*100*10^{-3}*\sqrt{10^{-8}}}$$

$E(W_{aimd})$ = 300000 MSS/Sec

Flow 3:

$$E(W_{aimd}) = \frac{\sqrt{2-\beta}\sqrt{\alpha}}{\sqrt{2\beta}*RTT*\sqrt{p}}$$

Given, $\alpha = 5$ and $\beta = 0.8$ $RTT = 300\ ms$ and $p = 10^{-9}$

$$= \frac{\sqrt{2-0.8}\sqrt{5}}{\sqrt{2*0.8}*300*10^{-3}*\sqrt{10^{-9}}}$$

$E(W_{aimd})$ = 204124.1452 MSS/Sec

Flow 4:

$$E(W_{aimd}) = \frac{\sqrt{2-\beta}\sqrt{\alpha}}{\sqrt{2\beta}*RTT*\sqrt{p}}$$

Given, $\alpha = 8$ and $\beta = 0.4$ $RTT = 1000\ ms$ and $p = 10^{-4}$

$$= \frac{\sqrt{2-0.4}\sqrt{8}}{\sqrt{2*0.4}*1000*10^{-3}*\sqrt{10^{-4}}}$$

$E(W_{aimd})$ = 400 MSS/Sec

Flow 5:

$$E(W_{aimd}) = \frac{\sqrt{2-\beta}\sqrt{\alpha}}{\sqrt{2\beta}*RTT*\sqrt{p}}$$

Given, $\alpha = 6$ and $\beta = 0.5$ $RTT = 100\ ms$ and $p = 10^{-10}$

$$= \frac{\sqrt{2-0.5}\sqrt{6}}{\sqrt{2*0.5}*100*10^{-3}*\sqrt{10^{-10}}}$$

$E(W_{aimd})$ = 3000000 MSS/Sec

Question 6

Suppose that TCP uses the combination of quick acknowledgements (quick ack) and delayed acknowledgements (delayed ack). The quick ack only triggers up to 8 packets (the cwnd at the sender becomes 16 after receiving 8 quick acks) starting from 1 packet during slow start. The maximum capacity of the link is 5000 KBps, the RTT is 10ms, and 1MSS = 1KB. Note that KBps is KB per second).

(a) (5 points) About what is cwnd at the time of first packet loss?

To calculate the cwnd at the time of first packet loss we need to calculate BDP

BDP = 5000 * $* 10 * 10^{-3}$ = 50. Using 50 as a threshold for the cwnd calculations

Cwnd changes after every RTT as follows:

RTT = 0	Cwnd=1
RTT = 1	Cwnd=2
RTT = 2	Cwnd=4
RTT = 3	Cwnd=8
RTT = 4	Cwnd=16
RTT = 5	Cwnd=24
RTT = 6	Cwnd=36
RTT = 7	Cwnd=54
RTT = 8	Cwnd=81

Therefore, the cwnd should be 81< Cwnd < 122 when the first packet loss occurs after RTT 7.

(b) (5 points) About how long until sender discovers first loss?

When a current packet is not received however if farther packet arrives, duplicate acknowledgement (DUPACK) will be triggered.

In the system Duplicated Acknowledgement (DUPACK) will never be delayed so received will send 3 DUPACK when 3 further packets are received. But we can easily calculate time taken by sender to locate first loss via below formulae.

Time	= 3 * Transmit Time	+ Propagation Time
	= 3 * (1Kbps/800 Kbps)	+ 0.5 RTT
	= 53.75 ms	

So, sender would require 53.75 ms before detecting first packet loss.

If additional packets are all lost after this minimum amount of time, the sender may not detect the loss until timeout=2RTT.

The sender will notice the loss between 9RTT and 10RTT if the total time since the beginning is considered.