Problem Set #3

Problem 1 (10pts)

Consider a network with MPLS enabled routers as shown in Figure 1 below. We would like to perform traffic engineering using MPLS so that traffic from R1 to R6 will be routed as R1->R3->R5->R6->A and traffic from R2 to R6 will be routed as R2->R3->R4->C.

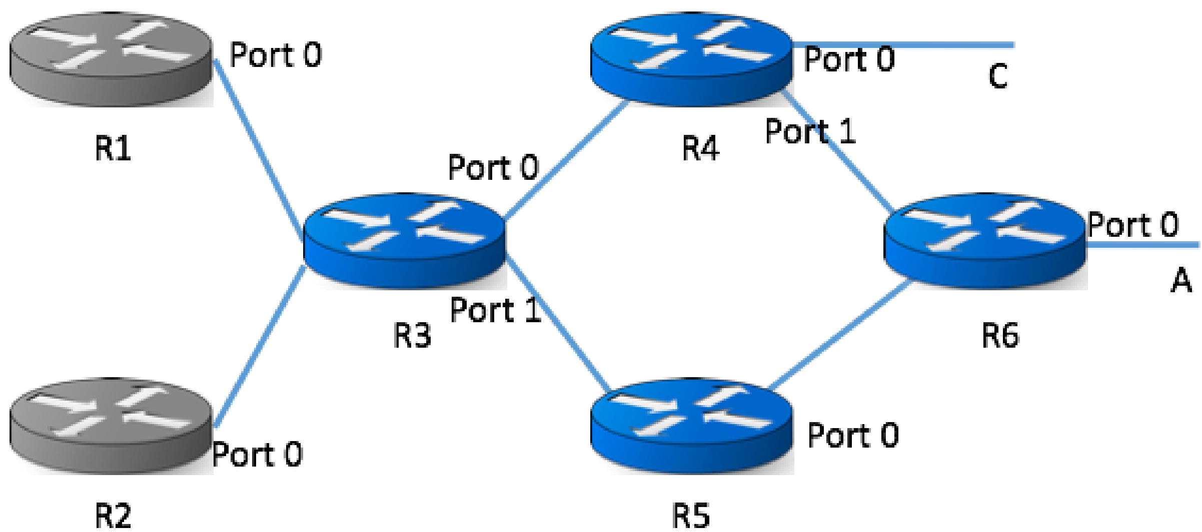


Figure 1. MPLS enabled network for Problem 1

Please fill in the following tables of MPLS entries for each router.

R1			
In Label	Out Label	Destination	Out Interface
-	1	A	0

R2			
In Label	Out Label	Destination	Out Interface
-	2	C	0

R3			
In Label	Out Label	Destination	Out Interface
2	3	C	0
1	4	A	1

R4			
In Label	Out Label	Destination	Out Interface
3	-	C	0

R5			
In Label	Out Label	Destination	Out Interface
4	5	A	0

R6			
In Label	Out Label	Destination	Out Interface
5	-	A	0

Problem 2 (20pt)

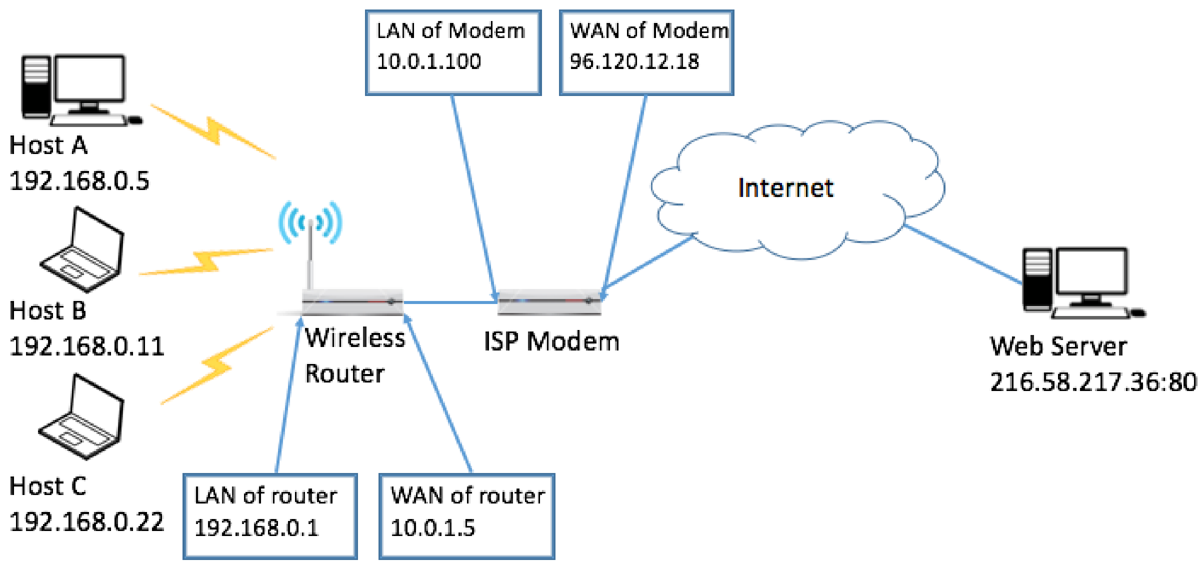


Figure 2: Network setup for Problem 2.

Figure 2, located above, is a typical home network setup. An ISP Modem provides internet service; a wireless router is connected to the ISP Modem via Ethernet. 3 hosts A, B, and C are connected to the wireless router to access the internet.

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

NAT Table of Wireless Router	
LAN side	WAN side
192.168.0.5:8001	10.0.1.5:2001
192.168.0.11:8002	10.0.1.5:2002
192.168.0.22:8003	10.0.1.5:2003

NAT Table of ISP Modem	
LAN side	WAN side
10.0.1.5:2001	96.120.12.18:3001
10.0.1.5:2002	96.120.12.18:3002
10.0.1.5:2003	96.120.12.18:3003

NOTE: All port numbers colored in blue (800x, 200x, 300x) can be any number as long as they fit in the range of requirements. Each port number should be used only once.

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

HTTP request Before entering the Router	
Src IP	192.168.0.11
Src Port	8002
Dst IP	216.58.217.36
Dst Port	80

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

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

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

HTTP response After exiting the Modem	
Src IP	216.58.217.36
Src Port	80
Dst IP	10.0.1.5
Dst Port	2002

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

NOTE: All port numbers can be any number as long as they match with the numbers from answer (a).

(c) Suppose now Host A also runs a webserver on port 8888, it is attached to a domain name www.tlen5330homeserver.com, explain what NAT entries should be added so that people from another part of the internet can access this webserver via URL.

(d) 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?

Sol:

(a) Ports can be random as long as they matchup and fit in range
(b) Ports need to match answers in (a)
(c) The following entries should be added for both router and modem
192.168.0.5 should have port 8888.
10.0.1.5 can have arbitrary port number.
96.120.12.18 can have arbitrary port number.

NAT Table of Wireless Router	
LAN side	WAN side
192.168.0.5:8888	10.0.1.5:XX

NAT Table of ISP Modem	
LAN side	WAN side
10.0.1.5:XX	96.120.12.18:YY

(d) Open question.

Problem 3 (10pt)

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:

(a) Fair queuing

(b) 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.

Packet	Size	Flow
1	200	1
2	200	1
3	160	2
4	120/140	2
5	160	2
6	210	3
7	150/140	3
8	90	3

Table 1.

Sol:

(a) Fair Queuing.

First we calculate the relative finishing time F_i for each incoming flow.

Packet	Size	Flow	F_i
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

Then the order will be obvious based on the finishing time:

P3, P1, P6, p7, p4, p2, p8, p5

(b) Weighted fair queuing

The difference of this one and (a) is now we use Weighted F_i instead of F_i

Now flow1 has weight of 2, flow2 has weight of 4, and flow3 has weight of 3.

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

Then the order will be obvious based on the Weighted finish time. Priority of flow with the smallest F_i first which leads to:

P3, P6, P4, P1, P7, P5, P8, P2

Problem 4 (15pt)

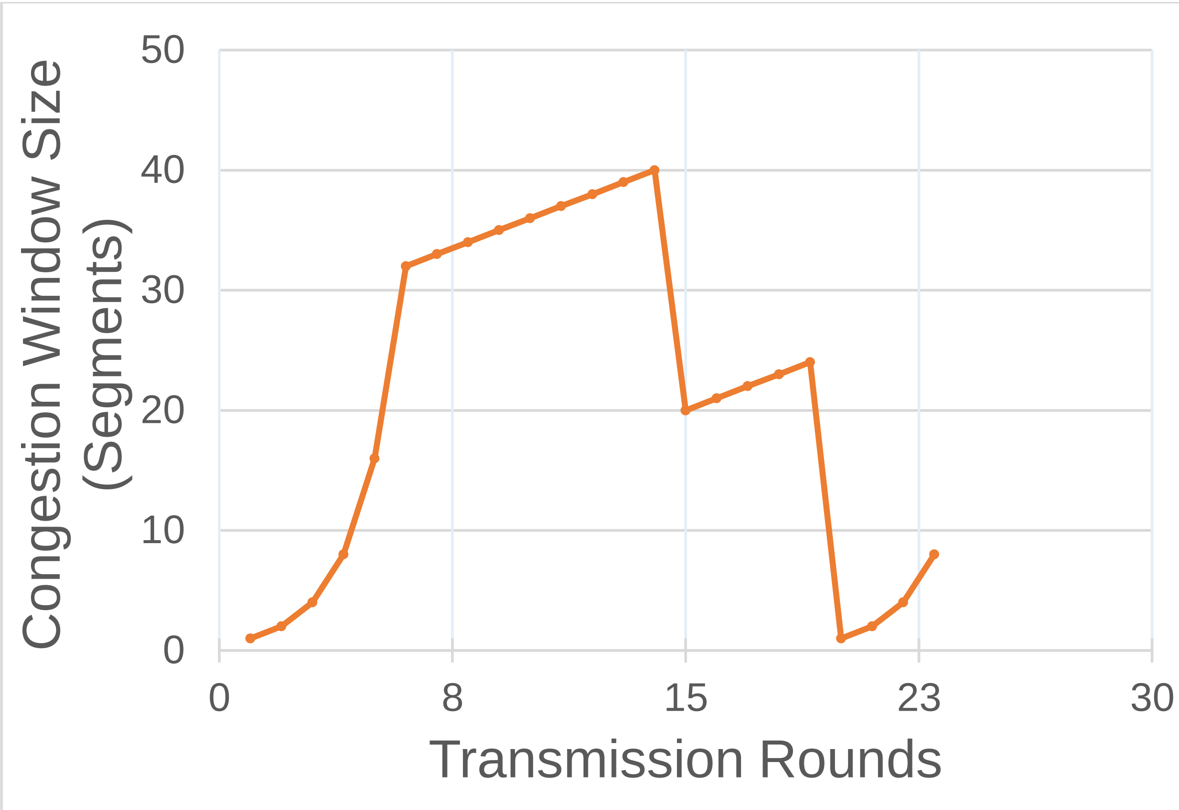


Figure. 1

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

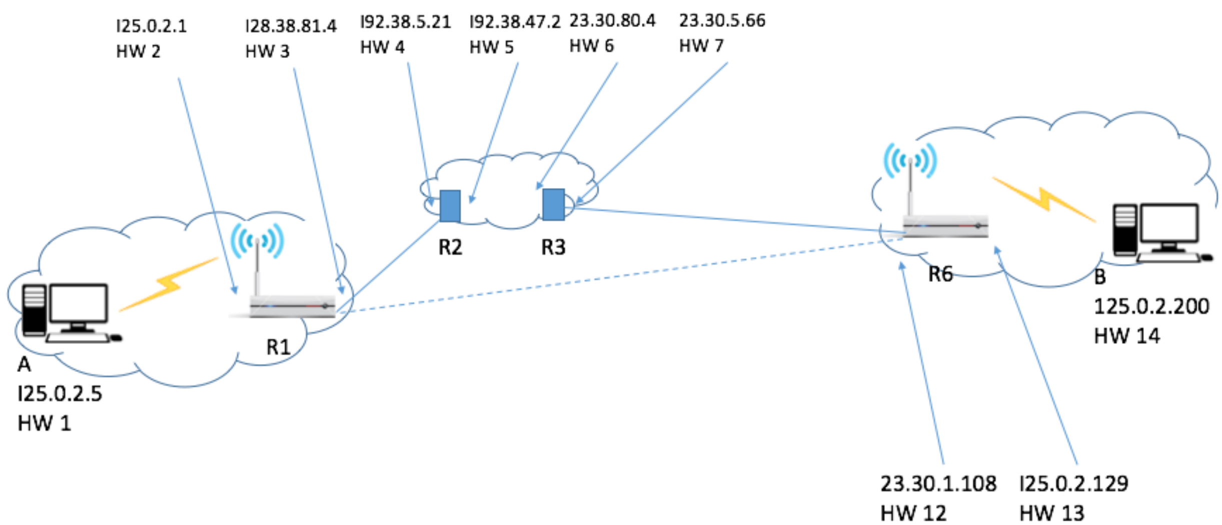
(a) Identify the RTT rounds when TCP runs Slow Start.
(b) Identify the RTT rounds when TCP runs Congestion Avoidance
(c) After the 14th RTT round, is segment loss detected by a triple duplicate ACK or by a timeout and why?
(d) During which RTT round is the 170th segment sent?
(e) Assuming a packet loss is detected after the 23th round by the receipt of triple duplicate ACKs, what will be the value of the congestion window?

Sol:

(a) TCP slow start operates for the first 6 RTT and the last 4RTT.
(b) TCP congestion avoidance is operating from the 6th transmission until the 19th transmission.
(c) Triple duplicate ACK, otherwise the window would drop to 0.
(d) ***10th*** Transmission.
(e) It will be ***4***.

Problem 5 (15pt)

Figure 3 below shows how 2 disconnected LAN are connected by an 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)



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.

Sol:

From B to R6

Src IP:	125.0.2.200
Src MAC:	HW14
Dst IP:	125.0.2.5
Dst MAC:	HW13

From R6 to R3

Outer IP header

Src IP:	23.30.1.108
Src MAC:	HW12
Dst IP:	128.38.81.4
Dst MAC:	HW7

Innter IP header

Same as From B to R6

From R3 to R2
Outer IP header
    Src IP: 23.30.1.108
    Src MAC: HW6
    Dst IP: 128.38.81.4
    Dst MAC: HW5
Innter IP header
    Same as From B to R6

From R2 to R1
Outer IP header
    Src IP: 23.30.1.108
    Src MAC: HW4
    Dst IP: 128.38.81.4
    Dst MAC: HW3
Innter IP header
    Same as From B to R6

From R1 to A (exit tunnel so no more outer IP)

    Src IP: 125.0.2.200
    Src MAC: HW2
    Dst IP: 125.0.2.5
    Dst MAC: HW1

Problem 6 (20pts)

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 window's size will change from **W** to **(1-β)W**. Please order the throughput for each flow. AIMD (a,b) means the cwnd increases after each round trip time and the cwnd set to (1-b)W from W when the loss happens.

Sol:

E = sqrt(2-b) * sqrt(a) / sqrt(2*b) / RTT / sqrt(p)

Flow 1:
    Throughput = 122,474 MSS/second
Flow 2:
    Throughput = 300,000 MSS/second
Flow 3:
    Throughput = 204,124 MSS/second
Flow 4:
    Throughput = 400 MSS/second
Flow 5:
    Throughput = 3,000,000 MSS/second
The order is ***Flow5,Flow2,Flow3,Flow1,Flow4***
Reverse order is also correct

Problem 7 (10pts)

Suppose that TCP uses the combination of quick acknowledgements (quick ack) and delayed acknowledgements (delayed ack). The quick ack only triggers up to 16 packets 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) About what is cwnd at the time of first packet loss?
(b) About how long until sender discovers first loss?

Sol:

(a)

Here is how the cwnd changes after each RTT:

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

So when first packet loss happens the cwnd should be $54<Cwnd<81$

Answers within this range are correct.

(b)

When a packet is not received and further packets arrive, it will trigger duplicate acknowledgement (DUPACK). DUPACK is never delayed so the receiver will send 3 DUPACKs when 3 further packets are received. The time for the sender to discover the first loss will be

T = 3 * transmit_time + propagation_time
= 3 * (1KB/5000KBps) + 0.5RTT = 0.6+5 =5.6ms

This is the minimum time for the sender to discover the loss. If further packets are all lost, it will take up to timeout=2RTT for the sender to discover the loss.

If considering the total time since the beginning, the sender will discover the loss between ***7RTT and 9RTT***.