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PROBLEM SET 3
FALL 2018
Due Wed, November 7th by 3:00 PM

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.

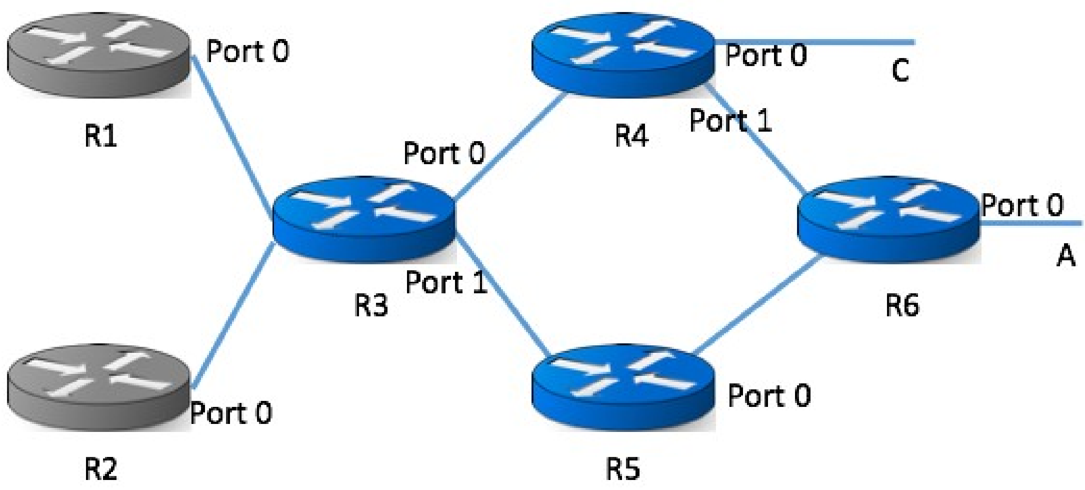

Figure 1. MPLS enabled network for Problem 1

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

R1			
In label	Out label	Dst	Out interface
-	**1**	**A**	**0**

R2			
In Label	Out Label	Dst	Out interface
-	**2**	**C**	**0**

R3			
In label	Out label	Dst	Out interface
1	**4**	**A**	**1**
2	**3**	**C**	**0**

R4			
In label	Out label	Dst	Out interface
3	**-**	**C**	**0**

R5			
In label	Out label	Dst	Out interface
4	**5**	**A**	**0**

R6			
In label	Out label	Dst	Out interface
5	**-**	**A**	**0**

Problem 2 (20pts)

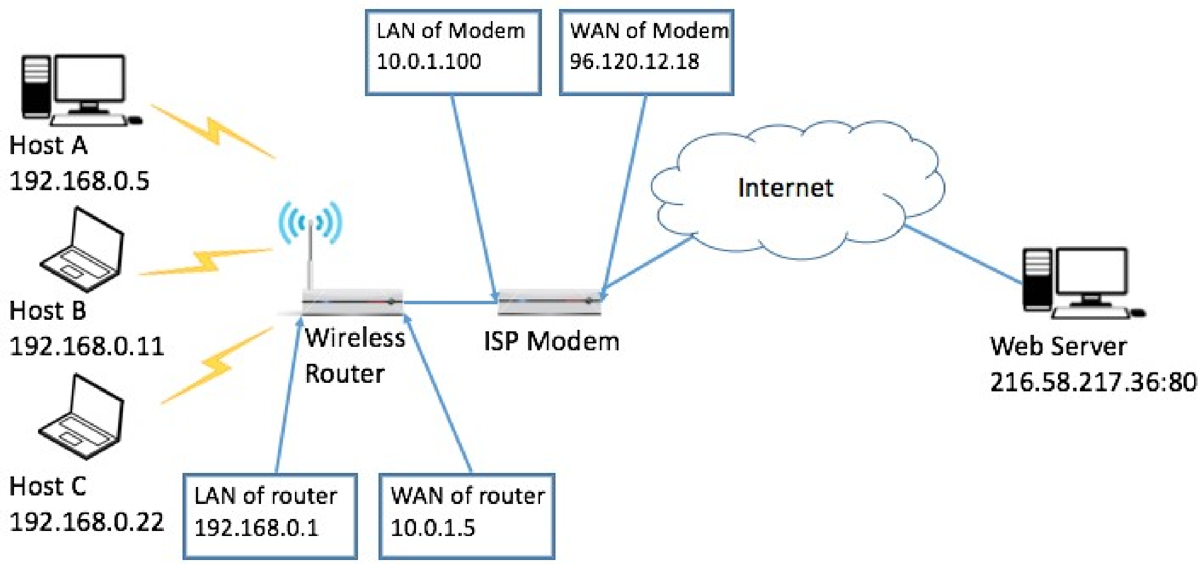

Figure 2. Network setup for Problem 2.

The Figure 2. 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) 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.

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**

(b) 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).)

HTTP request Before entering Router	
Src IP	**192.168.0.11**
Src Port	**8002**
Dst IP	**216.58.217.36**
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	2002

HTTP response After exiting Router	
Src IP	216.58.217.36

Src Port	**80**
Dst IP	**192.168.0.11**
Dst Port	**8002**

(c) 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.

Host A also runs a web server on port 8888
so Host A is 196.168.0.5:8888

NAT Table of Wireless Router	
LAN side	WAN side
192.168.0.5:8888	10.0.1.5:2222

NAT Table of ISP Modem	
LAN side	WAN side
10.0.1.5:2222	96.120.12.18:3333

(b) 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 and packet loss/ RTT are related as inverse proportional, so by decreasing the packet loss/RTT, the performance at the last mile can be improved.

Problem 3 (10pts)

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

Packet	**Size**	**Flow**	**Weight**	**Order**
1	**200**	**1**	**200**	**2**
2	**200**	**1**	**400**	**6**
3	**160**	**2**	**160**	**1**
4	**200**	**2**	**360**	**5**
5	**160**	**2**	**520**	**8**
6	**210**	**3**	**210**	**3**
7	**120**	**3**	**330**	**4**
8	**90**	**3**	**420**	**7**

In fair queuing , the order is based on finishing time and the order follows as:

P3→P1→P6→P7→P4→P2→P8→P5

(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.

flow 2 having twice as much share as flow 1
flow 3 having 1.5 times as much share as flow 1

Let F1 = 2;

F2 = 2x(F1)
F2 = 4

F3 = 1.5x(F1)
F3 = 3

Packet	Size	Flow	Weight	Order
1	200	1	100	4
2	200	1	100+100=200	8
3	160	2	40	1
4	200	2	40+50=90	3
5	160	2	40+50+40=130	6
6	210	3	70	2
7	120	3	70+40=110	5
8	90	3	70+40+30=140	7

In weighted queuing, the order follows as:
P3→P6→P4→P1→P7→P5→P8→P2

Problem 4 (15pts)

Figure 3. 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?)
Initially, for the first 6 RTT (1-6), the TCP operates with a slow starting. Towards the end, for the last 4 RTT(20-23) , the TCP runs Slow Start

(b) Identify the RTT rounds when TCP runs Congestion Avoidance
From 6^{th} RTT till 19^{th} RTT, 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?
After the 14th RTT round, segment loss is detected by a triple duplicate ACK as the window doesn't drop to zero

(d) During which RTT round the 170th segment is sent?
170^{th} segment is sent at 10^{th} transmission

(e) Assuming a packet loss is detected after the 23th RTT round by the receipt of triple duplicate ACKs, what will be the value of the congestion window?
The value of congestion window will be 4 (half of 8)

Problem 5 (15pts)

Figure 4. 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)

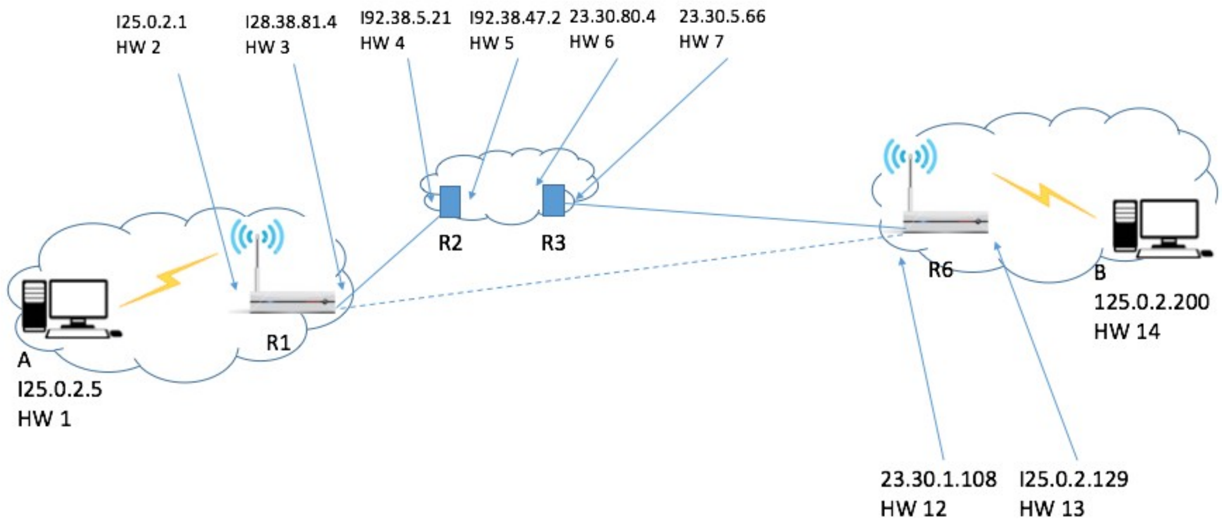

Figure 4. Network setup for Problem 5

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.

Host B sends a packet to Host A.
the pakcet follows the path as :
B → R6→ R3→ R2→ R1→ A

From B→ R6
Source IP: 125.0.2.200 Source MAC: HW14
Destination IP: 125.0.2.5 Destination MAC:HW13

From R6→ R3
(Outer IP Header)
Source IP: 23.30.1.108 Source MAC: HW12
Destination IP: 128.38.81.4 Destination MAC:HW7
(Inner IP Header)
From R6→ R3
Source IP: 125.0.2.200 Source MAC: HW14
Destination IP: 125.0.2.5 Destination MAC:HW13

From R3→ R2
(Outer IP Header)
Source IP: 23.30.1.108 Source MAC: HW6
Destination IP: 128.38.81.4 Destination MAC:HW5
(Inner IP Header)
Source IP: 125.0.2.200 Source MAC: HW14
Destination IP: 125.0.2.5 Destination MAC:HW13

From R2→ R1

(Outer IP Header)

Source IP: 23.30.1.108 Source MAC: HW4

Destination IP: 128.38.81.4 Destination MAC:HW3

(Inner IP Header)

Source IP: 125.0.2.200 Source MAC: HW14

Destination IP: 125.0.2.5 Destination MAC:HW13

From R1→ A

Source IP: 125.0.5.200 Source MAC: HW2

Destination IP: 125.0.2.5 Destination 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 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}

Throughput = Area/Time

Time = ((W x β)/ α) x RTT
Area =1/p=A1+A2

$=((W\beta * (W\beta/\alpha))x0.5) + ((1-\beta)W \times (W\beta/\alpha))$
$= (W^2 \times (2-\beta) \times \beta)/(2x\,\alpha)$

Throughput$=((2-\beta)^{1/2} \times (\alpha)^{1/2})/(RTT \times (2\beta)^{1/2} \times (\text{loss rate})^{1/2})$

1.Flow1: AIMD(α=1,β=0.5), RTT=10ms, loss rate = 10^{-6}
Throughput$=((2-\beta)^{1/2} \times (\alpha)^{1/2})/(RTT \times (2\beta)^{1/2} \times (\text{loss rate})^{1/2})$
$=((2-(0.5))^{1/2} \times (1)^{1/2})/((0.01) \times (2(0.5))^{1/2} \times (10^{-6})^{1/2})$
= 122474.4871 packets/second

2.Flow2: AIMD(α=2,β=0.2), RTT=100ms, loss rate = 10^{-8}
Throughput$=((2-\beta)^{1/2} \times (\alpha)^{1/2})/(RTT \times (2\beta)^{1/2} \times (\text{loss rate})^{1/2})$
$=((2-(0.2))^{1/2} \times (2)^{1/2})/((0.1) \times (2(0.2))^{1/2} \times (^{10-8})^{1/2})$
= 300000 packets/second
3.Flow3: AIMD(α=5,β=0.8), RTT=300ms, loss rate = 10^{-9}
Throughput$=((2-\beta)^{1/2} \times (\alpha)^{1/2})/(RTT \times (2\beta)^{1/2} \times (\text{loss rate})^{1/2})$
$=((2-(0.8))^{1/2} \times (5)^{1/2})/((0.3) \times (2(0.8))^{1/2} \times (10^{-9})^{1/2})$
= 204124.1452 packets/second
4.Flow4: AIMD(α=8,β=0.4), RTT=1000ms, loss rate = 10^{-4}
Throughput$=((2-\beta)^{1/2} \times (\alpha)^{1/2})/(RTT \times (2\beta)^{1/2} \times (\text{loss rate})^{1/2})$
$=((2-(0.4))^{1/2} \times (8)^{1/2})/((1) \times (2(0.4))^{1/2} \times (10^{-4})^{1/2})$
= 400 packets/second
5.Flow5: AIMD(α=6,β=0.5), RTT=100ms, loss rate = 10^{-10}
Throughput$=((2-\beta)^{1/2} \times (\alpha)^{1/2})/(RTT \times (2\beta)^{1/2} \times (\text{loss rate})^{1/2})$
$=((2-(0.5))^{1/2} \times (6)^{1/2})/((0.01) \times (2(0.5))^{1/2} \times (10^{-10})^{1/2})$
= 3000000 packets/second

Order is FLOW5, FLOW2, FLOW3, FLOW1, FLOW4

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?

BDP =capacity x RTT

5000KBps x 10ms
=50KB
Maximum Segment Size = 1KB
Maximum number of packets = BDP/MSS
= 50 packets

The congestion window increases by the formula (CWND + (CWND/2)) after 16 window size is set.

RTT	Number of Packets
0	1
1	2
2	4
3	8
4	16
5	24
6	36
7	54

The first packet occurs when window size is between 54-81

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

In the above case, only one packet is lost. The packets after that are received. The sender will realizes the first loss after triple duplicate acknowledgements
Time for triple duplicate acknowledgements is Transmission time for 3 Packets+ Propogation time
=3x(1KB)/(5000) + (0.5x10)
=5.6ms
No packet is delivered after the first packet loss, hence the timeout will occur at the sender side and it will be discovered after 2RTT, and the sender will thus discover the packet loss between 7RTT and 9RTT