

Problem Set 3

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Problem 1

Figure 1 below 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.

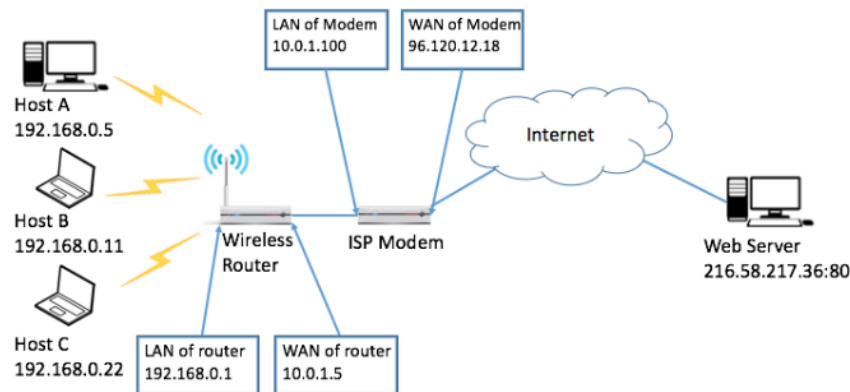


Figure 1

- In order for 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. Fill in the NAT table for the wireless router and ISP modem.

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

- 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. Fill in the tables below to show how the packet's IP header changes along the route.

Request Before Entering Router

Source IP	192.168.0.11
Source Port	8002
Destination IP	216.58.217.36

Destination Port	80
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Request After Exiting Router

Source IP	10.0.1.5
Source Port	2002
Destination IP	216.58.217.36
Destination Port	80

Request After Exiting Modem

Source IP	96.120.12.18
Source Port	3002
Destination IP	216.58.217.36
Destination Port	80

Response Before Entering Modem

Source IP	216.58.217.36
Source Port	80
Destination IP	96.120.12.18
Destination Port	3002

Response After Exiting Modem

Source IP	216.58.217.36
Source Port	80
Destination IP	10.0.1.5
Destination Port	2002

Response After Exiting Router

Source IP	216.58.217.36
Source Port	80
Destination IP	192.168.0.11
Destination Port	8002

1. Suppose now host A also runs a web server on port 8888 and 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 access this web server via URL. You can assume that the above domain name is registered properly.

The following entries should be added for the router and modem. IP address 192.168.0.5 should have port 8888, and address 10.0.1.5 can have a random port number.

NAT Table of Wireless Router

LAN Side	WAN Side
192.168.0.5:8888	10.0.1.5:8888

NAT Table of ISP Modem

LAN Side	WAN Side
10.0.1.5:8888	96.120.12.18:8888

- 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?

Problem 2

Suppose a router has three input flows and one output flow. It receives the packets listed in 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

- Fair Queueing

Packet	Size	Flow	Finish Time
1	200	1	200
2	200	1	400
3	160	2	160
4	200	2	300
5	160	2	460
6	210	3	210
7	120	3	350
8	90	3	440

The order of packet transmission is determined by the finishing time. So as per above, packets would transmit in the following order: **3, 1, 6, 4, 7, 2, 8, 5.**

- Weighted fair queueing 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 flow 1, 2, and 3.

Packet	Size	Flow	Finish Time (weighted)
1	200	1	100
2	200	1	200
3	160	2	40

Packet	Size	Flow	Finish Time (weighted)
4	200	2	75
5	160	2	115
6	210	3	70
7	120	3	116.67
8	90	3	146.67

The order of packet transmission is determined by the finishing time. So as per above, packets would transmit in the following order: **3, 6, 4, 1, 5, 7, 8, 2.**

Problem 3

Assume TCP Reno is the protocol experiencing the behaviour shown in Figure 2.

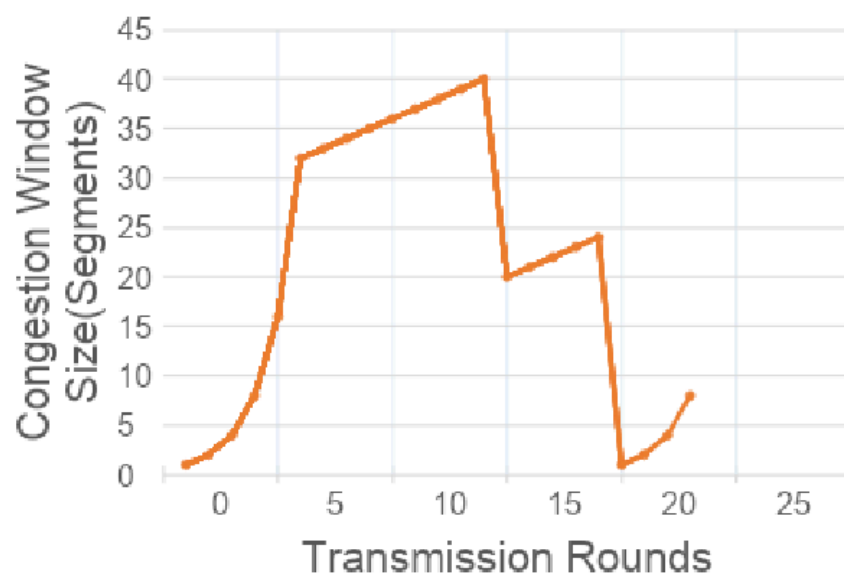


Figure 2

1. Identify the RTT rounds when TCP runs Slow Start. (eg. From the 1st round to which?)

Slow Start occurs for the initial 6 RTT's, and the final 4 RTT's.

1. Identify the RTT rounds when TCP runs Congestion Avoidance.

Congestion Avoidance occurs from the 6th transmission, to the 19th transmission.

1. After the 14th RTT round, is segment loss detected by a triple duplicate ACK or by a timeout and why?

Segment loss is detected by a triple duplicate ACK, as otherwise the window will have dropped to 0

1. During which RTT round is the 170th segment sent?

The 170th segment is sent during the 10th transmission.

1. Assuming a packet loss is detected after the 23rd RTT round by the receipt of the triple duplicate ACK's, what will be the value of the congestion window?

The value of the congestion window will be 4.

Problem 4

Figure 3 below shows how two disconnected LANs are connected by IP tunneling (the dashed line). For each interface, the IP and MAC addresses are shown in the figure (HW1 through HW14 are used to represent the hardware address).

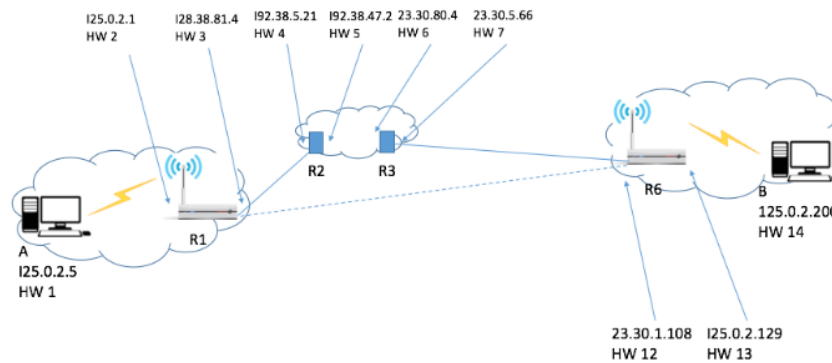


Figure 3

Now host B sends a packet to host A. Show how the packet travels along the route, describe header information along the route (B → R6, R6 → R3, R3 → R2, R2 → R1, R1 → A).

Host B to Router R6

Source IP	125.0.2.200
Source MAC	HW14
Destination IP	125.0.2.5
Destination MAC	HW13

Router R6 to Router R3 Inner IP header: Same as Host B to Router R6 Outer IP header:

Source IP	23.30.1.108
Source MAC	HW12
Destination IP	128.38.81.4
Destination MAC	HW7

Router R3 to Router R2 Inner IP header: Same as Host A to Router R1 Outer IP header:

Source IP	23.30.1.108
Source MAC	HW6
Destination IP	128.38.81.4
Destination MAC	HW5

Router R2 to Router R1 Inner IP header: Same as Host A to Router R1 Outer IP header:

Source IP	23.30.1.108
Source MAC	HW4
Destination IP	128.38.81.4
Destination MAC	HW3

Router R1 to Host A

Source IP	125.0.2.200
Source MAC	HW2
Destination IP	125.0.2.5
Destination MAC	HW1

Problem 5

Derive the expected throughput of the following TCP congestion algorithm: The additive increment factor is α . Multiplicative decrease β , which means after loss, the window's size will change from W to $(1 - \beta)W$. Order the throughput for each flow. AIMD(a , b) means the CWND increases per each round trip time and the CWND set to $(1 - \beta)W$ for W when the loss happens.

Flow	AIMD	RTT	Loss
1	$a = 1, b = 0.5$	10ms	10^{-6}
2	$a = 2, b = 0.2$	100ms	10^{-8}
3	$a = 5, b = 0.8$	300ms	10^{-9}
4	$a = 8, b = 0.4$	1000ms	10^{-4}
5	$a = 6, b = 0.5$	100ms	10^{-10}

To derive the expected throughput, use the Mathis equation for TCP throughput.

$$T \approx \frac{\alpha}{RTT \times \sqrt{p} \times \sqrt{\beta}}$$

Where α is the additive increase factor, β is the multiplicative decrease factor, p is the packet loss probability, and RTT is the round trip time. Apply this formula for each flow.

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

$$T_1 \approx \frac{1}{0.01 \times \sqrt{10^{-6}} \times \sqrt{0.5}} \approx 141.4 \text{ Mbps}$$

1. $\alpha = 2, RTT = 100 \text{ ms}, p = 10^{-8}, \beta = 0.2$

$$T_2 \approx \frac{2}{0.1 \times \sqrt{10^{-8}} \times \sqrt{0.2}} \approx 447.5 \text{ Mbps}$$

1. $\alpha = 5, RTT = 300 \text{ ms}, p = 10^{-9}, \beta = 0.8$

$$T_3 \approx \frac{5}{0.3 \times \sqrt{10^{-9}} \times \sqrt{0.8}} \approx 186.4 \text{ Mbps}$$

1. $\alpha = 8, RTT = 1000 \text{ ms}, p = 10^{-4}, \beta = 0.4$

$$T_4 \approx \frac{8}{1 \times \sqrt{10^{-4}} \times \sqrt{0.4}} \approx 1266.5 \text{ Kbps}$$

1. $\alpha = 6, RTT = 100 \text{ ms}, p = 10^{-10}, \beta = 0.5$

$$T_5 \approx \frac{6}{0.1 \times \sqrt{10^{-10}} \times \sqrt{0.5}} \approx 848.5 \text{ Mbps}$$

Thus, the ordered throughput for each flow is given in descending size: **5, 2, 3, 1, 4**.

Problem 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 1 MSS is equal to 1KB.

1. About what is CWND at the time of the first packet loss?

After the quick ACK phase, TCP switches to delayed ACKs, meaning the receiver sends one ACK for every two packets. In Slow Start, the CWND roughly doubles with each RTT, and begins at 16 in our current scenario. So after 1 RTT, CWND is 32 MSS, after 2 RTTs, CWND is 64 MSS, and so on. When considering packet loss, it will occur when the CWND reaches the capacity of the link, which is 5000 KBps. This would be reached after roughly 7 RTTs, or when the CWND is approximately 1024 MSS (1 MB).

1. About how long until the sender discovers the first loss?

As found above, it takes 7 RTTs to grow the CWND to 1024 MSS, which is the point where packet loss is expected. The RTT is 10 ms, so the time to discover packet loss is given by 7 RTTs * 10 ms = 70 ms.