CSE 473 – Introduction to Computer Networks *Jon Turner*

Exam 1 Solution

9/26/2013

1. (10 points). A user in Chicago, connected to the internet via a 100 Mb/s (b=bits) connection retrieves a 250 KB (B=bytes) web page from a server in London, where the page references three images of 500 KB each. Assume that the one way propagation delay is 75 ms and that the user's access link is the bandwidth bottleneck for this connection.

   Approximately how long does it take for the page (including images) to appear on the user's screen, assuming non-persistent HTTP using a single connection at a time (for this part, you should ignore queueing delay and transmission delays at other links in the network)?

   4(300) ms + (2 + 3*4 Mb)/(100 Mb/s) = 1200 ms + 140 ms = 1.34 seconds*

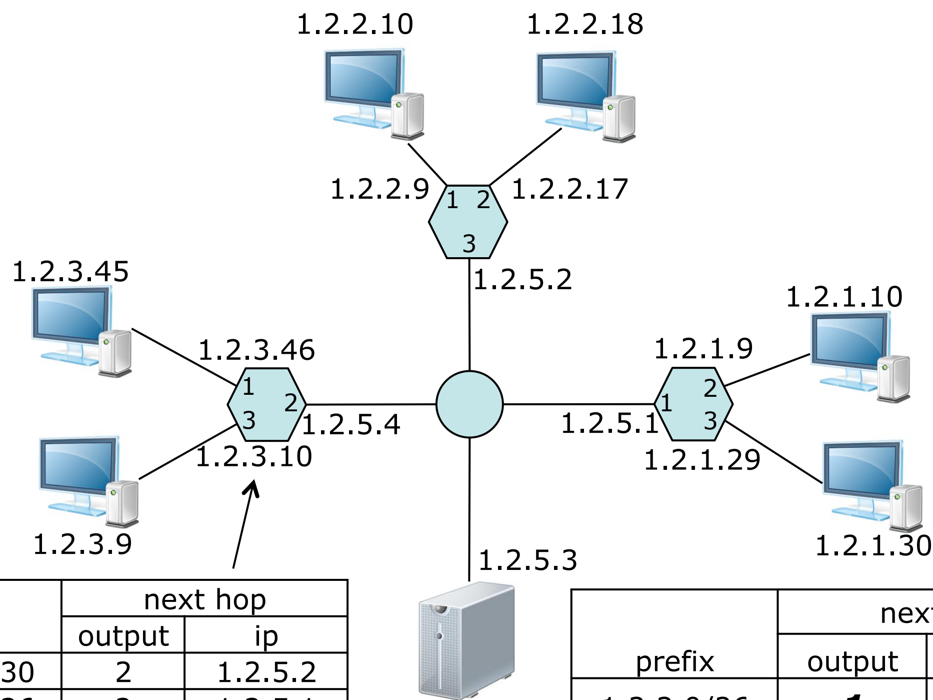
   How long does it take if the connection uses persistent HTTP (single connection)?

   *3*150 ms + 140 ms = 590 ms*

   Suppose that user's access router has a 4 MB buffer (B=byte) on the link from the router to the user. How much delay does this buffer add during periods when the buffer is full?

   A 4 MB buffer is 32 Mbits, so it adds 320 ms to the delay on a 100 Mb/s link.

2. (10 points). The diagram below shows a network with 3 routers (shown as hexagons) connected by an Ethernet switch. The routing table for the left-hand router is shown. Complete the routing table for the right-hand router, so that packets will be delivered appropriately (use no more than 5 route table entries).



prefix	next hop output	next hop ip
1.2.2.8/30	2	1.2.5.2
1.2.1.0/26	2	1.2.5.1
1.2.5.0/24	2	-
1.2.2.16/30	2	1.2.5.2
1.2.3.44/30	1	-
1.2.3.8/30	3	-

prefix	next hop output	next hop ip
1.2.2.0/26	***1***	***1.2.5.2***
1.2.3.0/26	***1***	***1.2.5.4***
1.2.5.0/24	***1***	***-***
1.2.1.28/30	***3***	***-***
1.2.1.8/30	***2***	***-***

Are all the entries in the left-hand router's table necessary? If not, show how to reduce the number of entries, without changing the routing behavior.

The two entries for subnets 1.2.2.8/30 and 1.2.2.16/30 could be replaced with a single entry that maps prefix 1.2.2.0/27 to next hop 2:1.2.5.2.

Suppose we wanted to add a switch at port 1 of the left-hand router, along with 10 new hosts (the existing host would now be connected to the switch, rather than the router). Which routing table entries would have to change as a result? What are the new entries?

The subnet at port 1 of the left-hand router is currently configured as a /30. After adding the switch, this subnet will require at least 12 IP addresses. This implies that it needs to be at least a /28 subnet. So, the route with prefix 1.2.3.44/30 at the left-hand router should be changed to 1.2.3.32/28.

3. (5 points). The diagram below shows the bytes that define a 16 bit integer and a 32 bit integer as they are stored in a computer's memory. Assume that the computer is big-endian and that the values are shown as the computer would normally store them.

When these bytes are sent to a remote computer over the internet, in what order would the bytes be sent?

The bytes would be sent cc, dd, 33, 44, 55, 66.

Address	Byte	
	...	
x13a	cc	16 bit value
x13b	dd	
x13c	33	32 bit value
x13d	44	
x13e	55	
x13f	66	
	...	

Is the 16 bit value odd or even?

Since the low order byte is dd, it is odd.

Suppose the bytes are delivered to a computer that is little-endian. Is it necessary for the remote computer to swap the bytes?

yes

Assume the diagram below shows the portion of remote computer's buffer where these bytes are stored. Show how the bytes would appear in the remote computer's after any required byte-swapping is done. If none is required, write the byte values as they are delivered.

Address	Byte
	...
x252	***dd***
x253	***cc***
x254	***66***
x255	***55***
x256	***44***
x257	***33***
	...

4. (15 points) Consider a router with links of 1 Gbs and a single queue at each output that can hold 5000 packets. Suppose traffic from five flows is being sent out on one of its links. Assume the packets in these flows are 10,000 bits long. Four of the flows (the "small flows") are sending 10 thousand packets per second, and the fifth one (the "large flow") is sending 50 thousand packets per second. What is the average number of packets in the queue? Is it likely that packets will get discarded in this situation?

   The link can forward 100 Kp/s. Since the arriving packet rate is 90 Kp/s, the traffic intensity is 0.9, so the average number of packets in the queue is .9/(1-.9)=9.

   No packet losses are likely to occur in this case.

   Now, suppose the large flow increases its sending rate to 80 thousand packets per second. What is the rate at which the large flow's packets are sent over the link?

   *The arriving packet rate is now 120 Kp/s, so the traffic intensity is 1.2. So only 5/6 of the arriving traffic can be sent on the link. So the large flow is able to send 80*5/6 or about 66.7 Kp/s.*

   What is the rate at which one of the slow flow's traffic leaves the queue?

   *10*5/6 or about 8.3 Kp/s*

   Suppose the router is equipped with 5 queues that can hold 1,000 packets each, and that are serviced in round-robin order, with each flow assigned to a separate queue. In this case, what is the output rate for the large flow?

   In this case, only the large flow will experience loss, so the 20 Kp/s of excess traffic is all taken from the large flow. Hence, its output rate is 60 Kp/s.

   Approximately what is the delay experienced by packets in the large flow (those that are not discarded)?

   Since the small flows use 40% of the link's capacity, the large flow sends a packet every 10/0.6 microseconds. This is 16.7 microseconds, so the total queueing delay is 16.7 ms.

5. (10 points) Consider a classical 10 Mbs Ethernet. Suppose we require that the network operate at an efficiency of at least 80% when all packets have minimum length (ignore the preamble and flag, when making this calculation). Approximately what is the largest propagation delay that is consistent with this requirement?

   $(T_{trans}/T_{prop})/(5+(T_{trans}/T_{prop})=0.8$ implies $(T_{trans}/T_{prop})=20$

   A minimum length packet is 64 bytes, which is 512 bits. So T_{trans} is about 50 μs, this implies T_{prop} can be at most 2.5 us.

   What is the maximum distance across the network, assuming signals travel at a speed of 200,000 km/s?

   The max distance is 500 meters.

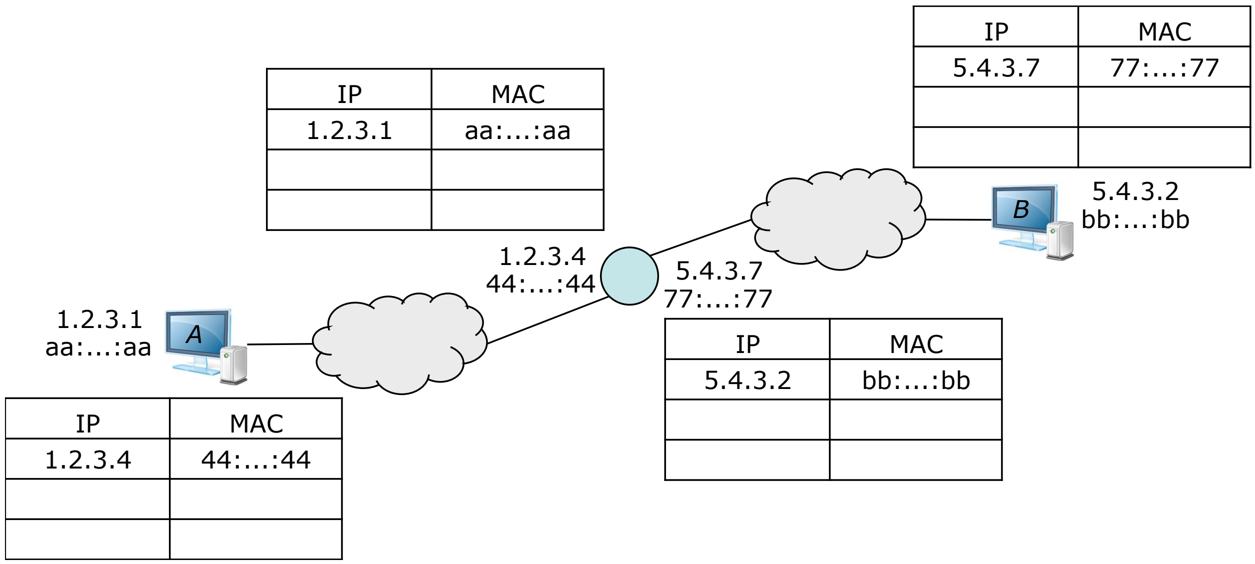
   What is the maximum distance if the Ethernet speed increases to 100 Mb/s?

   50 meters.

   Consider a 100 Mb/s ethernet with a maximum distance of 400 meters. What is the smallest packet length for which you can achieve an efficiency of 80%?

   8 times the minimum length, so 512 bytes.

6. (10 points) The diagram below shows two subnets connected by a router. For each host and router port, the IP address and MAC address (abbreviated) are shown. Initially the ARP tables of the hosts and router are empty. Suppose *A* sends a packet to *B*. Show the contents of the ARP tables after the packet reaches *B*.



Assuming that each of the switched subnets has 100 desktop client computers and one server machine, approximately how many ARP table entries would host *A* typically have.

Two, one for the router, and one for the server.

How many would the router have?

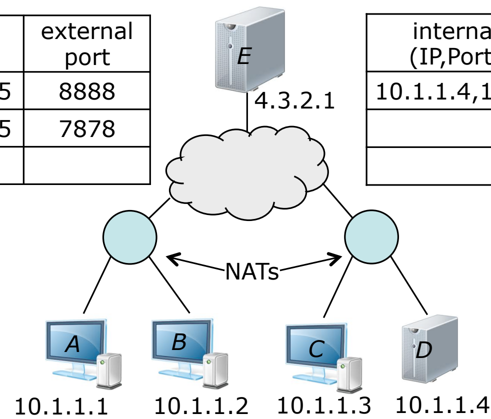
Close to 200, since it could be communicating with all the hosts in both networks.

Suppose there is a server connected to the router by a point-to-point link and no other network connection. How many ARP table entries would it require?

Just one.

7. (15 points). The diagram below shows two residential networks with routers that implement NAT and a remote server with a public internet address

internal (IP,Port)	external port
10.1.1.1,5555	8888
10.1.1.2,6565	7878



internal (IP,Port)	external port
10.1.1.4,1212	5454

The packet header diagrams at right are for a packet from a host in the left-hand network, going to the server. The first shows the header when the packet arrives at the router, the second shows it when the packet leaves the router. Add an entry to the left-hand NAT table that is consistent with these two packet headers. What is the public IP address of the left-hand router?

src adr	dest adr	src port	dest port
10.1.1.1	4.3.2.1	5555	3333
3.7.5.7	4.3.2.1	8888	3333

3.7.5.7

The three header diagrams at right are for a packet from a host in the right-hand network, going to a host in the left-hand network. Fill in the blank fields. Add entries to the two NAT tables that are consistent with this sequence of packet headers. What is the public IP address of the right-hand router?

src adr	dest adr	src port	dest port
10.1.1.4	3.7.5.7	1212	7878
5.3.5.2	3.7.5.7	5454	7878
5.3.5.2	10.1.1.2	5454	6565

5.3.5.2

In the diagrams at right, fill in the header fields that would be used by a response to the last packet, (the response goes from the right hand network to the left).

src adr	dest adr	src port	dest port
10.1.1.2	5.3.5.2	6565	5454
3.7.5.7	5.3.5.2	7878	5454
3.7.5.7	10.1.1.4	7878	1212