COMP 4621 Computer Communication Networks

Spring Semester 2014

Final Examination

Date: May 22, 2014 (Thursdays) **Time: 4:30 pm - 7:30 pm**

Name: __________________ Student ID: ________________Email: __________________

Note: Please write your *name*, *student ID,* and *section* **on this page**. Read the following instructions carefully.

1. This is a **CLOSED** book exam!
2. This examination paper consists of **7** questions and **10** pages (including this page).
3. You have 180 minutes to complete this exam.
4. All questions can be answered within the space provided on the examination paper. You may use back of the pages for your rough work. Be concise! This is NOT an essay contest.
5. Please read each question very carefully and answer the question clearly to the point.
6. Make sure that your answers are neatly written, legible, and readable.
7. Show all the steps used in deriving your answer, wherever appropriate.

Question	Points	Score
1	30	
2	20	
3	8	
4	10	
5	10	
6	12	
7	10	
Total	100	

1. Please answer following questions. (30 points)

a) What's the relationship between TCP RTT (round trip time) and RTO (retransmission timeout)? (5 points)

Answer:

Once getting a sample of RTT, TCP updates EstimatedRTT as follows:

$$EstimatedRTT = (1 - \alpha) \times EstimatedRTT + \alpha \times SampleRTT$$

Furthermore, we also maintain the deviation of RTT as follows:

$$DevRTT = (1 - \beta) \times DevRTT + \beta \times |SampleRTT - EstimaedRTT|$$

Based on above two formulations, RTT is given as:

$$RTO = EstimatedRTT + 4 \times DevRTT$$

1) RTO should be larger than EstimatedRTT. Otherwise, it will trigger many unnecessary spurious retransmissions. (3 points)
2) RTO should not be much larger than EstimatedRTT. Otherwise, TCP cannot retransmit lost packets as soon as possible. (2 points)

b) Please describe the principles of traceroute. (5 points)

Answer:

Traceroute works by sending serious of UDP packets with gradually increasing TTL value, starting with TTL value of 1. The first router receives the packet, decrements the TTL value and drops the packet because it then has TTL value zero. The router sends an ICMP Time Exceeded message back to the source. The next set of packets are given a TTL value of 2, so the first router forwards the packets, but the second router drops them and replies with ICMP Time Exceeded. Proceeding in this way, Traceroute uses the returned ICMP Time Exceeded messages to build a list of routers that packets traverse, until the destination is reached and returns an ICMP Echo Reply message.

c) What are the differences between switch (layer 2) and router? (5 points)

Answer:

Layer 2 switch forwards packets based on MAC addresses. It works on link layer.
Router forwards packets based on IP addresses. It works on network layer.

d) Why is an ARP (Address Resolution Protocol) query sent by using a broadcast frame? Why is an ARP response sent within a frame with a specific destination MAC address? (5 points)

Answer:

When sending the ARP query, you have no idea about which end host will reply this request. Using a broadcast frame ensures that every end host can receive this query. (3 points)

When sending the ARP response, you have already known which end host generates the ARP request. Using specific destination MAC address ensures that end host can receive your response. (2 points)

e) Why is slotted Aloha more efficient than pure (unslotted Aloha)? (5 points)

Answer:

Slotted Aloha:

Time is divided into equal size slots and all nodes are synchronized. Collision happens when two or more servers transmit the packets in the same time slot. The efficiency of the system is $Np(1-p)^{N-1} \leq \frac{1}{e}$

Unslotted Aloha:

Unslotted Aloha eliminates the synchronization of all nodes. **This increases the collision probability**. Frame sent at t0 collides with other frames sent in [t0-1,t0+1]. Its efficiency is $Np(1-p)^{2(N-1)} \leq \frac{1}{2e}$, even worse than slotted Aloha.

f) Please describe the principles of CSMA/CD. (5 points)

Answer:

1) If NIC senses channel idle, starts frame transmission. If NIC senses channel busy, waits until channel idle, then transmits.

2) If NIC transmits entire frame without detecting another transmission, NIC is done with frame.

3) If NIC detects another transmission while transmitting, aborts and sends jam signal. After aborting, NIC enters binary (exponential) backoff.

2. Consider that only a single TCP (Reno) connection uses one 10Mbps link which **does not buffer any data**. Suppose that this link is the only congested link between the sending and receiving hosts. Assume that the TCP sender has a huge file to send to the receiver, and the receiver's receive buffer is much larger than the congestion window. We also make the following assumptions: each TCP segment size is 1,500 bytes; the two-way propagation delay of this connection is 150 msec; and this TCP connection is always in congestion avoidance phase, that is, ignore slow start. It means that the congestion window is increased by one segment each RTT and reduced to half of current value when packet losses happen (20 points)

a) What is the maximum window size (in segments) that this TCP connection can achieve? (3 points)

Answer:

Let W denote the max window size measured in segments. Then, W*MSS/RTT = 10Mbps, as packets will be dropped if the maximum sending rate exceeds link capacity. Thus, we have W*1500*8/0.15=10*10^6, then W is about 125 segments.

Bps=Bit per second   1 Byte=8 Bits

Many students don't know this and get result of 1000. For this case, TA will give you 2 points.

b) What is the average window size (in segments) and average throughput (in bps) of this TCP connection? (4 points)

Answer:

As congestion window size varies from W/2 to W, then the average window size is 0.75W=94 (ceiling of 93.75) segments. Average throughput is 94*1500*8/0.15 =7.52Mbps.

If you have proved average window is 0.75 max window but got wrong result, TA will give you 2points.

c) How long would it take for this TCP connection to reach its maximum window again after recovering from a packet loss? (3 points)

Answer:

125/2 *0.15 = 9.375 seconds, as the number of RTTs (that this TCP connections needs in order to increase its window size from W/2 to W) is given by W/2. Recall the window size increases by one in each RTT.

d) Suppose that the 10Mbps link **can buffer a finite number of segments**. Argue that in order for the link to always be busy sending data, we would like to choose a buffer size that is at least the product of the link speed *C* and the two-way propagation delay between the sender and the receiver. (6 points)

Answer:

Let W denote max window size. Let S denote the buffer size. For simplicity, suppose TCP sender sends data packets in a round by round fashion, with each round corresponding to a RTT. If the window size reaches W, then a loss occurs. Then the sender will cut its congestion window size by half, and waits for the ACKs for W/2 outstanding packets before it starts sending data segments again. In order to make sure the link always busying sending data, we need to let the link busy sending data in the period W/(2*C) (this is the time interval where the sender is waiting for the ACKs for the W/2 outstanding packets). Thus, S/C must be no less than W/(2*C), that is, S>=W/2.

Let Tp denote the one-way propagation delay between the sender and the receiver.

When the window size reaches the minimum W/2 and the buffer is empty, we need to make sure the link is also busy sending data. Thus, we must have W/2/(2Tp)>=C, thus, W/2>=C*2Tp.

Thus, S>=C*2Tp.

e) Based on sub question d, can you summarize the functions of switch buffer? (4 points)

Answer:

Switch buffer is used to absorb bursty traffic and maintain high link utilization.

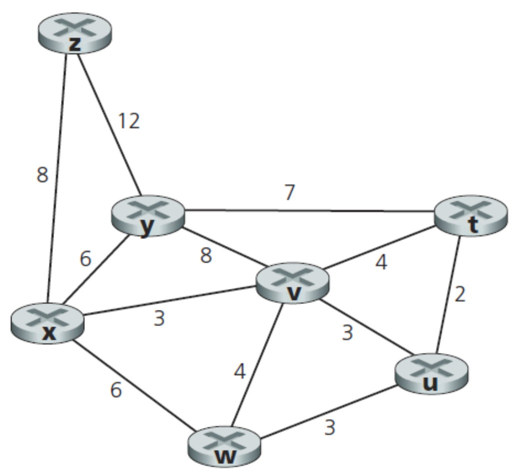
3. Consider sending a 4000 byte IP datagram into a link that has an MTU of 1500 bytes. The IP header length is 20 bytes. Suppose the original datagram is stamped with the identification number 422. How many fragments are generated? What are the values in the field IP length, ID, Fragmentation Flag and Offset in these IP datagrams? (8 points)

Answer:

Three fragments are generated.

	IP length	ID	Fragmentation Flag	Offset
Fragmentation 1	1500	422	1	0
Fragmentation 2	1500	422	1	185
Fragmentation 3	1040	422	0	370

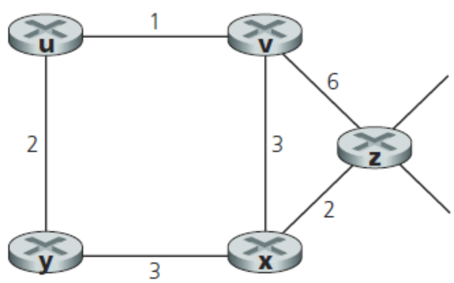
4. Consider the following network. With the indicated link costs, use Dijkstra's shortest-path algorithm to compute the shortest path from *x* to all network nodes. (Hint: for your convenience, you can show how algorithm works by computing a table.) (10 points)



Answer:

Step	*N'*	*D(t),p(t)*	*D(u),p(u)*	*D(v),p(v)*	*D(w),p(w)*	*D(y),p(y)*	*D(z),p(z)*
0	x	∞	∞	3,x	6,x	6,x	8,x
1	xv	7,v	6,v	3,x	6,x	6,x	8,x
2	xvu	7,v	6,v	3,x	6,x	6,x	8,x
3	xvuw	7,v	6,v	3,x	6,x	6,x	8,x
4	xvuwy	7,v	6,v	3,x	6,x	6,x	8,x
5	xvuwyt	7,v	6,v	3,x	6,x	6,x	8,x
6	xvuwytz	7,v	6,v	3,x	6,x	6,x	8,x

5. Consider the network shown below, and assume that each node initially knows the costs to each of its neighbors. Consider the distance-vector algorithm and show the distance table entries at node z. (10 points)



Answer:

Cost to

		u	v	x	y	z
	v	∞	∞	∞	∞	∞
From	x	∞	∞	∞	∞	∞
	z	∞	6	2	∞	0

Cost to

		u	v	x	y	z
	v	1	0	3	∞	6
From	x	∞	3	0	3	2
	z	7	5	2	5	0

Cost to

		u	v	x	y	z
	v	1	0	3	3	5
From	x	4	3	0	3	2
	z	6	5	2	5	0

Cost to

		u	v	x	y	z
	v	1	0	3	3	5
From	x	4	3	0	3	2
	z	6	5	2	5	0

6. Suppose three active nodes – Nodes A, B and C – are competing for access to a channel using slotted ALOHA. Assume each node has an infinite number of packets to send. Each node attempts to transmit in each slot with probability p. The first slot is numbered slot 1, the second slot is numbered slot 2, and so on. (12 points)

a) What is the probability that node A succeeds for the first time in slot 10? (3 points)

Answer:

p(A) = probability that A succeeds in a slot
p(A)= p(A transmits and B does not and C does not)
= p(A transmits) p(B does not transmit) p(C does not transmit)
= $p(1-p)^2$

Hence, p(A succeeds for first time in slot 10
= $\left(1-p(A)\right)^9 p(A)$
= $(1-p(1-p)^2)^9 p(1-p)^2$

b) What is the probability that some node (either A, B, or C) succeeds in slot 3? (3 points)

Answer:

p(A succeeds in slot 3) = $p(1-p)^2$
p(B succeeds in slot 3) = $p(1-p)^2$
p(C succeeds in slot 3) = $p(1-p)^2$
p(either A or B or C succeeds in slot 3= $3p(1-p)^2$

c) What is the probability that the first success occurs in slot 10? (3 points)

Answer:

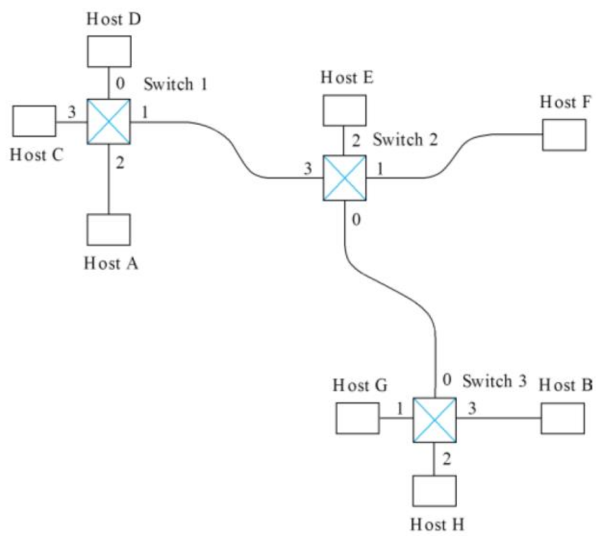
p(some node succeeds in a slot) = $3p(1-p)^2$
p(no node succeeds in a slot) = $1-3p(1-p)^2$
Hence, p(first success occurs in slot 10)
= p(no node succeeds in first 9 slots) p(some node succeeds in 10th slot)
= $(1-3p(1-p)^2)^9 3p(1-p)^2$

d) What is the efficiency of this three-node system? (3 points)

Answer:

efficiency = p(success in a slot) = $3p(1-p)^2$

7. Consider the local area network shown above where switches 1 2 and 3 are self-learning switches. Assume that initially the entire switch tables are empty and that host A sends a frame to host B. (10 points)



a) Do switches 1, 2 and 3 learn how to reach host A? (1 point)
Answer:

Yes, because the tables are initially empty the frame be flooded until it reaches B and thus will traverse all three switches and so all three switches will learn how to reach A

b) Do switches 1, 2, and 3 learn how to reach host B? (1 point)
Answer:

No switch learns how to reach host B

c) Does this frame reach the Interface card of host F? (1 point)
Answer:

Yes, because the tables are initially empty the frame is flooded so it will reach F.

Assume now that host F sends a frame to host A.

d) Do switches 1, 2 and 3 learn how to reach host F? (1 point)
Answer:

Switches 1 and 2 will learn how to reach F because the frame will traverse them. Switch 3 does not as it will not see this frame, because Switch 2 only forwards this frame to port 3.

e) Does this frame reach the Interface card of host C? (1 point)
Answer:

For the same reason as above switch 1 forwards this frame to port 2 only so C will not see this frame.

Assume now that host B sends a frame to host F.

f) Do switches 1, 2 and 3 learn how to reach host B? (1 point)

Answer:

Switches 3 and 2 will see this frame and so both will learn how to reach B. Switch 1 will not see the frame because Switch 2 only forwards it to port 1 and thus it will not reach Switch 1.

g) Does this frame reach the Interface card of hosts G, E? (1 point)

Answer:

Since switch 3 does not know how to reach F then it will flood the frame and thus host G will see it. Conversely, since switch 2 knows how to reach F it will forward the frame to F directly on port 1.

h) Show the contents of the switch tables for switches 1, 2 and 3 after the exchange of these frames is completed. (3 points)

Answer:

Switch 1

MAC	Port
Host A	2
Host F	1

Switch 2

MAC	Port
Host A	3
Host F	1
Host B	0

Switch 3

MAC	Port
Host A	0
Host B	3