Final Examination – Solutions

Closed Book, Closed Notes
(One A-4 sheet written on both sides is allowed without any magnifying glasses)
Time Allowed = 2 hours (17/05/2003)

“I certify that I have neither received nor given unpermitted aid on this examination and that I have reported all such incidents observed by me in which unpermitted aid is given.”

Signature ________________________________

Name ________________________________ Student ID ________________________________

Problem 1 ________________ [40]
Problem 2 ________________ [40]
Problem 3 ________________ [20]
Problem 4 ________________ [20]
Problem 5 ________________ [10]
Problem 6 ________________ [20]

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TOTAL ________________ [150]
Problem 1: True/False Questions [40pts] Each of the following statements is either true or false. Indicate so by circling the correct letter, T or F. For each correct indication you will get two points, and for each wrong indication you will lose one point. If you leave a statement or if you circle both T and F, you will get a 0 on that part.

(a) [ T / F ] A maximum-size match is always greater than a maximal-size match.
(b) [ T / F ] During “scanning”, in 802.11 MAC, a network interface card (NIC) in a station searches for an access point.
(c) [ T / F ] A problem with MPLS deployment is that MPLS clouds can not coexist with the IP-based networks.
(d) [ T / F ] Hidden terminal problem does not exist in wired (or wire line) networks.
(e) [ T / F ] Output-queued switches generally have longer mean queue lengths compared to those of input-queued switches.
(f) [ T / F ] In an input-queued switch with one queue per output at each input, maximum-weight matching is computationally more intensive than the maximum-size matching.
(g) [ T / F ] Round-robin queue scheduling policy is fair if the packet sizes are equal.
(h) [ T / F ] The iSLIP scheduling algorithm is applicable to output-queued switches.
(i) [ T / F ] In IPv4 addressing scheme, there are more class-B IP addresses than class-A IP addresses.
(j) [ T / F ] In IPv4 addressing scheme, there are more class-B IP addresses than class-C IP addresses.
(k) [ T / F ] A label in MPLS is a short, fixed-length field attached with a packet.
(l) [ T / F ] Functionally, there is no difference between a label switch router (LSR) and a label edge router (LER).
(m) [ T / F ] Primary difference between “IP switching” and MPLS is that switching is done on the basis of IP addresses in “IP switching”, while in MPLS switching is done on the basis of short labels.
(n) [ T / F ] In MPLS, label assignment/binding is always done by the downstream routers.
(o) [T / F] IEEE 802.11b is a standard for wireless LANs.

(p) [T / F] In TCP slow-start phase, the sender increases the window size by two for each ACK received.

(q) [T / F] In TCP slow-start phase, the sender sends two packets for each ACK received.

(r) [T / F] In TCP “congestion-avoidance” phase, the sender sends one packet for each ACK received.

(s) [T / F] In a wireless ad hoc network, stations communicate with each other with the help of a base station.

(t) [T / F] In a wireless ad hoc network, stations communicate with each other with the help of an access point.

(u) [T / F] This statement is false.
Problem 2: Multiple Choice Questions [40pts] For each of the following statements, multiple answers are given. Indicate the best choice by circling it. For each correct indication you will get three points, and for each wrong indication you will lose one point. If you leave a statement or if you circle more than one choices, you will get a 0 on that part.

(I) It is well-known that an input-queued switch with large number of inputs and outputs has a utilization of 58.6% for independent and uniform traffic. The switch is assumed to have infinite buffers at the inputs. Take such a switch and consider that the input rate is 38.6%. The output rate is:

(a) 0%
(b) [less than 38.6%]
(c) 58.6%
(d) 63.2
(e) 75%

(II) For the switch in above part, assume that we make a policy to drop packets at the end of each time slot. If the input rate is 78%, the output rate is less than:

(a) 0%
(b) 38.6%
(c) 48.6%
(d) 58.6%
(e) 63.2%

(III) For the switch in above part, the input rate is 94%, the output rate will be:

(a) 0%
(b) 38.6%
(c) 58.6%
(d) 63.2%
(e) 75%

(IV) A Knockout switch is:

(a) an input-queued switch
(b) an output-queued switch
(c) a combined input-output queued switch
(d) all of the above
(e) none of the above

(V) In a Batcher-Banyan network, the Banyan part is:
(a) optional if input sequence is a complete permutation with no missing tags
(b) used to correctly route the sequence sorted by the Batcher network
(c) required if the input sequence is a complete permutation but has missing tags
(d) all of the above
(e) none of the above

(VI) In computer networks, bridges do the following:
(a) they perform an IP address lookup
(b) they switch based on network layer address
(c) they forward physical packets
(d) both b) and c)
(e) none of the above

(VII) In computer networks, routers do the following:
(a) they perform an IP address lookup
(b) they switch based on network layer address
(c) they forward physical packets
(d) all of the above
(e) only a) and b)

(VIII) When a packet travels through an MPLS network, an upstream router would see the packet:
(a) before a corresponding downstream router
(b) after a corresponding downstream router
(c) at the same time as a corresponding downstream router
(d) both a) or c) can be correct  
(e) both b) or c) can be correct

(IX) In an MPLS network, a label switch router (LSR), which is neither an ingress router nor an egress router, can be:

(a) a downstream router  
(b) an upstream router  
(c) either a) or b) but not both  
(d) both a) and b)  
(e) none of the above

(X) In an MPLS network, a label edge router (LER), which is either an ingress router or an egress router, can be:

(a) a downstream router  
(b) an upstream router  
(c) either a) or b) but not both  
(d) both a) and b)  
(e) none of the above

(XI) An 802.11b network can:

(a) be an ad hoc network  
(b) be an infrastructure-based network  
(c) be operated at 55 Mb/s  
(d) all of the above  
(e) only a) and b)

(XII) The number of outstanding packets TCP/IP can send without receiving any acknowledgements (ACKs) is always:

(a) smaller than the congestion window size  
(b) greater than the congestion window size  
(c) smaller than or equal to the congestion window size  
(d) greater than or equal to the congestion window size
(e) none of the above

(XIII) RED gateways:

(a) can only be used when sources are cooperative
(b) can only be used when sources are non-cooperative
(c) require significant changes in the TCP/IP protocol stack
(d) lead to global synchronization of sources
(e) none of the above

(XIV) Amount of workload in this course is:

(a) way below average
(b) somewhat below average
(c) about average
(d) somewhat above average
(e) way above average
Problem 3: Short Questions [20pts] Answer the following questions only using the space provided. Write your short answers legibly and in a concise manner. It is guaranteed that there is a short and correct answer. Long answers are less likely to be correct. No credit will be given if you write more than one answer and at least one of them is wrong.

(A) [5pts] It is well-known that an input-queued switch with large number of inputs and outputs has a utilization of 58.6% for independent and uniform traffic. Without changing the switch size, number of queues per input, and input traffic pattern, this utilization can be increased to 63.2% by employing some queueing policy. What could be that policy? Intuitively, why would this policy work?

Solution: At the end of each packet slot, dropping the packets that could not be serviced would increase the maximum throughput to 63.2%. This policy works because it eliminates head-of-line (HOL) blocking.

(B) [5pts] What is the solution for hidden terminal problem? Is this solution available in 802.11b networks? Does this solution has any overheads? If there are overheads, what are those?

Solution: A solution for hidden terminal problem is to use request to send (RTS) and clear to send (CTS) signals prior to actual transmission. This solution is available in 802.11b networks. There are overheads associated with this solution. These overheads are extra signals (RTS and CTS) which decrease channel utilization.

(C) [5pts] Why would you ever want to adjust the window size in TCP? Note that this is done in both slow-start and congestion-avoidance phases. Simply state the objective.

Solution: This is simply to match the transmit characteristics to those of network (congestion control) and receiver (flow control).

(D) [5pts] For longest prefix matching using binary search, what is the entity on which the binary search is carried out? Provide a precise answer.

Solution: The length of the prefixes to which an input string is matched.
Problem 4: IP Prefixes [20pts] This problem is concerned with building a trie from a set (or dictionary) of prefixes which are strings of 0s and 1s. Recall that a trie is a modified binary tree in which each node keeps information about its own identity — the prefix it identifies. A node is flagged, perhaps by setting a boolean in the node data structure itself, if its identity matches any element in the dictionary of prefixes. Thus, the number of flagged nodes in a complete trie is equal to the number of elements—the prefixes—in the dictionary. Following rules are applied for creation, insertion, deletion, and lookup:

Creation: For each prefix in the dictionary, use the prefix and traverse with the convention of 0 to left and 1 to right, creating nodes on the way if they do not exist already. When the prefix is finished, flag the node as existing in the dictionary.

Insertion: same as creation.

Deletion: Traverse to the node to be deleted using the identity provided following the usual convention of 0 to left and 1 to right. For non-leaf nodes, simply unflag the node. For leaf nodes, delete the node noting the status of its parent; if the parent is either flagged or has other branches, leave it as is, otherwise, delete it recursively.

Lookup: Use the string whose prefix is to be looked up to traverse the trie with the usual convention of 0 to left and 1 to right. While traversing keep track of last flagged node until you can not proceed further along the trie for you have either reached a leaf node or there is no branch to follow according the given string.

(a) Draw a trie for the following dictionary of prefixes. Label each node and indicate if they are flagged by putting a star (*) on them. The start of your trie is given in the figure.

\{*, 00*, 101*, 1101*, 1101001*, 11110*, 111101*\}

Solution: See complete figure.
(b) In part (a), what is the longest matching prefix for:

$$1101\ 0001\ 1011\ 0000\ 1100\ 1010\ 0001\ 1111?$$

**Solution:** The longest matching prefix is 1101.

(c) Insert prefixes $1000^*$ and $1101000^*$ to the trie in part (a) and redraw the new trie.

**Solution:** See complete figure.

(d) In part (c), what is the longest matching prefix for:

$$1101\ 0001\ 1011\ 0000\ 1100\ 1010\ 0001\ 1111?$$

**Solution:** The longest matching prefix is 1101000.

(e) Now delete the prefix 1101001* from the trie in part (c) and redraw the new trie.

**Solution:** See complete figure.

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Problem 5: MPLS Label Associations [10pts] In this problem, we examine the scope and uniqueness of labels in an MPLS cloud. Recall that each single-hop link has an upstream router and a downstream router. In the following $R_d$ denotes the downstream router while $R_{u1}$ and $R_{u2}$ denote two upstream routers. Labels are indicated by $L_1$ and $L_2$ while forwarding equivalence classes (FECs) are indicated by $F_1$ and $F_2$.

Consider the following figure and provide YES/NO answers to the questions. In case your answer needs explanation or requires certain conditions, state those explicitly and clearly.

Figure 1: Figure: MPLS Label and FEC Associations

(i) [2pts] If $F_1 = F_2$, can $L_1$ be different from $L_2$?

Solution: YES!

(ii) [3pts] If $F_1 = F_2$, can $L_1$ be equal to $L_2$?

Solution: YES!

(iii) [2pts] If $L_1 = L_2$, can $F_1$ be same as $F_2$?

Solution: YES!

(iv) [3pts] If $L_1 = L_2$, can $F_1$ be different from $F_2$?

Solution: YES — only if $R_d$ can distinguish between packets coming from $R_{u1}$ and $R_{u2}$.

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Problem 6: Packet Radio [20pts] A wireless communication channel is shared by \( N \) users who transmit data packets at time \( t = 0, 1, 2, \ldots \), where \( t \) is in seconds. That is, transmissions may occur only at one second boundaries. It is assumed that all the transmitters are synchronized and each will transmit with a probability \( p \) at allowed time instants. A collision is said to occur at a transmission instant if and only if more than one packets are transmitted. Answer the following in terms of \( N \) and \( p \):

(a) [3pts] At a given transmission opportunity, what are the chances that a particular user would be able to transmit successfully?

\[ P_1 = p(1-p)^{N-1} \]

(b) [3pts] At a given transmission opportunity, what are the chances of no collision?

\[ P_2 = Np(1-p)^{N-1} + (1-p)^N = (1-p)^{N-1}(1 - p + Np) \]

(c) [3pts] What are the chances of no collision at three consecutive transmission opportunities? (Hint: A collision will not happen unless at least two stations transmit at the same instant)

\[ P_3^2 \]

(d) [3pts] For a particular user, how long will it take, on average, to transmit the first successful packet?

\[ \frac{1}{P_1} \]

(e) [4pts] For a particular user, how long will it take, on average, to transmit three successful packets?

\[ \frac{3}{P_1} \]

(f) [4pts] For a particular user, how long will it take, on average, to transmit three successful packets at three consecutive transmission opportunities?

\[ \frac{1}{P_3^2} \]