Name_____ Student ID_____ Department/Year_____

Final Examination

Introduction to Computer Networks
Class#: 901 E31110
Fall 2014

9:30-11:10 Wednesday
January 14, 2015

Prohibited

1. You are not allowed to write down the answers using pencils. Use only black- or blue-inked pens.
2. You are not allowed to read books or any references not on the question sheets.
3. You are not allowed to use calculators or electronic devices in any form.
4. You are not allowed to use extra sheets of papers.
5. You are not allowed to have any oral, visual, gesture exchange about the exam questions or answers during the exam.

Cautions

1. Check if you get 12 pages (including this title page), 6 questions.
2. Write your **name in Chinese**, student ID, and department/year down on top of the first page.
3. There are in total 100 points to earn. You have 100 minutes to answer the questions. Skim through all questions and start from the questions you are more confident with.
4. Use only English to answer the questions. Misspelling and grammar errors will be tolerated, but you want to make sure with those errors your answers will still make sense.
5. If you have any extra-exam emergency or problem regarding the exam questions, raise your hand quietly. The exam administrator will approach you and deal with the problem.

1. (TCP) Consider traces of TCP congestion window size recorded over time from 5 different connections.

   Connection A: 1, 2, 4, 8, 16, 17, 18, 19
   Connection B: 1, 2, 4, 8, 9, 10, 11, 12
   Connection C: 1, 2, 4, 5, 6, 3, 4, 5
   Connection D: 1, 2, 3, 4, 1, 2, 3, 4
   Connection E: 1, 2, 4, 8, 16, 32, 1, 2

   (a) Which of the connection(s) ended in the congestion avoidance state at the end of the recording? (4%)
   (b) Sort and list the initial slow start threshold of the 5 connections (from the highest to the lowest). (4%)
   (c) Which of the connection(s) experienced a packet loss detected by receiving 3 duplicate acknowledgement packets? (4%)
   (d) Which of the connection(s) experienced a packet loss detected by not receiving any new acknowledgement packet after a retransmission timeout event? (4%)

   Sample Solution:
   (a) ABCD
   (b) EABCD
   (c) C
   (d) DE

2. (Forwarding) One of the main jobs a router is responsible for is forwarding packets. Consider a router containing a forwarding table as follows.

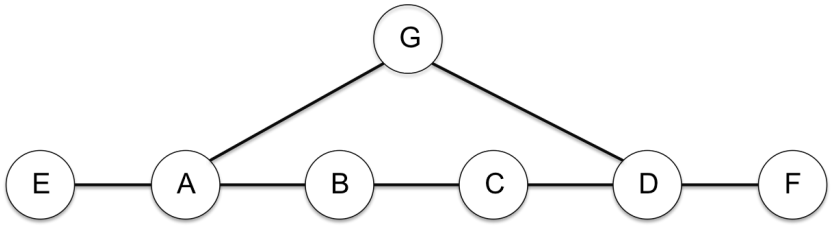
Destination Prefix	Interface
222.222.222.0/24	1
111.111.0.0/16	2
111.111.111.0/24	3
333.0.0.0/8	4
default	5

Now 4 packets come along with the following destination addresses. Based on the longest match principle, which interfaces will the 4 packets be forwarded to?

(a) 111.111.111.111 (4%)
(b) 222.222.222.222 (4%)
(c) 333.333.333.333 (4%)
(d) 444.444.444.444 (4%)

Sample Solution:
(a) 3
(b) 1
(c) 4
(d) 5

3. (Routing) Internet is a network of Autonomous Systems (ASs). Below is a hypothetical Internet at the AS level. It is observed that AS A, B, C, and D passes traffic coming from all adjacent ASs. AS G, however, does not.



(a) Which of the AS(s) are stub ASs, multi-homed stub ASs, and transit ASs? (4%)
(b) BGP is known as THE routing protocol running inter-AS. If AS G does not forward traffic from A to D, nor D to A, what is likely the path used to send an email from AS E to F? (4%)
(c) Assume all link costs are the same. If a link state routing protocol is running inter-AS instead of BGP, what is the path chosen to send an email from AS E to F? (4%)
(d) How may the administrator configure the BGP routers in AS G to prevent forwarding traffic for A to D, or for D to A? (4%)
(e) Why do you think AS G would prefer not to forward traffic for A to D, or for D to A? (4%)

Sample Solution:
(a) stub: EF, multi-homed stub: G, transit: ABCD
(b) E-A-B-C-D-F
(c) E-A-G-D-F
(d) Make sure the BGP route advertisements from AS G contain only destinations in AS G
(e) There's no 'one' correct answer for this question. Describe one possibility and justify for your answer. Here's one example answer: Sending out or receiving in traffic costs $$ for an AS. G would not mind receiving/sending traffic for users from within. The internal users pay for the cost of the traffic sent/received. But, for other traffic not originated/destined from/to G, the senders/receivers of the traffic do not pay G. To sustain financially, G would be reluctant to forward traffic from A to D or vice versa.

4. (MAC) Consider a multi-access link where there are 4 nodes sharing the link's bandwidth, B bps. During the day, users of the 4 nodes are all working and need to send data. During the night, only the users on 1 node remain.

   (a) Suppose this multi-access link runs a TDMA protocol where a cycle is equally divided into 4 slots. Each slot is allocated to each of the 4 nodes. How long does it take for all nodes to finish sending T bits each at the same time during the day? How long does it take for the working node to finish sending T bits during the night? (4%)
   (b) Suppose this multi-access link runs a Token Ring protocol. How long does it take for all nodes to finish sending T bits of data each at the same time during the day? How long does it take for the working node to finish sending T bits during the night? (4%)
   (c) Suppose this multi-access link runs a CSMA/CD protocol. How long does it take for each node to finish sending T bits at the same during the day? How long does it take for the working node to finish sending T bits during the night? In case of collisions, suppose the amount of extra bits to transmit due to collision is T' per node. (4%)
   (d) Can you identify a protocol that performs well both during the day and the night and which protocol is it? (4%)

   Sample Solution:
   (a) 4T/B, 4T/B
   (b) 4T/B, T/B
   (c) 4(T+T')/B, T/B
   (d) Yes, Token Ring

5. (Wireless) The MAC protocol used in Ethernet is based on CSMA/CD. CSMA/CD works as follows. A node on the multi-access link senses whether the link is idle before transmissions. If idle, then transmit. Otherwise, wait to sense at a later time. In case of simultaneous transmissions from multiple nodes, the collision is detected by sensing the link as well, and when a collision is detected, the transmission is dropped immediately so to reduce the bandwidth wastage. In Ethernet in particular, a retransmission will be attempted after a random exponential backoff wait. The MAC protocol used in WiFi is not CSMA/CD. It employs a mechanism based on CSMA/CA.

   (a) Why isn't CSMA/CD used for wireless links? (4%)
   (b) Describe how CSMA/CA works in principle? (4%)
   (c) What particular part of the mechanism in CSMA/CA is to ensure frames transmitted are indeed received by the receiver? (4%)
   (d) What particular part of the mechanism in CSMA/CA is to reduce the bandwidth wastage due to collision? (4%)

   Sample Solution:
   (a) Collisions might not be detected by all nodes involved in the transmission due to the hidden terminal effect.
   (b) A sender sends an RTS message before sending data. The receiver, upon receiving RTS, sends a CTS message back. The sender sends data after receiving the CTS message. The receiver sends an acknowledgement packet back when the data are received.
   (c) Sending of the acknowledgement packet back to data sender
   (d) Exchange of short RTS and CTS before sending of typically much bigger data packets.

6. (Playout) Internet telephone is the most prominent example of real-time interactive multimedia applications. In a typical telephone conversation, the users talk in spurts. There is then a short window of opportunity to adjust the playout delay before each talk spurt starts. Now consider an Internet call running on a steady path and the playout delay is determined based on the following equations.

$$d_i = (1-u) * d_{i-1} + u * (r_i - t_i)$$
$$v_i = (1-u) * v_{i-1} + u * (r_i - t_i - d_i)$$
$$pd_i = d_i + K * v_i$$

where

t_i : the time the ith packet is transmitted
r_i : the time the ith packet is received
d_i : the estimated average network delay after the ith packet
v_i : the estimated network delay deviation after the ith packet
pd_i : the playout delay, i.e., the time duration between the playout deadline and transmission time of the ith packet
u and K: constants and parameter choices

When pd_i is smaller than $r_i - t_i$, the ith packet has not yet arrived before the playout deadline and the ith packet will be a loss due to delay. Suppose the network delay between the caller and callee has remained 40ms consistently in the past. The initial average network delay (d_0) is therefore set to 40ms and the initial delay deviation (v_0) set to 0ms. Now suddenly, the network delay is changed to 80ms consistently for the rest of the call. Try if you can address the following questions.

(a) If u=0.5 and K=2, calculate (v_1, d_1). Would any of the packets miss the playout deadline and how many? (4%)
(b) Following (a), if K is reduced to 1, would any of the packets miss the playout deadline and how many? Show your calculation coming to the answer. (4%)
(c) Following (a), if u is reduced to 0.25, would any of the packets miss the playout deadline and how many? Show your calculation coming to the answer. (4%)
(d) We see from (b) and (c) how the value choices of u and K impact the amount of delay losses. Discuss how the choices of u and K impact the interactivity, i.e., the playout delay, comparing the playout delay in (a) to the playout delay in (b) and (c). (4%)

Sample Solution:
(a) (v_1, d_1) = (60, 10); no, 0; because pd_1 = 80 (>= 80)

(b) yes, 1; $(v_1, d_1) = (60, 10)$, $(v_2, d_2) = (70, 10)$; $pd_1 = 70$ (<80), $pd_2 = 80$

(c) yes, 1; $(v_1, d_1) = (50, 7.5)$, $(v_2, d_2) = (57.5, 11.25)$; $pd_1 = 65$ (<80), $pd_2 = 80$

(d) A smaller K always gives a higher level of interactivity (smaller playout delay). The value of u, however, is a bit tricky. In the scenario in consideration, a smaller u means the d_i is smaller. But the instantaneous deviation (r_i-t_i-d_i), as a result, is larger. The u value, used again in calculating the average deviation, is small enough to result in a smaller average deviation v_i after all. The level of interactivity reducing u from 0.5 to 0.25 in the scenario is also higher. In general, however and unlike K, a lowered u does not guarantee a higher level of interactivity.