Name_______________ Student ID____________________ Department/Year__________

Final Examination

Introduction to Computer Networks
Class#: 901 31110
Fall 2005

9:50-11:30 Tuesday
January 10, 2006

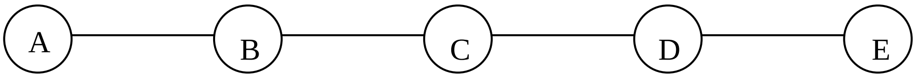
Prohibited

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 14 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 150 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. (LS Routing) Consider a 5-node string network as follows. The link costs are equal and the value is 1. Follow the link state (LS) routing principle to obtain the routing table.



(1) Suppose each node sends its link state (LS) report to all the outgoing links and then the LS reports are further propagated using the algorithm on the right to reach the whole network.

> ***if*** (LS report received on incoming link)
>   ***then*** flood LS report onto all but the incoming link

Suppose the LS reports are the same in size, M bytes each. In order for all nodes to receive LS reports from all other nodes, how many bytes of LS reports are transmitted over the network? (5%)

(2) Continue from (1). Suppose the delay to send a LS report over any link is T seconds. If A, B, C, D, and E nodes start sending their LS reports all at the same time, how much time does it take for all nodes to receive all LS reports? (5%)

(3) Continue from (1) and (2). Suppose all LS reports have arrived at all nodes. Compute the shortest paths from node A to every other node using the LS routing principle by filling in the blanks in the tables below. (5%)

Step	Travel Set	D(B),p(B)	D(C),p(C)	D(D),p(D)	D(E), p(E)
0	A	1,A	∞	∞	∞
1	AB	1,A	2,B	∞	∞
2	ABC	1,A	2,B	3,C	∞
3	ABCD	1,A	2,B	3,C	4,D
4	ABCDE				

Sample Solution:

(1) 20M bytes

Each LS report travels 4 links to reach all other nodes in the network. There are 5 reports in total. There are, therefore, 20M bytes consumed over the network to deliver the LS reports.

(2) 4T seconds

All nodes start simultaneously. In the worst case (A to E or E to A), it takes 4 hops to deliver the LS reports. That is, therefore, 4T seconds required to deliver the LS reports.

(3) See the filled-up table above

2. (DV Routing) Consider the same 5-node string network as in Problem 1. The link costs are equal and the value is 1. Follow the distance vector (DV) routing principle to obtain the routing table. Shown below are the initial routing tables for each node.

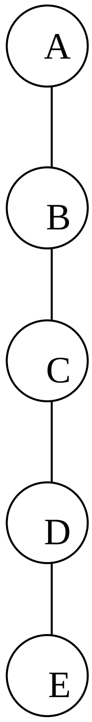
A	B	C	D	E
0.A	1.B	∞	∞	∞

A	B	C	D	E
1.A	0.B	1.C	∞	∞

A	B	C	D	E
∞	1.B	0.C	1.D	∞

A	B	C	D	E
∞	∞	1.C	0.D	1.E

A	B	C	D	E
∞	∞	∞	1.D	0.E



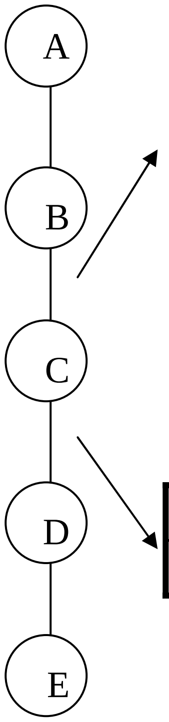
(1) C is the node who starts sending its routing table. Propagate the routing table and derive the final routing tables by filling in the blanks in the tables provided below. (5%)

(2) Continue from (1). Suppose the delay to send a DV routing table over any link is T seconds. What is the amount of time it takes for all nodes to converge to the shortest paths to all other nodes? (Hint: count the number of rounds.) (5%)

(3) Continue from (2). Suppose the DV routing tables are the same in size, M bytes each. In order for all nodes to converge to consistent shortest paths for all pairs, how many bytes of DV table are transmitted over all the links on the network? (Hint: count the number of arrows.) (5%)

Sample Solution:

(1)



A	B	C	D	E
0,A	1,B	**2,B**	**3,B**	∞

A	B	C	D	E
0,A	1,B	2,B	3,B	**4,B**

A	B	C	D	E
1,A	0,B	1,C	**2,C**	∞

A	B	C	D	E
1,A	0,B	1,C	2,C	**3,C**

A	B	C	D	E
1,A	0,B	1,C	2,C	3,C

A	B	C	D	E
2,B	1,B	0,C	1,D	**2,D**

A	B	C	D	E
2,B	1,B	0,C	1,D	2,D

A	B	C	D	E
∞	**2,C**	1,C	0,D	1,E

A	B	C	D	E
3,C	2,C	1,C	0,D	1,E

A	B	C	D	E
3,C	2,C	1,C	0,D	1,E

A	B	C	D	E
∞	**3,D**	**2,D**	1,D	0,E

A	B	C	D	E
4,D	3,D	2,D	1,D	0,E

(2) 5T seconds

5 rounds of DV routing table exchanges are done.

(3) 16M bytes

16 DV routing tables are sent in total.

3. (LS vs. DV) Continue from Problem 1 and 2. Suppose the LS report and DV routing tables are the same in size, M bytes each. And the delay to send a LS report or DV routing table over any link is T seconds. Compare and contrast the message overhead and convergence delay of LS and DV for a general 2K+1 node string network (K > 1).

   (1) If all nodes start sending their LS reports simultaneously, what is the time it takes for all nodes to receive all LS reports for a 2K+1 node string network? (5%)

   (2) Continue from (1). In order for all nodes to receive LS reports from all other nodes, how many bytes of LS reports are transmitted over a 2K+1 node string network? (5%)

   (3) Consider a 7-node string network. What is the time it takes for all nodes to converge to the shortest paths to every other node when the middle node is the starting point? (Hint: extend Problem 2 to populate the routing table exchanges for the 7-node string network.) (5%)

   (4) Continue from (3). In order for all nodes to converge to consistent shortest paths for all pairs, how many bytes of DV table are transmitted over all the links on the network? (5%)

   (5) Generalize (3) for 2K+1 node string network where the middle node is the starting point and represent the convergence delay in K and T. (Hint: observe routing table exchange for 3-node, 5-node, and 7-node string networks.) (5%)

   (6) Generalize (4) for 2K+1 node string network where the middle node is the starting point and represent the message overhead in K and M. (5%)

   (7) Compare for general 2K+1 string networks. Is LS or DV more bandwidth efficient? (5%)

   (8) Assume the route computation time is negligible. Compare for general 2K+1 string networks (K > 1). Is LS or DV faster in converging to the shortest paths for all pairs? (5%)

Sample Solution:

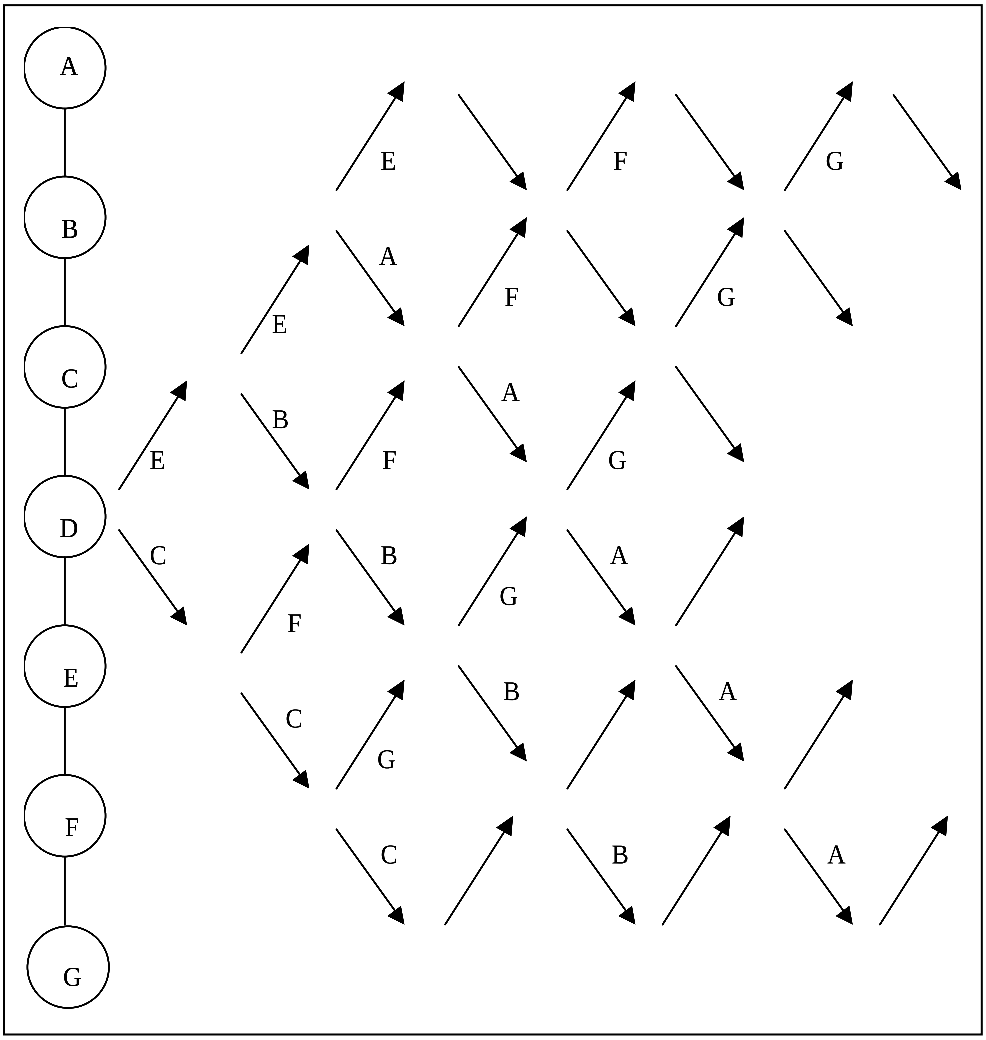
(1) LS – Overhead : (2K+1)*(2K) M = $(4K^2+2K)$M bytes

(2) LS – Time : 2KT seconds

(3) 8T seconds

(4) 36M bytes

7-node routing table exchange is illustrated below:



(5) DV – Overhead : $4K^2$ M bytes

3-node string: 4

5-node string: 16

7-node string: 36

(6) DV – Time : (3K-1)T seconds

3-node string: 2

5-node string: 5

7-node string: 8

(7) DV

(8) LS

4. (DHCP vs. ARP) Given the brief review of DHCP and ARP below, compare and contrast DHCP and ARP.

   DHCP works in 4 steps. (1) The DHCP client sends a DISCOVER message. (2) The DHCP server responds with an OFFER message. (3) The DHCP client sends a REQUEST message. (4) The DHCP server replies with an ACK message.

   ARP, on the other hand, works in 2 steps. (1) A host sends a QUERY message. (2) Whoever has the answer to the query sends back a REPLY message.

   (1) What is the network-layer mechanism that allows a host to dynamically obtain an IP address, i.e., creating a host-IP mapping, when it joins a network? (5%)
   (2) Which is the link-layer mechanism that allows a host to look up the Ethernet address for a particular IP address? (5%)
   (3) Which one, DHCP and/or ARP, uses the broadcast address in the DISCOVER/QUERY messages? Why or why not the messages are sent broadcast? (10%)
   (4) Which one, DHCP and/or ARP, uses the broadcast address in the OFFER/REPLY messages? Why or why not the messages are sent broadcast? (10%)
   (5) The DHCP client obtains the offered address from the server when it receives the OFFER message. Why doesn't the DHCP client take the address after receiving the OFFER message? Or why is it necessary for DHCP to take 2 more steps to complete the transaction? (10%)

Sample Solution:

(1) DHCP
(2) ARP
(3) DHCP and ARP
    The client does not know who has the host-IP or IP-Ethernet address mappings, so the DISCOVER/QUERY messages are broadcast to all hosts on the subnet.
(4) DHCP
    The DHCP client asking for an IP address does not have an IP address yet. Therefore, the OFFER message needs to be broadcast to all.
    The ARP host who has the IP-ARP mapping requested however can reply directly to the source's address.
(5) Potentially, there can be other hosts who are also requesting for IP addresses. If a client uses directly the IP in the OFFER message, multiple clients might configure themselves to the same IP, i.e., the IP address conflict problem. The REQUEST and ACK messages will allow the DHCP server to make sure that only one client gets to

use an IP address.   The DHCP server will send ACK to only one REQUEST for an IP address.

5. (MAC) We have come across three generations of Carrier Sense Multiple Access protocols -- the original CSMA, CSMA/CD, and CSMA/CA. Based on your knowledge to these variants of CSMA MAC protocols, address the following questions.
   (1) How does CSMA/CD work in principle? (5%)
   (2) Can frames collide in CSMA and how? What is the problem in CSMA that CSMA/CD is trying to resolve? (10%)
   (3) How does CSMA/CA work in principle? (5%)
   (4) How can collisions be detected? What is the problem in CSMA/CD that CSMA/CA is trying to resolve? (10%)

Sample Solution:

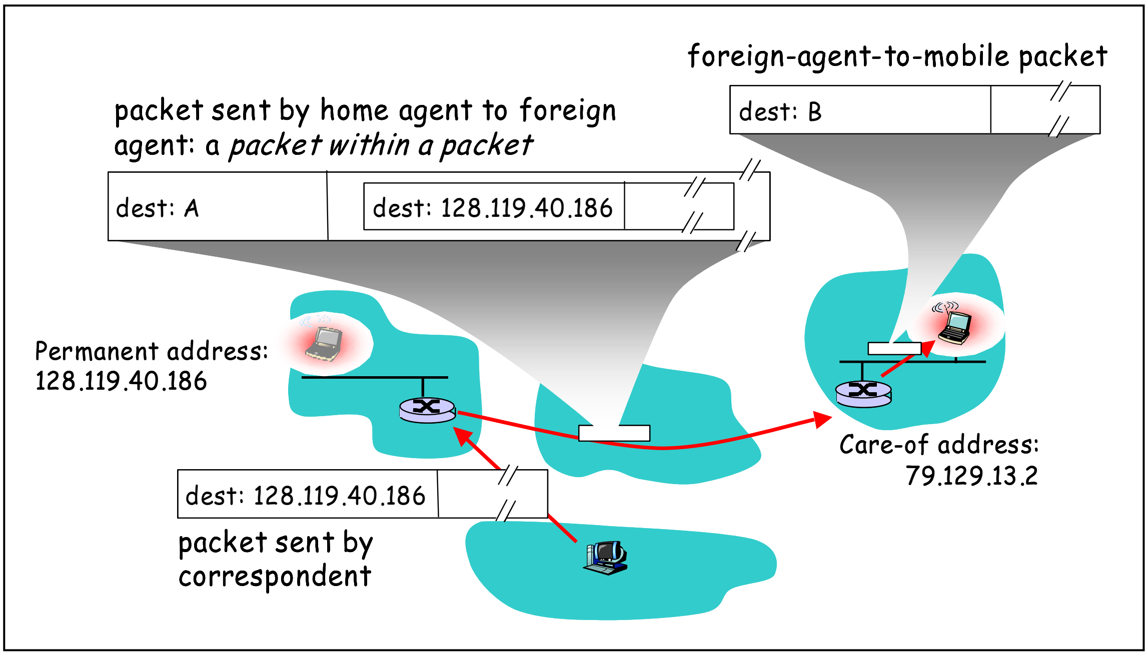
(1) Listen before transmit. Send when the channel is sensed idle. Hold when the channel is sensed busy. Abort when collisions are detected. (Re-send after a random exponential backoff.)

(2) Yes. Multiple CSMA transmissions might start about the same time when the channel is sensed idle. They could collide during the propagation delay. In CSMA, the entire frame transmission time will be wasted as the collision occurs. CSMA/CD tries to stop the frame transmission as soon as the collision is detected so to reduce the channel wastage.

(3) The sender sends a Ready-To-Send (RTS) message to indicate duration of transmission. In reply, the receiver sends a Clear-To-Send (CTS) message to notify reachable (possibly hidden) nodes. Those nodes receiving RTS and CTS but not involved in the transmission will not transmit for the specific interval of Network Allocation Vector (NAV) time. In the meantime, data and acknowledgement are exchanged between the sending and receiving nodes.

(4) Collision can be detected in the wired LAN by measuring signal strength or comparing the sending and receiving signals. It is however not the case for wireless LAN due to the hidden terminal problem, in which transmissions from certain nodes might not be visible by other nodes on the same wireless LAN. CSMA/CA avoids the potential collisions due to the hidden terminal problem by the sending of CTS and RTS frames which in a sense alerts all the visible nodes from the data sender and receiver of the data-ack exchange coming up next.

6. (Mobility) The indirect routing in Mobile IP is implemented by encapsulating the original data packet in another packet. Based on your knowledge of this packet encapsulation technique, address the following questions.
   (1) What should be the address values for A and B? (5%)
   (2) Can you name in other context the same technique is used to solve a computer network problem? (5%)



Sample Solution:

(1) A: 79.129.13.2, B:128.119.40.186

(2) IPv6 or Multicast Tunneling to connect IPv6/Multicast islands over the largely IPv4-based Internet.