Name_____ Student ID_____ Department/Year_____

Final Examination

Introduction to Computer Networks
Class#: 901 E31110
Fall 2007

9:20-11:00 Tuesday
January 15, 2008

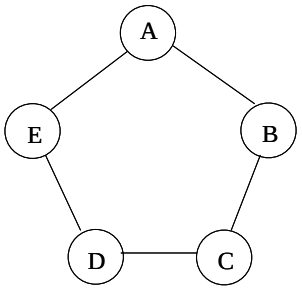
Prohibited

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 16 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 ring 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.



if (LS report received on incoming link && the LS report has not been received before)
then flood LS report onto all but the incoming link

(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 above to reach the whole network. 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 and the links are full-duplex. I.e., the packets will not collide. 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 E to every other node using the LS routing principle by filling in the blanks in the tables below. When 2 nodes have the same distance to the traversed set, pick the nodes to traverse next in alphabetic order. (5%)

Step	Travel Set	D(A),p(A)	D(B),p(B)	D(C),p(C)	D(D), p(D)
0	E	1,E	∞	∞	1,E
1	EA	1,E	2,A	∞	1,E
2	EAD	1,E	2,A	2,D	1,E
3	EADB	1,E	2,A	2,D	1,E
4	EADBC				

Sample Solution:

(1) 30M bytes

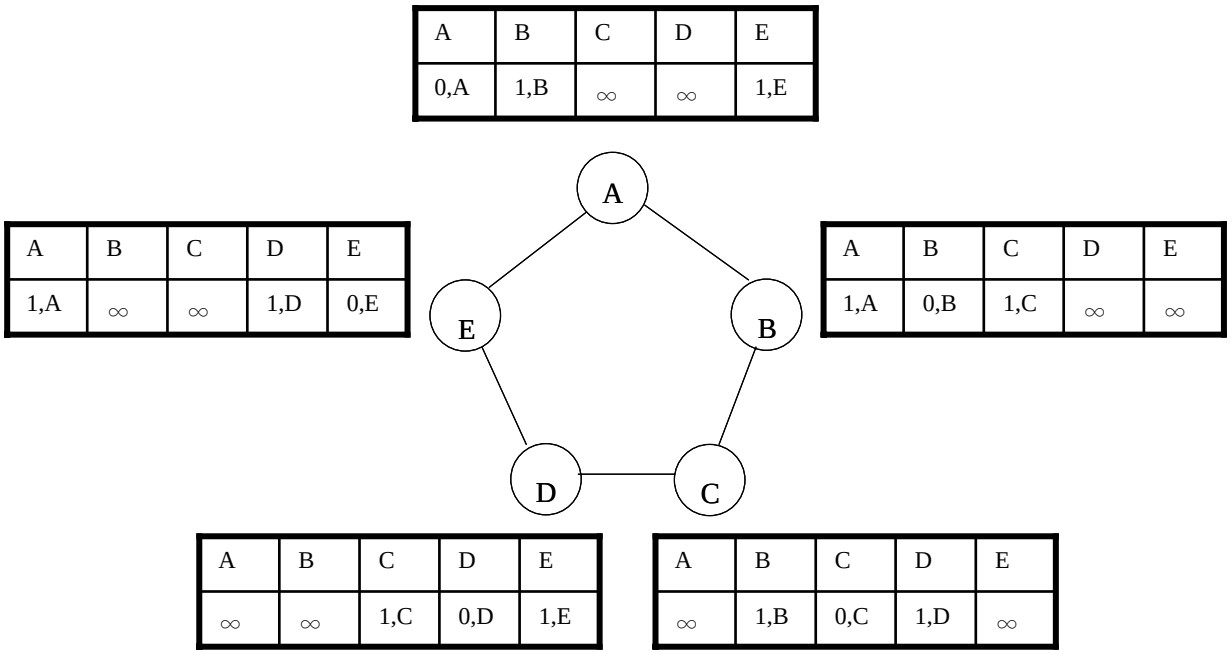
Each LS report travels the 5 links 6 times. Take the one starting from node A for example. Node A sends its LS report to B and E. B sends to C, and E sends to D. C, upon receiving the LS report from B, sends to D. D, upon receiving the LS report from E, sends to C. D, upon receiving the LS report from C, finds that this is a report that it has received before and thus does not send the LS report anymore. Similarly, C does not send the LS report from D anymore. The LS report travels link A-B, A-E, B-C, E-D, C-D, and D-C. That's 6 times in total. Since there are 5 LS reports, there are, therefore, 30M bytes consumed over the network to deliver the LS reports.

(2) 2T seconds

All nodes start simultaneously. It takes 2 hops for each LS report to reach all nodes. That is, therefore, 2T seconds required to deliver the LS reports.

(3) See the filled-up table above

2. (DV Routing) Consider the same 5-node ring 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	∞	∞	1,E

A	B	C	D	E
1,A	∞	∞	1,D	0,E

A	B	C	D	E
1,A	0,B	1,C	∞	∞

A	B	C	D	E
∞	∞	1,C	0,D	1,E

A	B	C	D	E
∞	1,B	0,C	1,D	∞

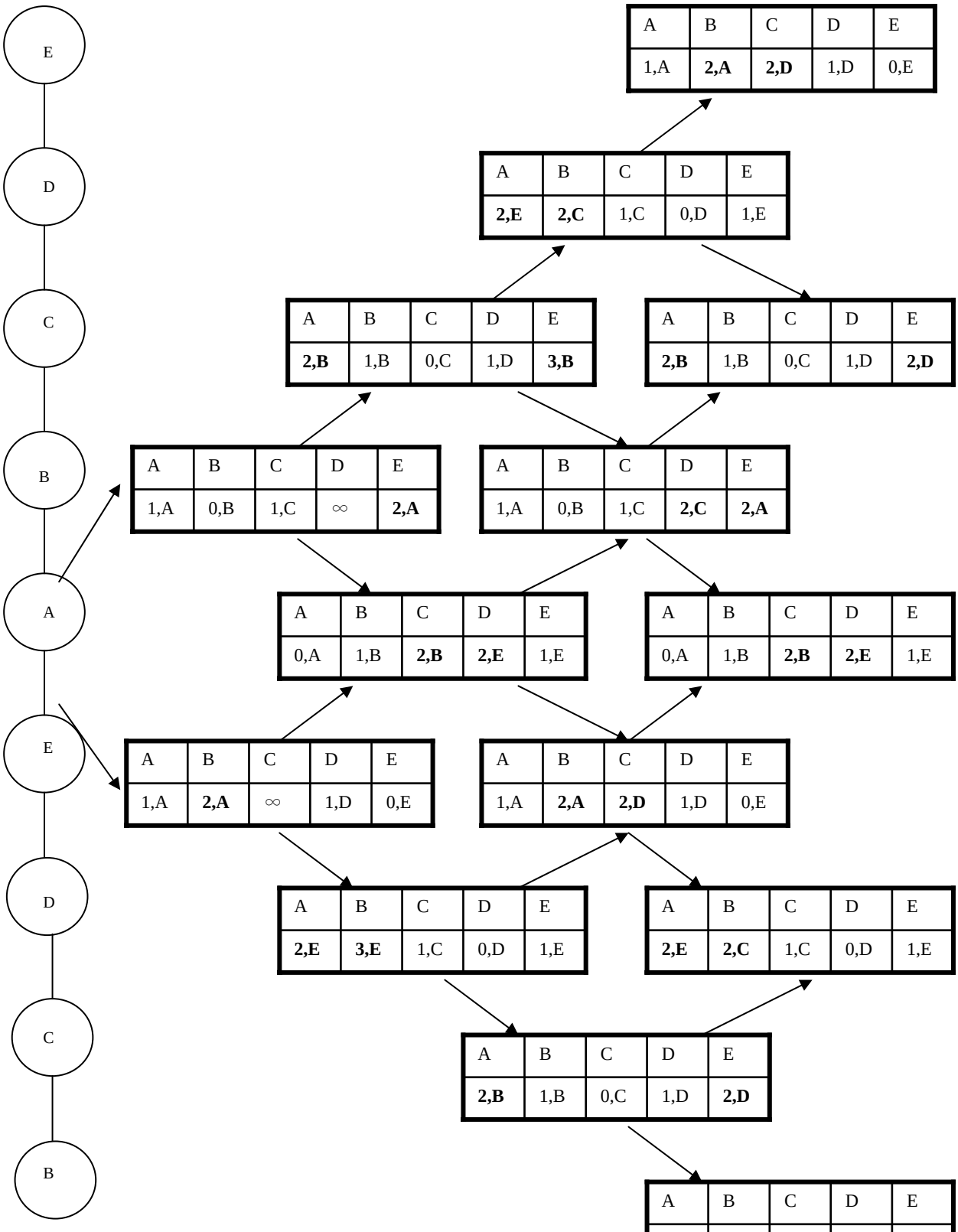
(1) A is the node who starts sending its routing table. Propagate the routing table and derive the final routing tables by filling in the blanks in the tables provided below. (5%)

(2) Continue from (1). Suppose the delay to send a DV routing table over any link is T seconds. The links are full-duplex. I.e., the packets will not collide on the links. 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)



(2) 4T seconds
4 rounds of DV routing table exchanges are done.

(3) 20M bytes
20 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 ring 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 ring 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 ring network? (5%)
   (3) Consider a 7-node ring network running DV routing. 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 ring 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 ring network and represent the convergence delay in K and T. (Hint: observe routing table exchange for 5-node and 7-node ring networks.) (5%)
   (6) Generalize (4) for 2K+1 node ring network and represent the message overhead in K and M. (5%)
   (7) Compare for general 2K+1 ring networks (K > 1). Is LS or DV more bandwidth efficient? (5%)
   (8) Assume the route computation time is negligible. Compare for general 2K+1 ring networks (K > 1). Is LS or DV faster in converging to the shortest paths for all pairs? (5%)

Sample Solution:

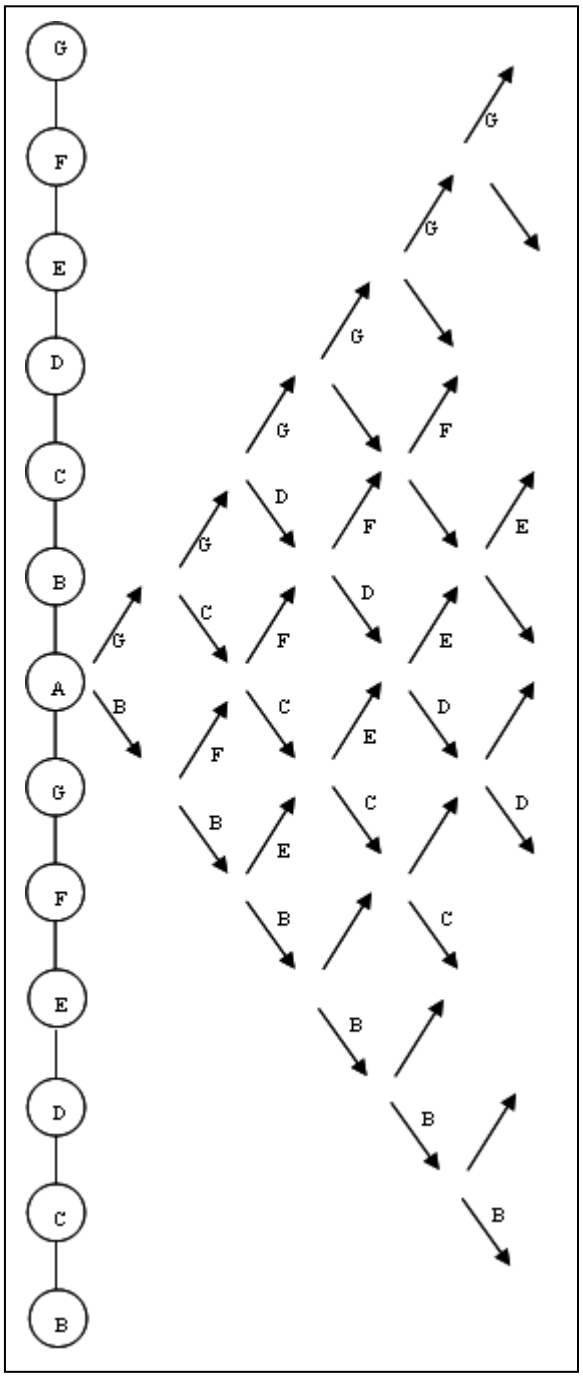
(1) LS – Time : KT seconds

(2) LS – Overhead : (2K+1)*(2K+2) M = $(4K^2+6K+2)$M bytes

(3) 6T seconds

(4) 38M bytes

7-node routing table exchange is illustrated below:



(5) DV – Overhead : $(K+3)(K+2)+(K+5)(K-2) = 2K^2+8K-4$ M bytes

5-node ring: 20

7-node ring: 38

(6) DV – Time : 2KT seconds

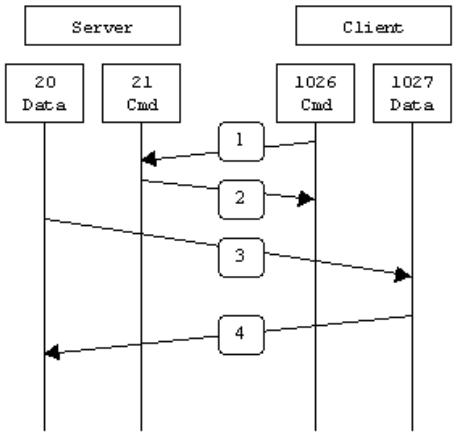
5-node ring: 4

7-node ring: 6

(7) DV is more bandwidth efficient.

(8) LS is faster

4. (NAT) Based on your understanding of Network Address Translation (NAT) service and the original (active) File Transfer Protocol (FTP) described below, try if you can address a problem earlier in the semester about submitting the homework assignments to the FTP server.



Active FTP:
In step 1, the client's command port contacts the server's command port and sends the data PORT 1027. The server then sends an ACK back to the client's command port in step 2. In step 3 the server initiates a connection on its local data port to the data port the client specified earlier. Finally, the client sends an ACK back as shown in step 4.

(1) Some of your classmates had trouble submitting homework assignments to the FTP server at the beginning of the semester. The FTP server, nslab.ee.ntu.edu.tw, might be a bit busy but it was running fine most of the time. Another possible reason is that these students might be trying to FTP from a host behind NAT. Could you explain why the host cannot upload/download files to the FTP server? (5%)

(2) When the instructor suggested that you connect to the FTP server using the 'passive' mode, the problem disappeared. What would you think the passive FTP and the active FTP work differently so the students behind NAT could submit homework assignments to the FTP server? (10%)

(3) The widespread use of NAT has forced a number of application-layer protocols to change. FTP is just one of the examples. What is your opinion about using NAT (give the advantages and disadvantages)? (10%)

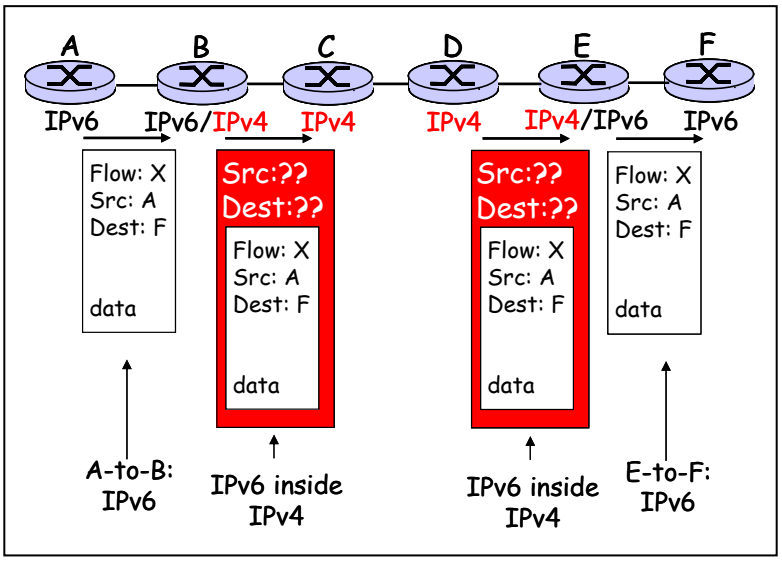
Sample Solution:

(1) port 1027 on NAT is not mapped to port 1027 on the client

(2) Instead of the FTP server making data connection to the client, when the client receives the ack in Step 2, the client initiates the data connection to the FTP server.

(3) State whatever your opinion is. Here is just one reference answer. NAT might be OK as a temporary solution to the IP address space shortage problem, but it violates the principle of layer transparency. As a consequence, applications such as FTP will need to change to get around clients behind NAT. It is not the best solution but it is better than doing nothing.

5. (Packet Encapsulation) This packet encapsulation technique is used when an IPv6 source wants to send data over IPv4 routers to another IPv6 node. When the IPv6 packets come to the edge of the IPv6 and IPv4 networks, they will be encapsulated in another packet in IPv4 format. Based on your knowledge of this packet encapsulation technique, address the following questions.



(1) What should be the address values in the source field (Src) and destination field (Dest) in the encapsulation packet? (Hint: A, B, C, D, E, or F?) (10%)

(2) Can you name in other context the same technique is used to solve a computer network problem? (10%)

Sample Solution:

(1) Src: B, Dest: E

(2) Mobile IP indirect routing or multicast tunneling

6. (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 work in principle? (5%)
   (2) Can frames collide using CSMA and how? (5%)
   (3) How does CSMA/CD work in principle? (5%)
   (4) Can frames collision be detected using CSMA/CD in a wireless network? Why or why not? (5%)
   (5) How does CSMA/CA work in principle? (5%)
   (6) Which part of the mechanism in CSMA/CA is to ensure data transmitted are indeed received by the receiver? (5%)
   (7) Which part of the mechanism in CSMA/CA is to reduce the chance of data collision? (5%)

Sample Solution:

(1) Listen before transmit. Send when the channel is sensed idle. Hold when the channel is sensed busy.
(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.
(3) CSMA/CD tries to stop the frame transmission as soon as the collision is detected so to reduce the channel wastage. (Re-send after a random exponential backoff.)
(4) Due to the hidden terminal problem, in which transmissions from certain nodes might not be visible by other nodes on the same wireless LAN.
(5) 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) For each data received, the receiver sends an acknowledgement packet back to the sender.
(7) The RTS and CTS frames to reserve the channel for the data frames coming up. The chance of smaller RTS or CTS frames colliding with other frames is lower than the longer data frames colliding with other frames.