Take-Home Final Exam
Csci4211: Introduction to Computer Networks
Spring 2020
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Instructions:

1. This is a **Take-Home** final exam.
2. There are **five** questions in total, each of which has several sub-questions. *There are a total of 100 points.* If you know the class material well, this exam should not take more than two hours. (An estimated time for each problem is given as a guide.)
3. **Please type your solutions (electronically, if possible), or write down your solutions on separate papers (instead of directly on the printed exam papers). Please put your name and student id. on the top of the document.** If you scan your *hand-written* solutions for electronic submission, please make sure that they are legible. *Please remember that we mus be able to read your handwriting in order to be able to grade your exam.*
4. Partial credit is possible for an answer. Please try to be as concise and make your exam as neat as possible.
5. **Please work on the exam *individually, by yourself only!* If you find the answers somewhere else (e.g., the Internet), please *cite* your source. Any violation of the University's *Student Conduct Code* will be reported to both the department and the University, and you may be suspended or expelled! Please note that if you let another student to copy your answers, you are also in violation of the University's *Student Conduct Code.***
6. Good luck. Enjoy!

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1. A Potpourri of True/False and Quick Q& A Questions. (15 points total. Approx. 15 minutes

For **true or false** *questions, please write down (***T** *or* **F***) as your answers; for quick* **Q&A** *questions, please provide a brief answer (1-2 sentences generally suffice).*

a. (3 points) **True or False:** Each Internet host with only one physical Interface can only have one IP address assigned to it at any given time, but may have multiple DNS names.

b. (3 points) **True or False:** Packet forwarding using a virtual circuit can guarantee reliable data delivery in the network layer.

c. (3 point) **True or False:** Given that the MAC addresses of two laptop computers are `5C:76:AF:01:10:15` and `5C:76:AF:01:11:16` (in hexadecimal representation, where ":" separates the 6 bytes in the 48 bit MAC address), they must reside on the same local area network (LAN).

d. (3 points) Is it necessary that every autonomous system (AS) on the Internet uses the same intra-AS (i.e., intra-domain) routing protocol such as OSPF or RIP? Why or why not?

e. (3 points) **True or False:** Under the heavy load (e.g., with high probability each machine on the network has a data frame (packet) to transmit at any given time), the 10Base Ethernet MAC protocol is less efficient than Token Ring.

2. Intra-Domain Routing Algorithms (26 points. Approx. 30 minutes)

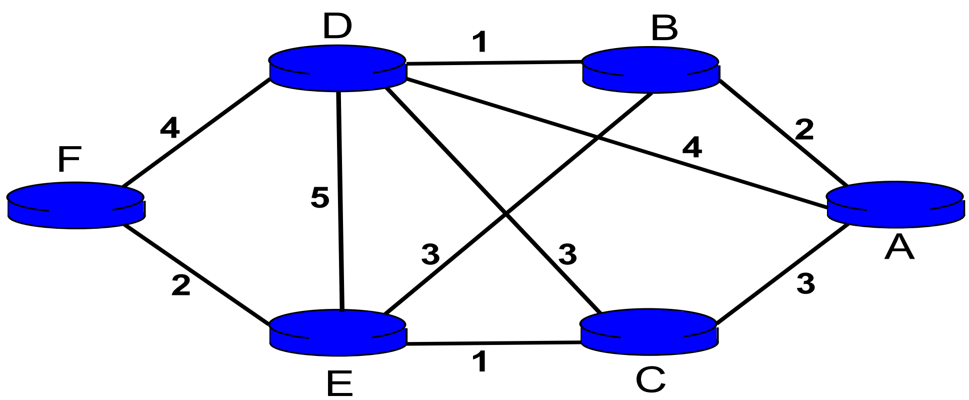


Figure 1: Figure for Question 2.**a**

a. (10 points) Consider the network shown in Figure 1, where the number on a link between two nodes are the distance (i.e., link cost) between them. Use Dijkstra's shortest path algorithm to find the shortest path from A to all other network nodes. Show how the algorithm works by completing the table below (the first row is already completed for you).

Table 1: **Please copy this table in your answer sheet and fill out the following steps in runnning Dijkstra's algorithm at router A:**

Step	N	$D(B)$, $p(B)$	$D(C)$, $p(C)$	$D(D)$, $p(D)$	$D(E)$, $p(E)$	$D(F)$, $p(F)$
1	A	2, A	3, A	4, A	∞, $-$	∞, $-$
2						
3						
4						
5						

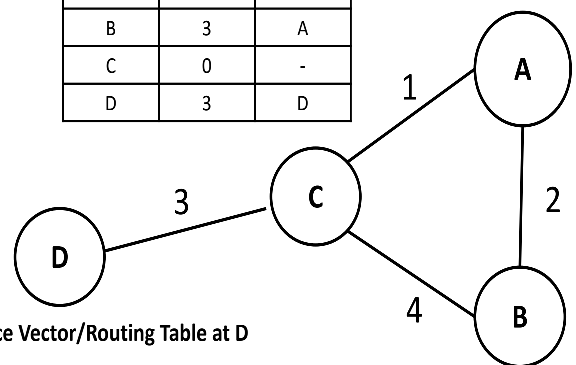
Questions **b** and **c.** refer to the network in Figure 2, where the cost of the links are given above the corresponding links. The network uses *distance-vector* (DV) routing algorithm with the *split horizon with poisonous reverse* hack (see Lecture Notes "network-layer-control-plane-part1.pptx", slides 24-40) to compute routing tables. The distance-vector (DV) routing tables at routers A, B, C, and D have been computed for you, as shown in the figure.

Distance Vector/Routing Table at C

dest.	cost	next-hop
A	1	A
B	3	A
C	0	-
D	3	D

Distance Vector/Routing Table at A

dest.	cost	next-hop
A	0	-
B	2	B
C	1	C
D	4	C



Distance Vector/Routing Table at D

dest.	cost	next-hop
A	4	C
B	6	C
C	3	C
D	0	-

Distance Vector/Routing Table at B

dest.	cost	next-hop
A	2	A
B	0	-
C	3	A
D	6	A

Figure 2: Figure for Question 2.**b**

b. (12 points) Now suppose the cost for the link between A and C is increased from 1 to 8. After the *next* round of routing information exchange among routers A, B, C, and D, what will the updated distance-vector (DV) routing tables at routers A, B, C and D look like?

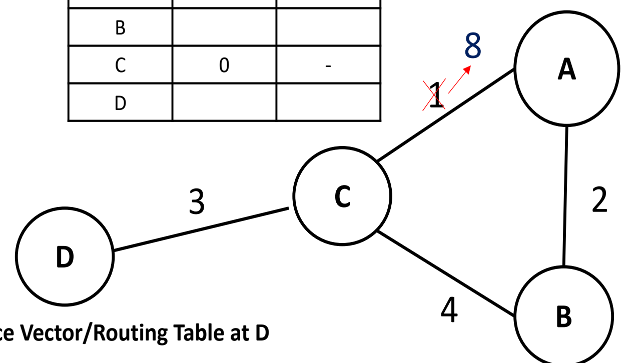
c. (4 points) Following up on **b.**, suppose that router A now receives a packet destined to router D. Which next-hop router will router A send the packet to? Upon receiving the packet from router A, which router will *this* next-hop router send the packet to?

Distance Vector/Routing Table at C

dest.	cost	next-hop
A		
B		
C	0	-
D		

Distance Vector/Routing Table at A

dest.	cost	next-hop
A	0	-
B		
C		
D		



Distance Vector/Routing Table at D

dest.	cost	next-hop
A		
B		
C		
D	0	-

Distance Vector/Routing Table at B

dest.	cost	next-hop
A		
B	0	-
C		
D		

Figure 3: Fill in your answers to Question 2.**b** by copying the tables in this figure.

3. Inter-Domain Routing and BGP (20 points. Approx. 15 minutes)

Consider Figure 4 , where AS A is a *customer* of AS X, and AS B is a *customer* of both AS X and AS V. AS X has two *providers* ASes U and V. AS C is a customer of AS W and AS U. The three ASes U, V and W have *peering* relationships among themselves. AS X owns the prefix `64.1.0.0/16`, and AS C owns the prefix `128.1.0.0/20`. AS A owns one network prefix: `64.1.0.0/20`, and AS B owns two prefixes: `64.1.0.0/24` and `101.10.128.0/20`. The inter-domain routing protocol BGP is used among the ASes to exchange routing information. Answer the following questions.

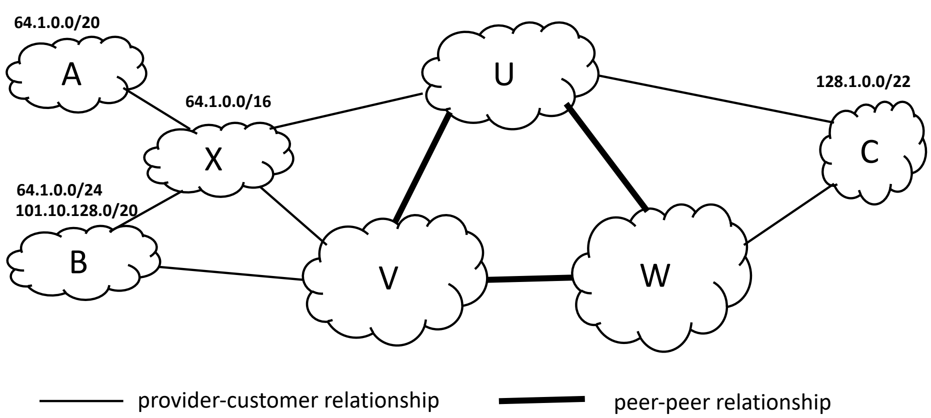


Figure 4: Figure for Question 3.

a. (6 points) Write down the path vectors AS U receives from AS V regarding V's routes to (the network prefixes owned by) ASes A and B, and the path vectors AS V receives from AS U regarding U's routes to AS A and AS B.

b. (4 points) Given your answer above for **a.**, AS U would have learned two routes to the network prefix `64.1.0.0/20` owned by AS A. Which of the two will AS U use to forward packets destined to the host with the IP address `64.1.64.11`? Briefly justify your answer.

c. (6 points) Write down *all* path vectors (to ASes A and B) AS W receives from U and V, and all path vectors (to the network prefixes of ASes A and B) AS C will/may receive from AS W and AS U.

d. (4 points) Given an IP packet with the destination IP address 64.1.0.111 and source IP address 128.1.1.1. Which AS path will this packet likely traverse from the AS originating the packet to reach its destination?

4. Media Access Control (14 points. Approx. 15 minutes)

a. (6 points) Recall that wireless LAN (802.11) uses CSMA/CA. Is there a need to impose a minimum frame size requirement in 802.11? Briefly explain your answer.

b. (8 points) Give an example to illustrate why the RTS/CTS mechanism used in 802.11 CSMA/CA may not completely avoid collision involving *data* frames. Hint: think about under what condition the following scenario may occirs: one frame sent from another host C to host B, say, a RTS request, collides with a data frame that is currently being transmitted from host A to host B.

5. Routers, Switches, 802.11 WiFi AP & ARP (25 points total. Approx. 25 minutes)

Consider a campus network as shown in Figure 5, which consists of multiple Ethernet LANs and an 802.11 wireless LAN connected through three Ethernet switches ($S1$, $S2$ and $S3$) and one 802.11 wireless access point (AP). There are also two IP routers, $R1$ (the border gateway router) and $R2$, which connect these LANs and several servers to each other and to the rest of the Internet. The numbers besides the three switches, the AP, two routers and one "dual-homed" machine indicate their network interface numbers (host L is currently connected to both the Ethernet switch $S3$ and the wireless access point AP.) Apart from the web, DNS and email servers which are directly connected to $R1$, the rest of the campus network is segmented into three IP *subnets*: IP subnet 1 with the IP address block 128.101.1.0/18, IP subnet 2 with the IP address block 128.101.164.0/22, and IP subnet 3 with the IP address block 128.101.100.0/20. (For your convenience, we have shaded the links and switch(es) belonging to each IP subnet in Figure 5.)

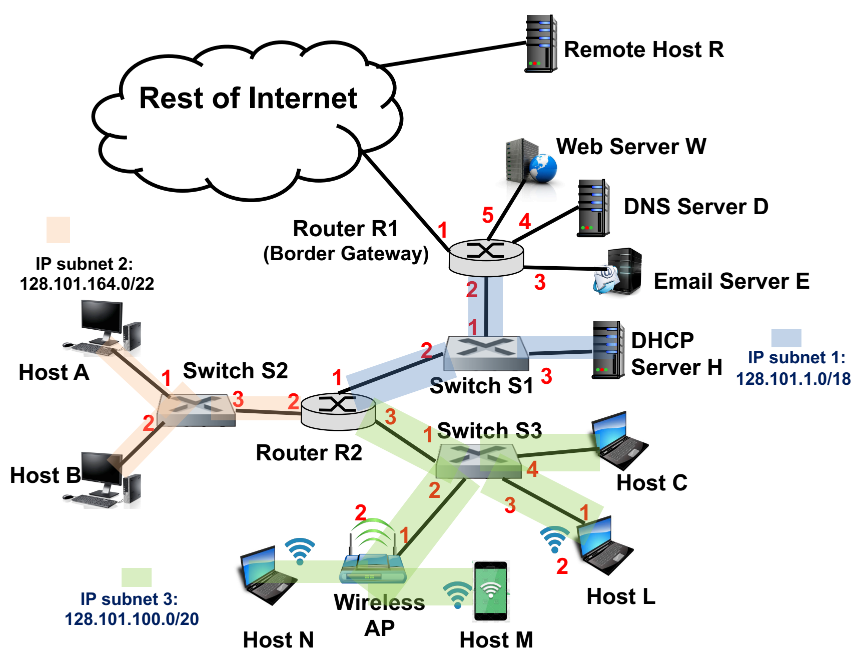


Figure 5: Figure for Question 5: a Campus Network with three IP subnets

The forwarding tables at routers $R1$ and $R2$ as well as $R2$'s ARP cache at *the current moment* are given in Figure 6; The *current* snap shots of the forwarding tables at the AP and the three Ethernet switches are also shown in the same figure. In particular, three machines (host/laptop L, host/laptop N and host/mobile device M) are currently *associated* with the wireless access point AP, and host C's ARP cache at the current moment is also given in the figure. Answer the following questions *briefly*. (A few sentences would be sufficient in general!)

Router R1's IP Forwarding Table

Destination Prefix	Next-hop	Interface
128.101.1.0/18	Direct	2
128.101.100.0/20	R2	2
128.101.164.0/22	R2	2
128.101.0.3/32	Direct	3
128.101.0.4/32	Direct	4
128.101.0.5/32	Direct	5
0.0.0.0/0	ISP's gateway	1

Router R2's IP Forwarding Table

Destination Prefix	Next-hop	Interface
128.101.1.0/18	Direct	1
128.101.100.0/20	Direct	3
128.101.164.0/22	Direct	2
0.0.0.0/0	R1	1

Router R2's ARP Cache

IP address	MAC address
R1's interface 2 IP address	R1's interface 2 MAC address
C's IP address	C's MAC address
A's IP address	A's MAC address

Switch S1's Forwarding Table

Host (MAC addr.)	Interface
R1	1
R2	2
H	3

Switch S3's Forwarding Table

Host (MAC addr.)	Interface
C	4
L	3
N	2
R2	1

Wireless AP's Forwarding Table

Host (MAC addr.)	Interface
L's wireless MAC addr	2 (wireless)
M	2 (wireless)
N	2 (wireless)
R2	1 (Ethernet)

Switch S2's Forwarding Table

Host (MAC addr.)	Interface
R2	3
A	1
B	2

Host C's ARP Cache

IP address	MAC address
R2's IP address	R2's MAC address
N's IP address	N's MAC address

Figure 6: Figure for Question 5: Routing Tables at $R1$ and $R2$, Snapshots of the Switch Forwarding Tables at Ethernet Switches $S1$, $S2$, $S3$ and WiFi Access Point AP and the ARP Caches at $R2$ and Host C.

a. (8 points) Consider the scenario where host N (the mobile device) wants to access the email server E, but doesn't know its IP address. Hence N issues a DNS query to the local DNS server D (whose IP address, `128.101.0.4`, which host N learned via DHCP when it joined the campus network using WiFi) to find out the IP address of E. Host N encapsulates the UDP packet containing the DNS query in an IP datagram, which is then encapsulated in a WiFi frame.

i) (1 point) What will be the destination IP address of the IP datagram?

ii) (2 point) What will be the address 1 of the WiFi frame?

iii) (2 point) What will be the address 2 of the WiFi frame?

iv) (2 point) What will be the address 3 of the WiFi frame?

v) (1 point) Which of the two bits, `To-AP` or `From-AP`, in the WiFi frame control header will be set to 1?

b. (4 points) Now look at the actions that the WiFi access point AP needs to perform when it receives this WiFi frame.

i) (2 points) First of all, how does AP know that it needs to deliver the IP datagram containing the DNS query to Ethernet switch $S3$? (In other words, what information is used to make this decision.) Incidentally, does it know the existence of $S3$?

ii) (2 points) In order to deliver the IP datagram to $S3$, AP first needs to translate the WiFi frame to an Ethernet frame in which the IP datagram will be encapsulated, what should the source and destination MAC addresses of this Ethernet frame be?

c. (4 points) Following up on **a.** and **b.**, when router $R2$ receives this IP datagram containing the DNS query, which interface will $R2$ forward the datagram to? What will be the source and destination MAC addresses that $R2$ will be using in the *new* Ethernet frame it will be creating so as to encapsulate the IP datagram for further delivery?

d. (9 points) Consider another scenario where host C wants to communicate with host M. It knows M's IP address, but it does not know M's MAC address. Since hosts C and M reside within the same IP subnet (IP subnet 3), it will issue an ARP request message encapsulated in an Ethernet broadcast frame with its MAC address as the source MAC and the MAC broadcast address `FF:FF:FF:FF:FF:FF` as the destination MAC address.

i) (1 point) What will switch $S3$ do when it receives this broadcast Ethernet frame?

ii) (1 point) What will router $R2$ do when it receives this broadcast Ethernet frame?

iii) (4 point) What will the WiFi access point AP do when it receives this broadcast Ethernet frame?

iv) (1 point) How many times (0, 1, or 2) will host L receive this ARP request from host C?

v) (2 points) Since host L is connected to both Ethernet switch $S3$ and the WiFi access point AP, will this create a loop where the broadcast frame will circulate forever in the network? Briefly justify your answer.