5617 **Name:** _____
Spring 2020 **Final**
05/04/2020 **Time Limit: 120 minutes**

- **Print** your name.
- Open-book policy: You may use the text book, printed class notes and/or any printed notes and handwritten study guides you have created. You may use a calculator. You may not use ebook or slides, or any search-able documents.

Problem	Points	Score
1	28	
2	40	
3	4	
4	2	
5	3	
6	4	
7	5	
8	9	
9	5	
Total:	100	

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1. **True or False**

(1.1) (1 point) The forwarding tables that determines the forwarding behavior of a router can only be configured by a routing protocol.
A. True B. False

(1.2) (1 point) A router forwards a packet based on the packet's IP (layer 2) address. A link-layer switch forwrds a packet based on the packet's MAC (layer 3) address.
A. true B. false

(1.3) (1 point) When a large IP packet is broken down into multiple smaller fragments, the resulting fragments will always be reassembled at the destination
A. True B. False

(1.4) (1 point) A datagram with a private network address should never be present in the larger public Internet.
A. true B. false

(1.5) (1 point) Suppose there are 5 routers between a source host and a destination host. Ignoring fragmentation, an IP datagram sent from the source host to the destination host will travel over 12 interfaces and 5 forwarding tables.
A. true B. false

(1.6) (1 point) Suppose Host A is sending Host B a large file over a TCP connection. The number of unacknowledged bytes that A sends cannot exceed the size of the receive buffer.
A. true B. false

(1.7) (1 point) It is not necessary that every autonomous system use the same intra-AS routing algorithm.
A. true B. false

(1.8) (1 point) It is not necessary that every autonomous system use the same inter-AS routing algorithm.
A. true B. false

(1.9) (1 point) When an OSPF router sends its link state information, it is sent only to those directly attached neighbors.
A. true B. false

(1.10) (1 point) Suppose you wanted to implement a new routing protocol in the SDN control plane. You would implement at the SDN's network-control application layer.
A. true B. false

(1.11) (1 point) BGP routers use the AS-PATH attribute to detect and prevent looping advertisements.
A. true B. false

(1.12) (1 point) A tier-1 ISP will always carry traffic between two other tier-1 ISPs.
A. true B. false

(1.13) (1 point) If all the links in the Internet were to provide reliable delivery service, the TCP reliable delivery service will be redundant.
A. true B. false

(1.14) (1 point) Suppose two nodes start to transmit at the same time a packet of length L over a broadcast channel of rate R. Denote the propagation delay as d_{prop}. There will be a collision if $d_{drop} < L/R$.
A. true B. false

(1.15) (1 point) Ethernet has been to local area networking what the Internet has been to global networking.
A. true B. false

(1.16) (1 point) Hot-potato routing — get a packet out of an AS as quickly as possible — is a selfish algorithm, it optimizes the local cost of its own AS rather than the overhead of the global Internet.
A. true B. false

(1.17) (1 point) The forwarding tables that determines the forwarding behavior of a router can only be configured by a routing protocol.
A. True B. False

(1.18) (1 point) A router's switching fabric is almost always implemented in hardware whereas the management and control plane are usually implemented in software.
A. True B. False

(1.19) (1 point) When a large IP packet is broken down into multiple smaller fragments, the resulting fragments will always be reassembled at the destination
A. True B. False

(1.20) (1 point) In an IPv4 header, the protocol field can be viewed as the glue that binds the network and the transport layer.
A. True B. False

(1.21) (1 point) With link state algorithm, a router will never advertise incorrect path cost.
A. True B. False

(1.22) (1 point) When network link cost changes, routers running distance vector algorithm will inform their neighbors of the change. Among the "good" news — link cost reduces and the "bad" news — when link cost increases, which one "travels faster" — taking effect on all nodes?
A. good news B. bad news

(1.23) (1 point) Medium access protocols like multiple access protocols are always needed to coordinate frame transmission on network links.
A. True B. False

(1.24) (1 point) An Autonomous System (AS) can control how traffic enter by tweaking the route advertisements sent via BGP.
A. True B. False

(1.25) (1 point) One drawback with BGP-based Internet traffic engineering is that, controlling incoming traffic by the selection of best route is limited by (availability) diversity of routes received from the upstream providers.
A. True B. False

(1.26) (1 point) classless inter-domain routing (CIDR) works best with an Internet organized into a provider-customer hierarchy.
A. True B. False

(1.27) (1 point) In the per-router control paradigm, each router has a routing component that performs two tasks: local routing computation and communication with other routers.
A. True B. False

(1.28) (1 point) With LS algorithm, a router will never advertise incorrect path cost.
A. True B. False

2. **Multiple choice questions**

(2.1) (1 point) Network layer protocols can run in

A. every host
B. every router
C. the network edge and core
D. all of the above

(2.2) (1 point) A router typically consists of input ports, output ports, a switching fabric, and a routing processor. Which of these is *NOT* implemented in hardware?

A. input ports
B. output ports
C. switching fabric
D. routing processor

(2.3) (1 point) Consider an HTTP client that wants to retrieve a Web document at a given URL. The IP address of the HTTP server is initially unknown. What transport layer protocols besides HTTP are needed in this scenario?

A. UDP for DNS; TCP for HTTP
B. UPD for DNS and HTTP
C. TCP for DNS; UDP for HTTP
D. TCP for DNS and HTTP

(2.4) (1 point) Which of the following applies to both a router and a link-level switch?

A. both forward packets
B. both maintain forwarding tables
C. both are store-and-forward devices
D. all of the above

(2.5) (1 point) What is the difference between a router and link-level switch?

A. switches have inherently higher packet processing rate
B. switches are better for small network with low traffic
C. routers are better for complex policy-based network with high traffic demand
D. all of the above

(2.6) (1 point) What protocol stitches together the link- and network- layer?

A. ARP B. TCP C. IP D. MAC

(2.7) (1 point) What is the difference between MAC address and IP address?

A. only MAC address is fixed while IP can change over time
B. only IP address reflects the structure of the Internet
C. both are global identifier, but only IP address is used for end to end packet delivery
D. all of the above

(2.8) (1 point) Among the various types of MAC protocols — channel partitioning, random access, and taking turns, which is the best?

A. channel partitioning
B. random access
C. taking turns

D. none of the above

(2.9) (1 point) In comparing link state (LS) and distance vector (DV), which of the following is true?

A. DV node can advertise incorrect link cost

B. LS node can advertise incorrect path cost

C. forwarding table computation in both the DV and LS algorithms is distributed

D. all of the above

(2.10) (1 point) If a router has 5 interfaces, how many IP addresses can be associated with the router?

A. 5 B. 4 C. 1 D. 6

(2.11) (1 point) What makes Ethernet the dominant local area network?

A. Ethernet was the first widely deployed high-speed LAN

B. Ethernet is simple and cheap

C. support higher data rate of alternate new technologies

D. all of the above

(2.12) (1 point) Which of the following applies to MAC address, but not IP address

A. universally unique

B. hierarchical

C. portable

D. associated with every NIC (adapter)

(2.13) (1 point) With two-dimensional parity check, suppose we have a data `D` of 35 bits arranged in a 5×7 matrix, how many extra parity bits will be added?

A. 5

B. 13

C. 35

D. 12

(2.14) (1 point) Which of the following does not belong to a broadcast channel

A. LANs

B. Ethernet

C. point-to-point link

D. wireless LANs

(2.15) (1 point) Which of the following table act(s) as the glue that stitches together the network layer's data and control planes in the traditional networks?

A. forwarding table

B. routing table

C. flow table

D. all of the above

(2.16) (1 point) Which of the following applies to link-state (LS) routing algorithm

A. each router has complete information of the network topology

B. routers do not exchange routing information

C. routers perform computation independent of each other

D. all of the above

(2.17) (1 point) In Dijkstra's algorithm, how many iterations are needed to compute the least-cost paths to m (closest) destinations in a network of n nodes.

A. m
B. n
C. $n - m$
D. none of the above

(2.18) (1 point) In Dijkstra's algorithm, define $c(x, y)$ to be the cost between nodes x, y, $D(v)$ the current value of cost of path from source to destination v, $p(v)$ the predecessor node along path from source to v, N' the set of nodes whose least cost path definitely known. Suppose we have $y \in N'$, $D(z) = 10, p(z) = y, c(y, z) = 3$, what is the value of $D(y)$

A. 3
B. 10
C. 7
D. not known

(2.19) (1 point) An SDN switch can simulate the behavior of a load balancer by what action(s)?

A. forward packet
B. send to normal processing pipeline
C. modify fields
D. all of of the above

(2.20) (1 point) With SDN, the packet matching fields can contain fields from

A. link layer
B. network layer
C. transport layer
D. all of the above

(2.21) (1 point) Software-defined networking unifies the behavior of

A. router
B. load balancer
C. firewall
D. all of the above

(2.22) (1 point) The primary functions of the network layer include

A. move traffic from sending host to a receiving host
B. forward traffic from a router's input link to its output link
C. coordinate the forwarding action of each router
D. all of the above

(2.23) (1 point) Network layer protocols can run in

A. every host
B. every router
C. the network edge and core
D. all of the above

(2.24) (1 point) A transit AS can control how traffic leaves its local network by control the local BGP decision process via which attribute?

A. MED B. AS path C. next hop D. local preference

(2.25) (1 point) The control functionalities supported by MPLS include:

A. destination-based forwarding B. load balancing C. explicit routes D. all of the above

(2.26) (1 point) IPv6 aims to improve performance as well as add new facility. Which of the following feature(s) is(are) designed for new facility?

A. fixed-length header
B. disallow fragmentation
C. allow priority and flow label
D. all of the above

(2.27) (1 point) With NAT sits between the external Internet and a local network, we can

A. change addresses of the devices in the local network without notifying the ISP
B. the devices in the local network is not visible by the Internet
C. the local network is more secure
D. all of the above

(2.28) (1 point) A network interface

A. acts as the boundary between a host and the physical link it connects to
B. associated with an IP address
C. acts as the boundary between a router and the physical link it connects to
D. all of the above

(2.29) (1 point) An SDN switch can simulate the behavior of a load balancer by what action(s)?

A. forward packet
B. send to normal processing pipeline
C. modify fields
D. all of of the above

(2.30) (1 point) With SDN, the packet matching fields can contain fields from

A. link layer
B. network layer
C. transport layer
D. all of the above

(2.31) (1 point) Software-defined networking unifies the behavior of

A. router
B. load balancer
C. firewall
D. all of the above

(2.32) (1 point) Forwarding in software-defined networking is more flexible, enabling the following behavior(s) that is(are) impossible with traditional destination-based forwarding.

A. firewall
B. load balancer
C. NAT
D. all of the above

(2.33) (1 point) Which of the following applies to link-state (LS) routing algorithm

A. each router has complete information of the network topology
B. routers do not exchange routing information
C. routers perform computation independent of each other
D. all of the above

(2.34) (1 point) Let $d_x(y)$ be the cost of the least cost path from x to y, $c(x, y)$ the cost of link between x, y, which of the following formula describes Bellman-Ford equation?

A. $d_x(v) = min_v\{c(x, v) + d_v(y)\}$
B. $d_x(y) = min_x\{c(x, v) + d_v(y)\}$
C. $d_x(v) = min_y\{c(x, v) + d_v(y)\}$
D. $d_x(y) = min_v\{c(x, v) + d_v(y)\}$

(2.35) (1 point) The limitation(s) of DV algorithm include?

A. may have oscillations
B. count to infinity problem
C. error can propagate through the network
D. all of the above

(2.36) (1 point) Which of the following applies (apply) to the routing infrastructure?

A. routers in different AS can run different intra-domain routing protocols
B. gateway routers, whether from same AS or not, must run the same inter-domain protocol
C. gateway routers perform intra-domain routing as well as inter-domain routing
D. all of the above

(2.37) (1 point) Which of the following applies (apply) to BGP (border gateway protocol)

A. the glue that stitches together the Internet
B. one of the many inter-domain routing protocols
C. also establishes routes within a domain
D. all of the above

(2.38) (1 point) Which of the following step(s) in BGP route selection process make BGP unselfish?

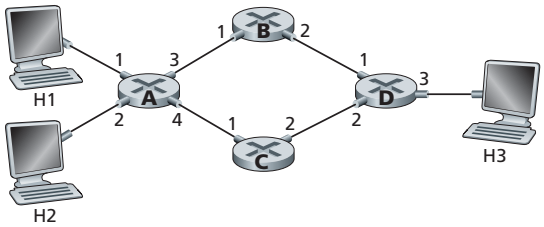
A. pick route with highest local preference
B. pick route with shortest AS-PATH
C. pick route with closest NEXT-HOP router
D. all of the above

(2.39) (1 point) With two-dimensional parity check, suppose we have a data `D` of 35 bits arranged in a 5×7 matrix, how many extra parity bits will be added?

A. 5
B. 13
C. 35
D. 12

(2.40) (1 point) Which of the following applies to MAC address, but not IP address

A. universally unique
B. hierarchical
C. portable
D. associated with every NIC (adapter)

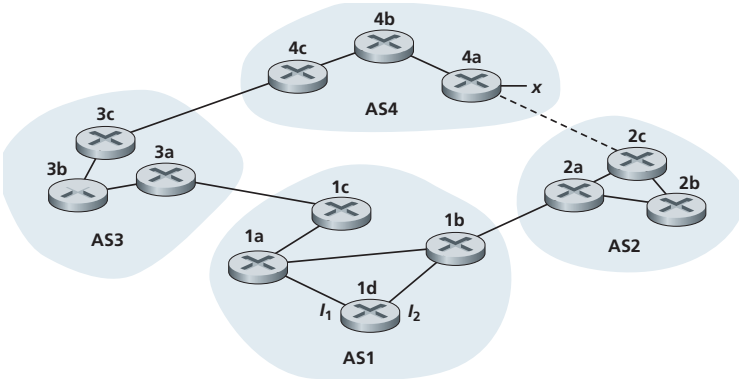


3. Consider the network above.

(3.1) (2 points) Show the forwarding table in router D, such that all traffic destined to host H2 is forwarded through interface 1.

(3.2) (2 points) Can you write down a forwarding table in router D, such that all traffic from H3 destined to host H1 is split and forwarded through the two paths DBA and DCA for load balancing?

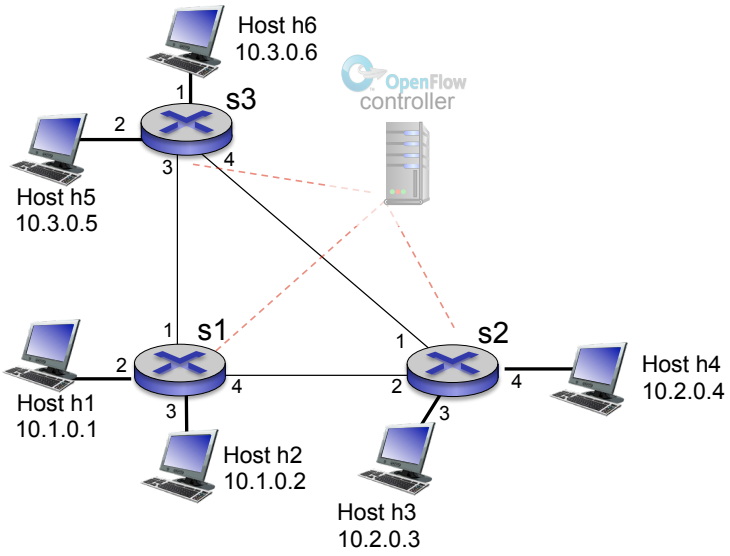
4. **Written questions (short answer)** Consider the network shown below. Suppose AS3 and AS2 are running OSPF for their intra-AS routing protocol. Suppose AS1 and AS4 are running RIP for their intra-AS routing protocol. Suppose eBGP and iBGP are used for the inter-AS routing protocol. Initially suppose there is no physical link between AS2 and AS4.



(4.1) (1 point) Router $3a$ learns about prefix x from which routing protocol?

(4.2) (1 point) Router $1d$ learns about prefix x from which routing protocol?

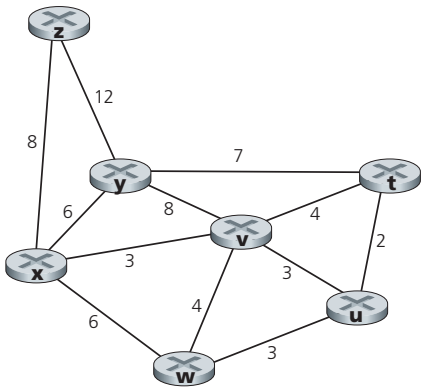
5. (3 points) **Written questions (essay, computational)** Consider the SDN OpenFlow network shown in the following Figure. Suppose that the desired forwarding behavior for datagram arriving at s2 is as follows:



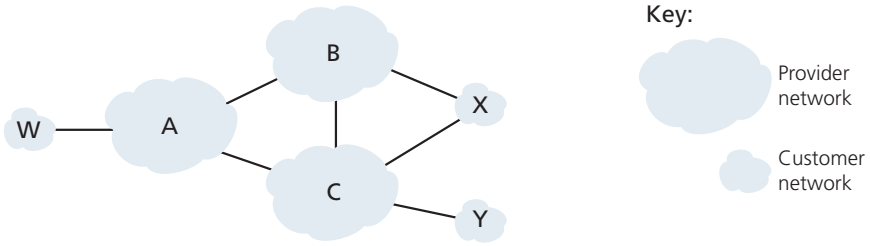
- any datagrams arriving on input port 1 from hosts h5 or h6 that are destined to hosts h1 or h2 should be forwarded over output port 2;
- any arriving datagrams on input ports 1 or 2 and destined to hosts h3 or h4 should be delivered to the host specified;
- hosts h3 and h4 should be able to send datagrams to each other.

Specify the flow table entries in s2 that implement this forwarding behavior.

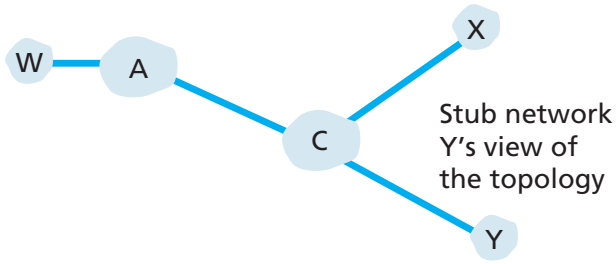
6. (4 points) **Written questions (essay, computational)** Consider the following network (left). With the indicated link costs, using Dijkstra's shortest-path algorithm to compute the shortest path from y to all other nodes. Show how the algorithm works by computing a table similar to the example (right in Figure):



step	N′	D(v),p(v)	D(w),p(w)	D(x),p(x)	D(y),p(y)	D(z),p(z)
0	u	2,u	5,u	1,u	∞	∞
1	ux	2,u	4,x		2,x	∞
2	uxy	2,u	3,y			4,y
3	uxyv		3,y			4,y
4	uxyvw					4,y
5	uxyvwz					

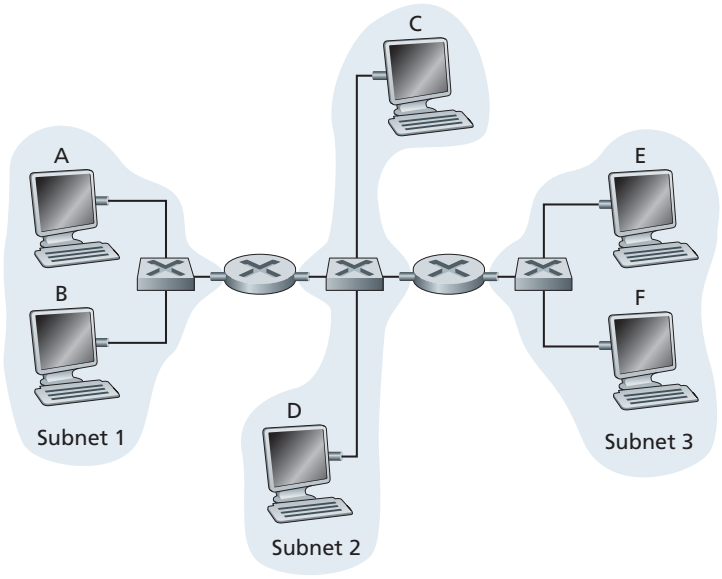


7. In the above figure, consider the path information that reaches stub networks W, X, and Y. The topology view at Y is shown below.

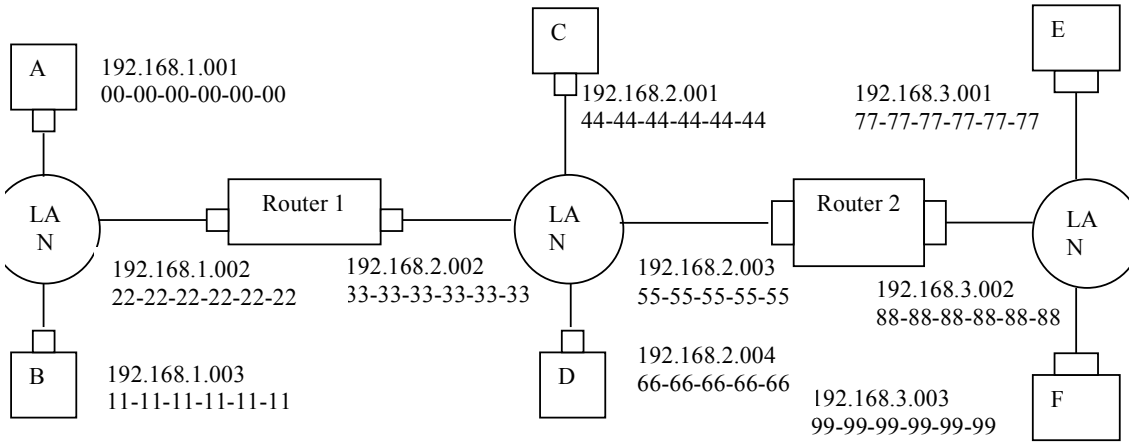


(7.1) (2 points) Based on the information available at W and X, what is W's view of the network topology? Justify your answer.

(7.2) (3 points) Suppose that there is another stub network V that is a customer of ISP A. Suppose that B and C have a peering relationship, and A is a customer of both B and C. Suppose that A would like to have the traffic destined to W to come from X only, and the traffic destined to V from either B or C. How should B advertise its routes to A and C? What AS routes does C receive?



8. **Written questions (essay, computational)** Consider three LANs interconnected by two routers, as shown in the above Figure. Assign IP addresses and MAC addresses to all of the interfaces and network adapters as follows



(8.1) (3 points) Consider sending an IP datagram from Host E to Host B. Suppose all of the ARP tables are up to date. Enumerate all the steps, describe the operationss of the two routers as the datagram moves from E to B.

(8.2) (3 points) Now we replace the router between subnets 1 and 2 with a switch S1, and label the router between subnets 2 and 3 as R1. Consider sending an IP datagram from Host E to Host F. Will Host E ask router R1 to help forward the datagram? Why? In the

Ethernet frame containing the IP datagram, what are the source and destination IP and MAC addresses?

(8.3) (3 points) Suppose E would like to send an IP datagram to B, and assume that E's ARP cache does not contain B's MAC address. Will E perform an ARP query to find B's MAC address? Why? In the Ethernet frame (containing the IP datagram destined to B) that is delivered to router R1, what are the source and destination IP and MAC addresses?

9. (5 points) **Written questions (essay, computational)** Consider the MPLS network shown in the following Figure. Specify for each router the tag forwarding information base (TFIB). You only need to show the incoming tag and the outgoing tag.