CMPE 150/L – Introduction to Computer Networks – Fall'16
Final Exam

Dec 5, 2016

Name :

Student ID :

E-mail :

- Duration: 180 minutes.
- Closed book, closed notes.
- 13 multi-item questions.
- Total of 150 points.
- Read all questions carefully before you start.
- Explain all your answers.
- Budget your time.

1	
2	
3	
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5	
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8	
9	
10	
11	
12	
13	
Total	

Question 1: [10 points] Match the following functions to one or more layers of the TCP/IP protocol stack:

(a) End-to-end error detection and correction:

Transport, Application

(b) Flow control:

Transport

(c) Transmission of signals:

Physical

(d) Process-to-process message delivery:

Transport

(e) Framing:

Link

(f) Routing:

Network

(g) Forwarding:

Network

(h) Congestion control:

Transport

(i) Hop-by-hop error detection and correction:

Link

(j) Name to IP address resolution:

Application

Question 2: [14 points] We saw in class that there are two types of network layer implementations: virtual circuit (VC) and datagram networks.

(a) In datagram networks, do packets from the same source to the same destination always follow the same route? Explain. (2 points)

No

(b) And in VC networks, do packets from the same source to the same destination always follow the same route? Explain. (2 points)

Yes

(c) Can packets in datagram networks arrive out-of-order? Explain. (2 points)

Yes

(d) Can packets in virtual circuit networks arrive out of order? Explain. (2 points)

No, but could be argued Yes

(e) Packets have to carry information in their header in order to be forwarded on their way from the source to the destination. What information VC packets carry in their header? What forwarding information datagrams carry in their header? (3 points)

VC: Virtual circuit ID; D: source and destination

(f) What information routers in VC networks maintain in their forwarding table? And datagram network routers? (3 points)

VC: Association between virtual circuit ID and output port, D: Association between destination and output prot

Question 3: [12 points] Suppose you have a network with 1,000 routers where each router is connected to 3 other routers on average.

(a) If Link State routing is used in this network, how many entries a routing update will carry? What information will each entry contain? Explain. (4 points)

3 entries (avg), the distance between the neighbors

(b) Same as (a) for Distance Vector routing. Explain. (4 points)

1000 entries, distance to all destinations

~~(c) How many routers on average will receive a Distance Vector update in this network?~~ Explain. (2 points) How many routing updates will a router receive for DV?

3 routing updates

~~(d) How many routers will receive a Link State update in this network? Explain.~~ (2 points)

How many routing updates will a router receive for Link State?

1000 routing updates

Question 4: [16 points] Suppose that two hosts are using TCP to communicate.

(a) Before they start exchanging data, they need to establish a TCP connection. Explain how this is accomplished including the information exchanged in the TCP header. (4 points)

SYN, SYN-ACK, ACK

(b) After the connection is opened, assuming that `ssthresh` is 64 KBytes and the maximum segment size (MSS) is 3 KBytes, how many bytes can be transmitted at the beginning of the fourth RTT? Show your work. (4 points)

1: 3KB
2: 6KB
3: 12KB
4: 24KB

(c) How many bytes in total are transmitted at the end of the fourth RTT? Show your work. (2 points)

1: 3KB
2: 9KB
3: 21KB
4: 45KB

(d) Suppose that a loss occurs during the fourth RTT, causing the TCP sender to time out. What congestion control mode will the TCP sender enter and how will it affect its congestion window? What will happen to `ssthresh`'s value? (3 points)

Slow Start, CWIND: 1, ssthresh = (old)CWIND/ 2

(e) In class, we discussed the Fast Retransmit mechanism. How does Fast Retransmit try to avoid timeouts? (1 point)

Lower traffic load

(f) For the scenario described in (d), what happens to TCP's congestion window if Fast Retransmit is able to avoid the timeout? (2 points)

Congestion Avoidance CWIND /= 2 (12KB), ssthresh = CWIND
CWIND = 12KB, 15KB after next RTT

Question 5: [15 points] You were hired by a start-up as their network administrator. The CIO gives you an estimate of the company's growth in the next 10 years as follows: it will likely grow to no more than 20 departments, each of which with 500 end-user devices.

(a) Assuming that the company's network address range is 145.20.0.0/16, how would you use subnetting to accommodate the company's growth, i.e. how many bits will you use for the subnet number and how many bits for the host number? What is the subnet mask? Show your work. (3 points)

20 -> 5 bits 2^5 = 32
500 -> 9 bits 2^9 = 512*

D1: 145.20.0.0/21 [00000]000 00000000
D2: 145.20.8.0/21 [00001]000 00000000
D3: 145.20.16.0/21 [00010]000 00000000
…

*We only need 14 bits for departments and users, so we have two more bits that can be assigned to subnet or devices. Let's assume they'll be assigned to devices, since we will have no more than 20 departments

(b) How many subnets can you accommodate? Explain. (2 points)

2^5 = 32

(c) How many hosts can each subnet have? Explain. (2 points)

2^11 ~= 2048

(d) Suppose that the company's subnets will all be inter-connected through a single router. How many entries does the router have in its forwarding table? Explain. (3 points)

20 entries

(e) Assuming the router has 20 interfaces, whose identifiers are numbered from 1 to 20, show the router's forwarding table. (3 points)

D1: 145.20.0.0/21	1
D2: 145.20.8.0/21	2
D3: 145.20.16.0/21	3
…	

(f) If no subnets are used, what would be the size of the router's forwarding table when the company's network grows to its maximum size? Explain. (2 points)

20*500

Question 6: [8 points] For the topology below:

```
U -----------------V
|                  |
|                  |
|                  |
|                  |
|                  |
Y------------------X
```

where link costs are: UY = 2, UV = 1, VX = 3, and YX = 3,

(a) Use the Bellman-Ford algorithm to compute the routing tables at U, Y, V, and X at time t = 0.

From U	From X	From Y	From V
to X: -	to U: -	to X: 3 (X)	to X: 3 (X)
to Y: 2 (Y)	to Y: 3 (Y)	to U: 2 (U)	to Y: -
to V: 1 (V)	to V: 3 (V)	to V: -	to U: 1 (U)

(b) Show the routing tables at U, Y, V, and X after the first iteration of the algorithm once all nodes received the first round of updates.

From U	From X	From Y	From V
to X: 4 (V)	to U: 4 (V)	to X: 3 (X)	to X: 3 (X)
to Y: 2 (Y)	to Y: 3 (Y)	to U: 2 (U)	to Y: 3 (U)
to V: 1 (V)	to V: 3 (V)	to V: 3 (X)	to U: 1 (U)

Question 7: [12 points] For the topology below:

```
U----------------V
|                |\
|                | \
|                |  \
|                |   \ Z
|                |   /
|                |  /
|                | /
|                |/
Y----------------X
```

where link costs are: UV = 1, UY = 2, YX = 3, XV = 3, XZ = 2, VZ = 6,

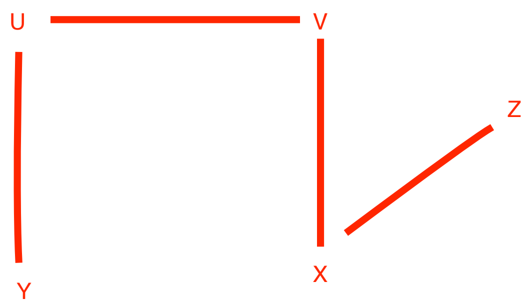
(a) Show how the Dijkstra algorithm running at router U would compute the shortest paths to the rest of the nodes in the network. Show each step of the algorithm. (6 points)

From U to —	V	Y	X	Z
Select V	1 (V)	2 (Y)	—	—
Select Y	1(V)	2 (Y)	4 (V)	7 (V)
Select X	1 (V)	2(Y)	4(V)	6 (X)
Select Z				

Table:

Destination	Distance	Predecessor
V	1	U
Y	2	U
X	4	V
Z	6	X

(b) Show the shortest-path tree rooted at U. (3 points)



(c) Show the forwarding table at node U. (3 points)

Table:

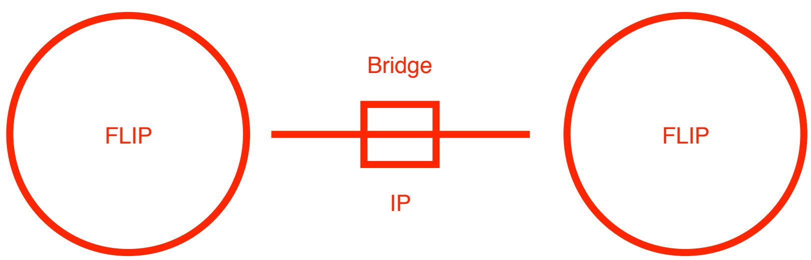
Destination	Through
V	V
Y	Y
X	V
Z	V

Question 8 [6 points] Internet of Things deployments will likely use protocols different from IP in order to be able to scale. One such protocol is called FLIP, short for Flexible Interconnection Protocol.

(a) What mechanism can be used to incrementally deploy FLIP in order to enable IoT solutions on the Internet which mostly uses IPv4? Explain. (2 points)

Bridging or
tunneling

(b) Show how communication between FLIP-enabled networks over the IPv4 Internet takes place using the technique described above. (4 points)



Question 9 [12 points] An Internet Content Provider (ICP) *GreatContent.com* has been receiving complaints from its users who have been experiencing considerably longer delays when accessing content hosted at the ICP Web servers over the Internet. The ICP service administrators decide to place a Web cache at the entrance/exit of the ICP's network.

(a) Does this cache reduce traffic on the Internet? Explain. (2 points)

No

(b) How do you think this cache could help improve user-perceived latency when accessing the ICP's service? (3 points)

Reduces server response time

(c) Propose a cache-based solution to further reduce latency. Explain. (3 points)

Add a cache at the ISP

(d) Suppose a user connected to comcast.com issues a request for content being serviced by *GreatContent.com*. Describe the steps needed to resolve *www.GreatContent.com* iteratively. (4 points)

User computer queries comcast.com DNS server (local) for www.GreatContent.com
Local DNS server queries root nameserver, receives address for .com TLD nameserver
Local DNS server queries .com TLD nameserver, receives address for GreatContent.com auth server
Local DNS server queries auth server, receives address and sends to user computer

Question 10 [8 points] "Delayed acknowledgments" are one type of acknowledgment that TCP uses.

(a) What is the goal of delayed acknowledgments? Explain. (2 points)

ACK more packets, reduce ACK traffic

(b) Explain how they work to accomplish their goal. (2 points)

Wait until many packets are received before
ACKing all packets through cummulative ACKS

(c) How does TCP guarantee that delayed acknowledgments are not delayed forever? Explain. (4 points)

Deadline for waiting before sending ACKs

Question 11 [8 points] Suppose that an IPv4 router has the following class-less entries in its forwarding table:

```
Destination address range                    Outgoing interface

11001000 00010111 00010000 00000000
through
11001000 00010111 00010111 11111111                 0

11001000 00010111 00011000 00000000
through
11001000 00010111 00011000 11111111                 1

11001000 00010111 00011001 00000000
through
11001000 00010111 00011111 11111111                 2

default                                             3
```

(a) Rewrite the forwarding table using the abbreviated $a.b.c.d/x$ notation. (4 points)

200.23.16.0/21 -> 0
200.23.24.0/24 -> 1
200.23.24.0/21 -> 2
default -> 3

(b) How does the router forward a packet with destination address 200.23.24.161? Show your work. (2 points)

Interface 1 (Matches 1 and 2, but 1 is more specific)

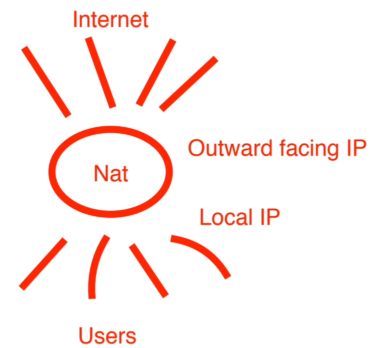
(c) And a packet with destination address 200.23.25.170? Show your work. (2 points)

Interface 2

Question 12: [6 points] You were hired to set up the network of your neighbors' small business *Cupcakes 4 All*. Because they are on a tight budget, they decided to buy just 1 "routable" IP address. However, they want to provide Internet access to their customers.

(a) How are you going to allow *Cupcakes 4 All* customers to connect to the Internet while they are enjoying cupcakes? Explain your solution by describing the steps that will be followed when a customer tries to connect to the Internet. Use a diagram to illustrate your answer. (4 points)

NAT and DHCP



(b) How many simultaneous connections can be supported by your solution? Explain. (2 points)

As many ports are available (TCP header has 16 bits for ports, so 2^16)

Question 13: [23 points] Medium Access Control

(a) What are collisions? (2 points)

When two nodes try to use the medium at the same time, interference impedes communication

(b) In *random access* medium access control protocols, also known as contention-based protocols (e.g., Aloha, CSMA, etc), a node tries to grab the shared channel and transmit whenever it has data to send. Do you think these kinds of protocols would work better in networks that are lightly loaded (i.e., are subject to light traffic loads) or heavily loaded? Explain. (4 points)

Lightly loaded, less possible contention (contention is costly for those)

(c) What about channel partitioning protocols such as TDMA? Explain. (4 points)

Heavily loaded, they waste channel otherwise

(d) In class we covered token-passing MAC protocols which, when operating in ring topologies, are also called token-ring protocols. Describe what is the worst-case latency a station on the ring will experience before it can transmit? Explain. (4 points)

Transmission to the node that transmitted right before, because then we have to wait for all other nodes to transmit before getting a response

(e) Suppose that a local-area network uses a polling-based MAC protocol. For a station in the network, what is the worst-case latency it will experience before it can transmit? Explain. (4 points)

Similar to (d), they have similar behavior, except that now access is controlled by a master polling nodes

(f) Slotted-Aloha is a variant of Aloha that was proposed to improve Aloha's efficiency. Describe how Slotted-Aloha works and how it improves on Aloha's performance. (2 points)

In Aloha the nodes transmit as soon as they have data to send. In slotted aloha, the nodes wait for the next slot to start transmission. This improves performance because it reduces the chance of collision

(g) Considering the three MAC protocol categories we covered in class, which one(s) are able to provide fairness? Explain. (3 points)

Channel partionning: provides
Random access: doesn't
Taking turns: provides