14-740: Fundamentals of Computer Networks

Fall 2020
Final Exam
Duration: 170 minutes

Name: ANSWER KEY Andrew ID: _____

Important:

- Each question is to be answered in the space provided. Material written on the back of the page or in space above or below the question will not be graded.
- This is a closed book exam -- you may not use any reference materials, crib sheets, or formula cards. Calculators are not allowed -- nor needed.
- **Write legibly**. Unreadable work will be considered incorrect.
- At the end of time, you will be told to "Cease Work." Immediately stop writing and turn in your paper. Any writing after this point will result in a zero grade.
- Answer all questions based on material presented in class. In the real world, there is an exception to just about every statement Prof Nace has made about networks. This exam is not the place to point out those situations.

Page 2	_____ (12 possible)
Page 3	_____ (12 possible)
Page 4	_____ (20 possible)
Page 5	_____ (30 possible)
Page 6	_____ (20 possible)
Page 7	_____ (27 possible)
Page 8	_____ (36 possible)
Page 9	_____ (33 possible)
Page 10	_____ (10 possible)
Total	_____ (200 possible)

I understand that the CMU and course policies on cheating apply to this exam.

_____

signature date

True or False: 2 points each

1. True or False (circle one): TCP uses a cumulative acknowledgement for receiver feedback. (TRUE)

2. True or False (circle one): Statistical multiplexing is used to divide a frequency range into separate channels to provide guaranteed bandwidth. (FALSE)

3. True or False (circle one): UDP is a transport protocol without any reliability guarantees. (TRUE)

4. True or False (circle one): TCP Vegas is a delay-based congestion control scheme. (TRUE)

5. True or False (circle one): **rabins** is an Argus program that reads data and adjusts it to be aligned with a set of bins or slots. (TRUE)

6. True or False (circle one): The Domain Name System is a distributed database holding network information, primarily the mapping of domain names to IP addresses.(TRUE)

For the following multiple choice questions, choose one **or more** of the available answers. Clearly indicate each choice by circling the letter at the beginning of the answer. (5 points each)

7. Which of the following were SDN flow-table actions described in class?

    a. Forward on outbound link (THIS ONE)

    b. Forward on inbound link

    c. Drop packet (THIS ONE)

    d. Decrement TTL

    e. Use legacy forwarding pipeline (THIS ONE)

8. A Kazaa P2P network consists of what two types of nodes?

    a. Unusual Nodes

    b. Ridiculous Nodes

    c. Ordinary Nodes (THIS ONE)

    d. Super Nodes (THIS ONE)

    e. Superstar Nodes

9. What protocol(s) translate between the addresses used in different layers?

    a. DNS (THIS ONE)

    b. NAT

    c. Skype

    d. ARP (THIS ONE)

    e. DHCP

10. Network measurement tools can be used for short-term monitoring or long-term planning. Give an example of a short-term use and another example of a long-term use.

In each case, specify a tool and the purpose it serves. Make it clear in your answer why it fits the short/long scenario. (12 points)

Short-term monitoring:

SMTP byte/packet counts can be combined with MRTG to detect hot-spots or attacks. These are things happening right now. Other tools might include ping, traceroute.

Long-term planning:

NetFlow shows origin and destination prefixes and can be used to build a traffic matrix. The matrix can be used for Traffic Engineering. Also, re-routing traffic, deciding to upgrade links. Other tools could include packet traces

11. Is the list of routers returned from traceroute guaranteed to describe a path that actually exists in the internet (i.e. hop *i* is connected to hop *i+1* for all *i*)? Justify your answer. (12 points)

No! The list is generated sequentially, meaning that after determining the router at hop *i*, only then are probes sent out to discover hop *i*+1. Any changes to the topology (due to failure, load-balancing, etc) in the meantime may cause the probes to find a router on a different path and thus not connected to i.

Don't write down here. This is not considered "space provided." Anything you write down here will not be graded (nor even read).

12. Answer the following questions about the RED Gateway algorithm: (12 points)

    a. How does it decide which category a packet should go in: don't drop/maybe drop/definitely drop?

The queue length is averaged with EWMA and compared to two thresholds, one for the boundary between don't and maybe, the other between maybe and definitely.

    b. What factors go into calculating the drop probability for a "maybe drop" packet?

Average queue length as a fraction of the distance between min and max thresholds, the number of packets since one was dropped, and a max probability defined by the administrator/implementor.

13. How is the forwarding process inside a router different between an IPv4 router and an MPLS Label Switching router?

There is something fundamentally different about the two; and that is what I'm looking for in your answer. (12 points)

The IPv4 router is using a destination address from the packet to look up in the forwarding table. The table includes an outbound link for every possible prefix. The MPLS router is looking up a label instead. The label has been assigned by the previous router and will be re-written to be a label agreed upon by this router and the next-hop router.

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14. In class, I listed 3 general categories of media-access protocols (this is in the data-link layer). Name them and, in one sentence, describe their general operation. I'll give you one of the names as a hint. (12 points)

Random Access: Transmitting nodes always send at full bandwidth, potentially causing collisions which must be avoided or detected.

Channel Partitioning: Divide the channel into N pieces, each with 1/Nth of the bandwidth, and let each node use a piece.

Taking Turns: Order the nodes, and let them use the entire channel bandwidth, one after the other.

15. Two Ethernet devices, A and B, are 100 bit times apart. At time 0, A starts to send a frame, consisting of 1000-bits (total frame size, including preamble, header and trailer). At time 50, B starts to send a frame, consisting of 500-bits.

At what time will A stop transmission? To be clear, I'm asking about a time that is either the end of the successful completion of a frame, or the time when the exponential backoff process begins. Show your work. (12 points)

Time 0: A starts transmitting

Time 50: B starts transmitting. A has transmitted the 50th bit

Time 150: B's first bit gets to A. A detects a collision. A aborts transmission.

Time 151: A starts to send the jam signal

Time 198: A finishes sending the jam signal and starts exponential backoff.

Don't write down here. This is not considered "space provided." Anything you write down here will not be graded (nor even read).

16. A normal, boring LAN consists of 3 hosts and a router (which also provides connectivity to the internet). All hosts have already been configured with DHCP, but it has been a long time during which no data has been transmitted on the LAN. For each scenario, describe the sequence of frames that would be transmitted on the LAN. For each frame, list the source, destination and purpose. (20 points)

Part A: The network layer on **host1** wishes to send a packet to **host2**, which is also on the LAN and whose IP address is already known to host1.

Host1 broadcasts an ARP frame, seeking the MAC address that matches host2's IP address. All interfaces on the LAN are the destination.

Host2 sends an ARP frame directly to host1, with its MAC address

Host1 sends a frame to host2, containing the IP packet.

Part B: The network layer on **host3** wishes to send a packet to **far_host**, which is not on the LAN. Fortunately, host3 already knows the IP address of far_host.

Host3 uses it's knowledge of the LAN prefix to determine the packet will need to leave the LAN. It therefore wants to send it to the default gateway (the router).

Host3 broadcasts an ARP frame, seeking the MAC address of the router.

The router sends an ARP frame directly to host3, with its MAC address.

Host 3 sends a frame to the router, containing the IP packet.

17. How many hosts are on the internet today? (Yes, this is time to take a short breather. Have 7 basically-free points!)

a. Between 200 and 400

b. Between 2000 and 4000

c. Exactly 65,536

d. Lots more than 4000 (THIS ONE)

18. TCP's Slow-start phase is designed to increase the congestion window by a certain quantity during each congestion round (i.e. each RTT amount of time). Tell me how much it should be increased as well as the mechanism TCP uses to actually achieve this increase. (12 points)

Slow start seeks to double the congestion window for each RTT.

It does this by increasing the congestion window by one MSS for each MSS-sized segment that is acknowledged.

19. Why does receiver shutdown require that wireless networks use a different media access protocol than wired networks? Note that I'm not asking for what the change would be, just the reason why. (12 points)

Receiver shutdown means the receiver must be turned off any time the node transmits a frame. Thus it cannot listen for collisions during the transmission time.

20. Web proxies cache HTTP replies in the hopes of using the result to answer a future question. However, if a WiFi access point ran a really bad proxy, one with a 100% cache miss rate (i.e. no result is ever re-used), it may still improve web performance for hosts in the BSS. Explain how that could be true. (15 points)

WiFi frames are commonly dropped in the BSS due to interference and noise. The proxy separates the end-to-end path into two parts (the client-proxy and the proxy-server).

Any packet lost on either part can be retransmitted independently. So, if a frame containing an HTTP reply is lost in the BSS, the client-proxy TCP connection will detect it quickly and the proxy will retransmit.

Without the proxy, this reply loss would need to be detected and retransmitted from the web server, which could be halfway around the world.

Note that the client may save the cost of repeated TCP connection establishment to the proxy. This is a somewhat incomplete answer, if given.

21. List the layer name and data type for each of the five layers of our network architecture model. (15 points)

Application Layer: Message

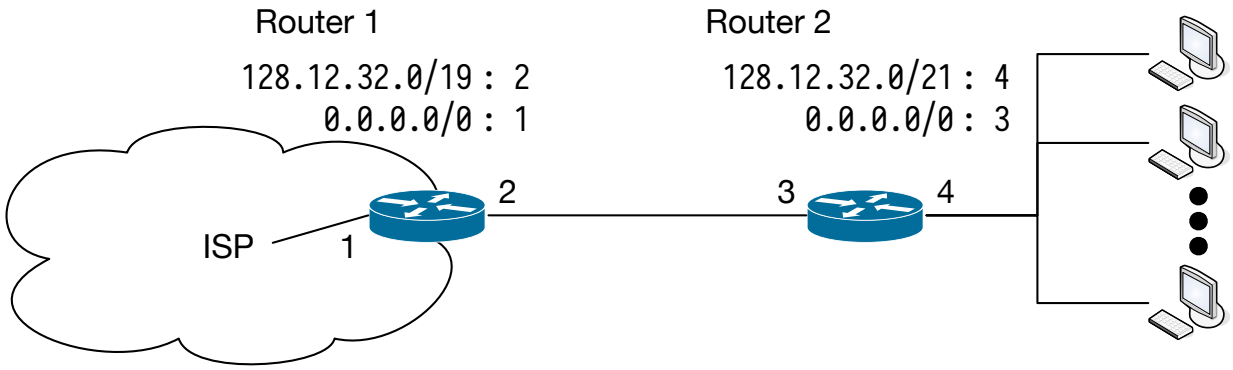
Transport Layer: Segment

Network Layer: Packet

Data Link Layer: Frame

Physical Layer: Bit

22. An ISP provides IPv4 service to a company with an assigned address block of 128.12.32.0/19, but the company only uses a portion of the address block, 128.12.32.0/21. The company only has this single connection to the internet. This image shows the situation, including the forwarding tables, for the ISP, company and the two routers that connect them.



Part A: How many addresses does the company have assigned to it in the 128.12.32.0/19 block? You may represent your answer as a power-of-two. (5 points)

32 - 19 is 13 bits in the address not specified by the prefix. Therefore, 2^{13} or 8192 addresses.

Part B: What are the largest and smallest IP addresses the company seems to be using, in the 128.12.32.0/21 block? (5 points)

32 - 21 is 11 bits, so the last 16 bits are 0010 0XXX. XXXX XXXX. That is a range of 128.12.32.0 to 128.12.39.255

Part C: If the ISP receives a packet with a destination IP address of 128.12.32.17, what inbound and outbound links does the packet follow? Your answer should be a list of 1,2,3,4 values. (5 points)

1 → 2 → 3 → 4

Part D: Same question as Part C, but the destination IP address is 128.12.63.200. (2 points)

1 → 2 → 3 → 2 → 3 → ...

Part E: What ultimately happens to the packet with destination IP address of 128.12.63.200. (3 points)

It will be discarded when it's IP TTL (Time-to-Live) is reduced to zero.