Part I: Multiple Choice (Circle all that are true) [7/7]

1. Which of the following is/are true about Address Resolution Protocol (ARP) and learning bridges?
   (a) A learning bridge maintains state that maps IP addresses to hardware (MAC) addresses.
   (b) A learning bridge maintains state that maps MAC addresses to IP addresses.
   (c) A host's ARP table maintains state that maps IP addresses to hardware (MAC) addresses.
   (d) A host's ARP table maintains state that maps hardware addresses to IP addresses.

2. Which of the following is/are true about Ethernet:
   (a) CRC error detection, as used in Ethernet, cannot always detect if there is a frame error.
   (b) **In the Ethernet CSMA/CD protocol, suppose that an adapter constructs a frame to send and then senses that the channel is busy. The adapter then enters exponential back-off.**
   (c) Entries in an Ethernet bridge table must be configured by a network administrator.
   (d) An Ethernet adapter always passes all non-corrupt frames that it receives up to the network layer.

3. Which best describes the Ethernet protocol?
   (a) Talk only if you hear no one else talking, but stop as soon as you hear anybody else.
   (b) Pass a ticket around and only talk if you are holding the ticket.
   (c) Raise your hand and wait till a moderator gives you permission to talk.
   (d) Every person is scheduled a time to talk.

4. When a UDP segment arrives at a host, in order to direct the segment to the appropriate socket, the operating system's network stack uses the following fields:
   (a) the source IP address.
   (b) the destination IP address
   (c) the source port number
   (d) the destination port number

5. Which of the following are true about Ethernet networks?
   (a) Ethernet frames have a minimum size to ensure good utilization of the network (i.e., senders could otherwise have a large overhead to send a small piece of data).
   (b) Bridges provide greater scalability for Ethernet networks than hubs.
   (c) Hosts on different segments of a switched Ethernet network will only see packets to hosts on their segments or to the broadcast address.
   (d) When an Ethernet sender detects that the media is idle, it sends a jam signal onto the media to tell other devices not to transmit, and then it sends its packet.

Part II: Routing [21/21]

6. What is the difference between routing and forwarding? **[2/2]**

   - `Forwarding - Directing data packet to an outgoing link`
   - `Routing - Computing paths the packets will follow`

7. List *four* fields of a packet that an IP router must modify before forwarding the packet to its next hop. **[4/4]**

   - `Source MAC address`
   - `Destination MAC address`
   - `IP time-to-live field`
   - `IP header checksum`

8. Describe three different scenarios when an IP router would drop packets that arrive on one of its interfaces. **[3/3]**

   - `Insufficient buffer space`
   - `No route for the destination`
   - `Badly formed packet (e.g., checksum error)`
   - `TTL expiry`

9. Suppose a router has built up the routing table as shown below. The router can deliver packets directly over interfaces 0 and 1, or it can forward packets to routers R2, R3, or R4. What will the router do with a packet addressed to each of the following destinations? **[5pts]**
   a) 128.93.39.10
      - Applying the subnet mask 255.255.255.128, we get 128.96.39.0. Use interface0 as the next hop.
      - NOTE: There was a typo for this question! I will accept both Interface 0 or R4 as the correct answers.

   b) 128.96.40.12
      - Applying subnet mask 255.255.255.128, we get 128.96.40.0. Use R2 as the next hop.

   c) 128.96.40.151
      - All subnet masks give 128.96.40.128 as the subnet number. Since there is no match, use the default entry. Next hop is R4.

SubnetNumber	SubnetMask	NextHop
128.96.39.0	255.255.255.128	Interface 0
128.96.39.128	255.255.254.128	Interface 1
128.96.40.0	255.255.255.128	R2
192.4.153.0	255.255.252.192	R3
(default)		R4

10. An ISP that has authority to assign addresses from a /16 prefix is working with a new company to allocate it a portion of address space based on CIDR. The new company needs IP addresses for machines in three divisions of its corporate network: Engineering, Marketing, and Sales. These divisions plan to grow as follows: Engineering has 5 machines as of the start of year 1 and intends to add 1 machine every week, Marketing will never need more than 16 machines, and Sales needs 1 machine for every 3 clients. As of the start of year 1, the company has no clients, but the sales model indicates that, by the start of year 2, the

company will have 6 clients and each week thereafter will get one new client with probability 60%, will lose one client with probability 20%, or will maintain the same number with probability 20%. **[6/6]**

(a) What address range would be required to support the company's growth plans for at least 7 years if Marketing uses all 16 of its addresses and Sales and Engineering plans behave as expected.

- each department expects the growth in the number of machines as follows
  a. Engineering expects machine number increase by one per week, thus by 52 per year. Note that we need 5 machines initially.
  b. Sales expects client number increase by (−1) x 0.20 + (+1) * 0.60 + 0 * 0.20 = 0.40, thus machine will increase by 0.40 * 1/3 = 0.13 per week, so by 0.13 * 52 = 7 per year. Note that we do not need any machines in the first year, but at the beginning of the second year, we need 2 machines since we have 6 clients then.
  c. Marketing expects no increase.

  To guarantee addresses for at least seven years, we need (5 + 52 * 7) + (2 + 7 * 6) + 16 = 429 addresses. Therefore, the new company needs a slash 23 address range to accommodate 512 addresses.

(b) If, instead of using CIDR addressing, it was necessary to use old-style classful addresses, what options would the new company have in terms of getting address space?

- Since class B supports 65534 host addresses and class C supports 254 addresses (note that two addresses are always reserved in each network class), the company could get one class B range or two class C ranges.

Part III: TCP and BGP [11/11]

11. How does the Border Gateway Protocol (BGP) avoid the count-to-infinity problem that plagues distance-vector protocols? **[2/2]**

    - BGP is a path-vector protocol. That is, BGP announcements include the entire path traversed by the message, not simply a total cost. A router, upon receiving a BGP announcement, can check for its own AS number in the path; if the AS number is present, the path has a loop and is immediately discarded.

12. Give two reasons why interdomain routing uses path-vector routing instead of distance vector routing. **[2/2]**

    - Faster convergence through loop detection, avoiding the "counting to infinity" problem
    - Flexible routing policies that depend on the hops in the AS-PATH.

13. List one advantage and one disadvantage of classless interdomain routing (CIDR) over the earlier use of classful routing. **[2/2]**

    - CIDR allows more efficient allocation of the limited address space, by permitting a wide variety of sizes of address blocks. However, CIDR requires routers to perform longest-prefix-match forwarding, which is hard to do quickly.

14. Suppose a TCP message that contains 1024 bytes of data and 20 bytes of TCP header is passed to IP for delivery across two networks interconnected by a router. The first network has an MTU of 1024 bytes; the second has an MTU of 576 bytes. Each network's MTU gives the size of the largest IP datagram that can be carried in a link-layer frame. Give the sizes and offsets of the sequence of fragments delivered to the network layer at the destination host. Assume all IP headers are 20 bytes. **[5/5]**

```
This is a TCP Payload, therefore size of payload is 1024 Bytes
of data + 20 bytes of TCP Header = 1044 Bytes
Max Bytes for MTU(1024) = 1024 bytes – 20 IP header byte = 1004
bytes /8 = 1000 bytes (divisible by 8)
First fragment is 1000 bytes, second fragment is 1044-1000 = 44
bytes, offset for second fragment is 1000/8 = 125

Max Bytes for MTU(576) = 576 bytes – 20 IP header byte = 556
bytes /8 = 552 bytes (divisible by 8)
We have 2 fragment coming down the second MTU one at 1000 bytes
and the other at 44 bytes.
1000 bytes – 552 bytes = 448 for the second fragment of the
first fragment, offset = 552/8 = 69
```

Fragment (First MTU)	**Bytes**	**Offset**	**Flag**
1	1000	0	1
2	44	125	0
(2nd MTU)			
1	552	0	1
2	448	69	0
3	44	125	0

Part IV: Tidbits [9/9]

15. Why do Ethernet adaptors select a *random* back-off time before trying to transmit a frame following a collision? Why do they pick the random back-off time from a *larger range* after each collision? **[2/2]**

- Random back-off times reduce the likelihood of a future collision, without requiring any explicit coordination between the senders to schedule their transmission times. When more collisions occur, this means that the link is likely quite heavily loaded (i.e., many adaptors are trying to transmit). Picking from a larger range helps avoid future collisions, and essentially expands the back-off times to allow each of the adaptors to have a turn, without explicit coordination to learn exactly how many adaptors have data awaiting transmission.

16. Calculate the total time required to transfer a 1.5 MB file if the link allows infinitely fast transmit, but limits bandwidth such that only 20 packets can be sent per RTT. Assume an RTT of 80 ms, a packet size of 1 KB data, and an initial 2 x RTT of "handshaking" before data is sent. *(Assume $K = 10^3$ and $M = 10^6$)* **[2/2]**

- Dividing the $1.5 \times 10^6 / 1 \times 10^3$ packets by 20 gives 75. This will take 74.5 RTTs (half an RTT for the first batch to arrive, plus 74 RTTs for the rest), plus the initial 2 RTTs, for $74.5 \times 80 \times 10^{-3} + 2 \times 80 \times 10^{-3}$ = **6.12 seconds**.

17. List one advantage and one disadvantage of switches over hubs and repeaters. **[2/2]**

- Advantage
  - Only forwards frame as needed
  - Extends geographic span of network
  - Improves privacy by limiting scope of frames

    - Joins segments using different technologies
- Disadvantage
    - Delay in forwarding frames
    - Need to learn where to forward frames
    - Higher cost

18. The OSI model is traditionally seen as a 7-layer stack consisting of the following. For several of the layers, give one or two examples of protocols that are associated with each layer. **[8/8]**

OSI Layers	**Example**	**Example**
Application	HTTP	FTP, SMTP, Telnet, SIP
Presentation		
Session		
Transport	TCP	UDP, DCCP
Network	IPv4, IPv6	
Data Link	Ethernet	PPP, Token Ring, FDDI, 802.11
Physical	Twisted Pair, CAT5/6, Fibre or Encodings (Manchester, NRZI, 4B/5B, NRZ)	