

## 1 Multiple Choice

- 1.1 NAT allows multiple hosts to share the same IP address in a way that conforms to the E2E principle.  
**False.** NAT is an example of middleboxes, which add additional functionalities besides packet forwarding to the network.
- 1.2 Port numbers are used to multiplex among hosts behind the same NAT.  
**True.**
- 1.3 Which protocol does a host use to learn its own IP address?  
(a) DHCP      (d) ICMP  
(b) DNS      (e) None of these  
(c) ARP  
**(a) DHCP**
- 1.4 Which protocol does a host use to learn its own MAC address?  
(a) DHCP      (d) ICMP  
(b) DNS      (e) None of these  
(c) ARP  
**(e) None of these**
- 1.5 Which protocol does a host use to learn the MAC address of another host on the same network?  
(a) DHCP      (d) ICMP  
(b) DNS      (e) None of these  
(c) ARP  
**(c) ARP**
- 1.6 DHCP is a protocol in which of the following layers?  
(a) Physical      (d) Transport  
(b) Datalink      (e) Application  
(c) Network  
**(e) Application**

1.7 ARP is a protocol in which of the following layers?

- (a) Physical
- (b) Datalink
- (c) Network
- (d) Transport
- (e) Application

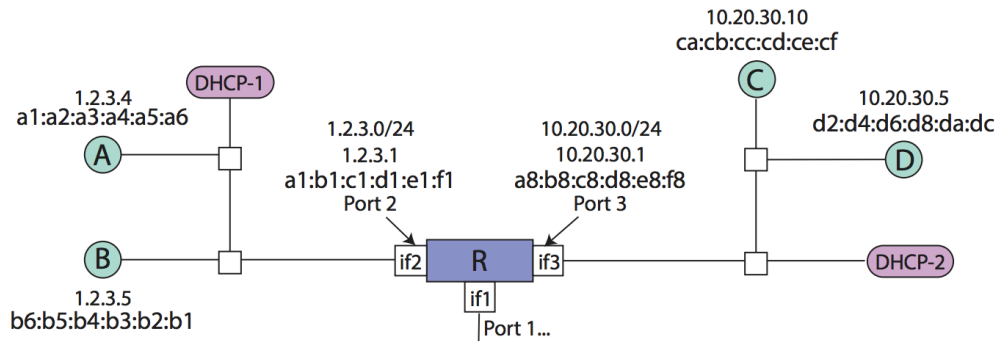
**(b) Datalink**

1.8 Which of the following can a host learn with DHCP? Select all that apply.

- (a) Its own MAC address.
- (b) Its own IP address.
- (c) The MAC address of another host.
- (d) The IP address of another host.
- (e) The IP address of its first-hop router.
- (f) The MAC address of its first-hop router.
- (g) Its own subnet mask.

**(b) Its own IP address, (e) The IP address of its first-hop router, and (g) Its own subnet mask.**

## 2 Host-to-Host



Consider the above topology. Here, two networks are connected through router *R*. *R* has three interfaces, each associated with a port, MAC address, IP address, and subnet.

We are going to consider what happens when *A* sends a packet to *C*. Assume that *A* just attached to the network, but already knows the IP address of *C* (10.20.30.10). No hosts or routers have sent any previous ARP requests.

2.1 First *A* needs to learn its own IP address, subnet mask, and the IP of its first-hop router by using DHCP. For each of the following DHCP messages, indicate the message’s timing in the packet exchange (1 is first, 4 is last), who sends the message, and whether the message is broadcast or unicast.

Message	Order	Sender	Message Type
DHCP request	3	Client	Broadcast
DHCP ACK	4	Server	Broadcast
DHCP discovery	1	Client	Broadcast

Message	Order	Sender	Message Type
DHCP offer	2	Server	Broadcast

2.2 Using this information, how does *A* determine if *C* is on the same subnet?

*A* uses its IP address, its subnet mask, and *C*'s IP address. If computing the bitwise AND between *A*'s IP and the subnet mask and computing the bitwise AND between *C*'s IP and the subnet mask yields the same result, then *A* and *C* are on the same subnet.

If this is true, then *C* is on the same subnet as *A*. In this example, we have:

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1 A's subnet:    11111111.11111111.11111111.00000000
2 A's IP:       00000001.00000010.00000011.00000100
3 C's IP:       00001010.00010100.00011110.00001010

```

The underscored portions are the network addresses, and since they are not equal, *A* and *C* are on different subnets.

2.3 Given that *C* is not on the same subnet as *A*, *A* must send the packet to its first hop router *R*. Which requests and responses are exchanged before this can happen?

Request	Response
ARP request for 1.2.3.4	ARP response: 1.2.3.4
ARP request for 1.2.3.1	ARP response: 1.2.3.1
ARP request for 10.20.30.10	ARP response: 10.20.30.10
ARP request for a1:a2:a3:a4:a5:a6	ARP response: a1:a2:a3:a4:a5:a6
ARP request for a1:b1:c1:d1:e1:f1	ARP response: a1:b1:c1:d1:e1:f1
ARP request for ca:cb:cc:cd:ce:cf	ARP response: ca:cb:cc:cd:ce:cf

ARP request for 1.2.3.1

ARP response: a1:b1:c1:d1:e1:f1

2.4 Is the ARP request broadcast or unicast? What about the ARP response?

The ARP **request** is broadcast. Since we're trying to learn the MAC address, we have no idea which address to use for unicast.

The ARP **response** is unicast. By looking at the source MAC address in the ARP request, the responder knows which address to unicast the response to.

2.5 In the packet *A* now sends to *R*, what are the source and destination IP and MAC addresses?

**Source IP:** 1.2.3.4 (*A*'s IP) **Source MAC:** a1:a2:a3:a4:a5:a6 (*A*'s MAC) **Destination IP:** 10.20.30.10 (*C*'s IP) **Destination MAC:** a1:b1:c1:d1:e1:f1 (MAC of *R*)

2.6 How does *R* know which interface to forward *A*'s packet on?

*R* looks in its routing table for a prefix that matches 10.20.30.10.

Assuming that the routing state has converged, *R*'s forwarding table maps packets destined for 10.20.30.0/24 to port 3.

2.7 Now *R* has the packet. List all remaining packets that are exchanged until *C* receives the packet from *A*.

*R* sends an ARP request for 10.20.30.10.

*R* receives an ARP response from *C* containing ca:cb:cc:cd:ce:cf.

*R* sends the packet to *C*.

2.8 What are the source and destination IP and MAC addresses for the packet that *R* sends to *C*?

**Source IP:** 1.2.3.4 (*A*'s IP)

**Source MAC:** a8:b8:c8:d8:e8:f8 (MAC of if3 on *R*)

**Destination IP:** 10.20.30.10 (*C*'s IP)

**Destination MAC:** ca:cb:cc:cd:ce:cf (*C*'s MAC)

### 3 Network Address Translation

Consider a host A behind a NAT, trying to communicate with a remote host B. When a packet headed for B leaves host A, its source port is 56789, destination port is 443, source IP is 192.168.1.10, destination IP is 8.8.8.8. When a packet headed for A leaves host B, its source port is 443, destination port is 60000, source IP is 8.8.8.8, destination IP is 203.0.113.5. Based on the information above, answer the following questions:

- 3.1 The packet from host A to host B arrives at the NAT. What are the fields in the packet after the NAT has altered it?

Source IP: **203.0.113.5**

Source Port: **60000**

Destination IP: **8.8.8.8**

Destination Port: **443**

- 3.2 The packet from host B to host A arrives at the NAT. What are the fields in the packet after the NAT has altered it?

Source IP: **8.8.8.8**

Source Port: **443**

Destination IP: **192.168.1.10**

Destination Port: **56789**