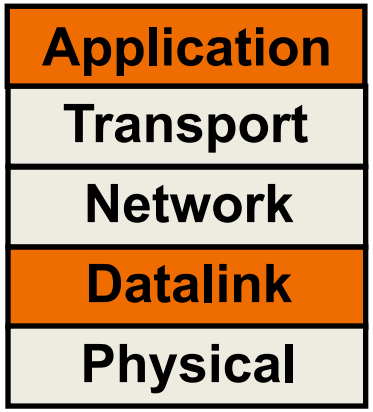
L2, End-to-End

CS 168 – Fall 2024– Section 11

Agenda

- Logistics
- Addressing
  - DHCP (Application)
  - ARP (Datalink)

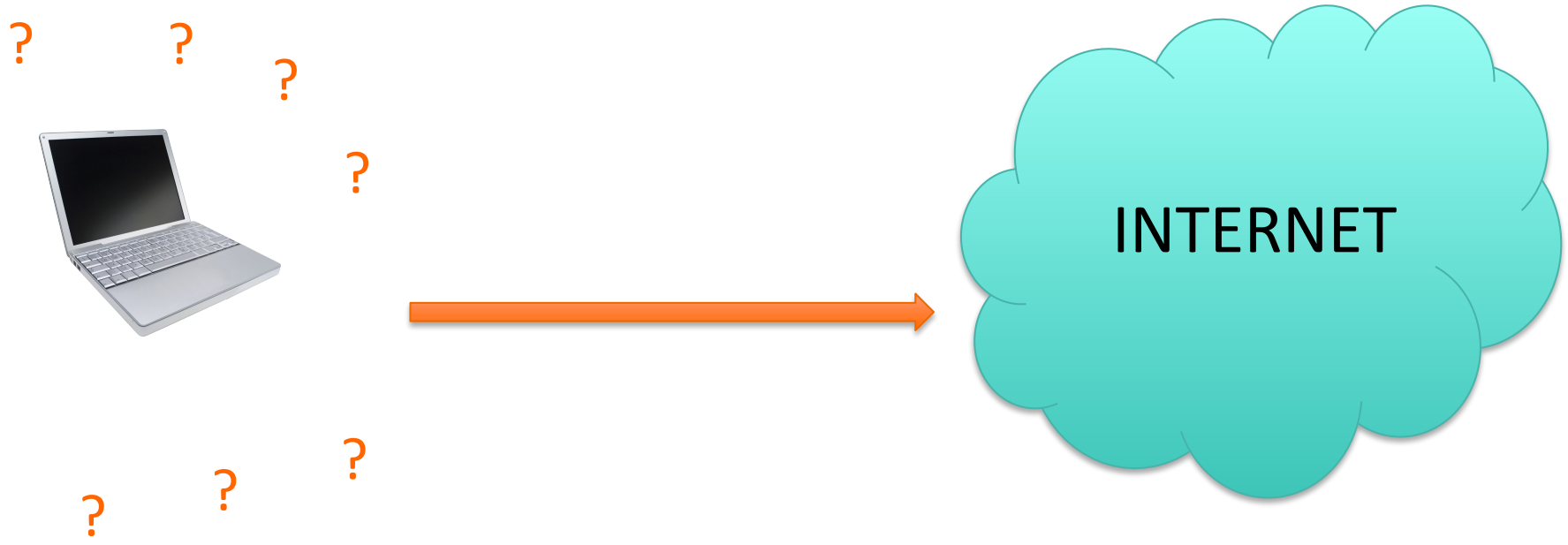


Logistics

- Project 3B due this Tuesday (November 12)
  - You can fill out an extension if needed!
- HW4 released on Gradescope; due Monday (November 18)

DHCP - Dynamic Host Configuration Protocol

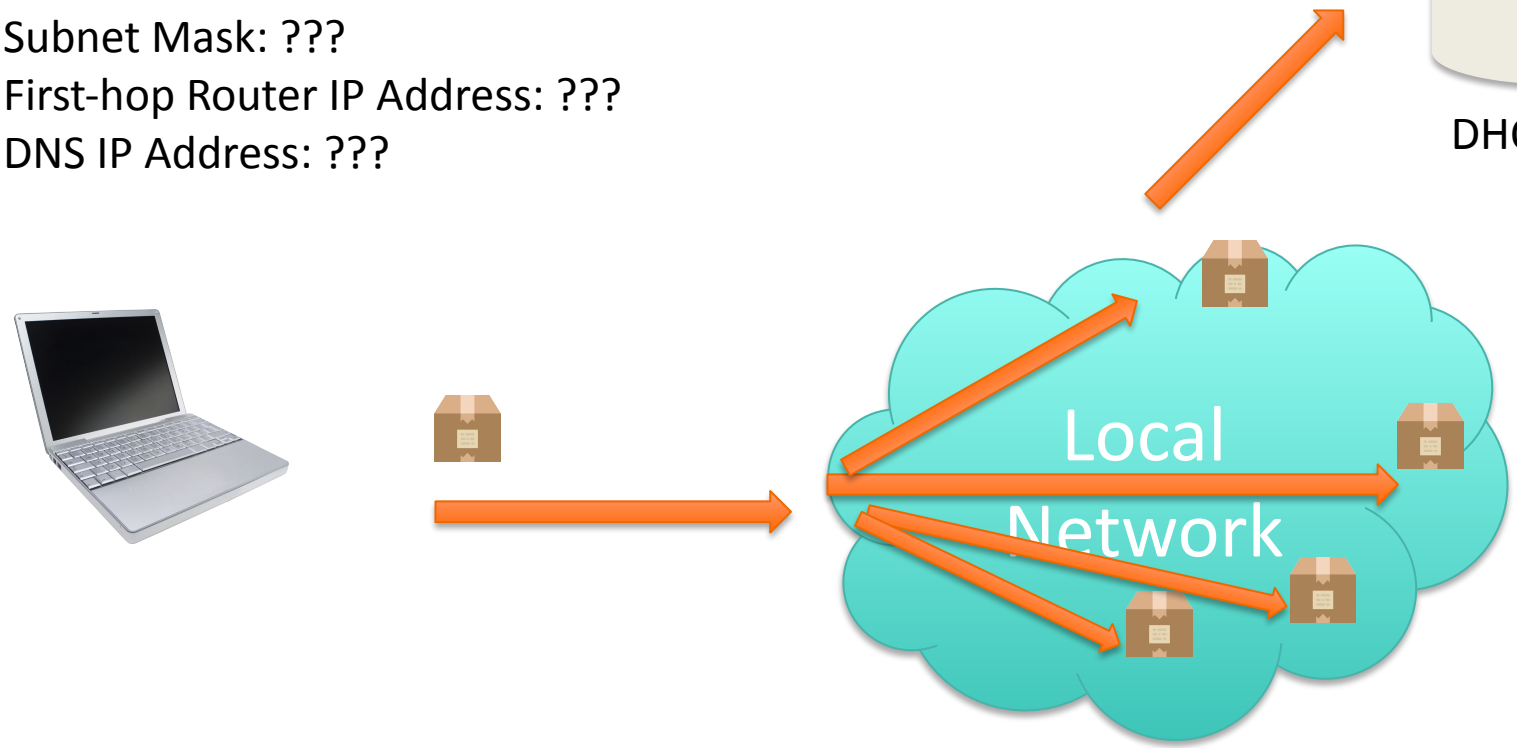
- Enables a host to learn about its….
  - Own IP Address
  - Network Mask
  - First-hop router's IP Address
  - DNS Server(s) IP Address(es)



DHCP Discovery

- DHCP server(s) located on same local network as host
- Host initially broadcasts **discover** message
- "Can anyone give me a configuration?"

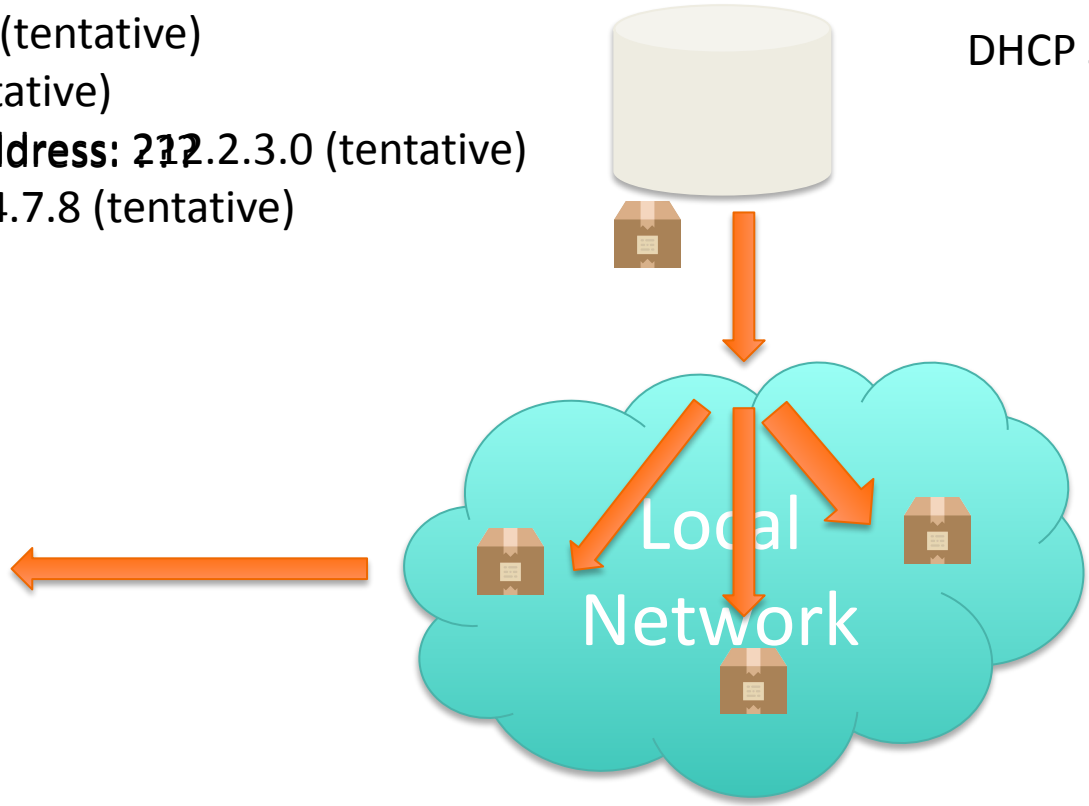
IP Address: ???
Subnet Mask: ???
First-hop Router IP Address: ???
DNS IP Address: ???



DHCP Offer

- DHCP server(s) responds by broadcasting **offer** message
- Message includes assigned IP address, network mask, first-hop router address, DNS server addresses

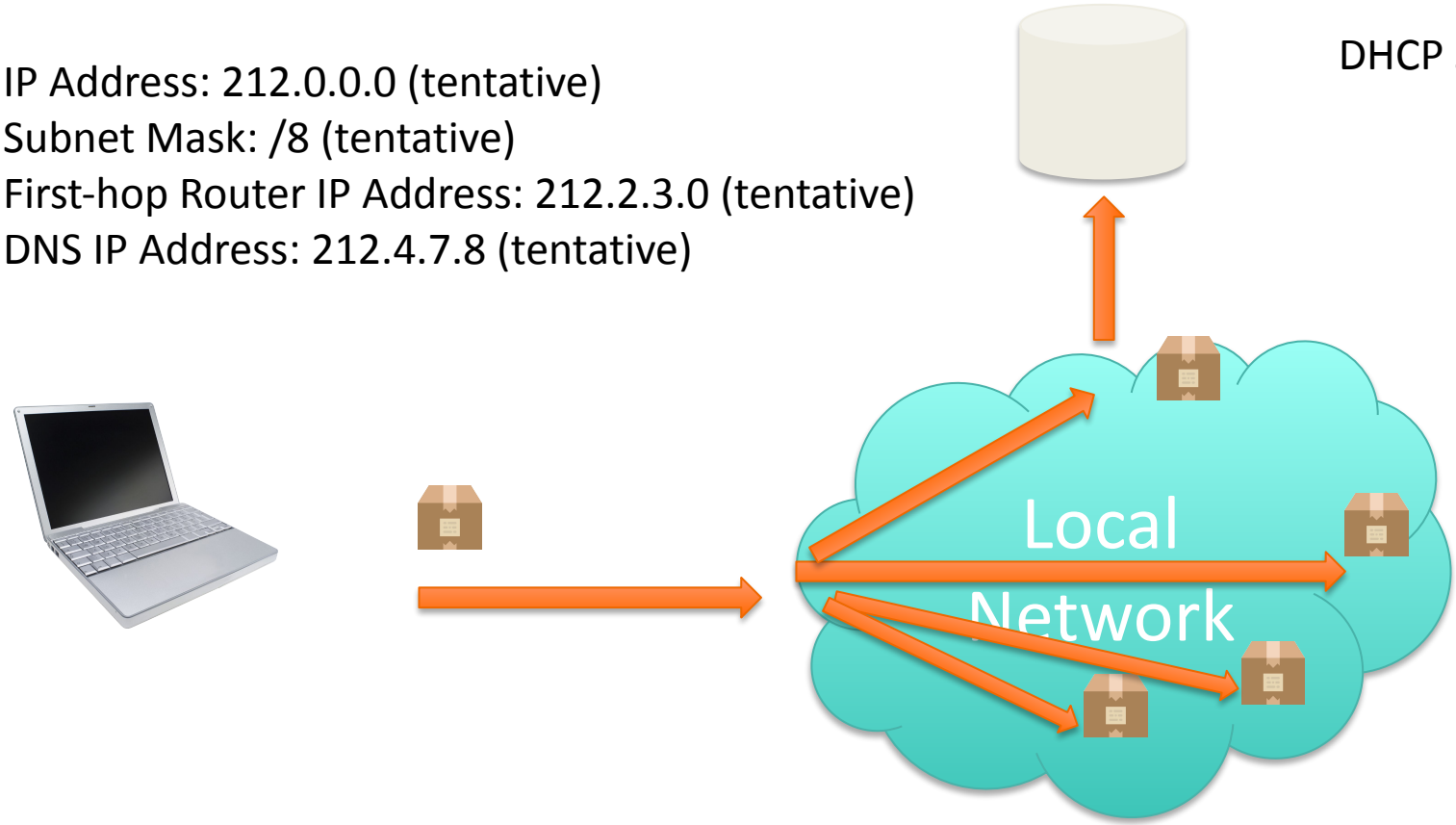
IP Address: 212.0.0.0 (tentative)
Subnet Mask: 255.255.255.0 (tentative)
First-hop Router IP Address: 212.2.3.0 (tentative)
DNS IP Address: 212.4.7.8 (tentative)



DHCP Request

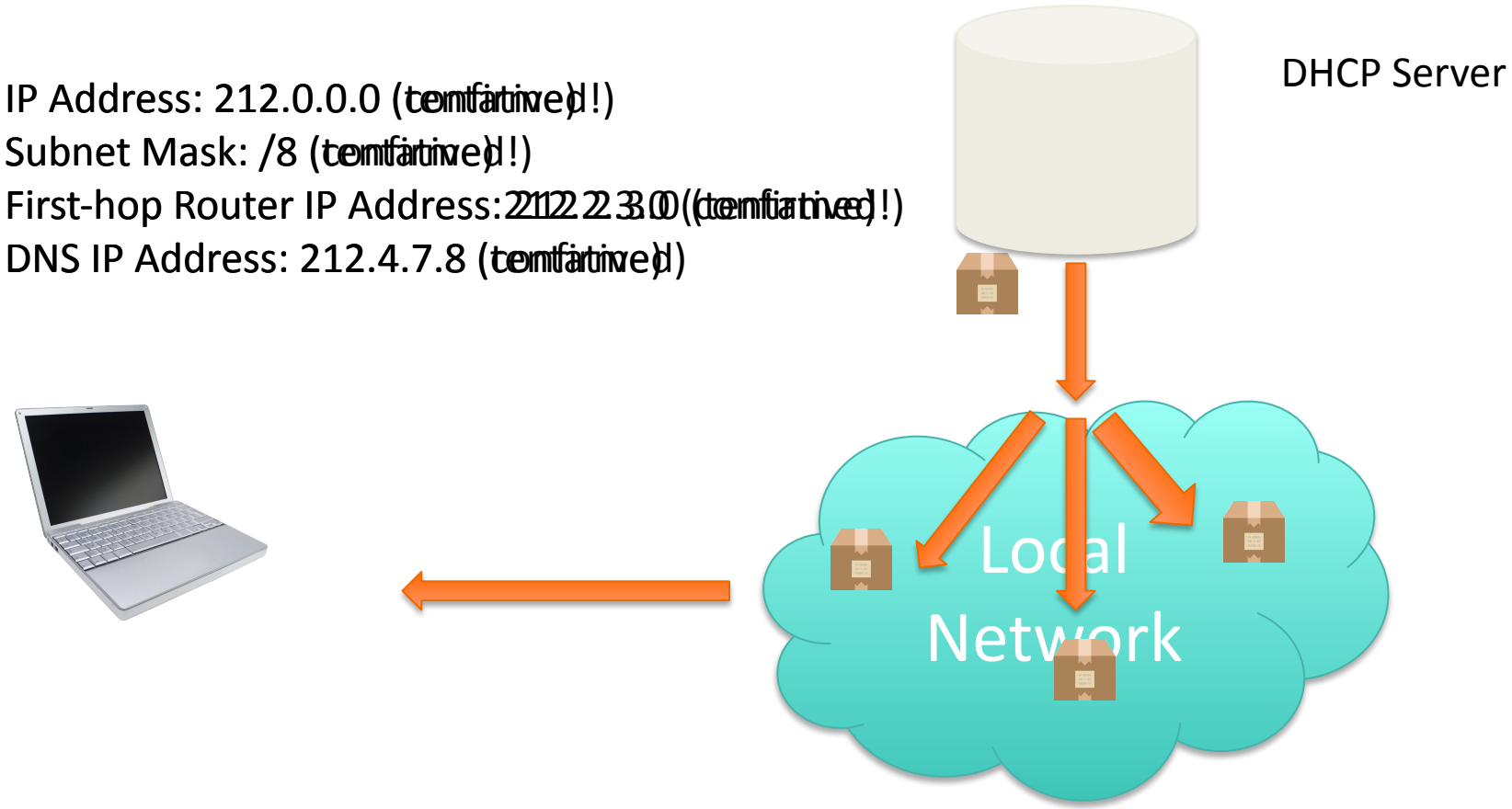
- Host responds by broadcasting **request** message
- This message identifies which offer was accepted (helps when there are multiple local DHCP servers)

IP Address: 212.0.0.0 (tentative)
Subnet Mask: /8 (tentative)
First-hop Router IP Address: 212.2.3.0 (tentative)
DNS IP Address: 212.4.7.8 (tentative)



DHCP Acknowledgement

- Chosen DHCP server responds by broadcasting **ACK**



DHCP Summary

1. **Client Discover**: The client broadcasts a request for a configuration.

2. **DHCP Offer**: One or more DHCP servers respond with a configuration offer.
   Offer includes subnet mask, router's IP address, DNS resolver, and IP for client.

3. **Client Request**: The client broadcasts which configuration it has chosen.
   If multiple DHCP servers made offers, the ones that were not chosen discard their offer.

4. **DHCP Acknowledgement**: The chosen server confirms that its configuration has been given to the client.

source: lecture 18 slide 20

A Couple Questions….

1. **Dealing with failures?**
   - Hosts have a lease periods for their IP addresses
   - Hosts must refresh before lease period ends

2. **Why do we need the first-hop router's IP address and the subnet mask?**
   - Answered when we talk about ARP.

ARP (Overview)

- When host sends packet, specify dest Ethernet (MAC) address so packet can traverse local networks
- Each host has ARP table, which maps IP to Ethernet
- If mapping unknown, ask (solicit) local network by broadcasting "Who has IP address **x**?"
  - Host with IP **x** responds "My Ethernet address is **y**"

ARP Table

IP Addr.	Ethernet Addr.
a.b.c.d	40:11:11:11:11:11
a.b.c.a	50:37:11:11:11:11

Dest Host
IP: a.b.c.d
Ethernet address:
40:11:11:11:11:11

ARP (Within local network)

Destination is in same local network

- Use ARP table to lookup Ethernet address of dest
- Specify Ethernet address when sending packet

ARP Table

IP Addr.	Ethernet Addr.
a.b.c.d	40:11:11:11:11:11
a.b.c.a	50:37:11:11:11:11

Dest Host
IP: a.b.c.d
Ethernet address:
40:11:11:11:11:11

Src Host

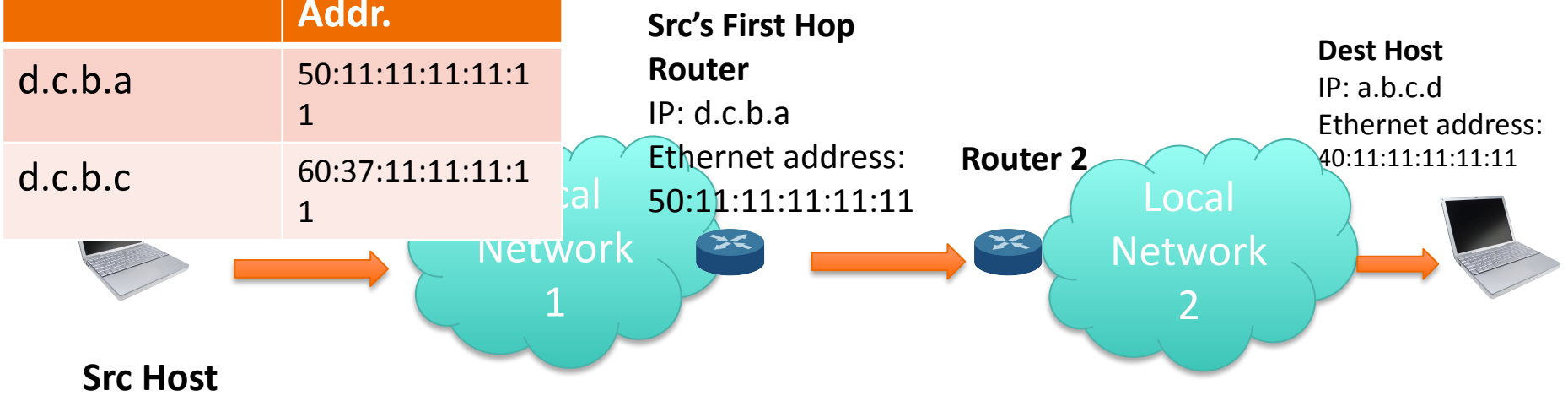
ARP (Across local networks)

Destination is NOT in same local network

- How can we tell?
  - Use subnet mask to check dest network address

ARP Table

IP Addr.	Ethernet Addr.
d.c.b.a	50:11:11:11:11:11
d.c.b.c	60:37:11:11:11:11

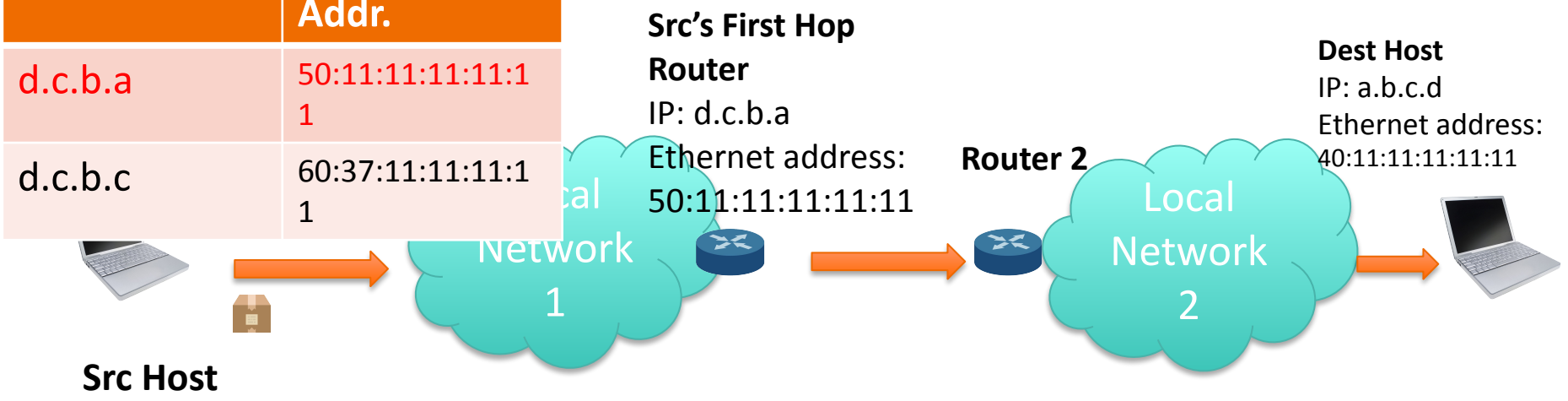


ARP (Across local networks)

- Use ARP table to lookup Ethernet address of first-hop-router (which is in same local network)
  - We know router's IP address through DHCP!
- Specify **first-hop router**'s Ethernet address in packet and send packet

ARP Table

IP Addr.	Ethernet Addr.
d.c.b.a	50:11:11:11:11:11
d.c.b.c	60:37:11:11:11:11

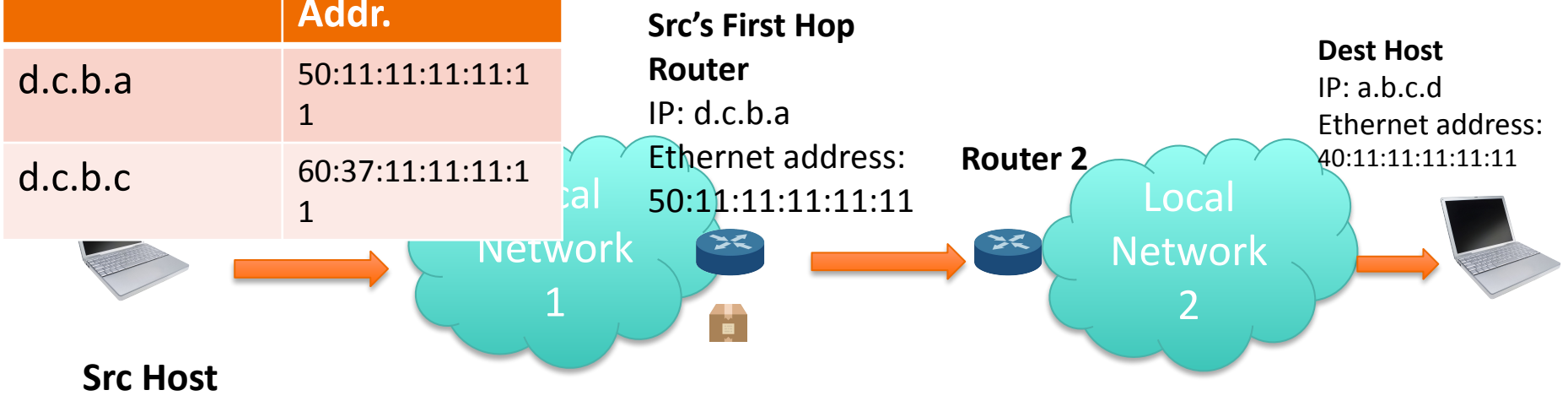


ARP (Across local networks)

- First-hop router will route packet to router 2 using dest IP address
  - Dest IP address is a.b.c.d. in this example

ARP Table

IP Addr.	Ethernet Addr.
d.c.b.a	50:11:11:11:11:11
d.c.b.c	60:37:11:11:11:11



ARP (Across local networks)

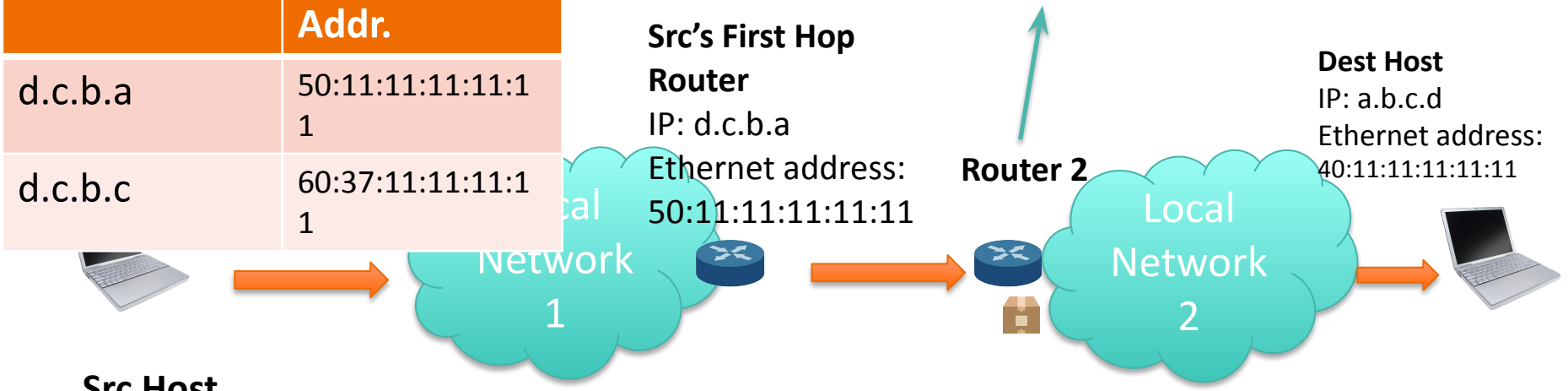
- Router 2 will use its ARP table to **set** packet's dest Ethernet address to actual dest host's Ethernet address:
  - Router 2 then sends packet to dest host

ARP Table

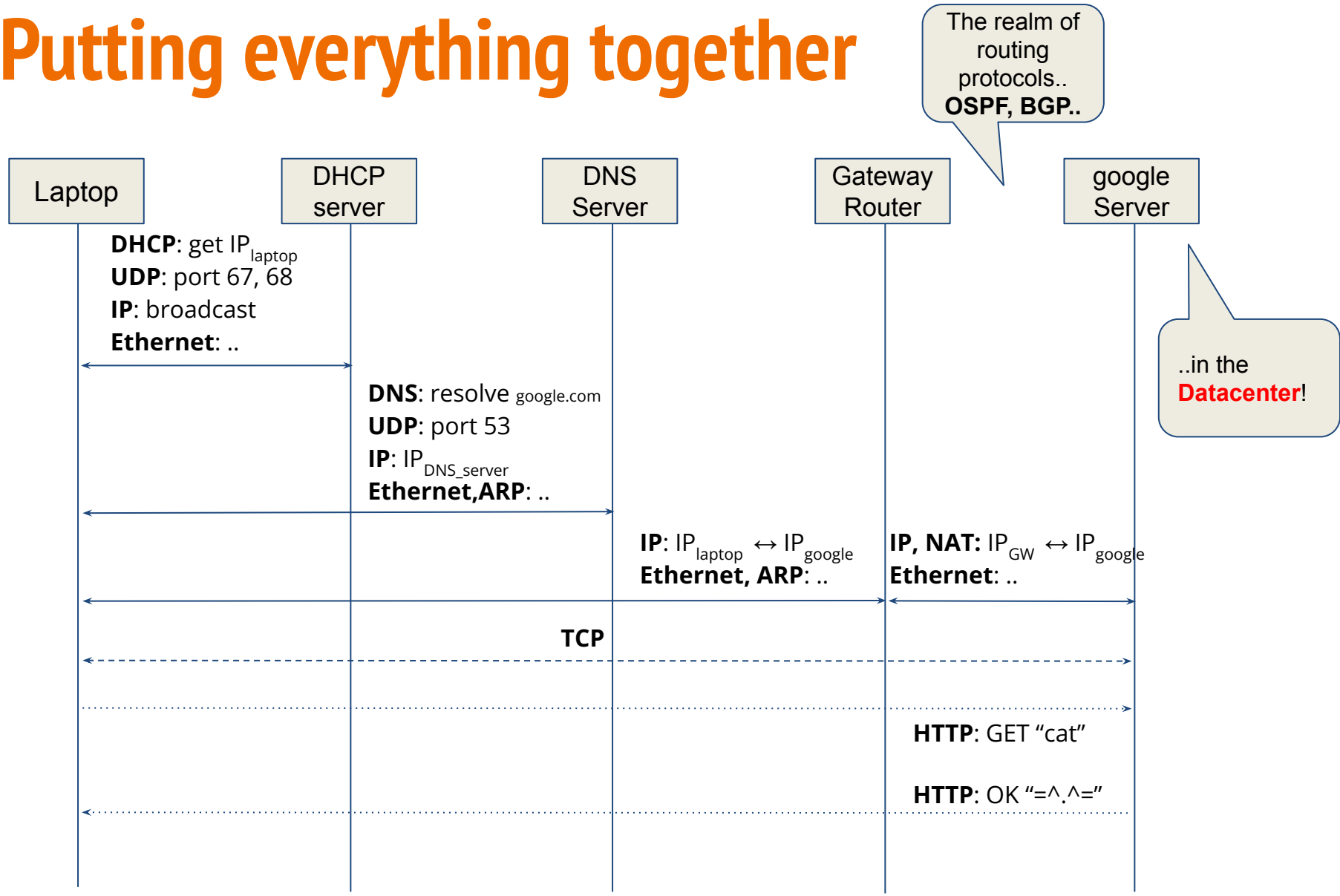
IP Addr.	Ethernet Addr.
a.b.c.d	40:11:11:11:11:11
a.b.c.c	70:33:33:33:11:11

ARP Table

IP Addr.	Ethernet Addr.
d.c.b.a	50:11:11:11:11:11
d.c.b.c	60:37:11:11:11:11



Putting everything together



*Gateway router: the first- and last-hop router of the laptop, e.g., a router at home

Feedback Form: https://tinyurl.com/cs168-disc-fa24

Worksheet

1. Which protocol does a host use to learn its own IP address?

(a) DHCP

(b) DNS

(c) ARP

(d) ICMP

(e) None of these

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(a) DHCP
(b) DNS
(c) ARP
(d) ICMP
(e) None of these

Solution: (a) DHCP

2. Which protocol does a host use to learn its own MAC address?

(a) DHCP
(b) DNS
(c) ARP
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2. Which protocol does a host use to learn its own MAC address?

(a) DHCP
(b) DNS
(c) ARP
(d) ICMP
(e) None of these

Solution: (e) None of these

3. Which protocol does a host use to learn the MAC address of another host on the same network?

(a) DHCP
(b) DNS
(c) ARP
(d) ICMP
(e) None of these

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(b) DNS
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(d) ICMP
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Solution: (c) ARP

4. DHCP is a protocol in which of the following layers?

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

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(e) Application

Solution: (e) Application

5. ARP is a protocol in which of the following layers?

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

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

Solution: (b) Datalink

6. 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.

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(b) Its own IP address.
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(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.

Solution: (b) It's own IP address, (e) The IP address of its first-hop router, and (g) Its own subnet mask. A host learns the IP address of its DNS server through DHCP, but not IP addresses of other hosts.

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.

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
DHCP offer	2	Server	Broadcast

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

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

Solution: *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:

A's subnet :	11111111 11111111 11111111 00000000
A's IP :	00000001 00000010 00000011 00000100
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.

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?

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

4. Is the ARP request broadcast or unicast? What about the ARP response?

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Solution: The ARP **request** is broadcast. After all, we're trying to learn the MAC address, so we would 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 can tell which address to unicast the response to.

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

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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 if2)

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

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

Solution: *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.

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

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Solution:

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*.

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

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)