



International School
Jinan University

Computer Networks

L7 – Network Layer II

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Topics in Network Layer

- Design Issues
- Internetworking
- Network Layer in the Internet
 - Internet Control Protocols
- Routing Algorithms
- Internet Routing and Multicasting

Internet Control Protocols

- IP works with the help of several control protocols:
 - ICMP is a companion to IP that returns error info
 - Required, and used in many ways, e.g., *traceroute*, *ping*
 - ARP finds Ethernet address of a local IP address
 - Glue that is needed to send any IP packets
 - Host queries an address and the owner replies
 - DHCP assigns a local IP address to a host
 - Gets host started by automatically configuring it
 - Host sends request to server, which grants a lease

Using UDP, study in application layer

Errors in IP Packet Delivery

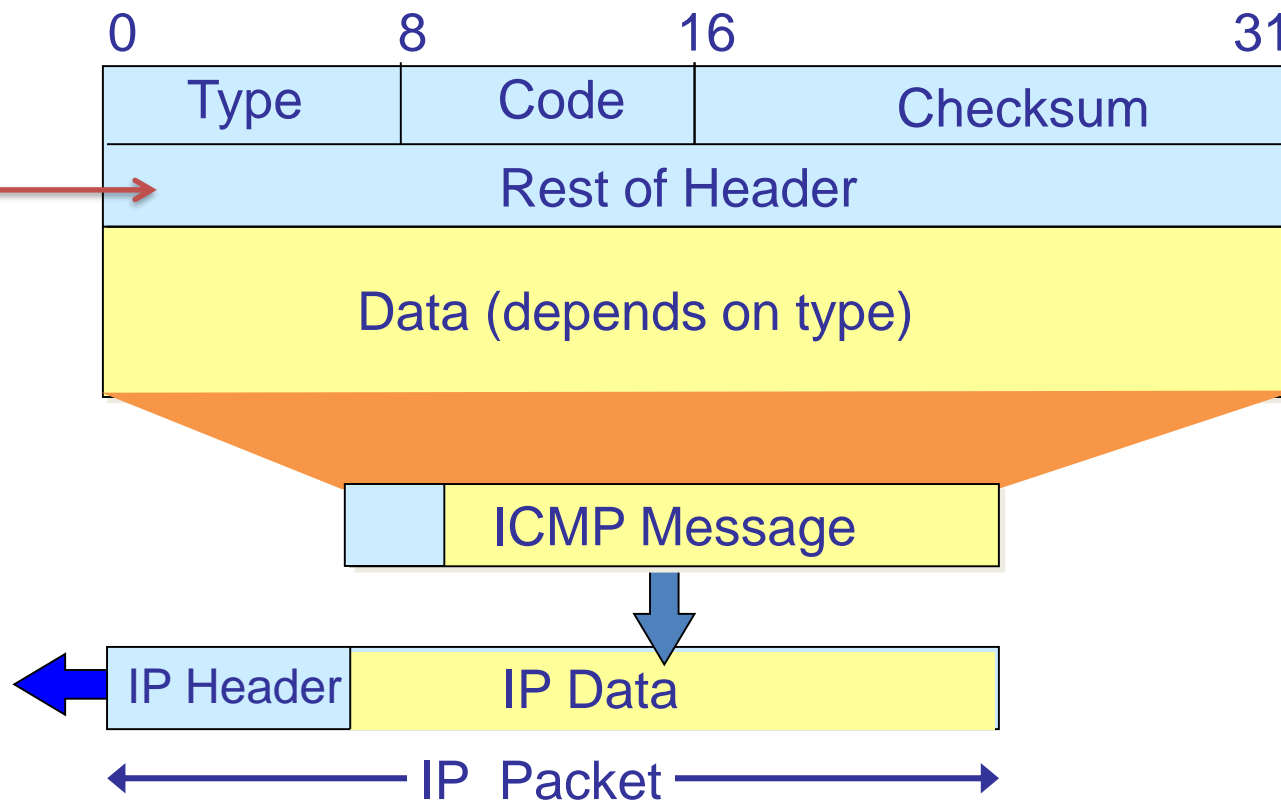
- What if a **router**
 - doesn't know how a datagram should be forwarded
 - finds the TTL counts to zero
 - finds the header has been destroyed
- And the **receiver** may **Just discards packets silently?**
 - find one fragment of a datagram doesn't arrive
 - find the packet contains data unrecognized
- Solution:
 - The **Internet Control Message Protocol** (ICMP)

ICMP

- ICMP (Internet Control Message Protocol) is used by hosts, routers, gateways to communicate network-level information
 - Error reporting: unreachable host, network, port, protocol
 - Echo request/reply (used by *ping*)
- Belongs to Network layer, but “above” IP:
 - ICMP messages is carried in IP datagrams

ICMP Message Format

4 bytes, will
vary based on
the ICMP type
and code



ICMP

- Main ICMP types:

Message type	Description
Destination unreachable	Packet could not be delivered
Time exceeded	Time to live field hit 0
Parameter problem	Invalid header field
Source quench	Choke packet rarely used today
Redirect	Teach a router about geography
Echo and Echo reply	Check if a machine is alive
Timestamp request/reply	Same as Echo, but with timestamp

tracert



rarely used today

ping



ICMP Error
Messages

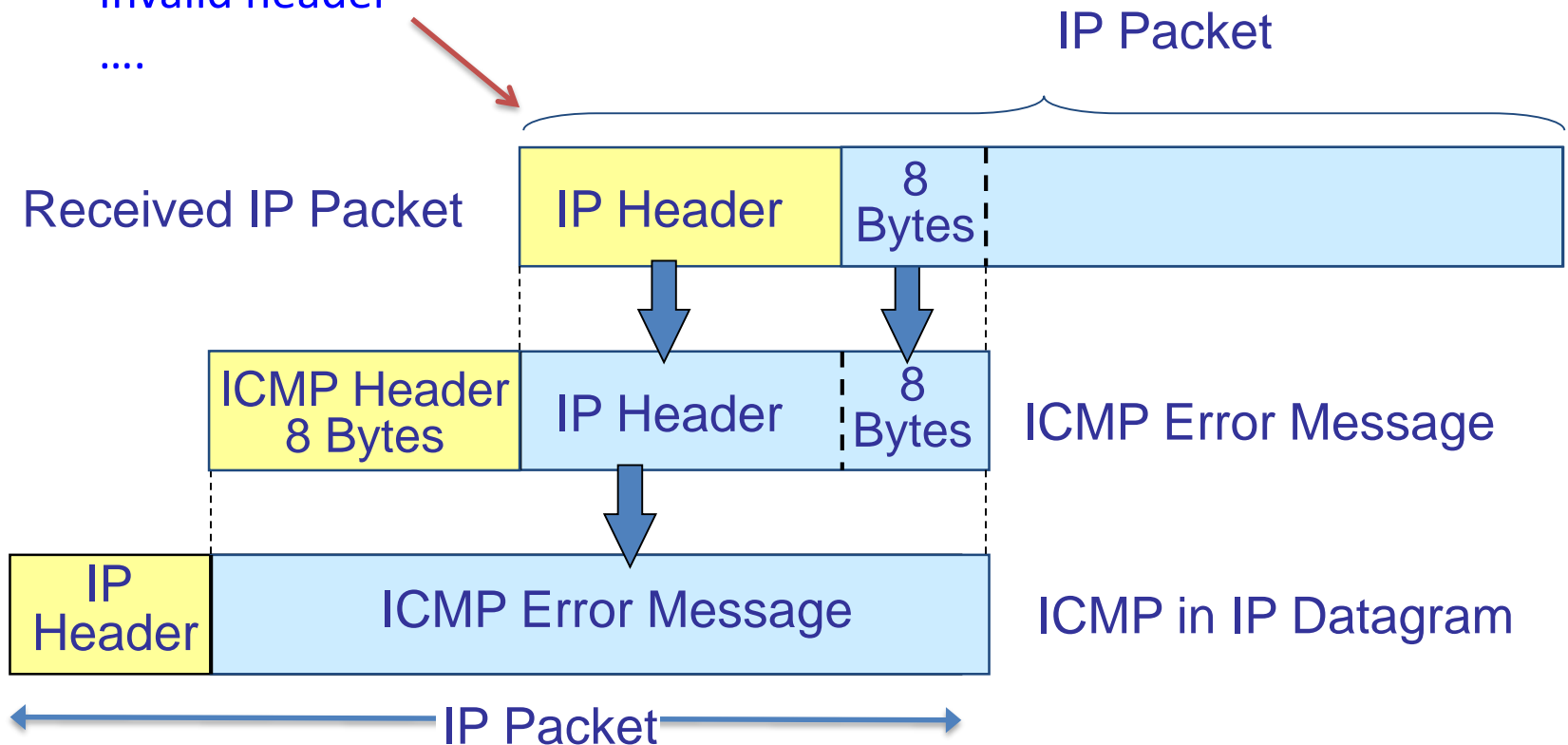


ICMP Informational
Messages



ICMP Error Messages

TTL = 0,
Invalid header
....



When Not to Send ICMP Errors

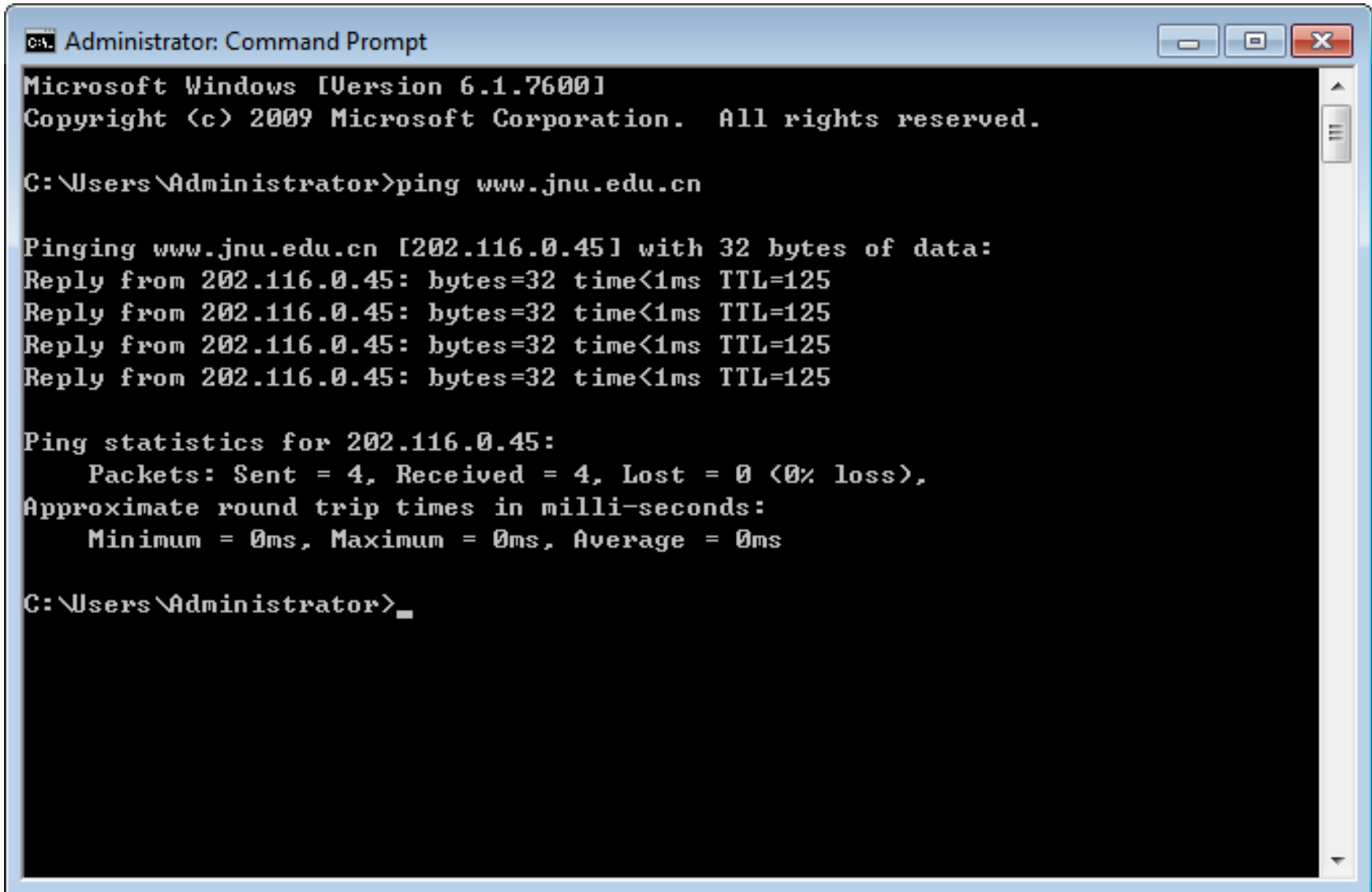
An ICMP error message MUST NOT be sent as the result of receiving:

- An **ICMP** error message
- A packet destined to an IP **broadcast** or IP **multicast** address
- A packet whose source address has a network **prefix of zero** or is an **invalid source address**, e.g., 127.0.0.0.
- Any fragment of a datagram other than the **first fragment**
-

ICMP Application Example - *ping*

- *ping* (Packet InterNet Groper) is used to
 - Check if target host is alive or on the Internet
 - Check the RTT
- *ping* uses ICMP Echo and Echo Reply message
- It is an example of Application layer calling Network layer directly, without TCP/UDP

Ping Example



```
Administrator: Command Prompt
Microsoft Windows [Version 6.1.7600]
Copyright (c) 2009 Microsoft Corporation. All rights reserved.

C:\Users\Administrator>ping www.jnu.edu.cn

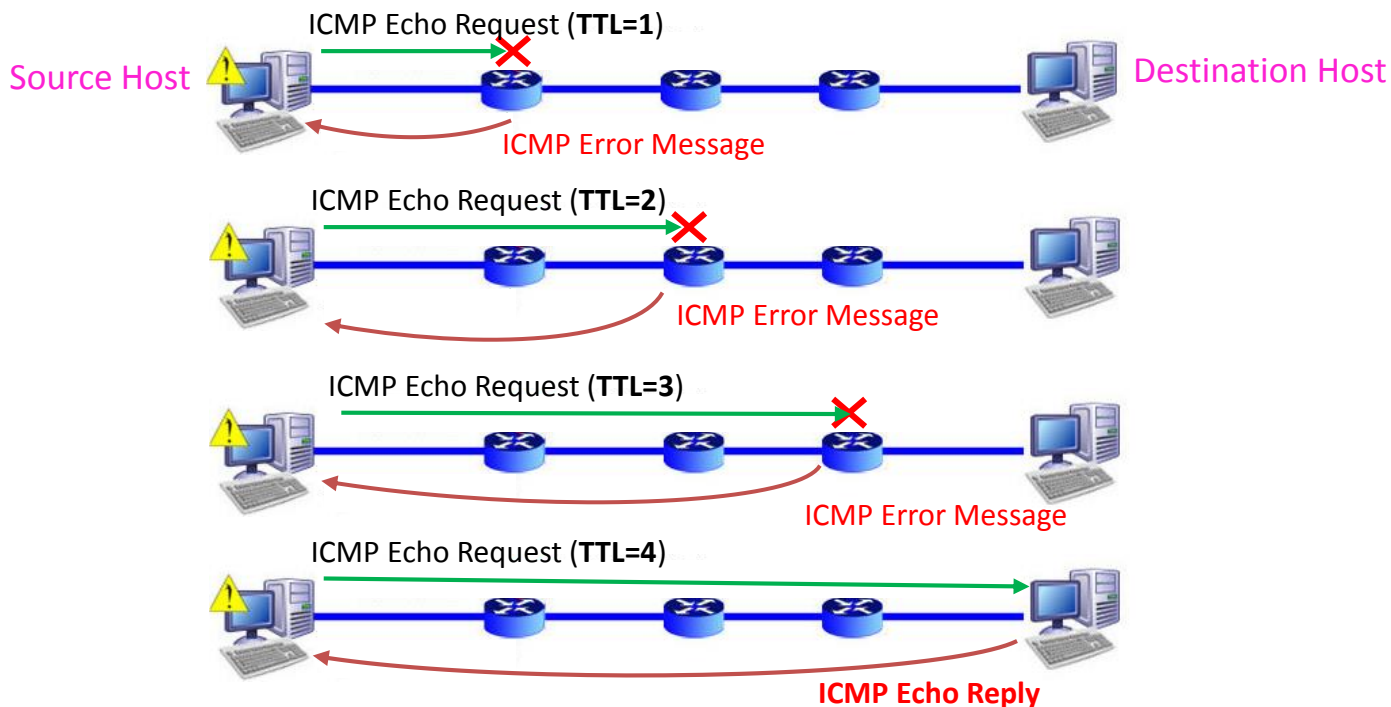
Pinging www.jnu.edu.cn [202.116.0.45] with 32 bytes of data:
Reply from 202.116.0.45: bytes=32 time<1ms TTL=125
Reply from 202.116.0.45: bytes=32 time<1ms TTL=125
Reply from 202.116.0.45: bytes=32 time<1ms TTL=125
Reply from 202.116.0.45: bytes=32 time<1ms TTL=125

Ping statistics for 202.116.0.45:
    Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),
    Approximate round trip times in milli-seconds:
        Minimum = 0ms, Maximum = 0ms, Average = 0ms

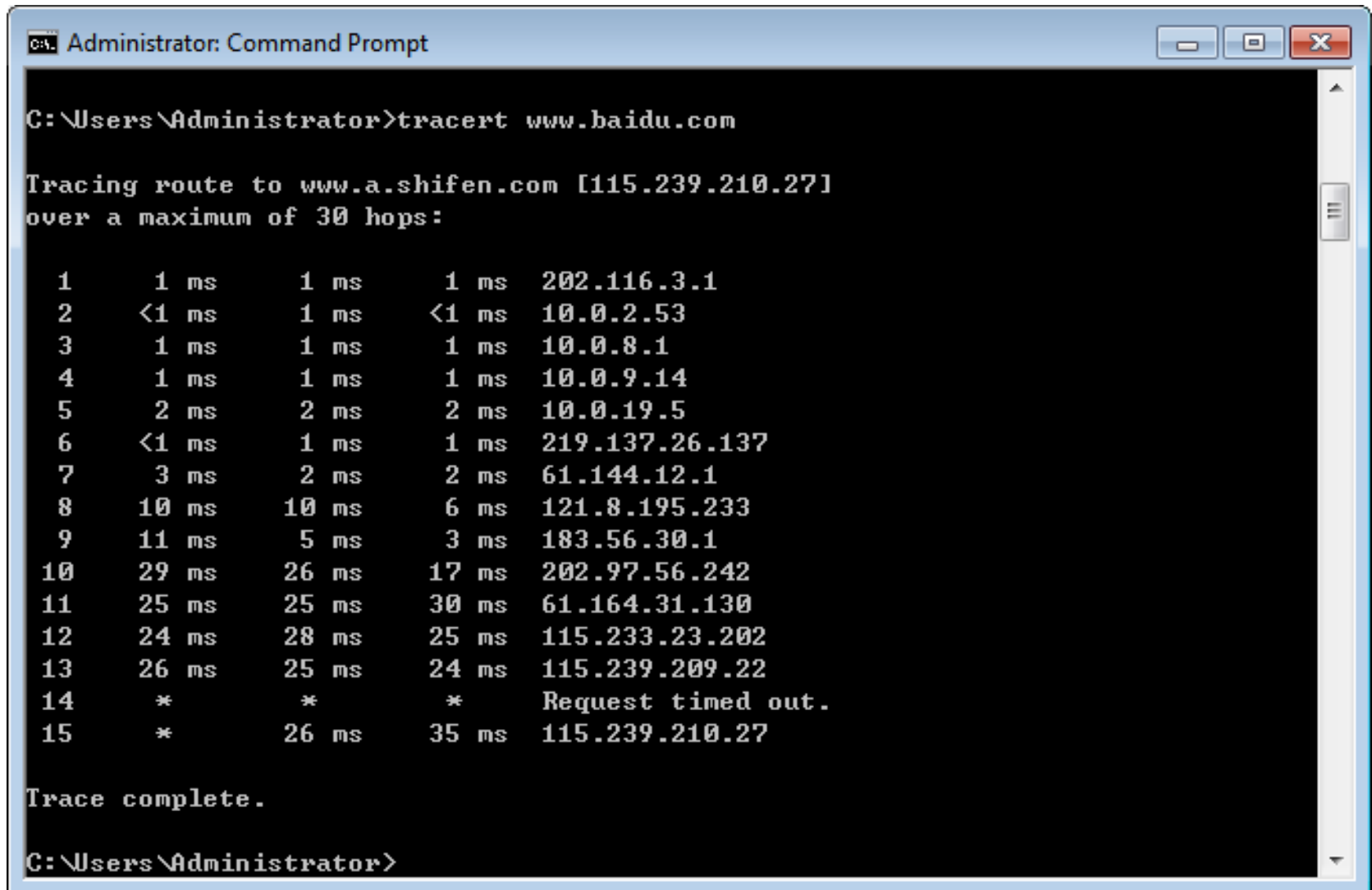
C:\Users\Administrator>
```

ICMP Application Example - *traceroute*

- *traceroute* finds the router along the path from source to destination:
 - Sending a sequence of packets with TTL= 1, 2, 3 and so on
 - Routers send back ICMP **Time Exceeded** message



Tracert Example on Windows



A screenshot of a Windows Command Prompt window titled "Administrator: Command Prompt". The window has a blue title bar and standard Windows window controls (minimize, maximize, close) on the right. The command prompt shows the following text:

```
C:\Users\Administrator>tracert www.baidu.com

Tracing route to www.a.shifen.com [115.239.210.27]
over a maximum of 30 hops:

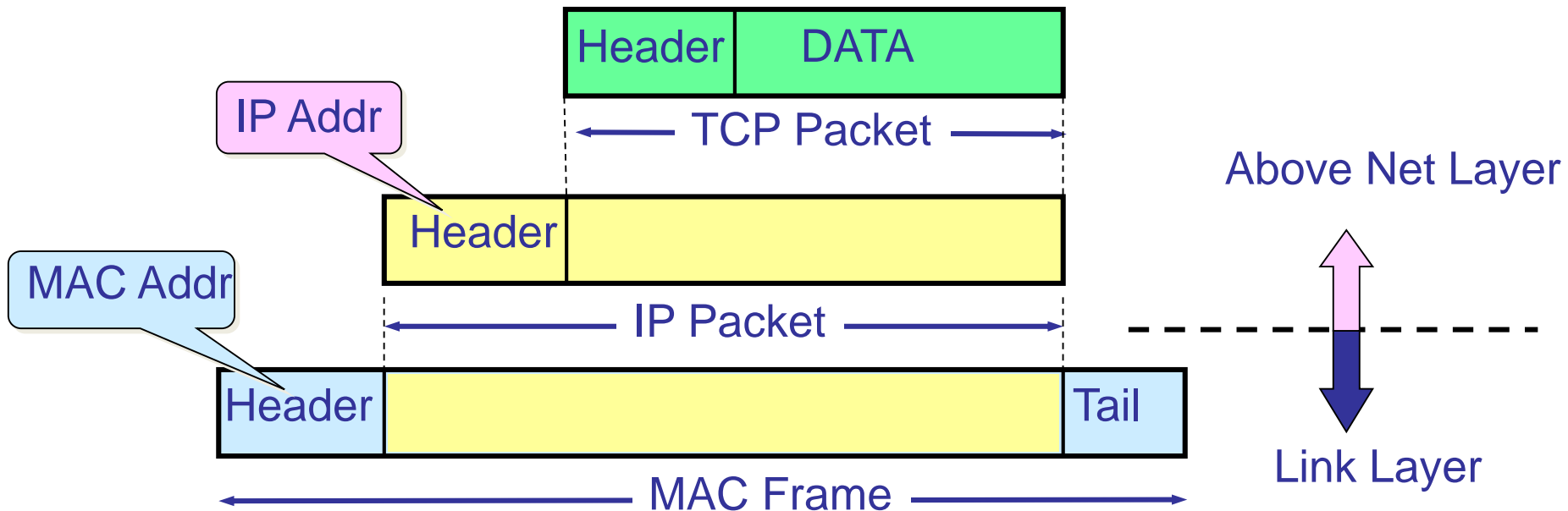
  1    1 ms    1 ms    1 ms    202.116.3.1
  2   <1 ms    1 ms   <1 ms   10.0.2.53
  3    1 ms    1 ms    1 ms   10.0.8.1
  4    1 ms    1 ms    1 ms   10.0.9.14
  5    2 ms    2 ms    2 ms   10.0.19.5
  6   <1 ms    1 ms    1 ms   219.137.26.137
  7    3 ms    2 ms    2 ms   61.144.12.1
  8   10 ms   10 ms    6 ms   121.8.195.233
  9   11 ms    5 ms    3 ms   183.56.30.1
 10   29 ms   26 ms   17 ms   202.97.56.242
 11   25 ms   25 ms   30 ms   61.164.31.130
 12   24 ms   28 ms   25 ms   115.233.23.202
 13   26 ms   25 ms   24 ms   115.239.209.22
 14    *      *      *      Request timed out.
 15    *    26 ms   35 ms   115.239.210.27

Trace complete.

C:\Users\Administrator>
```

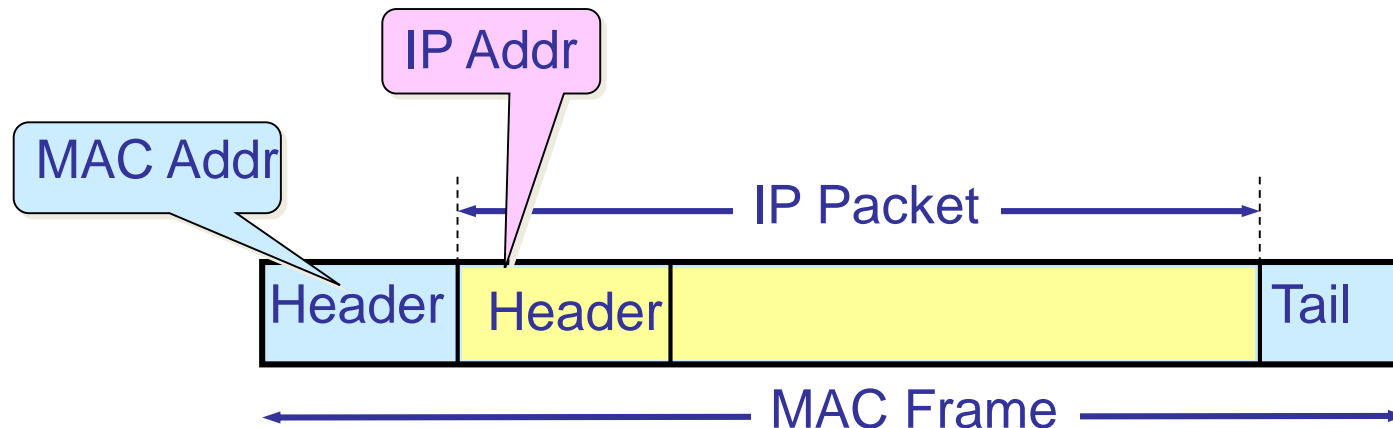
The output shows the path from the local machine to the destination IP address 115.239.210.27. The first three hops are local network addresses. The fourth hop is 10.0.9.14. The fifth hop is 10.0.19.5. The sixth hop is 219.137.26.137. The seventh hop is 61.144.12.1. The eighth hop is 121.8.195.233. The ninth hop is 183.56.30.1. The tenth hop is 202.97.56.242. The eleventh hop is 61.164.31.130. The twelfth hop is 115.233.23.202. The thirteenth hop is 115.239.209.22. The fourteenth hop is marked with an asterisk, indicating a request timed out. The fifteenth hop is 115.239.210.27, which is the destination IP address.

IP and MAC Address



IP and MAC Address

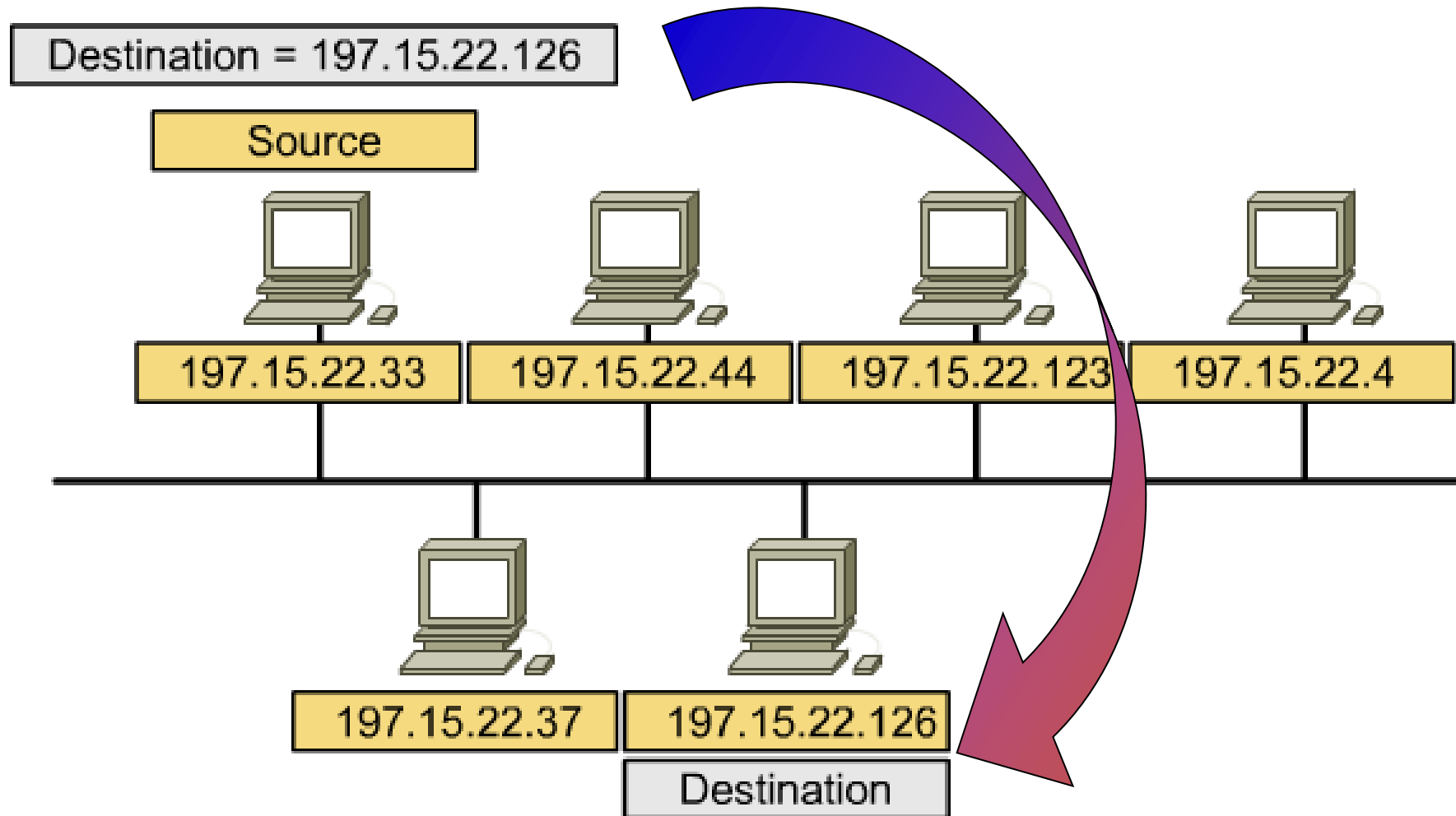
- In order to communicate, sending devices need both the **IP addresses** and the **MAC** addresses of destination devices
- When they try to communicate with devices whose IP addresses they know, they must determine the MAC addresses



ARP: Address Resolution Protocol

- **ARP** enables a computer to find the MAC address of the computer that is associated with an IP address
 - Maintain a table of IP to physical address mapping (**ARP cache**)
 - **Broadcast** request if an IP address is not in the table
 - Target machine responds with its physical address
 - Table entries are discarded if not refreshed

Address Resolution Protocol



ARP Table in Host

Physical Addresses	IP Addresses
02-60-8C-01-02-03	197.15.22.33
00-00-A2-05-09-89	197.15.22.44
09-00-20-67-92-89	197.15.22.123
08-00-02-90-90-90	197.15.22.4

Destination = 197.15.22.126

???

Source



197.15.22.33



197.15.22.44



197.15.22.123



197.15.22.4



197.15.22.37

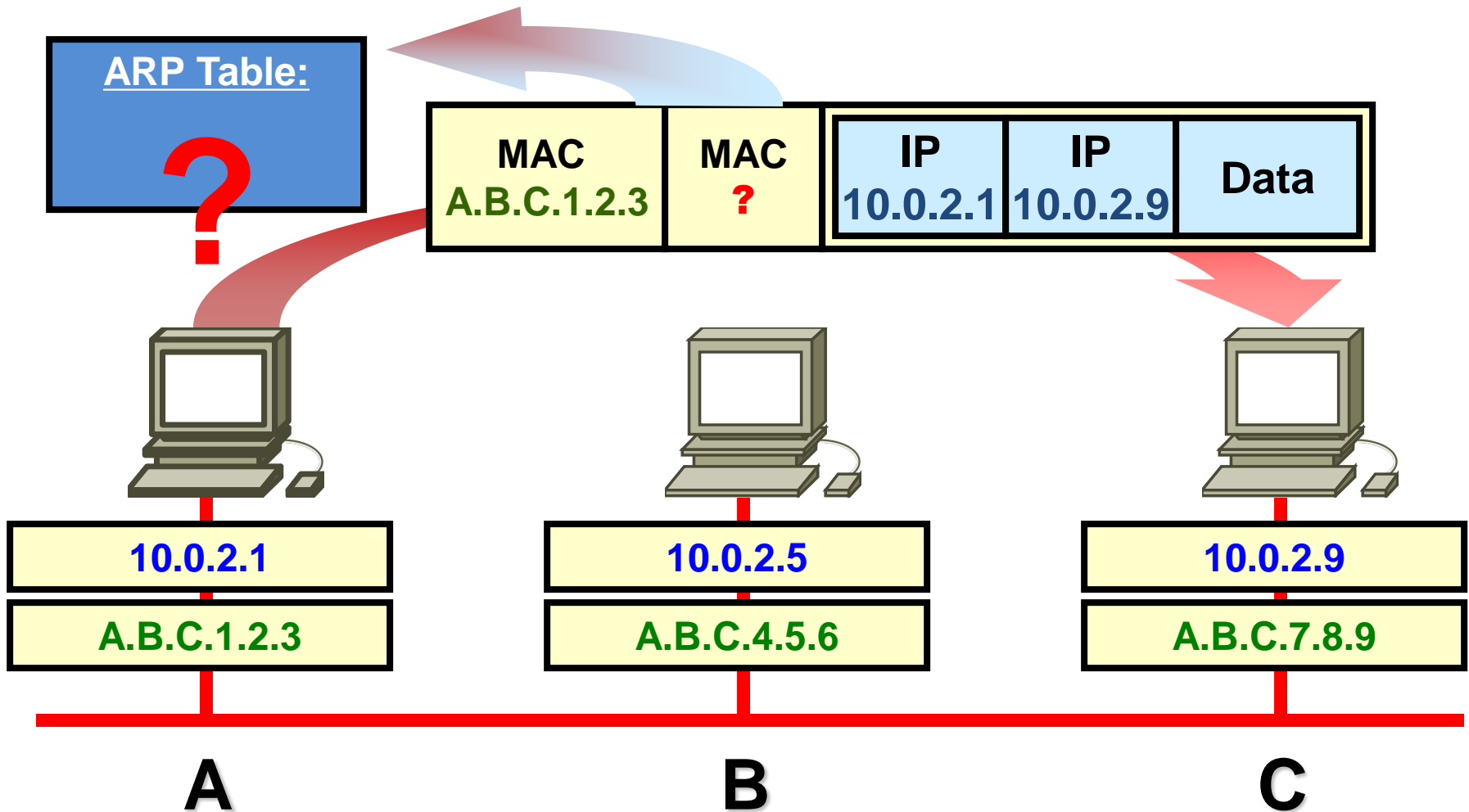


197.15.22.126

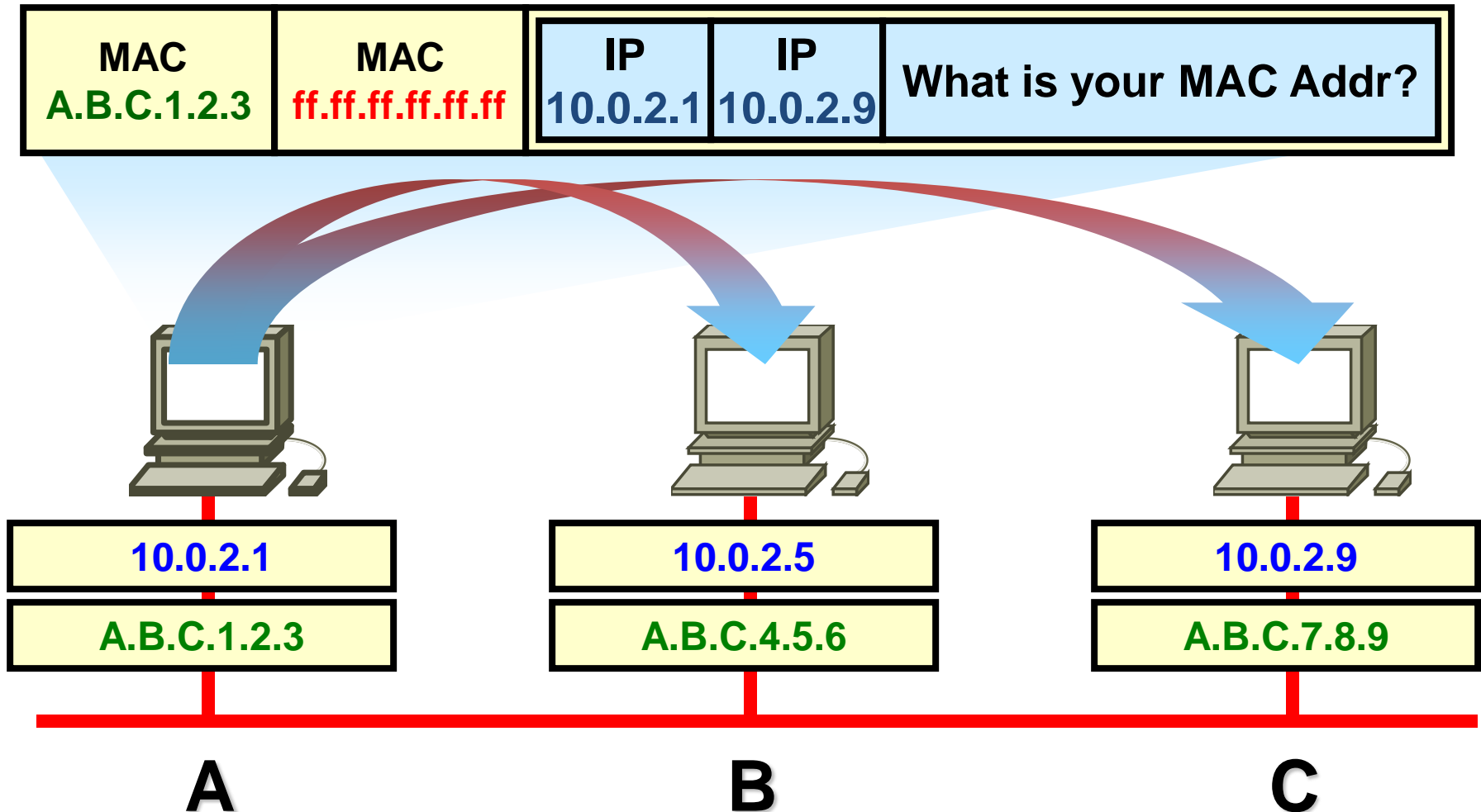
Destination

RAM

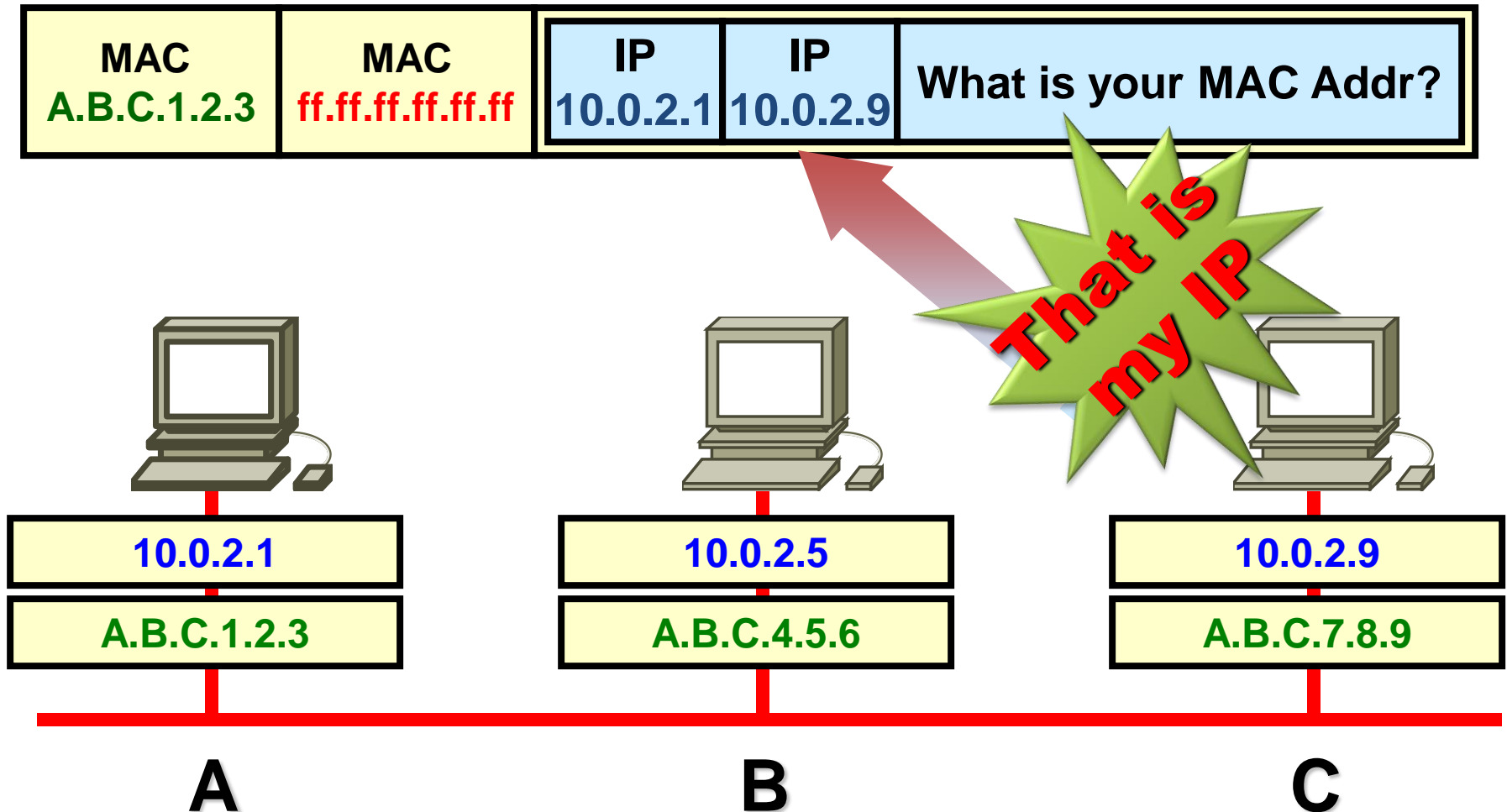
ARP Operation



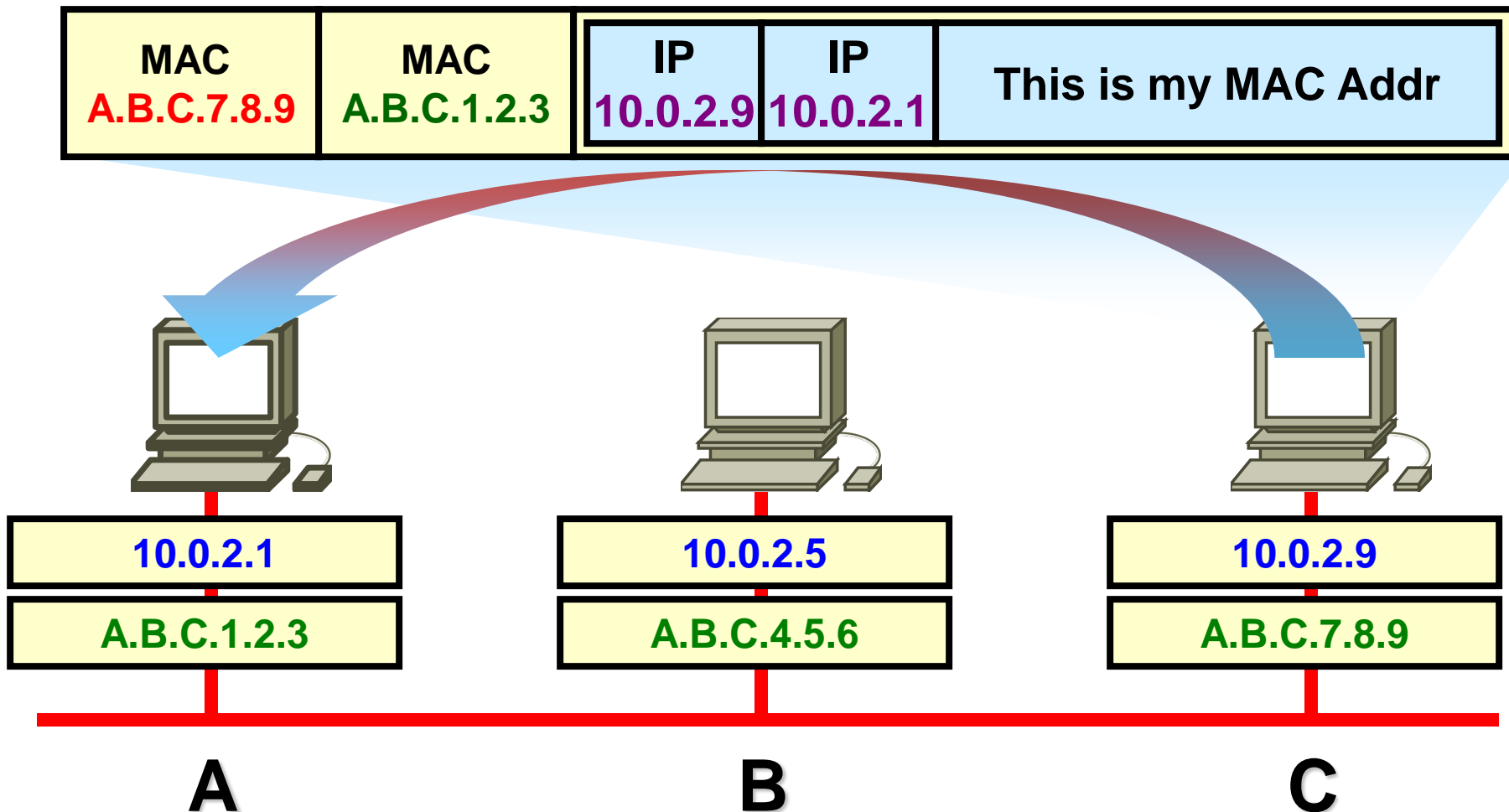
ARP operation: ARP Request



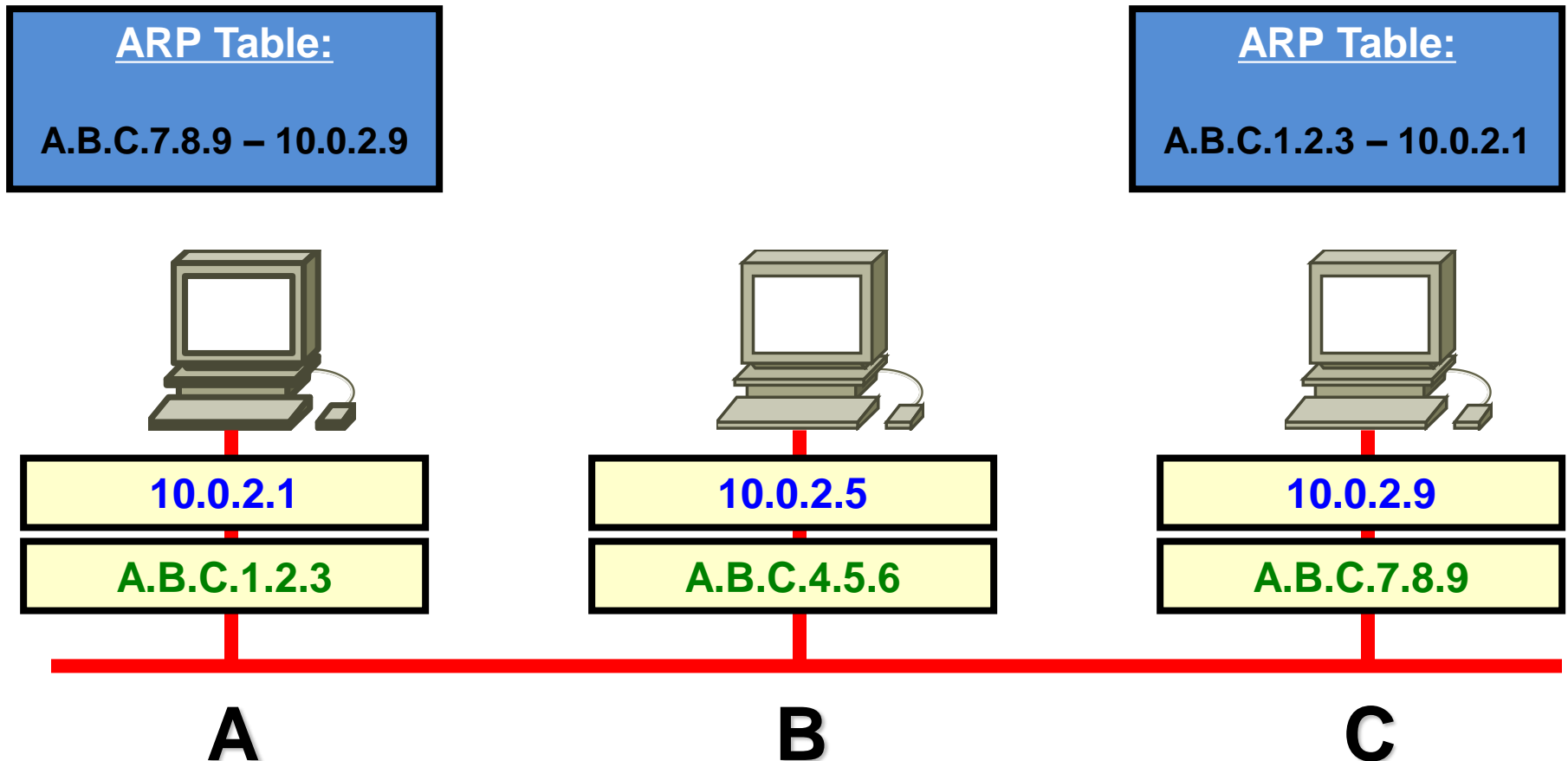
ARP operation: Checking



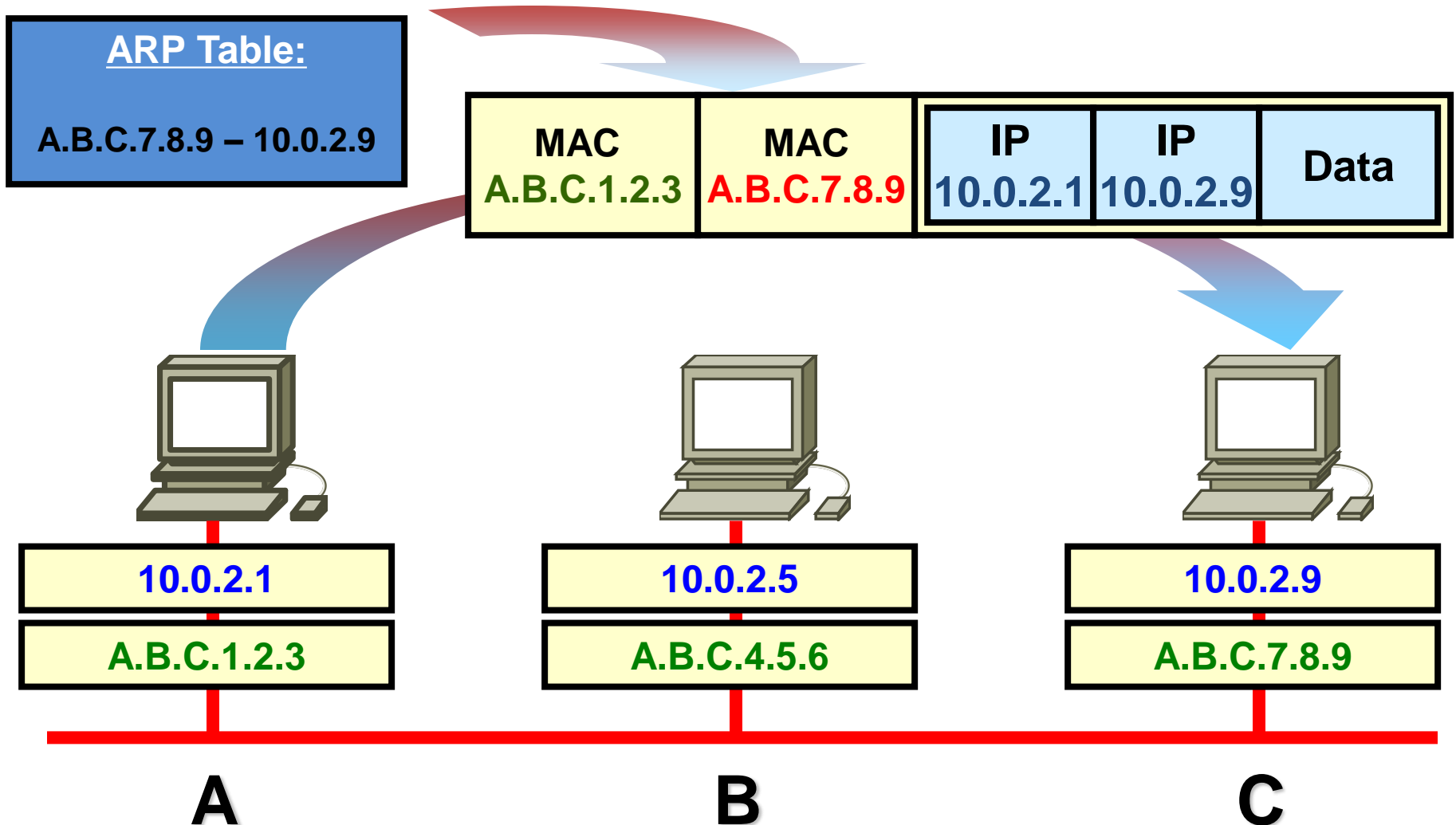
ARP Operation: ARP Reply



ARP Operation: Caching



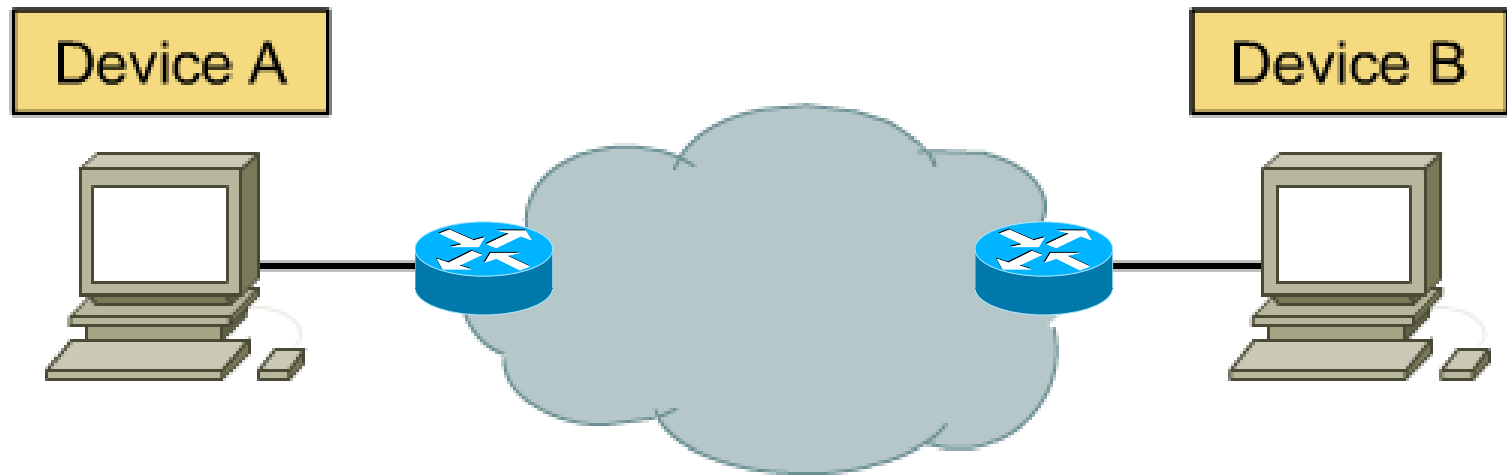
ARP Operation: Caching



ARP Table in Router

- The router interface connected to the network has an IP address for that network
- Just like every other devices on the network, router uses this IP address to send and receive data on the network
- If router connects to a LAN, it builds ARP tables that maps IP addresses to MAC addresses in that interface

Internetwork Communication

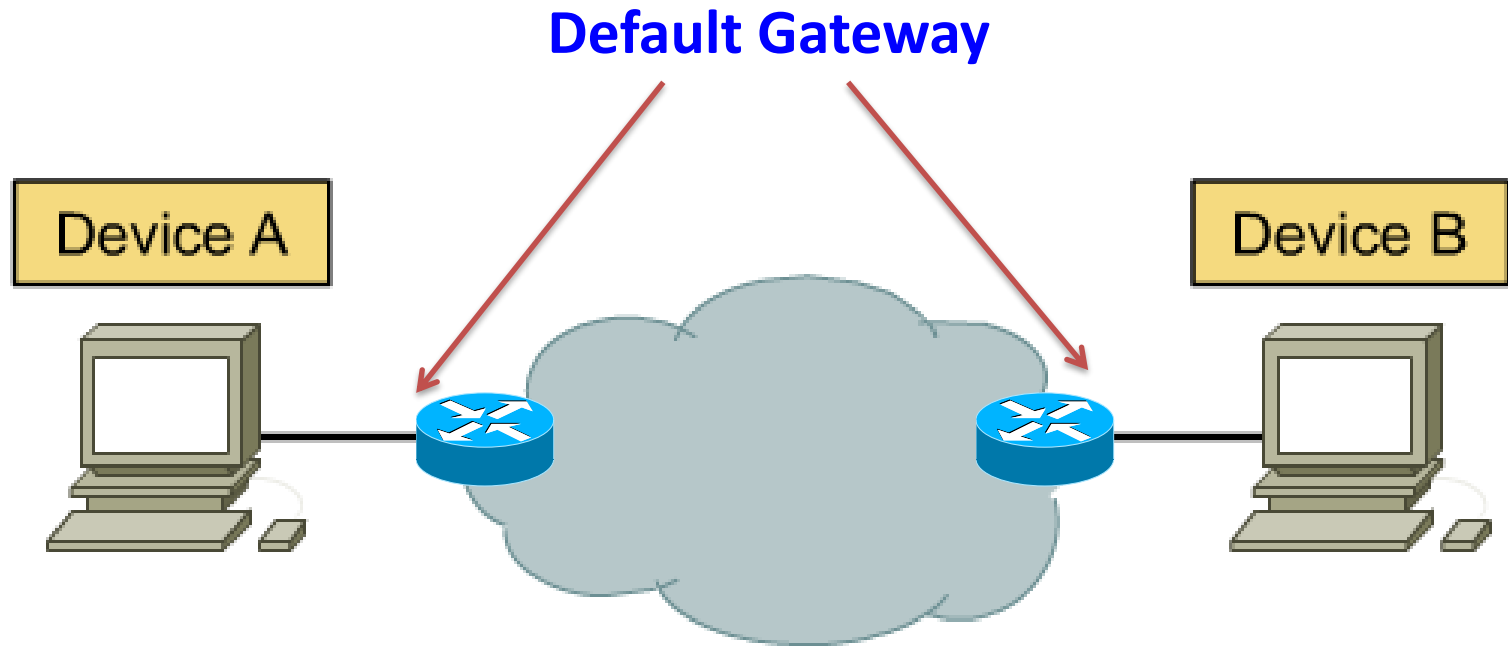


- How to communicate with devices that are not on the same physical network segment?

Default Gateway

- To communicate with a machine **on another network**, a source machine must have a **default gateway**
- Default gateway is **the IP address of the interface** on the router that connects to the network on which the source host is located

Default Gateway (默认网关)



- To send data to the address of a device that is on another network, the source device sends the data to a **default gateway**.

Route print on Windows

C:\>route print

Default route (Network ID and subnet mask are all 0)

IPv4 Route Table

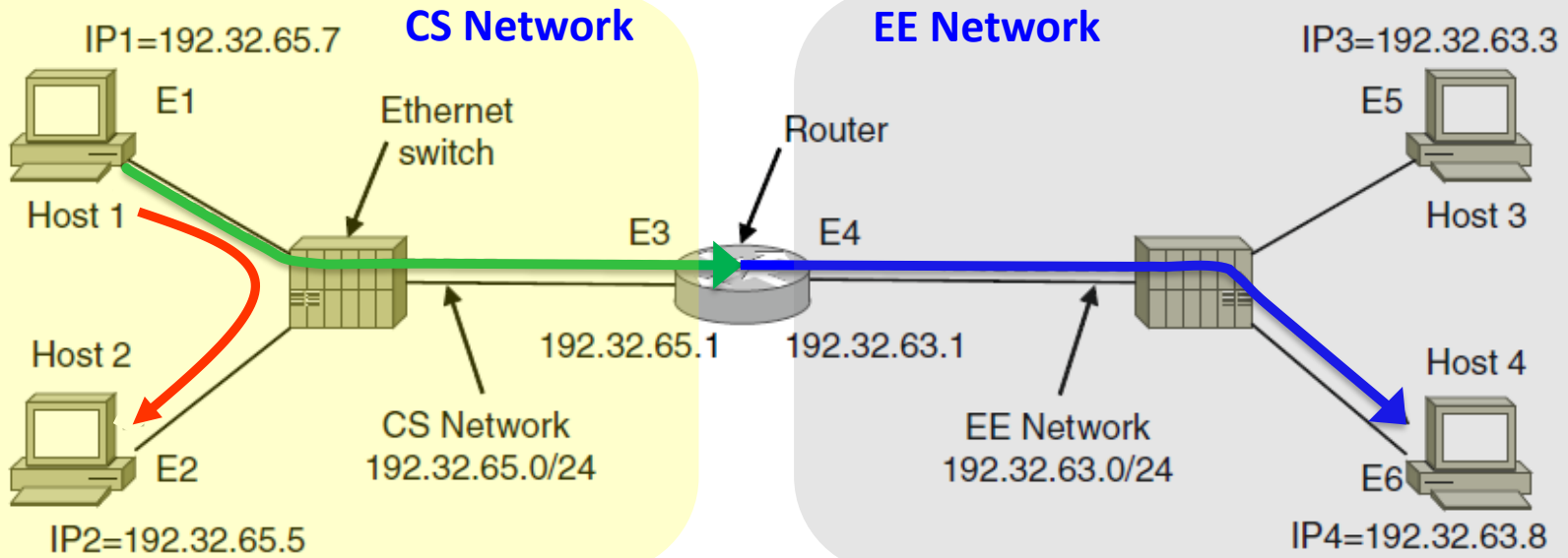
Active Routes:

Network Destination	Netmask	Gateway	Interface	Metric
0.0.0.0	0.0.0.0	222.31.76.254	222.31.76.155	30
127.0.0.0	255.0.0.0	On-link	127.0.0.1	306
127.0.0.1	255.255.255.255	On-link	127.0.0.1	306
127.255.255.255	255.255.255.255	On-link	127.0.0.1	306
222.31.76.0	255.255.255.0	On-link	222.31.76.155	286
222.31.76.155	255.255.255.255	On-link	222.31.76.155	286
222.31.76.255	255.255.255.255	On-link	222.31.76.155	286

Persistent Routes:

None

LANs Joined by Router



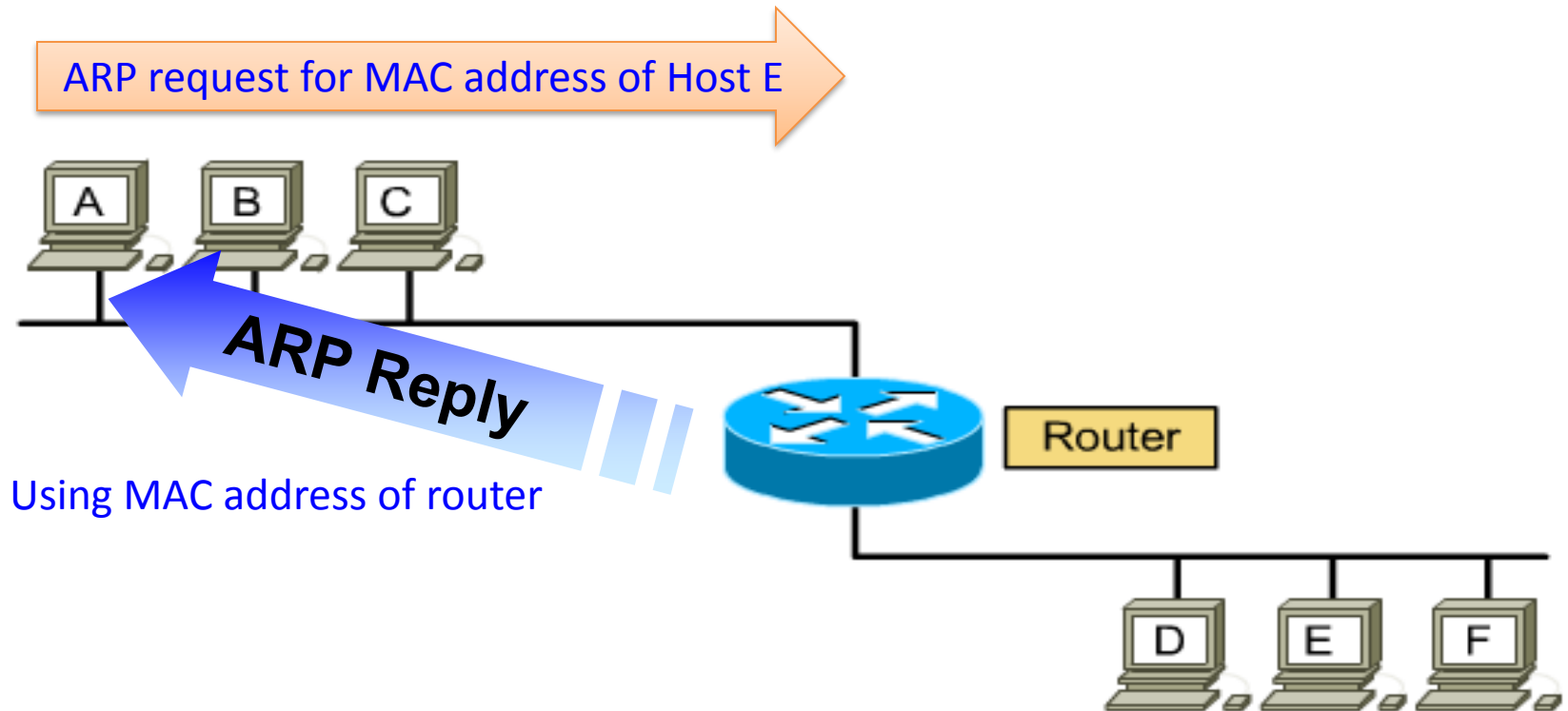
Frame	Source IP	Source Eth.	Destination IP	Destination Eth.
Host 1 to 2, on CS net	IP1	E1	IP2	E2
Host 1 to 4, on CS net	IP1	E1	IP4	E3
Host 1 to 4, on EE net	IP1	E4	IP4	E6

IP addr.
remain the same

MAC addr.
changed

Animation on course website:
Router operation in a simple
Internetwork

Proxy ARP



- **Proxy ARP** is a variation of the ARP.
- In the case the source host does not have a default gateway configured.

Thank you!

Q & A