Lecture 9.

Direct Datagram Forwarding:

Address Resolution Protocol (ARP)

G.Bianchi, G.Neglia, V.Mancuso

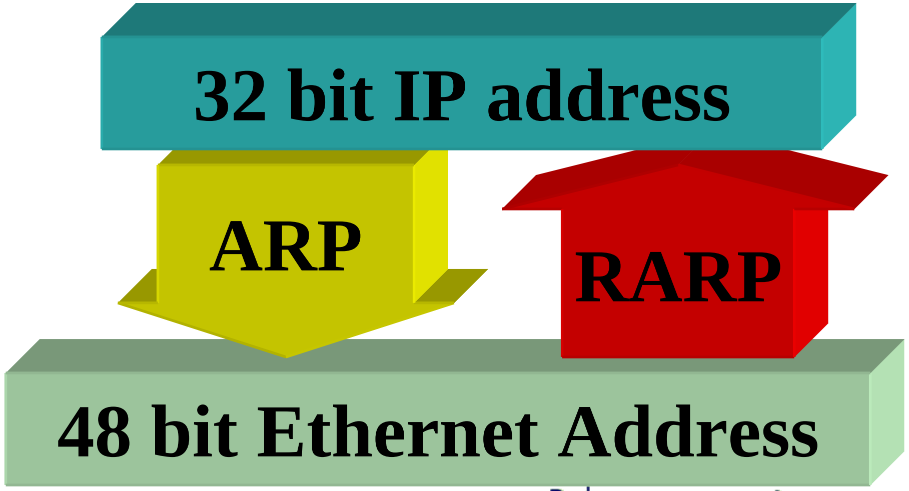
Università degli Studi di Palermo

Problem statement

- ➔**Routing decision for packet X has two possible outcomes:**
  - ⇨You are arrived to the final network: go to host X
  - ⇨You are not arrived to the final network: go through router interface Y
- ➔**In both cases we have an IP address on THIS network. How can we send data to the interface?**
- ➔**Need to use physical network facilities!**

Reaching a physical host

- ➔ **IP addresses only make sense to TCPIP protocol suite**
- ➔ **physical networks have their own hardware address**
  - ⇨ e.g. 48 bits Ethernet address, 16 or 48 bits Token Ring, 16 or 48 bit FDDI, ...
  - ⇨ datalink layers may provide the basis for several network layers, not only IP!



Address Resolution Protocol
RFC 826

Here described for Ethernet, but more general: designed for any datalink with broadcast capabilities

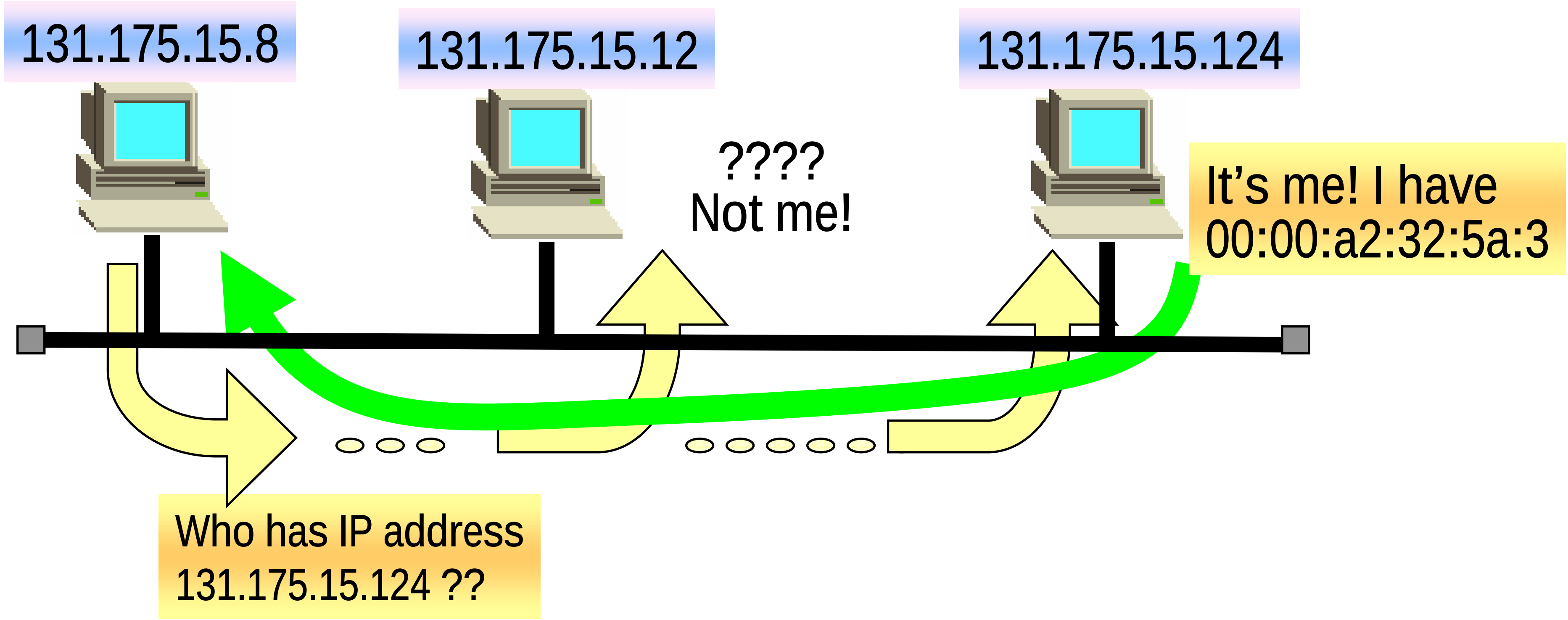
Manual mapping

- ➔ **A possibility, indeed!!**
  - ⇨ Nothing contrary, in principle
    - →actually done in X.25, ISDN (do not support broadcast)
  - ⇨ Simply keep in every host a mapping between IP address and hardware address for every IP device connected to the considered network
- ➔ **drawbacks**
  - ⇨ tedious
  - ⇨ error prone
  - ⇨ requires manual updating
    - →e.g. when attaching a new PC, must touch all others...

ARP

- ➔ **Dynamic mapping**
  - ⇨ not a concern for application & user
  - ⇨ not a concern for system administrator!
- ➔ **Any network layer protocol**
  - ⇨ not IP-specific
- ➔ **supported protocol in datalink layer**
  - ⇨ not a datalink layer protocol !!!!
- ➔ **Need datalink with broadcasting capability**
  - ⇨ e.g. ethernet shared bus

ARP idea



➔**Send broadcast request**

➔**receive unicast response**

ARP cache

➔**Avoids arp request for every IP datagram!**

- ⇨Entry lifetime defaults to 20min
  - →deleted if not used in this time
  - →3 minutes for “incomplete” cache entries (i.e. arp requests to non existent host)
  - →it may be changed in some implementations
    - » in particularly stable (or dynamic) environments
- ⇨*arp -a* to display all cache entries (arp –d to delete)

try a traceroute or ping to check ARP caching!

- →First packet generally delays more
- → includes an ARP request/reply!

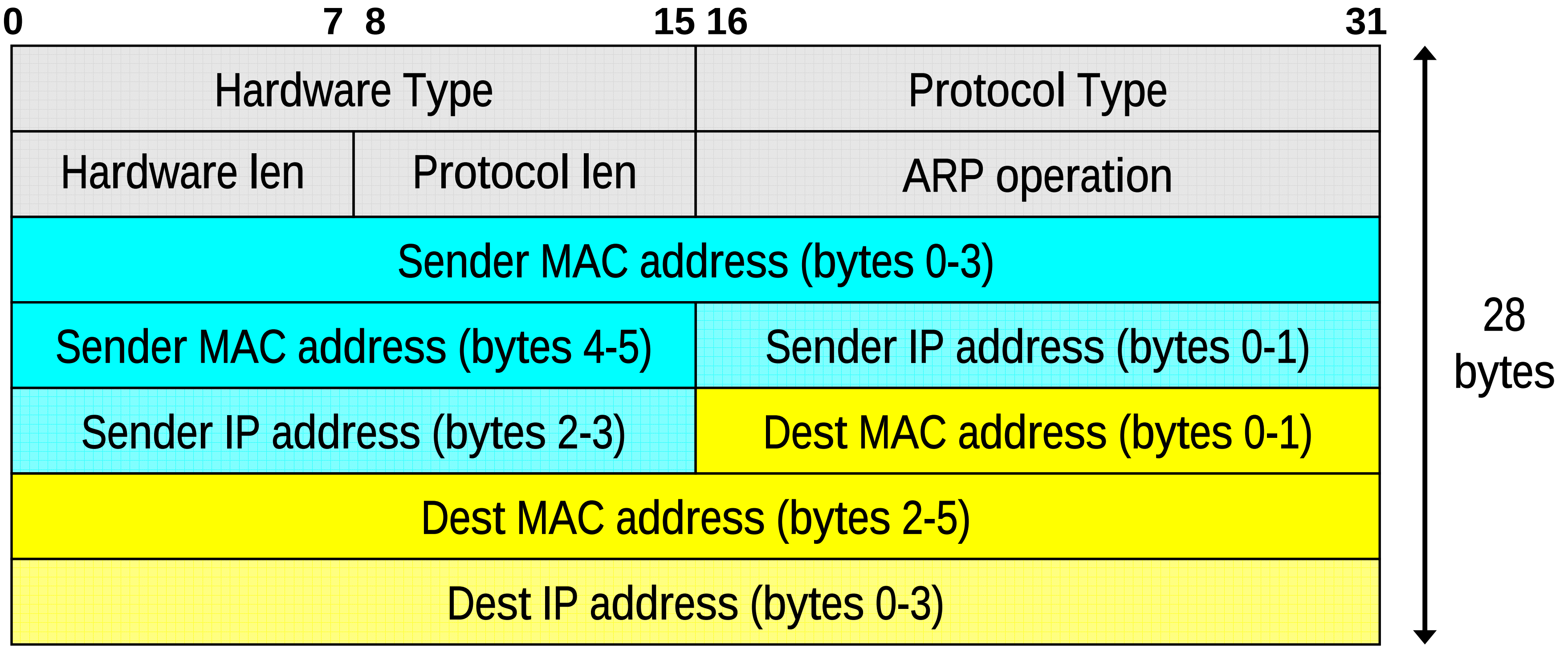
ARP request/reply
Incapsulation in Ethernet Frame

6 bytes	6 bytes	2 bytes	28 bytes (for IP)	4 bytes
Ethernet destination address	Ethernet source address	frame type	ARP Request / Reply	CRC

- ➔**Ethernet Destination Address**
  - ⇨ff:ff:ff:ff:ff:ff (broadcast) for ARP request
- ➔**Ethernet Source Address**
  - ⇨of ARP requester
- ➔**Frame Type**
  - ⇨ARP request/reply: 0x0806
  - ⇨RARP request/reply: 0x8035
  - ⇨IP datagram: 0x0800

Protocol demultiplexing codes!

ARP request/reply format



0 7 8 15 16 31

Hardware Type | Protocol Type

Hardware len | Protocol len | ARP operation

Sender MAC address (bytes 0-3)

Sender MAC address (bytes 4-5) | Sender IP address (bytes 0-1)

Sender IP address (bytes 2-3) | Dest MAC address (bytes 0-1)

Dest MAC address (bytes 2-5)

Dest IP address (bytes 0-3)

28 bytes

Hardware type: 1 for ethernet

Protocol type: 0x0800 for IP (0000.1000.0000.0000)

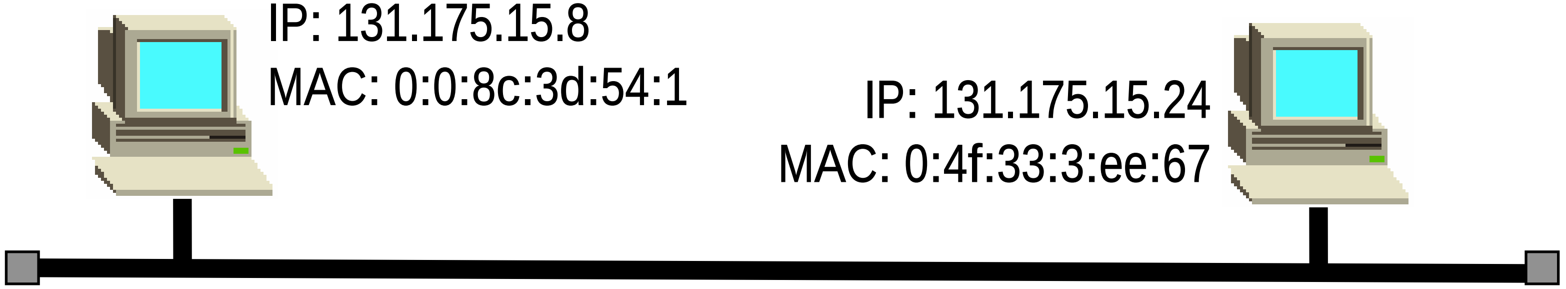
⇨ *the same of Ethernet header field carrying IP datagram!*

Hardware len = length in bytes of hardware addresses (6 bytes for ethernet)

Protocol len = length in bytes of logical addresses (4 bytes for IP)

ARP operation: 1=request; 2=reply; 3/4=RARP req/reply

Sample ARP request/reply



IP: 131.175.15.8
MAC: 0:0:8c:3d:54:1

IP: 131.175.15.24
MAC: 0:4f:33:3:ee:67

Ethernet Packet: ARP REQUEST

Ethernet Packet: ARP reply

FF:FF:FF:FF:FF:FF	**dest MAC**	00:00:8c:3d:54:01
00:00:8c:3d:54:01	**src MAC**	00:4f:33:03:ee:67
0x0806	**ARP frame type**	0x0806
0x0001 0x0800	**Ethernet / IP**	0x0001 0x0800
0x06 0x04 0x0001	**MAC=6 / IP=4 / rq=1,rpl=2**	0x06 0x04 0x0002
00:00:8c:3d:54:01	**src MAC**	00:4f:33:03:ee:67
131.175.15.8	**src IP**	131.175.15.24
00:00:00:00:00:00	**dest MAC**	00:00:8c:3d:54:01
131.175.15.24	**dest IP**	131.175.15.8
checksum	**Ethernet checksum**	checksum

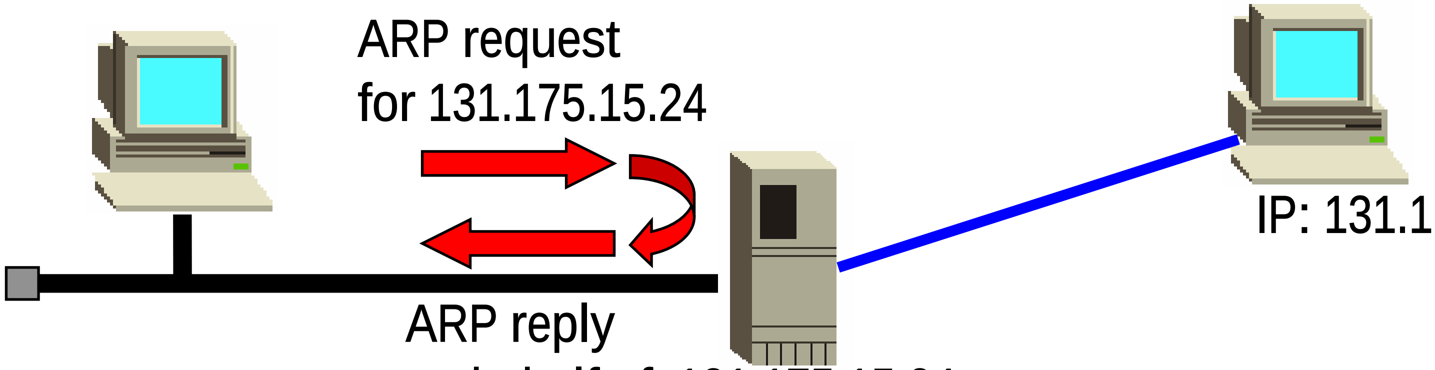
ARP cache updating

- ➔**ARP requests carry requestor IP/MAC pair**
- ➔**ARP requests are broadcast**
  - ⇨thus, they MUST be read by everyone
- ➔**Therefore, it comes for free, for every computer, to update its cache with requestor pair**

- ➔***Cannot do this with ARP reply, as it is unicast!***

Proxy ARP

- ➔ **Device that responds to an ARP request on behalf of some other machine**
  - ⇨ allows having ONE logical (IP) network composed of more physical networks
  - ⇨ especially important when different techologies used (e.g. 100 PC ethernet + 2 PC dialup SLIP)



ARP request
for 131.175.15.24

IP: 131.175.15.24

ARP reply
on behalf of 131.175.15.24

returns ***router MAC address****! Then router will forward packets to remote host*

Gratuitous ARP

- ➔ **ARP request issued by an IP address and addressed to *the same* IP address!!**
  - ⇨ Clearly nobody else than ME can answer!
  - ⇨ WHY asking the network which MAC address do I have???
- ➔ **Two main reasons:**
  - ⇨ determine if another host is configured with the same IP address
    - → in this case respond occurs, and MAC address of duplicated IP address is known.
  - ⇨ Use gratuitous ARP when just changed hardware address
    - → all other hosts update their cache entries!
    - → A problem is that, despite specified in RFC, not all ARP cache implementations operate as described….

ARP: not only *this* mechanism!

- ➔**Described mechanism for broadcast networks (e.g. based on shared media)**
- ➔**Non applicable for non broadcast networks**
  - ⇨in this case OTHER ARP protocols are used
    - →e.g. distributed ARP servers
    - →e.g. algorithms to map IP address in network address

Getting an IP address:

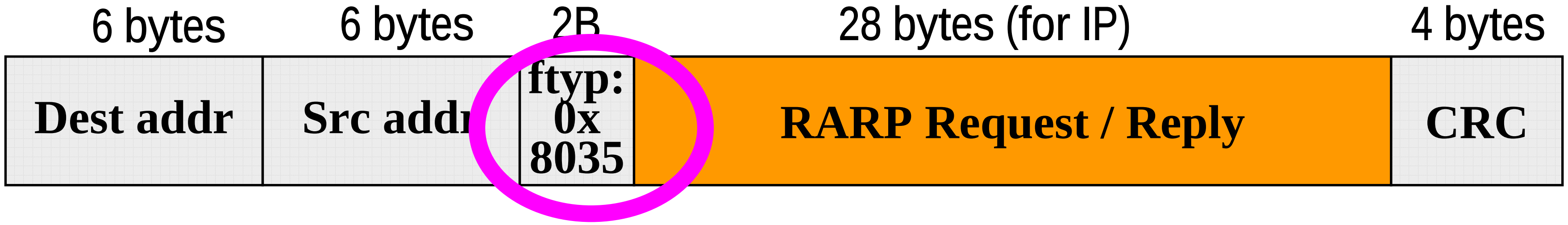
Reverse Address Resolution Protocol (RARP)

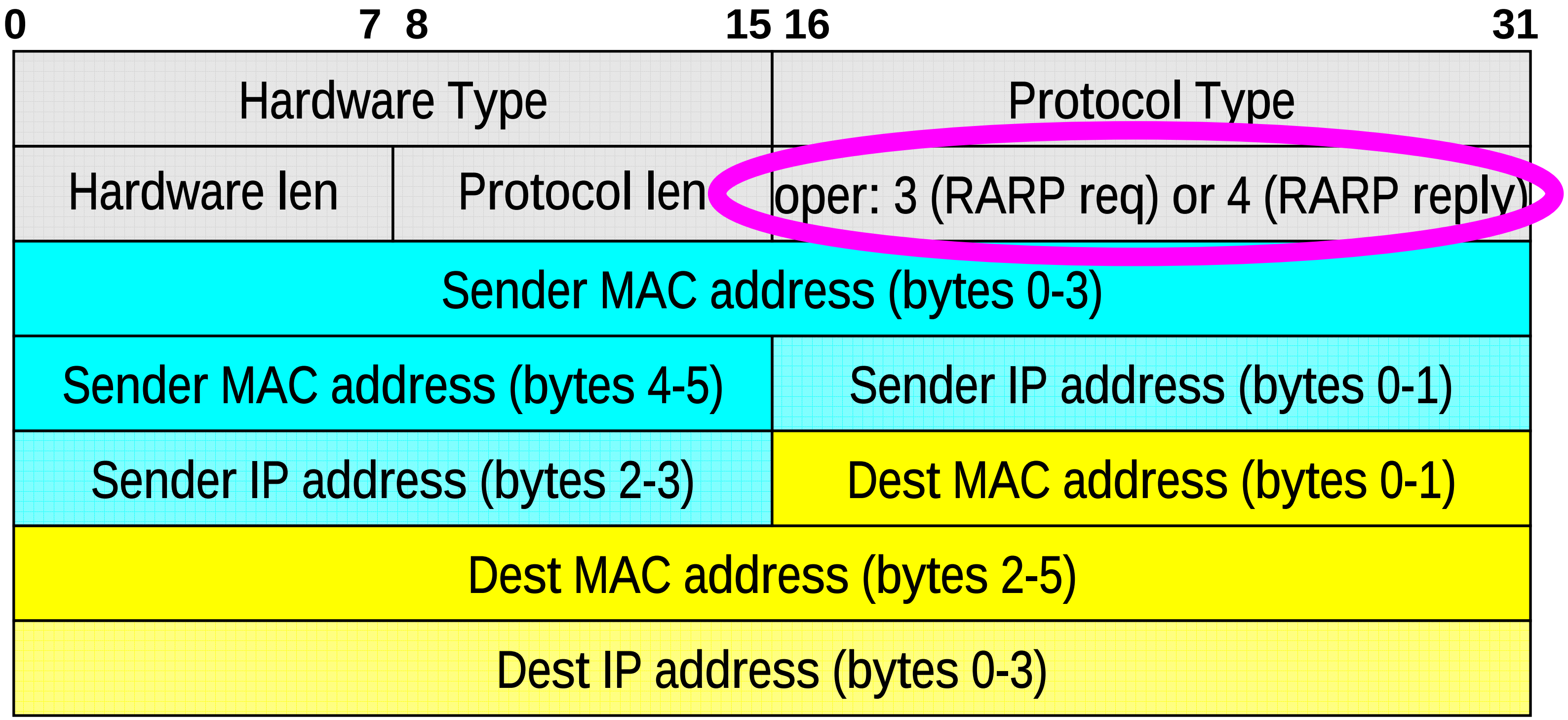
The problem

- ➔ **Bootstrapping a diskless terminal**
  - ⇨ this was the original problem in the 70s and 80s
- ➔ **Reverse ARP [RFC903]**
  - ⇨ a way to obtain an IP address starting from MAC address
- ➔ **Today problem: dynamic IP address assignment**
  - ⇨ limited pool of addresses assigned only when needed
- ➔ **RARP not sufficiently general for modern usage**
  - ⇨ BOOTP (Bootstrap Protocol - RFC 951): significant changes to RARP (a different approach)
  - ⇨ DHCP (Dynamic Host Configuration Protocol - RFC 1541): extends and replaces BOOTP

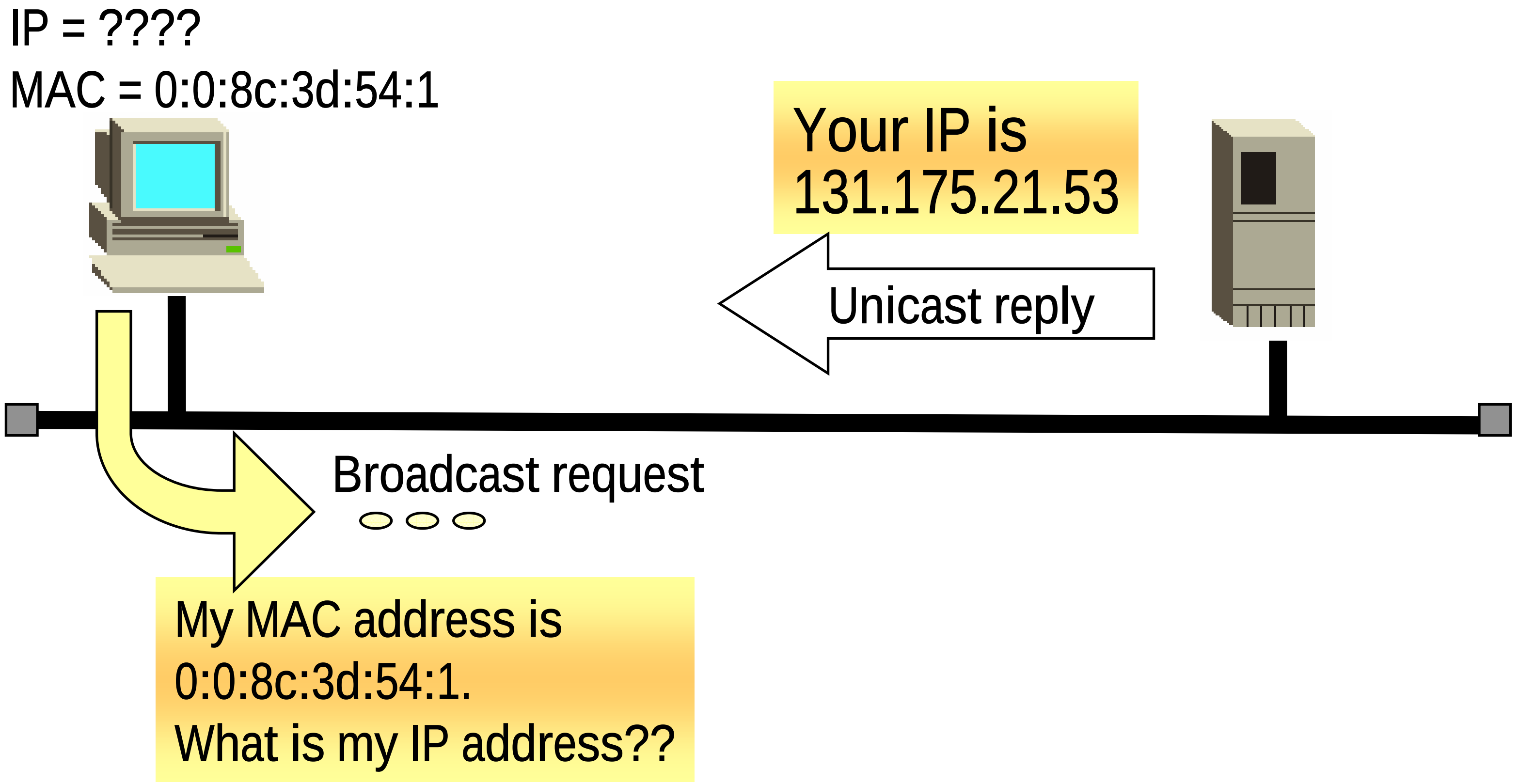
RARP packet format

almost identical to ARP. Differences:




0
7
8
15
16
31
Hardware Type
Protocol Type
Hardware len
Protocol len
oper: 3 (RARP req) or 4 (RARP reply)
Sender MAC address (bytes 0-3)
Sender MAC address (bytes 4-5)
Sender IP address (bytes 0-1)
Sender IP address (bytes 2-3)
Dest MAC address (bytes 0-1)
Dest MAC address (bytes 2-5)
Dest IP address (bytes 0-3)

RARP Request/reply



IP = ????

MAC = 0:0:8c:3d:54:1

Your IP is 131.175.21.53

Unicast reply

Broadcast request

My MAC address is 0:0:8c:3d:54:1. What is my IP address??

RARP problems

- ➔**Network traffic**
  - ⇨for reliability, multiple RARP servers need to be configured on the same Ethernet
    - →to allow bootstrap of terminals even when one server is down
  - ⇨But this implies that ALL servers simultaneously respond to RARP request
    - →contention on the Ethernet occurs
- ➔**RARP requests not forwarded by routers**
  - ⇨being hardware level broadcasts...

RARP fundamental limit

- ➔**Allows only to retrieve the IP address information**
  - ⇨and what about all the remaining full set of TCPIP configuration parameters???
    - →Netmask?
    - →name of servers, proxies, etc?
    - →other proprietary/vendor/ISP-specific info?
- ➔**This is the main reason that has driven to engineer and use BOOTP and DHCP**

BOOTP/DHCP approach

- ➔ **Requests/replies encapsulated in UDP datagrams**
  - ⇨ may cross routers
  - ⇨ no more dependent on physical medium
- ➔ **request addressing:**
  - ⇨ destination IP = 255.255.255.255
  - ⇨ source IP = 0.0.0.0
  - ⇨ destination port (BOOTP): 67
  - ⇨ source port (BOOTP): 68
- ➔ **router crossing:**
  - ⇨ router configured as BOOTP relay agent
  - ⇨ forwards broadcast UDP requests with destination port 67

BOOTP parameters exchange

- **Many more parameters**
  - client IP address (when static IP is assigned)
  - your IP address (when dynamic server assignment)
  - gateway IP address (bootp relay agent - router - IP)
  - server hostname
  - boot filename
- **Fundamental: vendor-specific information field (64 bytes)**
  - seems a lot of space: not true!
  - DHCP uses a 312 vendor-specific field!

Vendor specific information

format allows general information exchange

Tag 1 byte	Len 1 byte	Parameter exchanged

- **E.g.: subnet mask:**
  - tag=1, len=4, parameter=32 bit subnet mask
- **e.g.: time offset:**
  - tag=2, len=4, parameter=time
    (seconds after midnight, jan 1 1900 UTC)
- **e.g. gateway (variable item)**
  - tag=3, len=N, list of gateway IPaddr (first preferred)
- **e.g. DNS server (tag 6)**