Reti

(già "Reti di Calcolatori")

Livello Rete
ARP – ICMP - DHCP

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http://disi.unitn.it/locigno/teaching-duties/computer-networks

Acknowledgement

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  - *Part of the material is based on slides provided by the following authors*
    - *Jim Kurose, Keith Ross, "Computer Networking: A Top Down Approach," 4th edition, Addison-Wesley, July 2007*
    - *Douglas Comer, "Computer Networks and Internets," 5th edition, Prentice Hall*
    - *Behrouz A. Forouzan, Sophia Chung Fegan, "TCP/IP Protocol Suite," McGraw-Hill*, January 2005
- La traduzione, se presente, è in generale opera (e responsabilità) del docente

Contenuto e temi

- Spazio di indirizzamento
- Indirizzi IP e loro uso
- Consegna dei pacchetti
- **Configurazione dei PC e delle reti**
- Instradamento e Routing

ARP:
ADDRESS RESOLUTION PROTOCOL

Protocollo di supporto a IP per mappare gli indirizzi IP sulle interfacce fisiche, ovvero sugli indirizzi MAC (Ethernet)

Address Resolution

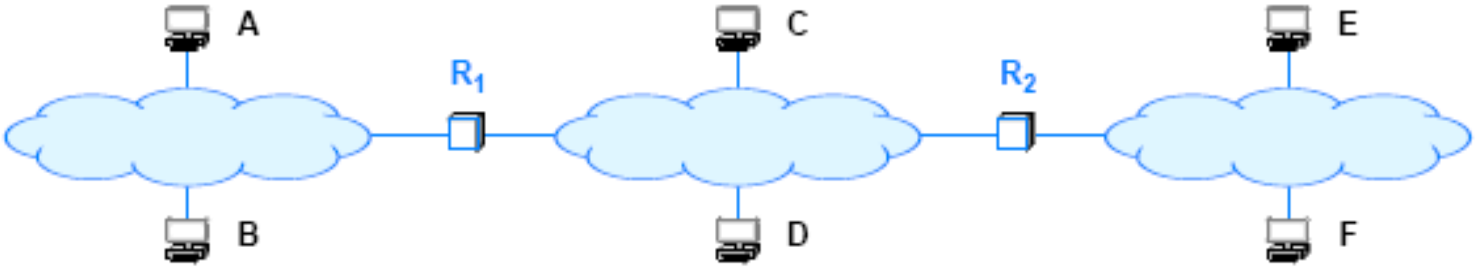
- A crucial step of the forwarding process requires a translation:
  - forwarding uses IP addresses
  - a frame transmitted must contain the MAC address of the next hop
  - IP must translate the next-hop IP address to a MAC address
- The principle is:
  - IP addresses are abstractions
    - provided by protocol software
  - The Data-Link does not know how to locate a computer from its IP address
    - the next-hop address must be translated to an equivalent MAC address

Address Resolution

- Translation from a computer's IP address to an equivalent hardware address is known as address resolution
  - And an IP address is said to be resolved to the correct MAC address
- Address resolution is local to a network
  - simple for Point-to-Point connections
  - need a protocol in the general case of shared access medium
- A server-based solution introduces delays and a weak point
- Local communications are cheap and often the medium is broadcast
- A “broadcast and select” solution is the one chosen by IETF

Address Resolution

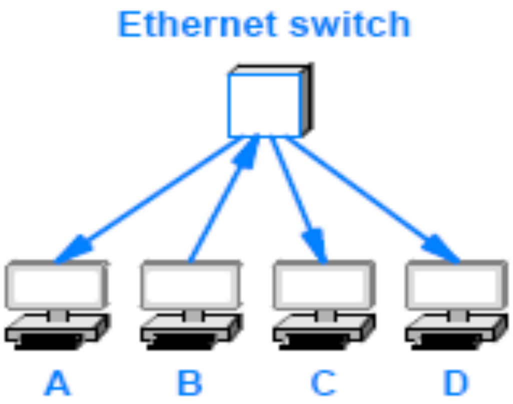
- One computer can resolve the address of another computer only if both computers attach to the same physical network
  - Direct delivery
  - A computer **never** resolves the address of a computer on a remote network
  - Address resolution is always restricted to a single network



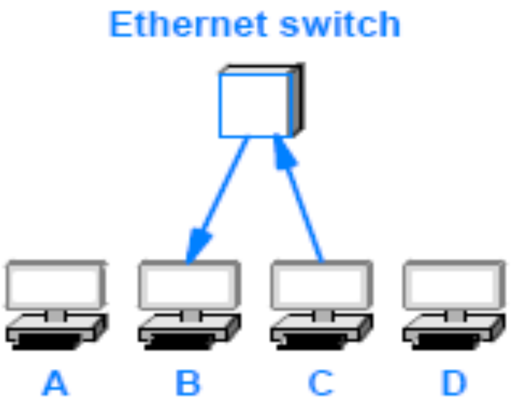
Address Resolution

- How can a host know if the address to resolve is local?
  - if it is local, the dest. IP address should have the same NetID (prefix) of the source IP address
- What happens if the address is not local?
  - Indirect delivery
  - Give the packet to a machine router that is on the way to the destination ➔ next topic
  - Must in any case translate the IP of the Router into its MAC address

Address Resolution Protocol (ARP)



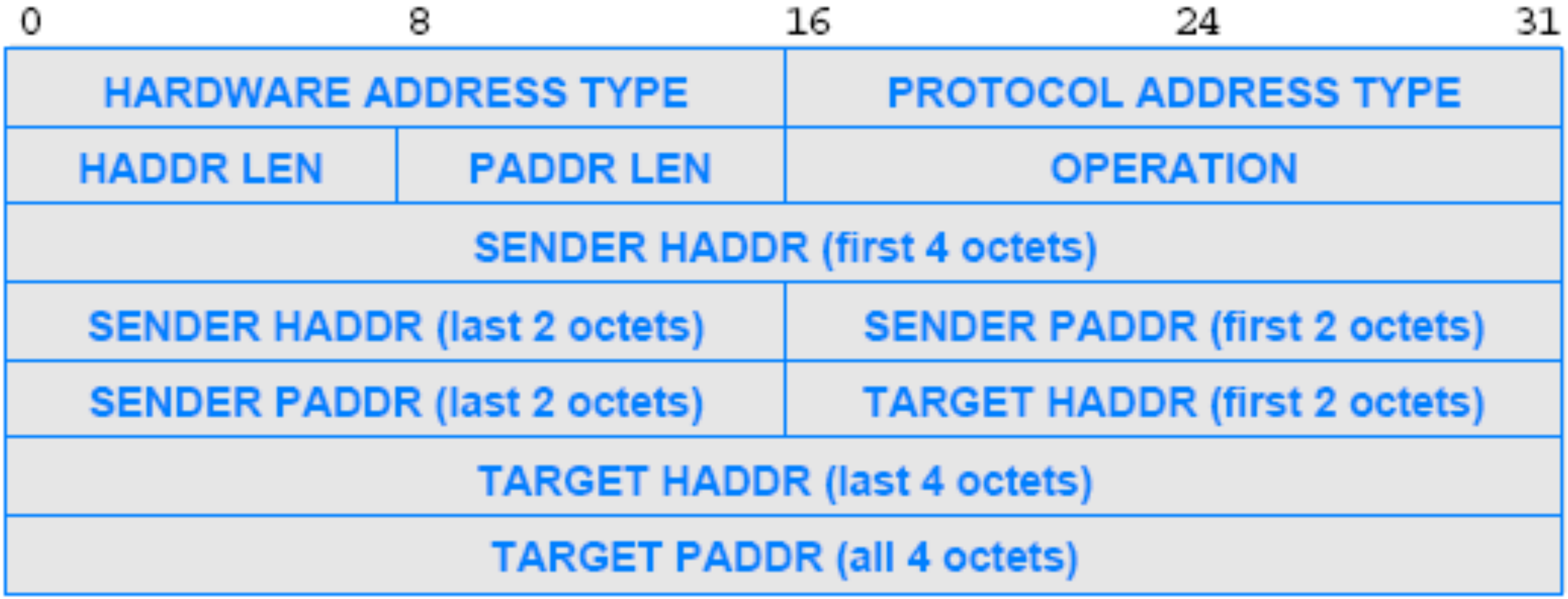
(a)



(a)

- Suppose B needs to resolve the IP address of C
- B broadcasts a request that says:
  - "I'm looking for the MAC address of a computer that has IP address C"
- The broadcast only travels across one network
- An ARP request message reaches all computers on a network
- When C receives a copy of the request it sends a directed reply back to B that says:
  - "I'm the computer with IP address C, and my MAC address is M"

ARP Message Format



0	8	16	24	31
HARDWARE ADDRESS TYPE		PROTOCOL ADDRESS TYPE		
HADDR LEN	PADDR LEN	OPERATION		
SENDER HADDR (first 4 octets)				
SENDER HADDR (last 2 octets)		SENDER PADDR (first 2 octets)		
SENDER PADDR (last 2 octets)		TARGET HADDR (first 2 octets)		
TARGET HADDR (last 4 octets)				
TARGET PADDR (all 4 octets)				

ARP Message Format

- HARDWARE ADDRESS TYPE
  - 16-bit field that specifies the type of hardware address
  - the value is 1 for Ethernet
- PROTOCOL ADDRESS TYPE
  - 16-bit field that specifies the type of protocol address
  - the value is 0x0800 for IPv4
- HADDR LEN
  - 8-bit integer that specifies the size of a hardware address in bytes
- PADDR LEN
  - 8-bit integer that specifies the size of a protocol address in bytes

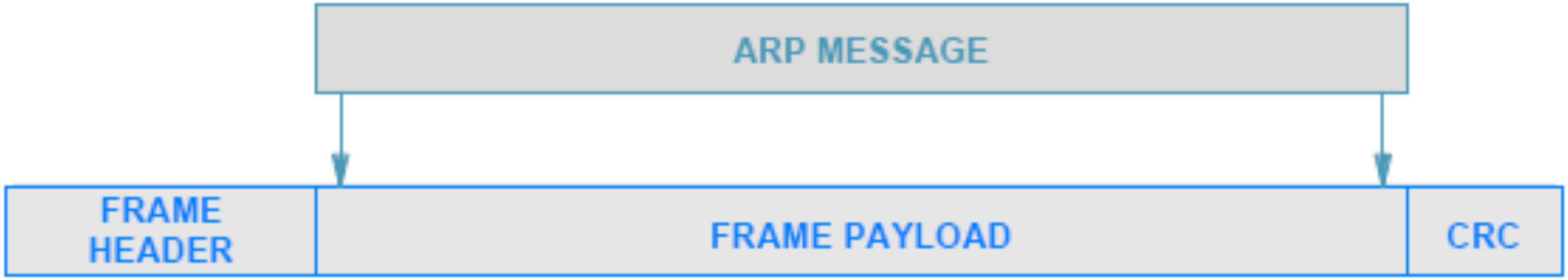
ARP Message Format

- OPERATION
  - 16-bit field that specifies whether the message
    - “request” (1) or “response” (2)
- SENDER HADDR
  - HADDR LEN bytes for the sender's hardware address
- SENDER PADDR
  - PADDR LEN bytes for the sender's protocol address
- TARGET HADDR
  - HADDR LEN bytes for the target's hardware address
- TARGET PADDR
  - PADDR LEN bytes for the target's protocol address

ARP Message Format

- An ARP message contains fields for two address bindings
  - one binding to the sender
  - other to the intended recipient, ARP calls it target
- When a request is sent
  - the sender does not know the target's hardware address (that is the information being requested)
    - field TARGET HADDR in an ARP request is filled with “0”
- In a response
  - the target binding refers to the initial computer that sent the request

ARP Encapsulation



- When it travels across a physical network an ARP message is encapsulated in a hardware frame
  - e.g., Ethernet
- An ARP message is treated as data being transported
  - the network does not parse the ARP message or interpret fields

ARP Encapsulation

- The type field in the frame header specifies that the frame contains an ARP message
- A sender must assign the appropriate value to the type field before transmitting the frame
- A receiver must examine the type field in each incoming frame
- Ethernet uses type field 0x806 to denote an ARP message
- The same value is used for both ARP requests/ responses
  - Frame type does not distinguish between types of ARP messages
  - A receiver must examine the OPERATION field in the message to determine whether an incoming message is a request or a response

ARP Caching and Message Processing

- Sending an ARP request for each datagram is inefficient
  - Three frames traverse the network for each datagram
    - an ARP request, ARP response, and the data datagram itself
- Most communications involve a sequence of packets
  - a sender is likely to repeat the exchange many times
- To reduce network traffic
  - ARP software extracts and saves the information from a response
    - so it can be used for subsequent packets
  - The software does not keep the information indefinitely
    - Instead, ARP maintains a small table of bindings in memory

ARP Caching and Message Processing

- ARP manages the table as a cache
  - an entry is replaced when a response arrives
  - the oldest entry is removed whenever the table runs out of space or after an entry has not been updated for some time
  - ARP starts by searching the cache when it needs to bind an address
- ARP entries expire after ~ 30s to avoid sending packets to the wrong destination if the mapping IP-MAC changes

ARP Caching and Message Processing

- If the binding is present in the cache
  - ARP uses the binding without transmitting a request
- If the binding is not present in the cache
  - ARP broadcasts a request
  - waits for a response
  - updates the cache
  - send the packet
- The cache is updated when an ARP message arrives
  - either a request or a response
  - since traffic is normally two-way updating the cache on requests reduces overhead

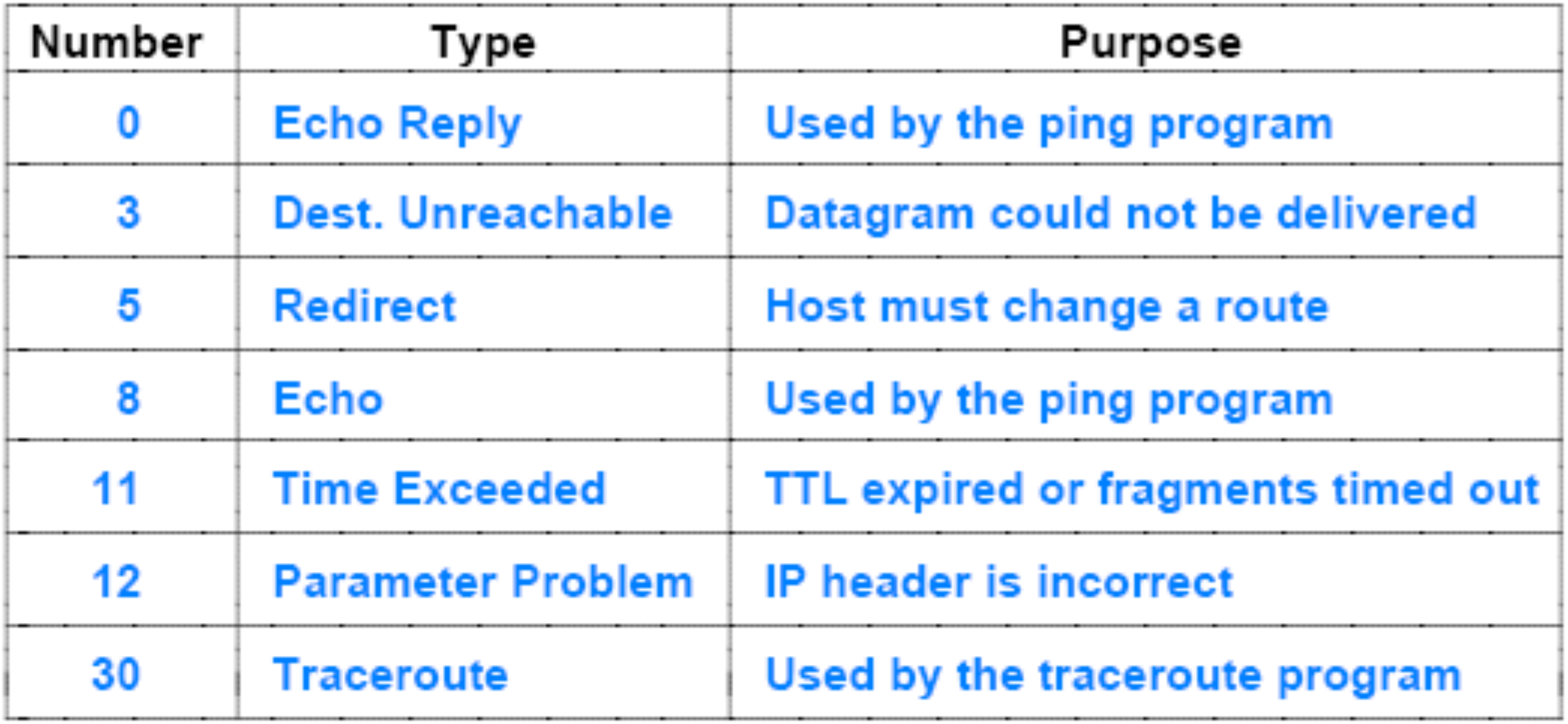
ICMP: INTERNET CONTROL MESSAGE PROTOCOL

Messaggi di controllo, segnalazione, errore al livello IP

Internet Control Message Protocol

- IP includes a companion protocol, ICMP
  - It is used to report errors back to the original source
- IP and ICMP are co-dependent
  - IP depends on ICMP to report errors
  - and ICMP uses IP to carry error messages
- ICMP can be seen as a signaling protocol for network management and maintenance
- Many ICMP messages have been defined

Internet Control Message Protocol

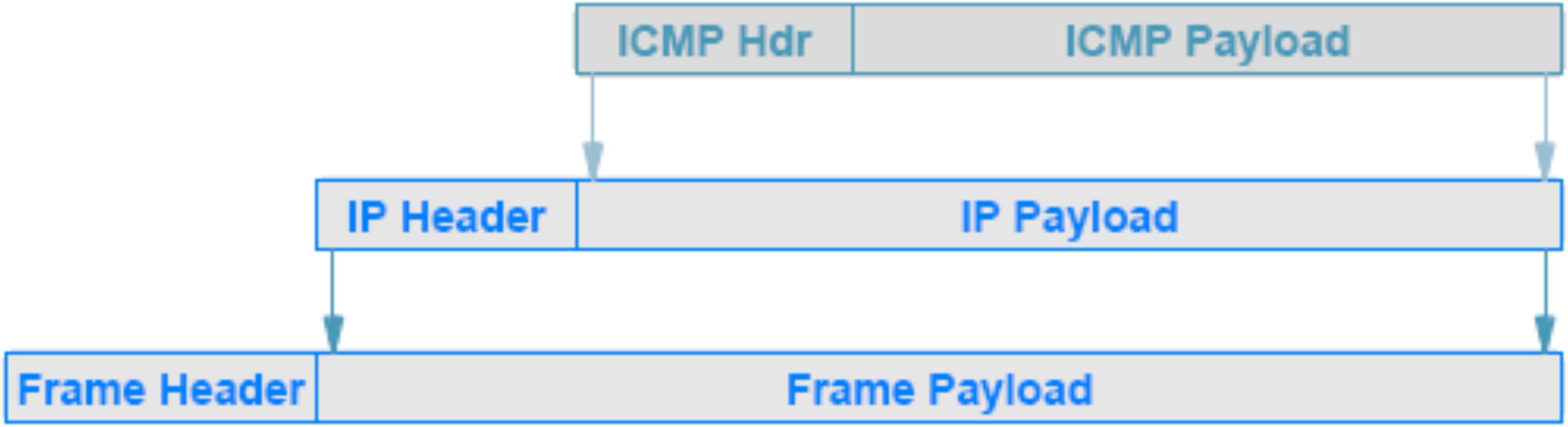


Number	Type	Purpose
0	Echo Reply	Used by the ping program
3	Dest. Unreachable	Datagram could not be delivered
5	Redirect	Host must change a route
8	Echo	Used by the ping program
11	Time Exceeded	TTL expired or fragments timed out
12	Parameter Problem	IP header is incorrect
30	Traceroute	Used by the traceroute program

Internet Control Message Protocol

- ICMP contains two message types:
  - messages used to report errors
    - e.g., Time Exceeded and Destination Unreachable
  - messages used to obtain information
    - e.g., Echo Request and Echo Reply
- Echo Request/Reply are used by the ping application to test connectivity
  - When a host receives an echo request message
    - ICMP software on a host or router sends an echo reply that carries the same data as the request

ICMP Format and Encapsulation



- ICMP uses IP to transport messages:
  - when a router has an ICMP message to send
    - creates an IP datagram and encapsulates the ICMP message in it
  - the ICMP message is the payload area of the IP datagram
  - the datagram is forwarded as usual

ICMP handling

- ICMP messages do not have special priority
  - They are forwarded like any other datagram, with one minor exception
- If an ICMP error message causes an error
  - no error message is sent
- The reason should be clear:
  - the designers wanted to avoid the Internet becoming congested carrying error messages about error messages

Uso di ICMP

- Comando “ping”
  - Echo Request + Echo Replay
- Comando traceroute
  - Il mittente invia normali pacchetti IP con TTL settato a 1, 2, 3, ...
  - Con TTL = 1, il primo router decrementa TTL che arriva a 0, quindi il pacchetto viene scartato e il router manda (dovrebbe mandare) un messaggio ICML Time Exceeded
  - Con TTL= 2 il primo router decrementa e inoltra, il secondo ...
  - E così via
- Esempi “live”
  - Con ping misuro RTT, con Traceroute capisco che strada fa il mio pacchetto

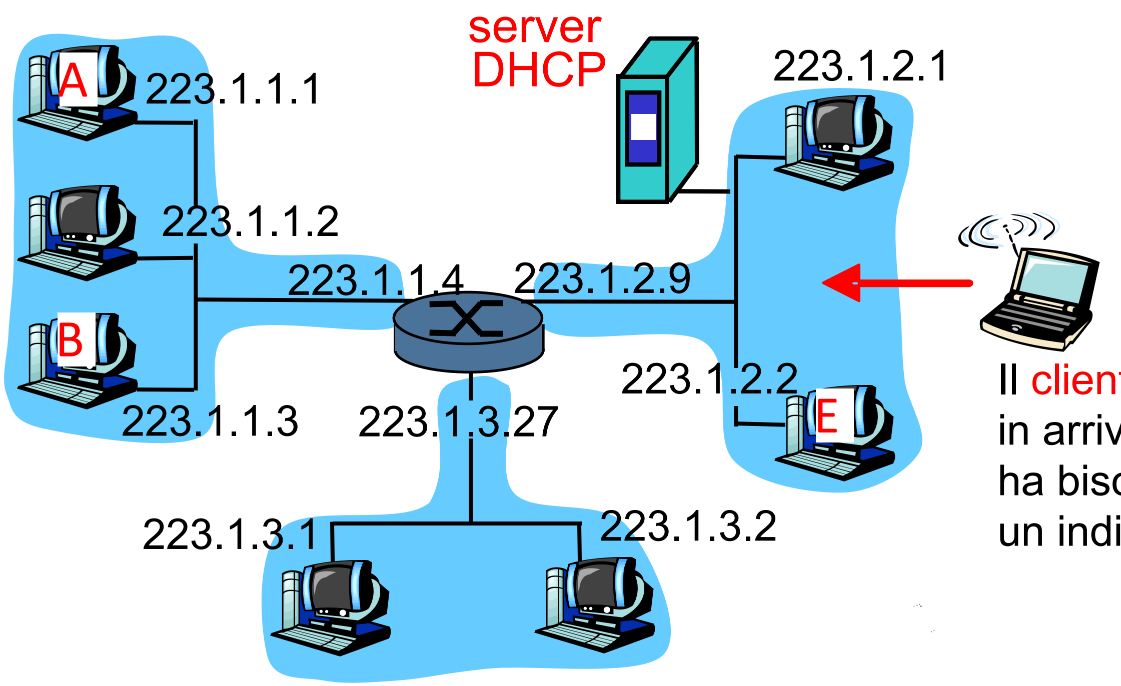
DHCP: DYNAMIC HOST CONFIGURATION PROTOCOL

Come bootstrappare una rete senza dover configurare i singoli host

Protocol Parameters and Configuration

- Once a host or router has been powered on, OS is started and the network software is initialized
- How does the network software in a host or router begin operation?
- For a router, the configuration manager must specify initial values for items such as
  - the IP address for each network interface
  - the protocol software to run
  - and initial values for a forwarding table
  - the configuration is saved, and a router loads the values during startup
- Host configuration usually uses a two-step process, known as bootstrapping
  - DHCP is used to take care of most configuration needs

Scenario client-server DHCP

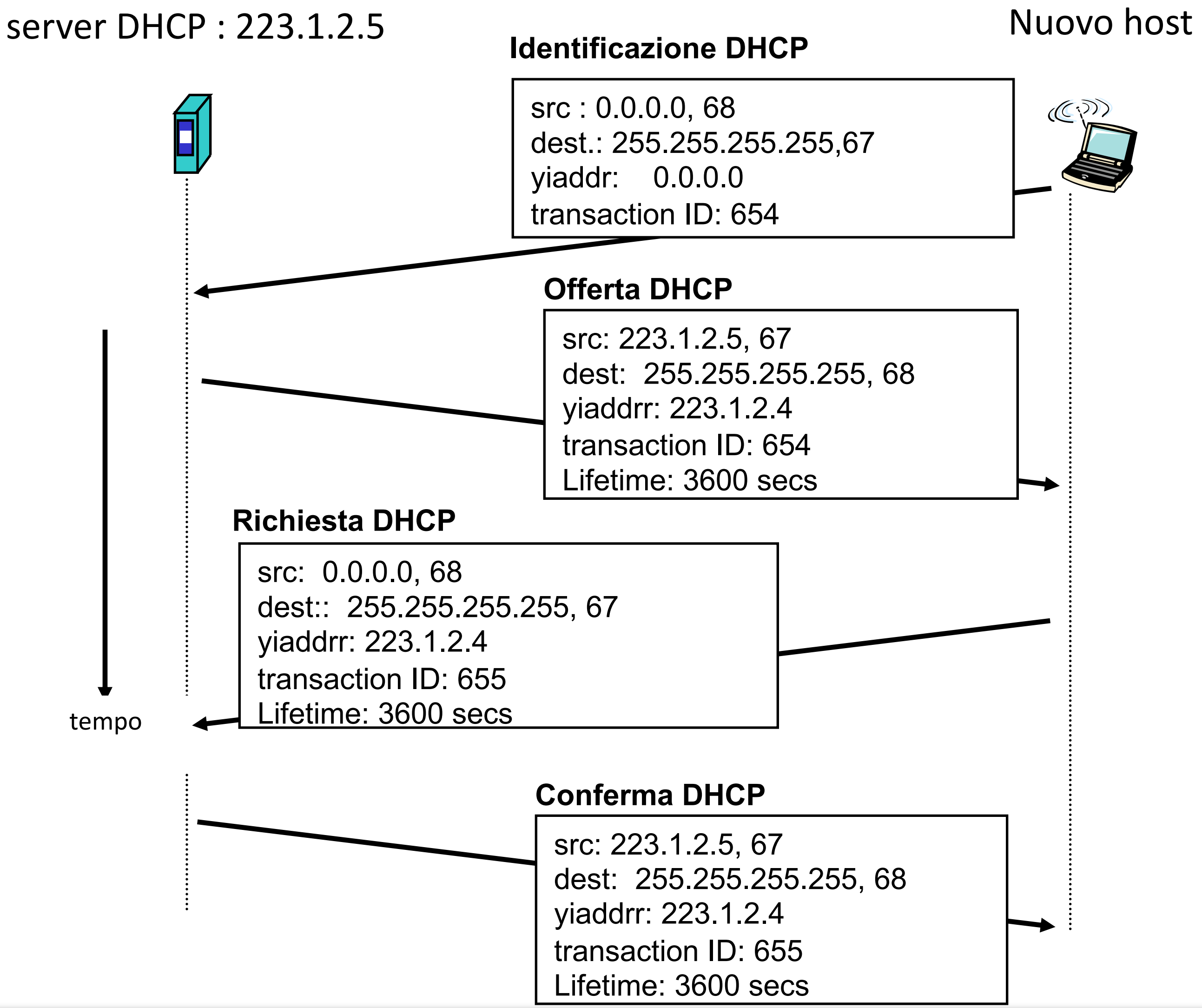


Il client DHCP
in arrivo su questa rete
ha bisogno di
un indirizzo

Dynamic Host Conf. Protocol (DHCP)

- When a computer boots
  - the DHCP client broadcasts a DHCP Request
  - the server(s) send a DHCP Reply
    - a server reply is called offer
    - the server is offering an address to the client
- We can configure a DHCP server to supply two types of addresses:
  - permanently assigned addresses
  - a pool of dynamic addresses to be allocated on demand
- Typically, a permanent address is assigned to a server, and a dynamic address is assigned to an arbitrary host
- Addresses assigned on demand are not given out for an arbitrary length of time

Scenario client-server DHCP



Identificazione DHCP

src : 0.0.0.0, 68
dest.: 255.255.255.255,67
yiaddr: 0.0.0.0
transaction ID: 654

Offerta DHCP

src: 223.1.2.5, 67
dest: 255.255.255.255, 68
yiaddrr: 223.1.2.4
transaction ID: 654
Lifetime: 3600 secs

Richiesta DHCP

src: 0.0.0.0, 68
dest:: 255.255.255.255, 67
yiaddrr: 223.1.2.4
transaction ID: 655
Lifetime: 3600 secs

Conferma DHCP

src: 223.1.2.5, 67
dest: 255.255.255.255, 68
yiaddrr: 223.1.2.4
transaction ID: 655
Lifetime: 3600 secs

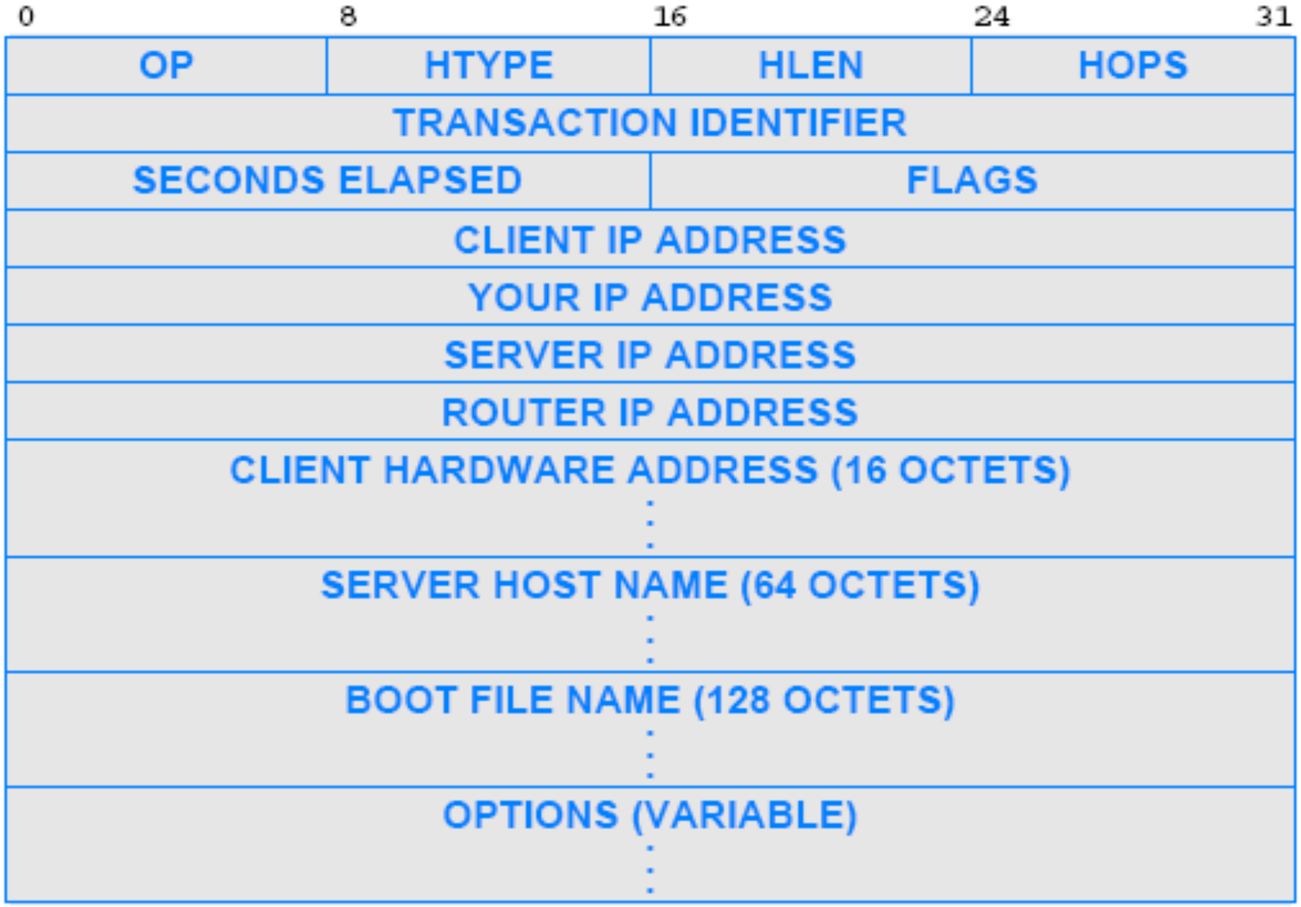
Dynamic Host Conf Protocol (DHCP)

- DHCP issues a lease on the address for a finite period
  - The use of leases allows a DHCP server to reclaim addresses
- When the lease expires
  - the server places the address to the pool of available addresses
- When a lease expires, a host can choose to relinquish the address or renegotiate with DHCP to extend the lease
  - Negotiation occurs concurrent with other activity
- Normally, DHCP approves each lease extension
  - A computer continues to operate without any interruption
  - However, a server may be configured to deny lease extension for administrative or technical reasons
  - DHCP grants absolute control of leasing to a server
  - If a server denies an extension request
    - the host must stop using the address

DHCP Protocol Operation

- Recovery from loss or duplication
  - DHCP is designed to insure that missing or duplicate packets do not result in misconfiguration
  - If no response is received
    - a host retransmits its request
  - If a duplicate response arrives
    - a host ignores the extra copy
- Caching of a server address
  - once a host finds a DHCP server
    - the host caches the server's address
- Avoidance of synchronized flooding
  - DHCP takes steps to prevent synchronized requests

DHCP Message Format



0 8 16 24 31

<table>
<tr><td>OP</td><td>HTYPE</td><td>HLEN</td><td>HOPS</td></tr>
<tr><td colspan="4">TRANSACTION IDENTIFIER</td></tr>
<tr><td colspan="2">SECONDS ELAPSED</td><td colspan="2">FLAGS</td></tr>
<tr><td colspan="4">CLIENT IP ADDRESS</td></tr>
<tr><td colspan="4">YOUR IP ADDRESS</td></tr>
<tr><td colspan="4">SERVER IP ADDRESS</td></tr>
<tr><td colspan="4">ROUTER IP ADDRESS</td></tr>
<tr><td colspan="4">CLIENT HARDWARE ADDRESS (16 OCTETS)
⋮</td></tr>
<tr><td colspan="4">SERVER HOST NAME (64 OCTETS)
⋮</td></tr>
<tr><td colspan="4">BOOT FILE NAME (128 OCTETS)
⋮</td></tr>
<tr><td colspan="4">OPTIONS (VARIABLE)
⋮</td></tr>
</table>

DHCP Message Format

- OP specifies whether the message is a Request or a Response
- HTYPE and HLEN fields specify the network hardware type and the length of a hardware address
- FLAGS specifies whether it can receive broadcast or directed replies
- HOPS specifies how many servers forwarded the request
- TRANSACTION IDENTIFIER provides a value that a client can use to determine if an incoming response matches its request
- SECONDS ELAPSED specifies how many seconds have elapsed since the host began to boot
- Except for OPTIONS (OP), each field in a DHCP message has a fixed size

DHCP Message Format

- Later fields in the message are used in a response to carry information back to the host that sent a request
  - if a host does not know its IP address, the server uses field YOUR IP ADDRESS to supply the value
  - server uses fields SERVER IP ADDRESS and SERVER HOST NAME to give the host information about the location of a server
  - ROUTER IP ADDRESS contains the IP address of a default router
  - Options may include (and normally do) the local DNS server
- DHCP allows a computer to negotiate to find a boot image
  - To do so, the host fills in field BOOT FILE NAME with a request
  - The DHCP server does not send an image