DHCP Basics
(Dynamic Host Configuration Protocol)

BUPT/QMUL

2021-04-08

Topics In This Course

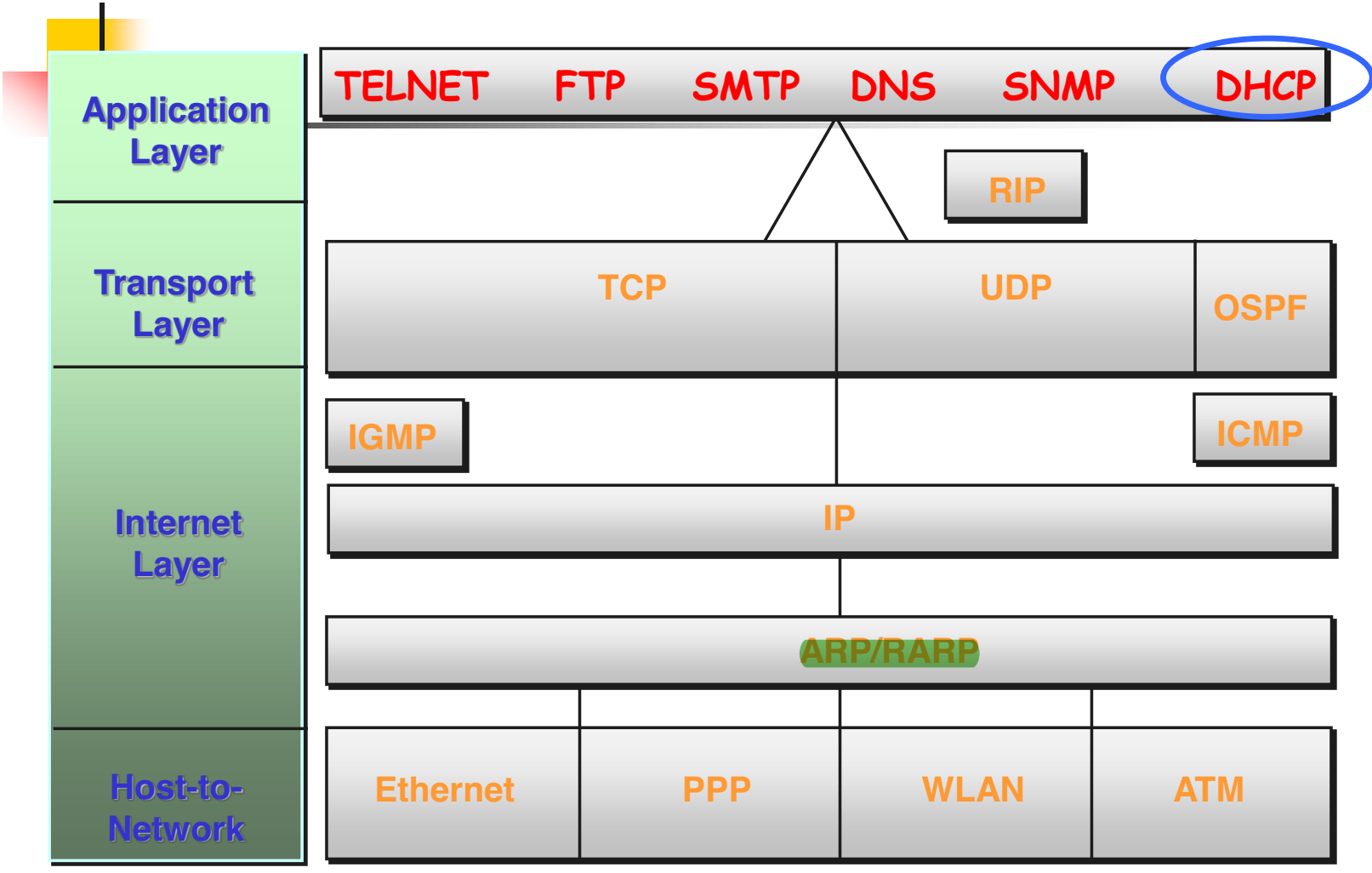
Background

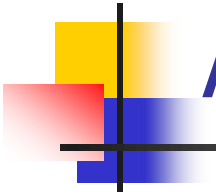
- Introduction of Internet
- TCP/IP and OSI/RM
- Socket Programming

Typical Internet Applications

- DNS (Domain Name System)
- DHCP (Dynamic Host Configuration Protocol)
- Remote Interactive Computing: TELNET/SSH
- Email: SMTP/POP/IMAP/MIME
- File Transfer and Access: FTP/TFTP/NFS
- World Wide Web: HTTP
- Network Management: SNMP
- Seminars about New applications

Protocols of Internet





Agenda

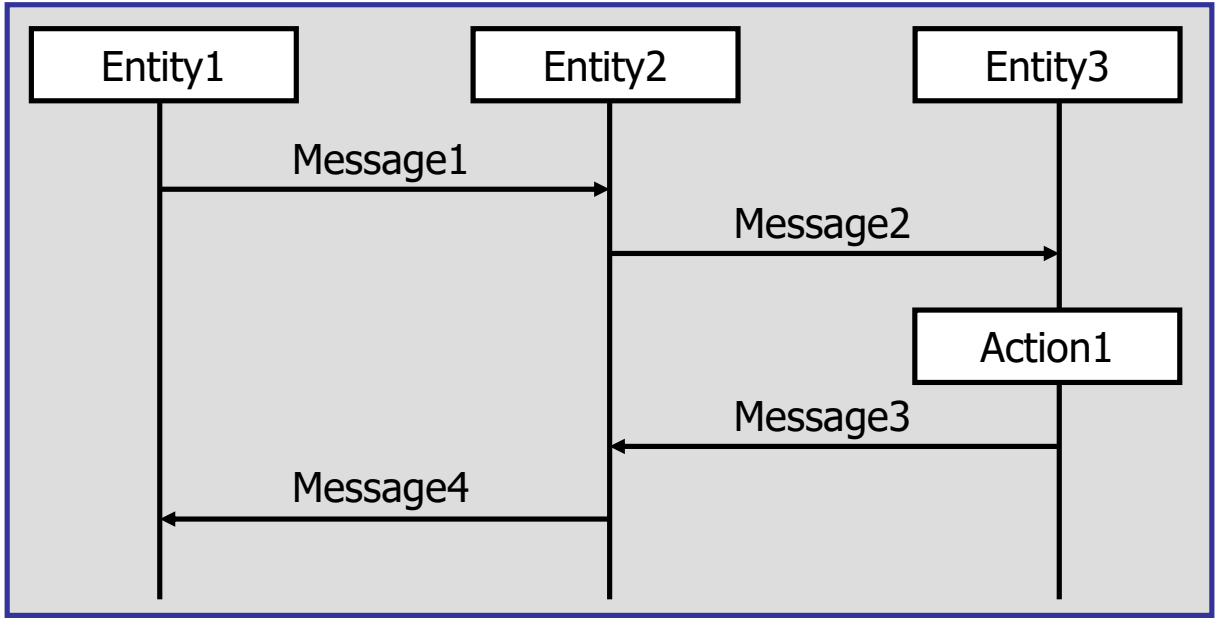
- Some useful information about learning a protocol
- Introduction to DHCP
- DHCP Protocol
- Examples about DHCP configuration

Refer to Chapter 22 of textbook

Some Useful Information About Learning A Protocol

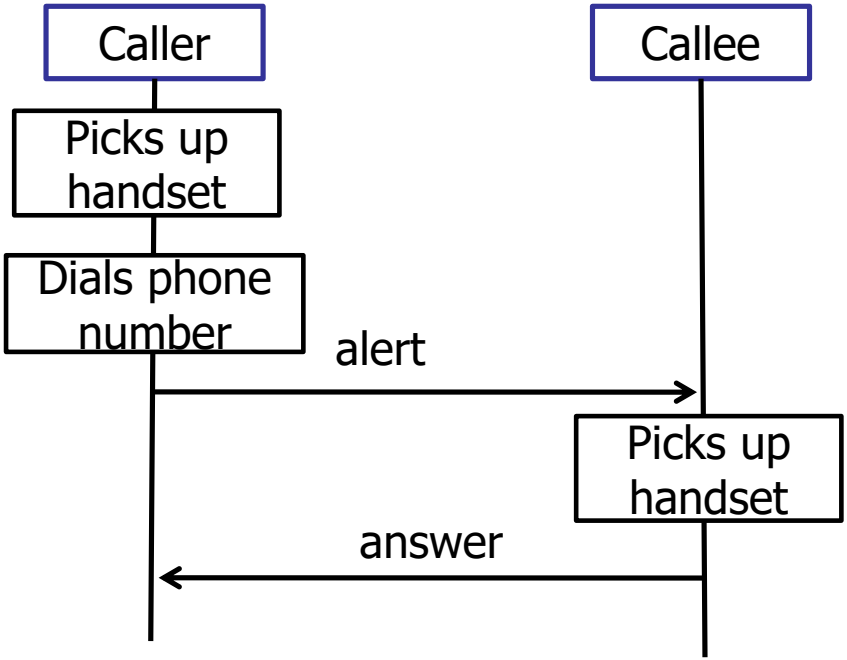
MSC (1)

- Message Sequence Chart
- Define the message exchange sequences between different network elements to complete a specific function
- Basic format: network entity, message, action



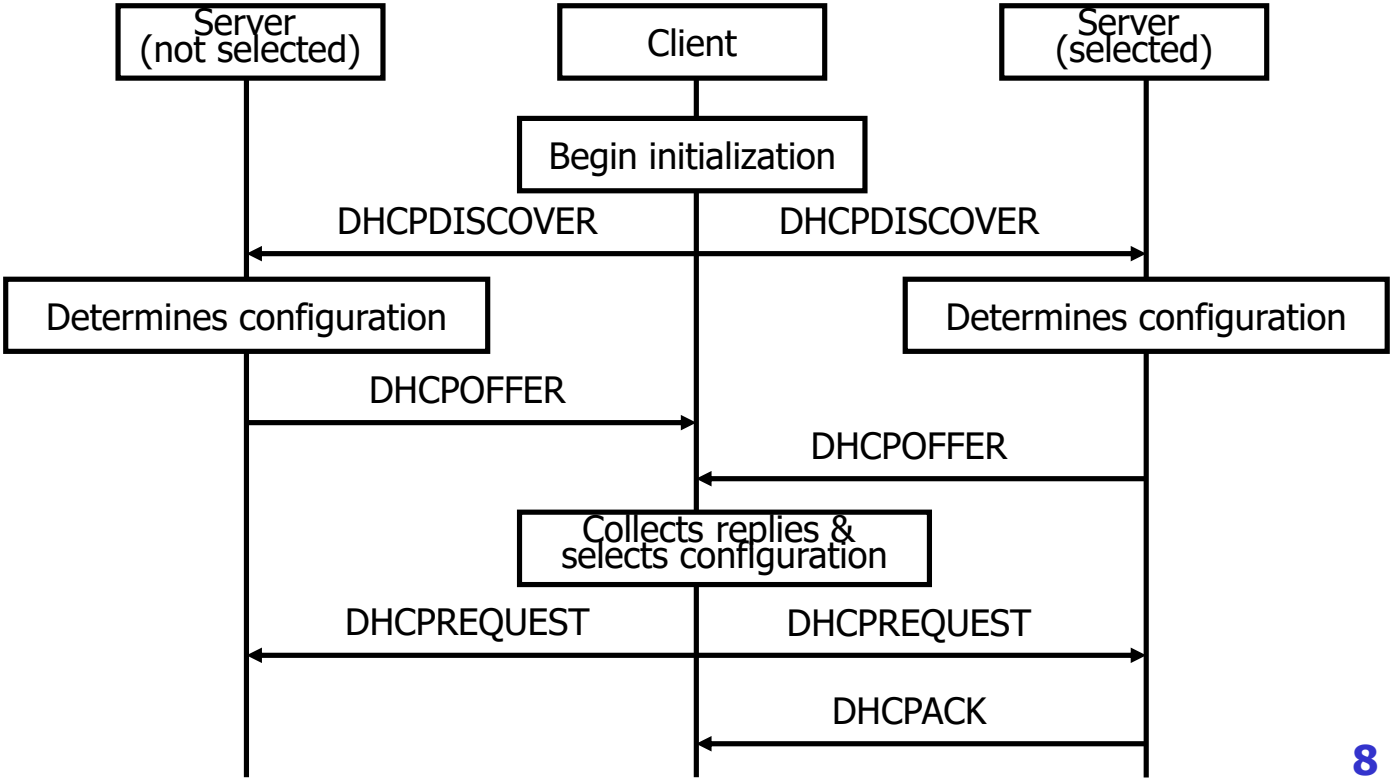
MSC (2)

- A MSC example of telephone call set up



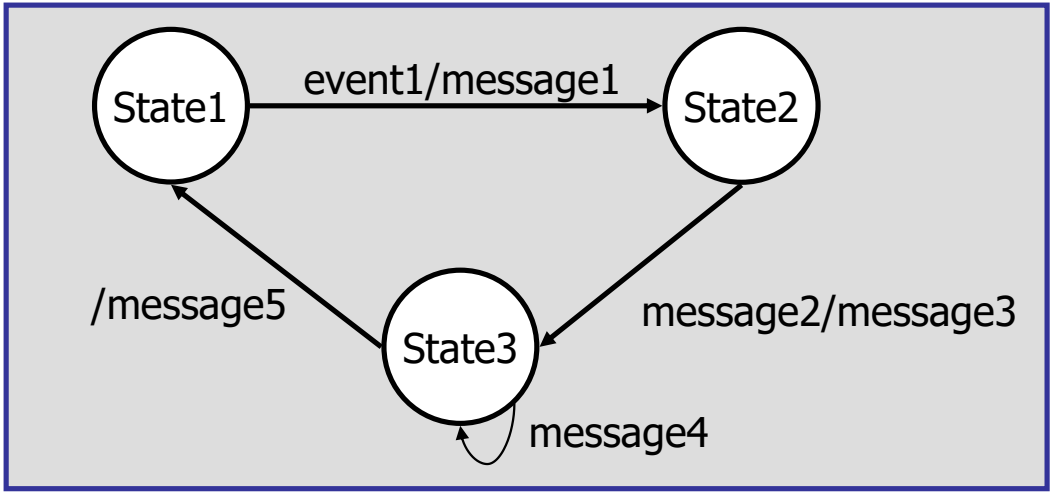
MSC (3)

- A MSC example



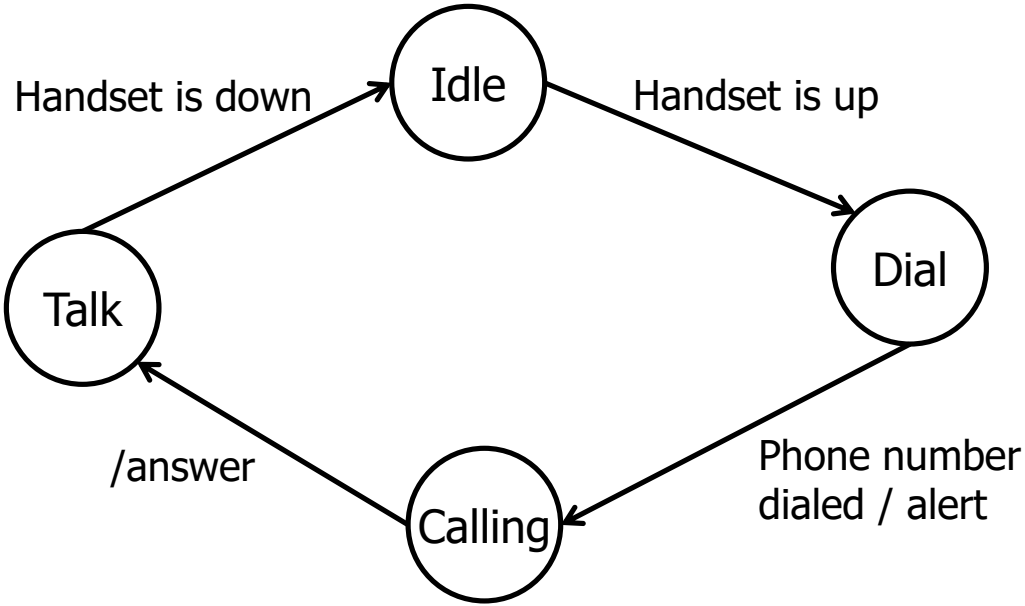
STD (1)

- State Transition Diagram
- Define the state transition relationship in a protocol
- The state transition may be triggered by an event or an incoming message, and may be together with an outgoing message
- Basic format: state, event, incoming message, outgoing message



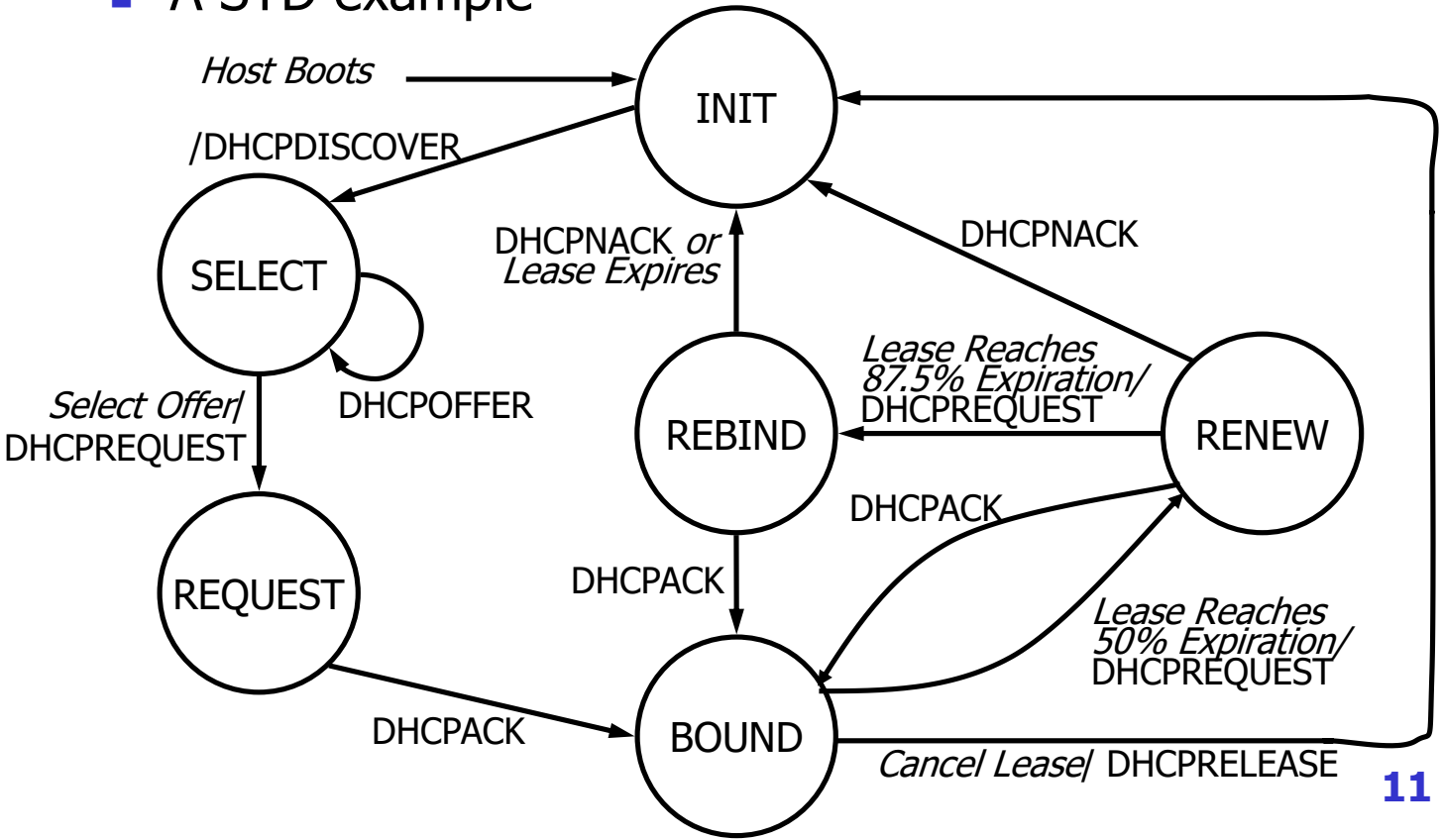
STD (2)

- A STD example of telephone call set up of the caller



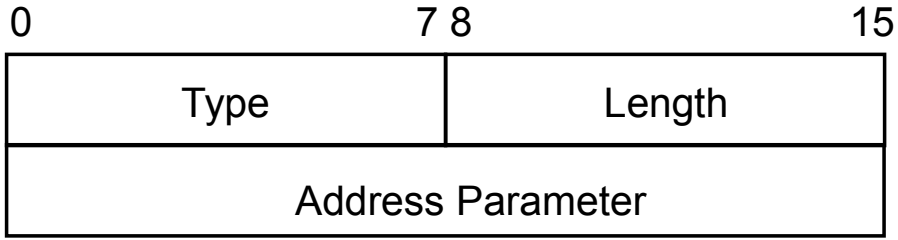
STD (3)

- A STD example



TLV

- Type-Length-Value
- A typical encoding style used in defining the fields with variable length in message
- Each item contains a *type* field, a *length* field, and followed by a *value* of the specified length
- Example

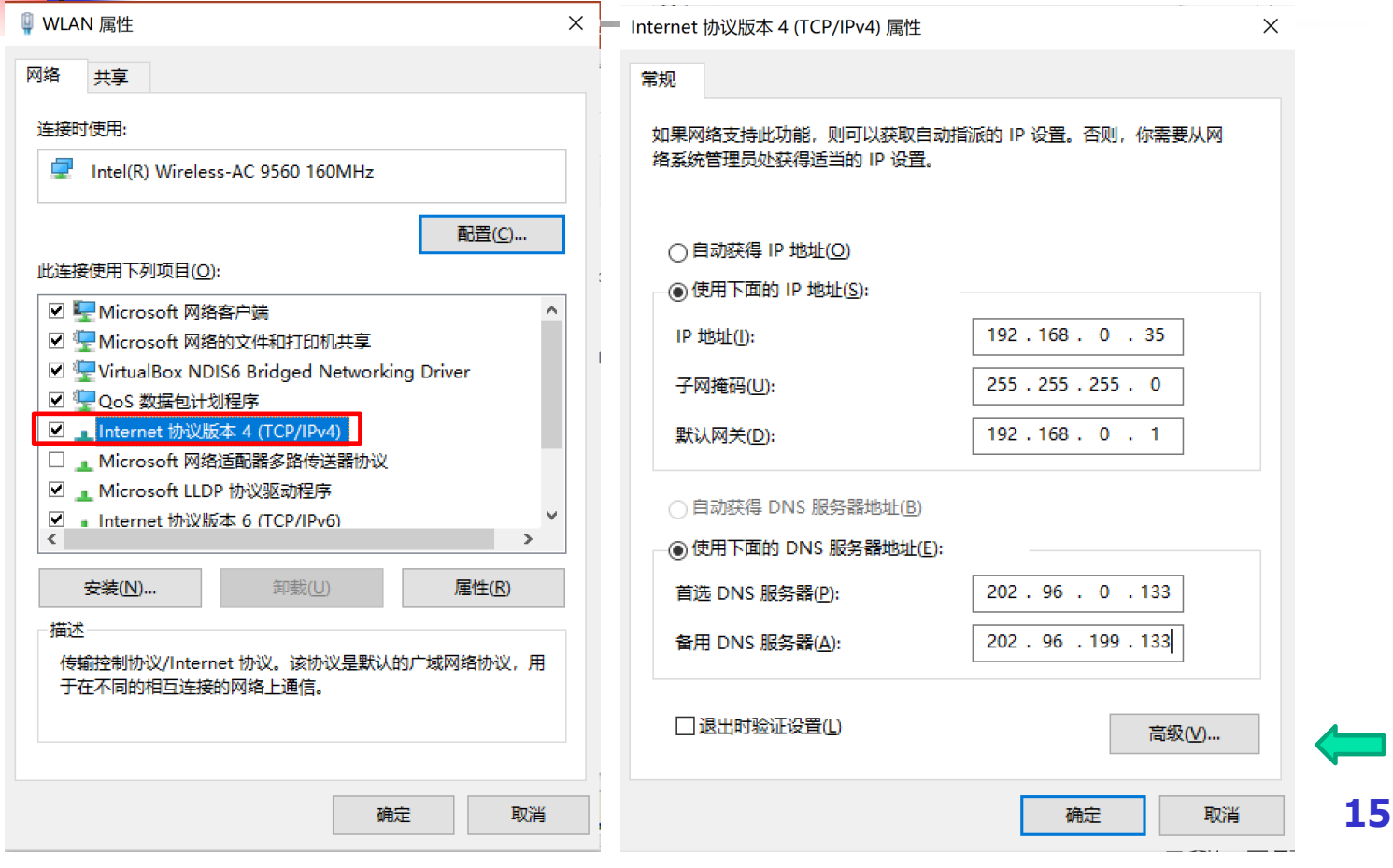


Introduction to DHCP

IP Address Allocation

- IP address management
  - Plan / recording / assignment / retrieval /renumbering
- Static allocation
- Dynamic allocation
  - BOOTP (BOOTstrap Protocol)
  - DHCP (Dynamic Host Configuration Protocol)

Static Allocation Example



What is BOOTP?

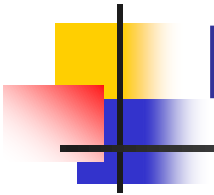
- Bootstrap Protocol
- used by a network client to obtain an IP address from a configuration server
- Used by diskless workstation to obtain boot information such as boot file name (TFTP is used to transfer boot file)
- originally defined in RFC 951

What is DHCP?

- Dynamic Host Configuration Protocol
- Provides automatic configuration of remote hosts
- An extension to BOOTP
- Using UDP as its transport protocol
- Following client-server paradigm
  - Using port 67 (for server) and 68 (for client)

DHCP Client & DHCP Server

- DHCP client
  - A DHCP client is an Internet host using DHCP to obtain configuration parameters such as a network address
- DHCP server
  - A DHCP server is an Internet host that returns configuration parameters to DHCP clients



DHCP Lease

- A DHCP lease is the amount of time that the DHCP server grants to the DHCP client permission to use a particular IP address
- A typical server allows its administrator to set the lease time
- The optimal time for a lease depends on the particular network and the needs of a particular host

DHCP Features

- *Simple administration*
  - **IP addresses**, **subnet masks**, and the **default gateway** do not need to be manually entered on every client machine
- *Moving machines*
  - When moving a machine to a different subnet, you simply move the machine and it acquires a new IP and subnet mask from the DHCP server on that subnet.
- *Eliminating erroneous IP information*
  - Taking the human factor out of the equation reduces problems, such as duplicate IP addresses
- *Eliminating additional configuration information*
  - **DNS servers,** default gateways and WINS servers are some of the widely used configuration option settings possible with DHCP.
- *Efficient use of IP addresses*
  - DHCP can help make the best use of limited IP addresses. All available IP address are put into a **pool** and used by active clients. Machines that are inactive do not use an IP address.

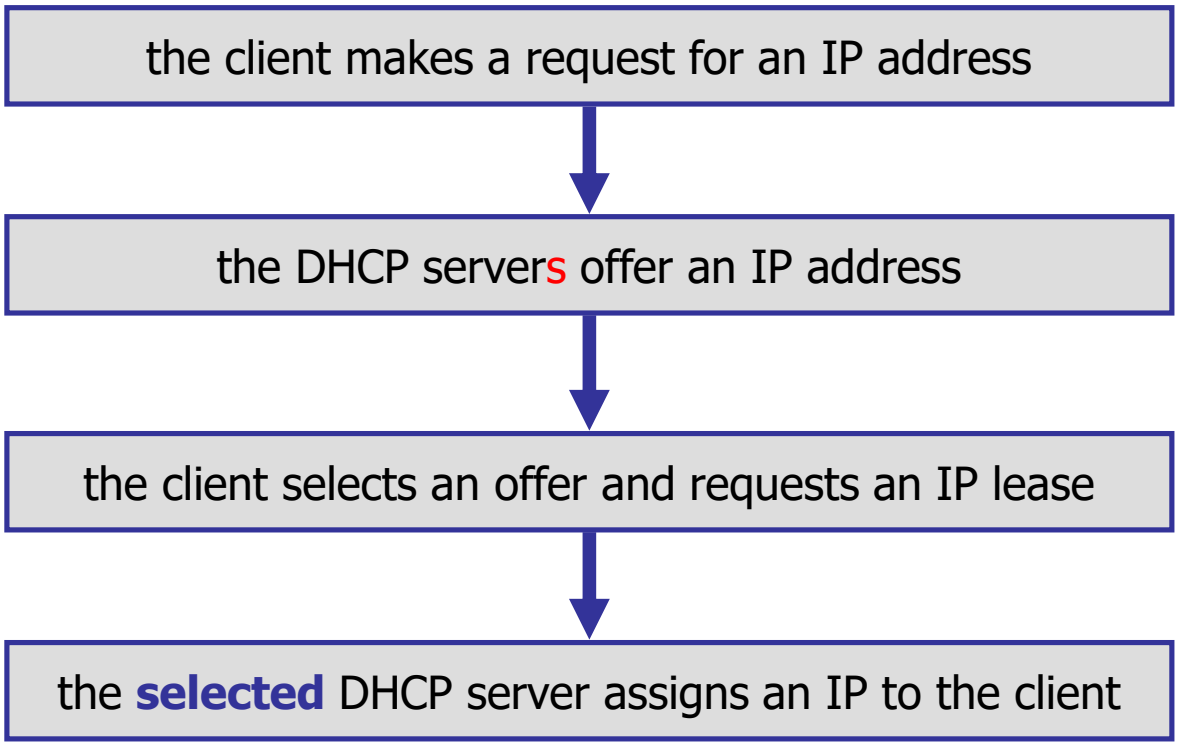
DHCP vs. BOOTP - Similarities

- The format structure each uses to exchange messages
- Use of well-known UDP ports for client/server communication
- IP address distribution as an integral part of configuration service

DHCP vs. BOOTP - Differences

- BOOTP
  - Prior to DHCP
  - Configure diskless workstations
  - Do not rebind or renew configuration
- DHCP
  - After BOOTP
  - Configure frequently relocated networked computers with local hard drives and full boot capabilities
  - Clients automatically enter a rebinding state at set timed intervals to renew their leased address allocation

Phases of IP Assignment with DHCP



DHCP Protocol

Related RFCs (1)

- BOOTP
  - RFC 951
- DHCP Specifications
  - **RFC 2131**, Dynamic Host Configuration Protocol
  - RFC 3315, Dynamic Host Configuration Protocol for IPv6 (DHCPv6)
  - RFC 3396, Encoding Long Options in the Dynamic Host Configuration Protocol (DHCPv4)
  - RFC 4361, Node-specific Client Identifiers for Dynamic Host Configuration Protocol Version Four (DHCPv4)
  - RFC 5494, IANA Allocation Guidelines for the Address Resolution Protocol (ARP)
  - RFC 6842, Client Identifier Option in DHCP Server Replies

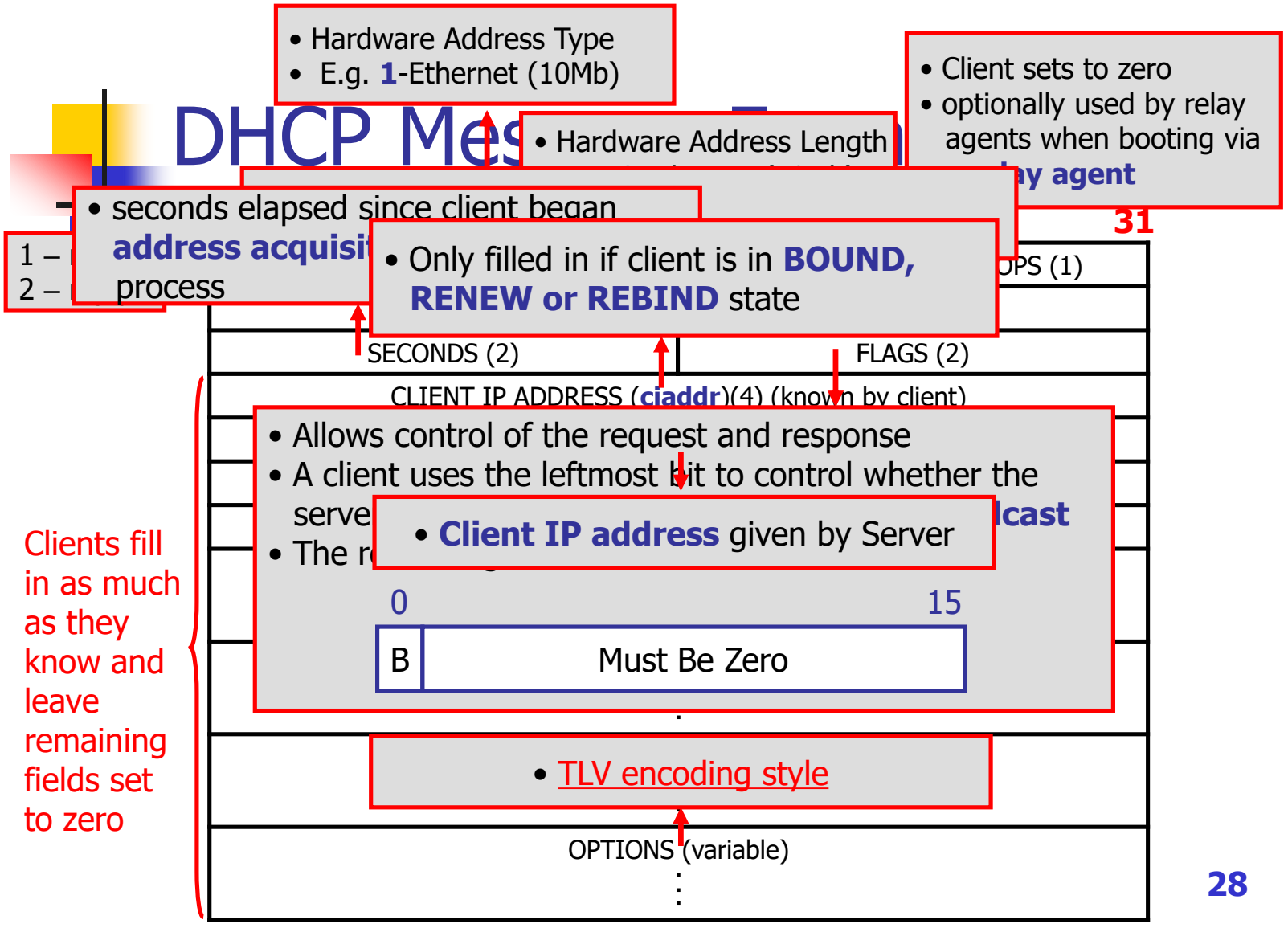
Related RFCs (2)

- DHCP Options
  - **RFC2132**, DHCP Options and BOOTP Vendor Extensions
  - RFC3442, The Classless Static Route Option for Dynamic Host Configuration Protocol (DHCP) version 4
  - RFC3942, Reclassifying Dynamic Host Configuration Protocol version 4 (DHCPv4) Options
  - RFC4833, Timezone Options for DHCP
- Interoperation between DHCP and BOOTP
  - **RFC1534**, Interoperation Between DHCP and BOOTP

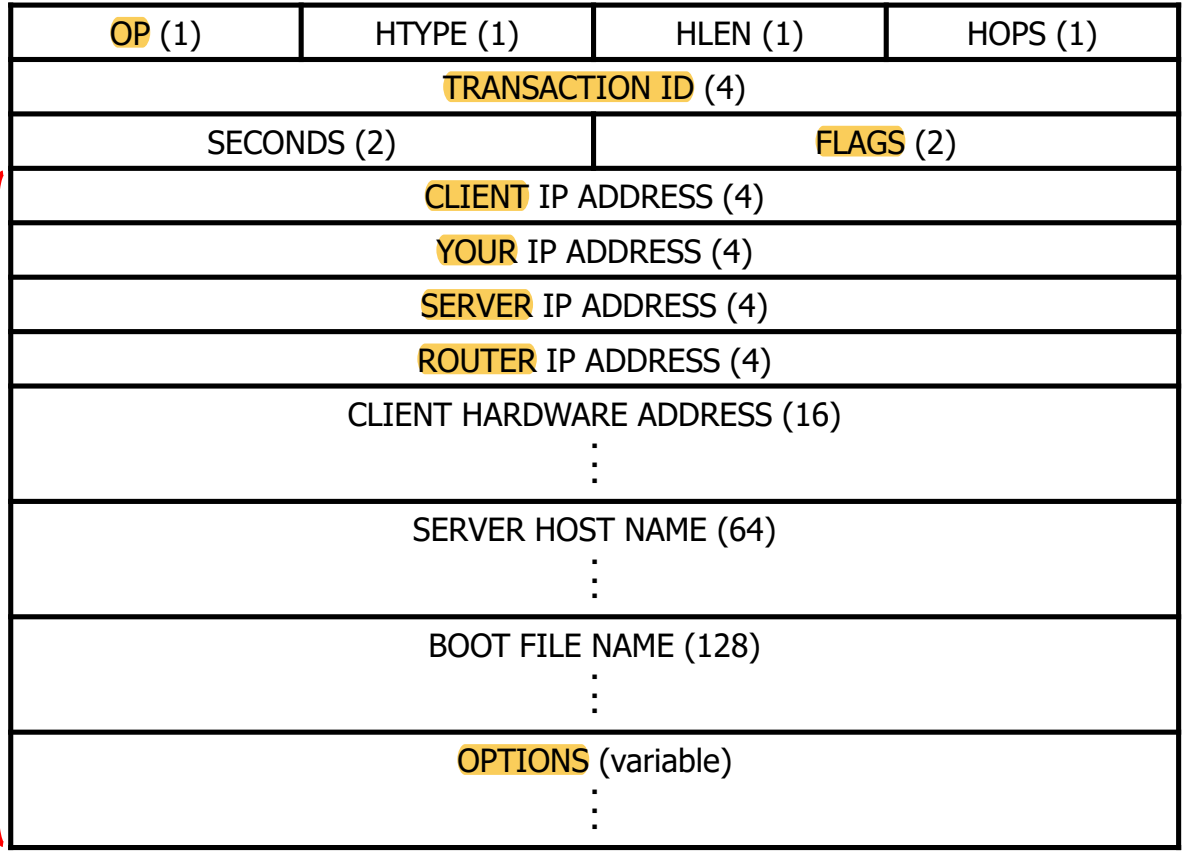
Related RFCs (3)

- Others
  - RFC2485, DHCP Option for The Open Group's User Authentication Protocol
  - RFC2563, DHCP Option to Disable Stateless Auto-Configuration in IPv4 Clients
  - RFC2610, DHCP Options for Service Location Protocol
  - RFC2937, The Name Service Search Option for DHCP
  - RFC3004, The User Class Option for DHCP
  - RFC3011, The IPv4 Subnet Selection Option for DHCP
  - RFC3046, DHCP Relay Agent Information Option
  - RFC3118, Authentication for DHCP Messages
  - RFC3203, DHCP reconfigure extension
  - RFC3319, Dynamic Host Configuration Protocol (DHCPv6) Options for Session Initiation Protocol (SIP) Servers
  - RFC3361, DHCP-for-IPv4 Option for Session Initiation Protocol (SIP) Servers
  - RFC3397, Dynamic Host Configuration Protocol (DHCP) Domain Search Option
  - RFC3736, Stateless DHCP Service for IPv6
  - RFC4030, The Authentication Suboption for the DHCP Relay Agent Option
  - RFC4477, DHCP: IPv4 and IPv6 Dual-Stack Issues
  - … …

DHCP Mes


• Hardware Address Type
• E.g. 1-Ethernet (10Mb)
• Hardware Address Length
• Client sets to zero
• optionally used by relay agents when booting via
ay agent
• seconds elapsed since client began
address acquisit
process
1 –
2 –
• Only filled in if client is in BOUND, RENEW or REBIND state
31
OPS (1)
SECONDS (2)
FLAGS (2)
CLIENT IP ADDRESS (ciaddr)(4) (known by client)
• Allows control of the request and response
• A client uses the leftmost bit to control whether the
serve
lcast
• The r
• Client IP address given by Server
0
15
B
Must Be Zero
Clients fill in as much as they know and leave remaining fields set to zero
• TLV encoding style
OPTIONS (variable)

DHCP Message Format



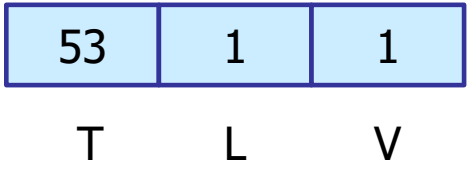
Clients fill in as much as they know and leave remaining fields set to zero

DHCP Message Format

- **OP: 1 – request, 2 – reply**
- **HTYPE: Hardware Address Type, Defined in the ARP section in the Assigned Numbers RFC, E.g. 1-Ethernet (10Mb)**
- **HLEN: Hardware Address Length, E.g. 6-Ethernet (10Mb)**
- **HOPS: Client sets to zero, optionally used by relay agents when booting via a relay agent**
- **TRANSACTION ID: an integer, Used by the client to match responses with requests**
- **SECONDS: seconds elapsed since client began address acquisition or renewal process**
- **FLAGS: Allows control of the request and response. A client uses the leftmost bit to control weather the server sends the response via unicast or broadcast. The remaining bits are reserved for future use**
- **CLIENT IP ADDRESS: Only filled in if client is in BOUND, RENEW or REBIND state**
- **YOUR IP ADDRESS: Client IP address**
- **OPTIONS: TLV encoding style**

Message type option

- TLV encoding
- Type=53 (type of the DHCP message)
- Length=1
- Value
  - 1: DHCPDISCOVER
  - 2: DHCPOFFER
  - 3: DHCPREQUEST
  - 4: DHCPDECLINE
  - 5: DHCPACK
  - 6: DHCPNAK
  - 7: DHCPRELEASE
  - 8: DHCPINFORM



DHCP Messages (1)

- **DHCPDISCOVER** - Client broadcast to locate available servers.
- **DHCPOFFER** - Server to client in response to DHCPDISCOVER with offer of configuration parameters.
- **DHCPREQUEST** - Client message to servers either
  - (a) requesting offered parameters from one server and implicitly declining offers from all others,
  - (b) confirming correctness of previously allocated address after, e.g., system reboot
  - (c) extending the lease on a particular network address.
- **DHCPACK** - Server to client with configuration parameters, including committed network address.

DHCP Messages (2)

- **DHCPNAK** - Server to client indicating client's notion of network address is incorrect (e.g., client has moved to new subnet) or client's lease as expired.
- **DHCPDECLINE** - Client to server indicating network address is already in use.
- **DHCPRELEASE** - Client to server relinquishing network address and cancelling remaining lease.
- **DHCPINFORM** - Client to server, asking only for local configuration parameters; client already has externally configured network address. For example, it can be used to obtain tunnel endpoint address.

Major Operations in DHCP

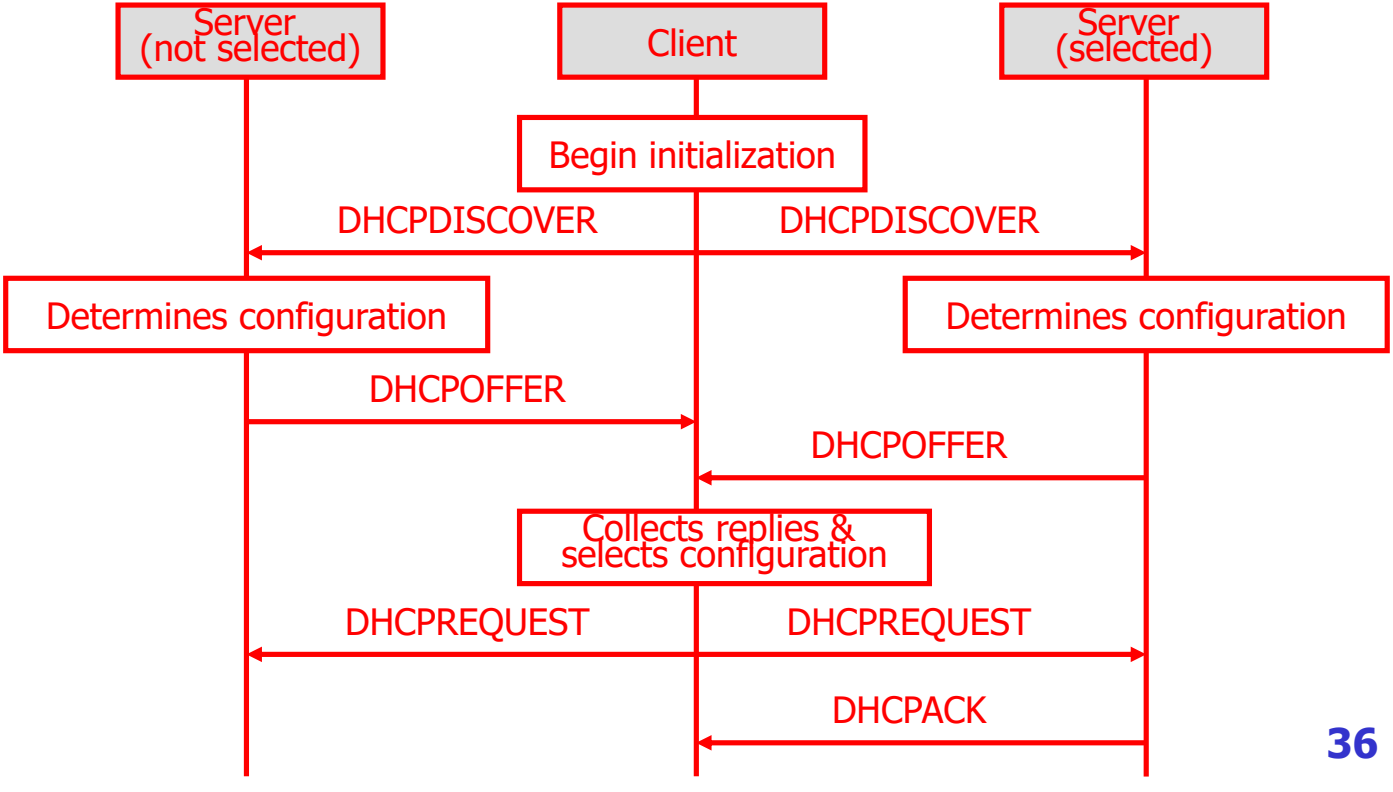
- Address acquisition
  - Getting an IP address
- Early lease termination
  - Returning IP address before lease expires
- Lease renewal
  - Updating a lease

Address Acquisition: phases

- ***IP lease request***
  - To boot up, the client sends a DHCPDISCOVER broadcast message, requesting the location of a DHCP server with IP address information
  - The DHCPDISCOVER packet is encapsulated in a UDP/IP packet and is sent to the local subnet broadcast address of 255.255.255.255
- ***IP lease offer***
  - After requesting a lease, the DHCP client waits for a response and is said to be in a SELECT state
  - Any available DHCP servers with IP addresses to offer respond to the client request with a DHCPOFFER message
- ***IP lease selection***
  - The client chooses one DHCPOFFER from all the offers it receives, regardless of which subnet the DHCP server is located in
  - The client then sends a broadcast DHCPREQUEST message, requesting a lease
- ***IP lease acknowledgment***
  - The DHCP server that made the offer responds to the client with a DHCPACK message while any other DHCP servers that made an offer withdraw
  - The IP address is assigned to the client

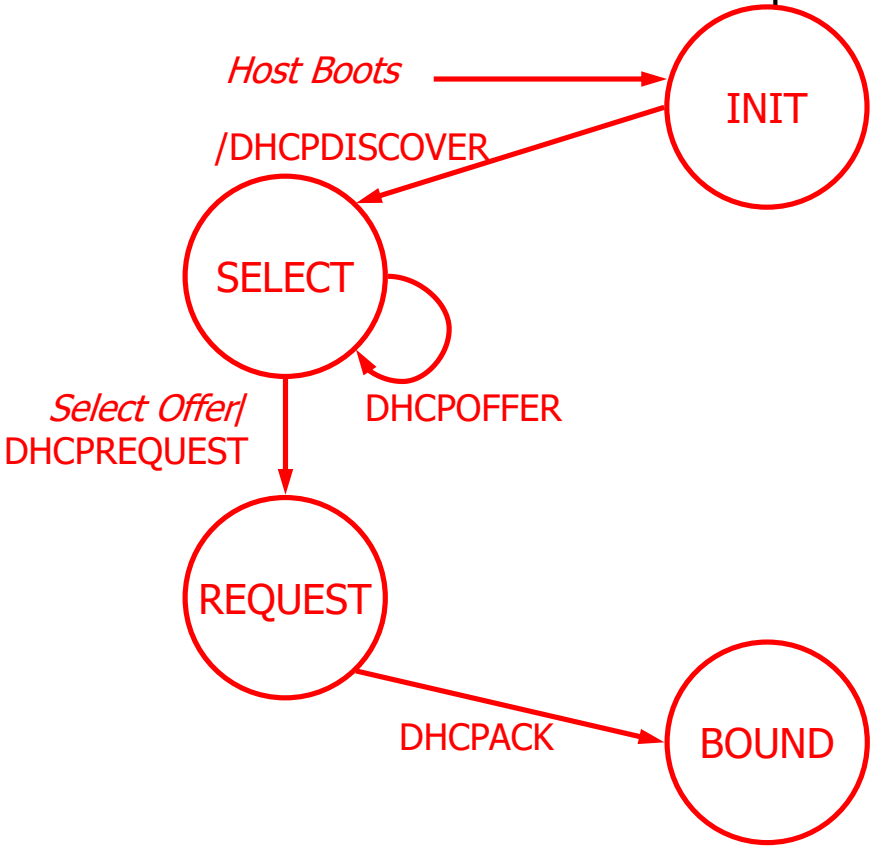
Address Acquisition (2)

- MSC for Address Acquisition



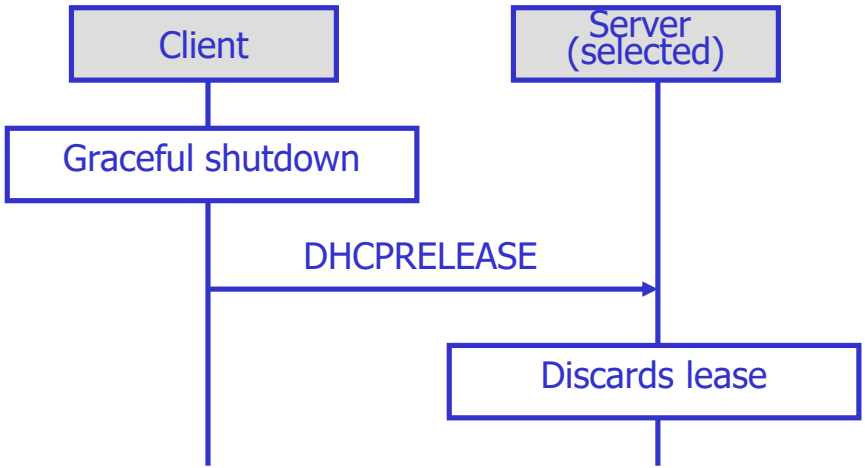
Address Acquisition (3)

- STD of client for Address Acquisition



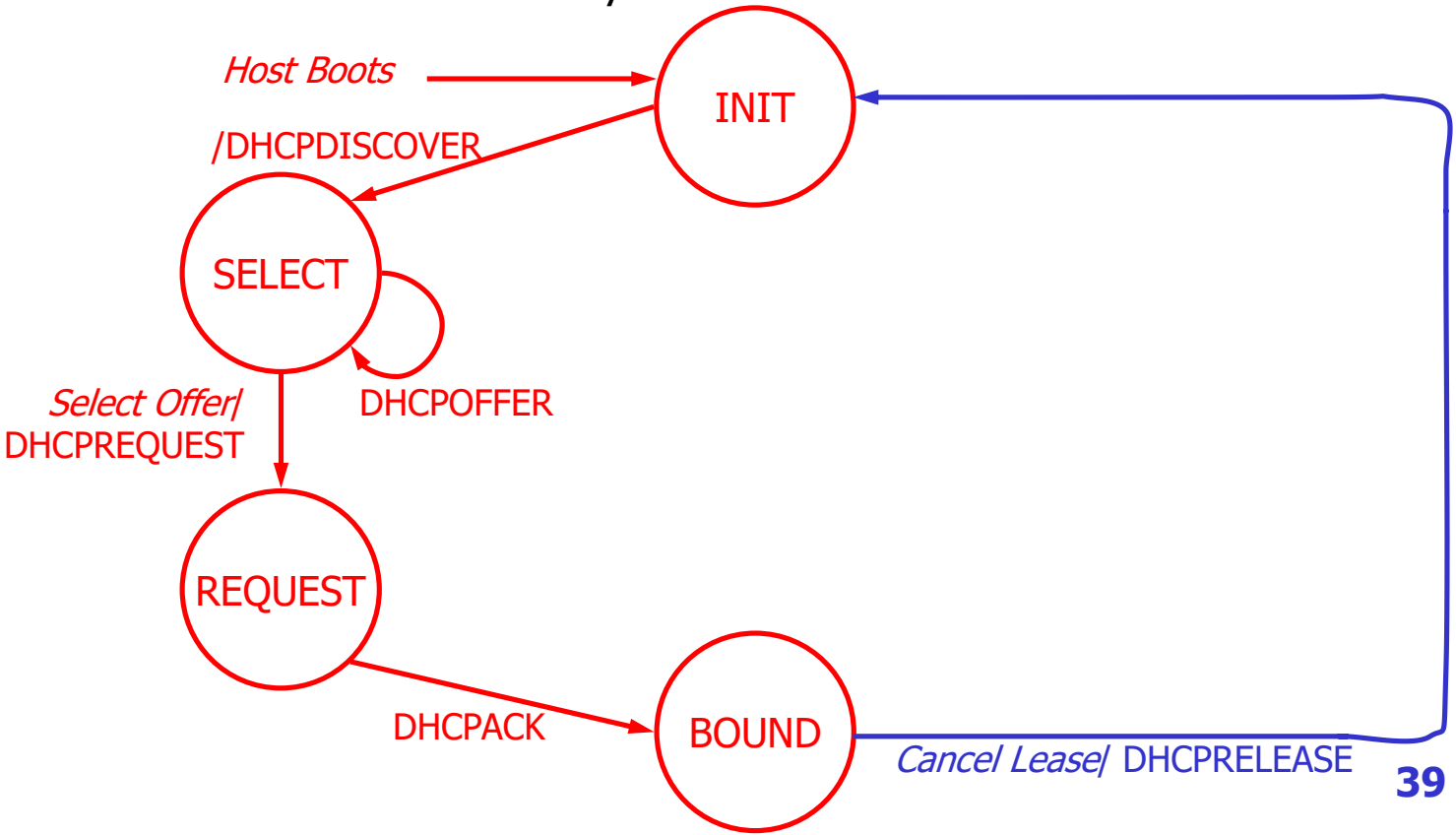
Early Lease Termination (1)

- MSC for Early Lease Termination



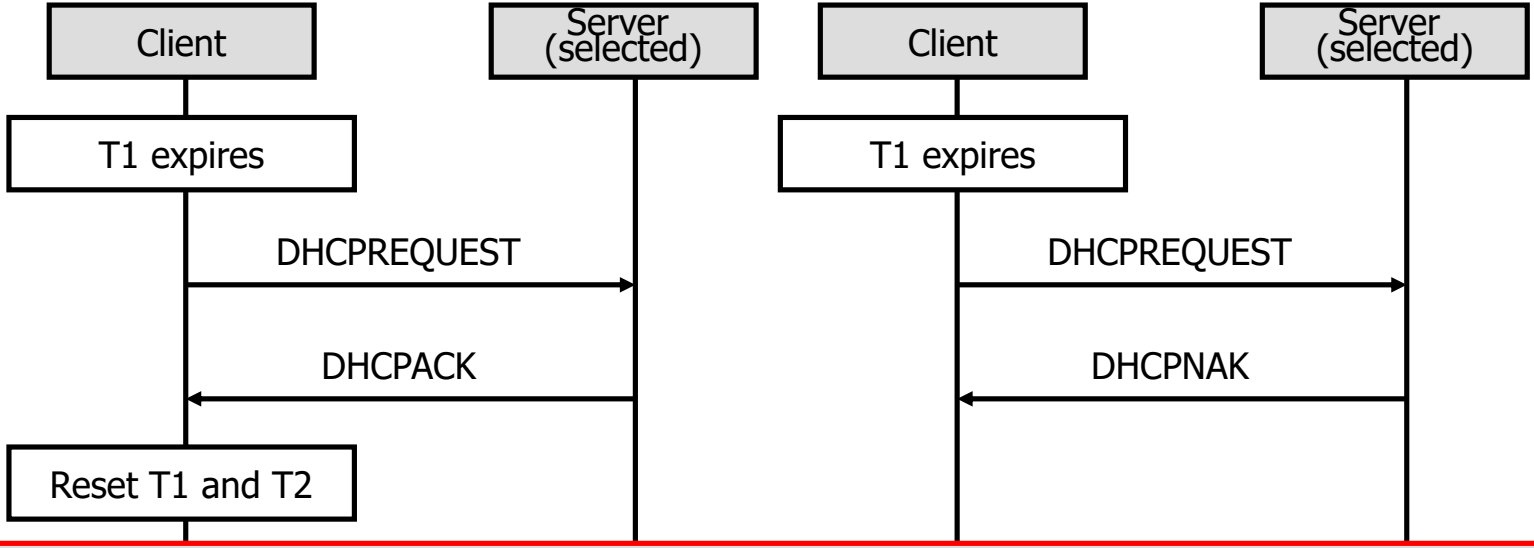
Early Lease Termination (2)

- STD of client for Early Lease Termination



Lease Renewal (1)

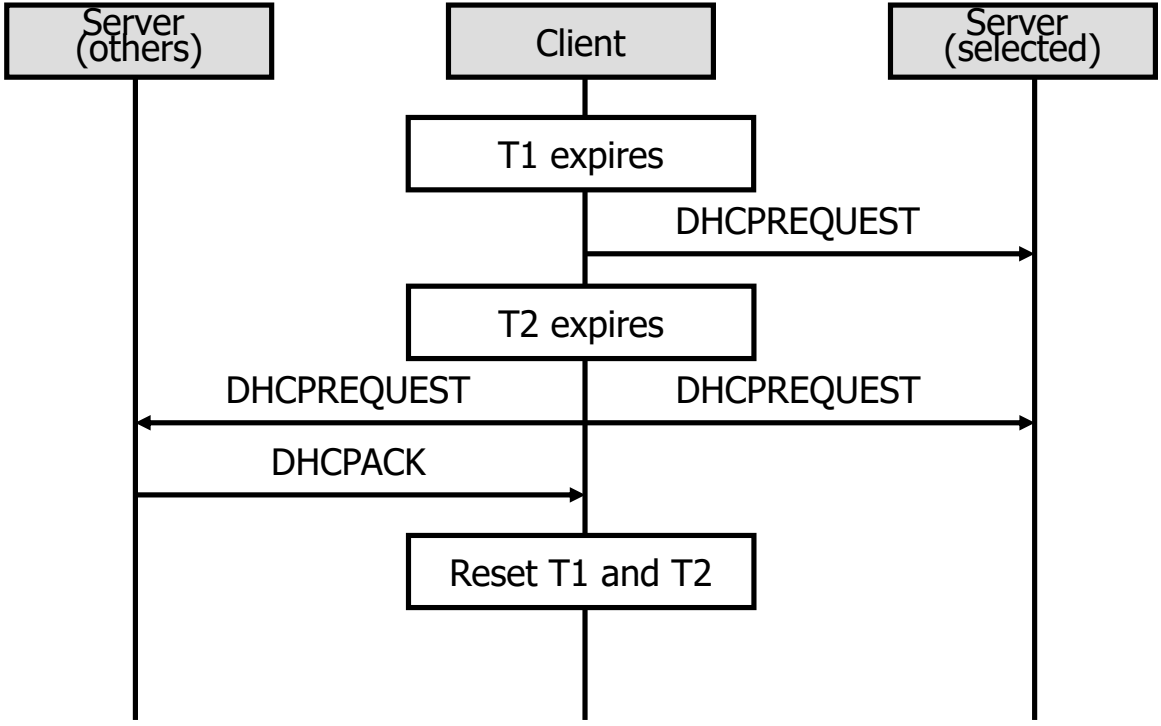
- MSCs for lease renewal



- **T1**: the time at which the client enters the RENEW state and attempts to contact the server that originally issued the client's network address
  - *0.5 * duration_of_lease*
- **T2**: the time at which the client enters the REBIND state and attempts to contact any server.
  - *0.875 * duration_of_lease*

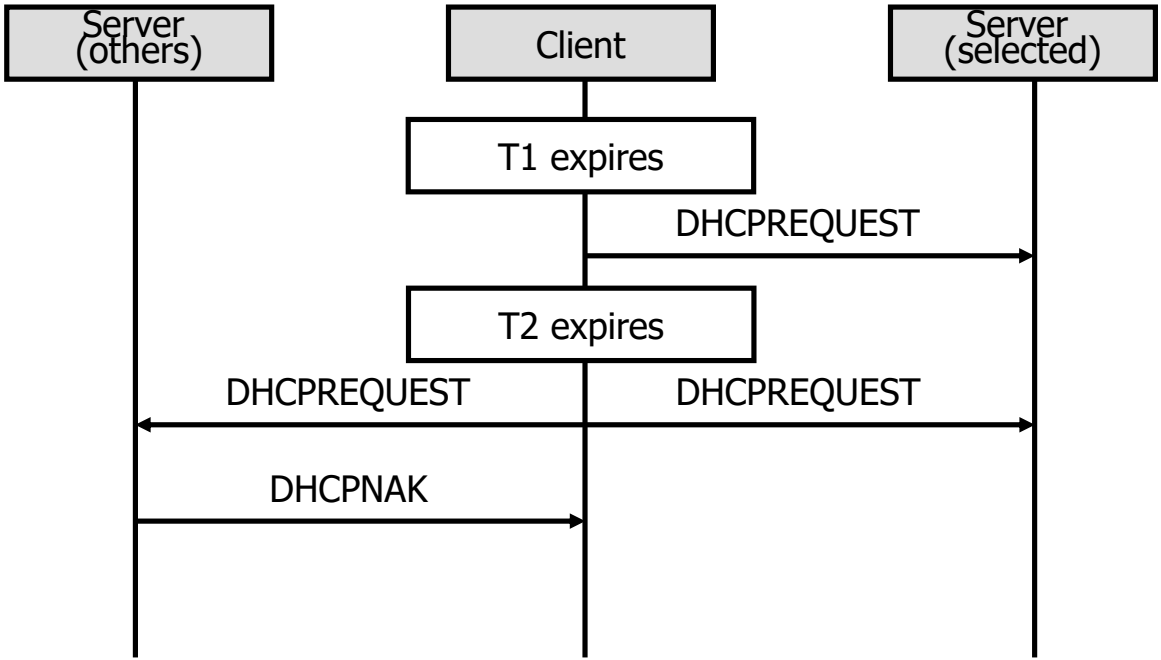
Lease Renewal (2)

- MSCs for lease renewal



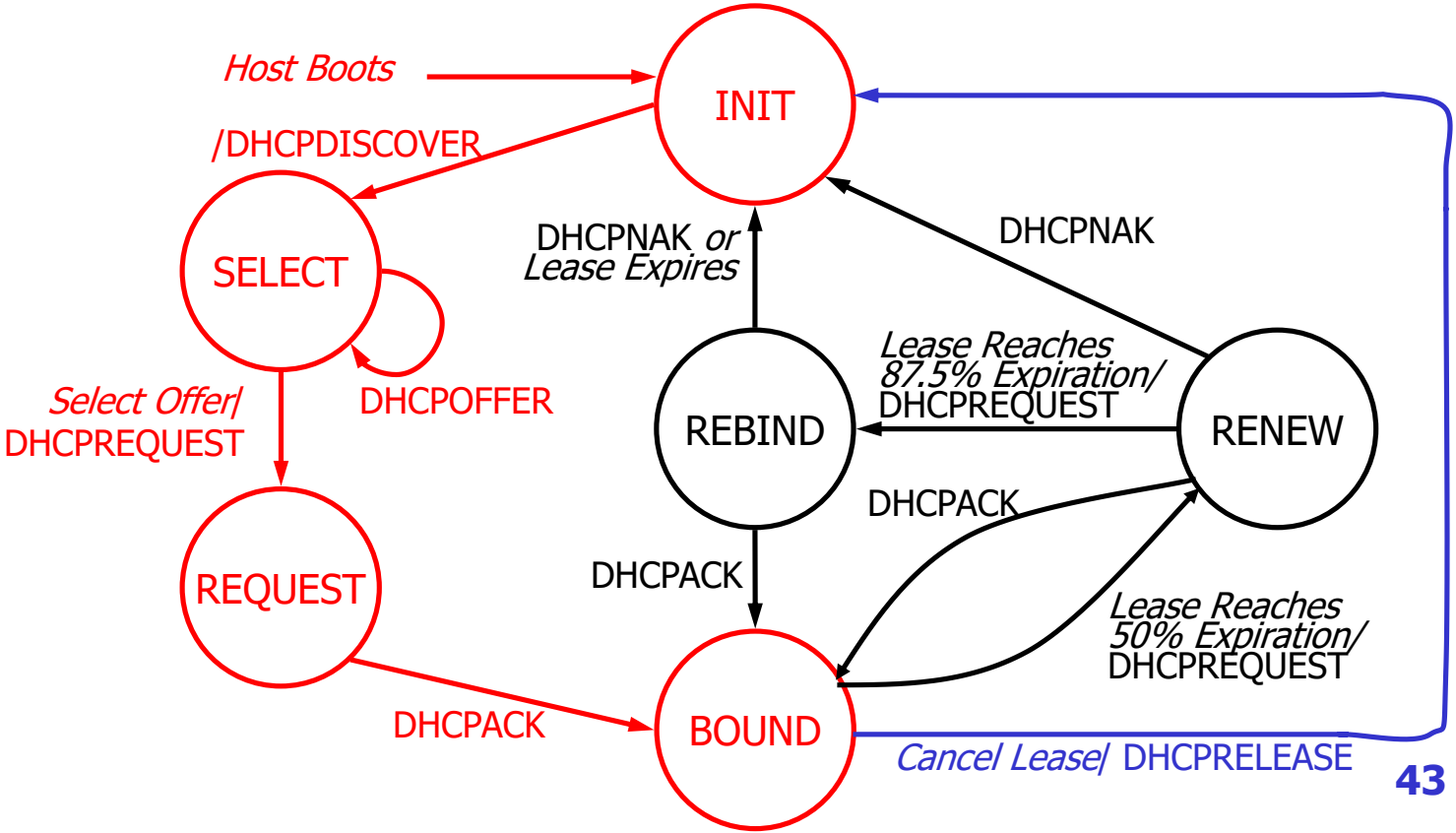
Lease Renewal (3)

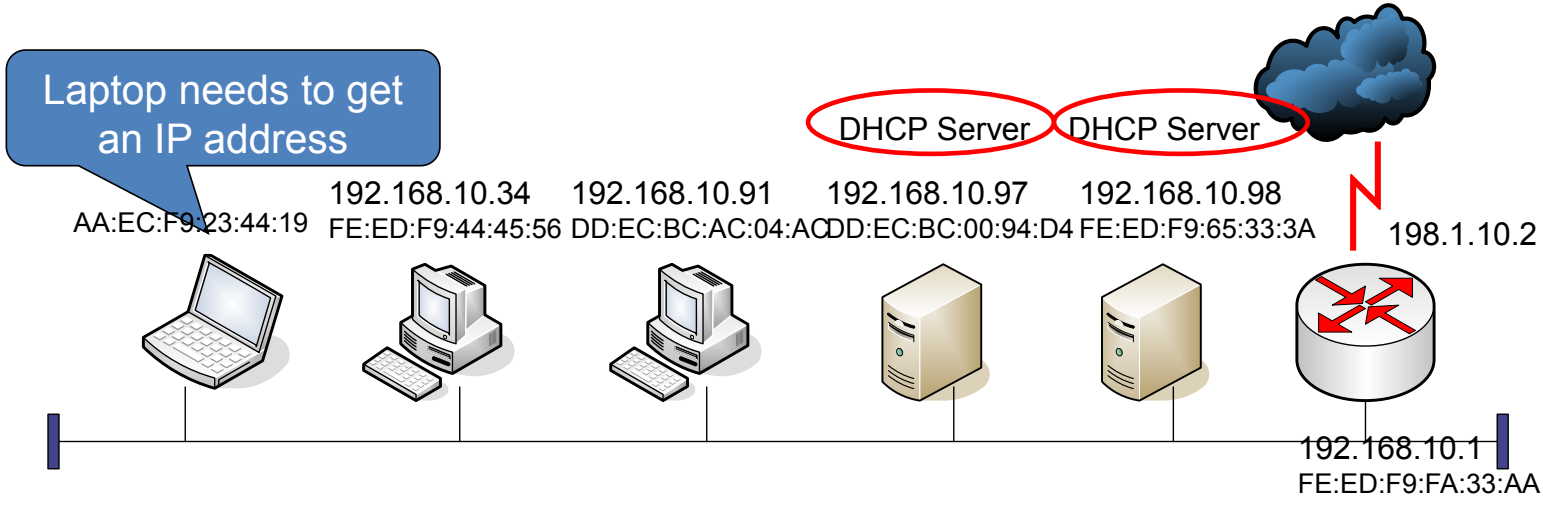
- MSCs for lease renewal

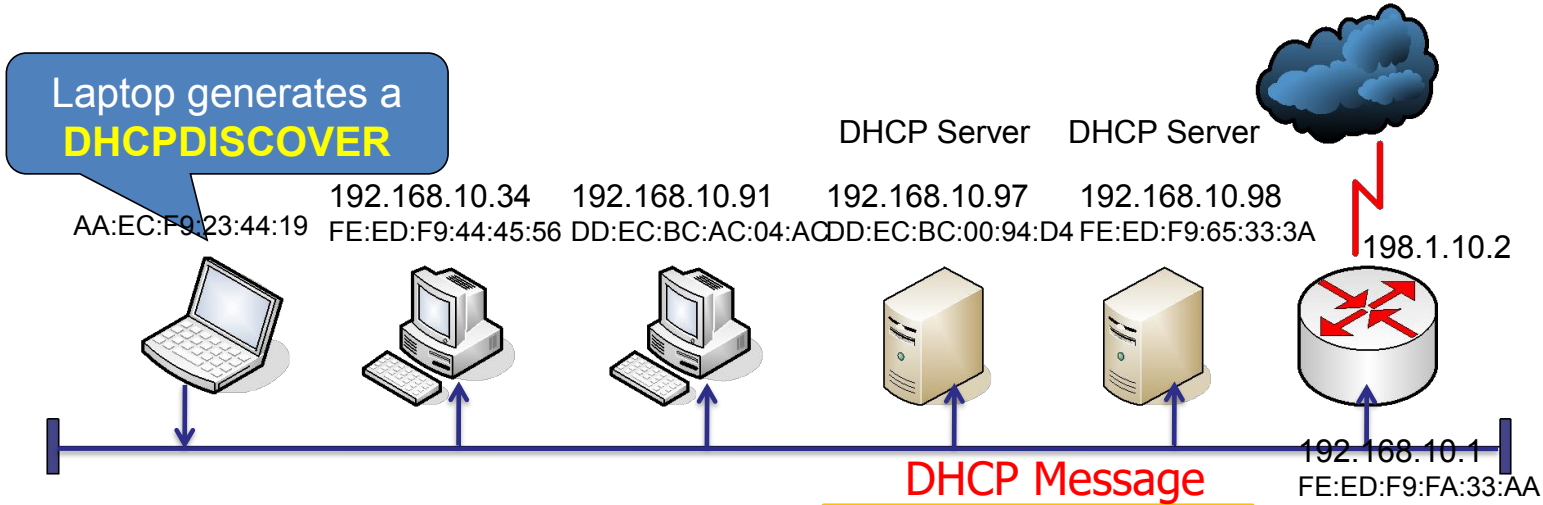


Lease Renewal (4)

- STD of client for lease renewal




Laptop needs to get an IP address
DHCP Server
DHCP Server
AA:EC:F9:23:44:19
192.168.10.34
FE:ED:F9:44:45:56
192.168.10.91
DD:EC:BC:AC:04:AC
192.168.10.97
DD:EC:BC:00:94:D4
192.168.10.98
FE:ED:F9:65:33:3A
198.1.10.2
192.168.10.1
FE:ED:F9:FA:33:AA

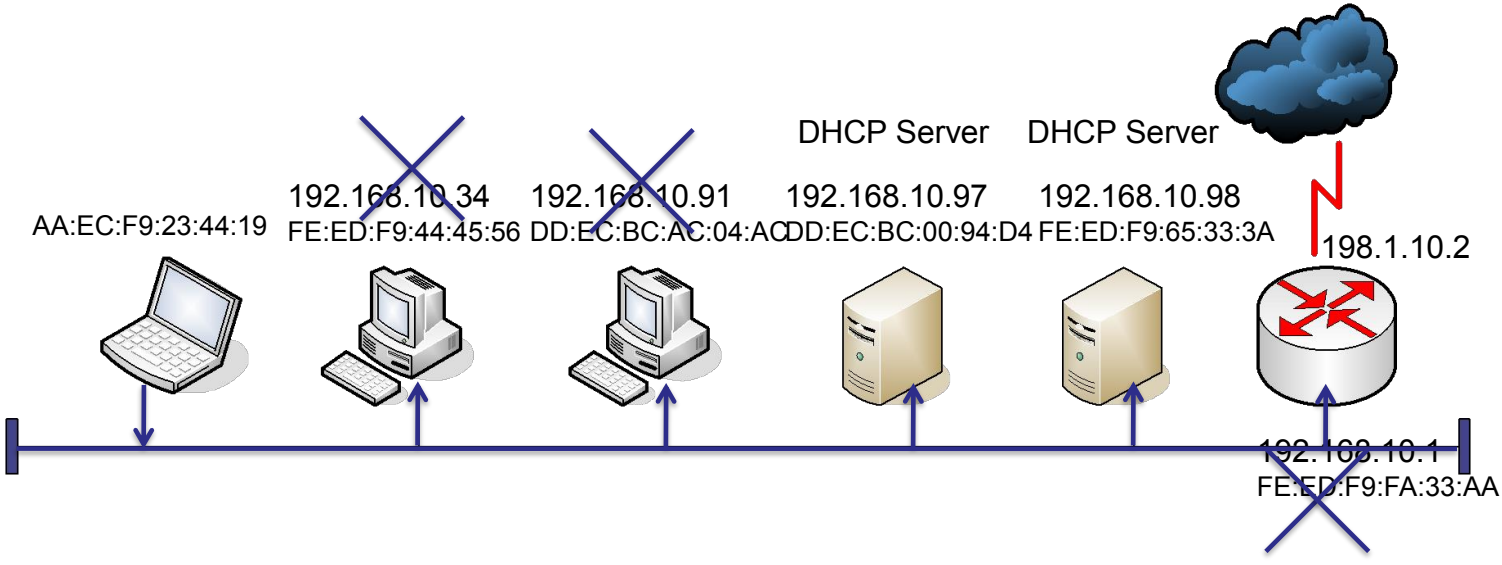


Frame header	Packet header
Source MAC	Source IP
AA:EC:F9:23:44:19	0.0.0.0
Destination MAC	Destination IP
FF:FF:FF:FF:FF:FF	255.255.255.255
Field Type	
0X8035(Ethernet)	

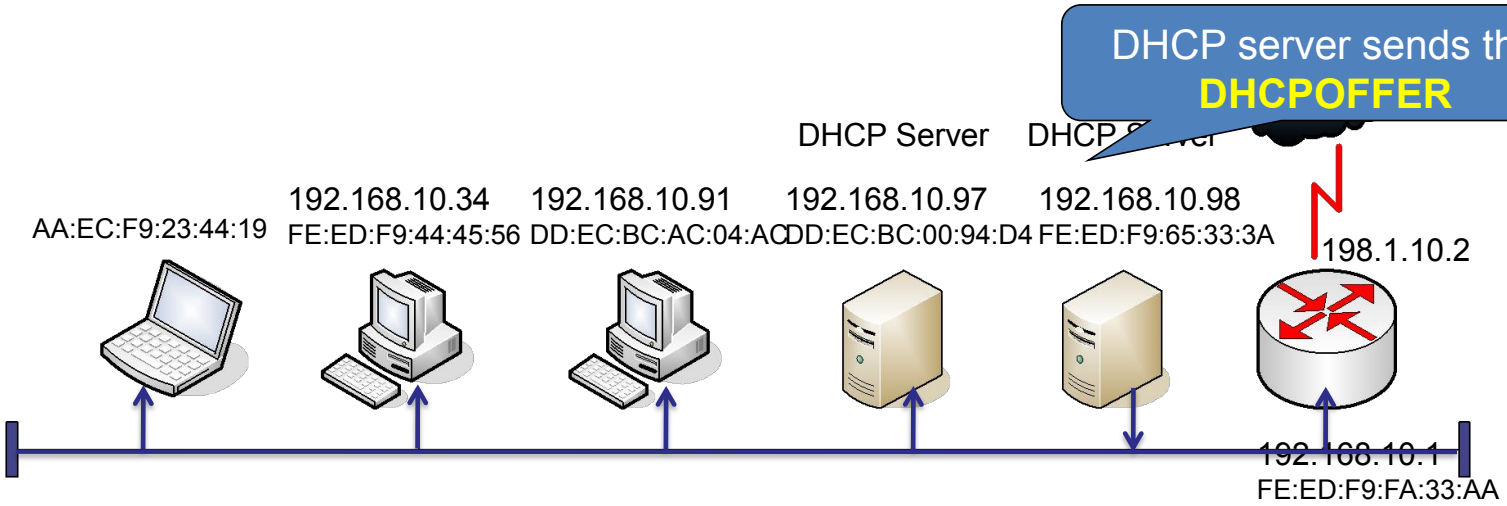
DHCP Message

1	1	6	0
12			
0		Flags	
0			
0			
0			
0			
AA:EC:F9:23:44:19			
53	1	1	

CRC Check



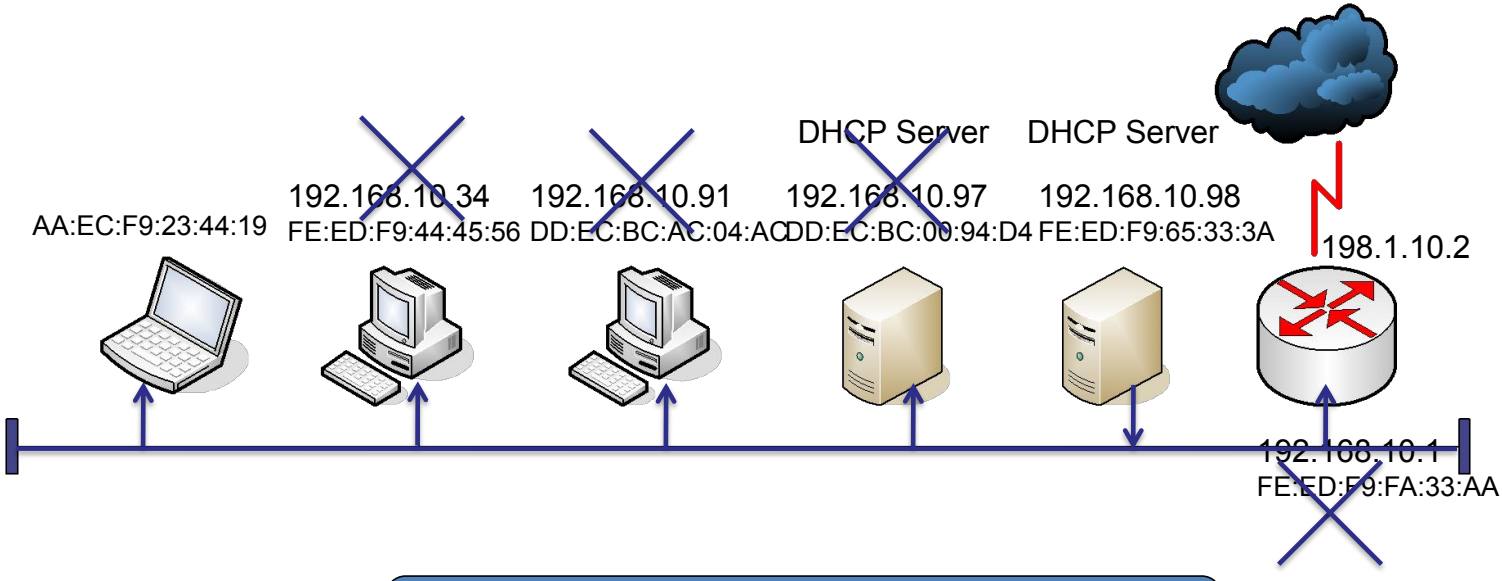
All devices except the DHCP servers discard the request



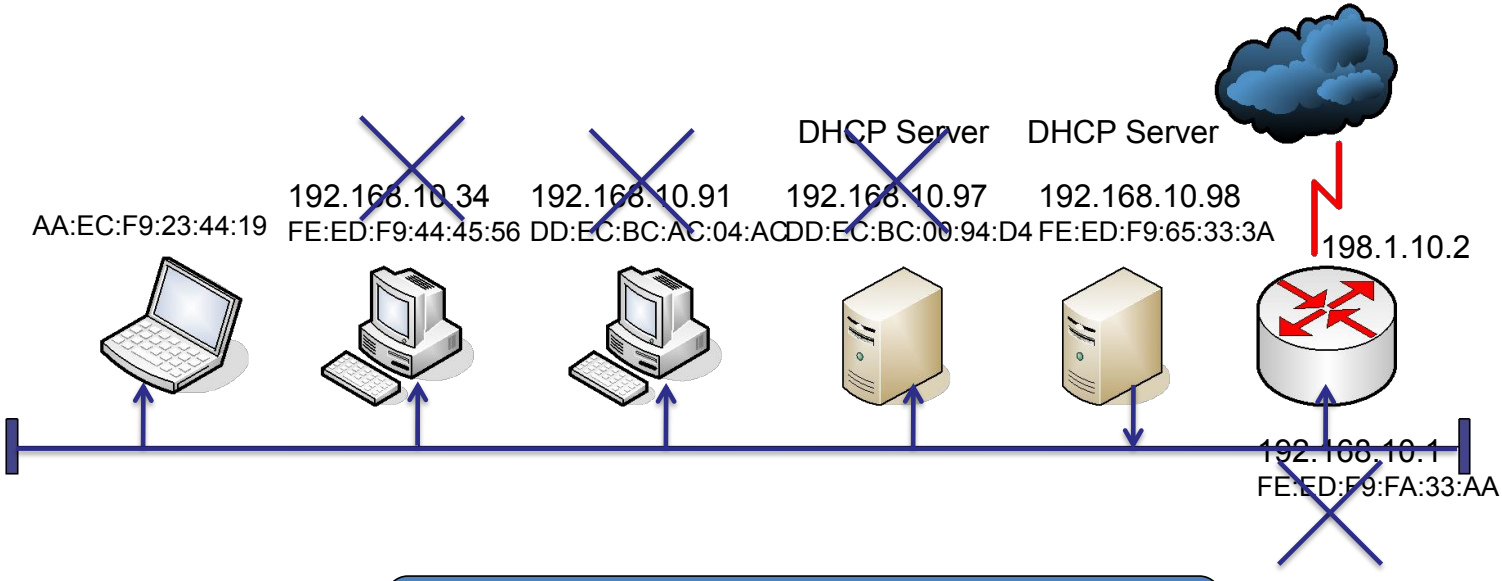
Frame header	Packet header
Source MAC	Source IP
FE:ED:F9:65:33:3A	192.168.10.98
Destination MAC	Destination IP
FF:FF:FF:FF:FF:FF	255.255.255.255
Field Type	
0X8035(Ethernet)	

2	1	6	0
12			
0		Flags	
0			
192.168.10.35			
192.168.10.98			
0			
AA:EC:F9:23:44:19			
53	1	2	

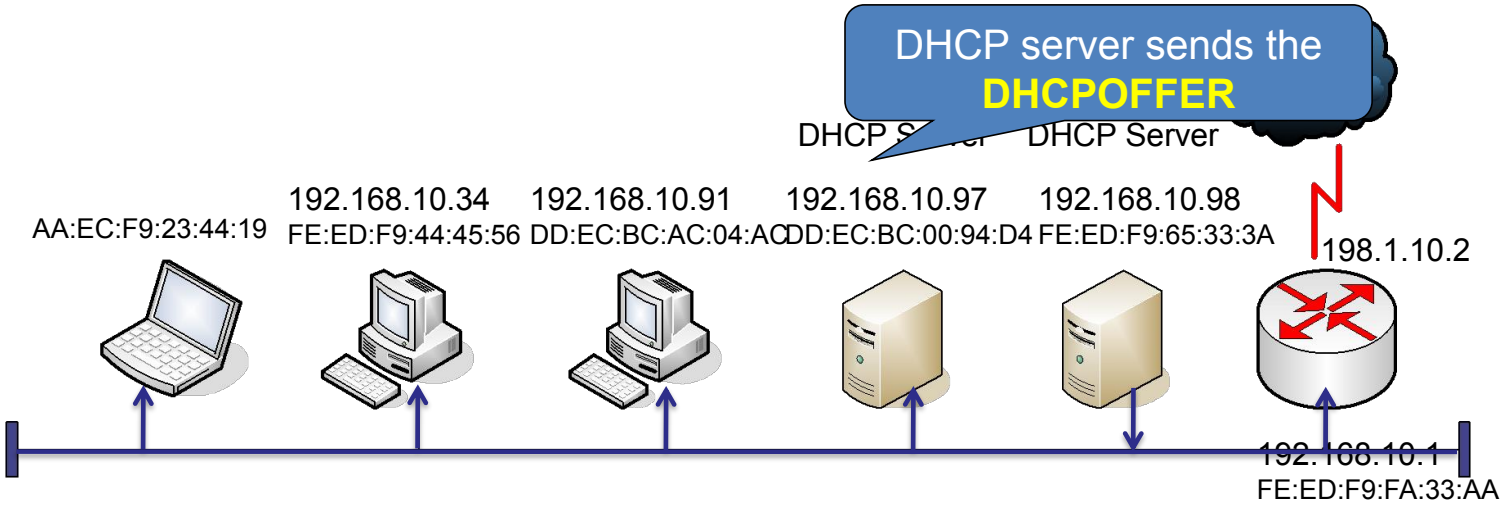
CRC Check



All devices except for the laptop discard the reply



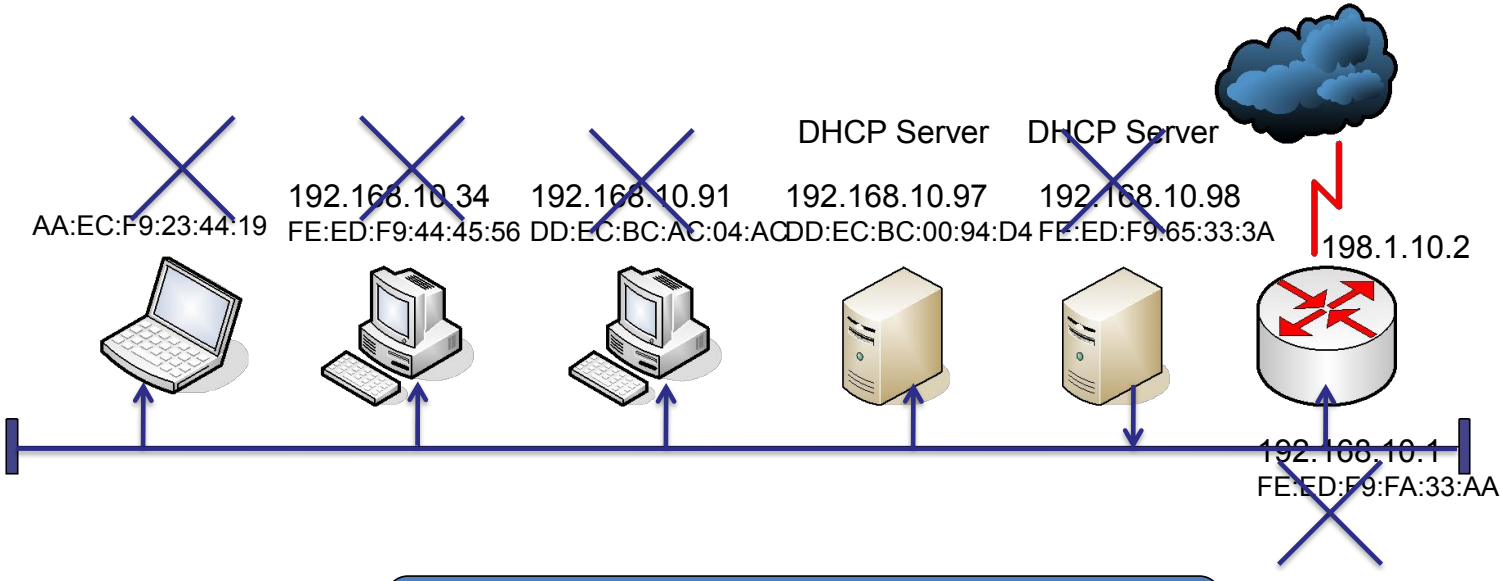
Source IP and MAC address of the DHCP server are stored in the ARP table



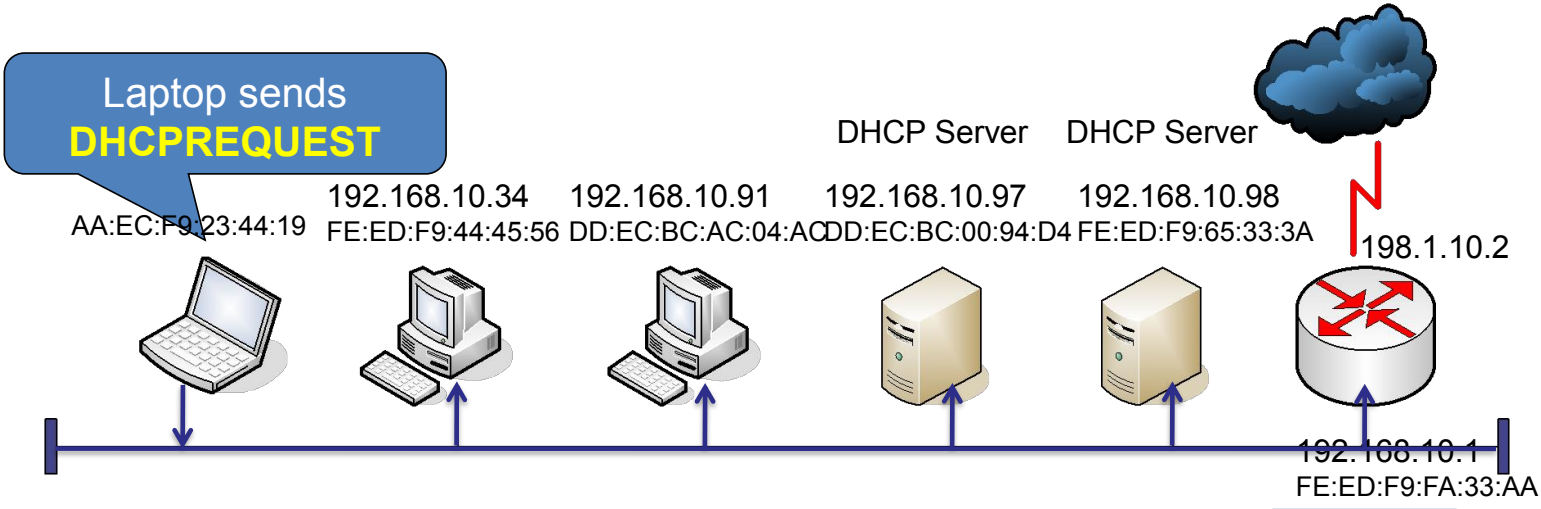
Frame header	Packet header
Source MAC	Source IP
DD:EC:BC:00:94:D4	192.168.10.97
Destination MAC	Destination IP
FF:FF:FF:FF:FF:FF	255.255.255.255
Field Type	
0X8035(Ethernet)	

2	1	6	0
12			
0		Flags	
0			
192.168.10.90			
192.168.10.97			
0			
AA:EC:F9:23:44:19			
53	1	2	

CRC Check



Laptop has already received DHCPOFFER, discard the frame

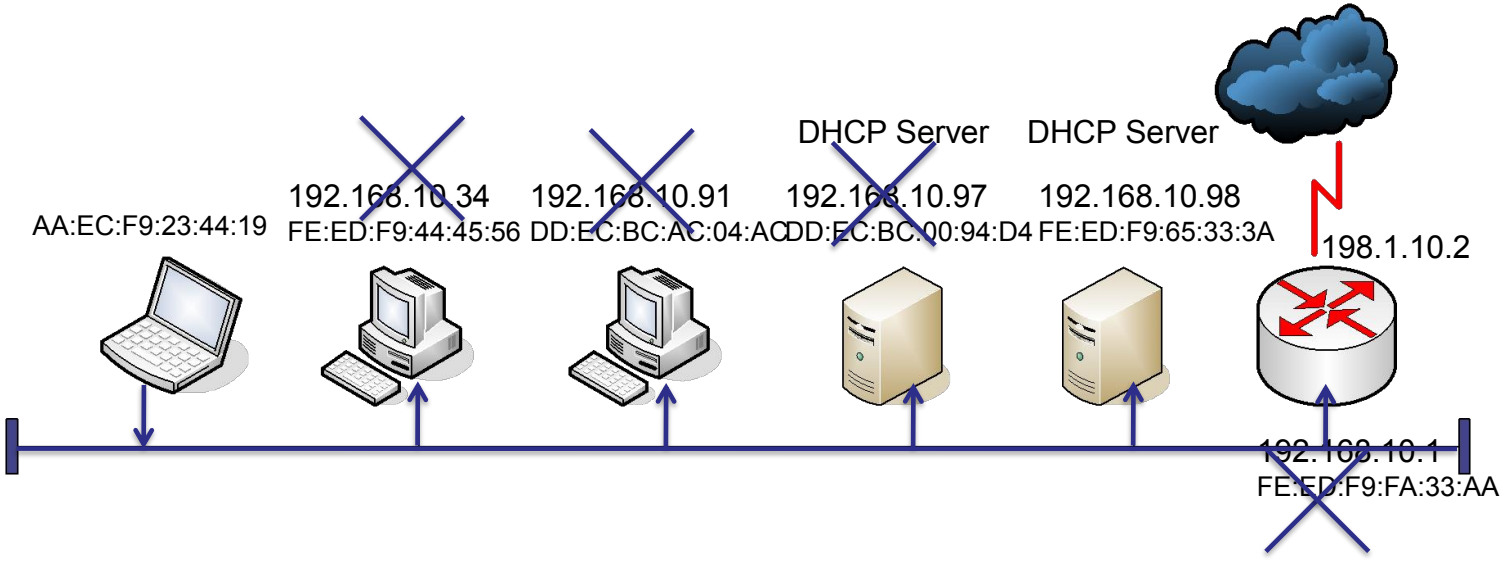


Frame header	Packet header
Source MAC	Source IP
AA:EC:F9:23:44:19	0.0.0.0
Destination MAC	Destination IP
FF:FF:FF:FF:FF:FF	255.255.255.255
Field Type	
0X8035(Ethernet)	

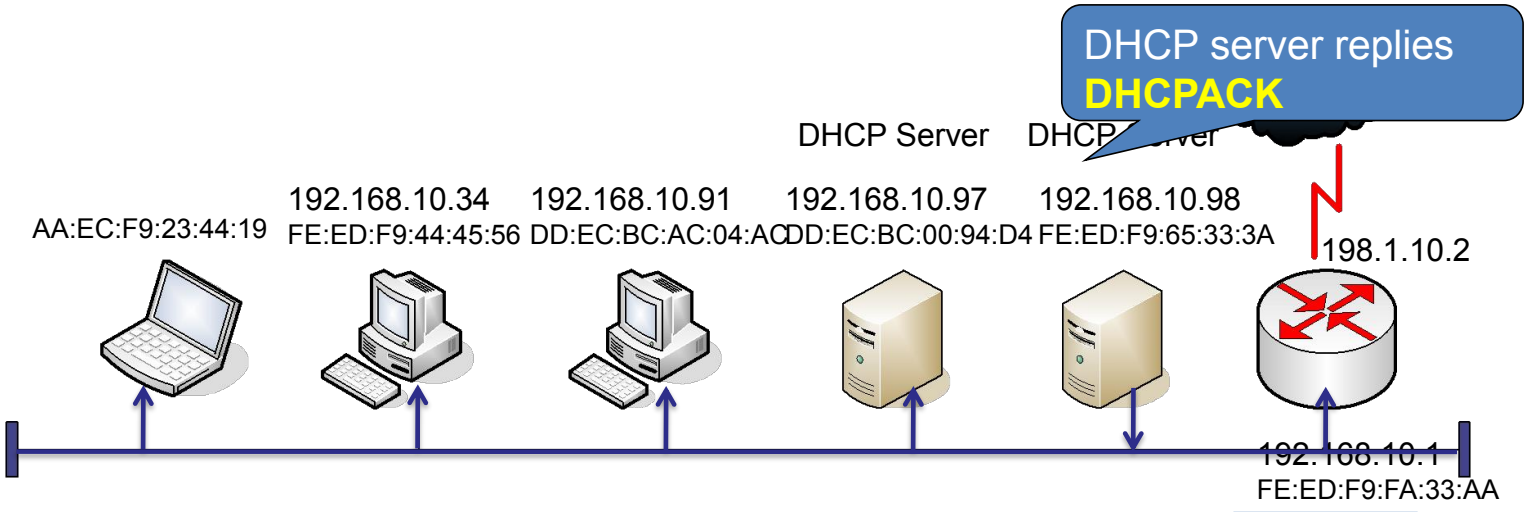
1	1	6	0
12			
0		Flags	
0			
0			
0			
0			
AA:EC:F9:23:44:19			
53	1	3	

CRC Check

client IP to use and server IP are stored in options



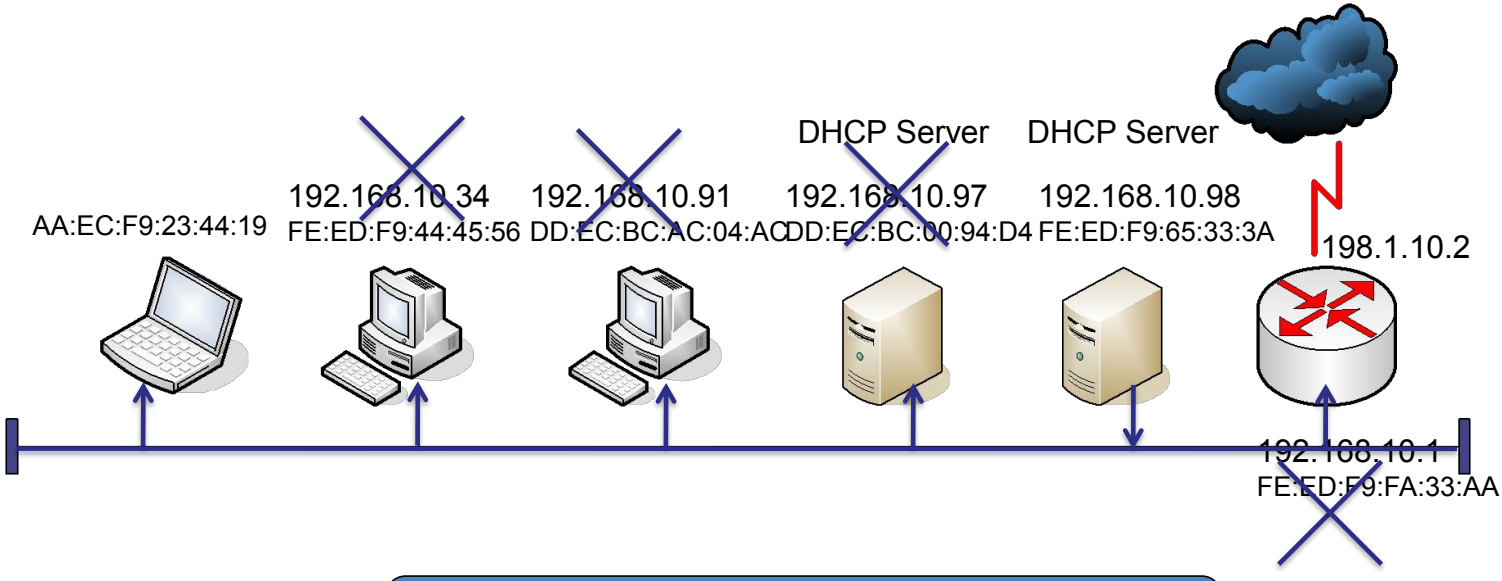
All devices discard the frame except the DHCP server that sends DHCPOFFER first



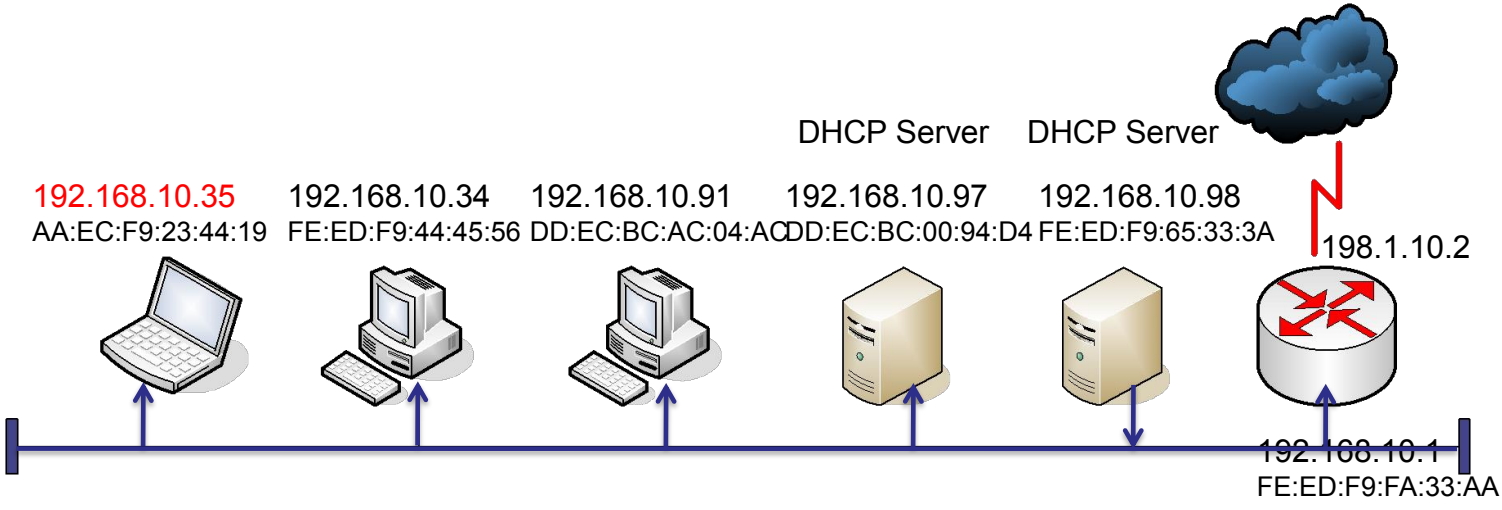
Frame header	Packet header
Source MAC	Source IP
FE:ED:F9:65:33:3A	192.168.10.98
Destination MAC	Destination IP
FF:FF:FF:FF:FF:FF	255.255.255.255
Field Type	
0X8035(Ethernet)	

2	1	6	0
12			
0		Flags	
0			
192.168.10.35			
192.168.10.98			
0			
AA:EC:F9:23:44:19			
53	1	5	

CRC Check



All devices except for the laptop discard the reply



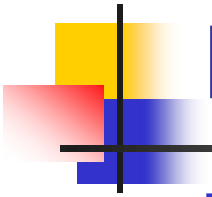
The laptop has the IP address.

Multicast address allocation

- MADCAP(RFC2730)
  - Multicast Address Dynamic Client Allocation Protocol
- Used for conferencing and audio
- The multicast address allocation features
  - A MADCAP server, which distributes multicast addresses
  - MADCAP clients can use client-side APIs to request, renew or release multicast address

DHCP client alternate configuration

- Static IP address configuration
- Dynamic IP address configuration without alternate configuration
- Dynamic IP address configuration with alternate configuration
  - User can move the computer between one statically configured network (Such as home network) and one or more dynamically configured networks without changing any settings.



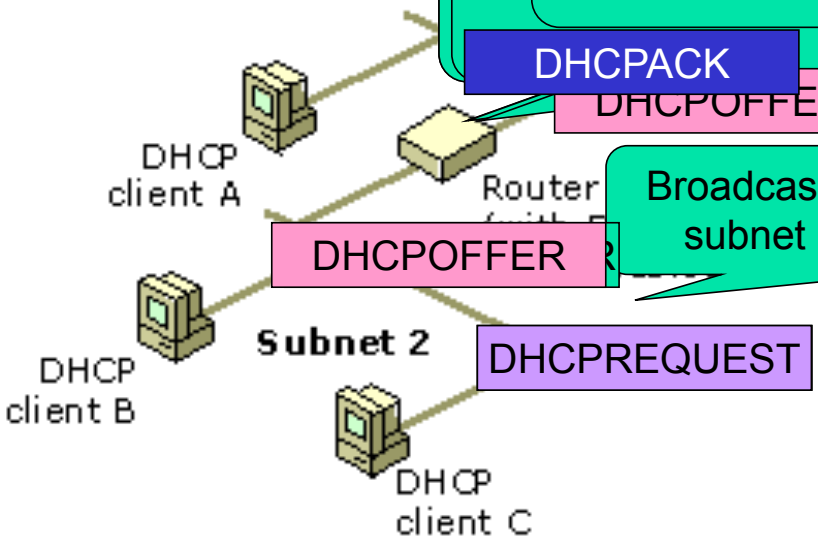
DHCP Relay

- Used to interconnect hardware and software on different physical network segments called subnets and forward IP packets between each of the subnets.
- Router must comply with DHCP/BOOTP relay agent capabilities.
- A computer that can function as a relay agent if router cannot function as a relay agent.

DHCP server processes and sends an DHCPOFFER directly to the **relay agent** identified in the **GIADDR** field

A DHCPREQUEST message is relayed from client to server

A DHCPACK message is relayed from server to client



Security Problems

- Built on UDP and IP
  - Inherently insecure
- DHCP is an unauthenticated protocol
- Denial-of-service attacks against the DNS server can be made through the DHCP server
- Unauthorized, non-Microsoft DHCP servers can lease IP addresses to DHCP clients

Recommendations

- Ensure that unauthorized persons do not have physical or wireless access to your network.
- Enable audit logging for every DHCP server on your network. Regularly check audit log files, and monitor them when the DHCP server receives an unusually high number of lease requests from clients.
- Use the DHCP audit logs to monitor DNS dynamic updates by the DHCP server.

Examples of DHCP Configuration

Examples of DHCP Configuration (1)

- Installation and configuration of DHCP server in Windows Server 2012
  - https://blog.csdn.net/weixin_42596182/article/details/100184129
- Installation and configuration of DHCP server in UNIX/LINUX
  - DHCP server configuration file: **`/etc/dhcp/dhcpd.conf`**
  - DHCP Lease information file: **`/var/lib/dhcp/dhcpd.leases`**
  - https://help.ubuntu.com/community/isc-dhcp-server
  - http://www.linuxidc.com/Linux/2014-05/101579.htm
  - http://www.linuxdiyf.com/linux/23299.html

Examples of DHCP Configuration (2)

- Configuration of DHCP server in a router (NU-MH300)

Summary of DHCP

- DHCP vs. Bootp
- DHCP Server, DHCP Client
- DHCP Lease
- Phases of IP assignment
- DHCP operations
  - Address acquisition(MSC)
  - Early lease termination
  - Lease renewal
- DHCP Relay