AIN SHAMS UNIVERSITY (FACULTY OF ENGINEERING)

I-CHEP

CESS (2024-2025)

DHCP Project Proposal

CSE351: COMPUTER NETWORKS

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1 Introduction

1.1 Overview

Fundamentally, DHCP is a network management protocol that gives devices connected to a network dynamic IP addresses and other crucial network configuration information. Network administrators manually give IP addresses to every device in a standard static IP addressing arrangement, which can be an exhaustive and error-prone procedure. This procedure is automated via DHCP, increasing its scalability and efficiency.

For this project, we will simulate a Simple DHCP server using Python. The DHCP server will be responsible for assigning network configurations to clients in a network. It will be responsible for:

- **IP address assignment**: When a new client enters the network, it requests the configuration. The DHCP server then provides it with a proposal, which includes a possible IP address and other network parameters (discussed in the next point).

- **Configuration parameter assignment**: Apart from the IP address allocation, the DHCP offers more parameters to the client such as subnet mask, default gateway, and DNS server addresses. This simplifies network setup for clients as they automatically receive all the necessary communication information.

- **Dynamic lease management**: A DHCP server periodically rotates the IP addresses assigned in the network. It does not give out permanent IP addresses to devices for multiple reasons (e.g., a device may be connected to the network only for a short time, a device may be inactive for long periods, etc.). This ensures non-exhaustion of resources (IP address pool).

- **Automatic IP configuration**: The DHCP server is designed to work with minimal to no manual intervention, making it indispensable in a large/complex environment.

In our efforts to produce an RFC-compliant server that follows the two RFCs:

- **RFC 2131**: Dynamic Host Configuration Protocol (DHCP) defines DHCP, as a protocol used to automate the assignment of IP addresses, subnet masks, gateways, and other network parameters. It allows devices on a network to request configuration information from a DHCP server dynamically.

- **RFC 2132**: DHCP Options and BOOTP Vendor Extensions. This RFC details additional options that can be used with DHCP, extending the base protocol to support various configuration parameters such as subnet masks, routers, and domain names.

We will include other network parameters assigned beyond just the IP address in our code.

2 Functionalities

This section provides a detailed recap of the core functionalities of the DHCP server being developed:

2.1 IP Address Management

- **Dynamic IP Address Assignment:** The DHCP server dynamically assigns IP addresses from a predefined pool to clients upon request. This ensures efficient utilization of available addresses while accommodating the dynamic nature of network devices.
- **Prevention of Duplication:** The server maintains an internal database to track leased IPs. This prevents the allocation of the same IP address to multiple clients, avoiding conflicts and ensuring network stability.
- **IP Address Recycling:** Addresses are returned to the pool when leases expire or are released by clients, making them available for reuse.

2.2 Lease Management

- **Time-Limited Leases:** Each IP address is issued with a lease, a time period during which the client can use the address. The lease duration is configurable based on network policies.
- **Lease Renewal and Release:** Clients can request lease renewals before expiration to retain their IP addresses. If no renewal is requested, the lease expires, and the IP is returned to the pool. Clients can also release leases manually when they no longer need the address.
- **Expiration Handling:** The server continuously monitors leases and triggers cleanup mechanisms for expired leases to optimize resource allocation.

2.3 Automatic Provisioning of Network Configuration

- **Additional Configuration Parameters:** The DHCP server provides not only IP addresses but also additional configuration data that clients need to operate effectively in a network. These include:
  - *Subnet Mask:* Defines the network's address range and determines which portion of an IP address corresponds to the network.

- *Default Gateway:* Specifies the router that acts as an access point to other networks.
- *DNS Server Addresses:* Directs clients to the servers that translate domain names into IP addresses.

- **Plug-and-Play Configuration:** Clients automatically receive all necessary configuration parameters upon connection, eliminating the need for manual setup.

2.4 Error Handling

- **Response to Invalid Requests:** The server validates incoming DHCP requests. If a request is malformed or violates protocol rules, the server responds with appropriate error codes to notify the client.
- **Fail-Safe Mechanisms:** The server includes mechanisms to handle scenarios like IP exhaustion (when no free IPs are available) or address conflicts. For instance:
  - *IP Exhaustion:* The server sends an error response (‘DHCPNAK‘) and logs the incident for administrative action.
  - *Conflict Resolution:* If a conflict arises (e.g., a client reports an address already in use), the server marks the address as unavailable and assigns a new IP.

These functionalities collectively ensure that the DHCP server operates reliably, efficiently, and in compliance with network standards.

3 Components

3.1 Address Pool

The Address Pool is a range of IP addresses maintained by the DHCP Server. These addresses are dynamically allocated to devices based on availability. The pool prevents conflicts by ensuring no two devices receive the same address simultaneously. For example, an address pool might include a range like `192.168.1.100` to `192.168.1.200`, where addresses are assigned on a first-come, first-served basis.

3.2 Lease Database

The Lease Database is an essential repository that tracks all active and expired leases. It includes details such as:

- Lease duration
- MAC address of the device
- Timestamp for lease initiation and expiration

This ensures efficient IP address recycling and helps in network audits.

3.3 Request Handler

The Request Handler acts as the DHCP server's interface with the network. It listens on designated UDP ports (e.g., port 67) for incoming client requests and initiates the appropriate response. For instance, it parses `DHCPDISCOVER` messages from clients and generates corresponding `DHCPOFFER` responses.

3.4 Packet Encoder/Decoder

This module manages the conversion of DHCP messages into BOOTP-compliant formats for network transmission and back into interpretable data for server processing. It ensures compatibility and adherence to protocol standards.

3.5 Timers

Timers manage critical timing events like:

- Lease expiration
- Renewal windows
- Retransmission of unacknowledged messages

For example, a timer might trigger a lease expiration process to reclaim an unused IP address after a client fails to renew.

3.6 Configuration Module

This module defines and manages network configuration parameters such as:

- Subnet masks
- DNS servers
- Gateways

It simplifies the management of network-wide settings and provides consistent configurations to all clients.

4 DHCP Communication Protocols

A DHCPv4 server and client communicate through DHCPv4 messages, which are transmitted using the User Datagram Protocol (UDP). Communication occurs as follows:

- A DHCPv4 client sends messages to a DHCPv4 server through UDP port 68.
- A DHCPv4 server sends messages to a DHCPv4 client through UDP port 67.

4.1 Message Types

- **DHCPDISCOVER:** Broadcasted by a DHCPv4 client to locate a DHCPv4 server when the client attempts to connect to a network for the first time.
- **DHCPOFFER:** Sent by a DHCPv4 server in response to a `DHCPDISCOVER` message to offer configuration details to the client.
- **DHCPREQUEST:** Sent by the client in three scenarios:
  1. After a client starts, it broadcasts a `DHCPREQUEST` message to respond to a `DHCPOFFER` message sent by a DHCPv4 server.
  2. After a client restarts, it broadcasts a `DHCPREQUEST` message to confirm the configuration, including the previously allocated IPv4 address.
  3. After a client obtains an IPv4 address, it unicasts or broadcasts a `DHCPREQUEST` message to renew the IPv4 address lease.
- **DHCPACK:** An acknowledgment message sent by the server to the client that confirms the configuration assigned in response to a `DHCPREQUEST` message.
- **DHCPNAK:** A rejection message sent by the server to a client's `DHCPREQUEST`, typically indicating that no available IPs can be assigned to the client.
- **DHCPDECLINE:** Sent by a client to notify the server that the allocated IPv4 address conflicts with another IPv4 address. The client then requests another IP address from the server.
- **DHCPRELEASE:** Sent by a client to release its IPv4 address. Upon receiving this message, the DHCPv4 server can allocate this address to another client.
- **DHCPINFORM:** Sent by a client to obtain additional network configuration parameters, such as the gateway address and DNS server address, after obtaining an IPv4 address.

5 Architecture

DHCP IP address allocation works on a client/server model in which the server assigns the client reusable IP information from an address pool. A DHCP client might receive offer messages from multiple DHCP servers and can accept any one of the offers; however, the client usually accepts the first offer it receives