Research and Development Document on IP Addressing, Subnetting, MAC Addressing, ARP & RARP

Table of Contents

1. **Introduction**
2. **IP Addressing**
    - 2.1 Overview of IP Addressing
    - 2.2 IPv4 Addressing
        - 2.2.1 Structure of IPv4
        - 2.2.2 IPv4 Address Classes (A, B, C, D, E)
        - 2.2.3 Private vs. Public IPv4 Addresses
        - 2.2.4 Special IPv4 Addresses (Loopback, Broadcast, APIPA)
    - 2.3 IPv6 Addressing
        - 2.3.1 Structure of IPv6
        - 2.3.2 IPv6 Address Types (Unicast, Multicast, Anycast)
        - 2.3.3 IPv6 vs. IPv4 Comparison
3. **Subnetting in IPv4**
    - 3.1 Understanding Subnetting
    - 3.2 Subnet Mask & CIDR Notation
    - 3.3 Calculating Subnets
        - 3.3.1 Fixed-Length Subnet Mask (FLSM)
        - 3.3.2 Variable-Length Subnet Mask (VLSM)
    - 3.4 Determining Usable Hosts per Subnet
    - 3.5 Subnetting Examples (Class A, B, C)
4. **Subnetting in IPv6**
    - 4.1 IPv6 Subnetting Basics
    - 4.2 IPv6 Prefix Length & Subnetting Example
5. **MAC Addressing**
    - 5.1 Basics of MAC Addresses
    - 5.2 Structure of MAC Address (OUI & NIC)
    - 5.3 Types of MAC Addresses (Unicast, Multicast, Broadcast)

6. **Address Resolution Protocol (ARP)**
    - 6.1 Functionality of ARP
    - 6.2 ARP Request & Reply Process
    - 6.3 ARP Cache & Timeout
    - 6.4 ARP Spoofing (Security Concern)
7. **Reverse Address Resolution Protocol (RARP)**
    - 7.1 Functionality of RARP
    - 7.2 RARP vs. ARP Comparison
    - 7.3 Limitations of RARP
8. **Conclusion**
9. **References**

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1. Introduction

IP addressing and subnetting are fundamental concepts in networking that enable efficient communication between devices. **IPv4** and **IPv6** are the two primary versions of IP addressing, each with unique structures and functionalities. **Subnetting** allows network administrators to divide large networks into smaller, manageable sub-networks.

Additionally, **MAC addressing** is used for local network communication, while **ARP (Address Resolution Protocol)** and **RARP (Reverse ARP)** help in mapping IP addresses to MAC addresses and vice versa.

This document provides a **detailed** breakdown of IP addressing, subnetting, MAC addressing, ARP, and RARP.

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2. IP Addressing

2.1 Overview of IP Addressing

- An **IP address** is a unique identifier assigned to devices in a network.
- Two versions: **IPv4 (32-bit)** and **IPv6 (128-bit)**.

2.2 IPv4 Addressing

2.2.1 Structure of IPv4

- **32-bit address** (e.g., 192.168.1.1).
- Divided into **4 octets** (8 bits each).
- Range: **0.0.0.0 to 255.255.255.255**.

2.2.2 IPv4 Address Classes

Class	Range	Default Subnet Mask	Purpose
A	1.0.0.0 - 126.255.255.255	255.0.0.0	Large Networks
B	128.0.0.0 - 191.255.255.255	255.255.0.0	Medium Networks
C	192.0.0.0 - 223.255.255.255	255.255.255.0	Small Networks
D	224.0.0.0 - 239.255.255.255	N/A	Multicasting
E	240.0.0.0 - 255.255.255.255	N/A	Experimental

2.2.3 Private vs. Public IPv4 Addresses

- **Private IPs** (Non-routable, used internally):
    - Class A: 10.0.0.0 – 10.255.255.255
    - Class B: 172.16.0.0 – 172.31.255.255
    - Class C: 192.168.0.0 – 192.168.255.255
- **Public IPs** (Globally routable, assigned by ISPs).

2.2.4 Special IPv4 Addresses

- **Loopback (127.0.0.1)**: Tests local network stack.
- **Broadcast (255.255.255.255)**: Sends data to all devices.
- **APIPA (169.254.x.x)**: Auto-assigned when DHCP fails.

2.3 IPv6 Addressing

2.3.1 Structure of IPv6

- **128-bit address** (e.g., 2001:0db8:85a3:0000:0000:8a2e:0370:7334).
- **Hexadecimal notation** (8 groups of 4 hex digits).
- **Shortening rules**:
    - Leading zeros can be omitted (2001:db8::8a2e:370:7334).
    - Consecutive zeros replaced with :: (only once per address).

2.3.2 IPv6 Address Types

Type	Description	Example
Unicast	One-to-one communication	2001:db8::1
Multicast	One-to-many communication	ff02::1 (All nodes)
Anycast	One-to-nearest communication	Used in CDNs

2.3.3 IPv6 vs. IPv4 Comparison

Feature	IPv4	IPv6
Address Size	32-bit	128-bit
Address Format	Dotted Decimal	Hexadecimal
Subnetting	Uses Subnet Mask	Uses Prefix Length
Security	Needs IPSec	Built-in IPSec

3. Subnetting in IPv4

3.1 Understanding Subnetting

- **Subnetting** divides a large network into smaller sub-networks.
- **Benefits**:
    - Reduces network congestion.
    - Improves security (isolates traffic).
    - Optimizes IP address usage.

3.2 Subnet Mask & CIDR Notation

- **Subnet Mask**: Defines network vs. host portion (e.g., 255.255.255.0).
- **CIDR (Classless Inter-Domain Routing)**: Compact representation (/24).

3.3 Calculating Subnets

3.3.1 Fixed-Length Subnet Mask (FLSM)

- **Same subnet size** for all subnets.
- **Formula**:
    - **Number of Subnets** = 2n2*n* (where n = borrowed bits).
    - **Hosts per Subnet** = 2(32−CIDR)−22(32−CIDR)−2 (Subtract Network & Broadcast).

3.3.2 Variable-Length Subnet Mask (VLSM)

- **Different subnet sizes** for efficient IP usage.

3.4 Determining Usable Hosts per Subnet

- **Example**: 192.168.1.0/26
    - **Subnet Mask**: 255.255.255.192
    - **Total Hosts**: 2(32−26)=642(32−26)=64
    - **Usable Hosts**: 64−2=6264−2=62

3.5 Subnetting Examples

Class C Example (192.168.1.0/24 → /26**)**

Subnet	Network ID	Usable Range	Broadcast
1	192.168.1.0	192.168.1.1 - 192.168.1.62	192.168.1.63
2	192.168.1.64	192.168.1.65 - 192.168.1.126	192.168.1.127

4. Subnetting in IPv6

- IPv6 uses **/64 prefix** for most subnets.
- Example: 2001:db8::/64 → Supports 264264 hosts.

5. MAC Addressing

5.1 Basics of MAC Addresses

- **48-bit** unique identifier (e.g., 00:1A:2B:3C:4D:5E).

- Assigned by IEEE to NIC manufacturers.

5.2 Structure of MAC Address

- **First 24 bits (OUI)**: Manufacturer ID.
- **Last 24 bits (NIC)**: Device-specific.

5.3 Types of MAC Addresses

Type	Description	Example
Unicast	Single device	00:1A:2B:3C:4D:5E
Multicast	Group of devices	01:00:5E:xx:xx:xx
Broadcast	All devices (FF:FF:FF:FF:FF:FF)	

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6. Address Resolution Protocol (ARP)

6.1 Functionality of ARP

- Maps **IPv4** to **MAC** addresses.

6.2 ARP Request & Reply Process

1. **Host A** sends **ARP Request** (Who has 192.168.1.2?).
2. **Host B** replies with **ARP Reply** (192.168.1.2 is at 00:1A:2B:3C:4D:5E).

6.3 ARP Cache & Timeout

- **ARP Cache** stores recent mappings (expires after ~2 mins).

6.4 ARP Spoofing (Security Concern)

- Attackers send fake ARP replies to intercept traffic.

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7. Reverse Address Resolution Protocol (RARP)

7.1 Functionality of RARP

- Maps **MAC** to **IPv4** (Opposite of ARP).

7.2 RARP vs. ARP Comparison

Feature	ARP	RARP
Function	IP → MAC	MAC → IP
Usage	Common	Mostly obsolete (Replaced by DHCP)

7.3 Limitations of RARP

- Requires a **RARP server**.
- Only provides **IP address** (No subnet mask, gateway).

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8. Conclusion

Understanding **IP addressing, subnetting, MAC addressing, ARP, and RARP** is essential for network design, troubleshooting, and security. IPv6 adoption is increasing due to IPv4 exhaustion, and subnetting remains a critical skill for network engineers.

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9. References

- RFC 791 (IPv4 Specification)
- RFC 2460 (IPv6 Specification)
- RFC 826 (ARP)
- RFC 903 (RARP)