**R&D Document**

**IP Addressing, Subnetting (IPv4 & IPv6), MAC Addressing, ARP & RARP**

**1. Introduction to IP Addressing**

IP (Internet Protocol) addressing is the cornerstone of network communication. An IP address is a unique string of numbers separated by periods (IPv4) or colons (IPv6) that identifies each computer using the Internet Protocol to communicate over a network.

Two versions are currently used:

* **IPv4**: 32-bit numeric address written in dotted decimal format (e.g., 192.168.1.1)
* **IPv6**: 128-bit address written in hexadecimal (e.g., 2001:0db8:85a3:0000:0000:8a2e:0370:7334)

IP addresses consist of two main parts:

* **Network ID**: Identifies the network.
* **Host ID**: Identifies a device on the network.

**2. IPv4 Addressing and Classes**

IPv4 addresses are grouped into five classes:

| **Class** | **Address Range** | **Default Subnet Mask** | **CIDR** |
| --- | --- | --- | --- |
| A | 1.0.0.0 to 126.255.255.255 | 255.0.0.0 | /8 |
| B | 128.0.0.0 to 191.255.255.255 | 255.255.0.0 | /16 |
| C | 192.0.0.0 to 223.255.255.255 | 255.255.255.0 | /24 |
| D | 224.0.0.0 to 239.255.255.255 | (Multicast) | — |
| E | 240.0.0.0 to 255.255.255.255 | (Experimental) | — |

Special IPv4 addresses:

* **127.0.0.1**: Loopback (localhost)
* **169.254.x.x**: APIPA (Automatic Private IP Addressing)
* **255.255.255.255**: Broadcast address

**3. Subnetting in IPv4**

Subnetting divides a larger network into smaller, manageable sub-networks.

**Key Concepts:**

* **Subnet Mask**: 32-bit number that separates the network and host parts of an IP address.
* **CIDR Notation**: Expresses subnet mask using a slash (/) and number of network bits (e.g., /24).
* **Number of Subnets**: 2^n where n = number of borrowed bits.
* **Usable Hosts per Subnet**: 2^h – 2 where h = number of host bits.

**Example: Subnetting 192.168.1.0/24**

* Borrow 2 bits → /26
* Subnets created: 4
* Hosts per subnet: 62 usable (64 total – network & broadcast)

**Subnet Breakdown:**

* 192.168.1.0/26 → Hosts: 192.168.1.1–192.168.1.62
* 192.168.1.64/26 → Hosts: 192.168.1.65–192.168.1.126
* 192.168.1.128/26 → Hosts: 192.168.1.129–192.168.1.190
* 192.168.1.192/26 → Hosts: 192.168.1.193–192.168.1.254

**4. IPv6 Addressing**

IPv6 addresses are 128 bits in length and written in hexadecimal. A full IPv6 address looks like:

makefile

CopyEdit

2001:0db8:85a3:0000:0000:8a2e:0370:7334

**Simplified Notation:**

* Remove leading zeros: 2001:db8:85a3:0:0:8a2e:370:7334
* Use :: for consecutive zero segments (once): 2001:db8:85a3::8a2e:370:7334

**IPv6 Address Types:**

* **Unicast**: One-to-one communication
* **Multicast**: One-to-many
* **Anycast**: One-to-nearest (in routing terms)

**Common Prefix Length**: /64  
**Usable Host Addresses**: 2^64 (for a single subnet)

IPv6 eliminates the need for NAT and supports auto-configuration and built-in security with IPSec.

**5. MAC Addressing**

A **MAC (Media Access Control)** address is a unique 48-bit hardware address burned into a network interface card (NIC). It functions at **Layer 2** (Data Link Layer) of the OSI model.

**Format**: 00:1A:2B:3C:4D:5E

**Structure:**

* **OUI (Organizationally Unique Identifier)** – First 24 bits (first 3 bytes): Identifies manufacturer.
* **NIC-Specific Bits** – Last 24 bits (last 3 bytes): Uniquely identify the device.

MAC addresses are **permanent** for the device, although they can be changed (spoofed) for security or testing purposes.

**6. ARP and RARP**

**Address Resolution Protocol (ARP)**

**ARP** is used to map an **IPv4 address to a MAC address** within a local network.

**How ARP works:**

1. Host A wants to communicate with IP 192.168.1.5.
2. It checks its ARP cache for the corresponding MAC address.
3. If not found, it sends an **ARP request** (broadcast).
4. The device with IP 192.168.1.5 replies with an **ARP response** containing its MAC address.
5. Host A stores the IP-MAC pair in its **ARP table** for future use.

**Reverse ARP (RARP)**

**RARP** maps a **MAC address to an IP address**, primarily used by **diskless systems** at boot time.

* The device sends a RARP request to the RARP server.
* Server assigns and returns an IP address.
* **RARP is now obsolete**, replaced by **BOOTP** and **DHCP**, which offer more features like gateway, DNS, etc.

**7. Summary and Practical Use**

| **Concept** | **Function** |
| --- | --- |
| IP Addressing | Logical identification for devices |
| Subnetting | Efficient division of networks |
| MAC Address | Unique physical address of NIC |
| ARP | Resolves IP to MAC address |
| RARP | Resolves MAC to IP address (obsolete) |

**Subnetting** is essential for:

* Traffic segmentation
* IP management
* Enhancing security

**IPv6** solves IPv4 limitations, supports auto-configuration, and simplifies routing.

**ARP** enables devices to discover MAC addresses on LANs for proper packet delivery.