R&D Document on IP Addressing and Subnetting (IPv4 & IPv6)

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Date: 15 June 2025

ABSTRACT

This R&D document traverses the basic principles and practical applications of IP addressing (Internet Protocol address) and subnetting, with a wide focus on both IPv4 and IPv6 protocols. It aims to provide a foundational understanding of how IP addresses work within modern networks, including their structure, types, and classification systems. The transition from IPv4 to IPv6 is also discussed, highlighting the constraints of IPv4 and how IPv6 addresses those challenges with an expanded address space and improved features.

Subnetting is a key concept studied in this document, as it plays a very important role in segmenting networks for optimal performance and security. The document presents natural masks, subnet masks, and CIDR (Classless Inter-Domain Routing) notation to explain how IP address blocks are divided. It also covers the methodology for creating subnets, calculating subnet ranges, determining the total and usable number of hosts per subnet, and aligning subnet design with specific network requirements.

Through a combination of theoretical insights and practical examples, this work provides readers with the skills necessary to effectively plan, implement, and manage IP addressing schemes in diverse networking environments. Whether for academic learning, certification preparation, or real-world network administration, the concepts presented here serve as a critical reference for understanding and deploying structured and efficient IP networks.

INTRODUCTION

IP addressing is a basic component of computer networking, allowing devices to identify and communicate with one another over a network. Every device connected to a network is assigned an IP address. This address serves two critical purposes: it identifies the host or network interface and specifies the device's location within the network.

There are two main types of IP addresses in use today: IPv4 and IPv6. IPv4 is the older and more widely adopted version, uses a 32-bit address scheme. However, due to the explosive growth of internet-connected devices, IPv6 was introduced with a 128-bit address format to provide a vastly larger pool of unique addresses.

As the digital landscape continues to expand, a strong understanding of IP addressing is needed. This includes knowledge of how addresses are structured, how they function within a network, and how they can be segmented using subnetting. Subnetting allows for more efficient network management, improved performance, and better security practices by logically dividing larger networks into smaller, manageable parts.

IPV4 ADDRESSING

Structure of IPv4

IPv4, or Internet Protocol version 4, uses a 32-bit address format. These 32 bits are divided into four sections each consisting of 8 bits. The address is written in decimal form, separated by dots. Each octet can range from 0 to 255. IPv4 is the most widely used protocol but has a limitation in the number of unique addresses it can provide—approximately 4.3 billion.

Classes of IPv4

IPv4 addresses are divided into five classes (A to E), based on their starting bits and address ranges. However, only Class A, Class B, and Class C are commonly used for host addressing:

- **Class A** is designed for very large networks used by large organisations or internet service providers and supports around 16 million hosts per network. It uses a default subnet mask of 255.0.0.0.
- **Class B** supports medium-sized networks with around 65,000 hosts per network, using a default subnet mask of 255.255.0.0.
- **Class C** is used for smaller networks and supports 254 hosts, with a subnet mask of 255.255.255.0.

Class D is reserved for multicast communication and **Class E** is reserved for experimental or future use.

The classification helps in understanding the default division between the network and host portions of an IP address.

SUBNETTING IN IPV4

Subnetting

Subnetting is a process used to divide a larger IP network into smaller, more manageable networks called subnets. It improves network performance and enhances security by isolating groups of hosts. Each subnet functions as an independent network, and routers use subnetting to direct traffic efficiently within a larger network.

Subnet Mask

A subnet mask is used to break the IP address into network and host portions. For example, in the IP address 192.168.1.1 with a subnet mask of 255.255.255.0, the first 24 bits (192.168.1) represent the network, and the last 8 bits (1) represent the host. Subnet masks are important in determining which part of the IP address designates the network and which part designates individual devices.

CIDR Notation (Classless Inter-Domain Routing)

CIDR notation is a method to represent an IP address and its associated network mask. It uses the format IP address/prefix length, where slash (/) separates the IP address from the prefix length and prefix length is a decimal number representing the number of bits that are part of the network portion of the IP address. For example,192.168.1.1/24: This represents an IP address 192.168.1.1 and a network mask of /24,which means the first 24 bits are the network portion and the remaining 8 bits are the host portion.

Subnet calculation in IPv4

It involves breaking a larger IP network into smaller sub-networks using subnet masks or CIDR notation. For example, if we have a network like 192.168.1.0/24 and we want to divide it into four smaller networks, you can borrow 2 bits from the host portion, making it /26 (since 24 + 2 = 26). This gives you $2^2 = 4$ subnets, each with 64 IP addresses, out of which 62 are usable (excluding the network and broadcast addresses). This helps organize devices more efficiently and control traffic within a network.

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IPv6 Addressing

Structure of IPv6

IPv6, or Internet Protocol version 6, was developed to solve the address exhaustion problem of IPv4. It uses 128-bit addresses, allowing for an almost unlimited number of unique IP addresses. IPv6 addresses are expressed using hexadecimal numbers, with eight groups of four hexadecimal digits separated by colons. A valid IPv6 address looks like 2001:0db8:85a3:0000:0000:8a2e:0370:7334.

Features of IPv6

IPv6 addresses have several key features: a significantly larger address space, simplified header structure, built-in security features, support for autoconfiguration, and improved routing efficiency and thus offers many advantages over IPv4. It is more efficient in routing and packet processing and is essential for the growth of the Internet of Things (IoT).

IPv6 Subnetting

IPv6 Subnetting involves dividing a larger network into smaller, more manageable networks. While IPv6 addresses are much larger, the core concept remains the same: using a subnet mask to define the network portion of an address and the host portion. The recommended subnet mask for end-host use in IPv6 is /64.

Subnet calculation in IPv6

It is simpler due to the larger address space. IPv6 commonly uses a /64 prefix for each subnet, and if you want to divide that further, say into 16 subnets, you can extend the prefix to /68. This means borrowing 4 bits (68 - 64 = 4), giving you $2^4 = 16$ subnets. Unlike IPv4, there's no need to worry about address exhaustion, and there is no concept of broadcast addresses, making IPv6 subnetting more straightforward for modern networks.

CONCLUSION

Understanding the principles of IP addressing and subnetting is very much needed for network engineers and system administrators, as these concepts create the backbone of efficient network design and communication. IPv4 uses 32-bit address space, continues to be widely used across existing infrastructures. IPv6, with its 128-bit addressing and advanced features, is designed to support the growing demands of modern internet connectivity, for IoT and mobile networks.

Subnetting plays a crucial role in optimizing IP address usage, improving network performance, and enhancing security. It enables the segmentation of larger networks into smaller, more manageable sub-networks, thereby reducing congestion and isolating traffic. Whether using subnet masks and CIDR notation in IPv4 or prefix lengths in IPv6, subnetting allows for scalable and logical network organization tailored to specific operational requirements.

As networks grow in complexity and size, mastering subnet calculations and address planning becomes more important. A strong grasp of both IPv4 and IPv6 subnetting techniques permits professionals to design robust, efficient, and future-ready network infrastructures. Continual learning and adaptation to evolving standards will ensure effective implementation and long-term success in managing modern networks.

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