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What is an IP Address?

- An Internet protocol (IP) is a unique numerical label assigned to every device connected to a computer network that uses IP to communicate.

- It acts as a digital identifier, allowing devices like computers, smartphones, servers, and routers to send and receive data.

- IP addresses are essential for both local network communication (like a home or office Wi-Fi) and global internet access.

- The IP address ensures that data packets are correctly routed from the source device to the intended destination, making seamless communication possible over the network.

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Internet Protocol (IP) is the fundamental communication protocol used for relaying packets of data across networks, including the internet. It enables devices to identify and locate each other using IP addresses and helps route the data from source to destination.

IPV4

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IPv4 is the fourth version of the Internet Protocol and the most widely used to date. It uses a 32-bit addressing scheme, allowing for around 4.3 billion unique IP addresses. These addresses are typically written in dotted decimal format, such as `192.168.1.1`, and are assigned to every device that connects to a network.IPv4 supports communication types like unicast, multicast, and broadcast. It uses subnetting to manage and divide large networks into smaller, more manageable ones**.** The **header is variable in length (20 to 60 bytes) and contains important information for routing and delivery. Though it was not originally designed with security in mind, IPv4 can be secured using additional tools like firewalls and VPNs.**

IPV6

IPv6 is the newest version of the Internet Protocol, designed to overcome the limitations of IPv4—most notably, the exhaustion of available IP addresses. IPv6 uses a 128-bit address format, allowing for an almost unlimited number of unique addresses (approximately 3.4×10^{38}), which is more than enough for all current and future devices. The addresses are written in hexadecimal and separated by colons, like `2001:0db8:85a3::8a2e:0370:7334`. IPv6 removes the need for NAT by allowing true end-to-end connectivity. It also offers simplified and more efficient packet headers, which are fixed at 40 bytes, and moves optional data to extension headers. IPv6 supports stateless and stateful auto-configuration, making it easier for devices to connect to the

network. One key architectural change is that packet fragmentation is done only by the source device, reducing router workload. While IPv6 adoption is still growing, it represents the future of internet communication with its scalability, security, and flexibility.

Subnetting

Subnetting is a technique used in computer networking to divide a single network into multiple smaller networks, known as subnetworks or subnets. The purpose of subnetting is to partition a large network into smaller, more efficient subnets, which can improve network performance, security, and organization.

Subnetting is often used in larger organizations, to create separate networks for different departments or groups of users. It can also be used to create separate networks for different types of devices, such as servers, workstations, and mobile devices.

CIDR Notation

CIDR notation combines the IP address with a suffix indicating how many bits are the network prefix. Example: `192.168.0.0/20` means the first 20 bits are the network part, and the remaining 12 bits are for host addresses. This allows subnet masks of any length (not limited to classful 8, 16, or 24 bits). The slash `/` notation is also called the prefix length.

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Subnet Mask vs. Prefix Length

The subnet mask is a 32-bit binary number where 1s indicate the network bits and 0s indicate host bits. The prefix length counts the number of leading 1 bits.

For example:

- Prefix `/24` = subnet mask `255.255.255.0` (binary: 11111111.11111111.11111111.00000000)

- Prefix `/22` = subnet mask `255.255.252.0` (binary: 11111111.11111111.11111100.00000000)

Calculating Number of Hosts

The number of usable hosts in a subnet is calculated as:

2(32−prefix length)−22^{(32 - \text{prefix length})} - 22(32−prefix length)−2

- Subtract 2 for the **network address** and **broadcast address** (except for /31 and /32, where exceptions apply).

Example:
`192.168.1.0/26` has 2(32−26)−2=64−2=622^{(32-26)} - 2 = 64 - 2 = 622(32−26)−2=64−2= 62 usable hosts.

Advantages of CIDR

- **Improved address space utilization** reduces waste.
- **Hierarchical routing** is more efficient, decreasing router workload.
- Supports **fine-grained subnetting** and better control over IP allocations.
- Helps delay IPv4 exhaustion by allowing smaller, precise IP blocks.

CIDR Block Examples

CIDR Block	Number of IPs	Usable Hosts	Subnet Mask	Example Usage
8	16,777,216	16,777,214	255.0.0.0	Very large networks, ISPs
16	65,536	65,534	255.255.0.0	Large organizations

20	4,096	4,094	255.255.240.0	Medium-sized subnet
24	256	254	255.255.255.0	Small networks or LANs
28	16	14	255.255.255.240	Very small subnet, point-to-point
30	4	2	255.255.255.252	Used for WAN links between routers

CIDR and Routing

- Routers use CIDR to create **route summaries**, which group many IP routes into one.
- This **reduces the size of routing tables** and speeds up routing decisions.
- For example, instead of storing routes for each subnet like `192.168.1.0/24` and `192.168.2.0/24`, routers store a single route for `192.168.0.0/22`.

CIDR vs Classful Addressing

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Feature	Classful Addressing	CIDR
Subnet Mask	Fixed based on class (A/B/C)	Variable prefix length
Address Wastage	High	Low (efficient allocation)
Routing	Many specific routes	Route aggregation/summarization
Flexibility	Limited	Highly flexible
Adoption	Obsolete, legacy	Standard since 1993

Summary

CIDR is a critical enhancement in IP networking that makes the internet scalable, efficient, and easier to manage by allowing variable-length subnet masks and route aggregation. It solved many of the IPv4 address exhaustion problems and remains a fundamental concept in both IPv4 and IPv6 networking.