Research and Development Document

ON

IP Addressing and Subnetting





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IP Addressing

Each device that uses a network receives an IP address and a special identifier number. IP Addresses are necessary for routing data packets between devices and enabling Internet communication between devices. Dotted decimal notation, which depicts four sets of bit. The network, separated by periods, is the most common way to express IP addresses. The address is 32 bits, and every number corresponds to a byte of the address.

There are two primary forms of IP addresses : IPv4 and IPv6. Because of the 32-bit length and the limited amount of unique IPv4 addresses, subnets and various methods for storing IP addresses have been developed. There are many more unique addresses available for IPv6 addresses that are 128-bit.

An IP address is an address used in order to uniquely identify a device on an IP network. The address is made up of 32 binary bits, which can be divisible into a network portion and host portion with the help of a subnet mask. The 32 binary bits are broken into four octets (1 octet = 8 bits). Each octet is converted to decimal and separated by a period (dot). For this reason, an IP address is said to be expressed in dotted decimal format (for example, 172.16.81.100). The value in each octet ranges from 0 to 255 decimal, or 00000000 - 11111111 binary.

Here is how binary octets convert to decimal: The rightmost bit, or least significant bit, of an octet holds a value of 20. The bit just to the left of that holds a value of 21. This continues until the left-most bit, or most significant bit, which holds a value of 27. So if all binary bits are a one, the decimal equivalent would be 255 as shown here:

1 1 1 1 1 1 1 1

128 64 32 16 8 4 2 1 (128+64+32+16+8+4+2+1=255)

Here is a sample octet conversion when not all of the bits are set to 1.

0 1 0 0 0 0 0 1

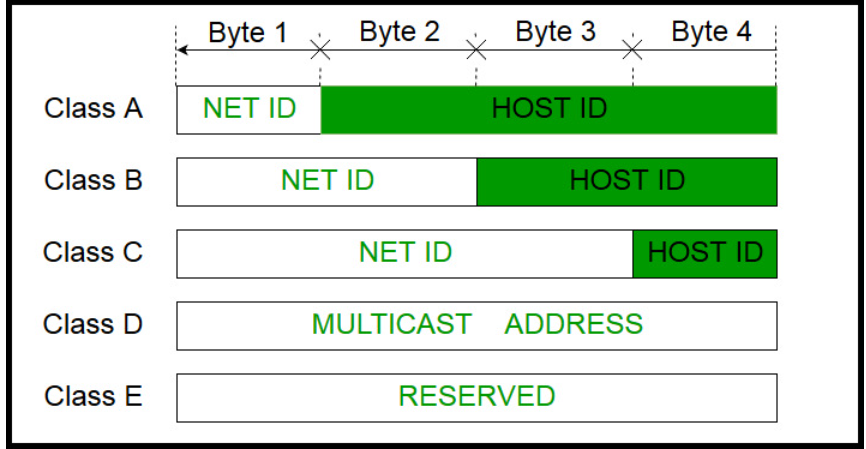
0 64 0 0 0 0 0 1 (0+64+0+0+0+0+0+1=65)

And this sample shows an IP address represented in both binary and decimal.

10. 1. 23. 19 (Decimal)

00001010. 00000001. 00010111. 00010011 (binary)

These octets are broken down to provide an addressing scheme that can accommodate large and small networks. There are five different classes of networks, A to E.



IPv4 addresses are 32 bits long and divided into five classes, primarily based on the first few bits of the address. These classes help determine the default subnet mask, network size, and intended use.

| Class | Starting Bits | Address Range | Default Subnet Mask | Networks |
| --- | --- | --- | --- | --- |
| A | 0 | 0.0.0.0 – 127.255.255.255 | 255.0.0.0 (/8) | 128 |
| B | 10 | 128.0.0.0 – 191.255.255.255 | 255.255.0.0 (/16) | 16384 |
| C | 110 | 192.0.0.0 – 223.255.255.255 | 255.255.255.0 (/24) | 2,000,000+ |
| D | 1110 | 224.0.0.0 – 239.255.255.255 | - | - |
| E | 1111 | 240.0.0.0 – 255.255.255.255 | - | - |

# IPv4 Addressing

IP stands for Internet Protocol version v4 stands for Version Four (IPv4), is the most widely used system for identifying devices on a network. It uses a set of four numbers, separated by periods (like 192.168.0.1), to give each device a unique address. This address helps data find its way from one device to another over the internet.

IPv4 was the primary version brought into action for production within the ARPANET in 1983. IP version four addresses are 32-bit integers which will be expressed in decimal notation. Example- 192.0.2.126 could be an IPv4 address.

Types of IPv4 Addressing

* Unicast Addressing Mode: This addressing mode is used to specify single sender and single receiver. Example: Accessing a website.
* Broadcast Addressing Mode: This addressing mode is used to send messages to all devices in a network. Example: sending a message in local network to all the devices.
* Multicast Addressing Mode: This addressing mode is typically used within a local network or across networks and sends messages to a group of devices. Example: Streaming audio to multiple devices at once.

Characteristics of IPv4

* IPv4 could be a 32-bit IP Address.
* IPv4 could be a numeric address, and its bits are separated by a dot.
* The number of header fields is twelve and the length of the header field is twenty.
* It has Unicast, broadcast, and multicast-style addresses.
* IPv4 supports VLSM (Virtual Length Subnet Mask).
* IPv4 uses the Post Address Resolution Protocol to map to the MAC address.
* Networks ought to be designed either manually or with DHCP.
* Packet fragmentation permits from routers and causes host.

## Advantages of IPv4

* IPv4 security permits encryption to keep up privacy and security.
* IPV4 network allocation is significant and presently has quite 85000 practical routers.
* It becomes easy to attach multiple devices across an outsized network while not NAT.
* This is a model of communication so provides quality service also as economical knowledge transfer.
* IPV4 addresses are redefined and permit flawless encoding.
* IPv4 has high System Management prices and it's labor-intensive, complex, slow & prone to errors.
* Routing is scalable and economical as a result of addressing its collective more effectively.

## Limitations of IPv4

* IP relies on network layer addresses to identify end-points on the network, and each network has a unique IP address.
* The world's supply of unique IP addresses is dwindling, and they might eventually run out theoretically.
* If there are multiple hosts, we need the IP addresses of the next class.
* Complex host and routing configuration, non-hierarchical addressing, difficult to re-numbering addresses, large routing tables, non-trivial implementations in providing security, QoS (Quality of Service), mobility, and multi-homing, multicasting, etc. are the big limitations of IPv4 so that's why IPv6 came into the picture.

# IPv6 Addressing

The next generation Internet Protocol (IP) address standard, known as IPv6, is meant to work in cooperation with IPv4. To communicate with other devices, a computer, smartphone, home automation component, Internet of Things sensor, or any other Internet-connected device needs a numerical IP address. Because so many connected devices are being used, the original IP address scheme, known as IPv4, is running out of addresses. This new IP address version is being deployed to fulfil the need for more Internet addresses. With 128-bit address space, it allows 340 undecillion unique address space. IPv6 support a theoretical maximum of 340, 282, 366, 920, 938, 463, 463, 374, 607, 431, 768, 211, 456.

## Representation of IPv6

An IPv6 address consists of eight groups of four hexadecimal digits separated by ' . ' and each Hex digit representing four bits so the total length of IPv6 is 128 bits. Structure given below.

IPV6-Representation : gggg.gggg.gggg.ssss.xxxx.xxxx.xxxx.xxxx

The first 48 bits represent Global Routing Prefix. The next 16 bits represent the student ID and the last 64 bits represent the host ID. The first 64 bits represent the network portion and the last 64 bits represent the interface id.

* Global Routing Prefix: The Global Routing Prefix is the portion of an IPv6 address that is used to identify a specific network or subnet within the larger IPv6 internet. It is assigned by an ISP or a regional internet registry (RIR).
* Student Id: The portion of the address used within an organization to identify subnets. This usually follows the Global Routing Prefix.
* Host Id: The last part of the address is used to identify a specific host on a network.

Example: 3001:0da8:75a3:0000:0000:8a2e:0370:7334

## Types of IPv6 Address

* Unicast Addresses : Only one interface is specified by the unicast address. A packet moves from one host to the destination host when it is sent to a unicast address destination.
* Multicast Addresses: It represents a group of IP devices and can only be used as the destination of a datagram.
* Anycast Addresses: The multicast address and the anycast address are the same. The way the anycast address varies from other addresses is that it can deliver the same IP address to several servers or devices. Keep in mind that the hosts do not receive the IP address. Stated differently, multiple interfaces or a collection of interfaces are assigned an anycast address.

## Advantages of IPv6

* Faster Speeds: IPv6 supports multicast rather than broadcast in IPv4.This feature allows bandwidth-intensive packet flows (like multimedia streams) to be sent to multiple destinations all at once.
* Stronger Security: IPSecurity, which provides confidentiality, and data integrity, is embedded into IPv6.
* Routing efficiency
* Reliability
* Internet protocol security is used to support security.
* Enable simple aggregation of prefixes allocated to IP networks; this saves bandwidth by enabling the simultaneous transmission of large data packages.

## Disadvantages of IPv6

* Conversion: Due to widespread present usage of IPv4 it will take a long period to completely shift to IPv6.
* Communication: IPv4 and IPv6 machines cannot communicate directly with each other.
* Not Going Backward Compatibility: IPv6 cannot be executed on IPv4-capable computers because it is not available on IPv4 systems.
* Conversion Time: One significant drawback of IPv6 is its inability to uniquely identify each device on the network, which makes the conversion to IPV4 extremely time-consuming.

## Network Masks

A network mask helps you know which portion of the address identifies the network and which portion of the address identifies the node. Class A, B, and C networks have default masks, also known as natural masks, as shown here:

Class A: 255.0.0.0

Class B: 255.255.0.0

Class C: 255.255.255.0

An IP address on a Class A network that has not been subnetted would have an address/mask pair similar to: 10.20.15.1 255.0.0.0.

Once you have the address and the mask represented in binary, then identification of the network and host ID is easier. Any address bits which have corresponding mask bits set to 1 represent the network ID. Any address bits that have corresponding mask bits set to 0 represent the node ID.

10.20.15.1 = 00001010.00010100.00001111.00000001

255.0.0.0 = 11111111.00000000.00000000.00000000

-----------------------------------

net id | host id

netid = 00001010 = 10

hostid = 00010100.00001111.00000001 = 20.15.1

Subnetting

A network is divided into smaller subnetworks, or subnetworks, through the process known as a subnetwork. For this purpose, a network part of the IP address is created by taking bits from the host part. The host party identifies the specific device on the subnetwork, while the network party identifies the subnetwork as a whole.

The sub-network enables network managers to create more controllable and segmented networks for performance or security needs. For example, a large enterprise could segment its network into subnetworks for multiple divisions or locations.

Subnetting allows you to create multiple logical networks that exist within a single Class A, B, or C network. If you do not subnet, you are only able to use one network from your Class A, B, or C network, which is unrealistic.

Each data link on a network must have a unique network ID, and every node on that link is a member of the same network. If you break a major network (Class A, B, or C) into smaller subnetworks, it allows you to create a network of interconnecting subnetworks. Each data link on this network would then have a unique network/subnetwork ID. Any device, or gateway, that connects n networks/subnetworks has n distinct IP addresses, one for each network / subnetwork that it interconnects.

Variable Length Subnet Masks (VLSM) allows us to use different masks for each subnet, thereby they use address space efficiently.

Creating a Subnet in natural masks :

Q. Given an IP address 192.168.10.0 with a natural mask (Class C), divide the network into 4 equal subnets. Write the new subnet mask, subnet addresses, broadcast addresses, and usable host ranges.

#### 1. Identify the Class and Natural Mask

* The given IP is 192.168.10.0
* Since it falls within 192.0.0.0 – 223.255.255.255,Class C
* Natural Mask (default): 255.255.255.0 = /24
* Total addresses in Class C: 256
* Usable hosts: 2^8 - 2 = 254 (subtracting network & broadcast)

#### 2. Number of Bits to Borrow

* Formula: 2^n ≥ required subnets = 2^2 = 4, so I borrow 2 bits from host part

#### 3. Calculating New Subnet Mask

* Original: /24
* Borrowed: 2 bits = /26
* New Subnet Mask: 255.255.255.192

#### 4. Determine Subnet Increments

* 4 subnets = each subnet has 256 / 4 = 64 IP addresses

#### 5. Listing All Subnets

| Subnet | Network Address | First Host | Last Host | Broadcast Address |
| --- | --- | --- | --- | --- |
| 1 | 192.168.10.0/26 | 192.168.10.1 | 192.168.10.62 | 192.168.10.63 |
| 2 | 192.168.10.64/26 | 192.168.10.65 | 192.168.10.126 | 192.168.10.127 |
| 3 | 192.168.10.128/26 | 192.168.10.129 | 192.168.10.190 | 192.168.10.191 |
| 4 | 192.168.10.192/26 | 192.168.10.193 | 192.168.10.254 | 192.168.10.255 |

Creating a Subnet in Subnet Masks:

## Q. Subnet 192.168.1.0 into 4 Subnets

This is a Class C IP = Natural Mask is 255.255.255.0 (/24)

### Step 1: bits to borrow

We want 4 subnets.

So borrow 2 bits from the host portion:

* Original subnet mask: /24
* New subnet mask: /26 = 255.255.255.192

### Step 2: Determine Subnet Block Size

Block size:

256−192=64

### Step 3: List Subnets

| Subnet # | Network Address | First Host | Last Host | Broadcast Address |
| --- | --- | --- | --- | --- |
| 1 | 192.168.1.0/26 | 192.168.1.1 | 192.168.1.62 | 192.168.1.63 |
| 2 | 192.168.1.64/26 | 192.168.1.65 | 192.168.1.126 | 192.168.1.127 |
| 3 | 192.168.1.128/26 | 192.168.1.129 | 192.168.1.190 | 192.168.1.191 |
| 4 | 192.168.1.192/26 | 192.168.1.193 | 192.168.1.254 | 192.168.1.255 |

CIDR Range

Q. IP Address: 192.168.10.0

Subnet Mask: 255.255.255.192

### Step 1: Convert the Subnet Mask to Prefix Length(Find how many bits are 1 in the subnet mask.)

255.255.255.192 → binary is:

11111111.11111111.11111111.11000000

Count the 1s = 26

CIDR Notation: 192.168.10.0/26

### Step 2: Calculate IP Range

Block size = 256 - 192 = 64

Subnets are:

* 192.168.10.0/26 = Range: 192.168.10.0 - 192.168.10.63
* Next would be 192.168.10.64/26, and so on.

Usable & Total Hosts

### Total Hosts=2^(32−CIDR Prefix)

Example: /26 =CIDR Prefix

2(32−26)=26=64 total hosts

Usable Hosts=Total Hosts−2 (Subtract network and Broadcast address)  
64−2=62 usable hosts

So for /26:

64−2=62 usable hosts

64 - 2 = 62 \text{ usable hosts}64−2=62 usable hosts

## Difference Between IP Addressing and Subnetting

| IP Addressing | Subnetting |
| --- | --- |
| Assign unique identifiers to devices on a network. | Divide a network into smaller subnetworks for better management and performance. |
| Assigns unique IP addresses to devices on a network. | Divides a network into smaller subnets by borrowing bits from the host portion of the IP address to create a network portion. |
| Each device on the network has a unique IP address. | The network is broken down into smaller subnets, each with its unique network ID and range of IP addresses. |
| Enables devices to communicate with each other over the Internet. | Improves network performance and security by reducing network congestion, isolating network traffic, and making it easier to manage IP address assignments and security. |
| IPv4 and IPv6 | CIDR (Classless Inter-Domain Routing) |
| Dotted decimal notation (e.g., 192.168.0.1) | Subnet mask (e.g., 255.255.255.0) or CIDR notation (e.g., /24) |
| 32 bits (IPv4) or 128 bits (IPv6) | Variable (depends on the number of bits borrowed for the network portion of the IP address). |
| 192.168.0.1 | 192.168.0.0/24 |

Classless Inter-Domain Routing (CIDR)

Classless Inter-Domain Routing (CIDR) is an IP address allocation method that improves data routing efficiency on the internet. Every machine, server, and end-user device that connects to the internet has a unique number, called an IP address, associated with it. Devices find and communicate with one another by using these IP addresses. Organizations use CIDR to allocate IP addresses flexibly and efficiently in their networks.

CIDR (Classless Inter-Domain Routing) expresses an IP network as:

<network\_address>/<prefix\_length>

## CIDR Working

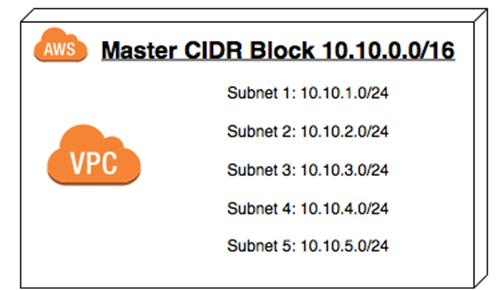
Classless Inter-Domain Routing (CIDR) allows network routers to route data packets to the respective device based on the indicated subnet. Instead of classifying the IP address based on classes, routers retrieve the network and host address as specified by the CIDR suffix.

It’s important to understand CIDR blocks and CIDR notation to learn how CIDR works.

### CIDR blocks

A CIDR block is a collection of IP addresses that share the same network prefix and number of bits. A large block consists of more IP addresses and a small suffix.

The Internet Assigned Numbers Authority (IANA) assigns large CIDR blocks to regional internet registries (RIR). Then, the RIR assigns smaller blocks to local internet registries (LIR), which then assign them to organizations. Meanwhile, private users apply for CIDR blocks from their internet service providers.



### CIDR notation

CIDR notation represents an IP address and a suffix that indicates network identifier bits in a specified format. For example, you could express 192.168.1.0 with a 22-bit network identifier as 192.168.1.0/22.

## CIDR in IPv6

IPv6 is a networking addressing system designed to replace IPv4. IPv6 uses a 128-bit unique identifier, which allows it to hold more IP addresses than IPv4.

An IPv6 address consists of 8 colon-separated hexadecimal values. IPv6 allows a much larger address space to accommodate the increasing number of devices that are connecting to the internet today.

Under Classless Inter-Domain Routing (CIDR), IPv6 addresses can be aggregated with prefixes of arbitrary bit length, similar to IPv4 addresses. For example, 2001:0db8:/32 is an IPv6 CIDR address, with the first 32 bits, or 2001:db8, as the network address.

CIDR moves away from the traditional IP classes (Class A, Class B, Class C, and so on). In CIDR , an IP network is represented by a prefix, which is an IP address and some indication of the length of the mask. Length means the number of left-most contiguous mask bits that are set to one. So, network 172.16.0.0 255.255.0.0 can be represented as 172.16.0.0/16. CIDR also depicts a more hierarchical Internet architecture, where each domain takes its IP addresses from a higher level. This allows for the summarization of the domains to be done at the higher level. For example, if an ISP owns a network 172.16.0.0/16, then the ISP can offer 172.16.1.0/24, 172.16.2.0/24, and so on to customers. Yet, when advertising to other providers, the ISP only needs to advertise 172.16.0.0/16.

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