

Internet Protocol Version4 (IPv4) & Subnetting Strategy

The Internet Protocol (IP)

- The Internet Protocol is the corner-stone of the TCP/IP architecture. All computers in the Internet understand IP.
- The main tasks of IP are:
 - The **addressing** of the computers, and the **fragmentation** of packets.

There are two types of Internet Protocol:

- **Internet Protocol version 4 (IPv4):** currently used version of Internet Protocol.
- **Internet Protocol version 6 (IPv6):** the upcoming replacement for IPv4. It contains some major improvements and new features.

IPv4 Address:

- An IPv4 address is a 32-bit address that uniquely and universally defines the connection of a device (for example, a computer or a router) to the Internet.
 - Connectionless protocol
 - Fragments (divides) packets where necessary
 - Addressing via 32 bit Internet addresses
- However, it contains no functions for end-to-end message reliability or flow control. IP makes the ‘best effort’ to forward packets to the next destination, but **does not guarantee delivery because it is connectionless.**

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The IP address can be classify into two classes:

➤ **Public address:**

This address considered as any valid address assigned to any user, and the organization who is responsible for registering IP ranges called Internet Service Providers (ISPs), and this address will be unique.

➤ **Private Address:**

Any number or address assigned to a device on a private TCP/IP Local Area Network that is accessible only within the Local Area Network.

Internet Protocol Version 6 (IPv6)

SIPP (Simple Internet Protocol Plus)

- Maintains good features of IPv4, discards bad ones.
- Not compatible with IPv4
- Compatible with all other Internet protocols including TCP, UDP, ICMP, DNS, etc.
- Main features:
 - Long addresses (128 bits) ⇒ supports billions of hosts.
 - Simplified, fixed size header ⇒ routers can process packets faster.
 - Support for authentication and privacy
 - Better support for type of service.

Internet addresses

Each network interface connected to the Internet has a unique address consisting of two parts:

- **Network address**, address of the network within the Internet (used by gateways for routing IP packets between networks).
- **Host address**, address of the computer within the network (used for delivering packets to a particular network interface within the network).

Internet address format

- The 32-bit IP address is separated into four 8-bit octets, allowing each octet to have a value ranging from 0 to 255.
- Furthermore, the IP address is logically separated into two distinct components: the network ID and the host ID. The network ID is used to identify the subnet upon which the host resides. The host ID is used to identify the host itself within the given subnet.

➤ **IP addresses can be displayed in three typical formats:**

- Binary notation Binary notation is the format that systems on the network use to process the address. An example of binary notation is **11000000.10101000.00000001.01100100**.
- Hexadecimal notation Hexadecimal notation is the format typically used when identifying IPv6 addresses. An example of hexadecimal notation of an IPv4 address is **C0.A8.01.64**

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- Dotted-decimal notation Dotted-decimal notation is the format that is typically used for displaying the IP address in a human-readable format. An example of dotted-decimal notation is **192.168.1.100**

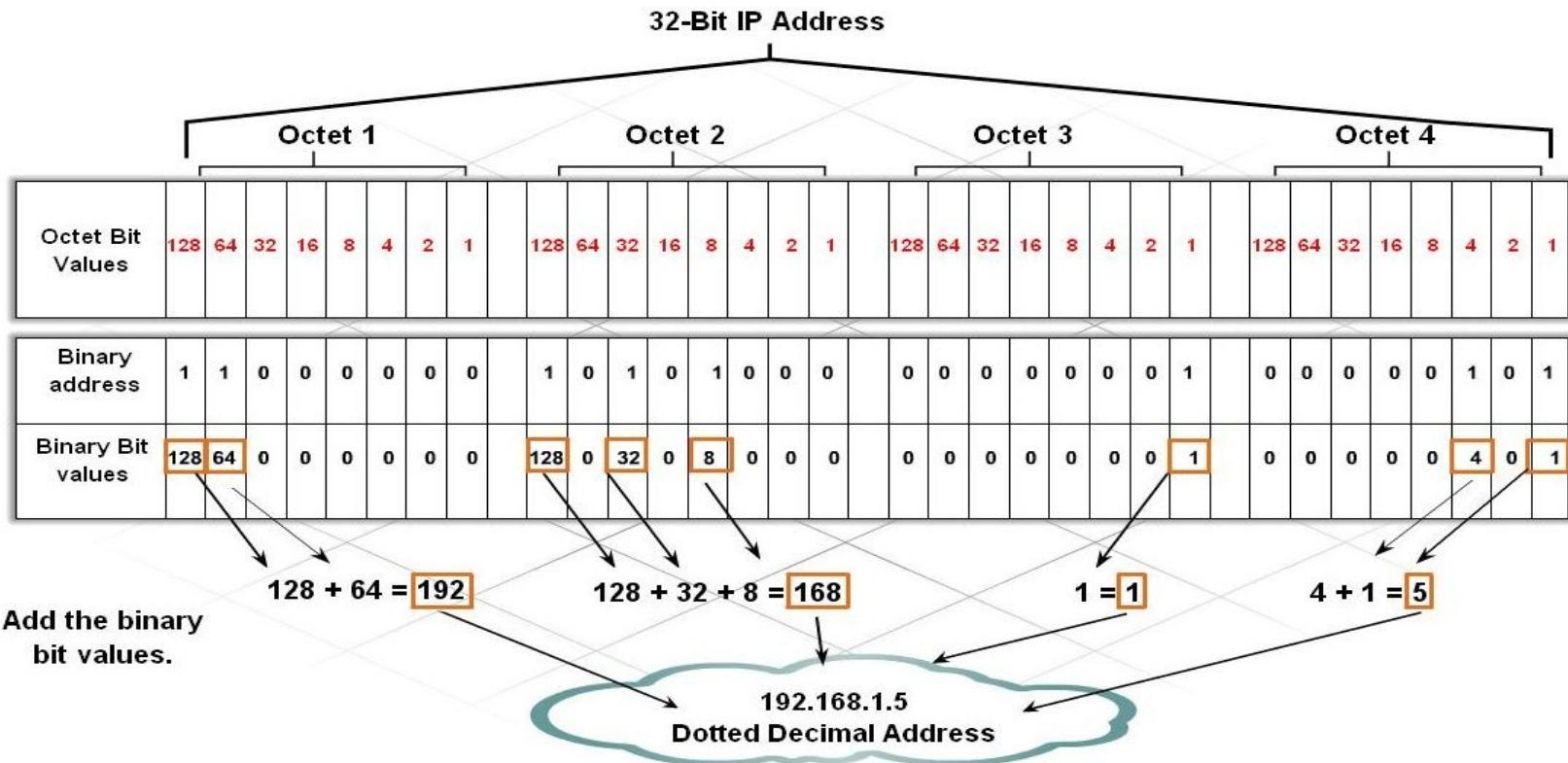


Figure 3: Structure of IP Address

Classes of IP addresses

- Different networks have different sizes. Basically, there are many small networks and few large networks.
- To provide efficient use of 32-bit address space, IPv4 defined several **address classes** and associated address formats:
 - **Class A:** allows 128 networks, 16 million hosts each.
The IP address start from **1.0.0.0** to **127.255.255.255**, and the mask address is **255.0.0.0**
 - **Class B:** allows 16,382 networks, 65,534 hosts each.
The IP address start from **128.0.0.0** to **191.255.255.255**, and the mask address is **255.255.0.0**

Classes of IP addresses

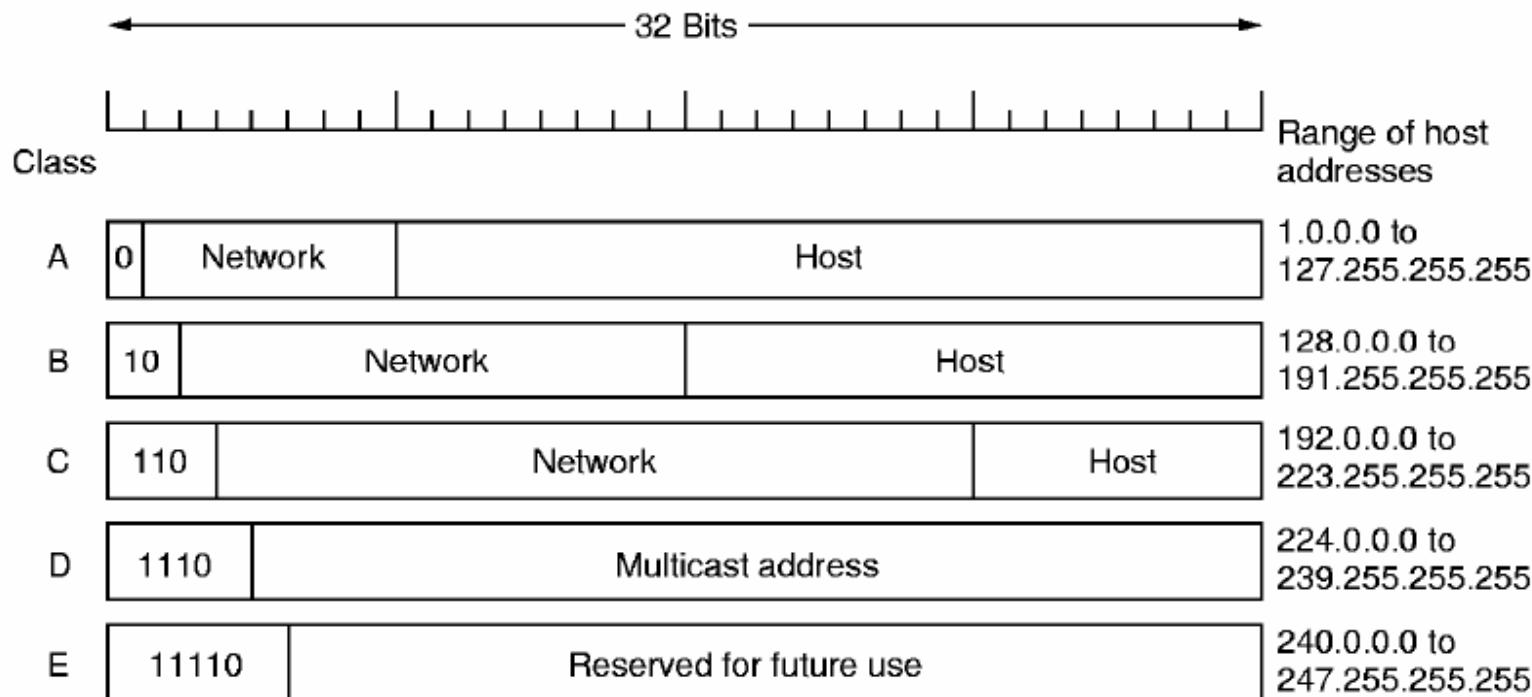
- **Class C:** allows 2 million networks, 254 hosts each.

The IP address start from **192.0.0.0** to **223.255.255.255**, and the mask address is **255.255.255.0**

- **Class D:** multicast networks The IP address start from 224.0.0.0 to 239.255.255.255.
- **Class E:** reserved for future use. From 240 to 255 and the 255.255.255.255 used for broadcast to all the subnet.

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- One of the benefits of classful addresses is that they provide a hierarchy to the network through the use of the network ID. This translates into an efficient routing environment because it is easy for a router to determine what networks can be grouped together and treated as a single routing entry.



Strategies to Conserve Addresses

- Several strategies have been developed and implemented to help the Internet community on how provides a good managing of IP addresses. These strategies help reduce the load on Internet routers and help administrators use globally unique IP addresses more efficiently. There are two common strategies, which are:
 - Private Addressing
 - Classless Inter-Domain Routing (CIDR)

Private Address

- It means If the internetwork is limited to one organization, the IP addresses need only be unique within that organization. Only networks that interface with public networks such as the Internet need public addresses. Using public addresses on the outside and private addresses for inside networks is very effective.

Private Addresses:-

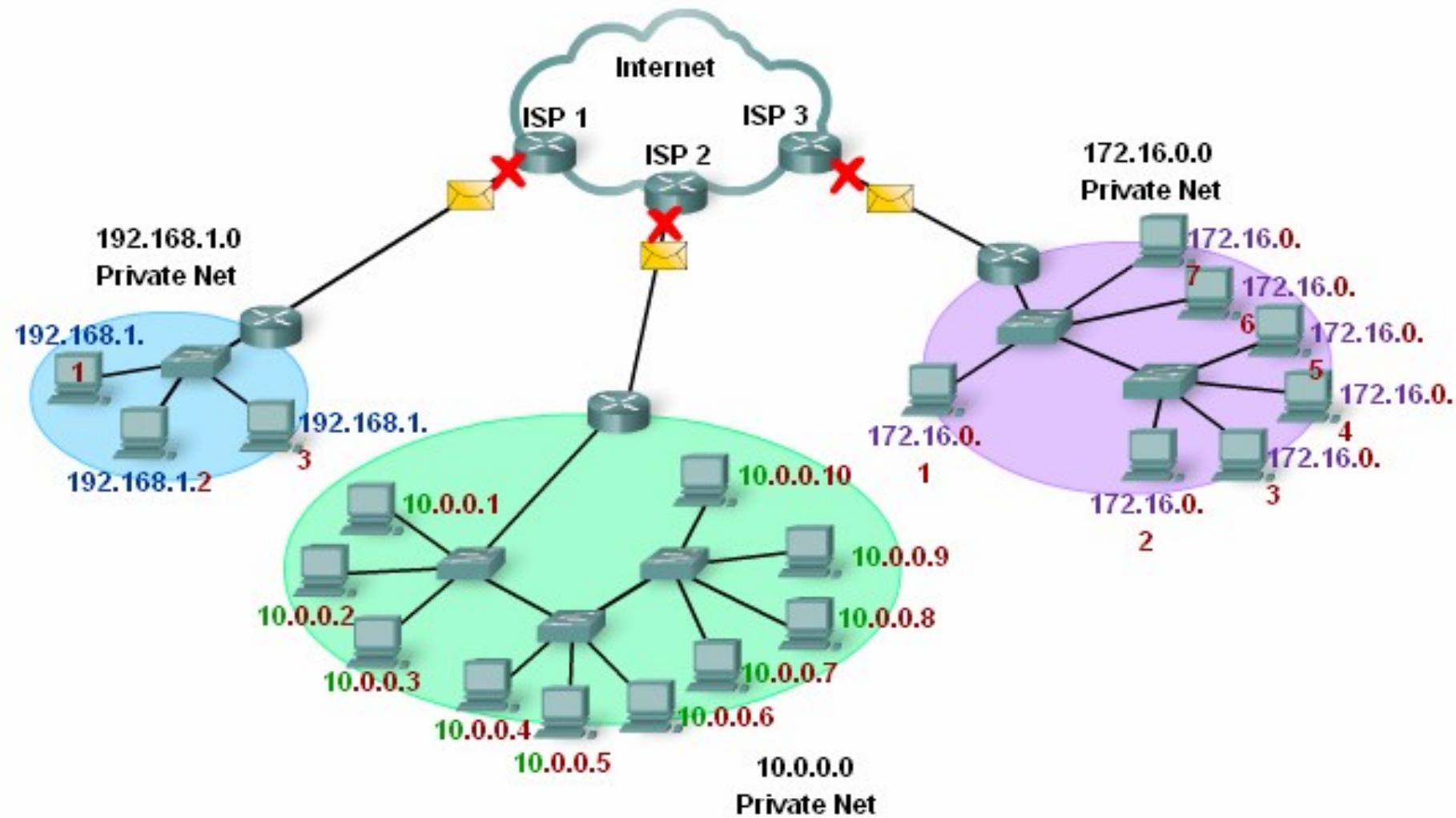
RFC1918 designates three ranges of IP addresses as private:

- 10.0.0.0 through 10.255.255.255
- 172.16.0.0 through 172.31.255.255
- 192.168.0.0 through 192.168.255.255

Address Block	Classful Equivalent	Prefix Length	Number of Addresses
10.0.0.0–10.255.255.255	1 Class A 256 Class B 65,536 Class C	/8	16,777,216
172.16.0.0–172.31.255.255	16 Class B 4,096 Class C	/12	1,048,576
192.168.0.0–192.168.255.255	1 Class B 256 Class C	/16	65,536

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Private Addresses Used in Networks without NAT



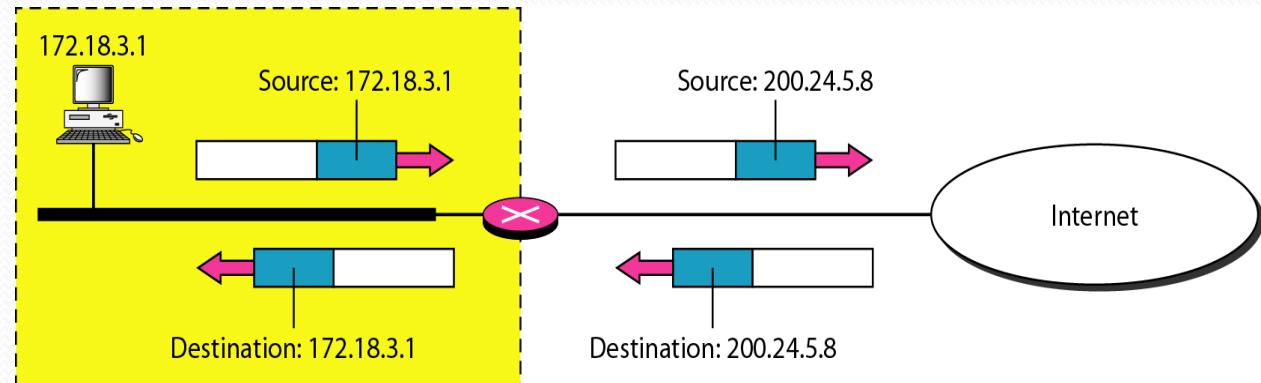
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- There are two ways to convert the private address to public address:

1. Network Address Translation (NAT).

This technique has been used to convert the private address to public address, the **NAT** allowing us to access the internet and get services. The basic idea, is that technique used pool of public addresses and assign for each private address one public address. Thus, this way is inefficient due to the fact that there are cost and delay associated with this operation. [The table and the figure below show how the NAT make the mapping.](#)

Private Address	Public Address
192.68.5.1	200.1.1.2
192.68.5.2	200.1.1.3
192.68.5.3	200.1.1.3



Cont..

2. Port Address Translation (PAT).

It's another technique used to convert the private address to public. During PAT, each computer on LAN is translated to the same IP address (public), but with a different port number assignment. This way is much better than the NAT because we can use one public address to translate any private address, therefore we saved the cost. The table below shows the process of the PAT

Private Address	Port address	Public Address	Port Number
192.68.1.3	50133	200.0.1.2	1
192.68.1.5	63887	200.0.1.2	2

- The port address will be any random number in the allowed range, that the device created it when wants to access the internet.
- The packet will contain the port number that assign to the device that wants to access the internet and through this port number, the router when get the response message will translate it and make map this message to it is private address based on the port number.

Addressing without Subnets

- If we have a class B with a Flat Network, the number of host will be more than $2^{16}=65536$ hosts,
- So the problem is here, that managing this network with this number of host is too tricky and the performance of this network will get down because of the heavy load. In other word, any single broadcast can slowdown the network.-
- Therefore, the solution is the **subnetting**. Subnetting means divide or separate the single network into multiple networks that can reduce the loading from one network.
- **The advantage of using subnetting is:-**
 1. Reduce the traffic and the increase the performance.
 2. The smaller network can easier to manage.

Subnetting

- As the number of distinct local networks grows, managing them become a serious headache. Every time a new network is installed the system administrator must contact NIC to get a new network number.
- The solution to the problem is to allow a network to be split into several independent parts for internal use but still act like a single network to the outside world. In the internet literature these parts are called **subnets**.

Subnet masks:-

- A mask is a 32-bit binary number that is expressed in dotted decimal notation. By default, a mask contains two fields, the network field and the host field. These correspond to the network number and the locally administered part of the network address. When an administrator subnets, they are adjusting the way they view the IP address. Table 1: Default masks for classful addressing

Address Class	Bits Used for Subnet Mask	Dotted Decimal Notation
Class A	1111111 00000000 00000000 00000000	255.0.0.0
Class B	11111111 11111111 00000000 00000000	255.255.0.0
Class C	11111111 11111111 11111111 00000000	255.255.255.0

Cont...

- Routers and hosts still assume class subnet masks by default:
- Class A /8 255.0.0.0
- Class B /16 255.255.0.0
- Class C /24 255.255.255.0
-
- The figure below gives an example to class C mask address:

192.	168.	21.	17
11000000	10101000	00010101	00010001
			
Prefix /24 Subnet mask:			
255.	255.	255.	0
11111111	11111111	11111111	00000000

The first three octets represent the network part and the last octet represent the host part.

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- There three important things that should be taken into our account when we thinking about subnetting:-
 1. Network address – the first one
 2. Broadcast address – the last one
 3. Host addresses – everything in between

As well as, to find the number of hosts per subnet. We can use formal $2^x - 2$, where (x) is the number of unmasked bits (0's) .

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- For example, in 11000000, the number of zeros gives us $2^6 - 2 = 62$ hosts. In this example, there are 62 hosts per subnet and we make subtract because the first IP address reserve for the network address and the last one for the network broadcast.
- While when we want to find number of networks, we can use this formal 2^y Where Y represent the number of masked bits, (1's). For example, in 11000000, the number of ones gives us =4

Reserved and Restricted Addresses

- In any subnet, there are certain addresses that cannot be assigned to an individual device because they have a special purpose. The subnet address is the first address in a range that identifies the subnet. The broadcast address is the last address in the range, and all hosts on the subnet receive traffic if anything is sent to it.
- Assume that a subnet address is **172.31.9.0** with a mask of **255.255.255.0**. The subnet address is **172.31.9.0**, and the broadcast address is **172.31.9.255**.

Classless Inter-Domain Routing (CIDR)

- Classless Inter Domain Routing (CIDR) is a method for assigning IP addresses without using the standard IP address classes like Class A, Class B or Class C. In CIDR , an IP address is represented as **A.B.C.D /n**, where "/n" is called the IP prefix or network prefix. The IP prefix identifies the number of significant bits used to identify a network.
- Example, 192.9.205.22 /18 means, the first 18 bits are used to represent the network and the remaining 14 bits are used to identify hosts.

- It's basically the method that ISPs (Internet Service Providers) use to allocate an amount of addresses to a company, a home—a customer. They provide addresses in a certain block size
- When you receive a block of addresses from an ISP, what you get will look something like this: 192.168.10.32/28. This is telling you what your subnet mask is. The slash notation (/) means how many bits are turned on (1s).
- The Class A default subnet mask, which is 255.0.0.0. This means that the first byte of the subnet mask is all ones (1s), or 11111111. When referring to a slash notation, you need to count all the 1s bits to figure out your mask. The 255.0.0.0 is considered a /8 because it has 8 bits that are 1s—that is, 8 bits that are turned on

Subnetting Class C Addresses

- ✓ In a Class C address, only 8 bits are available for defining the hosts
- ✓ subnet bits start at the left and go to the right without skipping bits. This means that the only Class C subnet masks can be the following:

Binary	Decimal	CIDR
10000000 = 128		/25
11000000 = 192		/26
11100000 = 224		/27
11110000 = 240		/28
11111000 = 248		/29
11111100 = 252		/30

The Fast Way Method: Subnetting a Class C Address

start by using the second subnet mask available with a Class C address, which borrows 2 bits for subnetting $192 = 11000000$

The 1s represent the subnet bits, and the 0's represent the host bits available in each subnet. 192 provides 2 bits for subnetting and 6 bits for defining the hosts in each subnet.

Example 255.255.255.192 (/26)

Let's use the Class C subnet mask from the preceding example, 255.255.255.192, to see how much simpler this method is than writing out the binary numbers. We're going to subnet the network address 192.168.10.0 and subnet mask 255.255.255.192.

192.168.10.0 = Network address

00000000 = 0

01000000 = 64

10000000 = 128

11000000 = 192

255.255.255.192 = Subnet mask

Now, let's answer the big five:

- *How many subnets?* Since 192 is 2 bits on (11000000), the answer would be 2^2 .
- *How many hosts per subnet?* We have 6 host bits off (11000000), so the equation would be $2^6 - 2 = 62$ hosts.
- *What are the valid subnets?* $256 - 192 = 64$. Remember, we start at zero and count in our block size, so our subnets are 0, 64, 128, and 192.

Example 255.255.255.224 (/27)

This time, we'll subnet the network address 192.168.10.0 and subnet mask 255.255.255.224.

192.168.10.0 = Network address

255.255.255.224 = Subnet mask

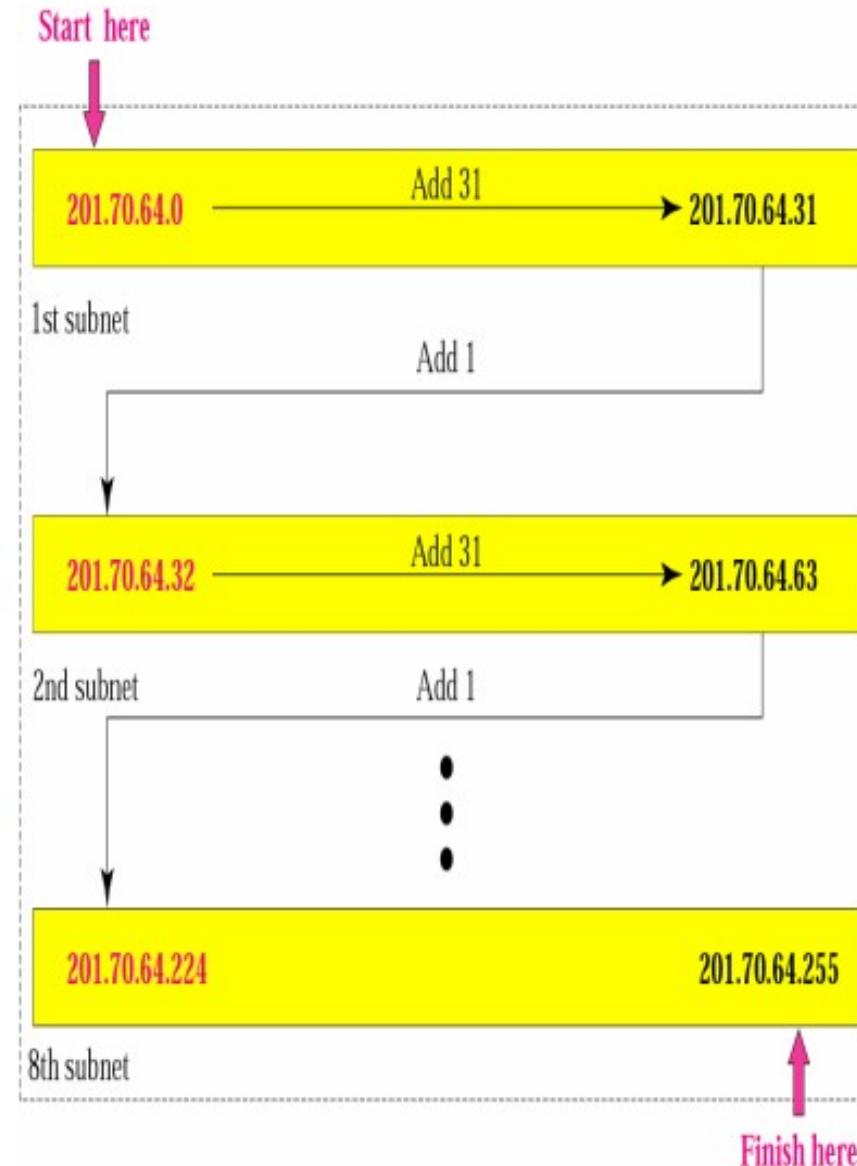
- *How many subnets?* 224 is 11100000, so our equation would be $2^3 = 8$.
- *How many hosts?* $2^5 - 2 = 30$.
- *What are the valid subnets?* $256 - 224 = 32$. We just start at zero and count to the subnet mask value in blocks (increments) of 32: 0, 32, 64, 96, 128, 160, 192, 224.

Example 3

A company is granted the site address 201.70.64.0 (class C). The company needs six subnets. Design the subnets.

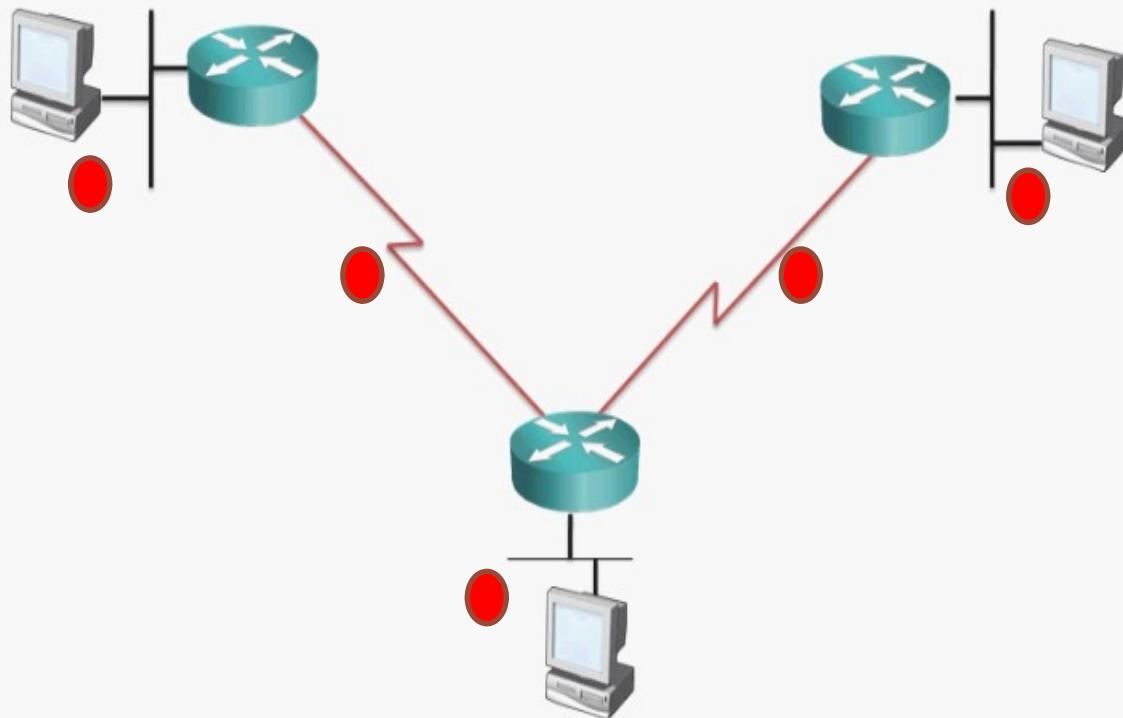
Solution

- The number of 1s in the default mask is 24 (class C).
- The company needs six subnets. This number 6 is not a power of 2. The next number that is a power of 2 is 8 (2^3). We need 3 more 1s in the subnet mask. The total number of 1s in the subnet mask is 27 ($24 + 3$).
- The total number of 0s is 5 ($32 - 27$). The mask is
11111111 11111111 11111111 11100000 or
255.255.255.224
- The number of subnets is 8.
- The number of addresses in each subnet is 2^5 (5 is the number of 0s) or 32.



Example 4

An organization has purchased the Class C Address **216.21.5.0** and would like to use it to address the following **5 networks**.



Cont...

IP: 216.21.5.0

Subnet Mask: 255.255.255.0

Networks number = 5

First: Convert the number of networks to binary.

5 = 00000101

3 bits

Second: Reserve bits in subnet mask and find your increment.

Subnet Mask: 255.255.255.0 = 11111111.11111111.11111111.00000000

11111111.11111111.11111111.11100000

3 bits

5 bits

No. of the networks = $2^{\text{number of 1's}} = 2^3 = 8$ Networks

No. of the hosts = $2^{\text{number of 0's}} - 2 = [2^5 = 32 - (2) = 30]$ Hosts number

The increment value:-

Bit Values in a Octet: 128 64 32 16 8 4 2 1

1 1 1 0 0 0 0 so our increment value is 32

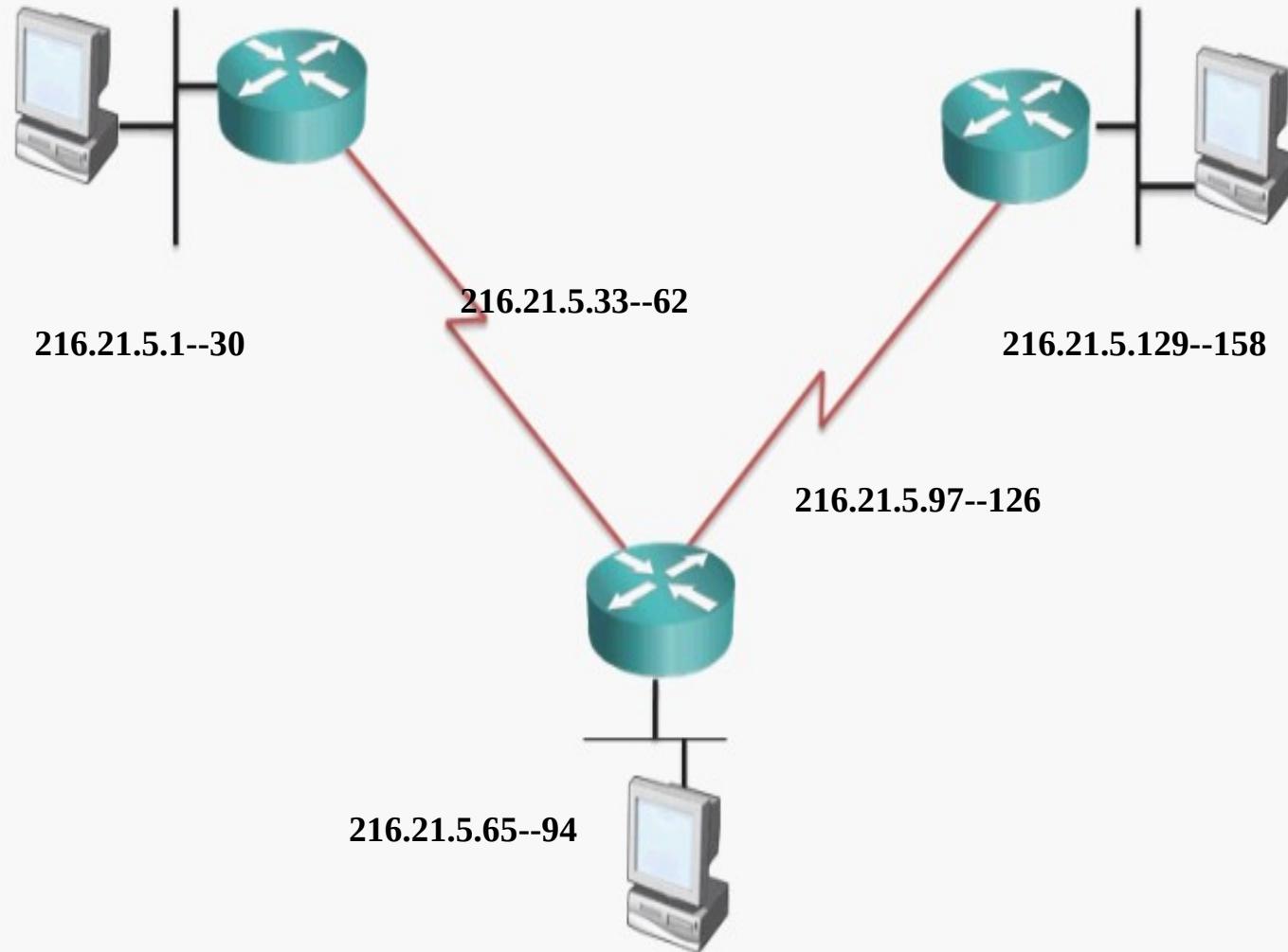
Lowest incrementing value

Cont...

- Third: Use increment to find the network ranges.

No.	Subnet address	First valid address	Last valid Address	Broadcast address
1	216.21.5.0	216.21.5.1	216.21.5.30	216.21.5.31
2	216.21.5.32	216.21.5.33	216.21.5.62	216.21.5.63
3	216.21.5.64	216.21.5.65	216.21.5.94	216.21.5.95
4	216.21.5.96	216.21.5.97	216.21.5.126	216.21.5.127
5	216.21.5.128	216.21.5.129	216.21.5.158	216.21.5.159
6	216.21.5.160	216.21.5.161	216.21.5.190	216.21.5.191
7	216.21.5.192	216.21.5.193	216.21.5.222	216.21.5.223
8	216.21.5.224	216.21.5.225	216.21.5.254	216.21.5.255

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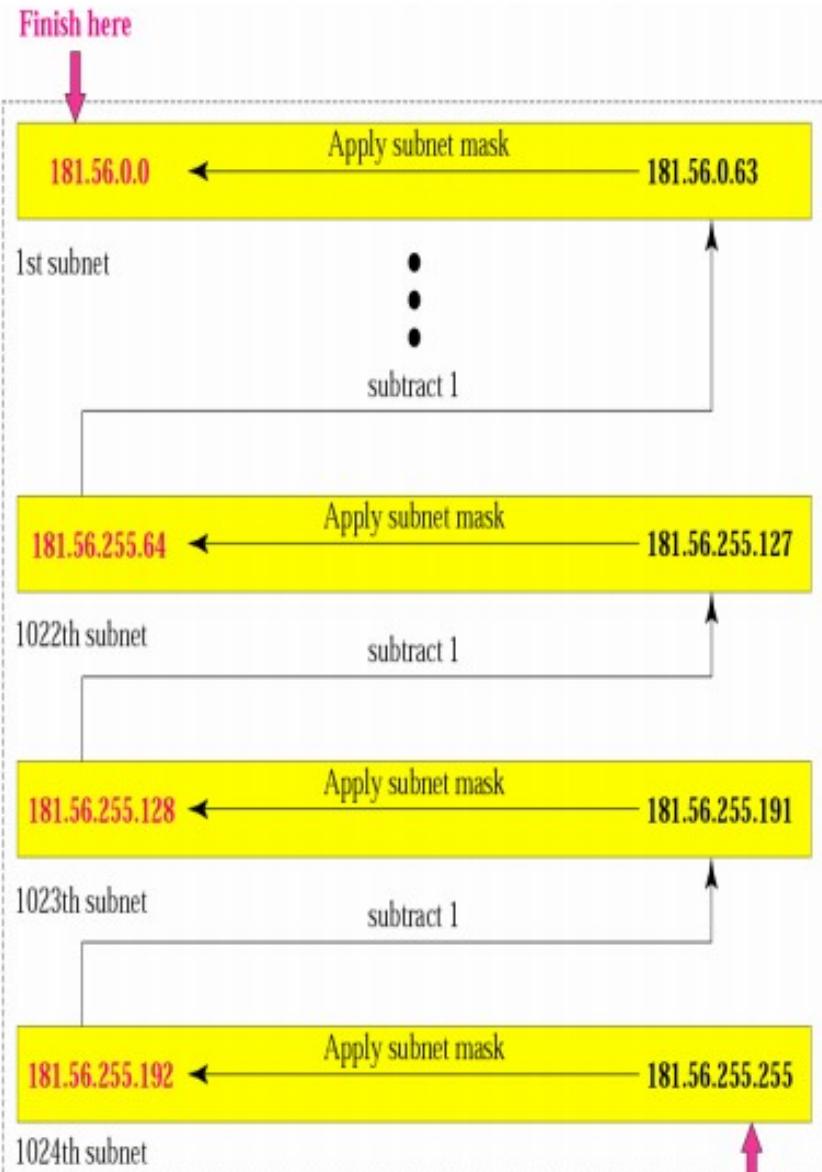


Example 5

A company is granted the site address 181.56.0.0 (class B). The company needs 1000 subnets. Design the subnets.

Solution

- The company needs 1000 subnets. This number is not a power of 2. The next number that is a power of 2 is 1024 (2^{10}). We need 10 more 1s in the subnet mask.
- The total number of 1s in the subnet mask is 26 ($16 + 10$).
- The total number of 0s is 6 ($32 - 26$). The mask is
11111111 11111111 11111111 11000000 or
255.255.255.192
- The number of subnets is 1024.
- The number of addresses in each subnet is 2^6 (6 is the number of 0s) or 64.



Example 6

What is the network address if one of the addresses is 167.199.170.82/27?

Solution

The prefix length is 27, which means that we must keep the first 27 bits as is and change the remaining bits (5) to 0s. The 5 bits affect only the last byte. The last byte is 01010010. Changing the last 5 bits to 0s, we get 01000000 or 64. The network address is 167.199.170.64/27.

Example 7

An ISP is granted a block of addresses starting with 190.100.0.0/16. The ISP needs to distribute these addresses to three groups of customers as follows:

1. The first group has 64 customers; each needs 256 addresses.
2. The second group has 128 customers; each needs 128 addresses.
3. The third group has 128 customers; each needs 64 addresses.

Design the subblocks and give the slash notation for each subblock. Find out how many addresses are still available after these allocations.

Group 1

For this group, each customer needs 256 addresses. This means the suffix length is 8 ($2^8 = 256$). The prefix length is then $32 - 8 = 24$.

01: 190.100.0.0/24 → 190.100.0.255/24

02: 190.100.1.0/24 → 190.100.1.255/24

.....

64: 190.100.63.0/24 → 190.100.63.255/24

Total = $64 \times 256 = 16,384$

Group 2

For this group, each customer needs 128 addresses. This means the suffix length is 7 ($2^7 = 128$). The prefix length is then $32 - 7 = 25$. The addresses are:

001: 190.100.64.0/25 → 190.100.64.127/25

002: 190.100.64.128/25 → 190.100.64.255/25

12 90.100.127.128/25 → 190.100.127.255/25

8:

Total = $128 \times 128 = 16,384$



*Thank you for your
attention*