Network Address & Subnetting

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Lessons Section

1 Introduction

1.1 Reserved IP Address

There are three IP network addresses reserved for private networks:

- 10.0.0.0/8
- 172.16.0.0/12
- 192.168.0.0/16

These addresses can be used by anyone setting up internal IP networks, such as an intranet. Internet routers never forward the private addresses over the public Internet.

1.2 IP Address Structure

An IP address is made up of 32 binary bits, which can be divided 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).

1.3 Subnetting & VLSM

Subnetting is a technique used to divide a larger network into smaller sub-networks.
Variable Length Subnet Masks (VLSM) are used to create sub-networks with different subnet masks.

1.4 Difference between IP Address & Subnetting

Table 1: IP Address Vs Subnetting

IP Address	**Subnetting**
Assign Unique identifiers to devices on a network	Divide a network into smaller subnetworks for better management & purpose
Assign unique ip address to device on a network	Divide a network into smaller subnets by borrowing bits from the host portion of the IP address to create a network portion
IP Address could be IPv4 & IPv6	CIDR(Classless Internet Domain Routing)
Dotted decimal notation	Subnet Mask(e.g;255.255.0.0) or CIDR notation /25
32 & 64 bits	Variable length
192.168.10.1	192.168.10.1/23

1.5 Vital Aspects

- IP addresses are used to identify devices on a computer network.
- There are three reserved IP network addresses for private networks.
- IP addresses are made up of 32 binary bits, divided into a network portion and host portion.
- Subnetting and VLSM are used to divide larger networks into smaller sub-networks and improve routing efficiency.

2 Classful Addressing

2.1 Classification of Classful Addressing

The 32-bit IP address is divided into five sub-classes. These are given below:

- Class A
- Class B
- Class C
- Class D
- Class E

Each of these classes has a valid range of IP addresses. Classes D and E are reserved for multicast and experimental purposes respectively. The order of bits in the first octet determines the classes of the IP address. The IPv4 address is divided into two parts:

- Network ID
- Host ID

The class of IP address is used to determine the bits used for network ID and host ID and the number of total networks and hosts possible in that particular class.

2.2 Class A

Table 2: Class A

Name	**Decimal Notation**
Prefix of class A	0, 0 is MSB Value
Network ID	8 bits
Host ID	24 bits
Public IP Range	1.0.0.0 to 127.0.0.0
Private IP Range	10.0.0.0 to 10.255.255.255
No of Networks	$\mathbf{2^7\text{-}2} = 126$
No of Hosts Per Network	$\mathbf{2^{24}\text{-}2} = 16{,}777{,}214$

2.3 Class B

Table 3: Class B

Name	**Decimal Notation**
Prefix of class B	1 0
Network ID	16 bits
Host ID	16 bits
Public IP Range	128.0.0.0 - 191.255.0.0
Private IP Range	172.16.0.0 to 172.31.255.255
No of Networks	$\mathbf{2^{14}\text{-}2} = 16{,}382$
No of Hosts Per Network	$\mathbf{2^{16}\text{-}2} = 65{,}534$

2.4 Class C

Table 4: Class C

Name	Decimal Notation
Prefix of class C	1 1 0
Network ID	24 bits
Host ID	8 bits
Public IP Range	192.0.0.0 - 223.255.255.0
Private IP Range	192.168.0.0 - 192.168.255.255
Special IP Range	127.0.0.1 - 127.255.255.255
No of Networks	$\mathbf{2^{21}-2}$ = 2,097,150
No of Hosts Per Network	$\mathbf{2^{8}-2}$ = 254

2.5 Important Note

IP addresses are globally managed by Internet Assigned Numbers Authority(IANA) and regional Internet registries(RIR). While finding the total number of host IP addresses, 2 IP addresses are not counted and are therefore, decreased from the total count because the first IP address of any network is the network number and whereas the last IP address is reserved for broadcast IP.

2.6 Question Answer Bank

1. How can we prove that we have 2,147,483,648 addresses in class A?
Ans: In class A, only 1 bit defines the class. The remaining 31 bits are available for the address. With 31 bits, we can have 2^{31} or 2,147,483,648 addresses

2. Given the network address 17.0.0.0, find the class, the block, and the range of the addresses.
Ans: The class is A because the first byte is between 0 and 127. The block has a netid of 17. The addresses range from 17.0.0.0 to 17.255.255.255

3. Given the network address 132.21.0.0, find the class, the block, and the range of the addresses.
Ans: The class is B because the first byte is between 128 and 191. The block has a netid of 132.21. The addresses range from 132.21.0.0 to 132.21.255.255

4. Given the network address 220.34.76.0, find the class, the block, and the range of the addresses.
Ans: The class is C because the first byte is between 192 and 223. The block has a netid of 220.34.76. The addresses range from 220.34.76.0 to 220.34.76.255

5. Given the address 23.56.7.91 and the default class A mask, find the beginning address (network address) Ans: The default mask is 255.0.0.0, which means that only the first byte is preserved and the other 3 bytes are set to 0s. The network address is 23.0.0.0

6. Given the address 132.6.17.85 and the default class B mask, find the beginning address (network address)) Ans: The default mask is 255.255.0.0, which means that the first 2 bytes are preserved and the other 2 bytes are set to 0s. The network address is 132.6.0.0

2.7 A SAMPLE INTERNET WITH CLASSFUL ADDRESSES

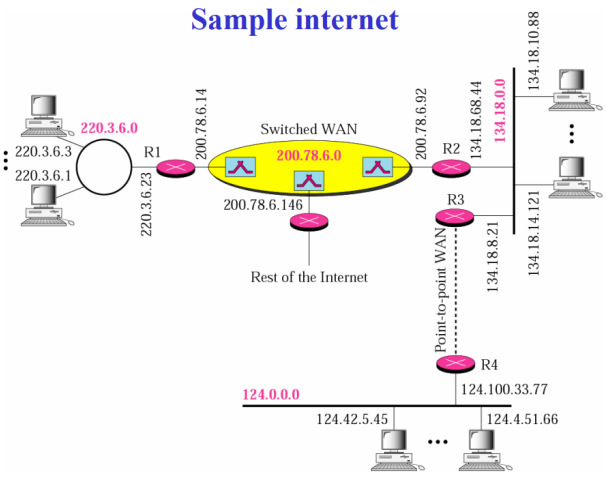

Figure 1: A Sample Internet with Classful Address

3 Classless Addressing

3.1 Classless Addressing

Classless Inter-Domain Routing (CIDR) is a method of IP address allocation and IP routing that allows for more efficient use of IP addresses. CIDR is based on the idea that IP addresses can be allocated and routed based on their network prefix rather than their class, which was the traditional way of IP address allocation.

3.2 Structure of Classless Addressing

The CIDR block comprises two parts. These are as follows:

- Block ID - Block id is used for the network identification, but the number of bits is not pre-defined as it is in the classful IP addressing scheme.
- Host ID - Host id is used to identify the host part of the network.

3.3 Notation of Classless Addressing

CIDR IP addresses look as follows:

w . x . y . z/n

In the example above, w,x,y,z each defines an 8-bit binary number, while n tells us about the number of bits used to identify the network and is called an IP network prefix or mask.

3.4 Advantages of Classless Addressing

IP addressing includes two types: Classful and Classless. Classless addressing offers a more effective method of allocating IP addresses than Classful addressing, which is the main difference between the two. To put it briefly, Classless addressing prevents the issue of IP address loss that can occur with Classful addressing.

3.5 Example of Classless Addressing

If we loop an example, if we need 1000 IP addresses, for an organization tells us a /23 block is much more efficient than a Class B allocation. /22 gives us 1022 usable host addresses. That means by switching to classless addressing, we've avoided wasting over 65,000 addresses.

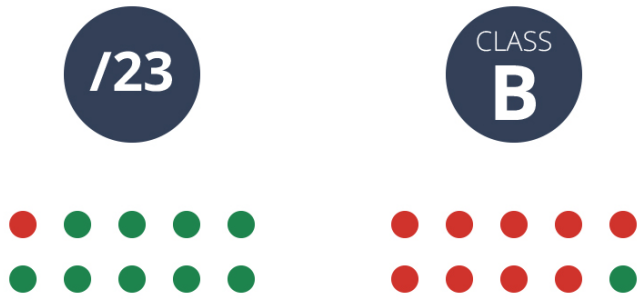

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Figure 2: With a /23, almost all IPs are used. With a Class B, 90% of IPs will be wasted.

4 Classless Address Subnetting

4.1 Subnetting Mathematical Examples

4.1.1 Practice Example 1

Find out the following things of this IP 19.23.21.78/29?

1. Block Size?
2. Number of Subnets
3. Total Number of Usable Hosts in every network?
4. Number of Usable Hosts in this network?
5. Find out Network Address?
6. Find out Usable Host IP Range
7. Find Out First Valid Host
8. Find Out Last Valid Host
9. Find Out Broadcast Address
10. Find Out Network Mask
11. Network Class Type?
12. Find Out Wildcard Mask

4.1.2 Answer of Practice Example 1

Here, CIDR Notation has given. It is 29. And, this IP belongs to class A. So, Network ID is 8 bit and Host id is 24 Bit. As, CIDR is 29 so, we use last octet. So, Binary representation will for Subnet Mask:

1 1 1 1 1 1 1 1 . 1 1 1 1 1 1 1 1 . 1 1 1 1 1 1 1 1 . 1 1 1 1 1 0 0 0

The last octet belongs to Host ID and there have 5 1s and 3 Os, that will work When we'll figure out no of Subnet ID and No of Hosts.

1. Block Size = 256-248 = 8
2. No of Subnets = $\mathbf{2}^5$ = **32**, here, power 5 means, the 5 1s of last octet in Host ID
3. Total No of Hosts Usage in every network=$\mathbf{2}^{24}$**-2** = 16,777,214 Hosts
4. Total No of Hosts in this network=$\mathbf{2}^3$**-2** = 6 Hosts Only, here, power 3 means, the 3 0s of last octet in Host ID
5. Netowrk Address = 19.23.21.72
6. First Valid Host = 19.23.21.73
7. Last Valid Host = 19.23.21.79
8. Broadcast Address = 19.23.21.80

9. Network Mask = 255.255.255.248
10. Class = A
11. Wildcard Mask = 0.0.0.7

4.1.3 Practice Example 2

Find out the following things of this IP 122.57.120.79/22?

1. Block Size?
2. Number of Subnets
3. Total Number of Usable Hosts in every network?
4. Number of Usable Hosts in this network?
5. Find out Network Address?
6. Find out Usable Host IP Range
7. Find Out First Valid Host
8. Find Out Last Valid Host
9. Find Out Broadcast Address
10. Find Out Network Mask
11. Network Class Type?
12. Find Out Wildcard Mask

4.1.4 Answer of Practice Example 2

Here, CIDR Notation has given. It is 22. And, this IP belongs to class A. So, Network ID is 8 bit and Host id is 24 Bit. As, CIDR is 22 so, we use last 2 octets. So, Binary representation will for Subnet Mask:

1 1 1 1 1 1 1 1 . 1 1 1 1 1 1 1 1 . 1 1 1 1 1 1 0 0 . 0 0 0 0 0 0 0 0

The last octet belongs to Host ID and there have 0 1s and 8 Os, that will work When we'll figure out no of Subnet ID and No of Hosts.

1. Block Size = 256-252 = 4
2. No of Subnets = $\mathbf{2^6}$ = **64**
3. Total No of Hosts Usage in every network=$\mathbf{2^{24}-2}$ = 16,777,214 Hosts
4. Total No of Hosts in this network=$\mathbf{2^{10}-2}$ = 1022 Hosts Only
5. Network Address = 122.57.120.0
6. First Valid Host = 122.57.120.1
7. Last Valid Host = 122.57.120.254

8. Broadcast Address = 122.57.120.255
9. Network Mask = 255.255.252.0
10. Class = A
11. Wildcard Mask = 0.0.3.255

4.1.5 Practice Example 3

Find out the following things of this IP 103.197.153.104/20?

1. Block Size?
2. Number of Subnets
3. Total Number of Usable Hosts in every network?
4. Number of Usable Hosts in this network?
5. Find out Network Address?
6. Find out Usable Host IP Range
7. Find Out First Valid Host
8. Find Out Last Valid Host
9. Find Out Broadcast Address
10. Find Out Network Mask
11. Network Class Type?
12. Find Out Wildcard Mask

4.1.6 Answer of Practice Example 3

Here, CIDR Notation has given. It is 20. And, this IP belongs to class A. So, Network ID is 8 bit and Host id is 24 Bit. As, CIDR is 20 so, we use last 2 octets. So, Binary representation will for Subnet Mask:

1 1 1 1 1 1 1 1 . 1 1 1 1 1 1 1 1 . 1 1 1 1 0 0 0 0 . 0 0 0 0 0 0 0 0

1. Block Size = 256-240 = 16
2. No of Subnets = $\mathbf{2^4}$ = **16**
3. Total No of Hosts Usage in every network=$\mathbf{2^{24}-2}$ = 16,777,214 Hosts
4. Total No of Hosts in this network=$\mathbf{2^{12}-2}$ = 4094 Hosts Only
5. Network Address = 103.197.144.0
6. First Valid Host = 103.197.144.1
7. Last Valid Host = 103.197.159.254

8. Broadcast Address = 103.197.159.255
9. Network Mask = 255.255.240.0
10. Class = A
11. Wildcard Mask = 0.0.15.255

4.1.7 Practice Example 4

Find out the following things of this IP 128.197.153.104/27?

1. Block Size?
2. Number of Subnets
3. Total Number of Usable Hosts in every network?
4. Number of Usable Hosts in this network?
5. Find out Network Address?
6. Find out Usable Host IP Range
7. Find Out First Valid Host
8. Find Out Last Valid Host
9. Find Out Broadcast Address
10. Find Out Network Mask
11. Network Class Type?
12. Find Out Wildcard Mask

4.1.8 Answer of Practice Example 4

Here, CIDR Notation has given. It is 27. And, this IP belongs to class B. So, Network ID is 16 bit and Host id is 16 Bit. As, CIDR is 27 so, we use last octet. So, Binary representation will for Subnet Mask:

1 1 1 1 1 1 1 1 . 1 1 1 1 1 1 1 1 . 1 1 1 1 1 1 1 1 . 1 1 1 0 0 0 0 0

1. Block Size = 256-224 = 32
2. No of Subnets = $\mathbf{2^3 = 8}$
3. Total No of Hosts Usage in every network=$\mathbf{2^{16}-2}$ = 65, 534 Hosts
4. Total No of Hosts in this network=$\mathbf{2^5-2}$ = 30 Hosts Only
5. Network Address = 128.197.153.96
6. First Valid Host = 128.197.153.97
7. Last Valid Host = 128.197.153.126

8. Broadcast Address = 128.197.153.127
9. Network Mask = 255.255.255.224
10. Class = B
11. Wildcard Mask = 0.0.0.31

4.1.9 Practice Example 5

Find out the following things of this IP 219.73.128.29/10?

1. Block Size?
2. Number of Subnets
3. Total Number of Usable Hosts in every network?
4. Number of Usable Hosts in this network?
5. Find out Network Address?
6. Find out Usable Host IP Range
7. Find Out First Valid Host
8. Find Out Last Valid Host
9. Find Out Broadcast Address
10. Find Out Network Mask
11. Network Class Type?
12. Find Out Wildcard Mask

4.1.10 Answer of Practice Example 5

Here, CIDR Notation has given. It is 10. And, this IP belongs to class C. So, Network ID is 24 bit and Host id is 8 Bit. As, CIDR is 10 so, we use last three octets. So, Binary representation will for Subnet Mask:

1 1 1 1 1 1 1 1 . 1 1 0 0 0 0 0 0 . 0 0 0 0 0 0 0 0 . 0 0 0 0 0 0 0 0

1. Block Size = 256-192 = 64
2. No of Subnets = $\mathbf{2^2 = 4}$
3. Total No of Hosts Usage in every network=$\mathbf{2^8-2}$ = 254 hosts per network
4. Total No of Hosts in this network=$\mathbf{2^{22}-2}$ = 4194302 Hosts Only
5. Network Address = 219.64.0.0
6. First Valid Host = 219.64.0.1
7. Last Valid Host = 19.127.255.254

8. Broadcast Address = 19.127.255.255
9. Network Mask = 255.192.0.0
10. Class = C
11. Wildcard Mask = 0.63.255.255

4.2 IPv4 Classless Subnet equation Bank

4.2.1 Questions

1. **192.168.1.65/28**

   Network Address: 192.168.1.64
   Broadcast Address: 192.168.1.79
   First Host Address: 192.168.1.65
   Last Host Address: 192.168.1.78

2. **192.168.20.166/25**

   Network Address: 192.168.20.128
   Broadcast Address: 192.168.20.255
   First Host Address: 192.168.20.129
   Last Host Address: 192.168.20.254

3. **192.168.30.14/29**

   Network Address: 192.168.30.8
   Broadcast Address: 192.168.30.15
   First Host Address: 192.168.30.9
   Last Host Address: 192.168.30.14

4. **192.168.20.86/30**

   Network Address: 192.168.20.84
   Broadcast Address: 192.168.20.87
   First Host Address: 192.168.20.85
   Last Host Address: 192.168.20.86

5. **How would we get no of IP addresses very easily?**

   From CIDR, we could easily get the no of IP addresses. Suppose, network prefix is /25 then, no of IP addresses will be

   2^{32-25} = 27 = 128 IPs total
   $2^{(32-25)}$-2 = 2^7-2 = 126 Useable IPs

6. **How many no of IP address will be allocated in /23?**