1. **Objective**:

- ✓ Explore IP Addressing and Subnetting IPv4 & IPv6. Understand IP addressing and subnetting. Learn to create Subnets in natural masks, subnet mask, CIDR range, count usable and total hosts in an IP address range

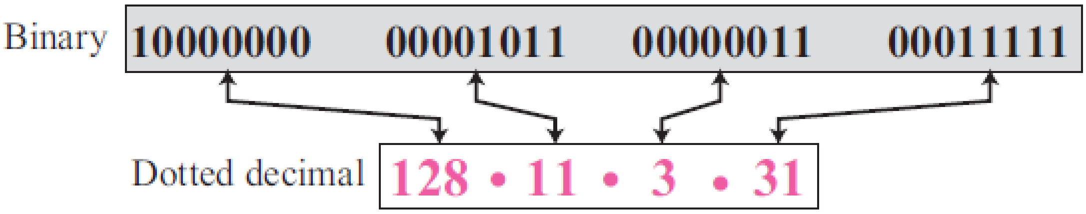
- ✓ To understand the Basics of MAC Addressing Functionality of ARP & RARP.

2. Introduction

A network is a group of connected, communicating devices such as computers and printers. An internet is two or more networks that can communicate with each other. The most notable internet is called the "Internet" which is composed of hundreds of thousands of interconnected networks.
The identifier used in the IP layer of the TCP/IP protocol suite to identify each device connected to the Internet is called the Internet address or IP address. An IPv4 address is a 32-bit address that uniquely and universally defines the connection of a host or a router to the Internet; an IP address is the address of the interface.
The IPv4 addresses are universal in the sense that the addressing system must be accepted by any host that wants to be connected to the Internet.

3. Important Definitions

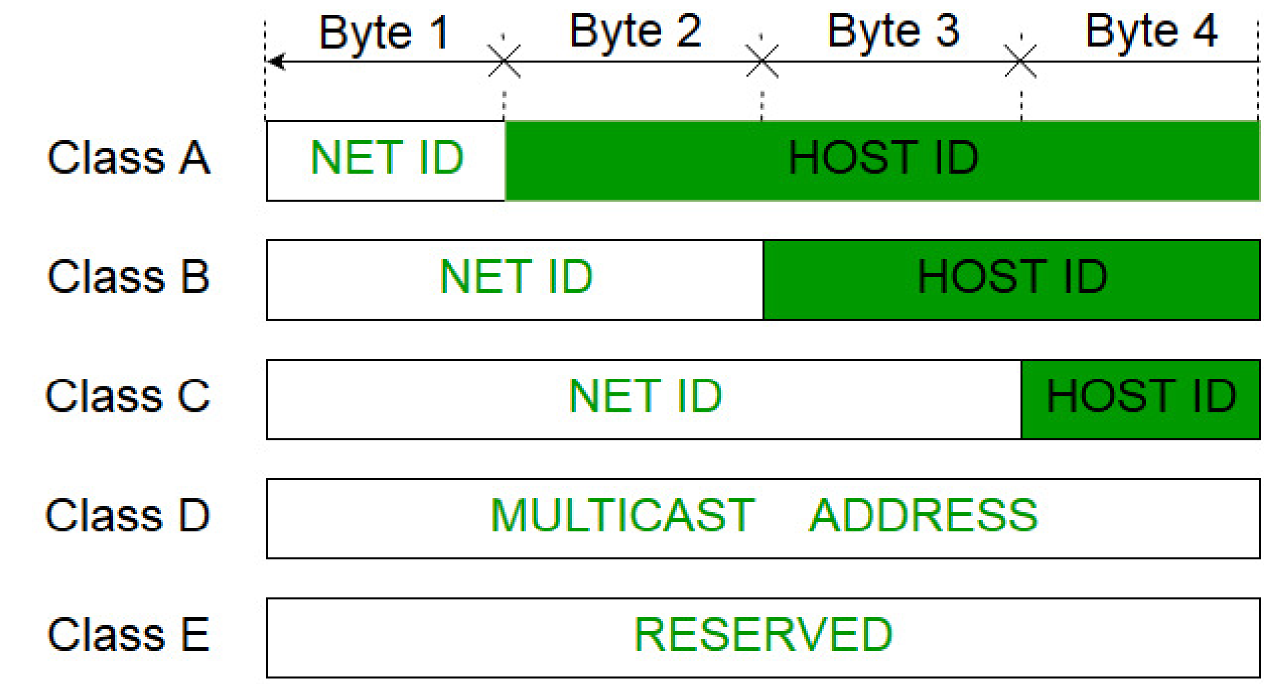
- **Bit** A *bit* is one digit, either a 1 or a 0.
- **Byte** A *byte* is 7 or 8 bits, depending on whether parity is used. For the rest of this chapter, always assume a byte is 8 bits.
- **Octet:** An octet, made up of 8 bits, is just an ordinary 8-bit binary number. In this chapter, the terms *byte* and *octet* are completely interchangeable.
- **Network address:** This is used in routing to send packets to a remote network—for example, 10.0.0.0, 172.16.0.0 and 192.168.10.0.
- **Broadcast address:** The address used by applications and hosts to send information to all nodes on a network is called the *broadcast address*. Examples include 255.255.255.255, which is any network, all nodes.
- An IP address consists of 32 bits of information. These bits are divided into four sections, referred to as octets or bytes, each containing 1 byte (8 bits). An IP address can be represented by using one of three methods:
  - Dotted-decimal as in 172.16.30.56
  - Binary, as in 10101100.00010000.00011110.00111000
  - Hexadecimal, as in AC.10.1E.38



➢ **Address Space:** An address space is the total number of addresses used by the protocol.

4. Classful Addressing

Classful IP addressing is an obsolete method for allocating IP addresses and dividing the available IP address space across networks. The IP address space is divided into five classes: A, B, C, D, and E.



Classful Addressing

In classful addressing, an IP address in classes A, B, and C is divided into netid and hostid. These parts are of varying lengths, depending on the class of the address.

Classes and Blocks

IP addresses belonging to class A are assigned to the networks that contain a large number of hosts.

- The network ID is 8 bits long.
- The host ID is 24 bits long.

The higher-order bit of the first octet in class A is always set to 0. The remaining 7 bits in the first octet are used to determine network ID. The 24 bits of host ID are used to determine the host in any network. The default subnet mask for Class A is 255.x.x.x. Therefore, class A has a total of:

- 224 - 2 = 16,777,214 host ID

IP addresses belonging to class A ranges from 0.0.0.0 - 127.255.255.255.

Class B

IP address belonging to class B is assigned to networks that range from medium-sized to large-sized networks.

- The network ID is 16 bits long.
- The host ID is 16 bits long.

The higher-order bits of the first octet of IP addresses of class B are always set to 10. The remaining 14 bits are used to determine the network ID. The 16 bits of host ID are used to determine the host in any network. The default subnet mask for class B is 255.255.x.x. Class B has a total of:

- 214 = 16384 network address
- 216 - 2 = 65534 host address

IP addresses belonging to class B ranges from 128.0.0.0 – 191.255.255.255.

Class C

IP addresses belonging to class C are assigned to small-sized networks.

- The network ID is 24 bits long.
- The host ID is 8 bits long.

The higher-order bits of the first octet of IP addresses of class C is always set to 110. The remaining 21 bits are used to determine the network ID. The 8 bits of host ID are used to determine the host in any network. The default subnet mask for class C is 255.255.255.x. Class C has a total of:

- 221 = 2097152 network address
- 28 – 2 = 254 host address

IP addresses belonging to class C range from 192.0.0.0 – 223.255.255.255.

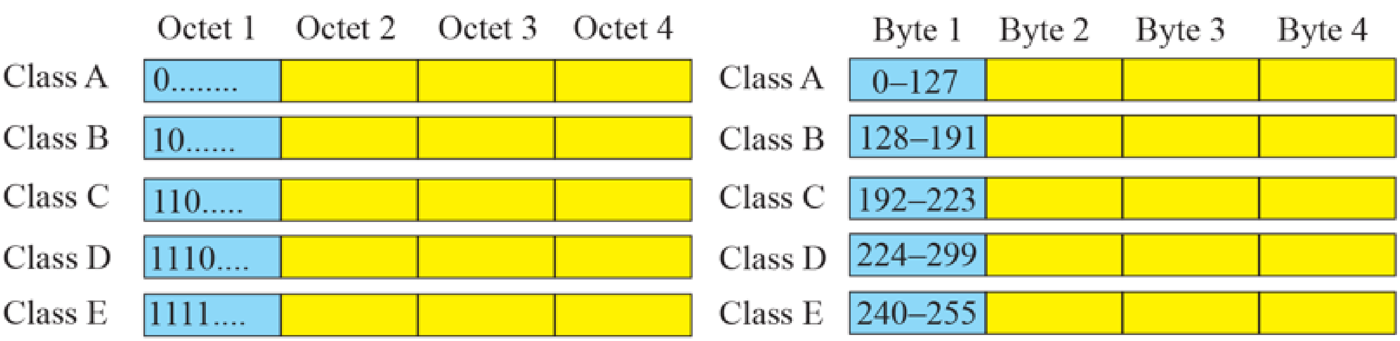
Class D

IP address belonging to class D is reserved for multi-casting. The higher-order bits of the first octet of IP addresses belonging to class D is always set to 1110. The remaining bits are for the address that interested hosts recognize.

Class D does not possess any subnet mask. IP addresses belonging to class D range from 224.0.0.0 – 239.255.255.255.

Class E

IP addresses belonging to class E are reserved for experimental and research purposes. IP addresses of class E range from 240.0.0.0 – 255.255.255.255. This class doesn't have any subnet mask. The higher-order bits of the first octet of class E are always set to 1111.



Binary notation Dotted-decimal notation

To find the class the address:

11000001 10000011 00011011 11111111

The first 2 bits are 1; the third bit is 0. This is a class C address.

5. 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.

First address = (any address) AND (network mask)

Last address = (any address) OR [NOT (network mask)]

Class A, B, and C networks have default masks, also known as natural masks:

Class A: 255.0.0.0
Class B: 255.255.0.0
Class C: 255.255.255.0
10.20.15.1= 00001010.00010100.00001111.00000001
255.0.0.0 = 11111111.00000000.00000000.00000000

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
hosted: 00010100.00001111.00000001 = 20.15.1

6. Subnetting

In subnetting, a network is divided into several smaller subnetworks (subnets) with each subnetwork having its own subnetwork address.

Subnet Mask: A Subnet mask is a 32-bit address that segregates an IP address into network bits that identify the network and host bits that identify the host device operating on that network.

Subnet Address:
When a network is subnetted, the first address in the subnet is the identifier of the subnet and is used by the router to route the packets destined for that subnetwork. Given any address in the subnet, the router can find the subnet address: ANDing the given address with the subnet mask.

Example 5.21

In Example 5.19, we show that a network is divided into four subnets. Since one of the addresses in subnet 2 is 141.14.120.77, we can find the subnet address as:

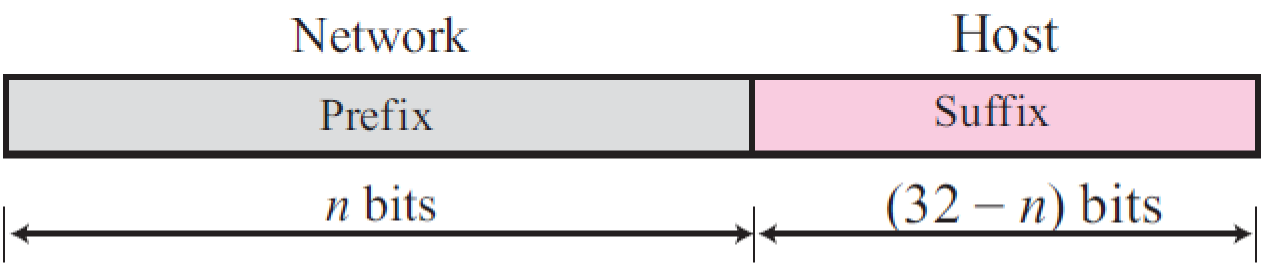
Address	→	141	.	14	.	120	.	77
Mask	→	255	.	255	.	192	.	0
Subnet Address	→	141	.	14	.	64	.	0

The values of the first, second, and fourth bytes are calculated using the first short cut for AND operation. The value of the third byte is calculated using the second short cut for the AND operation.

Address (120)	0	+	64	+	32	+	16	+	8	+	0	+	0	+	0
Mask (192)	128	+	64	+	0	+	0	+	0	+	0	+	0	+	0
Result (64)	0	+	64	+	0	+	0	+	0	+	0	+	0	+	0

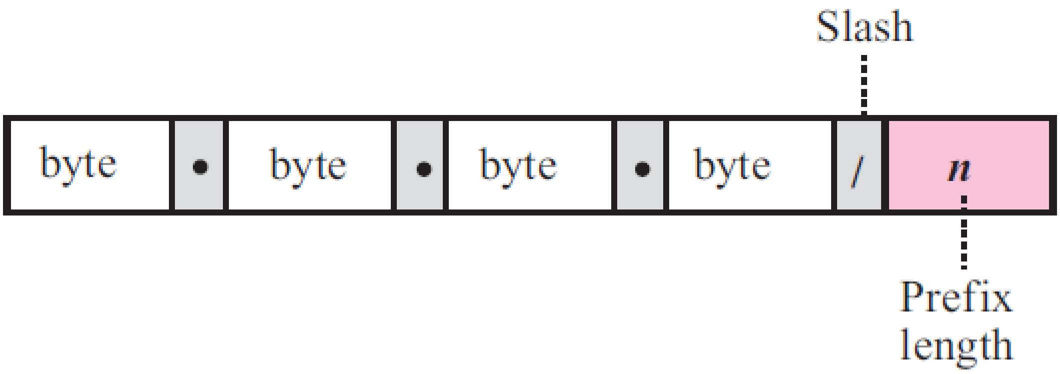
7. Classless Addressing

In classless addressing, the prefix defines the network and the suffix defines the host.



The prefix length in classless addressing can be 1 to 32.

Slash Notation: In classless addressing, we need to include the prefix length to each address if we need to find the block of the address. In this case, the prefix length, n, is added to the address separated by a slash. The notation is informally referred to as slash notation.
The slash notation is formally referred to as classless interdomain routing or CIDR (pronounced cider) notation.



8. Block Allocation

For the proper operation of the CIDR, three restrictions need to be applied to the allocated block.

1. The number of requested addresses, N, needs to be a power of 2. This is needed to provide an integer value for the prefix length, n (see the second restriction). The number of addresses can be 1, 2, 4, 8, 16, and so on.
2. The value of prefix length can be found from the number of addresses in the block. Since N = 232 − n, then n = log2 (232/N) = 32 − log2N. That is the reason why N needs to be a power of 2.

Example:

An ISP is granted a block of addresses starting with 190.100.0.0/16 (65,536 addresses). The ISP needs to distribute these addresses to three groups of customers as follows:

❑ The first group has 64 customers; each needs approximately 256 addresses.

❑ The second group has 128 customers; each needs approximately 128 addresses.

❑ The third group has 128 customers; each needs approximately 64 addresses.

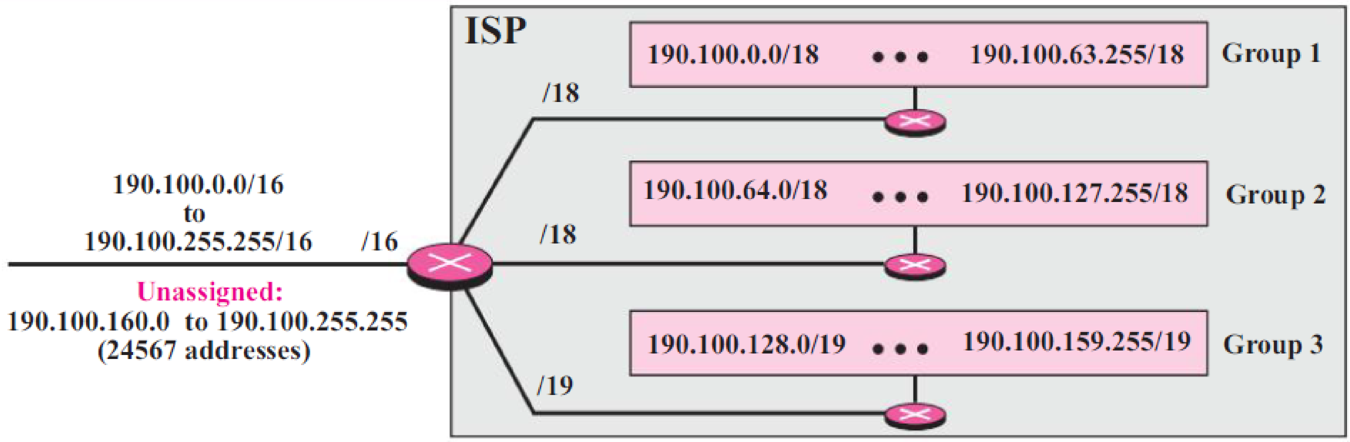
We design the subblocks and find out how many addresses are still available after these allocations.

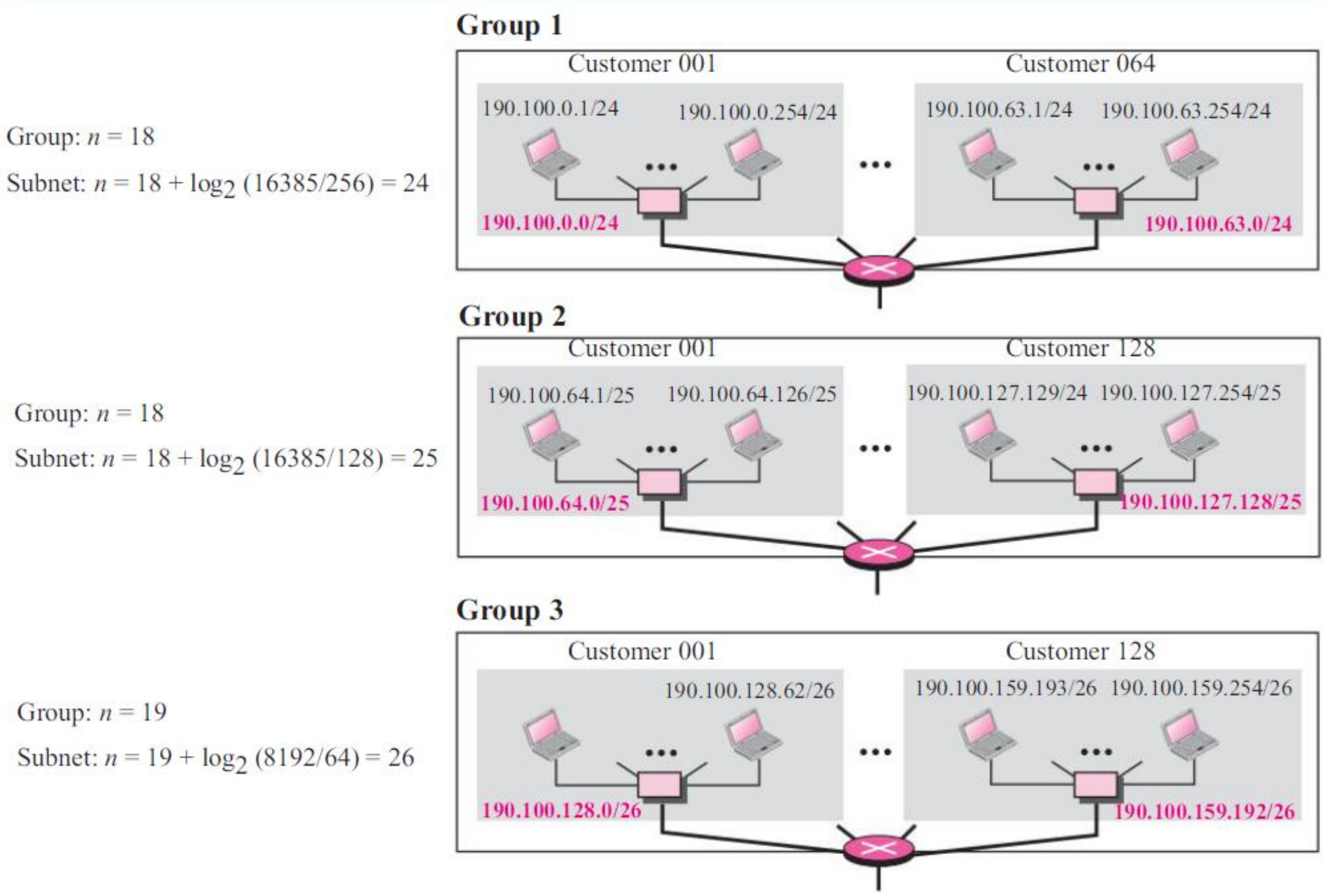
Solution:

Group 1: $64 \times 256 = 16{,}384$ $\qquad n_1 = 16 + \log_2 (65536/16384) = 18$

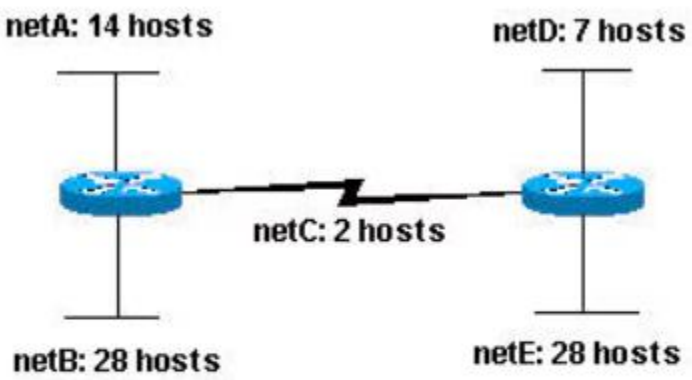
Group 2: $128 \times 128 = 16{,}384$ $\qquad n_2 = 16 + \log_2 (65536/16384) = 18$

Group 3: $128 \times 64 = 8192$ $\qquad n_3 = 16 + \log_2 (65536/8192) = 19$





Example:
Given the Class C network of 192.168.5.0/24, subnet the network to create the network in Figure 3 with the host requirements shown.



As you look at the network shown in Figure 3, you can see that you are required to create five subnets. The largest subnet must support 28 host addresses. Is this possible with a Class C network? And if so, then how?

Solution:
In order to start, look at the subnet requirement. In order to create the five needed subnets, you would need to use three bits from the Class C host bits. Two bits would only allow you four subnets (2^2).
Since you need three subnet bits, that leaves you with five bits for the host portion of the address. How many hosts does this support? $2^5 = 32$ (30 usable). This meets the requirement.
Therefore, you have determined that it is possible to create this network with a Class C network. An example of how you can assign the subnetworks is:
netA: 192.168.5.0/27 host address range 1 to 30
netB: 192.168.5.32/27 host address range 33 to 62
netC: 192.168.5.64/27 host address range 65 to 94
netD: 192.168.5.96/27 host address range 97 to 126
netE: 192.168.5.128/27 host address range 129 to 158

9. Conclusion

Understanding IP addressing and subnetting is *essential* for any network engineer, system admin, or even software dev working close to the infrastructure level. From managing devices in a network to optimizing routing and security, these concepts form the backbone of digital communication.

IPv4 and IPv6 address schemes define how devices identify and communicate. Subnetting empowers us to divide larger networks into smaller, efficient segments—boosting performance, scalability, and security. CIDR notation and subnet masks allow precise control over address distribution and host count.

10. References

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