Network Layer

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Addressing (Internet address, classful address)

several classes of IP Addresses to be used efficiently in various situations as per the requirement of hosts per network.

This addressing method divides the IP address into five separate classes .

Types of Classful IP Addresses:

- Class A: These addresses have the first octet ranging from 0 to 126 and are used for large-sized networks.
- Class B: These addresses have the first octet ranging from 128 to 191 and are used for medium-sized networks.
- Class C: These addresses have the first octet ranging from 192 to 223 and are used for small-sized networks.
- Class D: These addresses are reserved for multicast addresses and are not used for unicast communication.
- Class E: These addresses are reserved for future use and are not currently used.

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Classful IP Addressing

IP Header Classes:

Class	Address Range	Subnet masking	Example IP	Leading bits	Max number of networks	Application
IP Class A	1 to 126	255.0.0.0	1.1.1.1	8	128	Used for large number of hosts.
IP Class B	128 to 191	255.255.0.0	128.1.1.1	16	16384	Used for medium size network.
IP Class C	192 to 223	255.255.255.0	192.1.11.	24	2097157	Used for local area network.
IP Class D	224 to 239	NA	NA	NA	NA	Reserve for multi-tasking.
IP Class E	240 to 254	NA	NA	NA	NA	This class is reserved for research and Development Purposes.

Limitations

Limitations of classful IP addressing

Here are the drawbacks/ cons of the classful IP addressing method:

- Risk of running out of address space soon
- Class boundaries did not encourage efficient allocation of address space

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Private IP address

Private IP Addresses are those addresses that work within the local network.

These addresses are non-routable on the Internet.

Private IP address exists within the specific ranges as reserved by the Internet Assigned Numbers Authority (IANA).

- In **Class A**, the address range assigned to Private IP Address: **10.0.0.0 to 10.255.255.255**
- In **Class B**, the address range assigned to Private IP Address: **172.16.0.0 to 172.31.255.255**
- In **Class C**, the address range assigned to Private IP Address: **192.168.0.0 to 192.168.255.255**

Public IP Address

The range except assigned to Private IP Address is used to assign Public IP Address on a network as public IP addresses are unique for each device on the Internet.

Private IP addresses can be reused on another network which is not possible with Public IP addresses.

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Subnetting

When a bigger network is divided into smaller networks, this process is called subnetting.

Uses of Subnetting

1. Subnetting helps in organizing the network in an efficient way .
2. Subnetting divides domains of the broadcast so that traffic is routed efficiently, which helps in improving network performance.
3. Subnetting is used in increasing network security.

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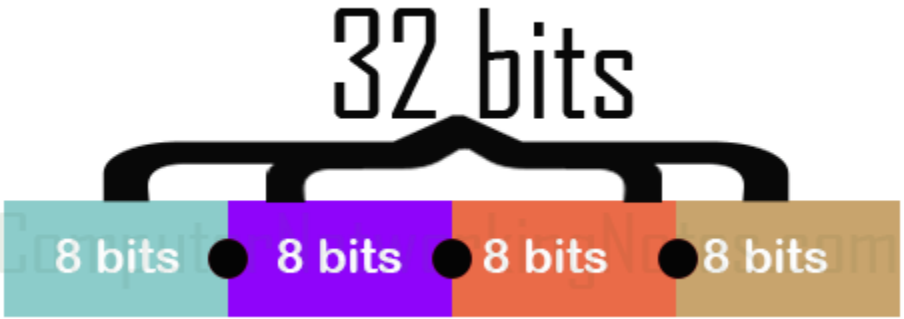
IP Address

An IP address contains two addresses: network address and host address

Both an IP address and subnet mask are 32 bits in length.

They arrange bits into four parts. Each part is known as an **octet** and contains 8 bits. Octets are separated by periods and written in a sequence.



Subnetting

All addresses between the network and broadcast addresses are known as valid host addresses.

Block size is the sum of network addresses, valid host addresses, and broadcast addresses. For example, if we have six valid host addresses, the block size will be 8 (1 network address + 6 valid host addresses + 1 broadcast address).

A class C network is subnetted in 4 subnets. Find the number of host bits used in subnetting and their location in the address space.

To create 4 subnets we need 2 ($2_2 = 4$) subnetting eligible host bits. Since in class C network space, subnetting eligible bits start from 25 and subnetting always goes from left to right without skipping any bit, the bits used in this network are 25 and 26.

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Example of subnetting

Example: Let's take a Class C network address 192.168.10.0/24. We want to create 8 sub-networks, each with 32 hosts.
Step 1: Determine the number of bits required for subnetting
To create 8 sub-networks, we need to borrow 3 bits from the host part of the address (2^3 = 8 sub-networks).
Step 2: Calculate the new subnet mask
The new subnet mask will be 24 + 3 = 27 bits.
Step 3: Calculate the new subnet mask in decimal
The new subnet mask in decimal is 255.255.255.224.
Step 4: Calculate the sub-network addresses
The sub-network addresses will be:

- 192.168.10.0/27 (first sub-network)
- 192.168.10.32/27 (second sub-network)
- ...
- 192.168.10.224/27 (eighth sub-network)

Step 5: Calculate the host addresses
Each sub-network will have 32 hosts (2^5 - 2).
Example:

- Sub-network 192.168.10.0/27:
  - Host addresses: 192.168.10.1 to 192.168.10.30
- Sub-network 192.168.10.32/27:
  - Host addresses: 192.168.10.33 to 192.168.10.62
- ...
- Sub-network 192.168.10.224/27:
  - Host addresses: 192.168.10.225 to 192.168.10.254

By subnetting the Class C network 192.168.10.0/24, we have created 8 sub-networks, each with 32 hosts. This allows for more efficient use of IP addresses and better network organization.

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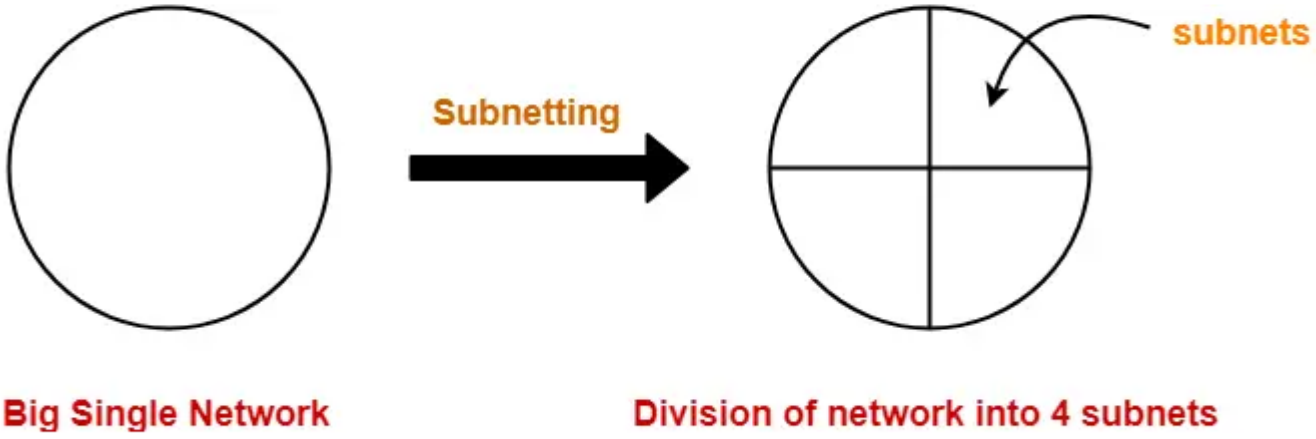
How subnetting looks like?

Following diagram shows the subnetting of a big single network into 4 smaller subnets-



Formulas

$$\text{The total number of IP Addresses creatable} = 2^{\text{The total number of Host ID Bits}} - 2.$$

- Network Address: First address in the subnet range.
- Broadcast Address: Last address in the subnet range.
- Usable Host Range: Addresses between the network and broadcast addresses

Tips: The network and broadcast addresses are not used for hosts.

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Concept of Subnets

The number of subnets created is indeed 2 to the power of the number of added or borrowed bits.

When you subnet a network, you either borrow bits from the host portion of the address to create more subnets or add bits to the network portion to create larger subnets. Regardless of which approach you take, the number of subnets is determined by 2 raised to the power of the number of added or borrowed bits.

For example:

- If you add 3 bits for subnetting (/27 subnet mask), you create 2^3 = 8 subnets.
- If you borrow 4 bits for subnetting (/28 subnet mask), you create 2^4 = 16 subnets.

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FLSM VS VLSM

FLSM (Fixed-Length Subnet Mask):

- In FLSM, the subnet masks are the same size for all subnets within a network.
- This means that all subnets have the same number of hosts.

VLSM

- VLSM allows for subnet masks of different sizes to be used for different subnets within the same network.
- This allows for more efficient utilization of IP addresses by allocating larger subnets to areas with more hosts and smaller subnets to areas with fewer hosts.

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Routing

Routing is a process that is performed by layer 3 (or network layer) devices in order to deliver the packet by choosing an optimal path from one network to another.

Routing

S.NO	Static Routing	Dynamic Routing
1.	In static routing routes are user-defined.	In dynamic routing, routes are updated according to the topology.
2.	Static routing does not use complex routing algorithms.	Dynamic routing uses complex routing algorithms.
3.	Static routing provides high or more security.	Dynamic routing provides less security.
4.	Static routing is manual.	Dynamic routing is automated.
5.	Static routing is implemented in small networks.	Dynamic routing is implemented in large networks.
6.	In static routing, additional resources are not required.	In dynamic routing, additional resources are required.
7.	In static routing, failure of the link disrupts the rerouting.	In dynamic routing, failure of the link does not interrupt the rerouting.
8.	Less Bandwidth is required in Static Routing.	More Bandwidth is required in Dynamic Routing.
9.	Static Routing is difficult to configure.	Dynamic Routing is easy to configure.
10.	Another name for static routing is non-adaptive routing.	Another name for dynamic routing is adaptive routing.

Image of Routing Table IN ROuter

```
R1>en
R1#show ip route
Codes: L - local, C - connected, S - static, R - RIP, M - mobile, B -
BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2, E - EGP
       i - IS-IS, L1 - IS-IS level-1, L2 - IS-IS level-2, ia - IS-IS
inter area
       * - candidate default, U - per-user static route, o - ODR
       P - periodic downloaded static route

Gateway of last resort is not set

     10.0.0.0/8 is variably subnetted, 2 subnets, 2 masks
C       10.10.10.0/29 is directly connected, GigabitEthernet0/0/1
L       10.10.10.1/32 is directly connected, GigabitEthernet0/0/1
     192.168.5.0/24 is variably subnetted, 2 subnets, 2 masks
C       192.168.5.0/24 is directly connected, GigabitEthernet0/0/0
L       192.168.5.1/32 is directly connected, GigabitEthernet0/0/0
O    192.168.6.0/24 [110/2] via 10.10.10.2, 01:17:43,
GigabitEthernet0/0/1
O    192.168.7.0/24 [110/2] via 10.10.10.3, 01:17:43,
GigabitEthernet0/0/1
```

```
R1#show ip route ospf
O    192.168.6.0 [110/2] via 10.10.10.2, 01:17:48,
GigabitEthernet0/0/1
O    192.168.7.0 [110/2] via 10.10.10.3, 01:17:48,
GigabitEthernet0/0/1
```

Dynamic Routing Protocols

RIP , OSPF , BGP are dynamic routing protocols.

Distance Vector Routing Protocols: Such as Routing Information Protocol (RIP) and Interior Gateway Routing Protocol (IGRP). These protocols calculate routes based on the number of hops between nodes.

Link State Routing Protocols: Such as Open Shortest Path First (OSPF) and Intermediate System to Intermediate System (IS-IS). These protocols build a detailed map of the network and calculate the shortest path to each destination.

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Distance vector vs Link State

S.No.	Distance Vector Routing	Link State Routing
1.	Bandwidth required is less due to local sharing, small packets and no flooding.	Bandwidth required is more due to flooding and sending of large link state packets.
2.	Based on local knowledge, since it updates table based on information from neighbours.	Based on global knowledge, it have knowledge about entire network.
3.	Make use of Bellman Ford Algorithm.	Make use of Dijakstra's algorithm.
4.	Traffic is less.	Traffic is more.
5.	Converges slowly i.e, good news spread fast and bad news spread slowly.	Converges faster.
6.	Count of infinity problem.	No count of infinity problem.
7.	Persistent looping problem i.e, loop will be there forever.	No persistent loops, only transient loops.
8.	Practical implementation is RIP and IGRP.	Practical implementation is OSPF and ISIS.

Distance Vector and Link State

- Distance Vector protocols work on the principle of sharing routing information between directly connected neighbors.
- Link State protocols focus on the concept of building a detailed map of the entire network.
- Each router independently gathers information about its directly connected links and advertises this information to all other routers in the network.

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RIP

Routing Information Protocol (RIP)

1. Routing Information Protocol or RIP is one of the dynamic routing protocols.

1. There are multiple versions of RIP including RIPv1 and RIPv2.
2. RIPv1 interacts with the network by broadcasting its IP table to all routers connected to the network.
3. RIPv2 is a little more sophisticated than this and sends its routing table onto a multicast address. RIPv2 also uses authentication to keep data more secure and chooses a subnet mask and gateway for future traffic.

1. The main limitation of RIP is that it has a maximum hop count of 15 which makes it unsuitable for larger networks.

OSPF

Open Shortest Path First (OSPF)

1. Open Shortest Path First or OSPF protocol is a link-state IGP that was tailor-made for IP networks using the Shortest Path First (SPF) algorithm.
2. The SPF routing algorithm is used to calculate the shortest path spanning tree to ensure efficient data transmission of packets.
3. OSPF routers maintain databases detailing information about the surrounding topology of the network. This database is filled with data taken from Link State Advertisements (LSAs) sent by other routers.
4. LSAs are packets that detail information about how many resources a given path would take.
5. OSPF also uses the Dijkstra algorithm to recalculate network paths when the topology changes. This protocol is also relatively secure as it can authenticate protocol changes to keep data secure.
6. It is used by many organizations because it's scalable to large environments.

BGP

Border Gateway Protocol (BGP)

1. Border Gateway Protocol or BGP is the **routing protocol of the internet** that is classified as a **distance path vector** protocol.
2. The BGP Best Path Selection Algorithm is used to select the best routes for data packet transfers. If you don't have any custom settings then BGP will select routes with the shortest path to the destination.

1. The best routing path selection algorithm can be customized by changing the BGP cost community attribute. BGP can make routing decisions based on Factors such as weight, local preference, locally generated, AS_Path length, origin type, multi-exit discriminator, eBGP over iBGP, IGP metric, router ID, cluster list, and neighbor IP address.

1. BGP only sends updated router table data when something changes. As a result, there is no auto-discovery of topology changes which means that the user has to configure BGP manually.

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1. In terms of security, the BGP protocol can be authenticated so that only approved routers can exchange data with each other.

IPV4 and IPV6 Important Points

Difference between IPV4 and IPV6

IPV4	IPV6
32 bits long	128 bits long
Header size 20-60 bytes	Header size 40 bytes
Dotted decimal notation	Hexadecimal notation
Separated with period(.)	Separated with colon(:)
Use of unicast, multicast and broadcast	No broadcast but has anycast

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Types of IPV6 Address

- **Unicast** – represents a single interface. Packets addressed to a unicast address are delivered to a single host.

- **Anycast** – identifies one or more interfaces. For example, servers that support the same function can use the same unicast IP address. Packets sent to that IP address are forwarded to the nearest server. Anycast addresses are used for load-balancing. Known as “one-to-nearest” address.

- **Multicast** – represents a dynamic group of hosts. Packets sent to this address are delivered to many interfaces. Multicast addresses in IPv6 have a similar purpose as their counterparts in IPv4.

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IPV6 shortening Principle

- Original: 2041:0000:140F:0000:0000:0000:875B:131B
- Shorter: 2041:0:140F::875B:131B

Rules of shortening IPV6 Address

- An entire string of zeros can be removed, you can only do this once.
- 4 zeros can be removed, leaving only a single zero.
- Leading zeros can be removed.

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Transition Techniques of IPV6

Tunneling is a technique used in networking to encapsulate one type of network protocol within another protocol. This is particularly useful when transitioning between different network architectures, such as from IPv4 to IPv6. In the context of IPv6, tunneling allows IPv6 packets to be transmitted over an IPv4 network by encapsulating the IPv6 packets within IPv4 packets.

Dual stack refers to a network configuration where devices run both IPv4 and IPv6 protocols simultaneously. This method allows seamless communication across both types of networks, facilitating the transition from IPv4 to IPv6.

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ARP and RARP

ARP Address Resolution Protocol

- **ARP is used to map a known IP address to a MAC (Media Access Control) address.**
- **It operates within the network layer of the OSI model.**

RARP (Reverse ARP)

RARP is used to map a known MAC address to an IP address.

It operates at the network layer of the OSI model, like ARP.

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Multicasting

Multicasting is a method of data transmission in which a single source sends data to multiple destinations simultaneously within a network. Unlike **broadcasting, which sends data to all devices** in a network, **multicasting targets a specific group of devices.**

Devices interested in receiving the same data stream join a multicast group.

Each multicast group is identified by a unique IP address, typically in the range **224.0.0.0 to 239.255.255.255 for IPv4.**

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1. **What is a key characteristic of Distance Vector routing protocols?** a) Routers send information only to their neighbors.
   b) Routers calculate the entire path to the destination.
   c) Routers maintain a complete map of the network topology.
   d) Routers do not share routing information with other routers.

   Ans : a

2. **Which of the following protocols is an example of a Distance Vector routing protocol?** a) OSPF (Open Shortest Path First)
   b) RIP (Routing Information Protocol)
   c) IS-IS (Intermediate System to Intermediate System)
   d) BGP (Border Gateway Protocol)

   Ans: b

3. **How often do routers using RIP (Routing Information Protocol) send their entire routing table to their neighbors?** a) Every 10 seconds
   b) Every 30 seconds
   c) Every 60 seconds
   d) Every 90 seconds

   Ans: b

4. **What is the primary algorithm used by Link State routing protocols?** a) Bellman-Ford algorithm
   b) Dijkstra's algorithm
   c) Floyd-Warshall algorithm
   d) A* algorithm

   Ans: b

5. **Which of the following protocols is an example of a Link State routing protocol?** a) RIP (Routing Information Protocol)
   b) EIGRP (Enhanced Interior Gateway Routing Protocol)
   c) OSPF (Open Shortest Path First)
   d) BGP (Border Gateway Protocol)

   Ans: c

6. **What information does a Link State routing protocol router use to create its routing table?**
   a) Information from the entire network topology
   b) Only the information from its immediate neighbors
   c) Only the information from the shortest path
   d) Information from a centralized server

   Ans: a

7. **How do routers using OSPF (Open Shortest Path First) maintain an accurate view of the network?** a) By periodically sending distance vectors to neighbors
   b) By sending Link State Advertisements (LSAs) to all routers in the network
   c) By calculating routes based on static configurations
   d) By using a combination of static and dynamic routes

   Ans: b

8. **What is a major advantage of Link State routing protocols over Distance Vector routing protocols?** a) Faster convergence
   b) Simpler to implement
   c) Uses less memory
   d) Sends updates less frequently

   Ans: a

9. **Which issue is a common drawback of Distance Vector routing protocols?** a) They require a large amount of memory.
   b) They are more complex to implement and maintain.
   c) They suffer from the "count to infinity" problem.
   d) They are less reliable in small networks.

   Ans: c

Answers:

1. a) Routers send information only to their neighbors.
2. b) RIP (Routing Information Protocol)
3. b) Every 30 seconds
4. b) Dijkstra's algorithm
5. c) OSPF (Open Shortest Path First)
6. a) Information from the entire network topology
7. b) By sending Link State Advertisements (LSAs) to all routers in the network
8. a) Faster convergence
9. b) To reduce the number of adjacencies required in a broadcast network
10. c) They suffer from the "count to infinity" problem