IP Addresses and Subnetting:

Device Requirements to connect to a Network:
- An IP Address
- Subnet Mask
- Default Gateway

An IPv4 Address:

- Is a 32-Bit Logical Address that identifies your computer on the Network
- *Logical means it's not fixed to the Computer/Device like the MAC Address which means if you change your Network your IP Address will change*
- is represented with the Dotted Decimal Notation to increase readibility for Humans
- *Four Numbers between 0 and 255 separated by a dot ' . '*
- Each number from 0-255 is a Sequence of 8 Bits or Octet and each bit can be a 0 or a 1
- *Octet = A Group of 8 and 0's and 1's means Binary Values or Bits*
- IPv4 Addresses are 32-Bits in Length so Max. Possible IP Address Values = 2^32 or approximately 4.3 Billion IP Addresses

IPv4 Address Classes

Class	IP Address Start	IP Address End	Number of Network ID Octets	Number of Host ID Octets	Max Number of Hosts	Default Subnet Mask	Use-cases
A	0.0.0.0	127.255.255.255	1	3	16 Million	255.0.0.0	ISP's and MNC's
B	128.0.0.0	191.255.255.255	2	2	65000	255.255.0.0	SMB's
C	192.0.0.0	223.255.255.255	3	1	254	255.255.255.0	General Public Use
D	224.0.0.0	239.255.255.255					Used for Multicast
E	240.0.0.0	255.255.255.255					Experiments/Testing

Why were the IP Addresses divided into these five Classes:
Let's look at the first Octet in Binary Form
Class A - Starts with all Zero : 0000 0000
Class B - 1st 2 Bits are One Zero : 1000 0000
Class C - 1st 3 Bits are One One Zero : 1100 0000
Class D - 1st 4 Bits are One One One Zero : 1110 0000
Class E - 1st 4 Bits are One One One One : 1111 0000
- Class A,B and C are used for Unicast Transmissions
- Class D is used for Multicast Transmissions
- Class E is used for research and experimentation purposes

Unicast : An Single Origin Point going towards a Single Destination
Multicast : An Single Origin Point to multiple destinations

The most fundamental unit of the data in a Computer is Bits, i.e. 0's and 1's, we use 8-Bit Binary Numbers

2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
128	64	32	16	8	4	2	1

A Subnet Mask :
- tells your computer what other Computers are present on the same network that it is on
- Splits the IP Address into 2 Sections - Network Section and Host Section
- It is represented in two ways: Dotted Decimal or CIDR

Possible Values for Subnet Masks according to Dotted Decimal Values:

Number	Binary Octet
0	0000 0000
128	1000 0000
192	1100 0000
224	1110 0000
240	1111 0000
248	1111 1000
252	1111 1100
254	1111 1110
255	1111 1111

For a subnet mask Only 1 Octet can be a value other than 0 or 255

A Subnet Mask splits the IP addresses into a Series of 1's followed by a series of 0's where:
- Network Portion is represented by a sequence of 1's
- Host Portion is represented by a sequence of 0's

Classful Subnet Masks	Binary Form
255.0.0.0	11111111.00000000.00000000.00000000
255.255.0.0	11111111.11111111.00000000.00000000
255.255.255.0	11111111.11111111.11111111.00000000

Subnets with Non 0/255 Values	Binary Form
255.255.240.0	11111111.11111111.11110000.00000000
255.254.0.0	11111111.11111110.00000000.00000000
255.255.255.248	11111111.11111111.11111111.11111000

The more Zeros which get added to the Subnet Mask the Larger the Host Portion of the IP Address but larger number of Hosts

The more Ones which get added to the Subnet Mask the Larger the Network Portion of the IP Address so smaller number of Hosts

IP Address:	172.16.15.25		Subnet Mask:	255.255.0.0			
IP Address:	1010 1100	.	0001 0000	.	0000 1111	.	0001 1001
Subnet Mask:	1111 1111	.	1111 1111	.	0000 0000	.	0000 0000
	Network Portion				Host Portion		
	If we want to reduce the number of IP's we add 1's to the Host Bits						
Subnet Mask:	1111 1111	.	1111 1111	.	1111 0000	.	0000 0000
	Network Portion				Host Portion		
New Subnet Mask			255.255.240.0				

Source IP:	172.16.15.25		Subnet Mask:	255.255.0.0			
Destination IP:	172.16.17.3						
It will use the Subnet Mask to determine if the IP Address resides on the same Network. So it will check if the Bits in the Network Portion matches for Both the IP's							
Source IP:	1010 1100	.	0001 0000	.	0000 1111	.	0001 1001
Subnet Mask:	1111 1111	.	1111 1111	.	0000 0000	.	0000 0000
	Network Portion				Host Portion		
Destination IP:	1010 1100	.	0001 0000	.	0001 0001	.	0000 0011
Yes the Bits in the Network Portion Matches so Destination is in it's own Network so send the Packet to it directly							

Source IP:	172.16.15.25		Changed Subnet Mask:					
Destination IP:	172.16.17.3		255.255.240.0					
It will use the Subnet Mask to determine if the IP Address resides on the same Network. So it will check if the Bits in the Network Portion matches for Both the IP's								
Source IP:	1010 1100	.	0001 0000	.	0000	1111	.	0001 1001
Subnet Mask:	1111 1111	.	1111 1111	.	1111	0000	.	0000 0000
	Network Portion					Host Portion		
Destination IP:	1010 1100	.	0001 0000	.	0001	0001	.	0000 0011
Here the last Bit in the Network Portion is different in the Source and Destination IP Addresses so the IP address resides in a different Network so we send it to the Default Gateway which then transfers it to the appropriate Network								

So if the Values in Network portion match - Same Network - Add Destination IP to Packet
If the Values in the Network portion don't Match - Different Network - Add Gateway Device IP to Packet

Calculating the Number of IP's in a Subnet:
1. Find the number of Zeros in a Subnet Mask
2. Raise 2 to the Power of the number from Step 1
Number of IP's in a Subnet = 2 ^ (Number of Zeros in a Subnet Mask)
3. Remove 2 from each calculated Values received to remove the Network IP and Broadcast IP Address
Number of IP's in a Subnet = 2 ^ (Number of Zeros in a Subnet Mask) - 2

Subnet Mask 255.255.0.0	Number of Hosts	=	2^16	=	65536	-2	65534	
Subnet Mask:	1111 1111	.	1111 1111	.	0000 0000	.	0000 0000	
	Network Portion				Host Portion			
Subnet Mask 255.255.240.0								
Subnet Mask:	1111 1111	.	1111 1111	.	1111	0000	.	0000 0000
	Network Portion					Host Portion		
Subnet Mask 255.255.240.0	Number of Hosts	=	2^12	=	4096	-2	4094	

Every Bit Added reduces the number of IP's by Half and the Every Bit Removed increases the Number of IP's by Double the Value

Network and Broadcast IP Addresses: Define the Boundary of the Subnet

For Every Subnet we have two reserved IP's One for the Network IP (1st IP) and One for the Broadcast IP (Last IP)

IP Address:	172.16.15.25		Subnet Mask:	255.255.0.0			
IP Address:	1010 1100	.	0001 0000	.	0000 1111	.	0001 1001
Subnet Mask:	1111 1111	.	1111 1111	.	0000 0000	.	0000 0000
	Network Portion				Host Portion		
					Network IP - All Zeroes in the Host portion		
Network IP	1010 1100	.	0001 0000	.	0000 0000	.	0000 0000
	Network IP - 172.16.0.0						
					Broadcast IP - All Ones in the Host Portion		
Broadcast IP	1010 1100	.	0001 0000	.	1111 1111	.	1111 1111
	Broadcast IP - 172.16.255.255						

IP Address	172.16.17.1		Subnet Mask:	255.255.240.0				
Binary Values:								
IP Address	1010 1100	.	0001 0000	.	0001	0001	.	0000 0001
Subnet Mask	1111 1111	.	1111 1111	.	1111	0000	.	0000 0000
	Network Portion					Host Portion		
						Network IP - All Zeroes in the Host portion		
Network IP	1010 1100	.	0001 0000	.	0001	0000	.	0000 0000
	Network IP - 172.16.16.0							
						Broadcast IP - All Ones in the Host Portion		
Broadcast IP	1010 1100	.	0001 0000	.	0001	1111	.	1111 1111
	Broadcast IP - 172.16.31.255							

CIDR - Classless Inter-Domain Routing

This represents the Number of 1's present in the Subnet Mask

Classful Subnet Masks	Binary Form	CIDR Notation
255.0.0.0	11111111.00000000.00000000.00000000	/8
255.255.0.0	11111111.11111111.00000000.00000000	/16
255.255.255.0	11111111.11111111.11111111.00000000	/24

Subnets with Non 0/255 Values	Binary Form	CIDR Notation
255.255.240.0	11111111.11111111.11110000.00000000	/20
255.254.0.0	11111111.11111110.00000000.00000000	/15
255.255.255.248	11111111.11111111.11111111.11111000	/29

It is written as : IP Address / CIDR Notation
For eg. 172.15.16.25/20 OR 192.168.1.38/24

Calculate the Values of Zero's as 32 - CIDR Value
For Eg. /20 = 32 - 20 = 12 Zeros OR /16 = 32 - 16 = 16 Zeros

Then calculate the Number of Hosts = 2^(Number of Zeros) -2
For Eg. /20 = 32-20 = 12 ; 2^12 - 2 = 4094 OR /16 = 32-16 = 16 ; 2^16 - 2 = 65534

Classfull IP's

Class	1st Octet	Usable IP's	Subnet Mask	CIDR
A	0-127	16,777,214	255.0.0.0	/8
B	128-191	65,534	255.255.0.0	/16
C	192-223	254	255.255.255.0	/24

Private IP Addresses: Private IP Blocks allocated in each IP Class

They can only be routed in the Local Area Network (LAN) and cannot be Routed accross the Internet (Not routable accross WAN or Internet)

Class	Private IP	
A	10.0.0.0/8	
B	172.16.0.0/12	
C	192.168.0.0/16	Most likely IP Address for Home Networks
		Then uses NAT to convert Private IP into Public

Loopback Address - Class A IP Address Used by a Computer to identify itself - 127.0.0.0/8

All IP Addresses Ranging from 127.0.0.0/8 to 127.255.255.255/8 can be used as a Loopback Address
For eg. ping 127.0.0.1 OR ping 127.240.131.42

APIPA - Automatic Private IP Addressing - Class B IP Address
Given to your System if it cannot connect to a DHCP Server -
IP Address : 169.254.0.0/16

IP address can be assigned Statically by giving IP Address manually or Dynamically using DHCP (Automatically leasing IP Addresses to it's connecting Hosts)