
CSPC53, COMPUTER NETWORKS
NITHYA MAM
IP ADDRESSING

IP Addressing / Local Addressing / Logical Addressing

Why do we need to have IP Address? It is needed when communication between two networks occurs – a unique address is required to uniquely identify the destination. It is used in the network layer.
[Within the same network, mac address is enough to locate the correct destination].

I/P Address defines one connection on the internet – no two devices on the internet can have the same I/P Address.
A single device with more than one interface can have many I/P Addresses. Examples of such devices are routers [each interface has a unique IP Address]. A router with 'n' interfaces will have 'n' IP Addresses.

Length of IP Address: 32 bits are used to represent an IP Address. So, 2^{32} IP Addresses are possible. By default, IPV4 is used. IPV6 addressing is also used, wherein 128 bits are present, leading to 2^{128} addresses are possible.

Notations:
1. Binary Notation – 4 bytes [4 x 8 = 32 bits]
Example – 01101110 10010101 00001111 11110000
2. Dotted Decimal Notation
Example – 117.25.18.15
Range of each decimal number – must lie from 0 to 255 [8 bits]

Combined notation is not allowed – no partial binary and partial decimal notation. Also, in dotted decimal notation, leading zeros are not allowed. 017 are not allowed – it must be mentioned as 17 only.

Types
1. Classful Addressing
2. Classless Addressing

Classful Addressing
There are 5 classes – A, B, C, D, E.

Class	*1st bits*	*1st byte in decimal not*	*Net ID*	*Host ID*	*Blocks*	*Block Size*	*Total addresses*
A	0	0 – 127	1 byte	3 bytes	2^7	2^{24}	2^{31}
B	10	128 – 191	2 bytes	2 bytes	2^{6+8}	2^{16}	2^{30}
C	110	192 – 223	3 bytes	1 byte	2^{5+8+8}	2^8	2^{29}
D	1110	224 – 239	1 block		1	2^{4+24}	2^{28}
E	1111	240 – 255	1 block		1	2^{4+24}	2^{28}

Classes A, B, and C are used for unicast communication. Class D is used for multicast communication. Class E is reserved (not used).

Class A – 1 byte for Net-ID and 3 bytes for Host-ID.

Class B – 2 bytes for Net-ID and 2 bytes for Host-ID.
Class C – 3 bytes for Net-ID and 1 byte for Host-ID.
Classes D and E – only one block, no concept of Net-ID and Host-ID.

Problem in class A – There are a very few numbers of networks. But each network has a very huge number of devices.
Problem in class C – There are too many networks. But each network has very a smaller number of devices.

Solution to the above problems:
Class A – We can divide the networks into smaller networks (sub-netting).
Class C – We can combine many networks (super-netting).

Class	*First Block*	*Second Block*	*Last Block*
A	0.0.0.0 to 0.255.255.255	1.0.0.0 to 1.255.255.255	127.0.0.0 to 127.255.255.255
B	128.0.0.0 to 128.0.255.255	128.1.0.0 to 128.1.255.255	191.255.0.0 to 191.255.255.255
C	192.0.0.0 to 192.0.0.255	192.0.1.0 to 192.0.1.255	223.255.255.0 to 223.255.255.255
D	224.0.0.0 to 239.255.255.255		
E	240.0.0.0 to 255.255.255.255		

50% of addresses are in class A, 25% in class B, 12.5% in class C and the rest in classes D and E.

Special Cases

1) All 32 bits are 0's – Whenever a device is booted, it has no knowledge of its IP address. It needs to communicate with the DHCP server to get its IP address. Till this occurs, it uses a default IP address of 0.0.0.0.

2) All 32 bits are 1's – 255.255.255.255 – used for limited broadcast. If information needs to be passed on to all devices in a network, all 1's needs to be used. However, if information needs to be passed on all devices only within a subnet, it is referred to as direct broadcast.

204.36.120.0 [class C, subnet 2] – to send information to all devices in subnet 2, the IP address must be set to 204.36.120.255.
Network Address – 204.36.120.0
Broadcast Address – 204.36.120.255

142.23.120.24 [class B], for this IP address:
Network Address – 142.23.0.0
Broadcast Address – 142.23.255.255

3) All 0's in the NetID – Example 142.23.120.24 – 0.0.120.24 – this indicates that the message must be passed within the same network (local network transmission).

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4) All 0's in the HostID – Example 142.23.120.24 – 142.23.0.0, it represents al devices in the network – it represents the whole network. It is used for direct broadcast.

Counting valid number of hosts: While doing this, the very first and last addresses must be omitted, as they represent the network address and broadcast address respectively.

5) 127.0.0.1 – Known as *loop back address* – used when the system wants to send information to itself.

Masking
Using masking, we can identify the number of bits assigned to NetID and HostID. Mask indicates the number of bits for NetID.
Class-A: 8 bits – 11111111 00000000 00000000 000000 (or) 255.0.0.0
Class-B: 16 bits – 11111111 11111111 00000000 00000000 (or) 255.255.0.0
Class-C: 24 bits – 11111111 11111111 11111111 00000000 (or) 255.255.255.0
Slash Notation: It denotes the number of bits assigned as 1.
Class-A: /8, Class-B: /16, Class-C: /24

Classless Addressing
Addresses are always assigned in a block. As it is classless addressing, we can have blocks of varying size, unlike in classful addressing.

Rules while using Classless Addressing:
1. Addresses in a block must be continuous (one after the other).
Example: 14.250.15.0, 14.250.15.1, 14.250.15.2, 14.250.15.3 ….
2. The number of addresses in a block must be a power of 2.
3. The first address in a block must be evenly divisible by the number of addresses.

Example: Considering the IP Addresses 205.16.37.32 to 205.16.37.47:
1. Addresses are continuous – satisfied.
2. Number of addresses – 16 – power of 2 – satisfied.
3. Starting Address is 205.16.37.32 = (256^3 x 205) + (256^2 x 16) + (256 x 37) + (1 x 32) = 256I + 32 (= 3440387360), which is divisible by 16 – satisfied.

Converting into decimal: 0.0.14.22 – corresponding decimal number = (256^3 x 0) + (256^2 x 0) + (256 x 14) + (1 x 22) = 3607.
Converting 3607 into decimal IP representation – done by repeated division by 256.

Questioning
Given: 1) any address in the block 2) mask
To find: 1) first address in the block 2) last address in the block

An IP Address and its mask are given by 205.16.37.39 / 28. Find out the first and last address in the block.

Mask = 28, 28 bits are assigned as 1, the last (32-28) = 4 bits are varied.
First address = set last 4 bits as 0.
Alternate approach: Number of addresses = 2^4 = 16, the first address must be divisible by 16.
205.16.37.39 = the first number before this that is divisible by 16 is *205.16.37.32*, which is the first address [the network address].
The last address is given by 205.16.37.32 + 16 - 1 = *205.16.37.47* [the broadcast address].

Alternate Approach: Bitwise AND operation of the IP Address and Mask gives the network address [the first address in the block].

1	1	0	0	1	1	0	1	0	0	0	1	0	0	0	0	0	0	1	0	0	1	0	1	0	0	1	0	0	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	1	1	0	0	0	0
1	1	0	0	1	1	0	1	0	0	0	1	0	0	0	0	0	0	1	0	0	1	0	1	0	0	1	0	0	0	0	0

Network Address = 205.16.37.32

To find the broadcast address, perform Bitwise OR between the IP Address and complement of the Mask.

1	1	0	0	1	1	0	1	0	0	0	1	0	0	0	0	0	0	1	0	0	1	0	1	0	0	1	0	0	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	0	0	0	0	0	0	1	1	1	1
1	1	0	0	1	1	0	1	0	0	0	1	0	0	0	0	0	0	1	0	0	1	0	1	0	0	1	0	1	1	1	1

Broadcast Address = 205.16.37.47

An IP Address is given as 172.26.209.179 / 20. Find the first and last address of the block in which it is present.
Mask = 20, Number of bits varied = 32-20 = 12. Number of blocks = 2^{12}.

1	0	1	0	1	1	0	0	0	0	0	1	1	0	1	0	1	1	0	1	0	0	0	1	1	0	1	1	0	0	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	0	0
1	0	1	0	1	1	0	0	0	0	0	1	1	0	1	0	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0

Network Address = 172.26.208.0

1	0	1	0	1	1	0	0	0	0	0	1	1	0	1	0	1	1	0	1	0	0	0	1	1	0	1	1	0	0	1	1
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1
1	0	1	0	1	1	0	0	0	0	0	1	1	0	1	0	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1

Broadcast Address = 172.26.223.255

An IP Address is given as 192.255.192.192. Find the maximum number of subnets.
This IP Address belongs to class C. Default mask is / 24 (or) 255.255.255.0.
Considering the last decimal place, number of extra 1's in 192 = 11000000 = 2. So, number of subnets = 2^2 = 4.

An IP Address is given as 10.0.0.0 and mask is given as 255.255.240.0. Find the maximum number of subnets.
255.255.240.0 = 11111111.11111111.11110000.00000000.
Default mask for class A – 8 bits. There are 8+4 = 12 extra 1's, so number of subnets = 2^{12}. Also, there are 4+8 = 12 zeros [host-id], so there are 2^{12} devices per subnet.

An IP Address and Mask are given as 192.168.123.0 and 255.255.255.192. Find the number of subnets and number of hosts per subnet.
Given IP Address belongs to class C. Default mask = 24 bits.
Mask = 11111111 11111111 11111111 11000000. Extra one's = 2. Zeros = 8.
Number of subnets = 2^2. Number of hosts per subnet = 2^6.

If number of subnets are given, find the mask [reverse process]:
If an IP address belonging to class B has 4 subnets, find the mask.
4 = 2^2, meaning there are 2 extra 1's.
Default mask for class B = 16 bits. Now, there are 18 bits of one's.
Mask = 11111111 11111111 11000000 00000000
Mask = 255.255.192.0

If an IP address belonging to class B has 32 subnets, find the mask.
32 = 25, so there are 5 extra 1's.
Default mask for class C = 16 bits. Now there are 21 bits of one's.
Mask = 11111111 11111111 11111000 00000000
Mask = 255.255.248.0

If an IP address belonging to class B has 30 subnets, find the mask.
To represent 30 subnets, 5 bits are needed compulsorily (ceil($\log_2$(30))).
Same as previous question – needed mask will be 255.255.248.0.

An IP Address is given as 192.168.157.208. Mask is given as 255.255.255.252. Find out the network address and broadcast address.
Mask = 11111111 11111111 11111111 11111100 == /30
Remaining zeros = 32-30 = 2
Number of addresses per subnet = 2^2 = 4 addresses.
First Address [network address] = 192.168.157.208
Last Address [broadcast address] = 192.168.157.211
Total number of valid hosts = 4-2 = 2 hosts.

An IP Address is given as 192.168.197.121 / 28. Find the network address, broadcast address and the number of valid hosts.
Mask = 11111111 11111111 11111111 11110000 = /28
Remaining zeros = 32-28 = 4
Number of addresses per subnet = 2^4 = 16 addresses.
Network Address must be divisible by 16.
Network Address = 192.168.197.112
Broadcast Address = 192.168.197.127
Total number of valid hosts = 16-2 = 14 hosts.
Valid host addresses = 192.168.192.113 to 192.168.197.126.

Two-Level Hierarchy
Classful addressing – NetID [prefix] + HostID [suffix]
Classless addressing – NetID + SubnetID [prefixes] + HostID [suffix]

An IP address is given as 17.12.14.0 / 26. 3 subnets are created, with 32 addresses in the first subnet and 16 addresses each in the second and third subnets.

Number of addresses = 2^{32-26} = 2^6 = 64 addresses = 32 + 16 + 16.
1st address = 17.12.14.0

1st subnet, 32 addresses, so 5 bits for subnet, so mask is 32-5 = /27
IP Addresses range from 17.12.14.0 /27 to 17.12.14.31 /27.
2nd subnet, 16 addresses, so 4 bits for subnet, so mask is 32-4 = /28
IP Addresses range from 17.12.14.32 /28 to 17.12.14.47 /28.
3rd subnet, 16 addresses, so 4 bits for subnet, so mask is 32-4 = /28
IP Addresses range from 17.12.14.48 /28 to 17.12.14.63 /28.

3 subnets are interconnected with a router. The router has 3 + 1 interfaces – 3 to connect to the subnets and 1 to connect to the rest of the world.
Each subnet has its own network address and a broadcast address. Remaining addresses are assigned to devices.

An IP address is given as 16.0.0.0 /8. 500 fixed sized subnets are created. Find 1) subnet mask 2) number of addresses per subnet 3) first and last address of the first subnet 4) first and last address of the 499th subnet 5) first and last address of the 500th subnet.

1) Closest power of 2 = 512, so 9 bits are required for subnet, so subnet mask is given 32-9 = */23*.
2) 8 bits for class A + 9 subnet bits = 17 bits [total mask]. Remaining = 32-17 = 15 bits for host ID. So, number of addresses per subnet = 2^{15}
3) 1st subnet: 16.0.0.0 /17 to 16.0.127.255 /17
   2nd subnet: 16.0.128.0 /17 to 16.0.255.255 /17 [adding 0.0.128.0]
4) 499th subnet: 16.249.0.0 /17 to 16.249.127.255 /17
5) 500th subnet: 16.249.128.0 /17 to 16.249.255.255 /17

An IP address is given as 211.17.180.0 / 24. Create 32 fixed size subnets. Find 1) subnet mask 2) number of addresses per subnet 3) first and last address of the first subnet 4) first and last address of the 32nd subnet.

1) 32 subnets = 5 bits required for subnet, so subnet mask is given by 32-5 = */27*.
2) 24 bits for mask + 5 subnet bits = 29 bits [total mask]. Remaining = 32-29 = 3 bits for host ID. So, number of addresses per subnet = 2^3.
3) 1st subnet: 211.17.180.0 /29 to 211.17.180.7 /29
4) Last subnet: 211.17.180.248 /29 to 211.17.180.255 /29.

A block of addresses starting from 190.100.0.0 / 16. Distribute the addresses to 3 groups. The first group contains 64 customers, with each customer needing 256 addresses. The second group contains 128 customers, with each customer needing 128 addresses. The third group contains 128 customers, with each customer needing 64 addresses. Design proper subnets and determine how many addresses are left free after performing the necessary allocations.

Total number of addresses in hand = 32-16 = 16 bits, so 2^{16} addresses are available, from 190.100.0.0 to 190.100.255.255.

Group1:
Number of addresses per customer = 256 = 8 bits for HostID, mask = 32-8 = /24.
1st customer = 190.100.0.0 /24 to 190.100.0.255 /24.
2nd customer = 190.100.1.0 /24 to 190.100.1.255 /24.
64th customer = 190.100.63.0 /24 to 190.100.63.255 /24.

Group2:
Number of addresses per customer = 128 = 7 bits for HostID, mask = 32-7 = /25.
1st customer = 190.100.64.0 /25 to 190.100.64.127 /25
2nd customer = 190.100.64.128 /25 to 190.100.64.255 /25
128th customer = 190.100.127.128 /25 to 190.100.127.255 /25

Group3:
Number of addresses per customer = 64 = 6 bits for HostID, mask = 32-6 = /26.
1st customer = 190.100.128.0 /26 to 190.100.128.63 /26
2nd customer = 190.100.128.64 /26 to 190.100.128.127 /26
128th customer = 190.100.159.192 /26 to 190.100.159.255 /26

Total addresses used = (64x256) + (128x128) + (128x64) = $2^{14} + 2^{14} + 2^{13} = 2^{15} + 2^{13}$ = 32768 + 8192 = 40960.
Total addresses available = 2^{16} = 65536.
Unused addresses = 65536 – 40960 = 24576 unused addresses are present.

A block of addresses starting at 14.24.74.0 /24 are given. These are to be distributed into 3 sub-blocks, with 120, 60 and 10 addresses each. Find the first and last address of each subnet and find the number of unused addresses after all allocation is done.

Total number of addresses in hand = 32-24 = 8 bits, so 256 addresses.

Group1:
Number of addresses per customer = 128 = 7 bits for HostID, mask = 32-7 = /25
14.24.74.0 /25 to 14.24.74.127 /25 are allocated, but only 120 are used.

Group2:
Number of addresses per customer = 64 = 6 bits for HostID, mask = 32-6 = /26
14.24.74.128 /26 to 14.24.74.191 /26 are allocated, but only 60 are used.

Group3:
Number of addresses per customer = 16 = 4 bits for HostID, mask = 32-4 = /28
14.24.74.192 /28 to 14.24.74.207 /28 are allocated, but only 10 are used.

Number of addresses used = 128 + 64 + 16 = 208 addresses.
Remaining = 256 – 208 = 48 addresses.

Network Address is given as 191.254.0.0. 11 bits are used for subnetting. Which of the following is a valid host address?

(A) 191.254.0.32 (B) 191.254.1.64 (C) 191.254.0.96 (D) 191.254.0.29

Class B Address – Default mask is 16. Total mask = 16+11 = /27
Number of subnets = 2^{27}, number of devices per subnet = 2^5

1st subnet: 191.254.0.0 to 191.254.0.31
2nd subnet: 191.254.0.32 to 191.254.0.63
3rd subnet: 191.254.0.64 to 191.254.0.95
4th subnet: 191.254.0.96 to 191.254.0.127

A – network address of 2nd subnet, not a valid host ID
B – network address of 3rd subnet, not a valid host ID
C – network address of 4th subnet, not a valid host ID
D – belongs to 1st subnet, is a valid host ID
So, 191.254.0.29 is the only valid host ID among the given IP Addresses.

A class-A IP Address is given. 1000 subnets were present, 100 more subnets are required with the largest number of possible host addresses per subnet. Find the subnet mask.
Total number of subnets = 1100, ceil($\log_2$(1100)) = 11, so 11 bits are required for subnet. Class A Address already has 8 bits for NetID, so total mask = 11+8 = */19* (or) 11111111 11111111 11100000 00000000 = 255.255.224.0.
