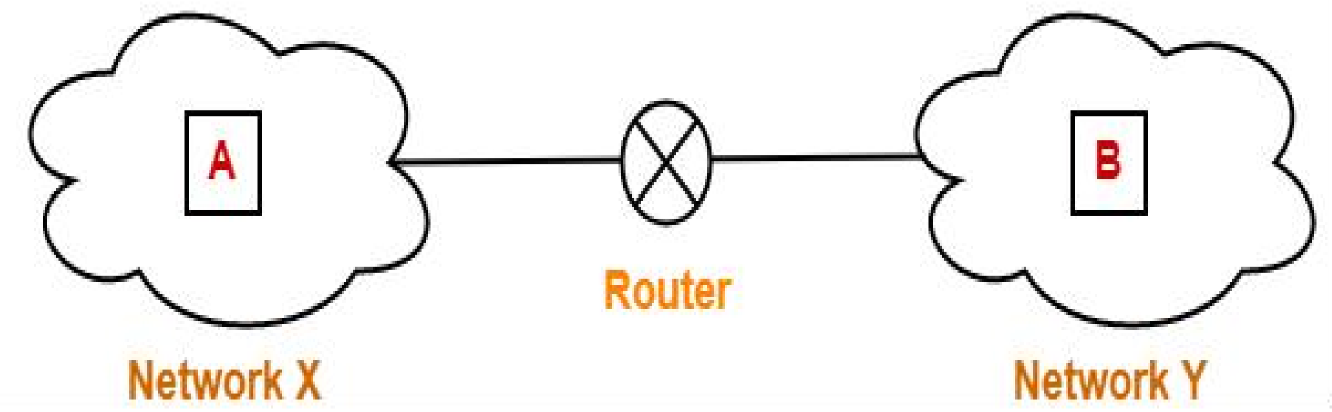
CN: WEEK 9

IP Fragmentation

IP Fragmentation is a process of dividing the datagram into fragments during its transmission.
It is done by intermediary devices such as routers at the destination host at network layer.



Why Fragmentation is needed:

- ***Each network has its maximum transmission unit (MTU).***
- ***It dictates the maximum size of the packet that can be transmitted through it.***
- ***Data packets of size greater than MTU can not be transmitted through the network.***
- ***So, datagrams are divided into fragments of size less than or equal to MTU.***

When router receives a datagram to transmit further, it examines the following:

- ✓ Size of the datagram
- ✓ MTU of the destination network
- ✓ DF bit value in the IP header

Case-01:

Size of the datagram is found to be smaller than or equal to MTU.
In this case, router transmits the datagram without any fragmentation.

Case-02:

Size of the datagram is found to be greater than MTU and DF bit set to 1.
In this case, router discards the datagram.

Case-03:

Size of the datagram is found to be greater than MTU and DF bit set to 0.
In this case, router divides the datagram into fragments of size less than or equal to MTU.
Router attaches an IP header with each fragment making the following changes in it.
Then, router transmits all the fragments of the datagram.

Changes Made By Router

- It changes the value of total length field to the size of fragment.
- It sets the MF bit to 1 for all the fragments except the last one.
- For the last fragment, it sets the MF bit to 0.
- It sets the fragment offset field value.
- It recalculates the header checksum.

Consider-
There is a host A present in network X having MTU = 520 bytes.
There is a host B present in network Y having MTU = 200 bytes.
Host A wants to send a message to host B.

Consider router receives a datagram from host A having-
Header length = 20 bytes
Payload length = 500 bytes
Total length = 520 bytes
DF bit set to 0

Router examines the datagram and finds-

- Size of the datagram = 520 bytes
- Destination is network Y having MTU = 200 bytes
- DF bit is set to 0

Router concludes-

- Size of the datagram is greater than MTU.
- So, it will have to divide the datagram into fragments.
- DF bit is set to 0.
- So, it is allowed to create fragments of the datagram.

Router decides the amount of data that it should transmit in each fragment.

Router knows-

- MTU of the destination network = 200 bytes.
- So, maximum total length of any fragment can be only 200 bytes.
- Out of 200 bytes, 20 bytes will be taken by the header.
- So, maximum amount of data that can be sent in any fragment = 180 bytes.

RULE

The amount of data sent in one fragment is chosen such that-

- It is as large as possible but less than or equal to MTU.
- It is a multiple of 8 so that pure decimal value can be obtained for the fragment offset field.

NOTE

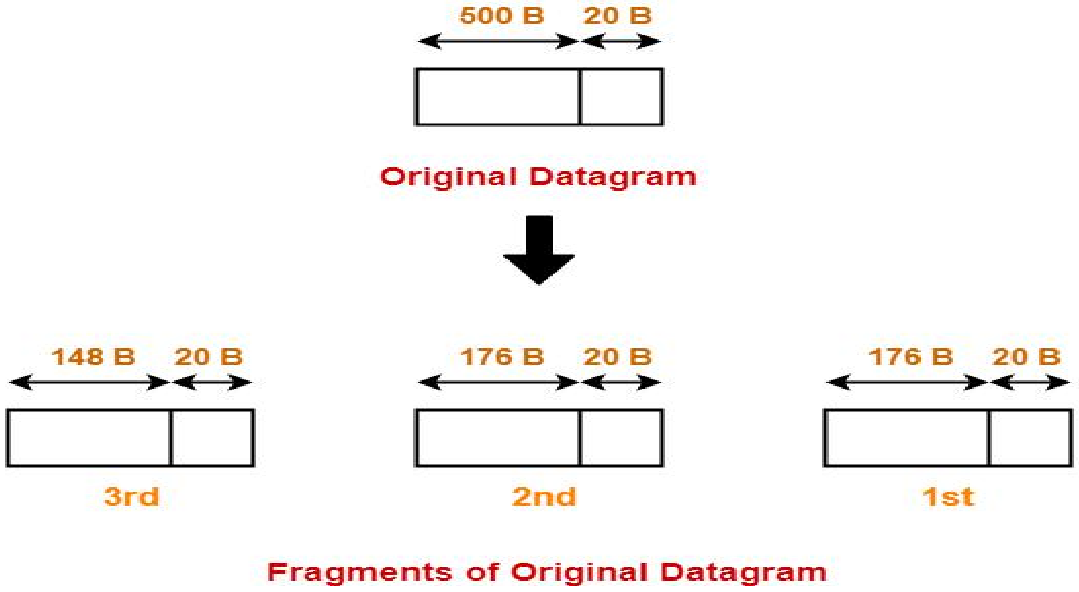
- It is not compulsory for the last fragment to contain the amount of data that is a multiple of 8.
- This is because it does not have to decide the fragment offset value for any other fragment.

Following the above rule,

- Router decides to send maximum 176 bytes of data in one fragment.
- This is because it is the greatest value that is a multiple of 8 and less than MTU.

Router creates three fragments of the original datagram where-

First fragment contains the data = 176 bytes
Second fragment contains the data = 176 byes
Third fragment contains the data = 148 bytes



Header Information Of 1st Fragment-

- Header length field value = 20 / 4 = 5
- Total length field value = 176 + 20 = 196
- MF bit = 1
- Fragment offset field value = 0
- Header checksum is recalculated.
- Identification number is same as that of original datagram.

Header Information Of 2nd Fragment-

- Header length field value = 20 / 4 = 5
- Total length field value = 176 + 20 = 196
- MF bit = 1
- Fragment offset field value = 176 / 8 = 22
- Header checksum is recalculated.
- Identification number is same as that of original datagram.

Header Information Of 3rd Fragment-

- Header length field value = 20 / 4 = 5
- Total length field value = 148 + 20 = 168
- MF bit = 0
- Fragment offset field value = (176 + 176) / 8 = 44
- Header checksum is recalculated.
- Identification number is same as that of original datagram.

At destination side,

- Receiver receives 3 fragments of the datagram.
- Reassembly algorithm is applied to combine all the fragments to obtain the original datagram.

Classless Addressing

- Classless Addressing is an improved IP Addressing system.
- It makes the allocation of IP Addresses more efficient.
- It replaces the older classful addressing system based on classes.
- It is also known as Classless Inter Domain Routing (CIDR).

When a user asks for specific number of IP Addresses,

- CIDR dynamically assigns a block of IP Addresses based on certain rules.
- This block contains the required number of IP Addresses as demanded by the user.
- This block of IP Addresses is called as a CIDR block.

Rule-01:
All the IP Addresses in the CIDR block must be contiguous.

Rule-02:
The size of the block must be presentable as power of 2.
Size of the block is the total number of IP Addresses contained in the block.
Size of any CIDR block will always be in the form 2^1, 2^2, 2^3, 2^4, 2^5 and so on.

Rule-03:
First IP Address of the block must be divisible by the size of the block.

CIDR Notation

CIDR IP Addresses look like-

a.b.c.d / n

They end with a slash followed by a number called as IP network prefix.
IP network prefix tells the number of bits used for the identification of network.
Remaining bits are used for the identification of hosts in the network.

Example:

182.0.1.2 / 28

It suggests-

28 bits are used for the identification of network.
Remaining 4 bits are used for the identification of hosts in the network.

Given the CIDR representation 20.10.30.35 / 27. Find the range of IP Addresses in the CIDR block.

Given CIDR representation is 20.10.30.35 / 27.

It suggests-

- 27 bits are used for the identification of network.
- Remaining 5 bits are used for the identification of hosts in the network.

Given CIDR IP Address may be represented as-

00010100.00001010.00011110.00100011 / 27

So,

- First IP Address = 00010100.00001010.00011110.001**00000** = 20.10.30.32
- Last IP Address = 00010100.00001010.00011110.001**11111** = 20.10.30.63

Thus, Range of IP Addresses = [20.10.30.32 , 20.10.30.63]

Consider a block of IP Addresses ranging from 100.1.2.32 to 100.1.2.47.
Is it a CIDR block?
If yes, give the CIDR representation.

For any given block to be a CIDR block, 3 rules must be satisfied-

Rule-01:

- According to Rule-01, all the IP Addresses must be contiguous.
- Clearly, all the given IP Addresses are contiguous.
- So, Rule-01 is satisfied.

Rule-02:

- According to Rule-02, size of the block must be presentable as 2^n.
- Number of IP Addresses in the given block = 47 – 32 + 1 = 16.
- Size of the block = 16 which can be represented as 2^4.
- So, Rule-02 is satisfied.

Rule-03:

- According to Rule-03, first IP Address must be divisible by size of the block.
- So, 100.1.2.32 must be divisible by 2^4.
- 100.1.2.32 = 100.1.2.0010**0000** is divisible by 2^4 since its 4 least significant bits are zero.
- So, Rule-03 is satisfied.

Since all the rules are satisfied, therefore given block is a CIDR block.

CIDR Representation-

We have-

- Size of the block = Total number of IP Addresses = 2^4.
- To have 2^4 total number of IP Addresses, total 4 bits are required in the Host ID part.
- So, Number of bits present in the Network ID part = 32 – 4 = 28.

CIDR Representation = 100.1.2.32 / 28

Perform CIDR aggregation on the following IP Addresses-

128.56.24.0/24

128.56.25.0/24

128.56.26.0/24

128.56.27.0/24

All the 4 given entities represent CIDR block in itself.
We have to now perform the aggregation of these 4 blocks.

Rule-01:

- According to Rule-01, all the IP Addresses must be contiguous.
- Clearly, all the IP Addresses are contiguous.
- So, Rule-01 is satisfied.

Rule-02:

- According to Rule-02, size of the block must be presentable as 2^n.
- Total number of IP Addresses = $2^8 + 2^8 + 2^8 + 2^8 = 2^2 \times 2^8 = 2^{10}$.
- So, Rule-02 is satisfied.

Rule-03:

- According to Rule-03, first IP Address must be divisible by size of the block.
- So, 128.56.24.0 must be divisible by 2^{10}.
- 128.56.24.0 = 128.56.000110**00.00000000** is divisible by 2^{10} since its 10 least significant bits are zero.
- So, Rule-03 is satisfied.

Since all the 3 rules are satisfied, so they can be aggregated.

CIDR Representation-

We have-

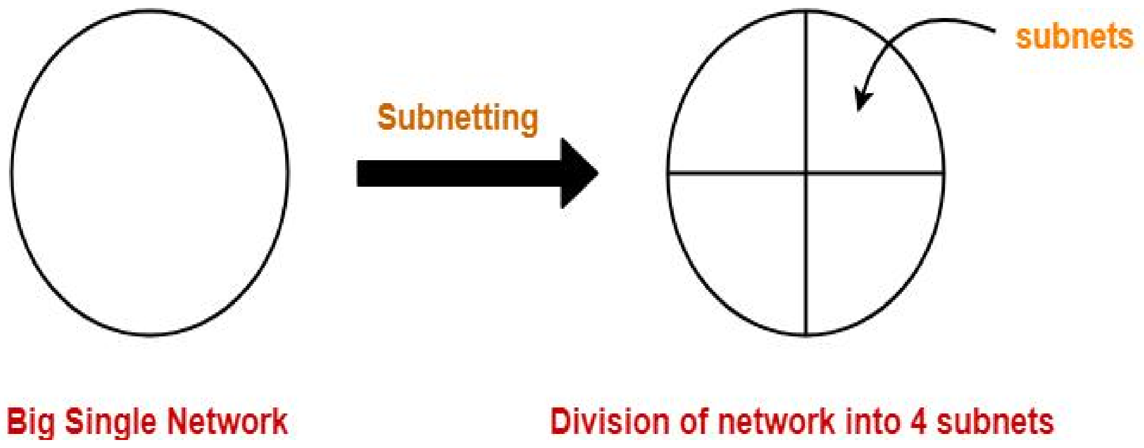
- Size of the block = Total number of IP Addresses = 2^{10}.
- To have 2^{10} total number of IP Addresses, 10 bits are required in the Host ID part.
- So, Number of bits in the Network ID part = 32 – 10 = 22.

CIDR Representation = 128.56.24.0/22

Subnetting in Networking

Each IP class is equipped with its own default subnet mask which bounds that IP class to have prefixed number of Networks and prefixed number of Hosts per network. Classful IP addressing does not provide any flexibility of having less number of Hosts per Network or more Networks per IP Class.

CIDR or Classless Inter Domain Routing provides the flexibility of borrowing bits of Host part of the IP address and using them as Network in Network, called Subnet. By using subnetting, one single Class A IP address can be used to have smaller sub-networks which provides better network management capabilities.



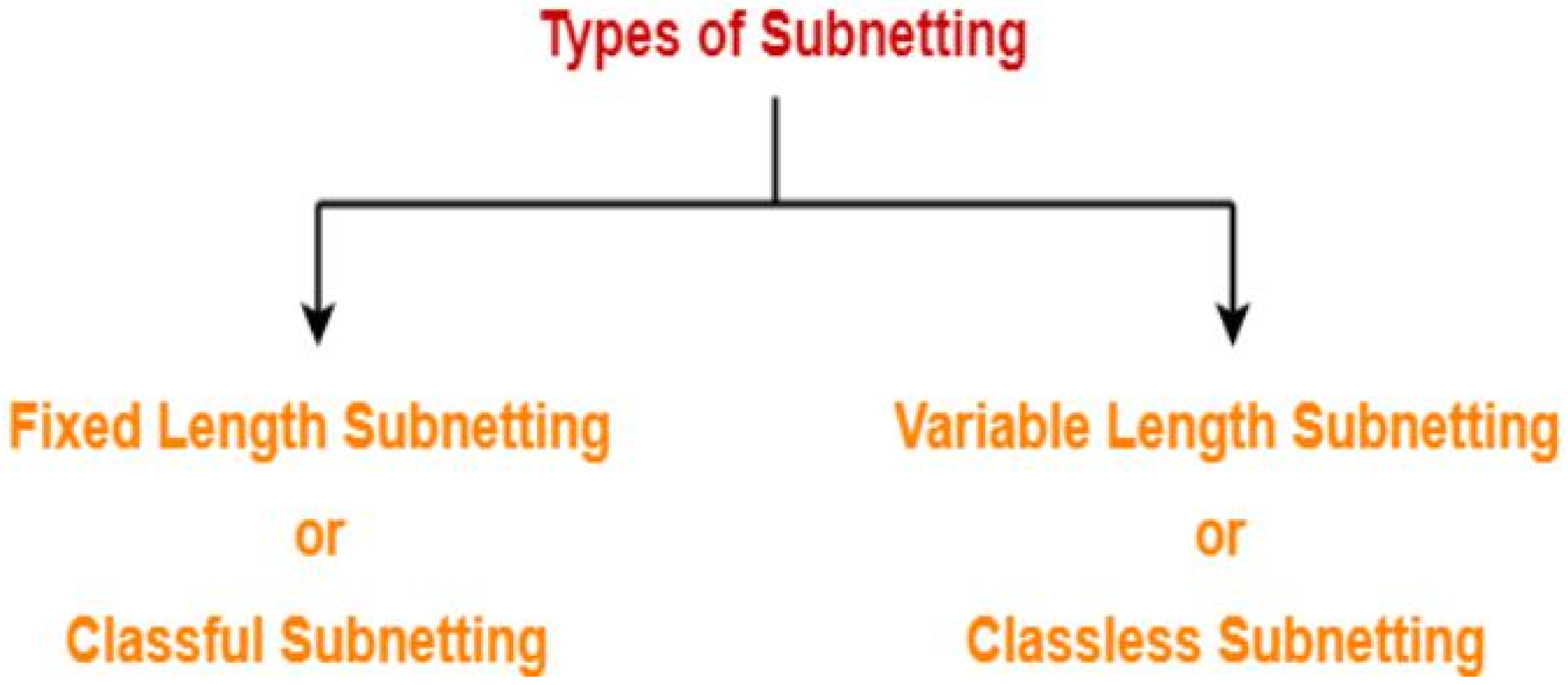
The process of dividing a single network into multiple sub networks is called as subnetting. The sub networks so created are called as subnets.

Subnet ID-

- ✓ *Each subnet has its unique network address known as its Subnet ID.*
- ✓ *The subnet ID is created by borrowing some bits from the Host ID part of the IP Address.*
- ✓ *The number of bits borrowed depends on the number of subnets created.*

Advantages-

- ➢ It improves the security.
- ➢ The maintenance and administration of subnets is easy.


Types of Subnetting
Fixed Length Subnetting
or
Classful Subnetting
Variable Length Subnetting
or
Classless Subnetting

Fixed Length Subnetting:

Fixed length subnetting also called as classful subnetting divides the network into subnets where-

- All the subnets are of same size.
- All the subnets have equal number of hosts.
- All the subnets have same subnet mask.

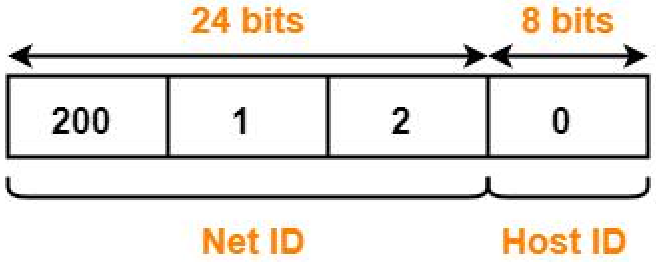
Variable Length Subnetting:

Variable length subnetting also called as classless subnetting divides the network into subnets where-

- All the subnets are not of same size.
- All the subnets do not have equal number of hosts.
- All the subnets do not have same subnet mask.

Consider-
We have a big single network having IP Address 200.1.2.0.
We want to do subnetting and divide this network into 2 subnets.

Clearly, the given network belongs to class C.

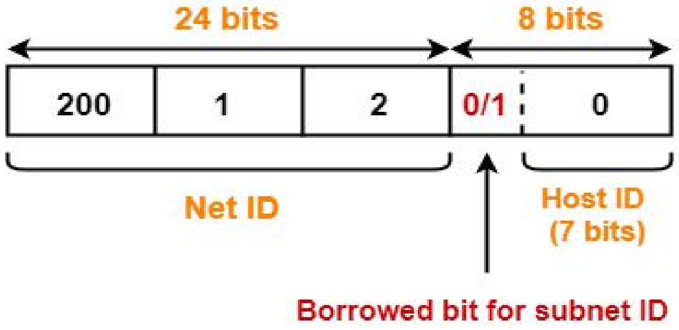


- We borrow one bit from the Host ID part.
- After borrowing one bit, Host ID part remains with only 7 bits.

- If borrowed bit = 0, then it represents the first subnet.
- If borrowed bit = 1, then it represents the second subnet.

IP Address of the two subnets are-

- 200.1.2.**0**0000000 = 200.1.2.0
- 200.1.2.**1**0000000 = 200.1.2.128

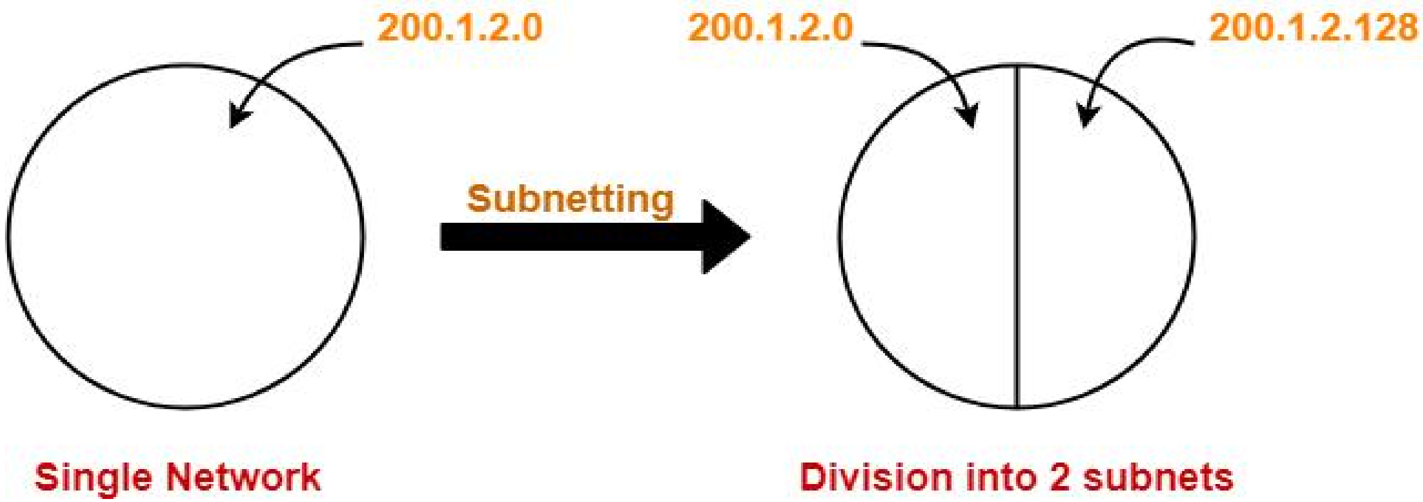


For 1st Subnet-

- IP Address of the subnet = 200.1.2.0
- Total number of IP Addresses = 2^7 = 128
- Total number of hosts that can be configured = 128 – 2 = 126
- Range of IP Addresses = [200.1.2.**0**0000000, 200.1.2.**0**1111111] = [200.1.2.0, 200.1.2.127]
- Direct Broadcast Address = 200.1.2.**0**1111111 = 200.1.2.127
- Limited Broadcast Address = 255.255.255.255

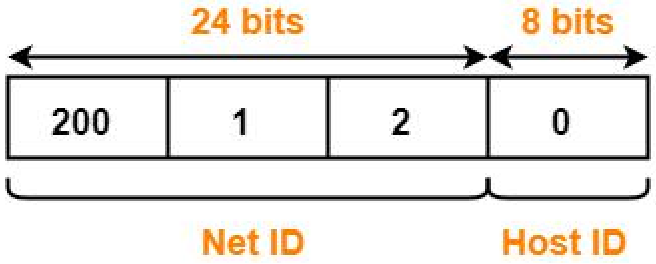
For 2nd Subnet-

- IP Address of the subnet = 200.1.2.128
- Total number of IP Addresses = 2^7 = 128
- Total number of hosts that can be configured = 128 – 2 = 126
- Range of IP Addresses = [200.1.2.**1**0000000, 200.1.2.**1**1111111] = [200.1.2.128, 200.1.2.255]
- Direct Broadcast Address = 200.1.2.**1**1111111 = 200.1.2.255
- Limited Broadcast Address = 255.255.255.255



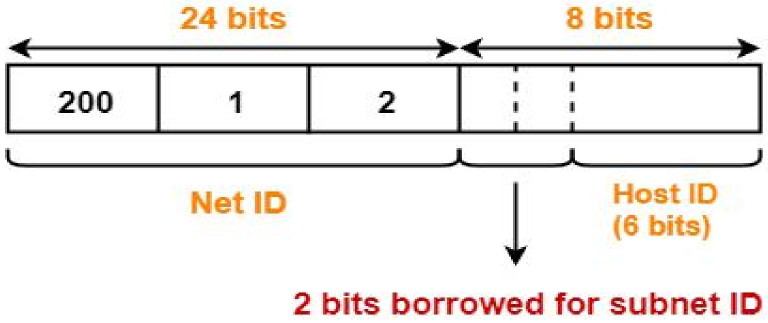
Consider we have a big single network having IP Address 200.1.2.0 and we want to do subnetting and divide this network into 4 subnets.

Clearly, the given network belongs to class C.



For creating four subnets and to represent their subnet IDs, we require 2 bits.

- We borrow two bits from the Host ID part.
- After borrowing two bits, Host ID part remains with only 6 bits.
  - If borrowed bits = 00, then it represents the 1st subnet.
  - If borrowed bits = 01, then it represents the 2nd subnet.
  - If borrowed bits = 10, then it represents the 3rd subnet.
  - If borrowed bits = 11, then it represents the 4th subnet.



- If borrowed bits = 00, then it represents the 1st subnet.
- If borrowed bits = 01, then it represents the 2nd subnet.
- If borrowed bits = 10, then it represents the 3rd subnet.
- If borrowed bits = 11, then it represents the 4th subnet.

IP Address of the four subnets are-

- 200.1.2.**00**000000 = 200.1.2.0
- 200.1.2.**01**000000 = 200.1.2.64
- 200.1.2.**10**000000 = 200.1.2.128
- 200.1.2.**11**000000 = 200.1.2.192

For 1st Subnet-

- IP Address of the subnet = 200.1.2.0
- Total number of IP Addresses = 2^6 = 64
- Total number of hosts that can be configured = 64 – 2 = 62
- Range of IP Addresses = [200.1.2.**00**000000, 200.1.2.**00**111111] = [200.1.2.0, 200.1.2.63]
- Direct Broadcast Address = 200.1.2.**00**111111 = 200.1.2.63
- Limited Broadcast Address = 255.255.255.255

For 2nd Subnet-

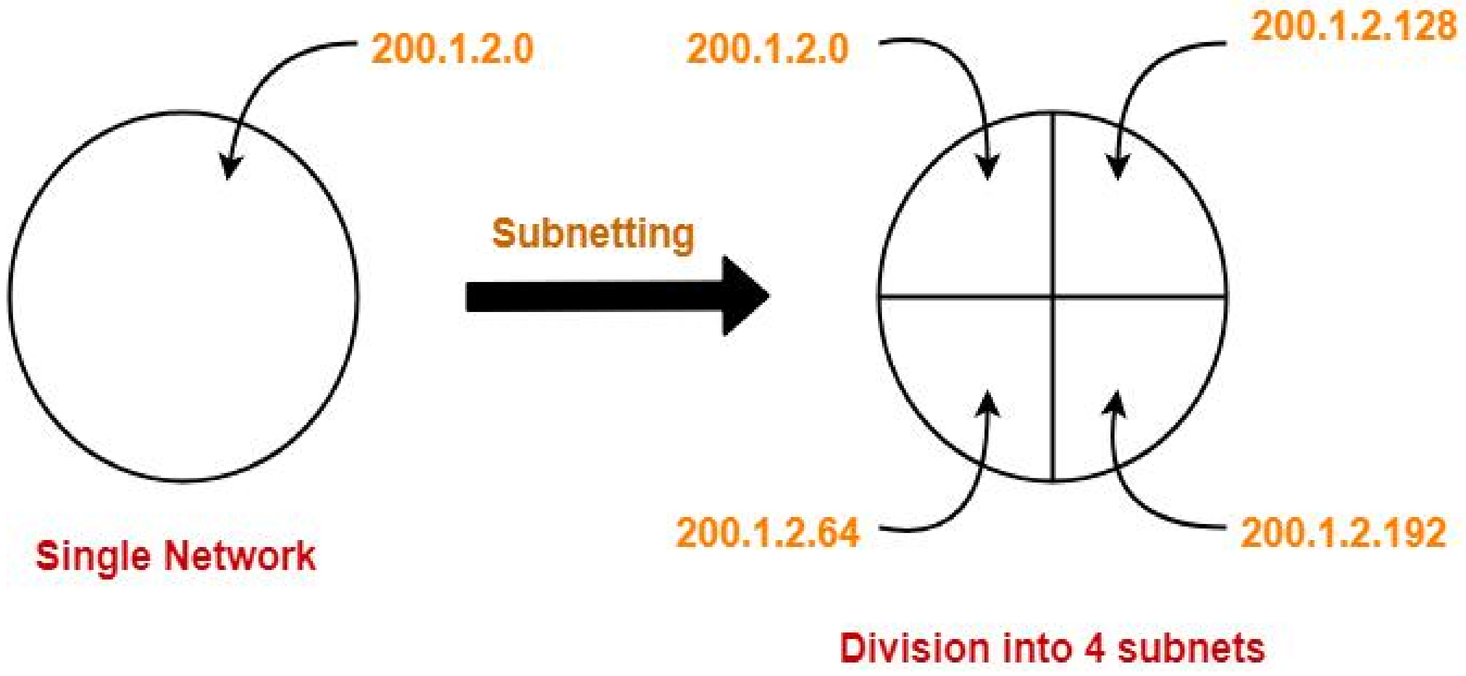
- IP Address of the subnet = 200.1.2.64
- Total number of IP Addresses = 2^6 = 64
- Total number of hosts that can be configured = 64 – 2 = 62
- Range of IP Addresses = [200.1.2.**01**000000, 200.1.2.**01**111111] = [200.1.2.64, 200.1.2.127]
- Direct Broadcast Address = 200.1.2.**01**111111 = 200.1.2.127
- Limited Broadcast Address = 255.255.255.255

For 3rd Subnet-

- IP Address of the subnet = 200.1.2.128
- Total number of IP Addresses = 2^6 = 64
- Total number of hosts that can be configured = 64 – 2 = 62
- Range of IP Addresses = [200.1.2.**10**000000, 200.1.2.**10**111111] = [200.1.2.128, 200.1.2.191]
- Direct Broadcast Address = 200.1.2.**10**111111 = 200.1.2.191
- Limited Broadcast Address = 255.255.255.255

For 4th Subnet-

- IP Address of the subnet = 200.1.2.192
- Total number of IP Addresses = 2^6 = 64
- Total number of hosts that can be configured = 64 – 2 = 62
- Range of IP Addresses = [200.1.2.**11**000000, 200.1.2.**11**111111] = [200.1.2.192, 200.1.2.255]
- Direct Broadcast Address = 200.1.2.**11**111111 = 200.1.2.255
- Limited Broadcast Address = 255.255.255.255



Q. Consider-

We have a big single network having IP Address 200.1.2.0.
We want to do subnetting and divide this network into 3 subnets.

Solve it

Disadvantages of Subnetting-

Subnetting leads to loss of IP Addresses.
During subnetting,

We have to face a loss of IP Addresses.
This is because two IP Addresses are wasted for each subnet.
One IP address is wasted for its network address.
Other IP Address is wasted for its direct broadcasting address.

Subnetting leads to complicated communication process.

After subnetting, the communication process becomes complex involving the following 4 steps-

Identifying the network
Identifying the sub network
Identifying the host
Identifying the process

Subnet mask is a 32 bit number consisting of a sequence of 1's and 0's.

It is used to identify the subnet to which the given IP Address belongs.

Suppose a network with IP Address 192.16.0.0. is divided into 2 subnets, find number of hosts per subnet.
Also for the first subnet, find-
Subnet Address
First Host ID
Last Host ID
Broadcast Address

Solution-

- Given IP Address belongs to class C.
- So. 24 bits are reserved for the Net ID.
- The given network is divided into 2 subnets.
- So, 1 bit is borrowed from the host ID part for the subnet IDs.
- Then, Number of bits remaining for the Host ID = 7.
- Thus, Number of hosts per subnet = 2^7 = 128.

For 1st Subnet-

- Subnet Address = First IP Address = 192.16.0.**0**0000000 = 172.16.0.0
- First Host ID = 192.16.0.**0**0000001 = 192.16.0.1
- Last Host ID = 192.16.0.**0**1111110 = 192.16.0.126
- Broadcast Address = Last IP Address = 192.16.0.**0**1111111 = 172.16.0.127

In a class B, network on the internet has a subnet mask of 255.255.240.0. What is the number of subnets and the maximum number of hosts per subnet?

- Number of bits reserved for network ID in the given subnet mask = 20.
- So, Number of bits reserved for Host ID = 32 – 20 = 12 bits.
- Thus, Number of hosts per subnet = $2^{12} - 2 = 4094$.
- In class B, 16 bits are reserved for the network.
- So, Number of bits reserved for subnet ID = 20 – 16 = 4 bits.
- Number of subnets possible = $2^4 = 16$.

Consider we have a network having IP Address 200.1.2.0. Calculate subnet mask

Clearly, this IP Address belongs to class C.
In class C-
24 bits are reserved for the Network ID part & 8 bits are reserved for the Host ID part.
Subnet mask is obtained-
By setting the first 24 bits to 1.
By setting the remaining 8 bits to 0.
So, Subnet mask
= 11111111.11111111.11111111.00000000
= 255.255.255.0

Consider a single network having IP Address 200.1.2.0 is divided into 4 subnets. Calculate the mask subnet for each subnet.

For each subnet-
24 bits identify the global network.
2 bits identify the subnet.
6 bits identify the host.
For each subnet, subnet mask is obtained-
By setting the first 26 bits to 1.
By setting the remaining 6 bits to 0.
So, Subnet mask
= 11111111.11111111.11111111.11000000
= 255.255.255.192

If the subnet mask 255.255.255.128 belongs to class C, find- Number of subnets and Number of hosts in each subnet

Given subnet mask
= 255.255.255.128
= 11111111.11111111.11111111.10000000

Since 25 bits contain the value 1 and 7 bits contain the value 0, so-
Number of Net ID bits + Number of Subnet ID bits = 25
Number of Host ID bits = 7

Now,
It is given that subnet mask belongs to class C.
So, Number of Net ID bits = 24.

Substituting in the above equation, we get-
Number of Subnet ID bits
= 25 – 24 = 1

Number of subnets = $2^1 = 2$
Since number of Host ID bits = 7,
so- Number of hosts per subnet = $2^7 - 2 = 126$

If a class B network has a subnet mask of 255.255.248.0, what is the maximum number of hosts per subnet?

Given subnet mask
= 255.255.248.0
= 11111111.11111111.11111000.00000000

Since 21 bits contain the value 1 and 11 bits contain the value 0, so-
Number of Net ID bits + Number of Subnet ID bits = 21
Number of Host ID bits = 11

Since number of Host ID bits = 11, so-

Number of hosts per subnet = $2^{11} - 2 = 2046$

For subnet mask is 255.128.0.0, find-
Number of hosts per subnet
Number of subnets if subnet mask belongs to class A
Number of subnets if subnet mask belongs to class B
Number of subnets if subnet mask belongs to class C
Number of subnets if total 10 bits are used for the global network ID

For subnet mask 255.255.255.224 ??

So,
Number of Net ID bits + Number of Subnet ID bits = 9
Number of Host ID bits = 23
Number of hosts per subnet = $2^{23} – 2$

If the given subnet mask belongs to class A, then number of Net ID bits = 8.
Substituting in the above equation, we get-
Number of Subnet ID bits = 9 – 8 = 1
Thus, Number of subnets = 2^1 = 2

First two octets of the subnet mask are not completely filled with 1's.
So, given subnet mask can not belong to class B.

First three octets of the subnet mask are not completely filled with 1's. So, given subnet mask can not belong to class C.

First 10 bits of the subnet mask are not completely filled with 1's. So, given subnet mask can not use 10 bits for the Network ID.

If the value available in “fragment offset” field of IP header is 100, then how many number of bytes are ahead of this fragment.

Fragment offset field use a scaling factor of 8.
If Fragment offset field value = 100, then fragment offset = 8 x 100 = 800.
It suggests 800 bytes of data is ahead of this fragment.

Suppose a router receives an IP packet containing 600 data bytes and has to forward the packet to a network with maximum transmission unit of 200 bytes. Assume that IP header is 20 bytes long. What are fragment offset values for divided packets?

Given-

- MTU size of the destination network = 200 bytes
- IP header length = 20

Now,

- Maximum amount of data that can be sent in one fragment = 200 – 20 = 180 bytes.
- Amount of data sent in a fragment must be a multiple of 8.
- So, maximum data sent that can be in one fragment = 176 bytes.

Thus, 4 fragments are created-

- 1st fragment contains 176 bytes of data.
- 2nd fragment contains 176 bytes of data.
- 3rd fragment contains 176 bytes of data.
- 4th fragment contains 72 bytes of data

So,

- Fragment offset value for 1st fragment = 0
- Fragment offset value for 2nd fragment = 176 / 8 = 22
- Fragment offset value for 3rd fragment = (176+176) / 8 = 44
- Fragment offset value for 4th fragment = (176 + 176 + 176) / 8 = 66

END