AMRITA
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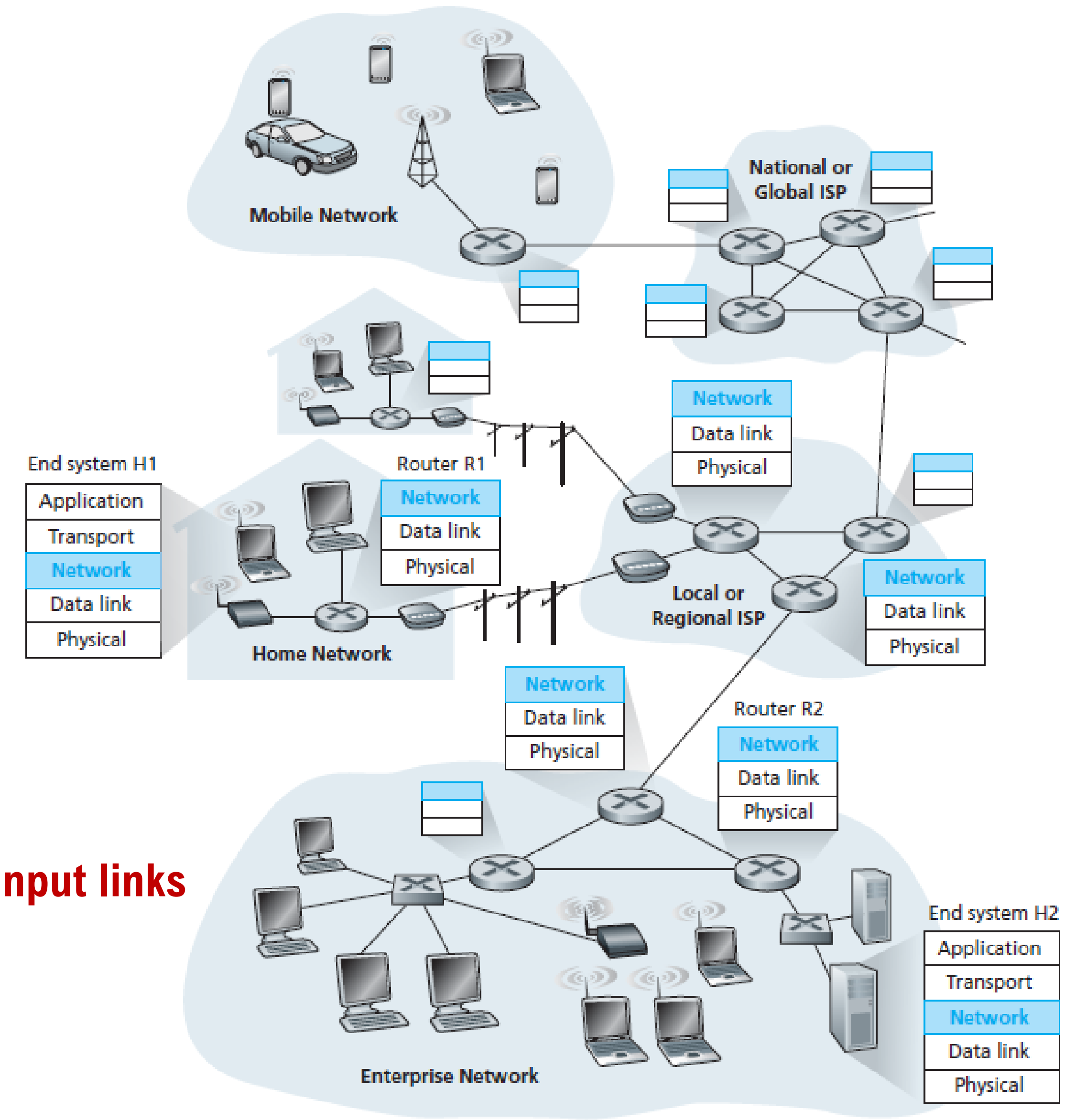
15CSE312
COMPUTER NETWORKS
3-0-0 3

Chapter 4: Network Layer
IP Addressing

Network Layer

The network layer in H1 takes segments from the transport layer in H1, encapsulates each segment into a datagram (that is, a network-layer packet), and then sends the datagrams to its nearby router, R1. At the receiving host, H2, the network layer receives the datagrams from its nearby router R2, extracts the transport-layer segments, and delivers the segments up to the transport layer at H2.



The primary role of the routers is to forward datagrams from input links to output links

Fig shows a simple network with two hosts, H1 and H2, and several routers on the path between H1 and H2

Network Layer- Functionality

- How a machine in a different network can communicate with a machine in another network
  - **Host to Host Delivery** (Source to Destination) using IP addressing
  - **Routing:** which is moving packets (the fundamental unit of data transport on modern computer networks) across the network using the most appropriate paths
  - **Fragmentation** : is done by the network layer when the maximum size of datagram is greater than maximum size of data that can be held in a frame i.e., its Maximum Transmission Unit (MTU). The network layer divides the datagram received from transport layer into fragments so that data flow is not disrupted.

- The network layer is responsible for carrying data from one host to another.
- It provides means to allocate logical addresses to hosts, and identify them uniquely using the same.
- Network layer takes data units from Transport Layer and cuts them in to smaller unit called Data Packet.
- Network layer defines the data path, the packets should follow to reach the destination. Routers work on this layer and provides mechanism to route data to its destination.

Classless Addressing- Classless Inter Domain Routing (CIDR)

What happened in classful addressing is that if any company needs more than 254 host machines but far fewer than the 65,533 host addresses then the only option for the company is to take the class B address.
Now suppose company needs only 1000 IP addresses for its host computers then in this (65533-1000=64533) IP addresses get wasted.
For this reason, the Internet was, until the arrival of CIDR, running out of address space much more quickly than necessary. CIDR effectively solved the problem by providing a new and more flexible way to specify network addresses in routers.

In order to reduce the wastage of IP addresses a new concept of Classless Inter-Domain Routing is introduced. Now a days IANA is using this technique to provide the IP addresses. Whenever any user asks for IP addresses, IANA is going to assign that many IP addresses to the User.

Classless Addressing-

Classless Addressing-

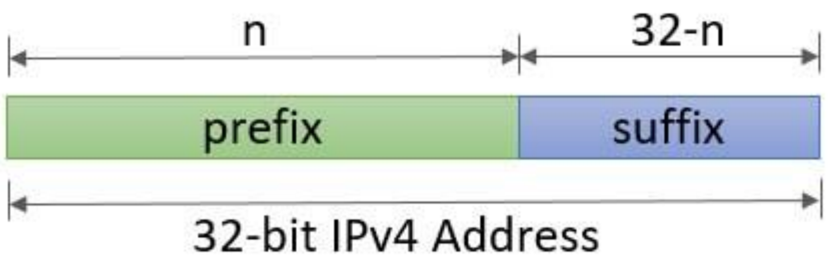
•Classless Addressing is an improved IP Addressing system.
•It makes the allocation of IP Addresses more efficient.
•It replaces the older classful addressing system based on classes.
•It is also known as **Classless Inter Domain Routing (CIDR)**.

CIDR Block-

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**.

Classless Addressing

the **classless** addressing divides the IPv4 address into two parts referred to as '**prefix**' and '**suffix**'. **Prefix** defines the **network id** whereas **suffix** defines the **host address** in the corresponding network.



Addresses belonging to the **same block** persist the **same prefix** whereas **each host in a block** has a **different suffix**

the **length of a prefix (n)** can be **0, 1, 2, 3, ..., 32**. So, the value of **suffix** would automatically be (32- length of the prefix).

In classless addressing, for a given address prefix length, could not be calculated as it can belong to a block of any prefix length. So, here the length of the prefix is included with each address to ease the extraction of block information.

The **length of the prefix (n)** is added to the last of address separated by a **slash**. This is called **slash notation** and more formally it is known as **Classless Inter-Domain Routing (CIDR) notation**.

CIDR notation

Classless addressing uses a variable number of bits for the network and host portions of the address.

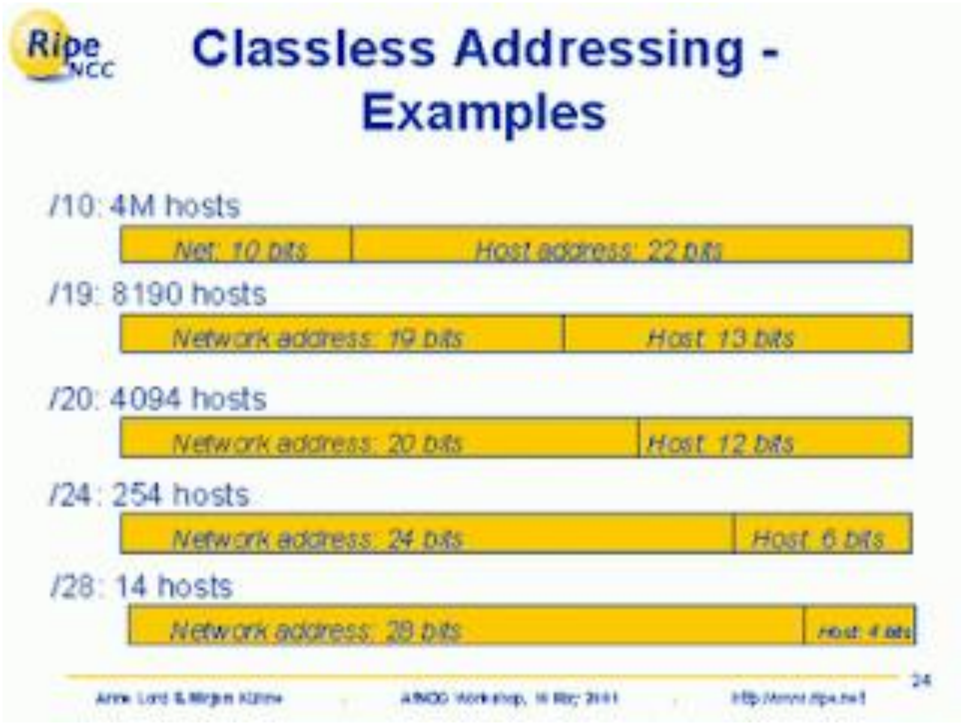
CIDR Notation-

CIDR IP Addresses look like-

a.b.c.d / n

167.199.170.82/27

- 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.
- Classless addressing treats the IP address as a 32 bit stream of ones and zeroes, where the boundary between network and host portions can fall anywhere between bit 0 and bit 31.



IPv4 address 167.199.170.82/27 have an added value '27 ' which is separated by a slash, is a CIDR notation of classless IPv4 address. The value '**27**' denotes the length of the **prefix**. So, the length of the **suffix** would be '3**2-27= 5**'.

Rules For Creating CIDR Block-

A CIDR block is created based on the following 3 rules-

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.

REMEMBER

If any binary pattern consisting of (m + n) bits is divided by 2^n, then-

- Remainder is least significant n bits
- Quotient is most significant m bits

So, any binary pattern is divisible by 2^n, if and only if its least significant n bits are 0.

Examples-

Consider a binary pattern-

01100100.00000001.00000010.01000000

(represented as 100.1.2.64)

- It is divisible by 2^5 since its least significant 5 bits are zero.
- It is divisible by 2^6 since its least significant 6 bits are zero.
- It is not divisible by 2^7 since its least significant 7 bits are not zero.

Problem I

Check whether 100.1.2.32 to 100.1.2.47 is a valid IP address block or not?

Solution

Rule 1 : All the IP addresses are contiguous.

Rule 2 : Total number of IP addresses in the Block = 16 = 2^4.

Rule 3

1st IP address: 100.1.2.00100000

Since, Host Id will contains last 4 bits and all the least significant 4 bits are zero. Hence, first IP address is evenly divisible by the size of the block.

All the three rules are followed by this Block. Hence, it is a valid IP address block.

Rule 1

A block of addresses allocated to an organization must have the contiguous unallocated addresses.

Rule 2

The number of addresses in a block allocated to an organization must be the power of 2.

Rule 3

The first address of every block must be divisible by the length of the block.

Calculations from CIDR

Given address is **192.168.20.166/25**. As we know that the value after the slash in IP address is prefix (n) value=25

No of bits of network ID is 25.
No of bits of host ID is 7 (32-25)

Network ID

11000000. 10101000. 00010100. 10100110
AND
11111111. 1111111. 11111111. 10000000
……………………………………………………………………………………
11000000. 10101000. 00010100. 1000000 (Network ID)

192 . 168 . 20 .128 (Network ID)

Network ID :192 . 168 . 20.128
No of bits of network ID is 25**.**
No of bits of host ID is 7
No of Host IDs : 2^7 = 128 (but first and last Host IDs are unusable. First is network ID,Last used as Indirect Broadcast address)
Range of HOST IDs [192. 168 . 20.128 to 192. 168 . 20. 255]
Usable Range: **[**192. 168 . 20.129 to 192. 168 . 20. 254]

First Host ID
192. 168 . 20.129

Last Host ID
192. 168 . 20. 254

Indirect BroadCast ID
192. 168 . 20. 255

Can u do?

- **Ex2: 192.168.30.14/29**

No of bits for network ID: 29
No of bits for Host ID:3

Network ID

11000000. 10101000.000 11110. 00001110

AND

11111111. 1111111. 11111111. 11111000

11000000. 10101000.000 11110. 00001000

92 . 168 . 30 . 8

No of bits of network ID is 29.
No of bits of host ID is 3
No of Host IDs : 2^3 =8

Range of HOST IDs
92 . 168 . 30 .8 to 92 . 168 . 30 .15

Range of usable HOST IDs
92 . 168 . 30 .9 to 92 . 168 . 30 .14

First Host ID
92 . 168 . 30 .9
Last Host ID
92 . 168 . 30 .14

Indirect BroadCast ID
92 . 168 . 30 .15

How to calculate IP address subnet information (Network, Broadcast, First IP, Last IP)?

Ex1: 192.168.20.166/25:

166/128 = 1.296875
Network ID: 1*128 = 128 (192.168.20.128)
Broadcast ID: 128+(128-1) = 255 (192.168.20.255)
First Host ID: 128 + 1 = 129 (192.168.20.129)
Last Host ID: 255 - 1 = 254 (192.168.20.254)

Ex2: 192.168.30.14/29:

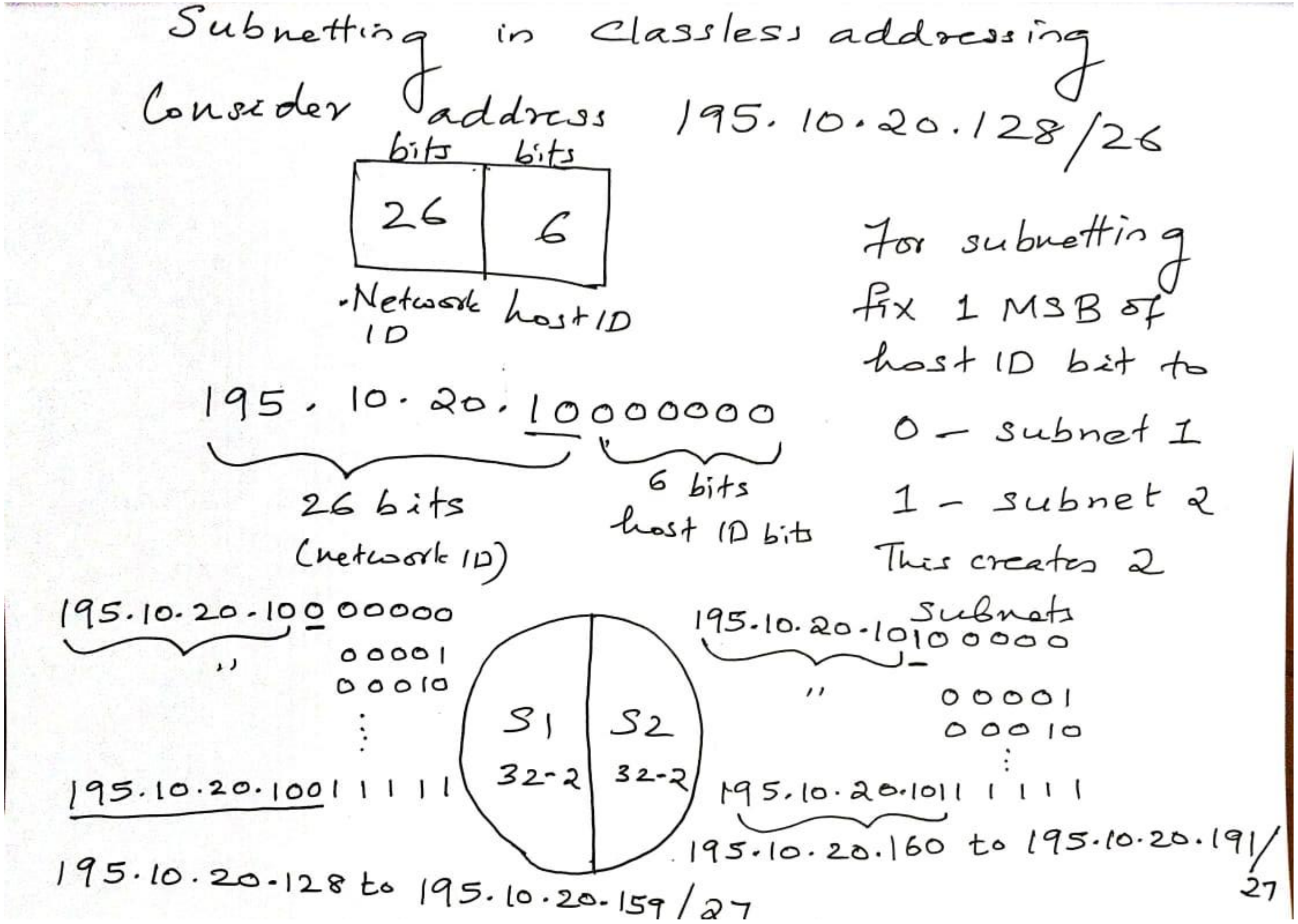
14/8 = 1.75
Network ID: 1*8 = 8 (192.168.30.8)
Broadcast ID: 8+(8-1) = 15 (192.168.30.15)
First Host ID: 8 + 1 = 9 (192.168.30.9)
Last Host ID: 15 - 1 = 14 (192.168.30.14)

Using Equation:

Network ID: floor(Host Address/Subnet Number of Hosts) * Subnet Number of Hosts
Broadcast ID: (Host ID + (Subnet Number of Hosts-1))
First Host: Network ID + 1
Last Host: Broadcast ID - 1

A short cut

Subnetting in Classless Addressing



Subnet1- Bit set to 0

Subnet2- Bit set to 1

Subnet1

195.10.20.128/27 to 195.10.20.159/27

195.10.20.10000000 to **195.10.20.100**11111

Subnet2

195.10.20.160/27 to 195.10.20.191/27

195.10.20.10100000 to **195.10.20.101**11111

Why slash 27?

27 bits are now fixed for network address

PRACTICE PROBLEMS BASED ON CLASSLESS INTER DOMAIN ROUTING-

Problem-01:

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

Solution-

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]

Problem-02:

Given the CIDR representation 100.1.2.35 / 20. Find the range of IP Addresses in the CIDR block.

Solution-

Given CIDR representation is 100.1.2.35 / 20.

It suggests-

- 20 bits are used for the identification of network.
- Remaining 12 bits are used for the identification of hosts in the network.

Given CIDR IP Address may be represented as-

01100100.00000001.00000010.00100011 / 20

So,

- First IP Address = 01100100.00000001.0000**0000.00000000** = 100.1.0.0
- Last IP Address = 01100100.00000001.0000**1111.11111111** = 100.1.15.255

Thus, Range of IP Addresses = [100.1.0.0 , 100.1.15.255]

Problem-03:

Consider a block of IP Addresses ranging from 100.1.2.32 to 100.1.2.47.

1. Is it a CIDR block?
2. If yes, give the CIDR representation.

Solution-

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

NOTE-

For writing the CIDR representation,

- We can choose to mention any IP Address from the CIDR block.
- The chosen IP Address is followed by a slash and IP network prefix.
- We generally choose to mention the first IP Address.

Problem-04:

Consider a block of IP Addresses ranging from 150.10.20.64 to 150.10.20.127.

1. Is it a CIDR block?
2. If yes, give the CIDR representation.

Solution-

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 given block = 127 – 64 + 1 = 64.
- Size of the block = 64 which can be represented as 2^6.
- So, Rule-02 is satisfied.

Rule-03:

- According to Rule-03, first IP Address must be divisible by size of the block.
- So, 150.10.20.64 must be divisible by 2^6.
- 150.10.20.64 = 150.10.20.01**000000** is divisible by 2^6 since its 6 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 = 2^6.
- To have 2^6 total number of IP Addresses, 6 bits are required in the Host ID part.
- So, Number of bits in the Network ID part = 32 – 6 = 26.

Thus,

CIDR Representation = 150.10.20.64 / 26

Problem-05:

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

Solution-

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.

Thus,

CIDR Representation = 128.56.24.0/22

Problem-06:

Perform CIDR aggregation on the following IP Addresses-

200.96.86.0/24

200.96.87.0/24

200.96.88.0/24

200.96.89.0/24

Solution-

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, 200.96.86.0 must be divisible by 2^{10}.
- 200.96.86.0 = 200.96.010101**10.00000000** is not divisible by 2^{10} since its 10 least significant bits are not zero.
- So, Rule-03 is unsatisfied.

Since all the 3 rules are not satisfied, so they can not be aggregated.

Classless interdomain routing (CIDR) receive a packet with address 131.23.151.76. The Router's routing table has following entities:

Prefix	output Interface
131.16.0.0/12	3
131.28.0.0/14	5
131.19.0.0/16	2
131.22.0.0/15	1

Packet will be forwarded to which interface ______

Namah Shivaya