National University of Sciences and Technology (NUST)
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EE-357 Computer and Communication Networks

Experiment – 10

Subnetting (Classless Inter-Domain Routing)

		PLO5/ CLO3		PLO5/ CLO3	PLO5/ CLO3	PLO5/ CLO3
Name	**Reg. No**	**Viva / Quiz / Lab Performance 5 Marks**	**Analysis of data in Lab Report 5 Marks**	**Modern Tool Usage 5 Marks**	**Ethics and Safety 5 Marks**	**Individual and Team Work 5 Marks**
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EXPERIMENT NO 10
Subnetting (Classless Inter-Domain Routing)

Objectives

To become acquainted with the *Internet Protocol* (TCP/IP) stack. Understand the main principles of IP addressing and division of a network into subnets.

Basic knowledge and theory

A computer network is an intricate complex of hardware and software components. The entire software-hardware complex of the network can be described by a multilayer model. Such description of the complex enables standardization of the characteristics of its various layers. Standardization allows interconnection of networks employing various technologies, using hardware and software of different manufacturers.

Internet Protocol Version 4 (IPv4)

Internet Protocol is one of the major protocols in the TCP/IP protocols suite. This protocol works at the network layer of the OSI model and at the Internet layer of the TCP/IP model. Thus this protocol has the responsibility of identifying hosts based upon their logical addresses and to route data among them over the underlying network.

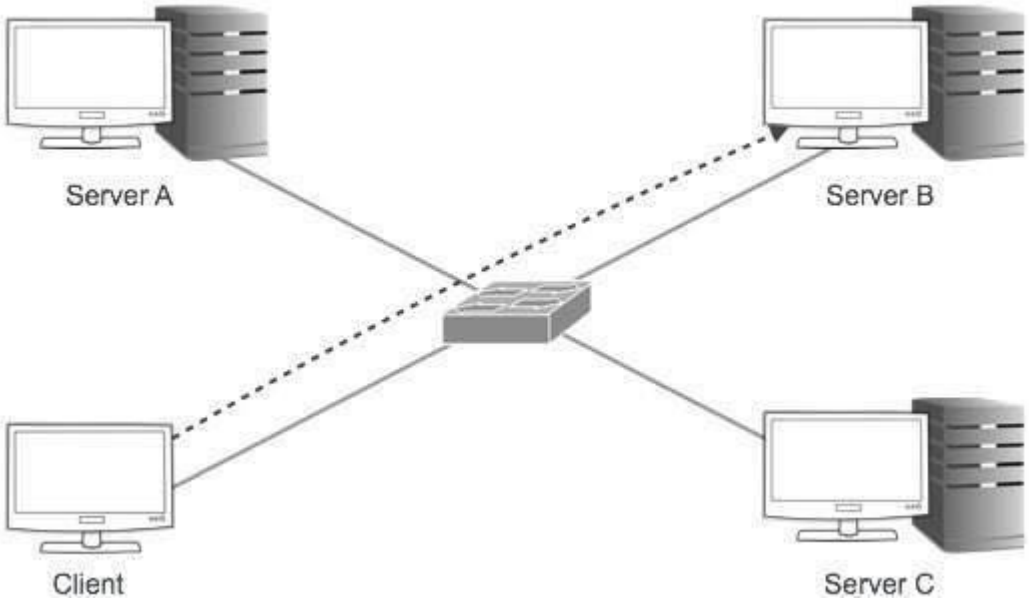
IP provides a mechanism to uniquely identify hosts by an IP addressing scheme. IP uses best effort delivery, i.e. it does not guarantee that packets would be delivered to the destined host, but it will do its best to reach the destination. Internet Protocol version 4 uses 32-bit logical address.

IPv4 - Addressing

IPv4 supports three different types of addressing modes:

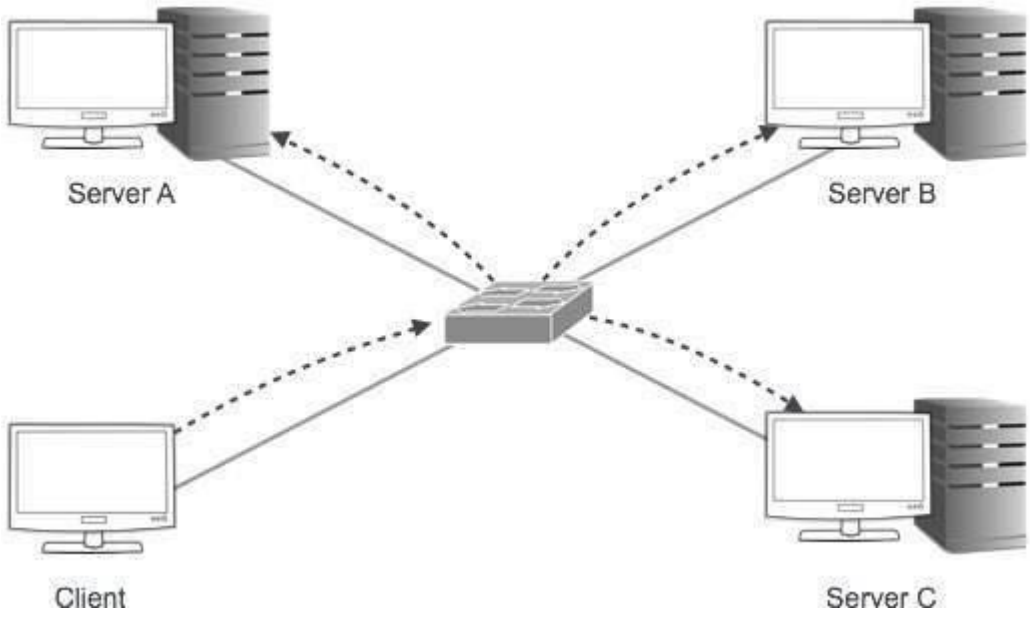
Unicast Addressing Mode:

In this mode, data is sent only to one destined host. The Destination Address field contains 32- bit IP address of the destination host. Here the client sends data to the targeted server:



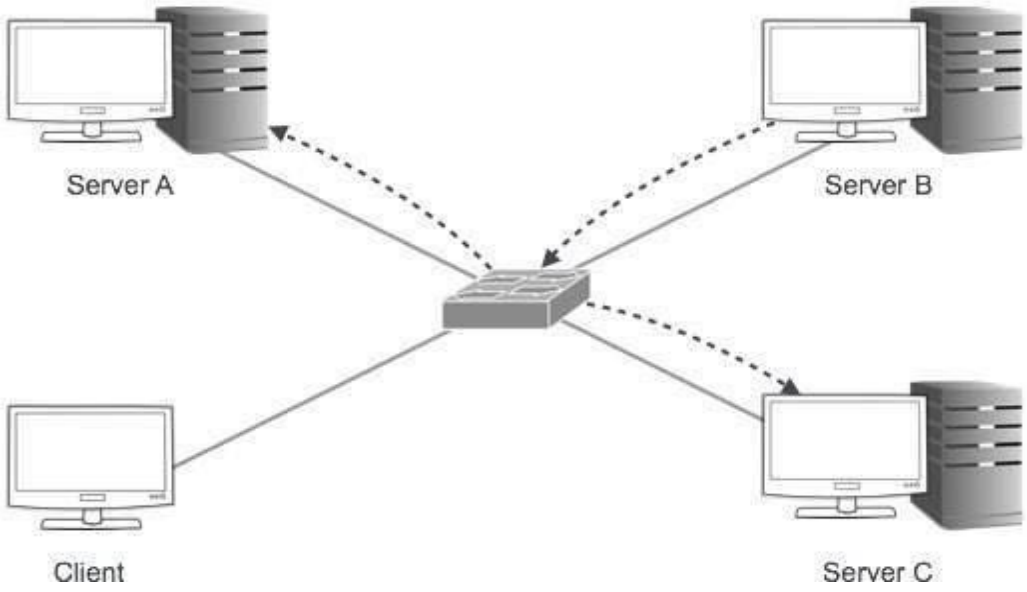
Broadcast Addressing Mode:

In this mode, the packet is addressed to all the hosts in a network segment. The Destination Address field contains a special broadcast address, i.e. **255.255.255.255**. When a host sees this packet on the network, it is bound to process it. Here the client sends a packet, which is entertained by all the Servers:



Multicast Addressing Mode:

This mode is a mix of the previous two modes, i.e. the packet sent is neither destined to a single host nor all the hosts on the segment. In this packet, the Destination Address contains a special address which starts with 224.x.x.x and can be entertained by more than one host.



Here a server sends packets which are entertained by more than one servers. Every network has one IP address reserved for the Network Number which represents the network and one IP address reserved for the Broadcast Address, which represents all the hosts in that network.

Hierarchical Addressing Scheme

IPv4 uses hierarchical addressing scheme. An IP address, which is 32-bits in length, is divided into two or three parts as depicted:

A single IP address can contain information about the network and its sub-network and ultimately the host. This scheme enables the IP Address to be hierarchical where a network can have many sub-networks which in turn can have many hosts.

Subnet Mask

The 32-bit IP address contains information about the host and its network. It is very necessary to distinguish both. For this, routers use Subnet Mask, which is as long as the size of the network address in the IP address. Subnet Mask is also 32 bits long. If the IP address in binary is ANDed with its Subnet Mask, the result yields the Network address. For example, say the IP Address is 192.168.1.152 and the Subnet Mask is 255.255.255.0 then:

IP	192.168.1.152	11000000	10101000	00000001	10011000	ANDed
Mask	255.255.255.0	11111111	11111111	11111111	00000000	
Network	192.168.1.0	11000000	10101000	00000001	00000000	Result

This way the Subnet Mask helps extract the Network ID and the Host from an IP Address. It can be identified now that 192.168.1.0 is the Network number and 192.168.1.152 is the host on that network.

Binary Representation

The positional value method is the simplest form of converting binary from decimal value. IP address is 32 bit value which is divided into 4 octets. A binary octet contains 8 bits and the value of each bit can be determined by the position of bit value '1' in the octet.

MSB	8^{th}	7^{th}	6^{th}	5^{th}	4^{th}	3^{rd}	2^{nd}	1^{st}	LSB
	1	1	1	1	1	1	1	1	
Positional Value	128	64	32	16	8	4	2	1	

Positional value of bits is determined by 2 raised to power (position – 1), that is the value of a bit 1 at position 6 is 2^(6-1) that is 2^5 that is 32. The total value of the octet is determined by adding up the positional value of bits. The value of 11000000 is 128+64 = 192. Some examples are shown in the table below:

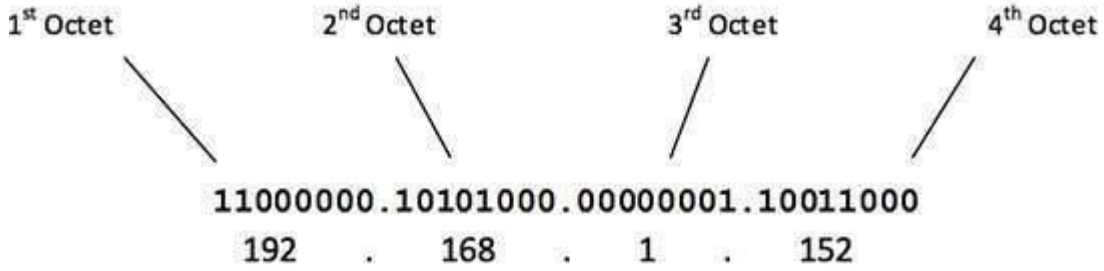
128	64	32	16	8	4	2	1	Value
0	0	0	0	0	0	0	1	1
0	0	0	0	0	0	1	0	2
0	0	0	0	0	0	1	1	3
0	0	0	0	0	1	0	0	4
0	0	0	0	0	1	0	1	5
0	0	0	0	0	1	1	0	6
0	0	0	0	0	1	1	1	7
0	0	0	0	1	0	0	0	8
0	0	0	0	1	0	0	1	9
0	0	0	0	1	0	1	0	10
0	0	0	1	0	0	0	0	16
0	0	1	0	0	0	0	0	32
0	1	0	0	0	0	0	0	64
0	1	1	0	0	1	0	0	100
0	1	1	1	1	1	1	1	127
1	0	0	0	0	0	0	0	128
1	0	1	0	1	0	0	0	168
1	1	0	0	0	0	0	0	192
1	1	1	1	1	1	1	1	255

IPv4 - Address Classes

Internet Protocol hierarchy contains several classes of IP Addresses to be used efficiently in various situations as per the requirement of hosts per network. Broadly, the IPv4 Addressing system is divided into five classes of IP Addresses. All the five classes are identified by the first octet of IP Address.

Internet Corporation for Assigned Names and Numbers is responsible for assigning IP addresses.

The first octet referred here is the left most of all. The octets numbered as follows depicting dotted decimal notation of IP Address:



The number of networks and the number of hosts per class can be derived by this formula:

Number of networks	= 2^network_bits
Number of Hosts/Network	= 2^host_bits – 2

When calculating hosts' IP addresses, 2 IP addresses are decreased because they cannot be assigned to hosts, i.e. the first IP of a network is network number and the last IP is reserved for Broadcast IP.

Class A Address

The first bit of the first octet is always set to 0 (zero). Thus the first octet ranges from 1 – 127, i.e.

```
00000001 - 01111111
       1 - 127
```

Class A addresses only include IP starting from 1.x.x.x to 126.x.x.x only. The IP range 127.x.x.x is reserved for loopback IP addresses.

The default subnet mask for Class A IP address is 255.0.0.0 which implies that Class A addressing can have 126 networks (2^7-2) and 16777214 hosts (2^{24}-2).

Class A IP address format is thus: **0NNNNNNN**.HHHHHHHH.HHHHHHHH.HHHHHHHH

Class B Address

An IP address which belongs to class B has the first two bits in the first octet set to 10, i.e.

```
10000000 - 10111111
     128 - 191
```

Class B IP Addresses range from 128.0.x.x to 191.255.x.x. The default subnet mask for Class B is 255.255.x.x.

Class B has 16384 (2^{14}) Network addresses and 65534 (2^{16}-2) Host addresses.
Class B IP address format is: **10NNNNNN.NNNNNNNN**.HHHHHHHH.HHHHHHHH

Class C Address

The first octet of Class C IP address has its first 3 bits set to 110, that is:

11000000 – **110**11111
192 – 223

Class C IP addresses range from 192.0.0.x to 223.255.255.x. The default subnet mask for Class C is 255.255.255.x.

Class C gives 2097152 (2^{21}) Network addresses and 254 (2^{8}-2) Host addresses.

Class C IP address format is: **110NNNNN.NNNNNNNN.NNNNNNNN**.HHHHHHHH

Class D Address

Very first four bits of the first octet in Class D IP addresses are set to 1110, giving a range of:

11100000 – **1110**1111
224 – 239

Class D has IP address rage from 224.0.0.0 to 239.255.255.255. Class D is reserved for Multicasting. In multicasting data is not destined for a particular host, that is why there is no need to extract host address from the IP address, and Class D does not have any subnet mask.

Class E Address

This IP Class is reserved for experimental purposes only for R&D or Study. IP addresses in this class ranges from 240.0.0.0 to 255.255.255.254. Like Class D, this class too is not equipped with any subnet mask.

IPv4 - Subnetting

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.

Class A Subnets

In Class A, only the first octet is used as Network identifier and rest of three octets are used to be assigned to Hosts (i.e. 16777214 Hosts per Network). To make more subnet in Class A, bits from Host part are borrowed and the subnet mask is changed accordingly.

For example, if one MSB (Most Significant Bit) is borrowed from host bits of second octet and added to Network address, it creates two Subnets (2^1=2) with (2^{23}-2) 8388606 Hosts per Subnet.

The Subnet mask is changed accordingly to reflect subnetting. Given below is a list of all possible combination of Class A subnets:

Network Bits	Subnet Mask	Bits Borrowed	Subnets	Hosts/Subnet
8	255.0.0.0	0	1	16777214
9	255.128.0.0	1	2	8388606
10	255.192.0.0	2	4	4194302
11	255.224.0.0	3	8	2097150
12	255.240.0.0	4	16	1048574
13	255.248.0.0	5	32	524286
14	255.252.0.0	6	64	262142
15	255.254.0.0	7	128	131070
16	255.255.0.0	8	256	65534
17	255.255.128.0	9	512	32766
18	255.255.192.0	10	1024	16382
19	255.255.224.0	11	2048	8190
20	255.255.240.0	12	4096	4094
21	255.255.248.0	13	8192	2046
22	255.255.252.0	14	16384	1022
23	255.255.254.0	15	32768	510
24	255.255.255.0	16	65536	254
25	255.255.255.128	17	131072	126
26	255.255.255.192	18	262144	62
27	255.255.255.224	19	524288	30
28	255.255.255.240	20	1048576	14
29	255.255.255.248	21	2097152	6
30	255.255.255.252	22	4194304	2

In case of subnetting too, the very first and last IP address of every subnet is used for Subnet Number and Subnet Broadcast IP address respectively. Because these two IP addresses cannot be assigned to hosts, sub-netting cannot be implemented by using more than 30 bits as Network Bits, which provides less than two hosts per subnet.

Class B Subnets

By default, using Classful Networking, 14 bits are used as Network bits providing (2^{14}) 16384 Networks and (2^{16}-2) 65534 Hosts. Class B IP Addresses can be subnetted the same way as Class A addresses, by borrowing bits from Host bits. Below is given all possible combination of Class B subnetting:

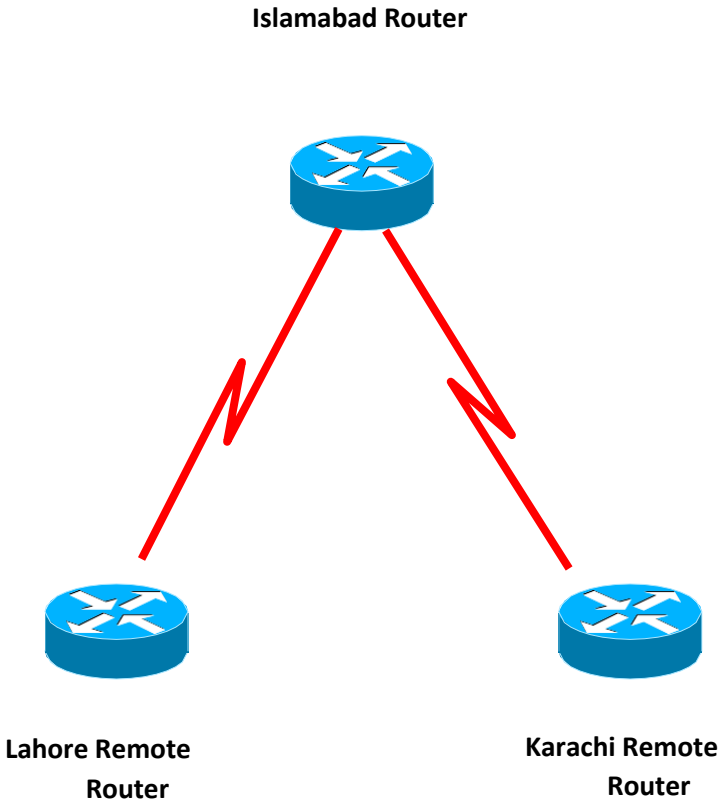
Network Bits	Subnet Mask	Bits Borrowed	Subnets	Hosts/Subnet
16	255.255.0.0	0	0	65534
17	255.255.128.0	1	2	32766
18	255.255.192.0	2	4	16382
19	255.255.224.0	3	8	8190
20	255.255.240.0	4	16	4094
21	255.255.248.0	5	32	2046
22	255.255.252.0	6	64	1022
23	255.255.254.0	7	128	510
24	255.255.255.0	8	256	254
25	255.255.255.128	9	512	126
26	255.255.255.192	10	1024	62
27	255.255.255.224	11	2048	30
28	255.255.255.240	12	4096	14
29	255.255.255.248	13	8192	6
30	255.255.255.252	14	16384	2

Class C Subnets

Class C IP addresses are normally assigned to a very small size network because it can only have 254 hosts in a network. Given below is a list of all possible combination of subnetted Class B IP address:

Network Bits	Subnet Mask	Bits Borrowed	Subnets	Hosts/Subnet
24	255.255.255.0	0	1	254
25	255.255.255.128	1	2	126
26	255.255.255.192	2	4	62
27	255.255.255.224	3	8	30
28	255.255.255.240	4	16	14
29	255.255.255.248	5	32	6
30	255.255.255.252	6	64	2

1) Example of Subnetting



IP Address Available 192.168.1.0

Q: If we have two remote sites then judge that how many bitsSubnetting and how many subnets available?

Ans: Remember that these things.

1) What is your class Address **Class C**

2) How many networks bits **24**

3) How many remote brunches **2**

4) Default subnet Mask **255 .255 .255 .0**

11111111.11111111.11111111. 0 0000000

That Bit Subnet (Subnetting)

5) How many bits barrows **1**

We have two remote sits then we see that table for subnetting and chose bits.

Bits	Formula	Total Subnets
1	2^1	2
2	2^2	4
3	2^3	8
4	2^4	16
5	2^5	32
6	2^6	64
7	2^7	128
8	2^8	256

1 Bit subnetting & 2 Subnets Available

6) 192.168. 1.0 0|0 0 0 0 0 0 0 =**0**
1|0 0 0 0 0 0 0 =**128**

OR

Formula called Block Size 256-128**=128**
=0
=128

7) Customize Subnet Mask

255 .255 .255 .128

8) Address and Range

Net ID 192.168.1.0

Valid Range 192.168.1.1
To **Total Address 126**
192.168.1.126

Broad Cast ID 192.168.1.127

Net ID 192.168.1.128

Valid Range 192.168.1.129
To **Total Address 126**
192.168.1.254

Broad Cast ID 192.168.1.255

9) Subnet Mask Selection

C	/24	/25	/26	/27	/28	/29	/30	/31
Result	**0**	**128**	**192**	**224**	**240**	**248**	**252**	**254**

/25
&
Subnets Mask is 128

10) How many hosts ($2^{8-1}=2^7$) Total Hosts(128-2) Usable Hosts(126)

1 In-Class Exercises

Most of these questions were sourced from SubnettingQuestions.com[1], which is a very useful resource for practicing these skills; recommended for your exam study. The last question is another style of question you could expect in any subnetting examination.

1. Which subnet does host 192.168.77.108/28 belong to?
2. What valid host range is the IP address 172.21.71.219/20 a part of?
3. What is the first valid host on the subnetwork that the node 172.16.139.35/26 belongs to?
4. What is the broadcast address of the network 172.30.134.0/23?
5. How many subnets and hosts can you get from the network 172.20.0.0/255.255.254.0?

ANS:

1)This indicates that four bits have been borrowed, hence its subnet mask would be 255.255.255.240; having 16 subnets.

2) It belongs to the host range 172.21.64.1 - 172.21.79.254.

3)The first valid host on that subnetwork range would be 172.16.128.1

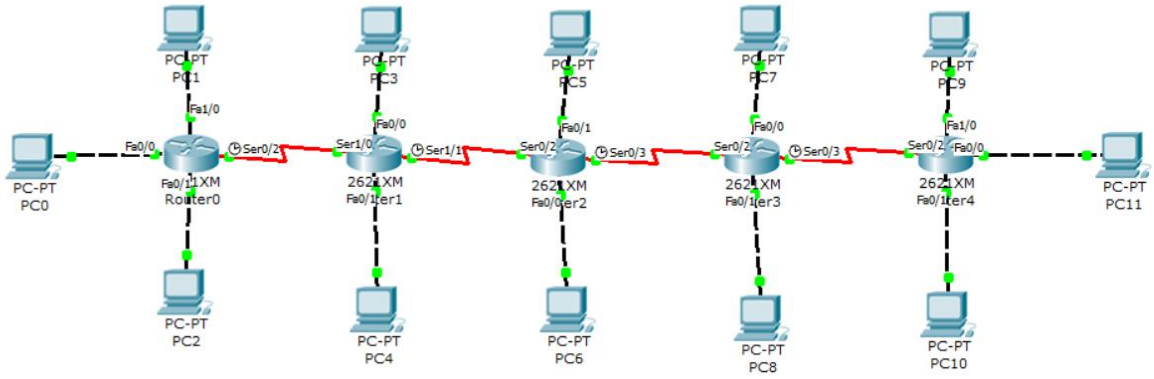
4)The broadcast address would be 172.30.143.255

5) You can get 512 hosts with 128 subnets.

Student Activity

Consider a network containing five routers with each router consisting four networks. Using the knowledge of subnetting, assign IP address to each device and run dynamic routing protocols. Attach screenshots of your configurations.

Network Topology:



Dynamic Rip Routing:

Router 0:

```
hostname "Router 0"
!
!
!
!
!
ip ssh version 1
!
!
interface FastEthernet0/0
 ip address 192.168.1.1 255.255.255.240
 duplex auto
 speed auto
!
interface FastEthernet0/1
 ip address 192.168.1.17 255.255.255.240
 duplex auto
 speed auto
!
interface Serial0/0
 ip address 192.168.1.49 255.255.255.240
 clock rate 64000
!
interface Serial0/1
 no ip address
 shutdown
!
interface FastEthernet1/0
 ip address 192.168.1.33 255.255.255.240
 duplex auto
 speed auto
!
router rip
 network 192.168.1.0
!
```

Router 1:

```
hostname "Router 1"
!
!
!
!
!
ip ssh version 1
!
!
interface FastEthernet0/0
 ip address 192.168.1.65 255.255.255.240
 duplex auto
 speed auto
!
interface FastEthernet0/1
 ip address 192.168.1.81 255.255.255.240
 duplex auto
 speed auto
!
interface Serial0/0
 ip address 192.168.1.50 255.255.255.240
!
interface Serial0/1
 ip address 192.168.1.97 255.255.255.240
 clock rate 64000
!
interface FastEthernet1/0
 no ip address
 duplex auto
 speed auto
 shutdown
!
router rip
 network 192.168.1.0
```

Router 2:

```
hostname "Router 2"
!
!
!
!
!
ip ssh version 1
!
!
interface FastEthernet0/0
 ip address 192.168.1.113 255.255.255.240
 duplex auto
 speed auto
!
interface FastEthernet0/1
 ip address 192.168.1.129 255.255.255.240
 duplex auto
 speed auto
!
interface Serial0/0
 ip address 192.168.1.98 255.255.255.240
!
interface Serial0/1
 ip address 192.168.1.145 255.255.255.240
 clock rate 64000
!
interface FastEthernet1/0
 no ip address
 duplex auto
 speed auto
 shutdown
!
router rip
 network 192.168.1.0
!
```

Router 3:

```
hostname "Router 3"
!
!
!
!
!
ip ssh version 1
!
!
interface FastEthernet0/0
 ip address 192.168.1.161 255.255.255.240
 duplex auto
 speed auto
!
interface FastEthernet0/1
 ip address 192.168.1.177 255.255.255.240
 duplex auto
 speed auto
!
interface Serial0/0
 ip address 192.168.1.146 255.255.255.240
!
interface Serial0/1
 ip address 192.168.1.193 255.255.255.240
 clock rate 64000
!
interface FastEthernet1/0
 no ip address
 duplex auto
 speed auto
 shutdown
!
router rip
 network 192.168.1.0
```

Router 4:

```
hostname "Router 4"
!
!
!
!
!
ip ssh version 1
!
!
interface FastEthernet0/0
 ip address 192.168.1.209 255.255.255.240
 duplex auto
 speed auto
!
interface FastEthernet0/1
 ip address 192.168.1.225 255.255.255.240
 duplex auto
 speed auto
!
interface Serial0/0
 ip address 192.168.1.194 255.255.255.240
!
interface Serial0/1
 no ip address
 shutdown
!
interface FastEthernet1/0
 ip address 192.168.1.241 255.255.255.240
 duplex auto
 speed auto
!
router rip
 network 192.168.1.0
!
```