LAB 3: Overview of IP Addressing and Subnetting

Objective(s):

- To understand theoretical knowledge of IPv4 Addressing and Subnetting.

Background:

An IP address (*internet protocol address*) is a numerical representation that uniquely identifies a specific interface on the network. Addresses in IPv4 are **32**-bits long. This allows for a maximum of 4,294,967,296 (2^{32}) unique addresses. Addresses in IPv6 are **128**-bits, which allows for 3.4 x 10^{38} (2^{128}) unique addresses. IP addresses are binary numbers but are typically expressed in decimal form (IPv4) or hexadecimal form (IPv6) to make reading and using them easier for humans.

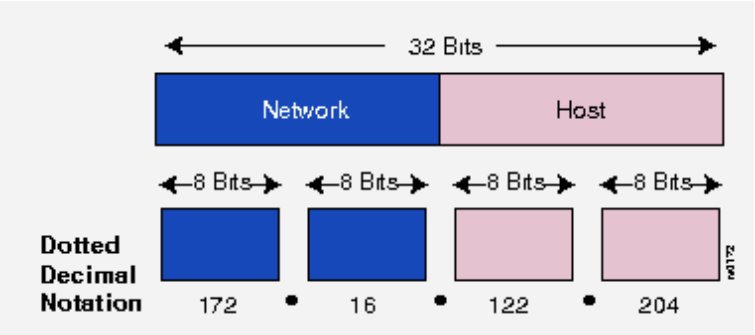
Terminologies

- **IPv4 address:** a 32-bit number, usually written in dotted decimal form, that uniquely identifies an interface of some computer
- **Host Address:** another term for IP address of the end device
- **Network:** a group of hosts, all of which have an identical beginning position of their ip addresses.
- **Broadcast Address:** a 32-bit number that is used to address all hosts in the network. It can't be assigned as an ip address of a host.
- **Subnet:** a group of hosts, all of which have an identical portion of their ip addresses, a subnet differs from a network in that a subnet is a further subdivision of a network.
- **Sub-netting:** the process of subdividing networks into smaller subnets.
- **Subnet mask:** A 32-bit combination used to describe which portion of an address refers to the subnet and which part refers to the host.

IPv4 Address representations

IPv4 addresses are actually 32-bit binary numbers, consisting of the two identifiers which, identify the network and the host to the network. It is generally represented as 4 octets of numbers from 0-255 represented in decimal form instead of binary form.

The IP address is divided into two main parts; the Network Number and the Host Number. The host number identifies a host in the network and is assigned by the local network administrator.



Subnet Masks

A single IP address identifies both a network, and a unique interface on that network. A subnet mask can also be written in dotted decimal notation and determines where the network part of an IP address ends, and the host portion of the address begins. When expressed in binary, any bit set to one means the corresponding bit in the IP address is part of the network address. All the bits set to zero mark the corresponding bits in the IP address as part of the host address. The bits marking the subnet mask must be consecutive ones. Most subnet masks start with 255. and continue on until the network mask ends.

A Class A network mask is defined as 255.0.0.0.
A Class B network mask is defined as 255.255.0.0.
A Class C network mask would be 255.255.255.0

IP Address Classes

IP address classes

Class	Leading bits	Size of *network number* bit field	Size of *rest* bit field	Number of networks	Addresses per network	Total addresses in class	Start address	End address
Class A	0	8	24	128 (2^7)	16,777,216 (2^{24})	2,147,483,648 (2^{31})	0.0.0.0	127.255.255.255
Class B	10	16	16	16,384 (2^{14})	65,536 (2^{16})	1,073,741,824 (2^{30})	128.0.0.0	191.255.255.255
Class C	110	24	8	2,097,152 (2^{21})	256 (2^8)	536,870,912 (2^{29})	192.0.0.0	223.255.255.255
Class D (multicast)	1110	not defined	not defined	not defined	not defined	268,435,456 (2^{28})	224.0.0.0	239.255.255.255
Class E (reserved)	1111	not defined	not defined	not defined	not defined	268,435,456 (2^{28})	240.0.0.0	255.255.255.255

Before variable length subnet masks allowed networks of any size to be configured, the IPv4 address space was broken into five classes.

Class A Address

The first bit of the first octet is always set to 0 (zero). Thus the first octet ranges from 1 – 127. 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 16,777,214 hosts (2^{24}-2).

(Note: 0 Octet is forbidden in RFC and 127 is reserved for loopback testing.)

Class B Address

An IP address which belongs to class B has the first two bits in the first octet set to 10. The default subnet mask for Class B is 255.255.0.0. Class B has 16384 (2^{14}) Network addresses and 65534 (2^{16}-2) Host addresses.

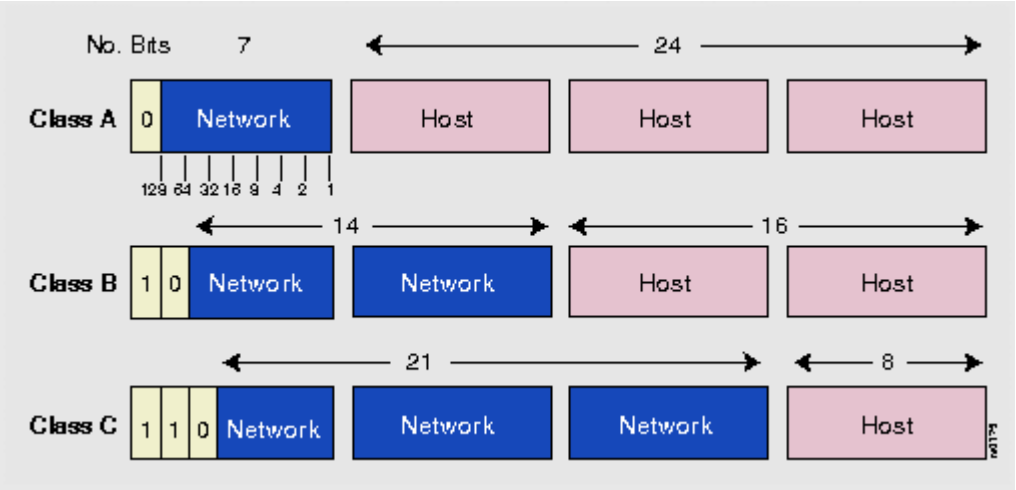
Class C Address
The first octet of Class C IP address has its first 3 bits set to 110. The default subnet mask for Class C is 255.255.255.0. Class C gives 2097152 (2^{21}) Network addresses and 254 (2^8-2) Host addresses.

Class D Address
The first four bits of the first octet in Class D IP addresses are set to 1110. Class D has IP address range 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
The first four bits of the first octet in Class D IP addresses are set to 1111. 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.

Network and Host Portion:

A Class A address has the first octet as the network portion and the remaining 3 octets as the host portion. A Class B address has the first and second octets as the network portion and the third and fourth octets as the host portion. A Class C address has the first, second, and third octet as the network portion and the last octet as the host portion.



Overview: IP Address Classes and Bit-Wise representations

Class A

```
  0.  0.  0.  0 = 00000000.00000000.00000000.00000000
127.255.255.255 = 01111111.11111111.11111111.11111111
                  0nnnnnnn.HHHHHHHH.HHHHHHHH.HHHHHHHH
```

Class B

```
128.  0.  0.  0 = 10000000.00000000.00000000.00000000
191.255.255.255 = 10111111.11111111.11111111.11111111
                  10nnnnnn.nnnnnnnn.HHHHHHHH.HHHHHHHH
```

Class C

```
 192.  0.  0.  0 = 11000000.00000000.00000000.00000000
 223.255.255.255 = 11011111.11111111.11111111.11111111
                   110nnnnn.nnnnnnnn.nnnnnnnn.HHHHHHHH
```

Class D

```
224.  0.  0.  0 = 11100000.00000000.00000000.00000000
239.255.255.255 = 11101111.11111111.11111111.11111111
                   1110XXXX.XXXXXXXX.XXXXXXXX.XXXXXXXX
```

Class E

```
240.  0.  0.  0 = 11110000.00000000.00000000.00000000
255.255.255.255 = 11111111.11111111.11111111.11111111
                   1111XXXX.XXXXXXXX.XXXXXXXX.XXXXXXXX
```

Private addresses

Within the address space, certain networks are reserved for private networks. Packets from these networks are not routed across the public internet. This provides a way for private networks to use internal IP addresses without interfering with other networks. The private networks are

- Class A Private Range: 10.0.0.0 to 10.255.255.255
- Class B Private APIPA Range: 169.254.0.0 to 169.254.255.255
    - *Automatic Private IP Addressing* (APIPA) is a feature on *Microsoft Windows*-based computers to automatically assign itself an IP address within this range if a *Dynamic Host Configuration Protocol* (DHCP) server is not available. A DHCP server is a device on a network that is responsible for assigning IP address to devices on the network.
- Class B Private Range: 172.16.0.0 to 172.31.255.255
- Class C Private Range: 192.168.0.0 to 192.168.255.255

Special addresses

Certain IPv4 addresses are set aside for specific uses:

127.0.0.0	Loopback address (the host's own interface)
224.0.0.0	IP Multicast
255.255.255.255	Broadcast (sent to all interfaces on network)

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

Exercise

Address Class

10.250.1.1- Class A

150.10.15.0- ClassB

192.14.2.0-Class C

148.17.9.1- Class B

193.42.1.1- Class C

126.8.156.0- ClassA

220.200.23.1- Class C

230.230.45.58- Class D

177.100.18.4- Class B

119.18.45.0-Class A

249.240.80.78- Class E

199.155.77.56- Class C

117.89.56.45- Class A

215.45.45.0- Class C

199.200.15.0- Class C

Network & Host Identification

Circle the network portion of these addresses:	Circle the host portion of these addresses:
177.100.18.4	10.15.123.50
119.18.45.0	171.2.199.31
209.240.80.78	198.125.87.177
199.155.77.56	223.250.200.222
117.89.56.45	17.45.222.45
215.45.45.0	126.201.54.231
192.200.15.0	191.41.35.112
10.250.1.1	155.25.169.227
150.10.15.0	192.15.155.2
192.14.2.0	123.102.45.254
148.17.9.1	148.17.9.155
193.42.1.1	100.25.1.1
126.8.156.0	195.0.21.98
220.200.23.1	25.250.135.46

Default Subnet Masks

Write the correct default subnet mask, network address and broadcast address for each of the following addresses:

IP Address	Default Subnet Mask	Network Address	Broadcast Address
177.100.18.4	255.255.0.0	177.100.0.0	177.100.255.255
119.18.45.0	255.0.0.0	119.0.0.0	119.255.255.255
191.249.234.191	255.255.0.0	191.249.0.0	191.249.255.255
223.23.223.109	255.255.255.0	223.23.223.0	223.23.223.255
10.10.250.1	255.0.0.0	10.0.0.0	10.255.255.255
126.123.23.1	255.255.0.0	126.123.0.0	126.123.255.255
223.69.230.250	255.255.255.0	223.69.230.0	223.69.230.255
192.12.35.105	255.255.255.0	192.12.35.0	192.12.35.255
77.251.200.51	255.0.0.0	77.0.0.0	77.255.255.255
189.210.50.1	255.255.0.0	189.210.0.0	189.210.255.255
88.45.65.35	255.0.0.0	88.0.0.0	88.255.255.255
193.100.77.8	255.255.255.0	193.100.77.0	193.100.77.255
125.125.250.1	255.0.0.0	125.0.0.0	125.255.255.255
220.90.130.45	255.255.255.0	220.90.130.0	220.90.130.255
134.125.34.9	255.255.0.0	134.125.0.0	134.125.255.255