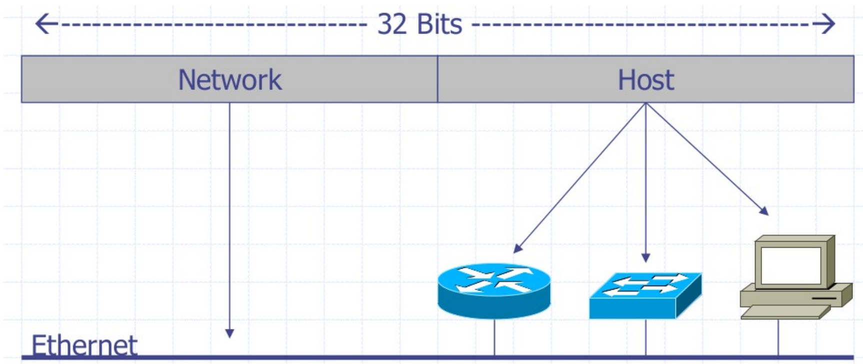
UNIVERSITY OF BIRMINGHAM

M.Sc. Computer Science
Computer Systems
Topic - IP Addressing and Subnets

What is an IP Address?

An IP address is an address used in order to uniquely identify a device on an IP network. The address is made up of 32 binary bits, which can be divisible into a network portion and host portion with the help of a subnet mask. The 32 binary bits are broken into four octets (1 octet = 8 bits). Each octet is converted to decimal and separated by a period (dot). For this reason, an IP address is said to be expressed in **dotted decimal** format (for example, 172.16.81.100). The value in each octet ranges from 0 to 255 decimal, or 00000000 - 11111111 binary.



Classful IP Addressing

These octets are broken down to provide an addressing scheme that can accommodate large and small networks. There are five different classes of networks, A, B, C, D & E. We focus on classes A to C, since classes D and E are reserved and discussion of them is beyond our scope. Also note that the terms "Class A, Class B" and so on are used in this document in order to help facilitate the understanding of IP addressing and subnetting. These terms are rarely used in the industry anymore because of the introduction of Classless Interdomain Routing (CIDR).

Given an IP address, its class can be determined from the four high-order bits (the four left-most bits in the first octet). The following table shows the significance of these high order bits and the range of addresses that fall into each class.

Network/Host Parts	**Class**	**Classful Mask**	**Addresses Range**
0nnnnnnn.hhhhhhhh.hhhhhhhh.hhhhhhhh	Class A	255.0.0.0	1.0.0.0 – 127.255.255.255
10nnnnnn.nnnnnnnn.hhhhhhhh.hhhhhhhh	Class B	255.255.0.0	128.0.0.0 – 191.255.255.255
110nnnnn.nnnnnnnn.nnnnnnnn.hhhhhhhh	Class C	255.255.255.0	192.0.0.0 – 223.255.255.255
1110hhhh.hhhhhhhh.hhhhhhhh.hhhhhhhh	Class D	Multicast Addr	224.0.0.0 – 239.255.255.255
1111hhhh.hhhhhhhh.hhhhhhhh.hhhhhhhh	Class E	Experimental	240.0.0.0 – 255.255.255.255

In a Class A address, the first octet is the network portion, so the Class A has a major network address of 1.0.0.0 - 127.255.255.255. Octets 2, 3, and 4 (the next 24 bits) are for the network manager to divide into subnets and hosts as he/she sees fit. Class A addresses are used for networks that have more than 65,536 hosts (actually, up to 16777214 hosts!).

In a Class B address, the first two octets are the network portion, so the Class has a major network address of 128.0.0.0 - 191.255.255.255. Octets 3 and 4 (16 bits) are for local subnets and hosts. Class B addresses are used for networks that have between 256 and 65534 hosts.

In a Class C address, the first three octets are the network portion. The Class has a major network address of 192.0.0.0 – 223.255.255.255. Octet 4 (8 bits) is for local subnets and hosts - perfect for networks with less than 254 hosts.

Network Masks

A network mask helps you know which portion of the address identifies the network and which portion of the address identifies the node. Class A, B, and C networks have default masks, also known as natural masks, as shown here:

```
Class A: 255.0.0.0
Class B: 255.255.0.0
Class C: 255.255.255.0
```

An IP address on a Class A network that has not been subnetted would have an address/mask pair similar to: 8.20.15.1 255.0.0.0. In order to see how the mask helps you identify the network and node parts of the address, convert the address and mask to binary numbers.

```
8.20.15.1 = 00001000.00010100.00001111.00000001
255.0.0.0 = 11111111.00000000.00000000.00000000
            -----------------------------------
             net id |        host id
netid = 00001000 = 8
hostid = 00010100.00001111.00000001 = 20.15.1
```

Once you have the address and the mask represented in binary, then identification of the network and host ID is easier. Any address bits which have corresponding mask bits set to 1 represent the network ID. Any address bits that have corresponding mask bits set to 0 represent the node ID.

Understanding Subnetting

Subnetting allows you to create multiple logical networks that exist within a single Class A, B, or C network. If you do not subnet, you are only able to use one network from your Class A, B, or C network, which is unrealistic.

Each data link on a network must have a unique network ID, with every node on that link being a member of the same network. If you break a major network (Class A, B, or C) into smaller subnetworks, it allows you to create a network of interconnecting subnetworks. Each data link on this network would then have a unique network/subnetwork ID. Any device, or gateway, that connects n networks/subnetworks has n distinct IP addresses, one for each network / subnetwork that it interconnects.

In order to subnet a network, extend the natural mask with some of the bits from the host ID portion of the address in order to create a subnetwork ID. For example, given a Class C network of 204.17.5.0 which has a natural mask of 255.255.255.0, you can create subnets in this manner:

```
204.17.5.0        - 11001100.00010001.00000101.00000000
255.255.255.224   - 11111111.11111111.11111111.11100000
                    --------------------------|sub|----
```

By extending the mask to be 255.255.255.224, you have taken three bits (indicated by "sub") from the original host portion of the address and used them to make subnets. With these three bits, it is possible to create **eight** subnets. With the remaining five host ID bits, each subnet can have up to 32 host addresses, **30 of which can actually be assigned to a device since host ids of all zeros or all ones are not allowed** *(it is very important to remember this)*. So, with this in mind, these subnets have been created.

Subnet #	Subnet Address	Subnet Mask	Host IP Address Range
1	204.17.5.0	255.255.255.224	204.17.5.1 - 204.17.5.30
2	204.17.5.32	255.255.255.224	204.17.5.33 - 204.17.5.62
3	204.17.5.64	255.255.255.224	204.17.5.65 - 204.17.5.94
4	204.17.5.96	255.255.255.224	204.17.5.97 - 204.17.5.126
5	204.17.5.128	255.255.255.224	204.17.5.129 - 204.17.5.158
6	204.17.5.160	255.255.255.224	204.17.5.161 - 204.17.5.190
7	204.17.5.192	255.255.255.224	204.17.5.193 - 204.17.5.222
8	204.17.5.224	255.255.255.224	204.17.5.225 - 204.17.5.254

Here are two ways to denote these masks. First, since you use three bits more than the "natural" Class C mask, you can denote these addresses as having a 3-bit subnet mask. Or, secondly, the mask of 255.255.255.224 can also be denoted as /27 as there are 27 bits that are set in the mask. This second method is used with CIDR. With this method, one of these networks can be described with the notation prefix/length. For example, 204.17.5.32/27 denotes the network 204.17.5.32 255.255.255.224.

The following figure shows the No of Hosts, prefix/length Masks, and Binary Representation of these masks as used in CIDR.

Hosts	Mask	Mask	Binary
1	/32	255.255.255.255	11111111.11111111.11111111.11111111
2	/31	255.255.255.254	11111111.11111111.11111111.11111110
4	/30	255.255.255.252	11111111.11111111.11111111.11111100
8	/29	255.255.255.248	11111111.11111111.11111111.11111000
16	/28	255.255.255.240	11111111.11111111.11111111.11110000
32	/27	255.255.255.224	11111111.11111111.11111111.11100000
64	/26	255.255.255.192	11111111.11111111.11111111.11000000
128	/25	255.255.255.128	11111111.11111111.11111111.10000000
256	/24	255.255.255.0	11111111.11111111.11111111.00000000
512	/23	255.255.254.0	11111111.11111111.11111110.00000000
1024	/22	255.255.252.0	11111111.11111111.11111100.00000000

And lastly, remember the following table by heart, it will help you a lot!

2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
128	64	32	16	8	4	2	1

Question #1

You are given two address / mask combinations, written with the prefix/length notation, which have been assigned to two devices. Your task is to determine if these devices are on the same subnet or different subnets. You can use the address and mask of each device in order to determine to which subnet each address belongs.

```
Device A: 172.16.17.30/20
Device B: 172.16.28.15/20
```

Determine the Subnet for Device A:

```
172.16.17.30 -    10101100.00010000.00010001.00011110
255.255.240.0 -   11111111.11111111.11110000.00000000
                  -----------------| sub|------------
subnet =          10101100.00010000.00010000.00000000 = 172.16.16.0
```

Looking at the address bits that have a corresponding mask bit set to one, and setting all the other address bits to zero (this is equivalent to performing a logical "AND" between the mask and address), shows you to which subnet this address belongs. In this case, Device A belongs to subnet 172.16.16.0.

Determine the Subnet for Device B:

```
172.16.28.15 -    10101100.00010000.00011100.00001111
255.255.240.0 -   11111111.11111111.11110000.00000000
                  -----------------| sub|------------
subnet =          10101100.00010000.00010000.00000000 = 172.16.16.0
```

From these determinations, DeviceA and DeviceB have addresses that are part of the same subnet.

Question #2: You are working in a company and have been asked to design a network where each subnet would contain around 50 hosts. How many subnets can you create using the Network Address of 200.100.50.0? What are the range of IP addresses for each subnet?

We can see that 200.100.50.0 is a Class C address with a default subnet mask of 255.255.255.0 or /24
The subnet mask in Binary looks like: `11111111.11111111.11111111.00000000`
As we need around 50 hosts per subnet, we will dedicate need at-least 6 bits for the host part i.e. $2^6 = 64$
So the subnet mask can be extended up to /26 bits i.e. `11111111.11111111.11111111.11000000`
Therefore, we will have four subnets in our network, as shown in the table below:

Subnet #	Subnet Address	Subnet Mask	Host IP Address Range
1	200.100.50.0	255.255.255.192	200.100.50.1 - 200.100.50.62
2	200.100.50.64	255.255.255.192	200.100.50.65 - 200.100.50.126
3	200.100.50.128	255.255.255.192	200.100.50.129 - 200.100.50.190
4	200.100.50.192	255.255.255.192	200.100.50.193 - 200.100.50.254