

CENG393 Computer Networks

Labwork 6

Internet Protocol Addresses

As of 2019, every device (computers, mobile phones, IoT¹ devices, etc) has to obtain an IP address in order to connect to a network. There are two IP specifications in use today: IPv4 and IPv6.

1 IPv4 - Internet Protocol Version 4

It is the most common internetworking protocol used today. IPv4 addresses has a fixed length of 32 bits, and approximately 2^{32} (≈ 4 billion) individual addresses can be assigned. Typically IPv4 addresses are displayed in **dotted decimal** format, denoted as “**a.b.c.d**”, where a, b, c and d are integers in range of 0 and 255. Do note that the first and last IP addresses of a network can not be assigned to any device in the network; they are reserved for **network ID** and **broadcast address** respectively.

Initially with IPv4's adoption in 80's, the first 8 bits of an IP address were designed as network bits and rest of the bits were designed as host bits. This resulted in 256 (2^8) different networks (each having a total of 16.777.216 IP addresses, of which 16.777.214 are assignable) for the whole IPv4, which was shortly found to be an inefficient way of address allocation. Just a few years later, classful network architecture was proposed.

1.1 Classful Networks

This method proposes dividing the whole range of IPv4 addresses into 5 classes as shown in Figure 1 below:

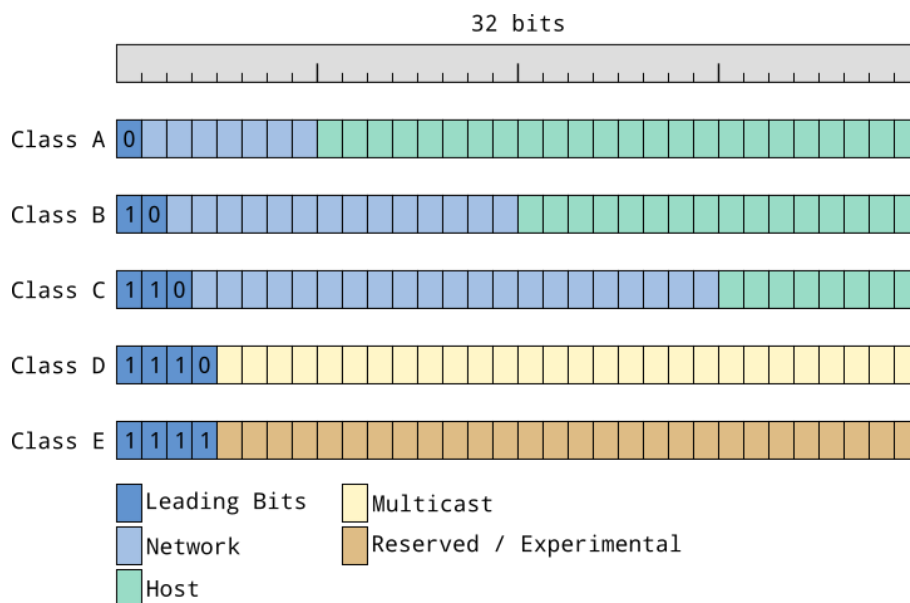


Figure 1: IPv4 Classes

The leading bits for each class is different from each other; for example all Class A addresses must begin with “0”, while all Class C addresses must begin with “110”. Range of each class can be identified by filling all host bits with 0's and counting up until all host bits are set to 1.

¹Internet of Things

This method has also become unefficient as time passed. Examine the following chart:

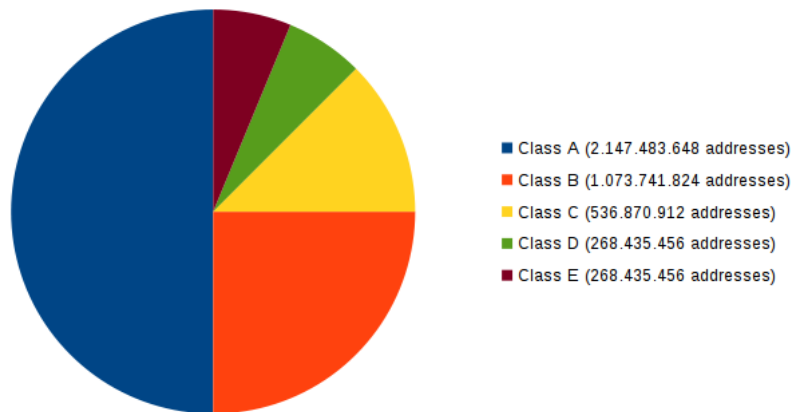


Figure 2: Distribution of IP Addresses Using Classful Networks

Figure 2 shows that by setting the first leading bit to “0”, half of the whole IPv4 addresses are assigned into Class A and they can be shared among only 128 networks all around the world; giving each network 16.777.216 individual IPv4 addresses. On the other hand, the other half is divided into much smaller groups. For example, there would be 2.097.152 different Class C networks on the world but each one of them could get only 256 individual IPv4 addresses.

This scheme also results in largely wasted amounts of IP addresses as well. For example if a network is to be constructed with 1.000 devices, they can not get a Class C network because Class C supports networks up to only 254 different hosts. Therefore these devices should get a Class B network. But every network in Class B can get 65.534 different addresses, which means 64.534 addresses are wasted after using only 1.000 of them.

Because of these problems, a better solution is adopted today.

1.2 Classless Inter-Domain Routing

Instead of setting fixed-size network and host portions in an IPv4 address as in Classful Networks, Classless Networks allow better allocation of available addresses into networks by dynamically changing how many bits are assigned to network part. This method introduces **subnet masks**, which are used for identifying how many bits of an IP address belongs to network part and how many bits belong to host part. Study the table below:

IP	Subnet mask	Network	Host	CIDR Notation
192.168.129.26	255.0.0.0	192.0.0.0	0.168.129.26	/8
192.168.129.26	255.224.0.0	192.160.0.0	0.8.129.26	/11
192.168.129.26	255.255.128.0	192.168.128.0	0.0.1.26	/17
192.168.129.26	255.255.255.0	192.168.129.0	0.0.0.26	/24
192.168.129.26	255.255.255.240	192.168.129.16	0.0.0.10	/28

Table 1: Network and host division of an IP address with various subnet masks

Table 1 shows how an IP address can behave differently when used with different subnet masks. In this approach, subnet masks are used for identifying how many bits are allocated for network and host portions of a given IPv4 address. When network part (denoted with 1-bits) increases to the right, networks with smaller amounts of IP addresses will be created. For example, lets assume a company has access to all IP addresses between 192.168.8.0 and 192.168.15.255 (≈ 4.096 addresses). Their network can be expressed as “192.168.8.0/255.255.240.0”, or “192.168.8.0/20”. In order to distribute IP addresses among different offices of this company, they can create sepearate networks for these offices by setting subnet masks as shown in Table 2 below:

Subnet mask	Networks	IP addresses per network
255.255.240.0	1	4.096
255.255.248.0	2	2.048
255.255.252.0	4	1.024
255.255.254.0	8	512
255.255.255.0	16	256
...

Table 2: Subnets and Their Sizes

Do note that in a valid subnet mask, 1’s are always aligned to the left and 0’s are always aligned to the right; they may not interweave.

1.3 Creating Subnetworks

When you have access to a pool of IP addresses, sometimes having only one network may not be enough for your requirements; you may need to create multiple networks from your IP address pool. Lets assume you have access to all IP addresses in the network 192.168.8.0/21. In this network you can assign all 2.046 IP addresses ($2^{11} - 2$) between 192.168.8.1 and 192.168.15.254 to your devices to create a single network as demonstrated below in Figure 3:

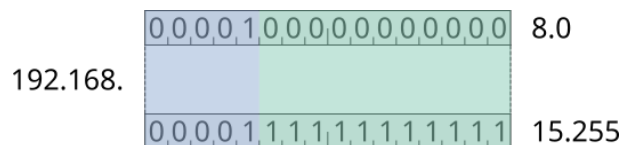


Figure 3: 192.168.8.0/21

But, by shifting the given subnet mask to right one bit, you get two *sub*networks:

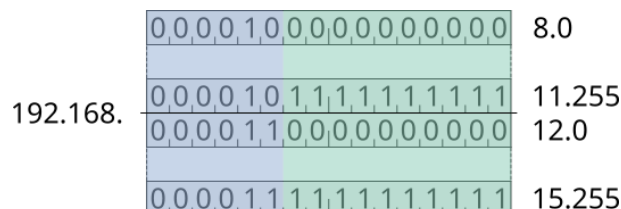


Figure 4: 192.168.8.0/22

Or four subnetworks by shifting two bits:

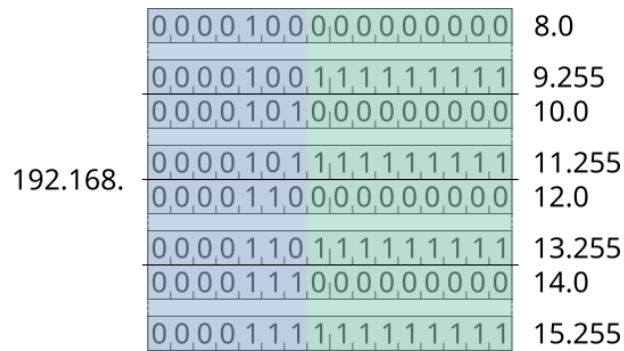


Figure 5: 192.168.8.0/23

You may divide your original range of IP addresses into smaller networks by borrowing as many host bits as required while still having access to all your original addresses. But although it is possible to create two subnetworks by shifting subnet mask one bit, the use of “all zeros” and “all ones” subnets are discouraged. Therefore, you actually have to shift two bits to create two usable subnetworks ($2^2 - 2$), or 3 bits to create 6 usable subnetworks ($2^3 - 2$), etc. You may use Formula 1 to find out how many bits you need to borrow from host bits for creating N subnetworks:

$$[\log_2(N + 2)] \tag{1}$$

2 Exercises

1. Find out start and end addresses for each IPv4 class.
2. Find out the first usable address of first network and last usable address of last network for each IPv4 class.
3. Find out the leading bits and classes of each IP address given below:

IP Address	Leading Bits	Class	IP Address	Leading Bits	Class
206.231.210.249			56.16.243.16		
146.248.60.74			230.111.93.240		
191.244.243.66			253.237.154.160		
246.145.80.231			155.200.24.146		

4. For each IP/subnet mask pair given below, calculate the network and host parts.

IP Address	Subnet Mask	Network	Host
206.231.210.249	255.255.192.0		
146.248.60.74	255.255.254.0		
191.244.243.66	255.240.0.0		
246.145.80.231	255.255.255.128		

5. What are the maximum number of assignable IP addresses offered by the following subnet masks?

Subnet Mask	# of Addresses	Subnet Mask	# of Addresses
255.255.128.0		255.255.255.192	
255.255.255.224		255.240.0.0	
255.255.0.0		254.0.0.0	
255.255.252.0		255.255.255.0	

Answer the questions below using the following table:

Network	Shift
253.237.154.160/28	2
206.231.210.0/24	3
146.248.48.0/20	4
191.244.0.0/16	2
246.145.64.0/20	3

6. How many subnetworks would you create if you shifted specified amounts of bits in subnet mask?

7. List ALL subnets' start and end ranges.

8. Highlight usable subnets' IP ranges.