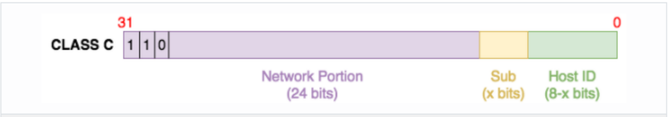
Subnetting Basics

Introduction to Subnets

Internet designers come with a solution to the issue of IP address wastage: Subnetting. Subnetting allows us to create a smaller network (sub-networks or subnets) inside a large network by borrowing bits from the Host ID portion of the address. We can use those borrowed bits to create additional networks, resulting in smaller-sized networks.



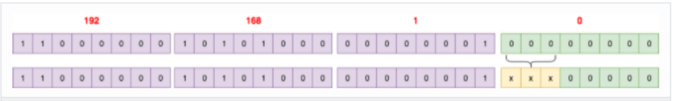
A Class C IP address

Imagine that we want to build four networks that will support up to 30 devices in different segments. Without subnetting, we will need four Class C IP addresses to support this design. For example:

```
Network #1: 192.168.1.0
Network #2: 192.168.2.0
Network #3: 192.168.3.0
Network #4: 192.168.4.0
```

With four Class C IP addresses we can subscribe 254 * 4 = 1016 hosts. But we have only 30 * 4 = 120 hosts. This means 1016 - 120 = 896 IP addresses will be wasted!

If you look at the design requirement of 30 hosts per network, you will see that 5 bits are enough to subscribe to 30 hosts in each network. And this means we still have 3 bits unused and with subnetting, we can use those three bits to create smaller networks. For this example, let's take the 192.168.1.0 network:

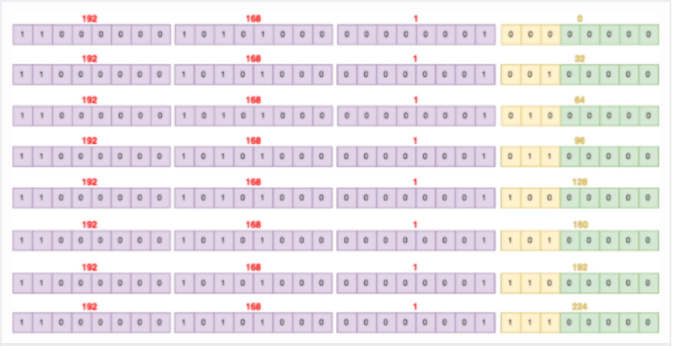


Borrowing bits from host segment of the IP address

By borrowing 3 bits, we can create 8 (2^3) subnets:

1. 192.168.1.0
2. 192.168.1.32
3. 192.168.1.64
4. 192.168.1.96
5. 192.168.1.128
6. 192.168.1.160
7. 192.168.1.192
8. 192.168.1.224

These subnet addresses look like normal IP addresses. However, looking at them in their binary form makes things clearer:



Subnet IP addresses

With subnetting, not only have we used only one Class C network, we have created 8 subnets from that network, each one supporting up to 30 hosts! We can use 4 of these subnets for our network and reserve the remaining 4 subnets for future expansion. This results in great waste reduction – from 896 wasted IP addresses to 120 reserved IP addresses.

Why do we need subnetting?

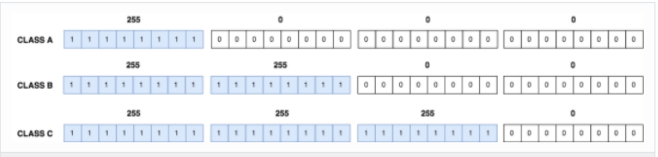
- **Reduce wastage:** As we have already seen, subnetting (and CIDR on a larger scale) helps us conserve IP addresses. While this is very important on the Internet (conserving public IP addresses), it is also useful on local area networks (LANs) where private IP addresses are used.
- **Improve Network Performance:** Subnetting improves the overall performance of a network. The larger a network is, the busier (more congested) it is. Consider the example of broadcasts – every host within an individual network will receive a broadcast even when it is not meant for them. This can affect performance especially during issues like broadcast storms. Therefore, the smaller the network, the more you can contain such issues within the subnet.
- **Isolation:** With smaller networks, you are able to isolate effectively as faults inside one subnet will not necessarily spread into other subnets. This is also important during security incidents so that even if one subnet is affected, the entire network is not brought down.
- **Easier administration:** Subnetting, when done properly, can make network administration more effective. For example, a multinational organization can design its network in such a way that each region is assigned an IP address block from a larger address block, and subnetting is used within regions to further divide the blocks among networks. This kind of design also improves routing as the routers in one region only need to know the "summarized" IP address block for other regions rather than all the smaller IP address blocks. This reduces the size of the routing table and ensures that fluctuations in one region do not affect the entire network

Subnet Masks

With what we have done, we have created a problem for computers and other networking devices: how are they supposed to differentiate between a subnet `192.168.1.32` and an IP address `192.168.1.32`? This is where **subnet masks** (also called network masks) come in. A **subnet mask** is the representation of the network portion of an address. It is also made up of 32 bits with all the bits that represent the network portion being marked as **1s** and the other parts marked as **0s**.

For example, the default subnet masks of the IP address classes are:

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

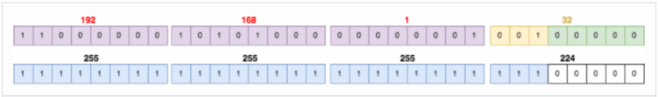


Therefore, a Class C network of `192.168.1.0` can be represented as `192.168.1.0 255.255.255.0`.

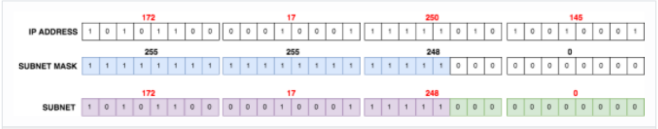
💡**Tip:**

- It can also be represented using prefix length (CIDR) notation where only the 1s that make up the network portion are counted and represented with a slash e.g. 192.168.1.0/24. We will talk about CIDR in the following lessons.

With subnetting, the borrowed bits from the host ID are counted as part of the network bits. So if we revisit our example above again, the `192.168.1.32` subnet can be represented as `192.168.1.32 255.255.255.224` (or `192.168.1.32/27`).



By comparing (logical AND) the "turned on" bits (i.e. 1s) in the subnet mask to an IP address, a network device can determine what network a particular IP address belongs to. For example, the `172.17.250.145` IP address with a subnet mask of `255.255.248.0` belongs to the `172.17.248.0 255.255.248.0` subnet:



Classless Inter-Domain Routing (CIDR)

In order to reduce the wastage of IP addresses, a new concept of **Classless Inter-Domain Routing (CIDR)** is introduced.

When you receive a block of addresses from an ISP (Internet Service Provider), what you get will look something like this: `192.168.10.32/28`. This is telling you what your subnet mask is. The slash notation **(/)** means how many bits are turned on (1s). Obviously, the maximum could only be **/32** because a byte is 8 bits and there are 4 bytes in an IP address: 4 × 8 = 32. But keep in mind that the largest subnet mask available (regardless of the class of address) can only be a **/30** because you have to keep at least 2 bits for host bits.

Take, for example, a *Class A* default subnet mask, which is `255.0.0.0`. This means that the first byte of the subnet mask is all ones (1s), or `11111111`. When referring to a slash notation, you need to count all the 1s bits to figure out your mask. The `255.0.0.0` is considered a **/8** because it has 8 bits that are 1s—that is, 8 bits that are turned on.

A *Class B* default mask would be `255.255.0.0`, which is a **/16** because 16 bits are (1s):

```
11111111.11111111.00000000.00000000.
```

Rules for forming CIDR Blocks:

1. All IP addresses must be contiguous.
2. Block size must be the power of 2 (2^n). If the size of the block is the power of 2, then it will be easy to divide the Network. Finding out the Block Id is very easy if the block size is of the power of 2.
3. The first IP address of the Block must be evenly divisible by the size of the block. In simple words, the least significant part should always start with zeroes in Host Id. Since all the least significant bits of Host Id is zero, then we can use it as Block Id part.

Example:

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

- All the IP addresses are contiguous.
- Total number of IP addresses in the Block = 16 = 2^4.
- 1st IP address: `100.1.2.00100000`

Since Host Id will contain the last 4 bits and all the least significant 4 bits are zero. Hence, the first IP address is evenly divisible by the size of the block. All three rules are followed by this Block. Hence, it is a valid IP address block.

Variable Length Subnet Masks (VLSM)

So far, we have used subnetting to create fixed-size subnets e.g. four `/26` subnets from one `/24` block. However, the use of subnet masks and prefix lengths provides more flexibility – we can create subnets of varying sizes from the same address block i.e. VLSM.

Let us consider the following example. We are given a block of `172.16.1.0/24` and we need to split it such that the following requirements are met:

- A subnet that can accommodate 100 hosts
- A subnet that can accommodate up to 55 hosts
- Two subnets that can accommodate up to 12 hosts each

To solve this problem, start with the biggest block and keep going down. For example, we need a minimum subnet of `/25` to accommodate 100 hosts. (`/25` means we have 7 bits left for the host ID.) Therefore, we can split the `172.16.1.0/24` block into two subnets:

```
172.16.1.0/25
172.16.1.128/25
```

We can use the first subnet `172.16.1.0/25` for the 100 hosts leaving us with the other subnet, `172.16.1.128/25`.

The next largest subnet needs 55 hosts which can be accommodated with a `/26` subnet. This means we can split the `172.16.1.128/25` subnet into two smaller subnets:

```
172.16.1.128/26
172.16.1.192/26
```

We can use the `172.16.1.128/26` subnet for the network requiring 55 hosts leaving us with the `172.16.1.192/26` subnet to further break down.

The two other networks require 12 hosts meaning we need a minimum of `/28` subnets. Therefore, we can split the `172.16.1.192/26` subnet into 4 smaller subnets:

```
172.16.1.192/28
172.16.1.208/28
172.16.1.224/28
172.16.1.240/28
```

Therefore, our subnets are:

- `172.16.1.0/25` for the network with 100 hosts
- `172.16.1.128/26` for the network with 55 hosts
- `172.16.1.192/28` for the first network with 12 hosts
- `172.16.1.208/28` for the second network with 12 hosts

This means we still have two subnets (`172.16.1.224/28` and `172.16.1.240/28`) to use in the future.

Subnetting Example-1

255.255.128.0 (/17)

Let's take a look at our first example:

```
172.16.0.0 = Network address
255.255.128.0 = Subnet mask
```

- **Subnets?**

$2^1 = 2$ (same as Class C).

- **Hosts?**

$2^{15} - 2 = 32,766$ (7 bits in the third octet, and 8 in the fourth).

- **Valid subnets?**

256 – 128 = 128. 0, 128. Remember that subnetting in Class B starts in the third octet, so the subnet numbers are really 0.0 and 128.0, as shown in the next table. These are the exact numbers we used with Class C; we use them in the third octet and add a 0 in the fourth octet for the network address. To find the host addresses easily, initially write the subnet address and the broadcast address. After that, host addresses are between them and more clear to see.

- **Broadcast address for each subnet?**

The following table shows the two subnets available, the valid host range, and the broadcast address of each:

Subnet (do first)	0.0	128.0
First host (host addressing last)	0.1	128.1
Last host	127.254	255.254
Broadcast (do second)	127.255	255.255

Notice that we just added the fourth octet's lowest and highest values and came up with the answers. And again, it's done exactly the same way as for a *Class C* subnet. We just use the same numbers in the third octet and added 0 and 255 in the fourth octet.

Subnetting Example-2

255.255.255.224 (/27)

This time, we'll subnet the network address `192.168.10.0` and subnet mask `255.255.255.224`.

```
192.168.10.0 = Network address
255.255.255.224 = Subnet mask
```

- **How many subnets?**

224 is `11100000`, so our equation is $2^3 = 8$.

- **How many hosts?**

$2^5 - 2 = 30$.

- **What are the valid subnets?**

256 – 224 = 32. We just start at zero and count to the subnet mask value in blocks (increments) of 32: 0, 32, 64, 96, 128, 160, 192, and 224.

- **What's the broadcast address for each subnet (always the number right before the next subnet)?**

- **What are the valid hosts (the numbers between the subnet number and the broadcast address)?**

To answer the last two questions, first, just write out the subnets, and then write out the broadcast address—the number right before the next subnet. Last, fill in the host address. The following table gives you all the subnets for the `255.255.255.224` Class C subnet mask:

The subnet address	0	32	64	96	128	160	192	224
The first valid host	1	33	65	97	129	161	193	225
The last valid host	30	62	94	126	158	190	222	254
The broadcast address	31	63	95	127	159	191	223	255