Subnetting

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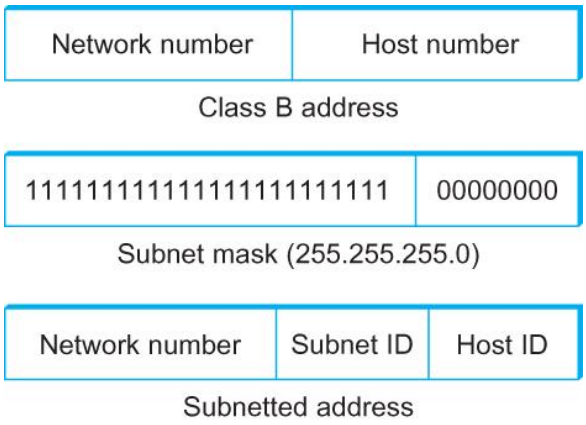
I. The purpose of subnetting

- split a large network IP into a grouping of smaller, interconnected networks to save IP address space and thus improve IP address allocation efficiency

II. Background

An IP includes two parts: **Network number** and **Host number**



Total bits of IP address are 32. Depending on the IP class (Class A-E), we can know the number of bits for network number and host number.

Five Different Classes of IPv4 Addresses

Class	First Octet decimal (range)	First Octet binary (range)	IP range	Subnet Mask	Hosts per Network ID	# of networks
Class A	0 – 127	0XXXXXXX	0.0.0.0-127.255.255.255	255.0.0.0	$2^{24}-2$	2^{7}
Class B	128 – 191	10XXXXXX	128.0.0.0-191.255.255.255	255.255.0.0	$2^{16}-2$	2^{14}
Class C	192 – 223	110XXXXX	192.0.0.0-223.255.255.255	255.255.255.0	$2^{8}-2$	2^{21}
Class D (Multicast)	224 – 239	1110XXXX	224.0.0.0-239.255.255.255			
Class E (Experimental)	240 – 255	1111XXXX	240.0.0.0-255.255.255.255			

For example,

- For IP addresses in class A (0.x.x.x~127.x.x.x), the network number includes 8 bits while the host number includes 24 bits
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- For IP addresses in class B (128.x.x.x~191.x.x.x), the network number includes 16 bits while the host number includes 16 bits
- For IP addresses in class C (192.x.x.x~223.x.x.x), the network number includes 24 bits while the host number includes 8 bits

Subnetting means borrowing bits from the host number to assign for the network number.

The formula to calculate the number of bits to borrow is

- Number of subnets = 2^N ➔ N is the number of bits to borrow to assign for the network number
- Number of hosts per subnet = (2^H) - 2 ➔ H is the number of remaining bits for the host number

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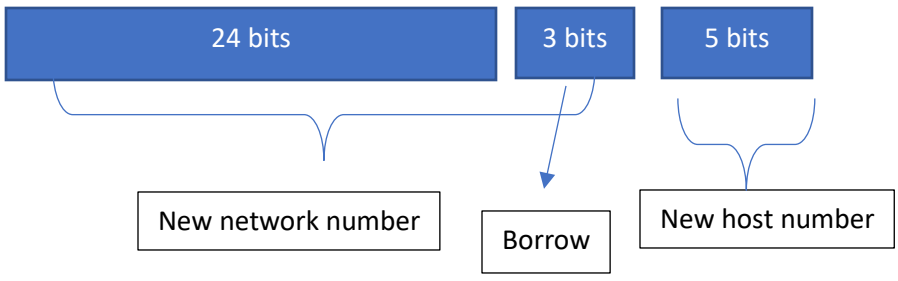
For example, from the IP 192.168.1.0/24, please split into 8 networks and 30 hosts per subnet (equal host space)

- Number of subnets: $2^N = 8$ ➔ N = 3 is the number of bits to borrow and assign for the network number
- Since the above IP is class C, the original network number includes 24 bits. The remaining bits for the host number is 8 bits.

- Now we borrow 3 bits from the host number to assign for the network number so the new number of bits for network and host is 24+3 = 27 and (8-3= 5), respectively



- Number of hosts per subnet is 2^5 - 2 = 30

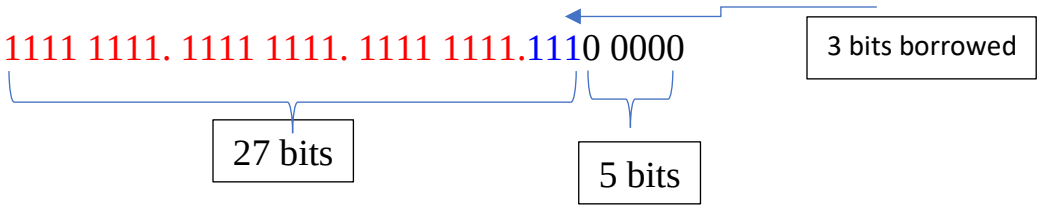
How to subnet

1. Step 1: Check the requirement of how many subnets and hosts per subnet

2. Step 2: Check the IP class or subnet mask of the IP, e.g., 192.168.1.0/24
   The IP is belonging to class C. Subnet mask /24 is equal to 255.255.255.0
3. Step 3: Use this formula to calculate

- Number of subnets = 2^N ➔ N is the number of bits to borrow
  Since the requirement requires 8 subnets so $2^N = 8$ ➔ N = 3
- Number of hosts per subnet = $(2^H) - 2$ ➔ H is the number of remaining bits for the host part : $(2^H) - 2 = 30$ → H = 5. If the requirement doesn't specify the exact number of hosts, you can calculate H = the number of bits in the original host number – borrowed bits (= 8 – 3 = 5)

4. Step 4: Transfer the new network number (24 + 3 = 27 bits) to 1, the rest is 0



   Convert into the decimal format to get new subnet mask
   1111 1111.1111 1111. 1111 1111.1110 0000 ➔ Decimal: 255.255. 255. 224
   So 255.255. 255. 224 is new subnet mask
5. Step 5: To find the network IP for each of 8 subnets, we use the combined options for three borrowed bits
   192.168.1.0000 0000 → 192.168.1.0
   192.168.1.0010 0000 → 192.168.1.32
   192.168.1.0100 0000 → 192.168.1.64
   192.168.1.0110 0000 → 192.168.1.96
   192.168.1.1000 0000 → 192.168.1.128
   192.168.1.1010 0000 → 192.168.1.160
   192.168.1.110 0000 → 192.168.1.192
   192.168.1.1110 0000 → 192.168.1.224
   The final address space as follows (the answer)

Network IP	Possible host IP	Subnet mask
192.168. 1.0	192.168. 1.1~192.168. 1.31	255.255.255.224
192.168. 1.32	192.168. 1.33~192.168. 1.63	
192.168. 1.64	192.168. 1.65~192.168. 1.95	
192.168. 1.96	192.168. 1.97~192.168. 1.127	
192.168. 1.128	192.168. 1.129~192.168. 1.159	
192.168. 1.160	192.168. 1.161~192.168. 1.191	
192.168. 1.192	192.168. 1.193~192.168. 1.223	
192.168. 1.224	192.168. 1.225~192.168. 1.254	

Besides the above manual calculation, we can use this table to refer once you determine the IP to split is in Class A, Class B or Class C.

- Subnet for Class A

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

- Subnet for Class B

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

- Subnet for Class C

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

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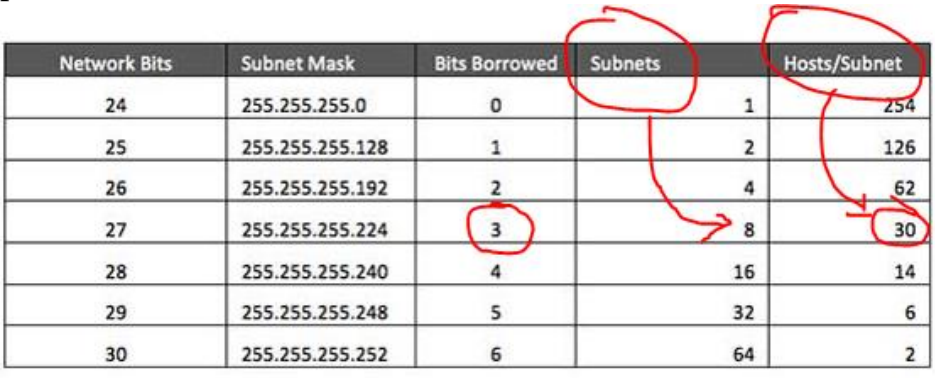
For example, from the IP 192.168.1.0/24 (the same above example), please split into 8 networks and 30 hosts per subnet (equal host space)

- Since 192.168.1.0/24 is at class C, to split into 8 networks and 30 hosts per subnet, refer Table “Subnet for Class C”, we see bits borrowed is 3



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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

So the new subnet mask is 255.255.255.224 (or /27)

Now you can start from step 5 to calculate the network IP and host IP details of each subnet: To find the network IP for each subnet, we use the combined options for three borrowed bits

192.168.1.0000 0000 → 192.168.1.0
192.168.1.0010 0000 → 192.168.1.32
192.168.1.0100 0000 → 192.168.1.64
192.168.1.0110 0000 → 192.168.1.96
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The final address space as follows(the answer)

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192.168. 1.96	192.168. 1.97~192.168. 1.127	
192.168. 1.128	192.168. 1.129~192.168. 1.159	
192.168. 1.160	192.168. 1.161~192.168. 1.191	
192.168. 1.192	192.168. 1.193~192.168. 1.223	
192.168. 1.224	192.168. 1.225~192.168. 1.254	

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If the requirement of subnetting is an odd value of number of subnets, e.g., from the IP 192.168.1.0/24 (the same above example), please split into 13 networks, you can use the round up value after solving $2^N = 13$. In this case, N ~ 4.