IPv4 Addressing and Subnetting

It is important to understand how to convert from IPv4 decimal notation to binary for subnetting and summarization.

- The binary system is based on ones (1) and zeros (0).
- There are 8 bits per octet, 4 octets per IPv4 address.
- The bit value is based on position.
- The bit set to 1 sets the value. The bit set to zero = 0
- There are 8 bits with 2 (nth power) so 2^8 = 255
- Per octet: set all bits to 1 = 255, set all bits to 0 = 0

0	0	0	0	0	0	0	0	= 0
1	1	1	1	1	1	1	1	= 255
128	**64**	**32**	**16**	**8**	**4**	**2**	**1**	**bit value**
8	7	6	5	4	3	2	1	bit position

Binary to Decimal Conversion

Converting binary number to an equivalent decimal number requires adding the values of each bit position set to (1) for each octet. The sum of each octet creates a dotted decimal address.

0 0 0 0 **1** 0 **1** 0 = 10

from right to left, 2nd bit = 2 and 4th bit = 8 = 2+8 = 10

Binary to Decimal Conversion

Converting the binary number to an equivalent decimal number requires adding the values of each bit position set to (1) for each octet. The sum of each octet creates a dotted decimal value (IP address).

0000**1**0**1**0.0**11**00**1**00.00**1**0**1**000.**1**0000000

(8+2) **.** (64+32+4) **.** (32+8) **.** 128 = 10.100.40.128

Decimal to Binary Conversion

Converting IPv4 address 192.168.64.10 to an equivalent binary number requires setting specific bits for each octet to (1) value. The sum of each octet adds up to decimal value for each octet.

192 **.** 168 **.** 64 **.** 10

11000000 **.** **1**0**1**0**1**000 **.** 0**1**000000 **.** 0000**1**0**1**0

(128+64) . (128+32+8) . 64 . (8+2)

Hexadecimal to Binary Conversion

IPv6 addressing is based on hexadecimal format instead of IPv4 octets. The IPv6 address is comprised of 32 hexadecimal values of 4 bits each. The IPv6 address is as a result 128 bits in length (4 bits x 32 hexadecimal values). Each hexadecimal number has 16 possible values that range from 0 to F derived from the lower 4 bits of an octet. The same values from 0-9 are used for IPv4 and IPv6 binary to decimal conversion. The values 10 to 15 however are A to F.

Hexadecimal D = **1 1** 0 **1**

8 4 0 **1** = 8 + 4 + 1 = 13 decimal

Hexadecimal F = **1 1 1 1**

8 4 2 1 = 8 + 4 + 2 + 1 = 15 decimal

A = 10 (1010)	B = 11 (1011)	C = 12 (1100)
D = 13 (1101)	E = 14 (1110)	F = 15 (1111)

Converting FDA4 to binary = **1111 1101 1**0**1**0 0**1**00

F D A 4

IPv4 Address Classes

The following are the assignable classes for IPv4 address space. The address range from 127.0.0.0 – 127.255.255.255 is reserved for host-based loopback address.

Class A = 255.0.0.0 (0.0.0.0 - 127.255.255.255)

Class B = 255.255.0.0 (128.0.0.0 - 191.255.255.255)

Class C = 255.255.255.0 (192.0.0.0 - 223.255.255.255)

Class D = 224.0.0.0 - 239.255.255.255 (multicast)

Class E = 240.0.0.0 - 255.255.255.255 (reserved)

RFC 1918 Private IPv4 Addressing

RFC 1918 defines private IP address space from each address class. The private IP addressing is not public routable across the internet. The standard practice is for companies to assign private addressing to all inside hosts. NAT is deployed at the internet edge where private addresses are translated to public routable addresses.

The following are the RFC 1918 private IP address ranges:

10.0.0.0 - 10.255.255.255 /8

172.16.0.0 - 172.31.255.255 /12

192.168.0.0 - 192.168.255.255 /16

Classful Subnet Mask

Classful subnet masks are based on the default mask length for each IP class. That includes Class A = /8, Class B = /16 and Class C = /24. Any routing protocol that only supports classful subnet masks must use the default for the address class deployed. The default subnet mask implies subnetting is not configured for an address class.

Class A = 255.0.0.0 (/8)

Class B = 255.255.0.0 (/16)

Class C = 255.255.255.0 (/24)

Classless Subnet Mask

Classless subnet masks are referred to as variable length subnet mask (VLSM). They are any subnet mask that is not the default for a particular address class. They enable more specific routes to a destination. In addition subnetting is enabled to optimize available address space. The network portion of an IP address is shifted to the right or left. That changes the subnet mask length and enable subnetting. The number of subnets and host assignments available is based on the subnet mask length.

Classless vs Classful Subnet Masks

255.0.0.0 = classful (default class A subnet mask)

255.255.224.0 = classless

255.255.255.248 = classless

255.255.0.0 = classful (default class B subnet mask)

255.255.255.0 = classful (default class C subnet mask)

Table 1 Class C Subnetting Table

Subnet Mask	CIDR	Subnet Bits	Subnets	Host Bits	* Hosts
255.255.255.0	/24	0	1	8	254
255.255.255.128	/25	1	2	7	126
255.255.255.192	/26	2	4	6	62
255.255.255.224	/27	3	8	5	30
255.255.255.240	/28	4	16	4	14
255.255.255.248	/29	5	32	3	6
255.255.255.252	/30	6	64	2	2
255.255.255.254	/31	not recommended			2
255.255.255.255	/32	-	-	-	1

* The host number does not include the network address and broadcast address. They are reserved for each individual subnet and are not assignable to any hosts. For example 8 host bits = 2^8 = 256 - 2 = 254

Subnetting Example 1:

What network address would allow the maximum number of subnets for 172.16.1.0/23 with 30 hosts? The subnet mask defines the network portion (bold) and host portion of an IP address. The subnet mask /23 (255.255.254.0) assigns 23 bits to the network portion and 9 bits to host portion. The number of assignable hosts is $2^9 = 512 - 2$.

network | host

172.16.1.0 = 10101100.00010000.0000000 1.00000000

255.255.254.0 = **11111111.11111111.1111111** **0.00000000**

network | host

255.255.255.224 = **11111111.11111111.11111111.111** **00000**

The question asked for a maximum of 30 hosts. The subnet mask is used to modify the network portion and consequently the host portion as well. Moving the subnet mask to the right will increase the network portion and decrease the host portion assignable. Assigning the rightmost 5 bits provides a maximum of 30 hosts from the subnetting table (32 - 2). The network address and broadcast address cannot be assigned to hosts.

The host portion must be decreased from 9 bits to 5 bits. That will require increasing the subnet mask from /23 to /27.

subnet with 30 hosts = **172.16.1.0/27**

Subnetting Example 2:

What IP address is assignable to a host based on subnet mask 255.255.255.224?

A. 192.168.10.31

B. 192.168.10.29

C. 192.168.10.0

D. 192.168.10.32

The network address and broadcast address are not assignable to hosts. The subnet multiple is calculated based on the bit value of bit position 6. Subnet multiples start at 0 with multiples of 32 (0, 32, 64, 96, 128, 160, 192, 224).

network | host

11111111.11111111.11111111.111 **00000**

255. 255. 255. 224

1. 4th octet is subnetted
2. subnet multiple = bit position 6 = decimal 32
3. network address of zero subnet = 192.168.10.0
4. host range = first 5 bits = $2^5 = 32 - 2 = 30$ host assignments

- network address = 192.168.10.0
- host range = 192.168.10.1 - 192.168.10.30
- broadcast address = 192.168.10.31

Subnetting Example 3:

Select the correct network address and subnet mask that allows at least ten web servers (hosts) to be assigned to the same subnet?

A. 192.168.100.0 255.255.255.252

B. 192.168.100.16 255.255.255.248

C. 192.168.100.16 255.255.255.240

D. 192.168.252.16 255.255.255.252

The subnet mask defines the network portion and host portion of a subnetted address. Increasing the subnet mask length will increase the number of subnets available. Creating 10 host assignments for web servers requires at least 4 host bits. That allows for 14 host assignments where network and broadcast addresses are not assignable.

2^3 = 3 host bits = 8 - 2 = 6 host assignments

2^4 = 4 host bits = 16 - 2 = 14 host assignments

network portion = 32 bits - 4 bits = 28 bits (/28)
= 255.255.255.240

network (28 bits) | host (4 bits)

11111111.11111111.11111111.1111 0000

255. 255. 255. 240

The 255.255.255.240 (/28) subnet mask starts at the bit 5 of the 4th octet and has a decimal value of 16. The subnets are multiples of 16 (0, 16, 32, 48 etc).

Correct Answer: **192.168.100.16/28**

Subnetting Example 4:

What is the second IP address available for host assignment from 172.33.1.64/30?

A. 172.33.1.64

B. 172.33.1.65

C. 172.33.1.66

D. 172.33.1.1

The IP address is a nondefault Class A address. The subnet mask defines the number of bits assigned to the network portion and host portion. The /30 subnet mask creates a network portion of 30 bits and a host portion of 2 bits. The number of host assignments available with 2 bits = 2^2 = 4. The network address and broadcast address are not assignable to hosts. As a result the number of host assignments = 4 - 2 = 2 IP addresses. The following is a list of all IP addresses for subnet 172.33.1.64/30.

- network (subnet) address = 172.33.1.64
- first assignable host IP address = 172.33.1.65
- second assignable host IP address = **172.33.1.66**
- broadcast address = 172.33.1.67

	network	| host
172.33.1.64	= 10101100.00100001.00000001.010000	00
255.255.255.252	= **11111111.11111111.11111111.111111**	**00**

The rightmost bit of the subnet mask (network bits) determines the subnet multiple and where it starts. For this example, bit 3 of the 4th octet has a decimal value of 4. The subnet multiple starts at 0 with multiples of 4 (0, 4, 8, 12 etc). The next subnet available is 172.33.1.68/30. Interfaces on the same router must be assigned to different subnets.

Wildcard Masks

The wildcard mask is a technique to match an IP address or range of IP addresses. It is used by routing protocols and access control lists (ACL) to manage routing and packet filtering. The wildcard mask is an inverted mask where the matching IP address or range is based on 0 bits. The additional bits are set to 1 as no match required. The wildcard 0.0.0.0 is used to match a single IP address. Wildcard mask for 255.255.224.0 is 0.0.31.255 (invert the bits so zero=1 and one=0)

11111111.11111111.111 00000.00000000 = subnet mask

00000000.00000000.000 11111.11111111 = wildcard mask

<u>Example 1: Classful Wildcard Mask</u>

The following wildcard will only match on the 192.168.3.0 subnet and not match on everything else. This could be used with an ACL for instance to permit or deny a subnet. It could define a single subnet to advertise from OSPF as well.

192.	168.	3.	0
11000000.	10101000.	00000011.	00000000
00000000.	**00000000.**	**00000000.**	**11111111** = 0.0.0.255

Example 2: Classless Wildcard Mask

The classless wildcard can filter based on any network boundary. The following wildcard mask matches on the subnet 192.168.4.0 serial link only. It is the equivalent of 255.255.255.252 subnet mask.

192. 168. 4. 0

11000000.10101000.00000100.00000000

00000000.00000000.00000000.00000011 = 0.0.0.3

192.168.4.0 0.0.0.3 = match on 192.168.4.1 and 192.168.4.2

The CIDR notation denotes the number of bits in the subnet mask. For instance a class C address with subnet mask 255.255.255.240 = /28