IPv4 Subnetting:

An IP address consists of 32 bits of information. These bits are divided into four sections, referred to as octets or bytes, with each containing 1 byte (8 bits). You can depict an IP address using one of three methods:
Dotted-decimal, as in 172.16.30.56
Binary, as in 10101100.00010000.00011110.00111000
Hexadecimal, as in AC.10.1E.38
The <u>network address</u> (which can also be called the network number) uniquely identifies each network.
The <u>node/host IP address</u> is assigned to, and uniquely identifies, each machine on a network.

	8 bits	8 bits	8 bits	8 bits
Class A:	Network	Host	Host	Host
Class B:	Network	Network	Host	Host
Class C:	Network	Network	Network	Host
Class D:	Multicast			
Class E:	Research			

<u>Starting Octet shows which class the IP belongs to:</u>

Class A: 0 - 126
Loopbak: 127
Class B: 128 - 191
Class C: 192 - 223
Class D: 224 - 239
Class E: 240 – 255

Address Class	Reserved Address Space
Class A	10.0.0.0 through 10.255.255.255
Class B	172.16.0.0 through 172.31.255.255
Class C	192.168.0.0 through 192.168.255.255

Class	Format	Default Subnet Mask
A	*network.node.node.node*	255.0.0.0
B	*network.network.node.node*	255.255.0.0
C	*network.network.network.node*	255.255.255.0

$2^1 = 2$
$2^2 = 4$
$2^3 = 8$
$2^4 = 16$
$2^5 = 32$
$2^6 = 64$
$2^7 = 128$
$2^8 = 256$
$2^9 = 512$
$2^{10} = 1{,}024$
$2^{11} = 2{,}048$
$2^{12} = 4{,}096$
$2^{13} = 8{,}192$
$2^{14} = 16{,}384$

<u>Loopback (localhost)</u> Used to test the IP stack on the local computer. Can be any address from 127.0.0.1 through 127.255.255.254.
<u>Broadcasts (layer 3)</u> These are sent to all nodes on the network.
<u>Unicast</u> This is an address for a single interface, and these are used to send packets to a single destination host.
<u>Multicast</u> These are packets sent from a single source and transmitted to many devices on different networks. Referred to as "one-to-many."

<u>Classless inter-domain routing (CIDR)</u> is a set of Internet protocol (IP) standards that is used to create unique identifiers for networks and individual devices. The IP addresses allow particular information packets to be sent to specific computers. Classless interdomain routing (CIDR) helps reduce the size of routing tables by aggregating routes, and Network Address Translation (NAT), which reduces the number of required public IP addresses used by each organization or company.
The primary goal of CIDR is to improve the scalability of Internet routers' routing tables. Imagine the implications of an Internet router being burdened by carrying a route to every class A, B, and C network on the planet.

CIDR uses both technical tools and administrative strategies to reduce the size of the Internet routing tables. Technically, CIDR uses route summarization, but with Internet scale in mind. For example, CIDR might be used to allow a large ISP to control a range of IP addresses from 198.0.0.0 to 198.255.255.255.
ISPs 2, 3, and 4 need only one route (198.0.0.0/8) in their routing tables to be able to forward packets to all destinations that begin with 198. Note that this summary actually summarizes multiple class C networks—a typical feature of CIDR. ISP 1's routers contain more detailed routing entries for addresses beginning with 198, based on where they allocate IP addresses for

Subnet Mask	CIDR Value
255.0.0.0	/8
255.128.0.0	/9
255.192.0.0	/10
255.224.0.0	/11
255.240.0.0	/12
255.248.0.0	/13
255.252.0.0	/14
255.254.0.0	/15
255.255.0.0	/16
255.255.128.0	/17
255.255.192.0	/18
255.255.224.0	/19
255.255.240.0	/20
255.255.248.0	/21
255.255.252.0	/22
255.255.254.0	/23
255.255.255.0	/24
255.255.255.128	/25
255.255.255.192	/26
255.255.255.224	/27
255.255.255.240	/28
255.255.255.248	/29
255.255.255.252	/30

their customers. ISP 1 would reduce its routing tables similarly with large ranges used by the other ISPs.
CIDR attacks the problem of large routing tables through administrative means as well. As shown in Figure 4-5 , ISPs are assigned contiguous blocks of addresses to use when assigning addresses for their customers. Likewise, regional authorities are assigned large address blocks, so when individual companies ask for registered public IP addresses, they ask their regional registry to assign them an address block. As a result, addresses assigned by the regional agency will at least be aggregatable into one large geographic region of the world.
CIDR refers to the administrative assignment of large address blocks, and the related summarized routes, for the purpose of reducing the size of the Internet routing tables.
Note: Because CIDR defines how to combine routes for multiple classful networks into a single route, some people think of this process as being the opposite of subnetting. As a result, many people refer to CIDR's summarization results as supernetting.

Private Addressing:

One of the issues with Internet growth was the assignment of all possible network numbers to a small number of companies or organizations. Private IP addressing helps to mitigate this problem by allowing computers that will never be directly connected to the Internet to not use public, Internet-routable addresses. For IP hosts that will purposefully have no direct Internet connectivity, you can use several reserved network numbers. In other words, any organization can use these network numbers. However, no organization is allowed to advertise these networks using a routing protocol on the Internet. Furthermore, all Internet routers should be configured to reject these routes.

Table 4-12 *RFC 1918 Private Address Space*

Range of IP Addresses	Class of Networks	Number of Networks
10.0.0.0 to 10.255.255.255	A	1
172.16.0.0 to 172.31.255.255	B	16
192.168.0.0 to 192.168.255.255	C	256

Class C Subnettng:

Binary Decimal CIDR

00000000 = 255.255.255.0 /24
10000000 = 255.255.255.128 /25
11000000 = 255.255.255.192 /26
11100000 = 255.255.255.224 /27
11110000 = 255.255.255.240 /28
11111000 = 255.255.255.248 /29
11111100 = 255.255.255.252 /30

Subnetting Steps:

1. How many subnets 2^x?
2. How many hosts per subnet 2^y - 2?
3. What are the valid subnets (256 - subnet_mask = each subnet block size)?
4. What is the broadcast address of each subnet?
5. What are valid hosts?

Example1:

192.168.10.0 = Network address
255.255.255.128 = Subnet mask /25
1. 2^1 = 2 subnets.
2. 2^7 - 2 = 126 hosts per subnet.
3. 256 - 128 = 128 block size

192.168.10.0 and 192.168.10.128 are two subnets.

4. 192.168.10.127 and 192.168.10.255 are broadcast addresses.
5. 192.168.10.1-126 and 192.168.10.129-254 are valid hosts.

Example2:

192.168.10.0 = Network address
255.255.255.252 = Subnet mask /30

1. 2^6 = 64 subnets.
2. 2^2 - 2 = 2 hosts per subnet.
3. 256 - 252 = 4 block size.

Subnet	0	4	8	12	...	240	244	248	252
First host	1	5	9	13	...	241	245	249	253
Last host	2	6	10	14	...	242	246	250	254
Broadcast	3	7	11	15	...	243	247	251	255

/30 is usually used by Point-to-point WAN links.

Class B Subnetting:

255.255.0.0 (/16)
255.255.128.0 (/17) 255.255.255.0 (/24)
255.255.192.0 (/18) 255.255.255.128 (/25)
255.255.224.0 (/19) 255.255.255.192 (/26)
255.255.240.0 (/20) 255.255.255.224 (/27)
255.255.248.0 (/21) 255.255.255.240 (/28)
255.255.252.0 (/22) 255.255.255.248 (/29)
255.255.254.0 (/23) 255.255.255.252 (/30)

Example1:

172.16.0.0 = Network address
255.255.254.0 = Subnet mask /23

1. 2^7 = 128 subnets.
2. 2^9 - 2 = 510 hosts per subnet.
3. 256 - 254 = 2 block size.

valid subnets are 0, 2, 4, 6, 8, etc., up to 254.
First five subnets:

Subnet	0.0	2.0	4.0	6.0	8.0
First host	0.1	2.1	4.1	6.1	8.1
Last host	1.254	3.254	5.254	7.254	9.254
Broadcast	1.255	3.255	5.255	7.255	9.255

Example2:

172.16.0.0 = Network address
255.255.255.0 = Subnet mask /24

1. 2^8 = 256 subnets.
2. 2^8 - 2 = 256 hosts per subnet.
3. 256 - 255 = 1 block size.

Valid subnets are 0, 1, 2, 3, etc., all the way to 255.

Subnet	0.0	1.0	2.0	3.0	...	254.0	255.0
First host	0.1	1.1	2.1	3.1	...	254.1	255.1
Last host	0.254	1.254	2.254	3.254	...	254.254	255.254
Broadcast	0.255	1.255	2.255	3.255	...	254.255	255.255

Example3:

172.16.0.0 = Network address
255.255.255.224 = Subnet mask /27

1. 2^11 = 2048.
2. 2^5 - 2 = 30 hosts per subnet.
3. 256 - 224 = 32 block size.

Valid subnets are 0, 32, 64, 96, 128, 160, 192, 224.

Subnet	0.0	0.32	0.64	0.96	0.128	0.160	0.192	0.224
First host	0.1	0.33	0.65	0.97	0.129	0.161	0.193	0.225
Last host	0.30	0.62	0.94	0.126	0.158	0.190	0.222	0.254
Broadcast	0.31	0.63	0.95	0.127	0.159	0.191	0.223	0.255

Subnet	255.0	255.32	255.64	255.96	255.128	255.160	255.192	255.224
First host	255.1	255.33	255.65	255.97	255.129	255.161	255.193	255.225
Last host	255.30	255.62	255.94	255.126	255.158	255.190	255.222	255.254
Broadcast	255.31	255.63	255.95	255.127	255.159	255.191	255.223	255.255

Class A Subnetting:
255.0.0.0 (/8)
255.128.0.0 (/9) 255.255.240.0 (/20)
255.192.0.0 (/10) 255.255.248.0 (/21)
255.224.0.0 (/11) 255.255.252.0 (/22)
255.240.0.0 (/12) 255.255.254.0 (/23)
255.248.0.0 (/13) 255.255.255.0 (/24)
255.252.0.0 (/14) 255.255.255.128 (/25)
255.254.0.0 (/15) 255.255.255.192 (/26)
255.255.0.0 (/16) 255.255.255.224 (/27)
255.255.128.0 (/17) 255.255.255.240 (/28)
255.255.192.0 (/18) 255.255.255.248 (/29)
255.255.224.0 (/19) 255.255.255.252 (/30)

Example1:
10.0.0.0
255.255.0.0 (/16)
1. Subnets? 28 = 256.
2. Hosts? 216 – 2 = 65,534.

Subnet	10.0.0.0	10.1.0.0	...	10.254.0.0	10.255.0.0
First host	10.0.0.1	10.1.0.1	...	10.254.0.1	10.255.0.1
Last host	10.0.255.254	10.1.255.254	...	10.254.255.254	10.255.255.254
Broadcast	10.0.255.255	10.1.255.255	...	10.254.255.255	10.255.255.255

3. Valid subnets? What is the interesting octet? 256 – 255 = 1. 0, 1, 2, 3, etc. (all in the second octet). The subnets would be 10.0.0.0, 10.1.0.0, 10.2.0.0, 10.3.0.0, etc., up to 10.255.0.0.

Example2:
10.0.0.0
255.255.240.0 (/20)
1. Subnets? 212 = 4096.
2. Hosts? 212 – 2 = 4094.

Subnet	10.0.0.0	10.0.16.0	10.0.32.0	...	10.255.240.0
First host	10.0.0.1	10.0.16.1	10.0.32.1	...	10.255.240.1
Last host	10.0.15.254	10.0.31.254	10.0.47.254	...	10.255.255.254
Broadcast	10.0.15.255	10.0.31.255	10.0.47.255	...	10.255.255.255

3. Valid subnets? What is your interesting octet? 256 – 240 = 16. The subnets in the second octet are a block size of 1 and the subnets in the third octet are 0, 16, 32, etc.

Example3:
10.0.0.0
255.255.255.192 (/26)
1. Subnets? 218 = 262,144.
2. Hosts? 26 – 2 = 62.
3. Valid subnets? In the second and third octet, the block size is 1, and in the fourth octet, the block size is 64.

Subnet	10.0.0.0	10.0.0.64	10.0.0.128	10.0.0.192
First host	10.0.0.1	10.0.0.65	10.0.0.129	10.0.0.193
Last host	10.0.0.62	10.0.0.126	10.0.0.190	10.0.0.254
Broadcast	10.0.0.63	10.0.0.127	10.0.0.191	10.0.0.255

Subnet	10.255.255.0	10.255.255.64	10.255.255.128	10.255.255.192
First host	10.255.255.1	10.255.255.65	10.255.255.129	10.255.255.193
Last host	10.255.255.62	10.255.255.126	10.255.255.190	10.255.255.254
Broadcast	10.255.255.63	10.255.255.127	10.255.255.191	10.255.255.255

VLSM:
Create many networks from a large single network using subnet masks of different lengths in various kinds of network designs is called VLSM (Variable Length Subnet Mask) networking.

192.168.10.0 = Network
255.255.255.240 (/28) = Mask

Prefix	Mask	Hosts	Block Size
/25	128	126	128
/26	192	62	64
/27	224	30	32
/28	240	14	16
/29	248	6	8
/30	252	2	4

Example1:

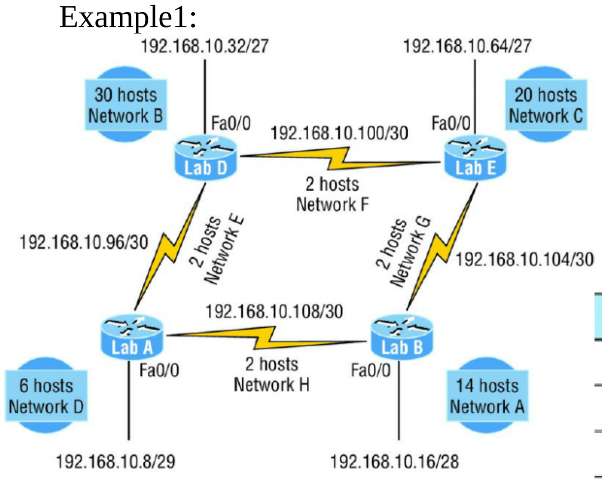
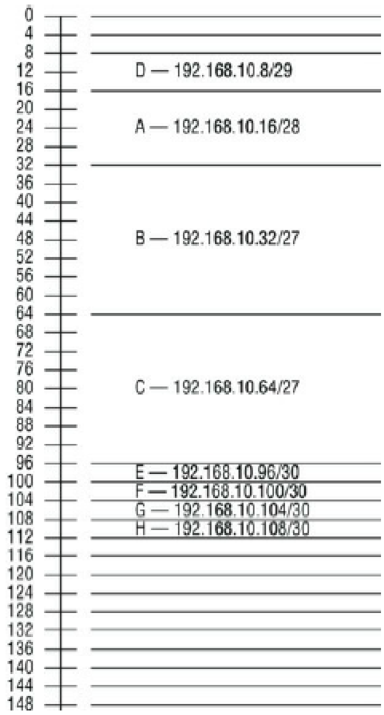


Figure 5.4 VLSM network example 1

Subnet	Mask	Subnets	Hosts	Block
/25	128	2	126	128
/26	192	4	62	64
/27	224	8	30	32
/28	240	16	14	16
/29	248	32	6	8
/30	252	64	2	4

Network	Hosts	Block	Subnet	Mask
A	14	16	/28	240
B	30	32	/27	224
C	20	32	/27	224
D	6	8	/29	248
E	2	4	/30	252
F	2	4	/30	252
G	2	4	/30	252
H	2	4	/30	252



Example2:

A: /27
B: /28
C: /28
D: /30
E: /30
F: /30
G: /28
H: /26
I: /28
J: /26
K: /28

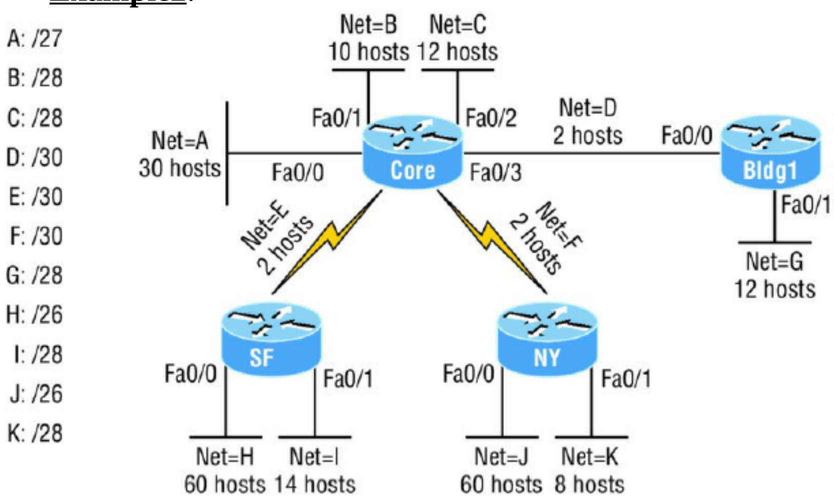
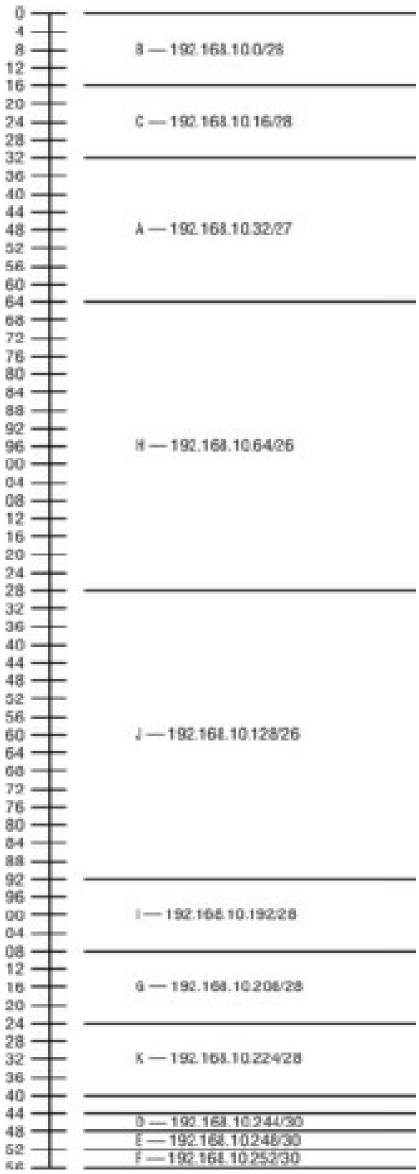


Figure 5.6 VLSM network example 2



192.168.10.0/28 - B
192.168.10.16/28 - C
192.168.10.32/27 - A
192.168.10.64/26 - H
192.168.10.128/26 - J
192.168.10.192/28 - I
192.168.10.208/28 - G
192.168.10.224/28 - K
192.168.10.244/30 - D
192.168.10.248/30 - E
192.168.10.252/30 - F

<u>Route summarization (also called route aggregation or supernetting):</u>

<u>Example1:</u>

Let's say we want to create the most optimal summary for the following 4 networks:

192.168.0.0 / 24 subnet mask 255.255.255.0
192.168.1.0 / 24 subnet mask 255.255.255.0
192.168.2.0 / 24 subnet mask 255.255.255.0
192.168.3.0 / 24 subnet mask 255.255.255.0

Let's convert these network addresses to binary:

192.168.0.0	11000000	10101000	00000000	00000000
192.168.1.0	11000000	10101000	00000001	00000000
192.168.2.0	11000000	10101000	00000010	00000000
192.168.3.0	11000000	10101000	00000011	00000000

Now we have to look how many bits these network addresses have in common. The first and second octets are the same, so that's 16 bits.

Let's zoom in on the third octet:

00000000
00000001
00000010
00000011

Our summary address will be 192.168.0.0 /22 (subnet mask 255.255.252.0).

<u>Example2:</u>

Let's look at another example. Let's say we want to summarize the following networks:

172.16.0.0 / 16	subnet mask 255.255.0.0
172.17.0.0 / 16	subnet mask 255.255.0.0
172.18.0.0 / 16	subnet mask 255.255.0.0
172.19.0.0 / 16	subnet mask 255.255.0.0
172.20.0.0 / 16	subnet mask 255.255.0.0
172.21.0.0 / 16	subnet mask 255.255.0.0
172.22.0.0 / 16	subnet mask 255.255.0.0
172.23.0.0 / 16	subnet mask 255.255.0.0

Let's look at it in binary first. I'll write down the second octet since the first one is the same for all network addresses:

16	00010000
17	00010001
18	00010010
19	00010011
20	00010100
21	00010101
22	00010110
23	00010111

The first 5 bits for all these addresses are the same. The first octet had 8 similar bits so that's 8 + 5 = 13 bits.

The summary address will be 172.16.0.0 /13 (subnet mask will be 255.248.0.0).