Which IP Subnet is Best for my Organization

2005-1

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Introduction

Many of the people I work with, use IP addressing and subnetting to configure their systems and networks. A Network Administrator often manages the IP address information and provides it when necessary. System Administrators usually know where to put the information, but quite often don't understand all the concepts and rules behind IP addressing and subnetting. This can become a stumbling block when it comes time to trouble shoot a problem or discuss network planning with other System Administrators or Network Administrators.

I wrote this paper to provide a practical approach to understand IP subnetting. To accomplish this goal the information will be provided in a logical building block style. The order of presentation is as follows:

IP address formats
IP address class information
Benefits of subnetting
Subnetting terms
Subnetting rules
How subnetting works
Subnet sample tables
Subnetting example
Specific HP9000 and HP3000 IP and subnet configurations

If you are involved in planning, configuring or trouble-shooting IP networking and would like a better understanding of IP subnetting then this paper is appropriate for you. The information presented here will allow you to participate confidently in discussion about IP addressing and subnetting. I quite often refer back to this information to refresh my memory, so don't expect to remember everything. The tables included in the document provide a quick reference to subnetting alternatives.

This paper deals with current 32 bit IP addresses and not Next Generation 128 bit IP addresses.

IP Address Formats

IP addresses are divided into five classes, A through to E. We are accustomed to using Class A, B and C. Classes A, B and C are assigned to networks, Class D is reserved for multicast addresses and Class E is reserved for future uses. You will configure Class A, B and C addresses into the systems and network components in your environment. A Class D or multicast address is when one node sends to multiple nodes. Each node would subscribe to the multicast transmission. A use for this type of design is a class room environment.

Each IP address consist consists of the following standards:

consists of 32 bits
divided into 4 groups of eight bits (octets), i.e. 11111111 11111111 11111111 11111111
or
divided into 4 groups of 3 decimal digits, i.e. ddd ddd ddd ddd
each octet is within the range of: binary 00000000 - 11111111 or decimal 0 - 255

IP Address Class Information

IP Address: Class A

Divided into 7 network bits (that you can modify) and 24 node or host bits
Highest order bit is set to 0 (left most bit) - 0 ^ 0 0 0 0 0 0 0
Network portion range is 1 - 126
Number of available networks is 126
Number of available nodes per network is 16,777,214
Networks 0.0.0.0 and 127.0.0.0 are reserved

IP Address: Class B

Divided into 14 network bits (that you can modify) and 16 node or host bits
Two highest order bits are set to 1-0 (left most) - 1 0 ^ 0 0 0 0 0 0
Network portion range is 128.1 to 191.254
Number of available networks is 16,384
Number of available nodes per network is 65,534

IP Address: Class C

Divided into 21 network bits (that you can modify) and 8 node or host bits
Three highest order bits are set to 1-1-0 (left most) - 1 1 0 ^ 0 0 0 0 0
Network portion range is 192.0.1 to 223.255.254
Number of available networks is 2,097,152
Number of available nodes per network is 254

Table 1: IP Address Review

Address Type	**Network Number**	**Node Number**
Class A	ddd	ddd.ddd.ddd
Class B	ddd.ddd	ddd.ddd
Class C	ddd.ddd.ddd	ddd
	Common	*Unique*

Benefits of Subnetting

Subnetting allows you to segment your network into logical units and manage the segments as different entities. Additionally, it allows you to route traffic within the same IP address space, rather than using unique IP addresses for each network. This reduces the number of different IP addresses required. In a situation where you have only one IP address, you can still use routers to filter LAN traffic between networks.

Subnetting Terms

Network Mask

The Network Mask are the bits used to mask out the network portion of an IP address. The network portion is the group of digits that identify the network, refer to Table 1 for a review. The network mask varies depending on the class and is unique for each class. A network mask always uses 255's to mask the network portion and 0's to mask the node portion of the IP address. Don't confuse this with Subnet Mask! This is only a portion of the Subnet Mask, the first part. The rest is following.

Table 2: Network Masks

IP Class	**Network Mask**
Class A IP address	255.0.0.0
Class B IP address	255.255.0.0
Class C IP address	255.255.255.0

Subnet Field

The Subnet Field is the other part of the Subnet Mask. It indicates the bits in the IP address used to identify the subnet number. This is where you steal bits of the node portion to create a subnet. You are masking over the node portion of the address with the Subnet Field. A 0 (zero) here means no subnet, which is the default**.** The Subnet Field value varies and some examples are:

0.0.0.240 - Class C network using 4 subnet bits
0.255.248.0 - Class A network using 5 subnet bits of the second last octet or group

Netmask

The Netmask is often called the Subnet Mask, both terms are acceptable. It is the complete mask; Network Mask + Subnet Field. Using the above information, the complete Netmask or Subnet masks are:

Class C - 255.255.255.240
Class A - 255.255.248.0

General Subnetting Rules

You can subnet all classes of IP addresses, the larger the node portion of the IP address the more subnets you can create. Therefore a Class A address allows the most subnets.
All subnets within the same network should use the same Netmask. Variable length subnets are starting to be supported now, but I intend to continue with fixed length Netmasks for this paper.
The Subnet Field should start adjacent to the Network IP portion
The Netmask or Subnet Mask bits should all be contiguous
The network portion of the IP address is always masked out using 255's or binary 1's

How Subnetting Works

Subnetting is applied by actually combining the IP address with the Netmask by performing a logical 'AND'. A logical 'AND' is performed according to these rules:

1 + 1 = 1
1 + 0 = 0
0 + 0 = 0

Below is an example to help you understand this concept. Try it on your own network for more practice. This example uses an IP address of 192.200.201.122 and a Netmask of 255.255.255.224. The first thing I like to do is to convert the decimal IP address to binary, so that the logical 'AND' can be performed.

Table 2: Logical 'AND' example

IP Address	192.00	200.00	201.00	122.00
IP Address	1 1 0 0 0 0 0 0	1 1 0 0 1 0 0 0	1 1 0 0 1 0 0 1	0 1 1 1 1 0 1 0
Netmask	1 1 1 1 1 1 1 1	1 1 1 1 1 1 1 1	1 1 1 1 1 1 1 1	1 1 1 0 0 0 0 0
Logical AND	1 1 0 0 0 0 0 0	1 1 0 0 1 0 0 0	1 1 0 0 1 0 0 1	0 1 1 0 0 0 0 0
Subnet	192.00	200.00	201.00	96.00

In the example above the Subnet Field (224) extends into the first three bits (111) of the IP address node portion. Therefore the last five bits remain for the node address. We can now calculate the ranges of addresses for this subnet. They are:

Bottom range - 00000 or 01100000 = 96
Top range - 11111 or 01111111 = 127

This indicates are range of 192.200.201.96 to 192.200.201.127 for this subnet. IP addressing rules state that host and node addresses can not contain all 1's or all 0's. Therefore the valid range is 192.200.201.97 to 192.200.201.126 or 30 nodes on this subnet. You have just realized one of the disadvantages of subnetting, you lose some of your IP addresses. You will not have as many unique IP addresses as you would have if subnetting was not used.

I like to convert the Subnet Field to binary also in order to do some calculations In this example the Subnet Field is 224 which is 11100000 in binary. The binary number shows us that the Subnet Field extends three bits (111) into the node portion of the IP address, leaving five bits for the node address. To calculate how many segments or nodes this Subnet Field allows, do the following:

There are (2^3) - 2 subnets = 6 subnets

There are (2^5) - 2 nodes = 30 nodes

Remember that all 0's and all 1's are invalid, therefore subtract 2

Table 3: Subnets and their ranges for Netmask of 255.255.255.224

Subnet field	Value	Subnet range - bottom	Value	Subnet range - top	Value
0 0 0 0 0 0 0 0	0	Not valid range		No hosts allowed	
0 0 1 0 0 0 0 0	32.00	0 0 1 0 0 0 0 0	32.00	0 0 1 1 1 1 1 1	63.00
0 1 0 0 0 0 0 0	64.00	0 1 0 0 0 0 0 0	64.00	0 1 0 1 1 1 1 1	95.00
0 1 1 0 0 0 0 0	96.00	0 1 1 0 0 0 0 0	96.00	0 1 1 1 1 1 1 1	127.00
1 0 0 0 0 0 0 0	128.00	1 0 0 0 0 0 0 0	128.00	1 0 0 1 1 1 1 1	159.00
1 0 1 0 0 0 0 0	160.00	1 0 1 0 0 0 0 0	160.00	1 0 1 1 1 1 1 1	191.00
1 1 0 0 0 0 0 0	192.00	1 1 0 0 0 0 0 0	192.00	1 1 0 1 1 1 1 1	223.00
1 1 1 0 0 0 0 0	224.00	Not valid range:		No hosts allowed	

Subnet Sample Tables

Table 4: Allowable Subnets for Class C IP Address - 24 network bit and 8 host bits

Number of bits (contiguous)	Netmask	Number of Subnets	Number of Nodes per Subnet
2.00	255.255.255.192	2.00	62.00
3.00	255.255.255.224	6.00	30.00
4.00	255.255.255.240	14.00	14.00
5.00	255.255.255.248	30.00	6.00
6.00	255.255.255.252	62.00	2.00

Table 5: Allowable Subnets for Class B IP Address - 16 network bits and 16 host bits

Number of bits (contiguous)	Netmask	Number of Subnets	Number of Nodes per Subnet
2.00	255.255.192.0	2.00	16,382
3.00	255.255.224.0	6.00	8,190
4.00	255.255.240.0	14.00	4,090
5.00	255.255.248.0	30.00	2,046
6.00	255.255.252.0	62.00	1,022
7.00	255.255.254.0	126.00	510.00
8.00	255.255.255.0	254.00	254.00
9.00	255.255.255.128	510.00	126.00
10.00	255.255.255.192	1,022	62.00
11.00	255.255.255.224	2,046	30.00
12.00	255.255.255.240	4,094	14.00
13.00	255.255.255.248	8,190	6.00
14.00	255.255.255.252	16,382	2.00

Table 6: Allowable Subnets for Class A IP Address - 8 network bits and 24 host bits

Number of bits (contiguous)	Netmask	Number of Subnets	Number of Nodes per Subnet
2.00	255.192.0.0	2.00	4,194,302
3.00	255.224.0.0	6.00	2,097,150
4.00	255.240.0.0	14.00	1,048,574
5.00	255.248.0.0	30.00	524,286
6.00	255.252.0.0	62.00	262,142
7.00	255.254.0.0	126.00	130,070
8.00	255.255.0.0	254.00	65,534
9.00	255.255.128.0	510.00	32,766
10.00	255.255.192.0	1,022	16,382
11.00	255.255.224.0	2,046	8,190
12.00	255.255.240.0	4,094	4,094
13.00	255.255.248.0	8,190	2,046
14.00	255.255.252.0	16,382	1,022
15.00	255.255.254.0	32,766	510.00
16.00	255.255.255.0	65,534	254.00
17.00	255.255.255.128	131,070	126.00
18.00	255.255.255.192	262,142	62.00
19.00	255.255.255.224	524,286	30.00
20.00	255.255.255.240	1,048,574	14.00
21.00	255.255.255.248	2,097,150	6.00
22.00	255.255.255.252	4,194,302	2.00

Subnetting Example

You have just received an IP address of 192.56.51.xxx and now you want to figure out which subnet scheme is best for your organization. Look at the requirements of your organization before deciding anything. In this example, let's say your company has four sites: Chicago, Toronto, Vancouver and Atlanta. Each sites has a requirement for 10 to 25 nodes.

The requirements for your organization are:

Minimum of four segments
10 to 25 nodes per segment

You can start calculating alternatives using the subnetting rules presented in this paper or you can used the tables included in this paper. Let's use the tables, go back to Table 4: Allowable Subnets for Class C IP Address and find the subnet that matches your requirements as closely as possible. You should find that a Netmask of 255.255.255.224 is the best alternative. It allows for 6 subnets and up to 30 nodes per subnet. This choice covers the organizations requirements and allows some room for growth. The table below outlines to assignment of addresses for the organization.

Table 7: Organization's Subnet Assignments for Netmask of 255.255.255.224

Location	Subnet	IP Address Range
Vancouver	0 0 1	192.56.51.33 to 192.56.51.62
Chicago	0 1 0	192.56.51.65 to 192.56.51.94
Atlanta	0 1 1	192.56.51.97 to 192.56.51.126
Free	1 0 0	192.56.51.129 to 192.56.51.158
Free	1 0 1	192.56.51.161 to 192.56.51.190
Toronto	1 1 0	192.56.51.193 to 192.56.51.222

HP9000 IP and subnet configuration example

- /etc/netconf on HP-UX 10.X

```
# Internet configuration parameters.  See ifconfig(1m), lanconfig(1m)
# INTERFACE_NAME:          Network interface name (see lanscan(1m))
# IP_ADDRESS:              Hostname (in /etc/hosts) or IP address  (eg. 192.1.2.3)
# SUBNET_MASK:             Subnet mask in decimal-dot notation, if different from default
# BROADCAST_ADDRESS:       Broadcast address in decimal-dot notation
# LANCONFIG_ARGS:          Link-layer encapsulation methods (e.g., ieee, ether).

INTERFACE_NAME[0]=lan0
IP_ADDRESS[0]=15.65.217.49
SUBNET_MASK[0]=255.255.248.0
BROADCAST_ADDRESS[0]=15.65.223.255
LANCONFIG_ARGS[0]="ether"

# Internet routing configuration.  See route(1m), routing(7)
# ROUTE_DESTINATION:       Destination hostname (in /etc/hosts) or host/net IP
# ROUTE_MASK:              Subnetwork mask in decimal-dot notation, optional
# ROUTE_GATEWAY:           Gateway hostname (in /etc/hosts) or IP address
# ROUTE_COUNT:             An integer  1 indicates remote, 0 indicates local
# ROUTE_ARGS:              Route command arguments and options.

ROUTE_DESTINATION[0]="default"
ROUTE_MASK[0]=""
ROUTE_GATEWAY[0]="15.65.216.1"
ROUTE_COUNT[0]="1"
ROUTE_ARGS[0]=""
```

HP3000 IP and subnet configuration example

MPE/iX 5.0 from NMMGR.PUB.SYS

NMMGR/3000 (B.04.07) #156 IP Protocol Configuration Data: Y
When Data Flag is "N", press "Save Data" to create the data record.
Command:

Path: NETXPORT.NI.LAN1.PROTOCOL.IP

[0] Store & Forward Buffers
(Enter 0 To Disable Store & Forward)

[A 015 035.072.111] IP Internet Address
[255.255.248.000] IP Subnet Mask (Optional)

File: NMCONFIG.PUB.SYS

NMMGR/3000 (B.04.07) #158 Neighbor Gateway Reachable Networks Data: Y
When Data Flag is "N", press "Save Data" to create the data record.
Command:

Path: NETXPORT.NI.LAN1.INTERNET.GATE1

[A 015 035.072.001] Neighbor Gateway IP Internet Address

Configured Reachable Networks

IP Network Address	IP Mask (Optional)	Hops
[@]	[255.255.248.000]	[1]
[ ]	[ ]	[ ]
[ ]	[ ]	[ ]

File: NMCONFIG.PUB.SYS PAGE 1

When you configure your systems for subnetting, don't forget the other network devices like routers. On the systems and PCs you must remember to add the gateway configurations. In HP-UX it is called the default gateway and on MPE/iX it is called the Neighbor Gateway, under the Internet screen of NMMGR.