IPv4 Classful Addresses

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This tutorial teaches you the network mask and how to construct five related addresses based on an original source address. It also teaches you the number of bits in the network and host portions of the address, and the number of IP addresses and host addresses that exist in a network. It prepares you to take quiz IPv4b.

We assume you are familiar with IPv4 addresses to the degree that: (1) you are familiar with dotted quad notation, and (2) you can identify the class of an address (e.g., A, B, or C). If not, see the handout and quiz on IPv4 Address Classes.

1 Network and Host

IP addresses consist of bits. These bits are divided into two parts. The first part always identifies the network. The last part identifies the host. The total number of bits is always 32.

In the original design of IP addressing, three sizes of networks were planned. The Pareto Principle (or 80-20 rule) suggested that there should be a few really big networks, and a lot of really small networks. Accordingly three classes (A, B, and C) were developed.

Each Class A network can handle about 16 million hosts ($2^{24} - 2$). Only about 128 Class A networks exist.

Each Class B network (the middle size) can handle 65,534 hosts ($2^{16} - 2$). About 16 thousand Class B networks exist.

Each Class C network (the smallest size) can handle 254 hosts ($2^8 - 2$). About 2 million Class C networks exist.

We can determine the class by looking at the first octet (quad) of the IP address.

2 Who Cares?

The whole point of networks is for your computer to talk to another computer somewhere else. To save on expense, your computer does not have a direct connection to every possible destination. Instead, you have a direct connection to your local area network, including one (sometimes more) special machine that serve as a gateway to the rest of the Internet.

Message passing is done using IP addresses. It works somewhat like ZIP codes in the United States. (Similar postal codes are common throughout the world.)

My local post office looks at its daily mail. It keeps mail to be delivered locally and sends the rest to a regional processing center. Mail from many local post offices comes together there and is sorted for return to each locality, or for sending to other regional centers.

My zip code is 96762 in Hawaii. If I send a letter with a destination of 96762, it will be kept locally and delivered tomorrow.

I am in the 967/968 region. If I send a letter with a destination of 96811, it will be sent to the regional processing center in Honolulu, sorted into trays for 96811, and returned to the 96811 local post office. It will then be delivered locally the next day.

If I send a letter with a destination of 99352, it will be sent to the 967/968 Honolulu regional processing center, sorted into trays for the mainland. It will then be flown to a 98/99 processing center near Seattle, and next to the 993 regional processing center in eastern Washington. Next it goes to the 99352 post office for eventual delivery.

ZIP codes make this easier because the next destination for my letter is easy to determine based on (a) the ZIP code where it is now, and (b) the ZIP code of its destination.

Computer networking works the same way. If my message can be delivered locally, it is. If not, it is sent through a gateway to another network that is closer to the destination.

Specifically, if the network address of the source and destination are the same, we get local (one hop) delivery. If not, our gateway forwards the message to the gateway of the destination for local delivery (two, three, or more hops).

3 Class A

If the first number is between 0 and 127, we have a Class A address. In a Class A address, the first octet is the network address. The last three octets are the host address: (net.host.host.host).

There are 2^7=128 Class A networks. The 7 comes from the fact that the first octet has eight bits, with the first one required to be "0." The other seven bits are free to vary between 0 and 1.

2^7 ??

The notation 2^7 means $2 \times 2 \times 2 \times 2 \times 2 \times 2 \times 2$ (there are seven 2s). 2^7 is shorter to read and write.

The "free to vary" part gives us our alternatives.

Let's look at coins. How many head/tail orders are there? If we have one coin, it can be either a head or a tail. We have two possible orders.

If we have two coins, they can be arranged as either HH, HT, TH, or TT. We have four alternatives. Notice that HT and TH are different, even though they each have one head and one tail.

If we have three coins, they can be either HHH, HHT, HTH, HTT, THH, THT, TTH, or TTT. We have eight possibilities. Notice that these eight alternatives are just the four two-coin alternatives each followed by H, and the four two-coin alternatives each followed by T. For three coins, there are $2 \times 2 \times 2 = 2^3 = 8$ alternatives.

If we have three coins, but the first two must be HT, then only the last coin is free to vary. In that case, we can get either HTH or HTT. We have only two possibilities. For three coins with only one free to vary, there are $2^1 = 2$ alternatives.

Each time we add a coin that is free to vary, we double the number of alternatives. We have all the old alternatives followed by H, plus all the old alternatives folled by T. For n coins free to vary between H and T, there are 2^n alternatives.

Similarly for IP addresses with n bits that are free to vary between 0 and 1, there are 2^n alternatives.

Back to Class A

There are 2^{24} (about 16 million) IP addresses per network, and 2^{24}-2 hosts per network. The 24 comes from the fact that the last three octets have twenty-four bits. The -2 comes from the fact that the first and last IP address cannot be used for hosts. They are reserved. The first address (net.0.0.0) is the network address. The last address (net.255.255.255) is the broadcast address.

10	192	47	31	Class A source address
255	0	0	0	Class A network mask
10	0	0	0	network portion of addr
0	192	47	31	host portion of address
10	0	0	1	first valid host address
10	255	255	254	last valid host address
10	255	255	255	broadcast address

4 Class B

If the first number is between 128 and 191, we have a Class B address. In a Class B address, the first two octets are the network address. The last two octets are the host address: (net.net.host.host).

There are 2^{14} (about 16 thousand) Class B networks. The 14 comes from the fact that the first two octets have sixteen bits. The first two bits are required to be "10." The other fourteen bits are free to vary between 0 and 1.

There are 2^{16} (about 64 thousand) IP addresses per network, and 2^{16}-2 hosts per network. The 16 comes from the fact that the last two octets have sixteen bits. The -2 comes from the fact that the first and last IP address cannot be used for hosts. They are reserved. The first address (net.net.0.0) is the network address. The last address (net.net.255.255) is the broadcast address.

172	210	19	7	Class B source address
255	255	0	0	Class B network mask
172	210	0	0	network portion of addr
0	0	19	7	host portion of address
172	210	0	1	first valid host address
172	210	255	254	last valid host address
172	210	255	255	broadcast address

5 Class C

If the first number is between 192 and 223, we have a Class C address. In a Class C address, the first three octets are the network address. The last octet is the host address: (net.net.net.host).

There are 2^{21} (about 2 million) Class C networks. The 21 comes from the fact that the first three octets have twenty-four bits. The first three bits are required to be "110." The other twenty-one bits are free to vary between 0 and 1.

There are 2^8=256 IP addresses per Class C network, and 2^8-2=254 hosts per network. The 8 comes from the fact that the last octet has eight bits. The -2 comes from the fact that the first and last IP address cannot be used for hosts. They are reserved. The first address (net.net.net.0) is the network address. The last address (net.net.net.255) is the broadcast address.

192	168	14	91	Class C source address
255	255	255	0	Class C network mask
192	168	14	0	network portion of addr
0	0	0	91	host portion of address
192	168	14	1	first valid host address
192	168	14	254	last valid host address
192	168	14	255	broadcast address

6 Binary Shortcut

How do we know that 2^{16} is about 64 thousand? To quickly answer such questions it is helpful to know two facts: (a) the powers of two up to 10, and (b) the fact that 2^{10}=1024 is almost one thousand.

Exact Powers of Two				Approximate	
$2^1 =$	2	$2^6 =$	64	$2^{10} =$	thousand
$2^2 =$	4	$2^7 =$	128	$2^{20} =$	million
$2^3 =$	8	$2^8 =$	256	$2^{30} =$	billion
$2^4 =$	16	$2^9 =$	512	$2^{40} =$	trillion
$2^5 =$	32	$2^{10} =$	1024	$2^{50} =$	quadrillion

In the case of 2^{16} we know that 2^6 is 64, so $2^{16}=2^6 \times 2^{10}$ is about 64 thousand and $2^{26}=2^6 \times 2^{10} \times 2^{10}$ is about 64 million.

Similarly, 2^4 is 16, so 2^{14} is about 16 thousand and 2^{24} is about 16 million.

7 Quiz

For each source address, give the answers. Cover the answers. Then test yourself.

For 8.163.248.34	Answer Column
network class (A, B, or C)	A
network address uses how many bits?	8
host address uses how many bits?	24
how many IP addresses exist?	2^{24}
how many host addresses exist?	2^{24}-2
net mask in dotted notation	255.0.0.0
network address	8.0.0.0
host part of address	0.163.248.34
broadcast address	8.255.255.255
first host address	8.0.0.1
last host address	8.255.255.254

For 197.42.189.74	Answer Column
network class (A, B, or C)	C
network address uses how many bits?	24
host address uses how many bits?	8
how many IP addresses exist?	256
how many host addresses exist?	254
net mask in dotted notation	255.255.255.0
network address	197.42.189.0
host part of address	0.0.0.74
broadcast address	197.42.189.255
first host address	197.42.189.1
last host address	197.42.189.254

For 141.121.234.134	Answer Column
network class (A, B, or C)	B
network address uses how many bits?	16
host address uses how many bits?	16
how many IP addresses exist?	2^{16}
how many host addresses exist?	2^{16}-2
net mask in dotted notation	255.255.0.0
network address	141.121.0.0
host part of address	0.0.234.134
broadcast address	141.121.255.255
first host address	141.121.0.1
last host address	141.121.255.254