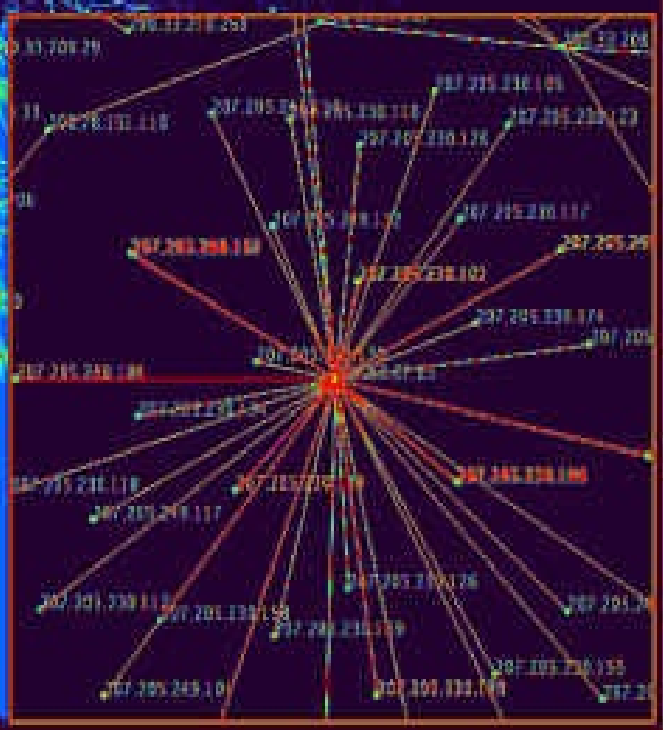
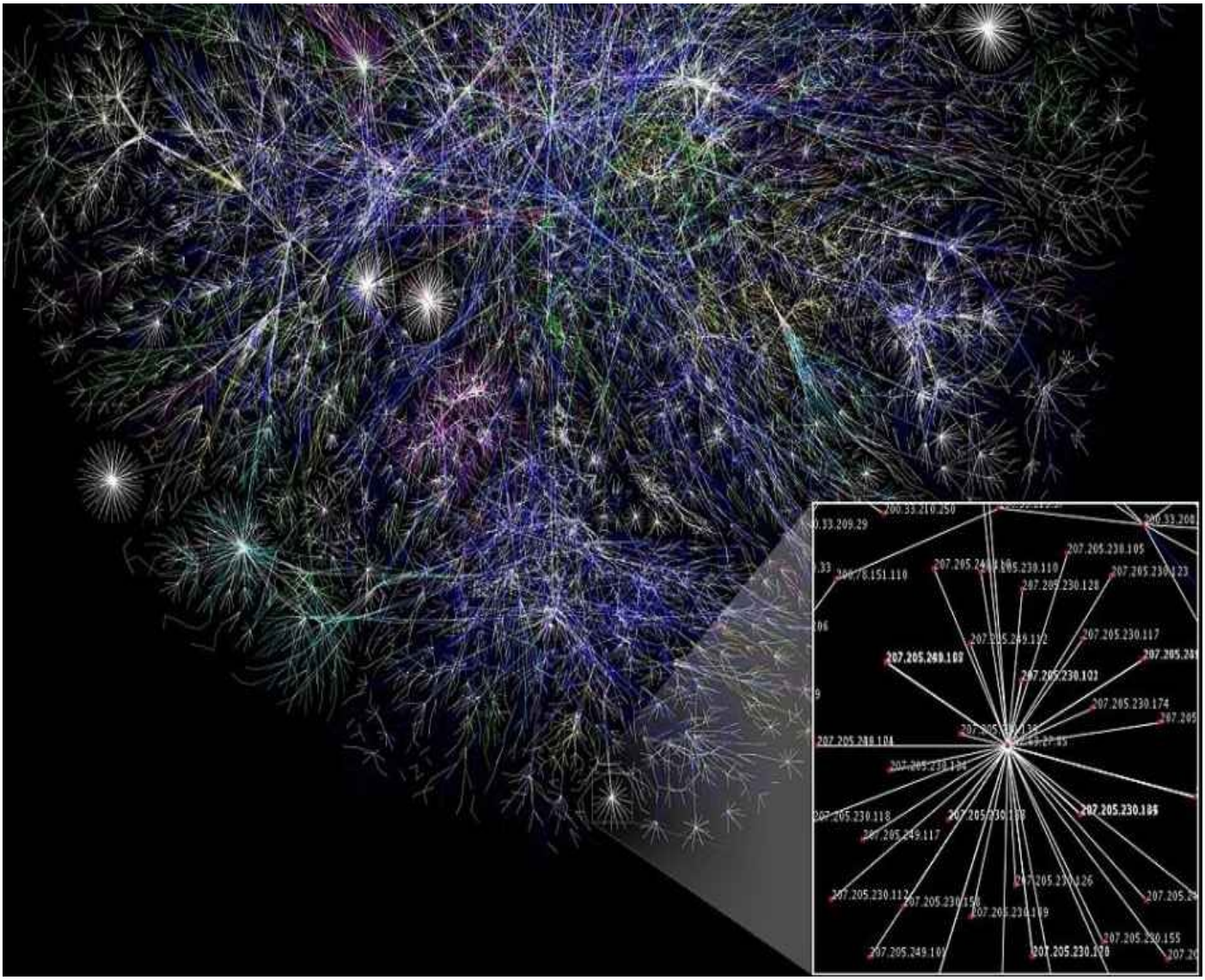
UNDERSTANDING TCP/IP SUBNETTING



Trung Nguyen



Understanding TCP/IP Subnetting

“When wireless is perfectly applied the whole earth will be converted into a huge brain, which in fact it is, all things being particles of a real and rhythmic whole. We shall be able to communicate with one another instantly, irrespective of distance. Not only this, but through television and telephony we shall see and hear one another as perfectly as though we were fact to face, despite intervening distances of thousands of miles, and the instruments through which we shall be able to do this will [fit in a] vest pocket…It will only be necessary to carry an inexpensive instrument not bigger than a watch, which will enable its bearer to hear anywhere on sea or land for distances of thousands of miles. One may listen or transmit speech or song to the uttermost parts of the world. In the same way any kind of picture, drawing, or print can be transferred from one place to another.” — Nikola Tesla (1856 - 1943), 1926

Let’s say that you have 100 computers in your company and you want to connect each

computer to the Internet. Before you do that, you'll need to get a network IP address for your network from www.internic.net. InterNIC is an organization that assigns IP addresses. When you connect to the Internet you are using the TCP/IP transport protocol (Transmission Control Protocol/Internet Protocol). I can't elaborate on the TCP/IP protocol in this novel because that would take a short novel. If you aren't familiar with it, just think of TCP/IP as a language that computers use to communicate with each other. It is also a very fast growing language and the most widely accepted one at the moment—similar to the English language is widely accepted in the business world. The TCP/IP protocol was developed by the U.S Department of Defense (DOD) and it is the native language of the Internet. Not too far in the future, all computers may be using the TCP/IP protocol to talk to each other because of the explosive growth of the Internet. The protocol is not owned by any company or organization and that is one of the reasons why it is so widely accepted.

In the example above, where you have 100 computers, you can choose your own IP address for your network if your network will use the TCP/IP Protocol but the network will NOT be connected to the Internet. In this case your network is known as an Intranet. In any case, anytime you're using the TCP/IP protocol, you'll be using IP addresses.

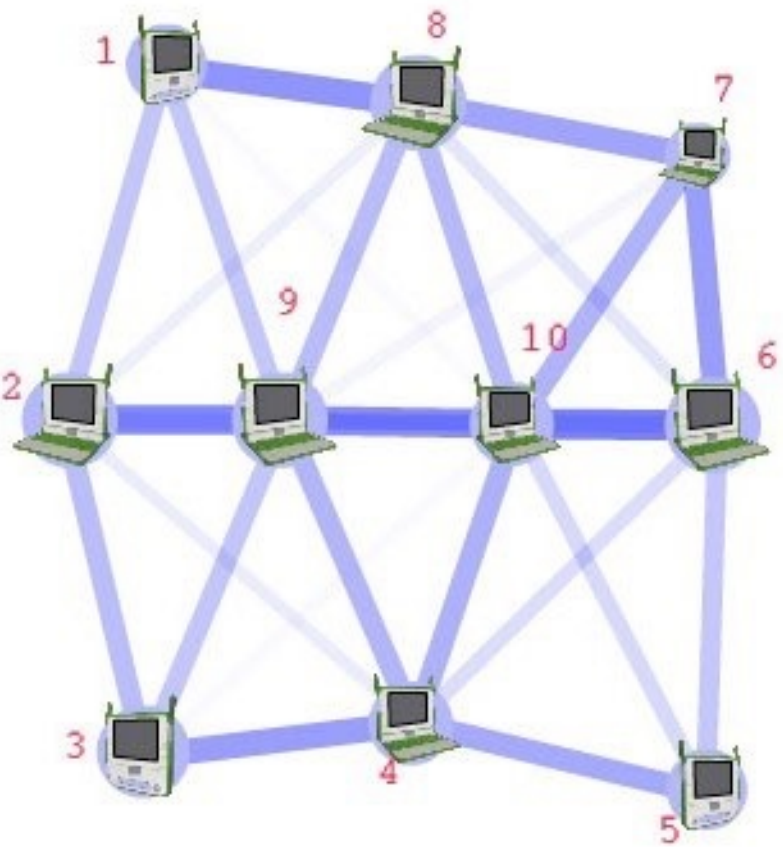


Photo: www.wikipedia.org

If you are reading this, then somewhere along the way you've typed

www.encognitive.com to get to this website. Whenever you type www.encognitive.com or any other URL, then you're using what is called a domain name. It's important to remember that **beneath every domain name is an IP address**. Domain names are used to mask IP addresses to help us remember the addresses (or URL: Uniform Resource Locator) better. For example: What is easier to remember: www.encognitive.com or http://69.164.208.4? Of course www.encognitive.com is easier to remember, unless you're an android. I am going to stop here with domain names and IP addresses. Just remember that beneath every domain name is an IP address.

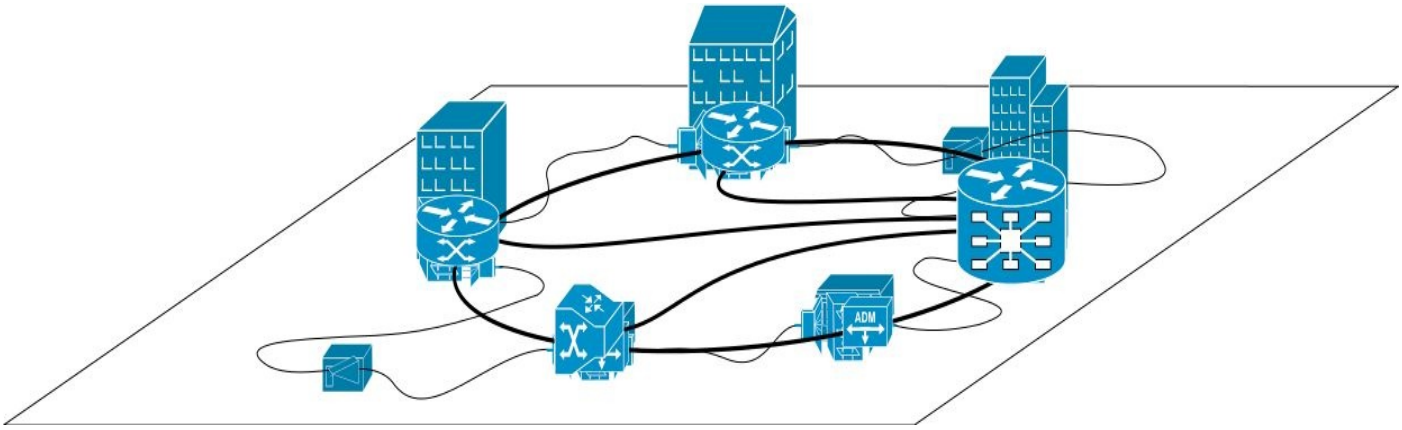


Photo: www.wikipedia.org

Each IP address is made of 4 bytes (32 bits). 1 byte = 8 bits. For example: If an given IP address is 69.164.208.4, then the:

1st byte (octet or 8 bits) = 69

2nd byte (octet) = 164

3rd byte (octet) = 208

4th byte (octet) = 4

Notice that each byte is separated by a dot. That's why IP addresses are expressed in "dotted notation" or some call it decimal notation. From now on instead of bytes we'll use octets. So each IP address has 4 octets. Octets is the proper lingual in the TCP/IP world. The value in each octet can only be from 0 to 255. However, the values 0 and 255 are reserved for special purposes which I'll explain later. You should note that there are 256 digits between 0 and 255. For example, there are 4 digits between 0 and 3: 0, 1, 2, and 3.

At the computer (machine) level the IP addresses are expressed in "binary notation." For example, if the IP address is 200.80.89.194, you can express this in binary notation. To do this, use the Windows Calculator, or any calculator with the scientific mode, found under START -> ACCESSORIES. On the calculator, be sure to choose VIEW -> SCIENTIFIC. Then punch in "200" in decimal notation, then punch the "Bin" radio button on the upper-

left corner of the calculator. You should get 1100 1000.

So 1100 1000 is the equivalent of 200 in binary notation. They mean exactly the same thing, but it's easier for us humans to remember 200 than it is to remember 1100 1000. Make sure you click the "Dec" button on the upper-left hand corner of the calculator to put it back in decimal mode. Now convert 80, 89 and 194 to binary numbers. If your calculator comes up with only 7 bits instead of 8, just add a 0 (zero) in front of the first bit. Or if your calculator only comes up with 6 bits, just add 2 zeroes in front (leading zeroes) of the first bit, and so on.

In binary notation, the IP address of 200.80.89.194 looks like this:

1100 1000. 0101 0000. 0101 1001. 1100 0010 = 200. 80. 89. 194

Notice that when the IP address is expressed in binary notation, the values can only be either 1 (one) or 0 (zero). This is computer language (binary language—the electron gate is either on (1) or off (0). You can also express computer language using the number 2 system raised to the power of n(2^n). Where n can be any number from 0 to 7. Thus, n can only be from 0 to 7 because there are only 8 bits in an octet. Again, there are 8 digits between 0 and 7. In computer language, the count starts at 0. In our world the count starts at 1. So all this switching back and forth may be confusing at first.

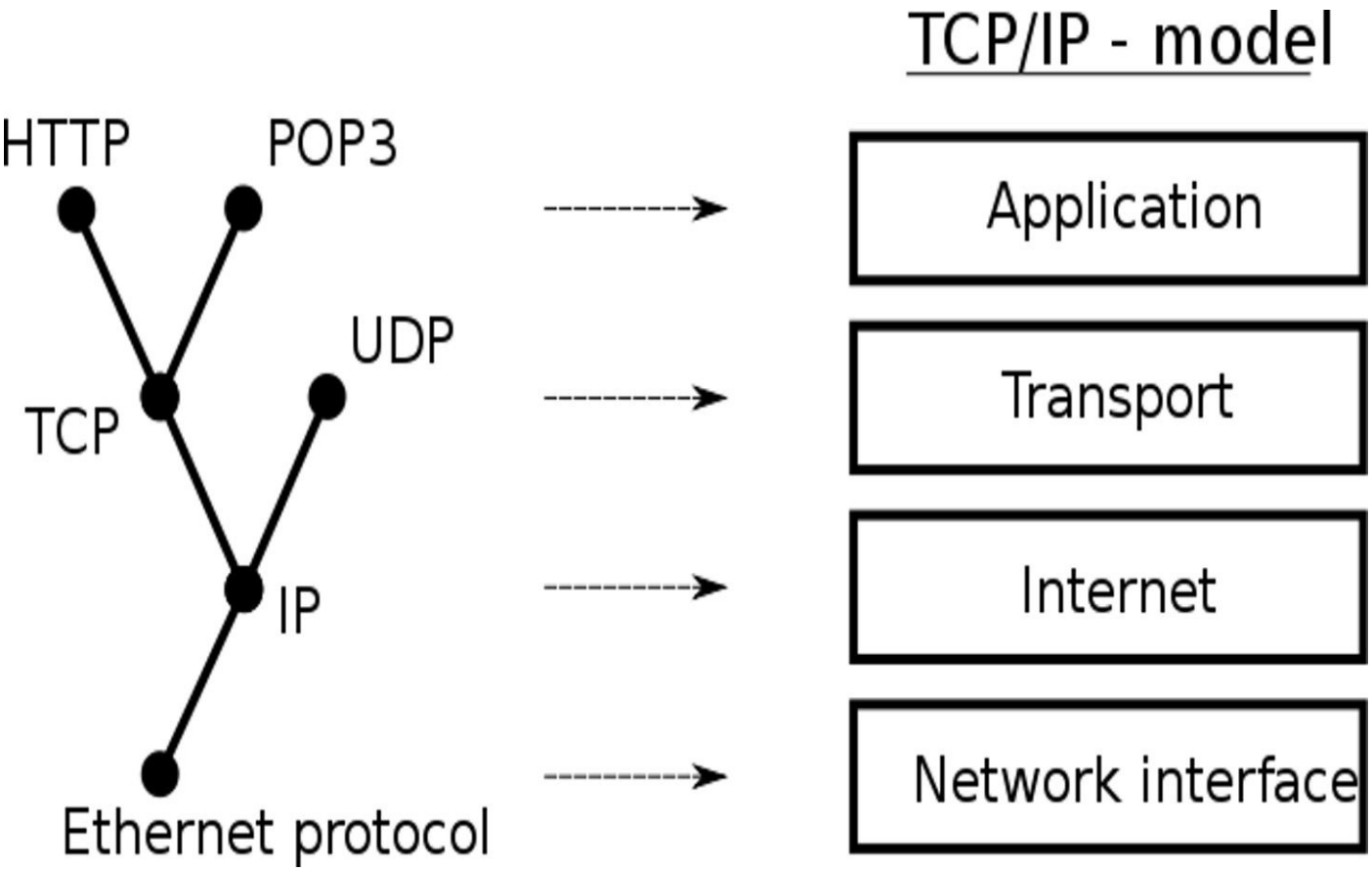


Photo: www.wikipedia.org

1. What is the binary value of 0?

2. What is the binary value of 255?

Answer to 1: 0000 0000.

Answer to 2: 1111 1111.

An IP address will always follow this pattern: W. X. Y. Z, where w, x, y and z can be any decimal number from 0 to 255. You should note the following about the values of w, x, y and z:

W, the first octet in the IP address, cannot be 127. You only use 127 in the 1st octet if you want to test your own computer's IP address (loopback function). You would use 127.0.0.1.

Your NETWORK ID and your HOST ID cannot be 0 or 255. I'll explain what a network ID and an host ID are later. To make it easier to remember, generally, the value of w, x, y and z CANNOT be 0 or 255. If there is a 0 (0000 0000) or 255 (1111 1111) in your IP address, then you are using the IP address for the purpose of broadcasting—sort of testing the network out. I am going to stop here about network IDs and host IDs for now.

Here are a few decimal and binary values that you should remember if you intend to pass the Microsoft or Cisco TCP/IP exam. For the chart below, don't worry about what subnets or hosts are. I'll explain them later. Just look at the math patterns.

Decimal	Binary	Number of Su $2^n - 2$
255	1111 1111 (eight 1s, n=8)	$2^8 - 2 = 25$
254	1111 1110 (seven 1s, n=7)	$2^7 - 2 = 12$

252	1111 11000 (six 1s, n=6)	$2^6 - 2 = 6$
248	1111 1000 (five 1s, n=5)	$2^5 - 2 = 3$
240	111 0000 (four 1s, n=4)	$2^4 - 2 = 1$
224	1110 0000 (three 1s, n=3)	$2^3 - 2 = 6$
192	1100 0000 (two 1s, n=2)	$2^2 - 2 = 2$

If you don’t already know what subnets are, don’t worry about them. I’ll explain them later. NOTICE THE PATTERN ON ALL 3 COLUMNS, especially notice the pattern for the n in the “Number of Subnets” column. For now, use the table above and try to answer the following questions mathematically:

1. If your network needs 7 subnets (sub-networks), what decimal value should you have in your IP address? (Look at the table. The answer is 240, which will give you 14 sub-networks.)

2. If your network needs 200 subnets, what decimal value should you have on your IP address? (Look at the table. The answer is 255, which will give you 254 sub-networks.)

3. If your network needs 30 subnets, what decimal value should you have on your IP address? (Look at the table. The answer is 248.)

4. Using the table above, notice the pattern of the 3 columns. Minimize the size of the columns as much as you can.

Answer: You can minimize the size of the table to look something like this:

# of subnets

255	8
254	7
252	6
248	5
240	4
224	3
192	2

Knowing what you know, why would you use 2^n - 2. That is, why would you subtract 2 from the equation? You subtract 2 because remember that you cannot have 0 or 255 in your IP address, unless you intend to use it for broadcasting purposes.

The table above is just the start of something really big and complicated. I'll try to explain the rest in the following sections.

IP Address Class

At last count there were about 5 classes of IP addresses: Class A, Class B, Class C, Class D, and Class E. For your TCP/IP exams, you'll need to remember Class A, Class B, and Class C. Class D is used for multicasting and Class E is used for experimental purposes. Don't worry about Class D and E until you get into a production environment. You won't be asked about them on the exams.

What separates a Class A, Class B, and Class C addresses is the first octet in their IP addresses. Here is the starting range for THE FIRST octet of Class A, B, and C networks:

Network class	First octet value
Class A	1 - 126
Class B	128 - 191
Class C	192 - 223

You can always tell which class a network belongs to by the first octet of its IP address. If your IP address is 112.x,y.z, then your network falls into the Class A category. This is because the 1st octet (112) falls between 1 - 126. In the meantime, do the following exercises:

1. Your IP address is 184.200.91.88. What class is your IP address in? (Class B).

2. Your IP address is 195.x.y.z. What class is your IP address in? (Class C).

3. Express 150.94.66.212 in binary notation. (Use the scientific calculator.)

Subnet Masks

There’s not enough room to go into extensive details about subnet masks, but I can tell you briefly in the following section what they are and what you need to know about them to pass the TCP/IP exams. So far, you know how to find whether an IP address falls into Class A, Class B, or Class C. That’s the first step to knowing subnet masks.

A subnet mask is used to distinguish the Network ID from the Host ID.

Host ID. Suppose that the following situation exists in an office building where you work: there are 100 computers hooked together with network cables on the same floor. Each computer (100 in this example) is known as a HOST or a client. Each host (computer in the network) has to have an ID to identify it from the other 99 computers in the network. For example, if you have 100 people in the same building, you can distinguish each person by THEIR NAMES. So think of an Host ID as a name to identify each computer in your network. Just remember in TCP/IP the host ID is a number. Also, if you have 100 people in one building, 2 or more people may have the same name. Using the TCP/IP protocol, you CANNOT have 2 or more computers with the same Host ID. Problems can arise if you have 2 or more hosts with the same host ID.

Network ID. A network is collection of computers linked together by cables or wireless technology. There are 3 types of networks: LAN (Local Area Network), MAN (Metropolitan Area Network), and WAN (Wide Area Network). Here are some quick and rough examples of the 3 types of networks:

A LAN is a collection of computers connected together in one location, such as a building.

A MAN is a collection of computers connected together within a city (city limit).

A WAN is collection of computers connected together from different cities, countries, continents, etc. The Internet is the largest WAN of all.

Going back to the example above where you have 100 computers connected together in one building , the network ID is used to identify the “address” of the network. Sorry, but I don’t have a good analogy for a network ID. Also, in the example above all 100 computers would have the SAME network ID because they belong to the SAME network.

Okay, back to subnet masks. A “subnet” is an abbreviation for “Sub Network.” You can think of a subnet (subnetwork) as a branch of the main network. Why would you want to split your network into subnetworks? Remember that when you connect computers together to form a network, the computers communicate with each other. When too many computers communicate with each other on the same network, this causes “network traffic.” Imagine that you have 100 people in the same room and they’re all talking. The noise level would be pretty high. If you want to reduce the noise level, you may want to divide them into 4 groups of 25. By dividing the 100 people into 4 logical groups with 25 people in each group, you can also manage them better.

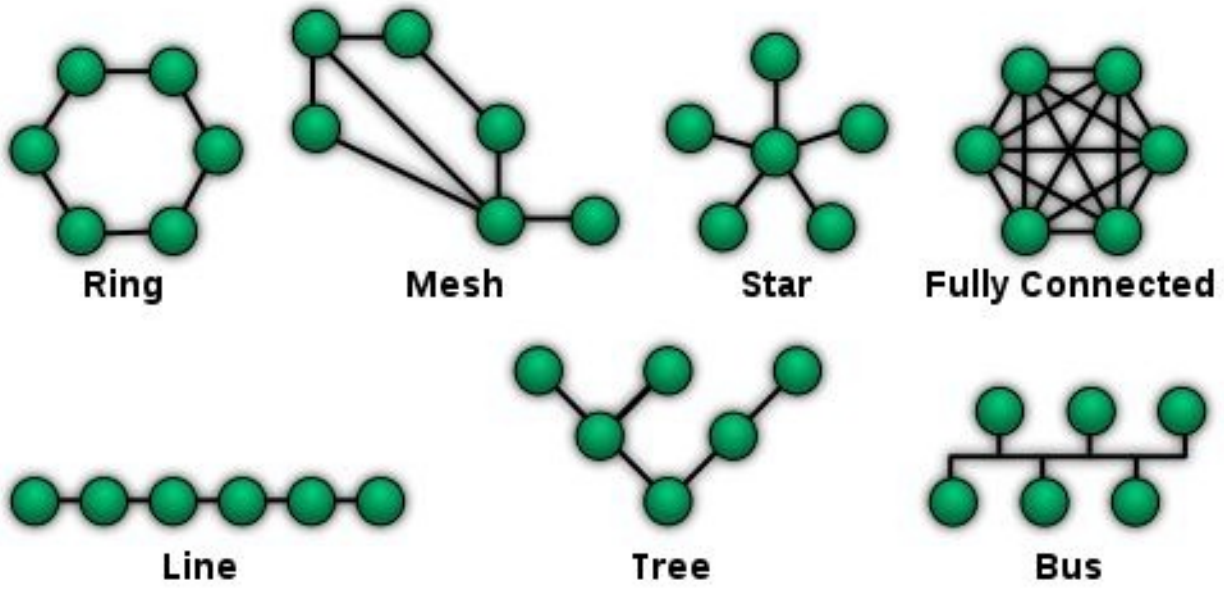


Photo: www.wikipedia.org

Again, back to subnetting. If you are the network administrator of the 100 computers mentioned above and you notice that there is too much network traffic and you want to improve the traffic, you may want to divide up your network into subnets. You may want to divide your network into 2 subnets or even 4 subnets. There are other reasons you may want to divide your network into subnets but I won't go into them here. When you divide your network into subnets, all the computers (hosts) on your network will still have the SAME network ID. However, their SUBNET IDs will be different. After you split up your network into subnets, you can join your subnets together by using special network devices such as a switch, bridge, and so on.

A subnet mask is used to distinguish the Network ID from the Host ID. What does a subnet mask have to do with subnetting? Let's say that you have a computer on a TCP/IP network and your computer has the following IP address: 147.122.72.9. What class does your network belong to? The answer is Class B because the first octet (147) falls between 128 and 191. Now here is the big leap:

Network class	First octet value	Default subnet mask	# of networks	# o n
Class A	1 - 126	255.0.0.0	126	16

Class B	128 - 191	255.255.0.0	16,384	
Class C	192 - 223	255.255.255.0	2,097,152	

In Part 3, I'll show you how you can recreate the table above from scratch. For now answer following the questions using the table above.

Question A. Which network class can have the highest number of hosts (computers) per network? Answer: Class A

Question B. Which network class can have the highest number of networks? Answer: Class C.

Question 1. Your IP address is 140.2.199.66 and your network is not subnetted. What class does your network belong to and what is your default subnet mask? Look at the table. The answer is Class B, 255.255.0.0.

Question 2. Your IP address is 200.194.26.88 and your network is not subnetted. What class does your network belong to and what is your default subnet mask? Look at the table. The answer is Class C, 255.255.255.0.

Question 3. Your IP address is 88. 254.44.22 and your network is not subnetted. What class does your network belong to and what is your default subnet mask? Look at the table. The answer is Class A, 255.0.0.0.

Answer to 1: Class B, 255.255.0.0.

Answer to 2: Class C, 255.255.255.0.

Answer to 3: Class A, 255.0.0.0.

Question 4. You have a Class A network address with no subnets. How many hosts (computers) can you have on your network? Look at the table above.

Question 5. You have a Class B network address with no subnets. How many hosts (computers) can you have on your network? Look at the table above.

Question 6. You have a Class C network address with no subnets. How many hosts (computers) can you have on your network? Look at the table above.

What the subnet mask tells you is that anytime you are assigned a network IP address, either class A, B, or C, then certain octet(s) on your network are FIXED. For example:

For Class A, your first octet is always fixed. Let's say that you are assigned an IP address of 88.125.127.4, which means that your address belongs to class A and your default subnet mask is 255.0.0.0. This means that you **cannot** change the value of the FIRST octet in your IP address. In this example, the first octet is 88. The 88.x.y.z identifies your network address, which is class A. The x, y and z identifies the hosts (computers) on your network.

For Class B, your first and second octets are fixed. Let's say that you are assigned an IP address of 140.99.120.8, which means that your network address belongs to class B and your default subnet mask is 255.255.0.0. This means that you **cannot** change the value of the FIRST and SECOND octets in your IP address. In this example the first octet is 140 and the second octet is 99. The 140.99.x.y identifies your network address. The x and y identifies the hosts on your network.

For Class C, your first, second and third octets are fixed. Let's say that you are assigned an IP address of 212.72.200.45, which means that your address belongs to class C and your default subnet mask is 255.255.255.0. This means that you **cannot** change the value of the FIRST, SECOND and THIRD octets in your IP address. In this example the first octet is 212, the second octet is 72, and the third octet is 200. The 212.72.200.y identifies your network address. The y identifies the hosts on your network.

You should note that, technically speaking, having a host on your network is not exactly the same as having a computer on your network. In TCP/IP a host is a computer with an assigned IP address. A computer is just the hardware until it becomes connected to a network, then it becomes known as either a client, server or host. I just wanted to clear this up before I get any email as to why I am freely interchanging "hosts" with "computers." I am doing it to make things easier to understand.

Part 2: Understanding the Basics of Subnetting

Network class	First octet value	Default subnet mask	# of networks	# o
Class A	1 - 126	255.0.0.0	126	16
Class B	128 - 191	255.255.0.0	16,384	
Class C	192 - 223	255.255.255.0	2,097,152	

Look at the “# of Networks” and the “# of Hosts per network” columns. I’ll do my best to explain what they mean:

# of Networks: If you look at Class A, you’ll notice that there can only be 126 networks. What this means is that in the entire Internet there can only be 126 companies or organizations that can have Class A addresses. Big companies such as IBM and organizations like the Department of Defense will probably have Class A addresses. If you have a Class A address, what is the maximum number of hosts you can have on your network?…If you look at the table, the answer is 16, 777, 214. This means that if you have a Class A address you can put 16, 777, 214 computers on your network. Of course, this is assuming that you will NOT be dividing your network into subnets, which I’ll get into a moment. Note: All 126 Class A addresses have already been taken, which means that no company can apply for a Class A address with InterNIC anymore.

If you look at Class B, you’ll notice that there can only be 16, 384 networks. What this means is that in the entire Internet there can only be 16, 384 companies or organizations with Class B addresses. If you have a Class B address, how many hosts can you have on your network?…From the table, the answer is 65, 534. Class B addresses are reserved for large or medium sized companies. You should also note that all Class B addresses have already been taken, which means that no one can apply for a Class B address with InterNIC anymore.

You should note the relationship between the # of Networks and the # of Hosts per network columns- - The more networks you have, the less hosts you can have per network.

Now let’s go back to our example where you’re an MCSE (Microsoft Certified Systems Engineer) with a gorgeous wife, driving a Ferrari Testarossa with a condo on Malibu Beach. All this from managing a network of 100 computers.

Suppose you want to hook up your 100 computers to the Internet. You go and apply with InterNIC for an IPv4 (Internet Protocol version 4) network address. What network class is InterNIC going to assign you? Well, you only have 100 hosts so the only choice InterNIC has is to give you a Class C address, which supports up to 254 hosts. Not that InterNIC has a choice since Class A and B are all used already. To make a long story short, you apply for an IP address with InterNIC and they assign you this network address: 206.125.22.x.

Note: As of 2015, IPv6 (Internet Protocol version 6) is the new TCP/IP standard. IPv6 ensures that the billions of smartphones and trillions of IoT (Internet of Things) devices coming online will all have IP addresses. Under IPv4, there would have been a shortage of IP addresses for these devices.

This means that you have a Class C address and you can put up to 254 hosts on your network. However, right now you only have 100 hosts. The x in your address can be any number from 1 to 254. Your default subnet mask is 255.255.255.0 because your network address is Class C. Now, 2 months down the road you notice that your network of 100 computers is causing a lot of “network traffic” and you decide to divide your network into 2 sections to reduce this network traffic so you can manage the network better. What do you do? You can go to InterNIC and apply for another network address, but there’s a high chance they’ll turn you down because they’ve already assigned you a network address of 206.125.22.x. What you have to do in this case is divide your network into SUBNETS.

Here is where all the action starts. Before we get the action going, remember these things about TCP/IP and subnetting:

			Hosts	Per
Binary value of Subnet Mask	Decimal Value of Subnet Mask	# of Subnets 2^n-2	Class A	Class

1111 1111 (n=8)	255	254	65, 534	254
1111 1110 (n=7)	254	126	131, 070	510
1111 1100 (n=6)	252	62	262, 142	1, 022
1111 1000 (n=5)	248	30	524, 286	2, 046
1111 0000 (n=4)	240	14	1, 048, 574	4, 094
1110 0000 (n=3)	224	6	2, 097, 150	8, 190
1100 0000 (n=2)	192	2	4, 194, 302	16, 38

Looking at the table, you know that the answer is 255.255.255.192. Remember that the first 3 octets of your Class C address are fixed, even for your subnet mask. So to subnet your network, you have to manipulate the 4th octet. Also remember that your default subnet mask for a Class C address is 255.255.255.0. You have a default subnet mask if your network is NOT divided into subnets. In the question above your network is divided into 2 subnets, so your subnet mask has to change from 255.255.255.0 to 255.255.255.192, which will give you 2 subnets with a maximum number of 62 hosts per subnet. The total number of hosts you can have on your internetwork is 124 (62 hosts per subnet * 2 subnets = 124 hosts for the internetwork). The total number of 124 hosts is down from 254. This is the general rule of subnetting: the more subnets you have on your

network, the fewer the number of hosts are available per subnet.

Question 1: Your IP address is 140.54.x.y. You want to divide your network into 28 subnets and allow for the maximum number of hosts per subnet. What subnet mask would you use?

First, the IP address 140.54.x.y belongs to class B because the first octet (140) falls between 128 and 191. If you look at class B on the table above, the answer is 255.255.248.0. Why would you use 248 and not 240 or 252? If you use 240, it will only give you 14 subnets and you need 28 of them. On the other hand, if you use 254 it will give you 126 subnets, which will dramatically reduce the number of hosts per subnet.

Question 2: You have a Class A address and you need 62 subnets on your network. What subnet mask should you use to allow for the maximum number of hosts per subnet?

Again, look at class A on the subnet table above. The answer is 255.252.0.0. This will give you exactly 62 subnets and 262, 142 hosts per subnet.

Question 3: Your subnet mask is 255.255.224.0. How many subnets do you have?

Look at the table. The answer should be 6, right? The answer is *not* 6. You cannot answer the question with the given information. First, you have to know what class the address belongs to. Remember if you have a class A address, you can manipulate the 2nd, 3rd and 4th octets in your subnet mask. If you have a class B address, you can manipulate the 3rd and 4th octets in your subnet mask. In Question 4, it could be a class B address with 6 subnets OR it could be a class A address with 2, 046 subnets. How did I come with 2, 046 subnets if it was a class A address? I'll show you in Part III.

Question 4: Your subnet mask is 255.255.255.192. How many subnets do you have?

Look at the table. Again, you cannot answer this question unless you know what class the address belongs to. The IP address of the subnet mask above could belong to either class A, B, or C.

Question 5: Your IP address is 140.98.x.y. Your subnet mask is 255.255.240.0.

How many subnets and hosts per subnet can you have on your internetwork?

Look at the table. You know that the IP address belongs to Class B because the first octet,

140, falls between 128 and 191. The answer is 14 subnets with 4, 094 hosts.

The subnet table above is fine to remember, but as you go deeper and deeper into subnets you end up having to remember several pages of IP addresses. Remember in Part I we started off with one small table, then in Part II the table became almost twice as big. The deeper you go, the more you have to memorize. Therefore, the goal is not to memorize the tables, but learn how to construct them.

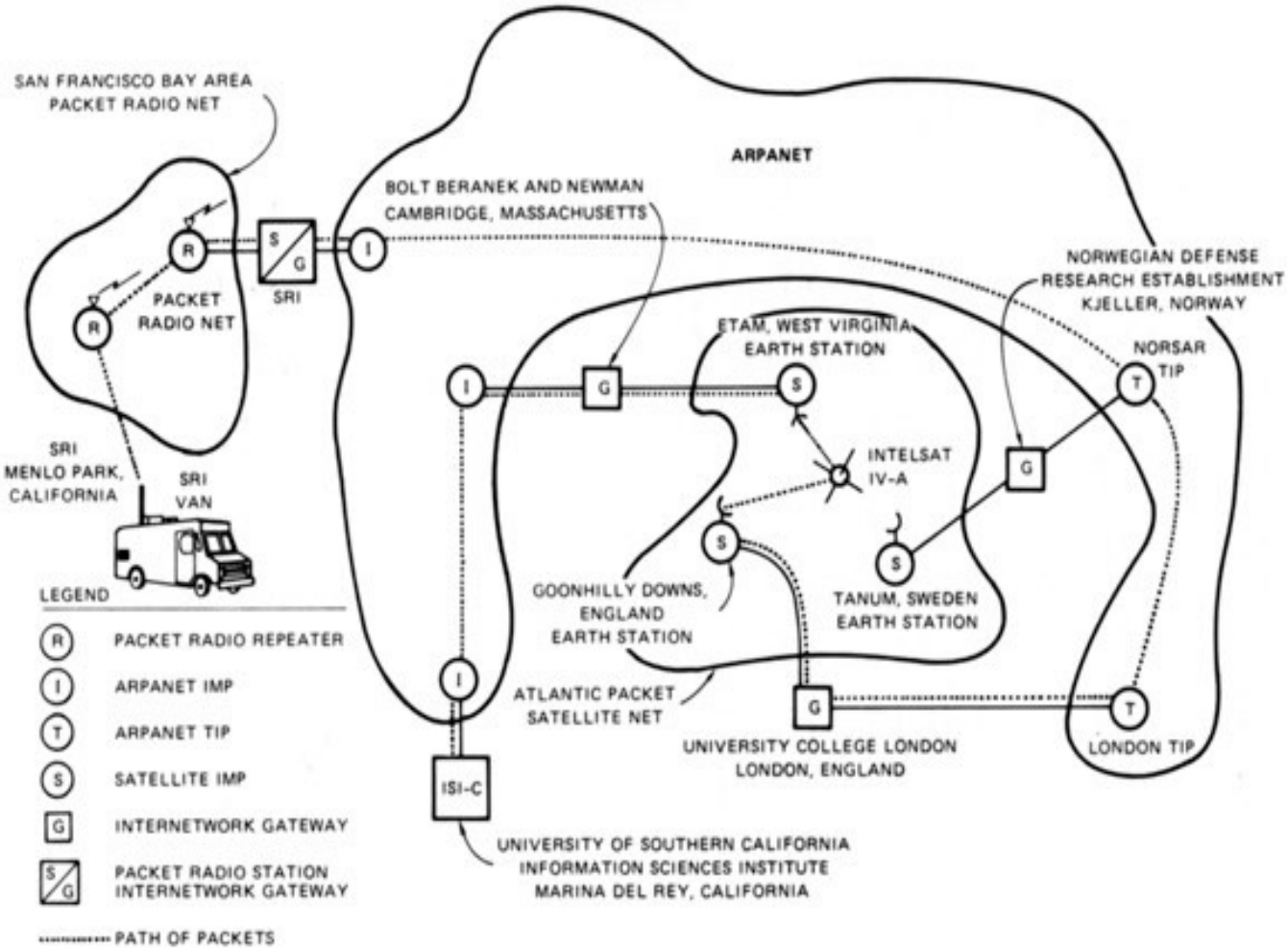
Remember that each time you divide your network into subnetworks, you are creating logical units, which together form the internetwork. Each subnet has its own identify (network name) and hosts that are unique to the rest of the subnets. But all the subnets put together make up your main network or "internetwork." Now try to answer the following 3 questions:

Question 1: Your IP address is 165.247.x.y and your subnet mask is 255.255.224.0. What is the valid range of IP addresses on your subnet?

Question 2: Your IP address is 165.247.200.100 and your subnet mask is 255.255.224.0. What is the valid range of IP addresses on your subnet?

Question 3: Your network belongs in class B and your subnet mask is 255.255.240. What decimal values can you have for the 3rd octet of your IP addresses?

To answer the 3 questions above, you have to memorize about 4 pages of IP addresses if you don't know how IP addresses work from the ground up. This is one of the pitfalls of trying to memorize the subnet tables. I think it's better to know how IP addresses work from the ground up than it is to memorize the tables. In Part 3, I'll show you how you can create all the tables from the ground up. This way, you can slice and dice your way through IP addresses and subnetting and pass your TCP/IP exams.



Part 3: Building IP Address and Subnetting Tables from Scratch

Network Class	First Octet Value	Default SUBNET MASK	# of Networks	# of H per net
Class A	1 - 126	255.0.0.0	1) 126	1A) 16 214

Class B	128 - 191	255.255.0.0	2) 16, 384	2A) 65
Class C	192 - 223	255.255.255.0	3) 2, 097, 152	3A) 2

Note: Th texts in the 3rd and 4th columns (1, 1A, 2, 2A, etc.) highlighted in red are used to illustrate the process.

In order to construct the table from scratch you have to remember the valid range of the first octet in each network class. You'll also have to remember the default subnet masks. Those are the only 2 things that you'll have to remember. You have to remember them because they were arbitrary assigned when IP addresses were created. This is really conceptual stuff, so I'll do the best I can in the following section.

To get 1). Your class A address follows this pattern 1-126. x. y. z. The first octet can be any value from 1 to 126, which means you can only have a total of 126 networks in the entire Internet. This one is easy.

To get 1A). The number of hosts per network in class A. Remember permutations and combinations in high school? Luckily, one of us does! In a class A address, the 2nd, 3rd and 4th octets can be any value from 0 - 255. But remember that there are 256 numbers between 0 and 255. What you do is you take all the possible values in the 2nd octet and multiply it by all the possible values in the 3rd and 4th octets. So ,

256 * 256 * 256 = 16, 777, 216.

But if you look at the table again, the answer is 16,777,214. What you have to do is subtract 2 from 16,777,216 and you get 1A). You subtract 2 from the answer because your hosts cannot have 0 or 255 in their IP addresses. Remember, they're used for broadcasting purposes.

To get 2). The number of networks in class B. Your class B address follows this pattern 128-191.255.x.y. The value of the first octet can be from 128-191, but remember there are 64 numbers between 128 and 191. For example, how many numbers are there between 2 and 8? The answer is 7 and not 6. Try it for yourself. Anytime you have a range of numbers, x - y, to find out how many numbers there are between them use: (y - x) + 1. For your class B address the second octet can be from 0-255. Also, this will be the last time that I will mention this: there are 256 numbers between 0 and 255. So to get 2) you

do this:

64 * 256 = 16,384.

Multiply all the possible values in the 1st octet by all the possible values in the second octet.

To get 2A). The number of hosts in class B. Again, your class B address follows this pattern 128-191.255.x.y. The x and the y can be any value from 0 - 255. So,

256 * 256 = 655,536.

You have to subtract 2 from the answer because 0 and 255 are used for broadcasting. If you subtract 2, you get the same answer as 2A) in the table above. Again, this has to do with combinations. Take all the possible values you can have in the 3rd octet and multiply it by all the possible values in the 4th octet.

To get 3). The number of networks in class C. Remember that the first 3 octets in a class C address identifies the network ID (network address). However, the first octet in a class C can only be from 192 - 223. All the possible values in the first octet of a class A address are: (223 - 192)+ 1 = 32. Now multiply all the possible values in the 1st, 2nd and 3rd octets

32 * 256 * 256 = 2, 097, 152,

which is exactly the same as 3) in the table above.

To get 3A). The number of hosts in class C. In a class C address ONLY the 4th octet identifies your hosts. The values in the 4th octet can be from 0 - 255. There can be 256 possible values but you have to subtract 2 from the answer; and you get 254.

Let’s say that you’ve typed in www.encognitive.com to get to this fabulous website. When you do this you are using a domain name, which is used to mask the IP address so you can remember the URL better. Beneath every domain name is an IP address. Also, beneath every IP address is a BINARY representation of the IP address itself. This binary code is used by the computer and the binary code is the only code that the computer understands. For example, if they mean the same thing, which is easier for *you* to remember?

A) www.encognitive.com

B) 69.164.208.4

C) 0100 0101.1010 0100.1101 0000.100 0100

Of course the answer is A, unless you're the Rain Man. Anytime you want to go to any website you can type in its domain name or you can type in its IP address at the URL locator of your browser. However, you should note that typing in the IP address will not always work because of the use of DHCP (Dynamic Host Configuration Protocol) servers in private networks. I won't go into any details about DHCP servers here. Just remember that there is an IP address beneath every domain name. In the question above, it doesn't matter to a computer what the answer is. It can remember all three just the same.

Remember that a computer is just a bunch of electronic switches, either the switch is on or off. The number 1 denotes an ON switch and a 0 denotes an OFF switch. Also remember that you can also represent computer language by using the base 2 number system raised to the power n. Okay, enough. Let's get hardcore about the subnetting table.

Question 1. Without using a calculator convert 1111 1110 to its decimal value.

These type of questions are really easy. Here is all you have to do:

128	64	32	16		8	4	2	1
1	1	1	1		1	1	1	0

Wherever you see the binary value of 1's, take the decimal value above them and add them all up. In this case:

128 + 64 + 32 + 16 + 8 + 4 + 2 = 254. The decimal value of 1111 1110 is 254.

Question 2. Without using a calculator convert 1100 1011 to its decimal value.

Again, wherever you see a 1 in the binary value, use the decimal value above it and add all

the values up.

128	64	32	16		8	4	2	1
1	1	0	0		1	0	1	1

In this case: 128 + 64 + 8 + 2 + 1 = 203. The decimal value of 1100 1011 is 203.

Question 3. Without using a calculator convert 1 1100 to its decimal value.

For this question, you have to be careful. There are 8 bits in an octet so what you have to do is add some leading zeroes. So 1 1100 becomes 0001 1100. Then use the table:

128	64	32	16		8	4	2	1
0	0	0	1		1	1	0	0

16 + 8 + 4 = 28. The decimal value of 1 1110 is 28.

Just remember to add leading zeroes to make the byte 8 bits before you apply the conversion. I hope by now you can see the pattern of 128, 64, 32…You see, there is a direct relationship between decimal numbers and the base 2 number system.

Now, we'll construct the subnet table. Remember the letters and numbers in red are used to illustrate the process.

			Hosts	Per

Binary value of Subnet Mask	Decimal Value of Subnet Mask	# of Subnets 2^n-2	Class A	Class
1111 1111 (n=8)	255	1) 254	1A) 65, 534	1B) 25
1111 1110 (n=7)	254	126	131, 070	510
1111 1100 (n=6)	252	62	262, 142	1, 022
1111 1000 (n=5)	248	30	524, 286	2, 046
1111 0000 (n=4)	240	14	1, 048, 574	4, 094
1110 0000 (n=3)	224	6) 6	6A) 2, 097, 150	6B) 8,
1100 0000 (n=2)	192	2	4, 194, 302	16, 38

To get 1). If you want to divide your network into 254 subnets, then you would use the decimal value of 255 somewhere in your subnet mask. We'll use class A in this example. If you want to divide your class A address into 254 subnets, then you would use the subnet mask of 255.255.0.0. If you express 255.255.0.0 in binary, it would look like this.

255. 1111 1111. 0000 000. 0000 0000

I didn't convert the 255 because the first octet is fixed in a class A address so it won't

figure into the calculation. To get the number of subnets convert the subnet mask to its binary notation, then count up all the bits with 1s and apply this formula: 2^n - 2. Where n represents all the bits with the value of 1s. In this case there are 8 1s, so 2^8 - 2= 254. You have to subtract 2 from the equation because your subnet IP addresses cannot include 0 or 255 in them.

To get 1A). The number of hosts allowed per subnet if you have 254 subnets in your class A address. If you have a class A address and you want to divide your network into 254 subnets then you would use the subnet mask of 255.255.0.0. Remember in a class A address the first octet is fixed. Again, the binary equivalent of 255.254.0.0 is:

255. 1111 1111. 0000 000. 0000 0000

To get the number of hosts per subnet, first convert the subnet into its binary equivalent, then apply this formula: 2^z -2. Where z represents the number of bits set to zero in your octets. In this case there are 16 zeroes in the subnet mask of 255.255.0.0. So applying the formula: 2^{16} - 2 = 65, 534, which is exactly the same as 1A). Again, you subtract 2 from the equation because the IP address of your hosts cannot include 0 or 255.

To get 1B). If you want to divide your class B network into 254 subnets, then you would use the subnet mask of 255.255.255.0. Remember that in a class B address the 1st and 2nd octets are fixed. The binary value of 255.255.255.0 is:

255.255. 1111 1111. 0000 0000

I didn't convert the 1st or 2nd octets into their binary equivalents because in a class B address the 1st and 2nd octets are fixed, even for their subnet masks. To get the number of subnets use: 2^n - 2. Where n is the number of bits with the value of 1's, in this case there are 8 of them, so 2^8 - 2 = 254 subnets. To get the number of hosts use: 2^z - 2, where z represents the the bits with 0s. In this case there are also 8 of them. So 2^8 - 2 = 254, which is the same as 1B).

To get 1C). The number of hosts per subnet if your network is divided into 254 subnets. If you want your class C network to have 254 subnets then your subnet mask would be 255.255.255.255, which would look something like:

255.255.255. 1111 1111.

I didn't convert the 1st, 2nd or 3rd octets because they are fixed in a class C network, even for their subnet masks. To get the number of hosts, apply 2^z - 2. Where z represents the

bits set to 0s. In this case there are no bits set to 0, so the equation will not work. You would end up with -1 hosts per subnet. What this means is that if you divide your class C network into 254 subnets, you can't have any hosts. In a production environment, if you have a class C network, you would probably never divide your network into more than 6 subnets. Look at the table to see how the number of hosts per subnet would be affected if you were to divide your Class C address into more than 6 subnets.

By now you should see a general pattern developing. I'll do a few more examples.

To get 6). If you want to divide your network into 6 subnets you would use the decimal value of 224 somewhere in your subnet mask. I'll use class A in this example again. If you want to divide your class A address into 6 subnets, you would use a subnet mask of 255.224.0.0. In binary form it would look like this:

255. 1110 0000. 0000 0000. 0000 0000

Again, I didn't convert the 1st octet because it is fixed in a class A address. To get the number of subnets use: 2^n - 2. Where n represents the number of bits set to 1, in this case there are 3 of them; so 2^3 - 2 = 6 subnets.

To get 6A). If you want to divide your class A address into 6 subnets how many hosts per subnet can you have? First, if you want to have 6 subnets in your class A address you would use a subnet mask of 255.224.0.0, which in binary form looks like:

255. 1110 0000. 0000 0000. 0000 0000

To get the number of hosts per subnet use 2^z - 2. Where z represents the number of bits set to 0 in the octets. In this case there are 21 of them. So 2^{21} - 2 = 2, 097, 150; which is exactly the same as 6A).

255.255. 1110 0000. 0000 0000

Again, I didn't convert the 1st and 2nd octets because they are fixed in a class B address, even for the subnet mask. To get the number of hosts per subnet use: 2^z - 2. Where z represents the 0s in your octets. In this case there are 13 of them. So 2^{13} - 2 = 8, 190 hosts per subnet, which is exactly the same as 6B).

To get 6C). If you want to divide your class C network into 6 subnets, then you would use the subnet mask of 255.255.255.224, which is:

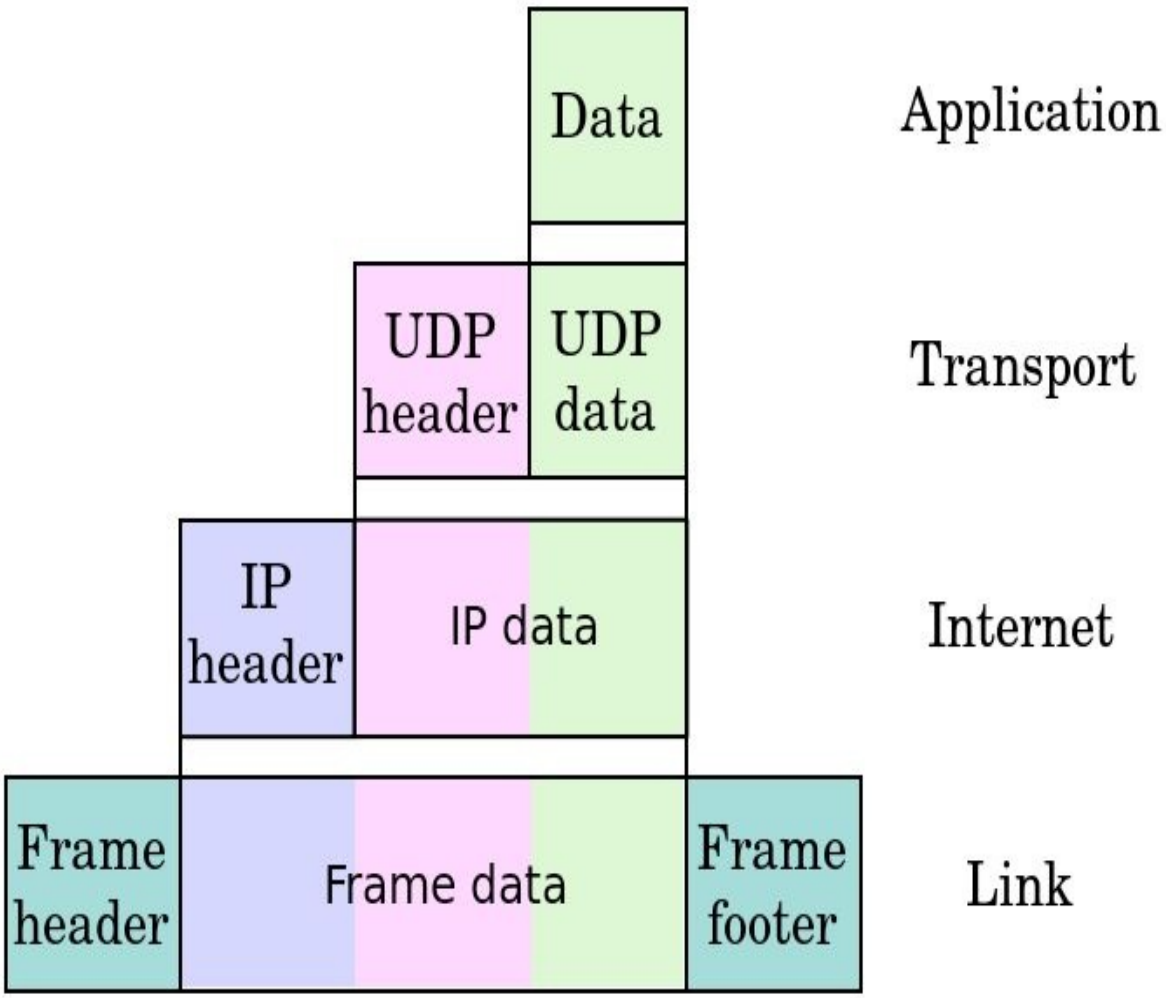
255.255.255. 1110 0000

Again, I didn't convert the 1st, 2nd and 3rd octets because they are fixed and do not figure into the calculations. To get the number of hosts per subnet use: $2^z - 2$. Where z is the number of 0s in your octets. In this case there are 5 of them. Using the formula: $2^5 - 2 = 30$ hosts per subnet, which is the same as 6C).

I am going to stop here. But by now you should be able to construct the IP address table and the subnet table by just remembering these two things:

1) The range of the first octets in each network class.

2) The network's subnet masks.



Question 1. Your IP address is 140.100. x. y and your subnet mask is 255.255.255.224. How many subnets and hosts can you have on your internetwork?

Answer: In this question, memorizing the subnet table will NOT help you. This is an example of one of the pitfalls of trying to memorize the tables. Back to the question: First, you know that the network address belongs in class B because the 1st octet (140) falls between 128 and 191. In a class B address the 1st and 2nd octets are fixed, even for the subnet mask. Now convert the subnet mask into its binary equivalent:

255.255. 1111 1111. 1110 0000

To get the number of subnets use: 2^n - 2. Where n represents the number of bits set to 1s in your octets. In this case there are 11 of them. Apply the formula: 2^{11} - 2 = 2, 046. This means that if you have a class B address with a subnet mask of 255.255.255.224, you can have 2, 046 subnets on your internetwork.

To get the number of hosts per subnet use: 2^z - 2. Where z represents the bits set to 0s in your octets. In this case, there are 5 of them. Apply the formula: 2^5 - 2 = 30. This means that you can have 2,046 subnets with 30 hosts per subnet if your network address is in class B with the subnet mask of 255.255.255.224. This is just an example. In a production environment, if you work for a company that has a class B address and you divide your network into 2,046 subnets, it's likely your IT manager will fire you the next day. Or ask what you've been smoking for lunch.

Question 2: Your subnet mask is 255.255.255.248. How many subnets and hosts can you have on your internetwork? Answer: You cannot answer the question with the information given. There are 3 possible answers:

If the network address belongs to class A, then:

255. 1111 1111. 1111 1111. 1111 1000

Number of subnets: 2^{21}- 2 = 2,097,150

Number of hosts per subnet: 2^3 - 2 = 6

If the network address belongs to class B, then:

255.255. 1111 1111. 1111 1000

Number of subnets: $2^{13} - 2 = 8{,}190$

Number of hosts per subnet: $2^3 - 2 = 6$.

If the network address belongs to class C, then:

255.255.255. 1111 1000

Number of subnets: $2^5 - 2 = 30$
Number of hosts per subnet = $2^3 - 2 = 6$.

In the question above, if you work for a company that has a class A address and you divide your network into 2,097,150 subnets, then your IT manager will fire you the next day. Or smoke with you with what you've been smoking on lunch break.

Remember these questions from Part 2?

Question 1: Your IP address is 165.247.x.y and your subnet mask is 255.255.224.0. What is the valid range of IP addresses on your subnet?

Question 2: Your IP address is 165.247.200.100 and your subnet mask is 255.255.224.0. What is the valid range of IP addresses on your subnet?

Question 3: Your network belongs in class B and your subnet mask is 255.255.240. What decimal values can you have for the 3rd octet of your IP addresses?

The above three questions can be answered using the previous examples.

All the best!

Author’s Note And Copyright

Author’s Note

This paper was originally written in circa 1998, Vancouver, B.C., Canada. The intent was to help Microsoft Certified Professionals (MCPs) and Cisco Certified Professionals pass their TCP/IP certification exams.

Around 2003, the website, www.certscape.com, was closed. Fortunately, through www.archive.org, another website managed to archive this paper.

As of 2015, IPv6 (Internet Protocol version 6) is the new version. IPv5 was skipped. Under IPv6, manual subnet calculations are no longer required, as they are automatically assigned.

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December 21, 2015

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Hardcoremcse.com

Hardcoremcse.com (aka www.certscape.com; mcse=Microsoft Certified Systems Engineer) was a tutorial website to help those who wanted to get Microsoft and Cisco certified. The website was founded by Trung Nguyen, a former Microsoft Certified Professional, and Asfaw Debela. Both resided in Vancouver, B.C., Canada in the late 1990s.

At one point hardcoremcse.com's clients included professionals from IBM, Intel, Lockheed-Martin, Dow Chemicals, Bell Atlantic, Digital Equipment Corporation, Compaq, The Department of Defense (OSD), Hewlett-Packard, Andersen Consulting, Turner Broadcasting Corporation, Siemens Nixdorf, General Electric, Boeing, and some of the largest training and software companies on the Internet.

The website became defunct as Linux began taking over the web server space and due to disagreements among the co-founders.

Using www.archive.org, the contents of www.certscape.com and www.hardcoremcse.com should still be available.

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“Hi Everyone, I took my TCP/IP today with score of 948/1000, your exam preparation is excellent and good value for money. What I like about your test is the layout, dividing test into different topics, that way it is easy to spot your weak areas. I would recommend anyone out there to check your Test Prep before taking any
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"Thanks! It is good that you break them in study sections, this way you can do them as you're studying. With Tr*nsc*nd*r, you cannot do this. I am very impressed. I'll be ordering more exams from you as they become available…I am using your NT Server Preparation Exam and love it. Your explanations are excellent - much easier to understand than their Tr*nsc*nd*r counterparts. As well, the way you categorize your questions allows the student to use your tool as they learn the material—chapter-by-chapter, as opposed to waiting until the very end. Thank you for your great products…I passed the exam with a score in the mid 900s… passed Workstation 4.0 exam with 901… your prep exam proved invaluable… passed SITE with 941! I am bouncing off the walls…you have a great product… Your format and explanations RULE! ..Passed TCP/IP in the mid-nineties! Glad I had your tool." —Robert Vettor, U.S.A.

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"I'm going for the full MCSE certification and if I were in America I would definitely be paying you to my tutors. Your site is a treasure trove of useful information, good advice and instruction. Should I pass Server and Workstation at the end of this week, I certainly owe a lot to your efforts in producing such an abundant resource…I only wish there were groups / companies of similar dedication available here in the UK I could access directly.

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"…As for TCP/IP, I made 965 which means I missed 2 out of 58. I was positive that two of the questions had no correct answers… As for your software, it is the "bomb". I don't know if you know that term [means] where you live, but my 15 year old daughter uses it to refer to something that is excellent. I was totally prepared and did not see anything that Hardcore did not cover in detail. I have gone through two modules for the IIS and it appears to be the same quality. Keep up the good work!" —Jim LeFell, U.S.A.

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"Just wanted to say this is the most awesome web page ever created." —Kathy, Canada.

"You've got a great web-site that has been a lot of help to me… thank- you for your superior products." —Nard Case, U.S.A.

"I'd like to start off by saying thanks for taking the time to put together the Hard Core MCSE web site. A few months ago I was looking in to what it would take to get certified, spent numerous hours reading and re-reading the information Microsoft provides on its' web site and still was not sure where to begin. Then, I was fortunate enough to stumble across your site, which promptly answered more than the basic questions I had…" — Richard Ellis.

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"…(all pass in FIRST time): NT WORKSTATION : 801, NT SERVER : 891, NT SERVER ENTERPRISE : 803. Basically, excellent jobs on the study guide reviews… For the NT SERVER prep exam, it really help me understand the materials because details explanation is give for each quest. You guys are too GENEROUS to make it free for download the whole full version. For the SITE exam, the 6 part of the domain management's quest have have just covers every nuts and bolts that need to understand before going to [the] exam… the prep exam really helps." —Roger, Hong Kong.

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plan on purchasing other practice exams when the time comes. I have purchased the Tr*nsc*nd*r Server 4 tests and personally believe yours are more well done and the information more, should I say, hardcore…keep up the good work." —James Sheehan.

Thank you very much friends!!! I am really happy about the service you are providing to the whole world to improve IT Skills. Keep up your great work and wish you all the best. If there is anything you need to be done in New Zealand, please do let me know and I would be glad to help you." —Srini, New Zealand.

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"Your site has been extremely helpful in my journeying into a new world called MCSE. I originally thought, I wouldn't be able to start this program; because of the expense, but I now know I can do this… I've decided I will will take one course at a time and work things from there. I was so confused with what courses I should take; but thanks to your site, that is one of the first thing you clarified. I will surely be back to purchase some of your tests. You certainly have earned a friend. Many thanks! —Regina D., U.S.A.

"Kudos: I love the website. You guys are right on. Thank-you!" —RFK.

"I am currently a Systems Analalyst for the worlds largest Aerospace company based in Seattle Washington (guess who) [Let us guess: AirBus? ;)], and I have always been looking towards the Systems Administration side of things… As for the content of your programs, I was amazed at how closely your questions seemed to mirror the complexity and nature of the questions in the actual Microsoft exams. I took the NT 4.0 server enterprise exam a few months ago and failed (I used Tr*nsc*nd*r to study for that one)… The answers with your exams explaining how to use "mapping" to decipher the true nature of the question was a big plus, and the in depth explanations of why answers are right or wrong was extremely valuable information! The cost of your programs at the time I ordered them ($**US) was what really amazed me. I've seen just about everyone else's programs out there, and for the price and the content, NOBODY can even come close to what you offer!… Thank God for the Internet so I could find you, and Thank You for a great program! — Andrew Toolan, Boeing Corporation.

"Thanks for your web site. You helped me pass TCP/IP and other MS Exams. Just wanted to say thanks, big time!! Thank you for your assistance in this matter." —John Devereaux, Compaq Computer Corporation.