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المرحلة الرابعة

صباحي + مسائي

(شبكات واتصالات - محاضرات النظري)

محاضرة رقم 7

Data communication and Networks

Lecture 7: IP addressing

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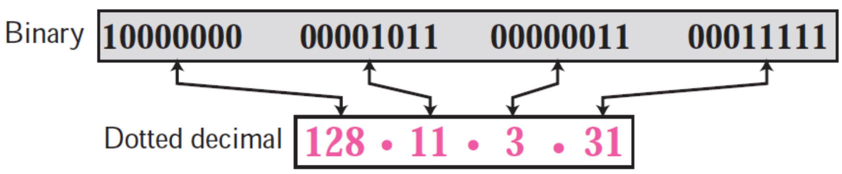

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صفحة فارغة

7. IPv4 address

The identifier used in the IP layer of the TCP/IP protocol suite to identify each device connected to the Internet is called the **Internet address** or **IP address**. **An IPv4 address** is a 32-bit address that *uniquely and universally* defines the connection of a host or a router to the Internet.

Two devices on the Internet can **never have** the *same address* at the same time. However, if a device has two connections to the Internet, via two networks, **it has two IPv4 addresses**.

7.1 Address Space

An address space is the total number of addresses used by the protocol. If a protocol uses b bits to define an address, the address space is 2^b because each bit can have two different values (0 or 1). IPv4 uses 32-bit addresses, which means that the address space is 2^{32} or 4,294,967,296 (more than four billion). Theoretically, if there were no restrictions, more than 4 billion devices could be connected to the Internet.

7.2 Notation

There are three common notations to show an IPv4 address: binary notation (base 2), dotted-decimal notation (base 256), and hexadecimal notation (base 16).

Binary Notation: Base 2

In binary notation, an IPv4 address is displayed as 32 bits (in four octets). Each octet (8 bits) is often referred to as a byte. The following is an example of an IPv4 address in binary notation:

```
01110101 10010101 00011101 11101010
```

First Octet (8 bits)

Dotted-Decimal Notation: Base 256

To make the IPv4 address more compact and easier to read, an IPv4 address is usually written in decimal form with a decimal point (dot) separating the bytes.

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Note that because each byte (octet) is only 8 bits, each number in the dotted-decimal notation is between 0 and 255 (see Figure 7.1).

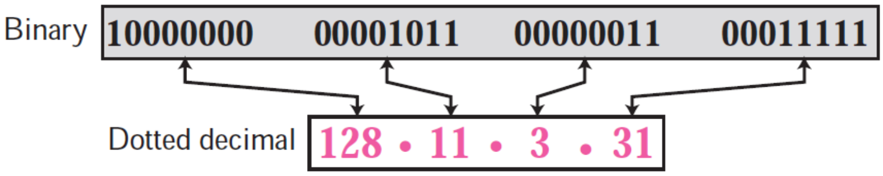

Figure 7.1 Dotted-decimal notation

Example 1
Change the following IPv4 addresses from binary notation to dotted-decimal notation.

a. 10000001 00001011 00001011 11101111

b. 11000001 10000011 00011011 11111111

<u>Solution</u>
We replace each group of 8 bits with its equivalent decimal number and add dots for separation:

a. 129.11.11.239

b. 193.131.27.255

Example 2
Change the following IPv4 addresses from dotted-decimal notation to binary notation.

a. 111.56.45.78

b. 221.34.7.82

<u>Solution</u>
We replace each decimal number with its binary equivalent:

a. 01101111 00111000 00101101 01001110

b. 11011101 00100010 00000111 01010010

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Example 3

Find the error, if any, in the following IPv4 addresses:

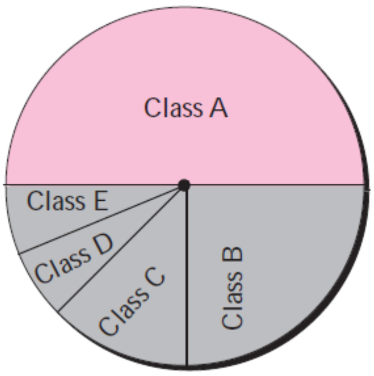
a. 111.56.045.78
b. 221.34.7.8.20
c. 75.45.301.14
d. 11100010.23.14.67

Solution

a. There should be no leading zeroes in dotted-decimal notation (045).
b. We may not have more than 4 bytes in an IPv4 address.
c. Each byte should be less than or equal to 255; 301 is outside this range.
d. A mixture of binary notation and dotted-decimal notation is not allowed.

7.3 Classful addressing

In classful addressing, the IP address space is divided into five classes: A, B, C, D, and E. Each class occupies some part of the whole address space. Figure 7.2 shows the class occupation of the address space.



Class A: 2^{31} = 2,147,483,648 addresses, 50%

Class B: 2^{30} = 1,073,741,824 addresses, 25%

Class C: 2^{29} = 536,870,912 addresses, 12.5%

Class D: 2^{28} = 268,435,456 addresses, 6.25%

Class E: 2^{28} = 268,435,456 addresses, 6.25%

Figure 7.2 Occupation of the address space

7.3.1 Recognizing Classes

We can find the class of an address when the address is given either in binary or dotted decimal notation. In the binary notation, the first few bits can immediately tell us the class of the address; in the dotted-decimal notation, the value of the first byte can give the class of an address (Figure 7.3).

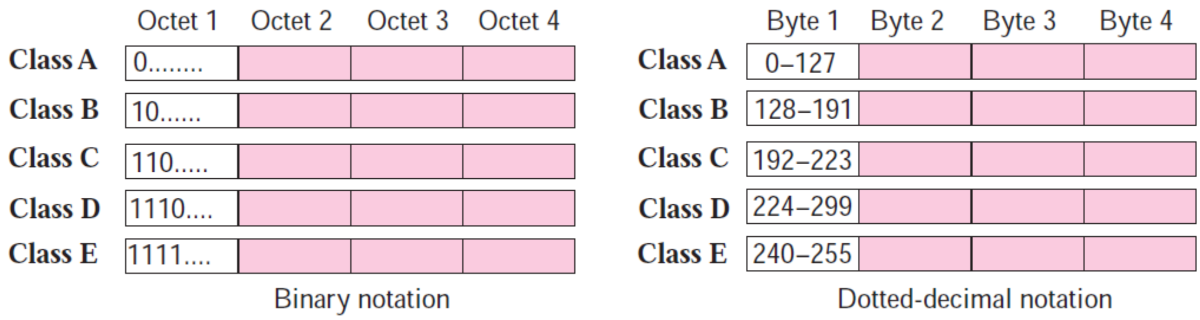


Figure 7.3 Finding the class of an address

Example 5

Find the class of each address:
a. 00000001 00001011 00001011 11101111
b. 11000001 10000011 00011011 11111111
c. 10100111 11011011 10001011 01101111
d. 11110011 10011011 11111011 00001111

Solution
a. The first bit is 0. This is a class A address.
b. The first 2 bits are 1; the third bit is 0. This is a class C address.
c. The first bit is 1; the second bit is 0. This is a class B address.
d. The first 4 bits are 1s. This is a class E address.

Example 6

Find the class of each address:
a. 227.12.14.87
b. 193.14.56.22
c. 14.23.120.8
d. 252.5.15.111

Solution
a. The first byte is 227 (between 224 and 239); the class is D.
b. The first byte is 193 (between 192 and 223); the class is C.
c. The first byte is 14 (between 0 and 127); the class is A.
d. The first byte is 252 (between 240 and 255); the class is E.

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7.3.2 NetId and HostId

In classful addressing, an IP address in classes A, B, and C is divided into NetId and HostId. Figure 7.4 shows the NetId and HostId bytes. Note that classes D and E are not divided into NetId and HostId.

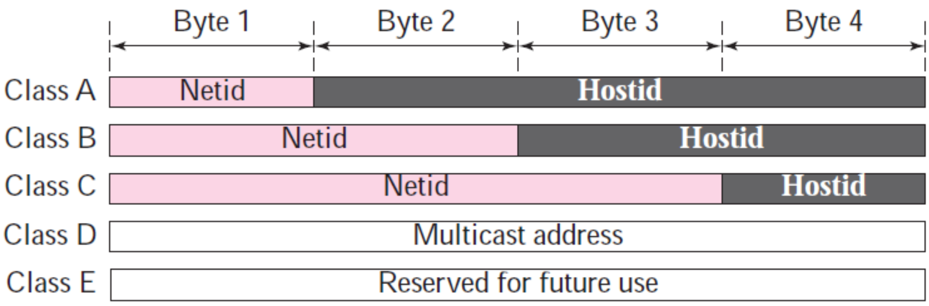

Figure 7.4 NetId and HostId

NetId / HostId	NetId / HostId	NetId / HostId
10.10.10.100	**150.100.70.150**	**192.168.1.100**
- Class A -	- Class B -	- Class C -

Class D
There is just one block of class D addresses. It is designed for **multicasting**. Each address in this class is used to define **one group of hosts** on the Internet. When a group is assigned an address in this class, every host that is a member of this group will have a multicast address in addition to its normal (unicast) address.

Class E
There is just one block of class E addresses. It was designed for use as reserved addresses for **future purposes**.

7.3.3 Extracting Information in a Block

The **block size** shows the number of IP addresses contained in a specific range. Given any address in the block, we normally like to know three pieces of information about the block: the number of addresses, the first address, and the last address. After the class of the block is found, **we know the value of n** (the length of NetId in bits). We can now find these three pieces of information as shown in the following:

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1. The number of addresses in the block, N, can be found using $N = 2^{32-n}$.
2. To find the first address, we keep the n leftmost bits and set the (32− n) rightmost bits all to 0s.
3. To find the last address, we keep the n leftmost bits and set the (32− n) rightmost bits all to 1s.

Example 7

An address in a block is given as 73.22.17.25. Find the number of addresses in the block, the first address, and the last address.

Solution

Since 73 is between 0 and 127, the class of the address is A. The value of n for class A is 8. Figure 7.8 shows a possible configuration of the network that uses this block. Note that we show the value of n in the network address after a slash.

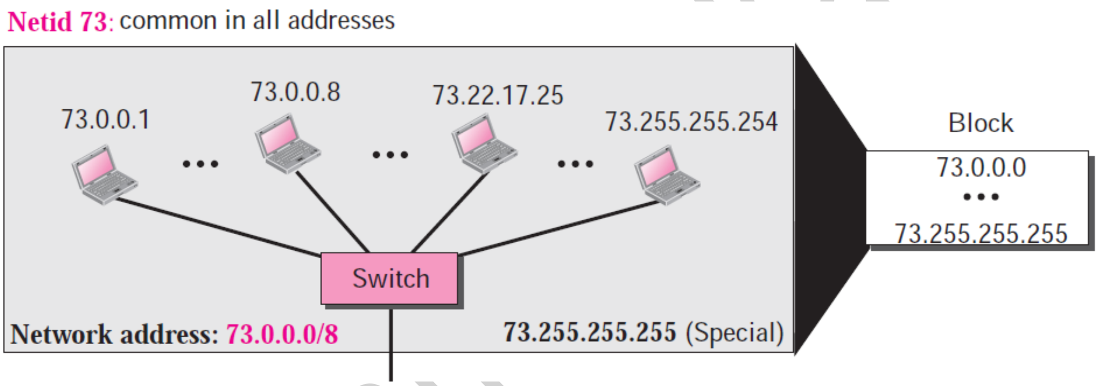

Figure 7.8 Solution to Example 7

1. The number of addresses in this block is $N = 2^{32-n} = 2^{24} = 16{,}777{,}216$.
2. The first address is 73.0.0.0/8 in which 8 is the value of n. The first address is called the **network ID** and is not assigned to any host. It is used to define the network.
3. The last address is 73.255.255.255. The last address (or called the **broadcast ID**) is normally used for a special purpose.

Example 8

An address in a block is given as 180.8.17.9. Find the number of addresses in the block, the first address, and the last address.

Solution

1. The number of addresses in this block is $N = 2^{32-n} = 2^{16} = 65{,}536$.
2. The first address (network address) is 18.8.0.0/16, in which 16 is the value of n.
3. The last address is 18.8.255.255.

Example 9

Figure 7.9 shows a hypothetical part of an internet with three networks.

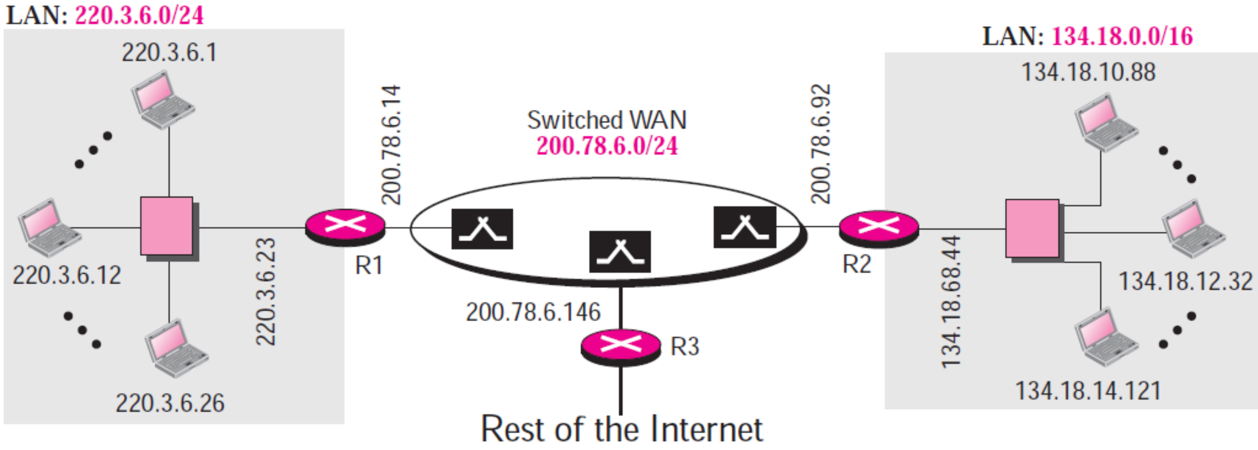

Figure 7.9 Sample internet

We have

1. A LAN with the network address 220.3.6.0 (class C).
2. A LAN with the network address 134.18.0.0 (class B).
3. A switched WAN (class C), that can be connected to many routers. We have shown three. One router connects the WAN to the left LAN, one connects the WAN to the right LAN, and one connects the WAN to the rest of the internet.

7.4 Network Mask

A network mask or a **default mask** in classful addressing is a 32-bit number with **n** leftmost bits all set to 1s and (32 − n) rightmost bits all set to 0s. Since n is different for each class in classful addressing, we have three default masks in classful addressing as shown in Figure 7.10.

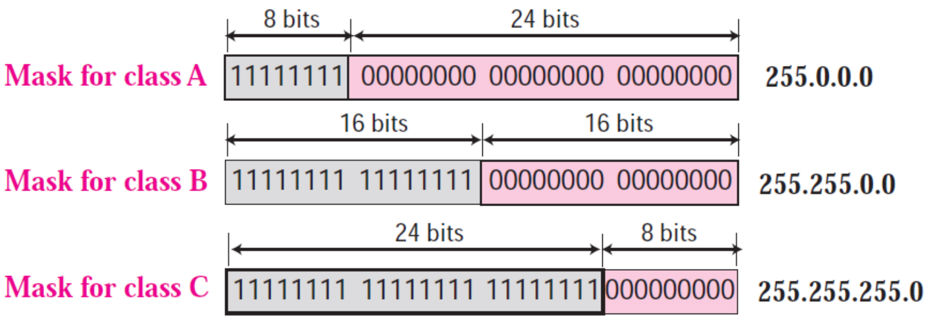

Figure 7.10 Network mask

The routers in the Internet normally use an algorithm to extract the network address from the destination address of a packet. A router uses the AND operation. When the destination address is ANDed with the default mask, the result is the network address.

Example 10

A router receives a packet with the destination address 201.24.67.32. Show how the router finds the network address of the packet.

Solution

Since the class of the address is B, we assume that the router applies the default mask for class B, 255.255.0.0 to find the network address.

Destination address	→	201	.	24	.	67	.	32
Default mask	→	255	.	255	.	0	.	0
Network address	→	201	.	24	.	0	.	0

The destination address is ANDed with the default mask as described in the previous section. The network address (or ID) is 201.24.0.0.

7.5 Special Addresses

Some blocks of addresses are **reserved for special purposes** and cannot be used as normal IP addresses as shown in the following:

1- All-Zeros Address The block **0.0.0.0/32**, which c**ontains only one single address**, is reserved for communication when a host needs to send an IPv4 packet but it does not know its own address. The host sends an IPv4 packet to a bootstrap server (called DHCP server) using this address as the source address and a **limited broadcast address (255.255.255.255)** as the destination address to find its own address (see figure 7.11).

2- All-Ones Address The block **255.255.255.255/32**, which contains one single address, is reserved for **limited broadcast address** in the current network.

3- Loopback Addresses The block 127.0.0.0/8 is used **to test** the software on a machine. When this address is used, **a packet never leaves the machine**; it simply returns to the protocol software.

4- Network ID and broadcast ID As we have already discussed, the network ID is the first address (with the suffix set all to 0s) in a block **defines the network address**. Broadcast ID **is t**he last address in a block or subnet (with the suffix set all to 1s) can be used as a direct broadcast address. **This address is usually used by a router to send a packet to all hosts in a specific network**.

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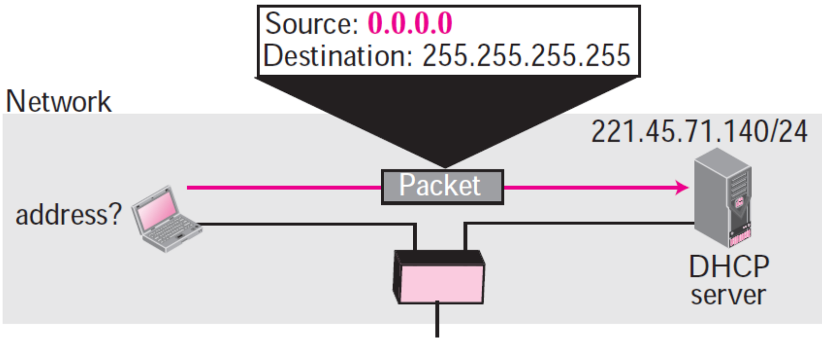

Figure 7.11 Examples of using the all-zeros and all-ones addresses

7.6 Internet Protocol version 6 (IPv6)

IPv6 was developed to deal with the problem of IPv4 address. IPv6 **is intended to replace** IPv4. With the rapid growth of the Internet after the 1990s, far more addresses would be needed to connect devices than the IPv4 address space had available.
By 1998, the IPv6 had been formalized with **128-bit**, theoretically allowing $\mathbf{2^{128}}$, or approximately 3.4×10^{38} addresses, whereas IPv4 uses only **32-bit** addresses and provides approximately $\mathbf{2^{32}}$, or 4.3 billion addresses.

IPv6 addresses are represented **as eight groups of four hexadecimal digits** with the groups being separated by colons, for example

3501:0cb8:0000:0052:0000:7a5e:0b70:9335

But methods are existed to abbreviate this full notation as shown in Figure 7.12.

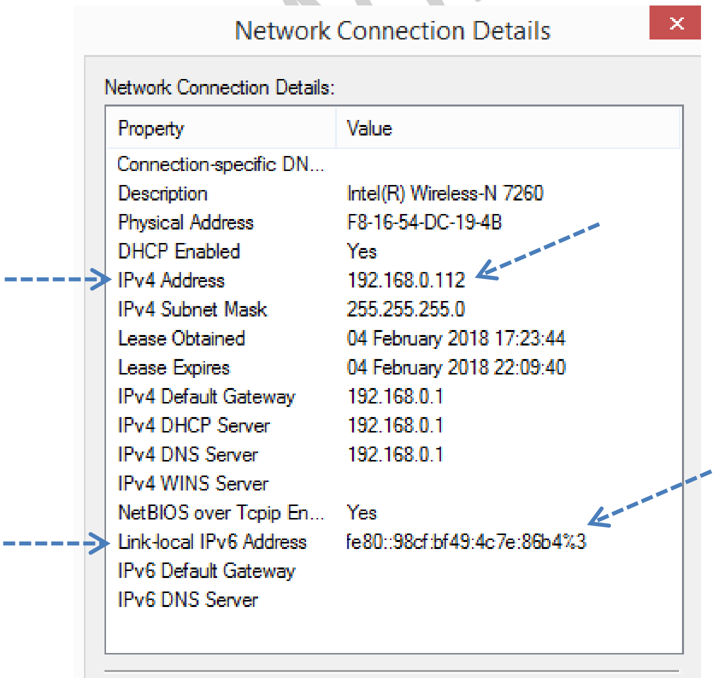

Figure 7.12 Example of IPv6 and IPv4 addresses in a host computer

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7.7 Subnetting

Subnetting is a process of breaking large network in small networks known as **subnets**.

Method of subnetting

In subnetting we need to find the following:

a. Finding the subnet mask

To find the subnet mask, we 1) need to write down the default subnet mask, 2) find the host bits borrowed to create subnets, and 3) put the borrowed bits (1s bits) in the left side instead of the 0s bits.

For example: find the subnet mask of address 188.25.45.48/20

1. The default subnet mask is 255.255.0.0 (/16),
2. The number of borrowed bits from HostId portion is 4 (20 - 16 = 4).
3. The subnet mask in binary would be 11111111. 11111111. **1111**0000. 00000000.
   Then subnet mask in decimal is **255.255.240.0**
   IP address: 188.25.45.48/20 subnet mask: 255.255.240.0

b. Finding the number of subnets

To calculate the number of subnets (sub-networks) provided by given subnet mask we use 2^b, where b = number of bits borrowed from HostId bits to create subnets.

For example: find the number of subnets in 192.168.1.0/27

The number of borrowed bits is 3 because 27-24=3. (24 is the default value of Class C IP).

Then the number of subnets is $2^3 = 8$
This means that we can make 8 sub-networks with the IP rang 192.168.1.0/27.

c. Finding the total hosts

Total hosts are the hosts available per subnet. 2^H = Total hosts. H is the number of host bits. For example in address 192.168.1.0/26 we have 32 - 26 = 6 (where 32 is the total bits in IP address). Total hosts per subnet would be $2^6 = 64$.

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Valid number of hosts

As we mentioned previously, we need to reduce two addresses per block (or subnet), one for network ID and another for broadcast ID. Therefore,

Valid hosts = Total hosts - 2.

In above example we have 64 hosts per subnet, so valid hosts in each subnet would be 64 - 2 = 62.

network ID → 192.168.1.0 broadcast ID → 192.168.1.63 (First subnet)
network ID → 192.168.1.64 broadcast ID → 192.168.1.127 (Second subnet)
network ID → 192.168.1.128 broadcast ID → 192.168.1.191 (Third subnet)
network ID → 192.168.1.192 broadcast ID → 192.168.1.255 (Forth subnet)

In the following we include some examples only from class C (**Class C Subnetting**).

Example 11: assume an organization has purchased the IP range: 192.168.55.0 and they need to use this IP range through four buildings with 55 host computer in each building. Find the 1) suitable subnet mask, 2) number of subnet, 3) number of hosts in each subnet, 4) valid number of hosts, 5) the network ID, broadcast ID and unused IPs of the third subnet.

<u>Solution</u>

Because we need to distribute the IP range through four buildings or networks, then the number of bits that will be borrowed from HostId is 2 as shown in the following:

Default subnet mask

Six bits available for Host address

H

11111111.11111111.11111111.11000000

b

Using 2 HostId bits for NetId bits to extend the default subnet mask

b=2
H=6

Decimal notation for the subnet mask: 255.255.255.192 (/26)

1) Subnet mask: 255.255.255.192 (/26) IP address: 192.168.55.0/26
2) Number of subnet: $2^b = 2^2 = 4$
3) Number of host in each subnet: $2^H = 2^6 = 64$ available hosts
4) Valid number of hosts: 64-2=62
5) Network ID → 192.168.1.128 , broadcast ID → 192.168.1.191 (for third subnet)
   Unused IP addresses: 62-55 = 7

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Example 12: assume that we have the IP address 200.10.73.0/28, find each of following: Find the 1) subnet mask, 2) number of subnets, 3) number of hosts in each subnet, 4) valid number of hosts, 5) the network ID, broadcast ID of the second subnet.

<u>Solution</u>

The **binary notation** for the subnet mask is as shown below:

Default subnet mask

Four bits available for Host address

H

11111111.11111111.11111111.11110000

b

Using 4 HostId bits for NetId bits to extend the default subnet mask

b=4

H=4

Binary notation for the subnet mask: 255.255.255.240 (/28)

1) Subnet mask: 255.255.255.240 (/28)   IP address: 200.10.73.0/28
2) Number of subnets: $2^b = 2^4 = 16$
3) Number of host in each subnet: $2^H = 2^4 = 16$ available hosts
4) Valid number of hosts: 16-2=14
5) Network ID → 192.168.1.16 , broadcast ID → 192.168.1.31 (for second subnet)

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