NETWORK PROTOCOLS & SECURITY
23EC2210 R/A/E

Topic:

IP ADDRESSING: CLASSFUL & CLASSLESS ADDRESSING

Session – 14

AIM OF THE SESSION

To familiarize students with the concept of IP Addressing

INSTRUCTIONAL OBJECTIVES

This Session is designed to:

1. Describe the concepts of Classful addressing.
2. Describe the concepts of Classless addressing.

LEARNING OUTCOMES

At the end of this session, you should be able to:

1. Solve the IP addressing problems related to Classful addressing.
2. Solve the IP addressing problems related to Classless addressing.

AGENDA

- ❖ IP Addresses
- ❖ IPv4 Address Space
- ❖ Notations
- ❖ Classful Addressing
- ❖ Classless Addressing
- ❖ IPv6
- ❖ Addressing Methods

IP ADDRESSES

- *An IP address is a numeric identifier assigned to each machine on an IP network.*
- *An IP address is a software or logical address, and it designates the specific location of a device on the network.*
- *IP addressing was designed to allow hosts on one network to communicate with a host on a different network regardless of the type of LANs the hosts are participating in.*
- *Versions: IPv4 and IPv6*

IPV4 ADDRESSES

An IPv4 address is a 32-bit address that uniquely and universally defines the connection of a device (for example, a computer or a router) to the Internet..

Topics discussed in this section:

1. **Address Space**
2. **Notations**
3. **Classful Addressing**
4. **Classless Addressing**

1. ADDRESS SPACE

- The total number of addresses used by the protocol. If a protocol uses N bits to define an address, the address space is 2^N because each bit can have two different values (0 or 1) and N bits can have 2^N values.
- The address space of IPv4 is 2^{32} or 4,294,967,296.
- The address space of IPv6 is 2^{128} or 40,282,366,920,938,463,463,374,607,431,768,211,456.

2. NOTATIONS

- There are two prevalent notations to show an IPv4 address:
  a. **Dotted-Decimal notation**
  b. **Binary notation**
  c. **Hexadecimal notation**

  2. a. *Dotted-Decimal Notation*

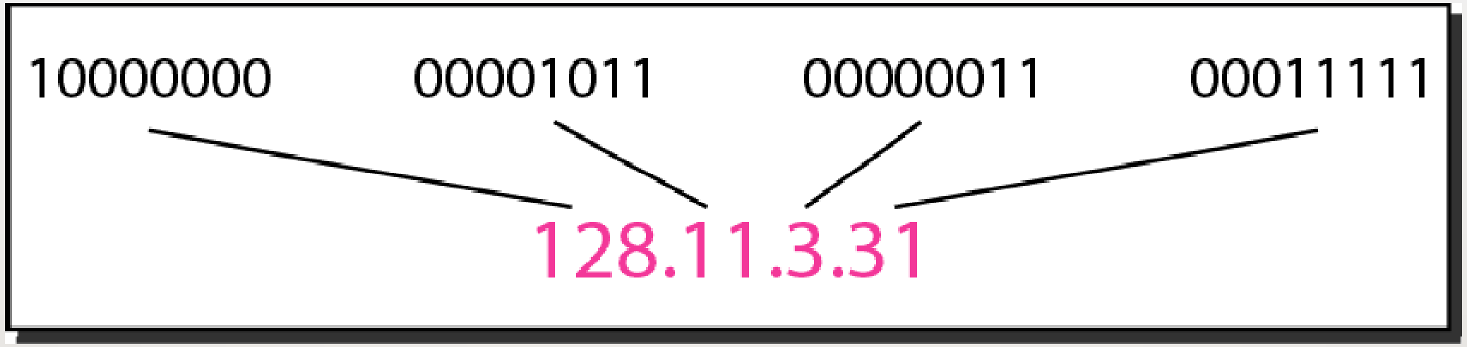
  - To make the IPv4 address more compact and easier to read, Internet addresses are usually written in decimal form with a decimal point (dot) separating the bytes.
  - The following is the dotted-decimal notation of an address: 132.11.3.31

2. NOTATIONS (CONTD…)

2.b. *Binary notation*

- In binary notation, the IPv4 address is displayed as 32 bits.
- Each octet is often referred to as a byte.
- it is common to hear an IPv4 address referred to as a 32-bit address or a 4-byte address.
- The following is an example of an IPv4 address in binary notation

DOTTED-DECIMAL NOTATION AND BINARY NOTATION FOR AN IPV4 ADDRESS



2. NOTATIONS (CONTD…)

2.c. *Hexadecimal notation*

- The IPv4 address is displayed as 8 hexadecimal digits.

Example: 10000001 00001011 00001011 11101111

Hexadecimal notation is: $810B0BEF_{16}$

EXAMPLE

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

a. 10000001 00001011 00001011 11101111

b. 11000001 10000011 00011011 11111111

EXAMPLE

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

a. 10000001 00001011 00001011 11101111
b. 11000001 10000011 00011011 11111111

Solution

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

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

a. 111.56.45.78

b. 221.34.7.82

Solution

We replace each decimal number with its binary equivalent

a. 01101111 00111000 00101101 01001110

b. 11011101 00100010 00000111 01010010

IPV4 ADDRESS RULES

RULES:

1. There must be no leading zero
2. There can be no more than four bytes in IPV4 address
3. Each number must be less than or equal to 255
4. A mixture of binary and decimal notation is not allowed.

EXAMPLE

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 must be no leading zero (045).***
b. ***There can be no more than four numbers.***
c. ***Each number needs to be less than or equal to 255.***
d. ***A mixture of binary notation and dotted-decimal notation is not allowed.***

3. CLASSFUL ADDRESSING

- IPv4 addressing, at its inception, used the concept of classes.
- The address space is divided into five classes: A, B, C, D, and E. Each class occupies some part of the address space
- We can find the class of an address when given the address in binary notation or dotted-decimal notation.
   - i. If the address is given in **binary notation**, the first few bits can immediately tell us the class of the address.
   - ii. If the address is given in **decimal-dotted notation**, the first byte defines the class.

CLASSFUL ADDRESSING CONTD…

	First byte	Second byte	Third byte	Fourth byte
Class A	0			
Class B	10			
Class C	110			
Class D	1110			
Class E	1111			

a. Binary notation

	First byte	Second byte	Third byte	Fourth byte
Class A	0–127			
Class B	128–191			
Class C	192–223			
Class D	224–239			
Class E	240–255			

b. Dotted-decimal notation

FINDING THE CLASSES IN BINARY AND DOTTED-DECIMAL NOTATION

CLASSFUL ADDRESSING CONTD…

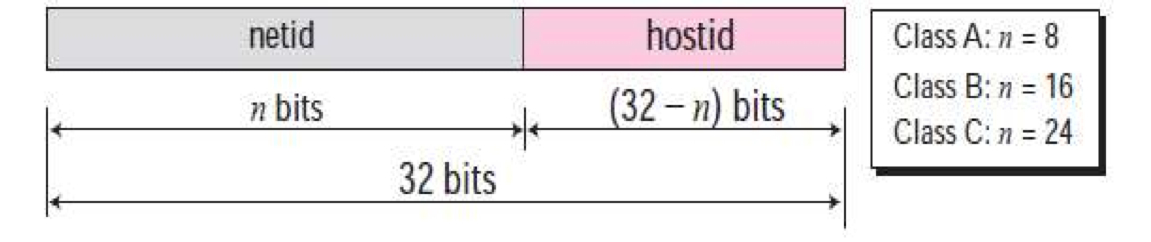
Class	*Number of Blocks*	*Block Size*	*Application*
A	128	16,777,216	Unicast
B	16,384	65,536	Unicast
C	2,097,152	256	Unicast
D	1	268,435,456	Multicast
E	1	268,435,456	Reserved

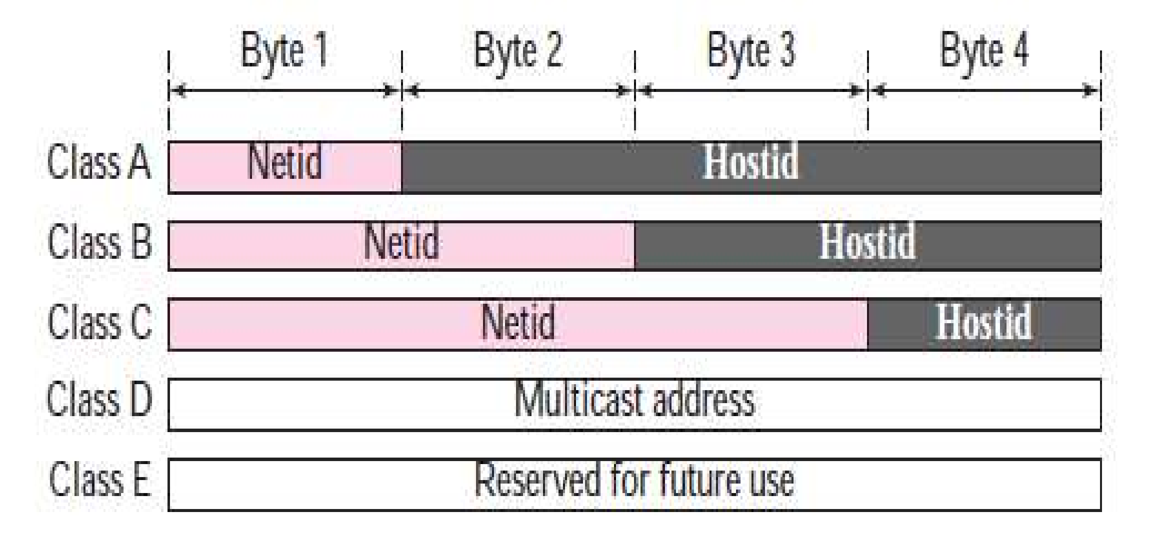
NUMBER OF BLOCKS AND BLOCK SIZE IN CLASSFUL IPV4 ADDRESSING

CLASSFUL ADDRESSING CONTD…

Netid and Hostid

- In classful addressing, an IP address in class A, B, or C is divided into **<u>netid</u>** and **<u>hostid</u>**.
- These parts are of varying lengths, depending on the class of the address.
- Classes D and E are not divided into netid and hosted.
- In *class A, one byte defines the netid and three bytes define the hostid.*
- *In class B, two bytes define the netid and two bytes define the hostid.*
- *In class C, three bytes define the netid and one byte defines the hostid.*





Example 19.4

Find the class of each address.

a. 00000001 00001011 00001011 11101111

b. 11000001 10000011 00011011 11111111

c. 14.23.120.8

d. 252.5.15.111

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 byte is 14; the class is A.

d. The first byte is 252; the class is E.

CLASSFUL ADDRESSING

Problems

1. 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

CLASSFUL ADDRESSING

Problems

2. 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

IPV4 ADDRESS

Problems on Range of Address

1. Find the number of addresses in a range if the first address is 146.102.29.0 and the last address is 146.102.32.255.

Sol: We can subtract the first address from the last address in base 256.

The result is 0.0.3.255 in this base.

To find the number of addresses in the range (in decimal), we convert this number to base 10 and add 1 to the result.

$$\text{Number of addresses} = (0 \times 256^3 + 0 \times 256^2 + 3 \times 256^1 + 255 \times 256^0) + 1 = 1024$$

IPV4 ADDRESS

Problems on Range of Address

2. The first address in a range of addresses is 14.11.45.96. If the number of addresses in the range is 32, what is the last address?

Sol: We convert the number of addresses minus 1 to base 256, which is 0.0.0.31. We then add it to the first address to get the last address. Addition is in base 256.

$$\text{Last address} = (14.11.45.96 + 0.0.0.31)_{256} = 14.11.45.127$$

CLASSFUL ADDRESSING CONTD…

Network Mask

- The routers in the Internet normally use an algorithm to extract the network address from the destination address of a packet. To do this, we need a 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.
- **Network Address = AND(IP, Network Mask)**

Class	*Binary*	*Dotted-Decimal*	*CIDR*
A	11111111 00000000 00000000 00000000	255.0.0.0	/8
B	11111111 11111111 00000000 00000000	255.255.0.0	/16
C	11111111 11111111 11111111 00000000	255.255.255.0	/24

IPV4 ADDRESS : BITWISE OPERATIONS…

2. Bitwise AND Operation

The AND operation compares the two corresponding bits in two inputs and selects the smaller bit from the two.

We can use two short cuts.

1. When at least one of the numbers is 0 or 255, the AND operation selects the smaller byte (or one of them if equal).

2. When none of the two bytes is either 0 or 255, we can write each byte as the sum of eight terms, where each term is a power of 2. We then select the smaller term in each pair (or one of them if equal) and add them to get the result.

IPV4 ADDRESS : BITWISE OPERATIONS…

First number:	00010001	01111001	00001110	00100011
Second number:	11111111	11111111	10001100	00000000
Result	00010001	01111001	00001100	00000000

We can use the same operation using the dotted-decimal representation and the short cut.

First number:	17	.	121	.	14	.	35
Second number:	255	.	255	.	140	.	0
Result:	17	.	121	.	12	.	0

We have applied the first short cut on the first, second, and the fourth byte; we have applied the second short cut on the third byte. We have written 14 and 140 as the sum of terms and selected the smaller term in each pair as shown below.

Powers	2^7		2^6		2^5		2^4		2^3		2^2		2^1		2^0
Byte (14)	0	+	0	+	0	+	0	+	8	+	4	+	2	+	0
Byte (140)	128	+	0	+	0	+	0	+	8	+	4	+	0	+	0
Result (12)	0	+	0	+	0	+	0	+	8	+	4	+	0	+	0

EXAMPLE

- An address in a block is given as 200.11.8.45. Find the number of addresses in the block, the first address, and the last address.
- **Solution:**

Given IP	: 200.11.8.45
Class	: C
Network Mask	: 255.255.255.0
IP	: 200 . 11 . 8 . 45
N/w addr (or) First address	: 200 . 11 . 8 . 0 ← [AND(IP, Network Mask)]
Broadcast addr (or) Last address	: 200 . 11 . 8 . 255
Total no. of addresses in a block	: 2^n = 2^8 = 256
Total no. of Host addresses	: (2^n)-2 = 256 – 2 = 254

4. CLASSLESS ADDRESSING

- To overcome address depletion and give more organizations access to the Internet, classless addressing was designed and implemented.
- Here are no classes, but the addresses are still granted in blocks.

Address Blocks

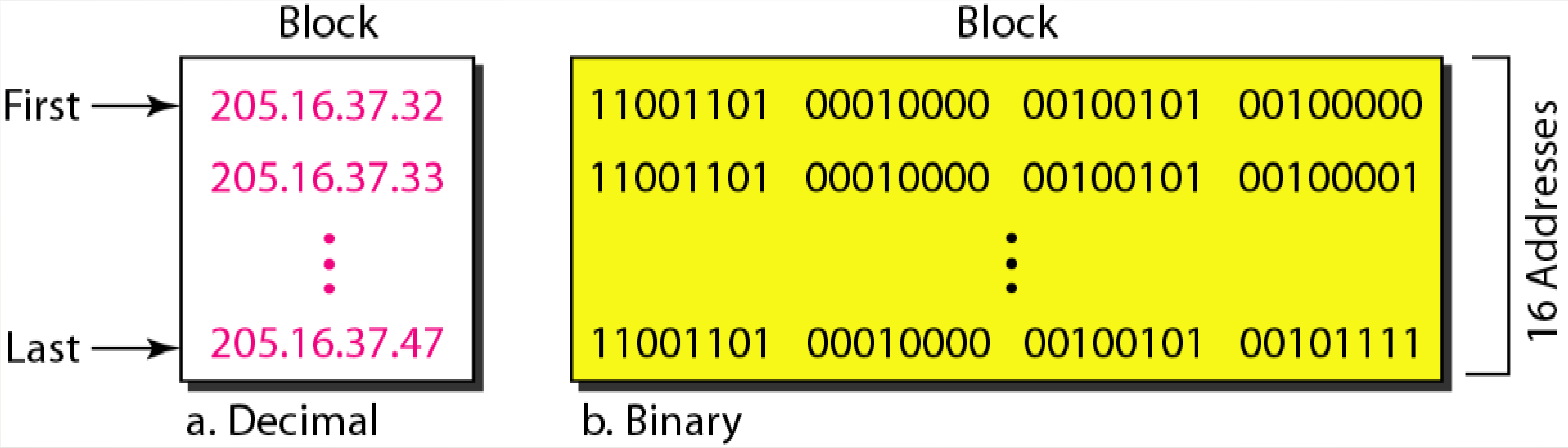
- In classless addressing, when an entity, small or large, needs to be connected to the Internet, it is granted a block (range) of addresses.
- The size of the block (the number of addresses) varies based on the nature and size of the entity.

CLASSLESS ADDRESSING CONTD…

- Restriction: To simplify the handling of addresses, the Internet authorities impose three restrictions on classless address blocks:

  1. The addresses in a block must be contiguous, one after another.
  2. The number of addresses in a block must be a power of 2 (I, 2, 4, 8, ...).
  3. The first address must be evenly divisible by the number of addresses.

CLASSLESS ADDRESSING CONTD…



A BLOCK OF 16 ADDRESSES GRANTED TO A SMALL ORGANIZATION

CLASSLESS ADDRESSING CONTD…

Mask

- In classless addressing the mask for a block can take any value from 0 to 32. It is very convenient to give just the value of *n* preceded by a slash (CIDR notation)

    i. /n [denotes the **prefix length**]

    ii. /(n-32) [denotes the **suffix length**]

In IPv4 addressing, a block of addresses can be defined as

x.y.z.t /n

x.y.z.t → *defines one of the addresses*

/n → *defines the mask.*

CLASSLESS ADDRESSING CONTD…

The first address in the block can be found by setting the rightmost $32 - n$ bits to 0s.

The last address in the block can be found by setting the rightmost $32 - n$ bits to 1s.

The number of addresses in the block can be found by using the formula 2^{32-n}.

EXAMPLE

1. A block of addresses is granted to a small organization. We know that one of the addresses is 205.16.37.39/28. What is the first address in the block?

SOLUTION

A block of addresses is granted to a small organization. We know that one of the addresses is 205.16.37.39/28. What is the first address in the block?

Solution

The binary representation of the given address is

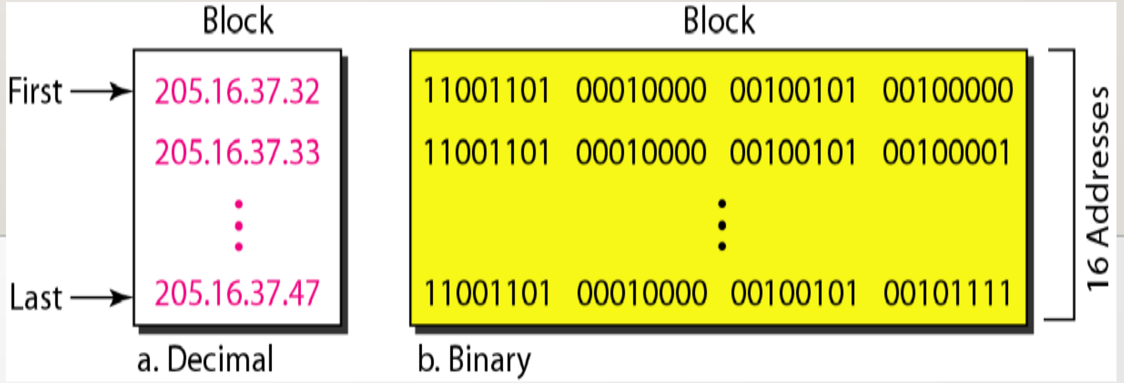
11001101 00010000 00100101 00100111

Method 1: If we set 32−28 rightmost bits to 0, we get the first address.

11001101 00010000 00100101 00100000 or *205.16.37.32*.

Method 2: AND(IP address, Network Mask)

Address:	11001101	00010000	00100101	00100111
Mask:	**11111111**	**11111111**	**11111111**	**11110000**
First address:	11001101	00010000	00100101	00100000



EXAMPLE

2. Find the last address for the block

SOLUTION

Find the last address for the block.

Solution

The binary representation of the given address is

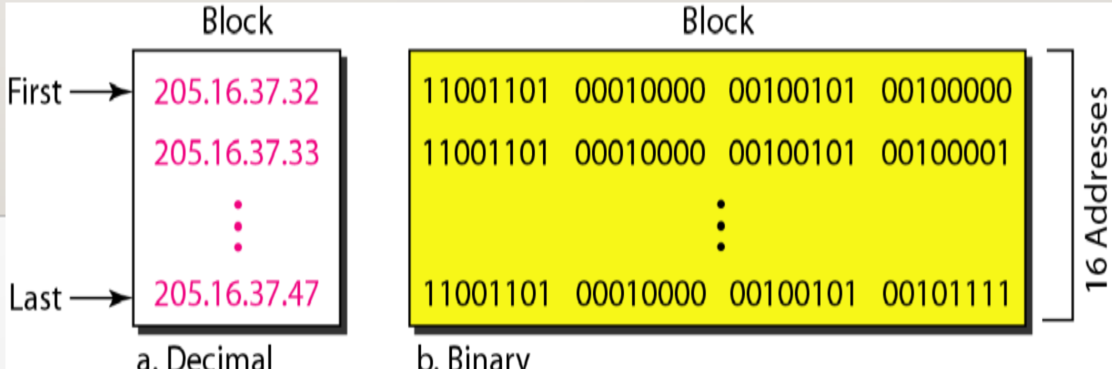
11001101 00010000 00100101 00100111

Method 1: If we set 32 − 28 rightmost bits to 1, we get the last address.

11001101 00010000 00100101 00101111 *or* *205.16.37.47*

Method 2: OR(IP address, Complement of Mask)

Address:	11001101 00010000 00100101 00100111
Mask complement:	00000000 00000000 00000000 00001111
Last address:	11001101 00010000 00100101 00101111



EXAMPLE

3. Find the number of addresses in the given Example.

Solution

The value of n is 28, which means that number of addresses is $\boldsymbol{2^{32-28}}$ **or 16.**

SELF-ASSESSMENT QUESTIONS

1. In a block of addresses, we know IP address of one host is 25.34.12.56/16. What is the first address (network address) and the last address (limited broadcast address) in this block?
2. Find the block if one of the addresses is 190.87.140.202/29
3. In a network the address of one computer is 201.78.24.56 and the address of another computer is 201.78.120. 202. How many addresses are in between?
4. What is the main difference between IPv4 and IPv6?
5. What are the key advantages of IPv6 over IPv4?

REFERENCES FOR FURTHER LEARNING OF THE SESSION

Reference Books:

1. Data Communications and Networking, Behrouz A. Forouzan, 4th Edition, McGraw Hill.
2. Computer Networks, Tanenbaum, 6th Edition, Pearson.

Sites and Web links:

CISCO Academy
NPTEL, Computer Networks and Internet Protocols, Prof. Soumya Kanti Ghosh, Prof. Sandip Chakraborty IIT Kharagpur. (https://nptel.ac.in/courses/106105183)

THANK YOU

Team – **Networks Protocols & Security**