IPv4 and Subnet

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Aim of the session

To understand the fundamental concepts on the allocation and management of IP addresses in computer networks

Learning Outcomes

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

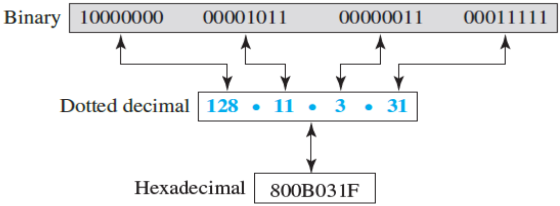
- Describe the structure and format of IPv4 addresses
- Classify IP addresses into appropriate address classes and identify the address ranges for each class

Internet Protocol

- Only two versions have survived: IP Version 4 (IPv4) and IP Version 6 (IPv6).
- IPv4 is almost depleted
- Logical address assigned to each device connected to the network
- An **address Space** is the total number of addresses used by the protocol
- If a protocol uses b bits to define an address $\implies$ the address space is 2^b
- IPv4 uses 32-bit addresses; So address space is $2^{32} = 4,294,967,296$

IPv4 Notation

- Three Notations: Binary (base 2), dotted-decimal notation (base 256), hexadecimal notation (base 16)



Rewrite the following IP addresses using binary notation.

a. 110.11.5.88

b. 12.74.16.18

c. 201.24.44.32

Rewrite the following IP addresses using dotted-decimal notation.

a. 01011110 10110000 01110101 00010101

b. 10001001 10001110 11010000 00110001

c. 01010111 10000100 00110111 00001111

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

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

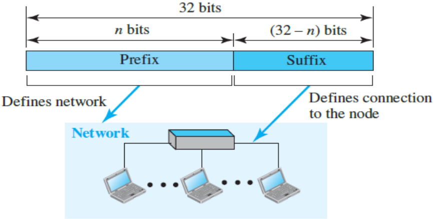
1. There must be no leading zero (045).
2. There can be no more than four numbers.
3. Each number needs to be less than or equal to 255.
4. A mixture of binary notation and dotted-decimal notation is not allowed.

Hierarchy in Addressing

Any communication network works on hierarchy.
Examples

- Postal network: The postal address (mailing address) includes
  - country, state, city, street, house number
    - Name of the mail recipient
- Telephone network
  - Country code, area code, local exchange
    - connection
- IPv4 Address
  - *prefix*: Defines the network
    - *suffix*: Defines the connection of a device to the Internet

Hierarchy in Addressing



- *prefix* length is n bits; *suffix* length is $(32 - n)$ bits
    - n is fixed length: classful addressing
    - n is variable length: classless addressing

Classful addressing

- When the Internet started, an IPv4 address was designed with a fixed-length prefix.
- To accommodate both small and large networks, three fixed-length ($n = 8, 16, 24$) prefixes were designed instead of one
- ★ The whole address space was divided into five classes (classes A, B, C, D, and E)

	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

Class A,B

- **Class A**
  - Network length= 8 bits
  - The first bit is always $(0)_2$
    - We can have only 7 bits as the network identifier
  - There are only $2^7 = 128$ networks in the world that can have a class A address
  - Each network can accommodate $2^{24} = 16,777,216$ nodes
- **Class B**
  - Network length=16 bits
  - The first 2 bits= $(10)_2$
    - We can have only 14 bits as the network identifier
  - There are only $2^{14} = 16,384$ networks in the world that can have a class B address
  - Each network can accommodate $2^{16} = 65,536$ nodes

Class C,D,E

- **Class C**
  - Network length=16 bits
  - The first 3 bits= $(110)_2$
    - We can have only 21 bits as the network identifier.
  - There are $2^{21} = 2,097,152$ networks in the world that can have a class C address.
  - Each network can accommodate $2^8 = 256$ nodes
- **Class D**
  - Class D is not divided into prefix and suffix
  - It is used for multicast addresses
  - The first 4 bits= $(1110)_2$
- **Class E**
  - The first 4 bits= $(1111)_2$
  - Used as reserve

CLASS	LEADING BITS	NET ID BITS	HOST ID BITS	NO. OF NETWORKS	ADDRESSES PER NETWORK	START ADDRESS	END ADDRESS
CLASS A	0	8	24	2^7 (128)	2^{24} (16,777,216)	0.0.0.0	127.255.255.255
CLASS B	10	16	16	2^{14} (16,384)	2^{16} (65,536)	128.0.0.0	191.255.255.255
CLASS C	110	24	8	2^{21} (2,097,152)	2^8 (256)	192.0.0.0	223.255.255.255
CLASS D	1110	NOT DEFINED	NOT DEFINED	NOT DEFINED	NOT DEFINED	224.0.0.0	239.255.255.255
CLASS E	1111	NOT DEFINED	NOT DEFINED	NOT DEFINED	NOT DEFINED	240.0.0.0	255.255.255.255

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

Figure: Number of blocks and block size

Address Depletion

- Internet faced with the problem of the addresses being rapidly used up
- Class A: can be assigned to only 128 organizations in the world
  - Each organization has a single network with 16,777,216 nodes
    - Most of the addresses in this class were wasted (unused).
- Class B addresses are designed for midsize organizations
  - Many of the addresses in this class also remained unused
- Class C: Most companies were not comfortable using a block in this address
  - The number of addresses that can be used in each network (256) was so small

Classless addressing

- The larger address space requires the length of IP addresses to be increased
- The format of the IP packets needs to be changed
- Long-range solution is IPv6
- Short-term solution: class privilege is removed
  - Use variable-length blocks[1] ($n = 1$ *to* 32 instead of $n = 8, 16, 24$)
- How to know the network portion?
  - Use **Slash Notation**
    - 12.24.76.8/8 $\Longrightarrow$ Prefix length=8
    - 23.14.67.92/12 $\Longrightarrow$ Prefix length=12
    - 220.8.24.255/25 $\Longrightarrow$ Prefix length=25

[1] prefix in an address defines the block (network);

Subnet

- Routing protocols must carry the prefixes to routers
  - Prefixes are described by their length: “/16” which is pronounced “slash 16”
  - Use Subnet mask
- It can be ANDed with the IP address to extract only the network portion.

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

Subnetting: Splitting an IP Prefix

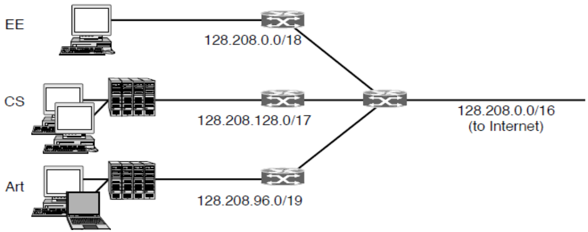


Figure: Prefix and a subnet mask

- Computer Science: 10000000 11010000 1xxxxxxx xxxxxxxx
- Electrical Eng: 10000000 11010000 00xxxxxx xxxxxxxx
- Art: 10000000 11010000 011xxxxx xxxxxxxx

Subnetting

An organization (or an ISP) that is granted a range of addresses may divide the range into several subranges and assign each subrange to a subnetwork (or subnet).

- Given Number of addresses required for a subnet N_{sub}
- The prefix length for each subnetwork $n_{sub} = 32 - log_2 N_{sub}$

Subnet

An organization is granted a block of addresses with the beginning address 14.24.74.0/24. The organization needs to have three subblocks (16,64,128) of addresses to use in its three subnets. Design the subblocks

- Number of addresses in 14.24.74.0/24: $2^{32-24} = 256$
- Block A: 128
  - prefix length=$32 - log_2 128$=25
    - First Add: 14.24.74.0/25; Last Add: 14.24.74.127/25.
- Block B: 64
  - prefix length=$32 - log_2 64$=26
    - First Add: 14.24.74.128/25; Last Add: 14.24.74.191/25.
- Block C: 16
  - prefix length=$32 - log_2 16$=28
    - First Add: 14.24.74.192/25; Last Add: 14.24.74.207/25.
- Unused 14.24.74.208 to 14.24.74.255

Problems

What is the network ID and Host ID of the following IPv4 address

- 56.89.34.25
- 165.25.242.8
- 212.115.65.24
- 227.54.68.26

Problems

What is the network ID and Host ID of the following IPv4 address

- 56.89.34.25:
  - Network id: 56, Host id: 89.34.25 (CLASS A)
- 165.25.242.8
  - Network id: 165.25, Host id: 242.8 (CLASS B)
- 212.115.65.24
  - Network id 212.115.65, Host id: 24 (CLASS C)
- 227.54.68.26
  - In Class D, an IP address is reserved for multicast addresses
  - Multicasting allows a single host to send a single stream of data to thousands of hosts across the Internet at the same time
    - It is often used for audio and video streaming, such as IP-based cable TV networks

Problems

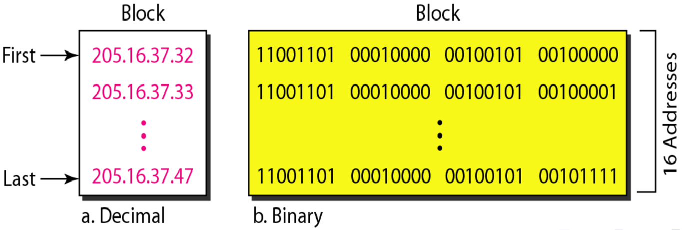
If a class B network on the Internet has a subnet mask of 255.255.240.0, what is the maximum number of hosts per subnet?

- Binary representation: 11111111.11111111.11110000.00000000
- Prefix size=20; Suffix size=12;
- Maximum number of hosts=$2^{12} = 4096$
  - The address with all bits as 1 is used to broadcast a message to every host on a network.
  - The address with all bits as '0' is used to specify a network without specifying a host.
  - Number of hosts $=2^{12} - 2$

Problem

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?

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



KLH IPv4

Given IPv4: 10.231.27.152; Subnet Mask: 255.255.192.0

- What is the starting and ending host id?
- How many maximum host ids are possible?

KLH IPv4

Given IPv4: 10.231.27.152; Subnet Mask: 255.255.192.0

- 255.255.192.0 $\Longrightarrow$ 11111111 11111111 11000000 00000000
- 10.231.27.152 $\Longrightarrow$ 00001010 11101001 00011011 10011000
- AND opern $\Longrightarrow$ 00001010 11101001 00000000 00000000
- Max host ids=2^{14}
- Starting hostid= 00001010 11101001 00000000 00000000
- Ending host id=00001010 11101001 00111111 11111111

Using fixed length subnetting divide the given network 196.220.84.32 into two parts. Give the first host ID, Last host ID, Subnet mask and the number of hosts connected.

- 196.220.84.32 Binary representation
  - 11000100 11011100 01010100 00100000
- Network mask is 255.255.255.0
  - Bin Rep: 11111111 11111111 11111111 00000000
- Starting host: 11000100 11011100 01010100 00000000 $\Longrightarrow$ 196.220.84.0
- Ending host: 11000100 11011100 01010100 11111111 $\Longrightarrow$ 196.220.84.255

- Subnet 1
  - 196.220.84.0 to 196.220.84.127
  - 11000100 11011100 01010100 0XXXXXXX
  - Prefix size n=25
  - Subnet=11111111 11111111 11111111 10000000 $\Longrightarrow$ 255.255.255.128
  - No of host configured=128-2
- Subnet 2
  - 196.220.84.128 to 196.220.84.255
  - 11000100 11011100 01010100 1XXXXXXX
  - Prefix size n=25
  - Subnet=11111111 11111111 11111111 10000000 $\Longrightarrow$ 255.255.255.128
  - No of host configured=128-2

Acknowledge various sources for the images.
Thankyou