Computer networks

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Based on the work of Dr. Mohamed BELAOUED

Chapter 1

Addressing – Network Layer

Network Layer

Responsible for:

- **Addressing** method to identify machines on the Internet;
  - **IPv4** (RFC 760, 1980)
  - **IPv6** (RFC 2460, 1998)
- **Routing** to find a path to any destination on the Internet;
- Interconnection of **heterogeneous networks**, (different hardware, different OS);

Principles of IP addressing

Objective: **locate/identify** a machine or group of machines on the **Internet**

- An **interface** (network card) ↔ an **IP address**;
    - So **N network cards** on a machine ↔ **N IP addresses**;
- **Unique** IP address on the Internet at any given time;
    - Exception: case of **private addresses**.

Two types of IP addresses that coexist on the Internet:

- **IPv4** encoded on **4 bytes >** 4.3 billion available addresses
- **IPv6** encoded on **16 bytes >** 3,4 x 10^{38} addresses available

Chapter 1

Addressing – IPv4

IPv4 Addresses

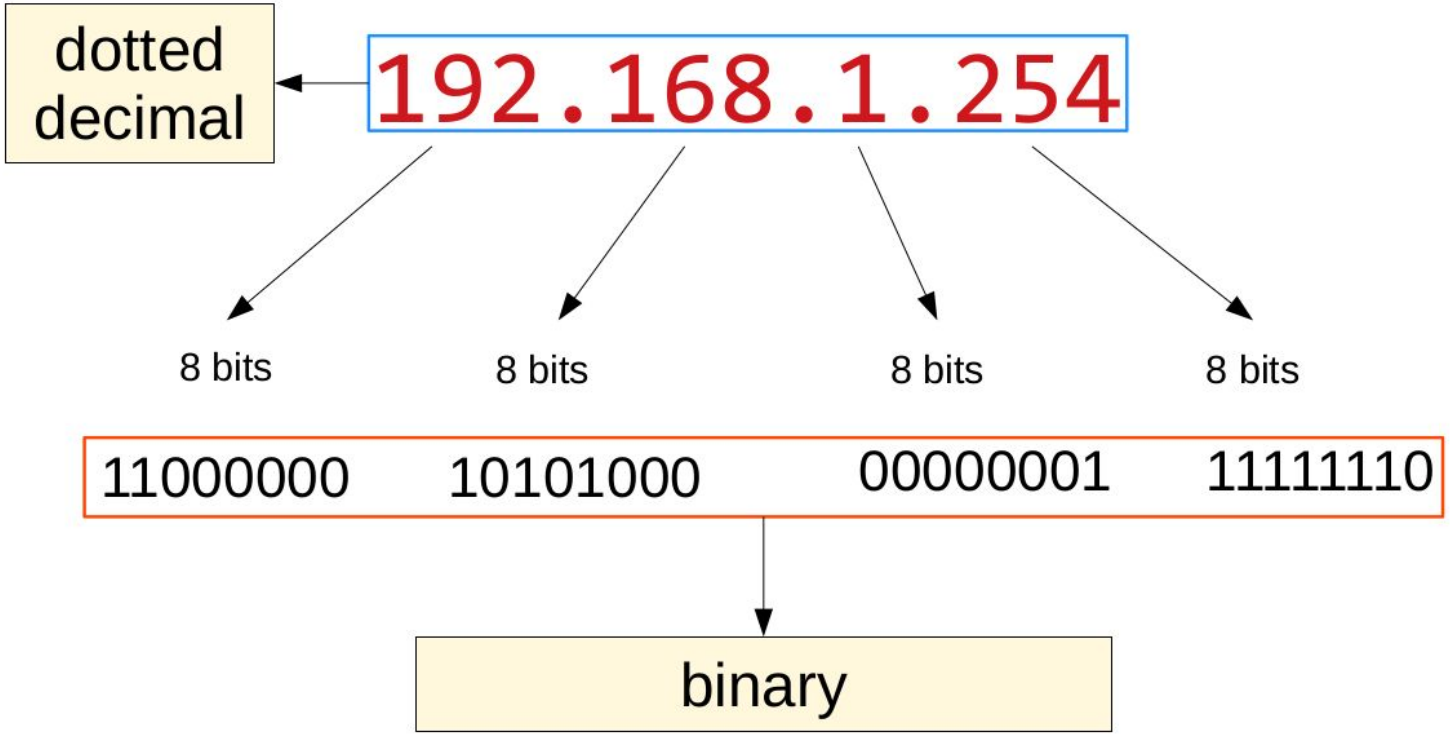
- Consists of **4 bytes = 32 bits**

- "**Dotted-decimal**" format of notation:
  - Each byte is written in **decimal**
    => Four decimal numbers separated by **periods: byte1.byte2.byte3.byte4**
    Ex. **193.55.44.200**, **10.10.1.15**, **172.168.0.36**, etc.

- **Three types** of IPv4 addresses:
  - **Unicast:** identifies **one interface** or a **single host** on the network;
  - **Multicast**: used for transmitting packets to **a group of interfaces**
  - **Broadcast:** used to broadcast the same packet to **all interfaces** of the same network.

- Special addresses:
  loopback (**127.0.0.1**) ; unspecified, default network (**0.0.0.0**) ; etc.

Addressing : IPv4



IPv4 Addresses

IP addresses consist of **two parts**:

- One part identifies **the network** to which the machine belongs;
- Another part identifies **the machine** on the network.

The two parts of IPv4 address**:**

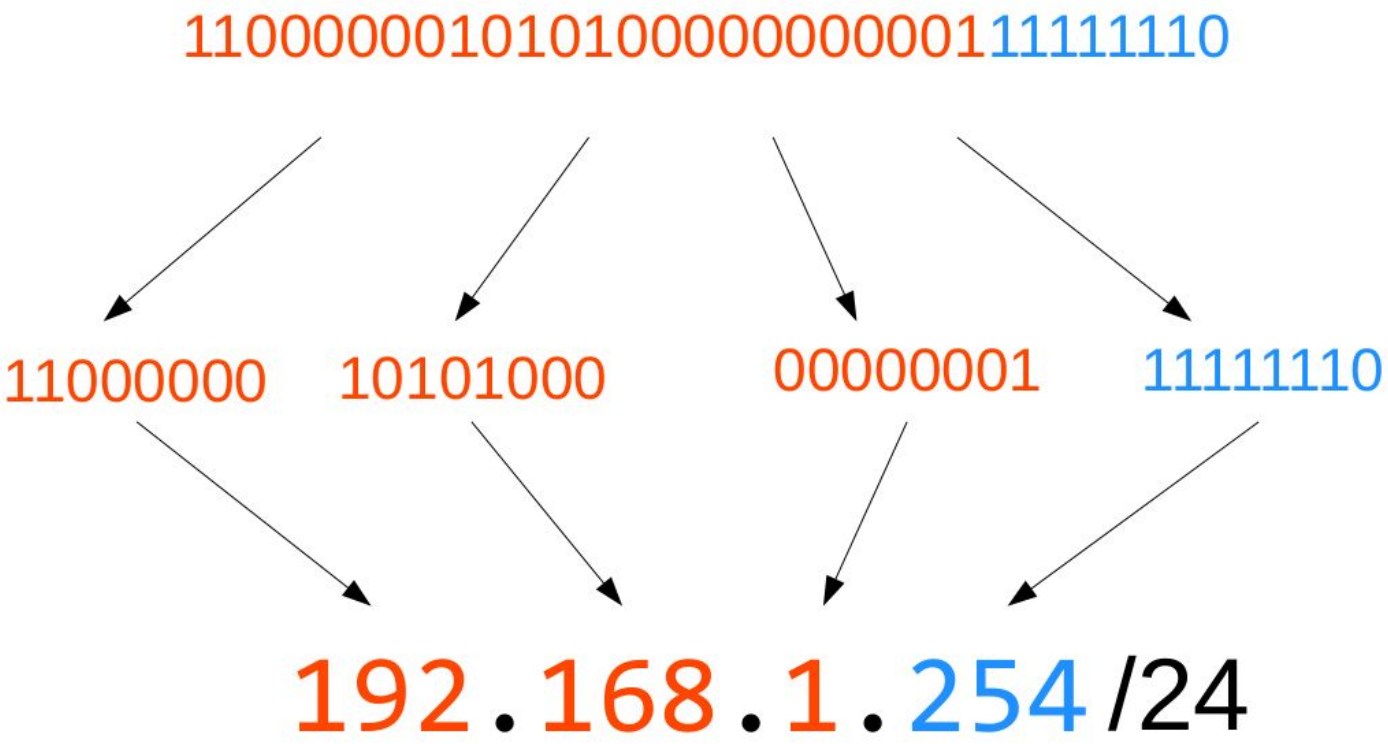
- The first **n bits** identify **the network (Net-id);**
- The following **(32-n) bits** identify **the machine** on the network **(Host-id)**;

  Notation : **$byte_1.byte_2.byte_3.byte_4$ /n**

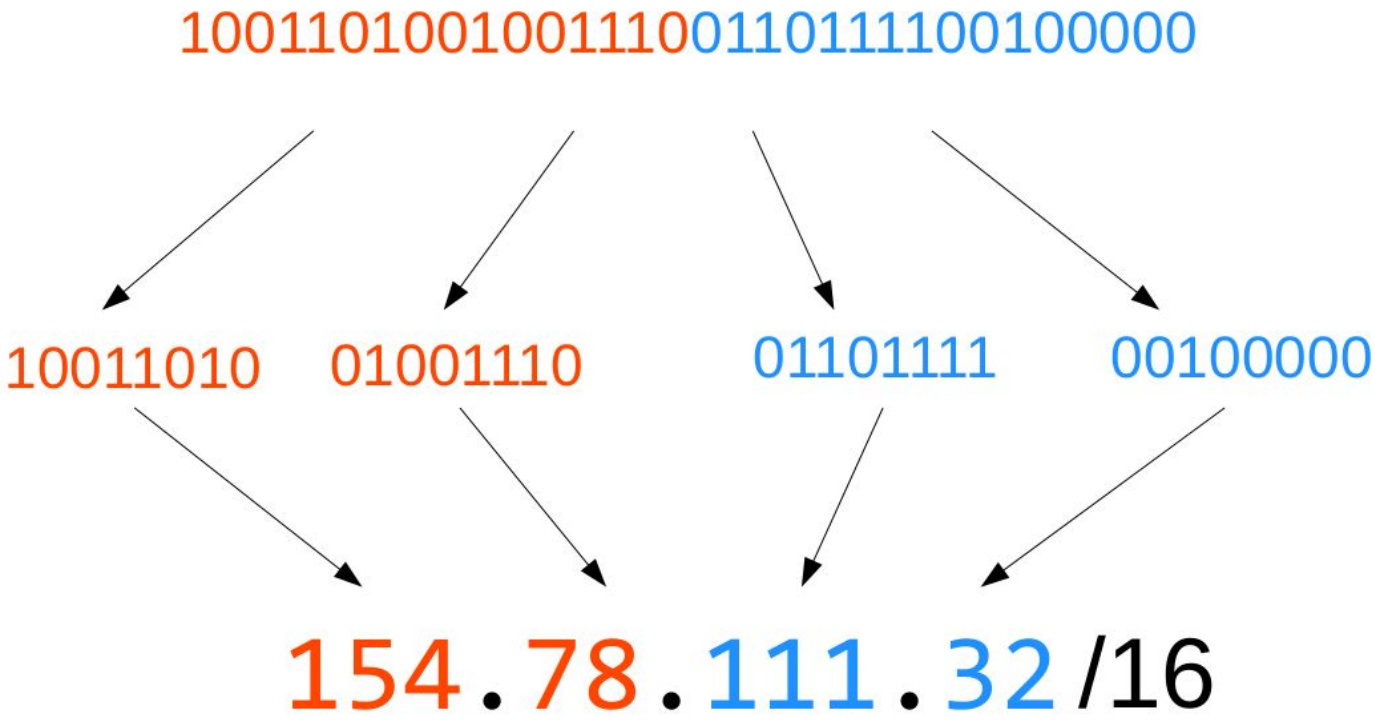
E.g.:

- 200.10.111.0/24
  - The **network** is identified by the first **3 bytes** (/24 => 24 bits = 3 bytes): **200.10.111**.0
  - **1 byte** (32-24 = 8 bits => 1 byte) is used to identify machines on the network;

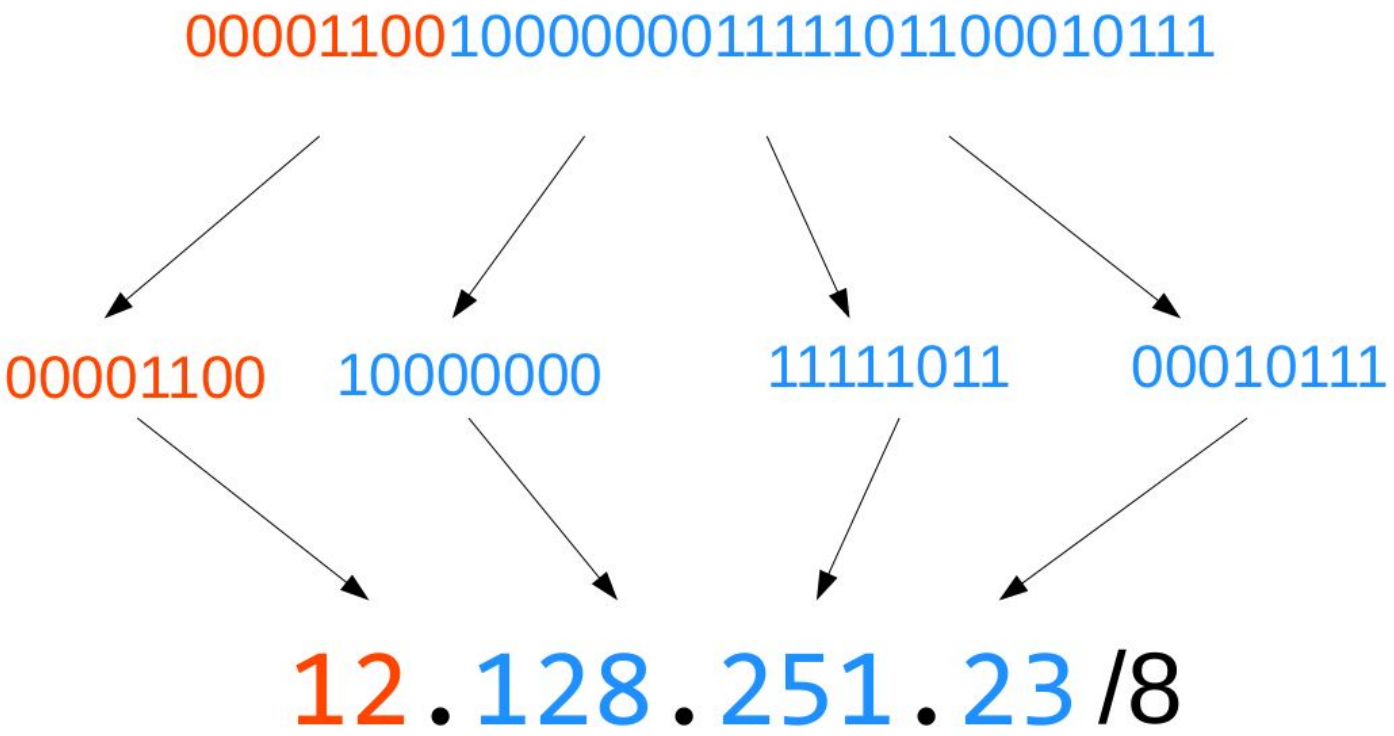
Addressing : IPv4



Addressing : IPv4



Addressing : IPv4



Addressing : IPv4

What is the network part and machine part in the following IP addresses :

- 192.168.1.200 / 16

- 10.0.1.1 / 8

- 192.127.255.254 / 12

Addressing : IPv4

Five Different Classes of IPv4 Addresses

Class	First Octet decimal (range)	First Octet binary (range)	IP range	Subnet Mask	# of networks
Class A	0 – 127	0XXXXXXX	0.0.0.0-127.255.255.255	/8	2^7
Class B	128 – 191	10XXXXXX	128.0.0.0-191.255.255.255	/16	2^{14}
Class C	192 – 223	110XXXXX	192.0.0.0-223.255.255.255	/24	2^{21}
Class D (Multicast)	224 – 239	1110XXXX	224.0.0.0-239.255.255.255		
Class E (Experimental)	240 – 255	1111XXXX	240.0.0.0-255.255.255.255		

IPv4 Addresses

- On a prefix network **/m,** you can address **$2^{(32-m)}$ – 2 machines** because:
  - The address with all bits of the **host-id at 1** is reserved for **broadcasting**;
  - The address with all bits of the **host-id at 0** is reserved for the **network address**.

- The **first** machine address is: **network address + 1**
- The **last** machine address is: **the broadcast address – 1**

- Example:

On the network address **121.96.0.0/16** (**0111 1001 . 0110 0000 . 0000 0000 . 0000 0000**),

  - We have **2^{16} - 2 = 65 534** addresses to identify machines on the network;
  - The **broadcast** address is 121.96**.255.255** (0111 1001 . 0110 0000 . **1111 1111 . 1111 1111**) ;
  - The first machine address is 121.96.**0.1** (0111 1001 . 0110 0000 . 0000 0000 .0000 0001);
  - The last machine address is 121.96**.255.254** (0111 1001 . 0110 0000 . **1111 1111 . 1111 1110**).

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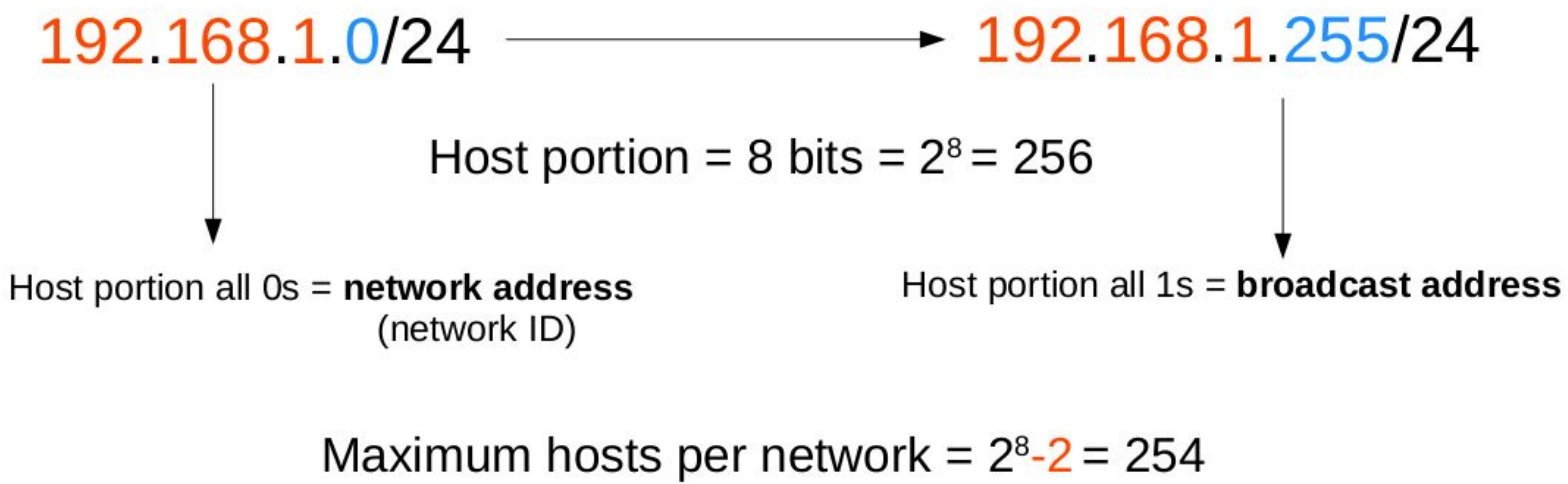
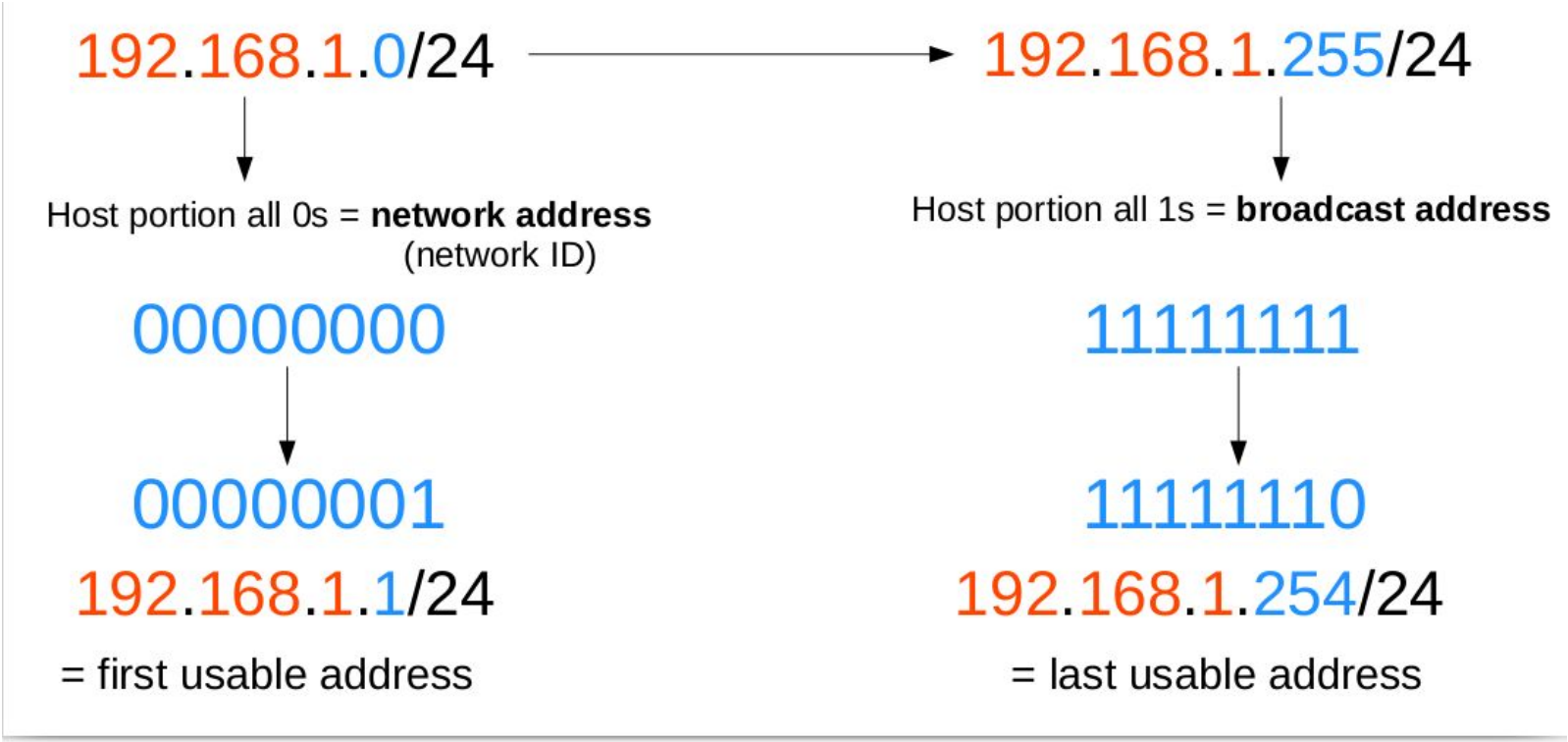
Addressing : IPv4



Maximum hosts per network = 2^8-2 = 254

Addressing : IPv4



IPv4 Addresses

For the network 172.16.0.0 /16 identify

- Maximum number of hosts :
- Broadcast address :
- First usable host address :
- Last usable host address :

For the network 10.0.0.0 /8 identify

- Maximum number of hosts :
- Broadcast address :
- First usable host address :
- Last usable host address :

For the network 170.16.0.0 /12 identify

- Maximum number of hosts :
- Broadcast address :
- First usable host address :
- Last usable host address :

IPv4 Addresses

Subnet Mask /n

/8 CIDR Notation
=> 1111 1111 . 0000 0000 . 0000 0000 => Binary Notation
=> **255 . 0. 0.0 => Decimal notation**

/16 CIDR NOTATION
=> 1111 1111 . 1111 1111 . 0000 0000 . 0000 0000 => Binary Notation
=> 255 .255. 0.0 => Decimal Notation

/12 CIDR Notation
=> 1111 1111 . 1111 0000 . 0000 0000 . 0000 0000 => Binary Notation
=> 255 . 240 . 0 . 0 => Decimal Notation

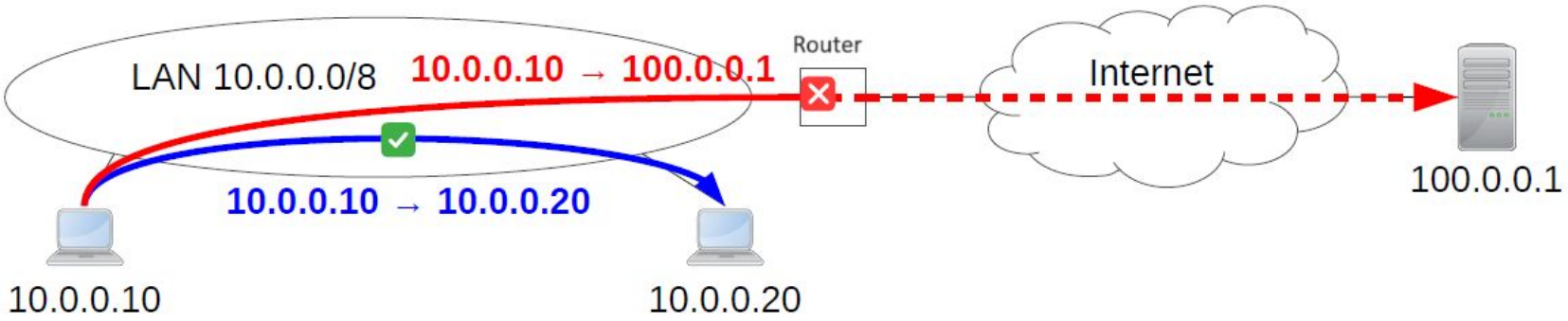
Network : 172.1.1.0 255.255.255.0 is same as **172.1.1.0 /16**

Addressing : IPv4

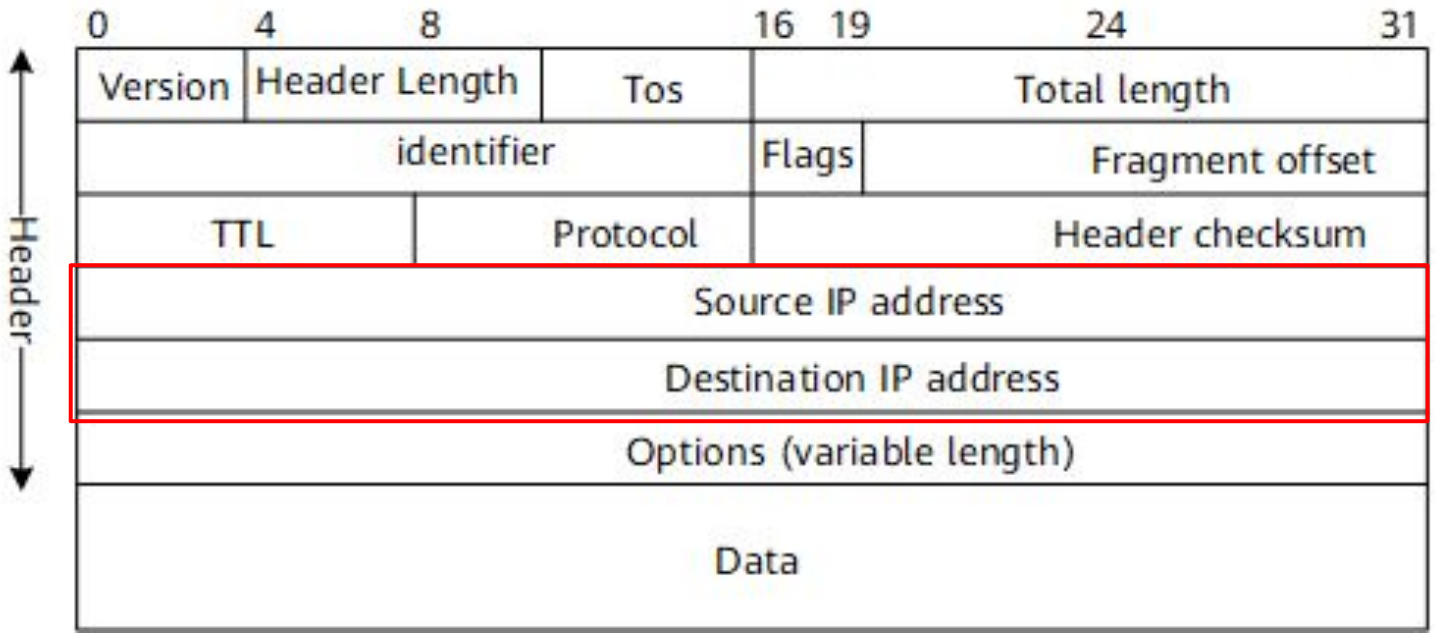
Private IPv4 Address Space

Class	Address Range	Network Prefix
A	10.0.0.0 - 10.255.255.255	10.0.0.0/8
B	172.16.0.0 - 172.31.255.255	172.16.0.0/12
C	192.168.0.0 - 192.168.255.255	192.168.0.0/16

Addressing : IPv4 – Private IP addresses



Addressing : IPv4

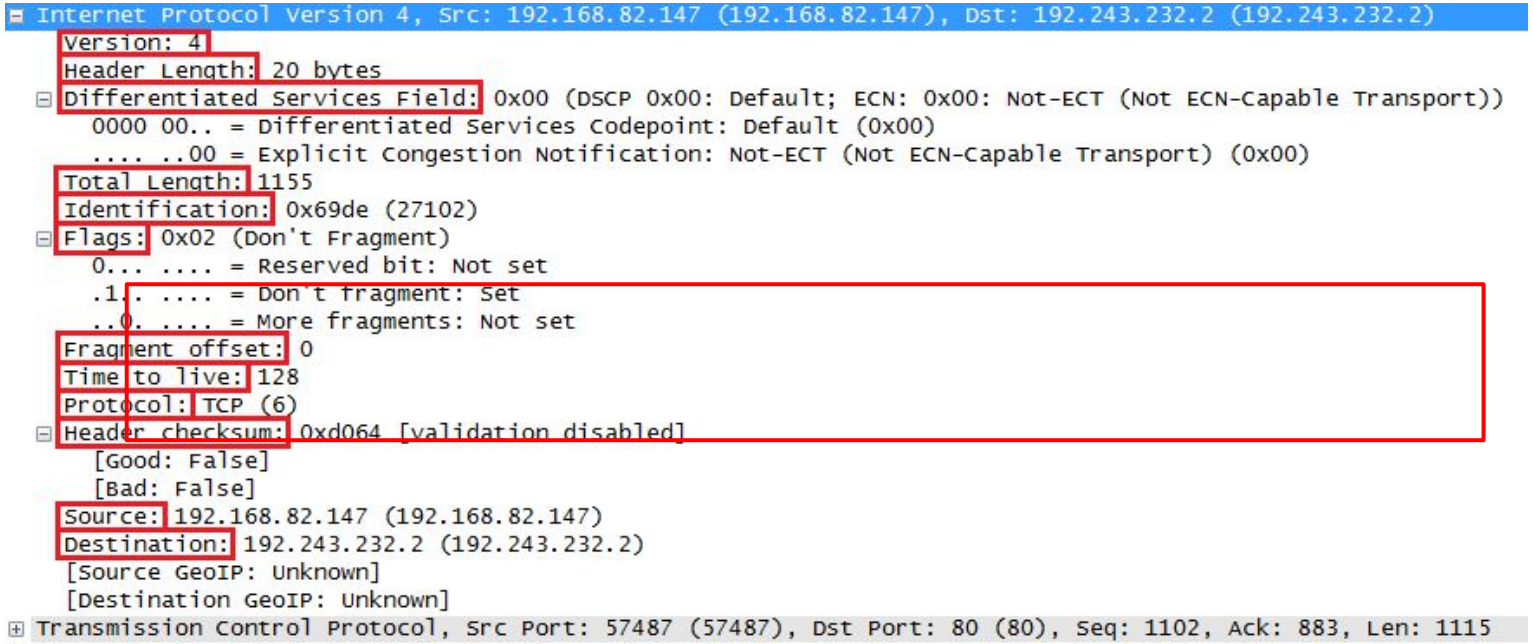


IPv4 header

Addressing : IPv4 header

- **Version**: which IP version is used,
- **Header Length**: the length of the IP header in 32 bits increments. The minimum length of an IP header is 20 bytes so with 32 bits increments, you would see value of 5 here. This field is also called the **Internet Header Length (IHL)**.
- **Type of Service**: used for QoS (Quality of Service).
- **Total Length**: the entire size of the IP packet (header and data) in bytes. The minimum size is 20 bytes (no data).
- **Identification**: If the IP packet is fragmented then each fragmented packet will use the same 16 bits identification number to identify to which IP packet they belong to.
- **IP Flags**: used for fragmentation: The first bit is always set to 0, The second bit is called the **DF (Don't Fragment) bit,** and the third bit is called the **MF (More Fragments)** bit and is set on all fragmented packets except the last one.
- **Fragment Offset**: specifies the position of the fragment in the original fragmented IP packet.
- **Time to Live**: The time to live field is used to prevent packets from looping around forever.
- **Protocol**: indicates which protocol is encapsulated in the IP packet, e.g. TCP has value 6 and UDP has value 17.
- **Header Checksum**: used to store a checksum of the header.
- **Source Address, Destination Address:** the source IP address, and the destination IP address.
- **IP Option**: not used often (optional). An example of a possible option is "source route" where the sender requests for a certain routing path.

Addressing : IPv4 header



IPv4 header

Quiz

Addressing : IPv4 - Quiz

A device has an IP address of 193.200.7.11/24

Complete the following information :

Network address:
Maximum number of hosts in the network:
Network broadcast address:
First usable address of the network:
Last usable address of the network:

Addressing : IPv4 - Quiz

A device has an IP address of 193.200.7.11/24

Complete the following information :

Network address: 193.200.7.0
Maximum number of hosts in the network: 254
Network broadcast address: 193.200.7.255
First usable address of the network: 193.200.7.1
Last usable address of the network: 193.200.7.254

Addressing : IPv4 - Quiz

A device has an IP address of 129.100.10.10/16

Complete the following information :

Network address:
Maximum number of hosts in the network:
Network broadcast address:
First usable address of the network:
Last usable address of the network:

Addressing : IPv4 - Quiz

A device has an IP address of 129.100.10.10/16

Complete the following information :

Network address: 129.100.0.0
Maximum number of hosts in the network: 65,534
Network broadcast address: 129.100.255.255
First usable address of the network: 129.100.0.1
Last usable address of the network: 129.100.255.254

End of Quiz

Chapter 1

Addressing – IPv6

Addressing : IPv6

IPV6 :

- Is the successor to the currently used IPv4
- Specification completed in 1994
- Makes improvements to IPv4 (no revolutionary changes)
- One (not the only !) feature of IPv6 is a significant increase of the IP address to 128 bits (16 bytes)
    - IPv6 will solve – for the foreseeable future – the problems with IP addressing 10 24 addresses per square inch on the surface of the Earth
- IPv4 has a maximum of 2^{32} 4 billion addresses
- IPv6 has a maximum of $2^{128} = (2^{32})^4$ 4 billion x 4 billion x 4 billion x 4 billion addresses

Addressing : IPv6

- **Convention:** The 128-bit IPv6 address is written as eight 16-bit integers (using hexadecimal digits for each integer)
  - CEDF:BC76:3245:4464:FACE:2E50:3025:DF12
  - 1100 1110 1101 1111 : 1011 1100 0111 0110 : 0011 0010 0100 0101 : 0100 0100 0110 0100 : 1111 1010 1100 1110……
- **Short notation** (Abbreviations of leading zeroes):
  - CEDF:BC76:0000:0000:009E:0000:3025:DF12
    → CEDF:BC76:0:0:9E :0:3025:DF12
  - CEDF:BC76:0:0:9E:0:3025:DF12
    → CEDF:BC76::9E:0:3025:DF12

Addressing : IPv6

Table 4-2 IPv6 Address Reduction

IPv6 Address	*Simplified Notation*
FF01:0000:0000:0000:0000:0000:0000:0001	FF01::1
2031:0000:130F:0000:0000:09C0:876A:130B	2031:0:130F::9C0:876A:130B
0000:0000:0000:0000:0000:0000:0000:0001	::1
FE80:0000:0000:5EFE:0192.0168.0001.0123	FE80::5EFE:192.168.1.123
FE80: 0000:0000:0000:1585:4868:495F:D521	FE80::1585:4868:495F:D521

Which is the wrong condense notation of the address: 2001:db8:A:0:0:12:0:80

a) 2001:db8:A::12:0:80
b) 2001:db8:A::12::80
c) 2001:db8:A:0:0:12::80

Addressing : IPv6 - Link Local Address

- A link-local address is an IPv6 address that is **automatically assigned** to every network interface.
  - Used only for communication within the same local network and is not routable beyond that local segment.
- Link-local addresses always begin with the prefix fe80:: /10

- EUI-64 method is often used to generate the interface identifier:
  - It is derived from MAC address. Example: 00:1A:2B:3C:4D:5E
  - By inserting the hexadecimal value **FFFE** in the middle of the MAC address and flip the 7th bit of the MAC address.
    - EUI-64: 021A:2B**FF:FE**3C:4D5E

Link-local addresses using EUI-64 : fe80::021A:2B**FF:FE**3C:4D5E

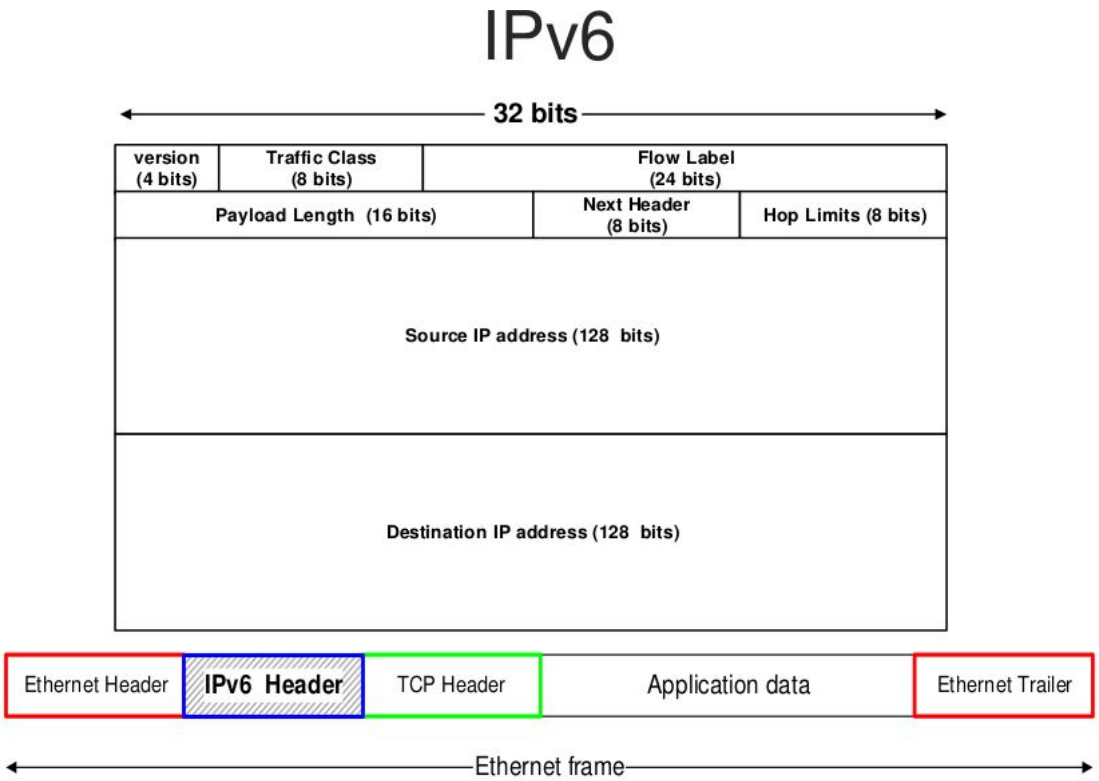
Addressing : IPv6 - IPv4-mapped IPv6 address

- IPv6 addresses derived from IPv4 addresses have **80 leading zero bits** followed by **FFFF**. Convention allows to use IPv4 notation for the last 32 bits.

  ::FFFF:128.143.137.144 ↔ ::FFFF:808F:8990 <= IPv4-mapped IPv6 address

This can be particularly useful in an environment where both IPv4 and IPv6 are in use, and some form of intercommunication is necessary.

Addressing : IPv6



Références

1. Course of Computer networks at ECE Paris given by T. MAGADIS, A. SEWERYN, M. CHAIEB.
2. Cisco Networking Academy materials
3. James Kurose, Computer Networking: A Top-Down Approach
4. Andrew S. Tanenbaum, David J. Wetherall, Computer Networks
5. ED Tittel, Schaum's outlines, Computer networking