Chapter 10

# IPv6

The address depletion of IPv4 and other shortcomings of this protocol prompted a new version of IP in the early 1990s. The new version, which is called ***Internet Protocol version 6 (IPv6)*** or ***IP new generation (IPng)*** was a proposal to augment the address space of IPv4 and at the same time redesign the format of the IP packet and revise some auxiliary protocols such as ICMP. It is interesting to know that IPv5 was a proposal, based on the OSI model that never materialized.

## 10.1 Definition

IPv6 (Internet Protocol version 6) is a set of specifications from the Internet Engineering Task Force (IETF) that is essentially an upgrade of IP version 4 (IPv4), a category of IP addresses in IPv4-based routing. The basics of IPv6 are similar to those of IPv4 -- devices can use IPv6 as source and destination addresses to pass packets over a network, and tools like ping work for network testing as they do in IPv4, with some slight variations.

The most obvious improvement in IPv6 over IPv4 is that IP addresses are lengthened from 32 bits to 128 bits. This extension anticipates considerable future growth of the Internet and provides relief for what was perceived as an impending shortage of network addresses. IPv6 also supports auto-configuration to help correct most of the shortcomings in version 4, and it has integrated security and mobility features.

## 10.2 Representation

A computer normally stores the address in binary, but it is clear that 128 bits cannot easily be handled by humans. Several notations have been proposed to represent IPv6 addresses when they are handled by humans. The following shows two of these notations: binary and colon hexadecimal.

**Binary (128 bits) 1111111011110110** … **1111111100000000**
**Colon Hexadecimal FEF6:BA98:7654:3210:ADEF:BBFF:2922:FF00**

Binary notation is used when the addresses are stored in a computer. The **colon hexadecimal notation** (or *colon hex* for short) divides the address into eight sections, each made of four hexadecimal digits separated by colons.

### *Abbreviation*

Although an IPv6 address, even in hexadecimal format, is very long, many of the digits are zeros. In this case, we can abbreviate the address. The leading zeros of a section can be omitted. Using this form of abbreviation, 0074 can be written as 74, 000F as F, and 0000 as 0. Note that 3210 cannot be abbreviated. Further abbreviation, often called ***zero compression,*** can be applied to colon hex notation if there are consecutive sections consisting of zeros only. We can remove all the zeros and replace them with a double semicolon.

**FDEC:0:0:0:0:BBFF:0:FFFF ---> FDEC::BBFF:0:FFFF**

Note that this type of abbreviation is allowed only once per address. If there is more than one run of zero sections, only one of them can be compressed.

### *Mixed Notation*

Sometimes we see a mixed representation of an IPv6 address: colon hex and dotted decimal notation. This is appropriate during the transition period in which an IPv4 address is embedded in an IPv6 address (as the rightmost 32 bits). We can use the colon hex notation for the leftmost six sections and four-byte dotted-decimal notation instead of the rightmost two sections. However, this happens when all or most of the leftmost sections of the IPv6 address are 0s. For example, the address (::130.24.24.18) is a legitimate address in IPv6, in which the zero compression shows that all 96 leftmost bits of the address are zeros.

### *CIDR Notation*

As we will see shortly, IPv6 uses hierarchical addressing. For this reason, IPv6 allows slash or CIDR notation. For example, the following shows how we can define a prefix of 60 bits using CIDR. We will later show how an IPv6 address is divided into a prefix and a suffix.

**FDEC::BBFF:0:FFFF/60**

## 10.3 Three Address Types

In IPv6, a destination address can belong to one of three categories: unicast, anycast and multicast.

### *Unicast Address*

A unicast address defines a single interface (computer or router). The packet sent to a unicast address will be routed to the intended recipient.

### *Anycast Address*

An **anycast address** defines a group of computers that all share a single address. A packet with an anycast address is delivered to only one member of the group, the most reachable one. An anycast communication is used, for example, when there are several servers that can respond to an inquiry. The request is sent to the one that is most reachable. The hardware and software generate only one copy of the request; the copy reaches only one of the servers. IPv6 does not designate a block for anycasting; the addresses are assigned from the unicast block.

### *Multicast Address*

A multicast address also defines a group of computers. However, there is a difference between anycasting and multicasting. In anycasting, only one copy of the packet is sent to one of the members of the group; in multicasting each member of the group receives a copy. As we will see shortly, IPv6 has designated a block for multicasting from which the same address is assigned to the members of the group. It is interesting that IPv6 does not define broadcasting, even in a limited version. IPv6 considers broadcasting as a special case of multicasting.

## 10.4 TRANSITION FROM IPv4 TO IPv6

Although we have a new version of the IP protocol, how can we make the transition to stop using IPv4 and start using IPv6? The first solution that comes to mind is to define a transition day on which every host or router should stop using the old version and start using the new version. However, this is not practical; because of the huge number of systems in the Internet, the transition from IPv4 to IPv6 cannot happen suddenly. It will take a considerable amount of time before every system in the Internet can move from IPv4 to IPv6. The transition must be smooth to prevent any problems between IPv4 and IPv6 systems.

There are a couple of main methods that can be used when transitioning a network from IPv4 to IPv6; these include:

- **Dual Stack** – Running both IPv4 and IPv6 on the same devices
- **Tunneling** – Transporting IPv6 traffic through an IPv4 network transparently
- **Translation** – Converting IPv6traffic to IPv4 traffic for transport and vice versa.

Dual Stack

The simplest approach when transitioning to IPv6 is to run IPv6 on all of the devices that are currently running IPv4. If this is something that is possible within the organizational network, it is very easy to implement. However, for many organizations, IPv6 is not supported on all of the IPv4 devices; in these situations other methods must be considered.

Tunneling

Most people with some networking knowledge are familiar with the concept of tunneling; a given packet is encapsulated into a *wrapper* than enables its transport from a source to destination transparently where it is decapsulated and retransmitted. There are a number of different tunneling methods that exist for IPv6, many that are integrated as part of Cisco and other manufactures certification tests.

Header Translation

**Header translation** is necessary when the majority of the Internet has moved to IPv6 but some systems still use IPv4. The sender wants to use IPv6, but the receiver does not understand IPv6. Tunneling does not work in this situation because the packet must be in the IPv4 format to be understood by the receiver. In this case, the header format must be totally changed through header translation. The header of the IPv6 packet is converted to an IPv4 header.

## 10.5 Link Local Address

Link-local IPv6 addresses have a smaller scope as to how far they can travel: only within a network segment that a host is connected to. Routers will not forward packets destined to a link-local address to other links. A link-local IPv6 address must be assigned to every network interface on which the IPv6 protocol is enabled. A host can automatically derive its own link local IP address or the address can be manually configured.

Link-local addresses have a prefix of **FE80::/10**. They are mostly used for auto-address configuration and neighbour discovery.

- All the link local address starts with FE80
- It is used for retrieving MAC address

FE80::5D39:84FF:FE29:3064

Rules to convert link local into MAC Address:

i) Drop the First four Hextets

ii) Flip the 7$^{th}$ bit of 5$^{th}$ Hextet

iii) Drop the 2$^{nd}$ Octet of 6$^{th}$ Hextet

iv) Drop the 1$^{st}$ Octet of 7$^{th}$ Hextet

FE80::5 D 3 9:84 FF:FE 29:3064

Drop→FE80 flip→D drop→ FF:FE

5D39=0101110100111001

7th bit flip →5F39

MAC address: 5F39:8429:3064

## Exercise

1. Show the unabbreviated colon hex notation for the following IPv6 addresses:
**a.** An address with 64 0s followed by 32 two-bit (01)s.
**b.** An address with 64 0s followed by 32 two-bit (10)s.
**c.** An address with 64 two-bit (01)s.
**d.** An address with 32 four-bit (0111)s.

2. Show abbreviations for the following addresses:
**a.** 0000:FFFF:FFFF:0000:0000:0000:0000:0000
**b.** 1234:2346:3456:0000:0000:0000:0000:FFFF
**c.** 0000:0001:0000:0000:0000:FFFF:1200:1000
**d.** 0000:0000:0000:0000:FFFF:FFFF:24.123.12.6

3. Decompress the following addresses and show the complete unabbreviated IPv6 address:
**a.** ::2222
**b.** 1111::
**c.** B:A:CC::1234:A

4. Show the original (unabbreviated) form of the following IPv6 addresses:
**a.** ::2
**b.** 0:23::0
**c.** 0:A::3