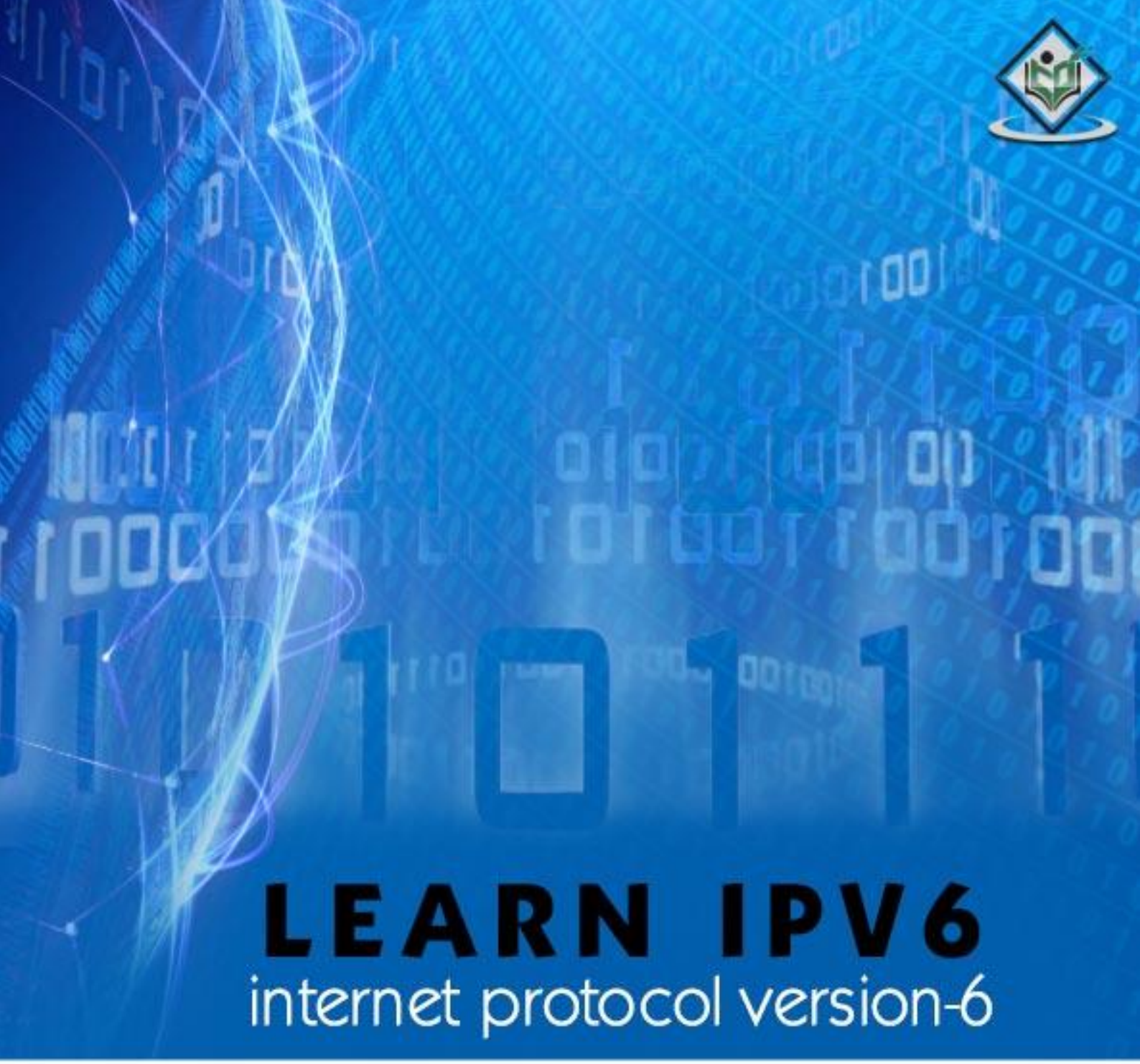

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About the Tutorial

Internet Protocol version 6 (IPv6) is the latest revision of the Internet Protocol (IP) and the first version of the protocol to be widely deployed. IPv6 was developed by the Internet Engineering Task Force (IETF) to deal with the long-anticipated problem of IPv4 address exhaustion.

This tutorial will help you in understanding IPv6 and its associated terminologies along with appropriate references and examples.

Audience

This tutorial has been designed to help beginners understand the basic concepts of IPv6 required to work with any TCP/IP based protocols. After completing this tutorial, you will find yourself at a moderate level of expertise of IPv6 from where you can take yourself to next levels.

Prerequisites

Before you start proceeding with this tutorial, we are assuming that you are already aware of basic computer and network concepts such as what is a protocol, why do we need protocol, network layers, etc.

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1. IPv6 – Overview

Internet Protocol version 6 is a new addressing protocol designed to incorporate all the possible requirements of future Internet known to us as Internet version 2. This protocol as its predecessor IPv4, works on the Network Layer (Layer-3). Along with its offering of an enormous amount of logical address space, this protocol has ample features to address the shortcoming of IPv4.

Why New IP Version?

So far, IPv4 has proven itself as a robust routable addressing protocol and has served us for decades on its best-effort-delivery mechanism. It was designed in the early 80s and did not get any major change afterward. At the time of its birth, Internet was limited only to a few universities for their research and to the Department of Defense. IPv4 is 32 bits long and offers around 4,294,967,296 (2^{32}) addresses. This address space was considered more than enough that time.

Given below are the major points that played a key role in the birth of IPv6:

- Internet has grown exponentially and the address space allowed by IPv4 is saturating. There is a requirement to have a protocol that can satisfy the needs of future Internet addresses that is expected to grow in an unexpected manner.
- IPv4 on its own does not provide any security features. Data has to be encrypted with some other security application before being sent on the Internet.
- Data prioritization in IPv4 is not up-to-date. Though IPv4 has a few bits reserved for Type of Service or Quality of Service, but they do not provide much functionality.
- IPv4 enabled clients can be configured manually or they need some address configuration mechanism. It does not have a mechanism to configure a device to have globally unique IP address.

Why Not IPv5?

Till date, Internet Protocol has been recognized has IPv4 only. Version 0 to 3 were used while the protocol was itself under development and experimental process. So, we can assume lots of background activities remain active before putting a protocol into production. Similarly, protocol version 5 was used while experimenting with the stream protocol for Internet. It is known to us as Internet Stream Protocol which used Internet Protocol number 5 to encapsulate its datagram. It was never brought into public use, but it was already used.

Here is a table of IP versions and how they are used:

Decimal	Keyword	Version
0-1		Reserved
2-3		Unassigned
4	IP	Internet Protocol
5	ST	ST Datagram mode
6	IPv6	Internet Protocol version 6
7	TP/IX	TP/IX: The Next Internet
8	PIP	The P Internet Protocol
9	TUBA	TUBA
10-14		Unassigned
15		Reserved

Brief History

After IPv4's development in the early 80s, the available IPv4 address pool begun to shrink rapidly as the demand of addresses exponentially increased with Internet. Taking pre-cognizance of the situation that might arise, IETF, in 1994, initiated the development of an addressing protocol to replace IPv4. The progress of IPv6 can be tracked by means of the RFC published:

- 1998 – RFC 2460 – Basic Protocol
- 2003 – RFC 2553 – Basic Socket API
- 2003 – RFC 3315 – DHCPv6
- 2004 – RFC 3775 – Mobile IPv6
- 2004 – RFC 3697 – Flow Label Specification
- 2006 – RFC 4291 – Address architecture (revision)
- 2006 – RFC 4294 – Node requirement

On June 06, 2012, some of the Internet giants chose to put their Servers on IPv6. Presently they are using Dual Stack mechanism to implement IPv6 in parallel with IPv4.

2. IPv6 – Features

The successor of IPv4 is not designed to be backward compatible. Trying to keep the basic functionalities of IP addressing, IPv6 is redesigned entirely. It offers the following features:

Larger Address Space

In contrast to IPv4, IPv6 uses 4 times more bits to address a device on the Internet. This much of extra bits can provide approximately 3.4×1038 different combinations of addresses. This address can accumulate the aggressive requirement of address allotment for almost everything in this world. According to an estimate, 1564 addresses can be allocated to every square meter of this earth.

Simplified Header

IPv6's header has been simplified by moving all unnecessary information and options (which are present in IPv4 header) to the end of the IPv6 header. IPv6 header is only twice as bigger than IPv4 provided the fact that IPv6 address is four times longer.

End-to-end Connectivity

Every system now has unique IP address and can traverse through the Internet without using NAT or other translating components. After IPv6 is fully implemented, every host can directly reach other hosts on the Internet, with some limitations involved like Firewall, organization policies, etc.

Auto-configuration

IPv6 supports both stateful and stateless auto-configuration mode of its host devices. This way, absence of a DHCP server does not put a halt on inter-segment communication.

Faster Forwarding/Routing

Simplified header puts all unnecessary information at the end of the header. The information contained in the first part of the header is adequate for a Router to take routing decisions, thus making routing decision as quickly as looking at the mandatory header.

IPSec

Initially it was decided that IPv6 must have IPSec security, making it more secure than IPv4. This feature has now been made optional.

No Broadcast

Though Ethernet/Token Ring are considered as broadcast network because they support Broadcasting, IPv6 does not have any broadcast support anymore. It uses multicast to communicate with multiple hosts.

Anycast Support

This is another characteristic of IPv6. IPv6 has introduced Anycast mode of packet routing. In this mode, multiple interfaces over the Internet are assigned same Anycast IP address. Routers, while routing, send the packet to the nearest destination.

Mobility

IPv6 was designed keeping mobility in mind. This feature enables hosts (such as mobile phone) to roam around in different geographical area and remain connected with the same IP address. The mobility feature of IPv6 takes advantage of auto IP configuration and Extension headers.

Enhanced Priority Support

IPv4 used 6 bits DSCP (Differential Service Code Point) and 2 bits ECN (Explicit Congestion Notification) to provide Quality of Service but it could only be used if the end-to-end devices support it, that is, the source and destination device and underlying network must support it.

In IPv6, Traffic class and Flow label are used to tell the underlying routers how to efficiently process the packet and route it.

Smooth Transition

Large IP address scheme in IPv6 enables to allocate devices with globally unique IP addresses. This mechanism saves IP addresses and NAT is not required. So devices can send/receive data among each other, for example, VoIP and/or any streaming media can be used much efficiently.

Other fact is, the header is less loaded, so routers can take forwarding decisions and forward them as quickly as they arrive.

Extensibility

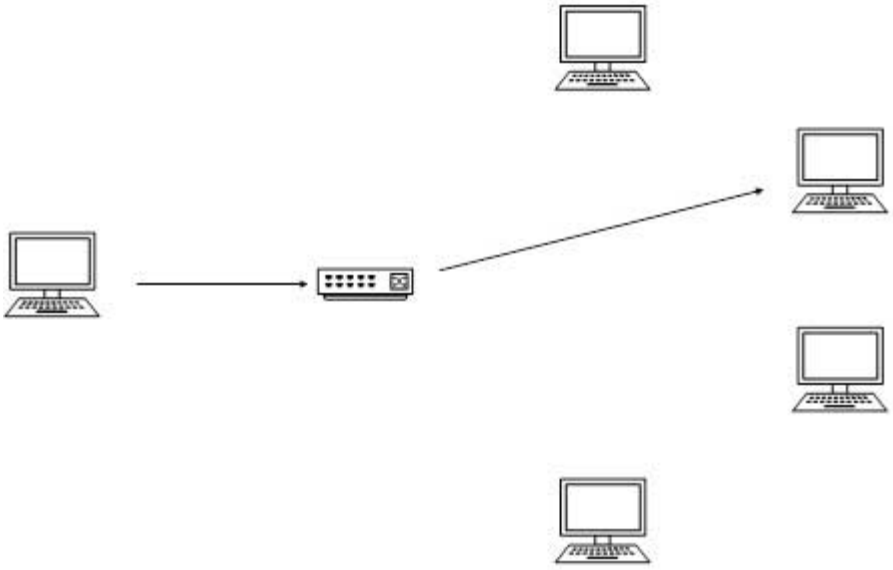
One of the major advantages of IPv6 header is that it is extensible to add more information in the option part. IPv4 provides only 40-bytes for options, whereas options in IPv6 can be as much as the size of IPv6 packet itself.

3. IPv6 – Addressing Modes

In computer networking, addressing mode refers to the mechanism of hosting an address on the network. IPv6 offers several types of modes by which a single host can be addressed. More than one host can be addressed at once or the host at the closest distance can be addressed.

Unicast

In unicast mode of addressing, an IPv6 interface (host) is uniquely identified in a network segment. The IPv6 packet contains both source and destination IP addresses. A host interface is equipped with an IP address which is unique in that network segment. When a network switch or a router receives a unicast IP packet, destined to a single host, it sends out one of its outgoing interface which connects to that particular host.



[*Image: Unicast Messaging*]

Multicast

The IPv6 multicast mode is same as that of IPv4. The packet destined to multiple hosts is sent on a special multicast address. All the hosts interested in that multicast information need to join that multicast group first. All the interfaces that joined the group receive the multicast packet and process it, while other hosts not interested in multicast packets ignore the multicast information.