Limitations of IPv4

IPv4 is still in use today. This topic is about IPv6, which will eventually replace IPv4. To better understand why you need to know the IPv6 protocol, it helps to know the limitations of IPv4 and the advantages of IPv6.

Through the years, additional protocols and processes have been developed to address new challenges. However, even with changes, IPv4 still has three major issues:

- **IPv4 address depletion -** IPv4 has a limited number of unique public addresses available. Although there are approximately 4 billion IPv4 addresses, the increasing number of new IP-enabled devices, always-on connections, and the potential growth of less-developed regions have increased the need for more addresses.
- **Lack of end-to-end connectivity -** Network Address Translation (NAT) is a technology commonly implemented within IPv4 networks. NAT provides a way for multiple devices to share a single public IPv4 address. However, because the public IPv4 address is shared, the IPv4 address of an internal network host is hidden. This can be problematic for technologies that require end-to-end connectivity.
- **Increased network complexity** – While NAT has extended the lifespan of IPv4 it was only meant as a transition mechanism to IPv6. NAT in its various implementation creates additional complexity in the network, creating latency and making troubleshooting more difficult.

IPv6 Overview

In the early 1990s, the Internet Engineering Task Force (IETF) grew concerned about the issues with IPv4 and began to look for a replacement. This activity led to the development of IP version 6 (IPv6). IPv6 overcomes the limitations of IPv4 and is a powerful enhancement with features that better suit current and foreseeable network demands.

Improvements that IPv6 provides include the following:

- **Increased address space** - IPv6 addresses are based on 128-bit hierarchical addressing as opposed to IPv4 with 32 bits.
- **Improved packet handling** - The IPv6 header has been simplified with fewer fields.
- **Eliminates the need for NAT** - With such a large number of public IPv6 addresses, NAT between a private IPv4 address and a public IPv4 is not needed. This avoids some of the NAT-induced problems experienced by applications that require end-to-end connectivity.

The 32-bit IPv4 address space provides approximately 4,294,967,296 unique addresses. IPv6 address space provides 340,282,366,920,938,463,463,374,607,431,768,211,456, or 340 undecillion addresses. This is roughly equivalent to every grain of sand on Earth.

The figure provides a visual to compare the IPv4 and IPv6 address space.

IPv4 and IPv6 Address Space Comparison

Number Name	Scientific Notation	Number of Zeros
1 Thousand	10^3	1,000
1 Million	10^6	1,000,000
1 Billion	10^9	1,000,000,000
1 Trillion	10^12	1,000,000,000,000
1 Quadrillion	10^15	1,000,000,000,000,000
1 Quintillion	10^18	1,000,000,000,000,000,000
1 Sextillion	10^21	1,000,000,000,000,000,000,000
1 Septillion	10^24	1,000,000,000,000,000,000,000,000
1 Octillion	10^27	1,000,000,000,000,000,000,000,000,000
1 Nonillion	10^30	1,000,000,000,000,000,000,000,000,000,000
1 Decillion	10^33	1,000,000,000,000,000,000,000,000,000,000,000
1 Undecillion	10^36	1,000,000,000,000,000,000,000,000,000,000,000,000

There are 4 billion IPv4 addressesThere are 340 undecillion IPv6 addresses

IPv4 Packet Header Fields in the IPv6 Packet Header

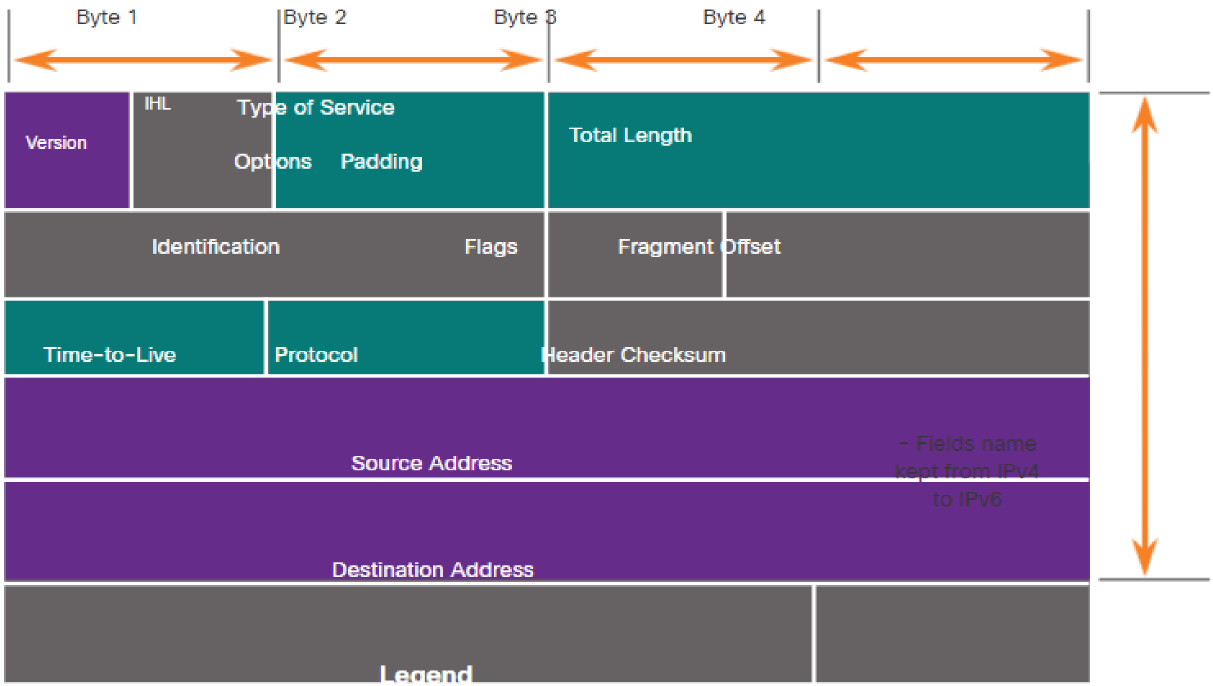
One of the major design improvements of IPv6 over IPv4 is the simplified IPv6 header.

For example, the IPv4 header consists of a variable length header of 20 octets (up to 60 bytes if the Options field is used) and 12 basic header fields, not including the Options field and Padding field.

For IPv6, some fields have remained the same, some fields have changed names and positions, and some IPv4 fields are no longer required, as highlighted in the figure.

IPv4 Packet Header

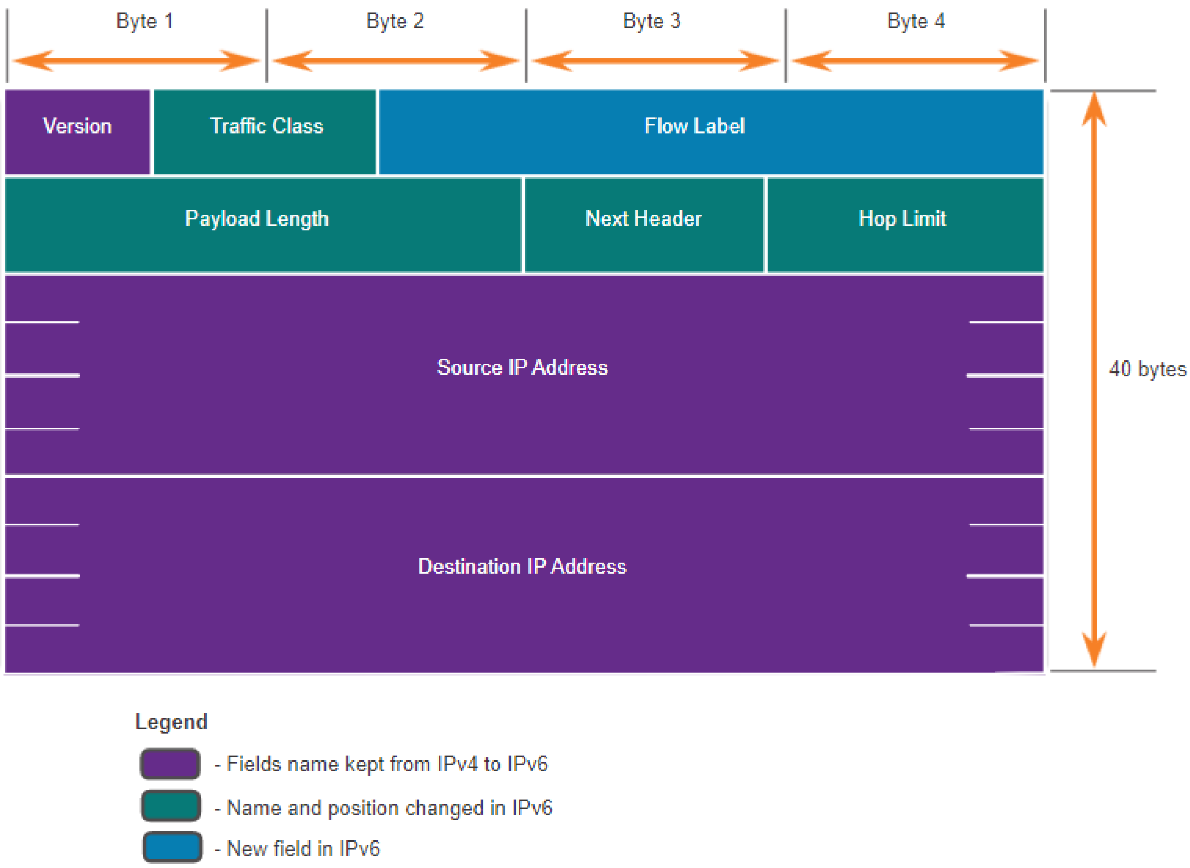
The diagram shows an IPv4 packet header and indicates which fields kept the same name, which fields changed names and position, and which fields were not kept in IPv6. The fields that kept the same name are: version, source address, and destination address. The fields that changed names and position are: type of service, total length, time-to-live, and protocol. The fields that were not kept in IPv6 are: IHL, identification, flags, fragment offset, header checksum, options, and padding.



In contrast, the simplified IPv6 header shown the next figure consists of a fixed length header of 40 octets (largely due to the length of the source and destination IPv6 addresses).

The IPv6 simplified header allows for more efficient processing of IPv6 headers.

IPv6 Packet Header

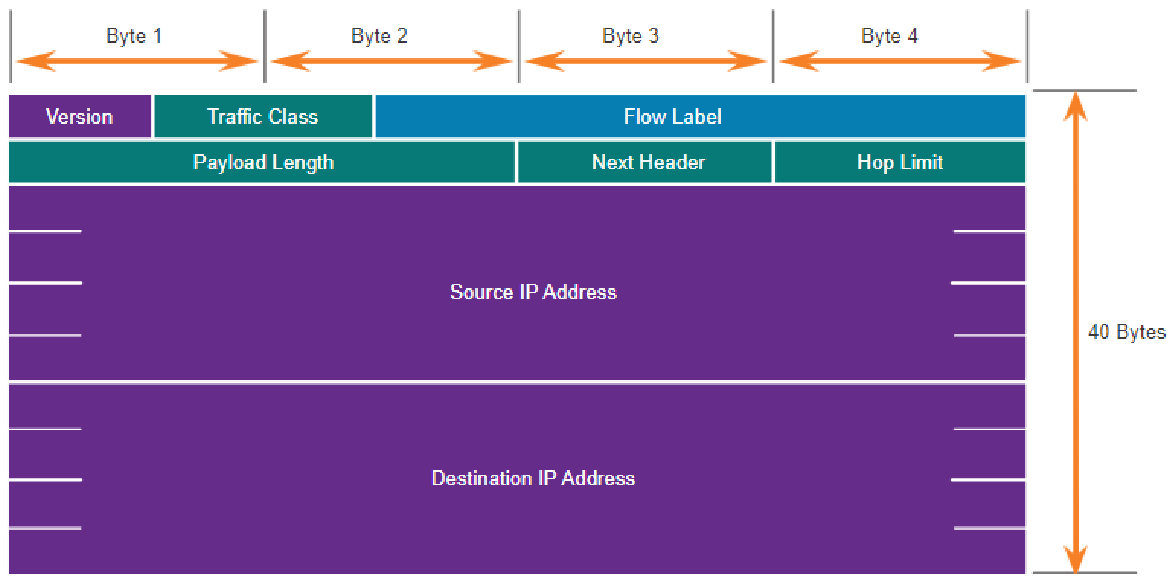


The figure shows the IPv4 packet header fields that were kept or moved along with the new IPv6 packet header fields.

IPv6 Packet Header

The IP protocol header diagram in the figure identifies the fields of an IPv6 packet.

names and bit length of fields in an IPv6 header



Fields in the IPv6 Packet Header

The fields in the IPv6 packet header include the following:

- **Version -** This field contains a 4-bit binary value set to 0110 that identifies this as an IP version 6 packet.
- **Traffic Class -** This 8-bit field is equivalent to the IPv4 Differentiated Services (DS) field.
- **Flow Label -** This 20-bit field suggests that all packets with the same flow label receive the same type of handling by routers.
- **Payload Length -** This 16-bit field indicates the length of the data portion or payload of the IPv6 packet. This does not include the length of the IPv6 header, which is a fixed 40-byte header.
- **Next Header -** This 8-bit field is equivalent to the IPv4 Protocol field. It indicates the data payload type that the packet is carrying, enabling the network layer to pass the data to the appropriate upper-layer protocol.
- **Hop Limit** - This 8-bit field replaces the IPv4 TTL field. This value is decremented by a value of 1 by each router that forwards the packet. When the counter reaches 0, the packet is discarded, and an ICMPv6 Time Exceeded message is forwarded to the sending host,. This indicates that the packet did not reach its destination because the hop limit was exceeded. Unlike IPv4, IPv6 does not include an IPv6 Header Checksum, because this function is performed at both the lower and upper layers. This means the checksum does not need to be recalculated by each router when it decrements the Hop Limit field, which also improves network performance.
- **Source IPv6 Address -** This 128-bit field identifies the IPv6 address of the sending host.

- **Destination IPv6 Address -** This 128-bit field identifies the IPv6 address of the receiving host.

  An IPv6 packet may also contain extension headers (EH), which provide optional network layer information. Extension headers are optional and are placed between the IPv6 header and the payload. EHs are used for fragmentation, security, to support mobility and more.

  Unlike IPv4, routers do not fragment routed IPv6 packets.