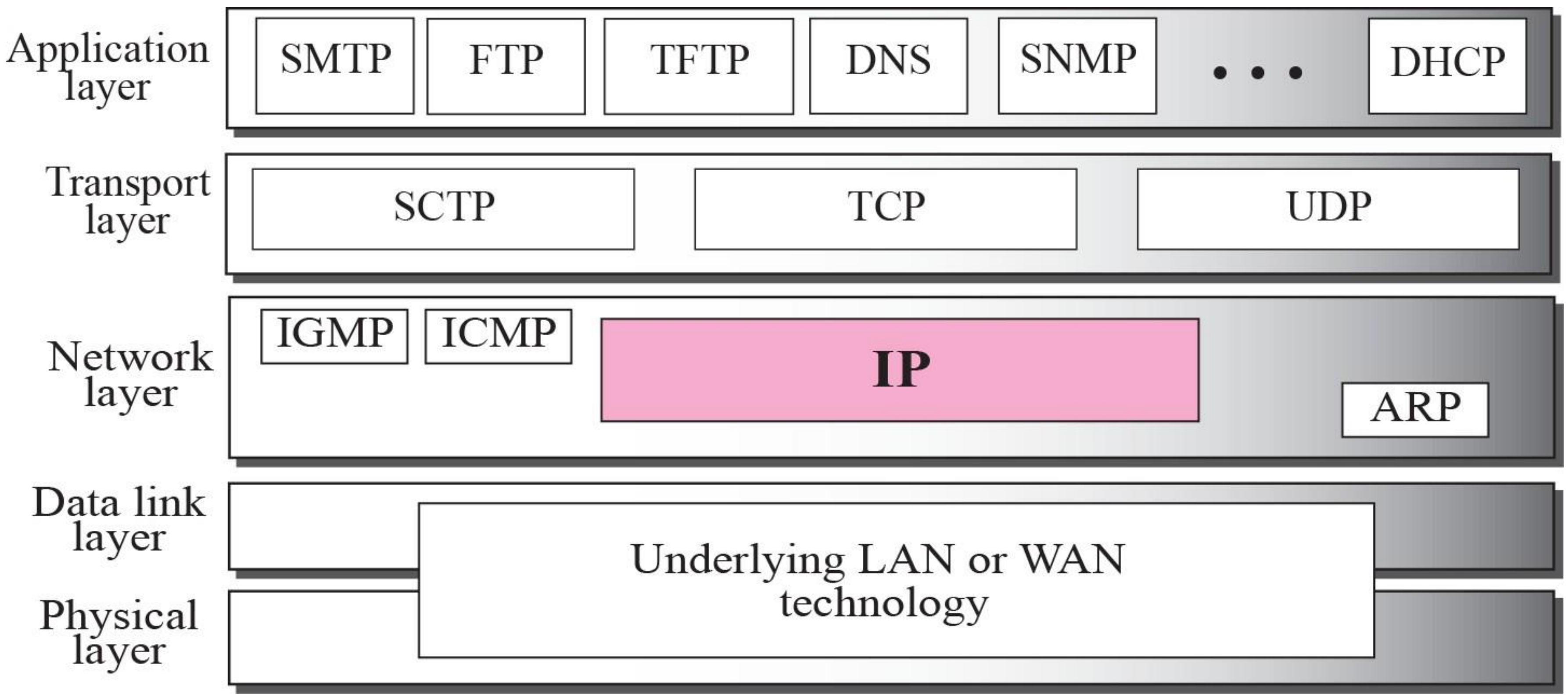
INTRODUCTION

The Internet Protocol (IP) is the transmission mechanism used by the TCP/IP protocols at the network layer.

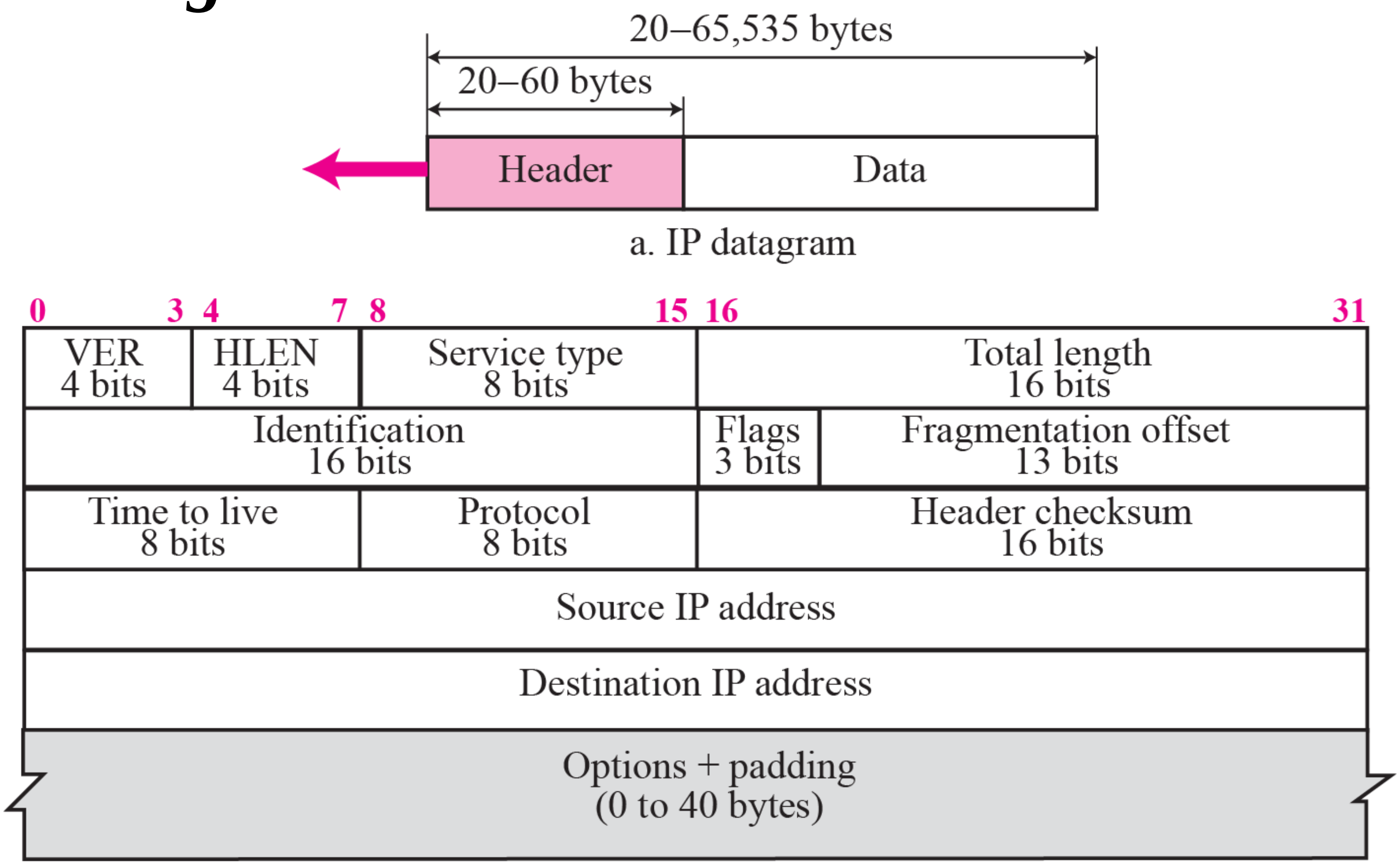
Figure *Position of IP in TCP/IP protocol suite*



DATAGRAMS

Packets in the network (internet) layer are called *datagrams*. A datagram is a variable-length packet consisting of two parts: header and data. The header is 20 to 60 bytes in length and contains information essential to routing and delivery. It is customary in TCP/IP to show the header in 4-byte sections. A brief description of each field is in order.

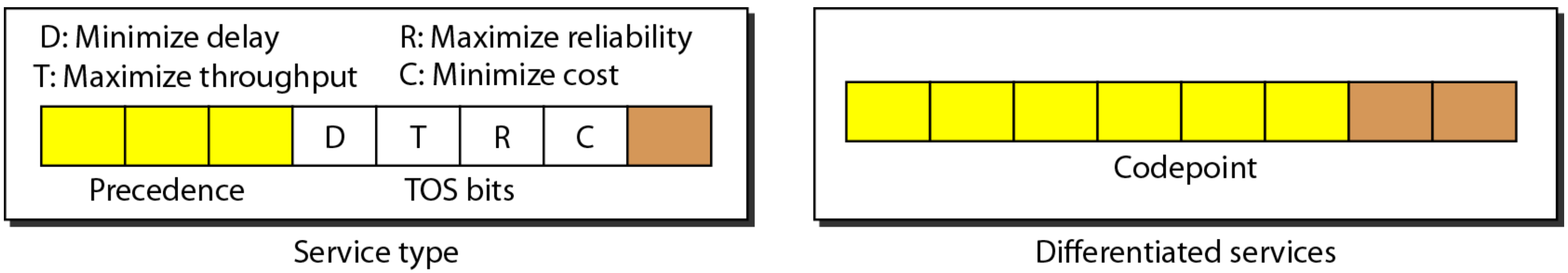
IP datagram



a. IP datagram

b. Header format

Service type or differentiated services



Types of service

TOS Bits	*Description*
0000	Normal (default)
0001	Minimize cost
0010	Maximize reliability
0100	Maximize throughput
1000	Minimize delay

Note

The total length field defines the total length of the datagram including the header.

Example

An IP packet has arrived with the first 8 bits as shown:

01000010

The receiver discards the packet. Why?

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01000010

The receiver discards the packet. Why?

Solution

There is an error in this packet. The 4 left-most bits (0100) show the version, which is correct. The next 4 bits (0010) show the wrong header length ($2 \times 4 = 8$). The minimum number of bytes in the header must be 20. The packet has been corrupted in transmission.

CODERINDEED

Example 7.2

In an IP packet, the value of HLEN is 1000 in binary. How many bytes of options are being carried by this packet?

a) 32
b) 12
c) 20

Example

In an IP packet, the value of HLEN is 1000 in binary. How many bytes of options are being carried by this packet?

Solution

The HLEN value is 8, which means the total number of bytes in the header is 8×4 or 32 bytes. The first 20 bytes are the base header, the next 12 bytes are the options.

Example

In an IP packet, the value of HLEN is 5_{16} and the value of the total length field is 0028_{16}. How many bytes of data are being carried by this packet?

a) 40
b) 30
c) 20

Example

In an IP packet, the value of HLEN is 5_{16} and the value of the total length field is 0028_{16}. How many bytes of data are being carried by this packet?

Solution

The HLEN value is 5, which means the total number of bytes in the header is 5 × 4 or 20 bytes (no options). The total length is 40 bytes, which means the packet is carrying 20 bytes of data (40 − 20).

An IP packet has arrived with the first few hexadecimal digits as shown below:

45000028000100000102 . . .

How many hops can this packet travel before being dropped? The data belong to what upper layer protocol?

Solution

To find the time-to-live field, we skip 8 bytes (16 hexadecimal digits). The time-to-live field is the ninth byte, which is 01. This means the packet can travel only one hop. The protocol field is the next byte (02), which means that the upper layer protocol is IGMP (see Table 7.2)

Figure ***Multiplexing***

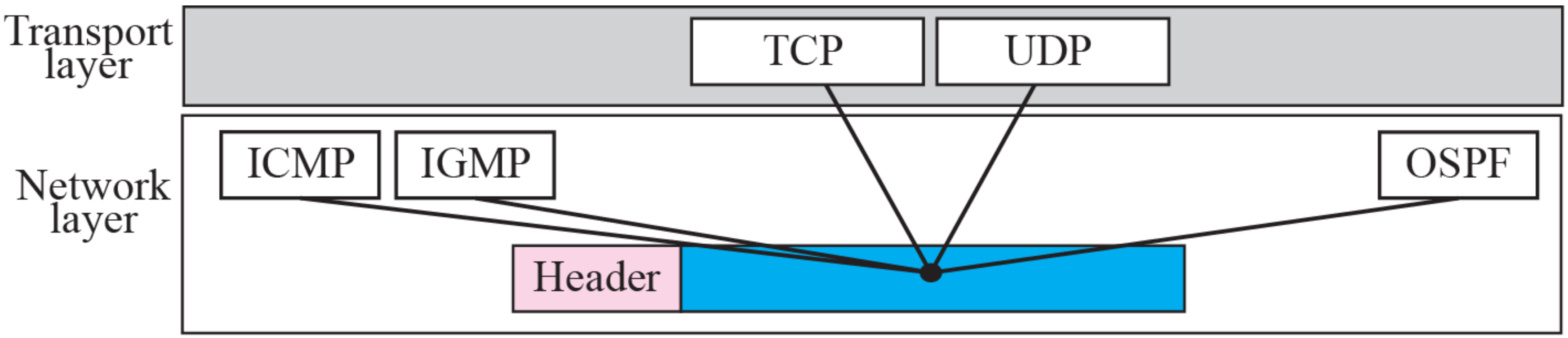


Table 7.2 *Protocols*

Value	*Protocol*	*Value*	*Protocol*
1	ICMP	17	UDP
2	IGMP	89	OSPF
6	TCP		

FRAGMENTATION

A datagram can travel through different networks. Each router decapsulates the IP datagram from the frame it receives, processes it, and then encapsulates it in another frame. The format and size of the received frame depend on the protocol used by the physical network through which the frame has just traveled. The format and size of the sent frame depend on the protocol used by the physical network through which the frame is going to travel.

Topics Discussed in the Section

- ✓ Maximum Transfer Unit (MTU)
- ✓ Fields Related to Fragmentation

Figure ***Encapsulation of a small datagram in an Ethernet frame***

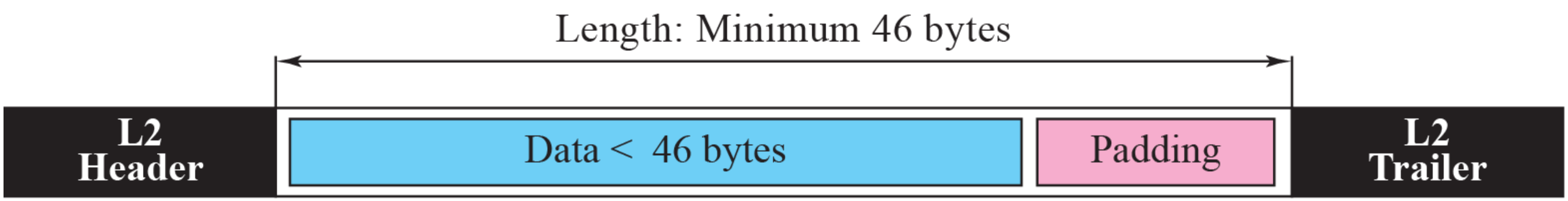


Figure ***MTU***

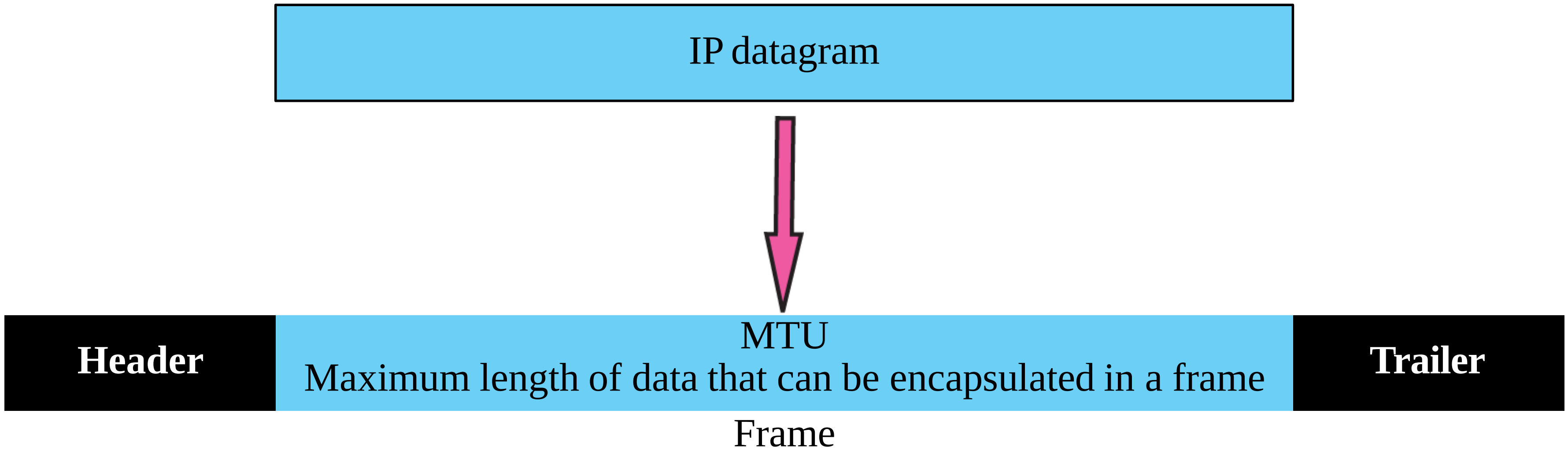

IP datagram
Header
MTU
Maximum length of data that can be encapsulated in a frame
Trailer
Frame

Table ***MTUs for some networks***

Protocol	*MTU*
Hyperchannel	65,535
Token Ring (16 Mbps)	17,914
Token Ring (4 Mbps)	4,464
FDDI	4,352
Ethernet	1,500
X.25	576
PPP	296

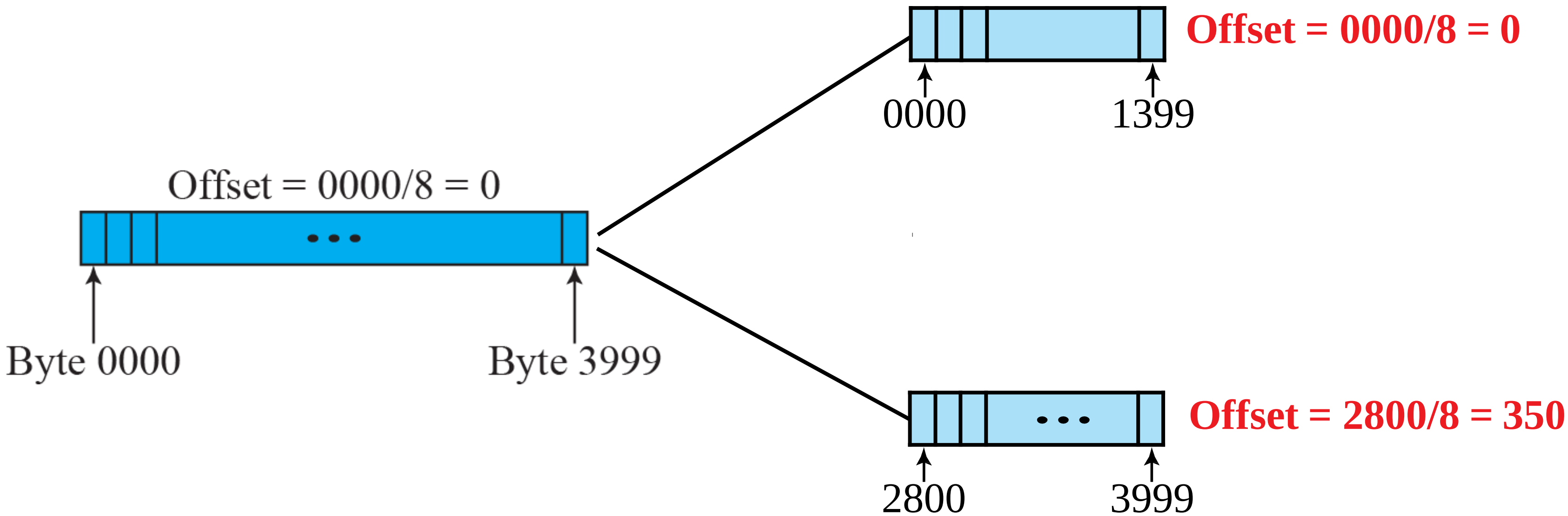
Note

Only data in a datagram is fragmented.

Figure ***Flags field***

D: Do not fragment
M: More fragments

Figure ***Fragmentation example***



In ipv4 header, which field is needed to allow the destination host to determine which datagram a newly arrived fragments belongs to.

a) Identification

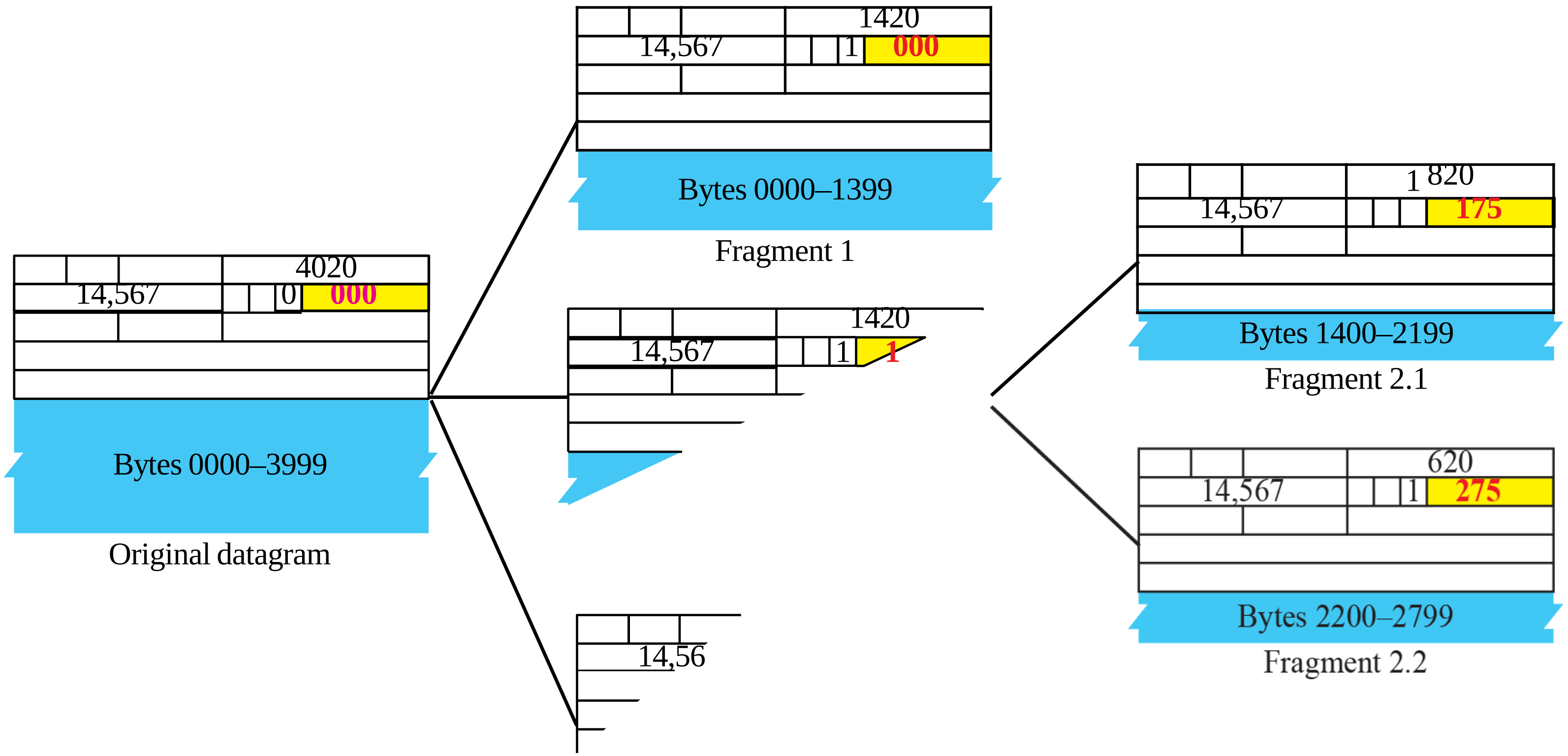
b) Fragment offset

c) Time to live

d) Header checksum

- Ans A

Figure *Detailed fragmentation example*



A packet has arrived with an M bit value of 0. Is this the first fragment, the last fragment, or a middle fragment? Do we know if the packet was fragmented?

Solution

If the M bit is 0, it means that there are no more fragments; the fragment is the last one. However, we cannot say if the original packet was fragmented or not. A non fragmented packet is considered the last fragment.

A packet has arrived with an M bit value of 1. Is this the first fragment, the last fragment, or a middle fragment? Do we know if the packet was fragmented?

Solution

If the M bit is 1, it means that there is at least one more fragment. This fragment can be the first one or a middle one, but not the last one. We don’t know if it is the first one or a middle one; we need more information (the value of the fragmentation offset). See also the next example.

A packet has arrived with an M bit value of 1 and a fragmentation offset value of zero. Is this

a) the first fragment
b) the last fragment
c) middle fragment

A packet has arrived with an M bit value of 1 and a fragmentation offset value of zero. Is this the first fragment, the last fragment, or a middle fragment?

Solution

Because the M bit is 1, it is either the first fragment or a middle one. Because the offset value is 0, it is the first fragment.

A packet has arrived in which the offset value is 100. What is the number of the first byte? Do we know the number of the last byte?

A packet has arrived in which the offset value is 100. What is the number of the first byte? Do we know the number of the last byte?

Solution

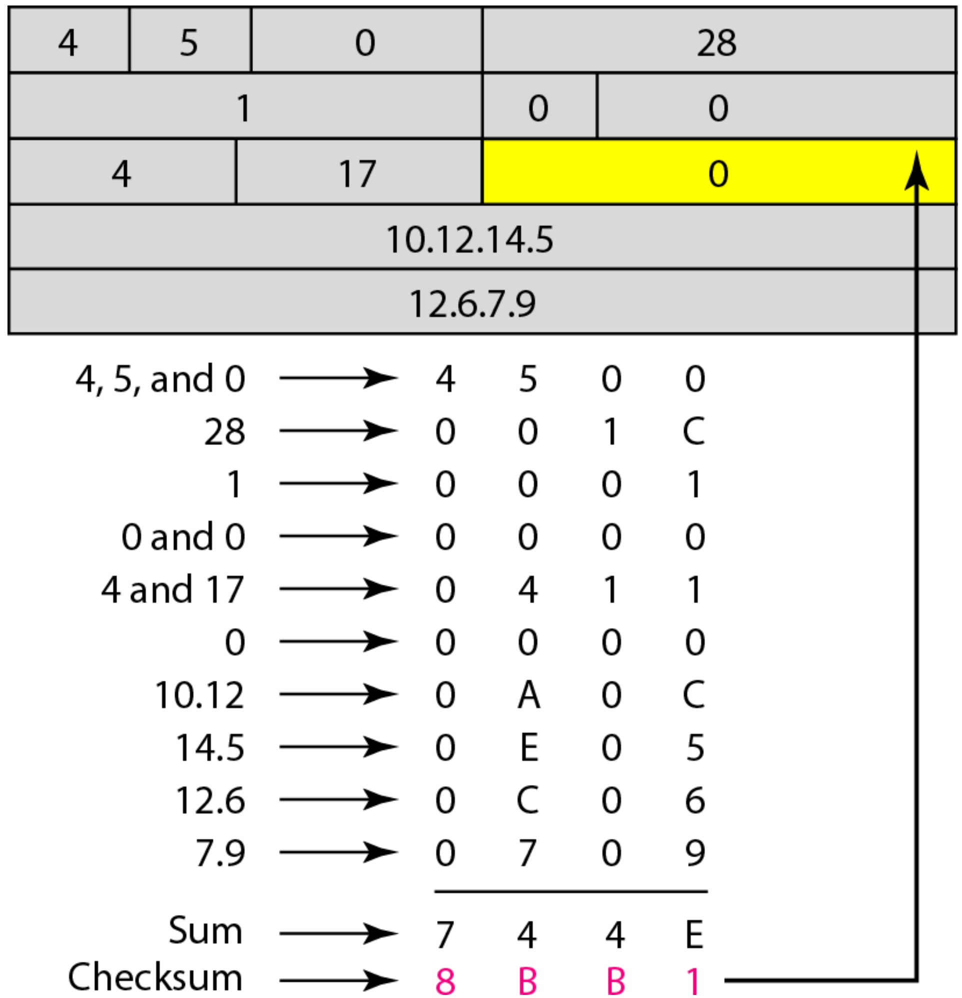
To find the number of the first byte, we multiply the offset value by 8. This means that the first byte number is 800. We cannot determine the number of the last byte unless we know the length of the data.

A packet has arrived in which the offset value is 100, the value of HLEN is 5 and the value of the total length field is 100. What is the number of the first byte and the last byte?

Solution

The first byte number is 100 $\times$ 8 = 800. The total length is 100 bytes and the header length is 20 bytes (5 $\times$ 4), which means that there are 80 bytes in this datagram. If the first byte number is 800, the last byte number must be 879.

Figure *Example of checksum calculation in IPv4*

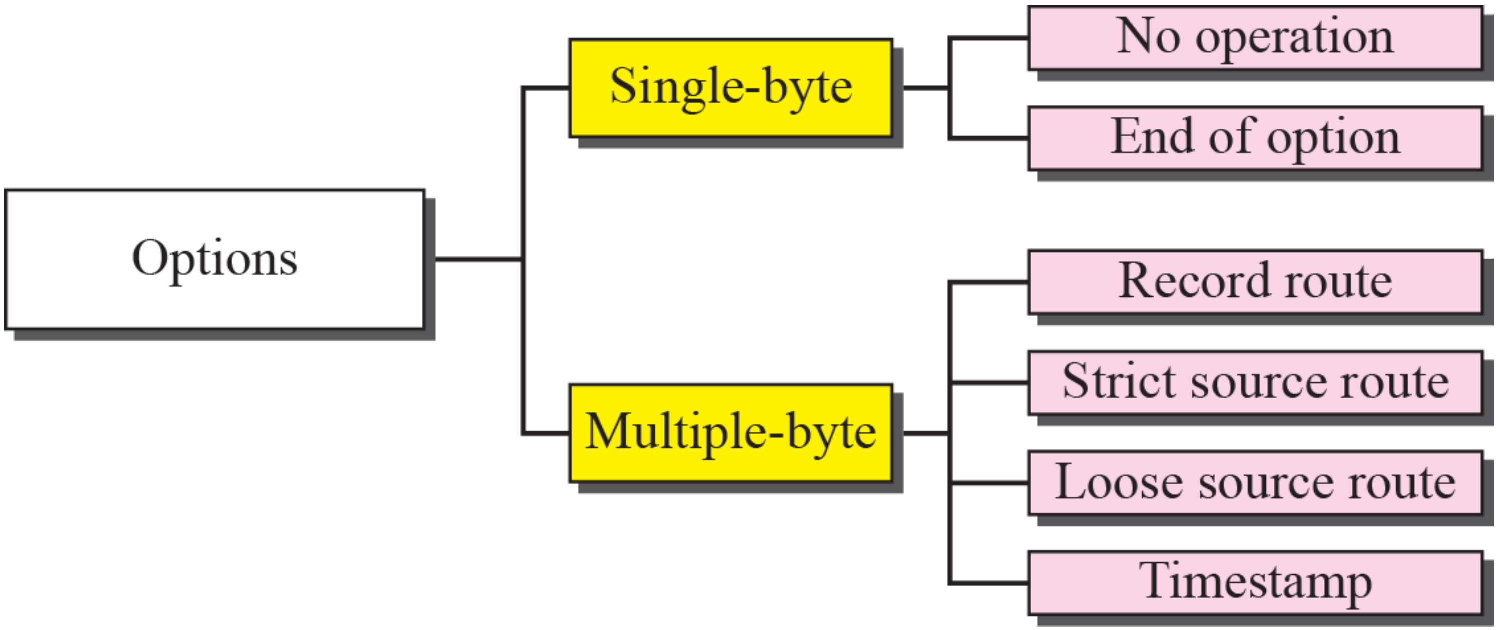


OPTIONS

The header of the IP datagram is made of two parts: a fixed part and a variable part. The fixed part is 20 bytes long and was discussed in the previous section. The variable part comprises the options, which can be a maximum of 40 bytes.

Options, as the name implies, are not required for a datagram. They can be used for network testing and debugging. Although options are not a required part of the IP header, option processing is required of the IP software.

Figure ***Categories of options***



IPv6 PACKET FORMAT

Each packet is composed of a mandatory base header followed by the payload. The payload consists of two parts: optional extension headers and data from an upper layer. The base header occupies 40 bytes, whereas the extension headers and data from the upper layer contain up to 65,535 bytes of information.

Figure ***IPv6 datagram header and payload***

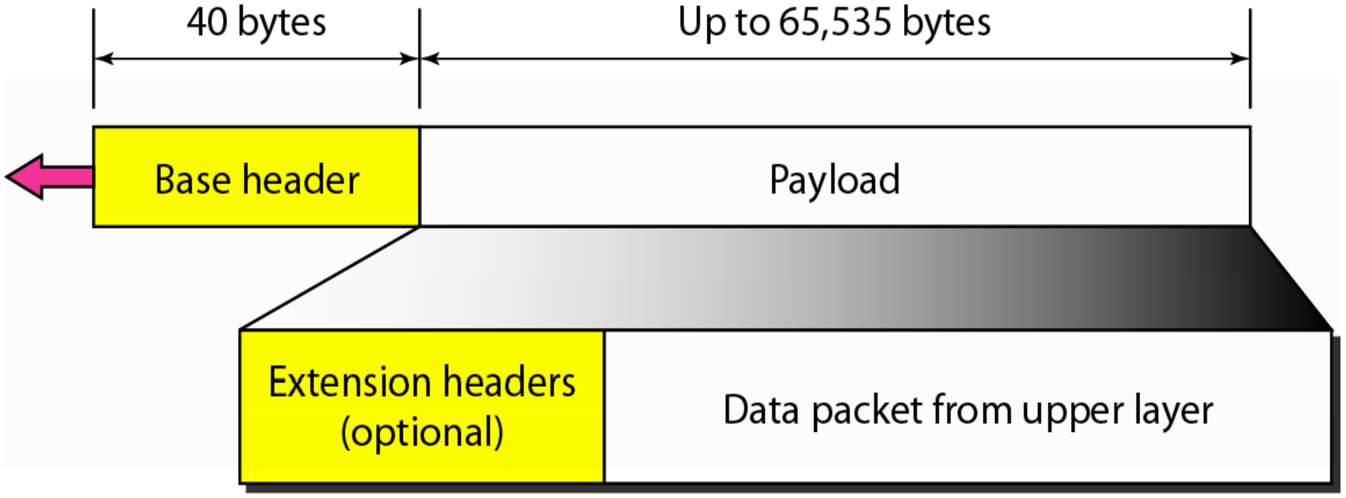


Figure ***Format of the base header***

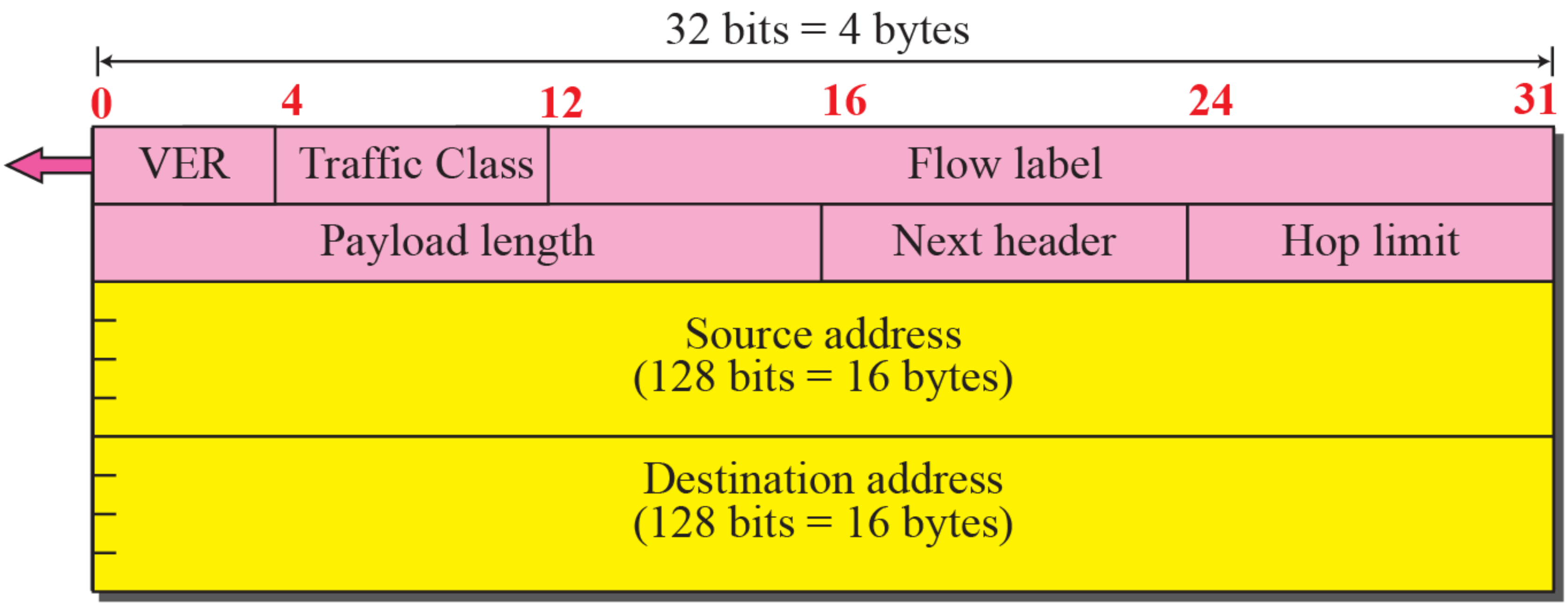
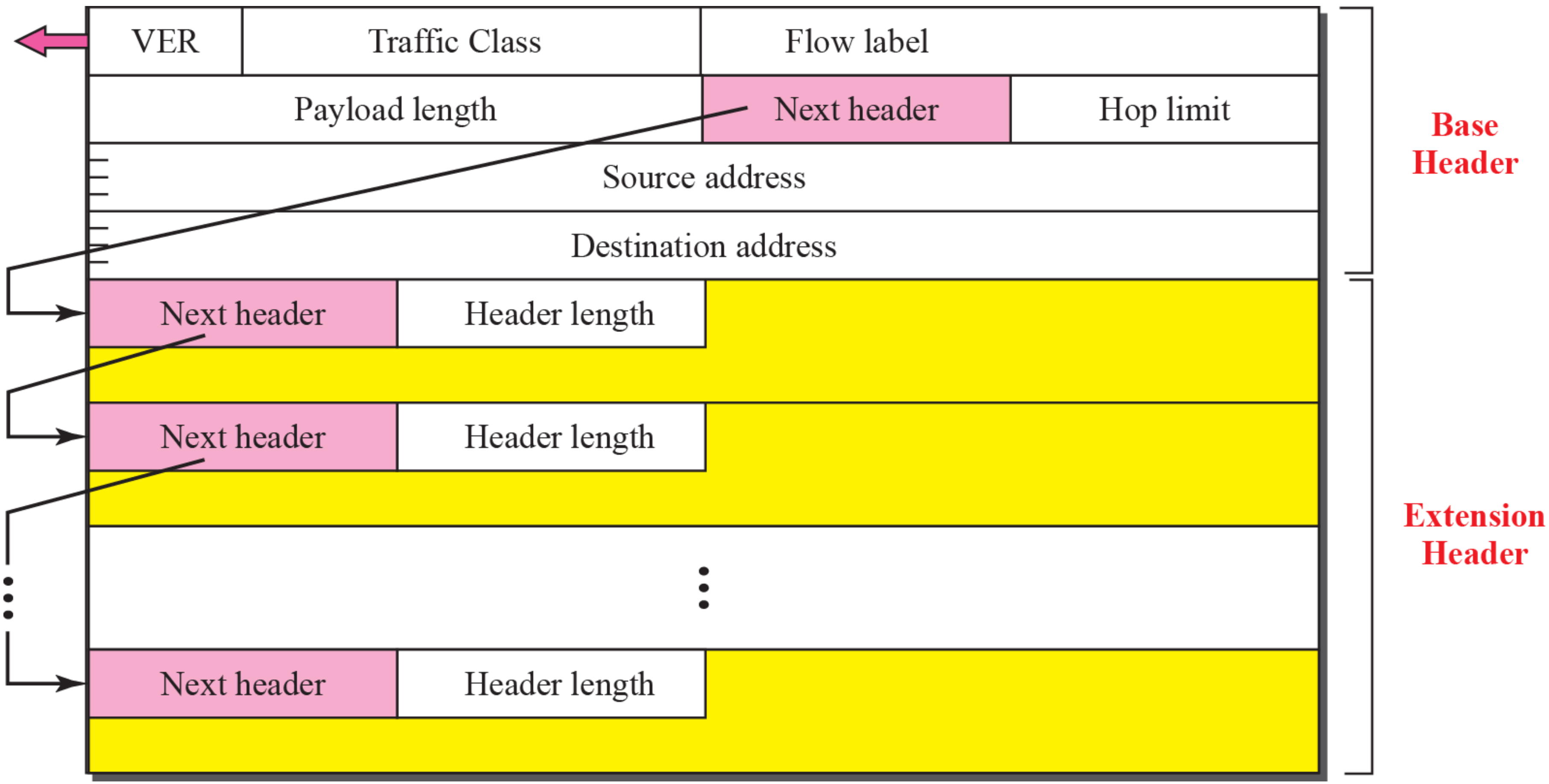


Table 27.1 *Next Header Codes*

Code	*Next Header*	*Code*	*Next Header*
0	Hop-by-hop option	44	Fragmentation
2	ICMP	50	Encrypted security payload
6	TCP	51	Authentication
17	UDP	59	Null (No next header)
43	Source routing	60	Destination option

Figure ***Extension header format***



The hop limit field has value 10. How many routers (max) can process this datagram?

A) 9

B) 5

C) 10

D) 1

Table ***Comparison between IPv4 and IPv6 packet***

Comparison
1. The header length field is eliminated in IPv6 because the length of the header is fixed in this version.
2. The service type field is eliminated in IPv6. The priority and flow label fields together take over the function of the service type field.
3. The total length field is eliminated in IPv6 and replaced by the payload length field.
4. The identification, flag, and offset fields are eliminated from the base header in IPv6. They are included in the fragmentation extension header.
5. The TTL field is called hop limit in IPv6.
6. The protocol field is replaced by the next header field.
7. The header checksum is eliminated because the checksum is provided by upper-layer protocols; it is therefore not needed at this level.
8. The option fields in IPv4 are implemented as extension headers in IPv6.

Figure *Extension header types*

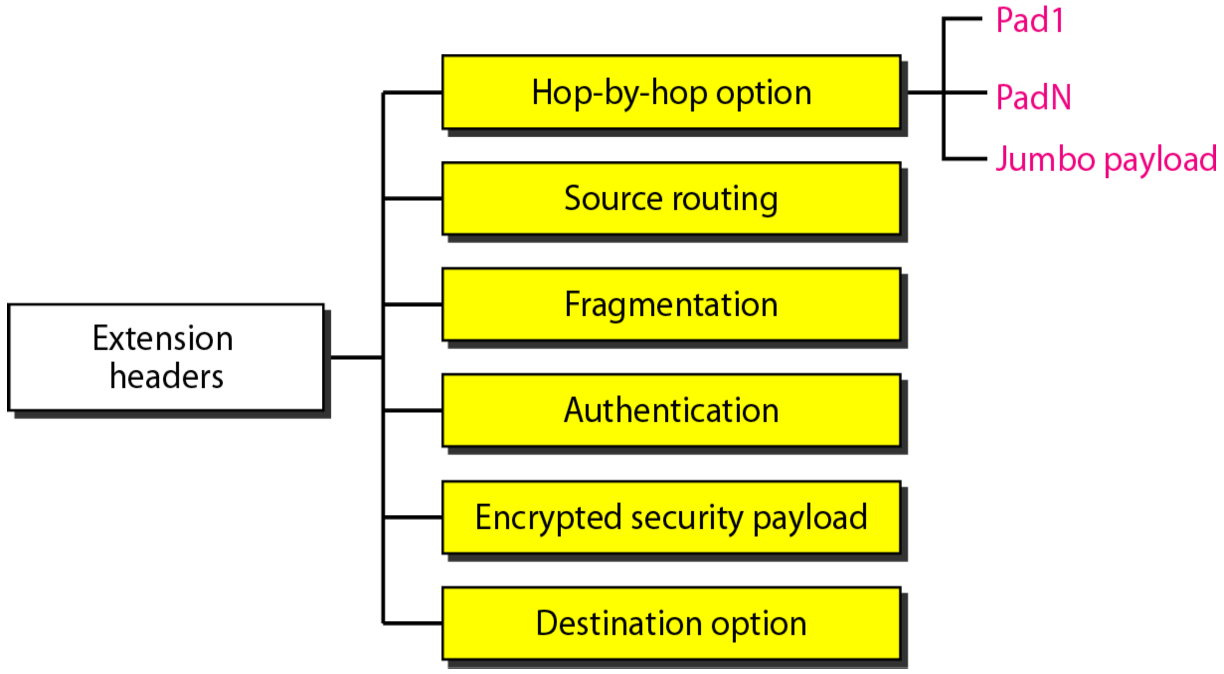


Table ***Comparison between IPv4 options and IPv6 extension headers***

Comparison
1. The no-operation and end-of-option options in IPv4 are replaced by Pad1 and PadN options in IPv6.
2. The record route option is not implemented in IPv6 because it was not used.
3. The timestamp option is not implemented because it was not used.
4. The source route option is called the source route extension header in IPv6.
5. The fragmentation fields in the base header section of IPv4 have moved to the fragmentation extension header in IPv6.
6. The authentication extension header is new in IPv6.
7. The encrypted security payload extension header is new in IPv6.

In the IPv6 header, the traffic class field is similar to which field in the IPv4 header?

a) Fragmentation field

b) Fast-switching

c) ToS field

d) Option field

Transition from IPv4 to IPv6

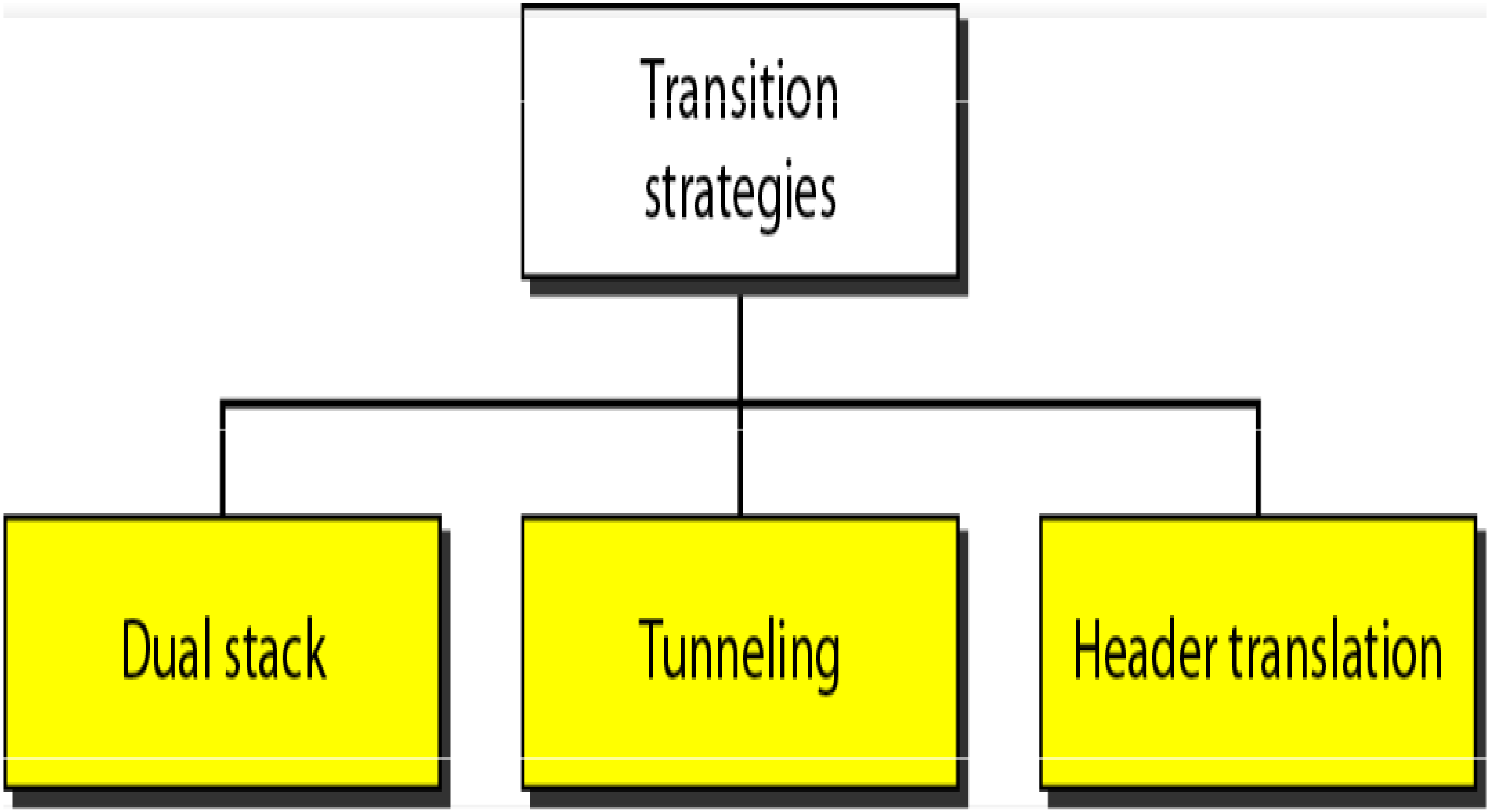


Figure *Dual stack*

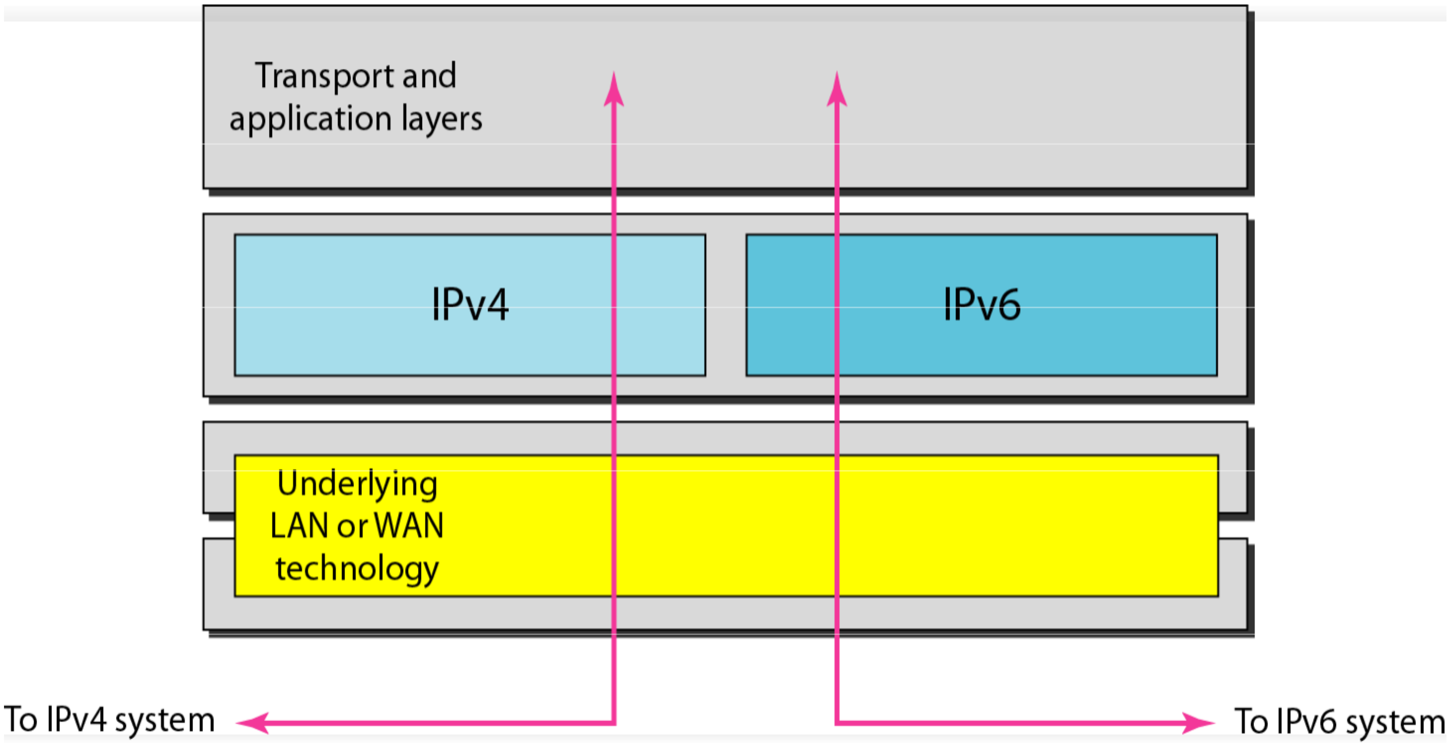


Figure *Tunneling strategy*

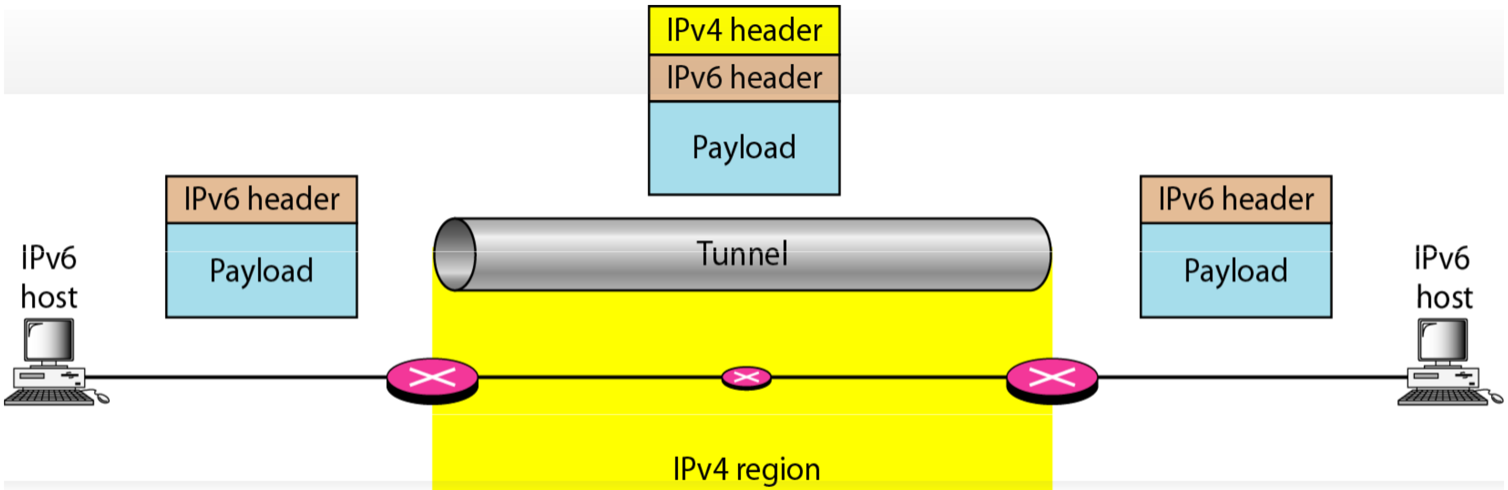


Figure 20.21 *Header translation strategy*