IP Header Format and Datagram

4. What is the maximum number of IP addresses that can be assigned to hosts on a local subnet that uses the 255.255.255.224 subnet mask?

A. ○ 14

B. ○ 15

C. ○ 16

D. ○ 30

1. Your router has the following IP address on Ethernet0: 172.16.2.1/23. Which of the following can be valid host IDs on the LAN interface attached to the router?
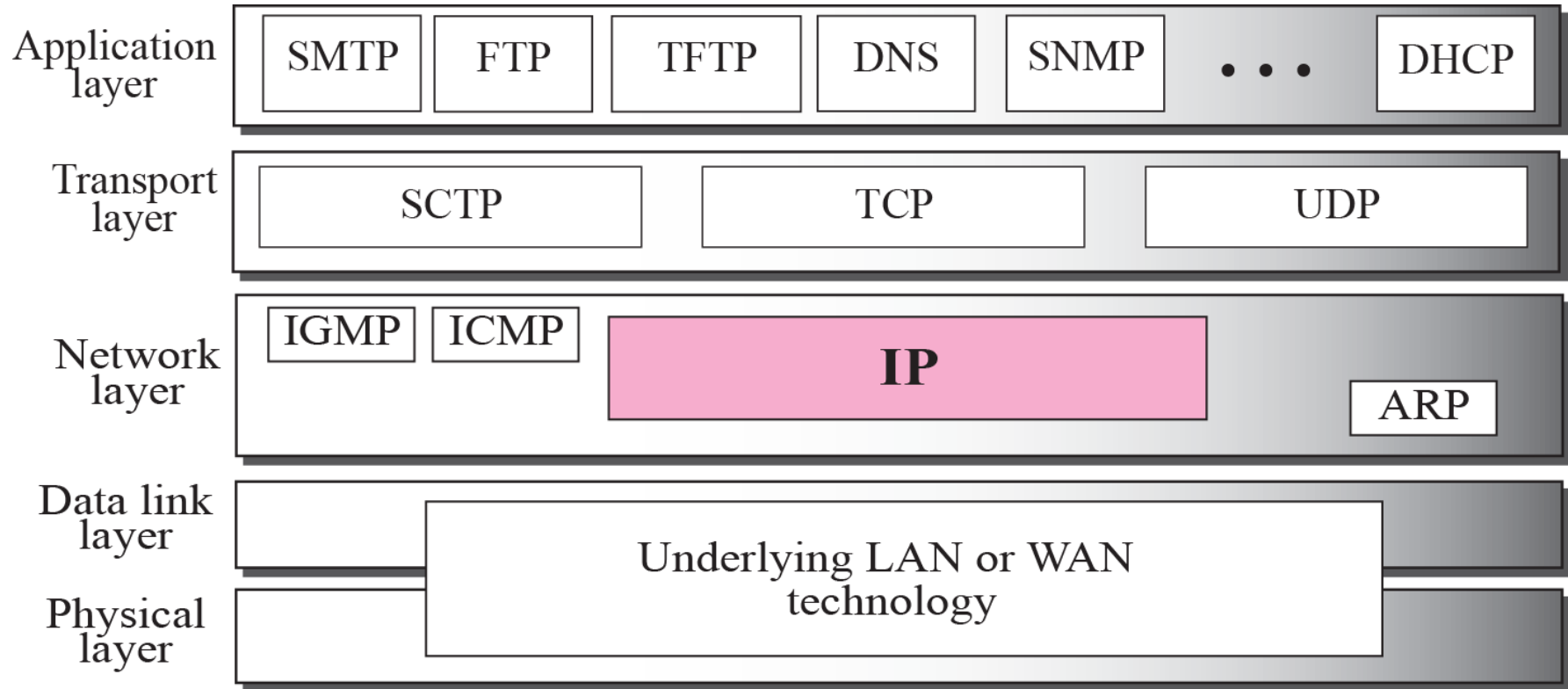
1. 172.16.1.100
2. 172.16.1.198
3. 172.16.2.255
4. 172.16.3.0

A. ○ 1 only

B. ○ 2 and 3 only

C. ○ 3 and 4 only

D. ○ None of the above

E. ○ 2 and 5 only

INTRODUCTION

The Internet Protocol (IP) is the transmission mechanism used by the TCP/IP protocols at the network layer.
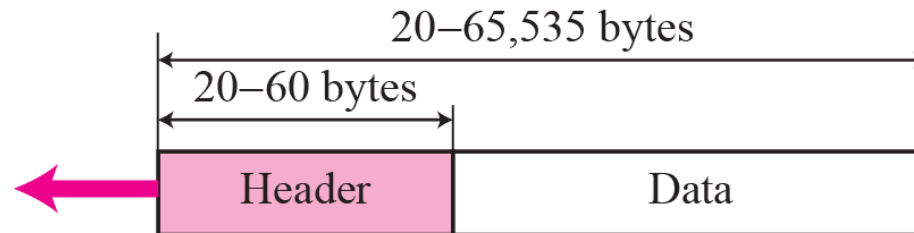
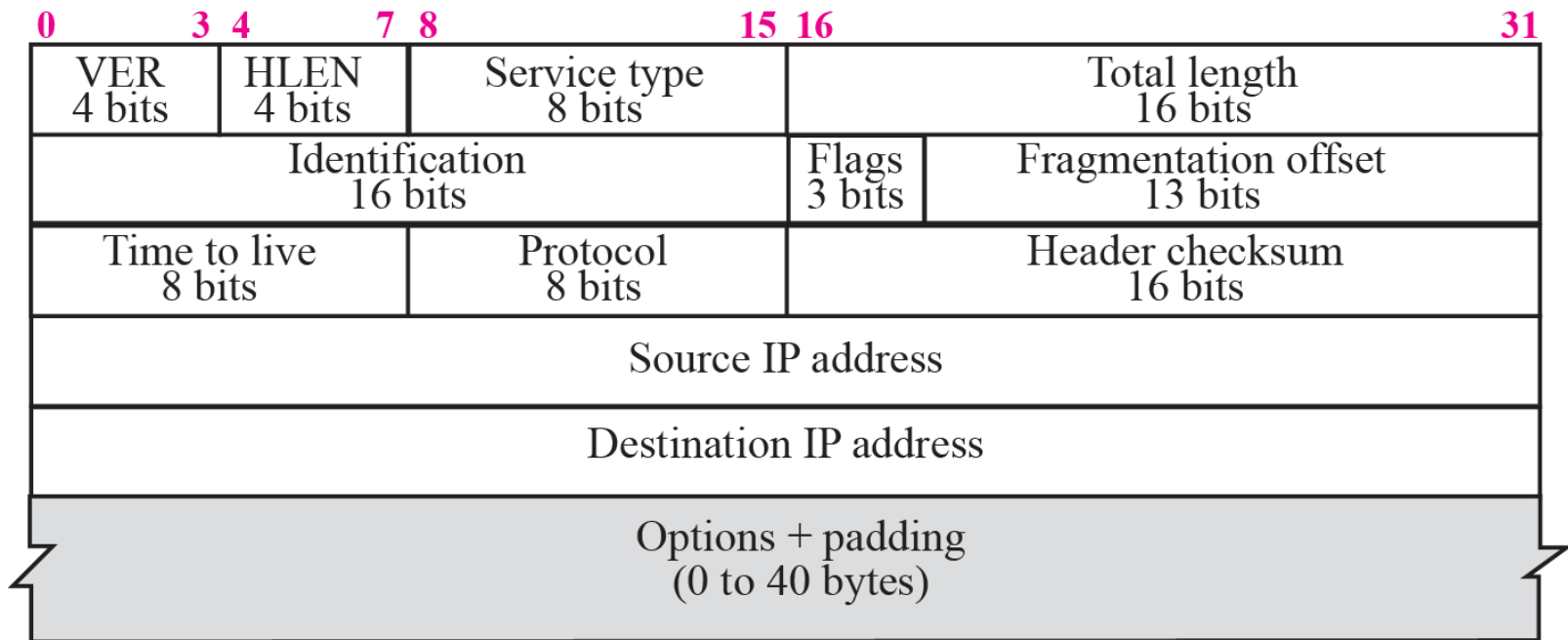| Application layer | SMTP | FTP | TFTP | DNS | SNMP | • • • | DHCP |
Transport layer	SCTP		TCP		UDP		
Network layer	IGMP	ICMP	IP			ARP	
Data link layer		Underlying LAN or WAN technology					
Physical layer							

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 normal in TCP/IP to show the header in 4-byte sections. A brief description of each field is in order.
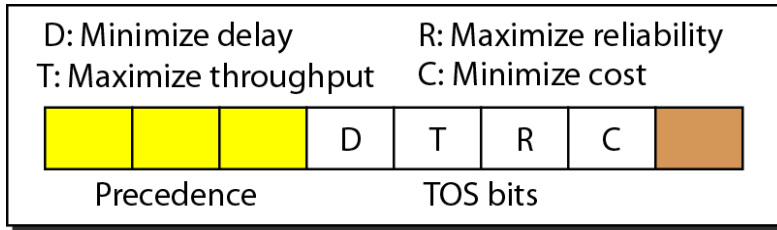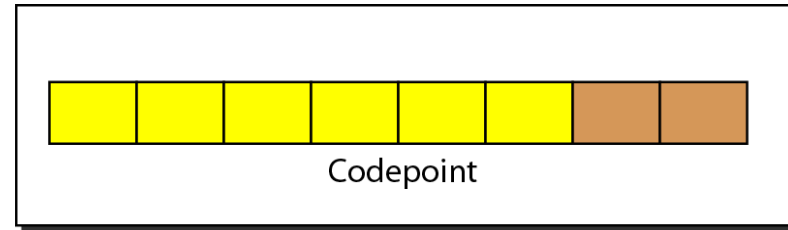
IP datagram

```
                    20–65,535 bytes
              20–60 bytes
       ←━━━  ┌─────────────┬─────────────────────┐
             │   Header    │        Data         │
             └─────────────┴─────────────────────┘
```

a. IP datagram

0 3	4 7	8 15	16 31
VER 4 bits	HLEN 4 bits	Service type 8 bits	Total length 16 bits
Identification 16 bits		Flags 3 bits	Fragmentation offset 13 bits
Time to live 8 bits		Protocol 8 bits	Header checksum 16 bits
Source IP address			
Destination IP address			
Options + padding (0 to 40 bytes)			

b. Header format

Service type or differentiated services

Service type

Differentiated services

Types of service

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

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 × 4 = 8). The minimum number of bytes in the header must be 20. The packet has been corrupted in transmission.

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 $\times$ 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?
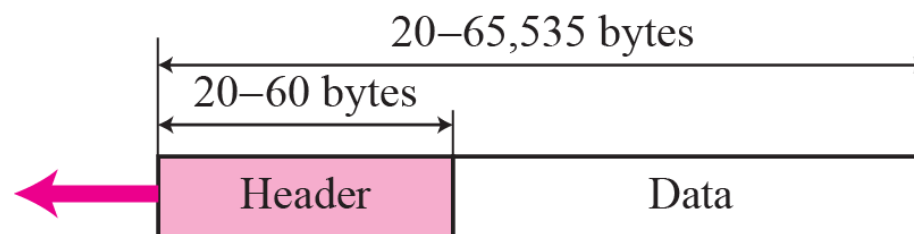
a) 40
b) 30
c) 20

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).
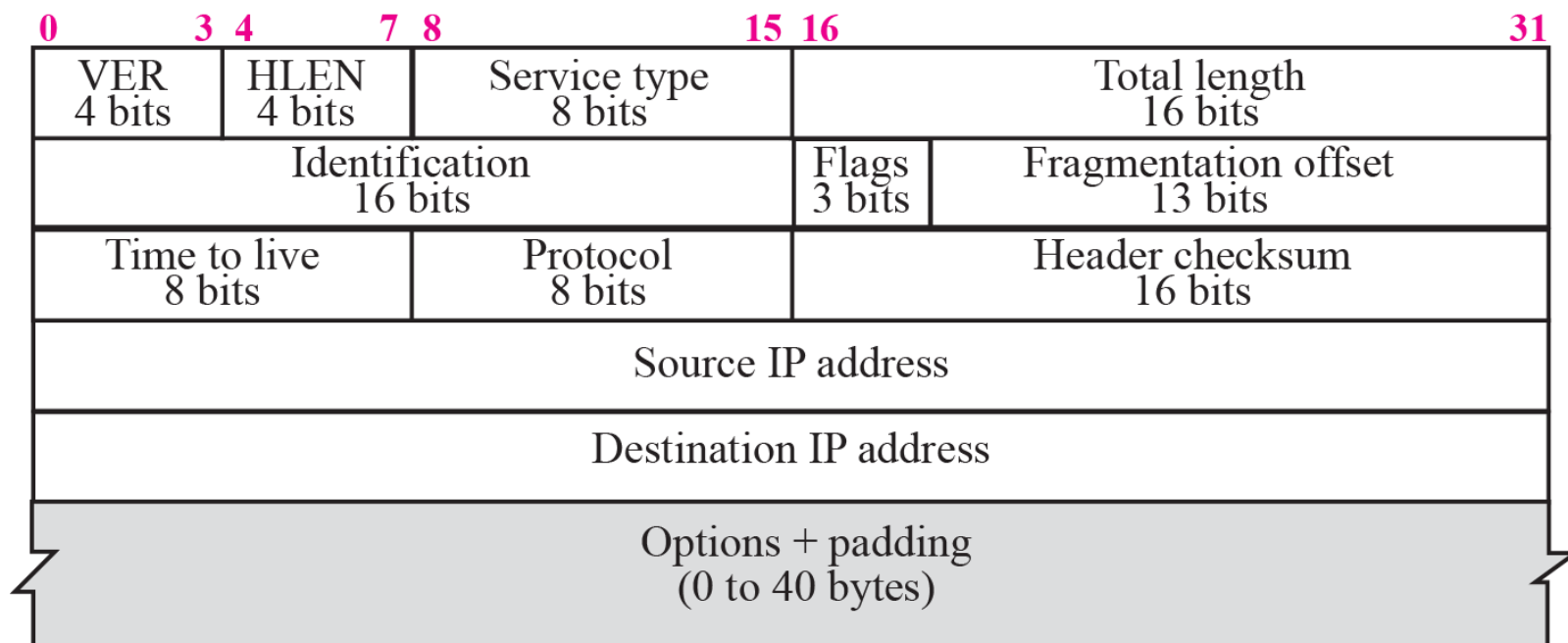
Table 7.2 Protocols

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

IP datagram

a. IP datagram

VER 4 bits	HLEN 4 bits	Service type 8 bits	Total length 16 bits		
Identification 16 bits			Flags 3 bits	Fragmentation offset 13 bits	
Time to live 8 bits		Protocol 8 bits	Header checksum 16 bits		
Source IP address					
Destination IP address					
Options + padding (0 to 40 bytes)					

b. Header format
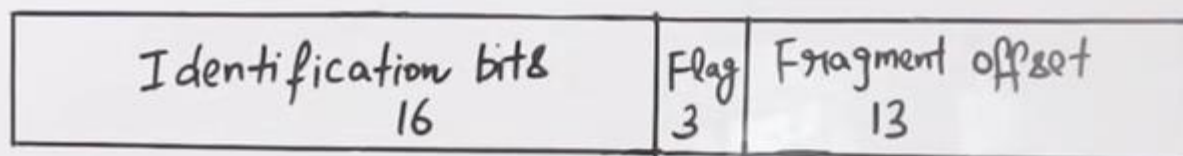
Topics Discussed in the Section

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

Figure *MTU*

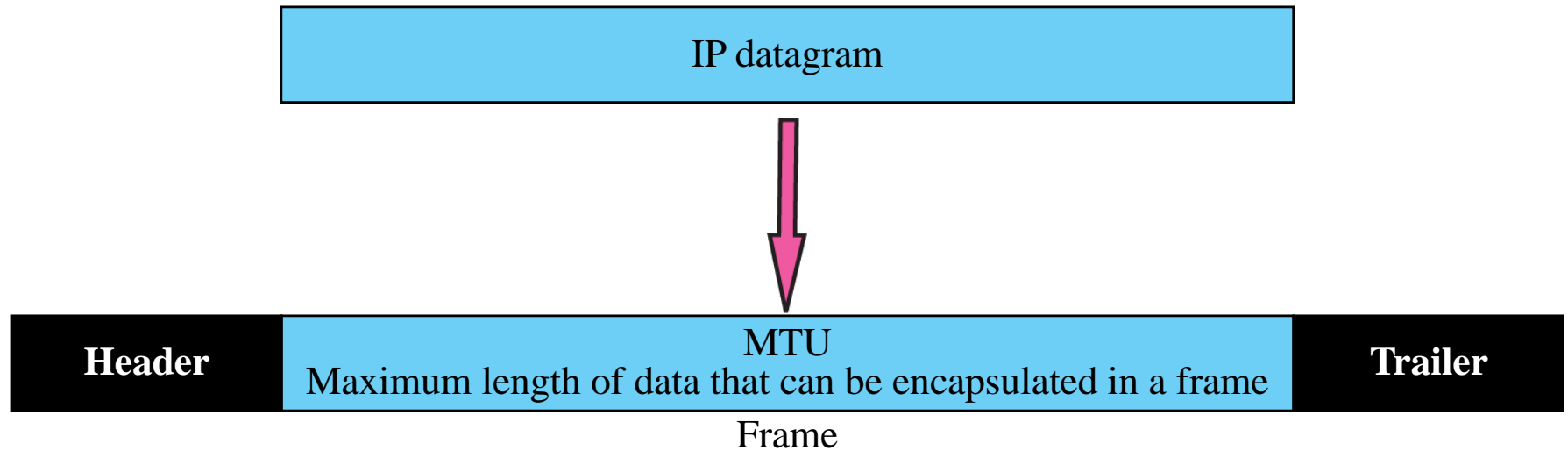IP datagram

| 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

Only data in a datagram is fragmented.

Figure *Flags field*

D: Do not fragment
M: More fragments

	D	M

A datagram of 3000 B (20 B of IP header + 2980 B IP Payload) reached at Router and must be forward to link with MTU of 500 B. How many fragments will be generated and also write MF, offset, Total length value for all.
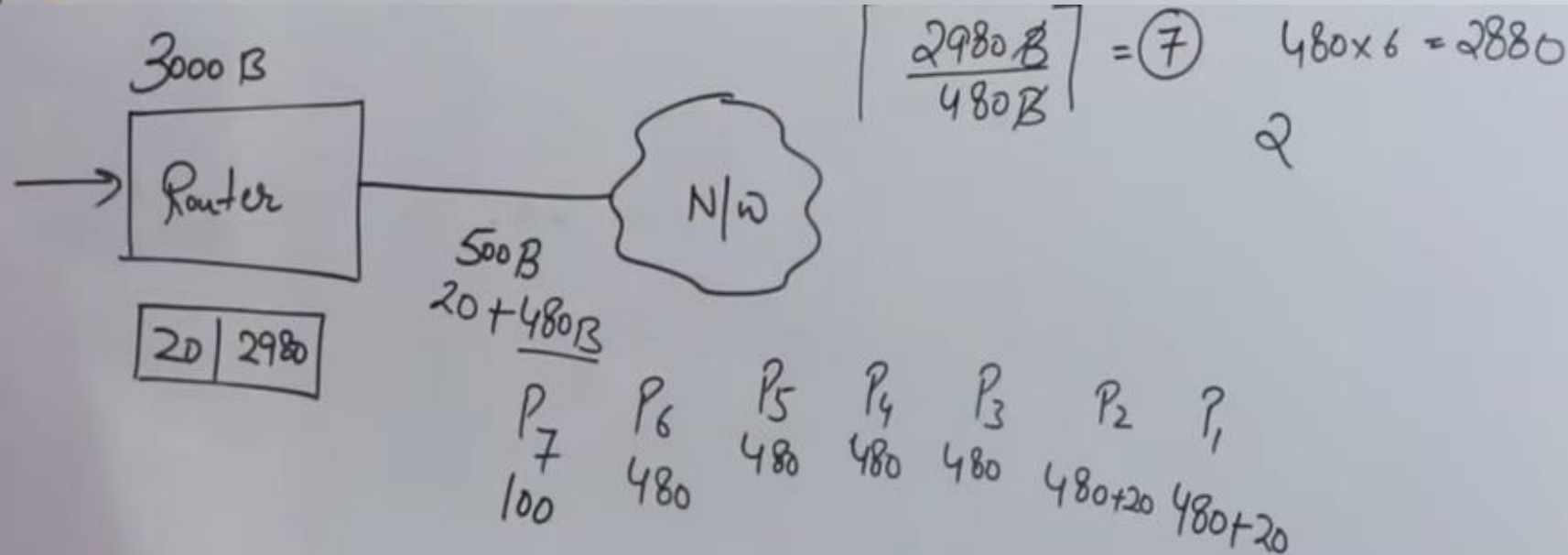
$$\left\lceil \frac{2980\,B}{480\,B} \right\rceil = \boxed{7} \qquad 480 \times 6 = 2880$$

3000 B

2

P_7	P_6	P_5	P_4	P_3	P_2	P_1
7	480	480	480	480	480+20	480+20
100						

Router

20 | 2980

500 B
20 + 480 B
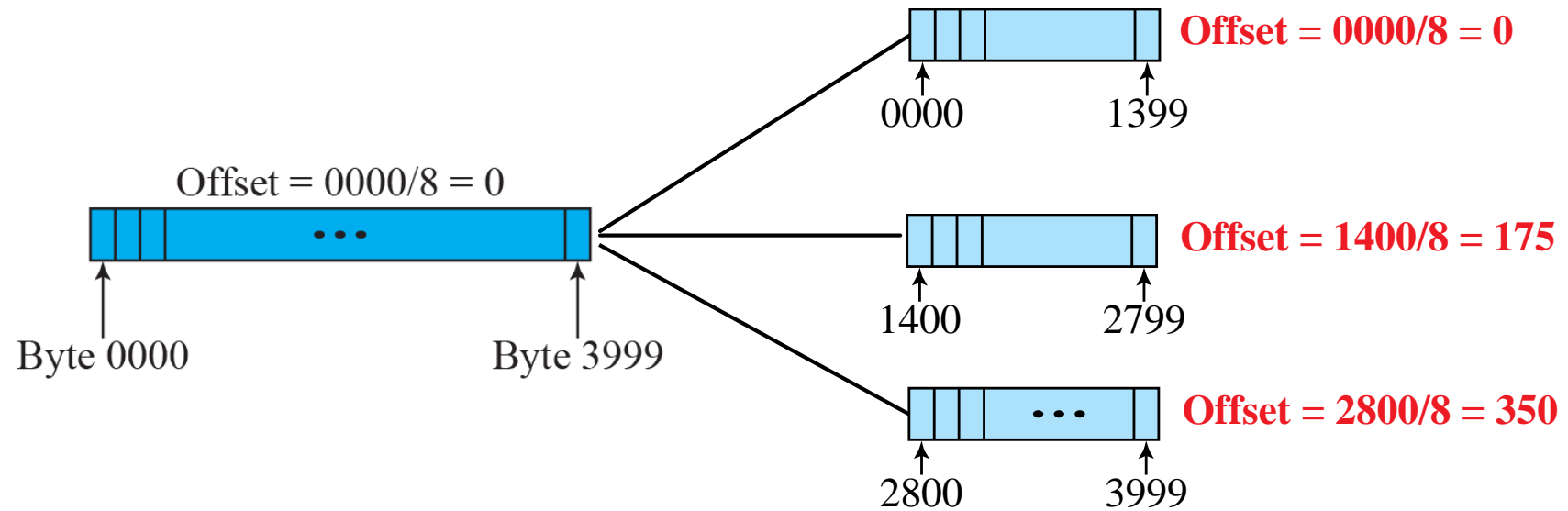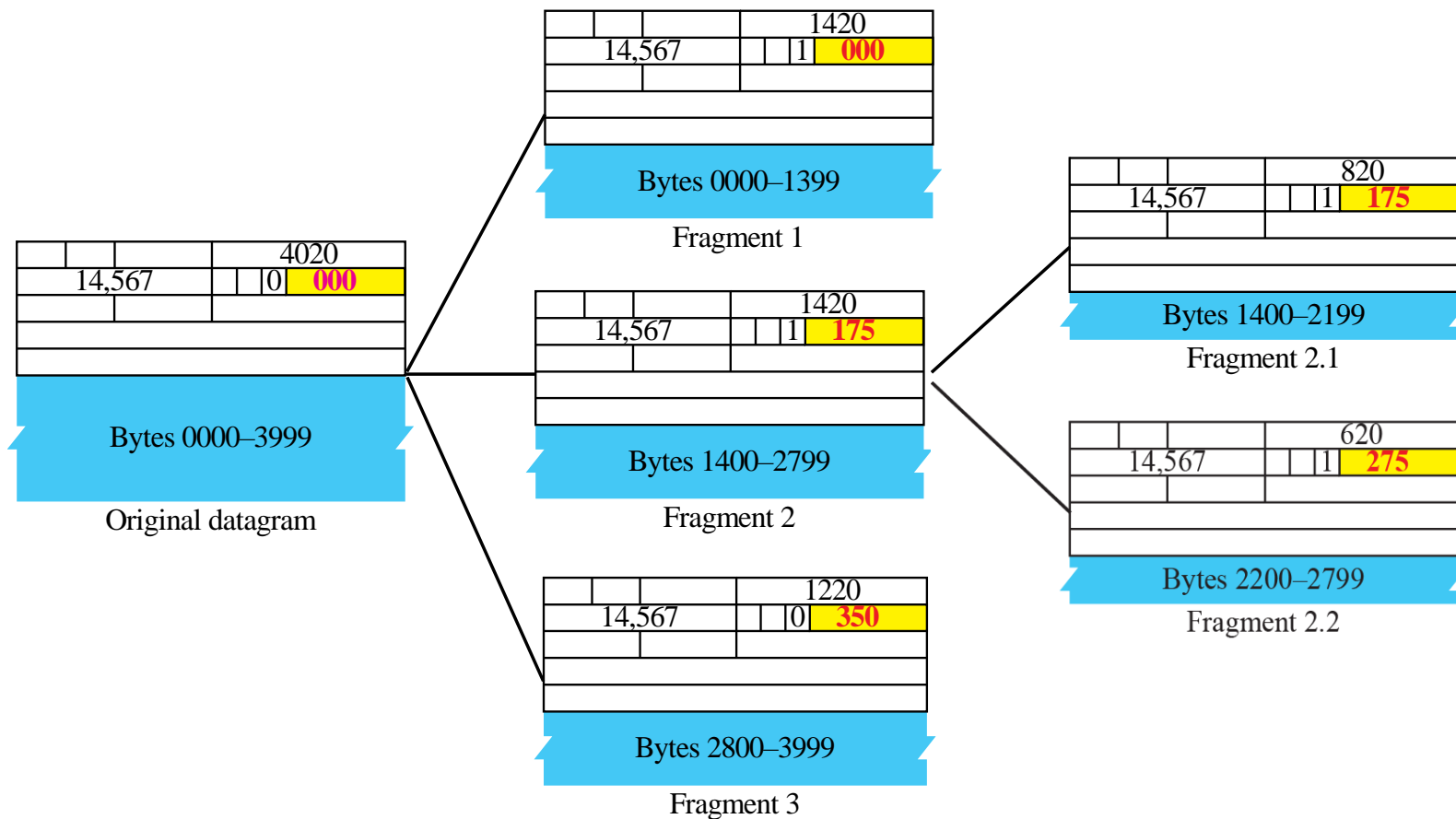
Figure *Fragmentation example*

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 × 8 = 800. The total length is 100 bytes and the header length is 20 bytes (5 × 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*

4	5	0	28
1		0	0
4	17	0	
10.12.14.5			
12.6.7.9			

4, 5, and 0	⟶	4	5	0	0
28	⟶	0	0	1	C
1	⟶	0	0	0	1
0 and 0	⟶	0	0	0	0
4 and 17	⟶	0	4	1	1
0	⟶	0	0	0	0
10.12	⟶	0	A	0	C
14.5	⟶	0	E	0	5
12.6	⟶	0	C	0	6
7.9	⟶	0	7	0	9
Sum	⟶	7	4	4	E
Checksum	⟶	8	B	B	1

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*
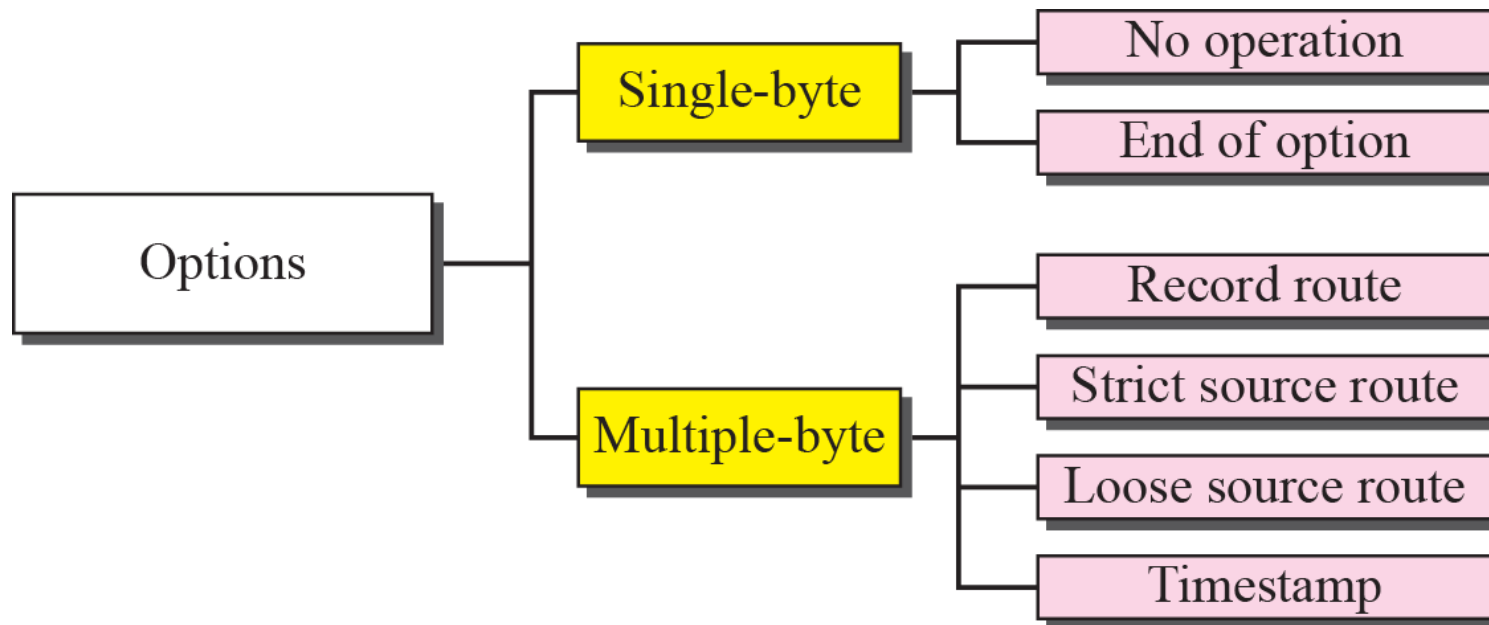
IPv6 PACKET FORMAT

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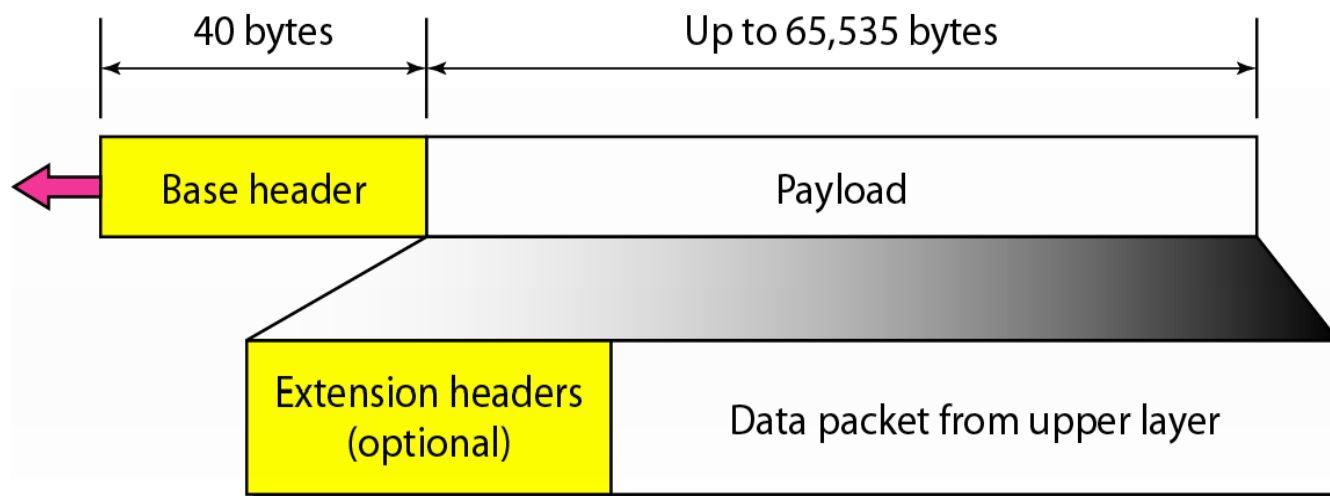
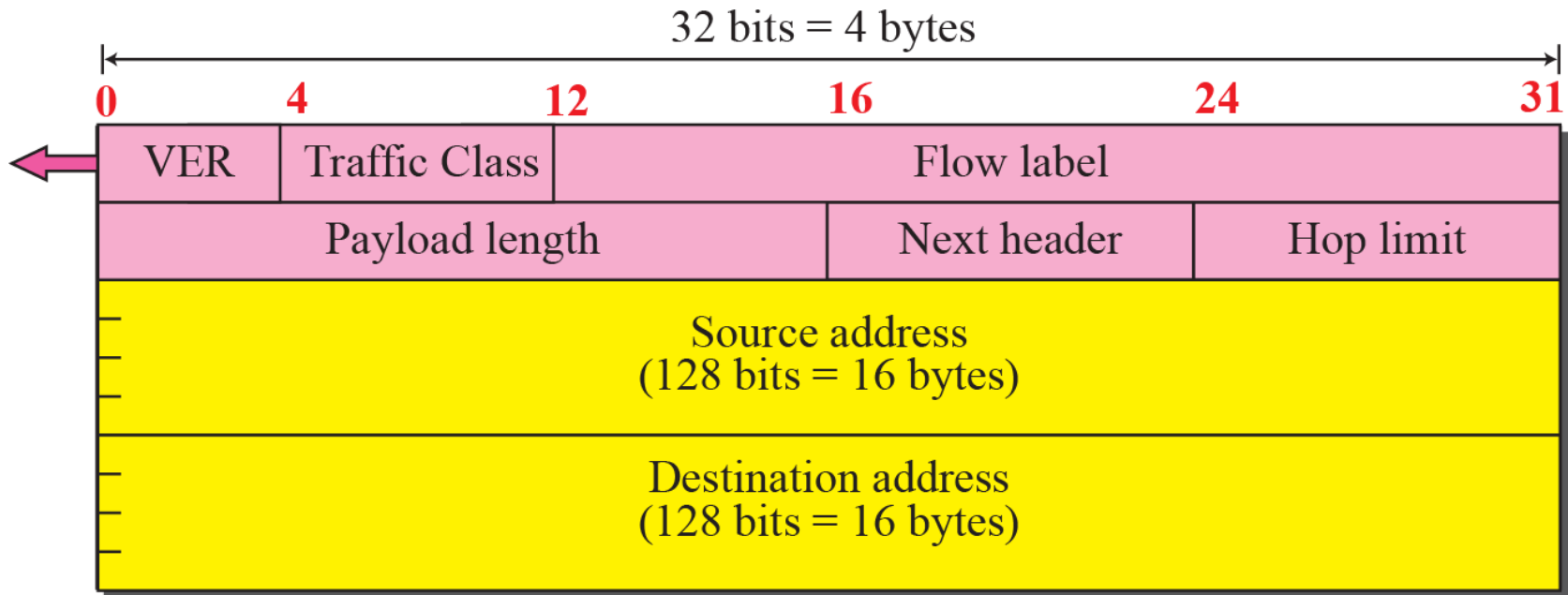**Figure** *IPv6 datagram header and payload*

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

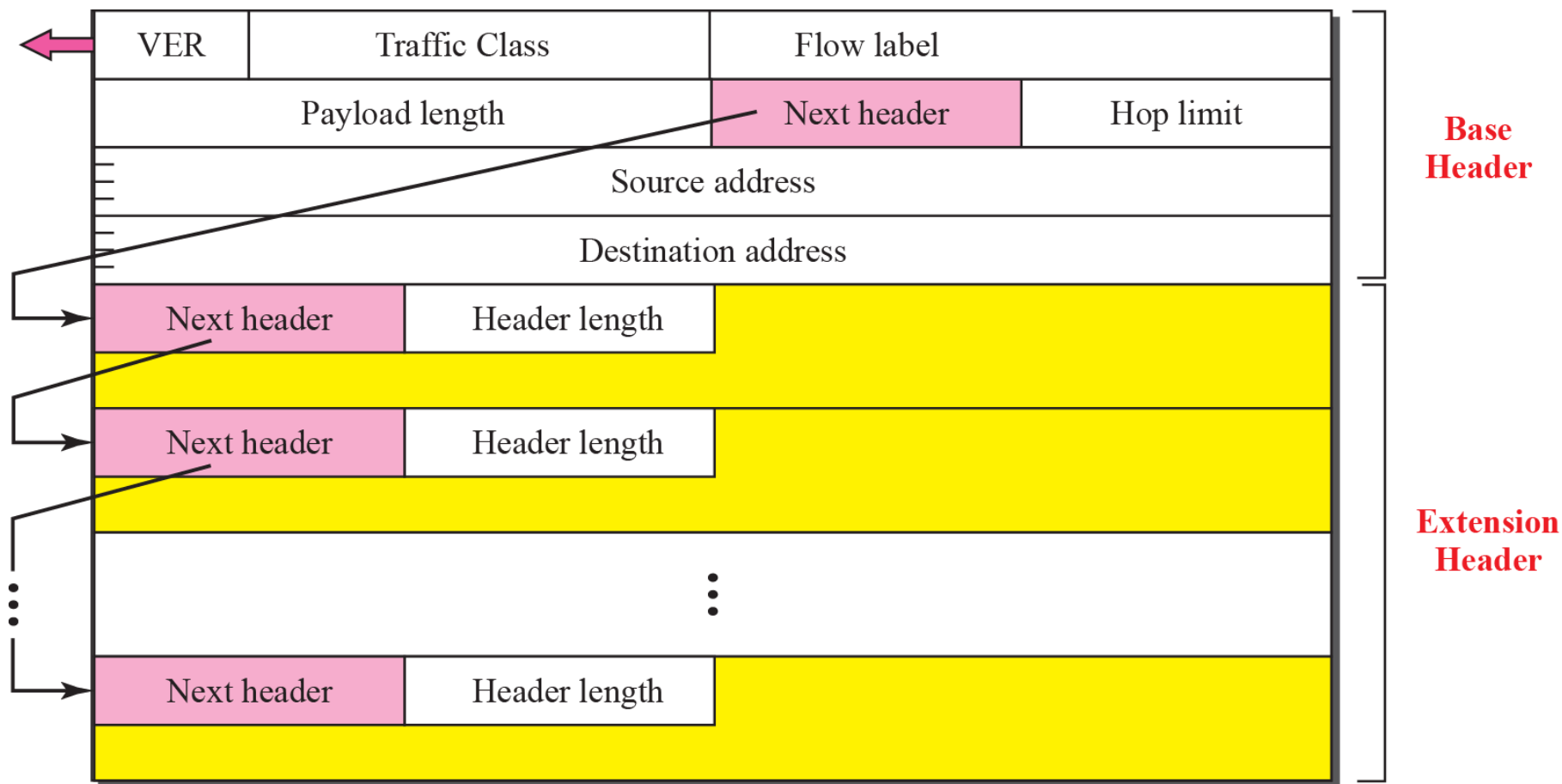**Figure** *Extension header format*

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.