Chapter 8

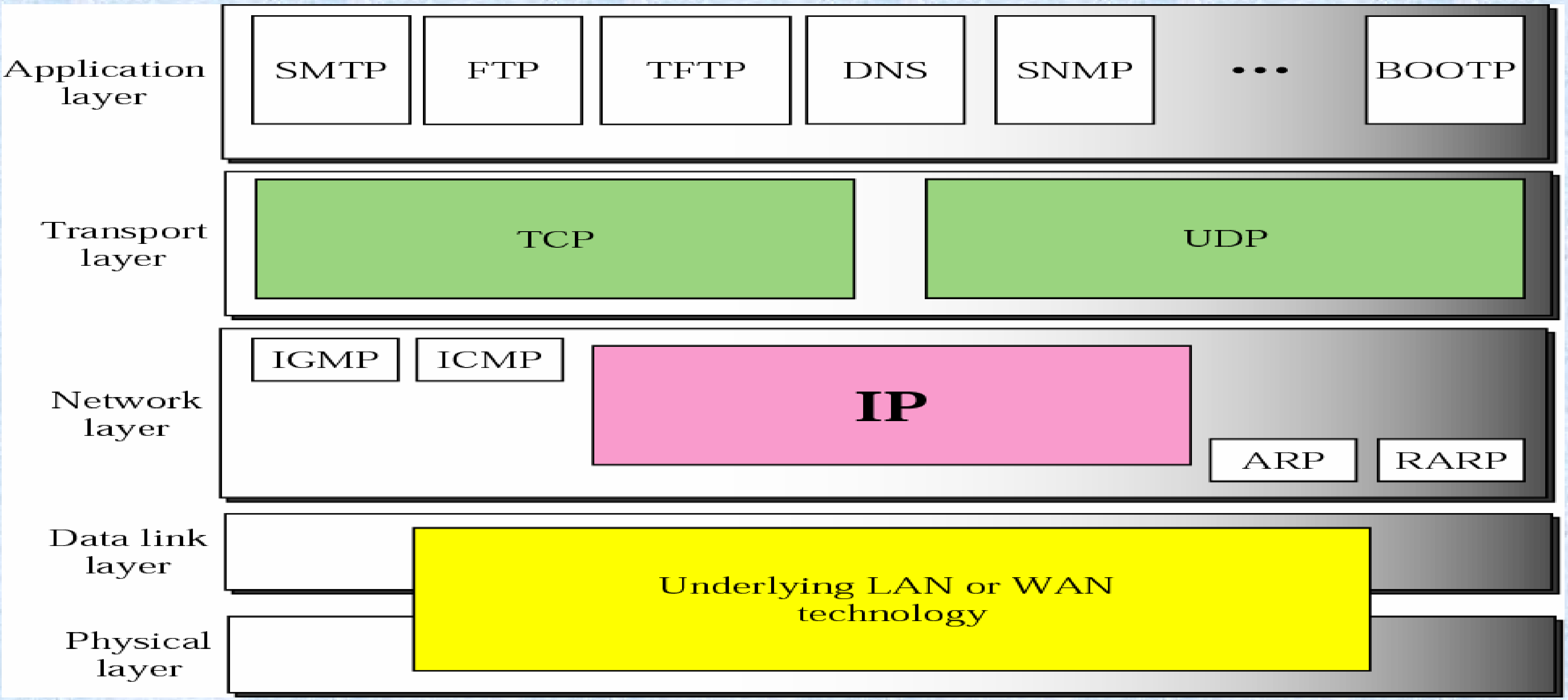
Internet Protocol (IP)

CONTENTS

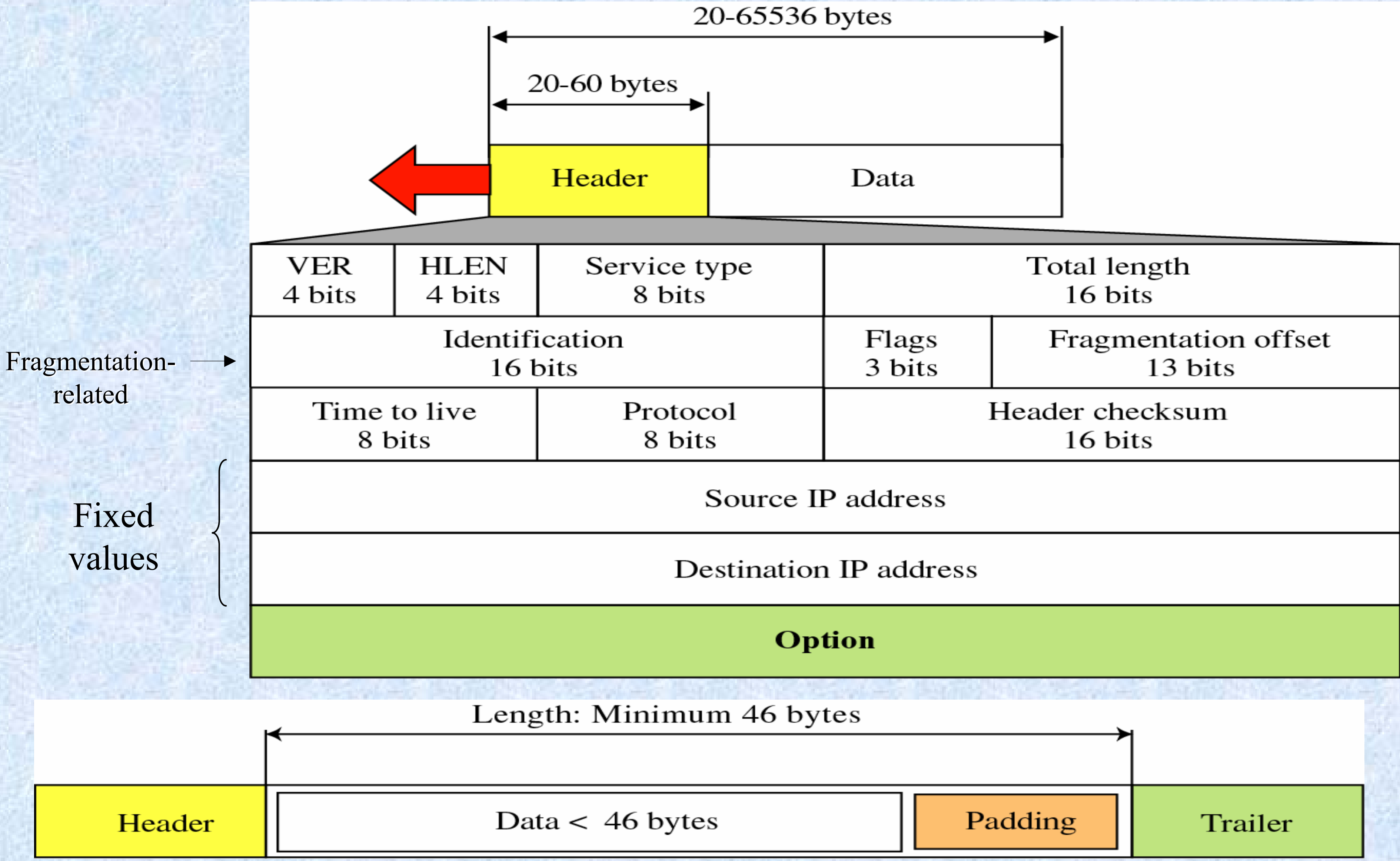
- DATAGRAM
- FRAGMENTATION
- OPTIONS
- CHECKSUM
- IP PACKAGE

Introduction to IP

- Connectionless datagram protocol for packet switching networks
- Best-effort Service:
  - No error checking
  - Possible out-of-order delivery
- To achieve reliability, use with TCP, or similar reliable protocol)

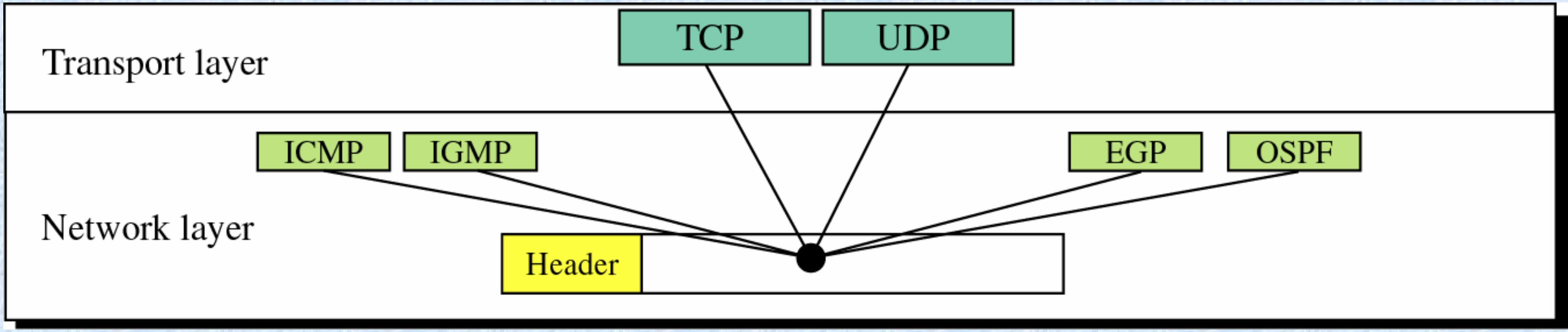


8.1 DATAGRAM



20-65536 bytes
20-60 bytes
Header
Data
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
Option
Fragmentation-related
Fixed values
Length: Minimum 46 bytes
Header
Data < 46 bytes
Padding
Trailer

The *Protocol* field and Multiplexing



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

Example 1

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

🡐 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 header length, which means ($2 \times 4 = 8$), which is wrong. The minimum number of bytes in the header must be 20. The packet has been corrupted in transmission.

Example 2

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 main header, the next 12 bytes are the options.

Example 3

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).

Example 4

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?

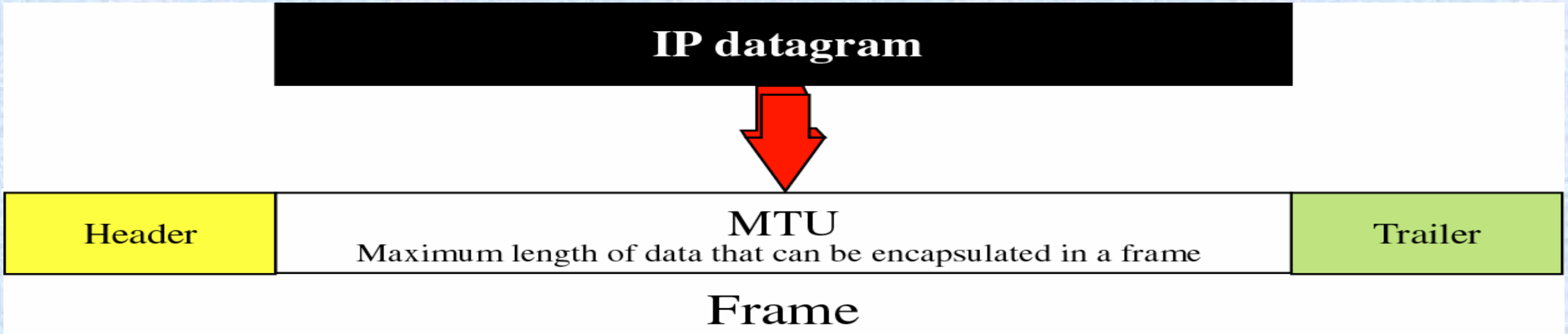
Value	Protocol
1	ICMP
2	IGMP
6	TCP
17	UDP
89	OSPF

Solution

To find the time-to-live field, we should 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.

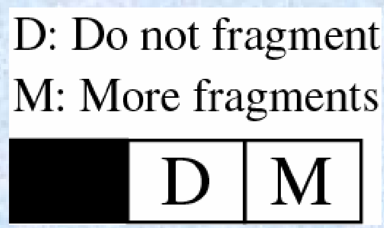
8.2 FRAGMENTATION

- A Router may connect different physical networks
  - Incoming IP datagram may be encapsulated inside an Ethernet frame
  - Outgoing same IP datagram may be encapsulated in a Token Ring frame
  - Each type of frame may have its Maximum Transfer Unit
- The size of an IP datagram may be up to 65,535. This is too big for some physical networks.
  - The IP datagram must be fragmented into smaller units to pass through. It could even be further fragmented by other routers ahead.
- Each fragment becomes a datagram with its own header. Reassembly is done at destination host.



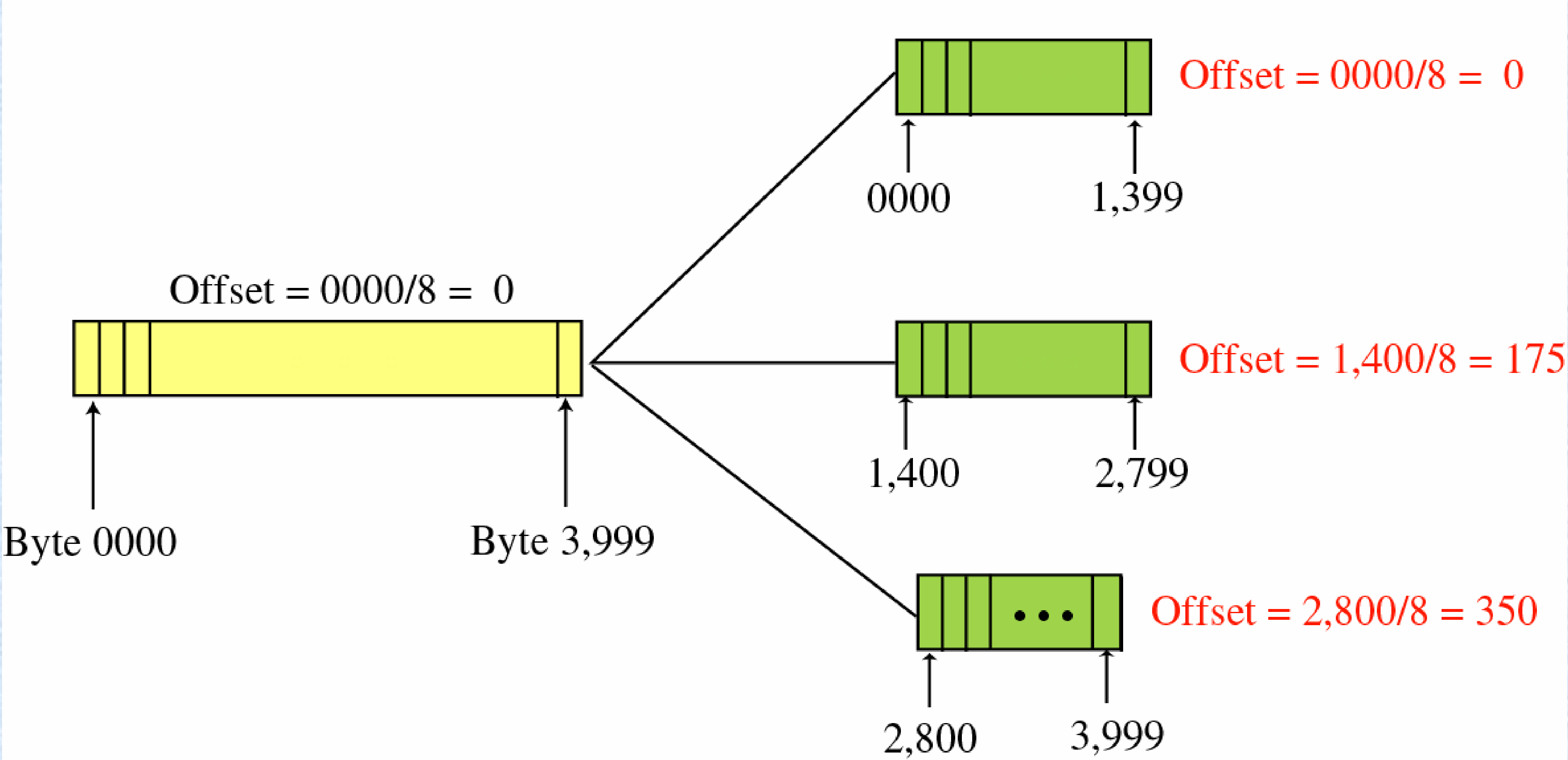
Fragmentation fields

1. Identification: Set by the source host (a counter incremented each time a datagram is emitted).
   - Together with the source IP address, it uniquely identifies the datagram
   - All fragments of this datagram will copy the same Identification
2. Flags: 3-bit field as shown:

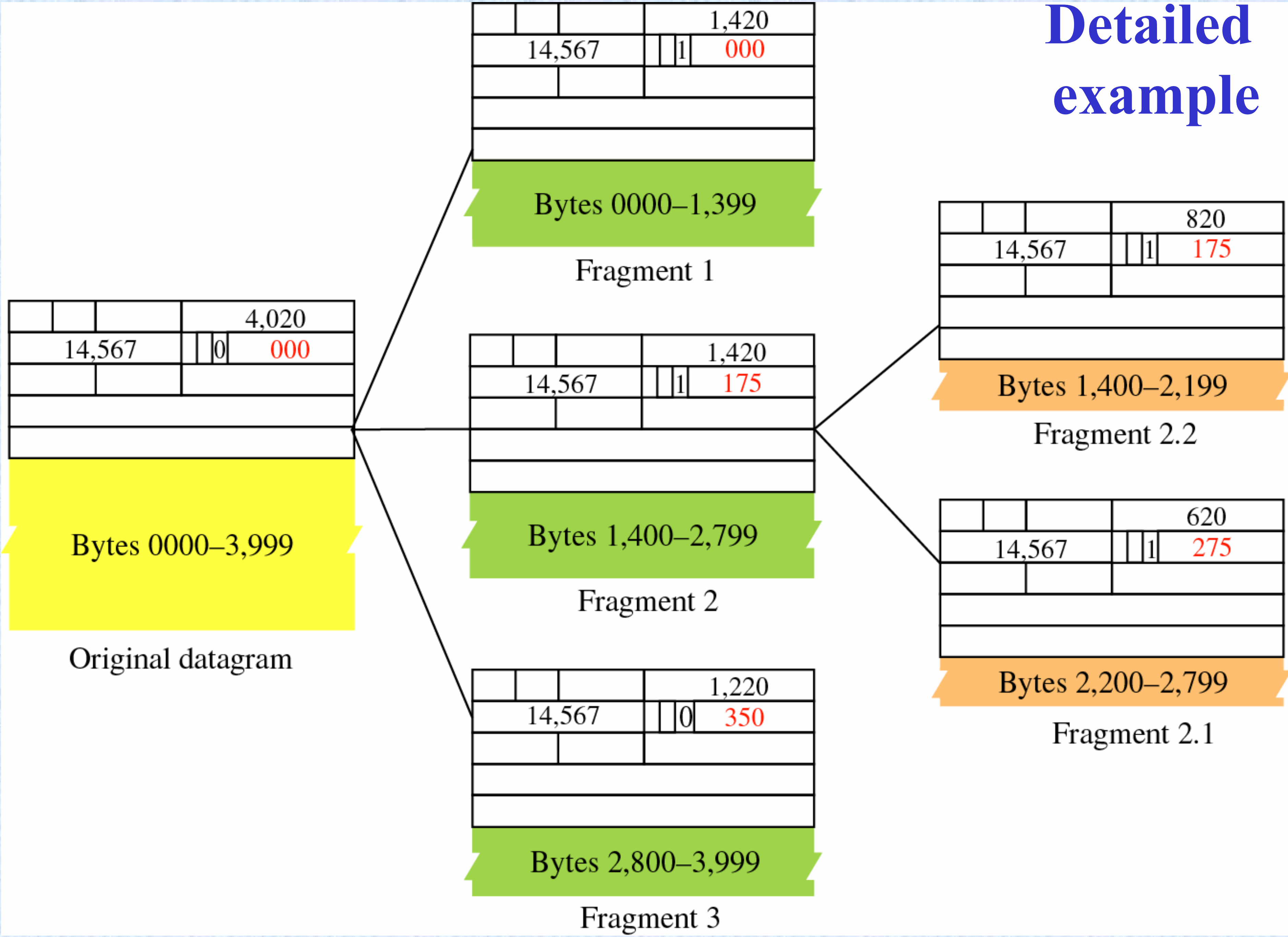


3. Fragmentation Offset: a 13-bit field, specifies the position of the fragment in the original datagram in multiples of 8 bytes.

Fragmentation example



Detailed example



Example 5

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 nonfragmented packet is considered the last fragment.

Example 6

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). However, we can definitely say the original packet has been fragmented because the *M* bit value is 1.

Example 7

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.

Example 8

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.

Example 9

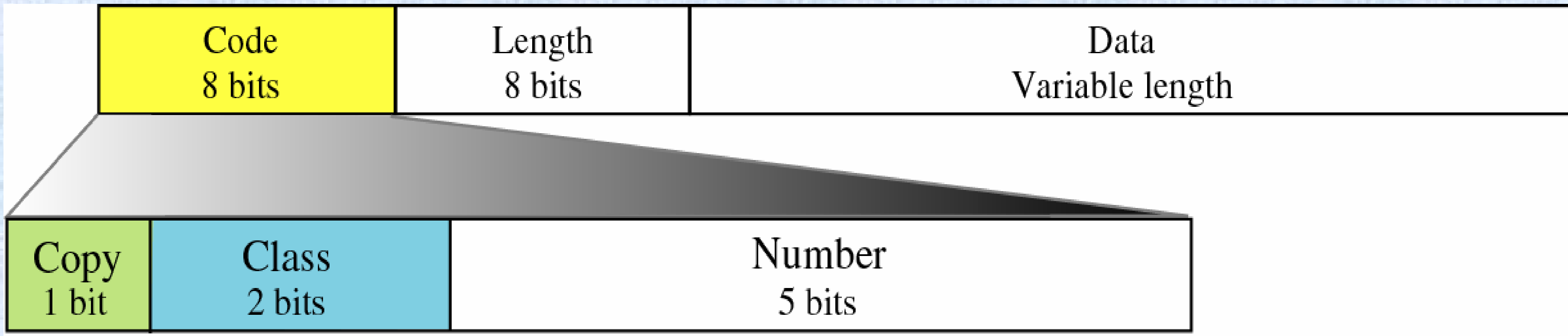
A packet has arrived in which the offset value is 100, the value of HLEN is 5 and the value of the total length field is 100. What is the number of the first byte and the last byte?

Solution

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

8.3 OPTIONS

- Used for network testing and debugging
- Each option follows the TLV (Type-Length-Value) format



Copy

0 Copy only in first fragment
1 Copy into all fragments

Class

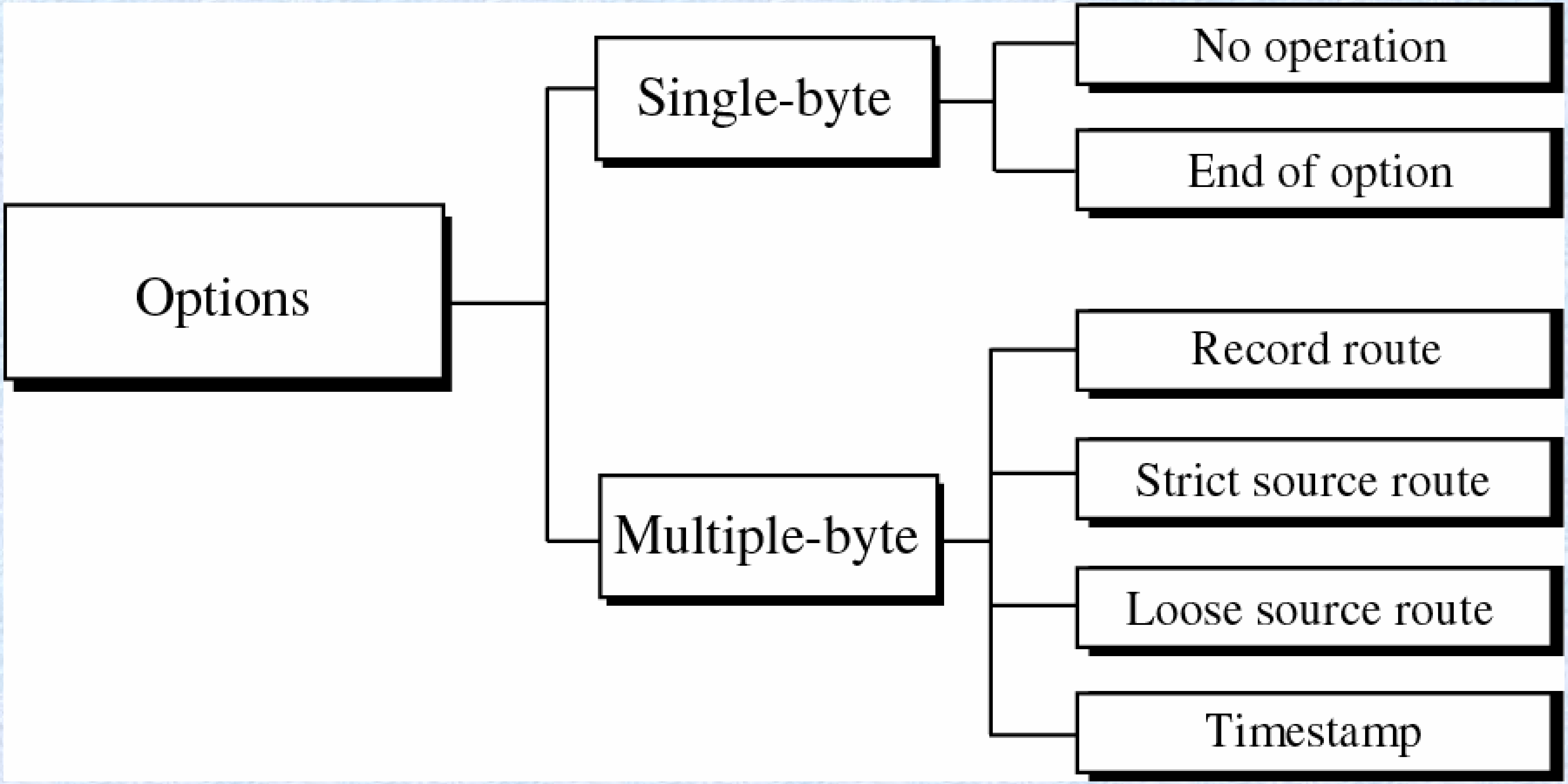
00 Datagram control
01 Reserved
10 Debugging and management
11 Reserved

Number

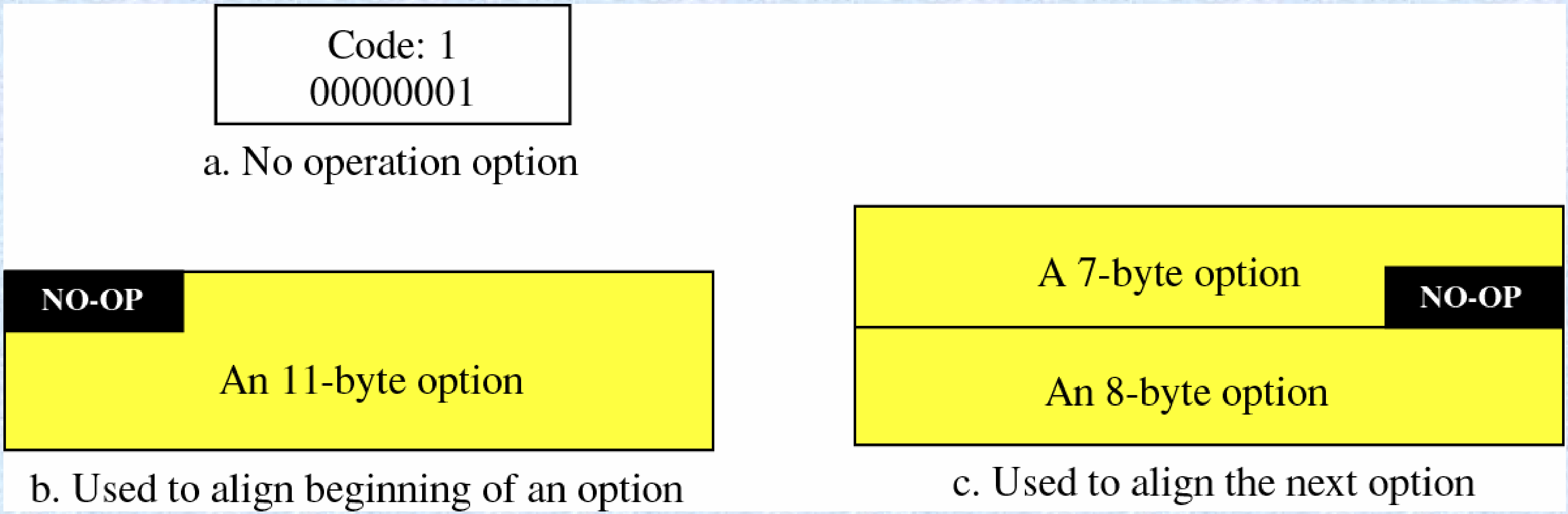
00000 End of option
00001 No operation
00011 Loose source route
00100 Timestamp
00111 Record route
01001 Strict source route

Figure 8-11

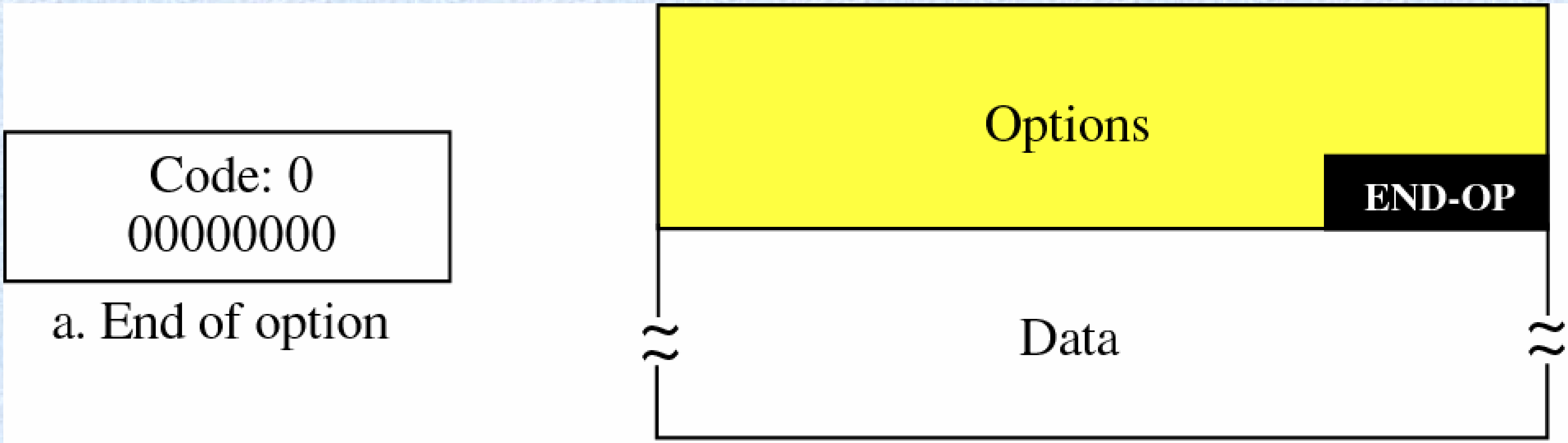
Categories of options



No operation option



End of option option



a. End of option

b. Used for padding