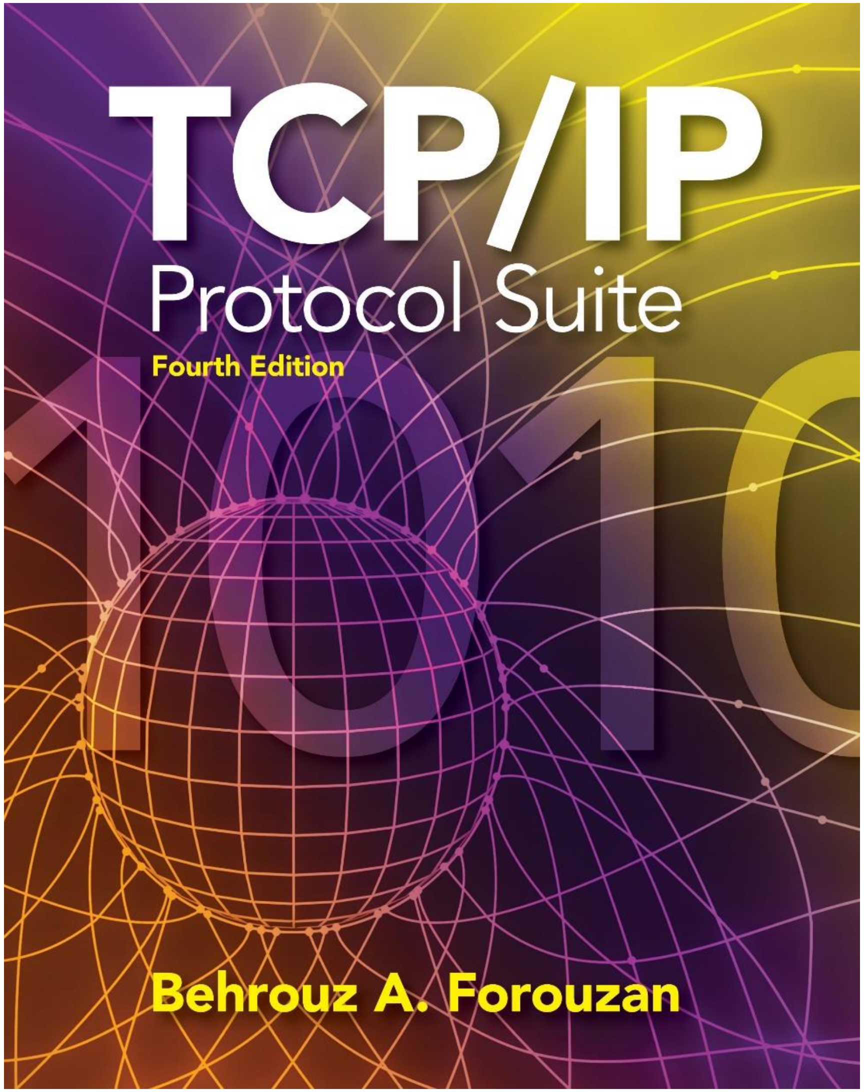
Chapter 7

Internet Protocol Version4 (IPv4)



OBJECTIVES:

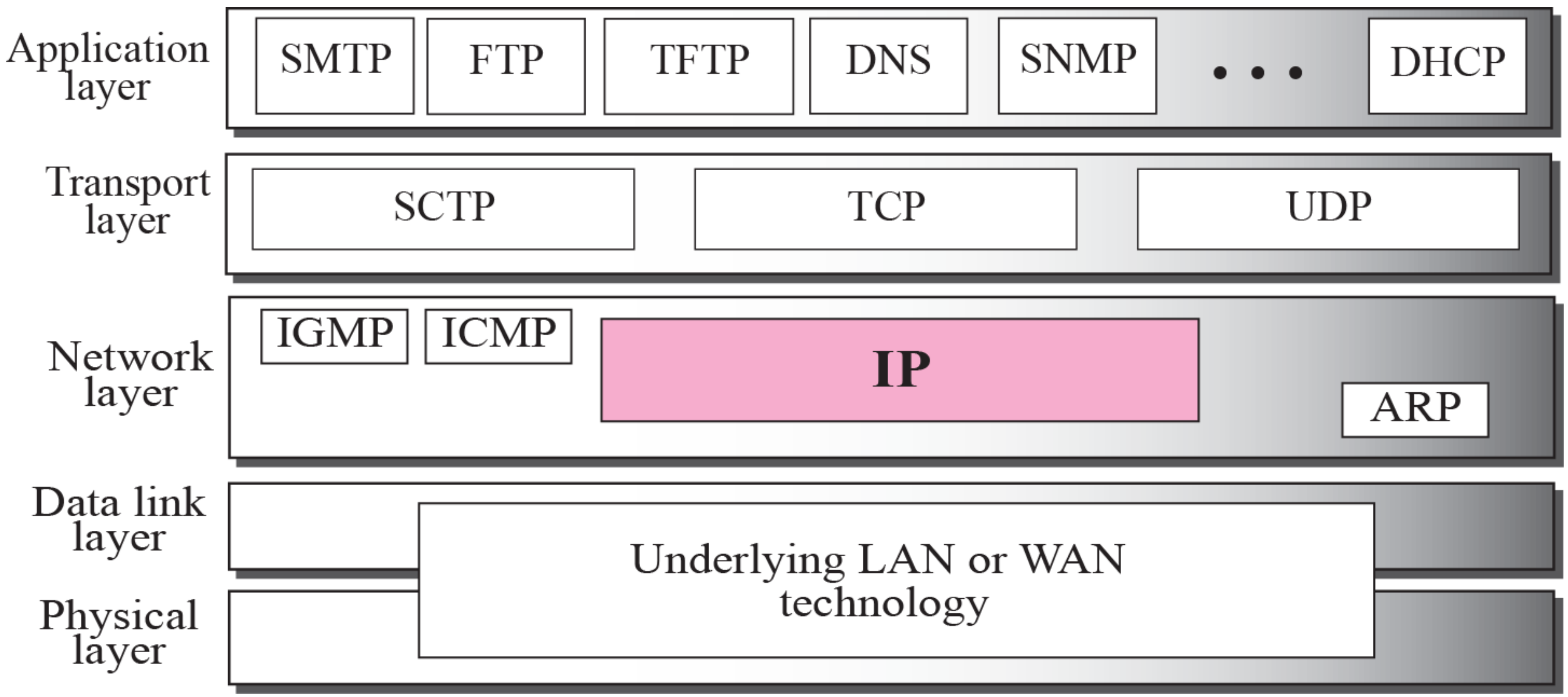
- To explain the general idea behind the IP protocol and the position of IP in TCP/IP protocol suite.
- To show the general format of an IPv4 datagram.
- To discuss fragmentation.
- To show how a checksum is calculated for the header of an IPv4 datagram at the sending site and how the checksum is checked at the receiver site.
- To show a simplified version of the IP package and give the pseudocode for some modules.

7-1 INTRODUCTION

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

IP is an unreliable and connectionless datagram protocol —a **best-effort delivery** service. The term *best-effort* means that IP packets can be corrupted, lost, arrive out of order, or delayed and may create congestion for the network.

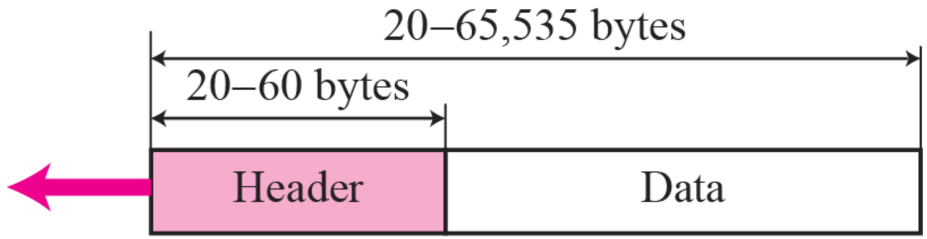
Figure 7.1 *Position of IP in TCP/IP protocol suite*



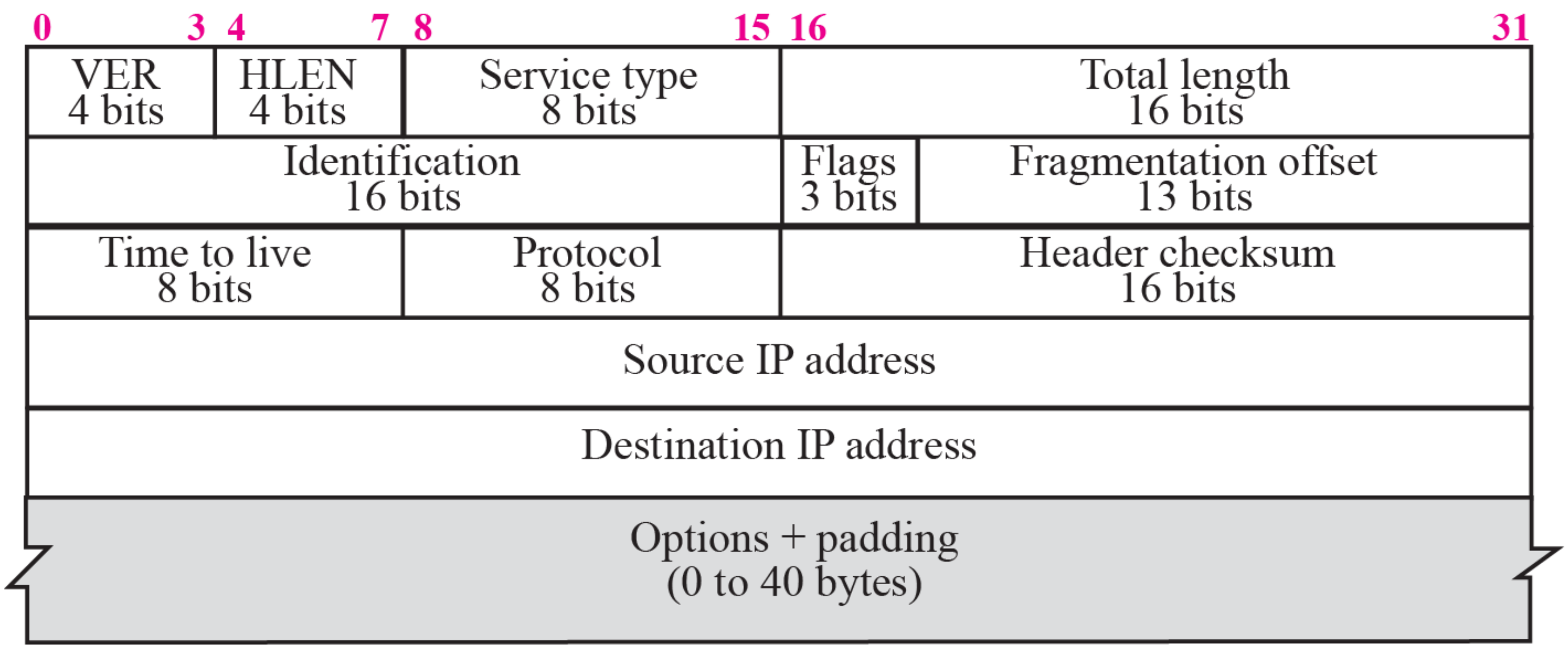
7-2 DATAGRAMS

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.

Figure 7.2 *IP datagram*



a. IP datagram



b. Header format

- **Version (VER).** This 4-bit field defines the version of the IP protocol i.e. 4 , 6.

- **Header length (HLEN).** This 4-bit field defines the total length of the datagram header in 4-byte words. This field is needed because the length of the header is variable (between 20 and 60 bytes). When there are no options, the **header length** is 20 bytes, and the value of this field is 5 ($5 \cdot 4 = 20$). When the option field is at its maximum size, the value of this field is 15 ($15 \cdot 4 = 60$).

- **Service type.** In the original is how the datagram should be used, e.g. delay, precedence, reliability, minimum cost, throughput etc.

- **Total length.** This is a 16-bit field that defines the total length (header plus data) of the IP datagram in bytes.

- **Identification, Flags and Fragmentation offset.**
  All these fields are used in fragmentation which will be discussed later.

- **Time to live.** A datagram has a limited lifetime in its travel through an internet. This field was originally designed to hold a timestamp, which was decremented by each visited router. The datagram was discarded when the value became zero

- **Protocol.** This 8-bit field defines the higher-level protocol that uses the services of the IP layer. An IP datagram can encapsulate data from several higher level protocols such as TCP, UDP, ICMP, and IGMP.

Table 7.2 *Protocols*

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

- **Checksum.** Used for error detection.

- **Source address.** This 32-bit field defines the IP address of the source. This field must remain unchanged during the time the IP datagram travels from the source host to the destination host.

- **Destination address.** This 32-bit field defines the IP address of the destination. This field must remain unchanged during the time the IP datagram travels from the source host to the destination host.

Example 7.1

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 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.

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?

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 7.3

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 7.4

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?

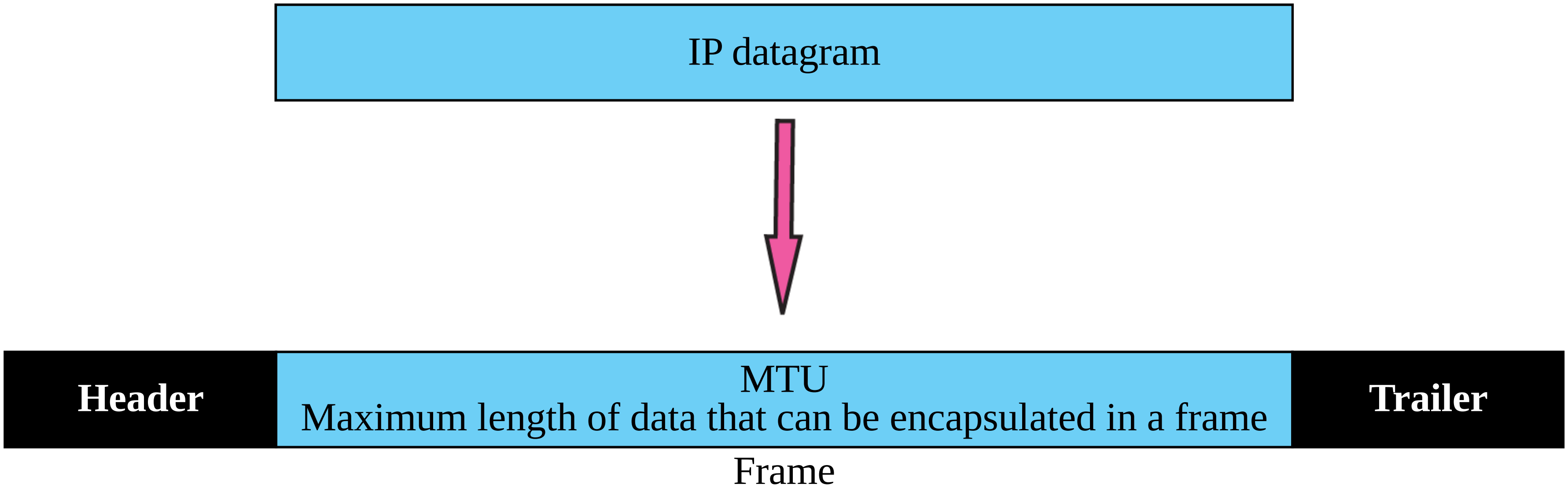
Solution

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)

7-3 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.

Figure 7.6 *MTU*



Note

Only data in a datagram is fragmented.

Figure 7.7 *Flags field*

D: Do not fragment
M: More fragments

Example 7.5

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 7.6

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). See also the next example.

Example 7.7

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.