COMPUTER networks

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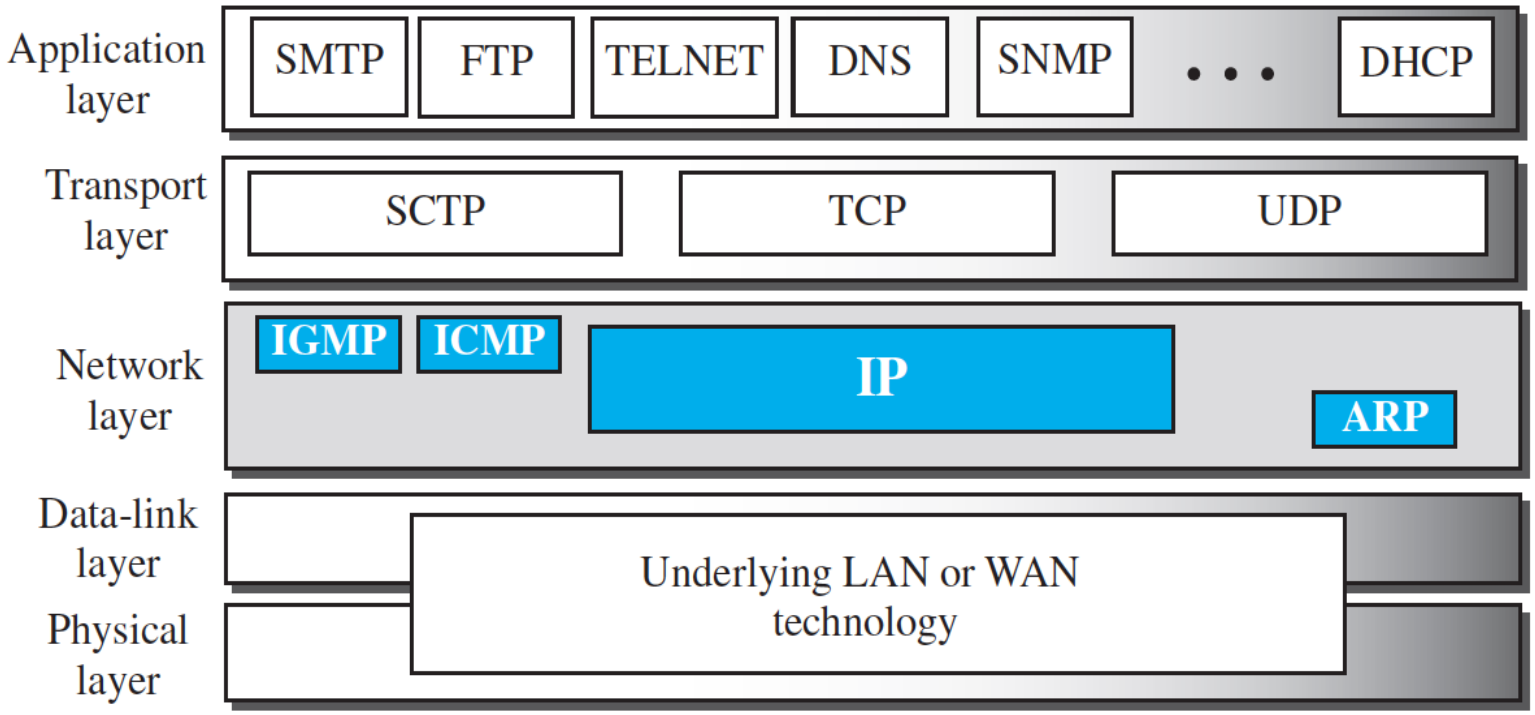


Position of IP and other network-layer protocols in TCP/IP protocol suite

- IPv4 is an unreliable datagram protocol—a best-effort delivery service.
- The term best-effort means that IPv4 packets can be corrupted, be lost, arrive out of order, or be delayed, and may create congestion for the network.
- If reliability is important, IPv4 must be paired with a reliable transport-layer protocol such as TCP

Example of Best Effort Delivery Service

- The post office does its best to deliver the regular mail but does not always succeed.
- If an unregistered letter is lost or damaged, it is up to the sender or would-be recipient to discover this.
- The post office itself does not keep track of every letter and cannot notify a sender of loss or damage of one

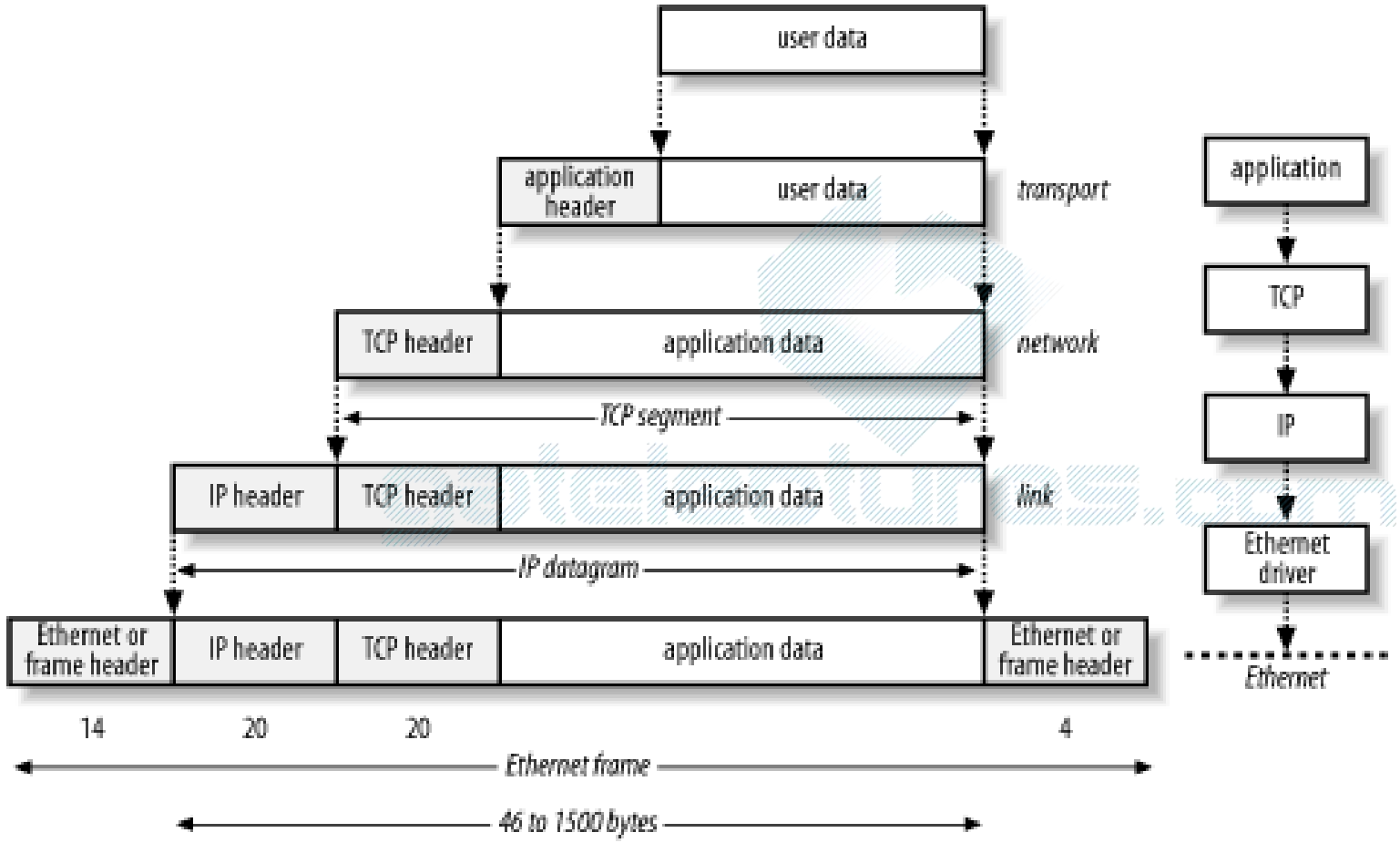
Connectionless Protocol

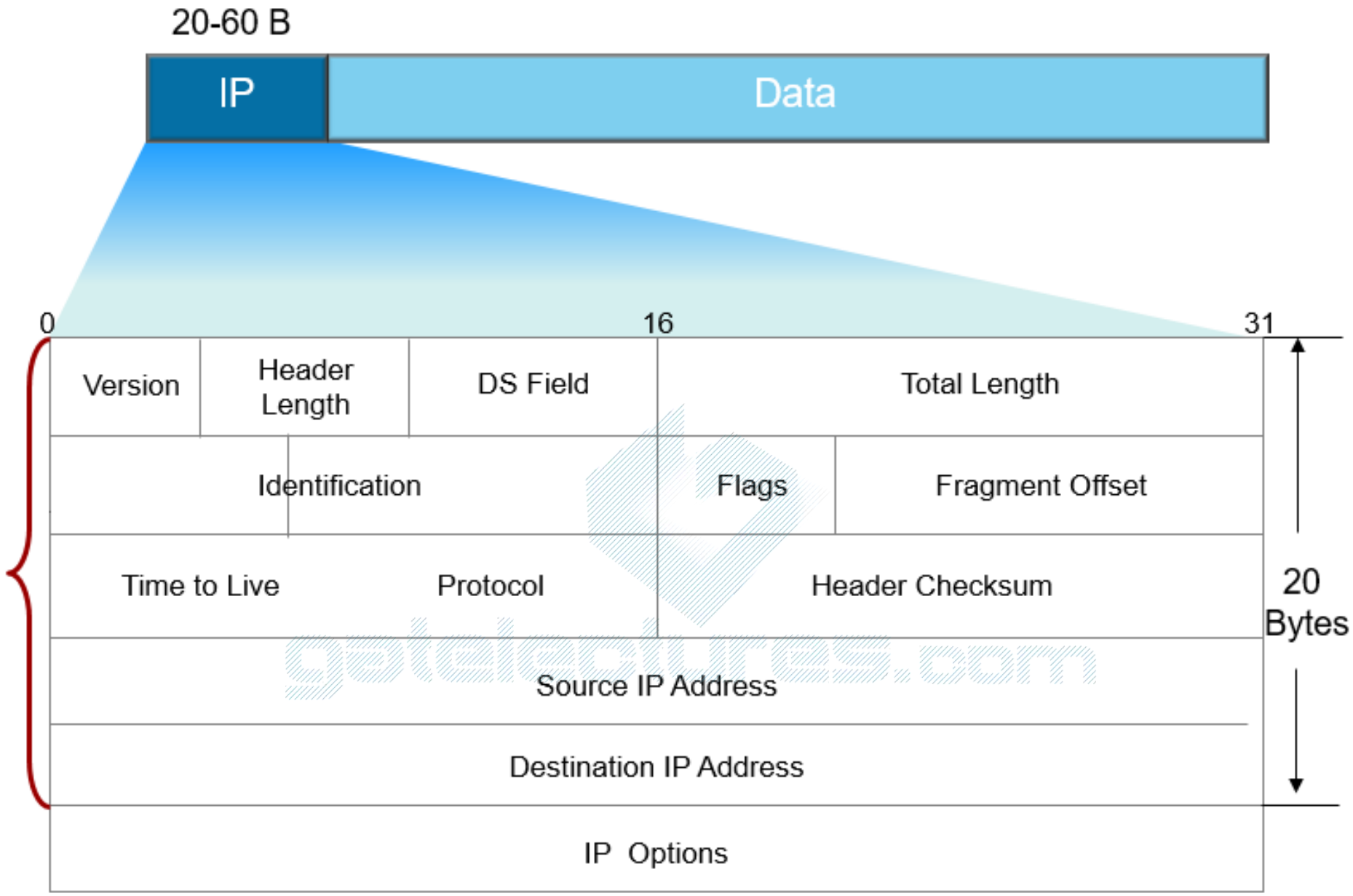
- IPv4 is also a connectionless protocol that uses the datagram approach.

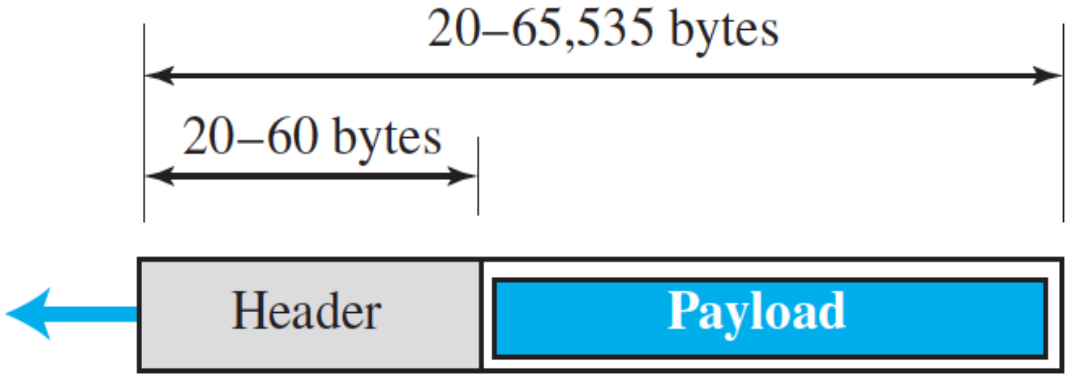
- Packets used by the IP are called datagrams .
- A datagram is a variable-length packet consisting of two parts: header and payload (data).
- The header is 20 to 60 bytes in length and contains information essential to routing and delivery.

Datagrams

Packet at various Layers




20-60 B
IP
Data
0
16
31
Version
Header Length
DS Field
Total Length
Identification
Flags
Fragment Offset
Time to Live
Protocol
Header Checksum
Source IP Address
Destination IP Address
IP Options
20 Bytes

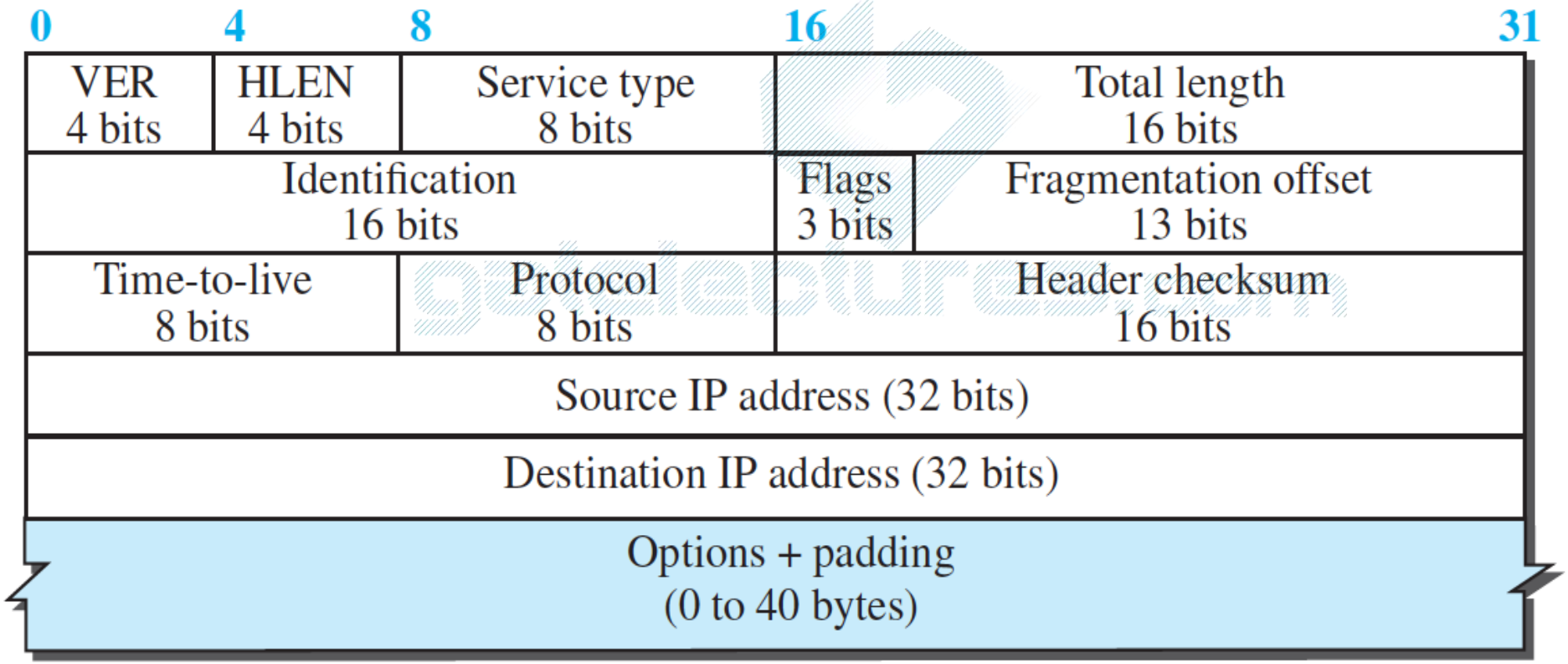


a. IP datagram

Legend

VER: version number
HLEN: header length
byte: 8 bits

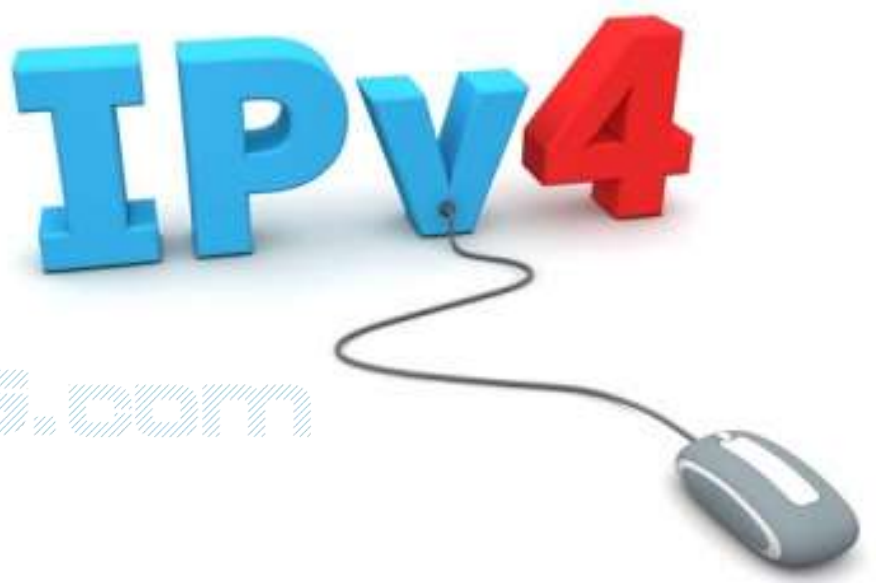
Flags D M



b. Header

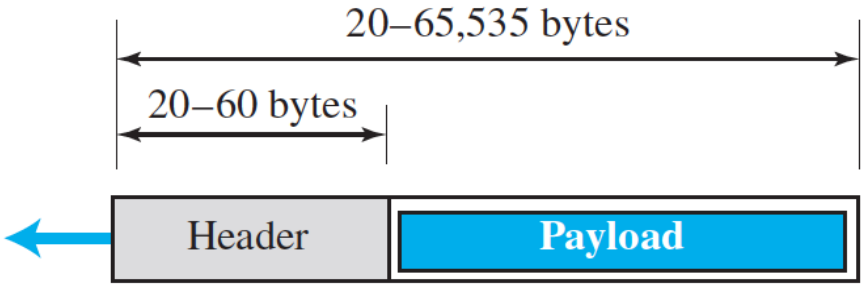
Version Number Field

The 4-bit version number (VER) field defines the version of the IPv4 protocol, which, obviously, has the value of 4.



Header Length

- The 4-bit header length (HLEN) field defines the total length of the datagram header in 4-byte words.
- The receiver needs to multiply the value of this field by 4 to find the total length.



a. IP datagram

Legend

VER: version number
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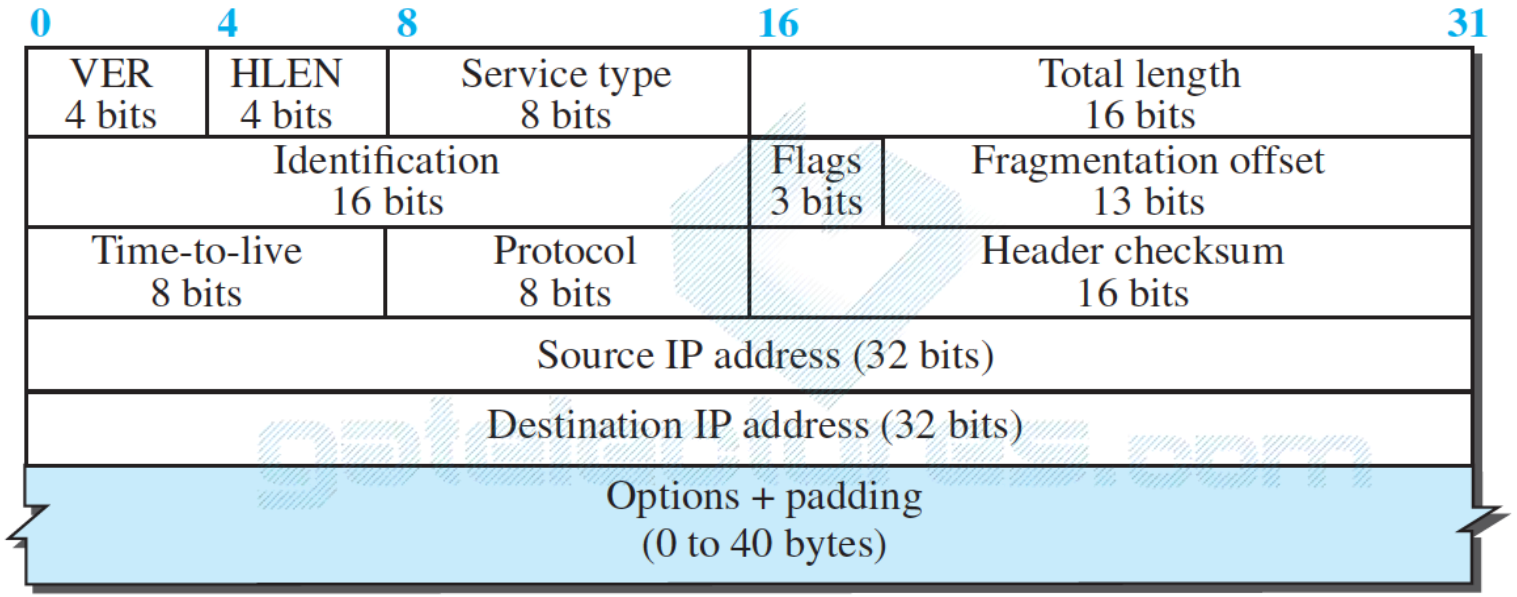
Flags D M



b. Header

Total Length

- ✓This 16-bit field defines the total length (header plus data) of the IP datagram in bytes.
- ✓This field helps the receiving device to know when the packet has completely arrived.

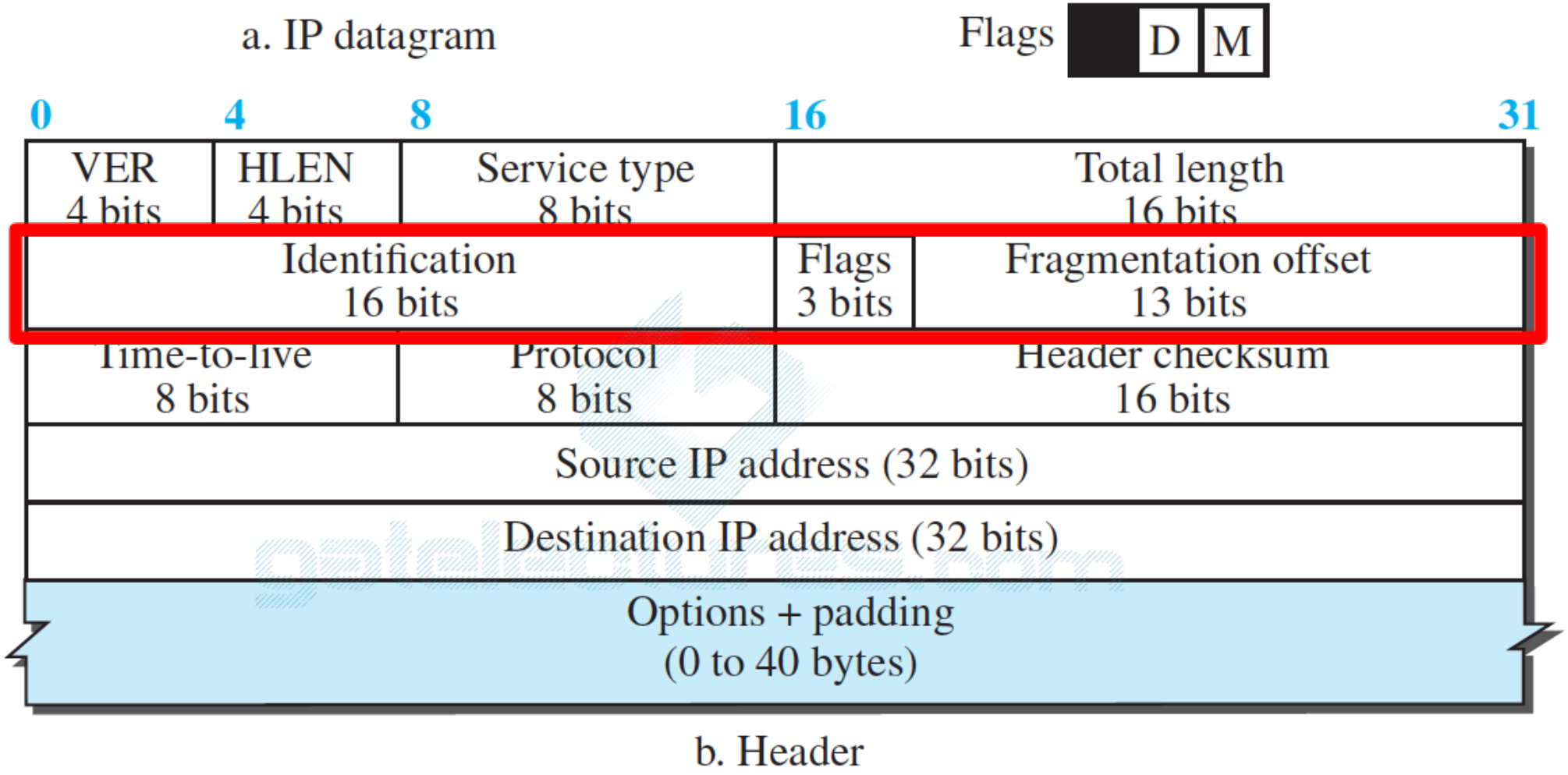
Length of Data in IP Datagram

$$\text{Length of data} = \text{total length} - (\text{HLEN}) \times 4$$

Why we need Total Length field

- However, there are occasions in which the datagram is not the only thing encapsulated in a frame; it may be that padding has been added.
- For example, the Ethernet protocol has a minimum and maximum restriction on the size of data that can be encapsulated in a frame (46 to 1500 bytes).
- If the size of an IPv4 datagram is less than 46 bytes, some padding will be added to meet this requirement.
- In this case, when a machine decapsulates the datagram, it needs to check the total length field to determine how much is really data and how much is padding.

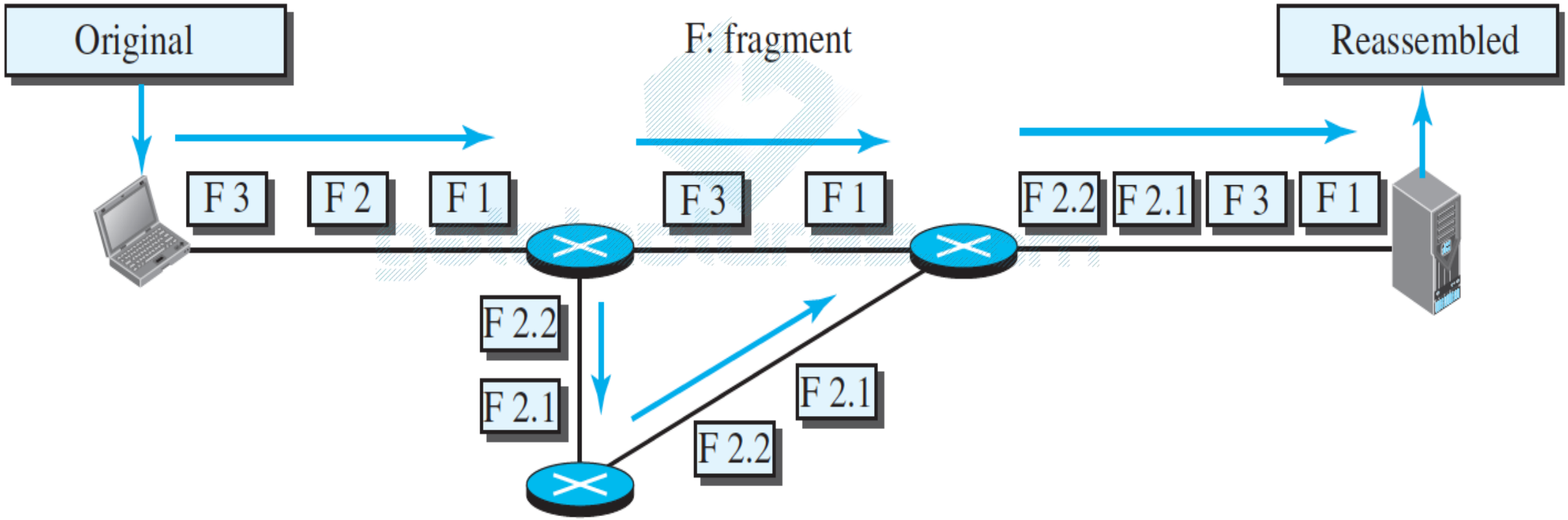
Identification, Flags, and Fragmentation Offset

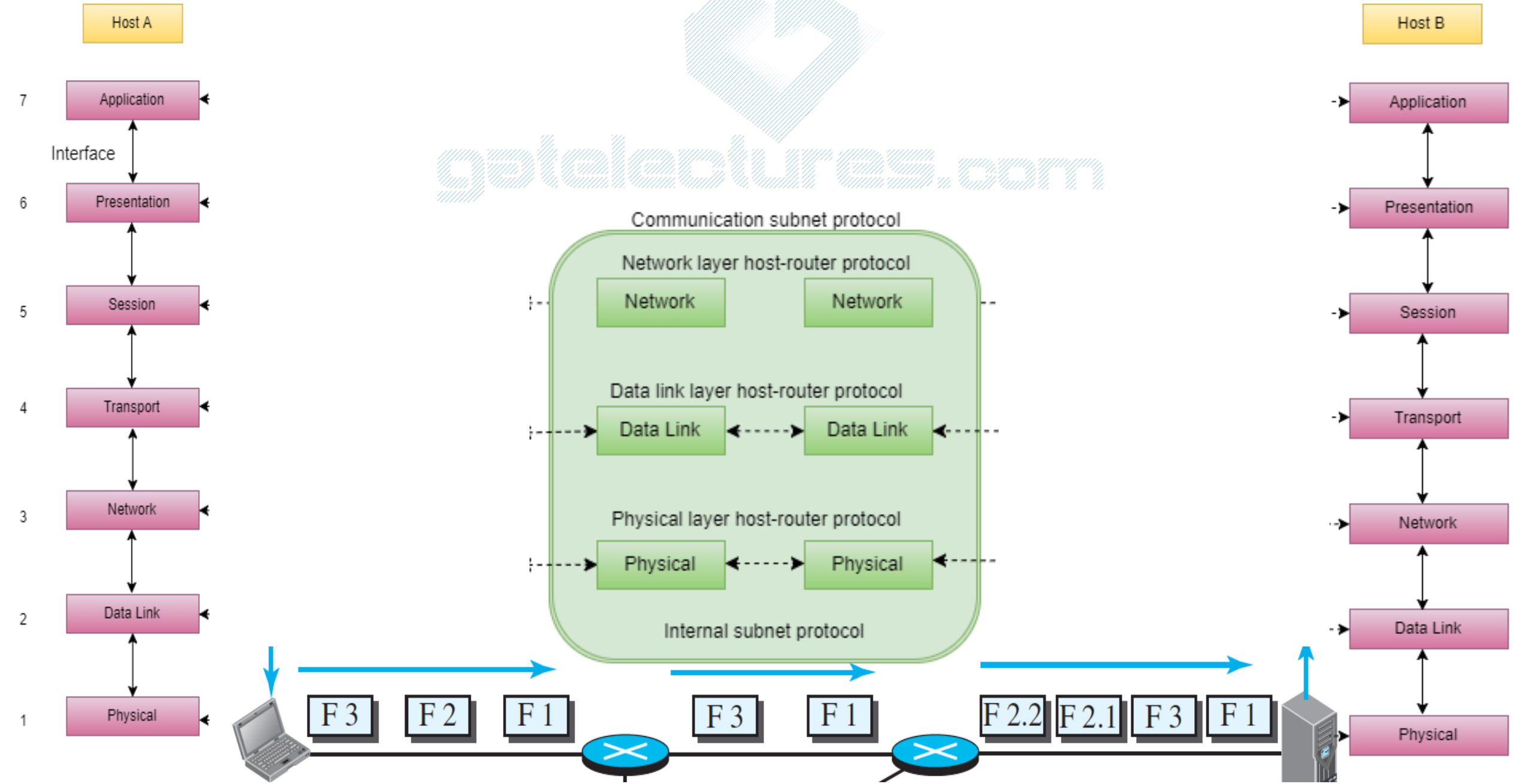


Fragmentation

- 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.
- For example, if a router connects a LAN to a WAN, it receives a frame in the LAN format and sends a frame in the WAN format.

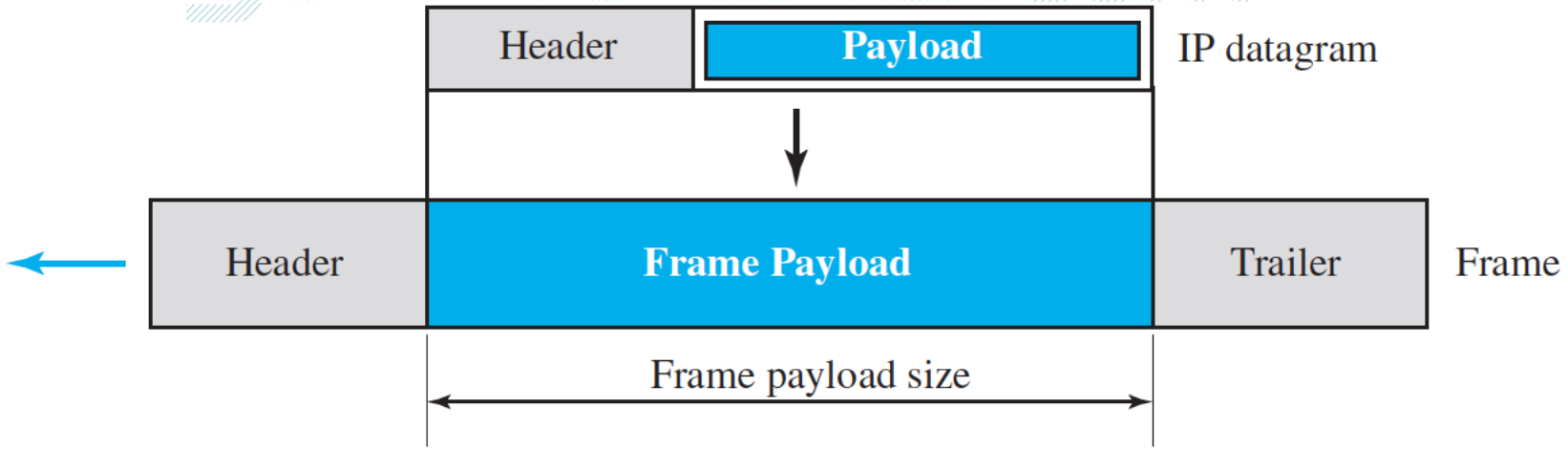
Fragmentation





Maximum Transfer Unit (MTU)

- Each link-layer protocol has its own frame format.
- One of the features of each format is the maximum size of the payload that can be encapsulated.
- In other words, when a datagram is encapsulated in a frame, the total size of the datagram must be less than this maximum size,



MTU: Maximum size of frame payload

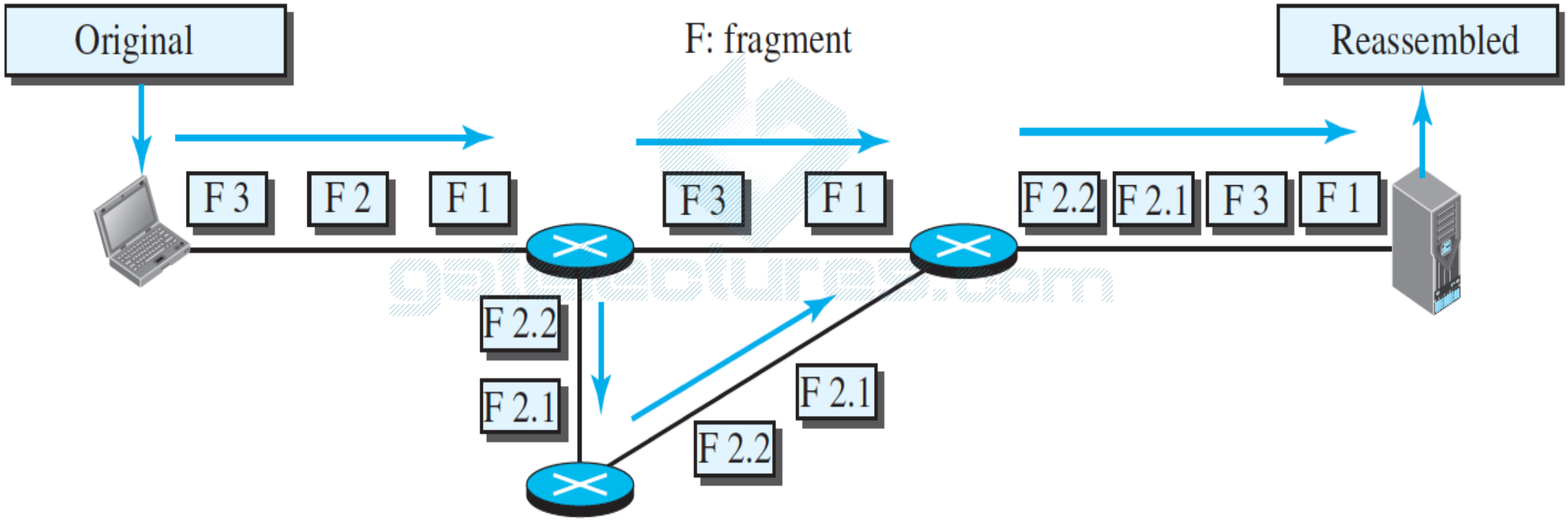
Fragmentation

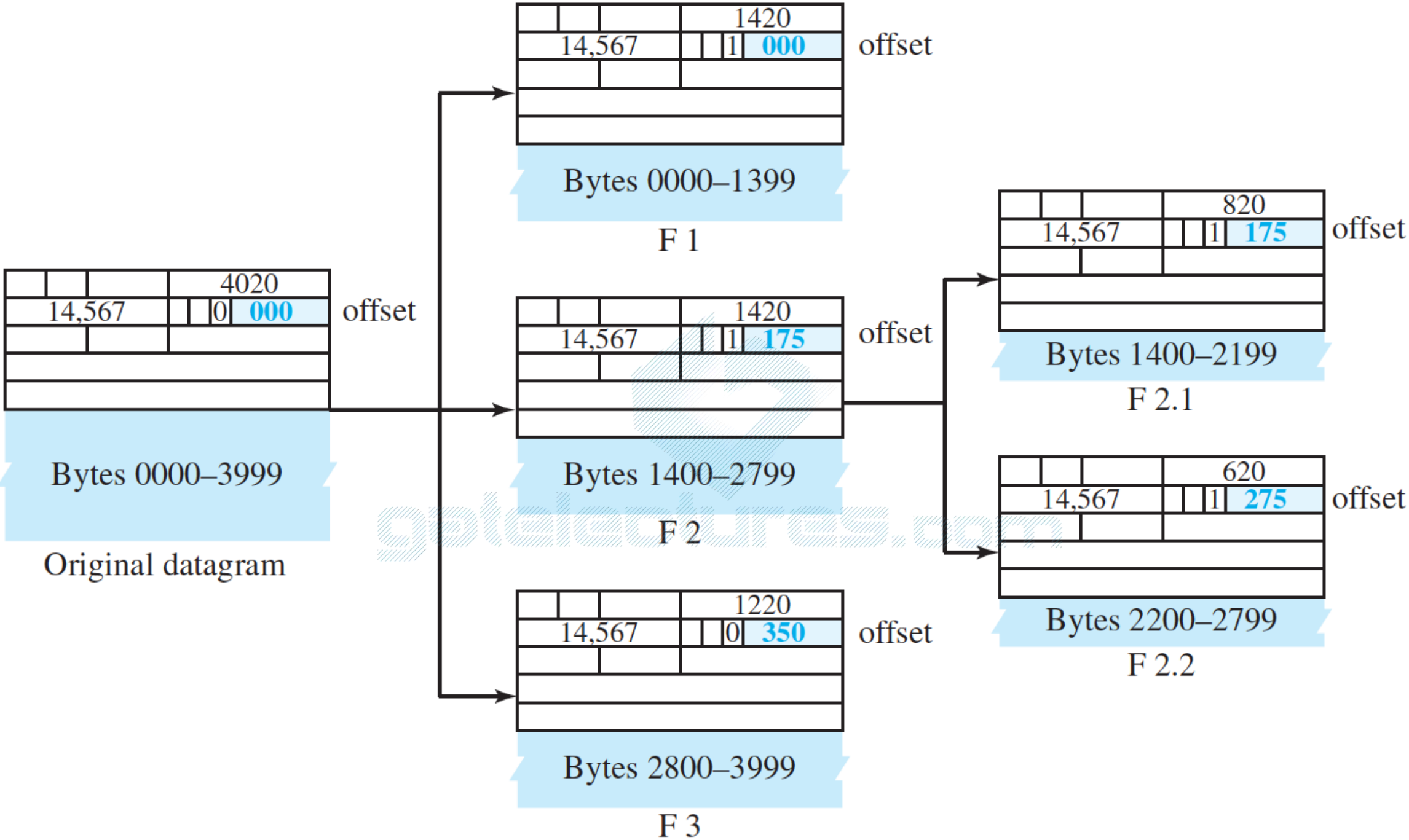
- The value of the MTU differs from one physical network protocol to another.
- For example, the value for a LAN is normally 1500 bytes, but for a WAN it can be larger or smaller.
- we must divide the datagram to make it possible for it to pass through these networks. This is called fragmentation

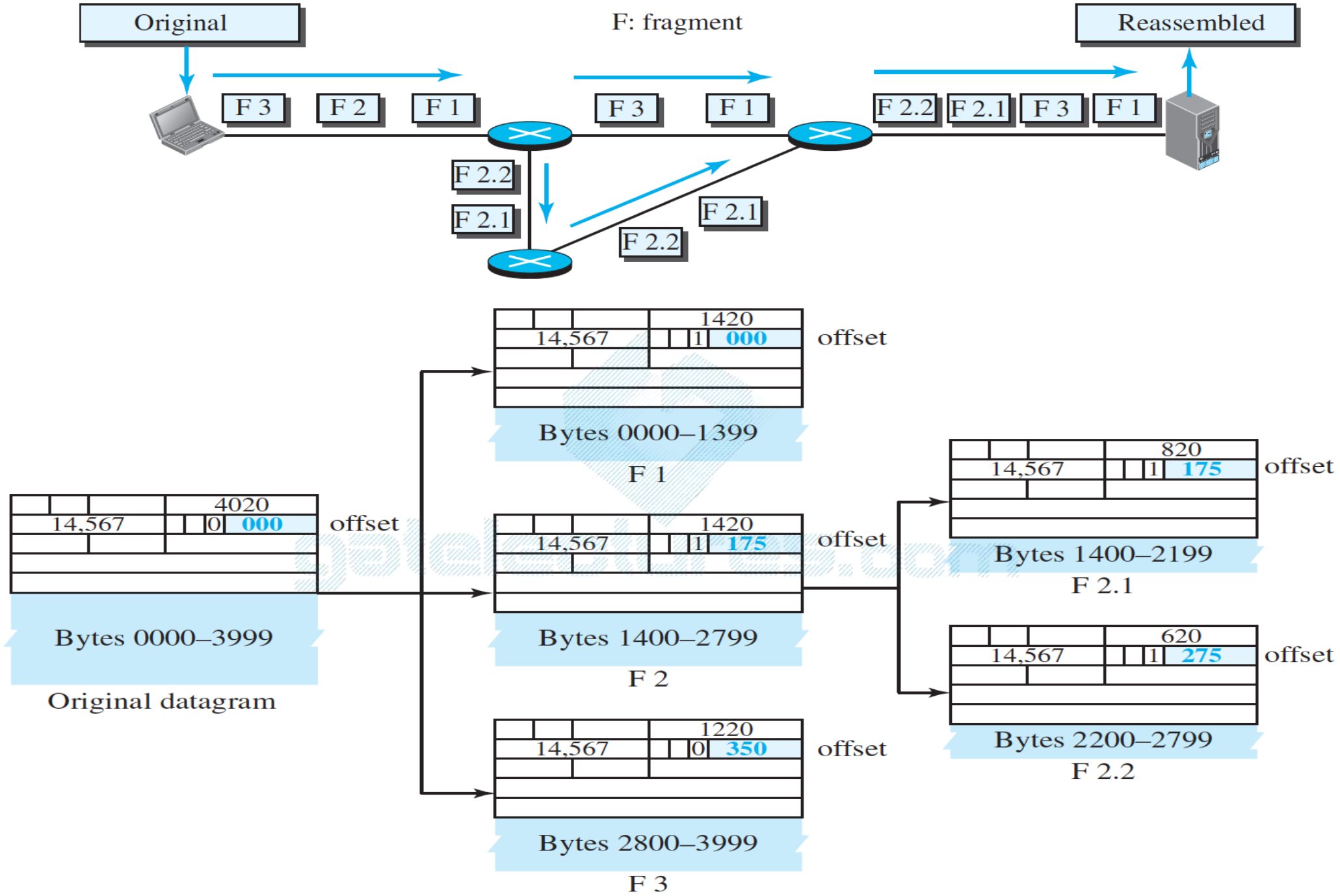
Fragmented Datagram and Reassembly

- When a datagram is fragmented, each fragment has its own header.
- A fragmented datagram may itself be fragmented if it encounters a network with an even smaller MTU.
- A datagram can be fragmented by the source host or any router in the path.
- The reassembly of the datagram, however, is done only by the destination host, because each fragment becomes an independent datagram.
- The fragmented datagram can travel through different routes

Fragmentation




4020
14,567
0
000
offset
Bytes 0000–3999
Original datagram
1420
14,567
1
000
offset
Bytes 0000–1399
F 1
1420
14,567
1
175
offset
Bytes 1400–2799
F 2
1220
14,567
0
350
offset
Bytes 2800–3999
F 3
820
14,567
1
175
offset
Bytes 1400–2199
F 2.1
620
14,567
1
275
offset
Bytes 2200–2799
F 2.2


Original
F: fragment
Reassembled
F 3
F 2
F 1
F 3
F 1
F 2.2
F 2.1
F 3
F 1
F 2.2
F 2.1
F 2.1
F 2.2
4020
14,567
0
000
offset
Bytes 0000–3999
Original datagram
1420
14,567
1
000
offset
Bytes 0000–1399
F 1
1420
14,567
1
175
offset
Bytes 1400–2799
F 2
1220
14,567
0
350
offset
Bytes 2800–3999
F 3
820
14,567
1
175
offset
Bytes 1400–2199
F 2.1
620
14,567
1
275
offset
Bytes 2200–2799
F 2.2

Fields Related to Fragmentation - Identification

- Identification + source IP address = uniquely define a datagram.
- When a datagram is fragmented, the value in the identification field is copied into all fragments. .
- The identification number helps the destination in reassembling the datagram.
- It knows that all fragments having the same identification value should be assembled into one datagram.

Fields Related to Fragmentation - Flags

The 3-bit flags field defines three flags.

- The **leftmost bit** is reserved (not used).
- The **second bit** (D bit) is called the do not fragment bit.
- The **third bit** (M bit) is called the more fragment bit.

fragmentation offset

- The 13-bit fragmentation offset field shows the relative position of this fragment with respect to the whole datagram.
- It is the offset of the data in the original datagram measured in units of 8 bytes.