IPv4 Fragmentation: Concept, Header Fields, and Solved Numerical Examples

Course: Computer Networks / IoT Networking

1 Introduction

IPv4 fragmentation is a mechanism that allows an IP packet larger than the Maximum Transmission Unit (MTU) of a network link to be divided into smaller fragments. These fragments are transmitted independently and reassembled only at the destination host.

Fragmentation is a network-layer operation and should not be confused with subnetting or TCP segmentation.

2 Why Fragmentation is Required

Different network technologies support different MTU sizes. When an IPv4 packet exceeds the MTU of a link, fragmentation becomes necessary unless the packet is dropped.

- Ethernet MTU: 1500 bytes
- Wi-Fi MTU: $\approx$ 1500 bytes
- PPP links: $\approx$ 576 bytes

3 IPv4 Header Fields Used in Fragmentation

Fragmentation relies on three IPv4 header fields:

3.1 Identification (16 bits)

All fragments of the same original packet share the same Identification value.

3.2 Flags (3 bits)

- Reserved (must be 0)
- DF (Don't Fragment)
- MF (More Fragments)

3.3 Fragment Offset (13 bits)

Specifies the position of the fragment relative to the start of the original packet. The offset is measured in units of **8 bytes**.

4 General Fragmentation Rules

- Fragmentation may occur at the source or intermediate routers
- All fragments carry the same Identification value
- Fragment offset is always a multiple of 8
- Reassembly occurs only at the destination host
- Loss of a single fragment results in loss of the entire packet

5 Solved Numerical Examples

5.1 Example 1: Basic Fragmentation

Given:

- Original IP packet size = 4000 bytes
- MTU = 1500 bytes
- IPv4 header size = 20 bytes

Step 1: Maximum payload per fragment

$$1500 - 20 = 1480 \text{ bytes}$$

Since 1480 is divisible by 8, it is valid.
Step 2: Number of fragments

$$\text{Payload size} = 4000 - 20 = 3980 \text{ bytes}$$

$$\text{Fragments} = \lceil 3980/1480 \rceil = 3$$

Step 3: Fragment details

Fragment	Payload (bytes)	Offset	MF
1	1480	0	1
2	1480	185	1
3	1020	370	0

Offsets are computed as:

$$\text{Offset} = \frac{\text{Bytes sent before}}{8}$$

5.2 Example 2: Fragmentation with Smaller MTU

Given:

- IP packet size = 2000 bytes
- MTU = 620 bytes
- Header size = 20 bytes

Maximum payload per fragment

$$620 - 20 = 600 \text{ bytes}$$

Payload size

$$2000 - 20 = 1980 \text{ bytes}$$

Number of fragments

$$\lceil 1980/600 \rceil = 4$$

Fragment	Payload	Offset	MF
1	600	0	1
2	600	75	1
3	600	150	1
4	180	225	0

5.3 Example 3: Effect of DF Flag

Given:

- Packet size = 1800 bytes
- MTU = 1500 bytes
- DF flag = 1

Result:

- Router cannot fragment the packet
- Packet is dropped
- ICMP message sent:

  Destination Unreachable – Fragmentation Needed

This mechanism is used in Path MTU Discovery (PMTUD).

5.4 Example 4: Fragment Offset Calculation

Given:

- Fragment offset = 250

Actual byte position:

$$250 \times 8 = 2000 \text{ bytes}$$

This fragment starts at byte 2000 of the original payload.

5.5 Example 5: Identifying the Last Fragment

Rule:

- MF = 1 ⇒ More fragments follow
- MF = 0 ⇒ Last fragment

Thus, the fragment with MF = 0 marks the end of the packet.

6 Common Mistakes in Fragmentation Numericals

- Forgetting to subtract header size from MTU
- Using byte offsets instead of 8-byte units
- Setting MF = 1 for the last fragment
- Assuming routers reassemble fragments

7 Fragmentation vs Segmentation

Aspect	Fragmentation	Segmentation
Layer	Network (L3)	Transport (L4)
Purpose	MTU compliance	Flow control
Reassembly	Destination host	Destination host
Protocol	IP	TCP

8 IPv4 vs IPv6 Fragmentation

Feature	IPv4	IPv6
Router fragmentation	Allowed	Not allowed
Source fragmentation	Allowed	Allowed
PMTUD	Optional	Mandatory

9 Exam-Oriented Key Points

- Fragment offset is always in multiples of 8 bytes
- Identification field is common for all fragments
- Only the destination reassembles fragments
- DF flag prevents fragmentation

10 Conclusion

IPv4 fragmentation is a fundamental mechanism that ensures packet delivery across heterogeneous networks with varying MTUs. However, due to performance, reliability, and security concerns, modern networks avoid fragmentation through Path MTU Discovery and careful packet sizing.