Internet Protocol (IP)

Dept. of Computer Science and Engineering
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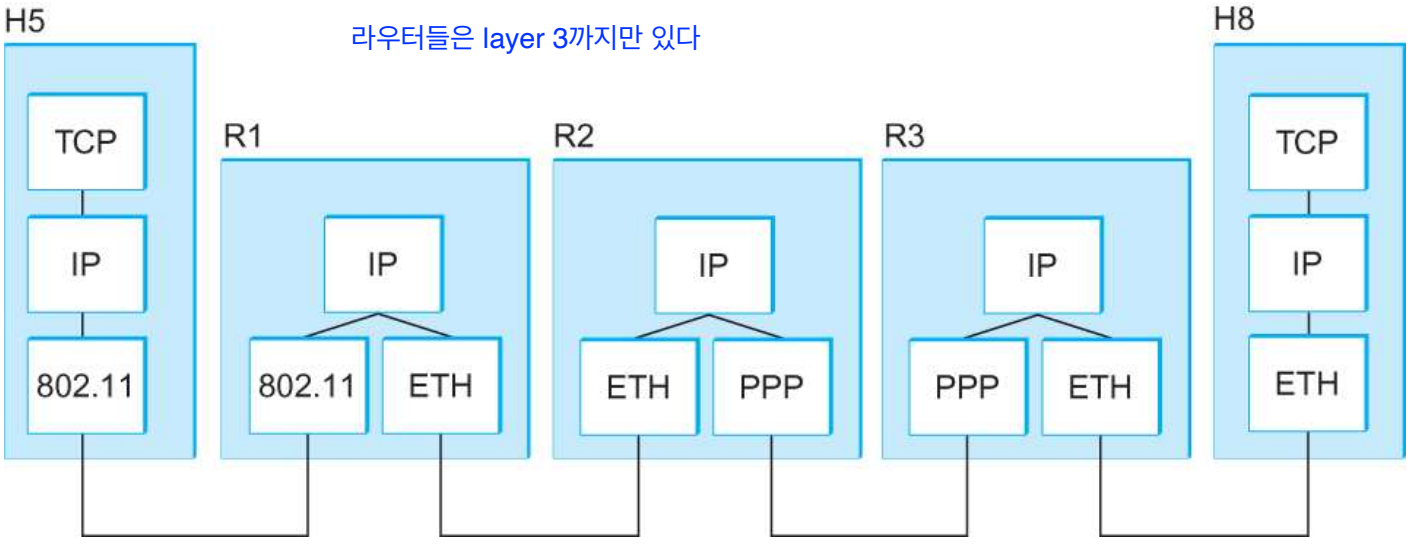
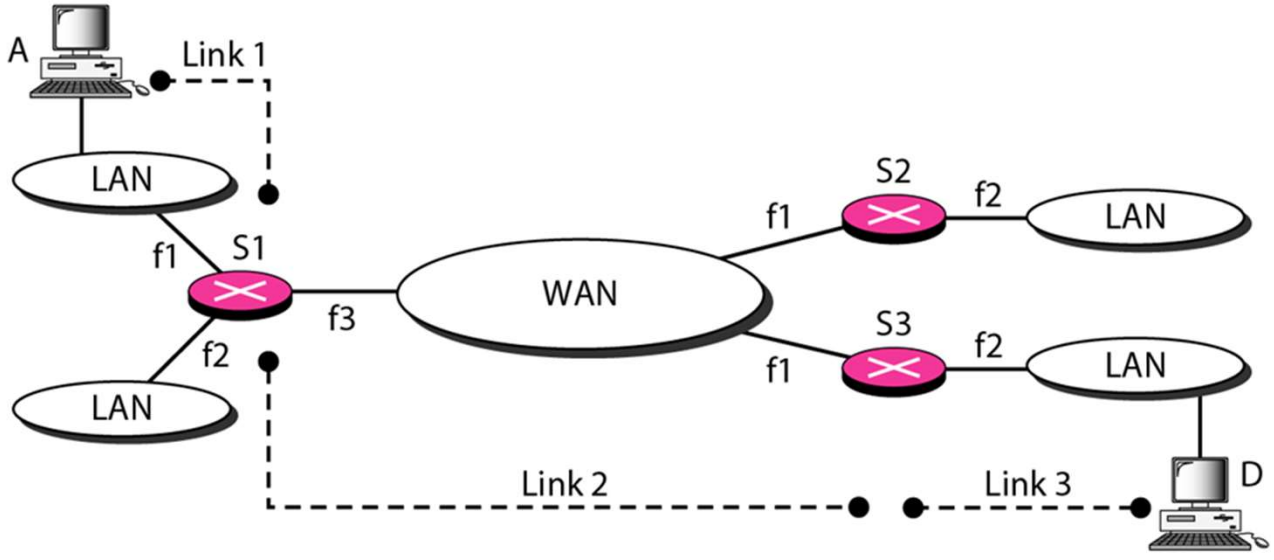
Internet Protocol (IP)

- A Network layer protocol
- Allows delivery of packets across heterogeneous systems



IP: A Network Layer Protocol

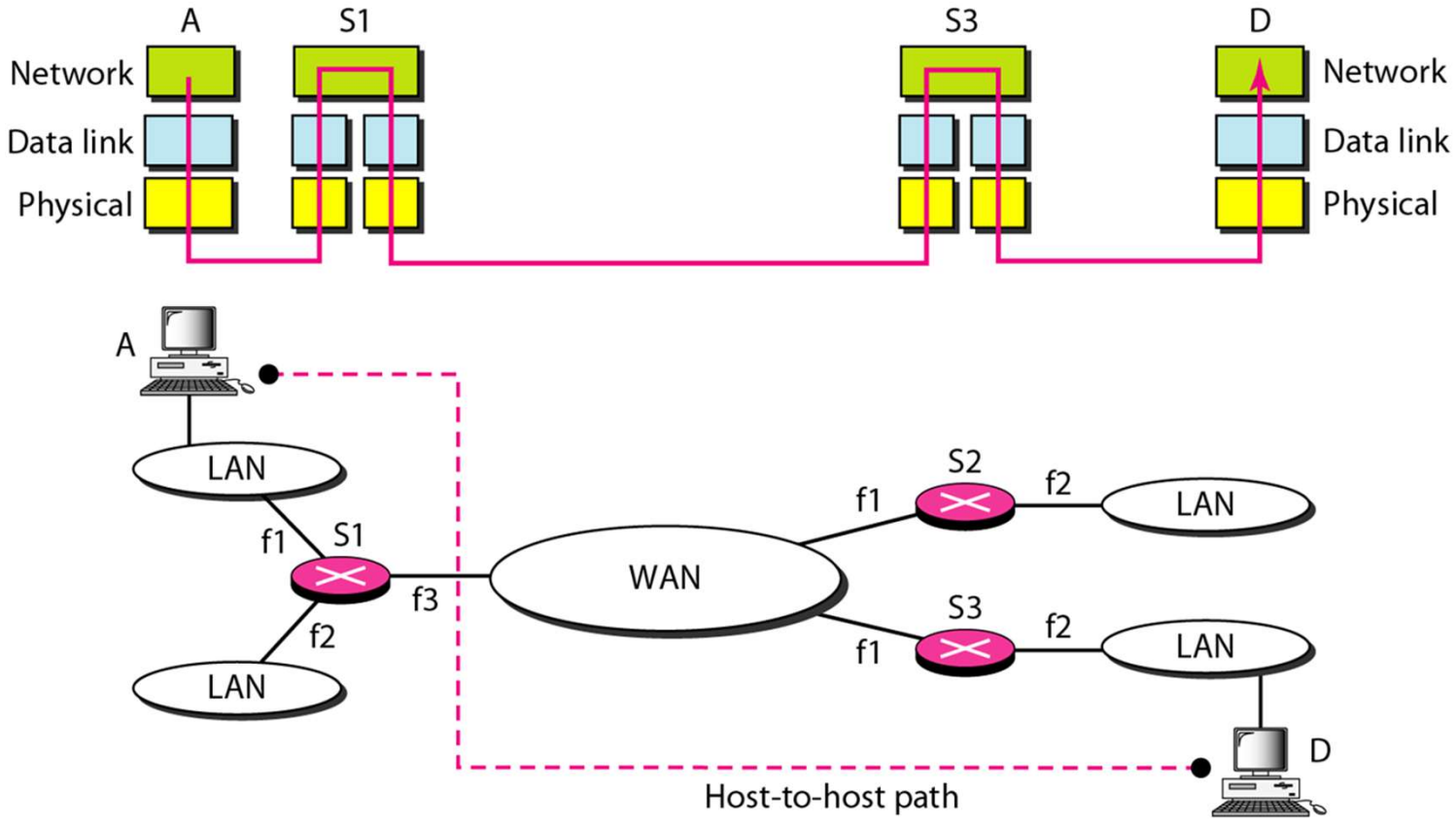
- Packet flow without Network layer



Communication only possible between physically connected hosts

IP: A Network Layer Protocol

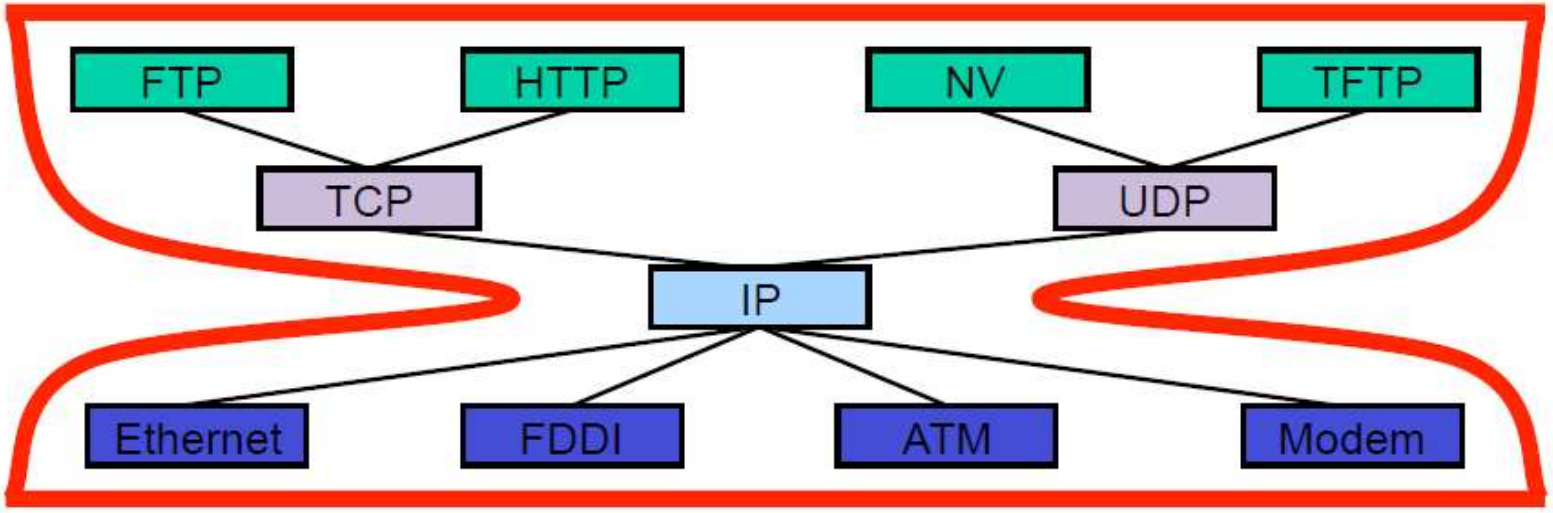
- Packet flow with Network layer



"Multi-hop" communication possible using routers

Hourglass model

- IP is the unified protocol required for all routers to implement
- Networks may implement different transport, data link, and physical layer protocols, but they all must implement IP



IP: Service Model

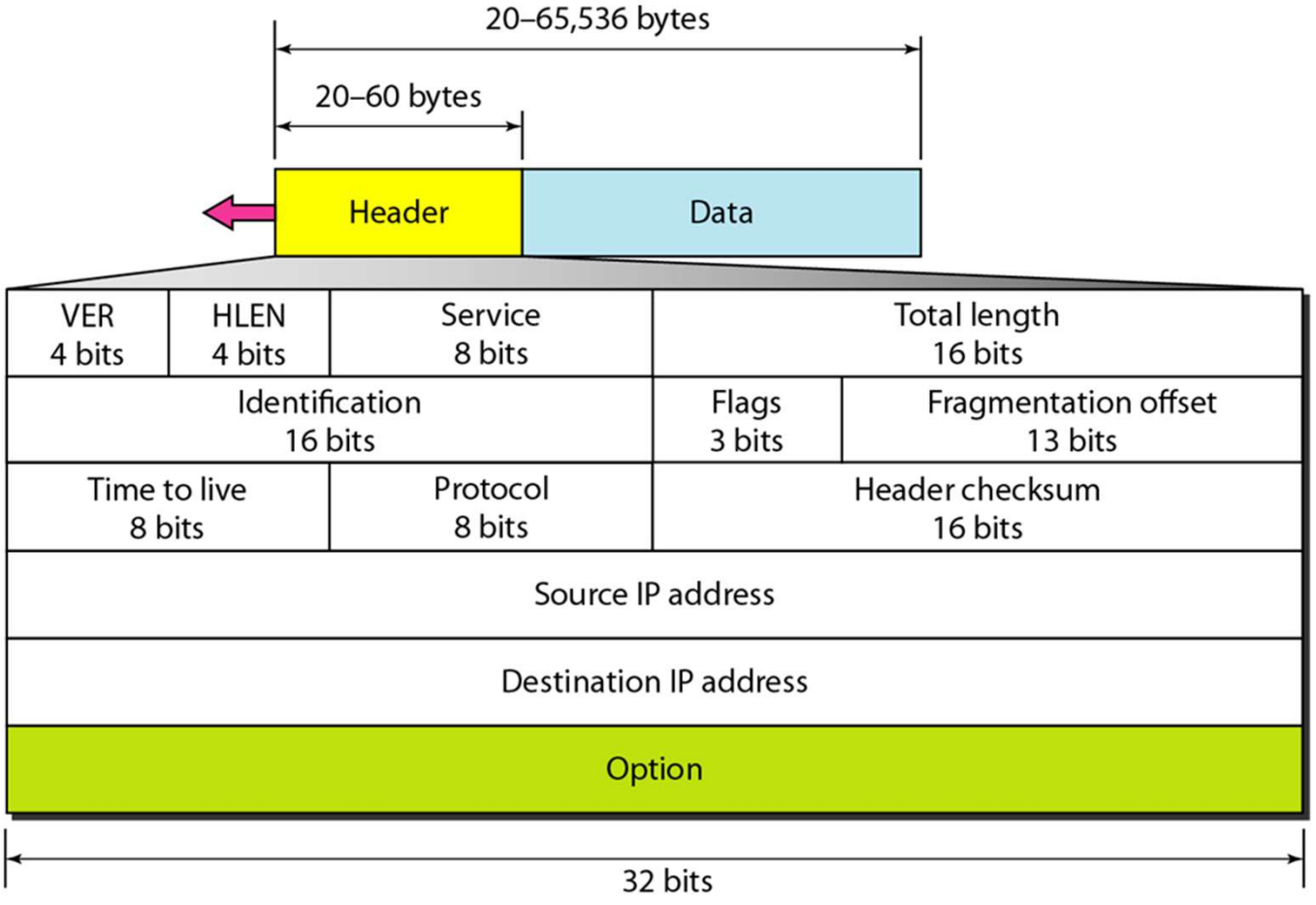
- Packet delivery model
  - Connectionless
    최선을 다하겠다 - 보장못한단 뜻
  - Best-effort (unreliable)
    - Packets may get lost
    - Packets can be delivered out-of-order
    - Duplicate copies may be delivered
    - Packets can be delayed for a long time

connection oriented - 전화
connectionless - 우표

- Global Addressing Scheme
  - Provides a way to identify all hosts in the network

IP: Packet Format

- IP Header is attached in front of the packet
- 20 bytes with no option, up to 60 bytes with option

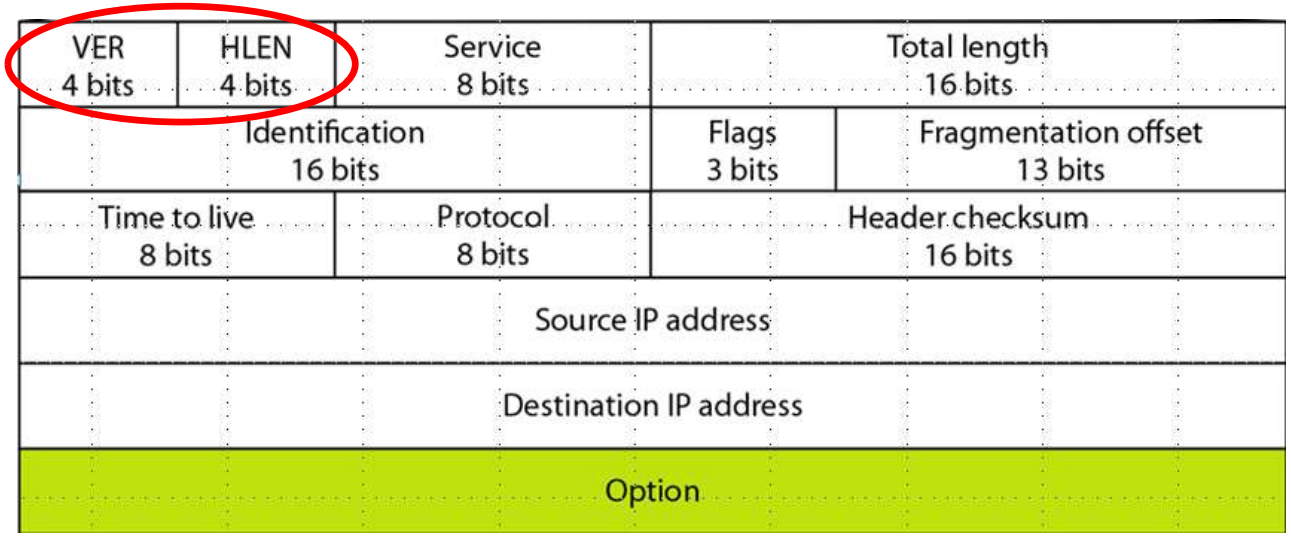


IP header

- VER: IPv4 or IPv6
- HLEN: length of the header
  - unit: word = 4 bytes
  - If the header is 20 bytes, then HLEN = 5

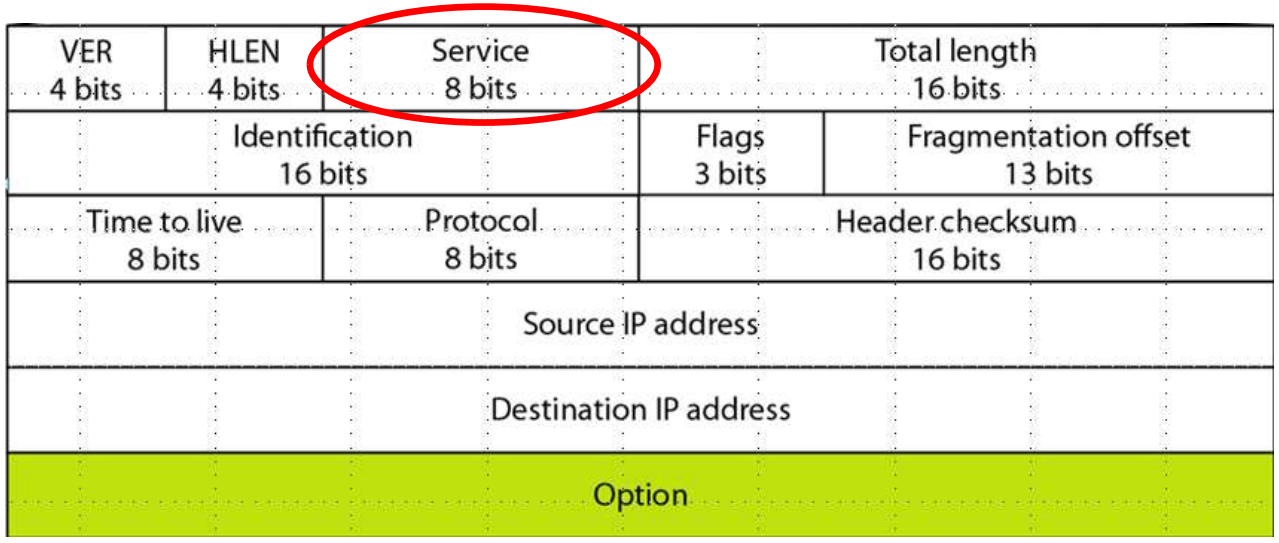
시험때 이 그림이랑 헤더를 16진수로 줘서
어느 부분이 src, dest ip 인지 아는 문제 나옴

hlen 값에 4를 곱해야 헤더 크기가 나옴
ex. hlen : 1111 - 15*4 byte



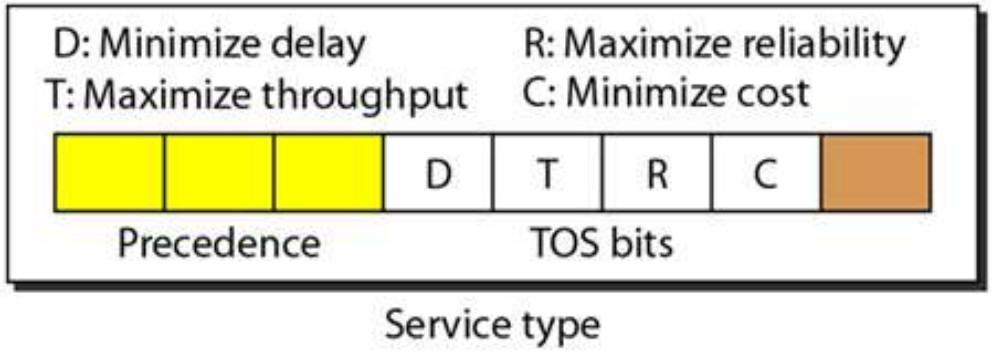
IP header

- Service: service class of the packet
  - The packet is processed at the router based on the service class



Service class

- Precedence: priority (0-7)
  - 7: the highest priority
  - When the router needs to drop a packet, it first drops the packet with the lowest priority
- TOS bits: Type of Service
  - None or only one of the bit can be 1



Service class

- Types of service

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

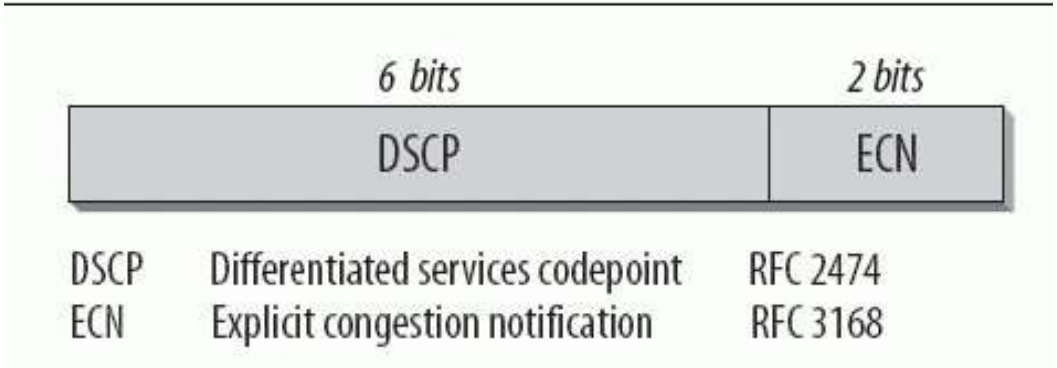
Service class

- Packet types and their service classes

Protocol	*TOS Bits*	*Description*
ICMP	0000	Normal
BOOTP	0000	Normal
NNTP	0001	Minimize cost
IGP	0010	Maximize reliability
SNMP	0010	Maximize reliability
TELNET	1000	Minimize delay
FTP (data)	0100	Maximize throughput
FTP (control)	1000	Minimize delay
TFTP	1000	Minimize delay
SMTP (command)	1000	Minimize delay
SMTP (data)	0100	Maximize throughput
DNS (UDP query)	1000	Minimize delay
DNS (TCP query)	0000	Normal
DNS (zone)	0100	Maximize throughput

Service class (Revised)

- The previous service class field is modified to indicate DSCP (Differentiated Service Code Point) ans ECN (Explicit Congestion Notification)



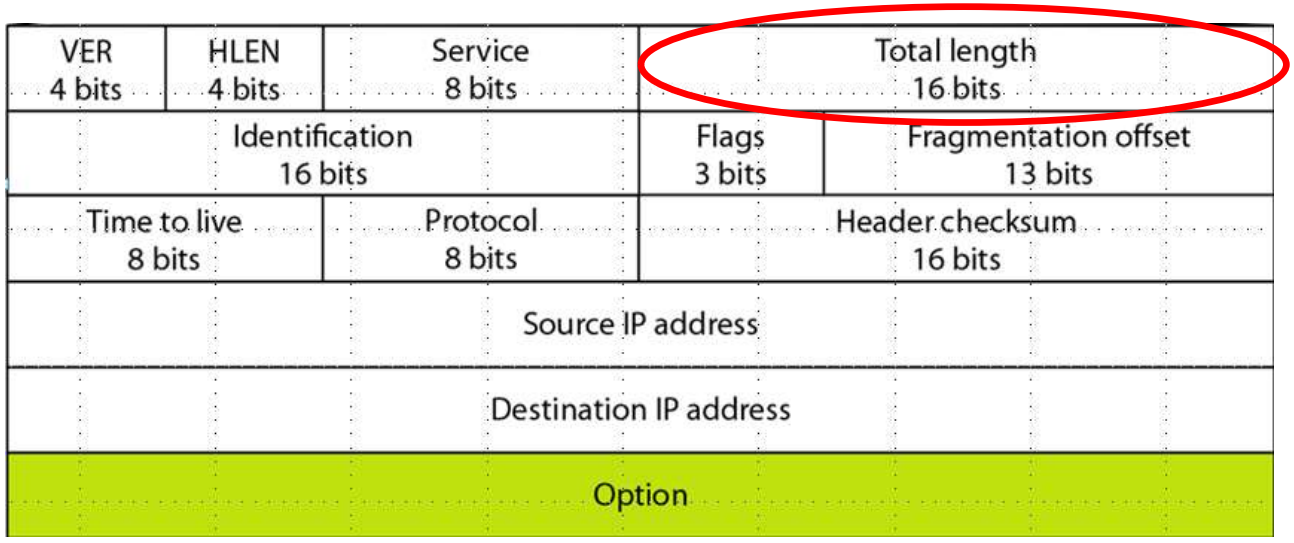
Service class (Revised)

- DSCP Table

Decimal	DSCP	Description
0	Default	Best Effort
8	CS1	Class 1 (CS1)
10	AF11	Class 1, Gold (AF11)
12	AF12	Class 1, Silver (AF12)
14	AF13	Class 1, Bronze (AF13)
16	CS2	Class 2 (CS2)
18	AF21	Class 2, Gold (AF21)
20	AF22	Class 2, Silver (AF22)
22	AF23	Class 2, Bronze (AF23)
24	CS3	Class 3 (CS3)
26	AF31	Class 3, Gold (AF31)
28	AF32	Class 3, Silver (AF32)
30	AF33	Class 3, Bronze (AF33)
32	CS4	Class 4 (CS4)
34	AF41	Class 4, Gold (AF41)
36	AF42	Class 4, Silver (AF42)
38	AF43	Class 4, Bronze (AF43)
40	CS5	Class 5 (CS5)
46	EF	Expedited Forwarding (EF)
48	CS6	Control (CS6)
56	CS7	Control (CS7)

IP header

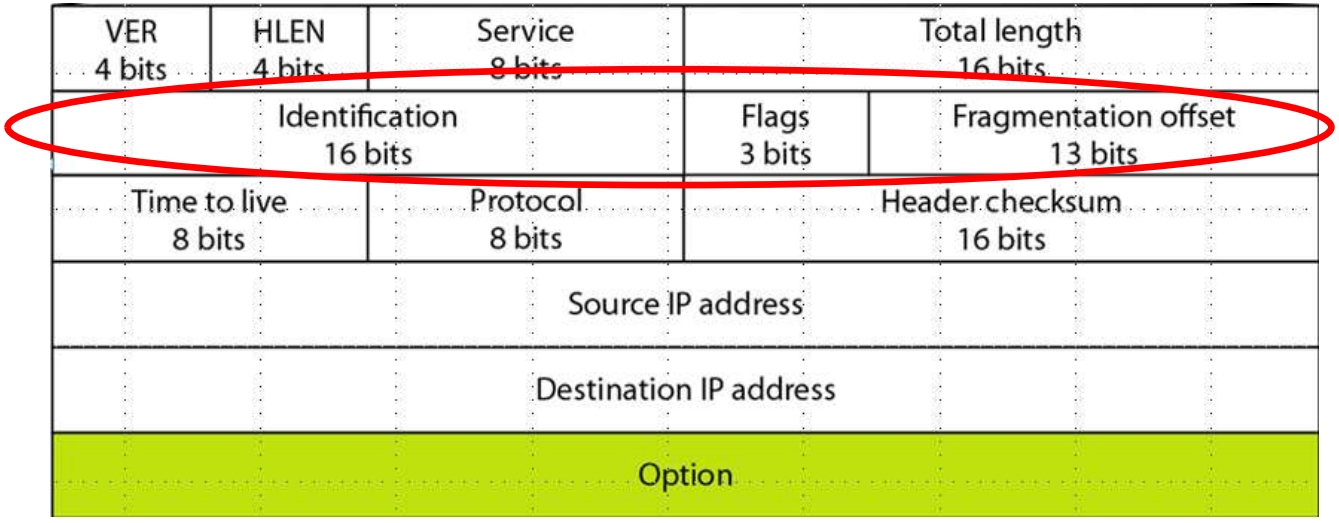
- Total length: the total packet length (header + data)
  - unit: byte



IP header

- Identification, Flags, Fragmentation offset

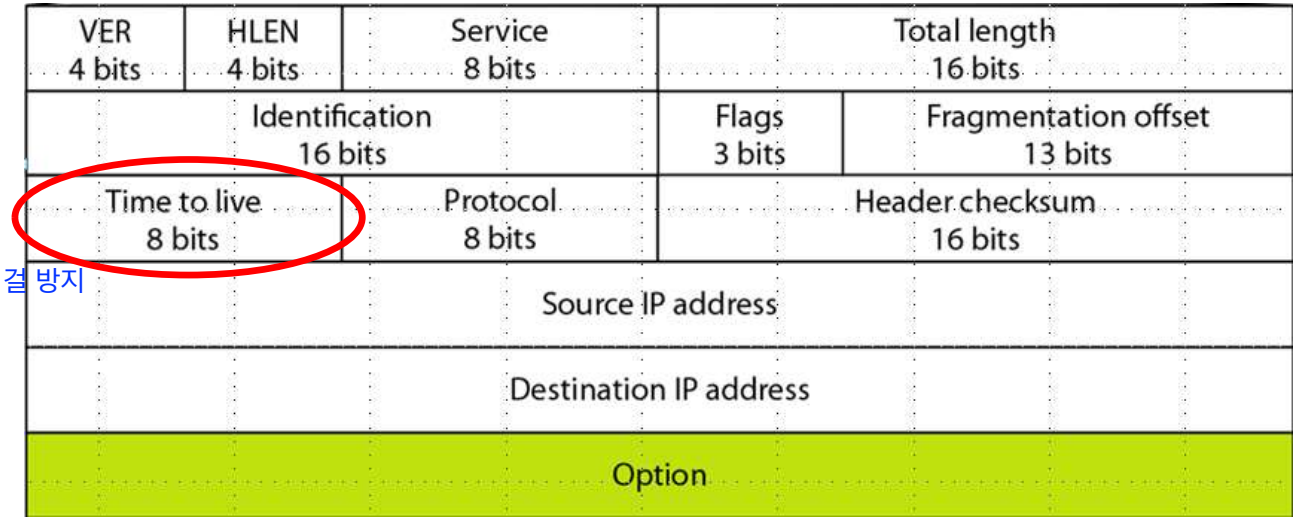
- Related to fragmentation and assembly
  - Explained later



IP header

- Time to live: the life of the packet
  - unit: number of hops
  - decremented after going through each router
  - when TTL becomes 0, the packet is no longer forwarded
    - If it did not reach the destination, it is dropped

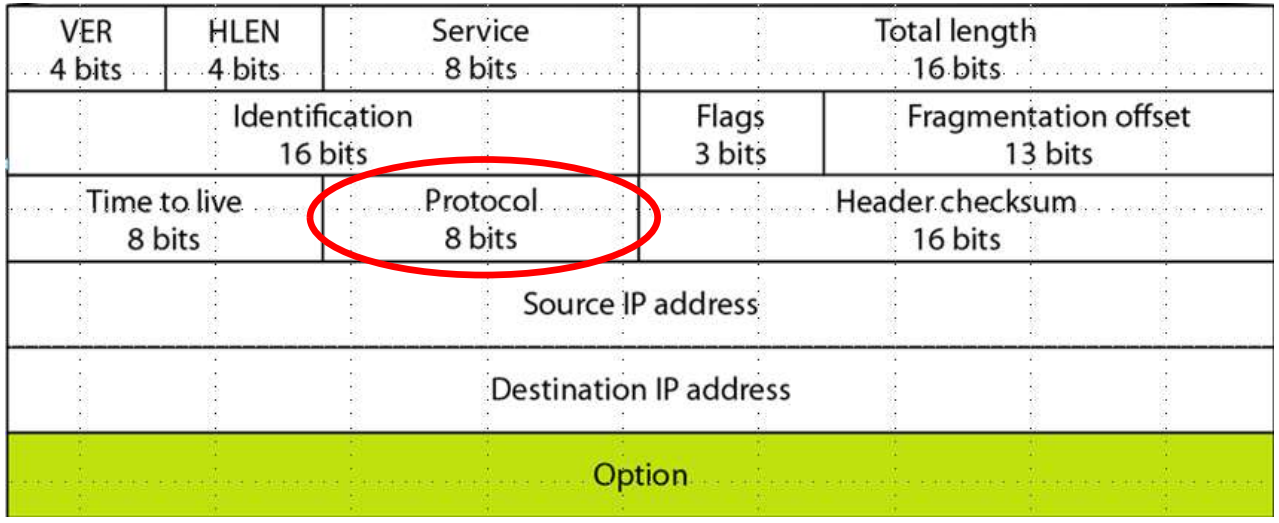
수명
라우터를 거칠 때마다
1씩 떨어짐
범위 제한의 목적 or
계속 라우터를 뺑뺑이 도는 걸 방지



IP header

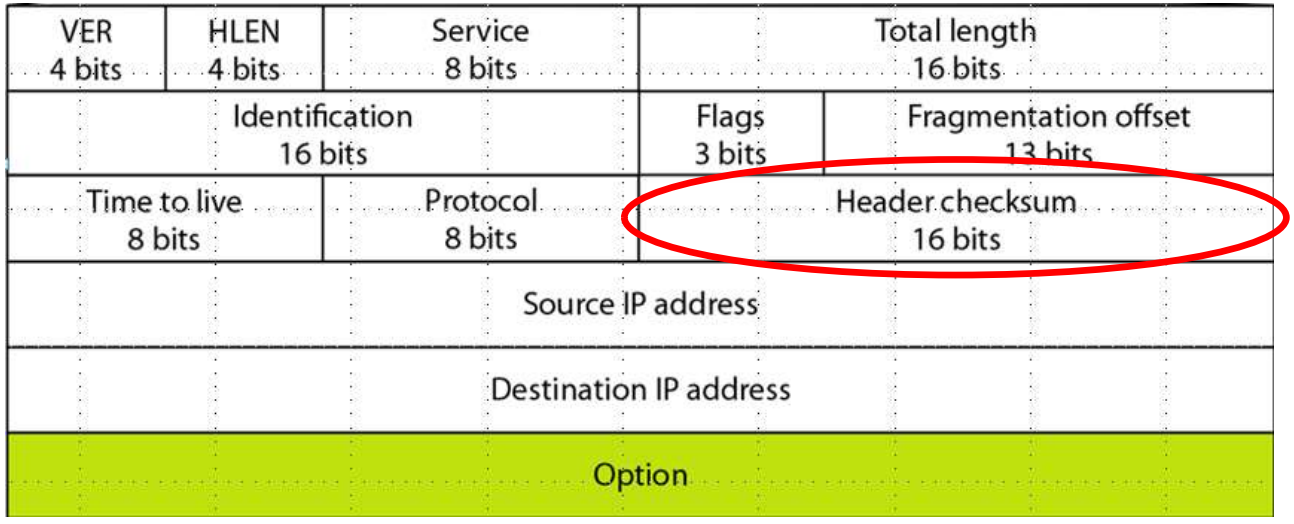
- Protocol: protocol of the upper layer (transport)

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



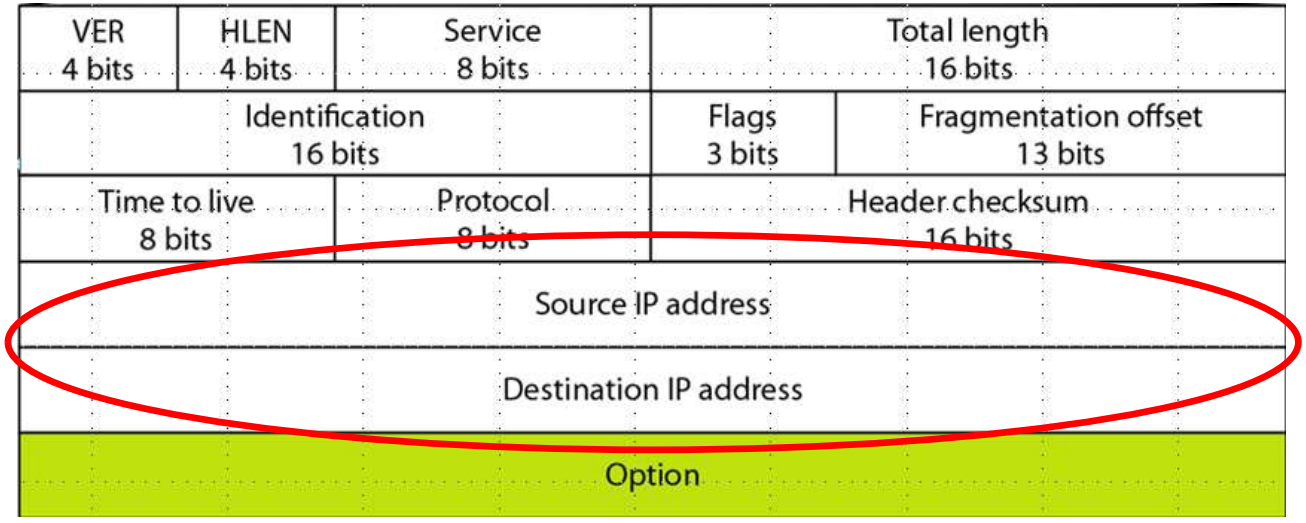
IP header

- Header checksum: used for error detection



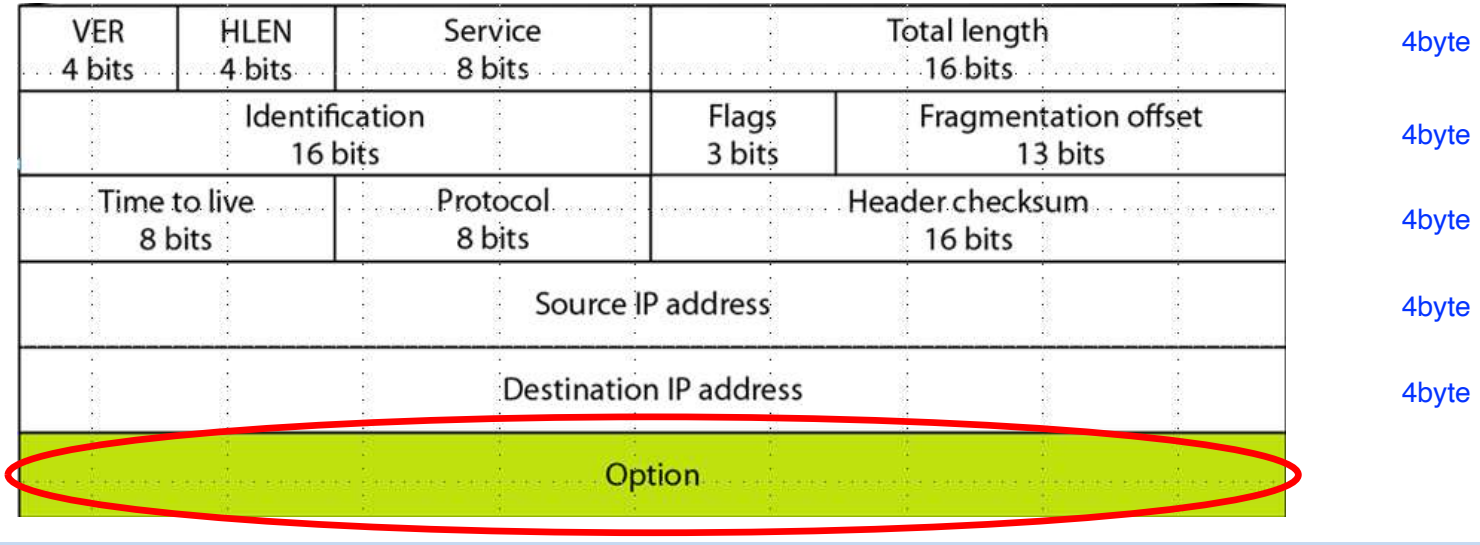
IP header

- Source IP address (32 bits)
- Destination IP address (32 bits)



IP header

- Option: optional, may not be present
  - Other 20 bytes are mandatory fields
  - Thus, the minimum HLEN is 5
  - When option fields are present, HLEN is larger than 5



IP header: exercise

- The initial 8 bits of an IPv4 packet was the following

ip4 4byte * 2

01000010 헤더는 최소 20 byte인데, 지금 HLEN 값은 2 -> 4byte라서 에러

- The router drops the packet since it is an erroneous packet. Why?

IP header: exercise

- HLEN value of an IPv4 packet is 1000 (in binary). What is the length of option fields in its IP header?

(1000)8*4byte = 32 byte
32 - 20 = 12 byte option

IP header: exercise

- HLEN of a packet is 5, and the total length field has the value 0x0028. What is the length of data in this IP packet?

20 byte

2*16 + 8 = 40byte total
40byte - 5*4byte = 20byte

IP header: exercise

- The initial part of an IPv4 packet is like the following:

0x45000028 0001 0000 01 02

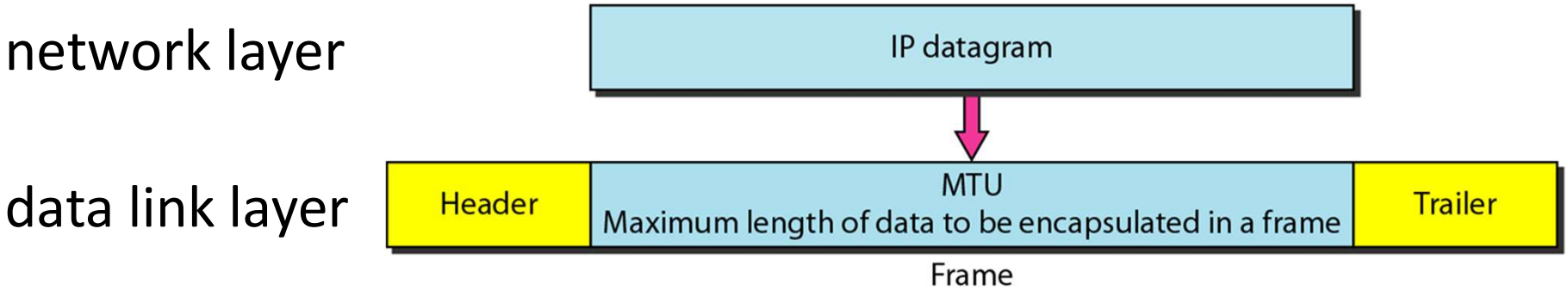
4byte 4byte 2byte

- What is the time-to-live of this packet?

1

MTU (Maximum Transfer Unit)

- Every data link layer protocol has an upper limit of IP packet



MTU (Maximum Transfer Unit)

링크 레이어에서 한번에 보낼 수 있는 프레임 제한

- Different protocols have different MTUs
  - MTU depends on forwarding and error detection methods

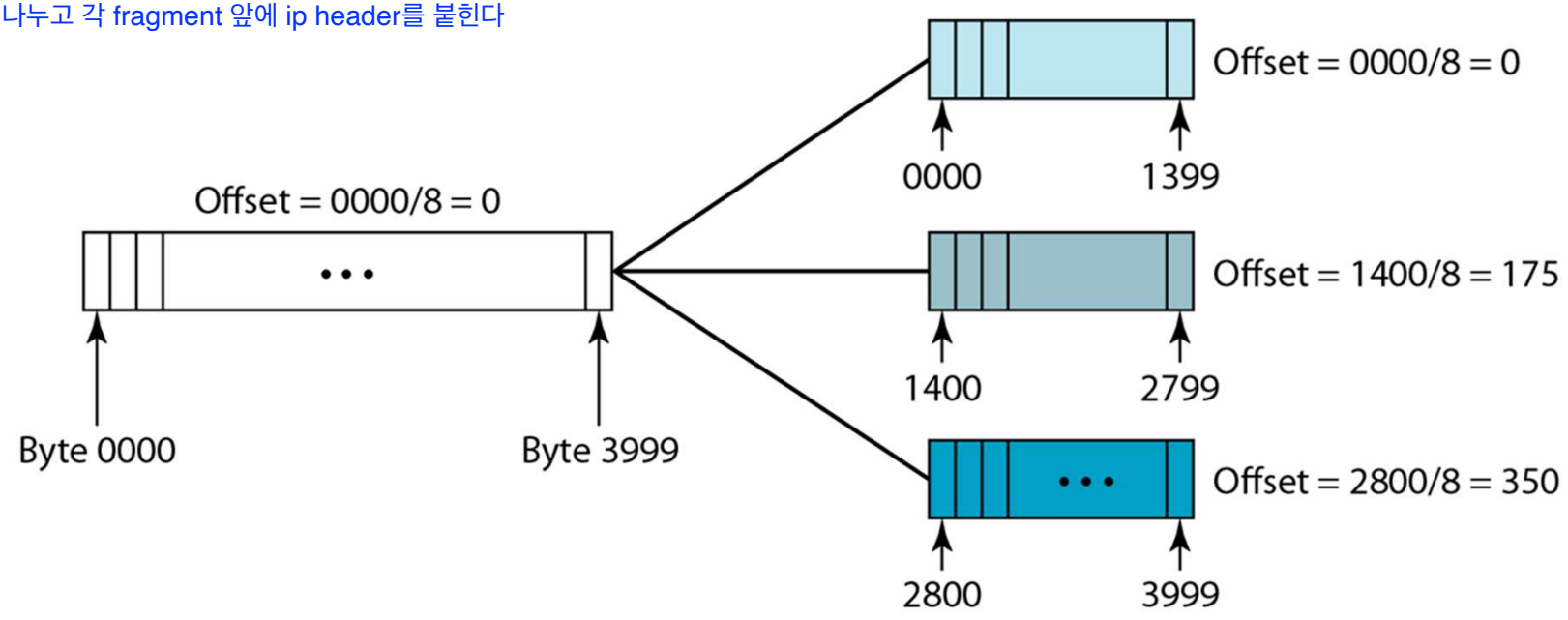
Protocol	*MTU*
Hyperchannel	65,535
Token Ring (16 Mbps)	17,914
Token Ring (4 Mbps)	4,464
FDDI	4,352
Ethernet	1,500
X.25	576
PPP	296

mtu에 맞추서 자르기

Fragmentation

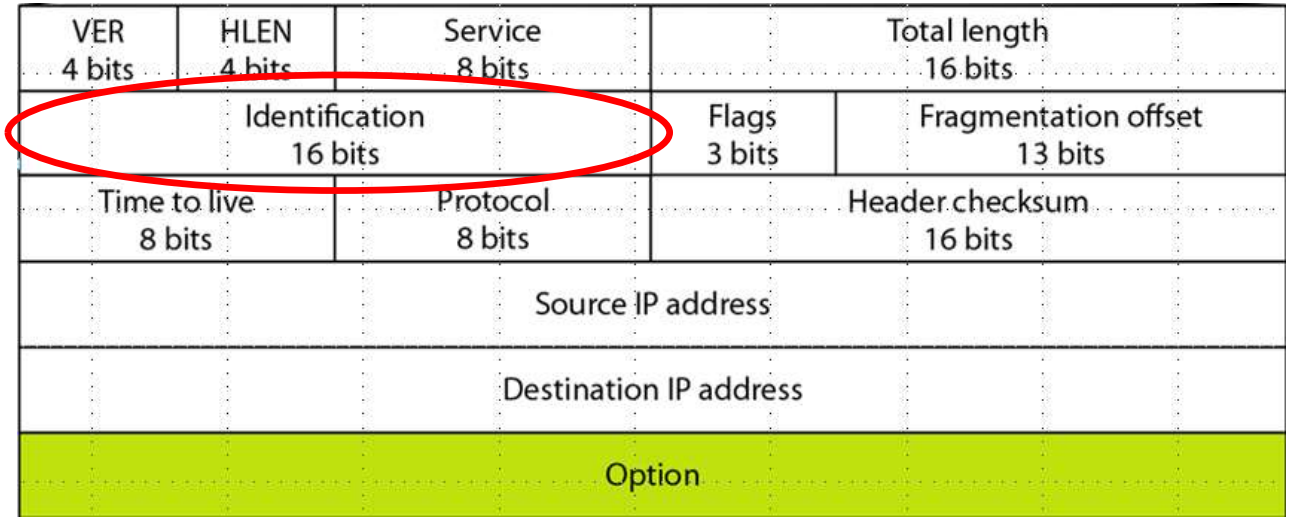
- If size of an IP packet is larger than MTU, then the packet needs to be fragmented into multiple packets
  - The IP header is attached to each fragment

fragment로 나누고 각 fragment 앞에 ip header를 붙힌다



Fields related to Fragmentation

- Identification: packet identifier
  - All fragments of the same packet has the same identification number



Fields related to Fragmentation

- Flag
  - If the bit ‘D’ is 1: this packet should not be fragmented
    - If packet size is larger than MTU, packet is discarded

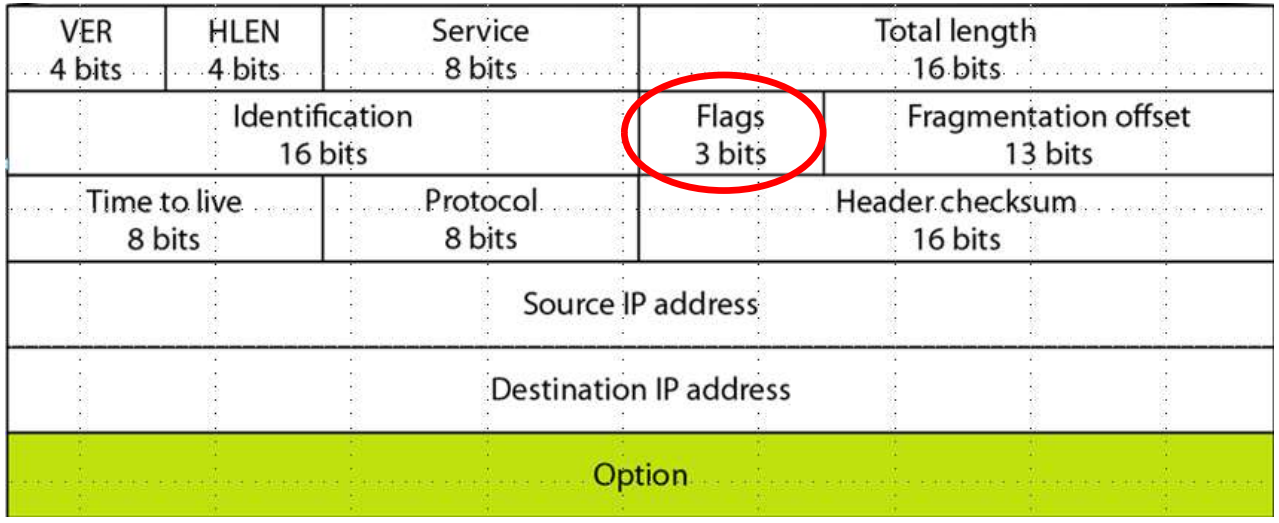
D - fragment 못하게 함
만약 D가 1인데 mtu 보다 크면 버림

  - If the bit ‘M’ is 1: there are more fragments after this

1이면 뒤에 fragment가 더 있다
0이면 뒤에 fragment가 없다

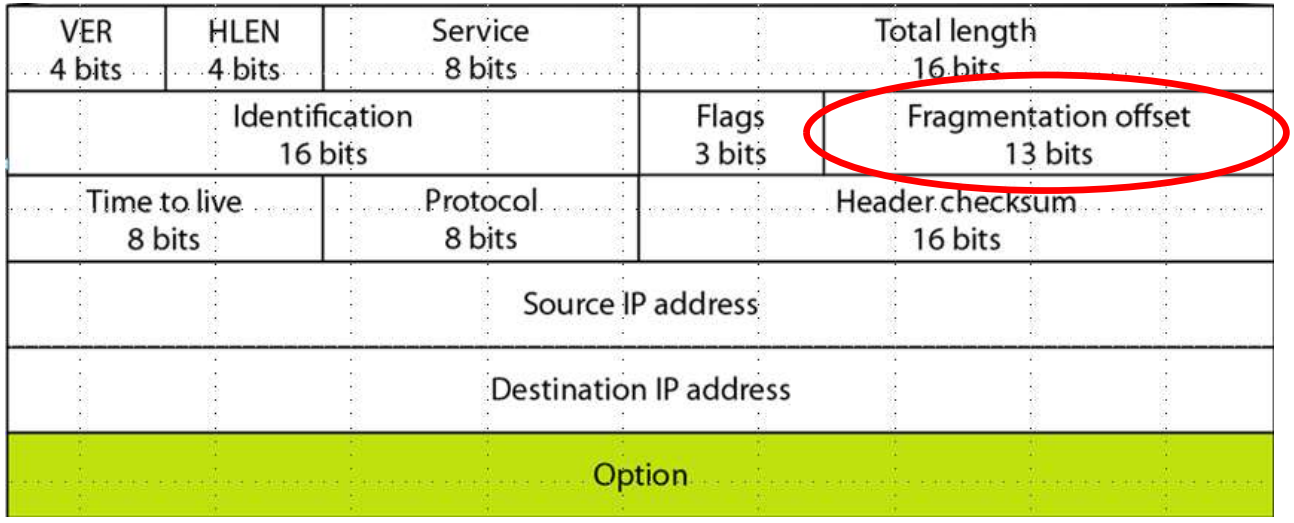
    - If ‘M’ is 0, this is the last fragment, or this is the only fragment

D: Do not fragment
M: More fragments



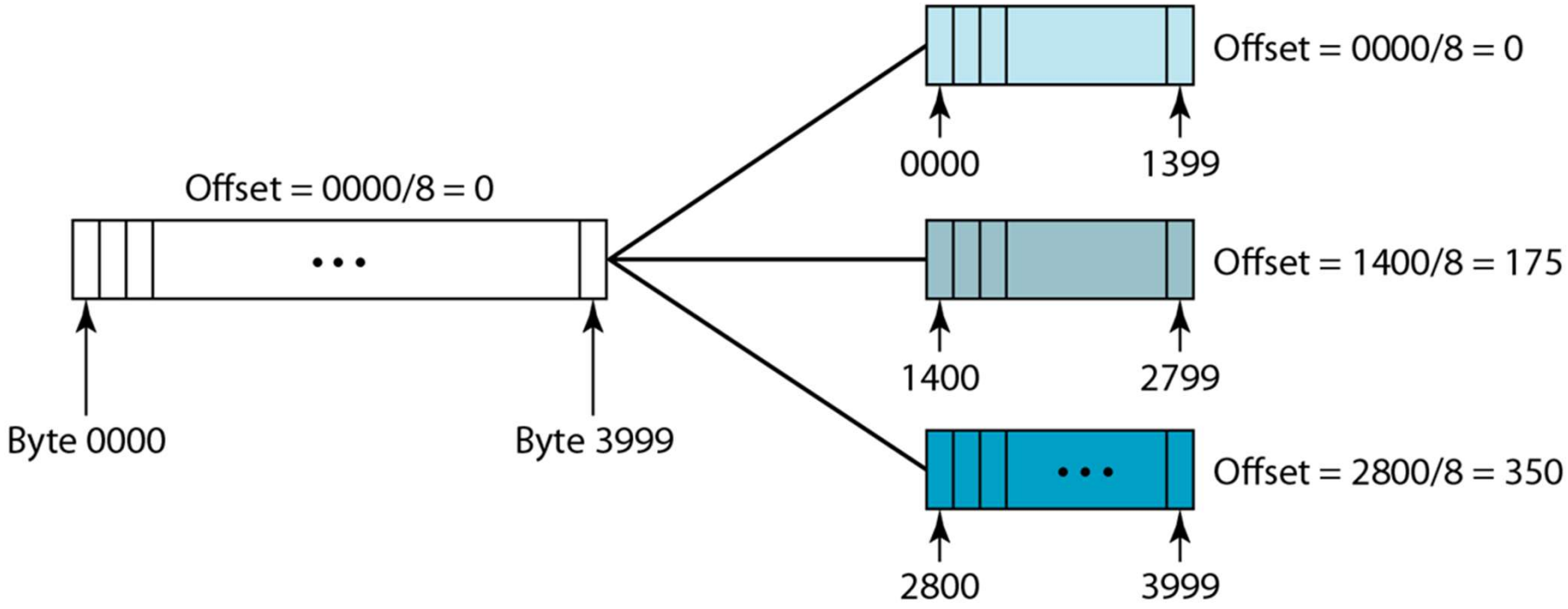
Fields related to Fragmentation

- Fragmentation offset
  - The position of this fragment in the original packet
    - unit: 8 bytes
    - only considers data bytes (refer to the figures in the next slides)

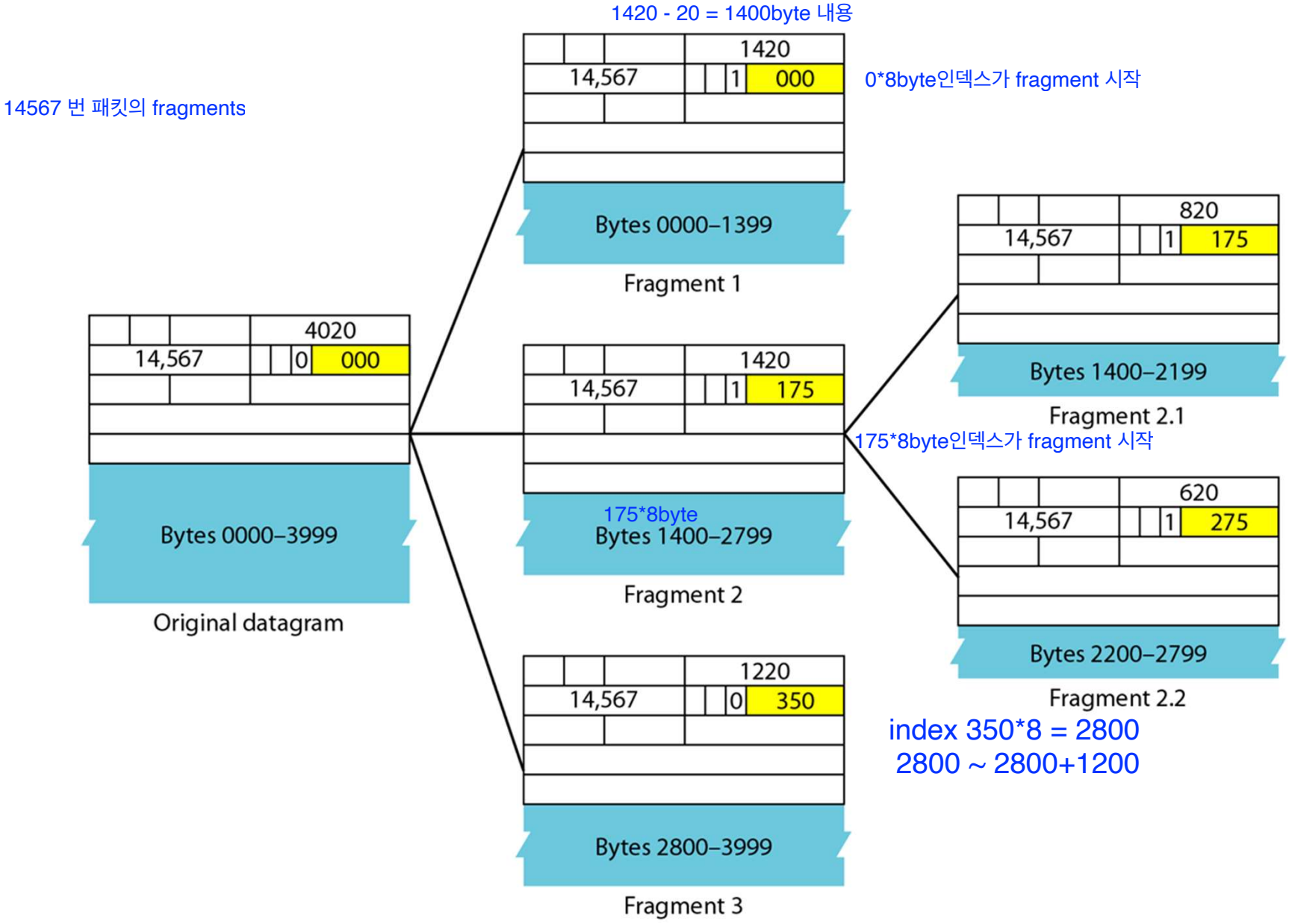


전체에서 이 fragment가 어느 위치인지
8byte 단위

Fragmentation offset

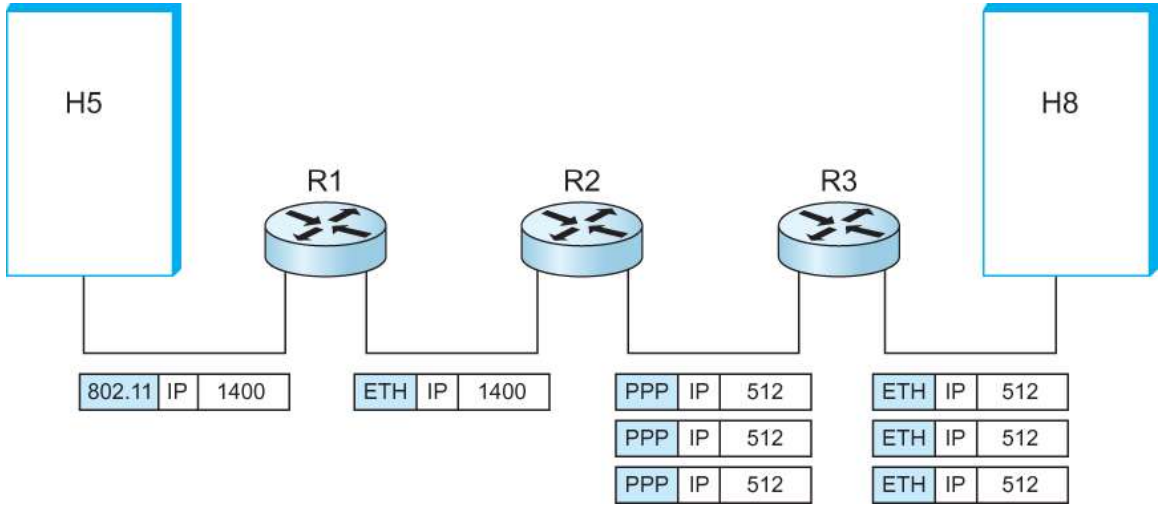


IP fragmentation: example



Fragmentation & reassembly

- Fragmentation can take place at any node
- Reassembly only occurs at the final destination
  - If the packet is reassembled at an intermediate node, it may need to be fragmented again
- The whole packet is discarded if one of the fragment does not arrive at the destination



Fragmentation & reassembly: exercise

- A packet has arrived, and its ‘M’ bit is 0. What is the meaning of this?

- Answer: either of the following
  - This packet is not fragmented
  - This packet is fragmented, and this fragment is the last one

Fragmentation & reassembly: exercise

- A packet has arrived, and its ‘M’ bit is 1. What is the meaning of this?

- Answer
  - This packet is fragmented, and this fragment is not the last one

Fragmentation & reassembly: exercise

- A packet has arrived, and its ‘M’ bit is 1, and the fragmentation offset is 0. What is the meaning of this?

- Answer
  - This packet is fragmented and this is the first fragment (there are more fragments after me)

Fragmentation & reassembly: exercise

- A packet has arrived, and its fragmentation offset is 100. What is the meaning of this?

- Answer
  - This packet is fragmented, and the position of this fragment is 800 bytes (only counting data bytes)

Fragmentation & reassembly: exercise

- A packet has arrived. Its fragmentation offset is 100, HLEN is 5, and total length is 100. What is the first and last position of this fragment in the original packet? (the first and the last bytes)

- the first byte: 100 x 8 = byte #800
- the last byte
  - total length: 100 bytes
  - header length: 5*4 20 bytes
  - data length: 100 – 20 = 80 bytes
  - Thus, the last byte is the byte #879

Fragmentation & reassembly: exercise

- Assume IP header is always 20 bytes
- An IP packet has a size of 5140 bytes (including header)
- If data link layer MTU is 1500 bytes, then how should the packet be fragmented?

Fragmentation & reassembly: exercise

- The packet should be fragmented as follows.
  - MTU = 1500