Computer Network

Data-Link Layer

Lecture : 11

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TCP/IP

TCP/IP Layer	**Hardware**	**Software/Protocols**
Application	None	HTTP, FTP, SMTP, POP3, IMAP, DNS, SSH
Transport	None	TCP, UDP
Internet	Routers	IP (IPv4/v6), ICMP, IGMP, ARP, RARP Routing(DVR(RIP), LSR(OSPF), BGP)
Data Link	Switches, Bridges, NICs	Ethernet (MAC framing), Wi-Fi (802.11 MAC), PPP, Frame Relay, HDLC
Physical	Cables (fiber, coaxial, twisted pair), Hubs, Repeaters, Connectors (RJ-45), Amplifier	ONLY physical standards (IEEE 802.3 for wiring, IEEE 802.11 PHY for Wi-Fi)

Data-Link Layer

	Responsibility	
HDLC, Ethernet *	**Framing**	Done
* * *	**Error Detection**	Done Parity bit, CheckSum, CRC, H.D
	Error Recovery	Done H.D
* * * *	**Flow Control**	
* * *	**Access Control**	
	Addressing	Done P.A { MAC: Unicast, Multi, Broadcast }
	Link Management	Done
	Framing and Encapsulation	Done

Ethernet (Protocol & Frame Standard)

- Ethernet is a **data link layer protocol** defined by IEEE **802.3**.
- It defines things like:
  - How **frames** are structured (Ether Type, MAC addresses, etc.)

    Packet, ARP
  - **Access method**: Carrier Sense Multiple Access with Collision Detection (**CSMA/CD**)
  - **Speed**, **duplex**, etc.

Note: Ethernet does **not mandate** a specific topology or physical media — it's **flexible**.

Evolution of Ethernet Topologies

Medium Access Control

Ethernet Version	Topology	Medium	Status
10Base5	Bus	Thick coaxial	Obsolete
10Base2	Bus	Thin coaxial	Obsolete
10Base-T	Star (Switch)	Twisted pair	✅ Used today
100Base-TX	Star	Twisted pair	✅ Common
1000Base-T	Star	Twisted pair	✅ Very common

Common Media Used in Point-to-Point Ethernet

Use Case	**Media**	**Standard**	**Topology**
PC ↔ Switch	**Twisted pair (UTP)**	1000Base-T	Point-to-point
Switch ↔ Switch (short range)	**Twisted pair (UTP)**	1000Base-T	Point-to-point
Switch ↔ Switch (long range)	**Fiber optic**	1000Base-SX/LX	Point-to-point
Data Center servers ↔ Switch	**Twinax (DAC cable)**	10GBase-CX	Point-to-point

Ethernet {802.3}, P.P.P, HDLC

Ethernet Frame Format (IEEE 802.3)

IPV4/ IPV6 NL

Preamble:	SFD:	Destination	Source	Length:	Data:	FCS (CRC):
7B	1 B	MAC: 6B	MAC: 6B	2B	(46 – 1500) B	4B

16 bits

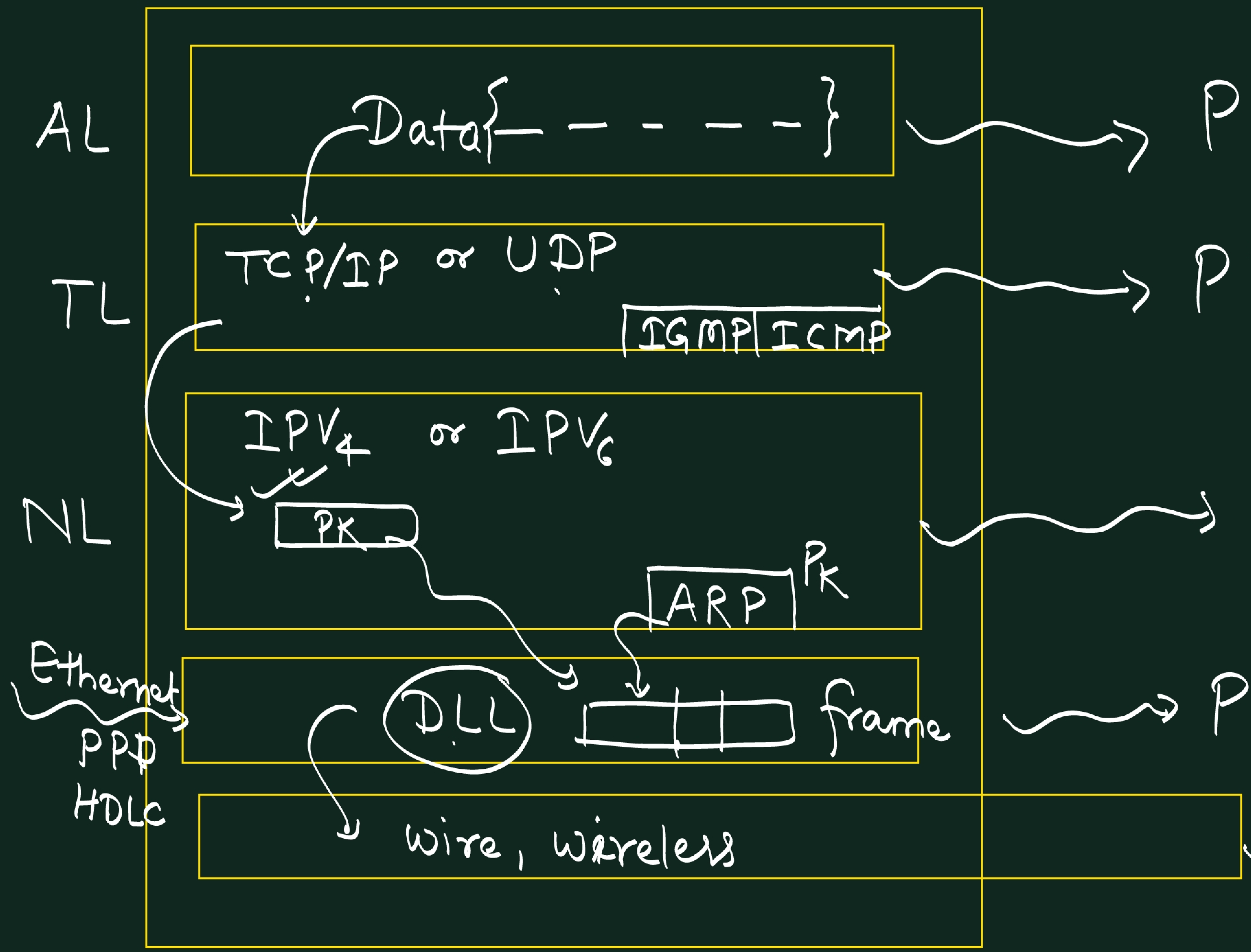
MTU : 1500B

Field	Size	Description
Destination MAC	6 Bytes	Receiver's address
Source MAC	6 Bytes	Sender's address
Length/Type	2 Bytes	Indicates either data length (if ≤ 1500) or Ethertype (if ≥ 0x0600 or 1536) ARP
Payload	46–1500 Bytes	Actual data being sent
FCS (CRC)	4 Bytes	Error detection using CRC-32

$0x\ 0\ 6\ 0\ 0$ (16^1, 16^0)

(4) (4) (4) (4)

$0 + \underbrace{16^2 \times 6}_{15} + 0 + 0$



PDU {Data or msg}

PDU {Segment, Datagram}

PDU {Packet}

PD {frame}

PDU

Ethernet Frame Format (IEEE 802.3)

Preamble: 7B	SFD: 1 B	Destination MAC: 6B	Source MAC: 6B	Length: 2B	Data: (46 – 1500) B	FCS (CRC): 4B

Preamble (7 Bytes)

- Value: $\boxed{\text{10101010 repeated}}$
- Purpose: Allows the receiver to **synchronize clock** with sender before actual data begins.
- Not considered part of the "actual Ethernet frame" as per IEEE 802.3.

SFD – Start Frame Delimiter (1 Byte)

- Value: $\boxed{10101011}$
- Marks the **end of preamble** and **start of frame**.
- Also, **not** part of the frame when calculating size (used only by PHY layer for alignment).

Ethernet Frame Format (IEEE 802.3)

Preamble: 7B	SFD: 1 B	Destination MAC: 6B	Source MAC: 6B	Length: 2B	Data: (46 – 1500) B	FCS (CRC): 4B

Ethernet Frame Size Calculation

➤ **Minimum Frame Size: 64 Bytes**

•Includes: 6 + 6 + 2 + 46 + 4 = 64 Bytes

•If payload < 46 bytes, **padding is added** to meet the minimum.

➤ **Maximum Frame Size: 1518 Bytes**

•Includes: 6 + 6 + 2 + 1500 + 4 = 1518 Bytes

•**Does not include preamble (7B) or SFD (1B)**

Ethernet Frame Format (IEEE 802.3)

Preamble: 7B	SFD: 1 B	Destination MAC: 6B	Source MAC: 6B	Length: 2B	Data: (46 – 1500) B	FCS (CRC): 4B

MTU (Maximum Transmission Unit)

- **Definition**: Maximum amount of data the network layer can pass to the data link layer in one frame.
- **Value for Ethernet**: 1500 bytes
- This is **only the payload** part — does **not** include header or CRC.

➤ Ethernet frame size with MTU:

- Payload: 1500 B
- Header (Dest + Src + Type): 14 B
- FCS: 4 B

➡️ **Total**: 1518 bytes (max frame size)

➡️ With preamble + SFD: 1518 + 8 = 1526 bytes (**on the wire**, not counted by MAC layer)

Ethernet Frame Format (IEEE 802.3)

Preamble: 7B	SFD: 1 B	Destination MAC: 6B	Source MAC: 6B	Length: 2B	Data: (46 – 1500) B	FCS (CRC): 4B

Length Field (2 Bytes)

- Appears **after Source MAC** and **before Payload**.
- Indicates the **length of the payload (data)** in **bytes**, not the full frame.
- **Range**: 0 – 1500 (decimal)

Important:

- If this field's value is **≤ 1500**, it is treated as a **length field** → tells the **number of bytes in the payload**.

Not in Syllabus

- If it's **≥ 1536 (0x0600)**, it is interpreted as a **Type field** (Ethertype — like ARP).

Ethernet Frame Format (IEEE 802.3)

Preamble:	SFD:	Destination	Source	Length:	Data:	FCS (CRC):
7B	1 B	MAC: 6B	MAC: 6B	2B	(46 – 1500) B	4B

Type	First Byte Pattern	Purpose
Unicast	LSB = 0	Single destination
Multicast	LSB = 1	Group destination
Broadcast	All bits 1	All devices on LAN

FF. FF. FF. FF. FF. FF

Preamble: 7B	SFD: 1 B	Destination MAC: 6B	Source MAC: 6B	Length: 2B	Data: (46 – 1500) B	FCS (CRC): 4B

Question	Answer
Is preamble + SFD part of Ethernet frame size?	No (not counted in 64–1518 bytes)
Is preamble + SFD transmitted?	Yes, by PHY layer
Does MTU include headers?	No, MTU = payload only (max 1500B)
Max frame size (excluding preamble)?	1518 bytes
Max size “on the wire”?	1526 bytes (with 8B preamble/SFD)

Q1. What type of address is FF:FF:FF:FF:FF:FF?

A. Unicast

B. Multicast

C. Broadcast

Q2. What type of address is 01:00:5E:00:00:FB?

A. Unicast

B. Multicast

C. Broadcast

B. Q3. Is the MAC address 00:1A:2B:3C:4D:5E unicast, multicast, or broadcast?

Answer:

Q4. Classify the MAC address 33:33:00:00:00:16

Q5. Is the MAC address 02:AB:CD:EF:12:34 unicast or multicast?

Q6. What type of MAC address is FF:00:00:00:00:00?

HDLC (High-Level Data Link Control)

01111110 | Address | Control | Payload | FCS | 01111110

Bit Stuffing

Field	Size	Description
Flag	8 bits (`01111110`)	Marks the beginning and end of a frame.
Address	8 or more bits	Identifies the sender or receiver.
Control	8 or 16 bits	Manages flow and error control.
Payload	Variable	Contains the actual data.
FCS (Frame Check Sequence)	16 or 32 bits	Provides error detection using CRC.
Flag	8 bits (`01111110`)	Marks the end of the frame.

Data Link Layer

Bit Stuffing in HDLC

HDLC uses **bit stuffing** to ensure that the flag sequence (01111110) does not appear within the frame's data field.

Bit Stuffing Rule:

- Whenever the sender detects **five consecutive 1s** in the data, it **inserts a 0** to break the sequence.
- The receiver removes the stuffed 0 upon reception.

Input Data:	**0111111011101111110**
After Bit Stuffing:	**011111010111011111010**

1. A bit-stuffing based framing protocol uses an 8-bit delimiter pattern of 01111110. If the output bit-string after stuffing is 01111100101, then the input bit-string is

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A. 111110100
B. 111110101
C. 111111101
D. 111111111

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Byte Stuffing (Character Stuffing)

- Used in **character-oriented protocols** (like PPP).

Before Byte Stuffing	After Byte Stuffing
HELLO$WORLD$	HELLO ESC$ WORLD ESC$

Byte Stuffing

Comparison of Framing in PPP, HDLC, and Ethernet

Feature	**PPP (Point-to-Point Protocol)**	**HDLC (High-Level Data Link Control)**	**Ethernet (IEEE 802.3)**
Framing Method	Byte-oriented Byte Stu	Bit-oriented Bit Stuff	Byte-oriented
Frame Delimiter	0x7E (01111110)	0x7E (01111110)	Preamble (7 bytes) + SFD (Start Frame Delimiter)
Addressing	No MAC address (only for PPPoE)	Address field (1 or 2 bytes)	MAC Address (6 bytes) NIC
Error Detection	CRC-16	CRC-16/CRC-32	CRC-32
Bit/Byte Stuffing	Byte stuffing (ESC + FLAG replacement)	Bit stuffing (adds ‘0’ after 5 consecutive ‘1’s)	No stuffing (fixed frame format)
Usage	WAN (PPP links, dial-up, DSL)	WAN, leased lines	LAN (wired networks)
Encapsulation	Supports multiple protocols (IP, IPv6, etc.)	Primarily used for synchronous communication	Ethernet frame with payload (IPv4, IPv6, ARP, etc.)
Control Mechanism	Link Control Protocol (LCP) and Network Control Protocols (NCPs)	Standardized frame structure with control field	Uses MAC for collision handling (CSMA/CD)
Feature	PPP (Point-to-Point Protocol)	HDLC (High-Level Data Link Control)	Ethernet (IEEE 802.3)

Transmission Delays and Bandwidth

Ethernet Transmission (No Modulation)
Frame → Parallel to Serial → Encoding (Manchester) → Transmission Delay → Bits sent over Wire

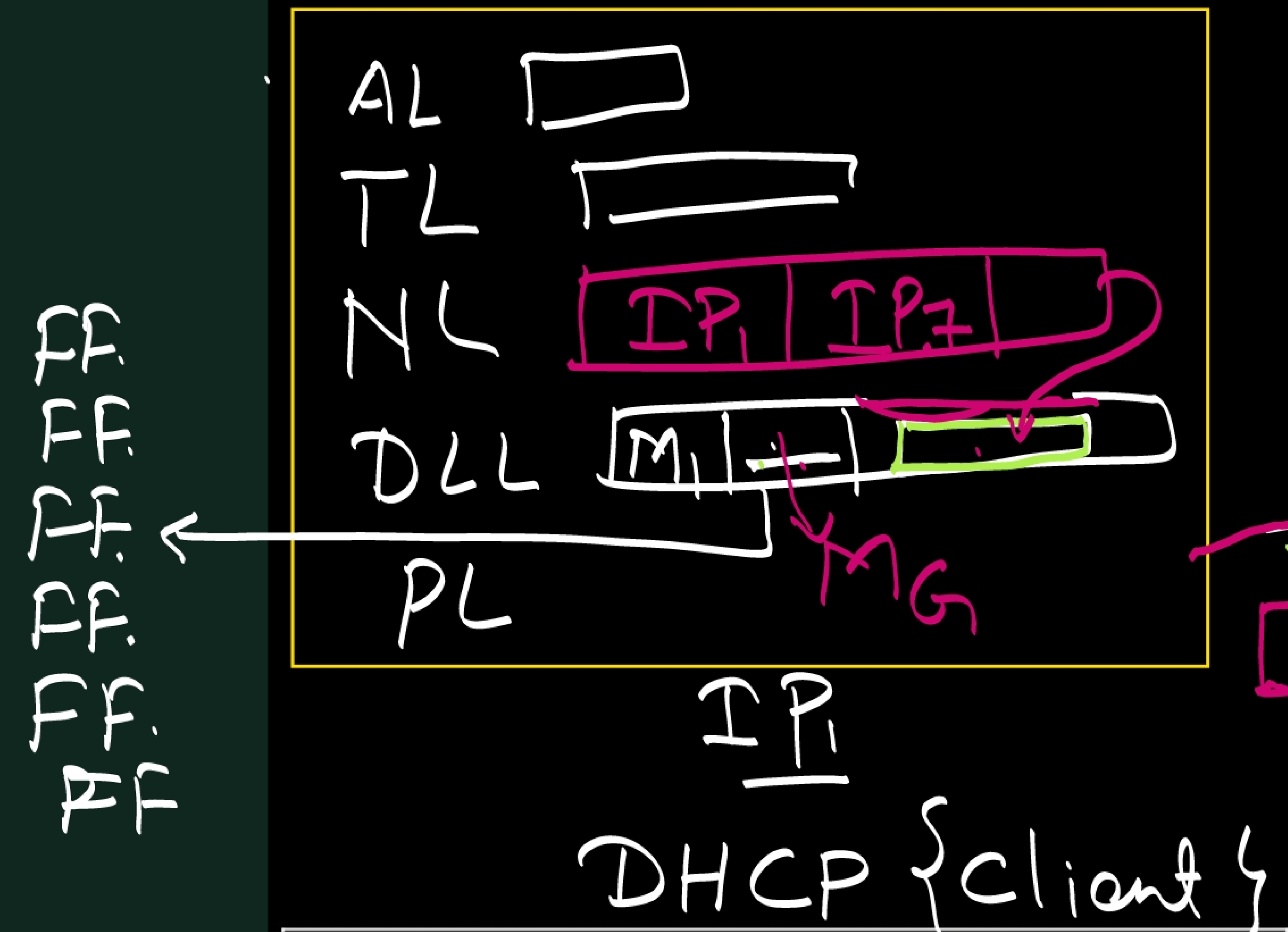
Wireless Transmission (Requires Modulation)
Frame → Parallel to Serial → Encoding → Modulation (Processing Delay) → Transmission Delay → Analog wave sent over Air

Radio waves

ARP: Address Resolution Protocol

Internal DHCP	
IP Address:	IP_1
DHCP Server:	IP_{17}
Default Gateway:	IP_G
DNS Server :	IP_D

ARP: Address Resolution Protocol



Internal DHCP	
IP Address:	IP_1
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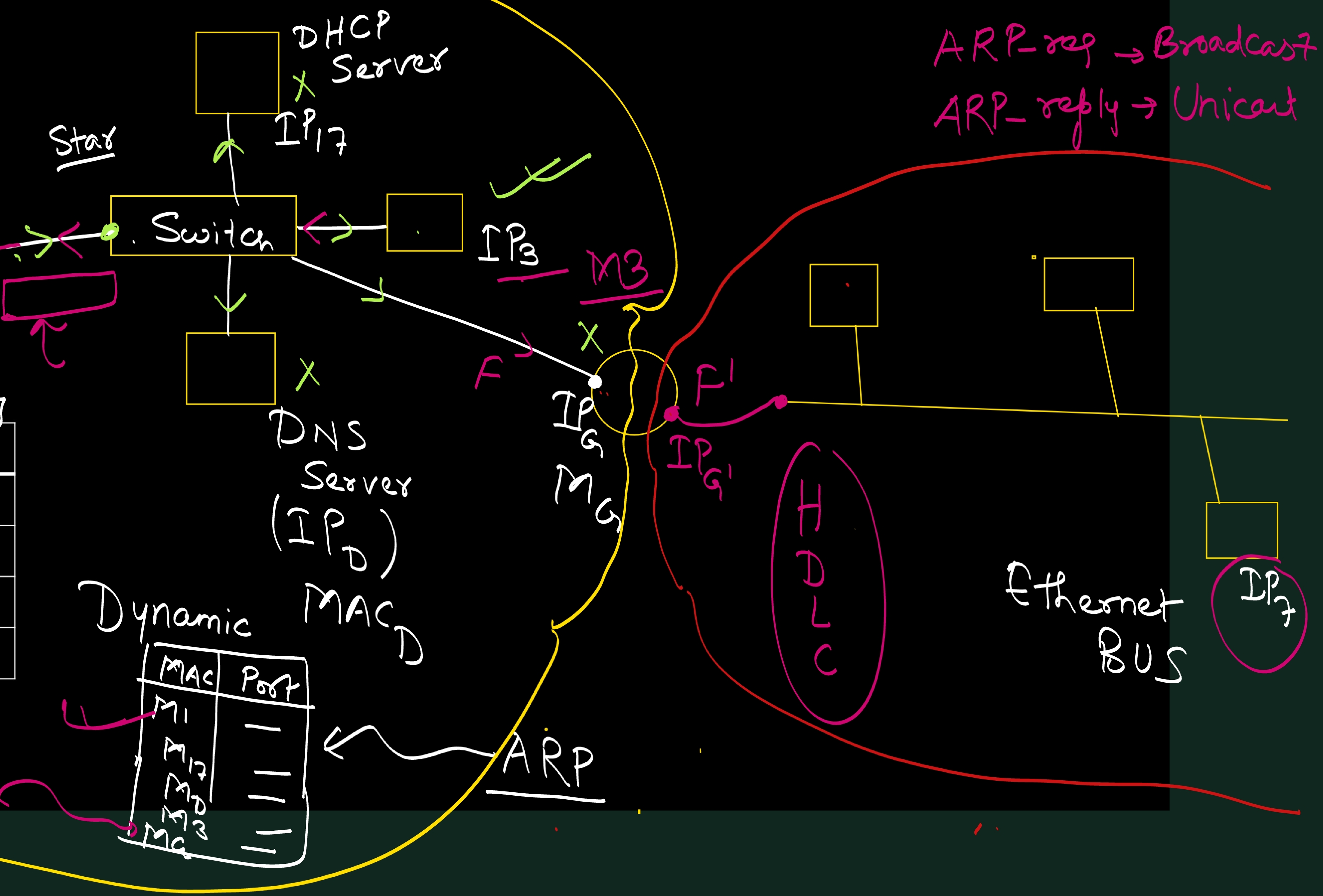

ARP Packet Fields (inside Ethernet frame)

Field	Size (bytes)	Description
Hardware Type	2	0x0001 = Ethernet
Protocol Type	2	0x0800 = IPv4
Hardware Address Length	1	6 (MAC address length)
Protocol Address Length	1	4 (IPv4 address length)
Operation	2	0x0001 = request, 0x0002 = reply
Sender MAC Address	6	MAC of sender
Sender IP Address	4	IP of sender
Target MAC Address	6	MAC of target (0s in request)
Target IP Address	4	IP of target

Encapsulated in an Ethernet Frame

Ethernet Field	**Size**	**Example Value**
Destination MAC	6 bytes	FF:FF:FF:FF:FF:FF (for broadcast ARP request)
Source MAC	6 bytes	Sender’s MAC
EtherType	2 bytes	0x0806 (for ARP)
Payload (ARP Packet)	28 bytes	As defined above
Padding (if needed)	varies	Ethernet requires **min 46-byte payload**
Frame Check Sequence (FCS)	4 bytes	CRC for error check (done by NIC, usually not shown in software capture)

1. Consider the following two statements.

S1: Destination MAC address of an ARP reply is a broadcast address.
S2: Destination MAC address of an ARP request is a broadcast address.

Which one of the following choices is correct?

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A. Both S1 and S2 are true
B. S1 is true and S2 is false
C. S1 is false and S2 is true
D. Both S1 and S2 are false

2. Suppose that in an IP-over-Ethernet network, a machine X wishes to find the MAC address of another machine Y in its subnet. Which one of the following techniques can be used for this?

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A. X sends an ARP request packet to the local gateway's IP address which then finds the MAC address of Y and sends to X

B. X sends an ARP request packet to the local gateway's MAC address which then finds the MAC address of Y and sends to X

C. X sends an ARP request packet with broadcast MAC address in its local subnet

D. X sends an ARP request packet with broadcast IP address in its local subnet

Thank You