Ethernet protocol in Automotive and Physical layer.

Pavel-Ioan Duta (IFAG ATV MC TM CES1)
Merwin Ebenezer (IFINS ATV MC TM PEW)
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Introduction to IEEE 802.3

- Ethernet is a family of wired computer networking technologies commonly used in local area networks (LAN), metropolitan area networks (MAN) and wide area networks (WAN).

- It was commercially introduced in 1980 and first standardized in 1983 as **IEEE 802.3.**

- **IEEE 802.3** is a working group and a collection of standards defining the physical layer and data link layer's media access control (MAC) of wired Ethernet.

- Some examples of communication standards that are part of **IEEE 802.3** group are:
  - **IEEE 802.3u** as known as **Fast Ethernet** e.g **100BASE-TX;**
  - **IEEE 802.3ab** as known as **Gigabit Ethernet** e.g **1000BASE-T**.

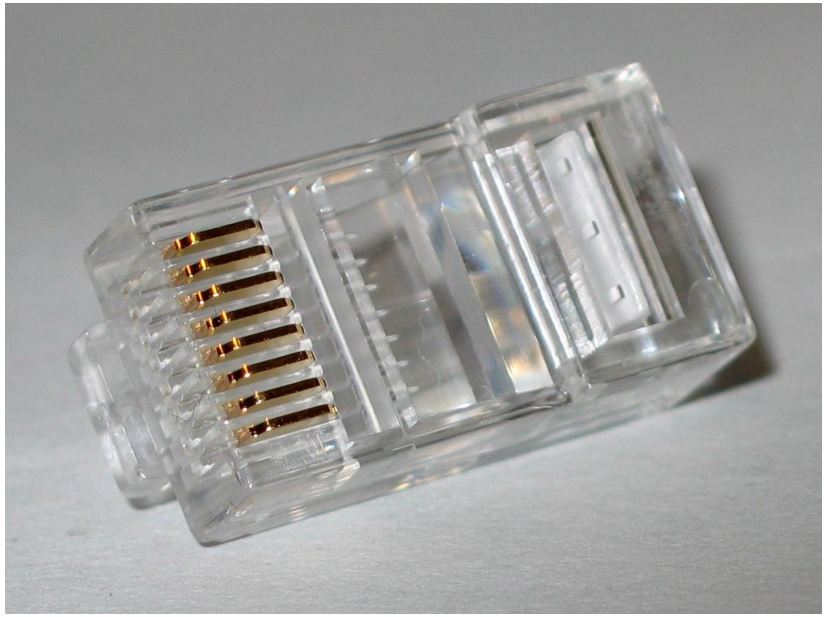
Introduction to IEEE 802.3

- The 100 in the media type designation refers to the transmission speed of 100 Mbit/s, while the BASE refers to baseband signaling. The letter following the dash (T or F) refers to the physical medium that carries the signal (twisted pair or fiber, respectively), while the last character (X, 4, etc.) refers to the line code method used.

- **10Base-T** – also called Standard Ethernet, 10Mbps using two pairs of UTP cable
- **100Base-TX** is the predominant form of Fast Ethernet, it and runs over two pairs of wire inside a Category 5 or above cable.(Cat5 and above)
- **1000Base-T** defines a Gigabit Ethernet over twisted-pair wiring, that runs over four pairs of wire inside a Category 5 or above cable.
- **100Base-T1** – 100Mbps Fast Ethernet over Single UTP cable most widely used in Automotive.
- **1000Base-T1** defines a Gigabit Ethernet over a single twisted pair wiring for automotive and industrial applications
- Older notable standards still supported in some PHYs (100Base-T2, 100Base-T4, 1000Base-TX)

Introduction to IEEE 802.3

- The **8 position 8 contact** (**8P8C**) connector is a modular connector commonly used to terminate twisted pair and multi-conductor flat cable. Although commonly referred to as **RJ45** in the context of Ethernet and category 5 cables, *RJ45* originally referred to a specific wiring configuration of an 8P8C connector. (RJ61 also uses same 8P8C connector) (**RJ** – Registered Jack)



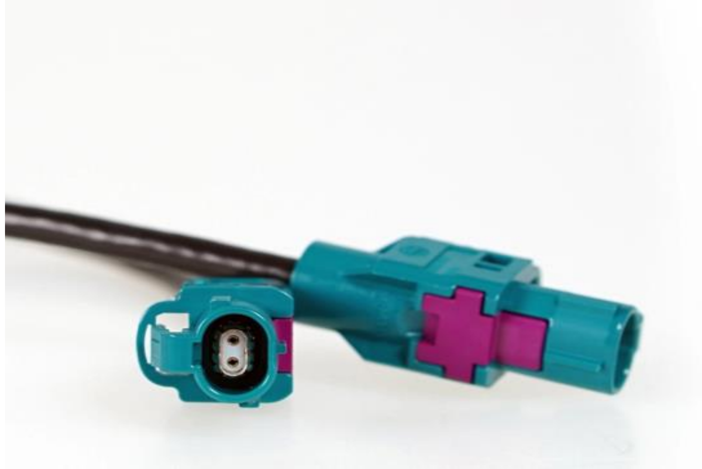
8P8C wiring (ANSI/TIA-568 T568B)

Pin	Pair	Wire	Color
1	2	+/tip	white/orange
2	2	−/ring	orange
3	3	+/tip	white/green
4	1	+/ring	blue
5	1	-/tip	white/blue
6	3	−/ring	green
7	4	+/tip	white/brown
8	4	−/ring	brown

T568A and T568B are the cabling standards used in 8P8C) – this is important as this gave rise to a feature called *auto-MDIX*

Introduction to IEEE 802.3

- In Automotive Ethernet, only H-MTD (*from Rosenberger*) and MATEnet (*TE Connectivity*) connectors are widely used.



H-MTD - High-Speed Modular Twisted-Pair Data
(Expensive, support higher data rate)

MATEnet - Miniaturized Automotive Ethernet
(Less expensive)

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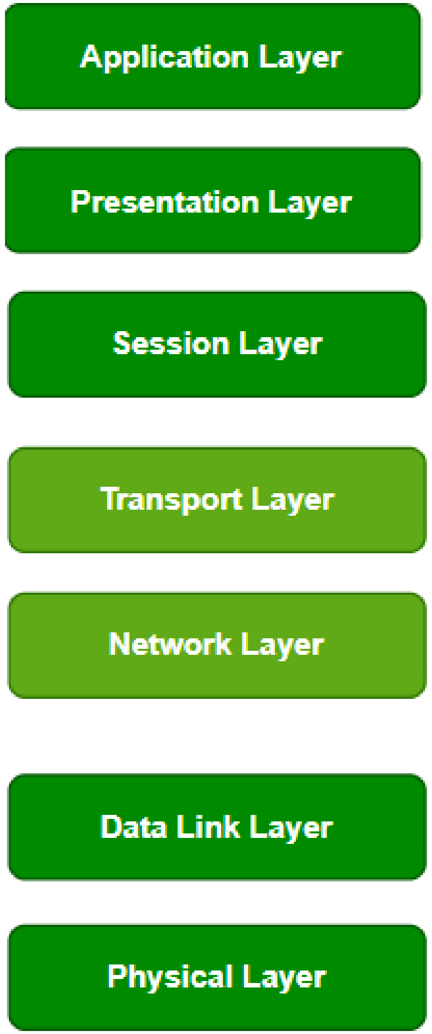
OSI reference model

- The **Open Systems Interconnection** (**OSI**) **model** is a reference model from the International Organization for Standardization (ISO) that "provides a common basis for the coordination of standards development for the purpose of systems interconnection.“

- The model partitions the flow of data in a communication system into seven abstraction layers to describe networked communication from the physical implementation of transmitting bits across a communications medium to the highest-level representation of data of a distributed application. Each intermediate layer serves a class of functionality to the layer above it and is served by the layer below it.

OSI reference model



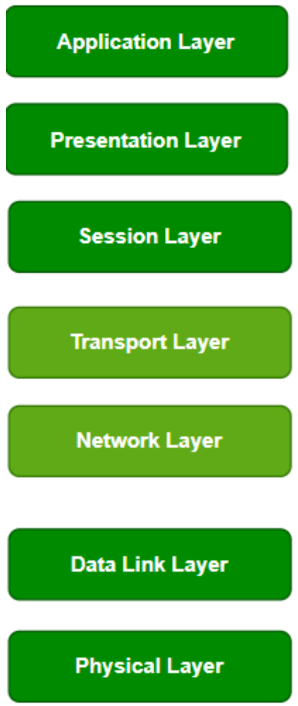
OSI reference model

Layer 1: Physical layer

- It’s responsible for the transmission and reception of unstructured raw data between a device and a physical transmission medium. It converts the digital bits into electrical, radio, or optical signals.

- Layer specifications define characteristics such as voltage levels, the timing of voltage changes, physical data rates, maximum transmission distances, physical connectors etc..

- This includes the layout of pins, voltages, line impedance, cable specifications, signal timing and frequency for wireless devices. Bit rate control is done at the physical layer and may define transmission mode as simplex, half duplex, and full duplex.



OSI reference model

Layer 2: Data link layer

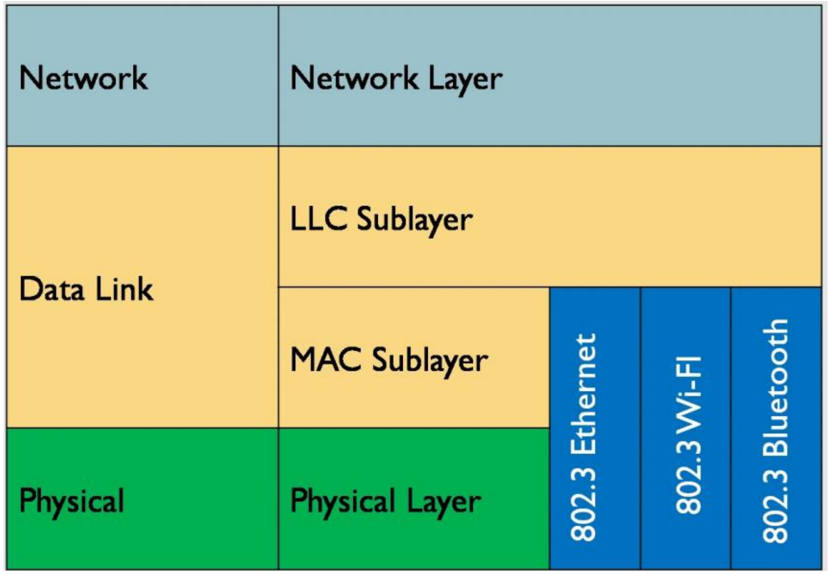
- The data link layer provides node-to-node data transfer—a link between two directly connected nodes. It detects and possibly corrects errors that may occur in the physical layer. It defines the protocol to establish and terminate a connection between two physically connected devices. It also defines the protocol for flow control between them.

- IEEE 802 divides the data link layer into two sublayers:
  - Medium access control (MAC) layer – responsible for controlling how devices in a network gain access to a medium and permission to transmit data;
  - Logical link control (LLC) layer – responsible for identifying and encapsulating network layer protocols, and controls error checking and frame synchronization.

OSI reference model

Layer 2: Data link layer

- The MAC and LLC layers of IEEE 802 networks such as 802.3 Ethernet, 802.11 Wi-Fi, and 802.15.4 Zigbee operate at the data link layer.

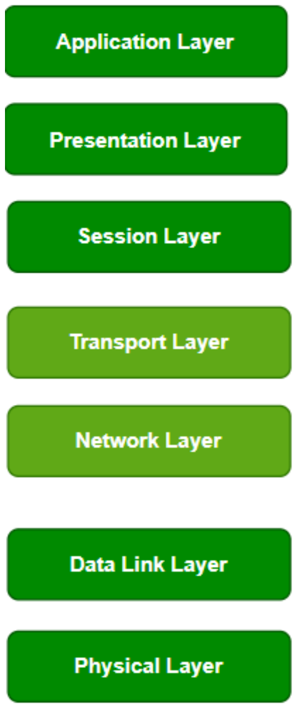


OSI reference model

Layer 3: Network layer

- The network layer provides the functional and procedural means of transferring packets from one node to another connected in "different networks".

- A network is a medium to which many nodes can be connected, on which every node has an *address,* and which permits nodes connected to it to transfer messages to other nodes connected to it by merely providing the content of a message and the address of the destination node and letting the network find the way to deliver the message to the destination node, possibly routing it through intermediate nodes.



OSI reference model

Layer 4: Transport Layer

- The transport layer provides the functional and procedural means of transferring variable-length data sequences from a source host to a destination host from one application to another across a network, while maintaining the quality-of-service functions.

Layer 5: Session Layer

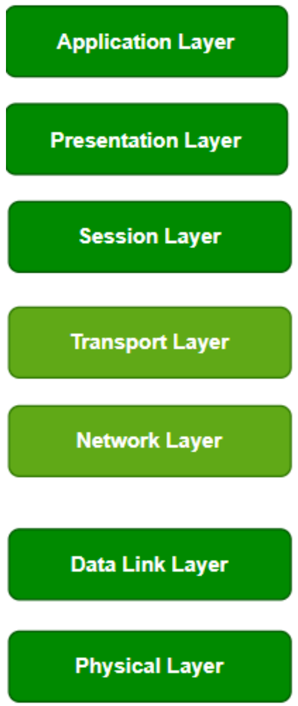
- The session layer creates the setup, controls the connections, and ends the teardown, between two or more computers, which is called a "session“.

Layer 6: Presentation Layer

- The presentation layer establishes data formatting and data translation into a format specified by the application layer.

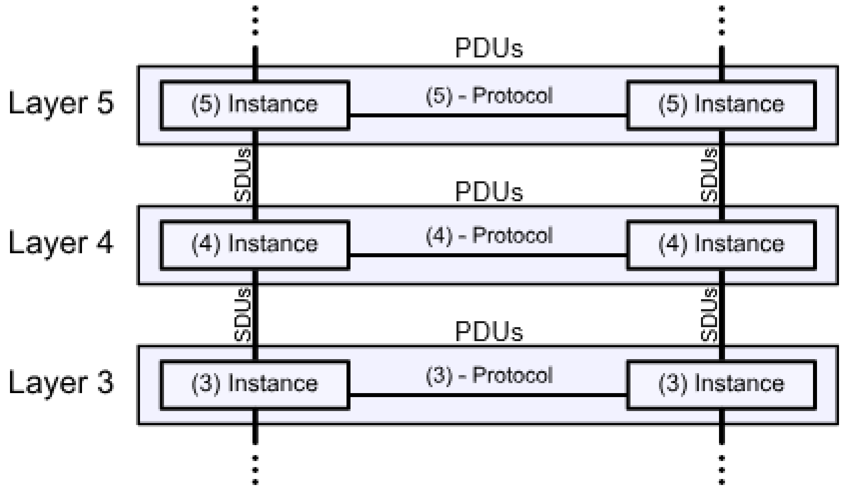
Layer 7: Application Layer

- The application layer is the layer of the OSI model that is closest to the end user.



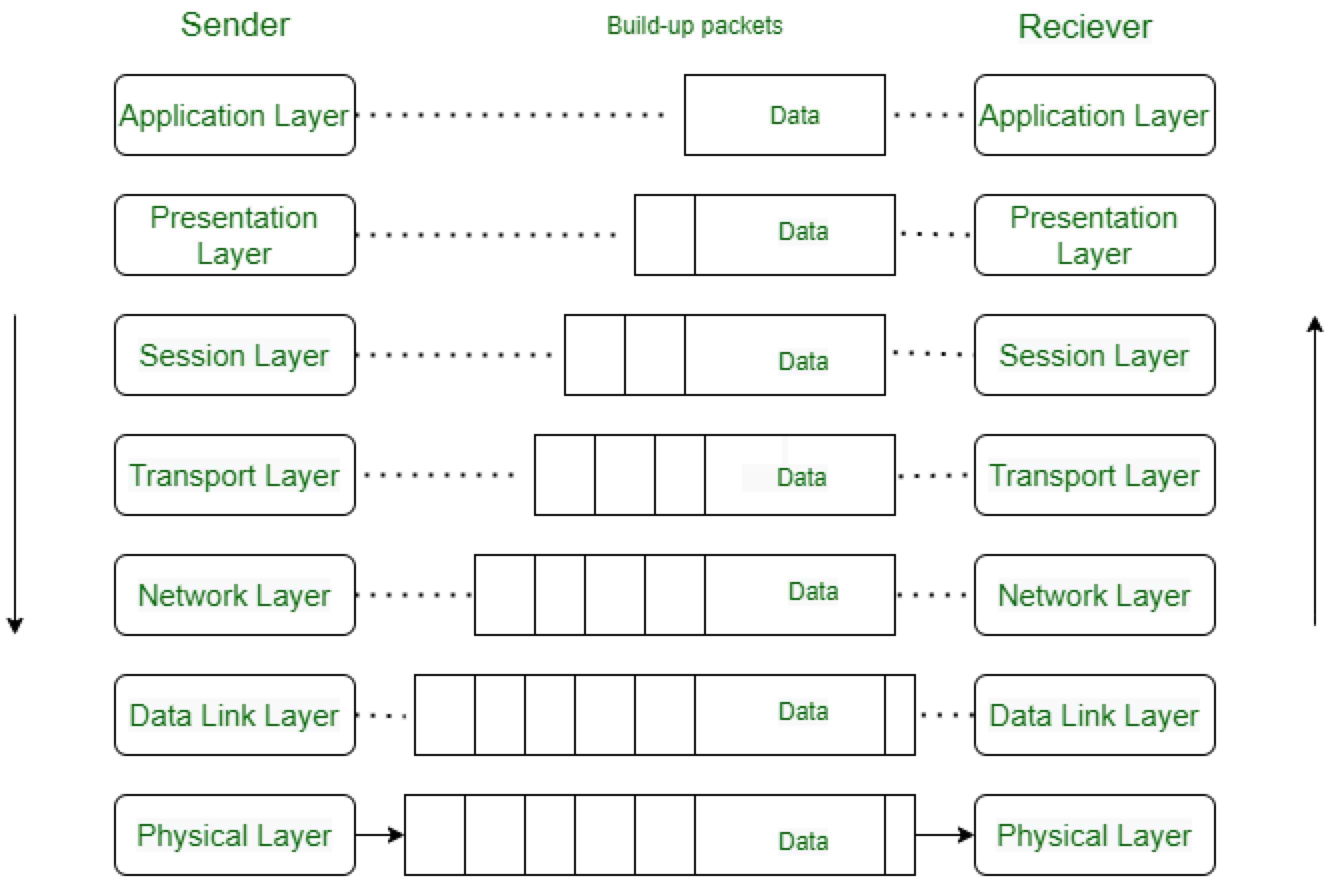
OSI reference model

- At each level *N*, two entities at the communicating devices (layer N *peers*) exchange protocol data units (PDUs) by means of a layer N *protocol*. Each PDU contains a payload, called the service data unit (SDU), along with protocol-related headers or footers.

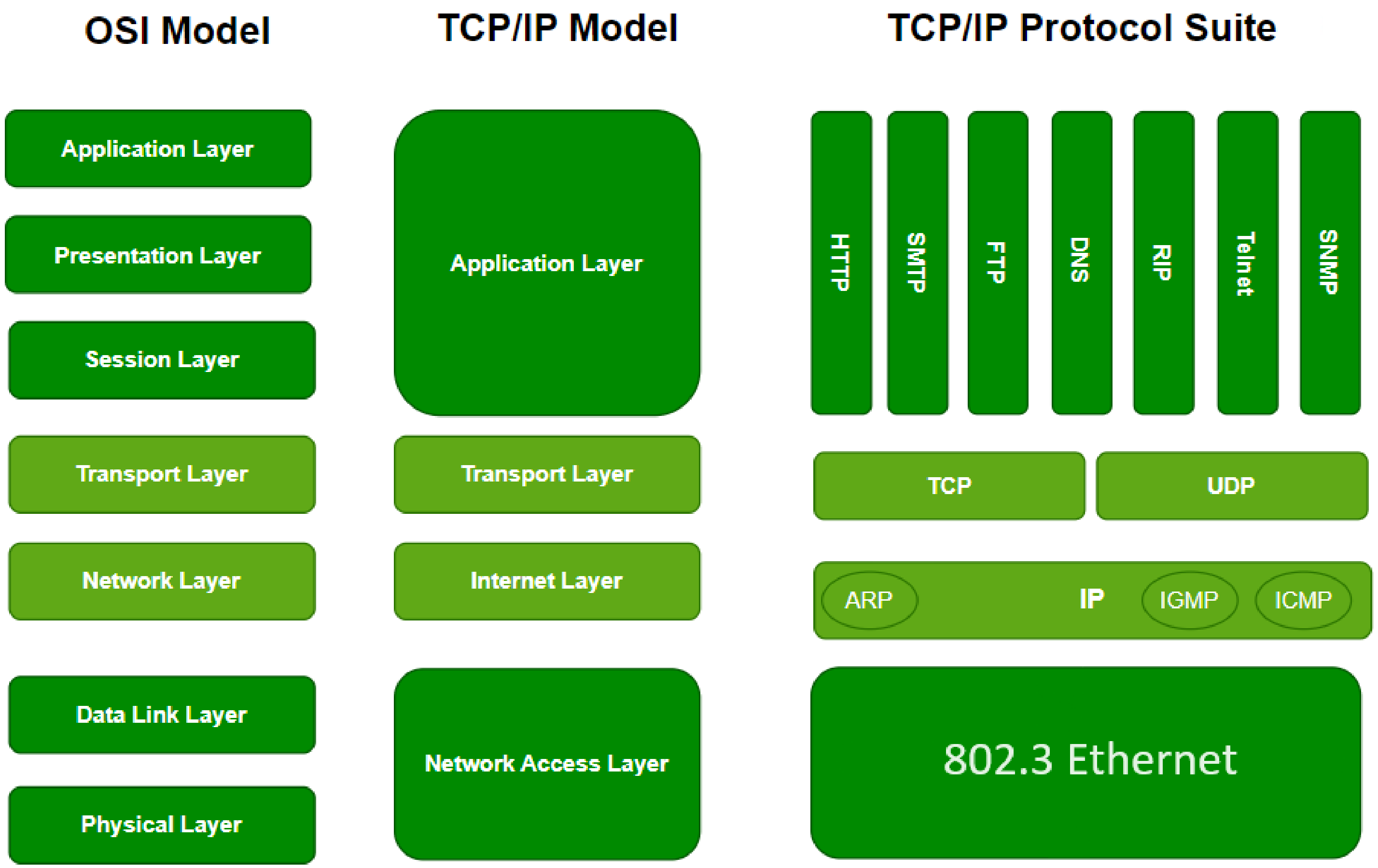


- Protocol data units of the OSI model are:
  - The Layer 4: transport layer PDU is the segment or the datagram;
  - The Layer 3: network layer PDU is the packet;
  - The Layer 2: data link layer PDU is the frame;
  - The Layer 1: physical layer PDU is the bit or, more generally, symbol.

OSI reference model



OSI reference model



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Introduction to the Ethernet frame format

- An **Ethernet frame** is a data link layer protocol data unit and uses the underlying Ethernet physical layer transport mechanisms. In other words, a data unit on an Ethernet link transports an Ethernet frame as its payload.

- An Ethernet frame is preceded by a preamble and start frame delimiter (SFD), which are both part of the Ethernet packet at the physical layer. Each Ethernet frame starts with an Ethernet header, which contains destination and source MAC addresses as its first two fields. The middle section of the frame is payload data including any headers for other protocols (for example, Internet Protocol) carried in the frame. The frame ends with a frame check sequence (FCS), which is a 32-bit cyclic redundancy check used to detect any in-transit corruption of data.

Preamble	SFD	Destination MAC	Source MAC	Type	Data and Pad	FCS
7 Bytes	1 Byte	6 Bytes	6 Bytes	2 Bytes	46-1500 Bytes	4 Bytes

Introduction to the Ethernet frame format

802.3 Ethernet packet and frame structure

Layer	Preamble	Start frame delimiter (SFD)	MAC destination	MAC source	802.1Q tag (optional)	Ethertype (Ethernet II) or length (IEEE 802.3)	Payload	Frame check sequence (32-bit CRC)	Interpacket gap (IPG)
Length (octets)	7	1	6	6	(4)	2	42–1500[c]	4	12
Layer 2 Ethernet frame	(not part of the frame)		← 64–1522 octets →						(not part of the frame)
Layer 1 Ethernet packet & IPG	← 72–1530 octets →								← 12 octets →

- If the Layer 2 Ethernet frame Ether-Type value is greater than or equal to 1536 (0x0600), the frame is called an Ethernet II frame. If the Ether-Type value is less than or equal to 1500 (0x05DC), the frame is called an IEEE 802.3 and the Ether-Type value it's the actual frame length. Values between 1500 and 1536, exclusive, are undefined. Some common Ether-Type values are 0x0800 for IPv4, 0x0806 for Address Resolution Protocol (ARP), 0x22F0 for Audio Video Transport Protocol (AVTP) etc..

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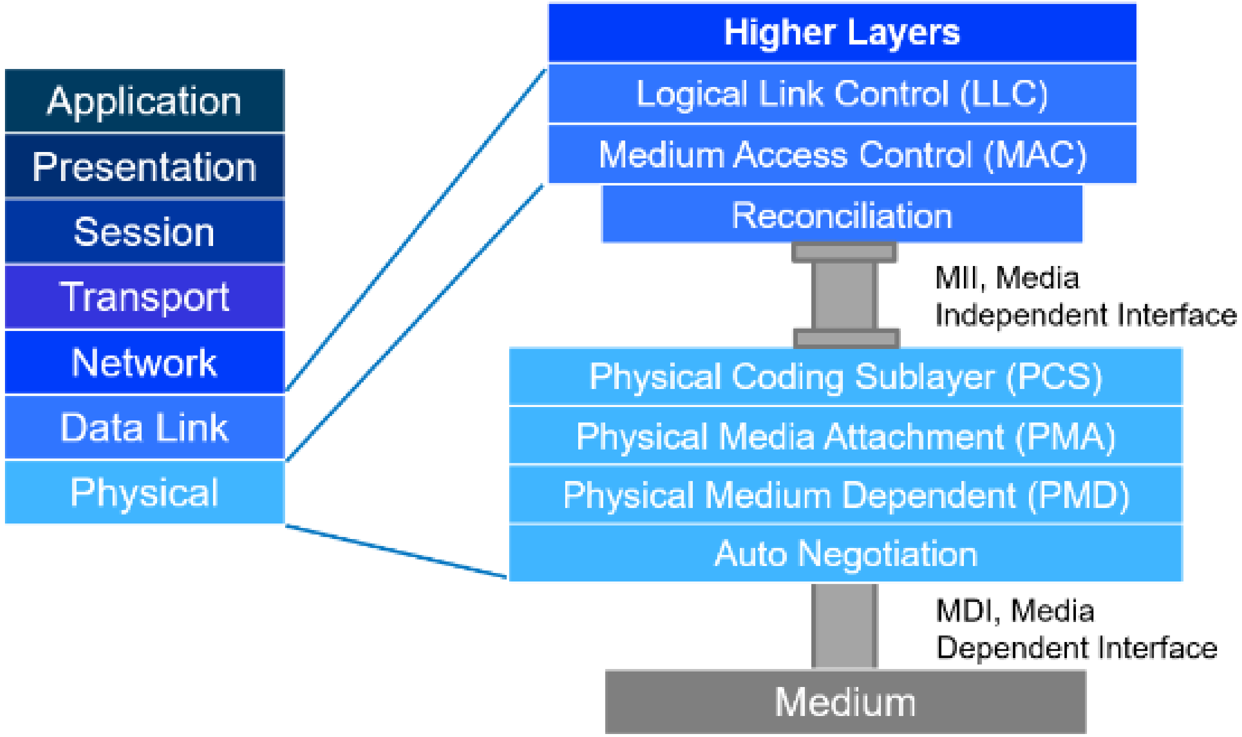
Introduction to physical sublayers and to the Media Independent Interface (MII)



Introduction to physical sublayers and to the Media Independent Interface (MII)

- PCS - Physical Coding Sublayer
  - Interface between the PMA sublayer and the MII responsible for data encoding/decoding, scrambling/descrambling, alignment marker insertion/removal, block/symbol redistribution, and lane block synchronization and de-skew.

- PMA - Physical Medium Attachment
  - Sublayer that defines the details of transmission and reception of individual bits on a physical medium.

- PMD - Physical medium dependent
  - This sublayer consists of a transceiver for the physical medium.

Introduction to physical sublayers and to the Media Independent Interface (MII)

- The **media-independent interface** (**MII**) was originally defined as a standard interface to connect a Fast Ethernet (i.e., 100 Mbit/s) medium access control (MAC) block to a PHY chip.

- A **PHY**, an abbreviation for *physical layer*, is an electronic circuit, usually implemented as an integrated circuit, required to implement physical layer functions of the OSI model in a network interface controller.

- A PHY connects a link layer device (MAC) to a physical medium such as an optical fiber or copper cable. A PHY device typically includes both physical coding sublayer (PCS) and physical medium dependent (PMD) layer functionality.

- The MII is standardized by **IEEE 802.3u** and connects different types of PHYs to MACs. Being *media independent* means that different types of PHY devices for connecting to different media (i.e. twisted pair, fiber optic, etc.) can be used without redesigning or replacing the MAC hardware. Thus, any MAC may be used with any PHY, independent of the network signal transmission medium.

Introduction to physical sublayers and to the Media Independent Interface (MII)

- The gigabit media-independent interface (GMII) is an interface between the medium access control (MAC) device and the physical layer (PHY). The interface operates at speeds up to 1000 Mbit/s and it's backwards compatible with the MII specification and it can operate on fallback speeds of 10 or 100 Mbit/s. The GMII interface was first defined for 1000BASE-X in IEEE 802.3z-1998 as clause 35.

- The MII (**IEEE 802.3u)** and the GMII (**IEEE 802.3z-1998**) are the only two **standard** interfaces to connect a medium access control (MAC) block to a PHY chip.

- In the industry, there are other Media Independent Interfaces available which are not standardized e.g. RGMII, RMII etc.. They are rather created based on an industry agreement between market vendors such as Marvell, Broadcom, AMD etc. (RGMII version 1.3 and RMII 1.2 consortium documents).

- The Reconciliation layer converts the non standardized Media Independent Interfaces into standardized Media Independent Interfaces. For example, if a MAC is connected to a PHY via an RGMII interface, the Reconciliation layer will be part of either the PHY or the MAC and it will convert the RGMII into MII or GMII.

Introduction to physical sublayers and to the Media Independent Interface (MII)

- **Auto-negotiation** is a signaling mechanism and procedure used by Ethernet over twisted pair by which two connected devices choose common transmission parameters, such as speed, duplex mode, and flow control. In this process, the connected devices first share their capabilities regarding these parameters and then choose the highest performance transmission mode they both support.

- Auto-negotiation for twisted pair is defined in clause 28 of **IEEE 802.3** and in a 1000BASE-T gigabit Ethernet over twisted pair connection it is mandatory since is used to communicate the master-slave parameters.

- A duplex communication system is a point-to-point system composed of two or more connected parties or devices that can communicate with one another in both directions. There are two types of duplex communication systems: full-duplex (FDX) and half-duplex (HDX).

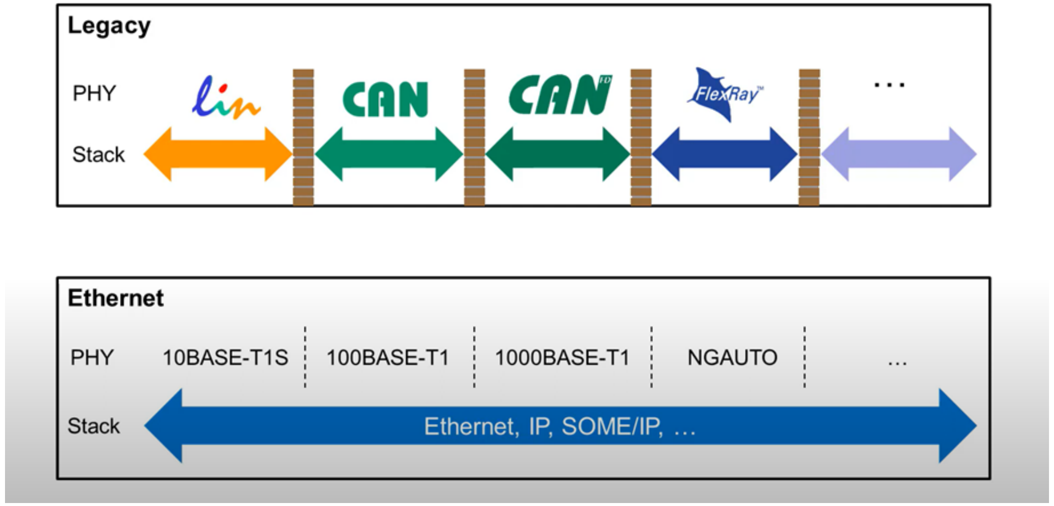
- In a full-duplex system, both parties can communicate with each other simultaneously.

- In a half-duplex or semi-duplex system, both parties can communicate with each other, but not simultaneously; the communication is one direction at a time.

Introduction to physical sublayers and to the Media Independent Interface (MII)

- A collision is the situation that occurs when two or more demands are made simultaneously on equipment that can handle only one at any given instant.

- Any bus networks must follow some methodology for accessing the shared medium.
  LIN - Master/Slave Approach. Master requests data from nodes.
  CAN/CAN-FD - Non-destructive arbitration. Based on priority the bus is taken by a node.
  FLEXRAY - TDMA based. Nodes pre-programmed when to transmit.
  ETHERNET - CSMA/CD. Collisions lead to random backoff and retransmission mostly in Hubs



Introduction to physical sublayers and to the Media Independent Interface (MII)

- Ethernet uses CSMA/CD for Media Access which is a medium access control (MAC) method.

- During initial days of Ethernet – physical collisions on the bus were possible due to the use of shared medium i.e., coaxial cable.

- After Ethernet moved from Coaxial Cable to Twisted pair ethernet, the collisions moved from Physical to more of a logical one, to maintain the fundamental CSMA/CD of Ethernet.

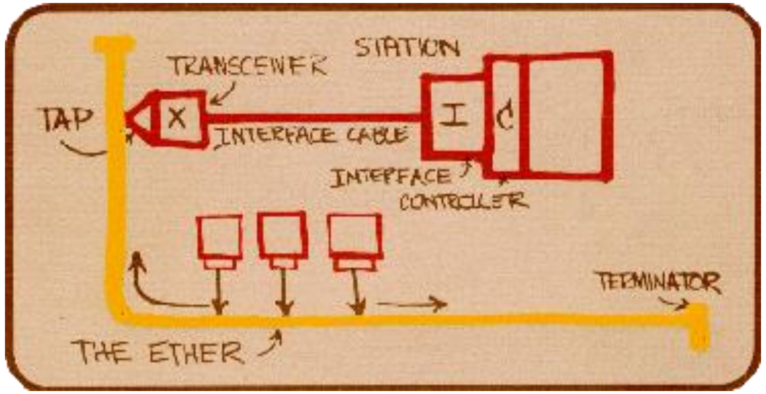
- Current standards of Ethernet 10Base-T, 100Base-TX and 1000Base-T all support both half/full duplex.

- Four signals are important to detect and inform collisions to the MAC Layer.
  1. CRS – Carrier Sense;
  2. COL – Collision;
  3. TX_EN – Transmit Enable;
  4. RX_DV – Receive Data Valid;

- Over the years as we moved from MII/GMII to other low pin count MII layers like RMII and RGMII, the way the above signals are encoded are also specified for each of them.

Introduction to physical sublayers and to the Media Independent Interface (MII)

- **Common terminologies:**
  1) Single Collision – 1 Collision has occurred before successful transmission of the frame;
  2) Multiple Collision - more than 1 collision has occurred before successful transmission of a frame;
  3) Late Collison - Rare scenario, usually due to long cabling, improper network infrastructure etc.;
  4) Backpressure – developed by Cisco, to control reception of frames by purposefully causing collisions on the bus.



- **Key takeaways**
  1) Ethernet using Coaxial Cable is now not used anymore;
  2) As Ethernet moved to switched networks, Half duplex is almost never used in current applications;
  3) New technologies aims to bring back the Ethernet again in a bus topology using UTP cabling (like CAN) through 10Base-T1S.

Introduction to physical sublayers and to the Media Independent Interface (MII)

- **Follow up:**
  - Why is there a minimum frame size of 64 Bytes required in Ethernet?
  - Why Source MAC Address not sent before Destination MAC Address?
  - Repeaters, Hubs, Bridges, Switches and Routers– operates on which Layer in OSI Model?
  - Collision Domain / Broadcast Domain – difference?

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