Advanced Automotive

Chapter Two – E

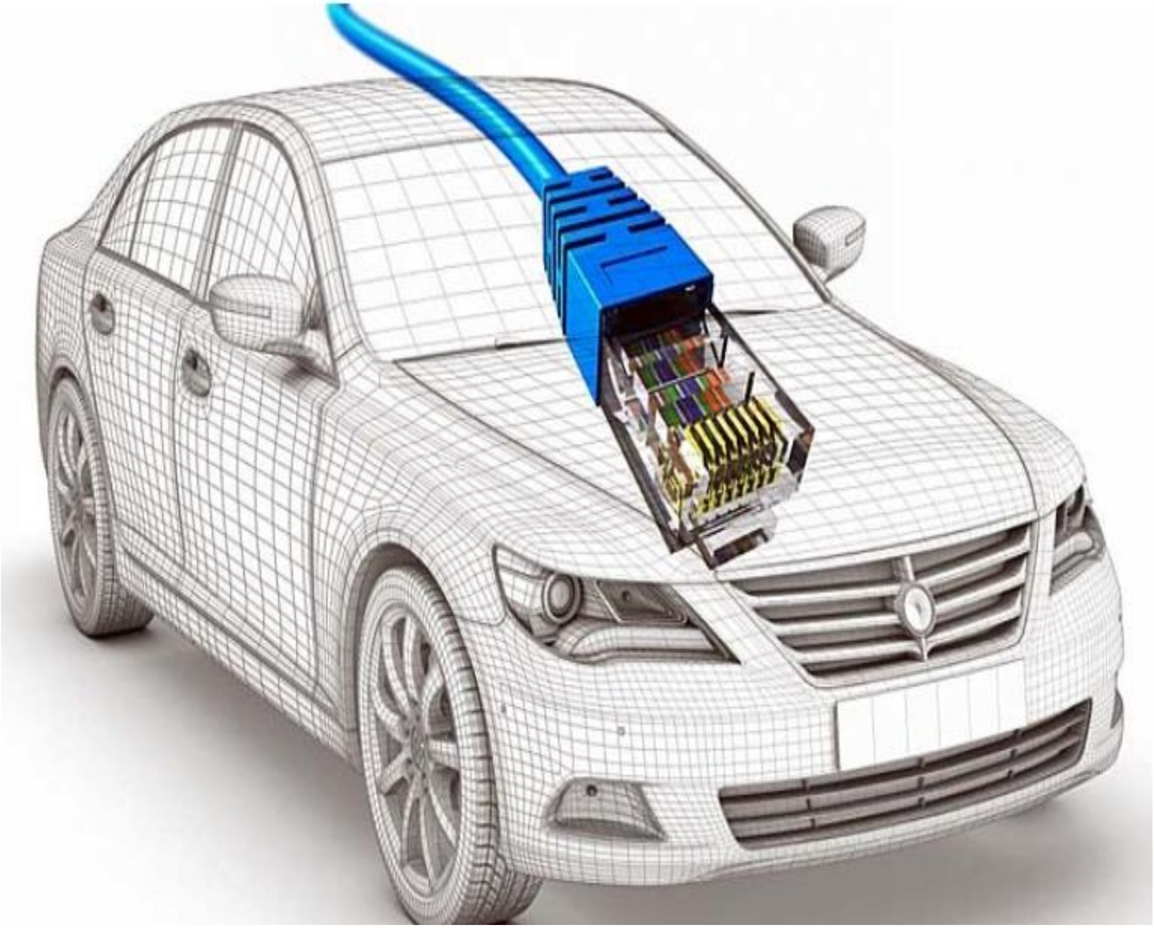
Ethernet

INTRODUCTION

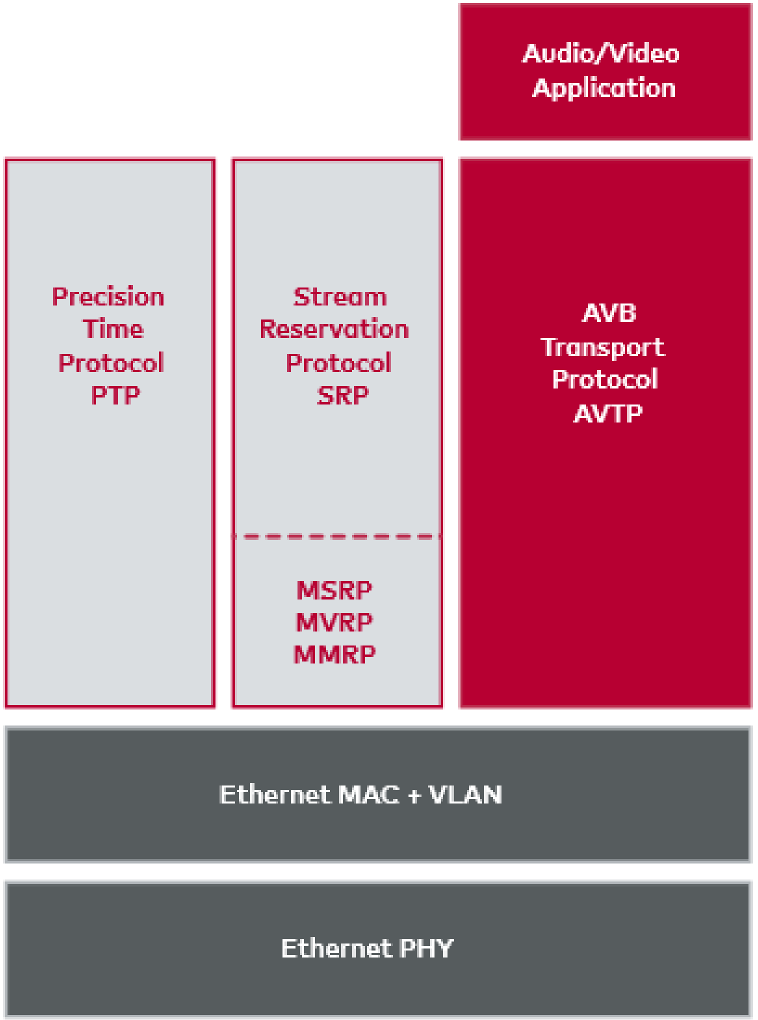
- In recent decades, more and more functions are being developed for motor vehicles for the purpose of making driving safer, more comfortable, and environmentally friendly.

- Besides the classic requirements for driving, the requirements for multimedia and infotainment in the motor vehicle are also increasing. The connection of smartphones or other Internet-capable devices is already an available feature in many vehicles, especially in the luxury cars.

- In parallel with development of the motor vehicle, Ethernet has established itself as a flexible and scalable network technology in communication systems, it introduced many powerful features and new concepts with increasing speeds & decreasing weight.



- Automotive Ethernet became not only for luxury cars, the car manufacturers are panning to move the Ethernet for all classes of cars.
- A large number of methods and protocols have been developed and implemented to provide functionalities running on top of Ethernet networks.
- TCP/IP which implements internet connectivity is based on Ethernet
- AVB (Audio Video bridging) is designed also to run over Ethernet
- There are more and more protocols that are designed to run on any type of Ethernet, regardless of its low level implementation.
- **Then putting Ethernet into cars means that these capabilities become available to cars as well.**



ETHERNET HISTORY

Norman Abramson, born 1932, Boston

- **Norman Abramson** was a surf freak. what was a surfing boy to do but to move to Hawaii in 1968 and enjoy the big waves.
- The only problem was that **Abramson** was a computer scientist and so had to do something to earn a living at the University of Hawaii.
- He was very upset by the fact that the university was spread across the islands and had computer users spread all across the islands.
- You have to remember that at the time Universities only had one big central computer for users to share. On the mainland this was relatively easy but on a group of islands it was much more difficult.
- He decided that the best way to solve the problem, was to link users to the central computer using radio channels.

- As a result, Abramson invented ALOHAnet. This used a small number of radio channels shared between the users. The problem that Abramson solved was how to share the channels without any master synchronizing signal being needed.

- The basic idea was to use the same technique we use to talk in a group, If two people speak at the same time the person listening doesn't hear what the other says and there is no response. That is humans notice when there is a "collision" of people speaking and modify their behavior to allow one person to speak - one or more of the speakers involved in the collision will "back off" and wait for a clear period when they can say something.

- The ALOHAnet worked in the same way, Terminals transmitted data on the channel whenever they felt like it and then waited for an acknowledgment from the central computer.

- If they got an acknowledgement then they knew that they had the channel to themselves and the message got through. If they didn’t receive an acknowledgment they knew that they had transmitted at the same time as one or more other users.

Aloha concept

- Aloha stations sends whenever it likes, then waits for acknowledgement.
- If no acknowledgement within a short time, collision is assumed as two stations transmitting in the same time.
- When collision, both transmitting stations would choose a random back-off time, and then retransmit their packets
- As the traffic increased, the collision rate would increase as well (**pure aloha**)
- **Slotted aloha**, assigned transmission slots and used a master clock to synchronize transmissions.

- The next stage of the story, **Robert Metcalfe**, an early Internet enthusiast. He knew about ALOHAnet and started to think about the problem of connecting computers together.
- With the primitive Internet only connecting a small number of computers it was reasonable to run a cable between each pair of machines but when the Internet started to grow this quickly became ridiculously expensive.
- Without a workable alternative, the Internet as we know it today wouldn't and couldn't exist.
- Metcalfe started to think about how a single wire connecting a number of machines could be shared. The clever idea he had was to extend the ALOHAnet idea of:

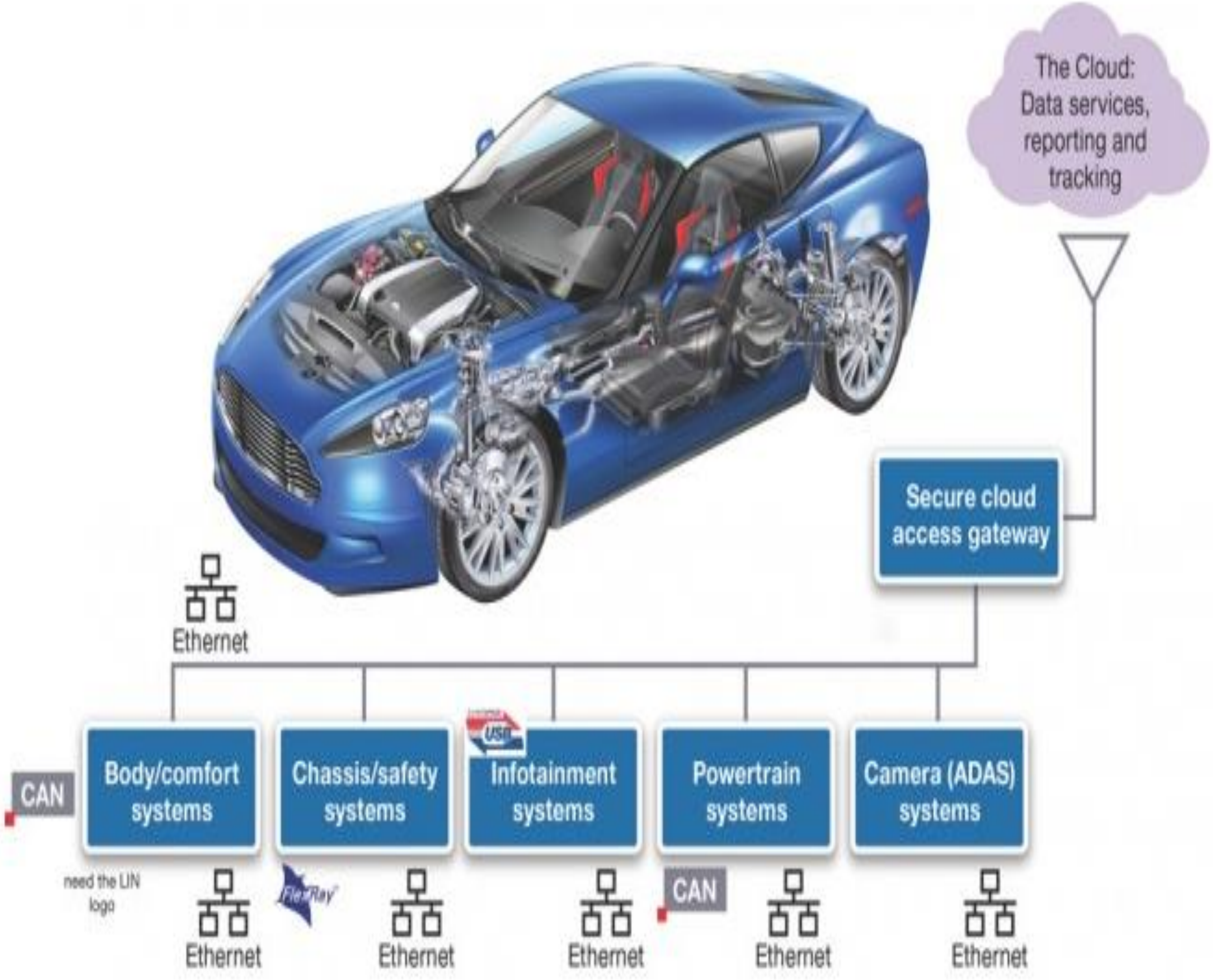
transmit, listen, back-off
to
listen, transmit, listen and back-off

Robert Melcanton Metcalfe
born 1946, Brooklyn, New York

- Any machine connected to the cable can transmit data and receive data but if more than one machine tries to transmit the result is a collision and nothing gets through. This is what Metcalfe invented.
- Each Ethernet interface contained the electronics necessary to listen for a quiet time on the cable – this is called "carrier sense" – with supported access to a shared channel by multiple stations (multiple access)
- If a collision is detected then all parties to the collision wait for a random time that is a multiple of the time slot and then try again.
- If they detect a second collision they back off for a random time that is on average twice as long and so on each time a collision is detected. This is called "exponential back off".
- The Ethernet protocol is usually referred to as CSMA/CD or "Carrier Sense Multiple Access/Collision Detection" and you should now be able to understand the origin of each of these terms.

ETHERNET FEATURES

- Ethernet played an enormous role in harmonizing Automotive industry networks with the ones used by the internet networks.
- Raised the bandwidth (data transmitted in bytes/sec) of in-vehicle networks.
- Full duplex, packet switching, address based networking.
- Reduction in vehicle weight and cost with high speed.
- Power over Ethernet (PoE) and power over data lines (PoDL).
- Wireless functionality.

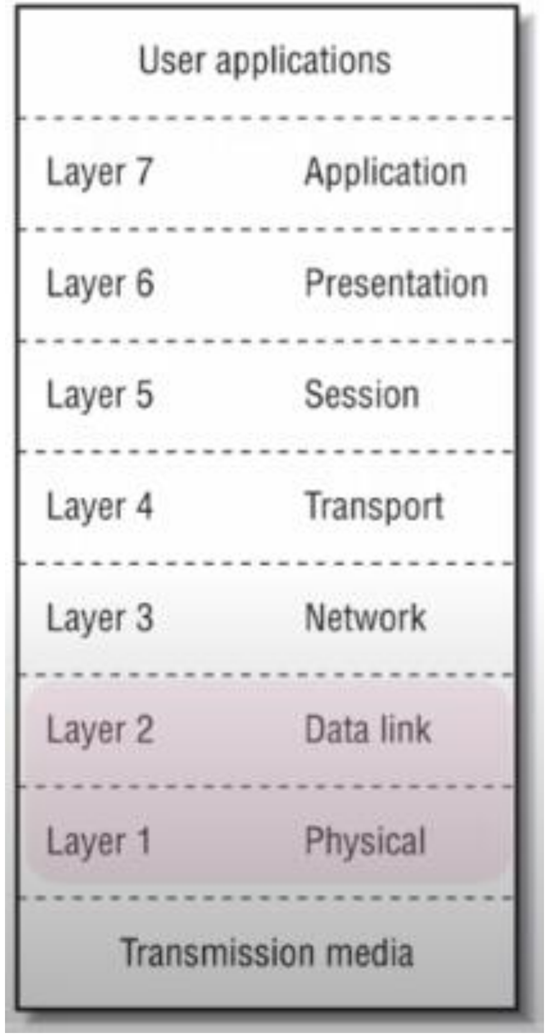


ETHERNET OPEN STANDARD

- Metcalfe and David Boggs, his assistant, published a paper in 1976 at Xerox Parc, describing Ethernet but it developed over a number of years.
- In 1979, Metcalfe set out to make Ethernet an open standard and Xerox agreed to join a multivendor consortium for the purposes of standardizing an Ethernet system.
- In 1980, Three big companies Digital-Equipment-Corporation, Intel and Xerox got together to produce the first standard for 10Mb/s Ethernet – called **DIX Ethernet**.
- The Institute of Electrical and Electronics Engineers (IEEE) has been responsible for maintenance and further development of Ethernet since 1980. Working Group 802 has responsibility for Ethernet. For this reason, all Ethernet-related standards are numbered starting with 802 (e.g., IEEE 802.1, IEEE 802.2, IEEE 802.3, etc.).
- IEEE standard 802.3, first published in 1985 and based on the network system described in the DIX Ethernet standard.

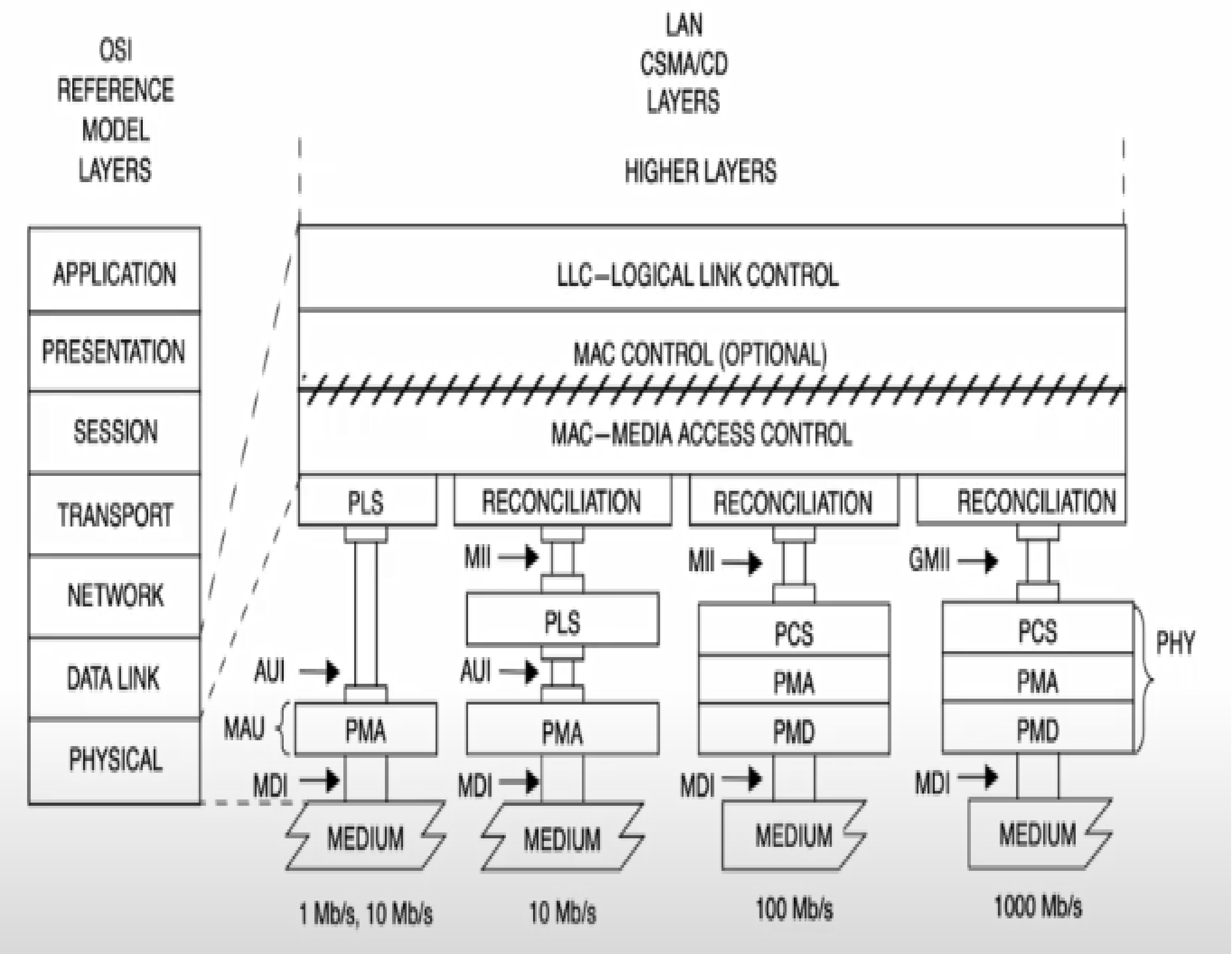
OPEN SYSTEM INTERCONNECTION
OSI

- Describes how the interlocking sets of networking hardware and software can be organized to work together in the networking world.
- Lower layers describes how a LAN system moves bits around.
- Higher layers describe how data is represented to the user.
- Ethernet exists in the lower 2 layers, Physical and Data layers.



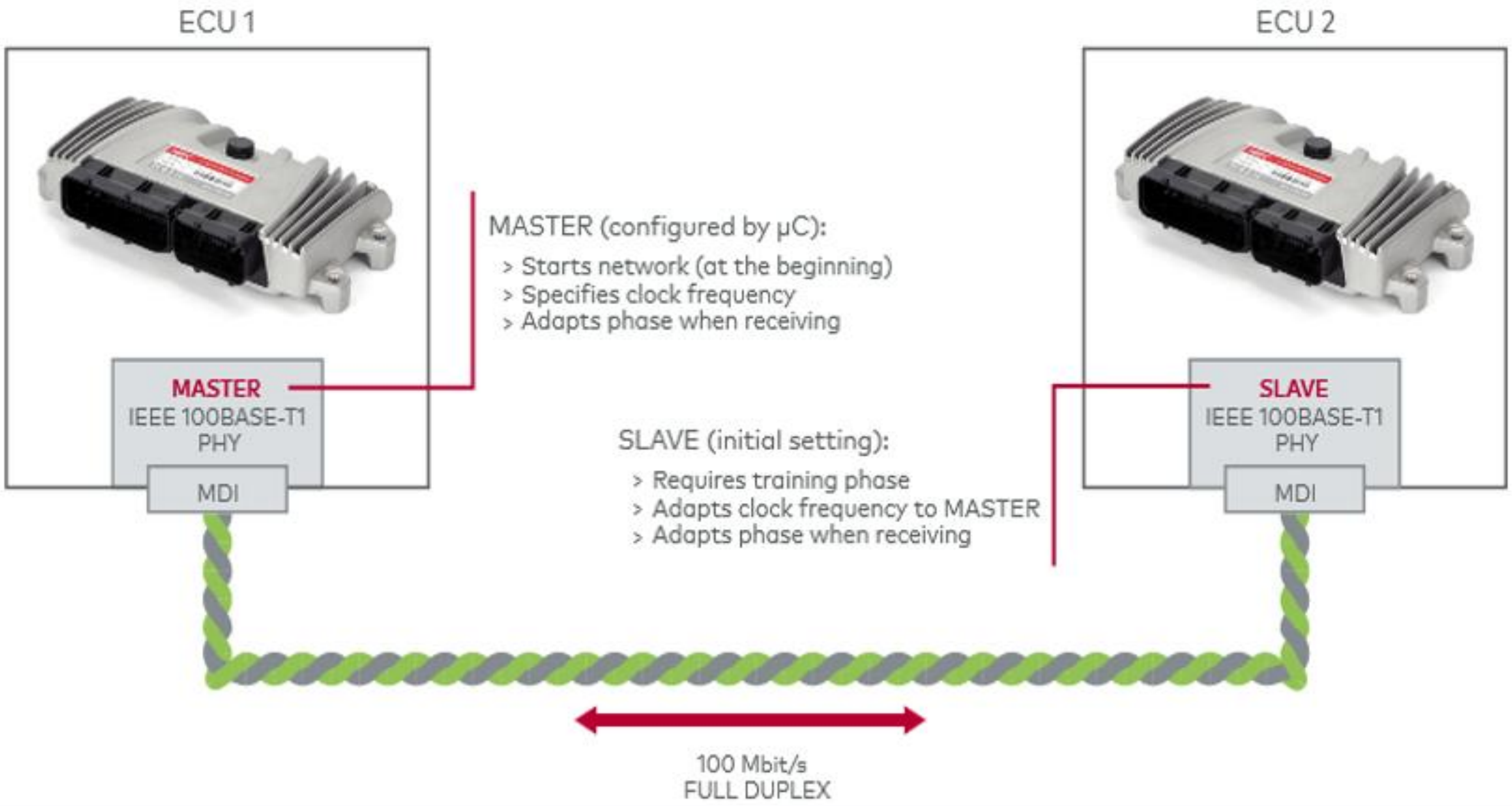
ETHERNET LAYERS

- MII: media independent interface as it connects between the MAC and the medium which may be coaxial cables, fiber optics or twisted pairs.
- The purpose of the MII is to have a uni-interface independent of the hardware
- MAC: it is the interface between the hardware and the upper layers, it extracts the data from a frame and responsible for CSMA/CD, frames in this layers are called MAC frames or Ethernet frames, and sends the data to the LLC, which in turns sends the data to the higher layers
- MAC CONTROL: optional sub-layer used as interface between the low layers and the higher layers

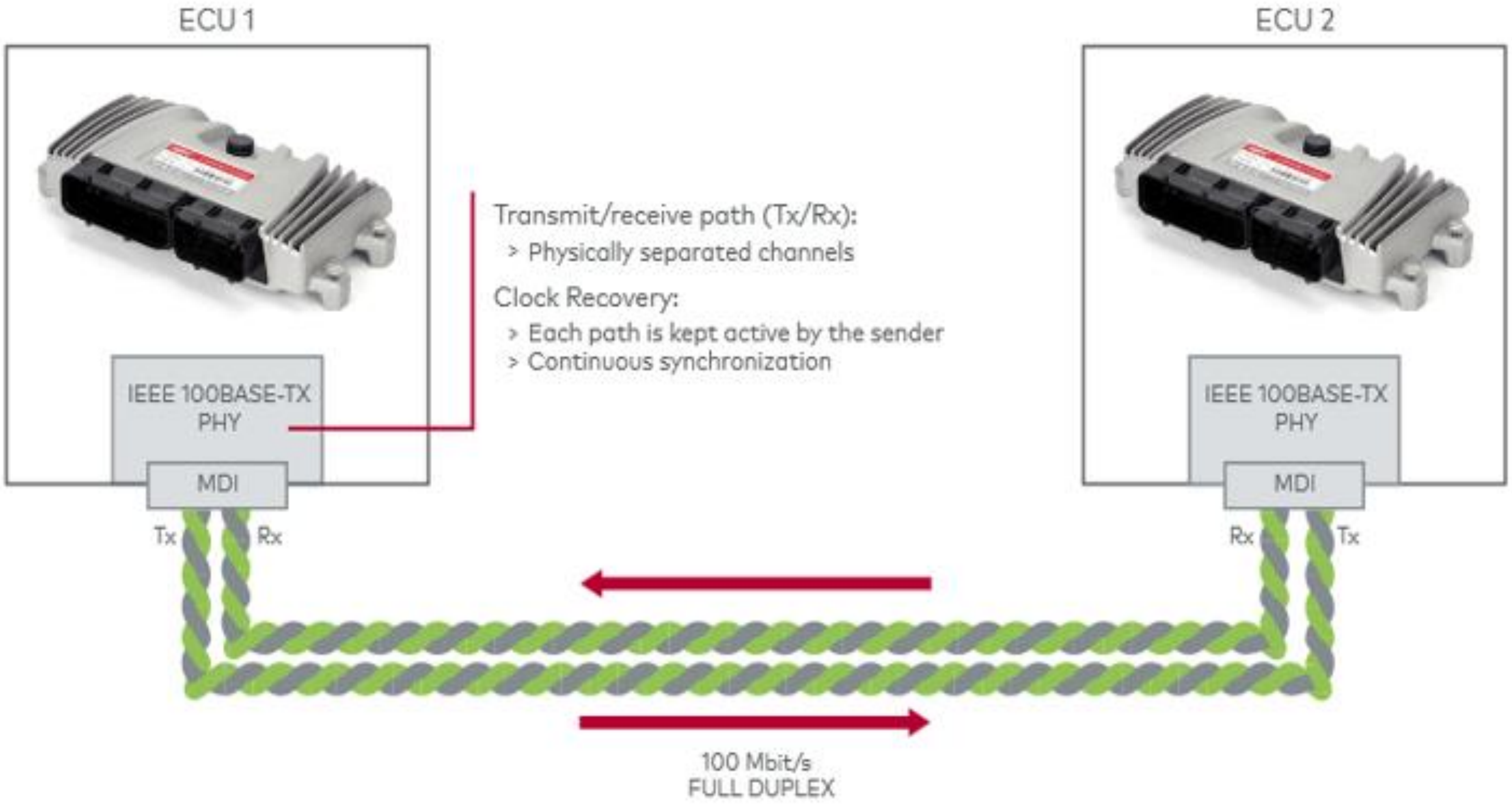


ETHERNET PHYSICAL LAYERS

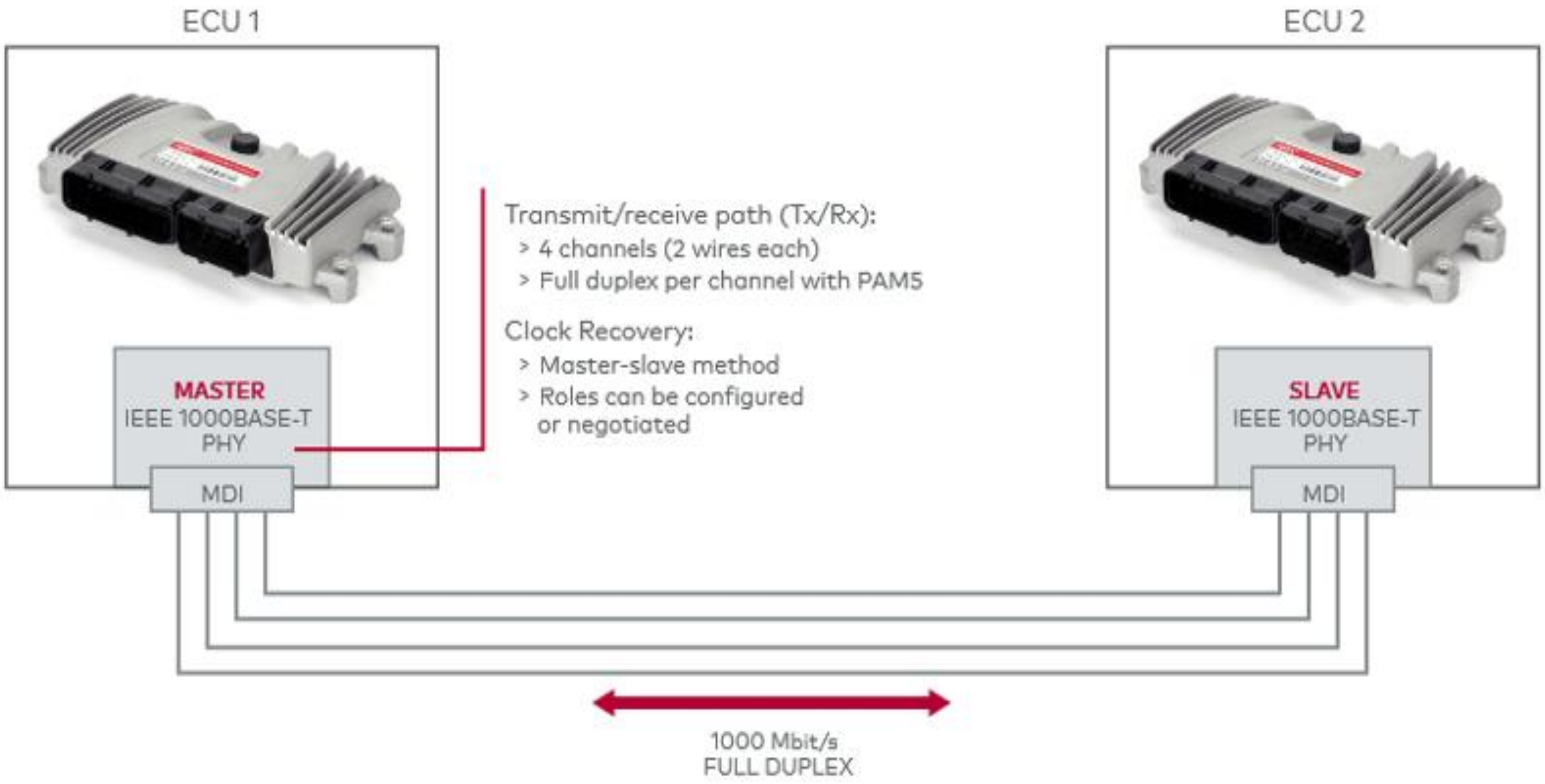
- IEEE 100BASE-T1 (formerly OABR)



- IEEE 100BASE-TX



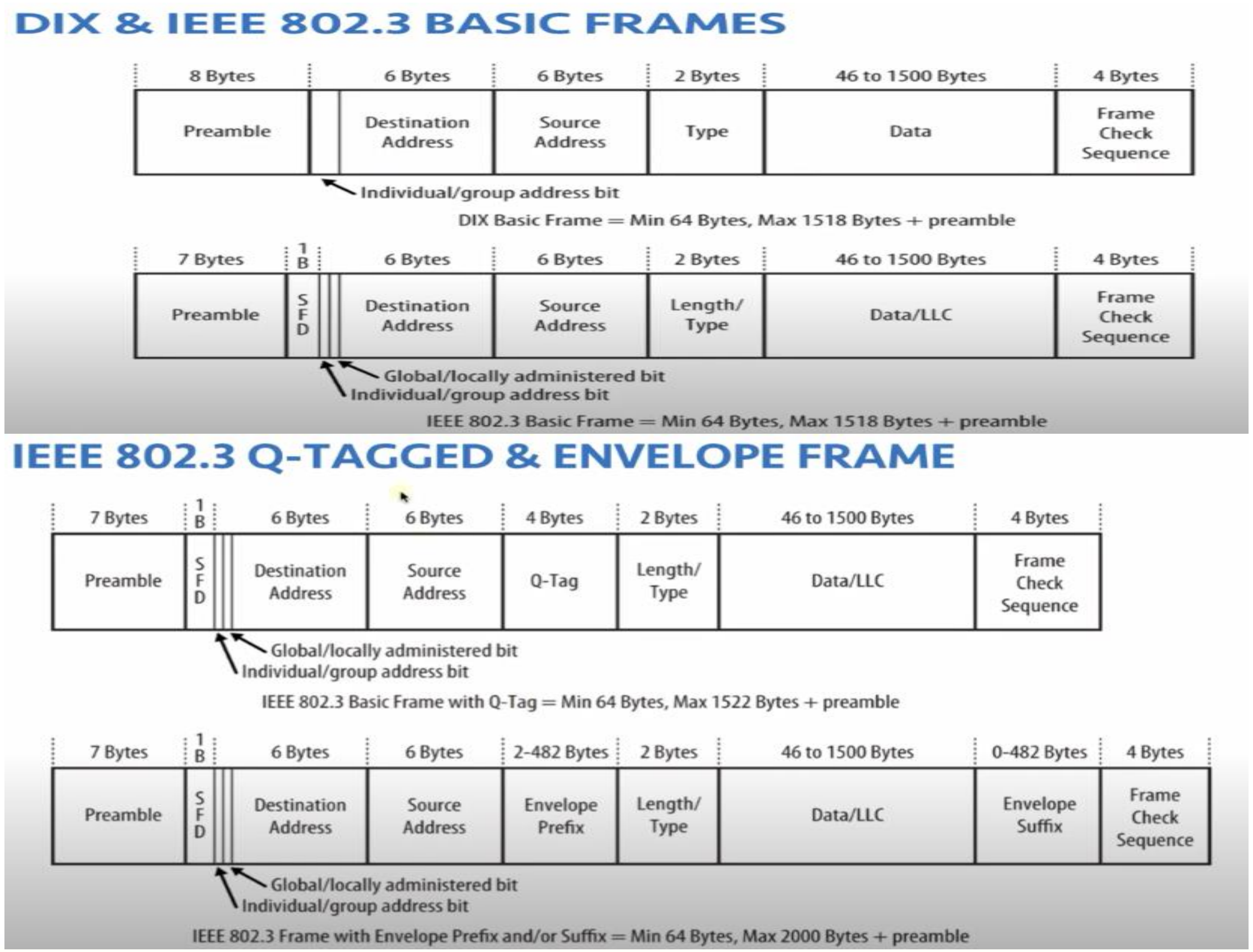
- IEEE 100BASE-TX



ETHERNET FRAME

- There are 4 types of Ethernet frame:

  1. DIX basic frame
  2. IEEE 802.3 basic frame
  3. IEEE 802.1 Q-tag frame
  4. IEEE 802.3 with envelope prefix and/or suffix



1- preamble:

- 7 Bytes + 1 Byte for Start Frame Delimiter, used for synchronization in 10Mb/sec Ethernet interfaces.
- provided protection against **start up delays (due to old cables)** as the signal propagates through a cabling system.
- higher speed Ethernet systems don’t need a preamble, but still kept for backward compatibility.
- 10101010 10101010 10101010 10101010 10101010 10101010 10101010 10101011 → last 2 bits are ones to indicate a start of frame, preamble is over.

2- Destination address:

- Contains 6-Byte address, the first 3 Bytes are for the IEEE, and the other 3 Bytes are for manufacturer to ensure that there is not 2 devices in the world have the same MAC address.

- There are 3 types of destination addresses:
  - A- unicast address: for single station
  - B- multicast address: for number of stations
  - C- broadcast address: for the whole network

- Individual group address bit:
  - 0: unicast address
  - 1: multicast address
  - when all bits of DA are ones: broadcast address

- Global locally administrated bit (IEEE)
  - 0: globally administrated (physical address is assigned by the manufacturer
  - 1: locally administrated

Example:

Assume we have a physical address of

44 : 4e : 6d : 17 : ad : 04

And note that this is a MAC address not IP address

Find out whether this is (unicast, multicast, broadcast)

And also whether it is (globally or locally administrated)

Solution:

The binary representation for this address is:

01000100 01001110 01101101 00010111 10101101 00000100

The address is transmitted from left to right and from LSB to MSB, then the transmitted data we will:

00100010 01110010 10110110 11101000 10110101 00100000

unicast

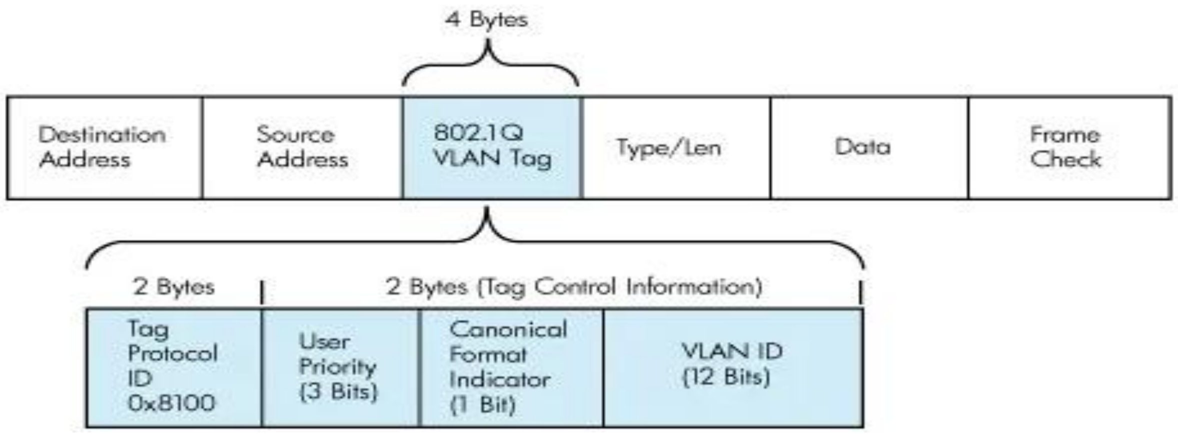
Globally administered (IEEE-SA + manufacturer)

3- Source address:

- Never used in MAC protocol, it is only used in the high level network protocols.
- Used by switches to build a table associating source address with switch ports.
- Vendor of Ethernet equipment acquires an Organizationally unique identifier (OUI) from IEEE.

4- VLAN Tag or Q Tag:

- Carries an 802.1 Q tag (4 bytes), also known as virtual LAN or priority tag and it is optional to use.
- Used when one or more switch ports that function as a separate Ethernet system on a switch.
- Ethernet traffic within a given VLAN will be sent and received only on those ports of the switch that are defined to be members of that particular VALN.
- It is only as per request from the vendors who want to connect switches, but for us, we won’t use it

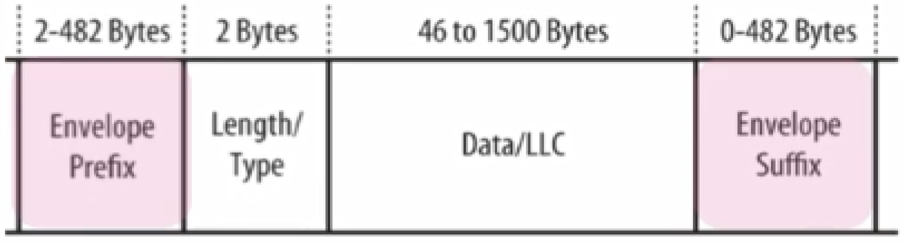


5- Envelope prefix and suffix:

- Intended to allow inclusion of additional prefixes and suffixes required by higher layer encapsulation protocols.

- They just increase the data bytes.

- Envelope prefix adds from (2 : 482) bytes and envelope suffix adds from (2 : 482) bytes, in addition of the main data bytes which are (46 : 1500) bytes, then we may have more than 2000 bytes of data.



5- Type or Length field:

- In the **DIX Ethernet standard**, contains an identifier what refers to the type of high level protocol (e.g. 0x0800 for the Internet Protocol IP)

- In the IEEE 802.3 standard,
  - If <= 1500: length field which indicates the number pf logical link control LLC data octets that follow in the data field of the frame
  - Padding data are added if the LLC octets less than reuired
  - If >= 1536: type field
  - 1501:1535: undefined

- Envelope prefix adds from (2 : 482) bytes and envelope suffix adds from (2 : 482) bytes, in addition of the main data bytes which are (46 : 1500) bytes, then we may have more than 2000 bytes of data.

6- Data field:

- In the DIX and IEEE standards, it must contain a minimum of 46 bytes of data, and a maximum of 1500 bytes of data.
- In IEEE standard, the logical link control protocol (IEEE 802.2 LLC) may added to provide control information.
- The payload has a minimum length of 46 bytes without VLAN tag or 42 bytes with VLAN tag.

7- Frame Check Sequence FCS field:

- 32 bit field contains a value (CRC) that is used to check the integrity of the frame fields (except the preamble/SFD).

- If the data is corrupted (CRC mismatch), then the interface can discard the frame and increment the frame error counter.

Invalid frame:

- The frame length is inconsistent with a length value specified in the length/type field.
- The bits of the incoming frame (exclusive of the FCS field itself) don’t generate a CRC value identical to the one received.
- The contents of invalid MAC frames shall not be passed to the LLC or MAC control sub-layres.

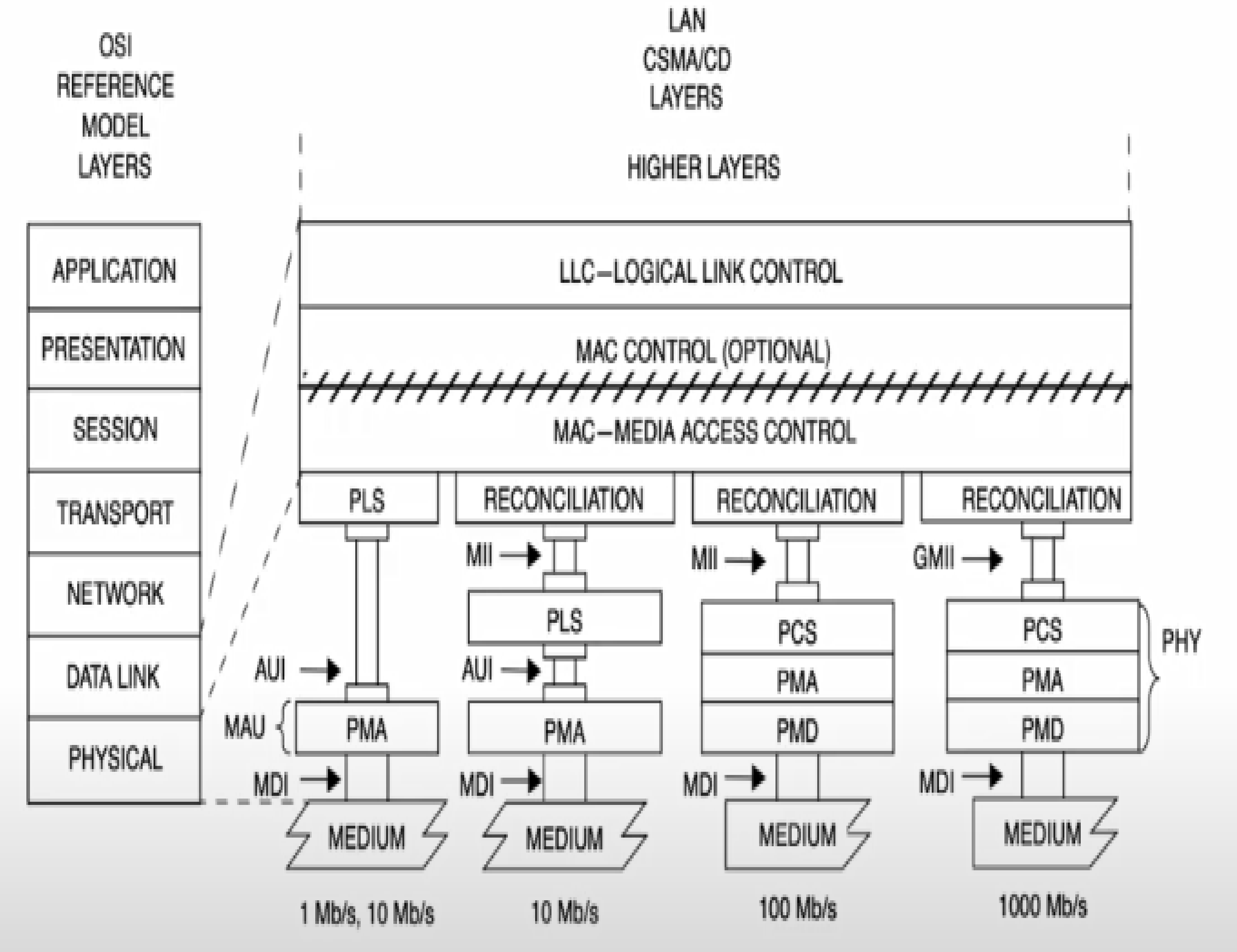
MAC

- Half duplex mode: multiple computers share access to a single Ethernet channel by using the (CSMA/CD)
- Full duplex mode: a channel between the station and a switch port, no need to control access to the link
- Each frame that is transmitted on the shared channel is heard by every station
- To send data in full duplex mode, station first listens to the channel, and if the channel is idle, the station transmits its data in the form of an Ethernet frame
- Each station connected to the channel reads the frame and compares the destination address with its own 48-bit unicast address and any multicast address. Reading is stopped when mismatch
- Carrier sense: each interface must wait until there is no signal on the shared channel before it can being transmitting
- Multiple access: all interfaces have the same priority, and all can attempt to access the channel when it is idle
- Collision detection: sense the collision and resend after random retransmission time (backoff)

ETHERNET BASIC CONCEPT

It is all about MAC (Media Access Control)

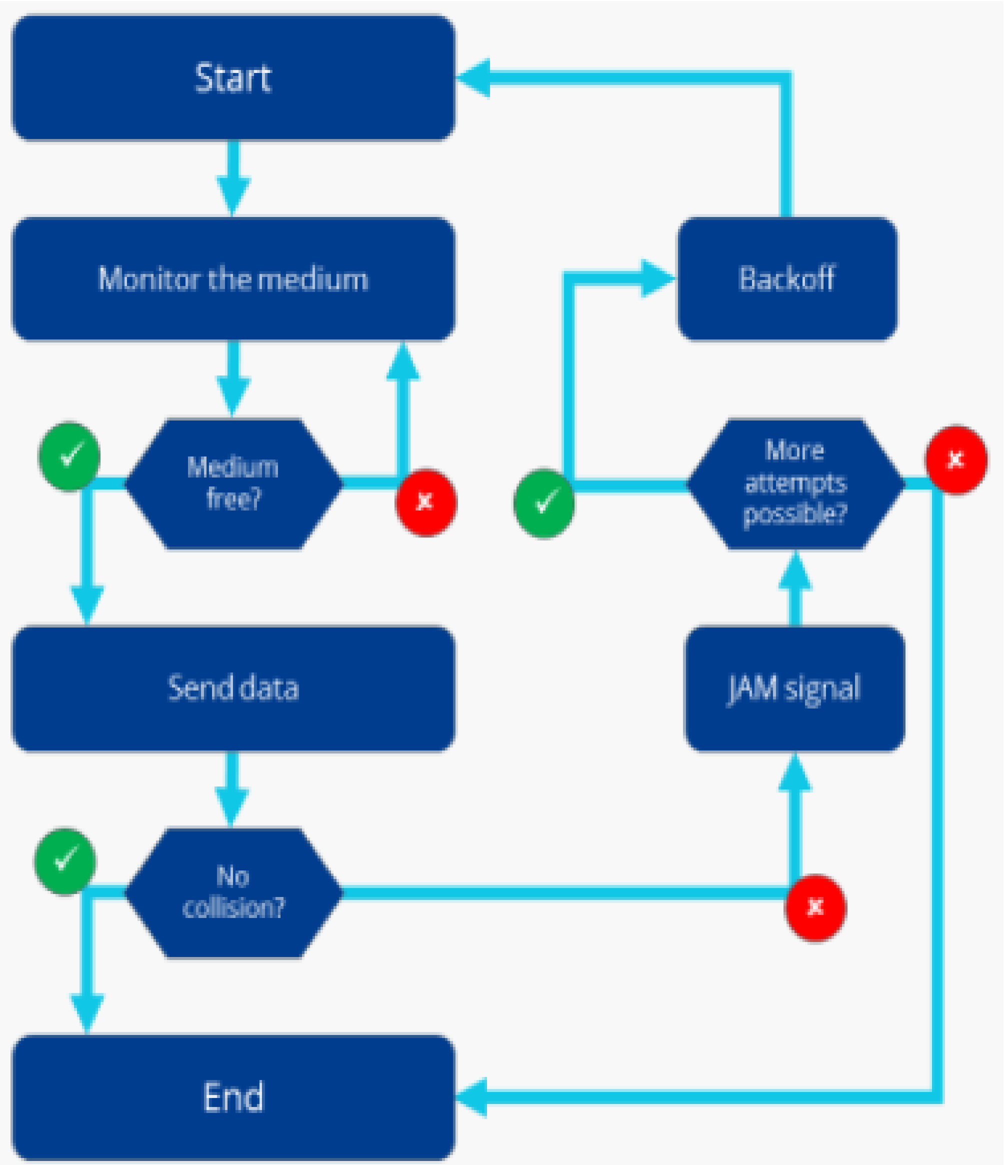
- It lies in the data link layer.
- Sends and receives the encapsulated data to and from the LOGICAL LINK CONTROL (LLC).
- These encapsulated data are nothing but an Ethernet frame.
- Specify whether it is a Half duplex mode or Full duplex mode.
- In Half duplex mode multiple computers share access to a single Ethernet channel by using the CSMA/CD.
- A channel b/w the station and a switch, where there is no need control access to the link.



HALF DUPLEX MAC

- When mentioning Ethernet half duplex mode, we must talk about the CSMA/CD because of many collisions that may occur due to the single channel.
- transmission:
  - If there is no carrier, transmit occurs.
  - If a station wishes to transmit multiple frames, it must wait IFG between successive frames.
  - If there is a carrier, then the station defer.
  - If a collision is detected, the station will continue to transmit 32 bits of data (collision enforcement jam signal).
  - If a collision is detected early (during the preamble), the station will continue sending the preamble, then it will send the 32 bits of jam (long enough for detection).
  - After sending the jam signal, the station waits for random retransmission time (back-off) based on the collision counter

- Delay times are always in multiples of the worst case round trip propagation delay of the network (slot time = 512 bit times).
- If a station has transmitted 512 bits (without the preamble) without a collision, then the station is said to have acquire the channel and clears its collision counter.



- Slot time:
  - 512 bit times for 10 and 100 Mb/s systems
  - Combination of:
    - physical layer round-trip propagation time, time takes for a signal to travel from one end of a maximum-sized system to the other end and return.
    - Maximum time required by collision enforcement, time required to detect a collision and to send the collision enforcement jam sequence.

- Collision detection:

  - It is medium dependent.

    In twisted pair or fiber optic cable:
    - There is an independent transmit and receive data paths.
    - Collision is detected in a link segment transceiver by the simultaneous occurrence of activity on both the transmit and receive data paths.

    On a coaxial cable medium:
    - The transceivers detect a collision by monitoring the average DC signal level coax

- Late collisions:
  - Collision that occurs after 512 bit times, considered an error.
  - Ethernet interface will not automatically retransmit, application software mst detect the lack of response sue to the lost frame (e.g. acknowledgement timers) and retransmit the information.
  - Happen commonly when a mismatch between the duplex configurations.

- Back-off algorithm:

  - Delay time for a station to wait before retransmitting is set at a multiple of the 512 bit Ethernet slot time.
  - $0 \le r < 2^k$ where k = min(n, 10)
  - r: multiplication of the slot time, randomly selected.
  - N: number of transmission attempts.
  - On the first retry after a collision, the interface is allowed to randomly choose a value of r from the range of integers 0 to 1.
  - On the second retry, r= 0, 1, 2, 3.
  - On the third retry?

MAXIMUM BACKOFF TIMES ON A 10 MB/S SYSTEM

Collision on attempt number	Estimated number of other stations	Range of random numbers	Range of backoff times[a]
1	1	0…1	0…51.2 µs
2	3	0…3	0…153.6 µs
3	7	0…7	0…358.4 µs
4	15	0…15	0…768 µs
5	31	0…31	0…1.59 ms
6	63	0…63	0…3.23 ms
7	127	0…127	0…6.50 ms
8	255	0…255	0…13.1 ms
9	511	0…511	0…26.2 ms
10–16	1023	0…1023	0…52.4 ms
17	Too high	N/A	Discard frame

- Collision domains:

  - Single half duplex Ethernet system whose elements (cables, repeaters, station interfaces, and other network hardware) are all part of the same signal timing system.

- Channel capture:

  - When a transmitting station returns to the channel contention with its back-off parameter in the initial range of 0 and 1, it has an advantage over the other stations, which have advanced in the algorithm to use wider back-off ranges.

  - The stations with higher collision counters will tend to choose longer back-off times.

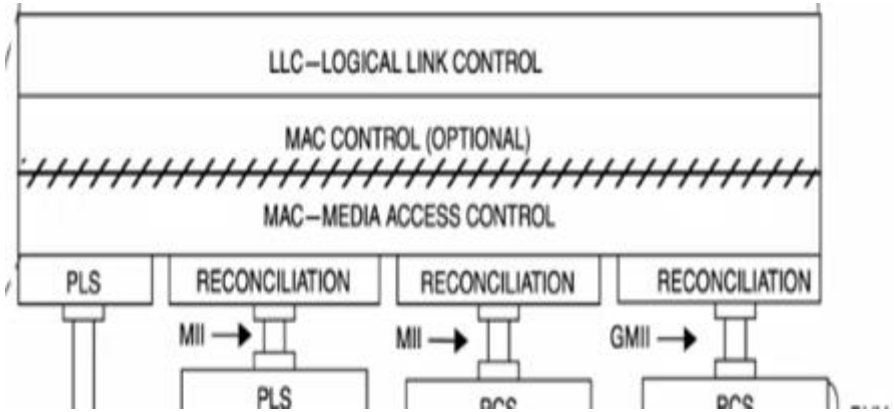
  - The station that wins which statistically, is likely to be the one that won the last round, it will effectively capture the channel for a brief period.

Full Duplex MAC

- Added to the standard in 1997
- The link between the stations must be composed of a point to point media segment, that provides independent transmit and receive data paths (e.g. twisted pair or fiber optic media)
- Doubles the aggregate capacity (bandwidth) of the link.
- Mechanisms used to establish flow control over fill duplex links are called MAC control and PAUSE.
- Stations still wait for an interframe gap period between frame transmissions.
- The standard recommends that Ethernet auto negotiation be used whenever possible to automatically configure full duplex mode.

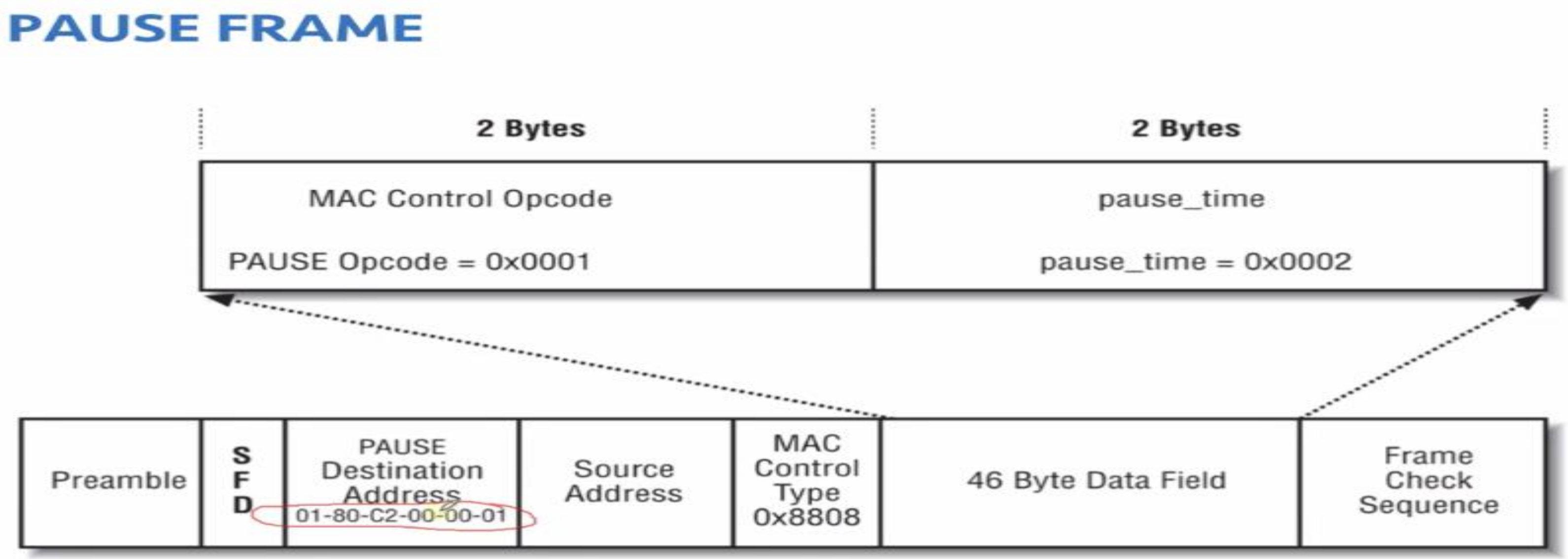
MAC CONTROL sub-layer:

- MAC defines how to go about transmitting and receiving frames.
- MAC control protocol provides mechanisms to control when Ethernet frames are sent and a way for the station to receive a MAC control frame and act upon it.
- Frames are identified with a type value of 0x8808 and contain operation codes (op-codes) in the first two bytes of the data field.



- Pause operation

  - Allows an interface or switch port to send a signal requesting a short pause in frame transmission.
  - Only stations configured for full duplex operation may send PAUSE frames.
  - PAUSE frame transmitted to the multicast address of 01-80-C2-00-00-01 (reserved for PAUSE frames).
  - The pause time is measured in units of pause "quanta" where each unit is equal to 512 bit times.

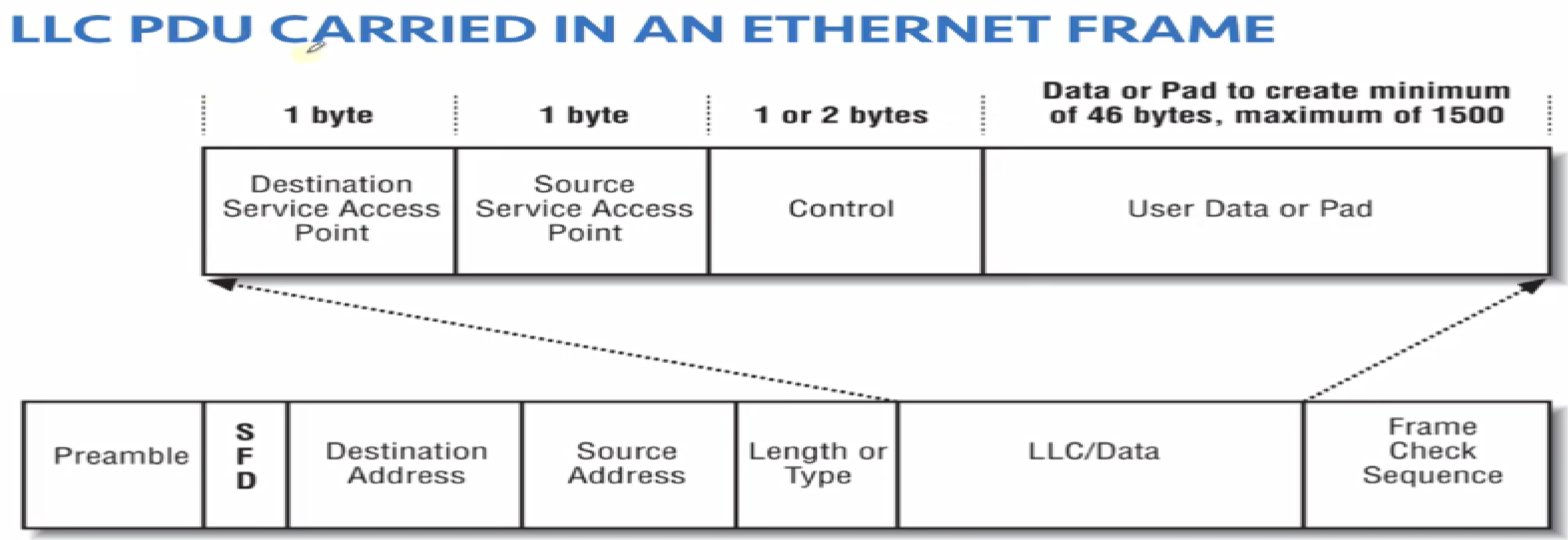


- Multiplexing data in frames:

   - Multiple high level protocols can be sent over the same Ethernet system in separate Ethernet frames using the type field

   - IEEE 802.2 logic link control (LLC) standard can be also used to identifying the data in a frame when the length field is used.

   - TCP/IP uses the type field in Ethernet frames.



The End ...

Any questions ...?

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