

Automotive Ethernet

General Ethernet :

Ethernet is used for **Bandwidth**

In vehicles, low power consumption is important. Also , requirement for ECU(Electronic Control Unit) is to be able to completely wake up from sleep under 100 milliseconds.

Standard 4 wires ethernet cannot handle this speed currently.

So instead of standard ethernet, we use **Automotive Ethernet** which can take care of these issues.

Bus technologies , compared to ethernet, can be more cost effective given cabling prices all through the vehicle.

Comparing Ethernet to CAN(Controller Area Network) and FLEXRAY

CAN:

it is a multidrop (bus) technology where user can add / remove nodes.

Multidrop or bus technology means every node or every ecu is physically, electrically connected to the same wires as every other node.

single twisted pair copper wire. => low cost/ light weight easy for **plug and play** Message or Packet based communication.

Unique for CAN is that **Non-Destructive Arbitration** for handling message or packet **collisions**.

This is handled in the arbitration section or the arbitration ID of the can network. So when there is a possible collision risk , the arbitration ID is used to identify the message or packet. and the packet or the message with the smaller ID is sent first, whereas the packet or the message with the larger ID is sent later but **WITHOUT A NEED FOR RE-TRANSMISSION**.

so lower ID number transmits first, other one waits, not not getting killed just waits. And nodes that transmits the higher ID packet also understands the situation and also waits.

This has a drawback: nodes that lost the arbitration (the ones sending the higher ID packet) will have to wait. *this makes CAN not as time-critical and accurate in time.*

This is why FlexRay was developed

FlexRay:

it is similar to CAN in terms of wiring. it is a **MultiDrop** technology BUT **all nodes must be pre-programmed with a fixed configuration**

up to 10Mb/s. speed. also good for plug and play. message or packet based communication.

==> Collision avoidance is based on time slots for each node

Every node in FlexRay is aware of time base so this helps each node to understand when it is allowed to transmit. So basically there is a cycle time, and it is divided into slices and each node has its own time slot where it is allowed to transmit. So collisions don't happen in FlexRay.

This helps very accurate in time and security critical.

Automotive Ethernet :

(100Base-T)/(1000Base-T)

==> base means this is the speed at the slowest rate ==> T1 means single twisted cable

Modern ethernet technologies, be it automotive or not, is NOT a bus technology anymore. Instead, it is *point-to-point technology*. This means that each node is connected to only one other node. for multiple communication, we need to introduce a **SWITCH**.

Switch distributes the traffic to the nodes within a network based on their **physical address** that.

Today commercially there are 100base and 1000base ethernet, 100 meaning 100Mb/s, 1000 meaning 1Gb/s.

Note that automotive ethernet is very cost effective network but not enough for **uncompressed audio and video streaming** since they handle around 10Mbits.

Automotive Ethernet

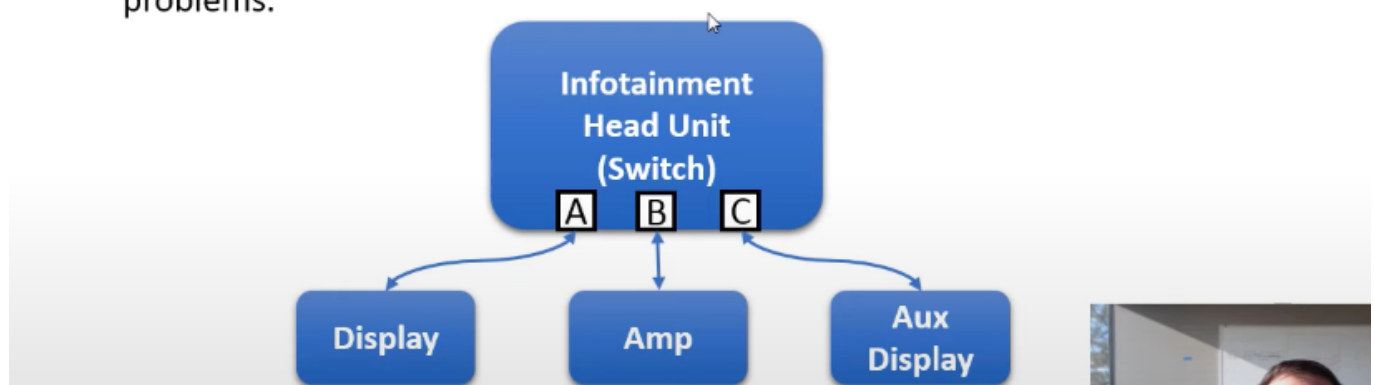
(100BASE-T1 / 1000BASE-T1)

Pros

- Up to 1000 Mb/s
(each direction and each leg)
- Widely used technology
(much support)
- Good clock synchronization
technology available (based on IEEE 1588)
- History of adaptation to solve new problems.

Cons

- Requires a switch
- Not possible to add or remove nodes unless the switch has spare ports
- Tools cannot just connect and sniff the bus



In bus technology, all the node load can be used and it is locked to 100 or 1000 mbits. in ethernet, however, it is not the case, aggregate bandwidth can exceed 100 or 1000.

Networking Topologies :

- Defines how device are connected to each other.
- Defines how the device communicate with each other.
- Determines network characteristics.
- Simple Technologies:
 - Point to Point(port)
 - Ring (Also Ethernet, used for safety critical technologies)
 - Star (ethernet) like one switch with many ports
 - Bus (chained or attached) like CAN , FLEXRAY
- Complex topologies can combine these (like mesh)

Hierarchical Star topology :

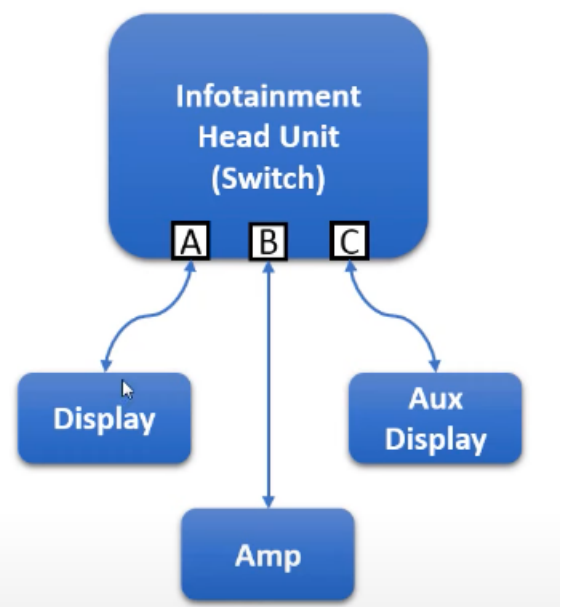
also known as **tree** topology, where each star topology represents a node and they are also interconnected to each other via a switch. you can add / remove nodes without effecting the rest of the nodes.

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Note that today's ethernet network are a **switched network**, devcices connected through switch, it optimizes the traffic flow, buffering eliminates the colisions.

Today's Ethernet Network

- Original Ethernet (Like CAN)
 - Bus architecture
 - Multiple Nodes / Single Medium
 - Collisions + Arbitration = Inefficient
- Most modern networks are a switched network
 - Devices connected through switches
 - Optimized traffic flow
 - Buffering eliminates collisions
- Each leg (A,B,C) acts as its own network.

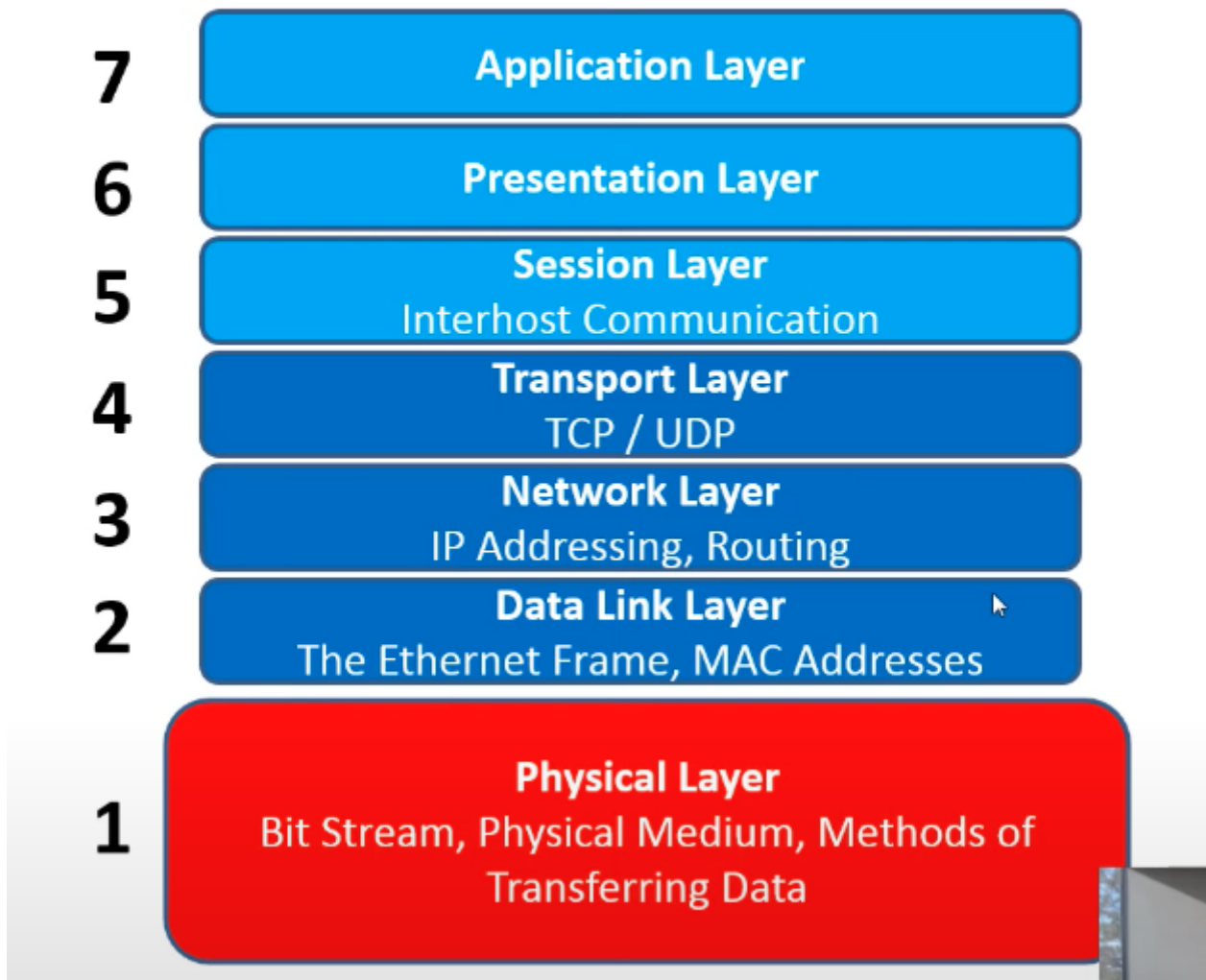


In this pic , there are three ports (A,B,C) and physically A is connected to only it's corresponding Port(Display), same for B and C. and Under each node, it works as a separate network. This eliminates the possibility of colisions because each node is communicating through only one dedicated port.

(this is the difference between this and CAN/FlexRay)

OSI Model

Physical Layer



Automotive ethernet, compared to normal ethernet, prioritizes the Physical layer of OSI model.

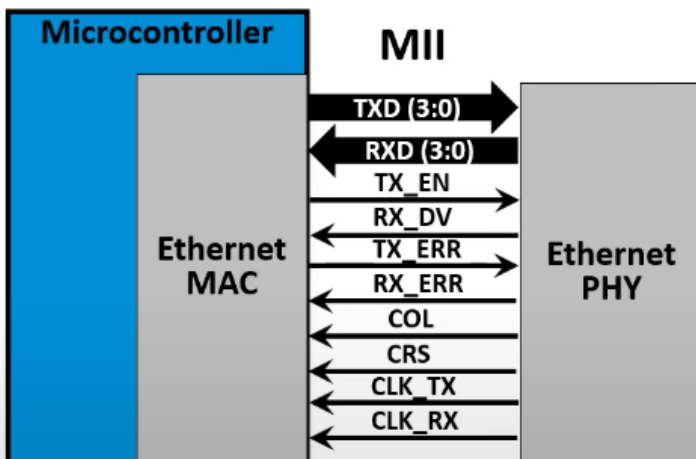
The Power of MII

• Ethernet Node

- Microcontroller
- Ethernet MAC controller
- Ethernet physical layer (PHY).

• MII

- Media Independent Interface
- Industry standard digital interface
- enables different PHYs to be used with any MAC.
- Evolved into a few variations
 - RMII: Reduced
 - GMII: Gigabit
 - RGMII: Reduced Gigabit
 - SGMII: Serial Gigabit



- Ethernet PHY = Physical layer
- MII = Media Independent Interface
- Ethernet MAC = Media Access Control

MII is connected to Ethernet MAC.

Punchline: Why Ethernet is Used and how it changes between regular vs automotive

MAC stays constant and all the layers under Physical layer are also stays constant. This MAC table, once connected, hosts all the addresses etc and statically keeps these. So it gives ability to easily swap the Ethernet PHY and MAC stays the same, also all the other layers are intact.

This gives ability to change and adapt overtime.

Automotive internet is an adaptation of it where only the physical layer is changed.

Hence talking about 'Automotive Ethernet' basically meaning a change in the Physical layer only

This is adaptability and flexibility for the thanks to Ethernet!

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Consumer Ethernet Media:

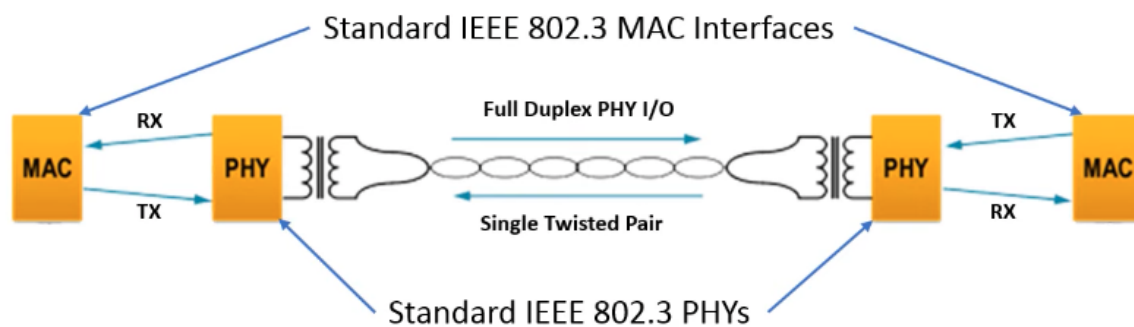
Coax ==> 100Base-2 ==> half duplex ==> obsolete in commercial, used in industry for **DiagnosticsOverIP** purposes. (OBD port)

10/100 Ethernet 100MB/s ==> 10/100BASE-TX ==> full duplex => 2 twisted=4 wires.

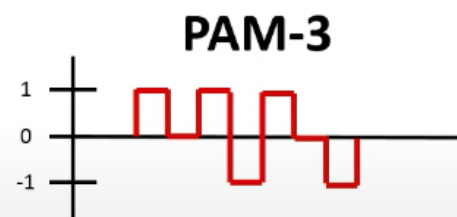
Gigabit Ethernet 1Gb/s ==> 1000BASE-T ==> full duplex => 4 twisted=8 wires.

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Automotive Physical Layer 100/1000 Mbps



- IEEE 802.3bw: 100BASE-T1
 - 66.6 Mbaud
 - 33.3 MHz Clock
 - Max length 25 meters
 - 2 symbols provide 3 bits of info: $66.6\text{M} \times 3/2 = 100\text{ Mb/s}$
- IEEE Std 802.3bp: 1000BASE-T1
 - 750 Mbaud
 - 125 MHz Clock
 - Max length 15 meters



in Bus systems like CAN, FLEXRAY, there is a **binary** state at a given time on the physical layer. Whereas in ethernet, more than 2 logical states can be passed. In Gigabit ethernet this is 5 different states(PAM-5). In automotive physical layer of 100/1000mbps, there are 3 different states(PAM-3).

Operates at base frequency of 33.3 MhzClock.(Gigabit on automotive operates at base freq of 125Mhz)

Gotcha Points :

Why Ethernet is good over bus topologies?

1. Ethernet is, DC-wise electronically isolated. So it is either capacitive coupled or transformer coupled. (capacitive or transformers are used to bridge)

This is another point why ethernet is so dominant in the industry. Because you can have lots of ground differences in and around the network and ethernet remains unaffected.

2. *Point2Point* ethernet is, in all moderns forms are **duplex** which means one node can communicate data in one direction **at full speed** and **at the same time** the other node can communicate data in the other direction **at full speed**

Which means, lets say 2 nodes communicating in two-directions in full speed, at 100BaseT connection, it makes $100 * 2 = 200$ Mbit per second data transfer. as for gigabit, thats 2 gbits aggregate data.

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A newer Ethhernet Technology that is getting commercially Available nowadays:

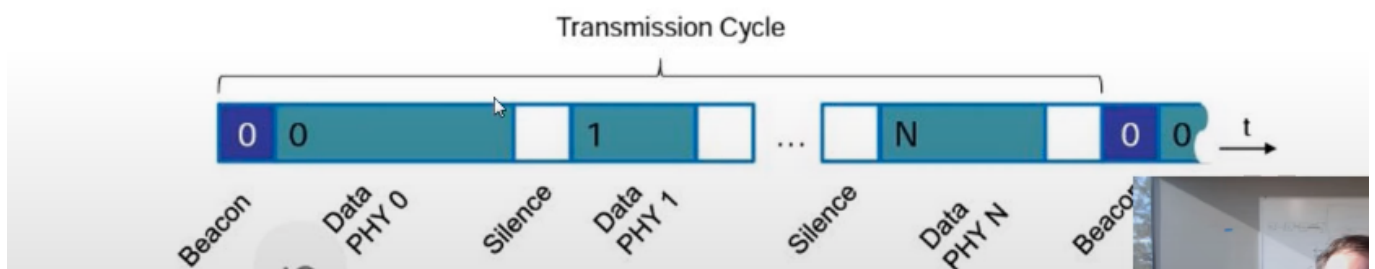
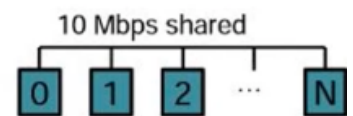
10Base-T1S

- This is an ethernet technology that is A BUS TECHNOLOGY, and created to compete CAN.
- To take advantage of cost-effectiveness of Bus technologies, this etthernet type is created.
- 10Base-T1S means **10 Mbit/s** and **single twisted cable** but **sitting on a bus topology**
- works very closely to FlexRay, using transmission cycle time, in each cycle a beacon is signalled and every node cross-checks its own time based on the beacon. Once it sees its own beacon, it transmits data.
- Puncline is : 10Base-T1s is a **time divided type of network** and this is how it avoids colisions.

10BASE-T1S

Differentiating Features

- **Goals**
 - Full bandwidth utilization
 - Reduce latency
 - Quality of Service (QoS)
- **Principle**
 - Avoid physical collisions on the medium by organizing the media access
 - Called Physical Layer Collision Avoidance (PLCA)
- **How it is done**
 - Only the PHY that owns a transmit opportunity is allowed to send data
 - Transmit opportunities are given in a round robin manner
 - A new cycle of transmit opportunities is started when the master node sends a BEACON
 - Works on top of Carrier Sense Multiple Access/Collision Detection (CSMA/CD)



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Mixing Pyhsical Medium

It is possible to mix the two technologies, for example, 1000Base-T and 100Base-TX.

- T implies 8-wire and backward compatible with 4-wire media(TX)
- Auto negotiation resolves the speed since two components have different speed rates.
- Does not work for all media, like optical cable into electrical connector.
- T/TX is are not compatible with T1
- So plugs are not compatible. Needs a media converter and **MII** in between.

– Unfortunately, T/TX are not compatible with T1

