FH AACHEN
UNIVERSITY OF APPLIED SCIENCES

Sensoren und Aktoren

Wahlpflichtfach 5. Semester Elektrotechnik

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FB Elektrotechnik und Informationstechnik
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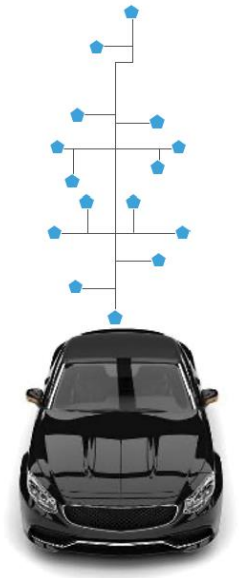
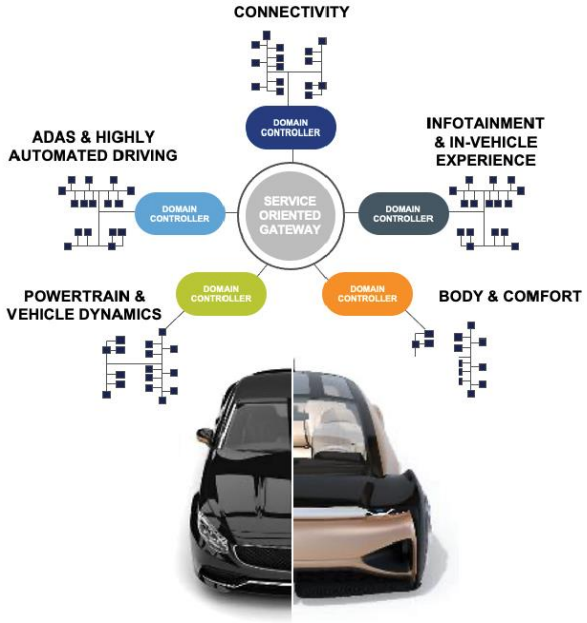
Automotive Ethernet

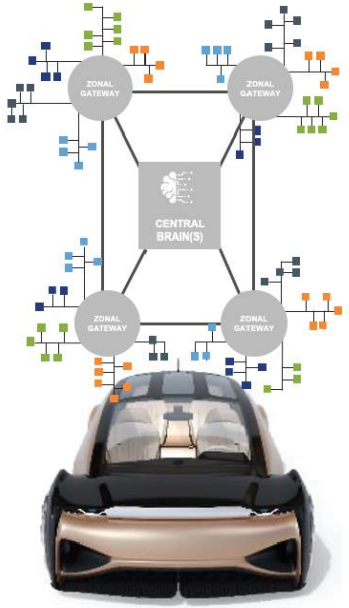
- (R)evolution of automotive network structure
- Infotainment, ADAS and autonomous driving functions generate and require a hugh amount of data
- High-speed network backbone: Ethernet



TODAY | FLAT
Unfit to future Mobility



LOGICAL RESTRUCTURE | DOMAINS
Enabling Autonomous Car

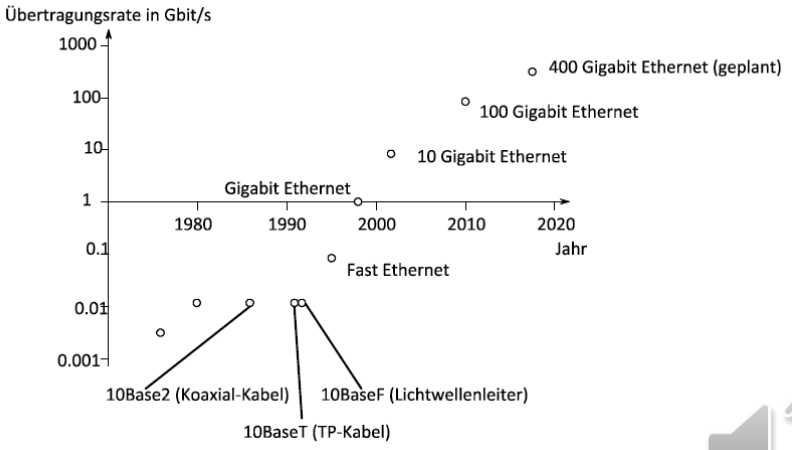


PHYSICAL RESTRUCTURE | ZONES
Enabling User-Defined Car

Source: NXP

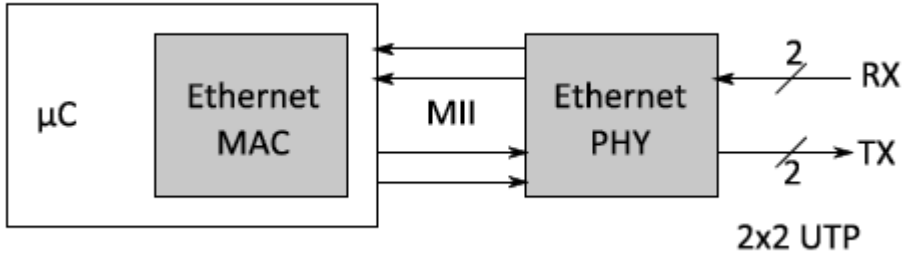
Ethernet

- Commonly used for all kind of connectivity (LAN, WAN, …)
- Ethernet standard IEEE 802.3 defines layers 1 & 2
- Several substandards like
  - 802.3 for 10 Base2
  - 802.3u for Fast Ethernet
  - 802-3z for Gb-Ethernet over fiber
- Success story
  - Strict seperation of layer 1 & 2 with clearly defined interface
  - Layer 2 (MAC) remains (nearly) unchanged
  - Layer 1 (PHY) evoloves toward higher data rates
  - Higher layers for applications



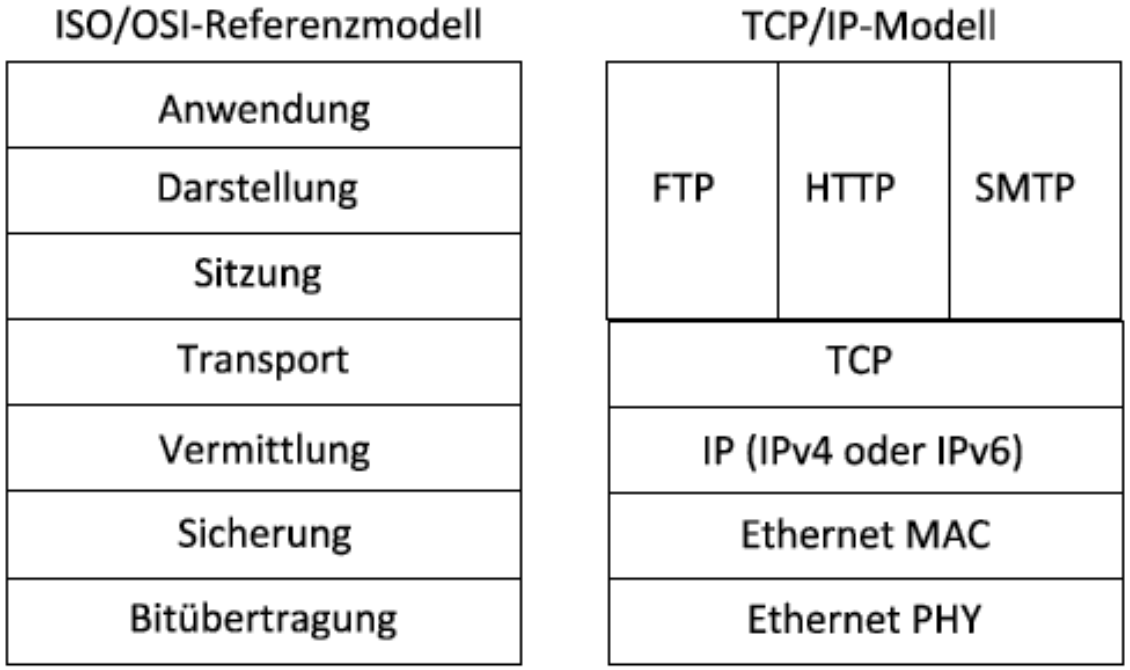
Ethernet

- Hardware implementation reflects the layer 1/2 separation
- (R)MII interface (Media Independent Interface) between MAC (layer 2) and PHY (layer 1)



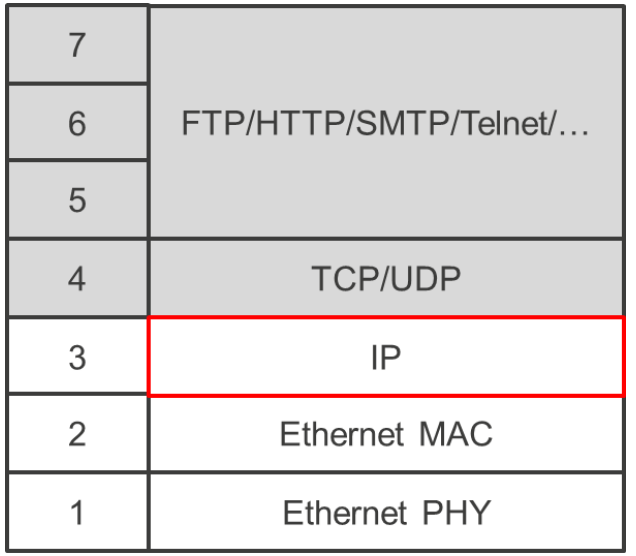
Ethernet

- Higher layers for applications like
  - TCP/IP in layer 3 & 4
  - FTP, HTTP, SMTP in layer 5-7



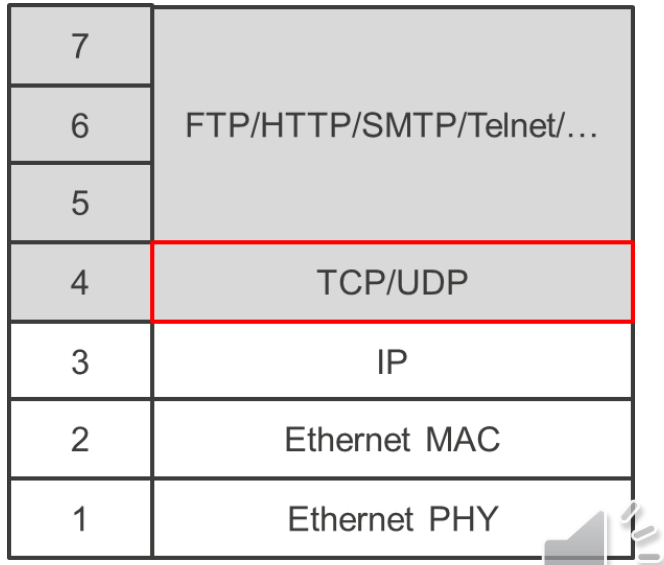
Ethernet

- IP layer (Internet Protocol)
  - Layer 3
  - Data transfer in packets
  - Defines routing of data
  - Routing and addressing based on IP-addresses
    - Each device has unique IP-address, e.g. 160.54.16.132
  - Two versions
    - IPv4 (RFC 791)
    - IPv6 (RFC 2460)



Ethernet

- TCP (Transmission Control Protocol)
  - Layer 4
  - RFC 1323 standard
  - Performs host-to-host communications
  - Provides a channel for communication needs of an application
  - Transmission and reception of reliable and error checked data streams
  - Control of successfull transmission
  - Rather high latency
  - Together with the IP layer it forms the famous internet protocol stack TCP/IP
  - Commonly used protocol for all kind of internet applications like www and mail



Ethernet

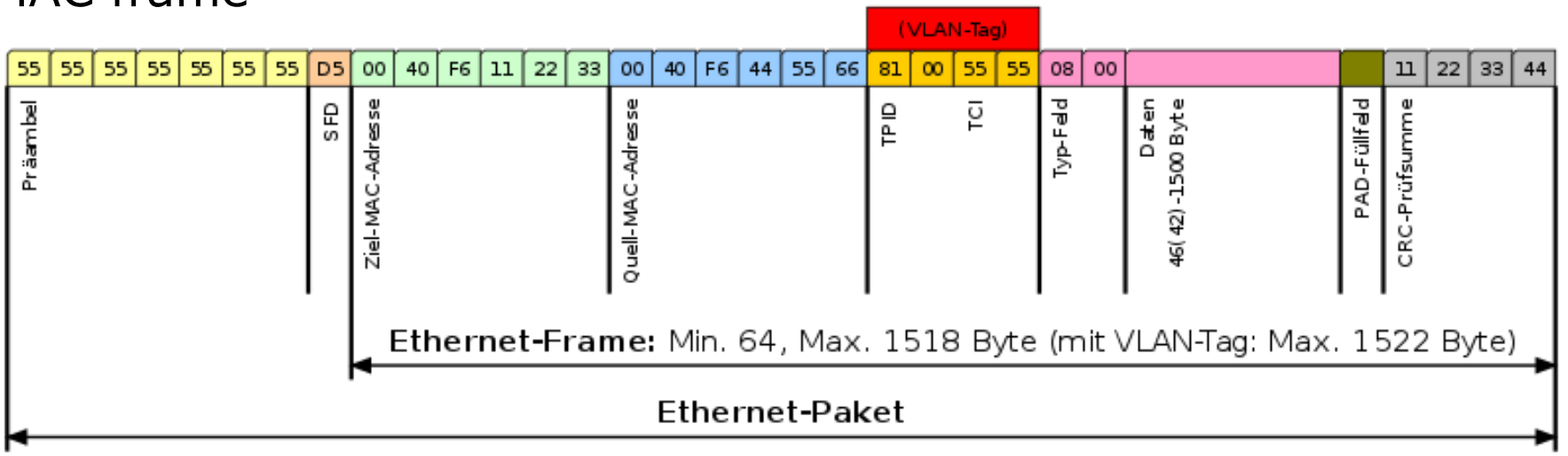
- UDP (User Datagram Protocol)
  - Layer 4
  - RFC 768 standard
  - No error checking
  - No reliability with regard to successfull data transmission
  - May change the order of data packets
  - Lower latency
  - E.g. used for multimedia applications

7	FTP/HTTP/SMTP/Telnet/…
6	
5	
4	TCP/UDP
3	IP
2	Ethernet MAC
1	Ethernet PHY

Ethernet

- Enable faster data transmission
  - LIN 19.2 kb/s
  - CAN 1 Mb/s
  - Flexray 10 Mb/s
  - MOST <150 Mb/s
  - Ethernet Up to 10 Gb/s

- Ethernet MAC frame



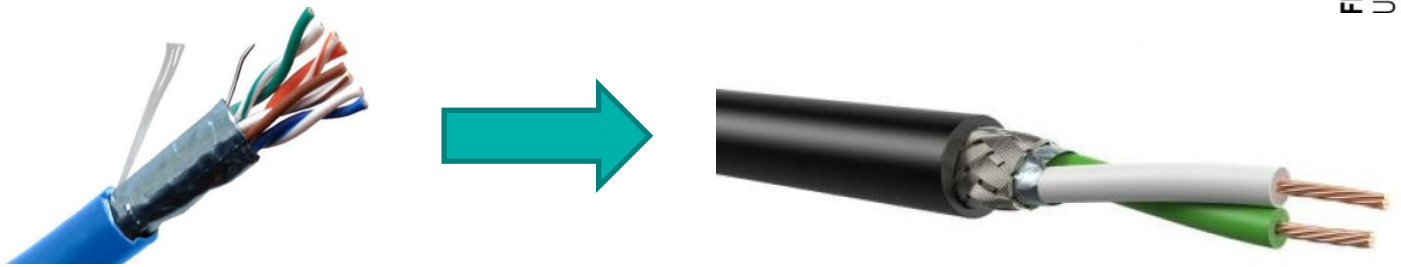
Automotive Ethernet

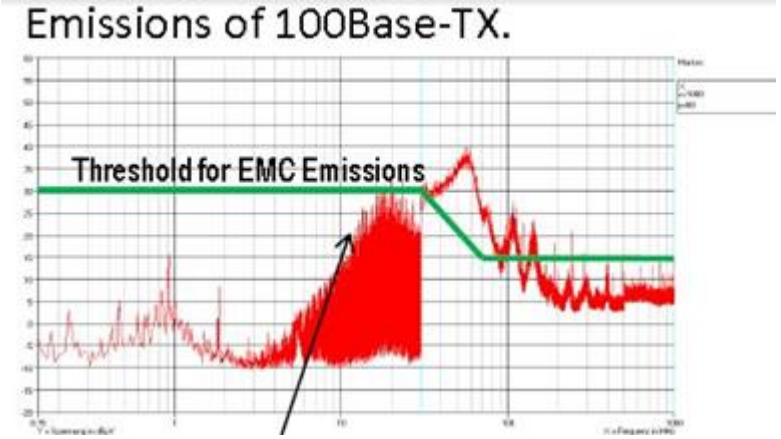
- Why is automotive Ethernet different?
  - Shorter link segments
  - Harsh environment (temperature, EMC, …)
  - Dedicated qualification
  - Reliability (e.g. higher MTBF)
  - Short startup time
  - Smaller latency
  - Safety/ASIL compliance

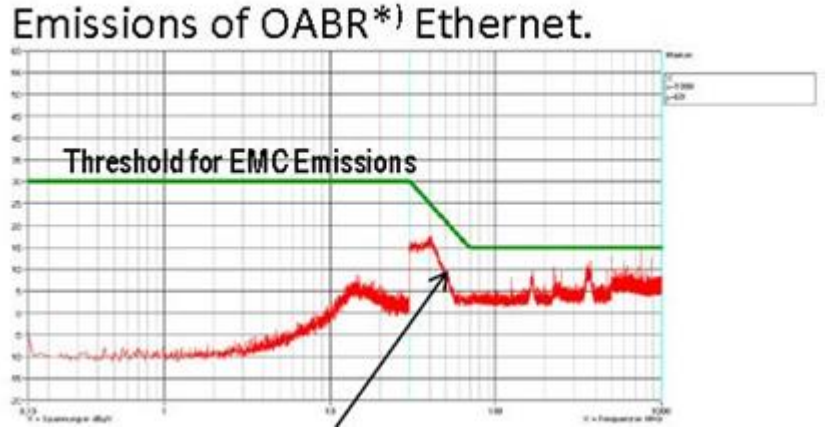
- Success of automotive Ethernet
  - Reliability
  - Predictability
  - Flexibility
  - Security

Automotive Ethernet

- Specifically tailored to meet the needs of automotive industry
  - Low cost cabling
  - EMC/EMI
  - Temperature
  - Mechanics







Automotive Ethernet

- T1: Single Twisted Pair

100Base-TX (Ethernet)

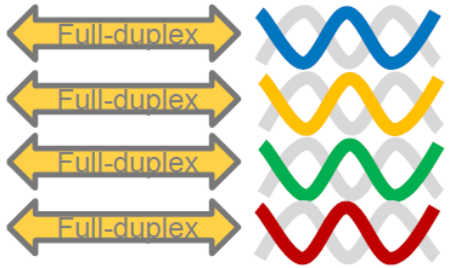
Upstream and downstream use two different pairs to form a full-duplex link

100Base-T1 (Automotive Ethernet)

Full-duplex operation over a single twisted pair

1000Base-T (Ethernet)

Full-duplex operation over 4 twisted pair of wires



1000Base-T1 (Automotive Ethernet)

Full-duplex operation over a single twisted pair

Source: Teledyne Lecroy

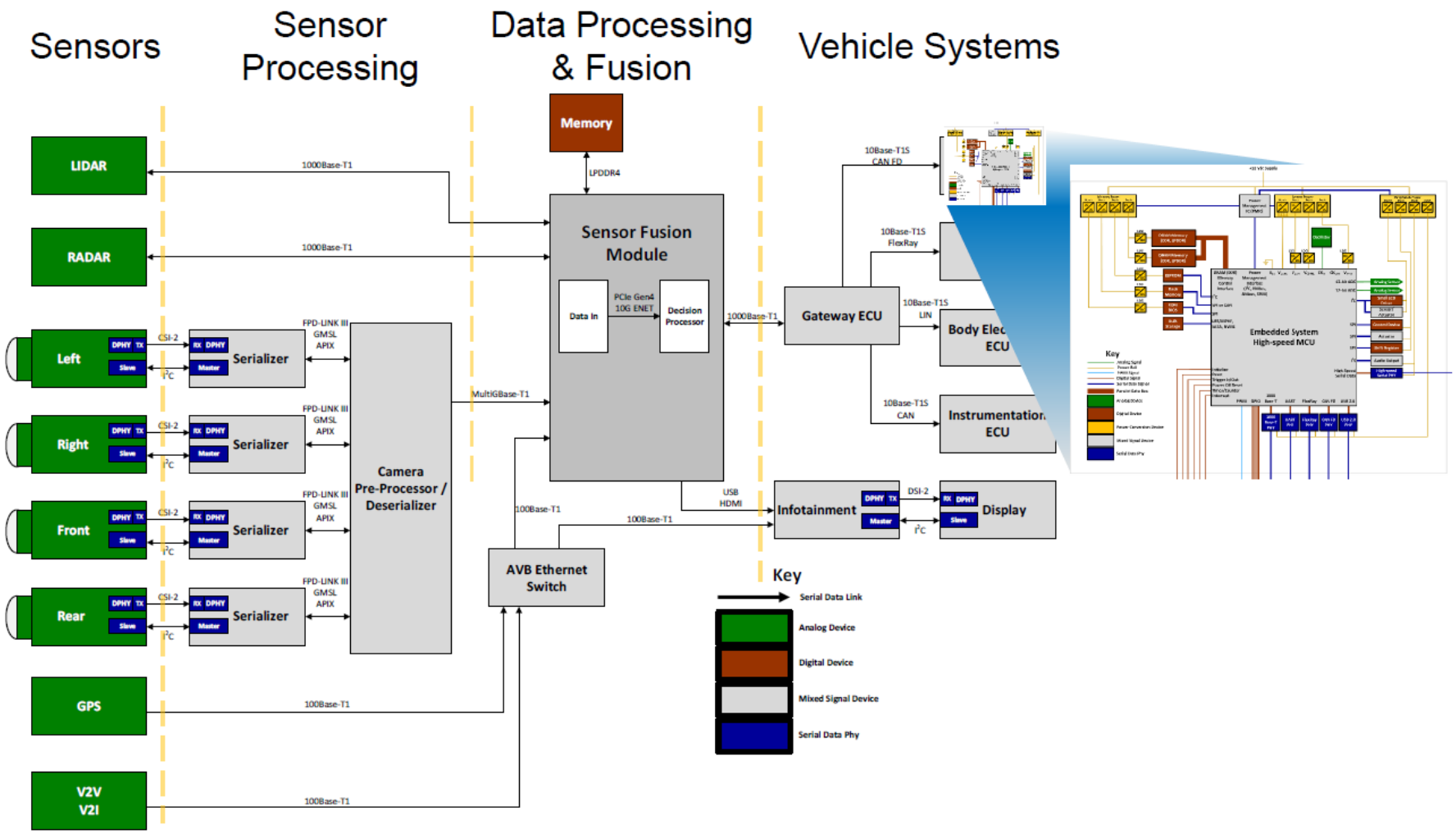
Automotive Ethernet

- Several variants of automotive Ethernet available
- Different use cases in the vehicle

Standard	IEEE Spec	Data Rate	Symbol Rate	Oscilloscope Bandwidth	Encoding	Topology
10Base-T1S	802.3cg (Feb 2020)	10 Mb/s	12.5 MHz	350 MHz	Manchester	Full or half-duplex Point-to-point, Multidrop
BroadR-Reach 100Base-T1	802.3bw (Oct 2015)	100 Mb/s	66.6 MHz	1 GHz	PAM3	Full-duplex Point-to-point
1000Base-T1	802.3bp (June 2016)	1000 Mb/s	750 MHz	2 GHz	PAM3	Full-duplex Point-to-point
MultiGBase-T1	802.3ch (June 2020)	2.5 Gb/s 5 Gb/s 10 Gb/s	1.4 GHz 2.8 GHz 5.6 GHz	4 GHz 8 GHz 13 GHz	PAM4	Full-duplex Point-to-point

Source: Teledyne Lecroy

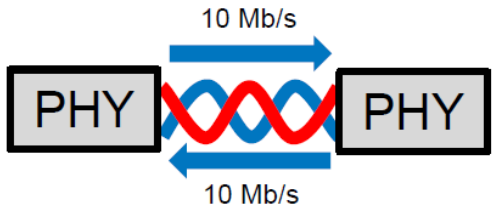
Automotive Ethernet – ADAS example

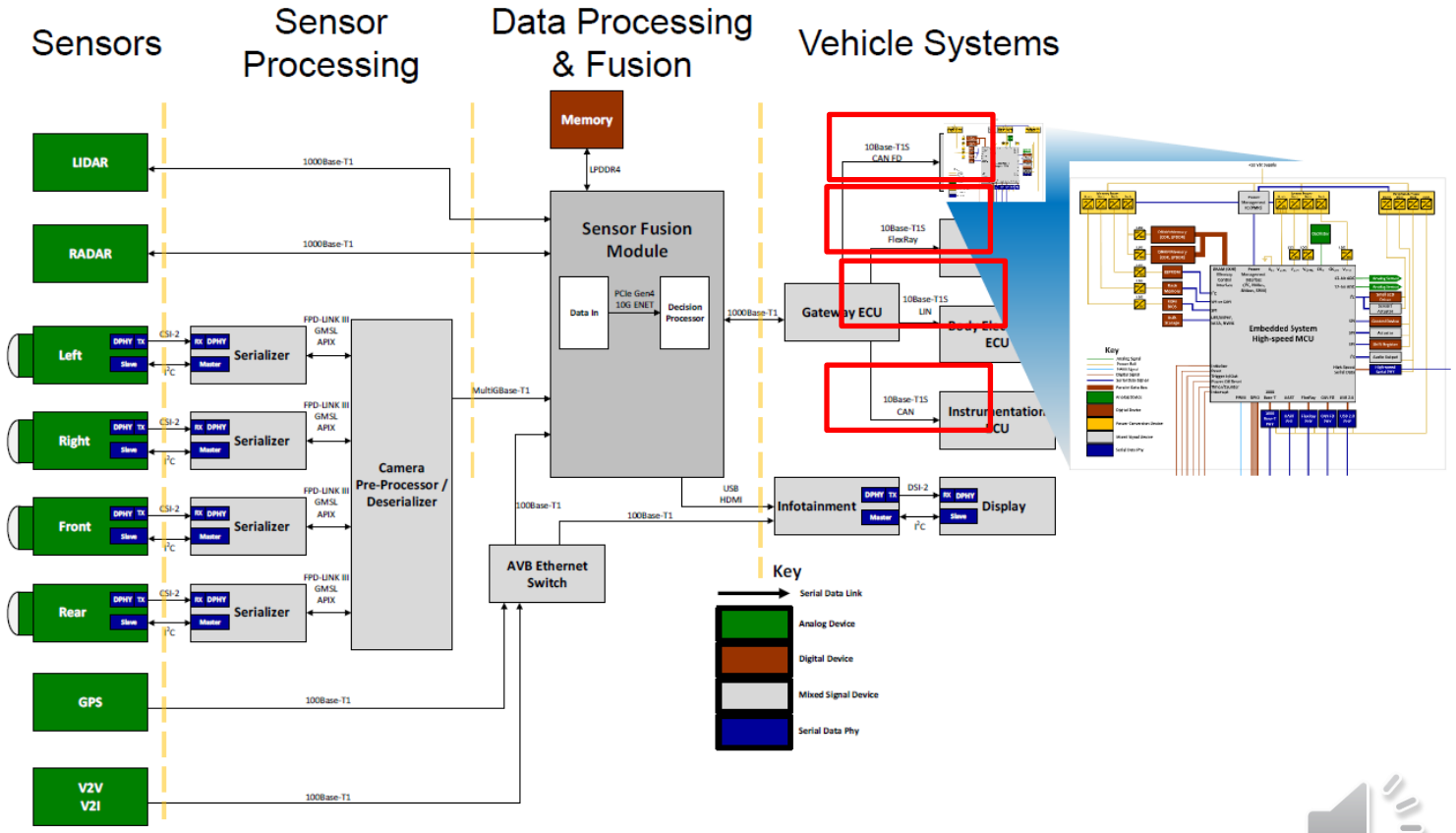


Source: Teledyne Lecroy

Automotive Ethernet – 10Base-T1S

- 10 Mb/s Automotive Ethernet
- 12.5 MHz baud rate
- Differential Manchester encoding
- Replacement of standard IVT
- Passive ADAS
- Short range
- Point-to-point
- Multidrop with 8+ nodes
- Low bandwidth requirements

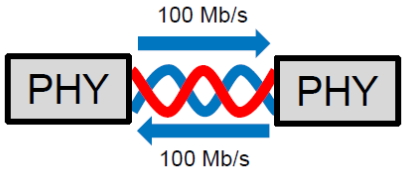


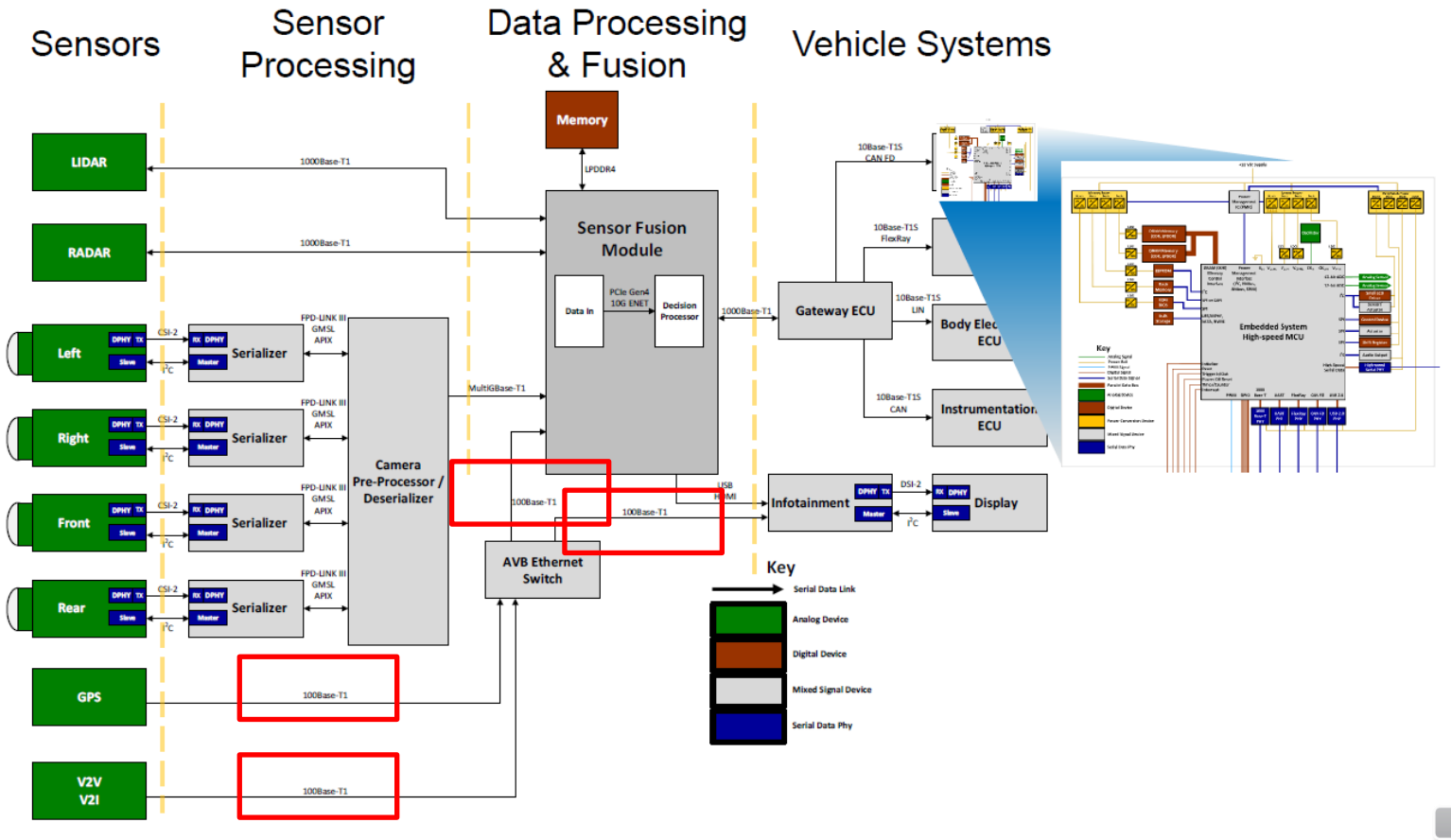


Source: Teledyne Lecroy

Automotive Ethernet – 100Base-T1

- 100 Mb/s Automotive Ethernet
- Also specified by Braodcom as BroadR-Reach
- 66.6 MHz baud rate
- PAM3 encoding
- Full-duplex
- Point-to-point
- MOST/LVDS replacement
- Passive ADAS

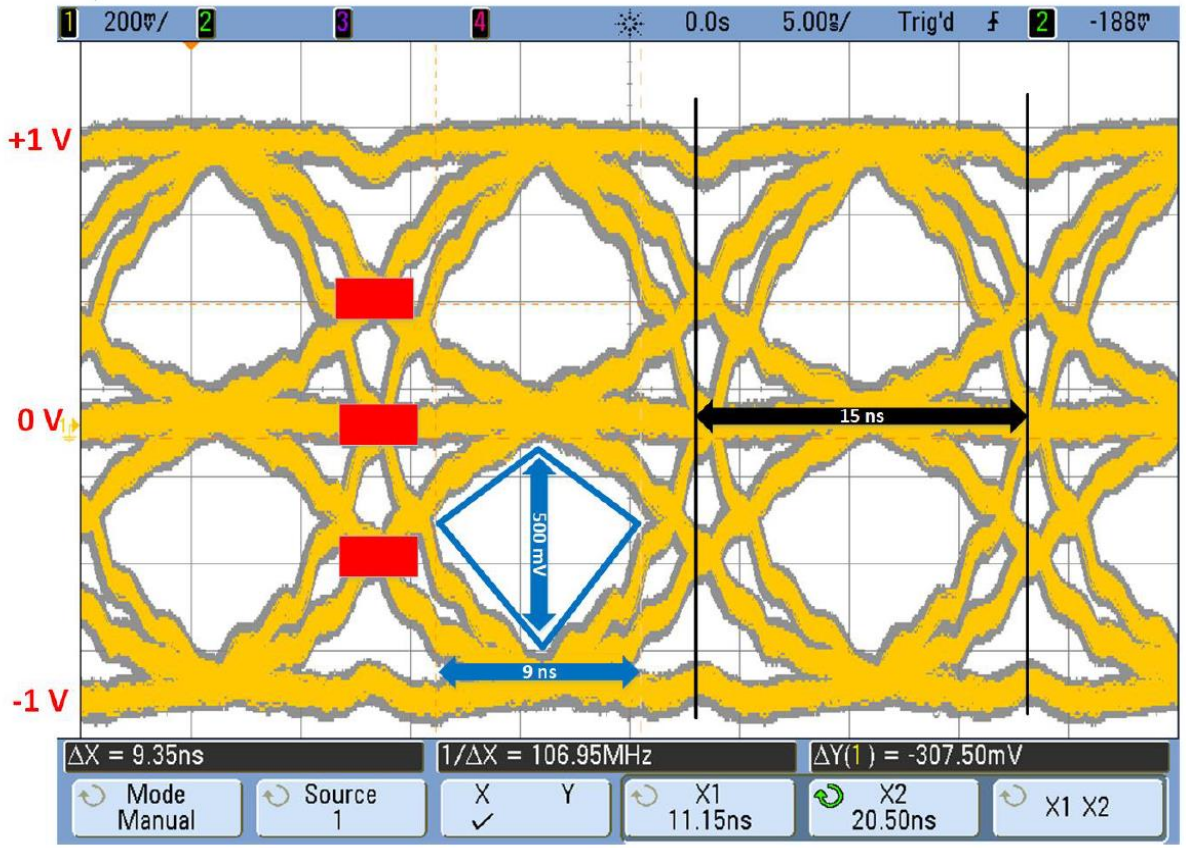




Source: Teledyne Lecroy

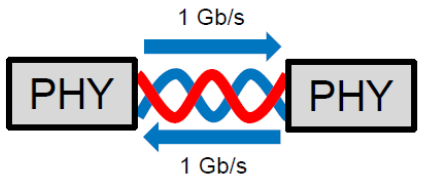
Automotive Ethernet – 100Base-T1

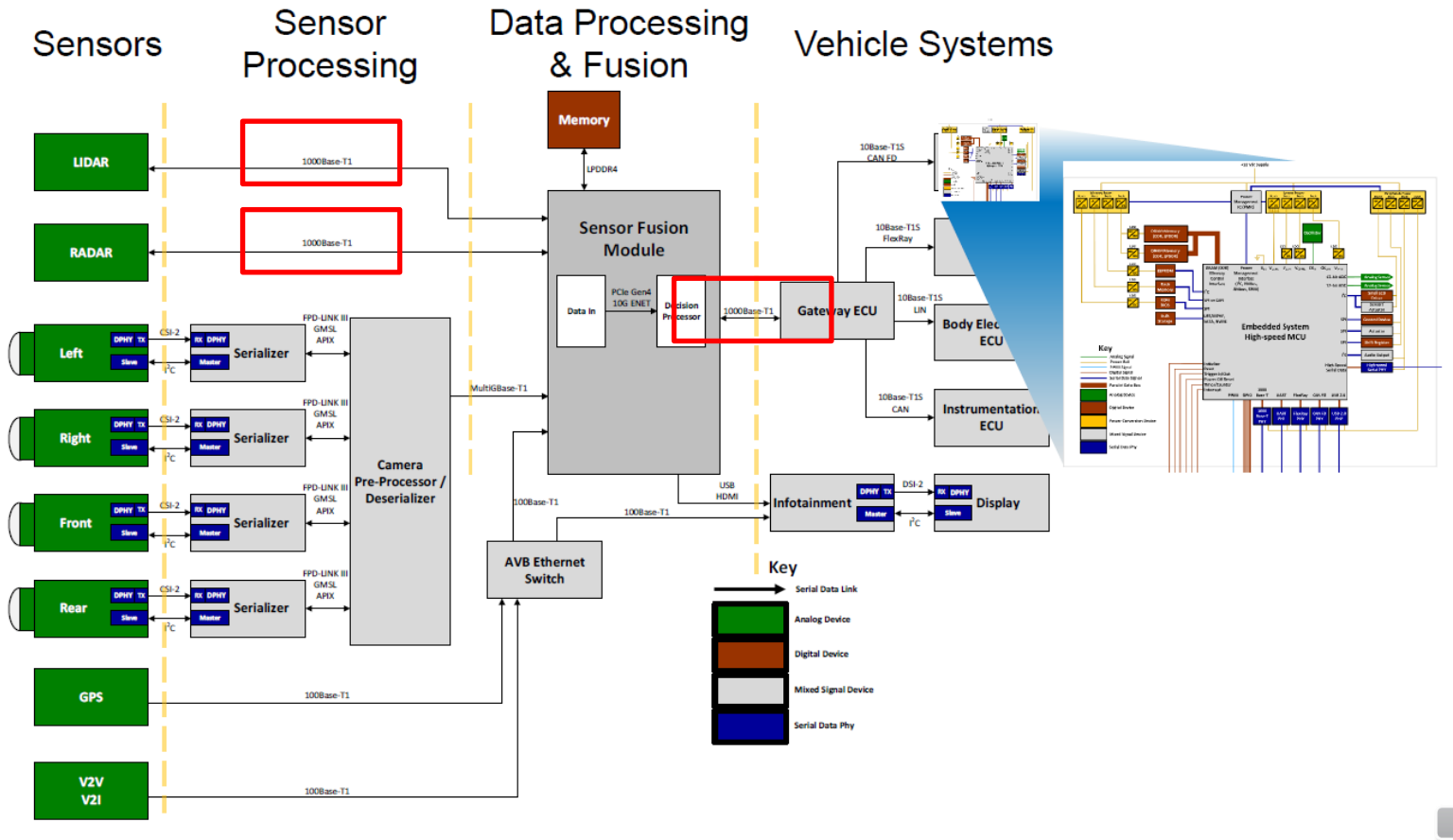
- Eye diagramm of 100Base-T1 communication
- Symbol time 15 ns (corresponding to 66.6 MHz)



Automotive Ethernet – 1000Base-T1

- 1 Gb/s Automotive Ethernet
- 750 MHz baud rate
- PAM3 encoding
- Full-duplex
- Point-to-point
- Backbone
- Active ADAS

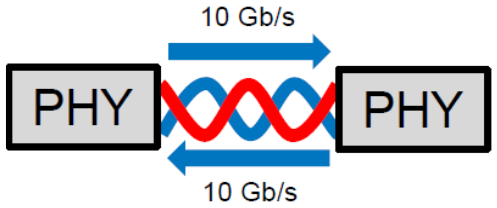


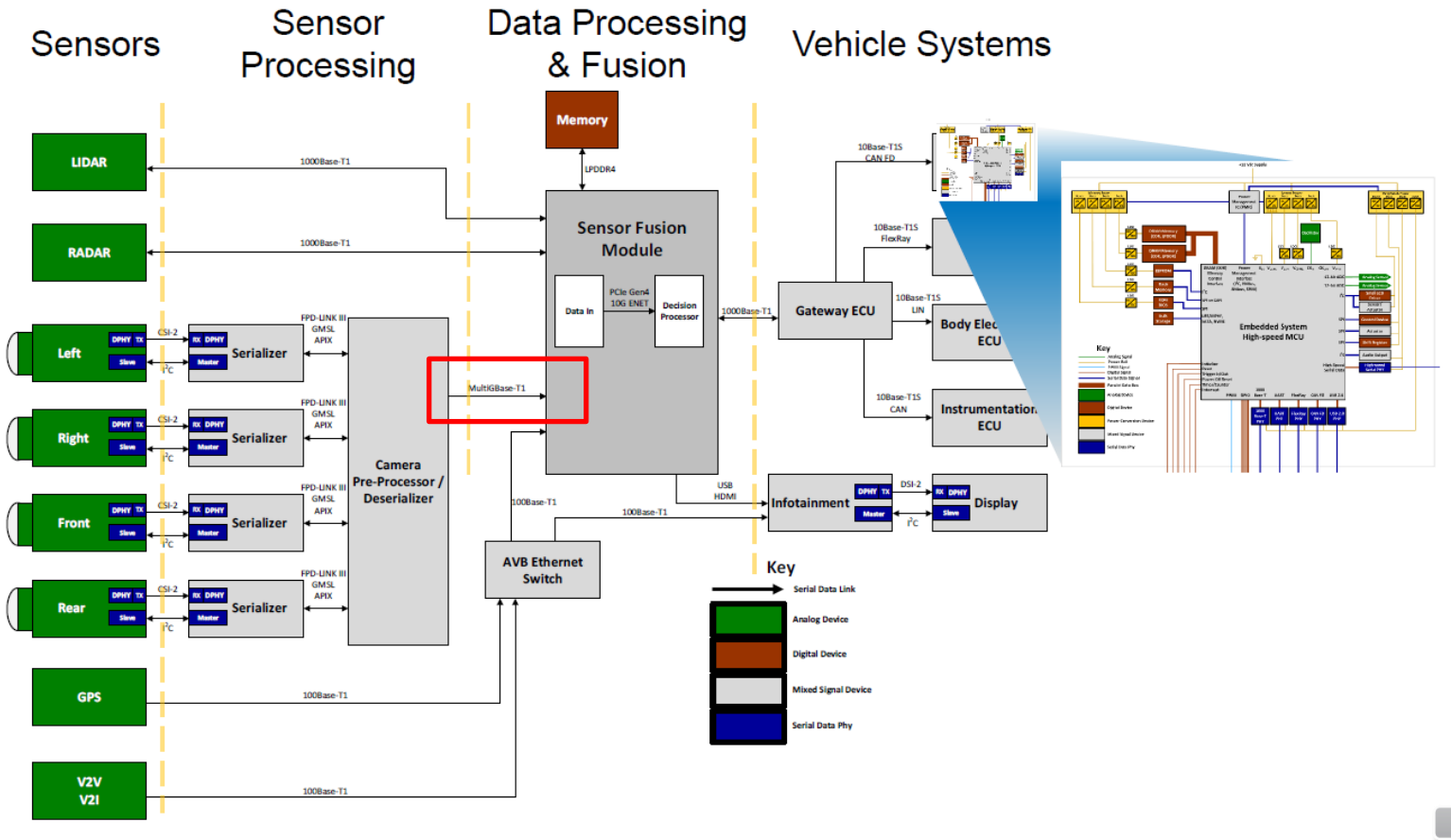


Source: Teledyne Lecroy

Automotive Ethernet – MultiGBase-T1

- 2.5/5/10 Gb/s Automotive Ethernet
- PAM4 encoding
- Full-duplex
- Point-to-point
- Autonomous driving



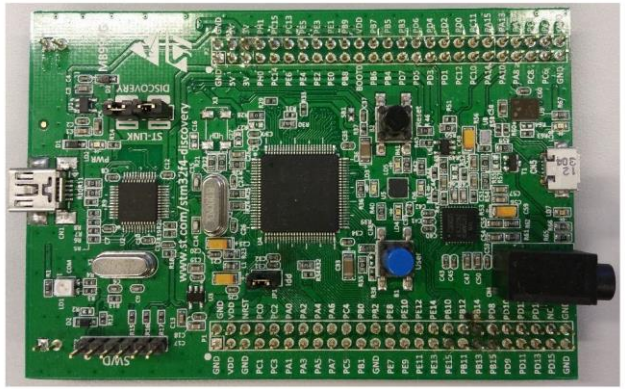


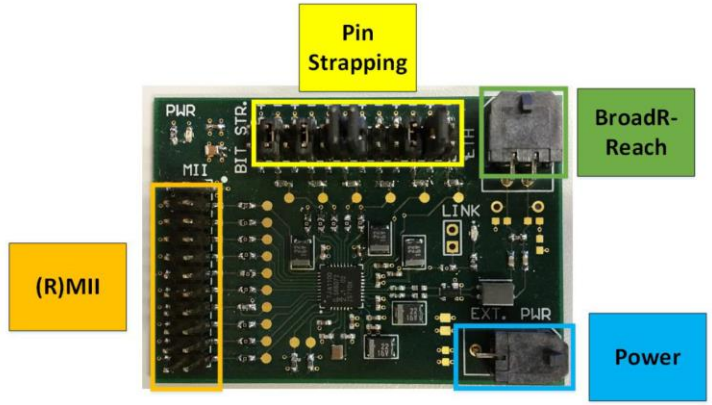
Source: Teledyne Lecroy

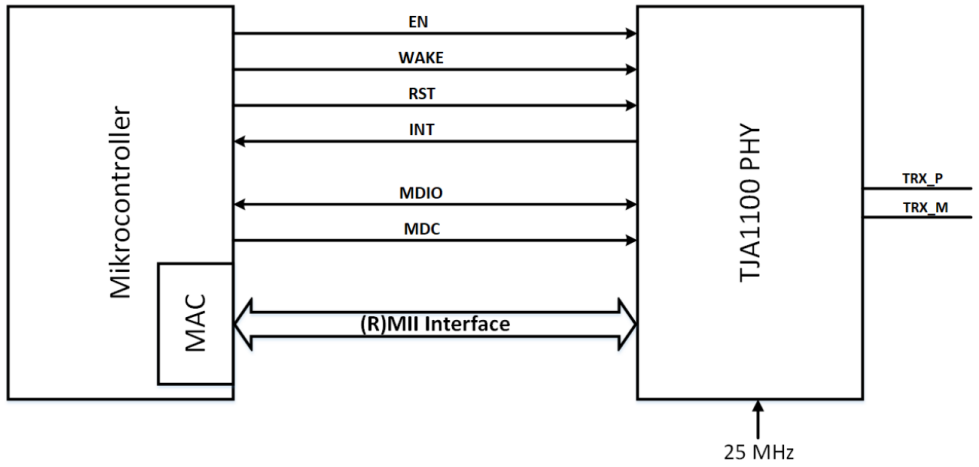
Automotive Ethernet – hardware example

- STM32F407VGT6 µC with MAC module
- 168 MHz
- DCMI-Interface for camera

- TJA1100 BroadR-Reach Board

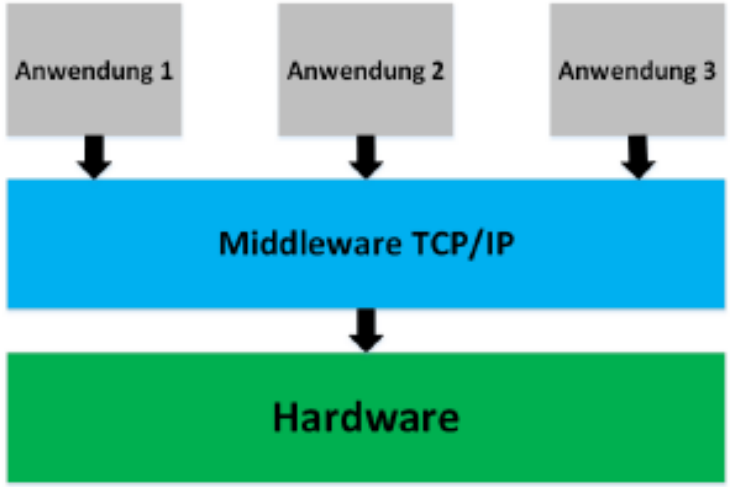






Automotive Ethernet – software example

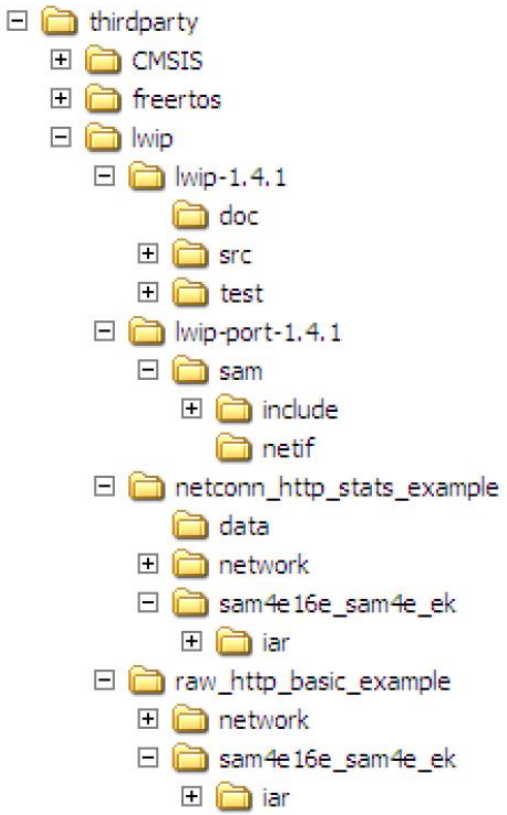
- Layers 3 – 7 are implemented in SW
- Use of middleware to separate application code from hardware related code
  - Flexibility
  - Portability
  - Reuseability
- Commonly used TCP/IP stack: lwIP



Automotive Ethernet – software example

- Lightweight Internet Protocol stack (lwIP)
- Dedicated to meet limited hardware resources like memory of embedded systems
- Open source stack supporting UDP, TCP, IPv4, …
- Offers three different APIs (Application Programming Interfaces), e.g. Raw API

	API function	Description
TCP connection setup	tcp_new	Creates a new connection PCB (Protocol Control Block). A PCB is a structure used to store connection status.
	tcp_bind	Binds the pcb to a local IP address and port number.
	tcp_listen	Commands a pcb to start listening for incoming connections.
	tcp_accept	Sets the callback function to call when a new connection arrives on a listening connection.
	tcp_accepted	Inform lwIP that an incoming connection has been accepted.
	tcp_connect	Connects to a remote TCP host.
Sending TCP data	tcp_write	Queues up data to be sent.
	tcp_sent	Sets the callback function that should be called when data has successfully been sent and acknowledged by the remote host.
Receiving TCP data	tcp_recv	Sets the callback function that will be called when new data arrives.
	tcp_recved	Informs lwIP core that the application has processed the data.



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