

Automotive Ethernet

The Future for In-Vehicle Networks

Dr. Nik Dimitrakopoulos
Automotive Ethernet & Infotainment



Rohde & Schwarz Automotive

Radar

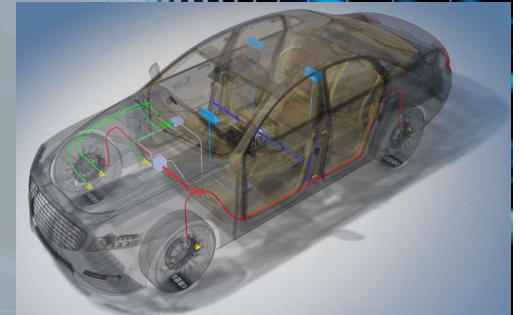
Automotive Ethernet (In-Vehicle Networks)

Connectivity

Infotainment

ECU Production Testing

EMC



Agenda

- Introduction to Automotive Ethernet
 - OPEN Alliance, Compliance testing

Trigger& Decode + EMI testing for Automotive Ethernet

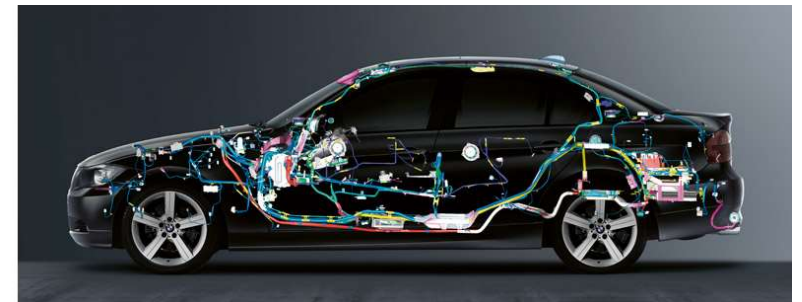
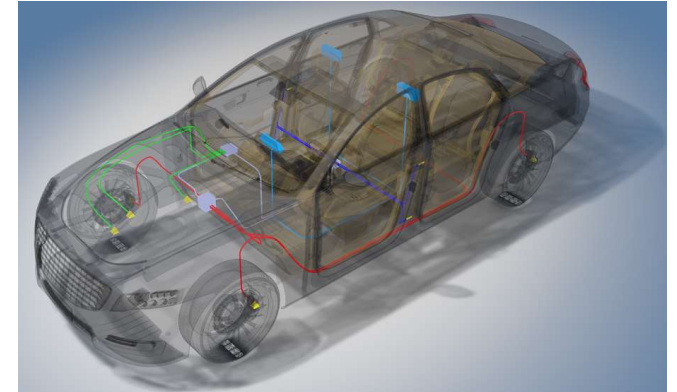
- Daimler case study

- Automotive Ethernet – 5 years into the future



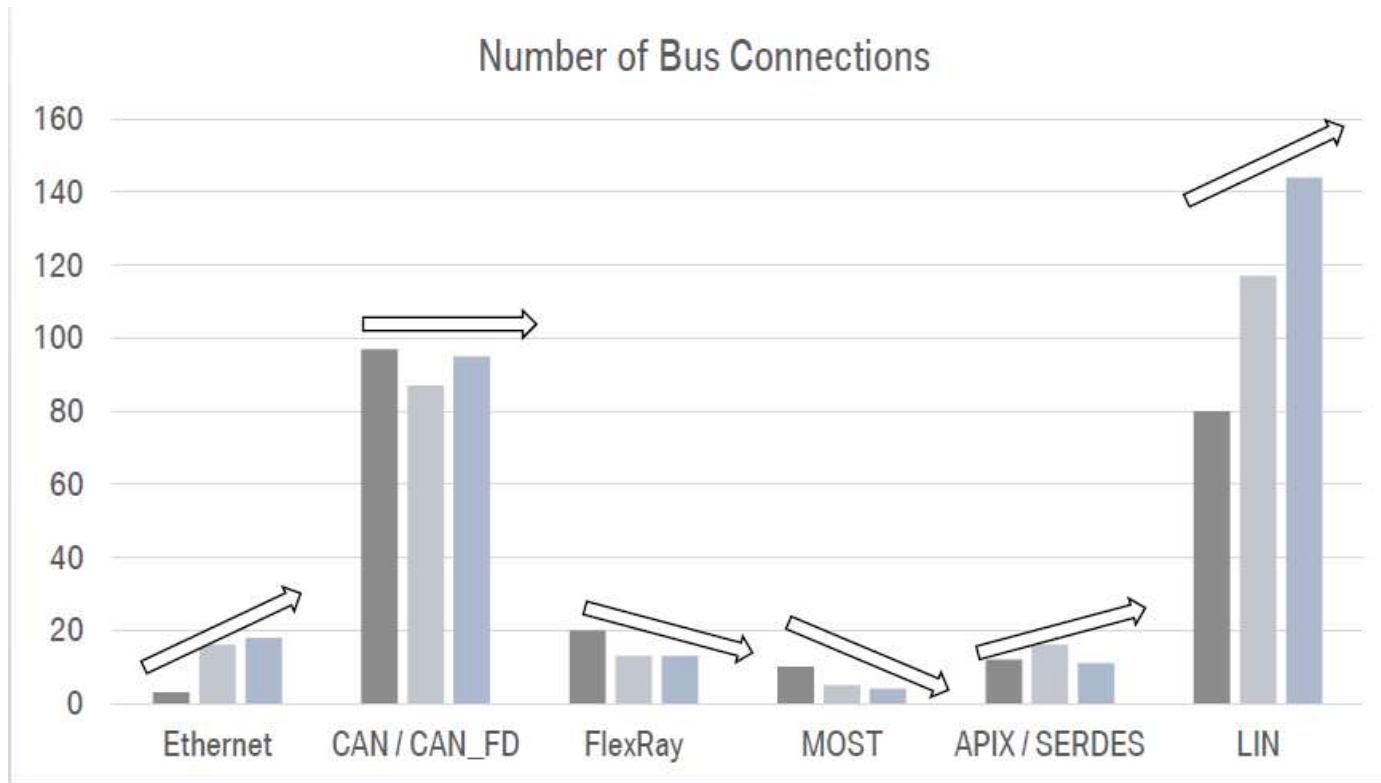
Why Automotive Ethernet ?

- Higher data throughput is required for ADAS like rear view or surround view camera systems
- Low latency is required for ADAS like for adaptive cruise control etc.
- Industry standards need to be integrated to save cost: 100BASE-T1 instead of MOST
- Reuse of TCP/IP in different application (flashing, camera, smart antennas) helps to reduce complexity
- Ethernet standards like Audio Video-Bridging, Time Sensitive Networks enable new applications
- Unshielded Twisted Pair cabling to save cost



Source: BMW

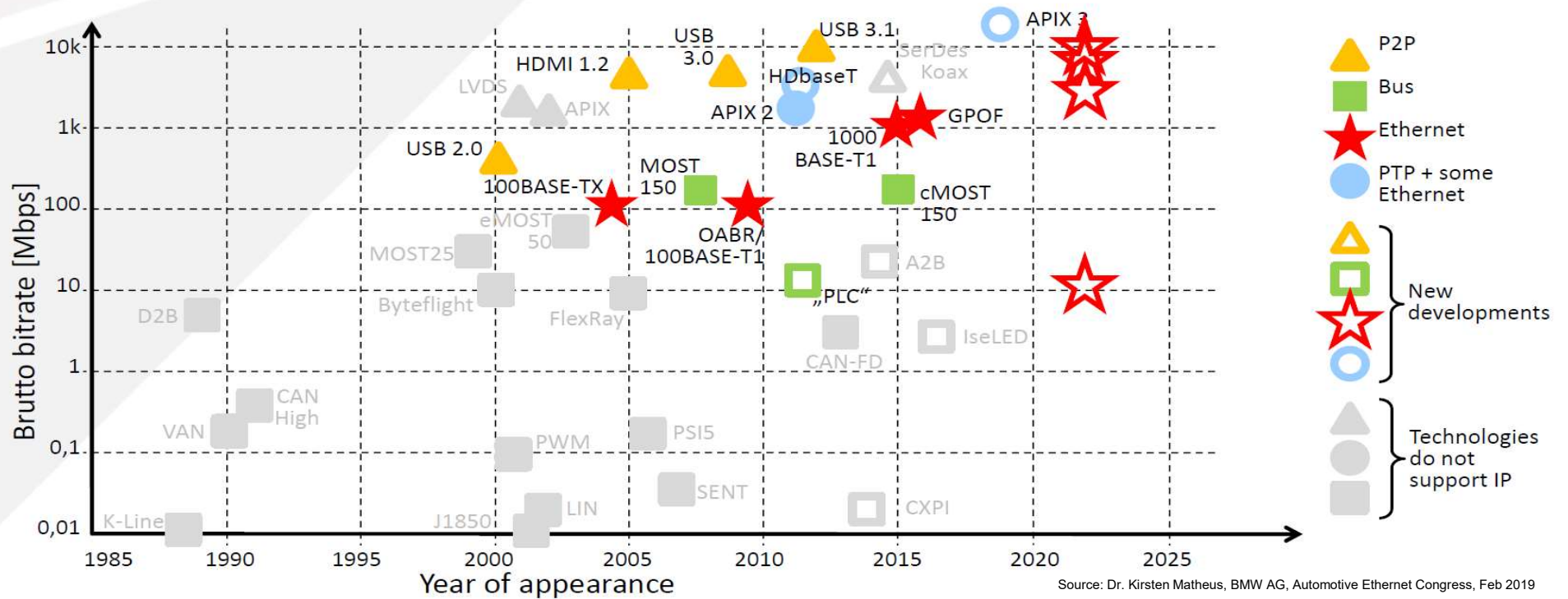
Automotive bus trends



Source: Brösse, BMW, March 2018



ONLY A SMALL NUMBER OF TECHNOLOGIES SUPPORT IP AND LARGE DATA.



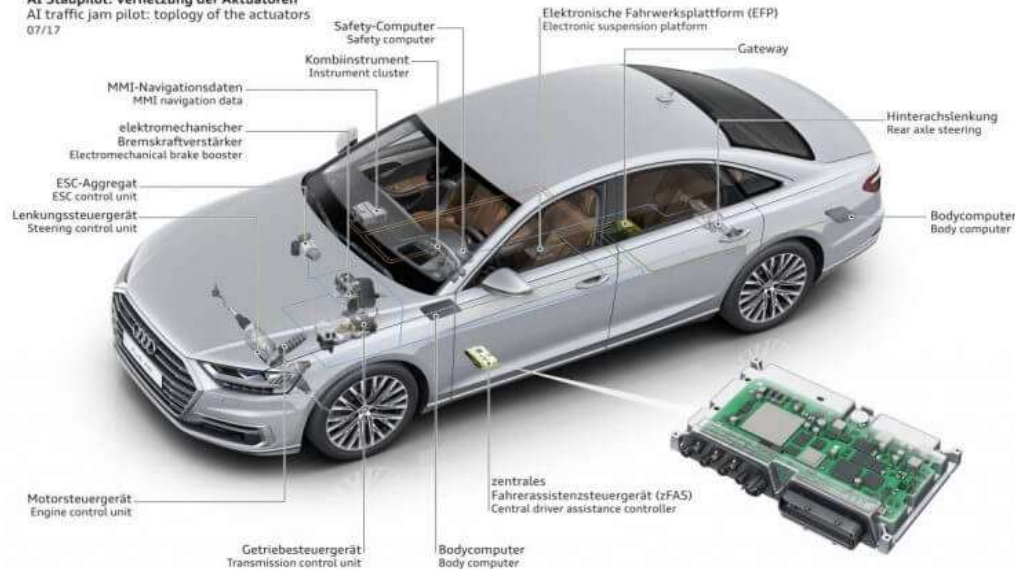
Source: Dr. Kirsten Matheus, BMW AG, Automotive Ethernet Congress, Feb 2019

Example Audi A8

Overview

Audi A8

AI Staupilot: Vernetzung der Aktuatoren
AI traffic jam pilot: topology of the actuators
07/17



- 48 V +12 V network
- ADAS controller zFAS with 70W
- 2.3 km cable
- 54 kg
- 3000 contacts
- 9 relays
- 380 fuses

Source: Audi, Boardnet Congress 2018



Automotive Ethernet is everywhere



Radar

Ensuring radar performance from development to production

Radar sensor to ADAS controller moves to 100/1000BASE-T1
Sensor fusion will use 10GBASE-T1



Connectivity

Testing conformance and performance of eCall, V2X, LTE-V, WLAN and Bluetooth®

Smart antennas have 1000BASE-T1



Bus systems

Debugging of bus systems such as automotive Ethernet and CAN-FD

Backbone 100/1000BASE-T1



Infotainment

Validating multimedia, audio, antenna and navigation equipment

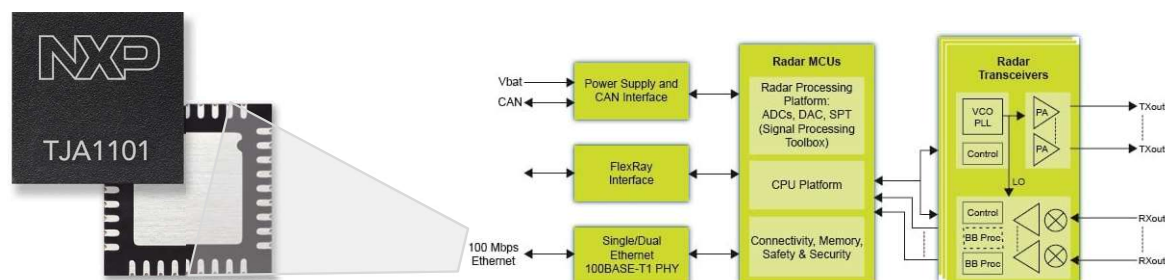
Connection to display, antenna etc based on 100/1000BASE-T1- AVB etc.

Radar + Automotive Ethernet



Features

- Automotive Qualified
- IEEE 100BASE-T1 compliant PHY transceiver
- OPEN Alliance TC-10 compliant sleep / wake up
- ISO26262 ASIL-A
- Optimized for Automotive Usecases
- Advanced Diagnostic Features
- HVQFN36 (6mm x 6mm)



ARS4-A 77GHz
Long & Short Range Radar

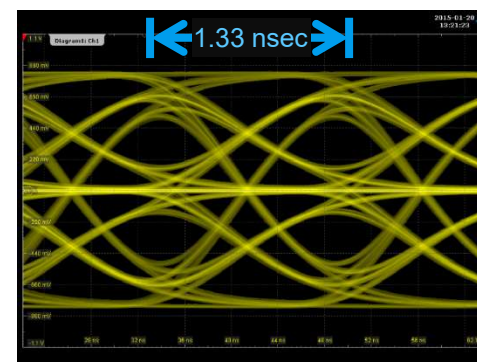
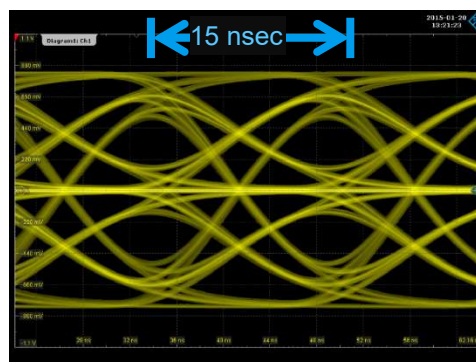
Vehicle Interface		
Vehicle interface	CAN, Flexray, Ethernet	A host wake-up or un wakeable CAN transceiver module
Power consumption	typ. 7 W	Power supply of 12 V on KL.15 (ignition), without optional DSP. 0.6A at 12VDC



What is the difference between 100BASE-T1 and 1000BASE-T1 ?

	100BASE-T1	1000BASE-T1
Symbol rate	66.66 MHz	750 MHz
DUT clock	66.66 MHz	125 MHz
Coding	PAM 3	PAM 3
IEEE PHY spec	802.3bp	802.3bw

OSI	TCP/IP
7 Application	Applications: FTP, HTTP, SMTP...)
6 Presentation	
5 Session	
4 Transport	TCP
3 Network	IP
2 Data Link	Network Access
1 Physical	100/1000BASE-T1



Difference between 100BASE-Tx and 100BASE-T1

100BASE-Tx standard Ethernet



Fast rise time

3 clear levels

100BASE-T1 Automotive Ethernet



Slower rise time

3 levels not clear

Agenda

What is Automotive Ethernet?

How to measure it

Questions to Ask

Example Configurations

Resources & Summary



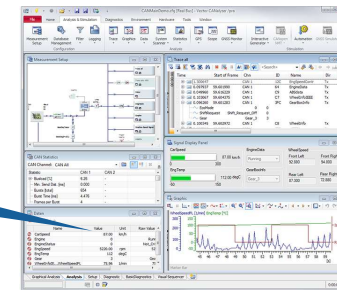
From CAN to Automotive Ethernet

OSI	CAN
7	Application
6	Presentation
5	Session
4	Transport
3	Network
2	Data Link
1	Physical

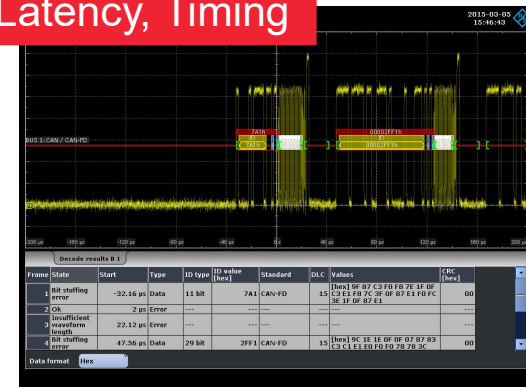
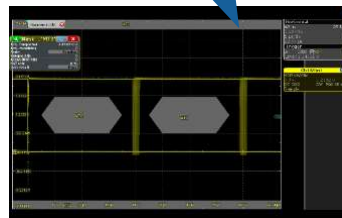
Protocol Test

Protocol Errors, EMI
Debug, Latency, Timing

Eye Test



Source: Vector



Quality Testing – Automotive Ethernet

OSI	100BASE-T1
7 Application	Applications: FTP, HTTP, SMTP...)
6 Presentation	
5 Session	
4 Transport	TCP, UDP
3 Network	IP
2 Data Link	Network Access
1 Physical	100/100BASE-T1

Protocol Test

Protocol Decoding

Compliance Test

All			
<input checked="" type="checkbox"/>	Transmitter Output Droop (5.4.1)		
<input checked="" type="checkbox"/>	Transmitter Distortion (5.4.2)		
<input checked="" type="checkbox"/>	Transmitter Timing Jitter Mastermode (5.4.3)		
<input type="checkbox"/>	Transmitter Timing Jitter Slavemode (5.4.3)		
<input checked="" type="checkbox"/>	Transmitter Power Spectral Density (5.4.4)		
<input checked="" type="checkbox"/>	Transmitter Clock Frequency (5.4.5)		
<input type="checkbox"/>	MDI Return Loss (8.2.2)		
<input type="checkbox"/>	MDI Mode Conversion Loss (96.8.2.2)		
<input type="checkbox"/>	MDI Mode Conversion Loss Adaptor Verification (96.8.2.2)		
<input type="checkbox"/>	MDI Common Mode Emission (96.5.1.2)		

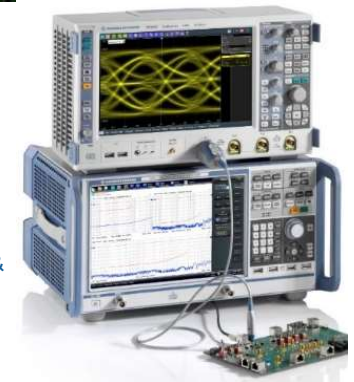
Spirent **Automotive C50**



Source: Spirent



R&S®RTO & R&S®ZND



Tech Committees



TC15 group created for MultiGig Ethernet 2.5/5/10GBase-T1.
Rohde & Schwarz is working closely with Open Alliance (contributor)

Automotive Ethernet ECU Test Specification

1000BASE-T1 Ethernet Channel & Passive Components



TC8 ECU Test Spec coverage

1.2.1 Test Scope Automotive Ethernet

Scope Automotive Ethernet includes the following ISO/OSI layers:

- Layer 1: Physical Layer OPEN Alliance BroadR-Reach (OABR)
- Layer 2: Data Link Layer, e.g IEEE Ethernet MAC + VLAN (802.1Q), ARP

1.2.2 Test Scope TCP/IP Protocol Family

Scope TCP/IP Protocol Family includes the following ISO/OSI layers:

- Layer 3: Network Layer, e.g. IP, ICMP
- Layer 4: Transport Layer, e.g. UDP, TCP, DHCP

1.2.3 Test Scope Automotive Protocols

Scope Automotive Protocols includes the following ISO/OSI layer:

- Layers 5-6-7: Application oriented layers, e.g. UDP-NM, SOME/IP, SD

OPEN Alliance Automotive Ethernet ECU Test Specification

TC8 ECU and Network Test



OPEN TC8 ECU Test Spec coverage Layer 1

■ **Mandatory** PMA test cases:

- Transmitter frequency,
- Transmitter timing jitter,
- MDI return loss,
- MDI mode conversion

■ **Optional** PMA test cases:

- Transmitter output droop
- Transmitter Power Spectral Density (PSD)
- MDI Common Mode emission
- Transmitter Distortion

■ **TC8** PMA tests the **Transmitter**

Receiver is tested on system level in **Signal Quality Tests**

OPEN Alliance Automotive Ethernet ECU Test Specification

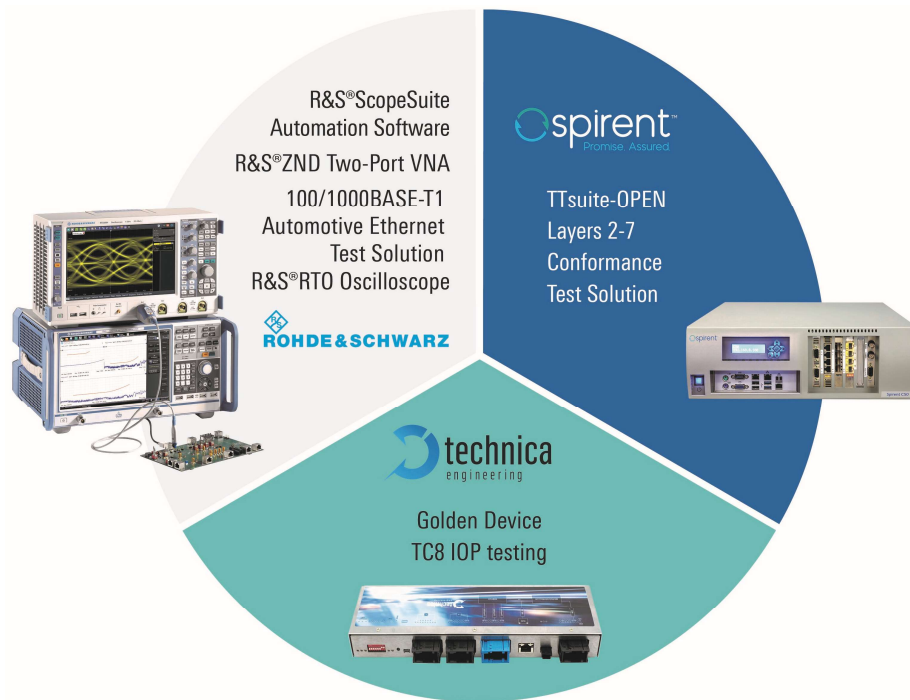
TC8 ECU and Network Test



V2.0 Aug 2017



Rohde&Schwarz, Spirent and Technica offer complete TC8 test



1.2.1 Test Scope Automotive Ethernet

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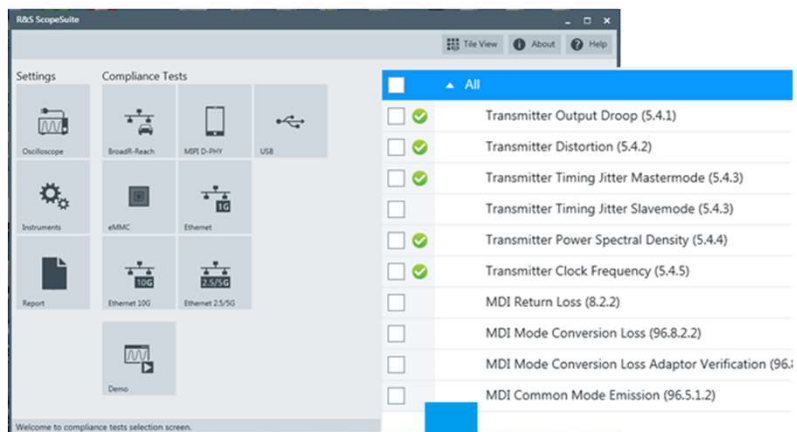
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1.2.3 Test Scope Automotive Protocols

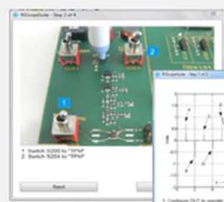
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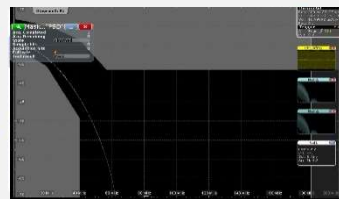
Built-in Compliance Test Software



Test



Guided steps



Auto measurements

Pass-Fail results

Test	Description	Run	Result	Detail
<input type="checkbox"/>	Output Droop	1	✓	2/2
<input type="checkbox"/>	Transmitter Distortion	1	✓	11/11
<input type="checkbox"/>	Transmitter Distortion No TX_TCLK No Disturber	1	✓	1/1
<input type="checkbox"/>	Transmitter Timing Jitter Mastermode	1	✓	1/1
<input type="checkbox"/>	Power Spectral Density	1	✗	0/1
<input type="checkbox"/>	Power Spectral Density	2	✓	1/1
<input type="checkbox"/>	Transmitter Clock Frequency	1	✓	1/1

Report



- Screenshot
- Measurement result
- Pass-Fail result
- Test summary

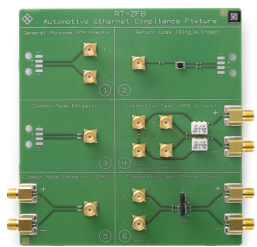
100BASE-T1 and 1000BASE-T1 Compliance Test



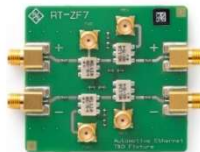
Key Features

- Complete test solution from R&S (PHY)
- Includes OEM required test cases
- Test is approved by UNH-IOL
- IOL uses RTO + ZNB for all automotive Ethernet tests

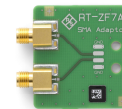
Complete PHY Test Solution including VNA, function generator and test fixtures!



Compliance Test
fixture RT-ZF8



Decoding fixture
RT-ZF7



SMA adapter for TD &
Compliance RT-ZF7A



Frequency converter
RT-ZF3/6

TC8 complete solution (what does it look like?)

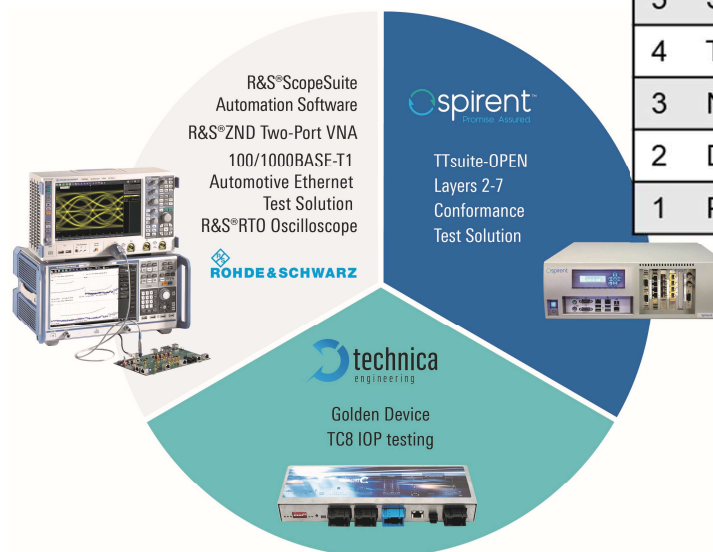


R&S®RTO

R&S®ZND

Spirent C50

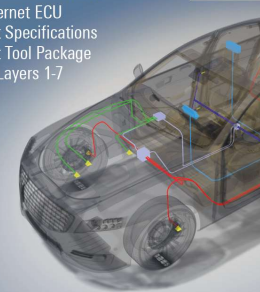
Technica
Golden
Device



OSI	
7	Application
6	Presentation
5	Session
4	Transport
3	Network
2	Data Link
1	Physical

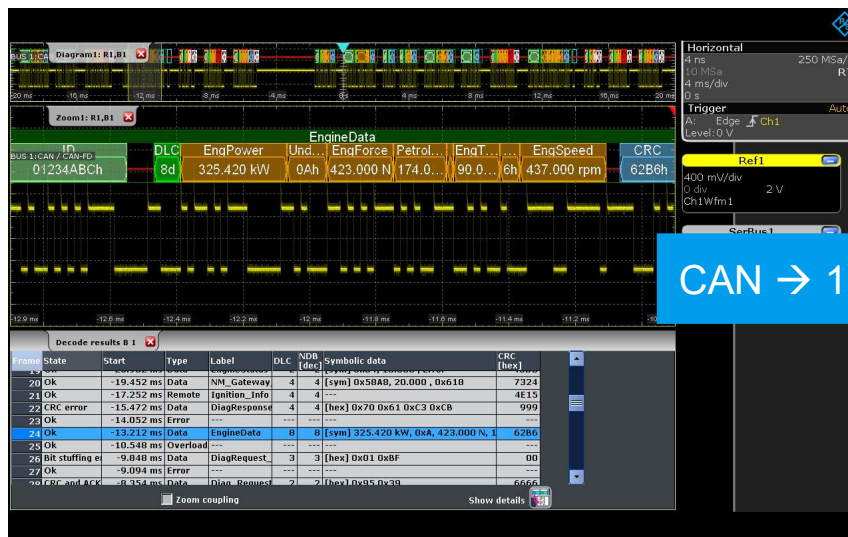
TC8 – OPEN
Alliance Automotive
Ethernet ECU
Test Specifications
Test Tool Package
for Layers 1-7

OPEN
ALLIANCE



ROHDE & SCHWARZ
Automotive

First and only Automotive Ethernet Triggering and Decoding



CAN → 100BASE-T1

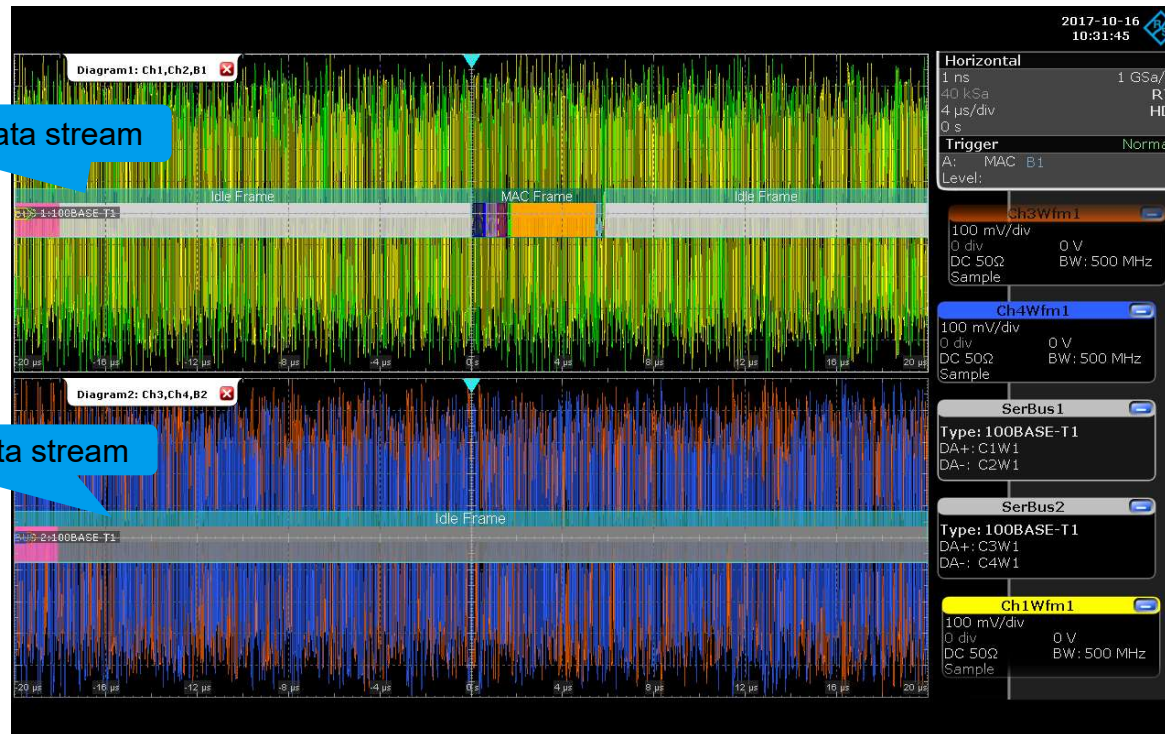


100BASE-T1 Triggering and Decoding

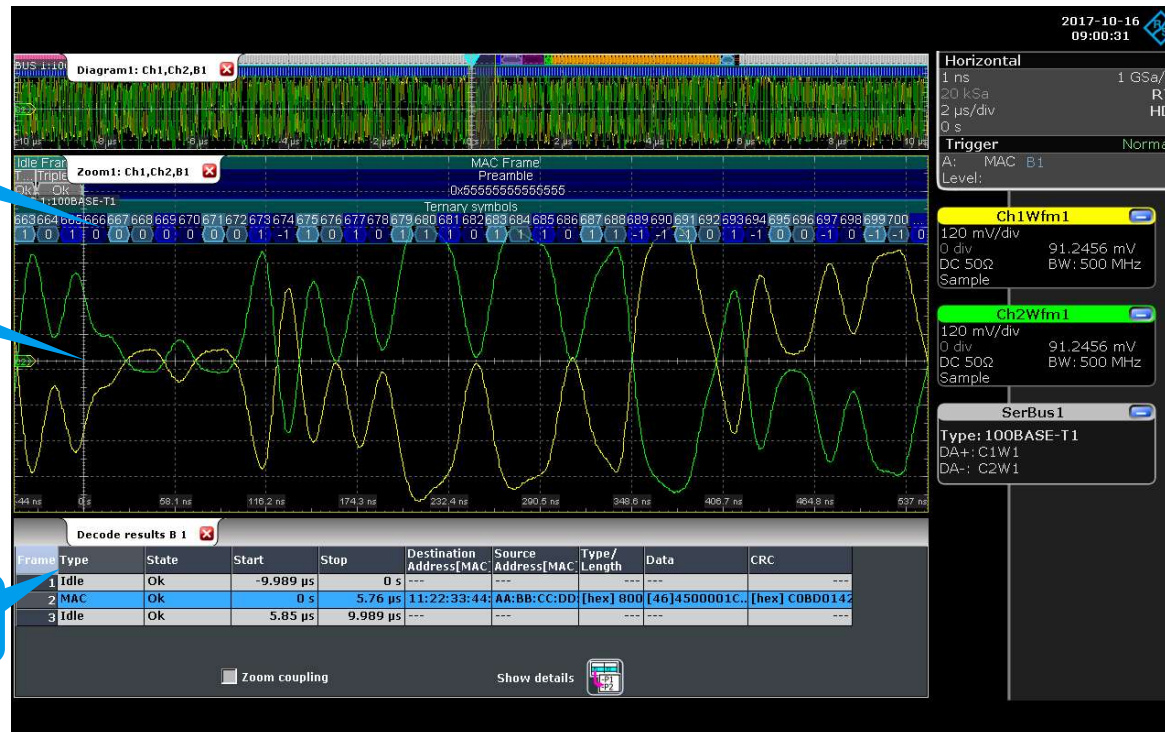
Decode both data streams simultaneously

Decoding forward data stream

Decoding reverse data stream



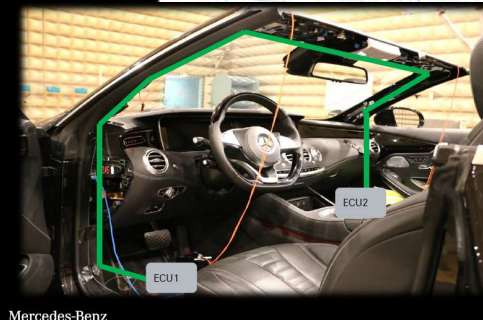
100BASE-T1 Triggering and Decoding – make details visible



The status of EMC of automotive Ethernet today

- EMC of **100BASE-T1** has been proven in various vehicle lines from different OEMs.
- Also countermeasures for EMC critical routings of **100BASE-T1** links are available (see 2017 presentation)
- As indicated in 2017 **1000BASE-T1** has much higher frequency bandwidth and therefore much more risks to disturb further bands like FM, DAB&TV III as well as TV IV/V.

BroadR-Reach DUT clock @66.7MHz
1000BASE-T1 DUT clock @125MHz



Mercedes-Benz

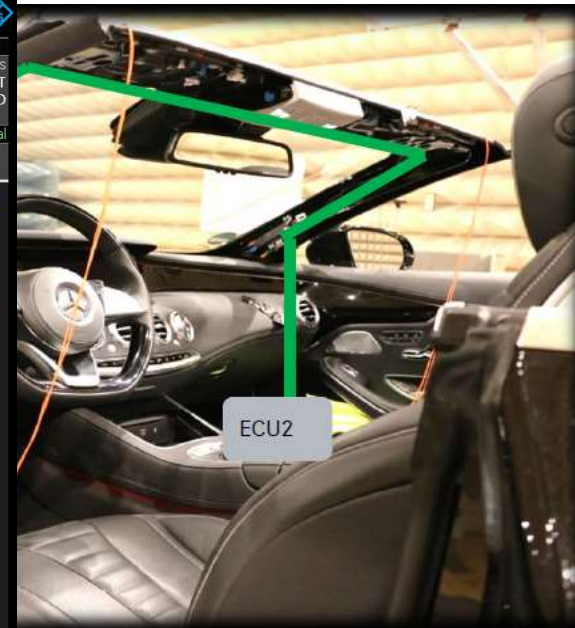
Dr. Stefan Buntz, Dr. Matthias Spägle | RD/FEQ

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Mercedes-Benz

100BASE-T1 Triggering and Decoding

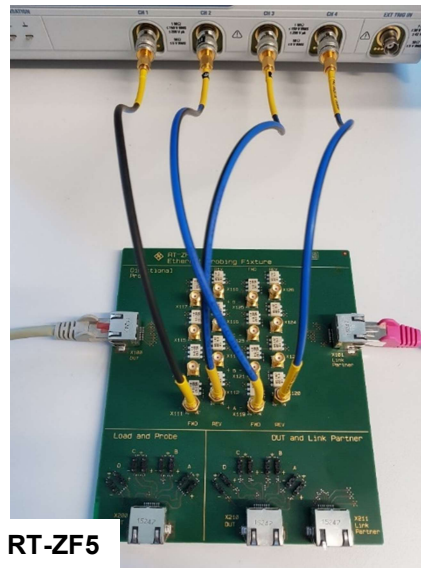
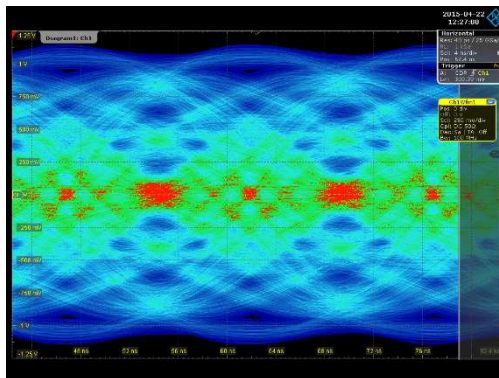
EMI Debugging of spurious communication errors



100BASE-T1 Probing

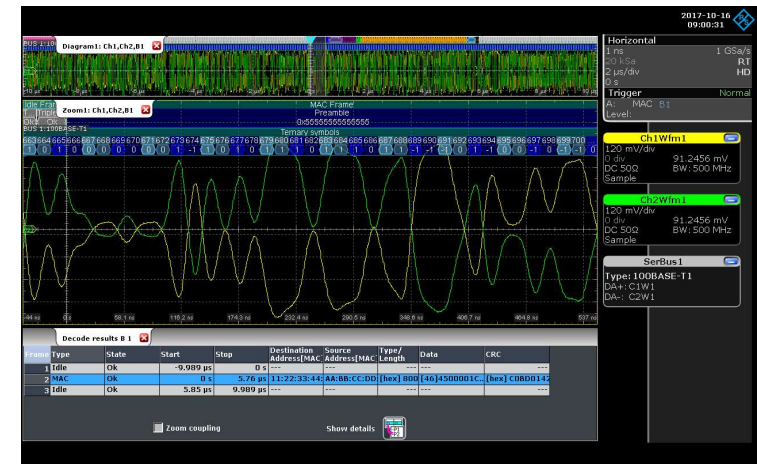


Probing the cable shows overlay of both data streams

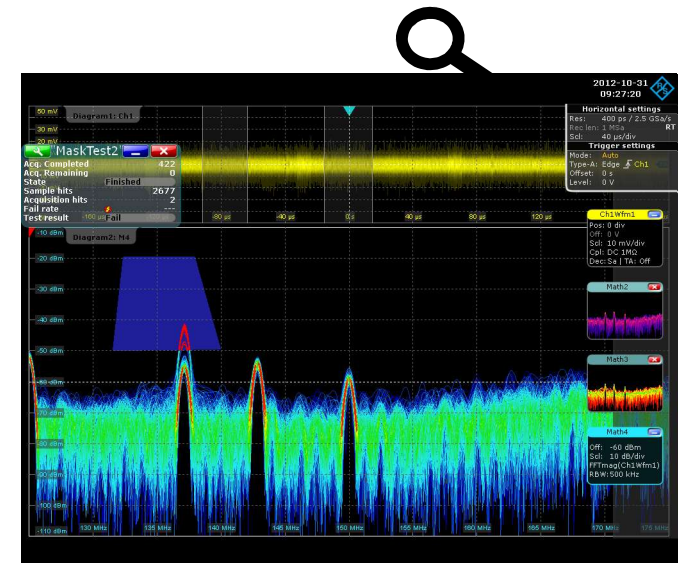
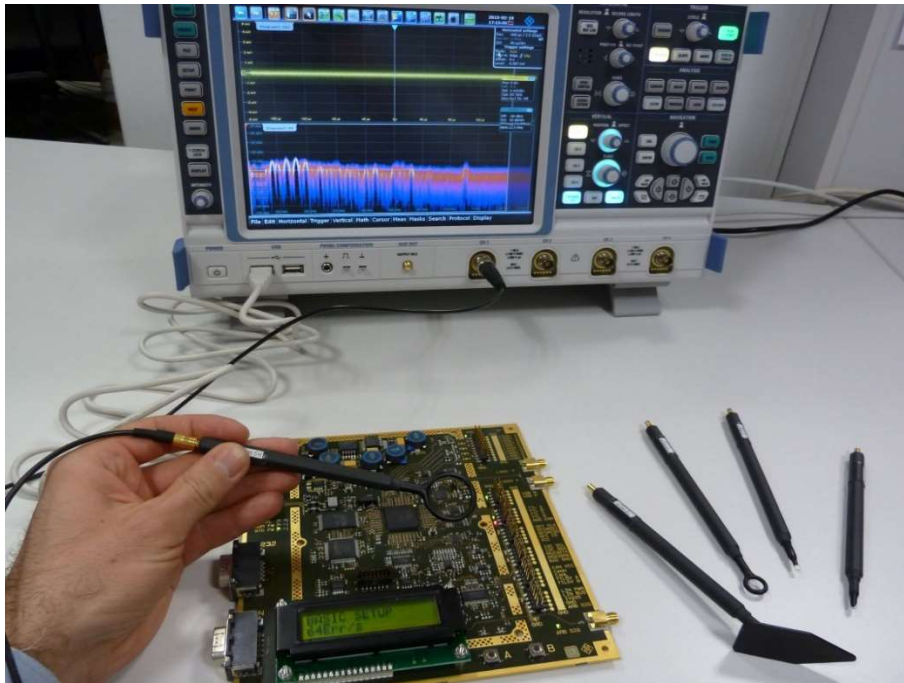


RT-ZF5

Directional coupler separates & enables decoding



Locate position of EMI faults



5 Years into the future!



How about higher speeds

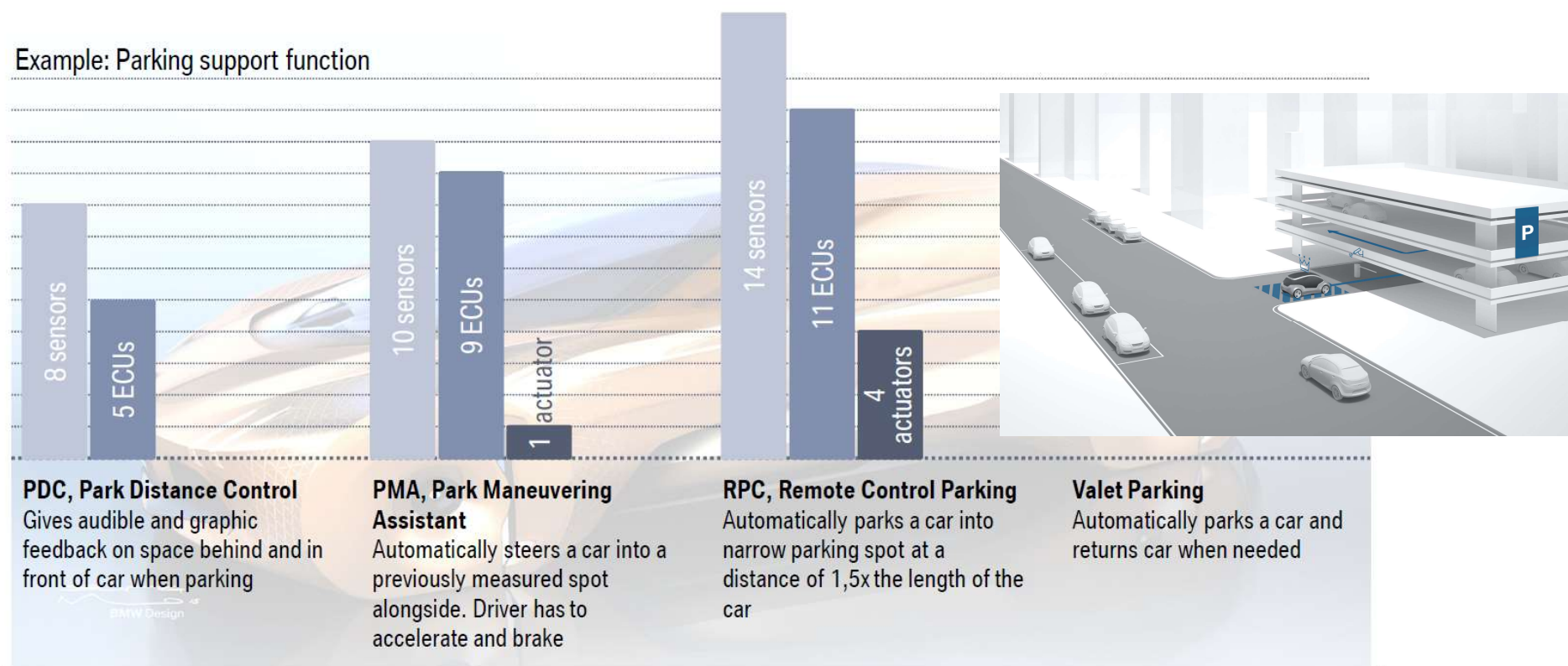
Name	Data rate	Status	SOP	Comment
100BASE-T1 (prev. BroadR-Reach, OABR)	100Mbps	Completed Standard	2013	12 of the 16 largest OEM plan introduction by 2020
1000BASE-T1	1Gbps	Completed Standard	2020/21	
10BASE-T1S	10Mbps	Taskforce at IEEE (first draft within 2017)	2022 ?	Additionally supports a bus topology
NGAUTO	2.5, 5, 10Gbps	Taskforce at IEEE	?	

K. Matheus, BMW AG, 31.1.2018, Automotive Ethernet Congress



APPLICATIONS ARE BECOMING MORE COMPLEX.

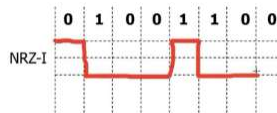
Example: Parking support function



Future Automotive Ethernet Standards

10BASE-T1S

Multidrop
PoDL
802.3cg
First discrete PHYs
available
OATC14



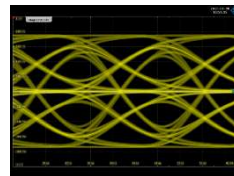
SPI clock 12MHz*
or 25MHz**

* CanovaTech proposal

**Broadcom proposal

100BASE-T1

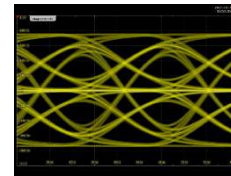
Established &
On the road



66.7 MHz
RTO2004
RTP044
ZND

1000BASE-T1

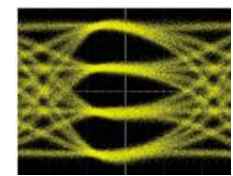
2 PHYs released
>2 PHYs in
development
SOP expected 2020



750 MHz
RTO2024
RTP044
ZND

NBASE-T1

2.5/5/10GBASE-T1
STP cable
802.3ch
spec expected 2020
OATC15



1.4/2.8/5.6 GHz
RTO2064
RTP084
ZND



Why MultiGig Ethernet?

Important to know:

- Some automotive 4G LTE modems implemented in the TCU can operate at 300-400 Mbps



Image source: Ficosa

----- Is 1000BASE-T1 enough? -----



HUAWEI

- T-Box 3.0: DA2300 will support 5G speeds up to 1.6Gbps*

*Maximum theoretical download speed
Image source: Huawei Autonomous Vehicles Show Shanghai Sept 2018



C-V2X 芯片
2018.02 巴塞罗那

T-Box 3.0
2018.02 C-V2X inside

C-V2X 特性	MBB 特性
PCS + Uu并发	3GPP Rel. 14
Mode3 + Mode4	下行峰值 1.6Gbps
	4CC CA + 4x4 MIMO
	2CC CA + 8x8 MIMO
	DL 256QAM

- 首款 T-Box 2016年上市，获众多车企认可
- C-V2X、5G先发优势



10GBASE-T1: Benefits

Sensor Fusion & Rich Data Drive Bandwidth To Multi-Gig

Cameras

Increasing resolution from 720p to 4K and improving dynamic range

=

Multi-Gigabit/s of raw bandwidth

Hres	Vres	Fps	8bit	12bit	16bit	20bit	24bit
1280	720	30	0,22	0,33	0,44	0,55	0,66
1280	1080	30	0,33	0,50	0,66	0,83	1
1280	720	60	0,44	0,66	0,88	1,11	1,33
1920	1080	30	0,50	0,75	1,00	1,24	1,49
1280	1080	60	0,66	1,00	1,33	1,66	1,99
1920	1080	60	1,00	1,49	1,99	2,49	2,99
3840	2160	30	1,99	2,99	3,98	4,98	5,97
3840	2160	60	3,98	5,97	7,96	9,95	11,94

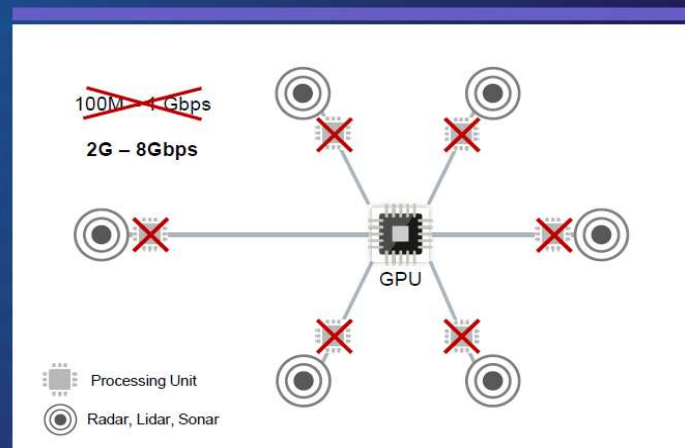
100BASE-T1	1000BASE-T1	Multi-Gig Ethernet 2,5 Gbps	Multi-Gig Ethernet 5 Gbps	Multi-Gig Ethernet 10 Gbps
No Use Case	Available	Speed grades which are currently discussed		

Sensor Fusion

Moving processing of data from sensors to a centralized GPU

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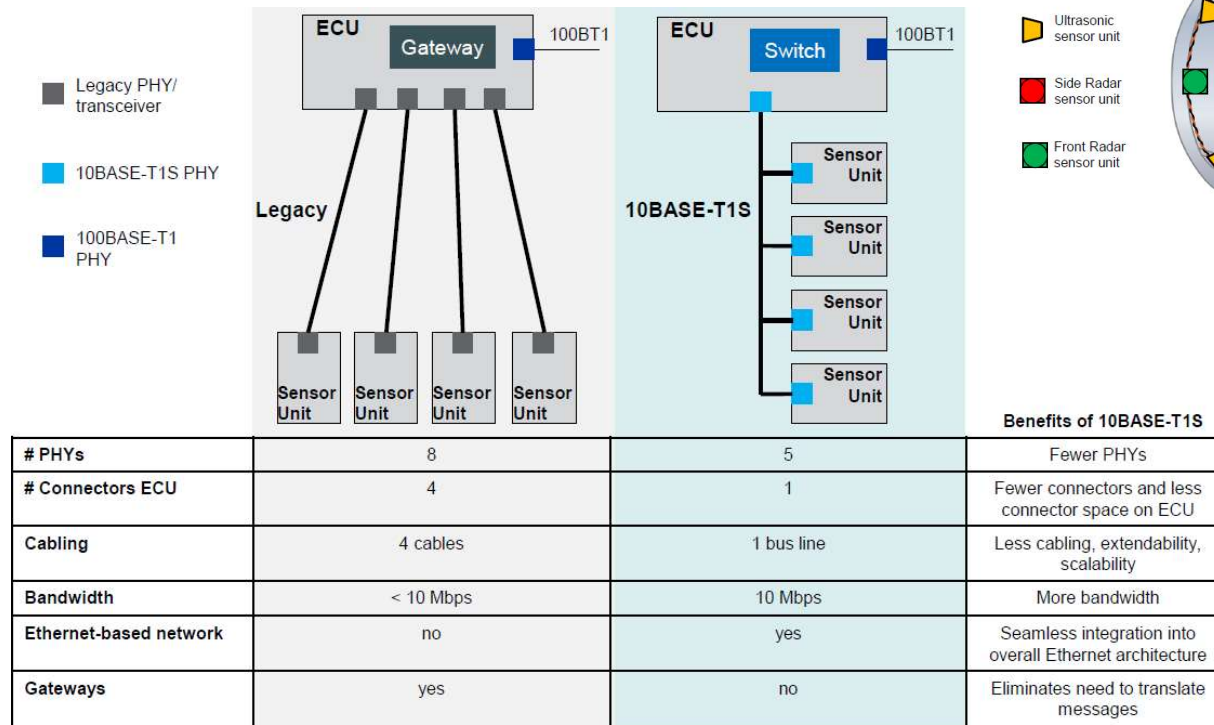
Multi-Gigabit/s data over the network



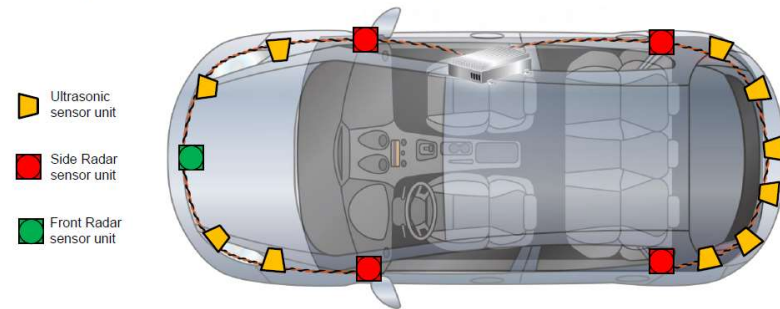
IEEE Automotive Ethernet London: Oct 2018

AQUANTIA
ACCELERATING CONNECTIVITY

10BASE-T1S: Benefits



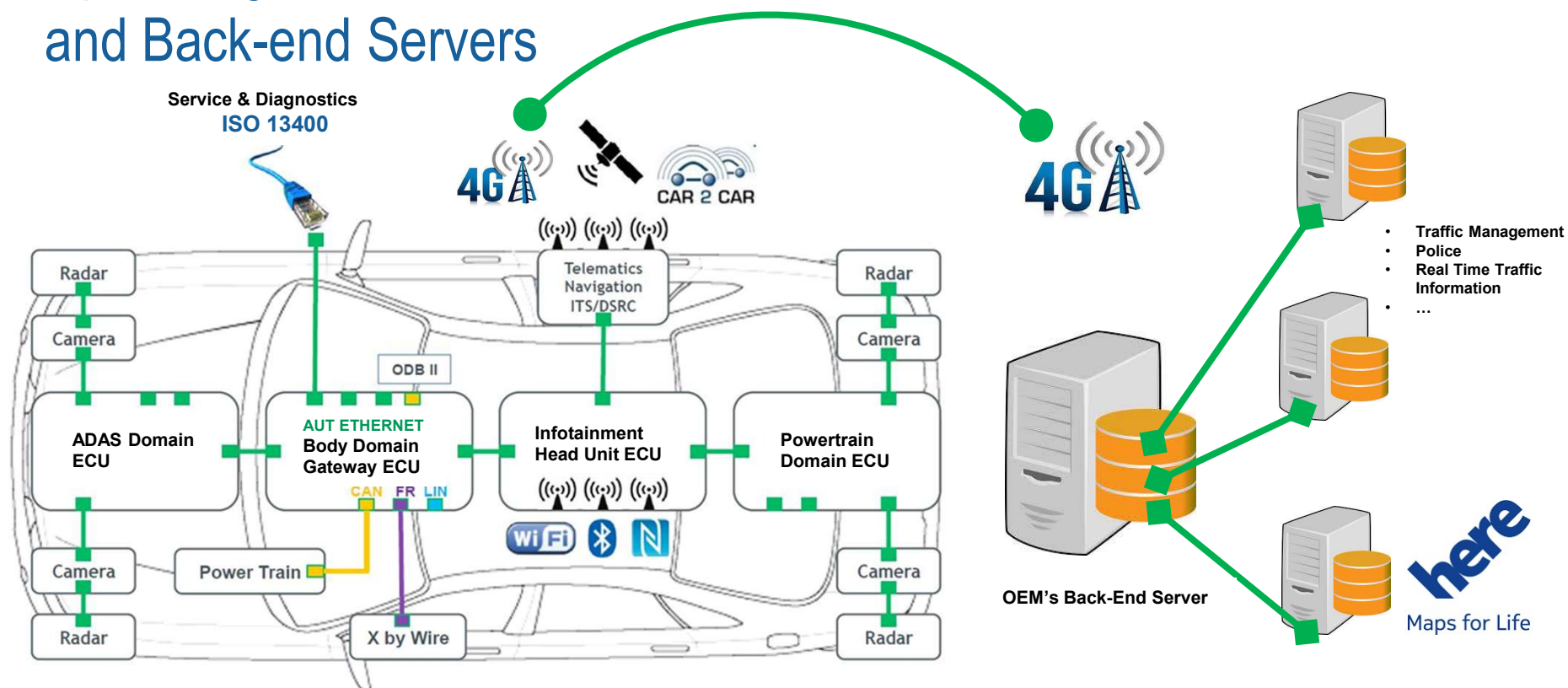
Example: Ultrasonic and Short Range Radar



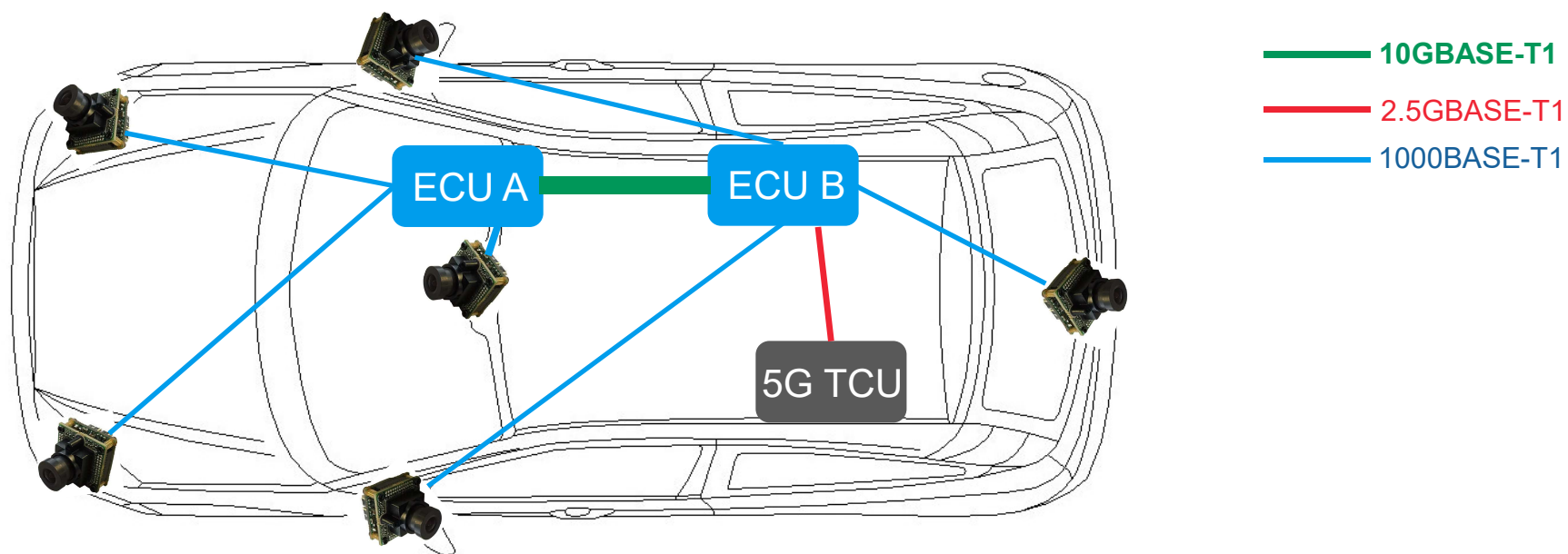
Source: Miller, Microchip, Oct 2018

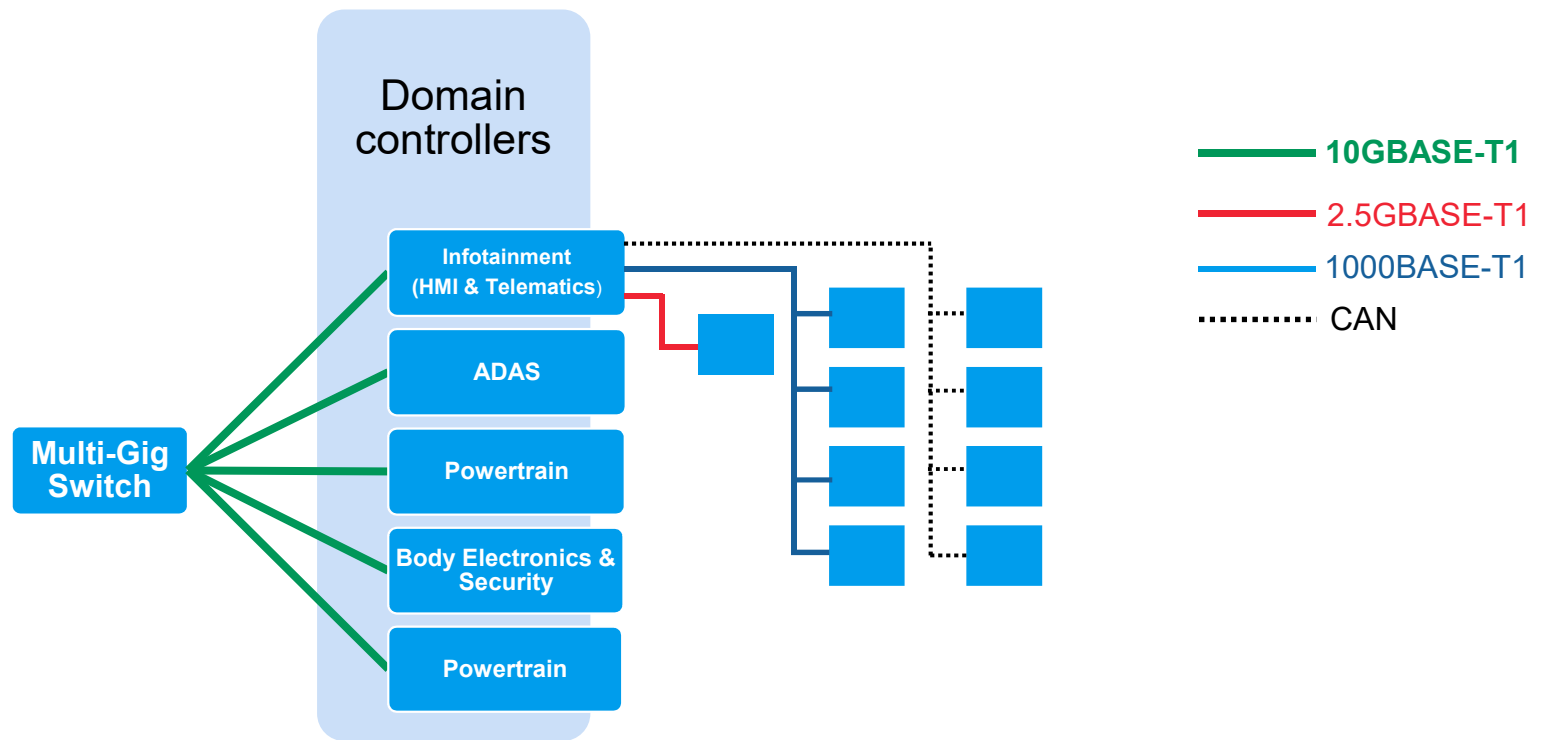


Upcoming Vehicle Architecture with Domain Controllers, Ethernet and Back-end Servers



Camera topology with Automotive Ethernet





Domain controllers



Image source: NXP

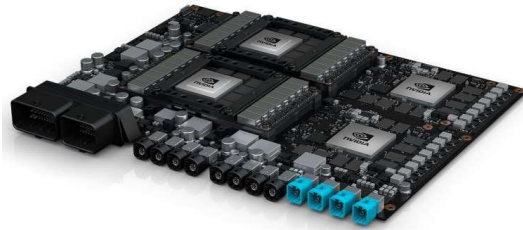


Image source: Nvidia

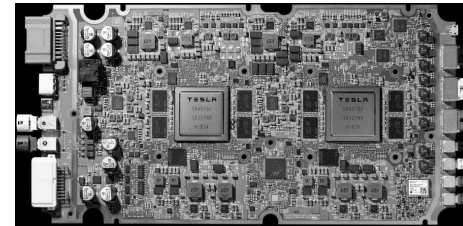


Image source: Tesla



Image source: TTTech

Domain controllers:

Infotainment

Powertrain

(engine, brakes, gearbox)

Body electronics & security

(windows, wipers, car seat etc)

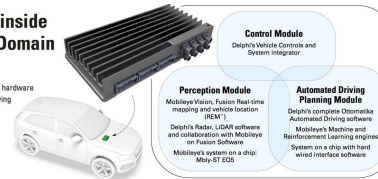
Radar



Image source: Veoneer

Mobileye Tech inside Delphi's Multi-Domain Controller

Mobileye will add new software and hardware into Delphi's existing Automated Driving Multi-Domain Controller. Here's a breakdown of what's inside:



DELPHI

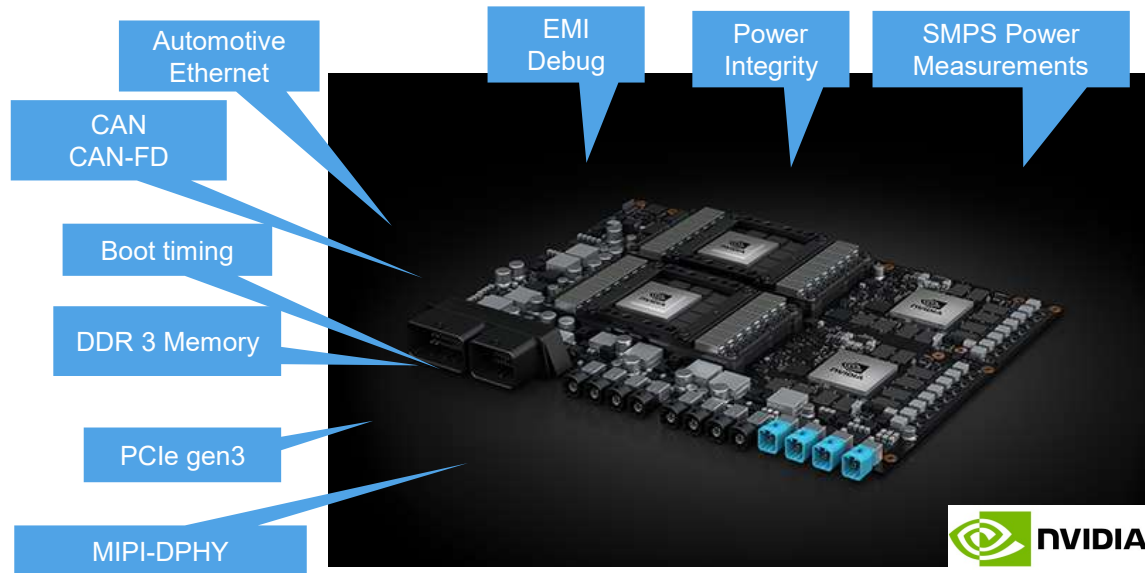
Image source: Delphi



Image source: Continental



What and how to test next generation ECU for ADAS



Example Nvidia Pegasus using RTO

8-16 CPU cores
+ GPU
5-10 TFLOPS
200-600 W TDP (SMPS)
Liquid cooling

DDR 3 RAM, 8 GB
FLASH NVMe (PCIe 3), 64 GB
100/1000/10GBASE-T1
CAN-FD

R&S®RTO



R&S®RTP

