Automotive

EVOLUTION OF IN-VEHICLE NETWORKS TO ZONAL ARCHITECTURE

Jithu Abraham Product Manager, Oscilloscopes
Ralf Oestreicher Market Segment Manager, Automotive

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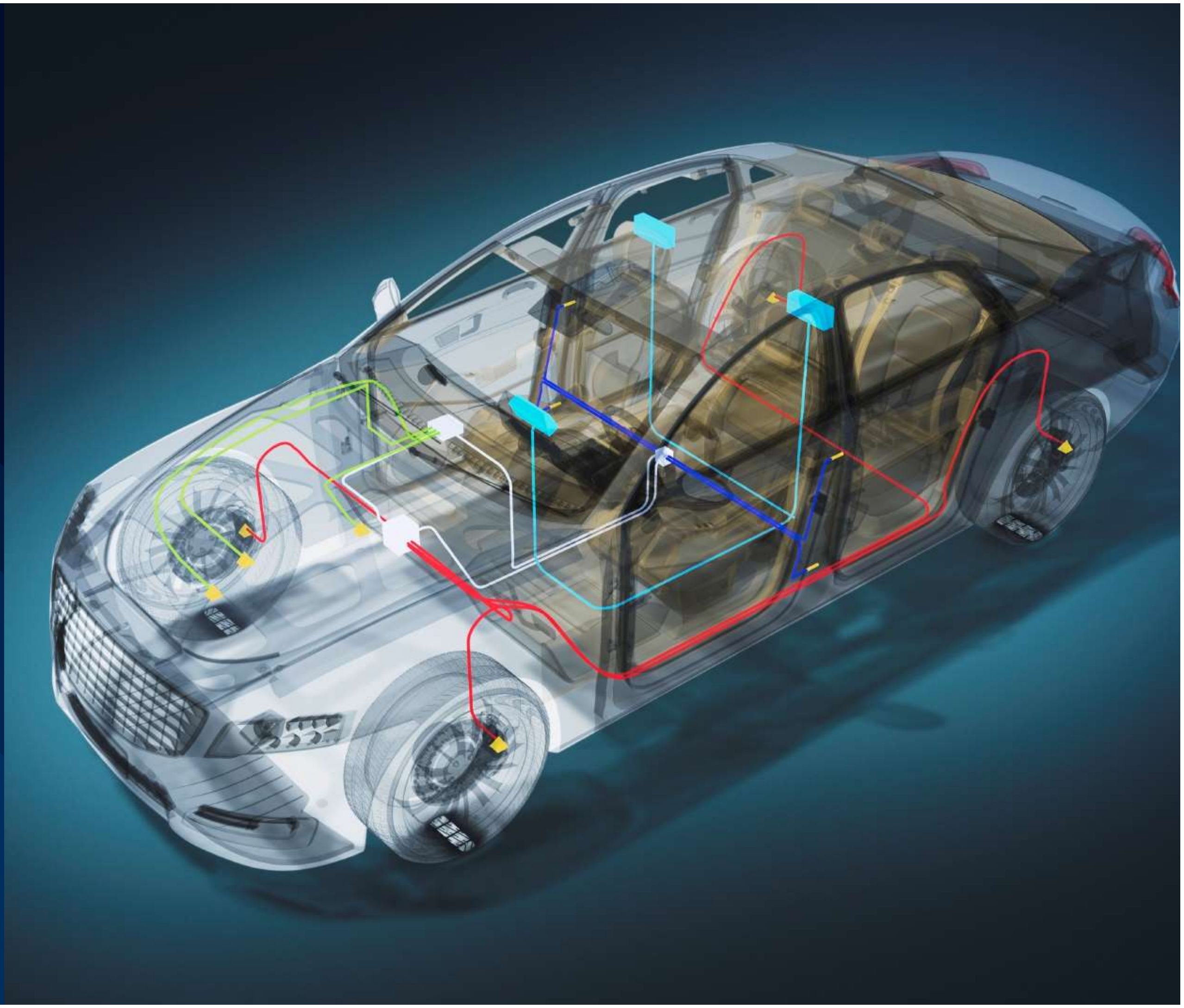
Make ideas real

AGENDA

- ► Introduction
- ► Challenge
- ► Evolution of in-vehicle network architecture
- ► Transition from domain to zonal architecture
- ► Automotive Ethernet
  - – Overview
  - – The need for testing
  - – Practical demonstration
- ► Technology and testing summary



INTRODUCTION

- ► Automotive megatrends have strong implications for the future of automotive electronics and SW.
- ► The industry is continuously striving to realize higher levels of autonomous driving.
- ► The car of the future is autonomous, connected, electrified and shared which gives the acronym ACES.

Source: Denso Automotive Ethernet Congress 2022

Technology megatrends have strong implications for the future of automotive electronics and software.

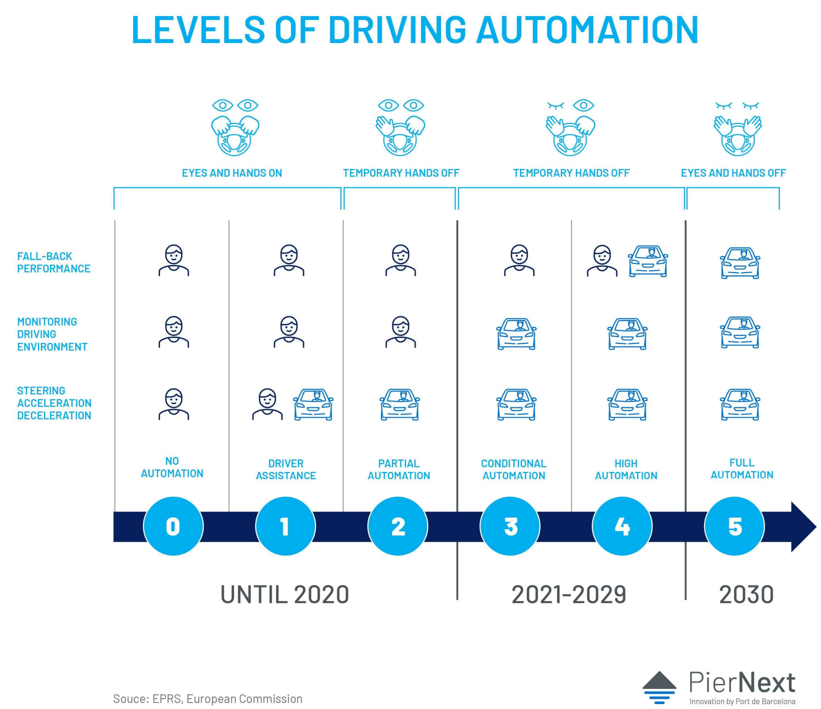
ACES trends	Implications for automotive electronics and software	Relevance	
Autonomous driving	Complex and safety-relevant software High-performance computers	64%	of customers would switch OEMs for better autonomous-driving capabilities
Connectivity	Performant in-vehicle network (Ethernet) Over-the-air updates Cybersecurity	95%	of new vehicles sold in 2030 will be connected
Electrification	New electrical package New powertrain applications	53%	of new vehicles sold in Europe in 2030 could be electric vehicles[1]
Shared mobility	Features for individualization Keyless entry	2/3	of US customers expect their shared-mobility usage will increase over the next 2 years

[1]Includes battery electric vehicles (EVs), plug-in hybrid EVs, and fuel-cell EVs.
Source: McKinsey analysis

CHALLENGE

- The developing trend from a traditional vehicle design towards ACES requires the secure handling of data from an increased number of complex sensors.

- Moving towards the ACES trends such as fully autonomous driving or connected cars requires:
  - faster in vehicle networks (IVN) supporting high computing power and high data throughput
  - reduction of IVN complexity
  - power consumption and weight efficiency



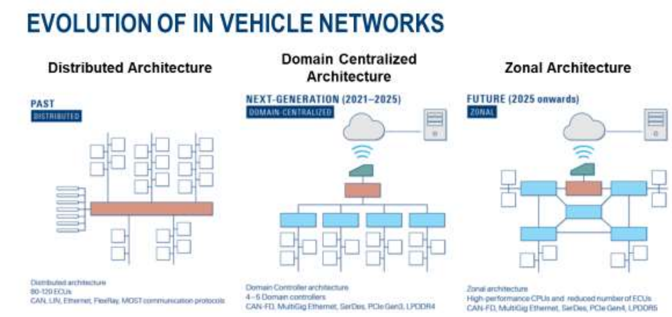
EVOLUTION OF IN-VEHICLE NETWORK ARCHITECTURE

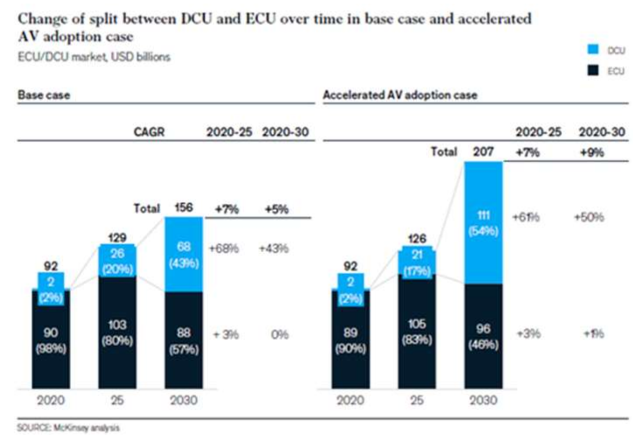
- IVN architecture evolved from a distributed gateway architecture with independent ECUs towards a domain centralized architecture.

- In a domain-centralized architecture, vehicle systems are grouped by function. Few domain controller units (DCUs) covering one vehicle domain each, such as connectivity, chassis, or infotainment.

- Communication is limited between domains that are controlled by a central gateway.

- Domain centralized architecture is suitable up to SAE level 3.

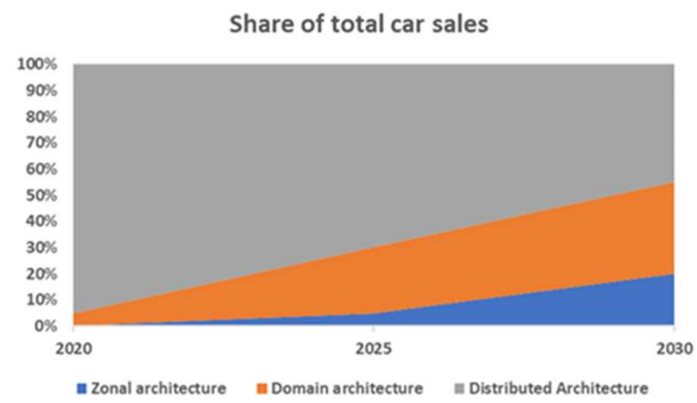


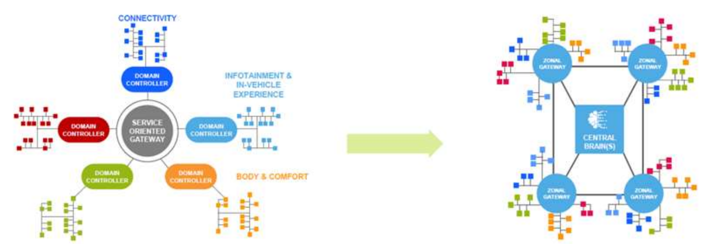


EVOLUTION OF IN-VEHICLE NETWORK ARCHITECTURE

- ► Future cars will be based on a zonal architecture:
  - – vehicle domains grouped into several zones
  - – in each zone, devices are connected to a locally installed zonal gateway → short cable lengths
  - – each zonal gateway is connected to the central computer via high-speed ethernet
  - – domain functionality is handled in the central computer (centralized SW)

- ► Redundancy within zonal architecture support autonomous driving above level 3.



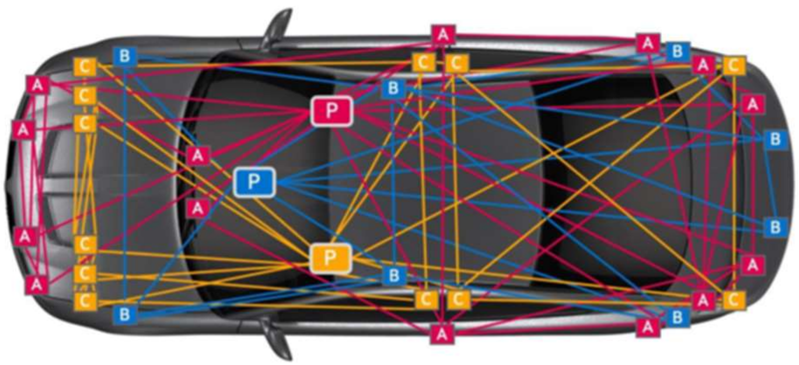


Source: NXP Automotive Ethernet Congress 2022

TRANSITION FROM DOMAIN TO ZONAL ARCHITECTURE

Domain architecture

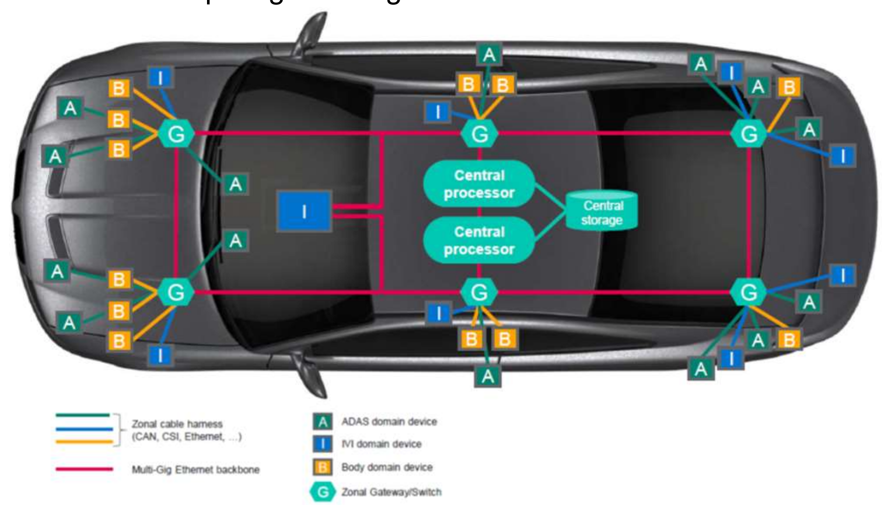
- Central domain controller/high performance computer
- Ability to handle more complex functions
- Consolidation of functions (cost optimization)
- But: cable harness is rigid and expensive



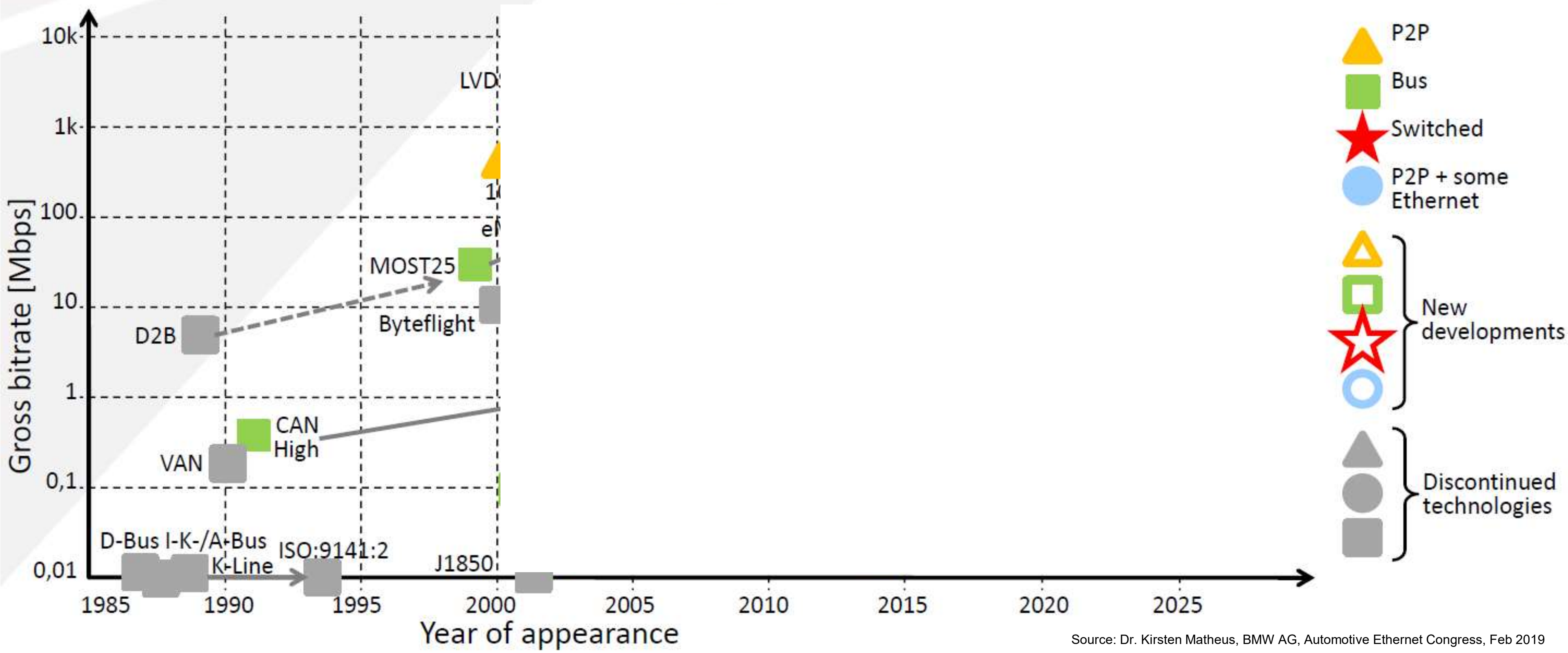
Source: Marvell Automotive Ethernet Congress 2022

Zonal architecture

- Local ethernet gateway per zone
- Ultra high-speed secured backbone between zones
- Centralized SW
- Central computing & storage

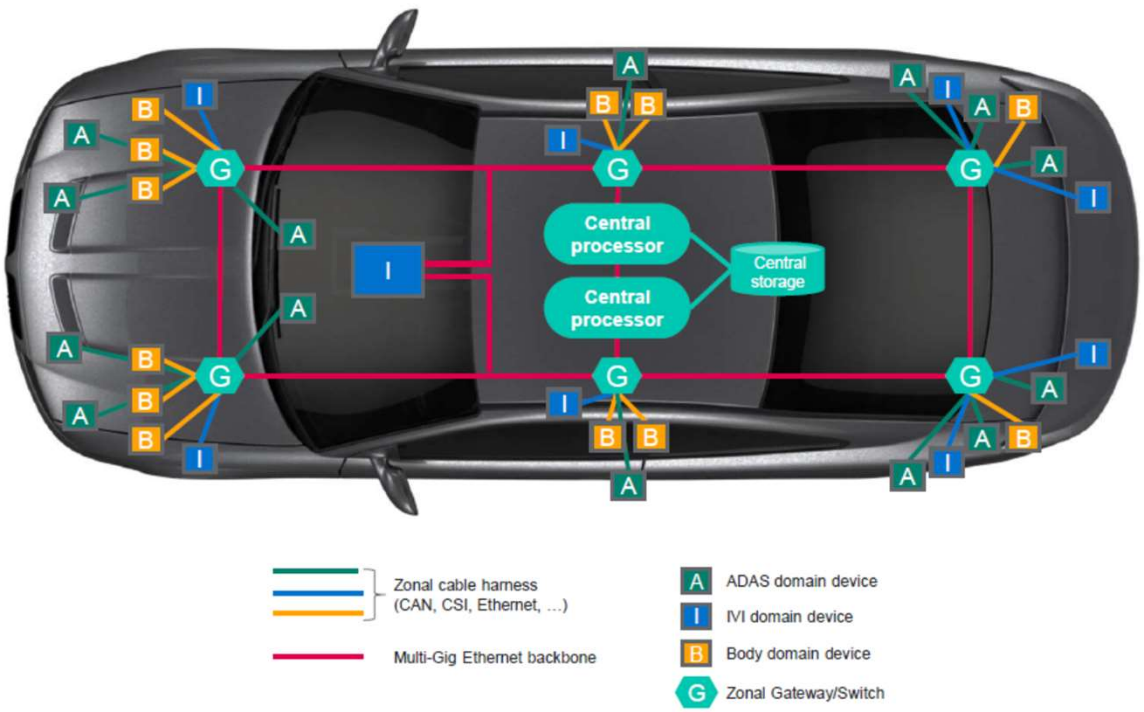


IN-VEHICLE NETWORKING TECHNOLOGIES



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

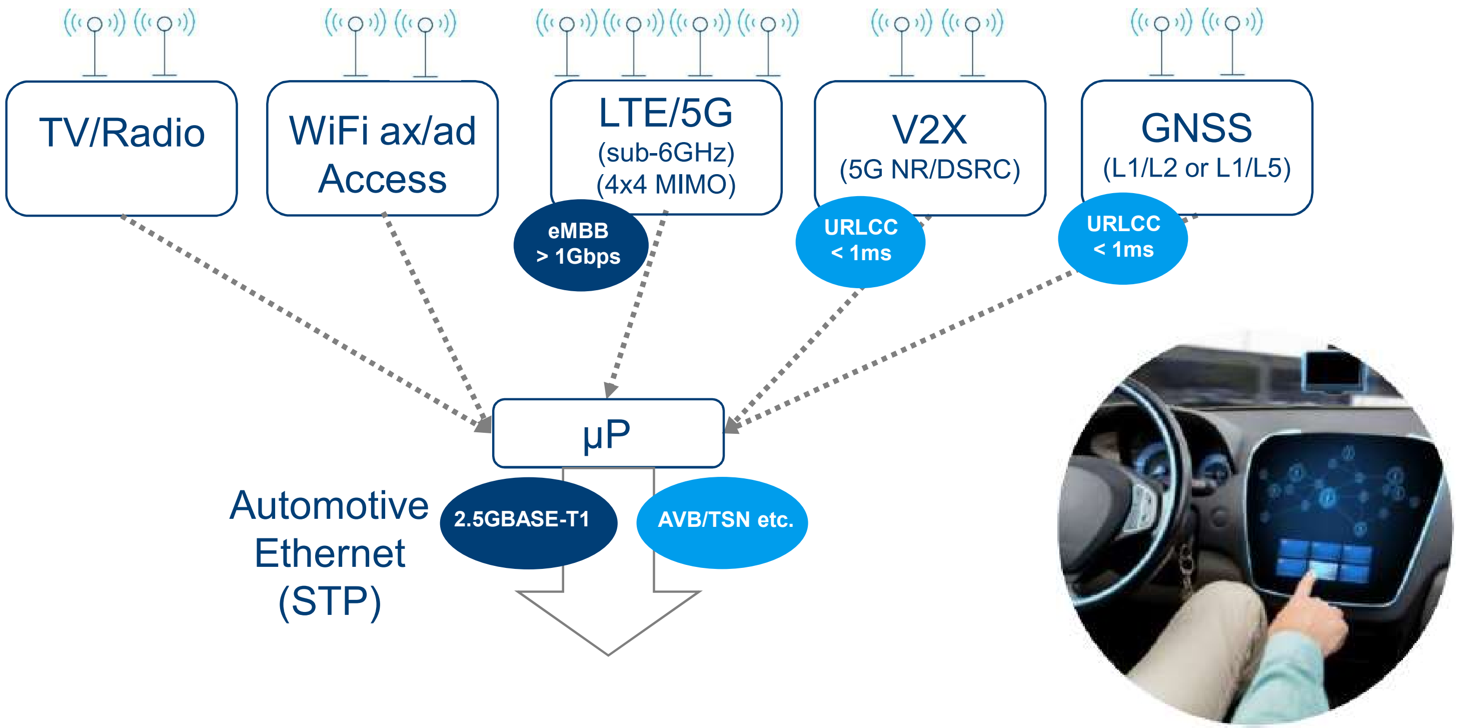
ZONAL ARCHITECTURE
AUTOMOTIVE ETHERNET BACKBONE



TRENDS IN AUTOMOTIVE ETHERNET

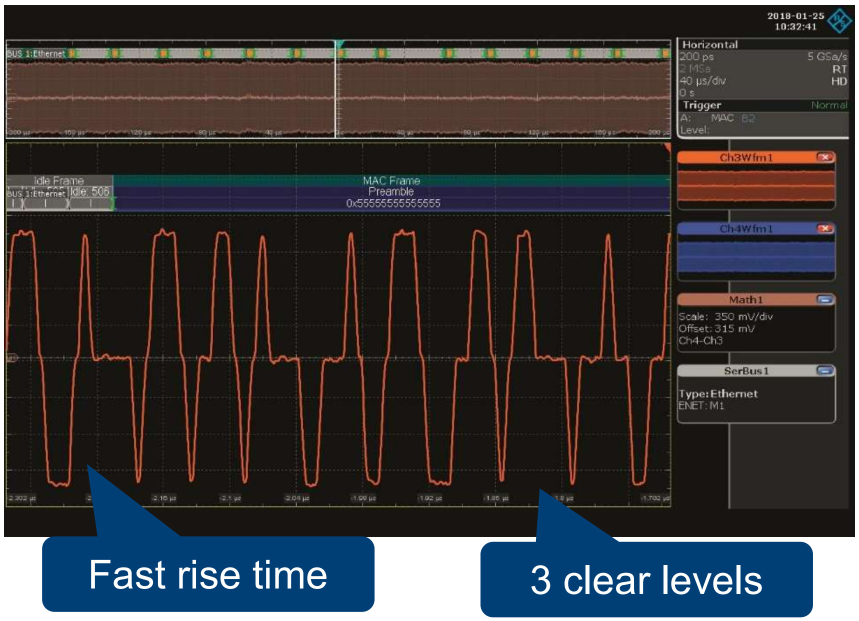
*average Ethernet ports per vehicle
Photo courtesy of Marvell Technology Group

REAL WORLD APPLICATION
NEXT-GEN TCUs



DIFFERENCE BETWEEN 100BASE-TX AND 100BASE-T1

100BASE-Tx standard Ethernet



100BASE-T1 Automotive Ethernet

OBJECTIVE FOR AUTOMOTIVE ETHERNET TESTING

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	10/100/1000/MultiGBASE-T1

Correct protocol and data transmission

Error free communication

Validate Sleep/Wakeup Cycles

Resistant to EMI

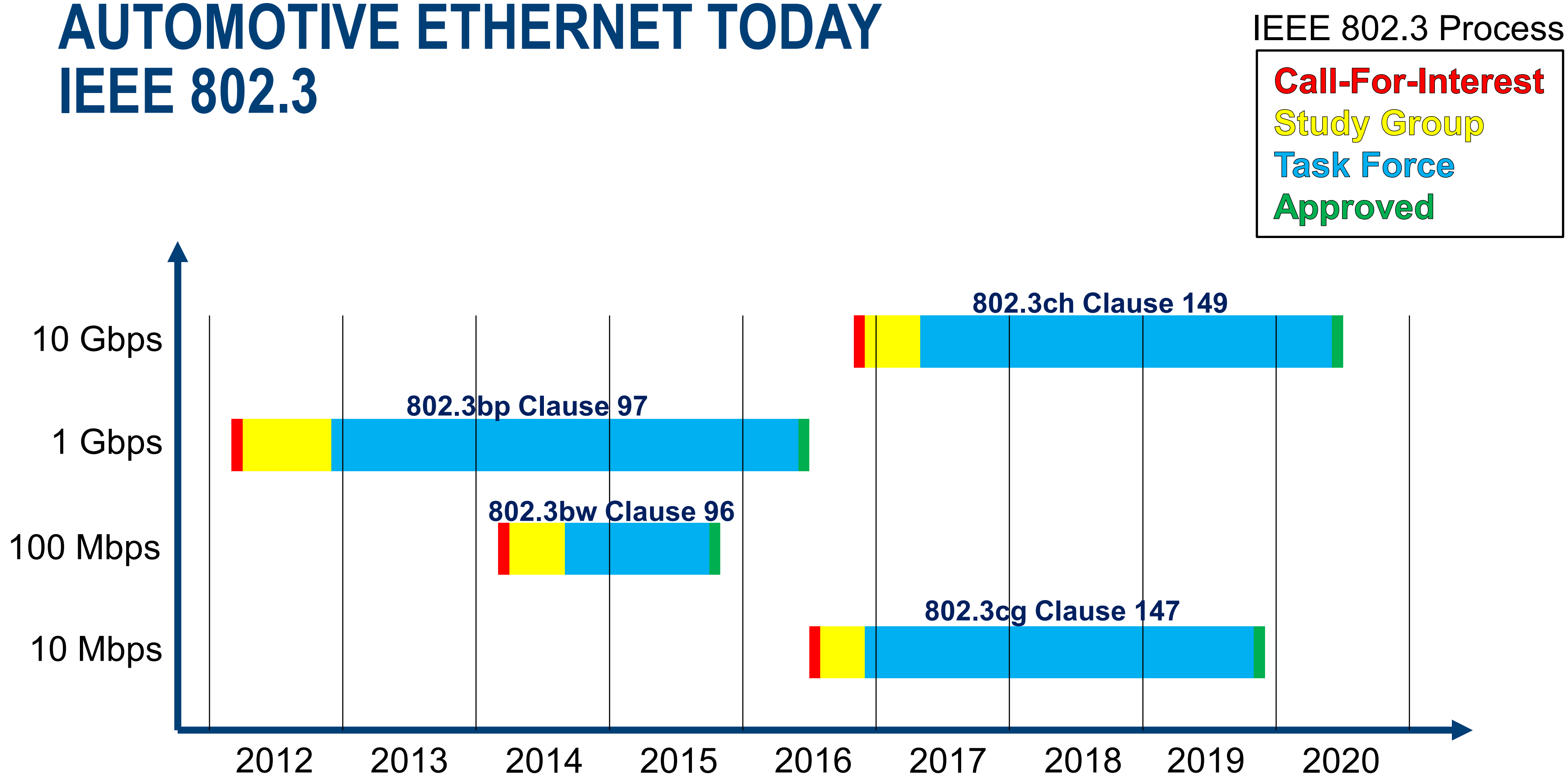
Correct latency

Correct boot time

Test OEM requirement

10/100/1000/MultiGBASE-T1 interface compliance

AUTOMOTIVE ETHERNET TODAY
IEEE 802.3



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Driven by OEMs

12 Promoters
124 Adopters

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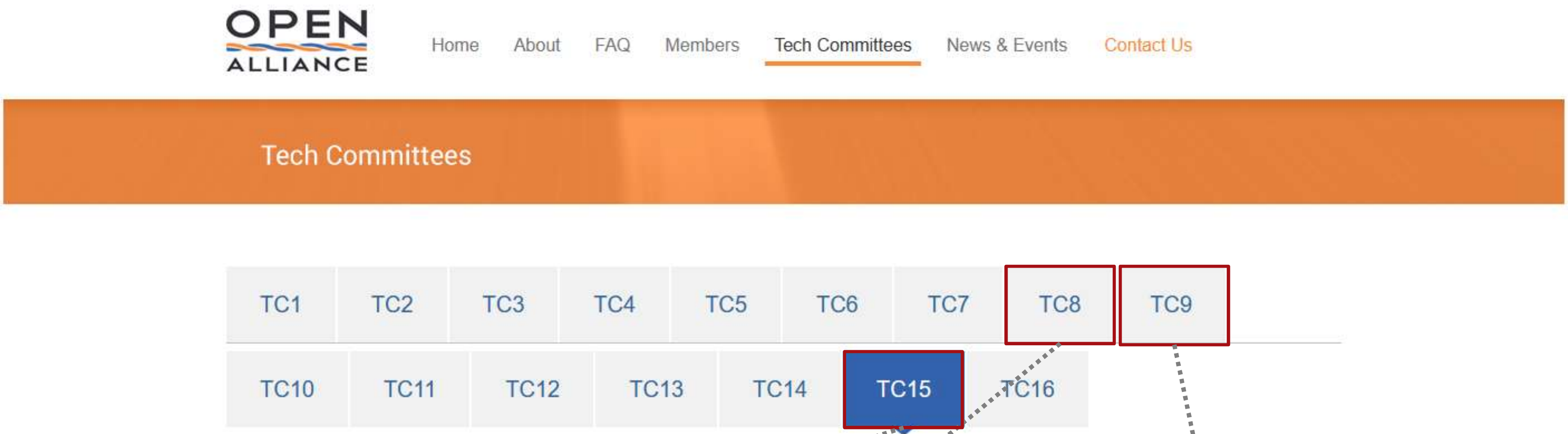
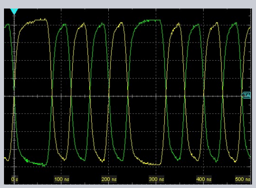
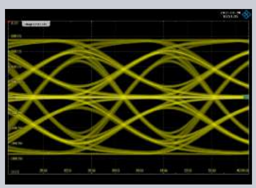
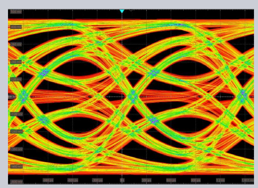
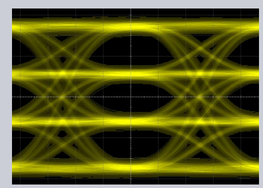


TC15 group created for MultiGig Ethernet for 2.5/5/10GBASE-T1. (PMA under preparation)

1000BASE-T1 Ethernet Channel & Passive Components (v2.3)
NGAuto Channel & Components for 1000BASE-T1
2.5/5/10GBASE-T1 Link Segments (draft v0.3)

Automotive Ethernet ECU Test Specification (v3.0)
Currently supports 100/1000BASE-T1

AUTOMOTIVE ETHERNET TODAY

	10BASE-T1S	100BASE-T1	1000BASE-T1	2.5GBASE-T1	5GBASE-T1	10GBASE-T1
IEEE 802.3 Reference	802.3cg-2019 Clause 147	802.3bw-2015 Clause 96	802.3bp-2016 Clause 97	802.3ch-2020 Clause 149		
OPEN Alliance PHY Compliance Tech Committee	TC14	TC1 (Closed)	TC12	TC15		
Bit Rate (Mbps)	10	100	1000	2500	5000	10000
Baud Rate (MBd)	12.5	66.66	750	1406.25	2812.5	5625
Encoding	2-Level DME 	PAM3 		PAM4 		
Cabling	UTP		UTP (STP optional)	STP		

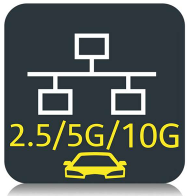
ROHDE & SCHWARZ
AUTOMOTIVE ETHERNET TEST SOLUTIONS

R&S RTP

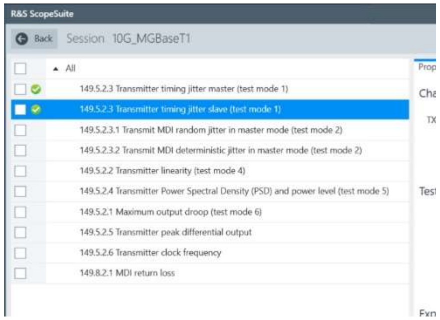
R&S ZNB

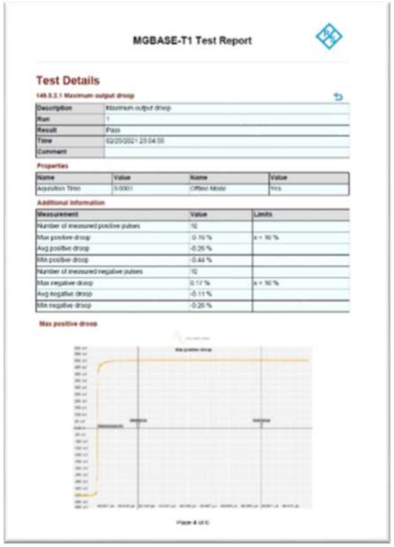
- Support OPEN Alliance
  - TC1, TC8, TC9, TC12, TC14, TC15
- PMA Compliance Test Coverage:
  - 10BASE-T1S
  - 100BASE-T1
  - 1000BASE-T1
  - 2.5G/5G/10GBASE-T1
- Trigger & Decode capabilities for debug
- Characterization of cables and connectors
- Automatic test execution
- Automated controlling of Scope, VNA, and signal generator

NEW MULTIGBASE-T1 COMPLIANCE TEST SOLUTION



- New K88 AUT Ethernet compliance option for 2.5/5/10G speeds
- Based on the IEEE 802.3ch
- Uses PAM4 modulation with symbol rates of 1.4/2.8/5.6 GHz
- Runs exclusively on shielded twisted pair (STP)
- Additional information:
  - Available on both the RTO (up to 2.5G) and RTP
  - Coverage of all relevant test cases
  - No additional options required (e.g. jitter)
  - Complete solution with VNA & fixtures

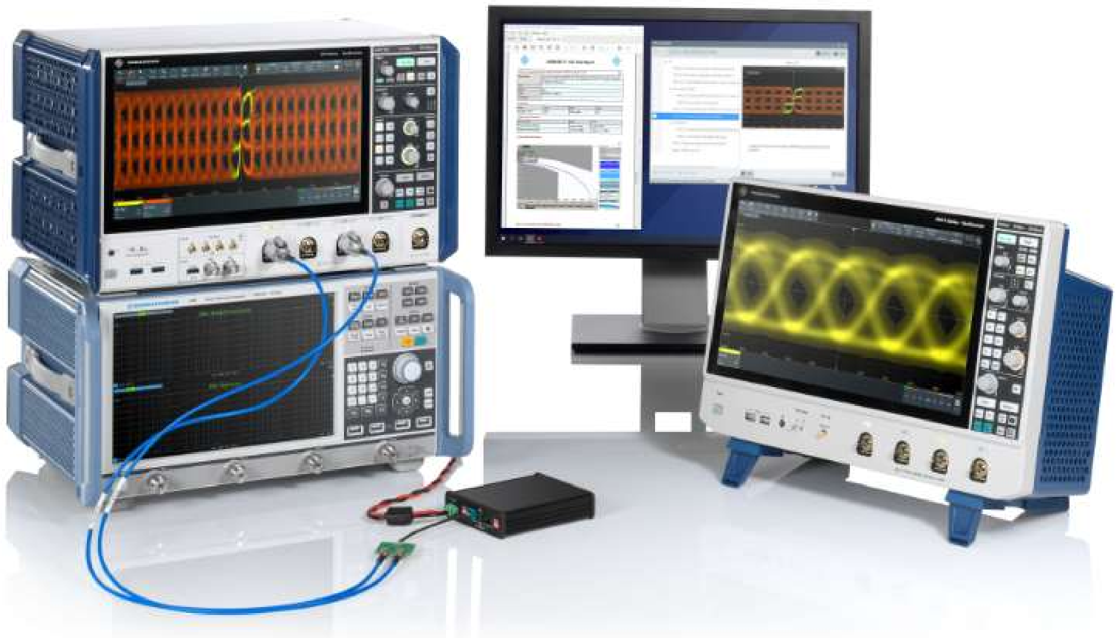




OPEN TC15 TEST SPEC COVERAGE LAYER 1

- **Group 1: PMA Transmit Tests:**
  - Maximum Output Droop
  - Transmitter Linearity
  - Transmitter **T**iming **J**itter
  - Transmit MDI **R**andom **J**itter in master mode
  - Transmit MDI **D**eterministic **J**itter in master mode
  - Transmitter Power Spectral Density (PSD) and power level
  - Transmitter Peak Differential Output
  - Transmitter Clock Frequency
  - Transmitter Distortion
- **Group 2: PMA Receive Tests:**
  - Bit Error Rate Verification
  - Alien Crosstalk Noise Rejection
  - Receiver Frequency Tolerance (Optional)
- **Group 3: MDI Impedance Requirements:**
  - MDI return Loss

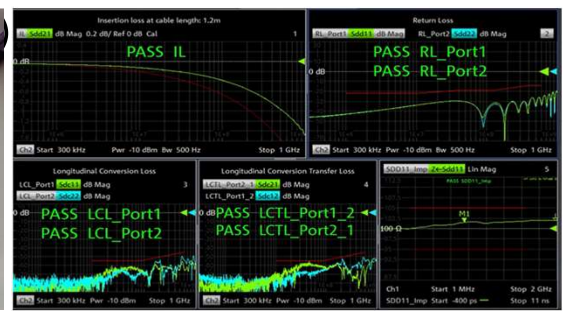
Specification is in draft version

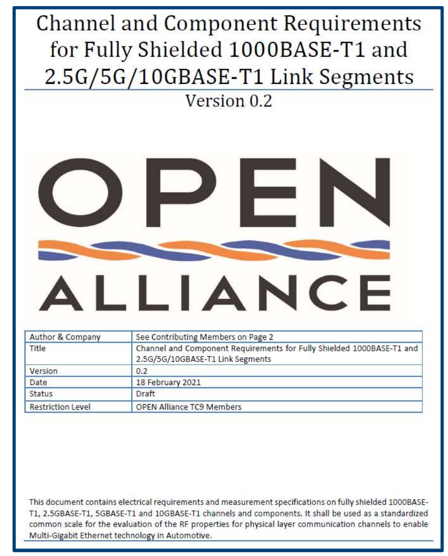


DEMO

OPEN ALLIANCE AUTOMOTIVE ETHERNET – TC9 UTP/STP

- TC9 **UTP** (Unshielded twisted pair) 1000BASE-T1
- TC9 **STP** (Shielded twisted pair) 1000BASE-T1 (ver.2.3), 2.5/5/10GBASE-T1 (draft 0.3)
  Test of cable, connector and whole communication channel
  - 4-Port Device needed: ZNB8 for compliance, ZNB20 for cable/connector manufacturers
  - Differential return loss and insertion loss
  - Differential impedance (TDR)
  - **Mode Conversion (-61 dB)**
    → High VNA calibration accuracy required





Channel and Component Requirements for Fully Shielded 1000BASE-T1 and 2.5G/5G/10GBASE-T1 Link Segments

Version 0.2

Author & Company	See Contributing Members on Page 2
Title	Channel and Component Requirements for Fully Shielded 1000BASE-T1 and 2.5G/5G/10GBASE-T1 Link Segments
Version	0.2
Date	18 February 2021
Status	Draft
Restriction Level	OPEN Alliance TC9 Members

This document contains electrical requirements and measurement specifications on fully shielded 1000BASE-T1, 2.5GBASE-T1, 5GBASE-T1 and 10GBASE-T1 channels and components. It shall be used as a standardized common scale for the evaluation of the RF properties for physical layer communication channels to enable Multi-Gigabit Ethernet technology in Automotive.

OA COMPLIANCE TESTING PHY LAYER SUMMARY

	R&S®RTP	Max freq. 16GHz	OA TC8 & OA TC15 Supports speeds up to 10GBASE-T1
	R&S®RTO	Max freq. 6GHz	OA TC8 & OA TC15 Supports speeds up to 2.5GBASE-T1
	R&S®ZNB	4-port VNA 9kHz – 40GHz	OA TC9, OA TC8 & OA TC15 8GHz VNA sufficient for 10GBASE-T1

TECHNOLOGY AND TESTING SUMMARY

- The car of the future is autonomous, connected, electrified and shared (ACES).
- Fast and flexible in vehicle networks (IVN) support high computing power and high data throughput.
- The in-vehicle network will evolve from a domain-centralized architecture to a zonal architecture.
- Domain centralized architecture enables driving up to SAE level 3, zonal architecture supports autonomous driving above level 3.
- Multi-Gig Ethernet backbone enables fast and flexible data transmission within a vehicle.
- Shorter vehicle wiring harness reduces cost and weight.
- Compatibility and performance of different vendors' equipment can be ensured via OPEN Alliance compliance testing.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TEST IT. TRUST IT.

Find out more

www.rohde-schwarz.com/automotive/ivn

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