TIMING IN THE FUTURE(-PROOF) AUTOMOTIVE COMMUNICATION NETWORK

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INTERNATIONAL TIMING AND SYNC FORUM

BMW GROUP

THE NEXT 100 YEARS

DIGITIZATION CHANGES CARS INTO MOBILITY.

The car manufacturers are facing a time in which they need to continue to strive in ever fiercer competition while having to embrace the changes induced by a digitized world.

With digitization, data and software are the new currency.

This can change everything. From the way we build cars to the products and services we offer.

It results in new requirements on the infrastructure inside the car: the EE-architecture and also the in-vehicle network.

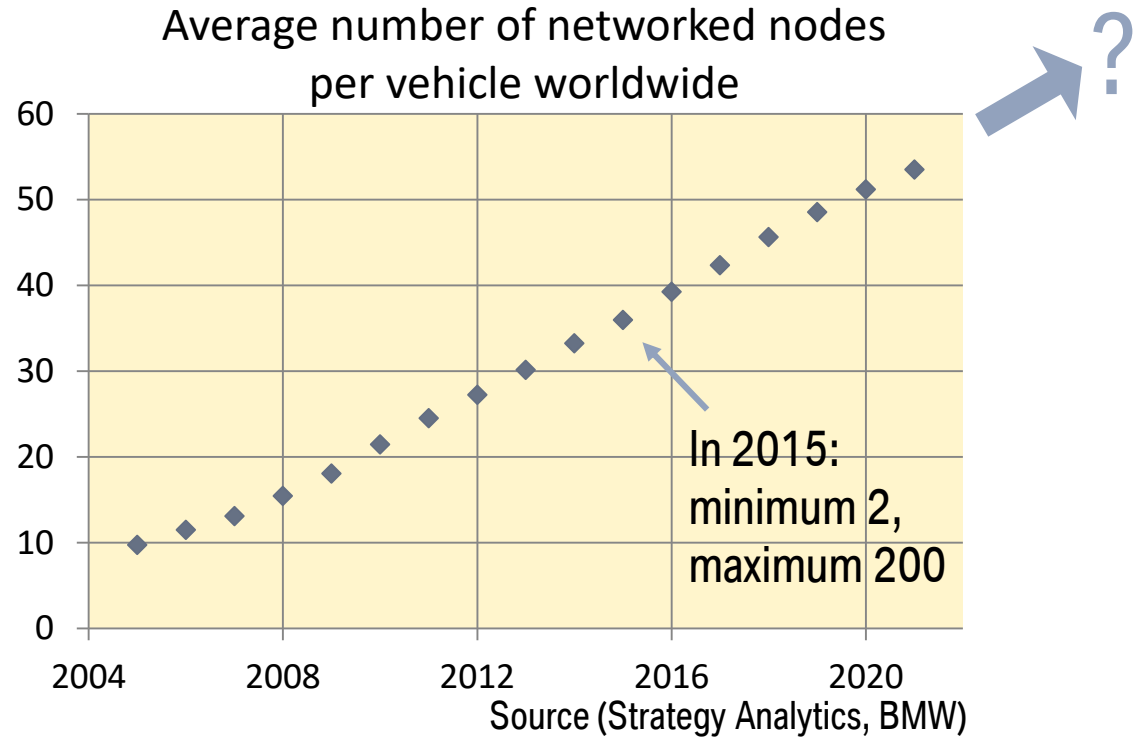
THE IN-VEHICLE COMMUNICATION NETWORK (IVN) IS AN ESSENTIAL ELEMENT FOR BOTH EFFICIENCY AND ENABLING THE FUTURE.

Key features of the IVN today:

1. It is predefined (per car model in size and variations).
   - There is no plug and play (exception: a specific, also predefined number of consumer devices can be connected plug and play).
   - There are no later extensions (that have not been provided for within the original design).
   - Changes during the life of a car are made in a defined way (preferably at the dealer).
2. Needs to cover a large number of different communication requirements (data rates, data types, timing, …).
3. It is invisible to the customer.
4. (Hardware) Costs and energy efficiencies are major design criteria.
5. Its core challenge is complexity.

THE FUNCTIONS AND FEATURES OF A CAR RELY ON A GROWING NUMBER OF ELECTRONIC CONTROL UNITS (ECUS).

Cars started as purely mechanical devices with all know how at the car manufacturer. Electronics made driving more comfortable and safer, but also changed the business model. Tier 1s supply the ECUs. The car manufacturer defines and integrates a growing number.

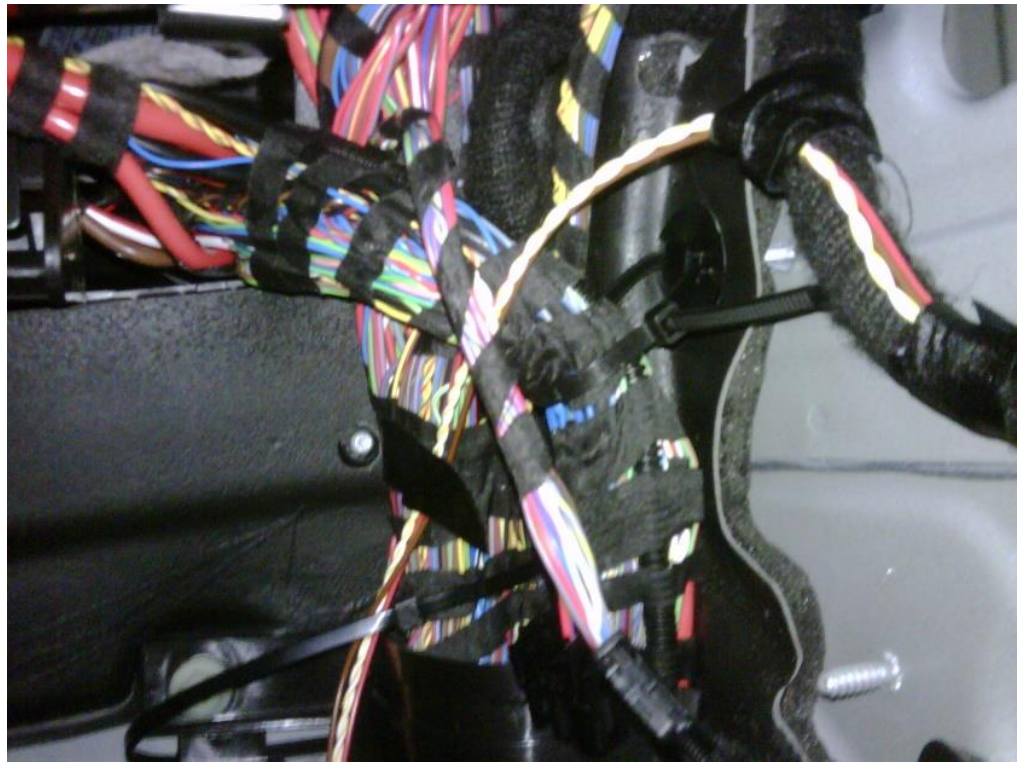


THE HARNESS CONNECTING THESE ECUS IS THE THIRD MOST EXPENSIVE AND THE THIRD HEAVIEST COMPONENT IN A CAR (AFTER ENGINE AND CHASSIS).

Example of main harness spread out

Source: http://www.ieee802.org/3/RTPGE/public/mar12/CFI_01_0312.pdf

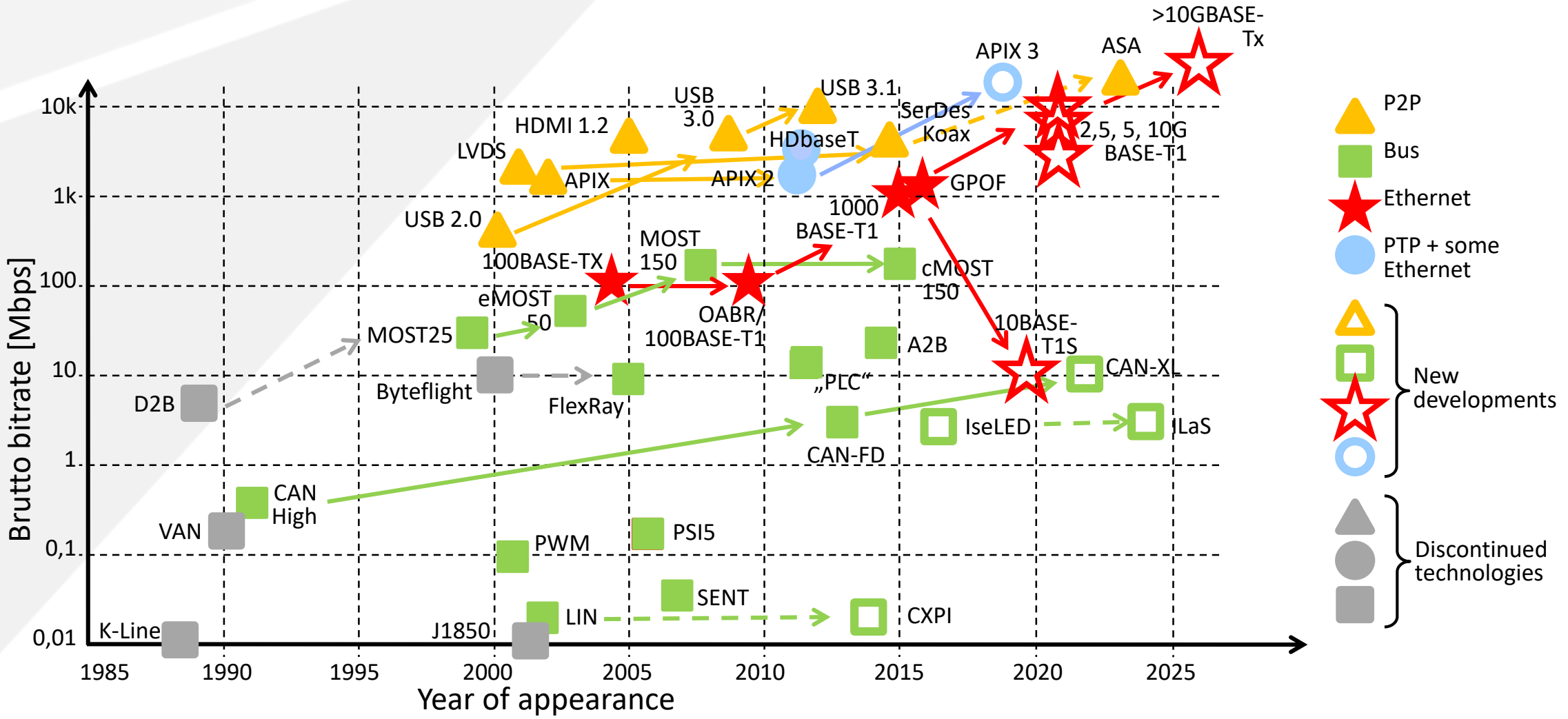
Example of harness detail in production process



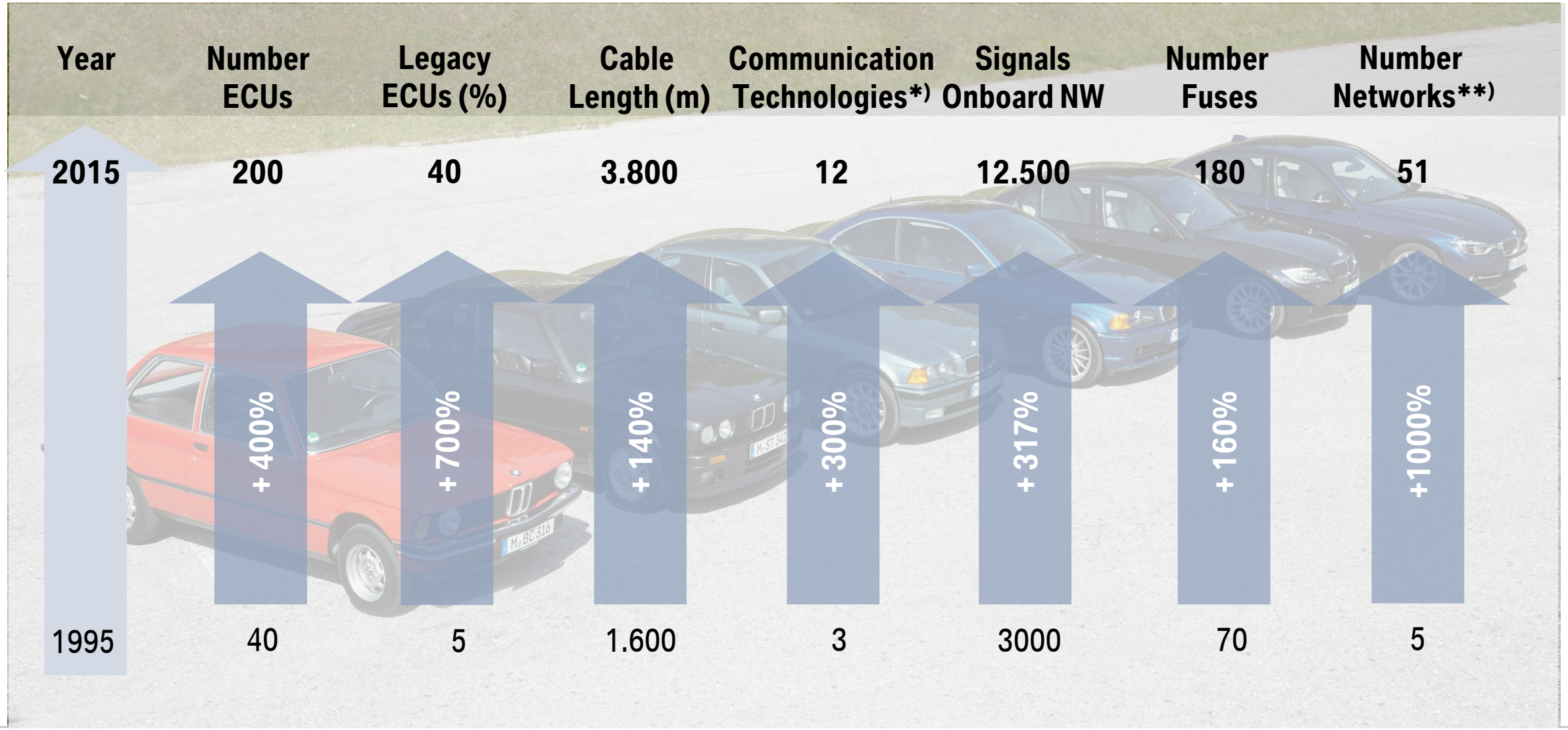
Source: BMW

For every car the harness is custom made. With Millions of theoretical variants and 100.000s practical ones.

CAR MANUFACTURERS CAN CHOOSE FROM A LARGE NUMBER OF DIFFERENT IN-VEHICLE NETWORKING TECHNOLOGIES CONNECTING THE ECUS.



AS A RESULT ALL ASPECTS OF THE IVN ARE BECOMING MORE COMPLEX.



*) P2P or network

**) Often requiring some form of bridge or gateway in between

DIFFERENT TIMING CONCEPTS ARE THE CORE CHALLENGE WHEN TRANSLATING BETWEEN THESE TECHNOLOGIES.

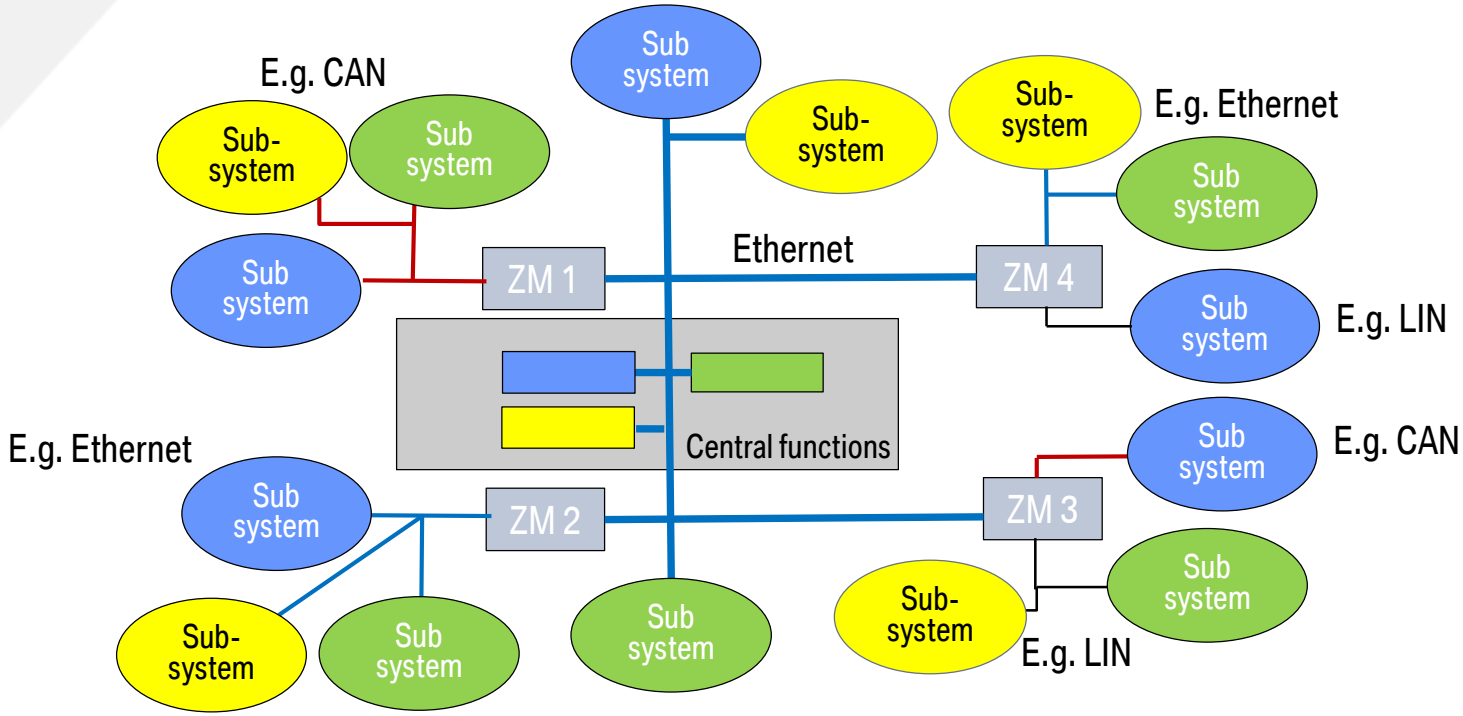
	LIN	CAN(-FD)	FlexRay	Ethernet	SerDes
Data rate	19.2 kbps	0.5-2/5Mbps (more in development)	10Mbps	10Mbps – 10Gbps (more being specified)	1.3-5.3Gbps (more in dev.)
Packet payload size [Bytes]	1-8	8 (64)	254 (64)	46 -1500	n/a
Channel Access	Master/slave schedule table	Message priority	TDMA	Switched (P2P), PLCA	P2P
Latency guarantees	Guaranteed according to schedule	With 50% load, delivery is guaranteed within cycle time (typ. >10ms).	Cycle time 2.5/5ms*)	AVB/TSN for >= 100Mbps, 5 hops <2ms, For PLCA: No. IDs*packet time	Only two participants, depends a little on technology, very small
Jitter	None	See above	See above	PLCA: No. IDs*packet time	See above

*) Derived from mechanical reaction time. Changes with electric engines.

THERE IS A NECESSITY TO REDUCE COMPLEXITY WHILE BEING MORE CAPABLE AND FLEXIBLE.

APPROACH 1: USE A ZONAL ARCHITECTURE TO SIMPLIFY THE WIRING HARNESS.

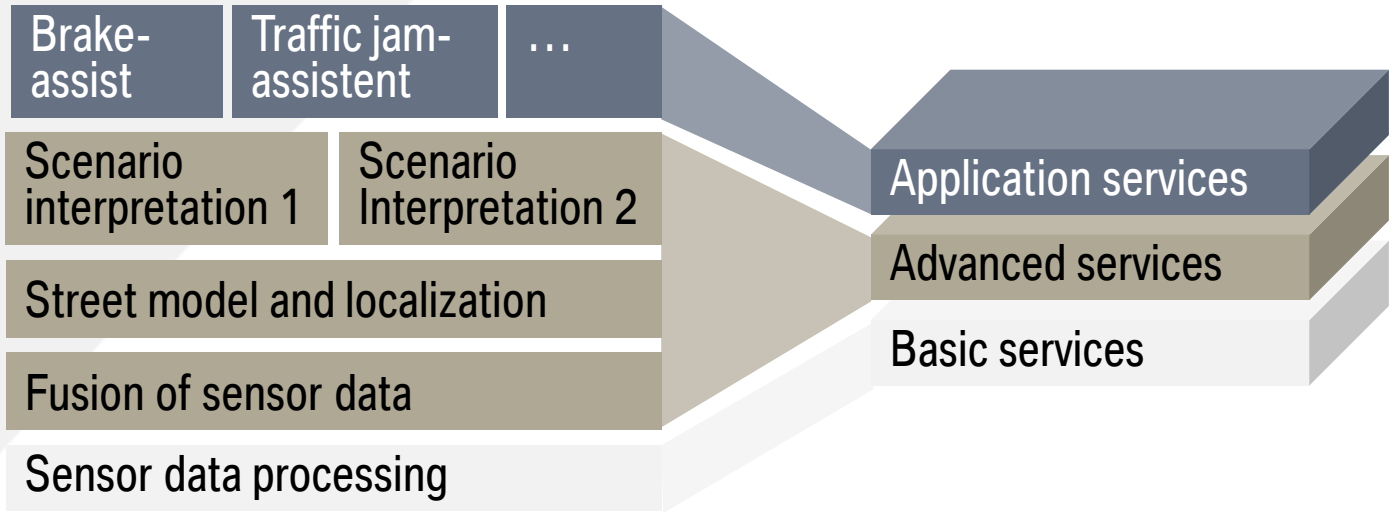
- Allows for automated production.
- Reduced weight and length of harness.
- Requires good tunneling mechanisms (adds to the timing constraints).

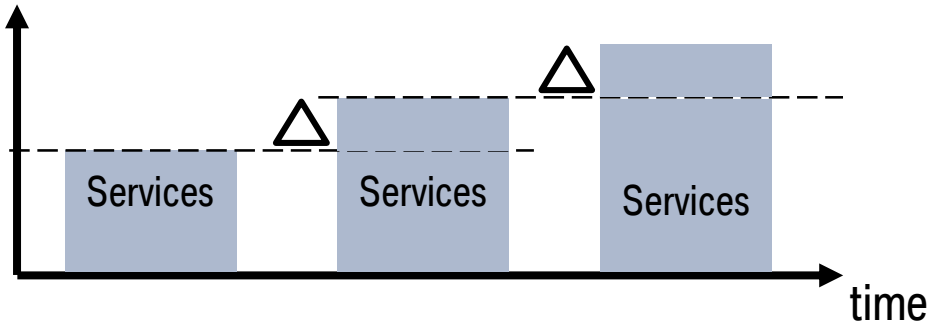


APPROACH 2: SERVICE BASED ARCHITECTURE PROVIDES A SOLUTION FOR HIGHLY COMPLEX SYSTEMS.

- Provides services and transparency in the complete system (across domains).
- Allows handling the complexity, as it supports encapsulation and hierarchies and testing against interfaces.
- The reuse over vehicle generations is significantly simplified.
- But, large change for control loops with stringent timing requirements.

Example:





THERE IS ONLY ONE IVN-TECHNOLOGY THAT HAS THE CHANCE TO REDUCE THE NUMBER OF IVN-TECHNOLOGIES: AUTOMOTIVE ETHERNET

– Fewer technologies

↗ No gateways, no gateway tables, no complex coupling.

↗ Reduced number of different tools, simpler analysis.

- Ethernet/IP

↗ Flexible (for many different applications), scalable (in data rates and features).

↗ „Automatically“ supports a service based architecture.

↗ State of the art security standards.

↗ Eco system goes beyond the borders of automotive.

↗ Unified software architecture possible.

↗ Inherently supports a zonal architecture (allow one physical network).

↗ Unified connectivity to the outside world/cloud.

BECAUSE OF THE STRICT LAYERING NEW SPEED GRADES OR MEDIA INTEGRATE SEAMLESSLY INTO THE NETWORK.

Name	Data rate	Status	Cabling	SOP
100BASE-T1*)	100Mbps	Completed Standard	UTP P2P	2013
1000BASE-T1	1Gbps	Completed Standard	Jacketed UTP P2P or STP	2020
10BASE-T1S	10Mbps	Taskforce at IEEE, complete within 2019	UTP P2P or multidrop	2022 possible
2.5,5,10GBASE-T1	2.5, 5, 10Gbps	Taskforce at IEEE, complete 2020	STP (Coax in discussion)	2024 possible
>10G	25, 50Gbps	Study group at IEEE, NAV Alliance	Open, STP likely	2027 target

Additional features on PHY level are: PoDL, autonegotiation, EEE, wake-up/sleep

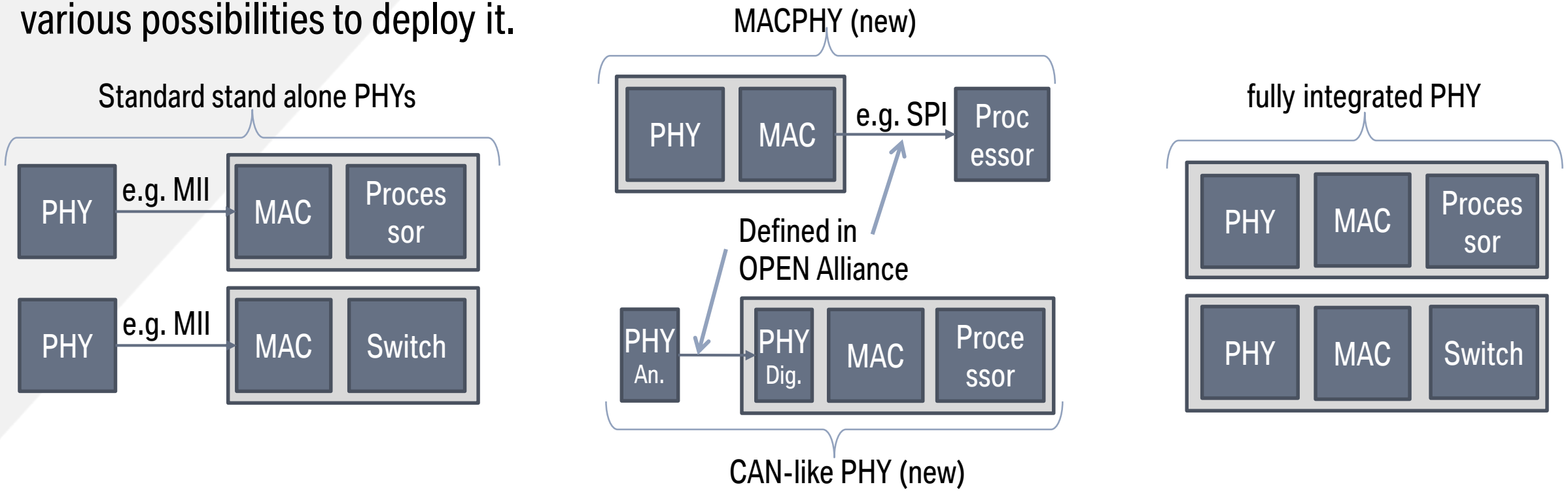
Challenges on PHY level: Automotive EMC validation for every speed grade. Patience to wait for the next standard.

*) prev. BroadR-Reach or OPEN Alliance BroadR Reach (OABR)

COSTS ARE A DECISIVE FACTOR. 10BASE-T1S WAS THEREFORE DEVELOPED IN ORDER TO BE COST COMPETITIVE.

The costs factors generally considered in comparisons are: PHY, CMC, crystal, connectors, cables, sometimes peripherals, sometimes effort in processor, sometimes software (licenses).

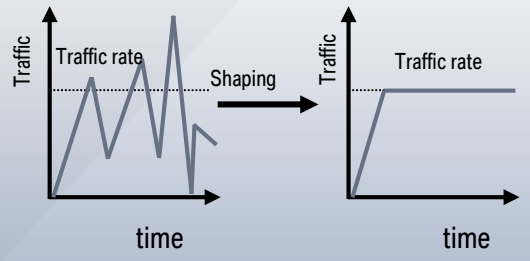
In order to have an attractive PHY cost, 10BASE-T1S is developed such that there are (will be) various possibilities to deploy it.



IEEE TSN STANDARDS ENABLE TO SUPPORT A LARGE NUMBER OF DIFFERENT REQUIREMENTS AND TIMING CONSTRAINTS.

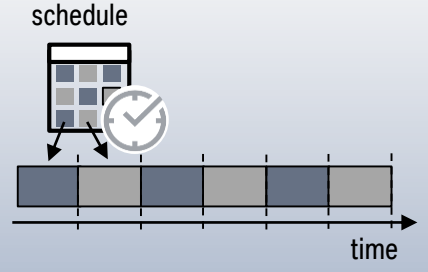
IEEE 802.1 Qav
(credit-based)

- eliminates bursts
- mitigates data loss
- ensures that QoS goals are achievable (latency) in ms-range



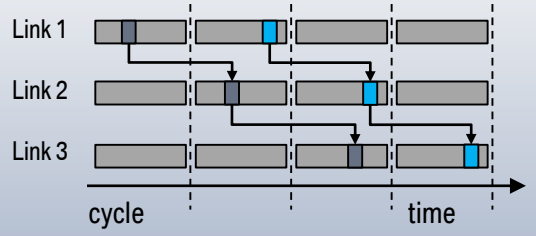
IEEE 802.1 Qbv
(time-aware)

- enables a highly predictable frame transmission (µs range)
- deterministic arrival possible
- OS support needed
- relies on sync. time base



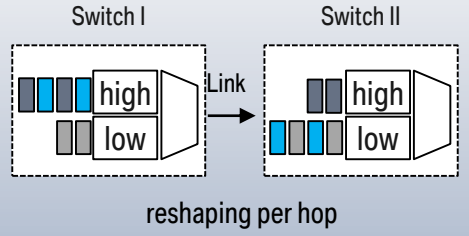
IEEE 802.1 Qch
(cycle-based)

- enables a predictable frame transmission
- fixed delay for each stream
- relies on sync. time-base
- 1 cycle delay per hop



IEEE 802.1 Qcr
(asynchronous)

- enables low latency for links with mixed traffic types and different traffic pattern
- asynchronous shaping
- no need for ingress policing and time sync



Network design tools for Ethernet IVN have to cover the right set of features to make the right design choices.

SUMMARY AND CONCLUSION.

- The car manufacturers are facing a time in which they need to continue to strive in ever fiercer competition while having to embrace the changes induced by a digitized world.
- The in-vehicle communication network (IVN) is an essential element for both efficiency and enabling the future.
- Complexity is a core challenge in today's IVN because of the number of nodes, technologies, and requirements that need to be met (different timing requirements especially).
- Automotive Ethernet offers the chance to simplify the IVN while at the same supporting existing functions and future innovations.
- The IEEE TSN toolbox offers essential features to handle the different timing requirements in one network.

THANK YOU FOR YOUR ATTENTION

Dr. Kirsten Matheus

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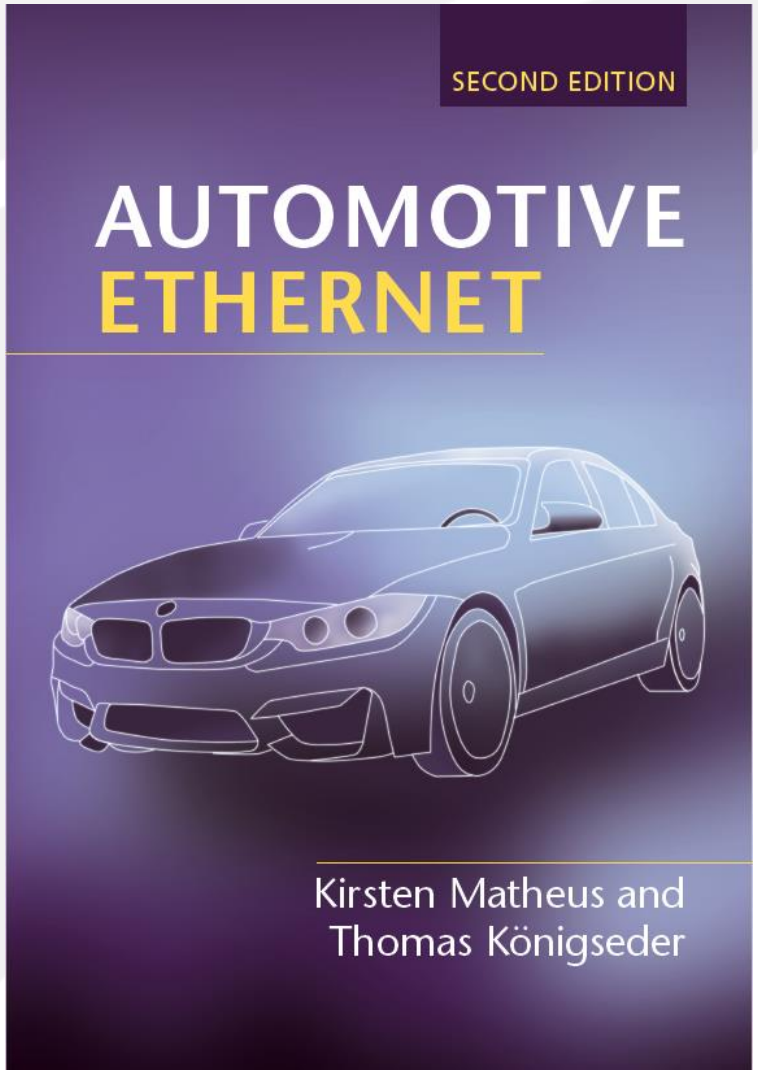
MORE INFORMATION ON AUTOMOTIVE ETHERNET CAN BE FOUND IN:



New content includes:

- Detailed explanations of how the 100BASE-T1 PHY and 1000 BASE-T1 PHY technologies actually work.
- A step-by-step description of how the 1000BASE-T1 channel was derived.
- A summary of the content and uses of the new TSN standards.
- A framework for security in Automotive Ethernet.
- Discussion of the interrelation between power supply and Automotive Ethernet communication.