EVOLUTION OF ETHERNET-BASED AUTOMOTIVE NETWORKS: FASTER AND CHEAPER.

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BMW GROUP

THE NEXT 100 YEARS

AGENDA.

–How did it all start?

–Where are we today?

–Why is automotive Ethernet more than just another IVN technology?

–What is the role of higher data rates?

–What is the role of lower data rates?

–Conclusion

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AUTOMOTIVE ETHERNET STARTED AS AN IVN TECHNOLOGY TO ADDRESS THE DEMANDS FOR HIGHER DATA RATES.

- 1. Use case: To limit the time needed for flash updates to 15minutes for 1GByte of flash data.
- With the existing CAN the updates would have taken 16h.
- With 100BASE-TX Ethernet it was possible to meet the target.

- 2. Use case: To allow the RSE to access the map data stored in the HU for new customer functions.
- MOST25 as such does not allow to transmit 20Mbps of data packets. Additionally the bandwidth of the existing MOST25 was used up in any case
- With 100BASE-TX it was possible to meet the target.

- 3. Use case: To transmit digitized (camera) video data.
- For the introductory use case chosen, it was more cost efficient to compress the video data and to transmit it over 100BASE-T than the LVDS technologies available at the time.

INITIAL IMPROVEMENTS OF AUTOMOTIVE ETHERNET MADE IT MORE POWERFUL AS A TECHNOLOGY FOR HIGH(ER) DATA RATES.

Extension in the infotainment and driver assistance domains

- Replacement of MOST25
- Adding the antenna module and other (new) infotainment systems
- Adding systems from the driver assist domain, which require the bandwidth during runtime/for flash or for IP and Ethernet communication

Extended use of AVB

- Time synch 802.1AS, in parts also usable over CAN&Co
- 1722 to bypass IP in case of audio/video transmission
- Stream reservation, traffic class C
- Traffic shaping

Standardization of 1000BASE-T1

- Growth possibility needed to be initiated early in order to be future proof
- CFI in March 2012
- Publication of 1000BASE-T1 standard in June 2016
- SOP at BMW planned for 2021

Standardization of TSN

- Addressing safety critical applications
- Redundancy
- Preemption, time aware shaping
- Multiple master clocks …

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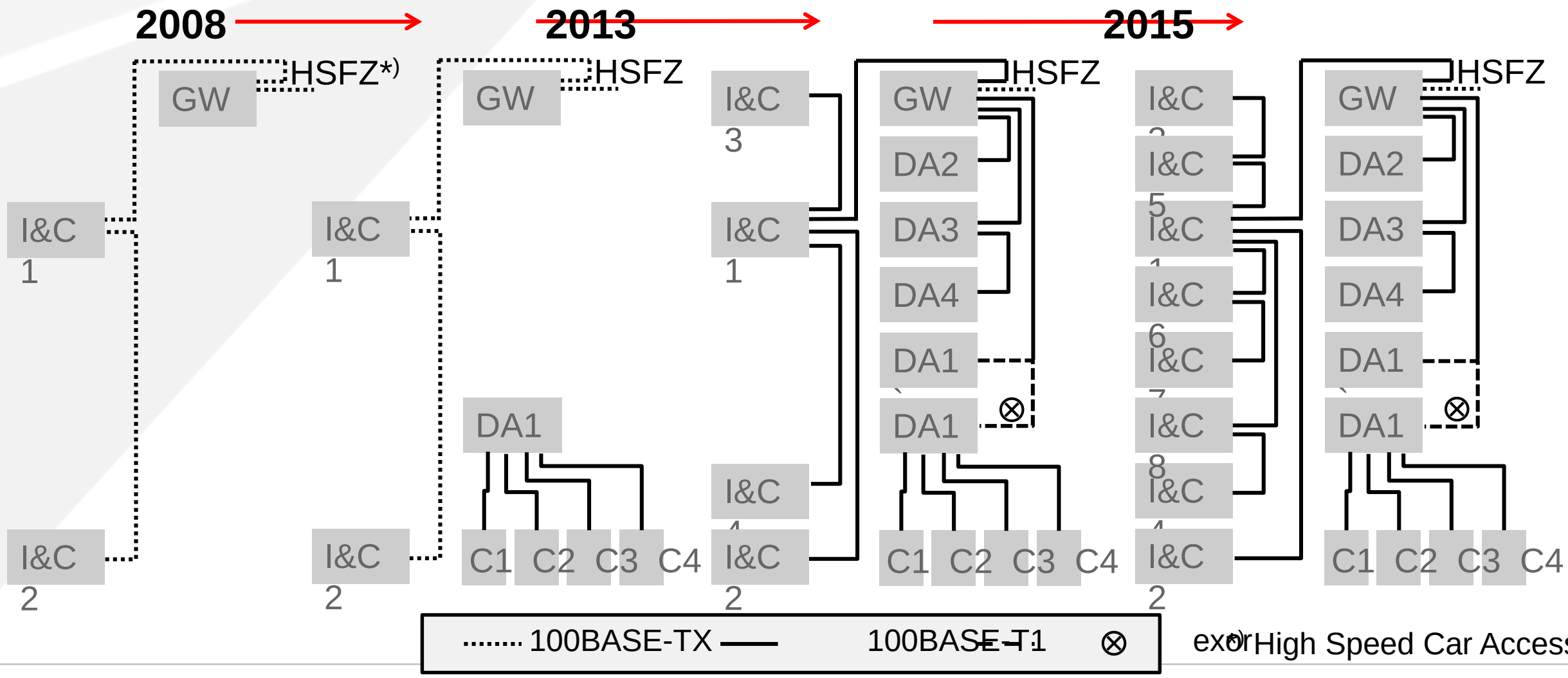
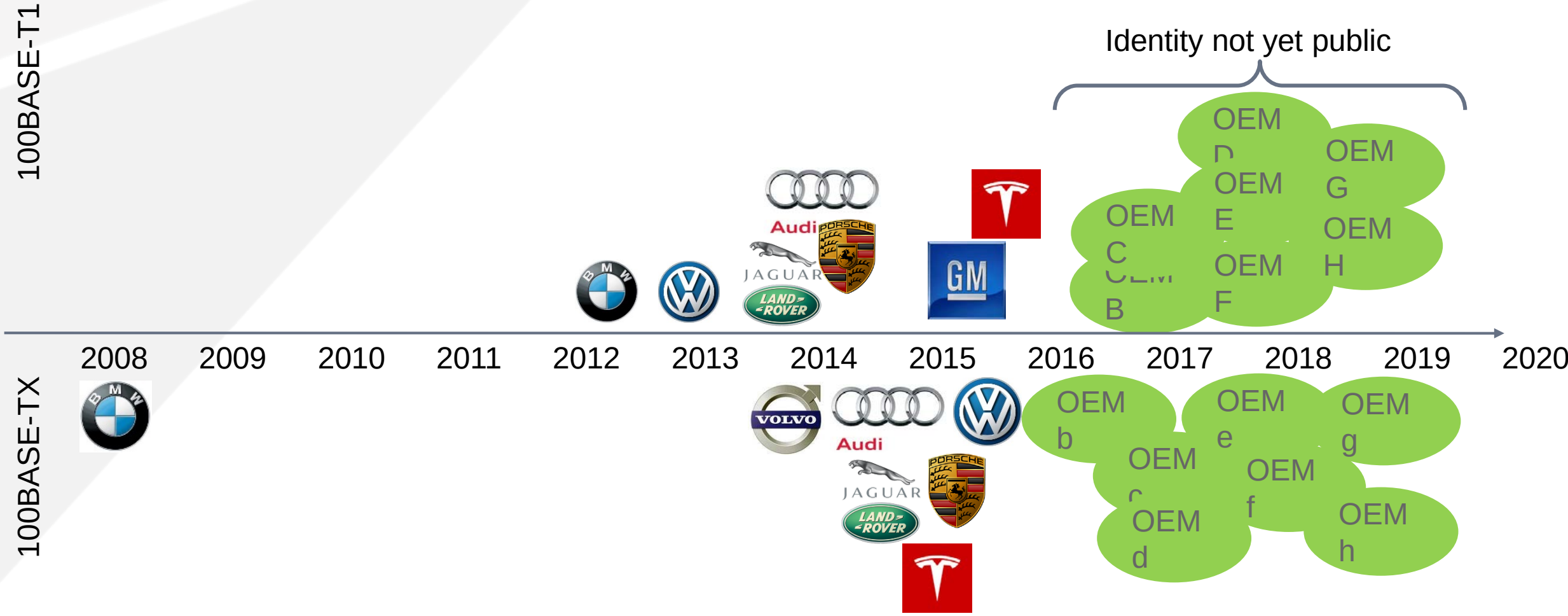
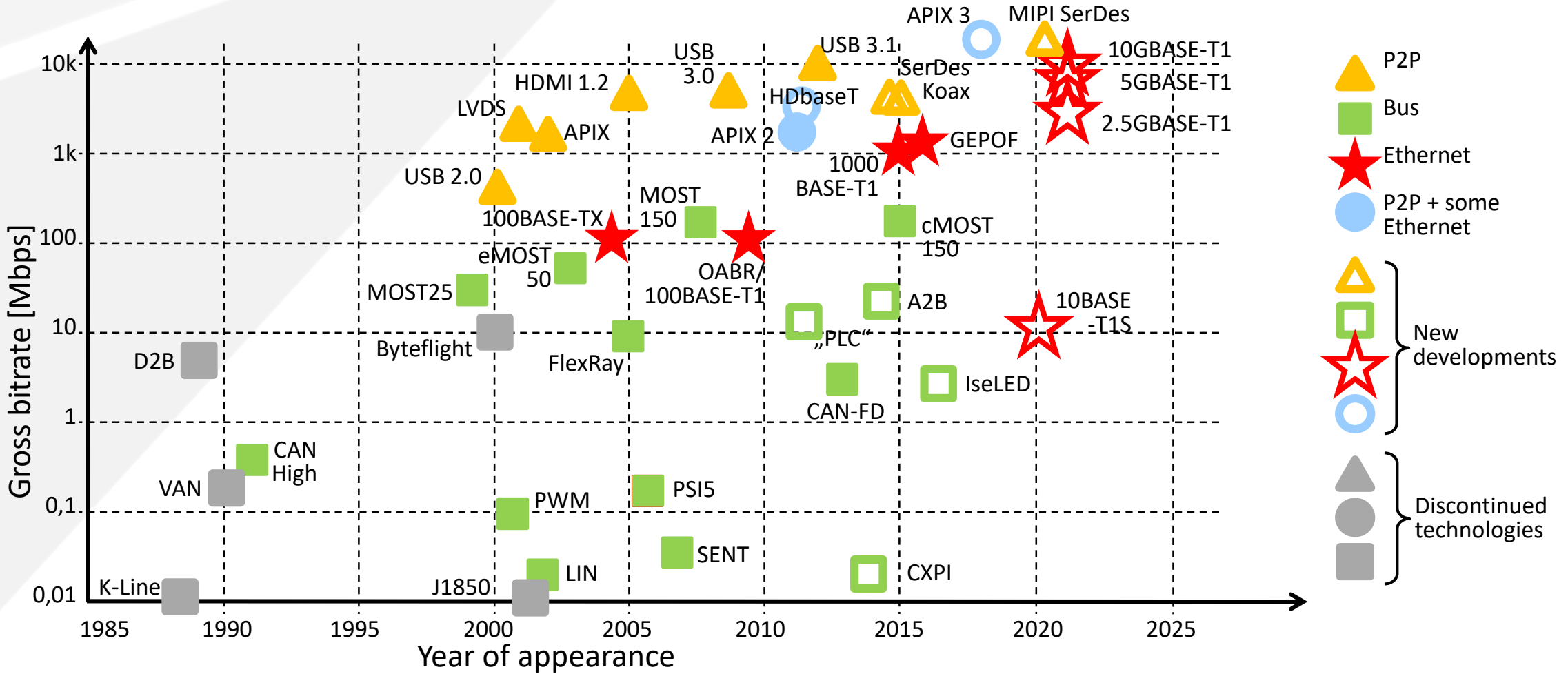
SINCE ITS INTRODUCTION, THE NUMBER OF ETHERNET ECUS HAS CONTINUOUSLY INCREASED IN THE BMW E/E ARCHITECTURE.



TRACTION IS ALSO SEEN IN THE INDUSTRY AS SUCH AS OTHER CAR MANUFACTURERS ARE FOLLOWING SUIT.



HOWEVER, WITH ETHERNET BEING JUST ANOTHER IVN, THERE IS AN INCREASING NUMBER OF IVN-TECHNOLOGIES WHICH NEED TO BE SUPPORTED.



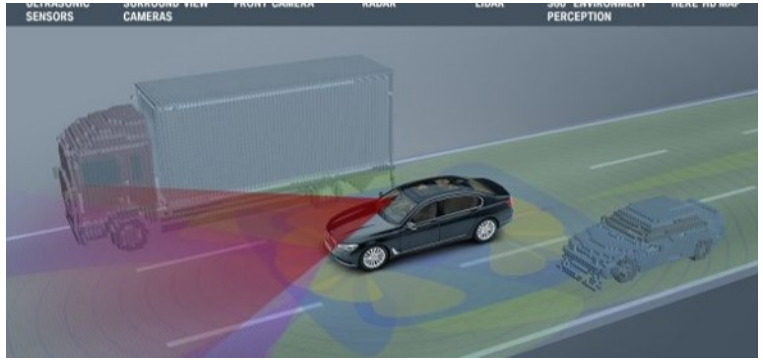
WHILE AT THE SAME TIME THE IVN NEEDS TO BE MORE POWERFUL AND ROBUST TO SUPPORT CHALLENGING NEW REQUIREMENTS.

Mobile services and data:

- Many new apps and services during the lifetime of a car.
- Regular software updates (also over the air, also 3rd party software).
- Always on, with the car as just another node in the world wide network.
- More communication in- and outside.

E-mobility:

- Regulation/legislation supported.
- Continuous updates on routes, reach, and charging during runtime.
- Car has a unique identity in the world wide grid (smart billing).
- Cross-domain communication inside the car.



Autonomous Driving:

- Large amounts of sensor data.
- Processing across different ECUs (powerful communication network).
- Algorithms enhanced by offsite information and processing.
- Service oriented architecture.
- Regular software updates.
- Always latest security standards.

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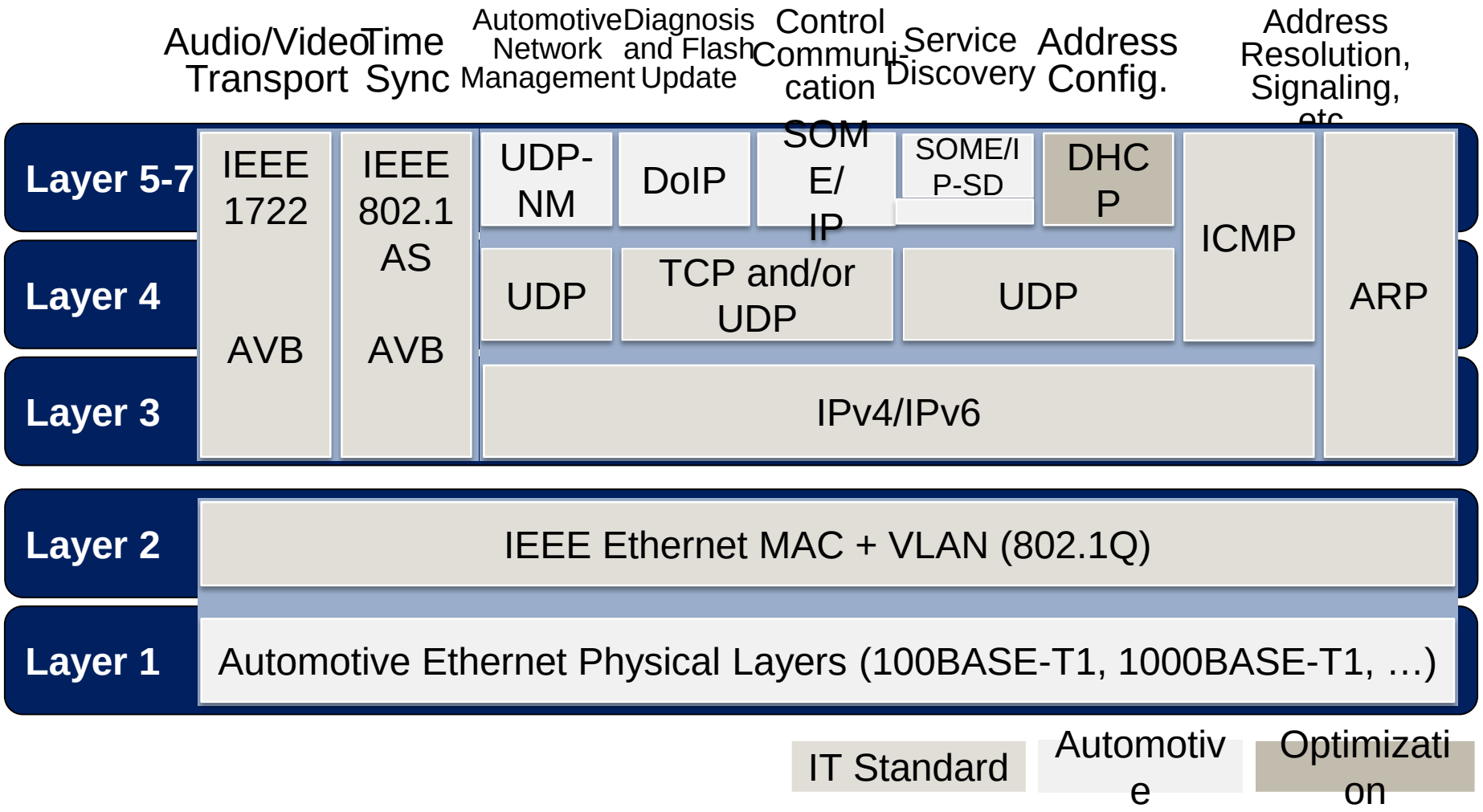
AUTOMOTIVE ETHERNET AS DEFINED IN THIS PRESENTATION COVERS THE COMPLETE PROTOCOL STACK WITH STRICT LAYER SEPARATION.



AUTOMOTIVE ETHERNET ALLOWS FOR SIGNIFICANTLY IMPROVED SECURITY MEASURES OVER LEGACY NETWORKS.

		Auth? Enc?	Multicast Broadcast	100% protected?	# of keys?	Dyn. Keys?	Minimum Overhead	Selector	Implementation	Config Complexity
Ethernet	MACSec	Yes/Yes	Yes	Yes	Lowest	Yes	~2%	L1/L2	State-of-the-art **Hardware** + Software	Low
	IPsec	Yes/Yes	No	No	Low	Yes	~2%	L3 + L4	State-of-the-art Software	Low-Medium
	(D)TLS	Yes/Yes	No	No	Medium	Yes	~2%	L4 only	State-of-the-art Software	Low-Medium
CAN …	SecOC Eth	Yes/*1	somewhat possible	No	High	*2	~2%	Depends	New Software + *4	High
	SecOC CAN	Yes/*1	somewhat possible	somewhat possible	High	*2	**~100%** *3 *5	ID	New Software + *4	High
	SecOC CAN-FD	Yes/*1	somewhat possible	somewhat possible	High	*2	~25% (CAN-FD)	ID	New Software + *4	High

*1 Possible to integrate in standard
*2 No standardized solution exists.
*3 Only reduced security.
*4 Additional new Hardware might be needed to reduce group key trust limitatio
*5 Avoiding Transport Protocol due to safety reasons.

AUTOMOTIVE ETHERNET OFFERS THE RIGHT FLEXIBILITY AND TOPOLOGY CHOICES TO SERVE AS A HOMOGENEOUS IVN.

	Automotive Ethernet	E.g. CAN(-FD), FlexRay
Number of ECUs in network	256 → unlimited, bandwidth can be added	CAN e.g. 16 (SAE), FR e.g. 4/x, limited by bandwidth
Different speed grades supported in the same network	Various (different PHYs but same protocol stack)	One (change over to new IVN if data rate no longer sufficient)
Bandwidth efficiency	50-90%	20-55%
Topologies	Extremely flexible	Limited
Priority and timing schemes	AVB-TSN (various)	Message or ID/timeslot based (one)
Addressing	MAC and IP	None
Security	State of the art	Limited
Domain separation	Physical or virtual	Physical
Extendibility	Switch port, no changes to existing nodes	CAN: no changes to existing nodes, FR: might need active star port + timing
Service orientation	Possible	Not really possible

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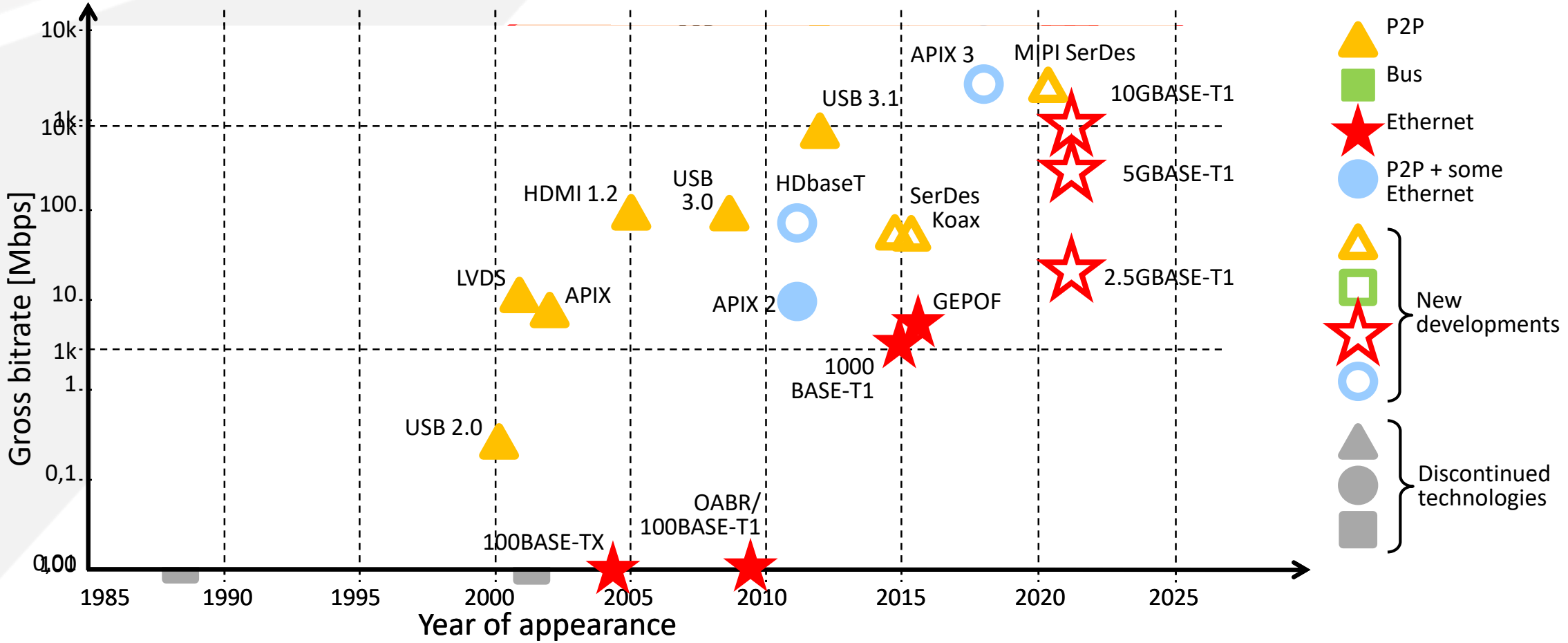
THE LARGE NUMBER OF TECHNOLOGIES ADDRESSING HIGHER DATA RATES SHOWS THAT THE DEMAND IS THERE TODAY.



FOR AUTOMOTIVE ETHERNET AUTONOMOUS DRIVING IS DRIVING THE NEED FOR HIGHER DATA RATES.

The main drivers are

–Higher resolution for sensor data & displays.

–Fast communication between high end computing platforms.

–The need for using the Ethernet protocols.

The existing technologies for higher data rates are unsuitable because they are

–P2P (i.e. they do not support networking functions/Ethernet protocols) and/or

–Consumer technologies (i.e. their cabling is not efficient in the car) and/or

THE MAIN CHALLENGES FOR HIGHER DATA RATES ARE COSTS, POWER CONSUMPTION AND TIMING.

Technical challenges:

–Robustness of the PHY technology (→ BER < 10^{-12}).

–EMC behavior at high frequencies (→ affects cabling and implementation choices).

–Power consumption (→ data rate and error avoidance/correction).

Other challenges:

–High data rate Ethernet has to compete with proprietary solutions (cost, timing).

–It is a constant race: The data rate provided is never enough. The need for data rates beyond 10Gbps is envisioned, while the standardization process needs time.

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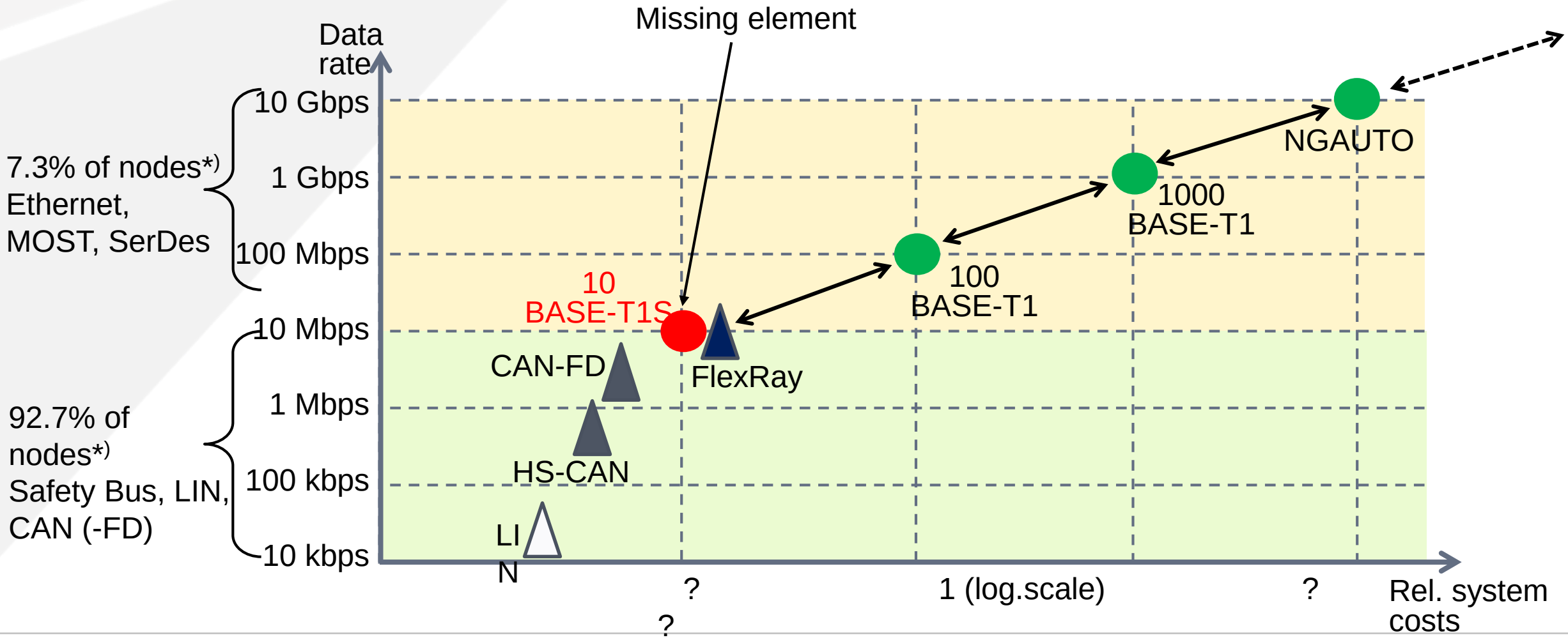
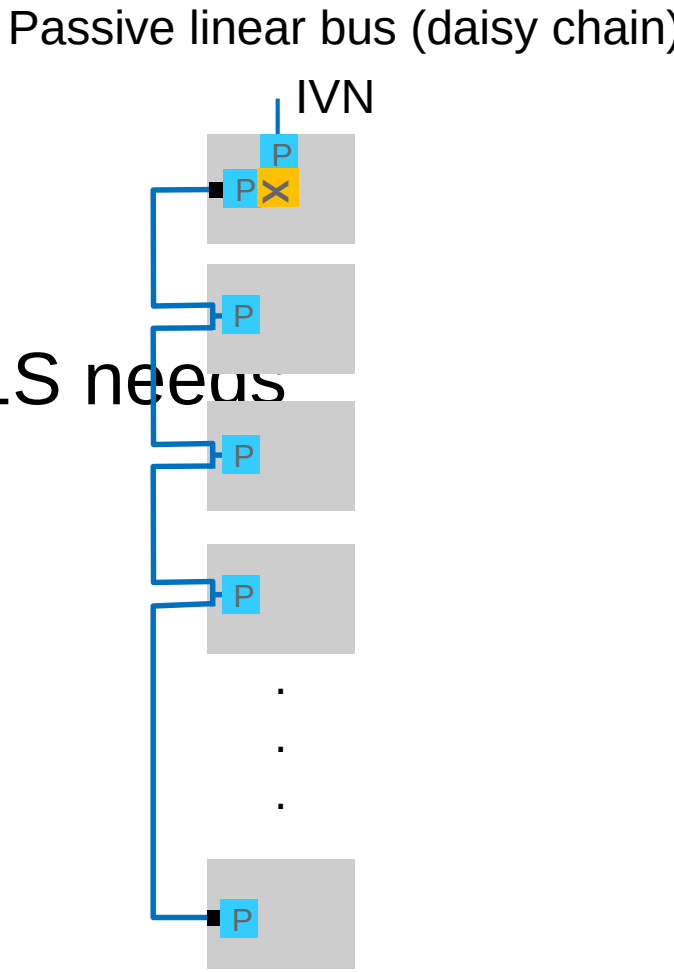
90% OF IVN COMMUNICATION IS BELOW 10MBPS. TO USE 100MBPS ETHERNET FOR THOSE CASES IS NOT COST AND POWER EFFICIENT.



*) forecast for 2020, source: Strategy Analytics

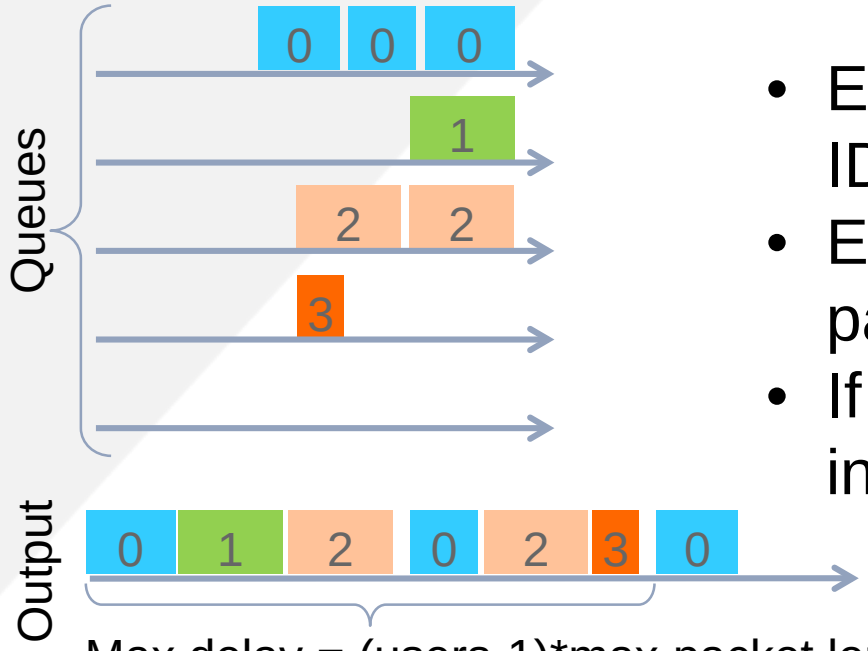
COST REDUCTION FOR 10BASE-T1S IS ACHIEVED BY SIMPLIFIED PHY SPECIFICATION AND MULTIDROP CAPABILITY.

- Low frequency channel and “low” data rate allow for
  - Simple equalization
  - No forward error correction
- Because of the half duplex transmission 10BASE-T1S needs
  - No echo cancellation
  - No hybrid
- Multidrop (bus topology) allows for
  - One PHY per ECU instead of two per link



MULTIDROP REQUIRES A (NEW) MEDIUM ACCESS SCHEME, WHICH USES THE BANDWIDTH EFFICIENTLY.

- PLCA is based on a fairness per packet bases.
- It can be used with the existing CSMA interface in MAC and switches.
- It guarantees a maximum latency.



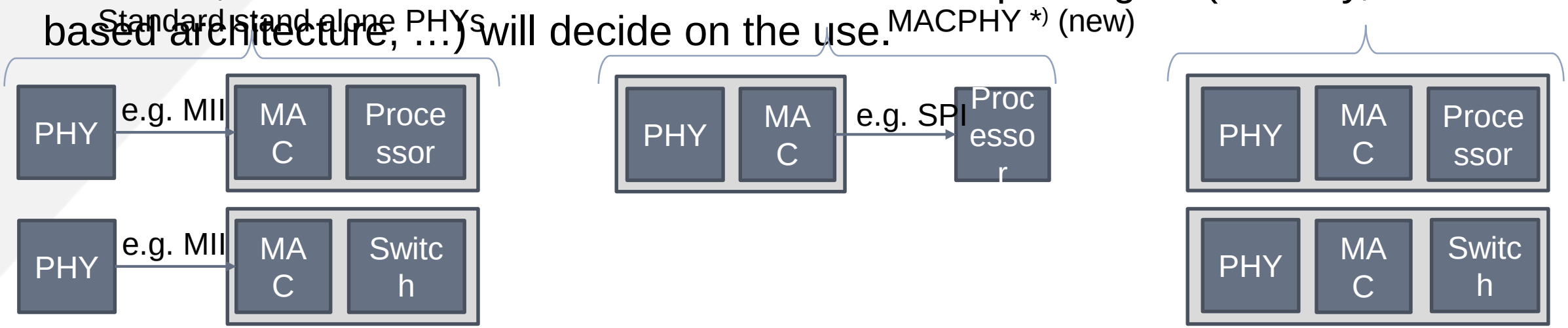
- Every node receives (minimum 1) access ID
- Every node is allowed to transmit one packet in order of the IDs
- If a node does not transmit, the next node in line can use the transmit slot

Max delay = (users-1)*max packet length*), min delay can be immediate

*) max packet length for an Ethernet packet (1500 bytes payload) on a 10Mbps link ~1.2ms.

THE MAIN CHALLENGE FOR 10BASE-T1S IS COST EFFECTIVENESS.

- IVN decisions within car manufacturers are often based on hardware costs only.
- Ethernet thus has to compete with legacy networks like CAN, CAN-FD, FlexRay, etc.
- The possibility to fully integrate PHY/MAC with processors offers further cost saving potential.
- However, the relevance of modern communication paradigms (security, service based architecture, …) will decide on the use.



*) Allows the use of smaller processors typically used in CAN

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CONCLUSION.

- Automotive Ethernet started as yet another IVN technology in order to address the demand for higher data rates in the IVN.
- But, Automotive Ethernet can do a lot more: It can change the way we design the EE-Architecture and IVN, i.e. the way we develop cars.
- With an extensive Ethernet IVN we can address security, service based architecture, unambiguous addressing, software updates etc. more efficiently than with legacy IVN technologies.
- However, we need to fully exploit the potential of Ethernet, we need to use Ethernet as a growing system that also addresses demands of lower AND higher data rates while becoming more cost efficient.

THANK YOU FOR YOUR ATTENTION

Dr. Kirsten Matheus

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