1 Twisted Pair 100 [C] Mbit/s Ethernet

Call for Interest at IEEE802.3 Working Group
Beijing, March 2014 Plenary Meeting

Chair & Presenter:

Thomas Hogenmüller (Bosch, Car System Supplier)

Supporters and Experts for the Q&A Session:

Steffen Abbenseth (Volkswagen, Car Maker)
Stefan Buntz (Daimler, Car Maker)
Albert Kuo (Realtek, Semiconductor Vendor)
Kirsten Matheus (BMW, Car Maker)
Mehmet Tazebay (Broadcom, Semiconductor Vendor)
Helge Zinner (Continental, Car System Supplier)

CFI 1 Twisted Pair 100 Mbit/s Ethernet (1TPCE)

Supporters (max. 3 per company)

Automotive Industry Car Makers:

Steffen Abbenseth (Volkswagen)
Fan Bai (General Motors)
Stefan Buntz (Daimler)
Eric Dequi (Peugeot Citroen)
Keigo Fukuda (Mazda)
Harald Eisele (Opel)
Doarte Goncalves (Peugeot Citroen)
Hideki Goto (Toyota)
Yukihiro Ino (Nissan)
Philip Jackson (Jaguar Land Rover)
Markus Jochim (General Motors)
Dongok Kim (Hyundai)
Stephane Korzin (Renault)
Olaf Krieger (Volkswagen)
Jim Lawlis (Ford Motor Company)
Helmut Leier (Daimler)
John Leslie (Jaguar Land Rover)
Shehnaz Louvart (Renault)
Maitre Julien (Volvo Trucks)
V3 Kirsten Matheus (BMW)
Masaaki Miyashaita (Nissan)
Takashi Matsumoto (Nissan)
Yasuhiro Okuno (Honda)
Nicolas Morand (Peugeot Citroen)
Samuel Sigfridsson (Volvocars)
Thilo Streichert (Daimler)
Josetxo Villanueva (Renault)
Natalie Wienckowski (General Motors)

Automotive Industry System Suppliers:

Andreas Arlt (Bosch)
Robert Boatright (Harman)
V3 Thomas Hogenmüller (Bosch)
Christian Loske (Schaeffler Engineering)
Christopher Lupini (Delphi)
Ralf Machauer (Bosch Engineering)
Larry Matola (Delphi)
Waseem Mir (Delphi)
Josef Nöbauer (Continental Engineering Services)
Jürgen Röder (Continental)
Michael Schaffert (Bosch)
Koike Tomoyuki (Denso)
Kaku Yoshifumi (Denso)
Helge Zinner (Continental)

Automotive Industry Components & Tools:

V3 Sasha Babenko (Molex)
Bert Bergner (TE Connectivity)
Christian Boiger (b-plus GmbH)
Theodore Brillhart (Fluke Networks)
Lars Bröhne (Time Critical Networks)
David Bolati (C&S Group)
V3 Mike Gardner (Molex)
Robby Gurdan (Uman Networks)
Farid Hamidy (Pulse)
Marcos Hsiao (Würth Electronics)
Martin Huber (MD Elektronik)
Matthias Jaenecke (Yazaki)
Georg Janker (Ruetz System Solutions)
James Kahkoska (Fluke Networks)
Bernd Körber (FTZ Zwickau)
Andreas Kürzdörfer (Murata)
Jonas Lext (Time Critical Networks)
Martin Meurer (MD Elektronik)
Jean-Michel Marchisio (Acome)
Simon Muff (Ansys)
V3 Thomas Müller (Rosenberger)
Rainer Pöhmerer (Leoni Kabel)
Steve Pytel (Ansys)
Jürgen Scheuring (Uman Networks)
Dmitrij Semilovsky (MD Elektronik)
Markus Stark (Würth Electronics)
Hiroshi Tanaka (Murata)
Burkhard Triess (ETAS)
Jens Wülfing (TE Connectivity)

Statistics:
- **145** individuals
- **34** 802.3 voters
- **71** affiliated with the automotive industry
- **13** affiliated with the industrial automation

CFI 1 Twisted Pair 100 Mbit/s Ethernet (1TPCE)

Supporters (max. 3 per company)

Industrial Automation Industry:

Matthias Pfaller (marco Systemanalyse und Entwicklung)
Bernd Horrmeyer (Phoenix Contact)
Stephane Kehrer (Belden)
Oliver Kleineberg (Belden)
Johannes König (marco Systemanalyse und Entwicklung)
Ludwig Leurs (Bosch Rexroth)
Friedrich Scheurer (Bosch Rexroth)
V3 Albert Tretter (Siemens)
Karl Weber (Beckhoff Automation)
V3 Ludwig Winkel (Siemens)
Andreas Wöber (TE Connectivity)
Dayin Xu (Rockwell)
V3 Mitsuru Iwaoka (Yokogawa)

Avionics Industry:

Stefan Schneele (Airbus Group)

Semiconductor Industry:

Dale Amason (Freescale)
Tom Brown (Vitesse)
V3 Mandeep Chadha (Vitesse)
V3 Yair Darshan (Microsemi)
Klaus Durr (ON Semiconductor)
V3 Dave Dwelley (Linear Technologies)
Daniel Feldman (Microsemi)
V3 Xiaofeng Wang (Qualcomm)
Peter Hank (NXP)
V3 Jeff Heat (Linear Technologies)
V3 Benson Huang (Realtek)
Brian Jaroszewski (Vitesse)
Mike Jones (Micrel)
V3 William Keasler (Ikanos Communication Inc.)
Takeshi Kataoka (Renesas)
V3 Yong Kim (Broadcom)
V3 Albert Kuo (Realtek)
Michael Lerchenmüller (Cadence)
Wim van de Maele (ON Semiconductor)
V3 Chris Mash (Marvell)
Andy McLean (Texas Instruments)
Henry Muyshondt (Microchip Technology)
V3 Sujan Pandey (NXP)
Jan Polfliet (ON Semiconductor)
V3 Adee Ran (Intel)
V3 Pavlick Rimboim (Microsemi)
Takaharu Sato (THine Electronics)
Kevin Stanton (Intel)
Peter Schulmeyer (Freescale)
Robert Schweiger (Cadence)
Ole-Kristian Skroppa (Infineon)
Günter Sporer (NXP)
Nobukatsu Kitajima (Renesas)
V3 Pat Thaler (Broadcom)
Yoshiya Tsutsumi (Renesas)
Alexander Tan (Marvell)
V3 Mehmet Tazebay (Broadcom)
V3 Stefano Valle (ST Microelectronics)
Radoslaw Watroba (ST Microelectronics)

Connector & Cable Industry:

V3 Yakov Belopolsky (Bel Stewart Connector)
Todd Herman (Commscope)

Academia:

Hans Doran (Zurich University of Applied Sciences)
Andreas Grzemba (HS-Deggendorf)
Thomas Müller (Zurich University of Applied Sciences)
Axel Sikora (HS-Offenburg)
Hans Weibel (Zurich University of Applied Sciences)

additional:

V3 John D'Ambrosia (Dell)
V3 Hugh Barrass (Cisco)
V3 Koussalya Balasubramanian (Cisco System)
V3 Steve Carlson (High Speed Design)
Greg Destexhe (Techpoint Consulting)

Statistics:

- **145** individuals
- **34** 802.3 voters
- **71** affiliated with the automotive industry
- **13** affiliated with the industrial automation

Supporters (max. 3 per company)

additional:

V3 Curtis Donahue (UNH-IOL)
V3 David Estes (UNH-IOL)
Norman Finn (Cisco)
Peter Johnson (Sifos Technologies)
David Lucia (Sifos Technologies)
Harshang Pandya (Psiber Data)
V3 Geoff Thompson (GraCaSI Standards Advisors)
V3 Sterling Vaden (Vaden Enterprises)
V3 Georg Zimmerman (CME Consulting)

Statistics:
- **145** individuals
- **34** 802.3 voters
- **71** affiliated with the automotive industry
- **13** affiliated with the industrial automation

CFI Objective

- To gauge the interest in starting a study group developing a

1 Twisted Pair
100 [C] Mbit/s Ethernet

- This Meeting will NOT:
  - Fully explore the problem
  - Choose any one solution
  - Debate strengths and weaknesses of solutions
  - Create a PAR or 5 Criteria
  - Create a standard or specification
- Anyone in the room may speak / vote
- Respect … give it, get it

Agenda

- Overview
- The need for 100 Mbit/s
  - Target Markets
  - Use Cases
  - Why now?
- Technical Viability
- Automotive Market Potential
- Q&A
- Straw Polls

- Backup
  - Automotive Networking and Ethernet
  - Automotive Challenges

CFI 1 Twisted Pair 100 Mbit/s Ethernet (1TPCE)

Increase in ECUs, Signals and Especially Bandwidth

Agenda

- Overview
- The need for 100 Mbit/s
  - Target Markets
  - Use Cases
  - Why now?
- Technical Viability
- Automotive Market Potential
- Q&A
- Straw Polls

- Backup
  - Automotive Networking and Ethernet
  - Automotive Challenges

The Need for 100 Mbit/s – Target Markets

- **Automotive networking**
  - The dominant driving market for this CFI
  - Increasing bandwidth and interconnecting requirements for in-vehicle control systems
    - Starting point of automotive networking is CAN (< 1 Mbit/s) and FlexRay (< 10 Mbit/s) on shared medium
    - Large market volume (i. e., port count)
  - This presentation will focus on this segment

A 1 Twisted Pair 100 Mbit/s PHY could be leveraged across other segments including:

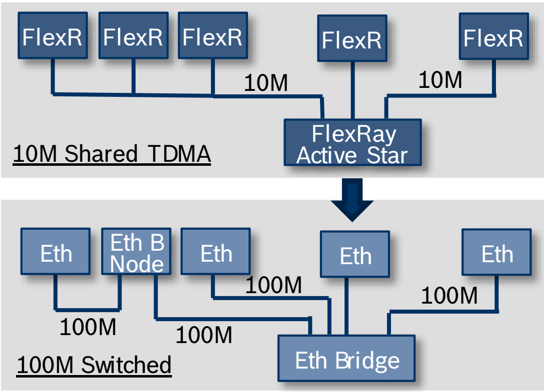
- **Industrial networking**
  - Re-use of current installed cable infrastructure with increased bandwidth
- **Avionics networking**
  - The need for weight savings for the cabling infrastructure is even more dominant than in the automotive industry

Why 100Mbit/s 1TPCE in Addition to 1000BASE-T1 / RTPGE

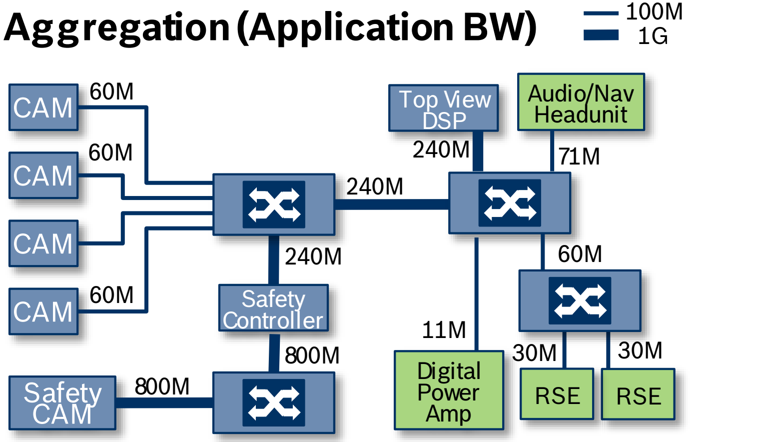
- 1TPCE is likely less expensive than 1000BASE-T1 / RTPGE (balanced costs, e. g. including µCs, component, power, wiring, etc.)
- Optimizing power and cost for each of the provisioned use case
  - Selecting optimized power and cost per vehicle sub-system is relevant
  - Required data rate of applications will determine choice of technology
  - Future proofing per node (relevant to IT Ethernet) is not needed
- 1000BASE-T1 / RTPGE use cases are:
  - ADAS cameras, infotainment video, network backbone and diagnostics
  - GE is needed when a single applications exceed 100 Mbit/s, the next speed up
- 1TPCE use cases for are :
  - Advanced Driver Assistance Systems (Radar Sensors, Inter-ECU connections)
  - Powertrain (Sensors and Inter-ECU connections)
  - Platform ECUs like Engine Control, **A**nti-lock **B**reaking **S**ystems (**ABS**), **E**lectronic **S**tability **P**rogram (**ESP**) (also know as **ESC** or **DSC**)
  - Infotainment and connectivity

Use Cases Automotive Ethernet

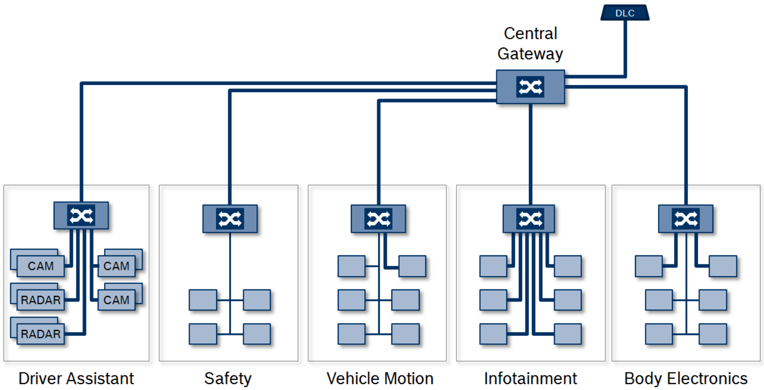
Control Network



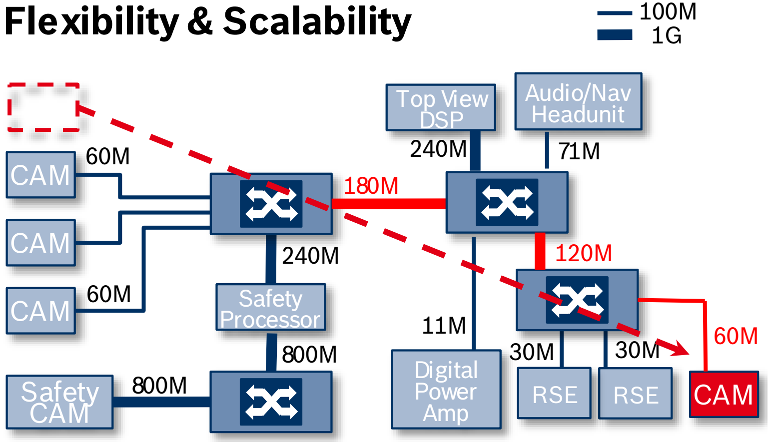
Aggregation (Application BW)



Control Backbone

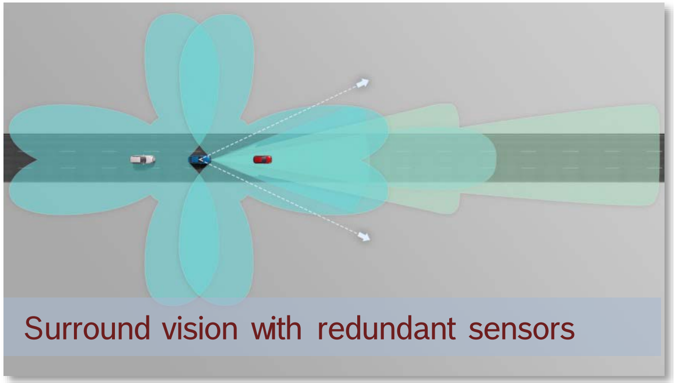


Flexibility & Scalability



Use Case: Advanced Driver Assistance Systems

- 4-6 mono cameras (100 Mbit/s, 1 Gbit/s)
- 1-2 stereo cameras (100 Mbit/s, 1 Gbit/s)
- 2-4 mid-range radar (100 Mbit/s)
- 2 long range radar (100 Mbit/s)
- 0- 4 LiDAR (100 Mbit/s)
- 8-16 ultrasonic sensors, 4 wheel speed sensors,
- Redundant data centers (100 Mbit/s, 1 Gbit/s)
  - Number crunchers for data fusion
  - ABS, ESP, ...
  - Some ECUs we cannot tell you details today ☺
- Interaction with powertrain, body domain, navigation, airbag, CAR2CAR, CAR2Infrastructure



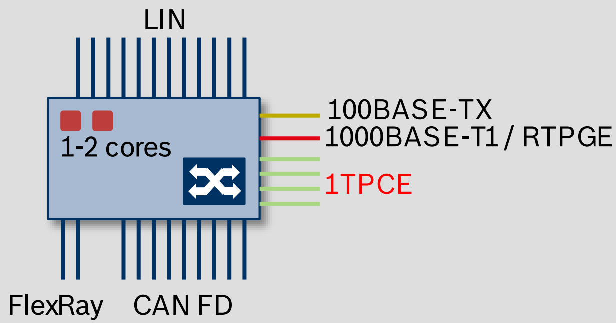
Surround vision with redundant sensors

Automated driving is leaving the research labs. Soon it will be in mass production.

Does this look familiar to data centers?

Use Case: Typical Gateway Requirements SOP 2018-20

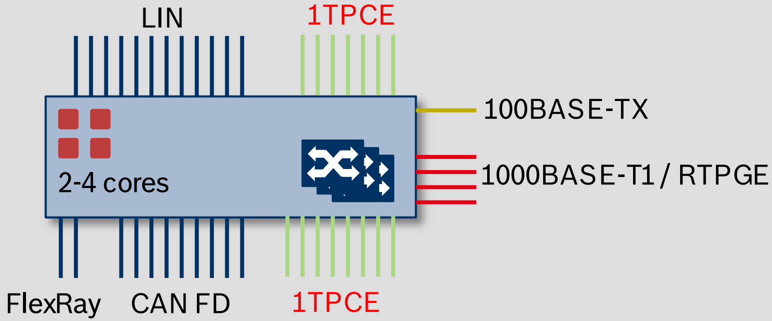
Volume segment cars



Number of ports / busses

- 4 - 10 x CAN FD
- 0 - 2 x FlexRay
- 8 - 16 x LIN
- 1 x 100BASE-TX
- 2 - 6 x 1TPCE
- 0 - 2 x 1000BASE-T1 / RTPGE

Premium segment cars



Number of ports / busses

- 6 - 10 x CAN FD
- 0 - 2 x FlexRay
- 8 - 16 x LIN
- 1 x 100BASE-TX
- 5 - 15 x 1TPCE
- 0 - 4 x 1000BASE-T1 / RTPGE

Remark: Automotive gateways work on all 7 OSI-Layers. There is no unified network layer for typical automotive bus-systems. Routers in IT work on Layer 3 (Internet Protocol).

Market Communication Systems View

Possibility to phase out

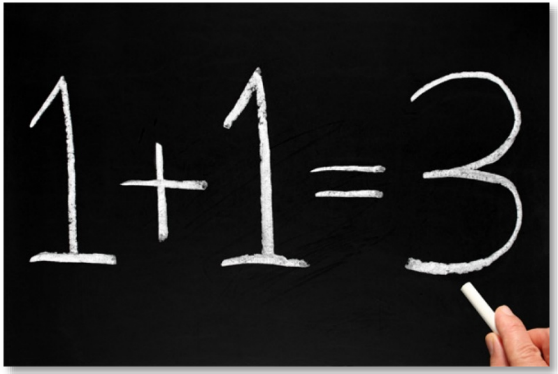
		2010	2015	2020
Vehicle Domains	Powertrain	CAN, FR	CAN, FR	CAN FD, FR, 1TPCE
	Body	CAN	CAN	CAN FD, 1TPCE
	Infotainment	CAN, MOST	CAN, MOST, OABR*	CAN FD, MOST, 1TPCE, RTPGE
	Vehicle Motion & Safety	CAN, FR	CAN, FR	CAN FD, FR, 1TPCE, RTPGE
Specific Apps	Camera Systems	LVDS, Analog	LVDS, Analog, OABR*	LVDS, 1TPCE, RTPGE
	Diagnostics	CAN, FE	CAN, FE	CAN, FE, RTPGE
	Domain ECU Backbone			1TPCE, RTPGE

*OABR: OPEN Alliance BroadR-Reach

Advantages of Comprehensive IEEE Eco-System

- Car manufacturers are already installing a 100 Mbit/s PHY solution existing outside IEEE (Unshielded Twisted Single Pair UTSP)
- 1000BASE-T1 / RTPGE leveraged some of the work accomplished with this external solution (EMC, automotive environment, wiring, etc.)
- Standardization in IEEE means synergies:
  - 1 + 1 equals more than 2
  - X-referencing between standards (e.g. PoDL)
  - Coexistence with 1000BASE-T1 / RTPGE
  - One time development of additional features like energy efficiency for multiple speed grades

- **Bring the technology back home to IEEE 802.3**

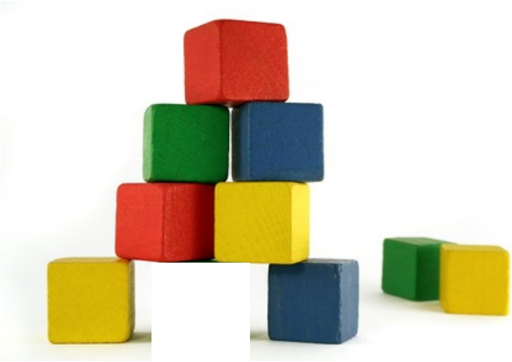


IEEE 802 Automotive Ethernet Eco-System

- IEEE 802.3 for Diagnostics and Flashing
  - S 100BASE-TX

- IEEE 802.3 for In-vehicle communication
  - T 802.3bp 1000BASE-T1 / RTPGE
  - T 802.3bu PoDL
  - T 802.3br Interspersing Express
  - **C 1TPCE**
  - C Gigabit over Plastic Optical Fiber (POF)
  - I 10 GE for Automotive

- IEEE 802.1 Data Link Layer
  - S Audio Video Bridging
    802.1 BA, 802.1 AS, 802.1 Qat, 802.1 Qav
  - T Time Sensitive Networks
    802.1 CB, 802.1 ASbt, 802.1 Qbv, 802.1 Qbu, 802.1 Qca, 802.1 Qcc



Something is missing!

I= Idea; C = CFI; T = TaskForce; S = Standard

Why Now? Why Single Pair?

- Automotive decision process
  - To capture share of the rising automotive Ethernet market standard needs to be available ASAP
  - Decisions in automotive are taken at least 3 years ahead of **S**tart **O**f **P**roduction (SOP)
- We standardize GE for automotive on a single pair with the underlying cabling harness infrastructure
  - Less weight
  - Less size
- Lower cost ECUs with 100 Mbit/s port

- Recap: cable harness is 3rd heaviest and 3rd most costly component

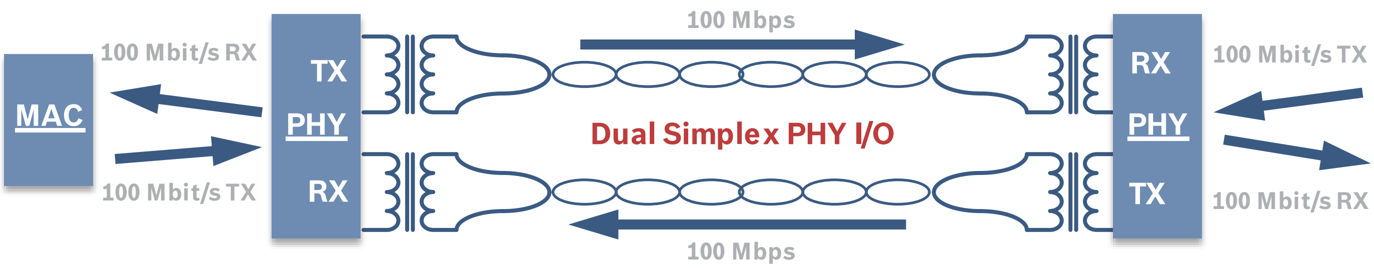
Agenda

- Overview
- The need for 100 Mbit/s
  - Target Markets
  - Use Cases
  - Why now?
- Technical Viability
- Automotive Market Potential
- Q&A
- Straw Polls

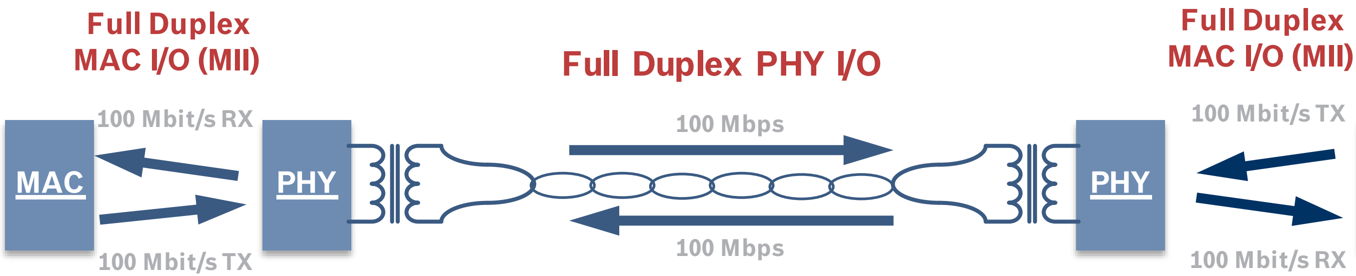
- Backup
  - Automotive Networking and Ethernet
  - Automotive Challenges

Duplicity: MAC View and PHY View

- **SerDes, 10BASE-T, 100BASE-TX all operate with unidirectional transmission per wire pair**



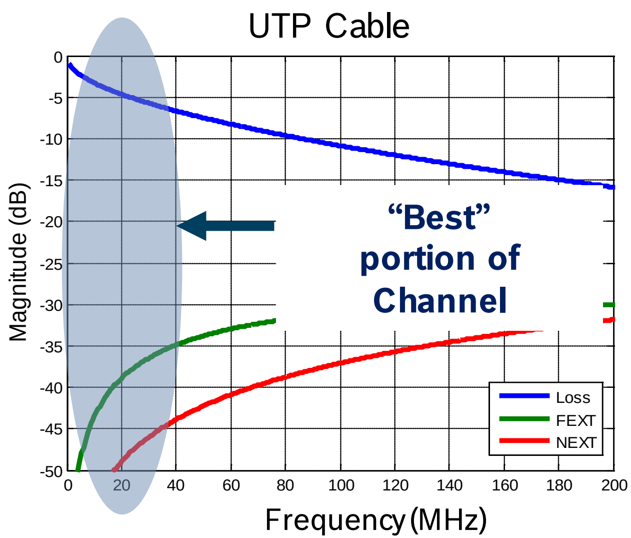
- **OABR*, 1000BASE-T, 10GBASE-T all operate with bi-directional transmission per wire pair**



*OABR: OPEN Alliance BroadR-Reach

PHY Strategy for TP Cable Channels

- **Twisted pair cable channels favor narrow baseband communications strategies**
  - Insertion loss increases with frequency
  - Impairments increase with frequency
    - Crosstalk, return loss
  - ***Balance degrades with frequency***
    - Emissions, immunity



- **Best strategy is to minimize bandwidth**
  - Maximizes available channel capacity

- **Techniques for bandwidth efficient data transmission**
  - Multi-level signaling
  - Equalization
  - Full duplex operation (echo cancellation)

Widely deployed in Std IEEE PHYs

OABR* 100 Mbit/s Ethernet Physical Layer

IEEE Gigabit (1000BASE-T) uses 5 level signaling

- Full Duplex
- PAM-5, 125 Msps, 65~80MHz bandwidth
- Four twisted pairs
- Partial response transmit filter
- Additional level for error correction coding
- Echo and crosstalk cancellation in DSP
- Decision Feedback Equalization (DFE)

OABR* Ethernet uses 3 level signaling

- Full Duplex
- Echo cancellation
- PAM-3, 66.7Msps, **33.3MHz bandwidth**
- Single twisted pair
- Decision Feedback Equalization (DFE)

IEEE 100BASE-TX uses 3 level signaling

- Dual Simplex
- MLT-3, 125Msps, 65~80MHz bandwidth
- Two twisted pairs
- Decision Feedback Equalization (DFE)

- **Bandwidth reduced by over 2x**
- **Operates over lower quality cabling**
- **Permits aggressive filtering for improved emissions & immunity**

*OABR: OPEN Alliance BroadR-Reach

Technical Viability Summary

- OPEN Alliance adopted 802.3 framework and was developed outside of the IEEE 802.3
- This development effort proliferated the creation of the complete "Eco-System" for one-pair 100Mbit/s Automotive Ethernet
  - UTP cables, connectors, magnetics, test equipment & software for the support of one-pair 100Mbit/s solution well beyond the PHY definition
- Leverages parts of IEEE 802.3 100BASE-TX and 1000BASE-T standards
- This is deployed technology in automotive industry today

Agenda

- Overview
- The need for 100 Mbit/s
  - Target Markets
  - Use Cases
  - Why now?
- Technical Viability
- Automotive Market Potential
- Q&A
- Straw Polls

- Backup
  - Automotive Networking and Ethernet
  - Automotive Challenges

Automotive Market Potential

Updated forecast from 2012 CFI for RTPGE

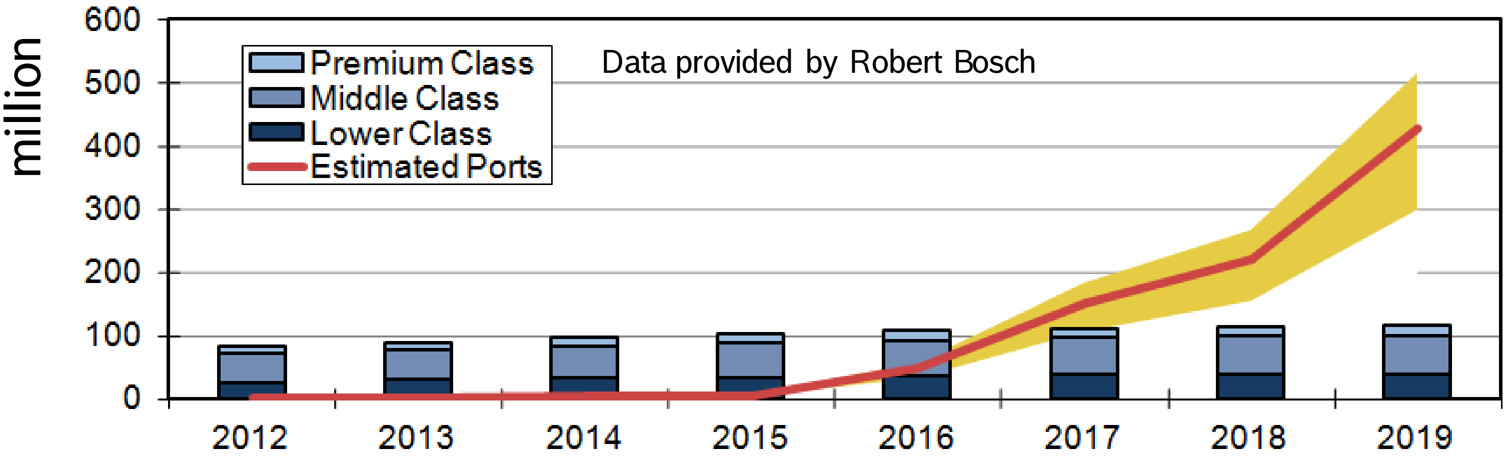
- For RTPGE CFI we forecasted 270 million Ethernet ports by 2019/20
- We were wrong, sorry!
- We now assume about 400 million ports

Some numbers

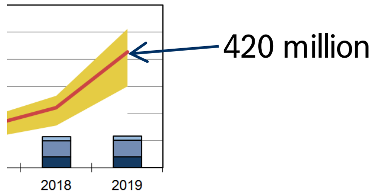
- In 2019 the automotive industry will produce 117 million vehicles
- Up to 35 ports (20 avg.) in premium class vehicles and 20 (8 avg.) in medium class vehicles that have Ethernet

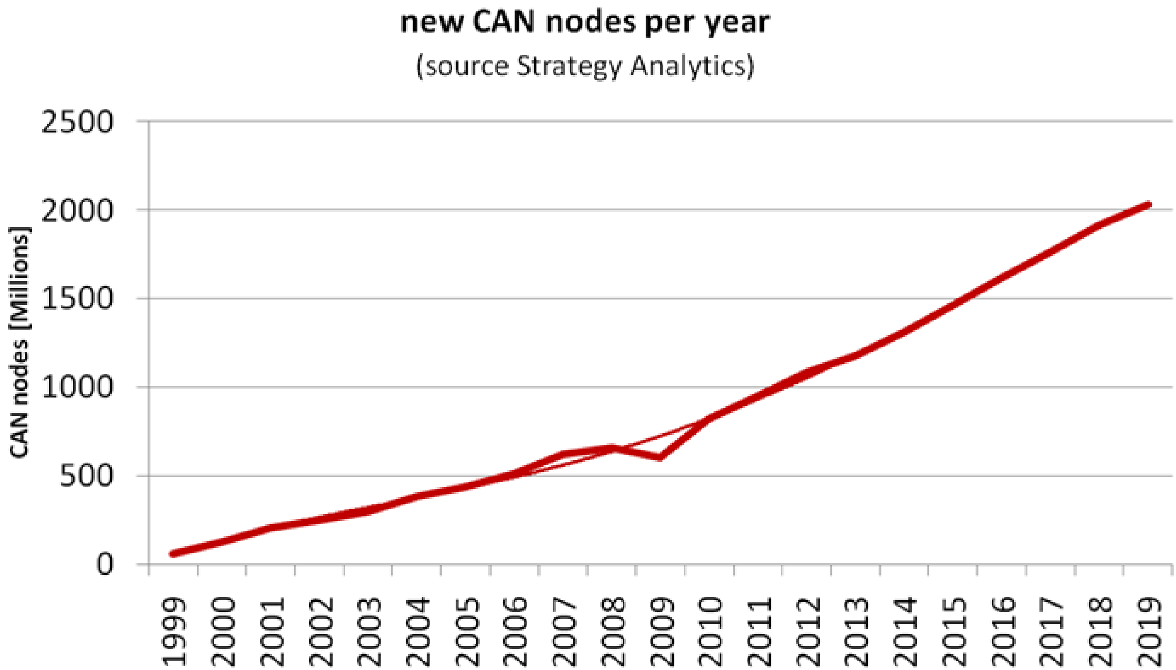
Ethernet increases creativity for new applications

- Ethernet provides an infrastructure for automotive innovations



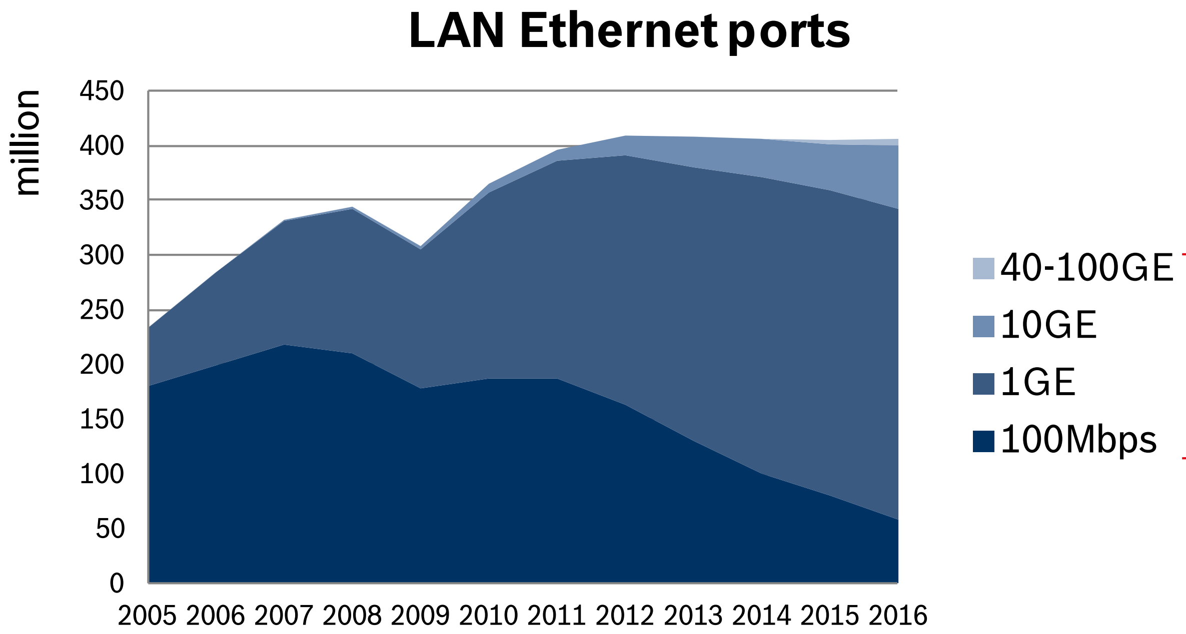
How the Use of a Base Technology CAN Evolves





- CAN (ISO11898) has seen a continuous increase of nodes
- 1 CAN link = 1 PHY, 1 Ethernet link = 2 PHYs
- Automotive business is compared to consumer electronics a very stable business
- Once in, it will stay for several vehicle platform generations (typical platform cycle ≈ 7 years)

Comparison with 400 Million Ethernet LAN Ports



Using various media: twisted pair, fiber, copper, twin-ax → > 10 solutions

Source: Dell'Oro Ethernet Switch Forecast Report, July 2012

Summary

- Automotive electronic/electric architecture is changing; Ethernet based in-car networking facilitates these changes
  - New ADAS like highly automated driving require new high bandwidth real-time networks
  - Higher integration of ECU to domain based architectures
  - Backbone architectures
- 100 Mbit/s is needed as well as 1 Gbit/s for balanced cost reasons
  - Power consumption
  - Potentially easier to achieve EMC
  - Simplicity, the simpler the technology the less effort it is to implement the complete system
- 1TPCE enhances the IEEE automotive Ethernet ecosystem
- Synergy potential

Agenda

- Overview
- The need for 100 Mbit/s
  - Target Markets
  - Use Cases
  - Why now?
- Technical Viability
- Automotive Market Potential
- Q&A
- Straw Polls

- Backup
  - Automotive Networking and Ethernet
  - Automotive Challenges

1 Twisted Pair
100 Mbit/s Ethernet
PHY

Q&A 15 min

Straw Polls

60 Number of people in the room

30 Individuals who would attend and contribute to a
1 Twisted Pair 100 Mbit/s Ethernet (1TPCE) PHY Study Group

31 Companies that support the formation of a
1 Twisted Pair 100 Mbit/s Ethernet (1TPCE) PHY Study Group

Straw Polls

Request that IEEE 802.3 WG form a study group to develop a PAR and 5 Criteria for a:

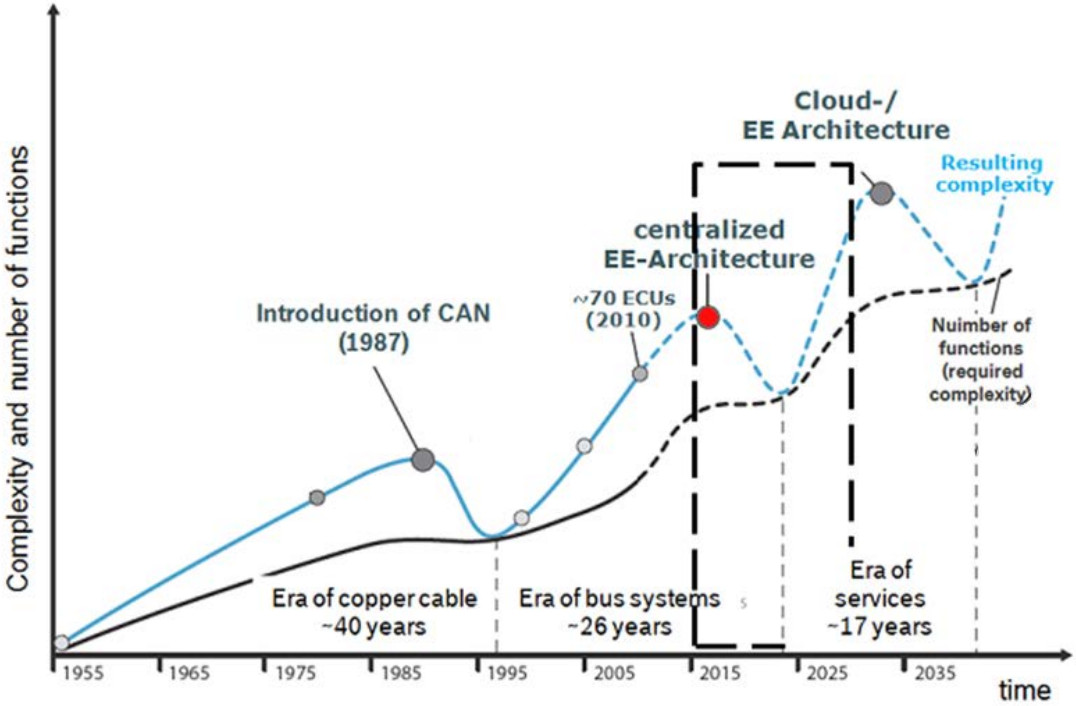
1 Twisted Pair 100 Mbit/s Ethernet (1TPCE) PHY

People in the Room	Dot 3 Voters Only
Y: 52	Y: 35
N: 0	N: 0
A: 6	A: 2

Backup

- Automotive Networking and Ethernet
- Automotive technical challenges

Electronic/Electric Architecture Cycles in Automotive



- CAN dominated E-/E-architectures for the last three decades because of robustness and good flexibility
- CAN cannot fulfill all needs of future E-/E-architectures:
  - New **A**dvanced **D**river **A**ssistant **S**ystems (ADAS) and multimedia systems demand for more data rate and QoS
  - Need for reduction of complexity leads to domain based, centralized and backbone driven architectures

Illustration Source: Bundesminsterium für Wirtschaft und Technik: "eCar-IKT-Systemarchitektur für Elektromobilität"

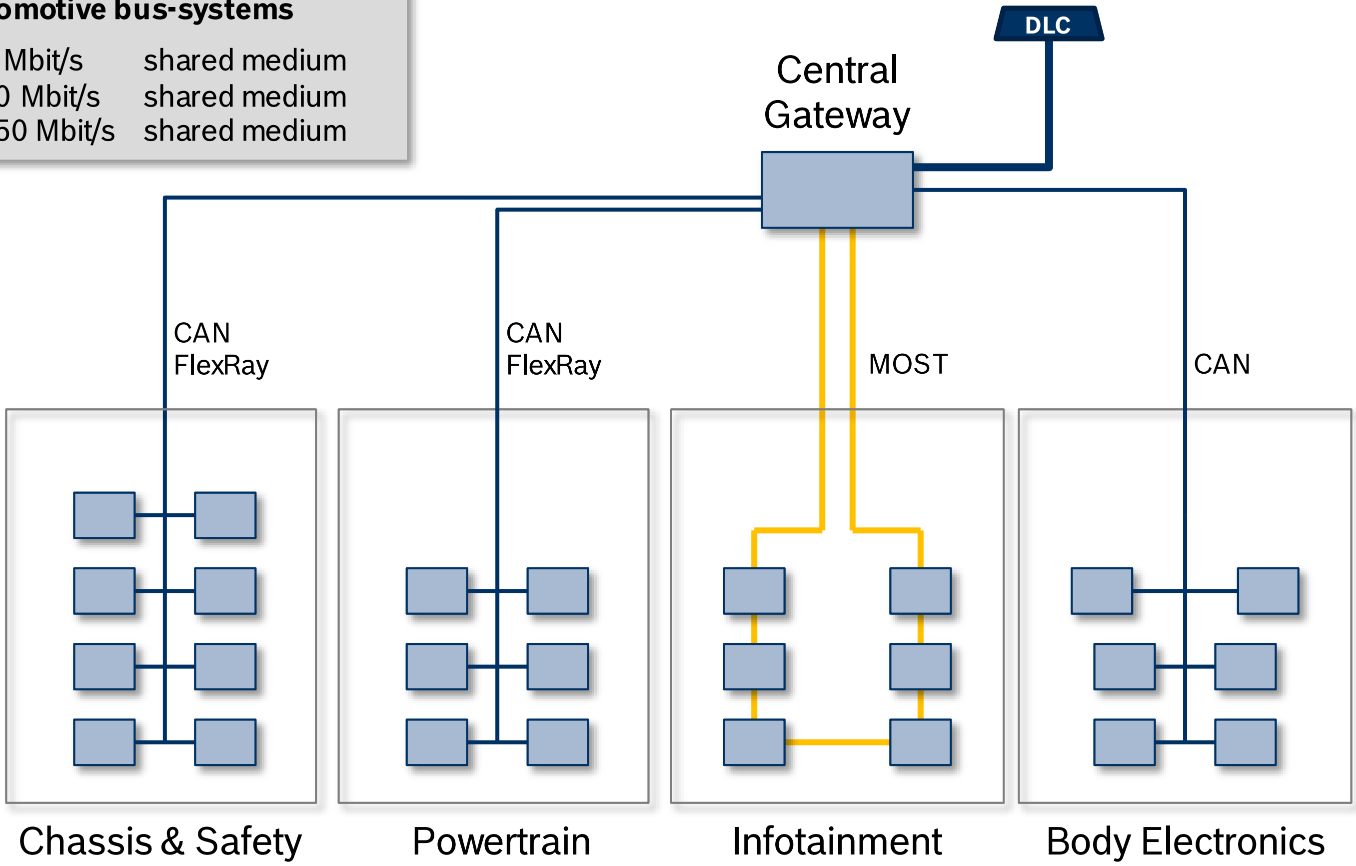
Example of Current E/E Architecture

Properties of typical automotive bus-systems

CAN	ISO11898	< 1 Mbit/s	shared medium
FlexRay	ISO 17458	< 10 Mbit/s	shared medium
MOST		< 150 Mbit/s	shared medium

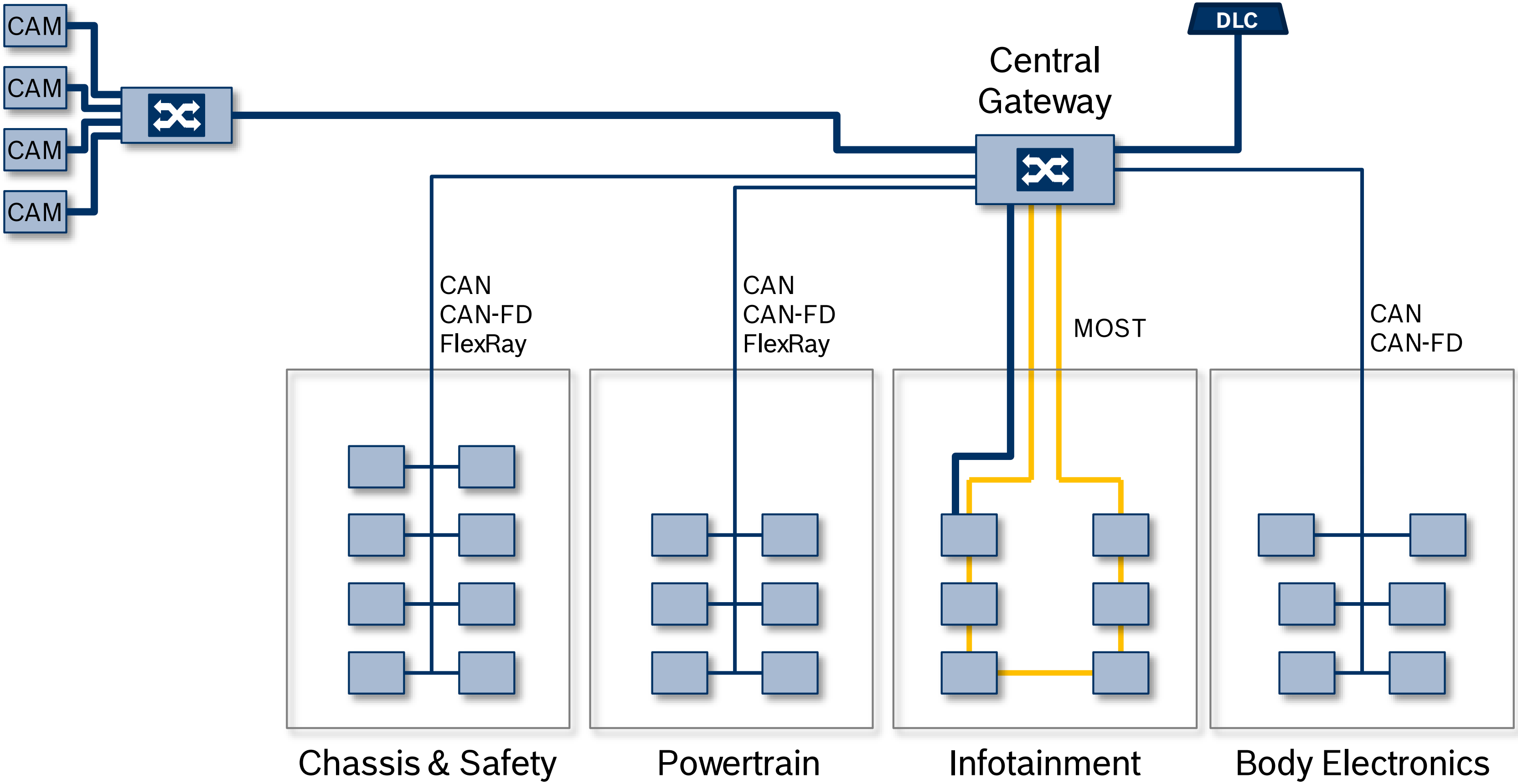
Ethernet

Bus-Systems



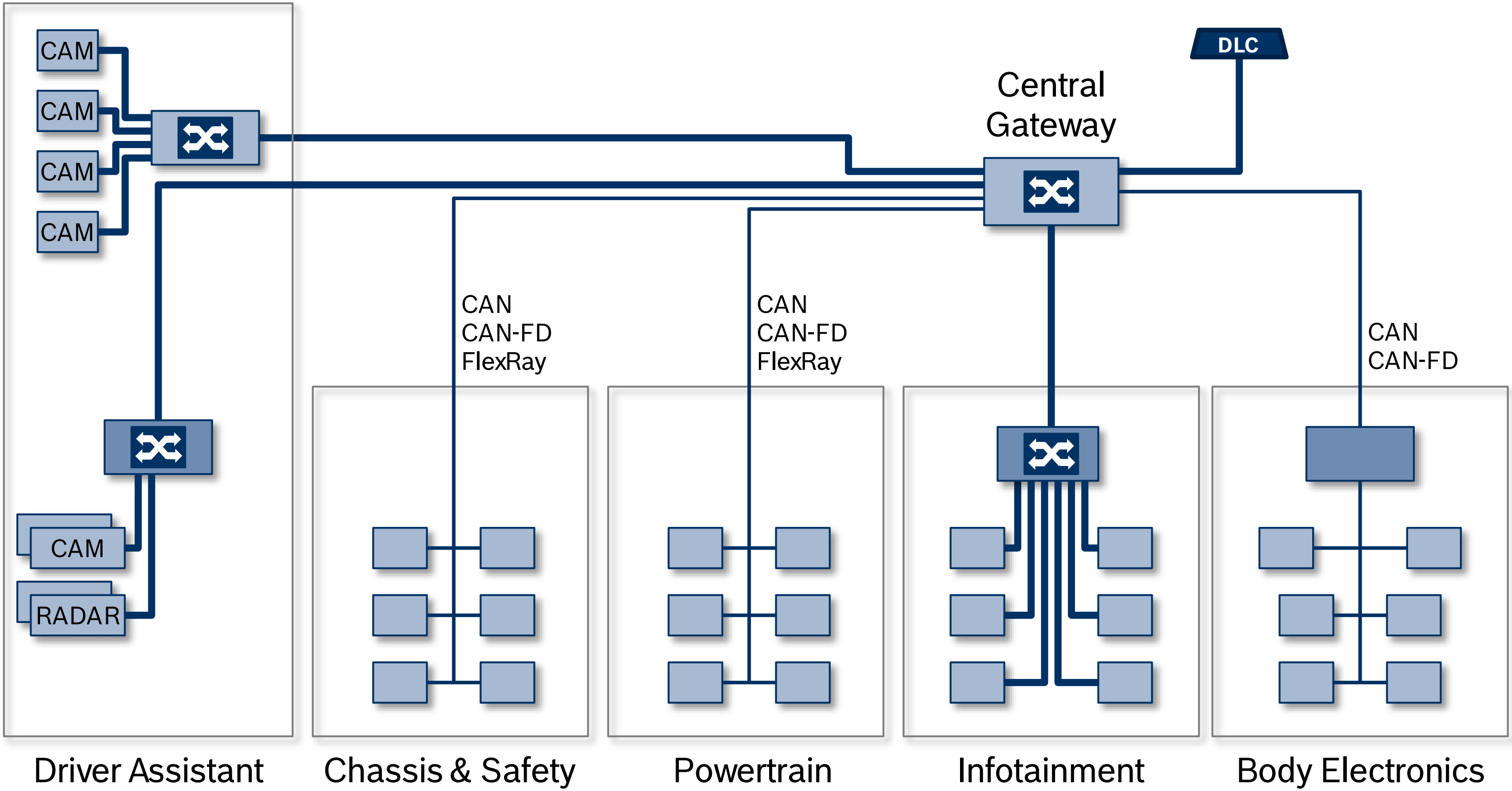
Switch ECU Domain-ECU

Introduction - Automotive Ethernet in 2015



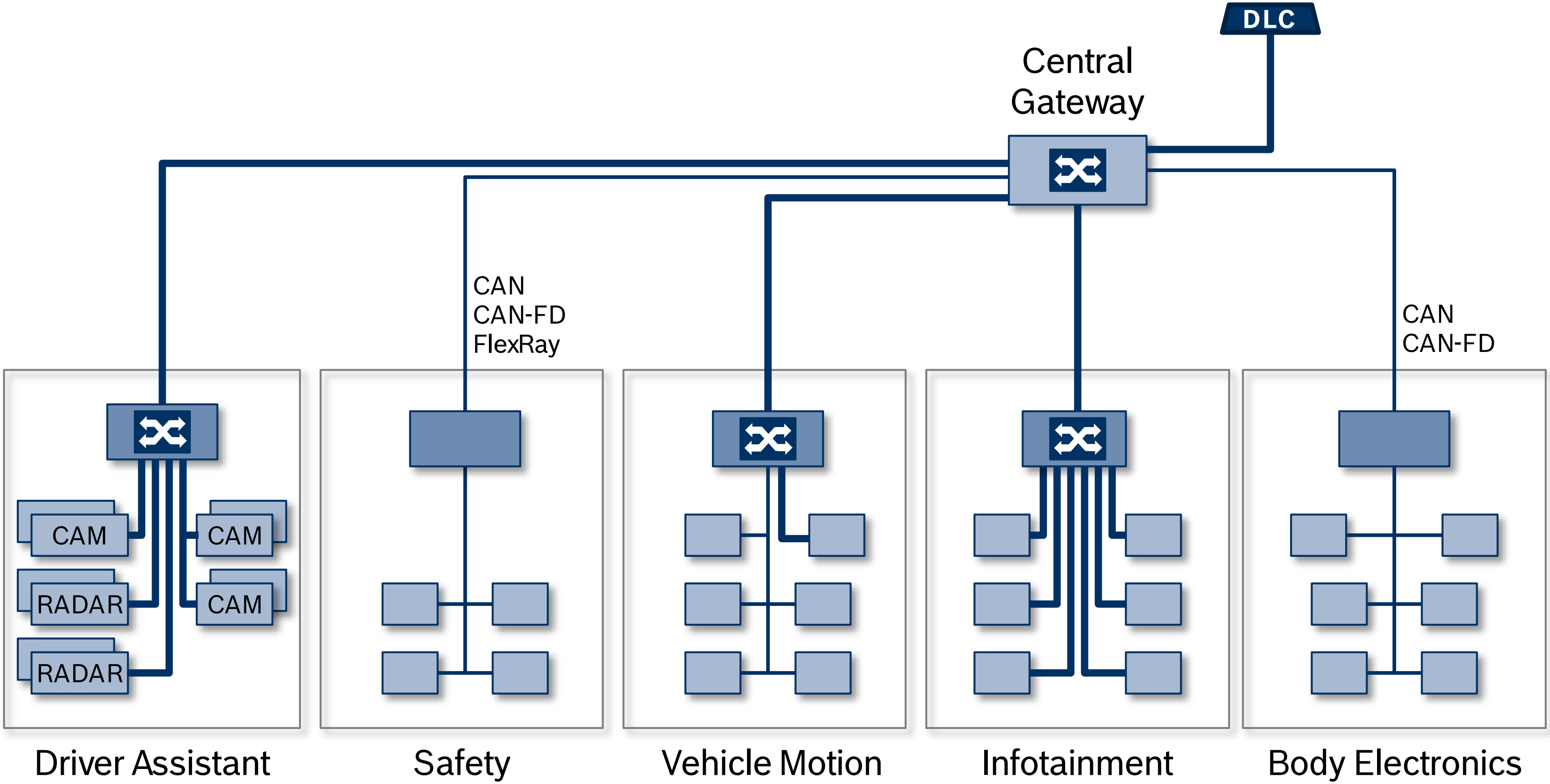
Surround-view camera systems and infotainment

Automotive Ethernet - 2015...2017



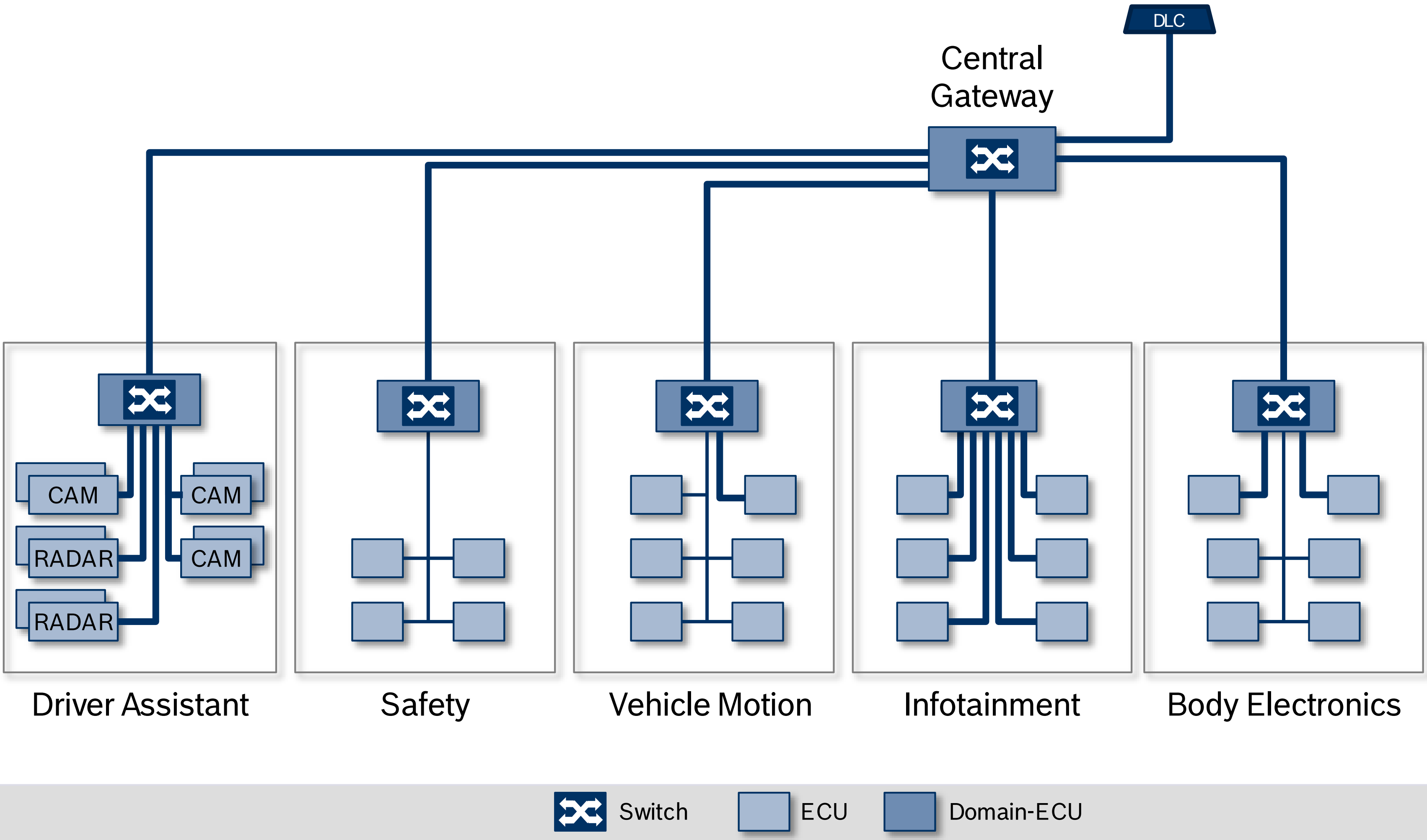
Higher bandwidth requirements for ADAS and Infotainment System

Hybrid Backbone with Domain-ECUs in ~2018ff

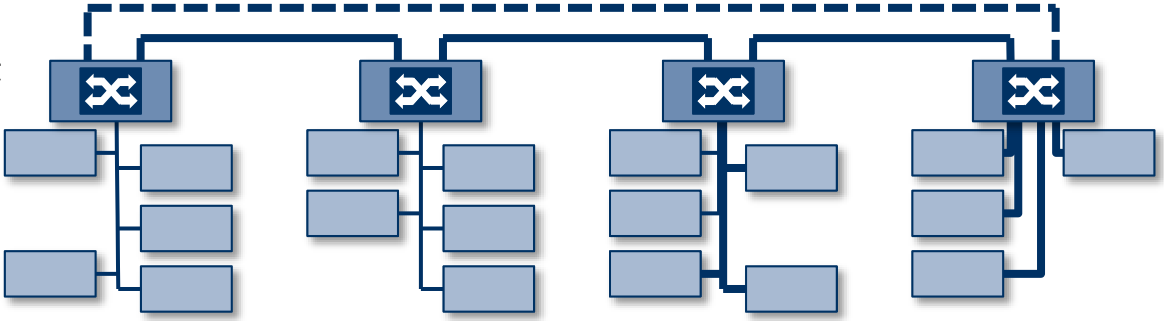


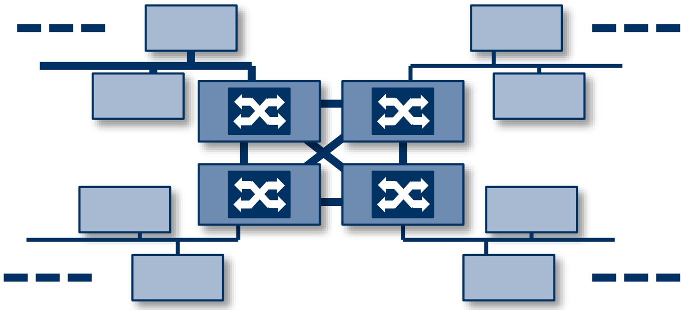
Ethernet, CAN/CAN-FD and FlexRay connected to one Central Gateway

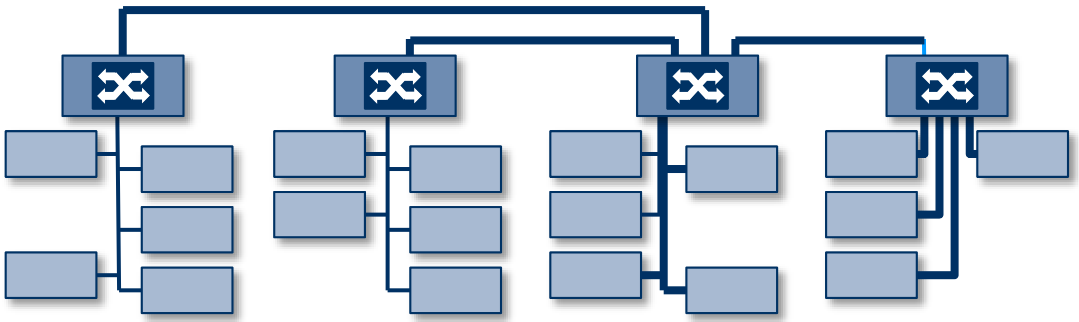
Domain-ECUs & Ethernet-Backbone



Variants of Backbone Architecture







Backbone can be implemented in different ways

Automotive Challenges

- Harsh Environmental Conditions
  - Operating temperatures:
    - Body & cabin: -40°C to 85°C
    - Chassis & powertrain: -40°C to 125°C or even 150°C
  - Mechanical accelerations:
    - Body & cabin: up to 4 G
  - Dirt, water, salt, dust, ice, snow, mud, oil, grease, transmission fluid, brake fluid, engine coolant, hydraulic fluid, fuel, etc. (i.e., this is not a data center)

- Automotive EMC requirements are stringent!
  - Tighter requirements than Class A/Class B EMI specs for consumer products
  - Automotive EMC test specs exist, e.g., CISPR25 & ISO11452-2 & -4
  - Cost and weight constraints - unshielded twisted pair cabling only

- Very low standby power requirements
  - Standby power needs << 100 uA

You may want to review the very good tutorials at IEEE802.3bp (Link 1; Link 2; Link 3; Link 4)