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Future Automotive E/E Architectures – On the Path towards a new E/E Paradigm

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Agenda

- Introduction and Motivation
- Vehicle Cloud & Edge Computing
- Software-Defined Vehicles
- Centralized Hardware Architectures
- Implications for Automotive Players

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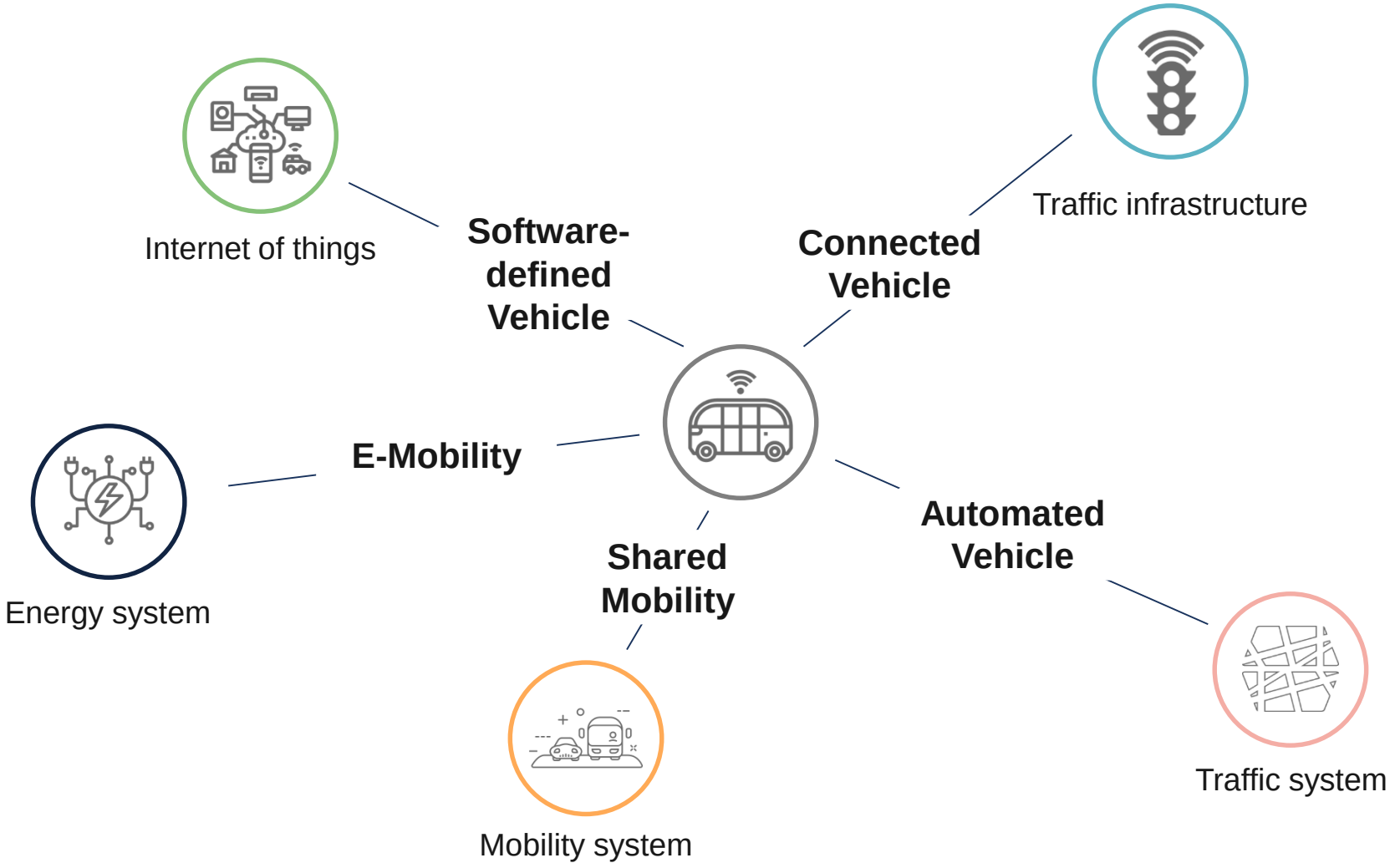
As a consequence of digital mobility, the vehicle becomes a component of large higher-level systems



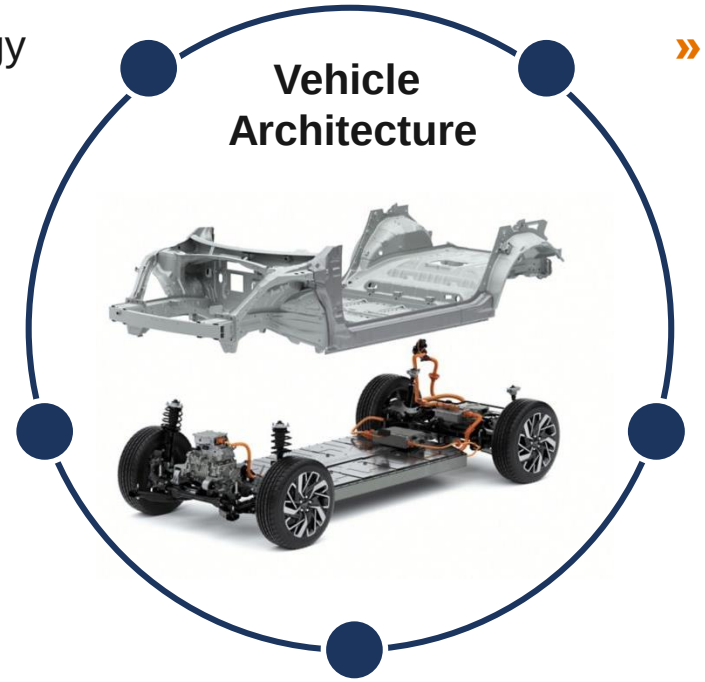
Current development trends in the automotive industry imply comprehensive changes to vehicles' E/E architecture

Electric Mobility

- New high-voltage levels
- Impact on energy network topology

Automated Driving

- Impact on basic vehicle functions
- New hardware and software architectures



Shared mobility

- Completely new vehicle layouts
- Normally purpose-design approach

Software-defined vehicles

- Enabler for all vehicle functions
- Vehicle as a software-centric product

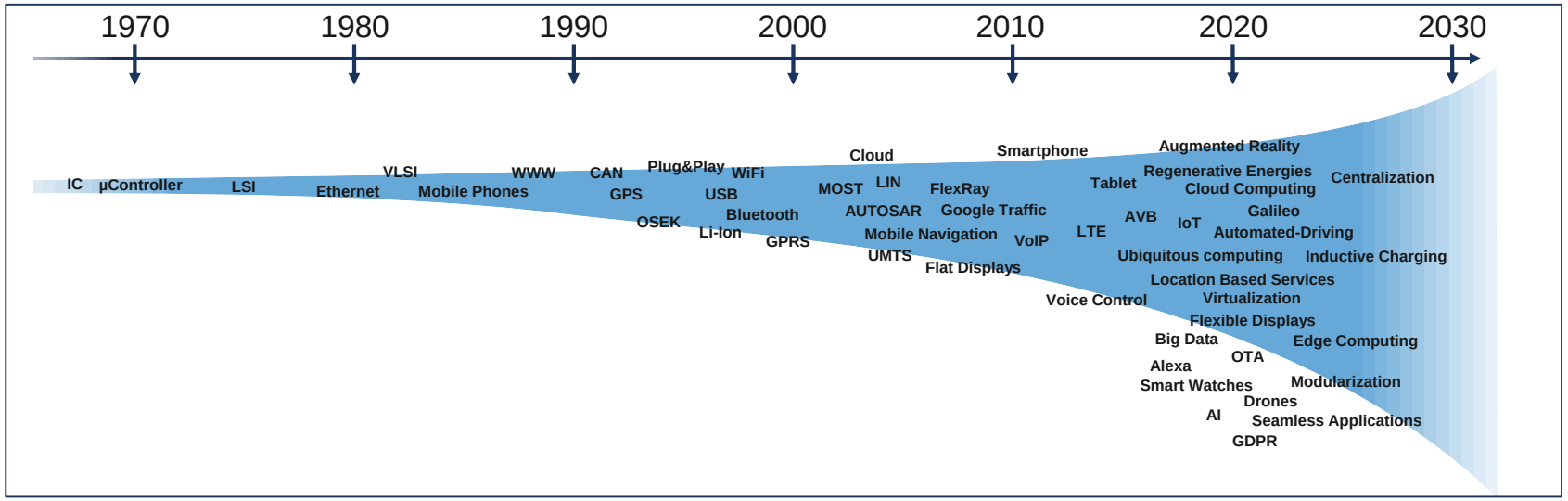
Connected vehicles

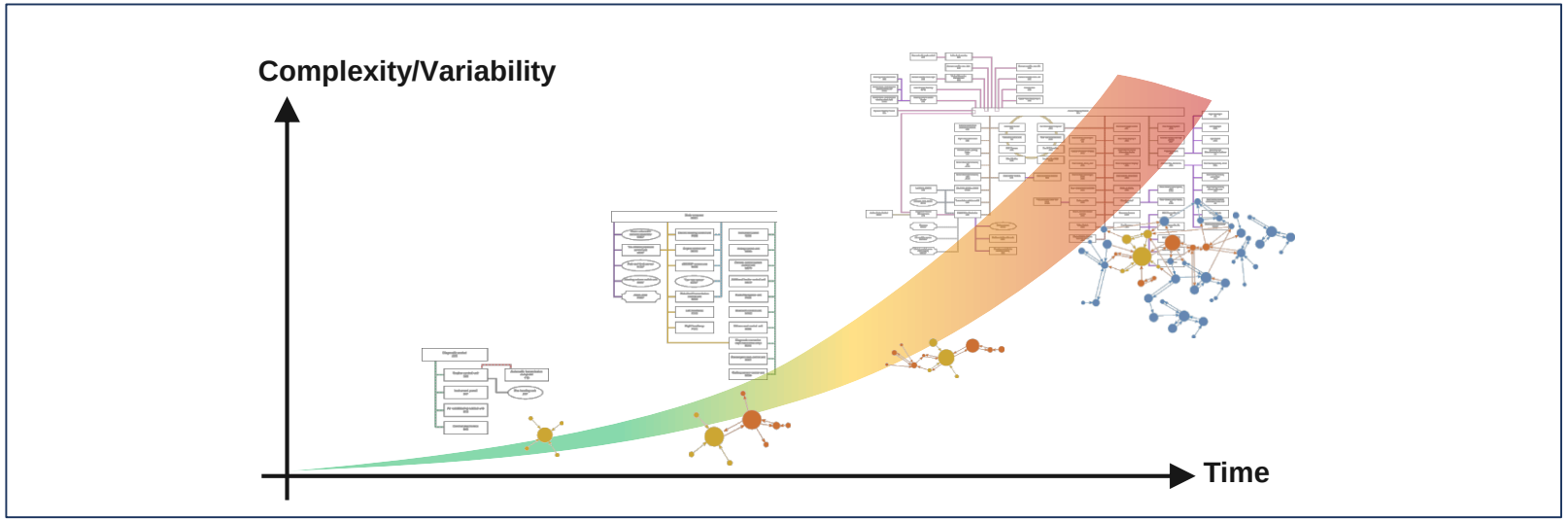
- Functions based on vehicle-external data
- Upgradeability becomes key requirement

The high technological variance of future mobility requires new approaches to manage complexity

Image Source: Hyundai

Technological progress for E/E systems further accelerating, hence also increasing complexity in the automotive E/E domain





Technological dynamics:

- Technological development pace for general E/E systems has increased significantly
- High number of potentially disruptive technologies

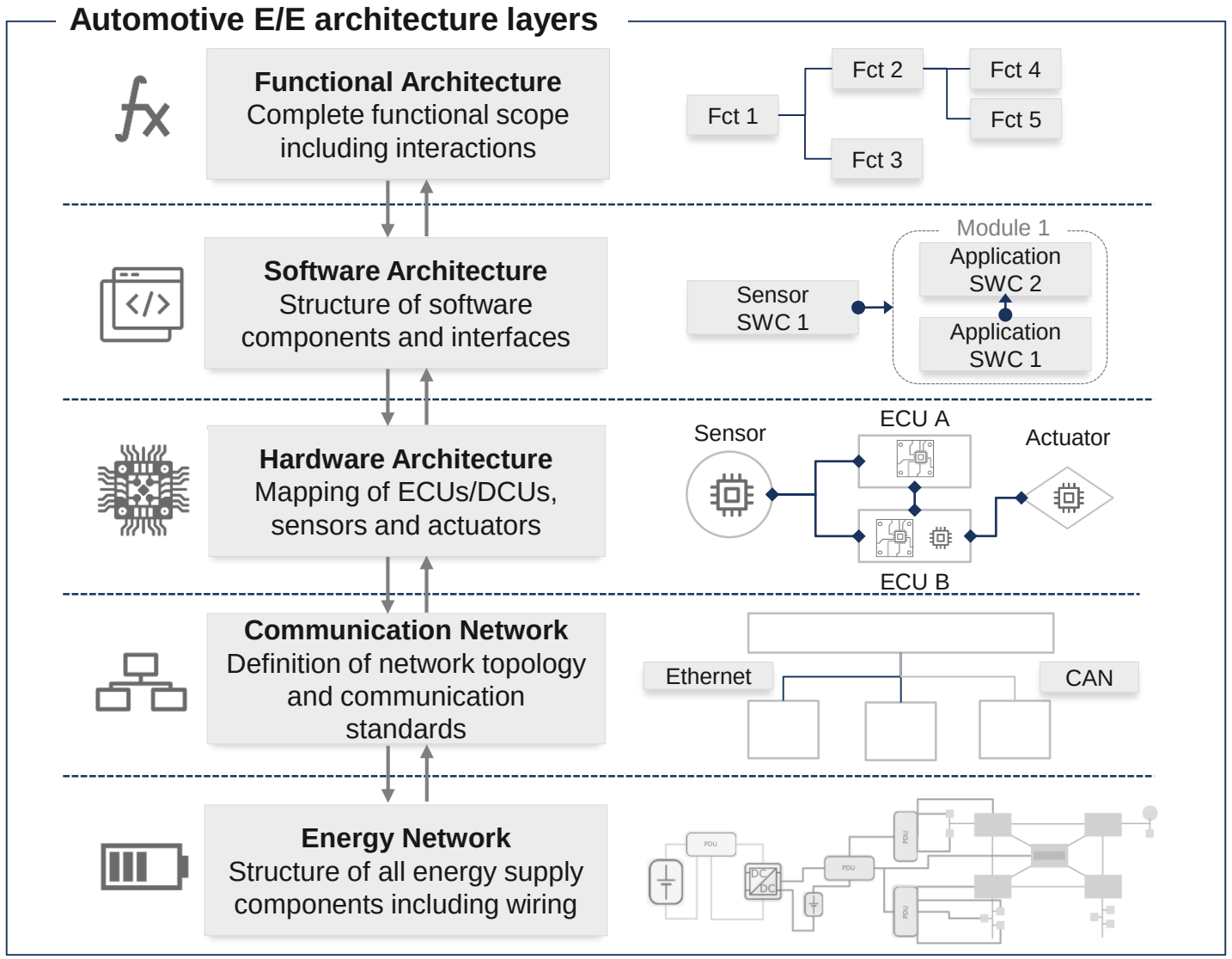
Automotive E/E impact:

- Continuous integration of new technologies and functions
- Reduction of development cycle times required
- Increasing complexity on HW and SW level

New development and implementation approaches for automotive E/E architectures affect all architectural layers

Emergence of a new E/E paradigm:

- Previous decades: Rather **evolutionary development** path of vehicle's E/E domain
- **Requirements** for E/E architectures have **increased** extremely, multitude of new functions have to be implemented
- **New development and implementation approaches for** automotive E/E architectures are currently gaining traction
- **Traditional OEM are restructuring** their processes, supply chains and organizational structure
- Automotive industry is about to **switch to a new E/E paradigm**, affecting all players with any kind of E/E hardware or software



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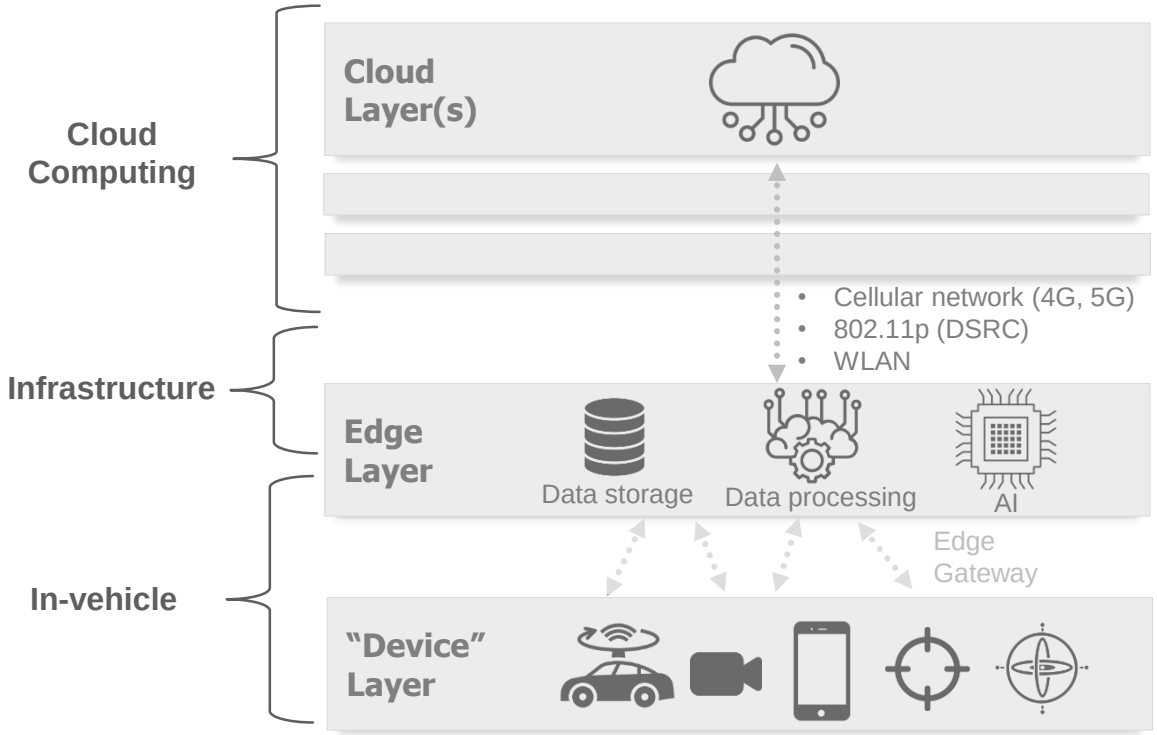
Vehicle Edge and Cloud Computing extend the system scope beyond the actual vehicle and enable new functions

Automotive E/E architecture layers



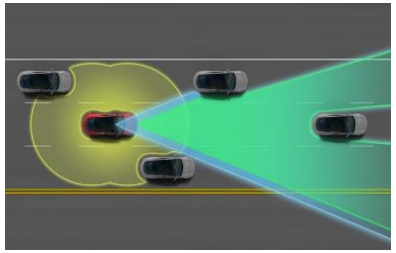
Definition: Vehicle Edge Computing

- **Basic concept:** Capturing and processing data as close to the data source as possible
- **"Network edge":** Network-embedded infrastructure
- **"Device edge":** Devices connected to the wireless network
- **"Vehicular edge computing (VEC)"**: Utilization of edge nodes in close proximity of vehicles (e.g. in road side units)
- **Reasons for edge computing** (compared to cloud computing)
  - Reduced latency and increased speed
  - Reduce congestion of (future) networks
  - Improved security and privacy
  - Reliability and robustness

Tesla extensively uses Edge and Cloud Computing approaches to further develop ADAS/AD functions of their vehicles

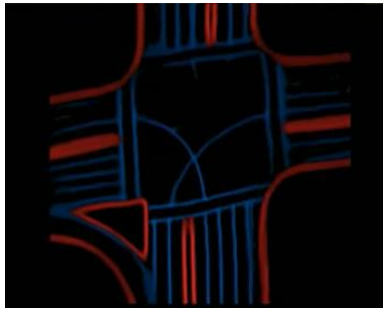
Example: Neural network training data

- Using complete **Tesla fleet for generating training data** for neural networks incl. shadow mode
- Identification of **training data for transmission to cloud** from vehicles, e.g. to identify “edge cases”
- Additionally: **Shadow mode** calculated trajectories are offset against actual driver trajectories



Data sources

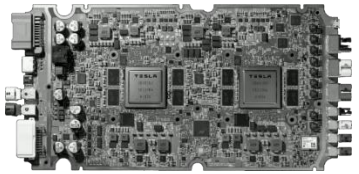
- 8 cameras
- Odometry etc.
- Localization information



Data usage

- Trajectory planning
- Object recognition

Edge (in-veh.)



- Hardware: FSD computer
- High specialization on convolutional neural networks (CNN)
- Shadow mode execution

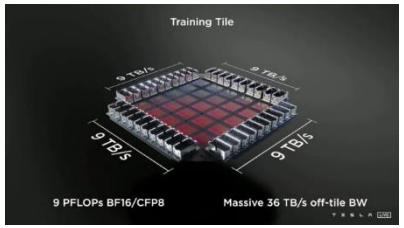
4G mobile network / WLAN

- Raw or processed image data and further data
- Evaluation data in shadow mode

4G mobile network / WLAN

- Trained neural network updates, also in shadow mode

Cloud



- 3 computing clusters for labelling and training
- Automated & manual labeling
- Automated distributed iterative training and evaluation of neural networks
- Development of own cloud architecture

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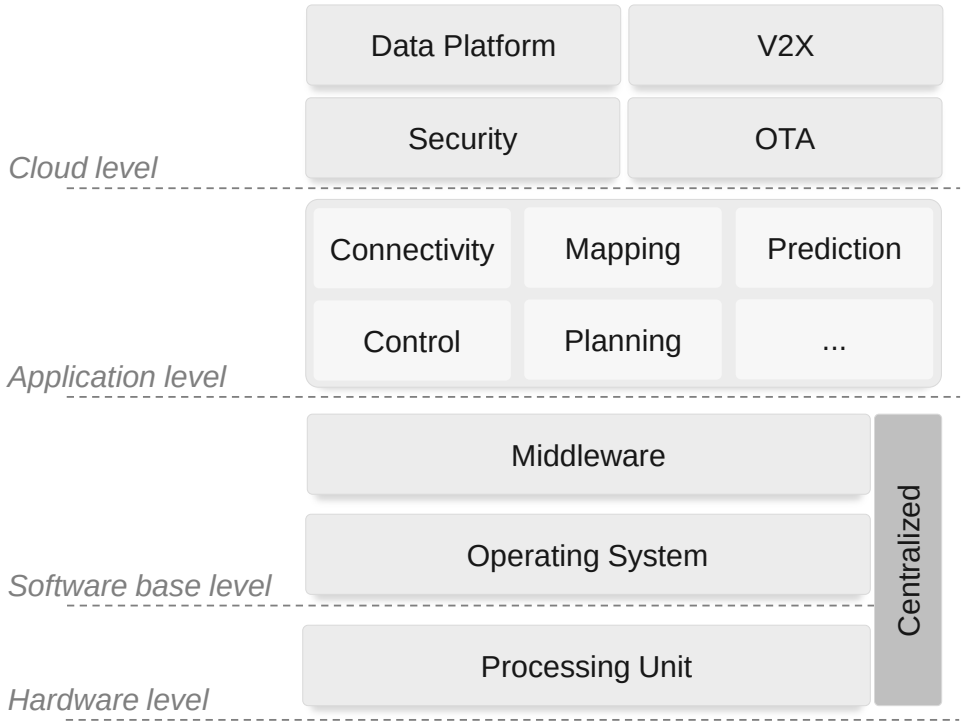
The emergence of Software-Defined Vehicles represents a fundamental change of development focus for the industry

Definition: Software-Defined Vehicle (SDV)

- **Software-first approach**: Vehicle functions and features are mainly as software
- **Shift of focus** from hardware-based electromechanical product **to software-centric system**
- Enables an **abstraction from** the underlying **hardware**, hence **facilitating updates and upgrades** of functions

Automotive software stack



- **SDVs** require a **complete redesign** of the automotive software architecture
- Hardware abstraction is realized by a **strict separation between software and hardware**
- **Middleware:**
  - Software to enable interaction of applications
  - Provision of services for all applications (e.g. data management, messaging)
  - Abstraction layer between applications and the operating system

Multiple players are currently competing in the market for future Automotive Operating Systems (OS)

Selected Automotive OS stakeholders

OS Specialists All-in-one solutions	OEMs In-house development	Tech Players New market entrants
WNDRVR *WindRiver VxWorks* BlackBerry QNX *QNX Neutrino* Green Hills SOFTWARE *Green Hills INTEGRITY*	VW TESLA TOYOTA	Google *Android Automotive* NVIDIA *NVIDIA DRIVE OS* + *Apple and others will strive in the market*

Consortia / Open Source
Common standards and basic software

AUTOMOTIVE GRADE LINUX *Linux AGL*	apollo *Apollo IOV OS*	AUTOSAR *Autosar Adaptive*

Description

- **Automotive OS:** Basis of the automotive software stack, l**ow level hardware-oriented layer**
- **Manages hardware resources** and performs tasks on the associated hardware (e.g. memory allocation, processor time scheduling)
- **Strict requirements** regarding **safety** and **cybersecurity** acting as drivers for new OS
- **Intensive development** and market **activities** by multiple automotive stakeholders
- **Open-source based OS** will become increasingly important, new forms of cooperation between OEMs emerging

Realization of Over-the-Air (OTA) updates represents a basic requirement for automated and connected vehicles

Definition: OTA updates and upgrades

- **Over-the-Air (OTA) capability:** Remote modification of in-vehicle software (without workshop visit)
- **OTA updates:** Improvement of existing software, e.g. to close security gaps or to remove software errors
- **OTA upgrades:** Provision of new functions and features for customers after vehicle purchase (e.g. personalization)

Cybersecurity

- **Connected vehicles:** regular SW updates needed
- Closing of critical security gaps, protection against **cyber-attacks**

Bug-fixing

- **Removal of bugs** after vehicle production
- Reduction of **cost intensive software updates** in workshop or product recalls

Function improvement

- Esp. for **safety critical SW components**
- **Continuous improvement** of functions based on learnings from past situations

New features

- Provision of **new functions and features** after vehicle purchase
- New **revenue opportunities**
- Higher flexibility

Service-Oriented Architectures (SOA) facilitates OTA updates and will be established as a standard for automotive software

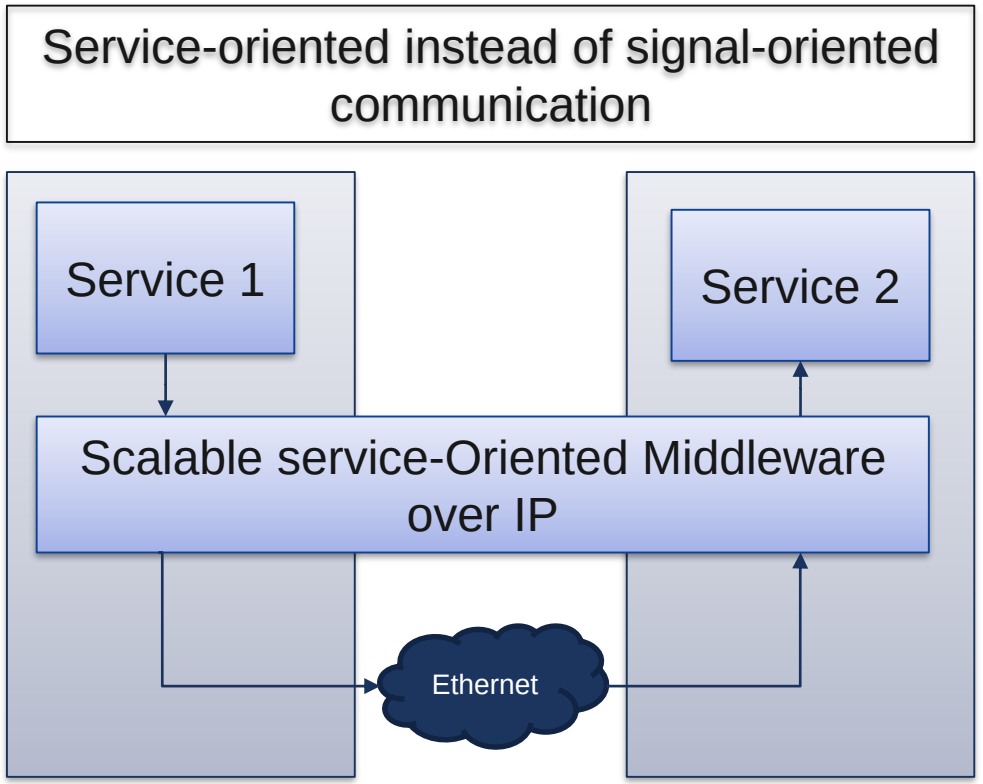
Functionality

- Each software function is **separated into a different service** that can be integrated during runtime
  - **Signal-oriented communication**: static signal libraries and communication matrices must be defined during development.
  - **SoA:** Services are linked to a specific activity, they have a standardized interface through which they can exchange data and are self-contained.

Benefits

- Enables **modification of services after the design process** is finalized
- **Modular approach**, improves **reusability** and **scalability** of software components
- Realization of **hardware independency**

Example: SOME/IP protocol



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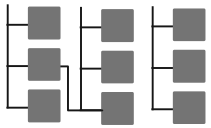
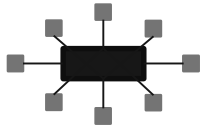
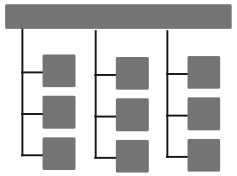
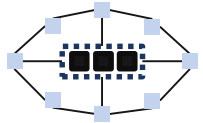
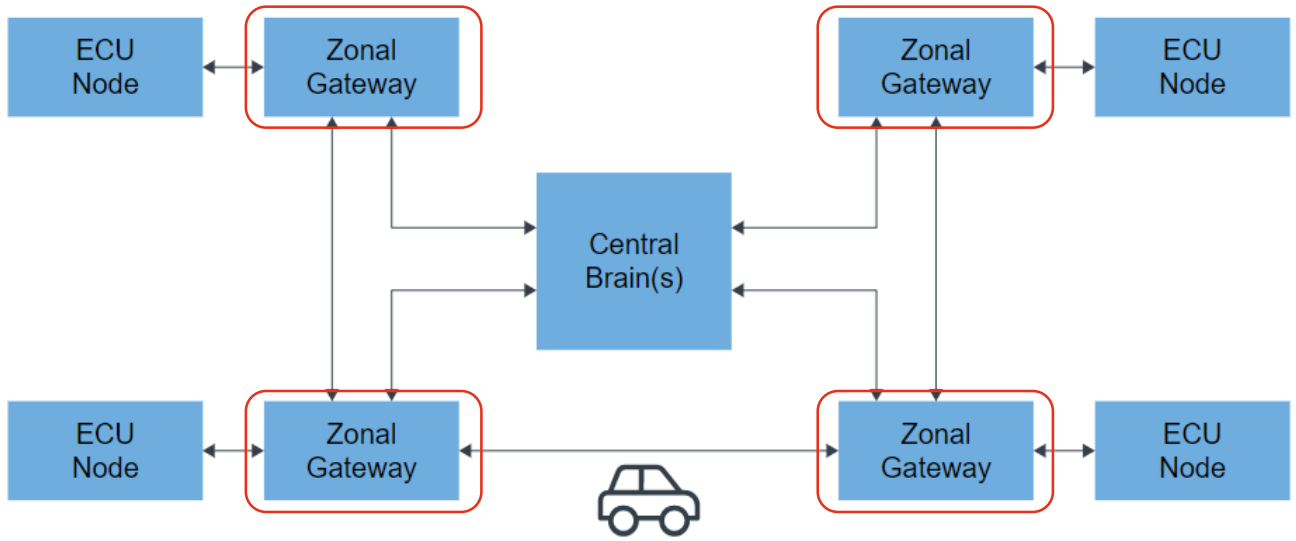
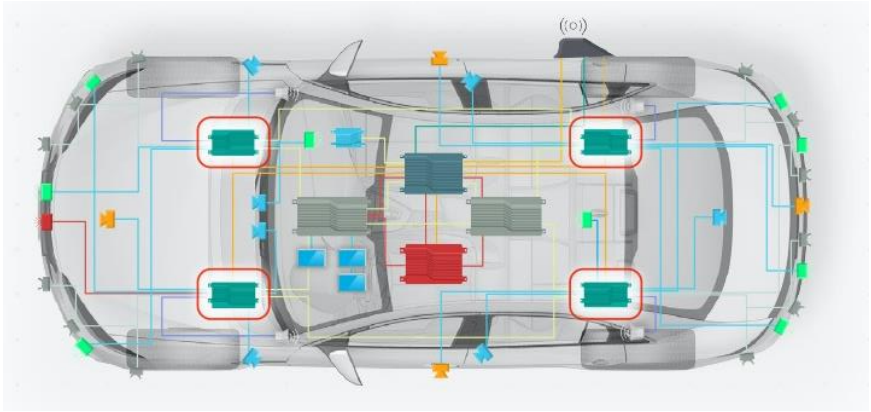
Hardware architectures are currently undergoing a comprehensive transformation process towards centralized architectures

Distributed Architecture	Domain-oriented Architecture	Centralized Architecture
Distributed	*Full-domain centralization*	*Central computer*
		
Central Gateway	*Selected-domain centralization*	*Zonal computers*
		
1 Legacy	**2 Status-quo**	**3 Future (> 2025)**
» **Limited communication** among domains » **Stronger collaboration** via central gateway	» **Selective domains** using DCUs » Full-domain centralization: used **for all domains**	» Central **virtual domain units** with distributed zonal computers » Central **general-purpose** processing unit

An evolutionary development towards zonal architectures and an emergence of mixed architectures is expected

Overview: Zonal architecture





Zone Controller

Description

- **Basis:** Domain-independent **high performance vehicle computer**, executing complex functions from all domains
- **Few zone controllers** are distributed in the vehicle, physically located near sensors and actuators
- Zone controllers **distribute power and data** within the zone and can perform zone-individual functions
- **Reduction of ECUs**, HW complexity and wiring
- **Standardization** of hardware

Image Source: NXP, Aptiv

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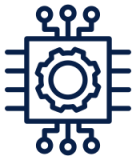
Automotive players have to address three main fields of action on the path towards a new E/E paradigm

Implications for automotive players

Software perspective

- Implement strict **separation between hardware and software**
- Realize **modular structure for functional software** to improve reusability
- Extend **scope of software functions** beyond actual vehicle

Hardware perspective



- Short-term: Manage **coexistence of different hardware** architectures and requirements
- **Reduce complexity** of the hardware architecture on all architectural layers
- Mid-term: Pursue **standardization of hardware components**, e.g. vehicle computers

Business perspective

- Business model: Offer and purchase functional **software** as a **stand-alone product**
- Organization: Align process and organizational structure for **feature-driven development**
- Strategy: Define a suitable **product portfolio** and **technology strategy**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