Enhancing Automotive Ethernet Efficiency for Emerging, Asymmetrical Use Cases

Ethernet & IP @ Automotive Technology Week

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Personalized, Automated, Connected and Electrified cars need new E/E-architecture to address several important needs

PACE changes… | **…customer and OEM needs; which needs to be addressed by…** | **…a new E/E-architecture**

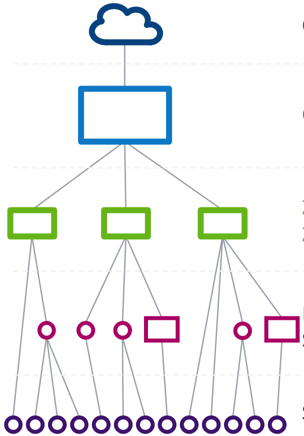
P **P**ersonalized

A **A**utomated

C **C**onnected

E **E**lectrified

- Fast and easy integration of new features update/upgrade
- Improve multi-party collaboration for X-domain features
- Manage EE architecture complexity
- **Minimize TCO[1]**
- Enable UX feature (deep in vehicle data access for smarter vehicles)
- Security & Safety (Ensure freedom of interference, OBD, …)
- Resource efficiency (power consumption, weight, size, bus-load, memory, …)



1) **TCO: Total Cost of Ownership** considering total vehicle lifetime

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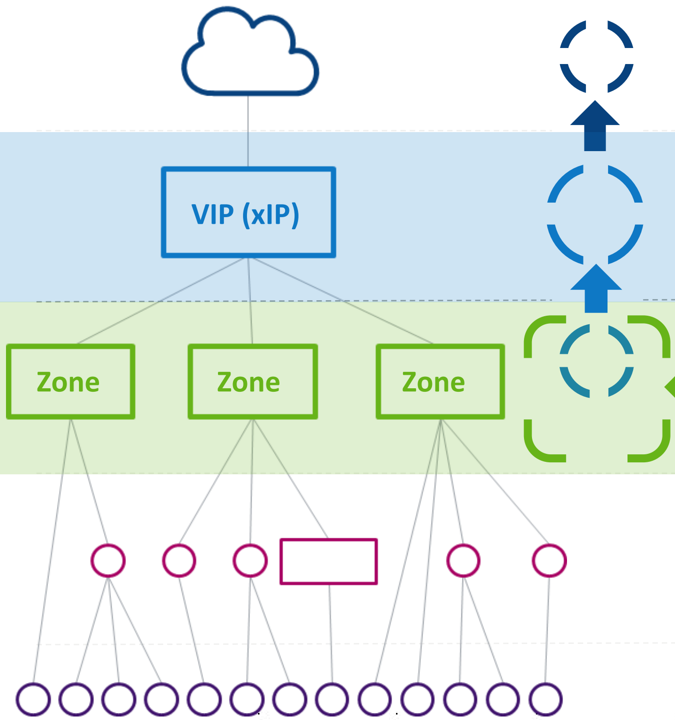
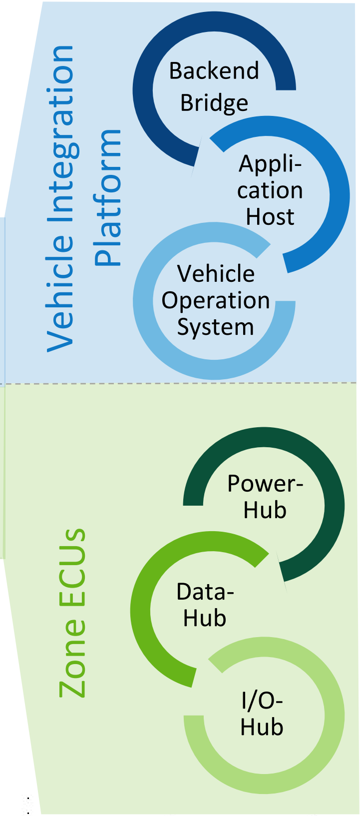
“True North” with centralization of application in Vehicle Integration Platform (VIP) and hardware in Zone ECUs



Application transferred to CLOUD

Application centralized in „BRAIN“ VIP

Hardware centralized into ZONEs

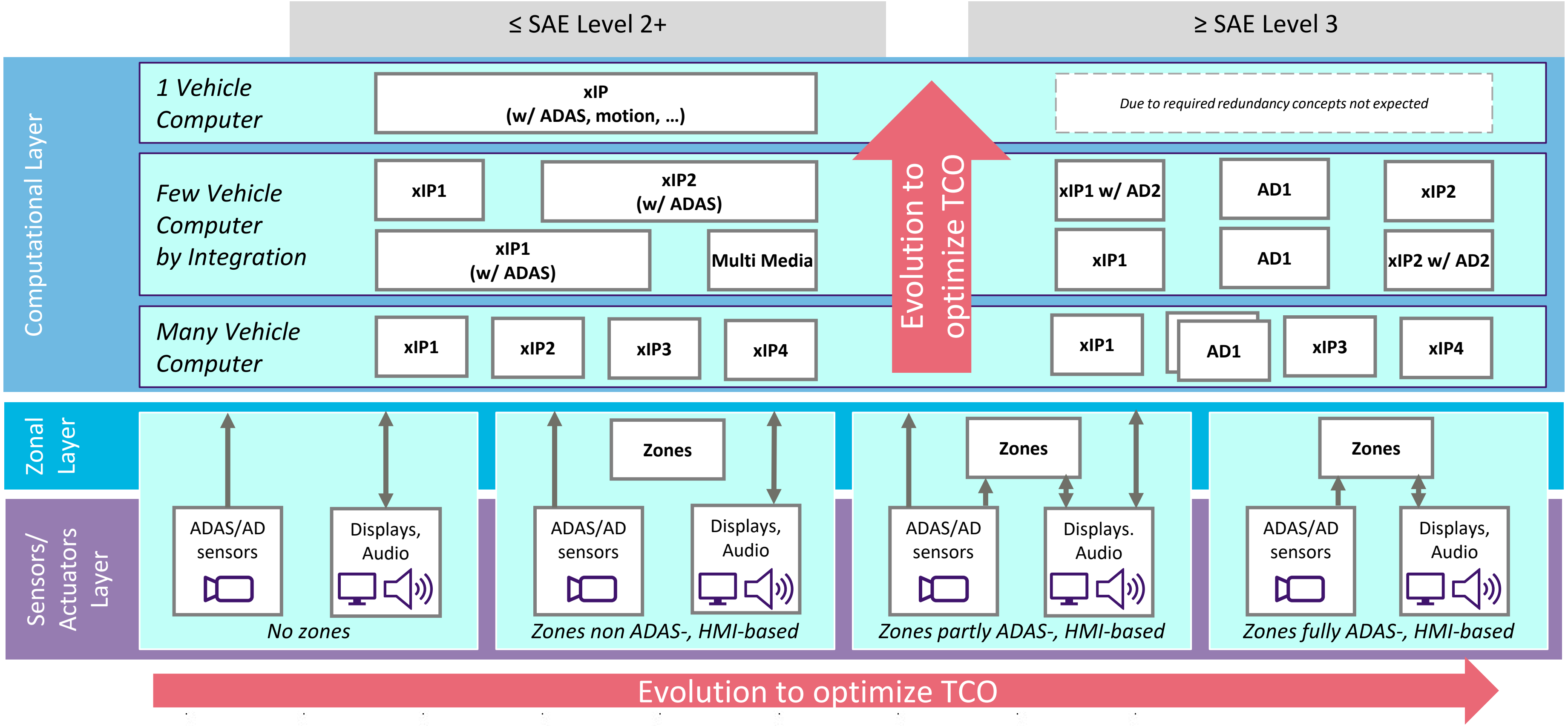


- Central data processing
- High integrated SoCs (uC, uP)
- SW integration platform
- Multiple operation systems (Classic -, Adaptive Autosar, Linux, …)
- Central Gateway to backend and zonal layer

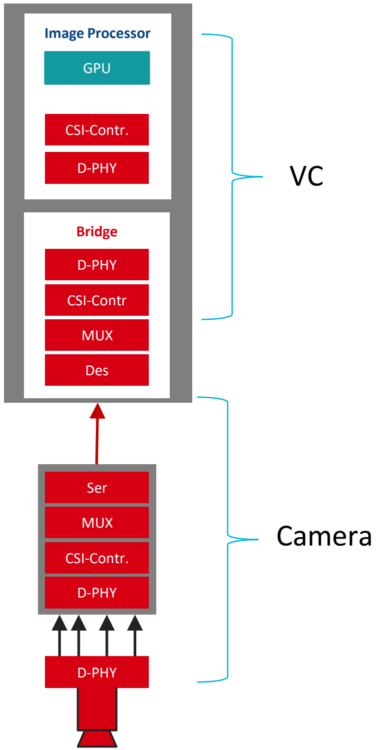
Zone ECU is “Hardware Middleware” link between VC and Smart ECUs, mechatronics, sensors and actuators:

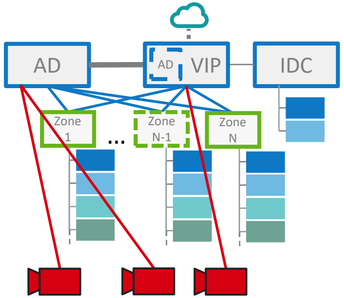
- Smart power supply
- Communication gateway to smart ECUs, mechatronics, sensors and actuators
- Direct input and power driver I/O

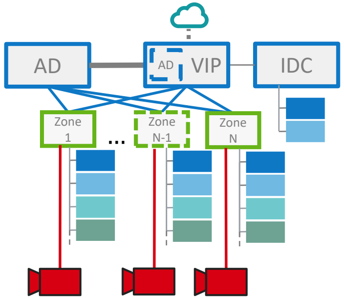
Evolution of Zonal E/E-Architecture



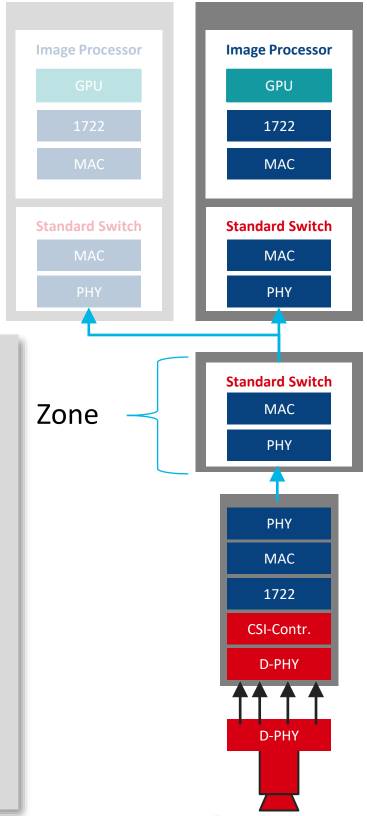
Ethernet reduces the amount of different IVN Technologies







- Used Serdes (LVDS) technology today are proprietary point to point technologies
- Asymmetric Ethernet offers modern network technology
  - Standardized at IEEE → Strong Multi-Vendor Eco System
  - Unification of traffic at zone of different sensors on one Ethernet backbone with TSN and MACsec
  - Same Communication mechanism for Sensors (Radar, Lidar, Camera), I/O, encapsulated CAN/LIN using IEEE1722
    - Harmonization of sensor data enables plug & play for OEMs
    - Lowers costs and increases performance
- Universal components leads to higher volumes and lower costs



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Key success factor “Standardization”

- IEEE 1722 – Video, Radar, Lidar, I/O, CAN, encapsulation over Ethernet
- OPEN TC16 – Compliance for EEE-based Asymmetrical Ethernet
- IEEE 802.3cy – 25G-T1 PHY standard
- NAV Alliance TWG4 – proposal for sensors encapsulation over Ethernet

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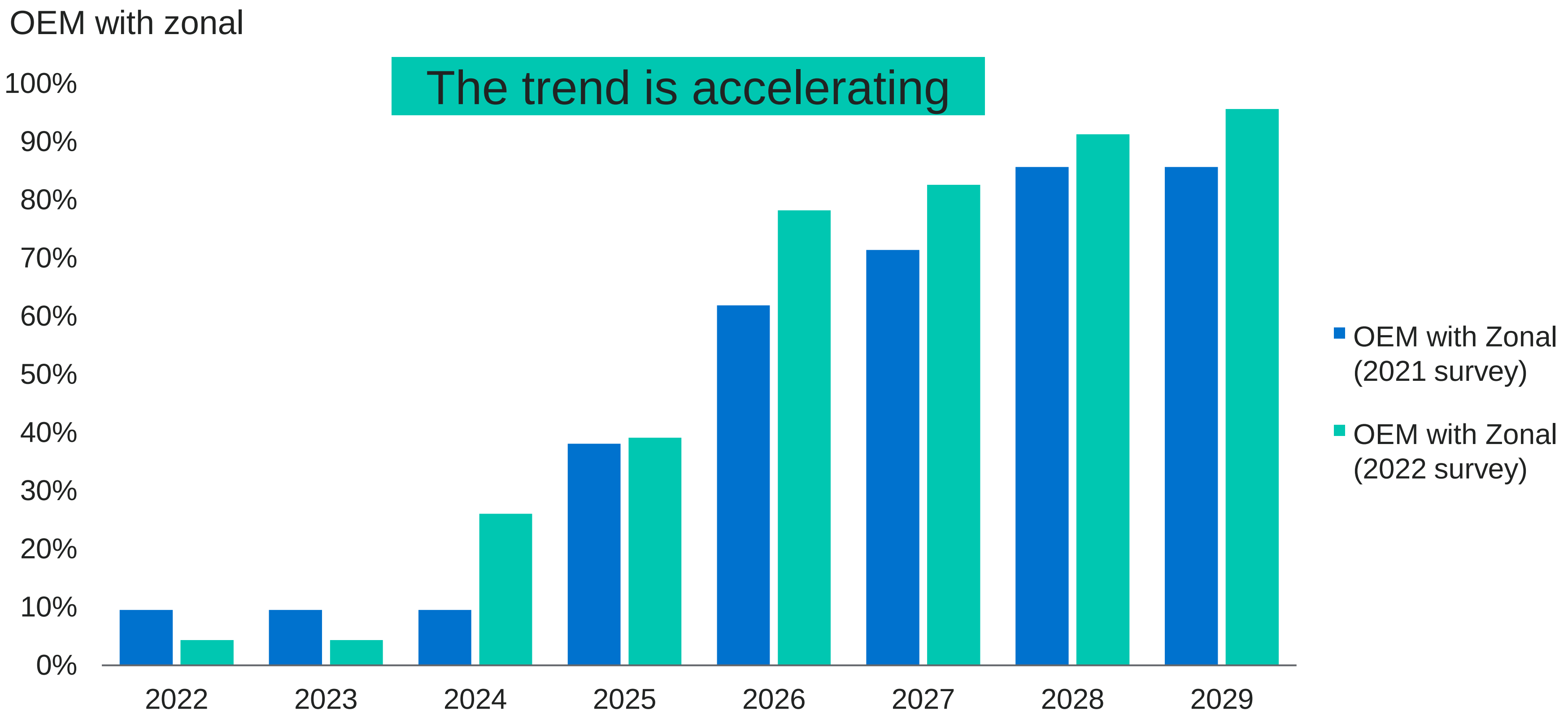
Key challenges to be addressed

- Fast wake up time < 100ms
- TSN and EEE Coexistence
- Dynamical reconfiguration for multiple data sinks
- Low latency
- Low power consumption comparable to SerDes
- Low total cost of ownership
- Cable flexibility – STP and Coax

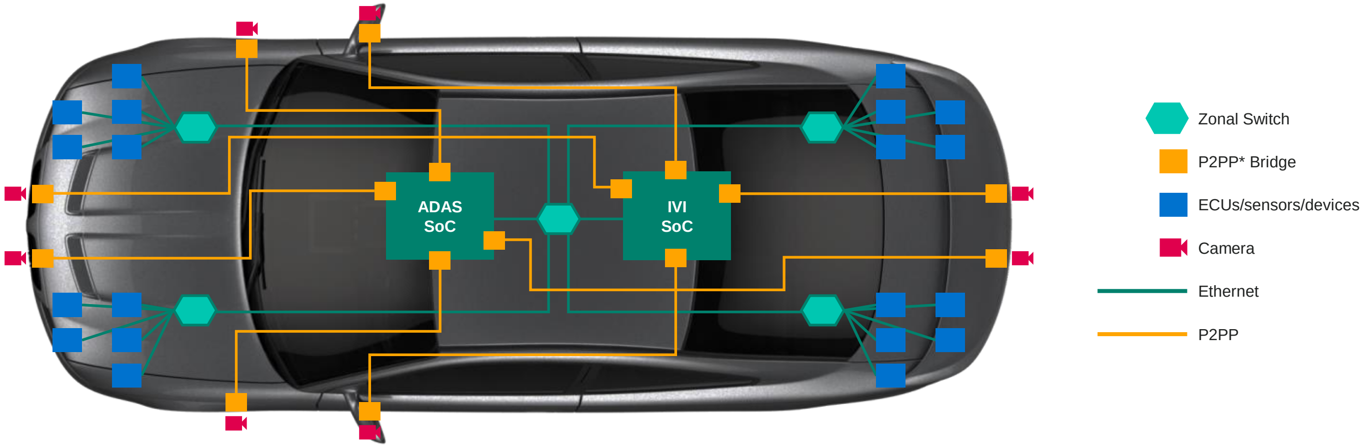
OEM transition to zonal architecture



Zonal network

Camera **point-to-point** connectivity

- Long cables. Bypass the zonal network.
- No camera sharing between domains.
- Proprietary protocols.
- High number of pins on SoC.

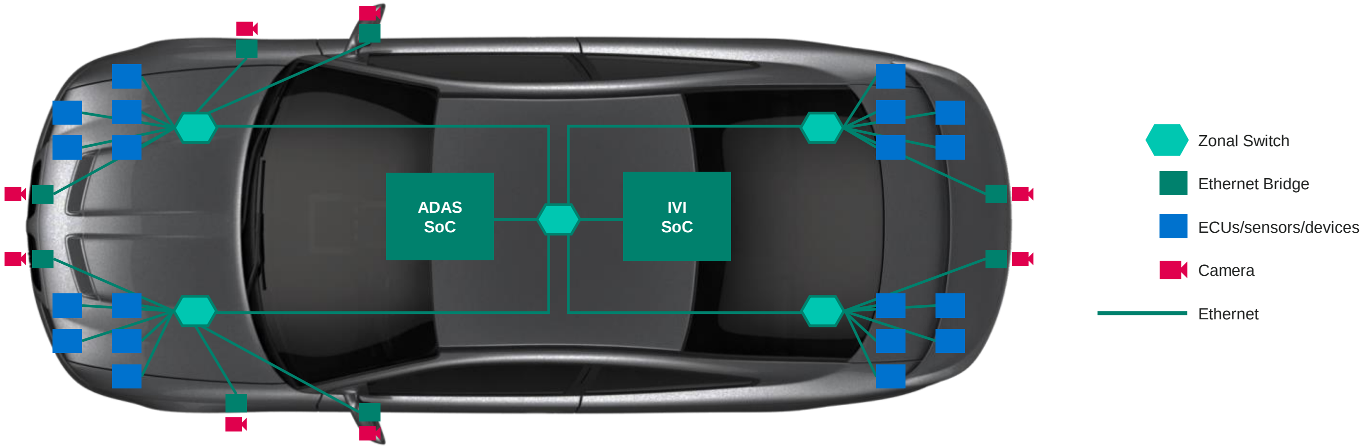


* - P2PP = Point-to-point protocol

Zonal network

Ethernet camera bridge

- **Standard-based**
- Enable the Ethernet end-to-end ecosystem
- Enable Software end-to-end
- Support Zonal architecture
- Reduce cable length and weight
- Reduce number of pins on SoC



Ethernet key advantages for camera interface

- **Switching and virtualization** – IEEE 802.1
- **Security** – Authentication and encryption – IEEE 802.1AE MACsec
- **Time-synchronization over network** – IEEE PTP 1588
- **Power over cable** – IEEE PoDL 802.3bu
- **Audio/video bridging** – IEEE 802.1 AVB/TSN
- **Asymmetrical transmission, using energy efficient Ethernet protocol** – IEEE 802.3az
- **Support for all topologies** – Mesh, star, ring, daisy-chain, point-to-point

Testing houses
for PHY compliance, interoperability and EMC

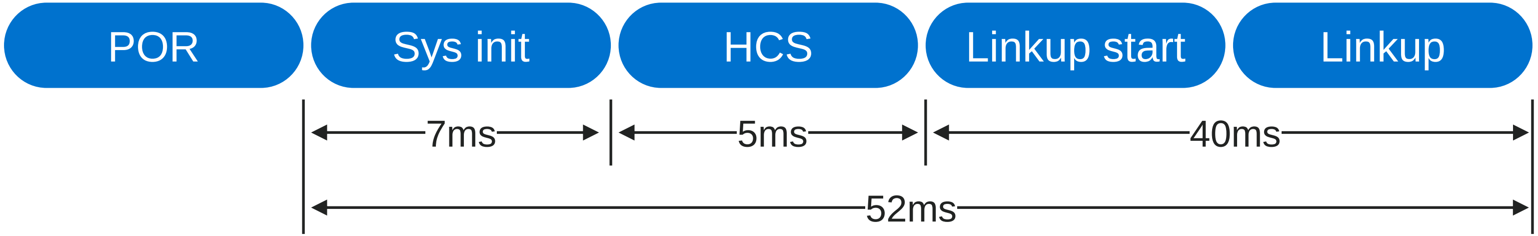
Ecosystem for hardware and software/utilities infrastructure

Requirements Analysis

Wake up time analysis (target: < 100ms)

Four stages:

- **Sys init:** Includes reset, crystal oscillator startup, PLL startup, Efuse read back, firmware code initialization
- **HCS:** Optional host config stage. Typical 5ms, maximum 20ms
- **Link start:** Initialize analog front end
- **Link up:** 802.3ch link training

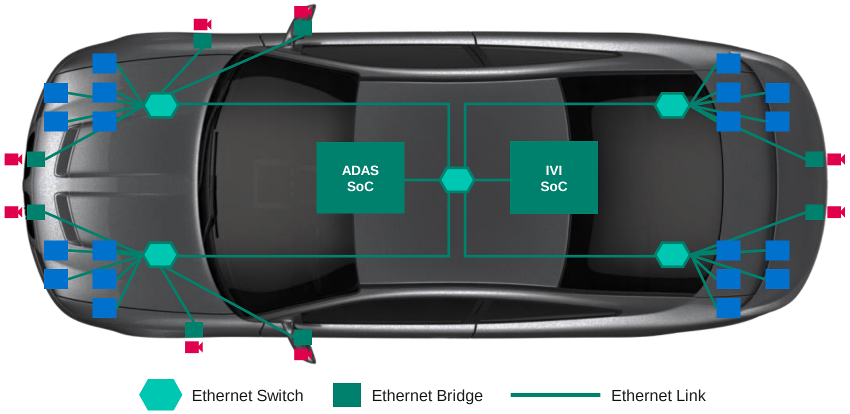


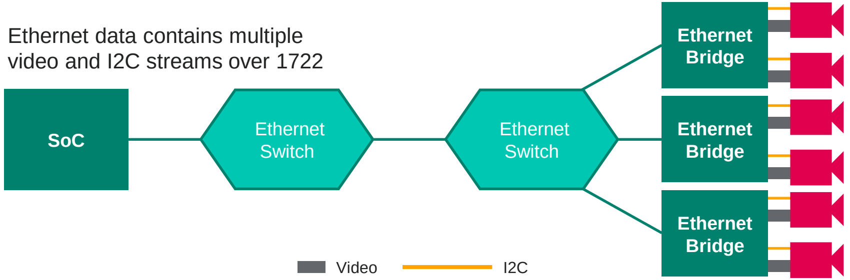
TSN and EEE coexistence

- Link enters EEE Low Power Idle mode (LPI) when link is idle
  - Entry typically triggered by a transmit idle timer
- Asymmetric EEE, allowing independent LPI entry for each direction
  - Forward channel idle during video blank time
  - Reverse channel idle during active video time
- LPI exit requires an initial packet transmit delay
  - Link rate dependent - 9/18/36us for 10/5/2.5G rates
- Only first packet in burst will experience wake delay
  - Assumes idle timeout larger than packet spacing
  - Minimal overall effect on TSN traffic
- High bandwidth traffic prevents idle timeout – no effect on TSN

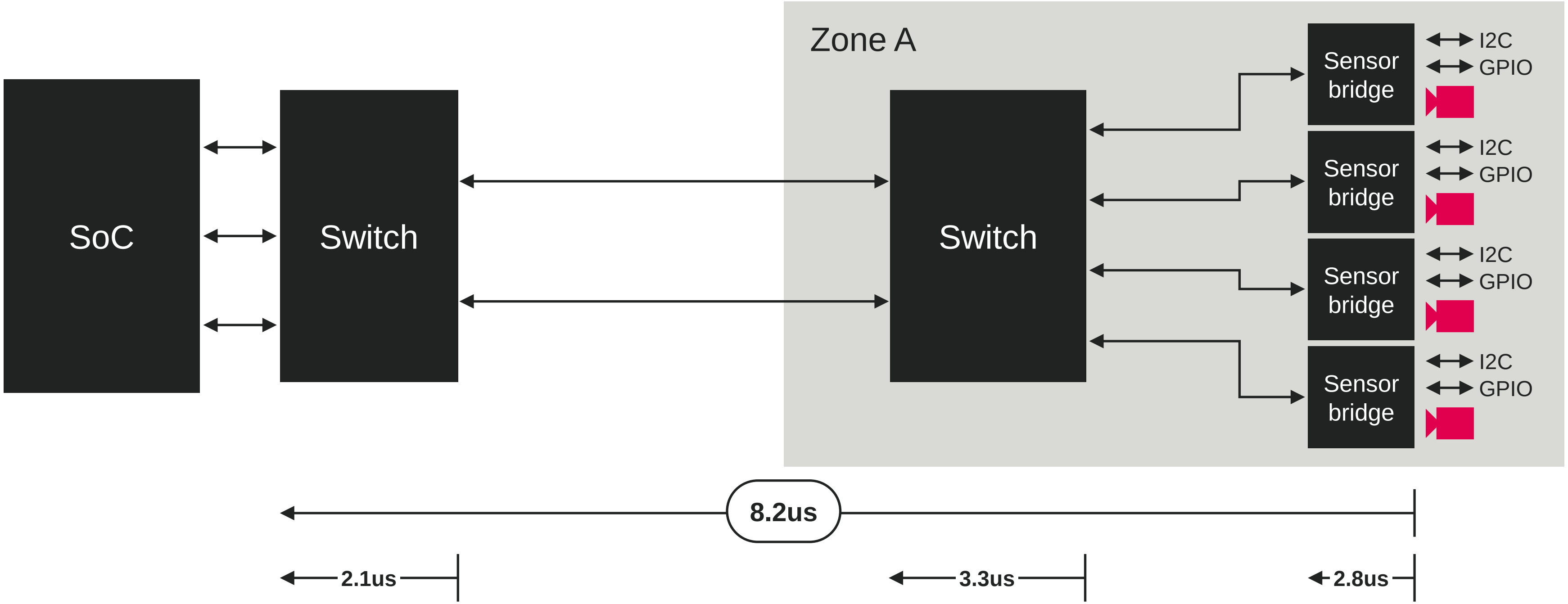
Dynamical reconfiguration for multiple data sinks

- Cameras traditionally use I2C for control
- 1722b I2C control format allows bridging of I2C busses
  - I2C transactions bridged byte at a time
- 1722b Generic Byte Bus (GBB) can provide remote I2C access
  - Entire I2C transaction passed in a single packet
  - Multiple transactions can be carried in a single packet
  - Eliminates need for physical I2C bus at SoC/controller endpoint





Latency in network

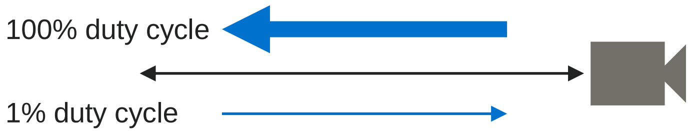


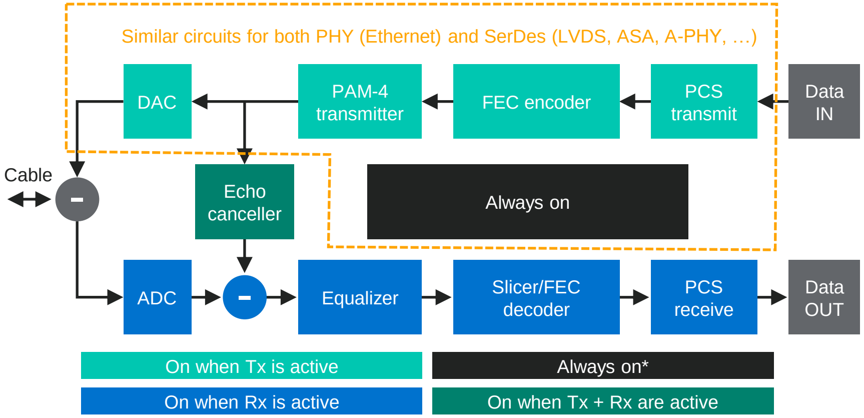
Latency
SOF (T1) to SOF (XFI)
#1 #2

Latency
SOF (T1) to SOF (T1)
#1 #2

Latency
SOF (Video-In) to SOF (T1)
#1 #2

Relative power in asymmetric Ethernet with EEE





Relative PHY power consumption

Block	Relative power	% of time on camera side
Always On	25%	100%
Tx	15%	100%
Tx + Rx (Echo Canceller)	30%	1%
Rx	30%	5%**

- EEE saves power by only transmitting data when needed (Asymmetrical Ethernet)
- The table shows relative power numbers based on duty-cycles for 10Gbps from the camera and 100Mbps (1%) to the camera
- **The circuits that are continuously ACTIVE in the camera module (Tx and Always On) are very similar between Ethernet PHY based camera and SerDes based camera, which results in similar power consumption**

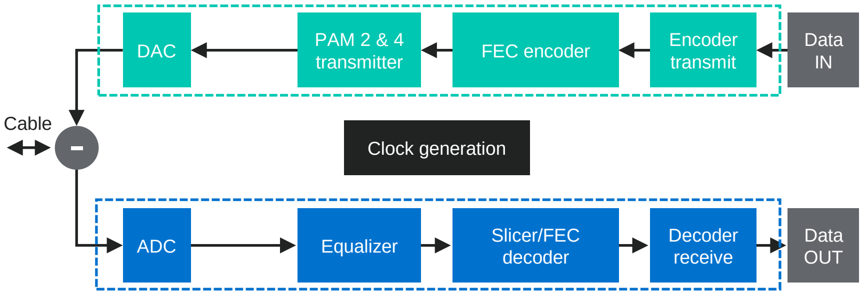
* - "Always On" includes circuits like some of the clocks, bandgap, LDOs, pads, etc.

** - Although the Rx works 1% of the time, there is some additional power due to some filters' requirements

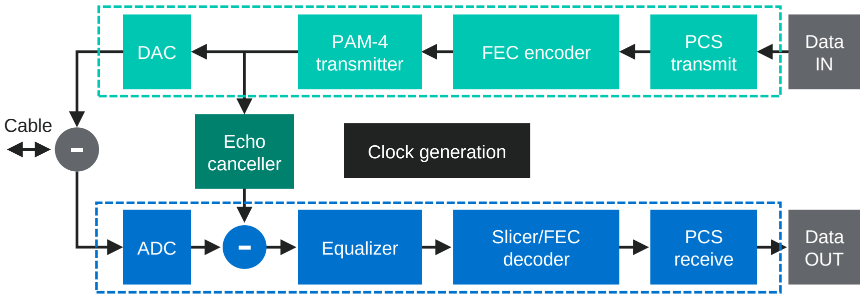
PHY cost analysis

- The main difference between the Ethernet PHY and SerDes technologies is the addition of the Echo Canceller
- Ethernet T1 PHY is very size efficient (small)
- Eliminating the echo canceler saves less than 5% of the total product ASP

SerDes block diagram

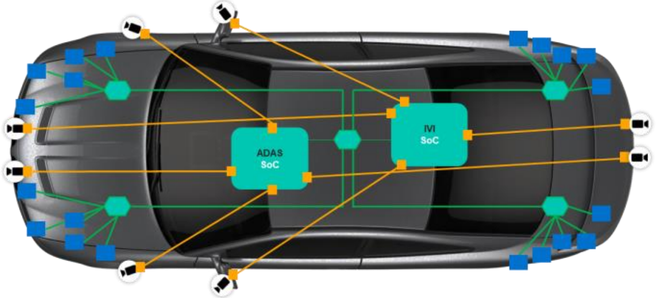


Ethernet PHY block diagram

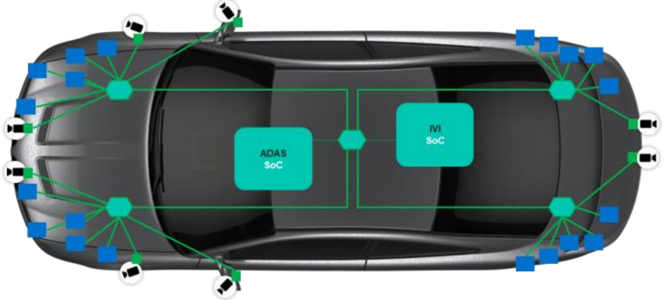


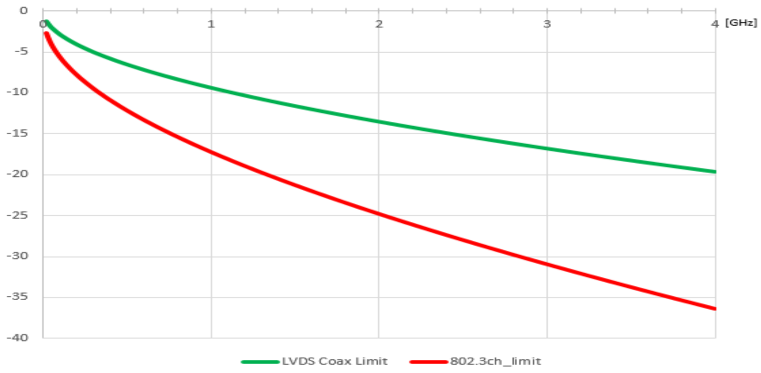
Cable harness cost reduction

Zonal with **point-to-point** cameras – **long/expensive cables**



Zonal with **Ethernet** cameras – **short/cheaper cables**





Insertion loss for coax cables*:

Ethernet 10G:	IL at 3GHz is	-25dB
LVDS 12G:	IL at 3GHz is	-18dB

* - 802.3ch is defined for STP cable (differential). At 3GHz, the PHY can accommodate insertion loss of 31dB. Ethernet can also run over coax cables. For coax (single ended), need to reduce 6dB, which results at insertion loss of 25dB.

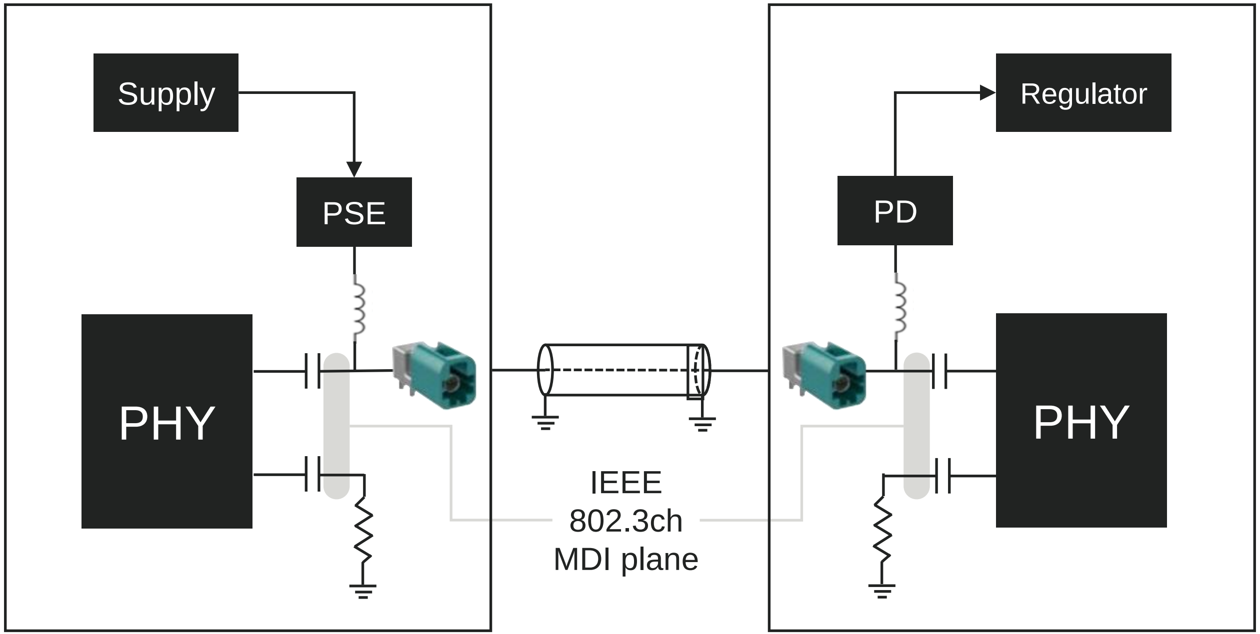
1. **Zonal with Ethernet cameras uses very short cables**
2. **For the same length, the Ethernet 802.3ch cables will always be cheaper than LVDS cables**

Ethernet cost advantages

	Serdes	Ethernet
Camera bridge cost	Same	Same
Cable cost	Higher	Lower
External chip next to switch	Required	Not required
Number of pins on SoC	Very high	Very low

Ethernet multi-gig PHY over coax

The specifications of Ethernet IEEE 802.3ch PHY make it suitable to work on both STP and coax cables



Key takeaways on asymmetrical Ethernet PHY

Camera Ethernet PHY

- Standard based (switching, virtualization, security, ……)
- Software and ecosystem leverage
- Fast wake up time
- Easy integration into TSN based backbone
- Simple reconfiguration of multiple data sinks
- Meet latency target
- Low power consumption
- Comparable price to SerDes devices; No need for Deserielizer
- Lowest cost of cable harness
- Cable flexibility – STP and coax

Thank You

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