

# Zone-Based Automotive-Backbones

Automotive Ethernet Congress

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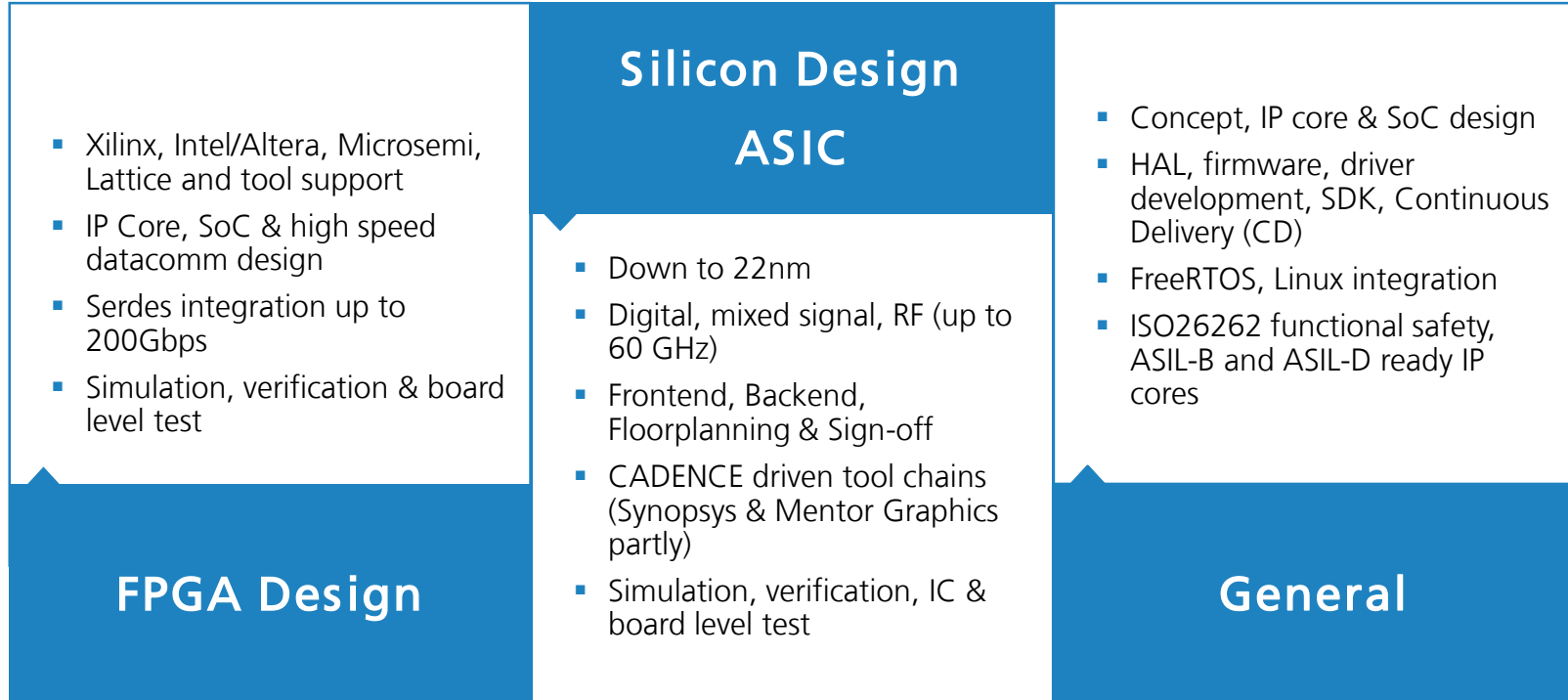
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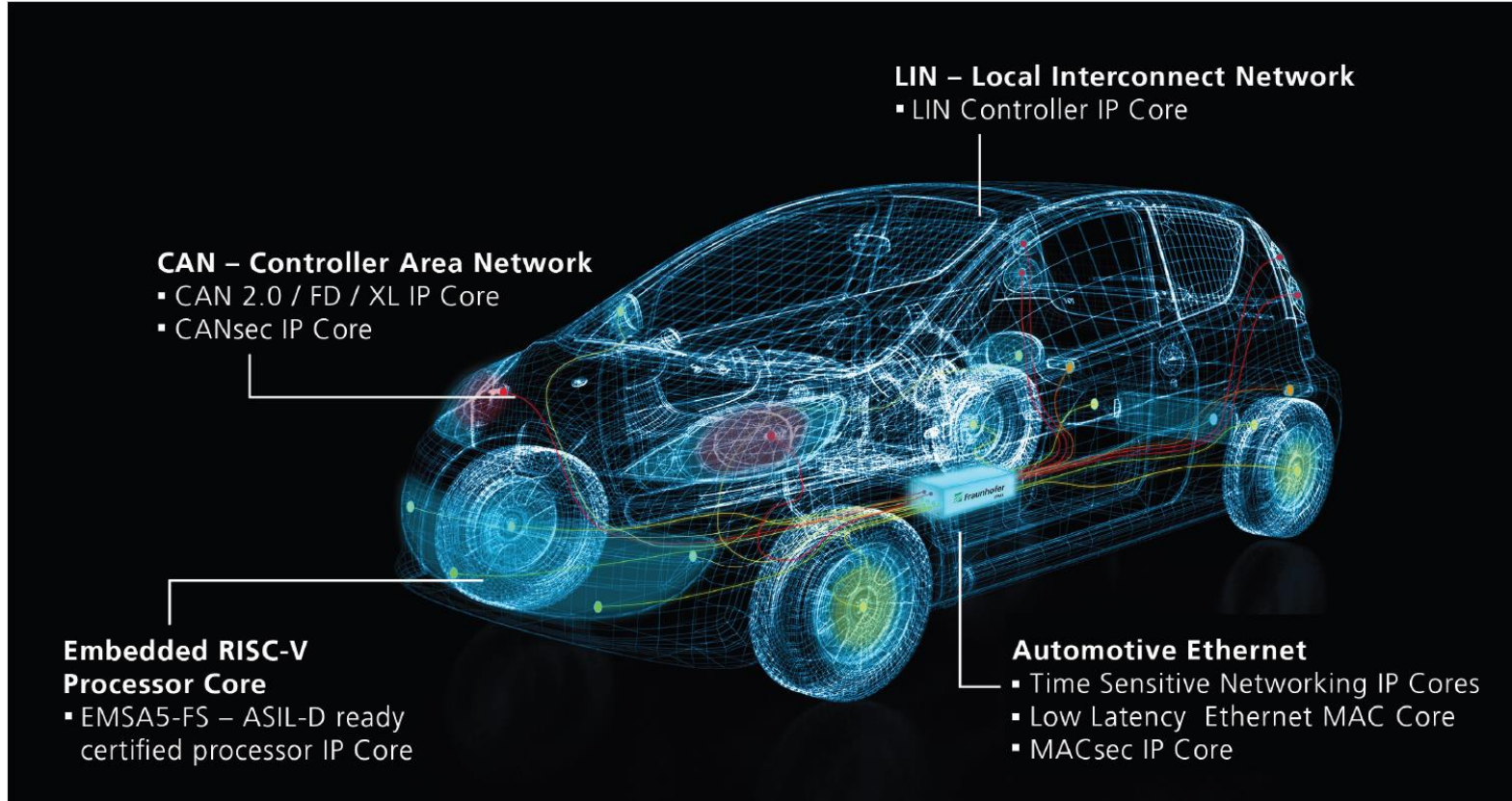
# Fraunhofer IPMS

## IP Cores, ASIC & FPGA Design



# IP Cores from Fraunhofer IPMS

## Overview



# Missing Link Electronics

Mission: "If It Is Packets, We Make It Go Faster!"

High-Performance (Embedded) Compute & Connected Systems-of-Systems

- PCIe (CXL, ISB, NVMe)
- Ethernet (TCP/IP, TSN)
- Audio/Video (HDMI, SDI)

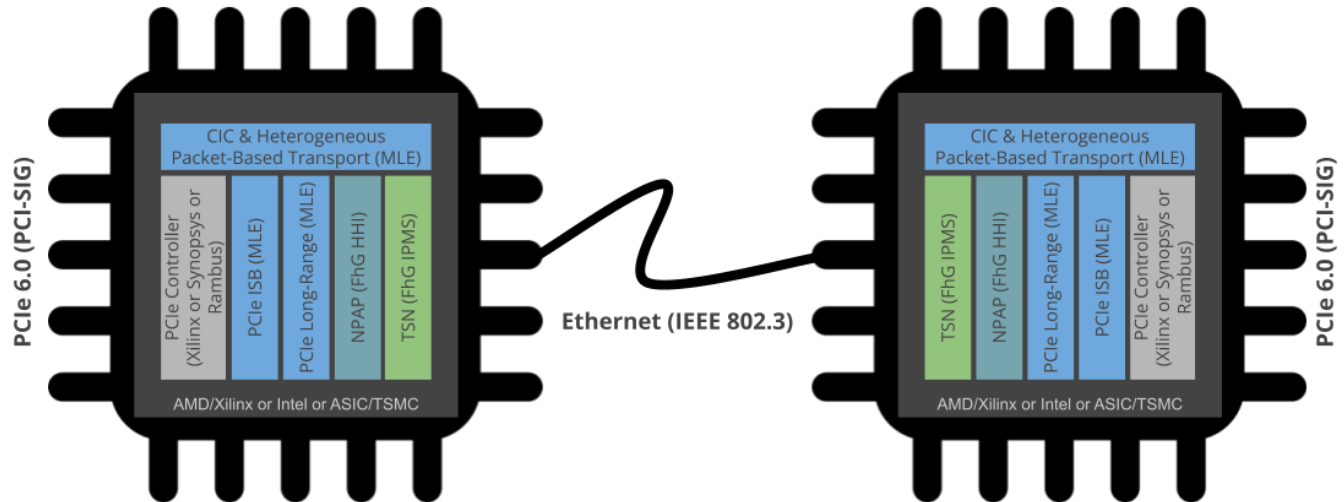


# Foundation Technology With Many Applications

Implemented as a unique IP combination from Fraunhofer and MLE

Built on top of open standards from PCI-SIG and IEEE

Implemented in ASIC and FPGA



# Fraunhofer IPMS + Missing Link Electronics

## Partnership

- Fusing expertise in
  - Ethernet
  - TSN
  - PCIe
  - Automotive enabled design
- Aim
  - Zone based Automotive Backbones
  - Enabling future Automotive network architectures
  - Saving costs on wiring

# Why Ethernet?

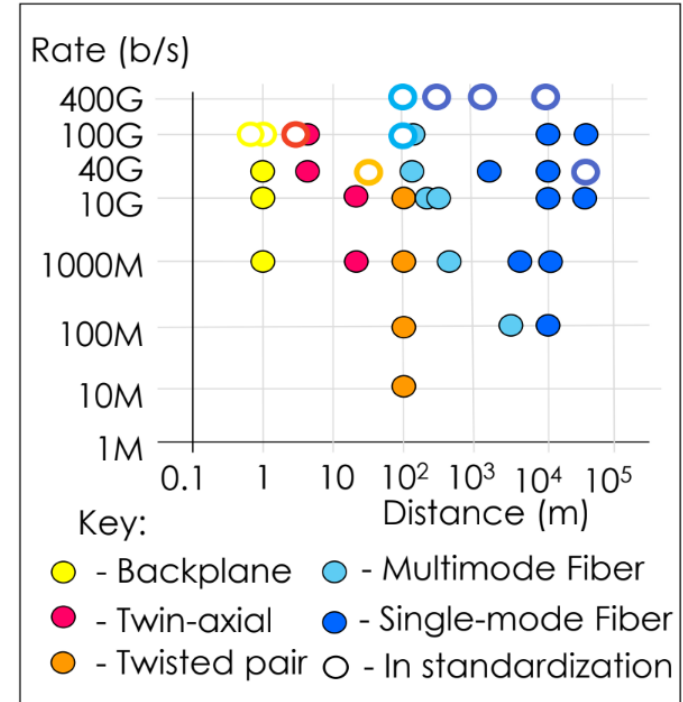
- Future-proof road-map
- PC, Cloud Computing, Embedded Systems drive this roadmap
- Best-in-class price (\$) per performance (Gbps) per length (meters) ratio

## Distance vs Speed



Ethernet operates at different speeds over different distances depending on the media :

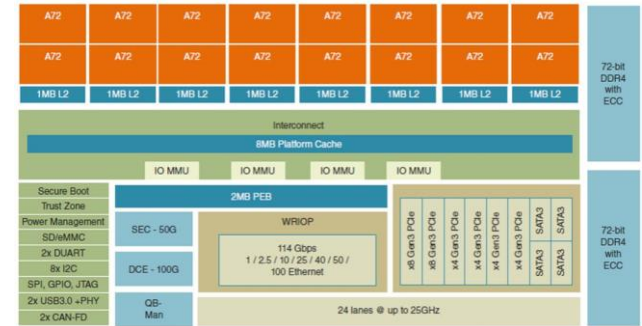
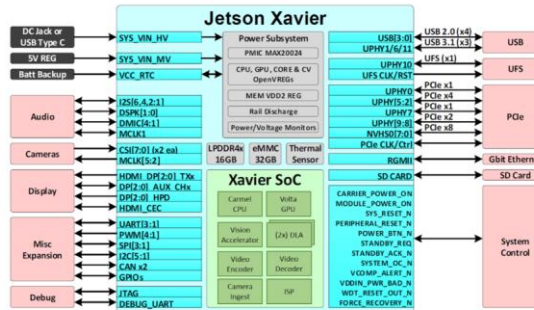
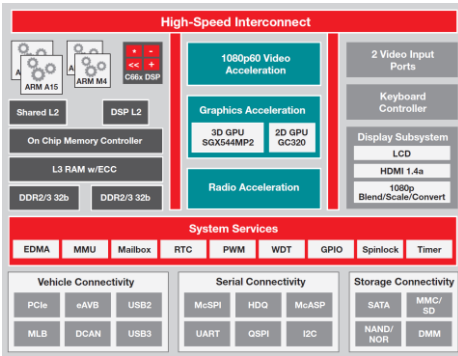
- backplanes up to 1m
- Twinax to 15m
- Twisted pair to 100m
- Multimode fiber to 5km
- Single-mode fiber to 40km





# Why PCIe?

- Future-proof road-map, driven by PCI-SIG
- PC, Cloud Computing, Embedded Systems drive this roadmap
- Best-in-class price (\$) per performance (Gbps) ratio
- Common to modern SoCs, ability to commoditize silicon





# Why TSN?

- **T**ime **S**ensitive **N**etworking
- The history
  - AVB Task Group for latency free delivery of audio/video data
  - 2012 the TSN Task Group evolved from the AVB Task Group (IEEE 802.1)
- TSN is not a single standard
- It's a collection of sub standards and extensions
  - Network wide time synchronization
  - Determinism
  - Low latency
  - Low jitter
- Scalable speed



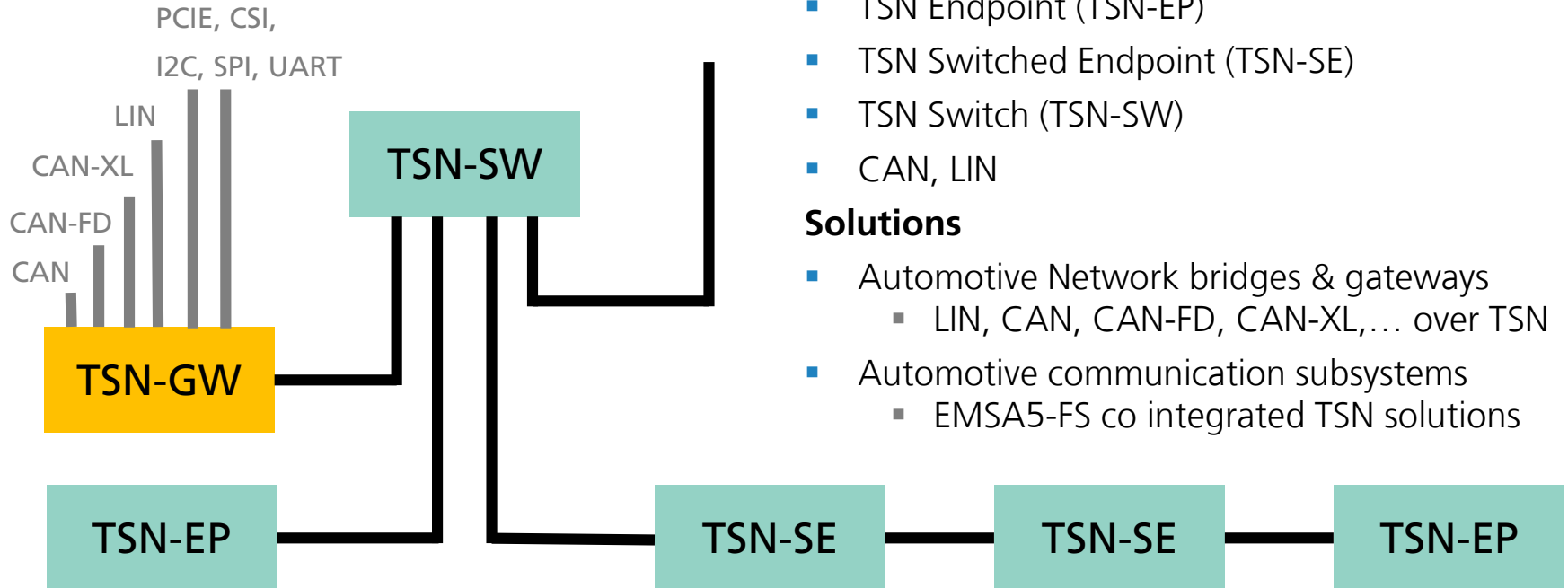
# TSN profiles & standards

## Overview

- Standards
  - **Time Synchronization** (802.1AS & it's profile IEEE 1588, 802.1AS/-2020)
  - **Bounded low latency** (802.1Qav, 802.1Qbv, 802.3br & 802.1Qbu, 802.1Qch, P802.1Qcr, P802.1Qcr, P802.1DC..)
  - **High availability/reliability** (802.1CB, 802.1Qci, 802.1Qca)
  - Resources and API (802.1Qat, 802.1Qcc, 802.1Qcp, P802.1Qcx, P802.1ABcu, P802.1Qcw, 802.1CBcv, P802.1CS, P802.1Qdd, P802.1CBdb..)
- Profiles
  - Audio Video Bridging (802.1BA)
  - Fronthaul (802.1CM)
  - Industrial Automation( IEC/IEEE P60802)
  - **Automotive In-Vehicle (P802.1DG)**
  - Service Provider (P802.1DF)
  - TSN for Aerospace Onboard Ethernet (P802.1DP)
  - TSN for Avionics (SAE AS-1A2\*)

# TSN IP Cores from Fraunhofer IPMS

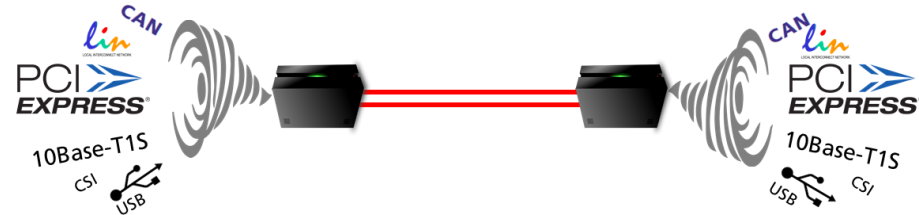
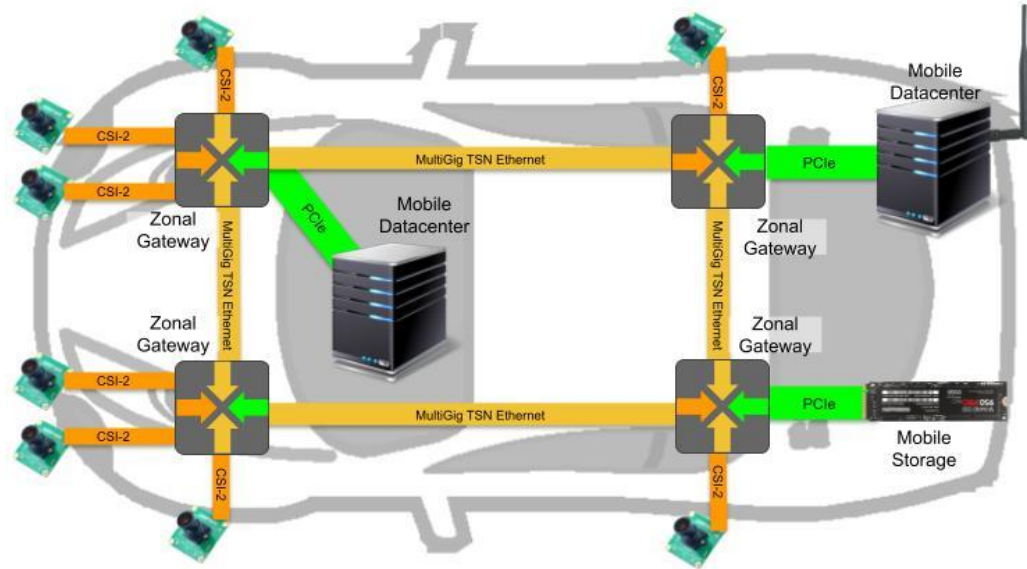
## Overview



# Automotive functional safety enhanced backbone

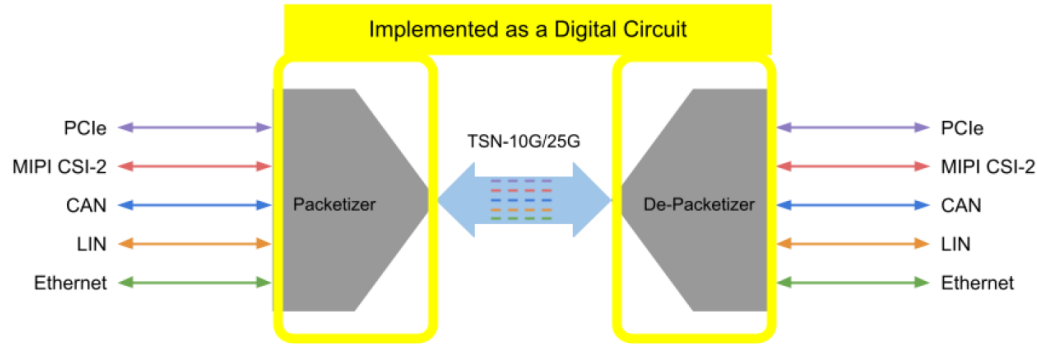
## Architectural approach

- Discrete Gateways
- Integrated Gateways
- Multi protocol tunneling
- High bandwidth
- Realtime
- Low latency
- Low jitter



# Automotive functional safety enhanced backbone

TSN-GW zonal gateway ... Multi Protocol Tunneling

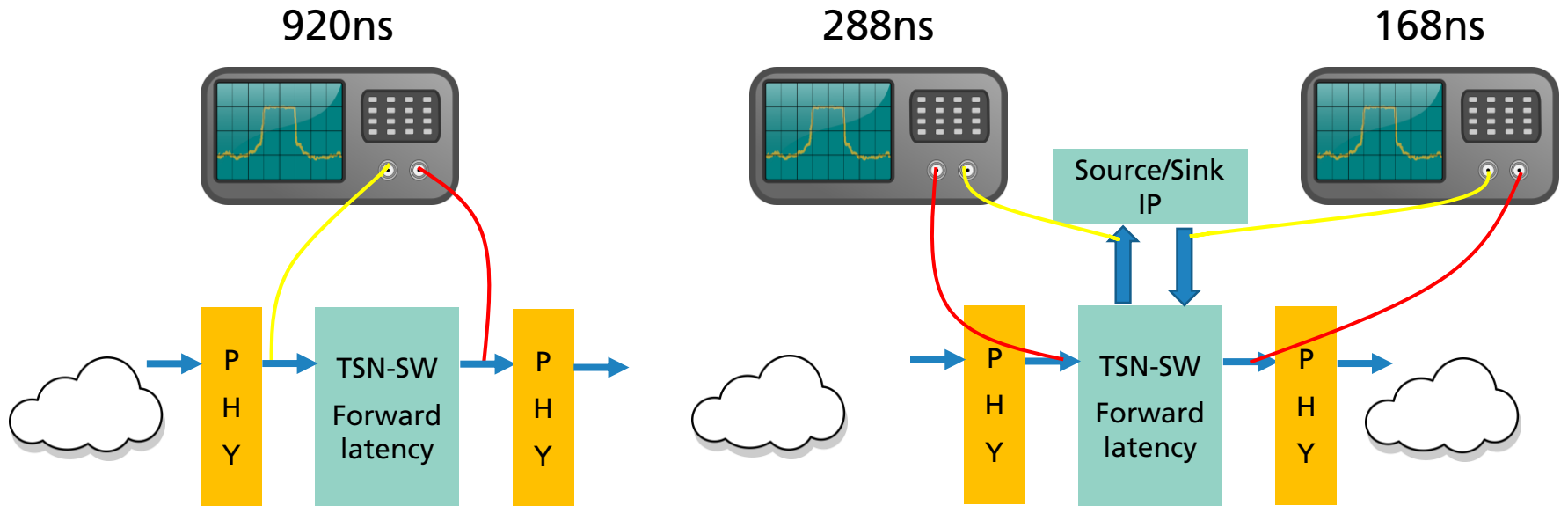


- Tunneling
  - Packetizing/Enveloping data
  - Tunneling via redundant TSN backbones
  - Maintaining real time and latency requirements
  - De-packetizing/De-enveloping data
- Multi-Protocol Switching
  - Repackaging
  - Switching

# Latency

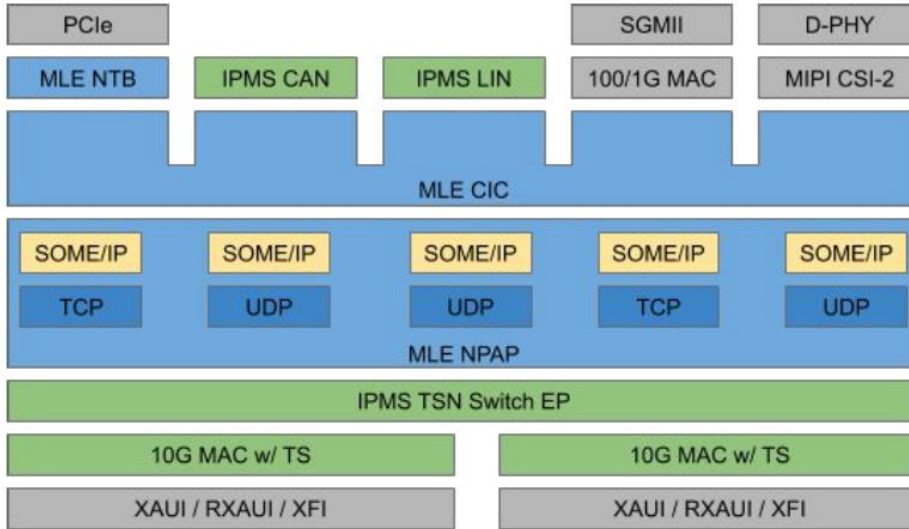
## Forward & Injection latency TSN-SW

- FPGA (Cyclone V SoC)

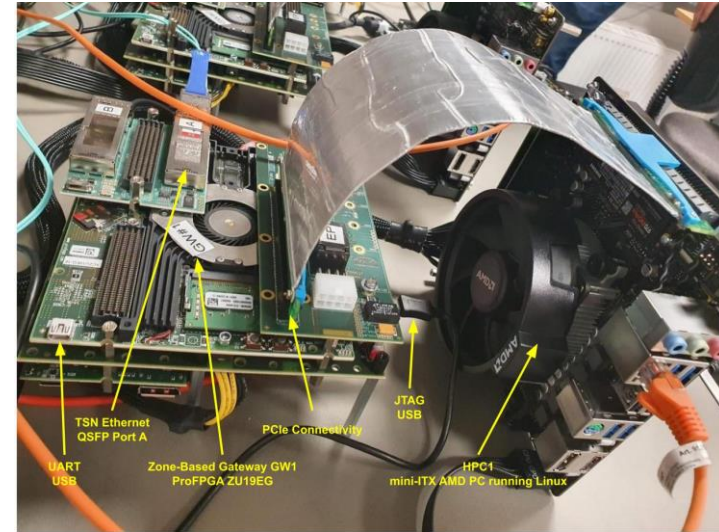


# Automotive functional safety enhanced backbone

## PCIe Protocol Tunneling



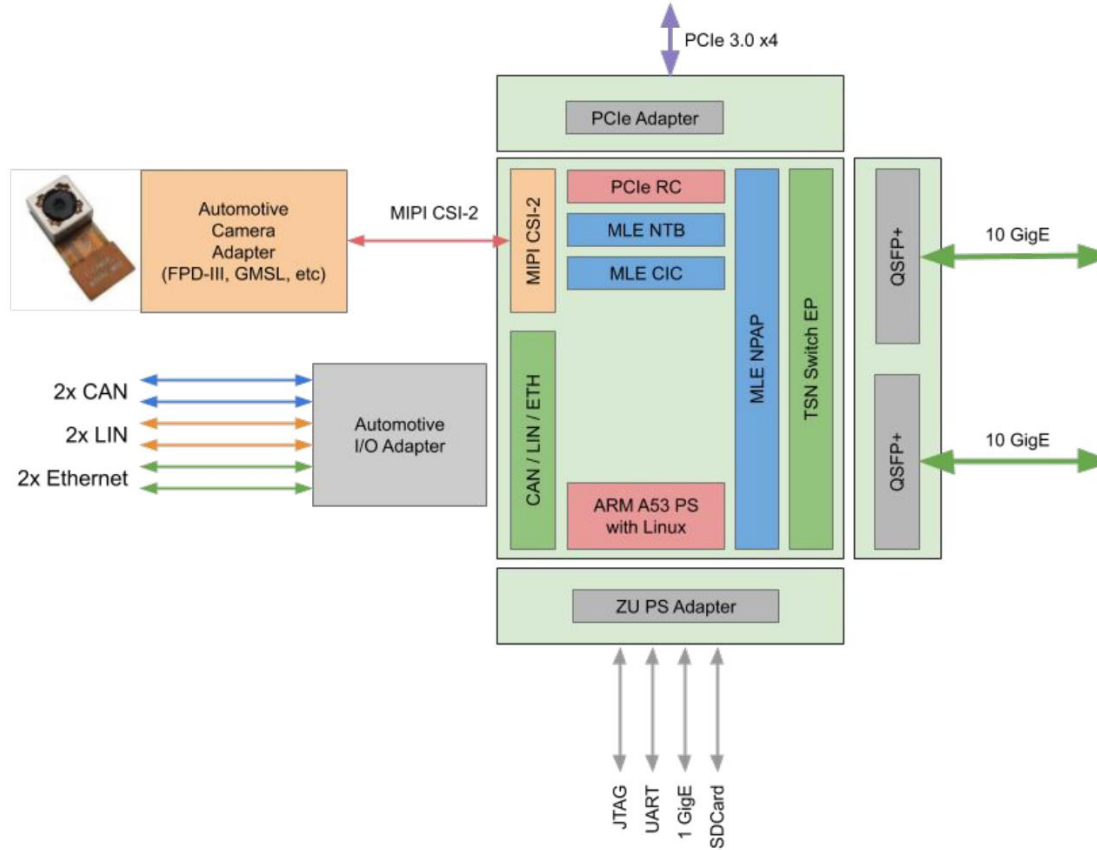
- PCIe Endpoint and Root-Port in FPGA/ASIC
- PCIe Switch in FPGA/ASIC
- PCIe NTB in FPGA/ASIC
- TCP/UDP/IP over TSN in FPGA/ASIC
- netdev Linux Device Drivers





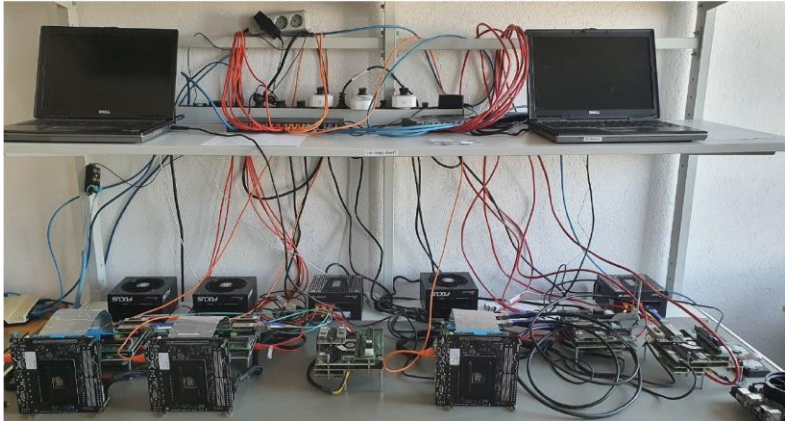
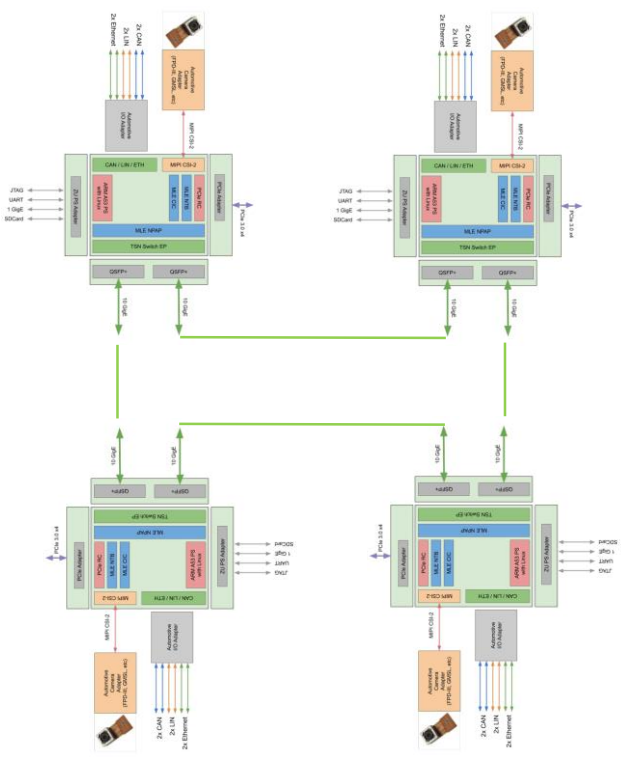
# Automotive functional safety enhanced backbone

LabCar for parallel tunneling automotive protocols



# Automotive functional safety enhanced backbone

LabCar for tunneling automotive protocols



# Summary

## Zone based Automotive Backbones



- TSN is a good solution for tunneling all kinds of time critical communication
- TSN can cope with huge network loads while maintaining real time requirements
- Cut-Through IP is the best choice for ultra low latency networks
- TSN is defined by open IEEE standards
- TSN is scaling with the evolution of Ethernet
- PCIe offers high performance and superior integration
- Fraunhofer IPMS is your partner for custom TSN Solutions
- MLE provides High-Performance (Embedded) Compute & Connected Systems

# Contact Information

- Fraunhofer IPMS



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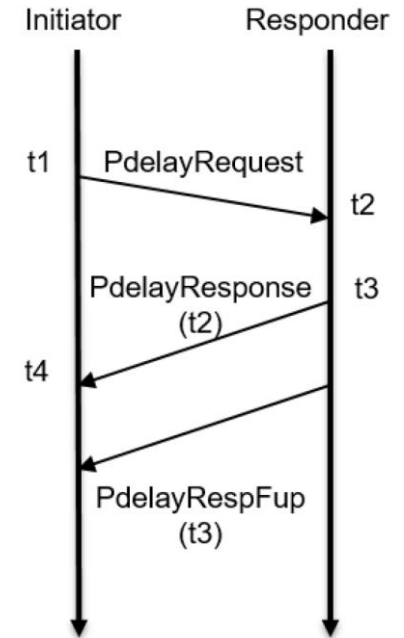
Missing Link Electronics GmbH  
Neu-Ulm, Germany

# BACKUP

# TSN standards

## Time synchronization - IEEE 802.1AS (AS-2020)

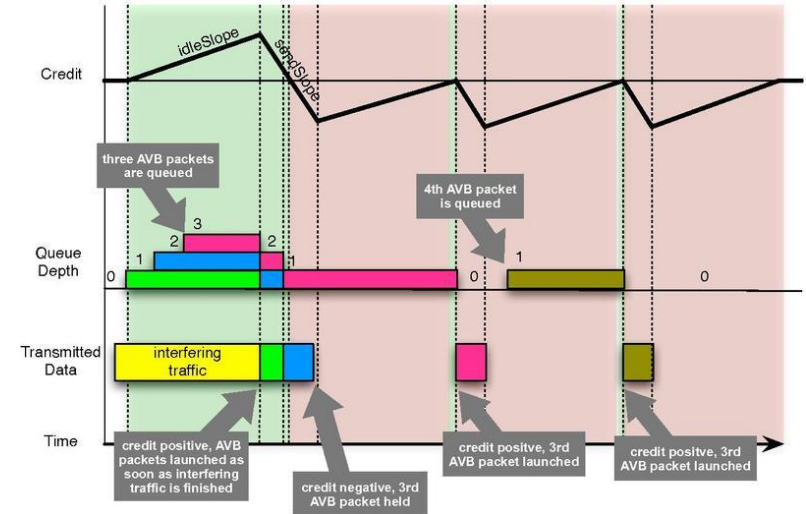
- Network wide operation
- Non 802.1as capable devices break up network
- Periodic announce messages
- Grand Master (GM) is selected for device with the best master clock algorithm (BMCA)
- Periodical Sync + Followup frames
- delay measurement is a two-step peer-to-peer path delay algorithm



# TSN standards

## IEEE 802.1Qav - Credit Based Shaper

- Forwarding and Queuing Enhancements for Time-Sensitive Streams
- Already used in AVB
- Credit based scheduling
- Positive credit allowing traffic to be sent
- Negative credit will prevent packets to be send



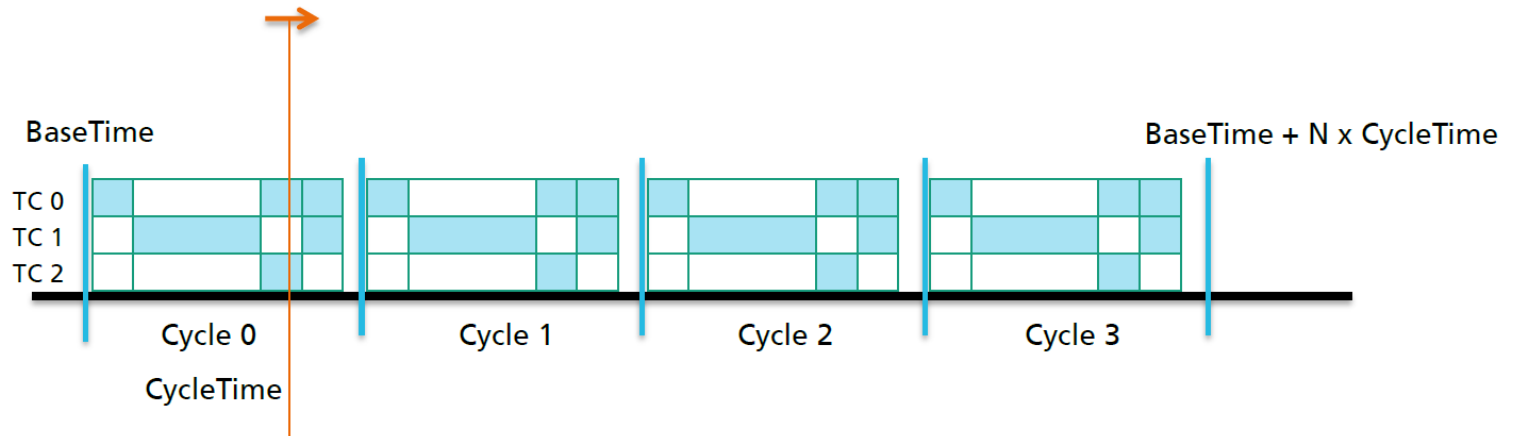
Source: <https://en.wikipedia.org/wiki/File:Traffic-shaping.pdf>



# TSN standards

## IEEE 802.1Qbv - Time Aware Shaper

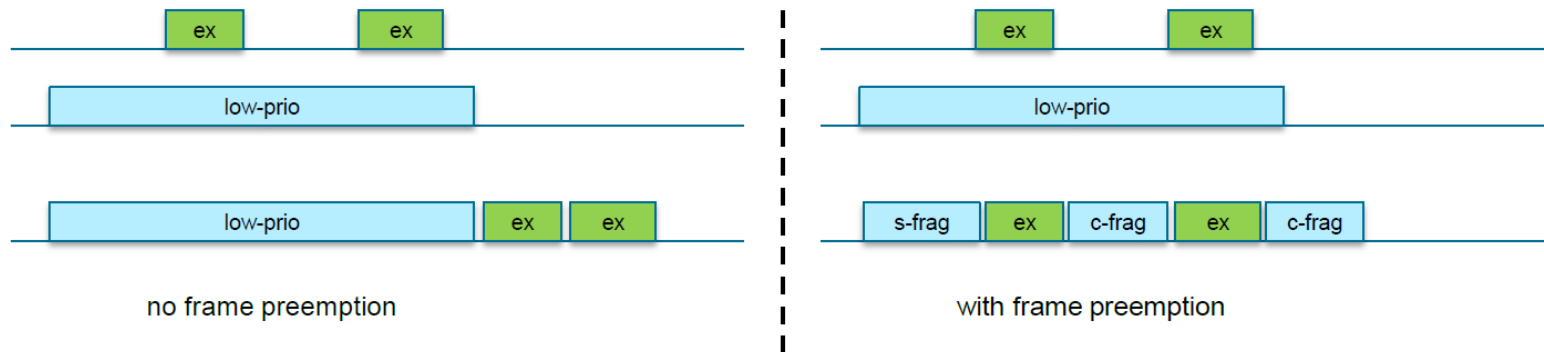
- Cycle based scheduling of frames
- Cycle length
- A number of gate operations
- Guard bands prevent violation of cycle timings



# TSN standards

## 802.3br & 802.1Qbu – Frame preemption

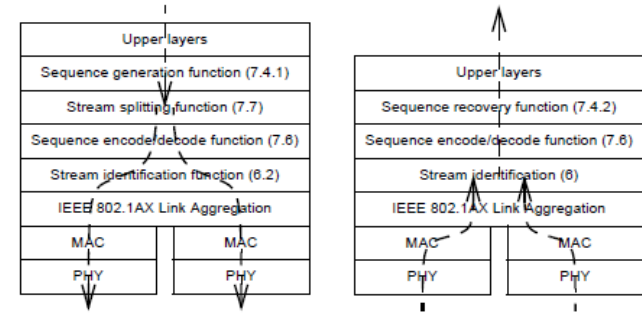
- Extreme low latency for chosen traffic (express traffic)
- Special mPackets (express packet, preemptable packet, fragment of a packet)
- 64bytes of minimal fragment size



# TSN standards

## IEEE 802.1CB - Frame replication and elimination for redundancy

- Sequence generation
- Split/Recovery
- Redundancy tag seq encode/decode
- Stream identification
- Link aggregation (802.1AX)



# TSN standards

## IEEE 802.1Qci – Per-Stream Filtering and Policing (PSFP)

- Filtering and policing and frame queue decisions made on a per-stream basis for received frames
- Stream gate id → open/closed

