IF IT'S NOT MIPI, IT'S NOT MOBILE

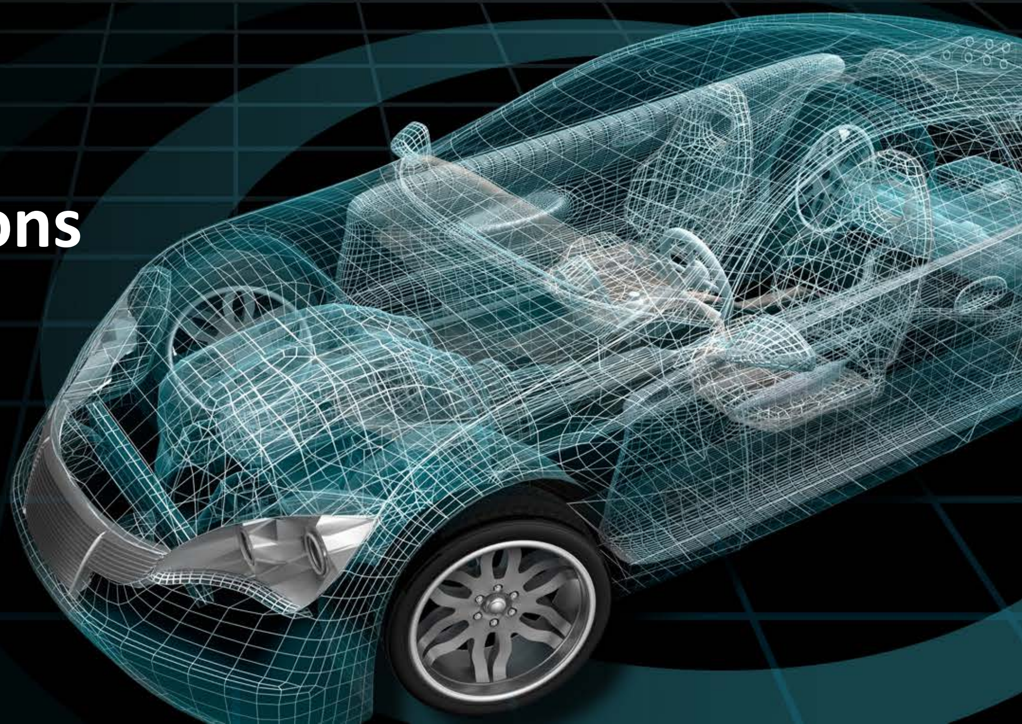
# A-PHY: The Cornerstone of MIPI Automotive System Solutions

**Ariel Lasry**

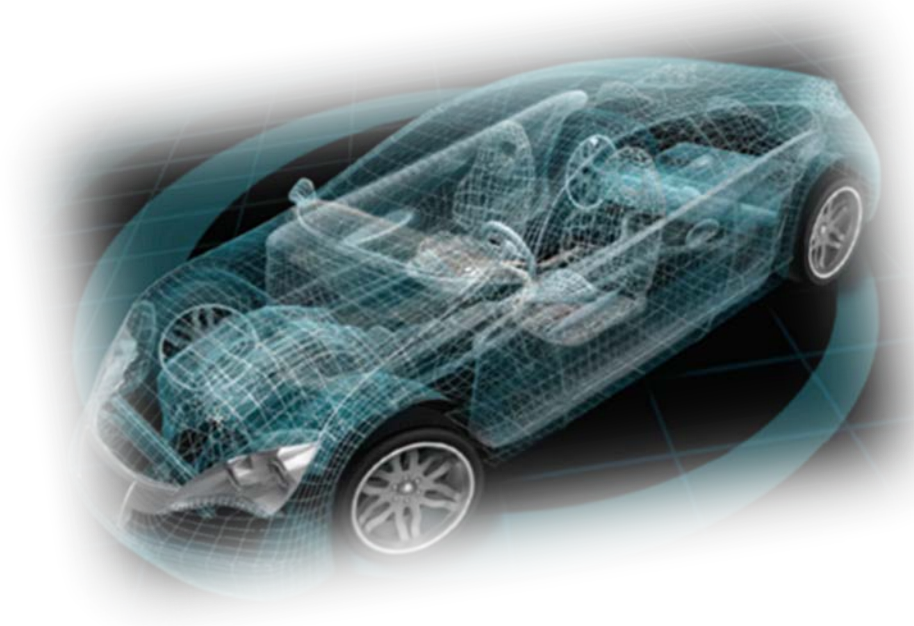
Director, MIPI Alliance Board of Directors, Toshiba

**Edo Cohen**

MIPI A-PHY Subgroup Vice-Lead, Valens



# Presentation Outline



## About MIPI Alliance
**Peter Lefkin**

*MIPI Alliance Managing Director*

## MIPI A-PHY – System View
**Ariel Lasry**

*Director, MIPI Alliance Board of Directors*

## MIPI A-PHY - Specification Overview
**Edo Cohen**

*MIPI A-PHY Subgroup Vice-Lead*

## Q&A

mipi alliance

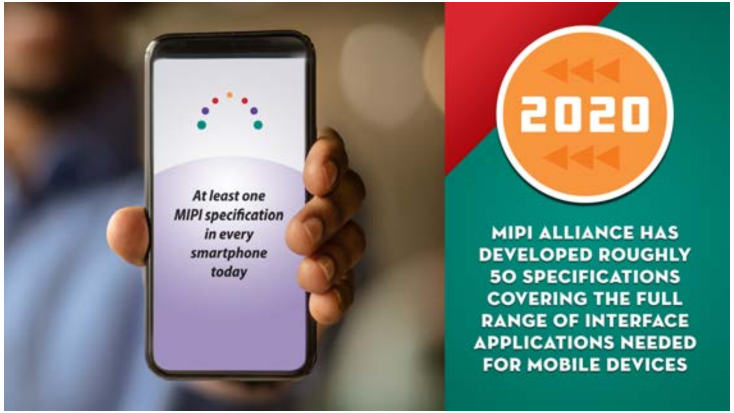
 

# About MIPI Alliance

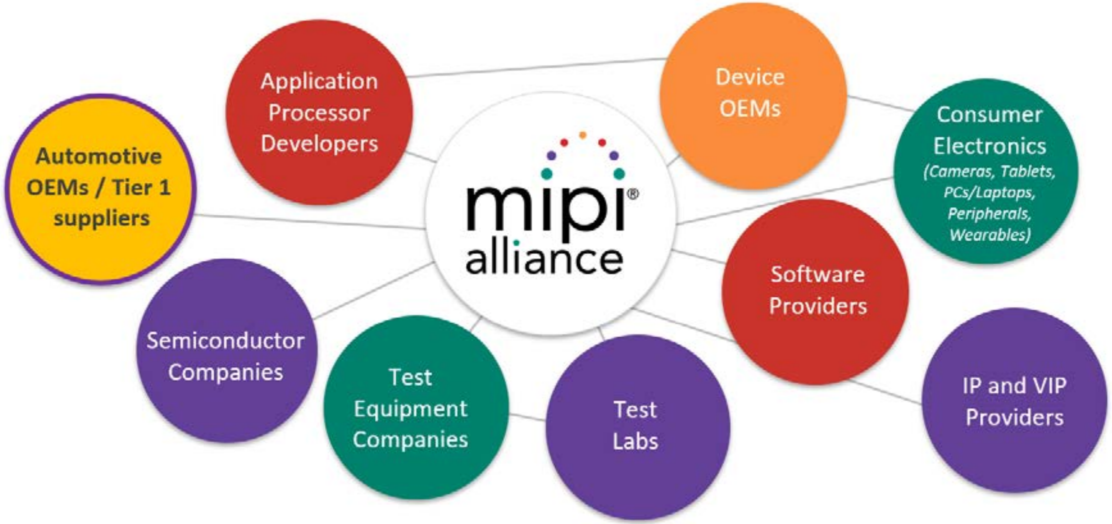
**Peter Lefkin**
MIPI Alliance Managing Director

# About MIPI Alliance


## TODAY'S MIPI MEMBER ECOSYSTEM




# MIPI Beyond Mobile


***Fundamentally, usage rights are granted to members royalty free for implementation of MIPI specifications from all MIPI members***

## MIPI SPECIFICATIONS IN AUTOMOTIVE

**CSI-2**
Camera Serial Interface protocol
*Protocol for cameras, lidar, radar sensors*

**DSI-2**
Display Serial Interface protocol
*Protocol for smartphone, IOT and automotive displays*

**C-PHY**
3-phase physical layer for CSI-2 & DSI-2
*Short-reach physical layer for cameras and displays*

**D-PHY**
Differential physical layer for CSI-2 & DSI-2
*Short-reach physical layer for cameras and displays*

**I3C**
Control and data bus protocol and interface
*Sensor and general purpose data and control interface within a module*

**RFFE**
RF control protocol
*Front end control within a wireless module*

**SoundWire & SWI3S**
Digital audio and control interface
*Audio interface within a module*

**UniPro for JEDEC UFS**
Data transport protocol for UFS over M-PHY
*Transport protocol for UFS storage*

**M-PHY for JEDEC UFS**
Differential physical layer for UFS storage
*Short-reach physical transport for UFS storage*

# MIPI A-PHY – System View

**Ariel Lasry**
Director, MIPI Alliance Board of Directors

# Auto Industry Transformation


***Honda and GM Partner to Develop Mass Produced, Driverless Cars***
Source: October 4, 2018, Automotive News

MIPI directly supports *CASE* via:
- Connected (RFFE, others)
- Automated (A-PHY, CSI-2, others)

***CASE:***
***• Connected • Automated***
***• Shared • Electrified***

- Connected: The move to 5G
- Automated: The move to L3 and beyond
- Shared: New OEMs, new business models, new alliances
- Electrified: Tesla and others

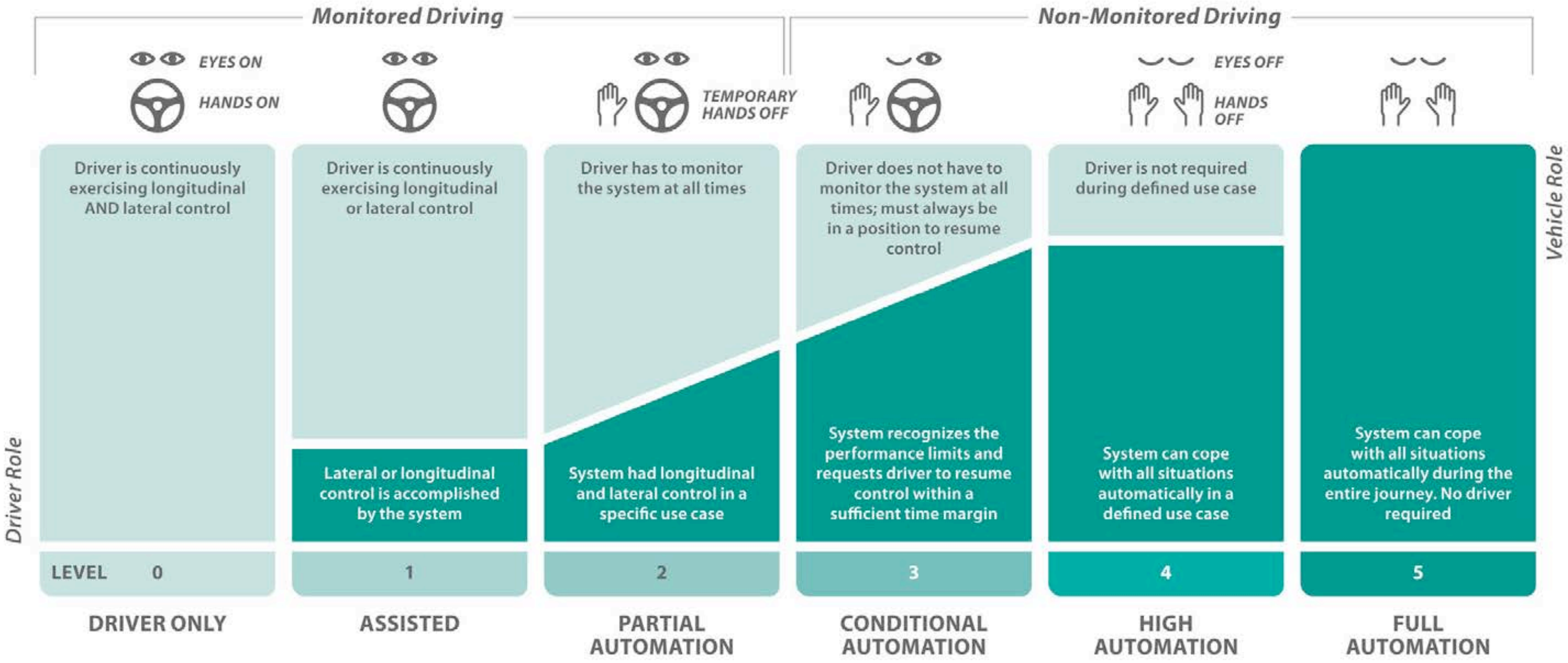
And . . .

Safety: Improved government safety regulations (FCWS, AEBS, RVS, LDWS, etc.)
Fuel economy: Aggressive regulations

mipi alliance

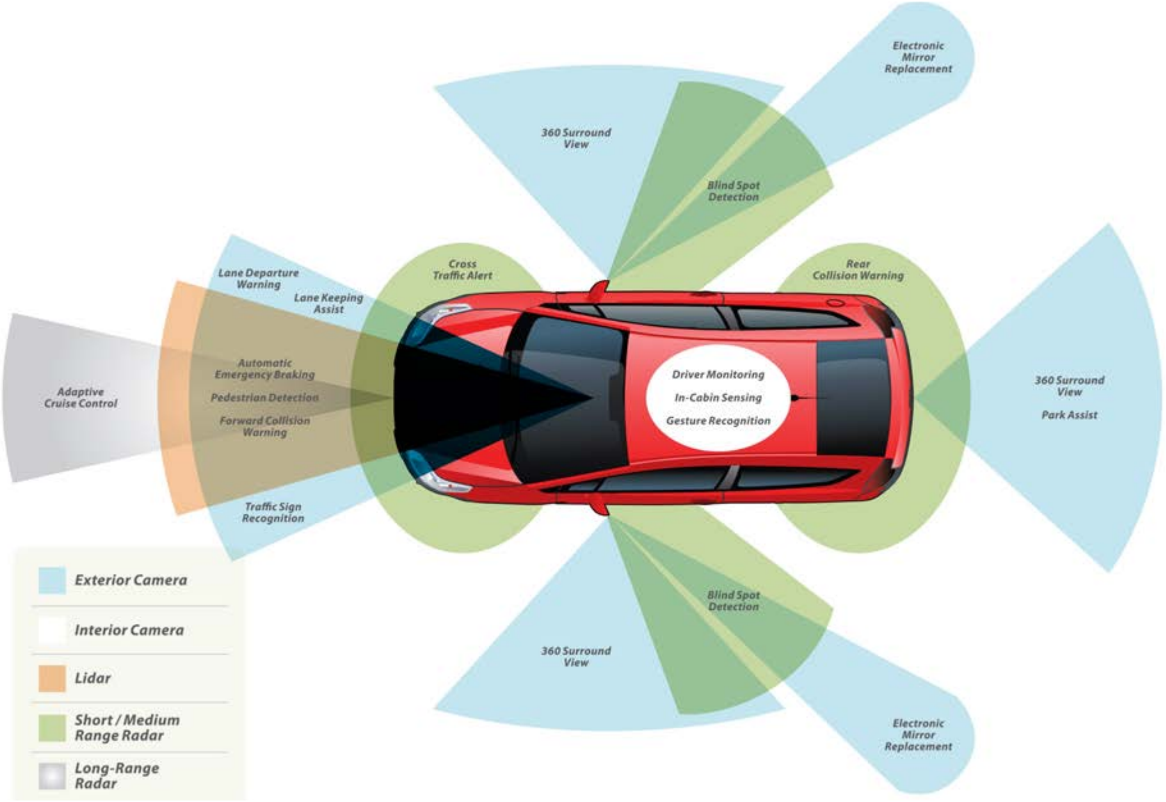
# Levels of Driving Automation:
# MIPI A-PHY Contributes to Levels 2-5, Moving Sensor Data Efficiently




*MIPI A-PHY contributes to Levels 2-5*

# NCAP Regulations Driving Sensors & Display Adoption



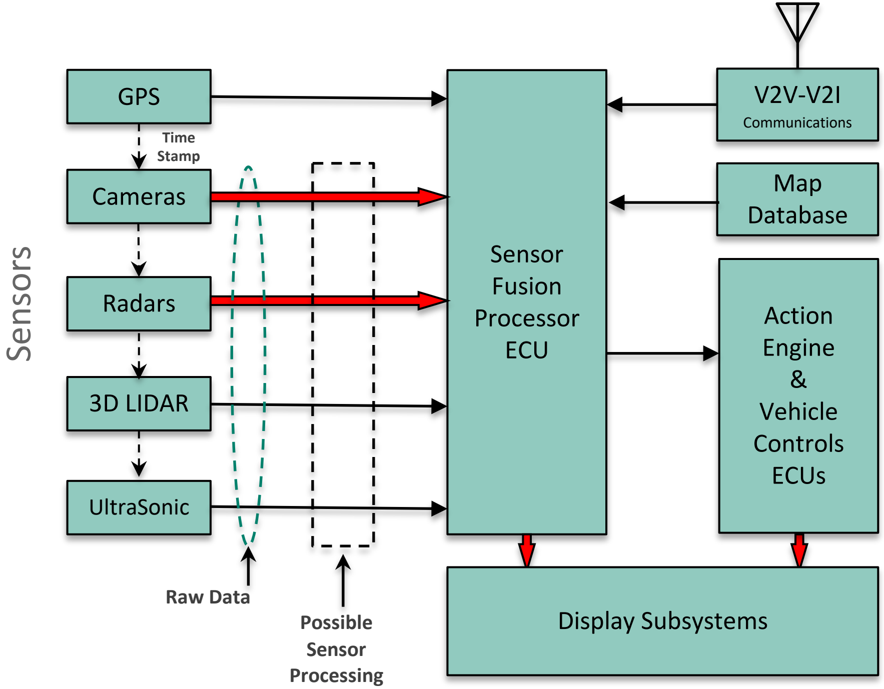

- Worldwide NCAP ADAS standards driving adoption of multiple high data rate "surround sensors"
- Displays for driver viewing of assistance imaging and information also required

Source: Jabil, Inc

# Autonomous Driving System/Architecture

**CENTRAL CHALLENGE:** Transport raw image sensor and/or radar data to fusion processor, and processor/other generated data to the displays




Highest data rate asymmetrical interfaces include those for camera, radar and display

## Data Rates

***For camera/image sensors***, 10Gbps link could support:

- RAW16 10MP 1 max exposure channel @ 60fps
- RAW 16 2MP 4 max exposure channels @ 60fps

***For radar***, 12.5Gbps link could support:

- Four "typical" 4-RX-channel (50MS/sec, 12b res)
- Two "max" 4-RX-channel (80MS/sec, 16b res)

***For display subsystems***, 16Gbps link could support:

- Ultra-HD 3840x2160 24-bits/pixel RGB 4:4:4 60 Hz



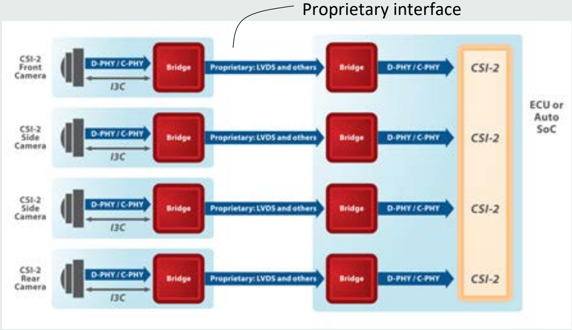
 | 

# What is MIPI A-PHY?

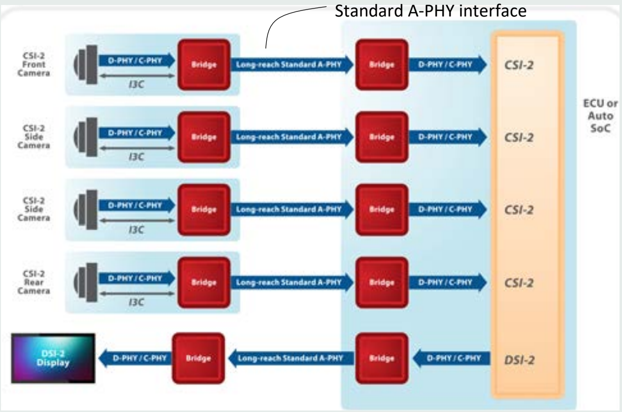
MIPI A-PHY is a physical layer specification targeted for ADAS/ADS surround sensor applications and Infotainment display applications in automotive. Version 1.0 will provide a 15-meter reach and data rates of 2-16 Gbps, with a roadmap to 24, 48 Gbps and beyond.

MIPI A-PHY is the ONLY standard interface to support native camera (CSI-2) and display (DSI-2) interfaces for automotive. An adaptation layer is also being developed for VESA DisplayPort and eDP.

**TODAY'S PROPRIETARY INTERFACE BRIDGE SOLUTIONS**




**TOMORROW A-PHY STANDARD INTERFACE BRIDGE SOLUTIONS**



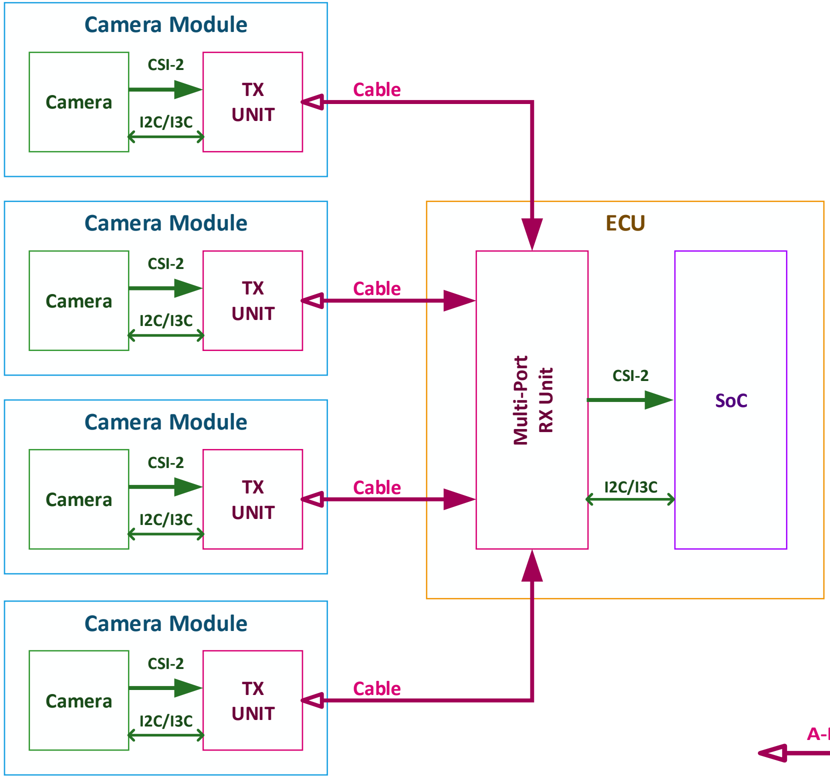

**FUTURE INTEGRATED A-PHY**
(NO BRIDGES: Lower cost, weight, power)


mipi alliance

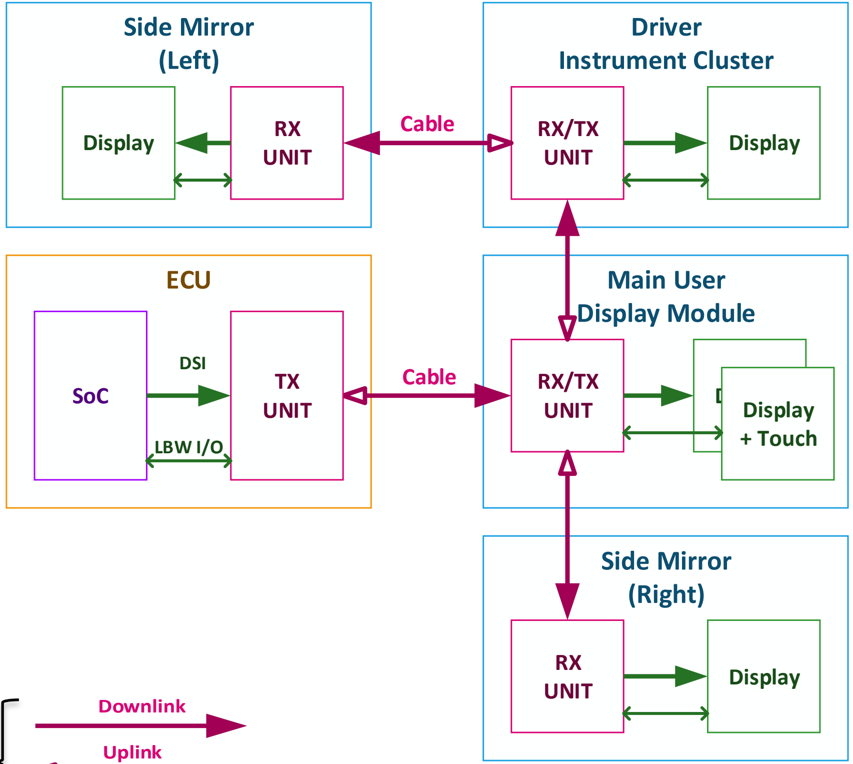
 

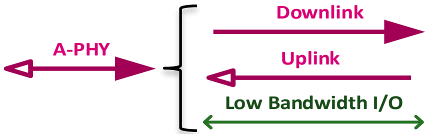
# A-PHY Topology Examples

## Cameras example with direct connection



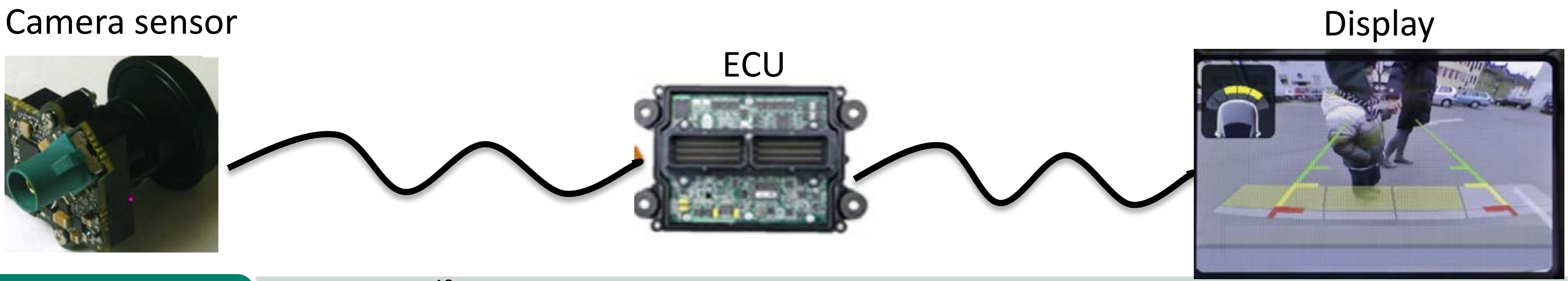

## Displays example with daisy-chain



# Challenges To Be Solved Require: A-PHY + MIPI Protocols




**Robust Automotive Long-Reach Link**

- PER = $10^{-18}$ : 1 packet error in ~10,000 car-lifetimes
- High speed downlink and aggregation to support **multiple** 4K cameras and displays
- Asymmetric high speed link with fixed low latency ~6µs @G5

**End to End Functional Safety**

- Enabling integration of devices using MIPI protocols over A-PHY in ASIL B or ASIL D systems
- A-PHY **and** Protocols (CSI-2, DSI-2) FuSa from Source to Sink

**End to End Security**

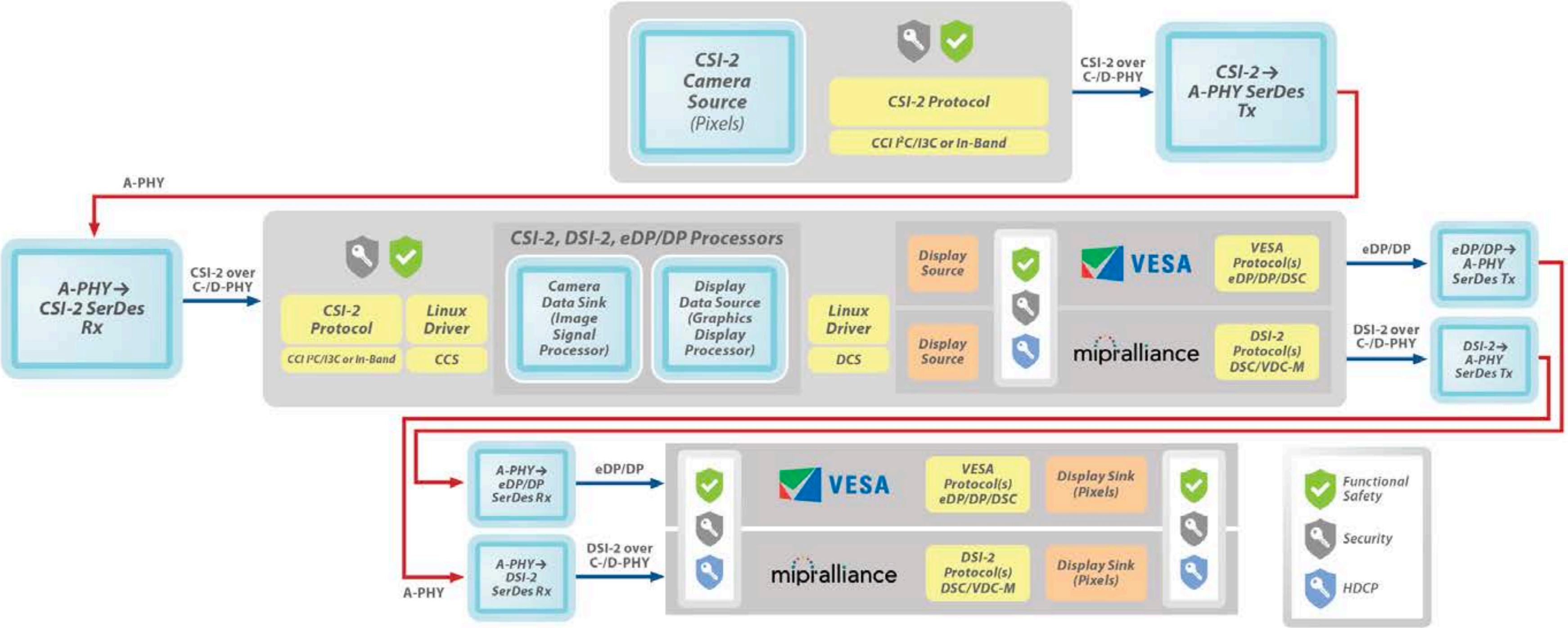
- Authentication; prevention of tampering (malicious and non-malicious)
- Content protection for display applications (HDCP)

**Heterogeneous Interfaces**

- Common support for multiple display protocols: DSI, DisplayPort, eDP, OpenLDI
- Agnostic to source/sink PHY configuration: C-PHY, D-PHY, Lanes count

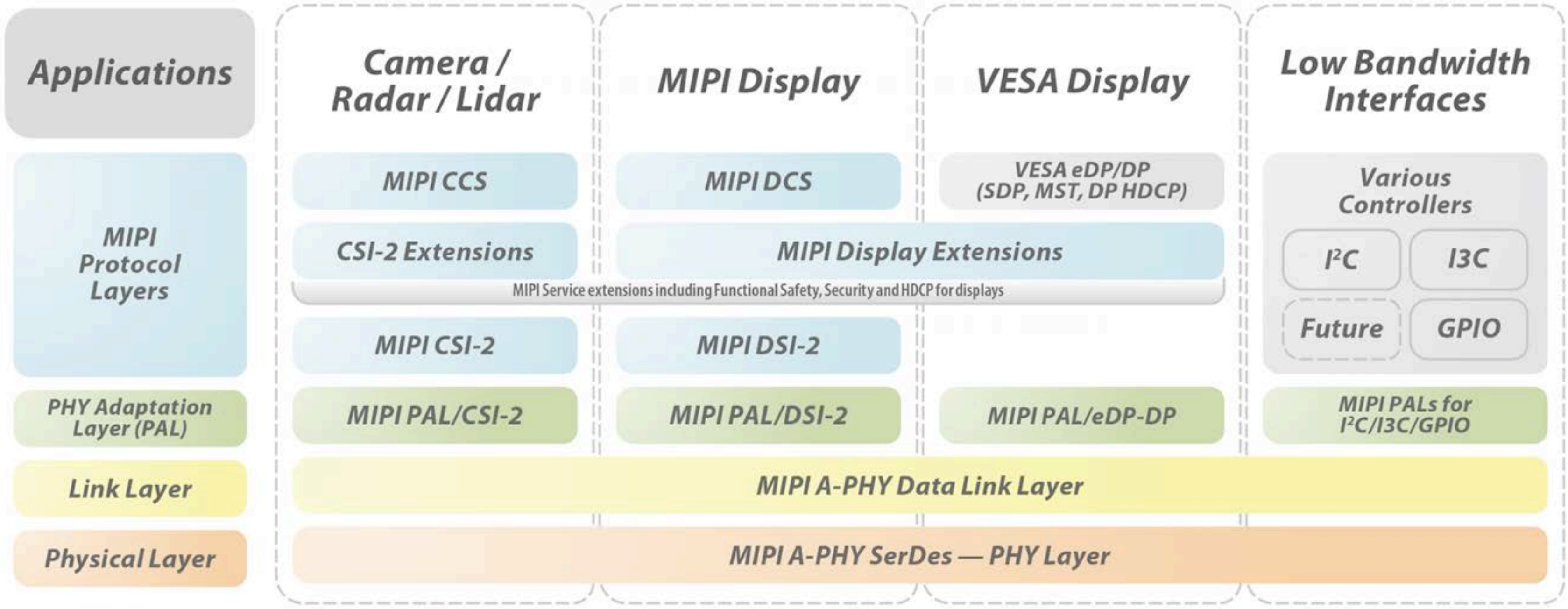
# MIPI Vision for End-to-End System




mipi alliance

# MIPI Automotive Stack for A-PHY




- Scalability: Additional PHY Adaptation Layers (PALs) can be developed to expand interoperability

mipi alliance

 | 

# An Overview of A-PHY

**Edo Cohen**
MIPI A-PHY Subgroup Vice-Chair

# Gears and Profiles

- One rate/line-code/modulation per downlink gear
- Single uplink gear
- A-PHY Device supporting Gear N (i.e., N could be 1–5) shall support all lower gears.
- Two noise/performance profiles (with full inter-profile interoperability):
  - **Profile 1:** Optimized for low cost/power implementations for the lower gears with lower noise immunity and target BER of $<10^{-12}$
  - **Profile 2:** Optimized for vehicle lifespan, link robustness for all gears with high noise immunity and target PER of $<10^{-19}$

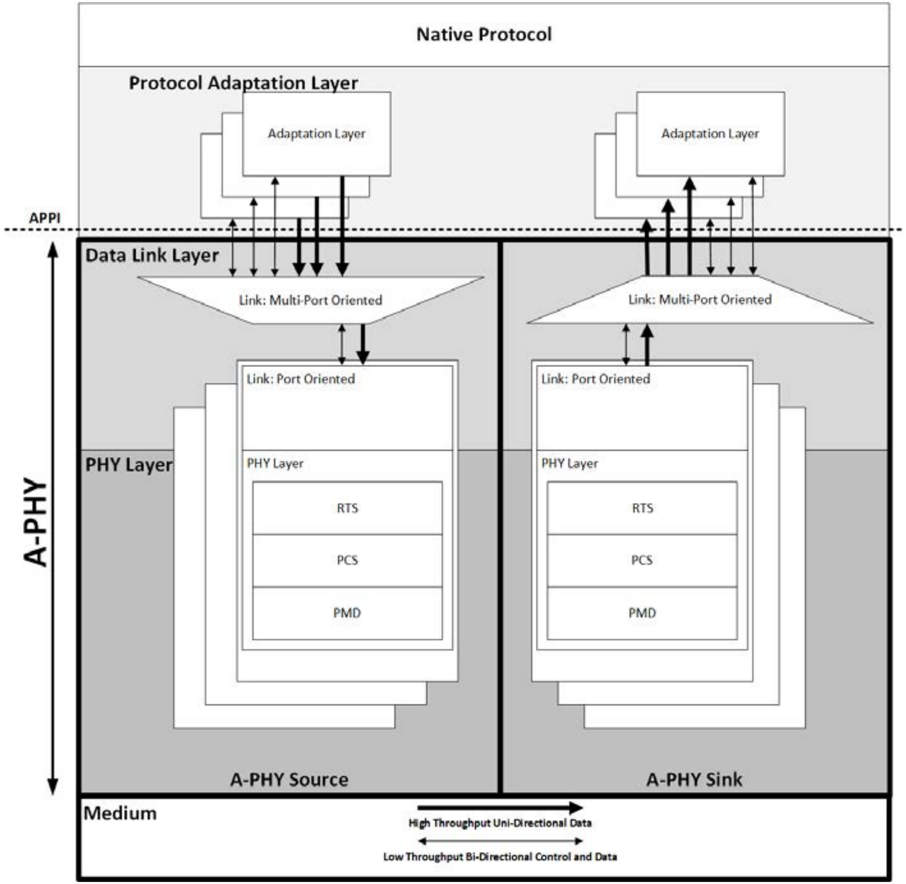
| Gear Data Rate | Modulation [One modulation per Gear] | Symbol Rate [GBaud] | Net Application Data Rate [Gbps] |
|---|---|---|---|
| **G1** 2 Gbps | NRZ-8b/10b | 2 | 1.5 |
| **G2** 4 Gbps | NRZ-8b/10b | 4 | 3 |
| **G3** 8 Gbps | PAM4 | 4 | 7.2 |
| **G4** 12 Gbps | PAM8 | 4 | 10.8 |
| **G5** 16 Gbps | PAM16 | 4 | 14.4 |
| **Uplink, All Gears** 100Mbps | NRZ-8b/10b | 0.1 | 0.055 (55Mbps) |

mipi alliance

 | 

# High Level Structure

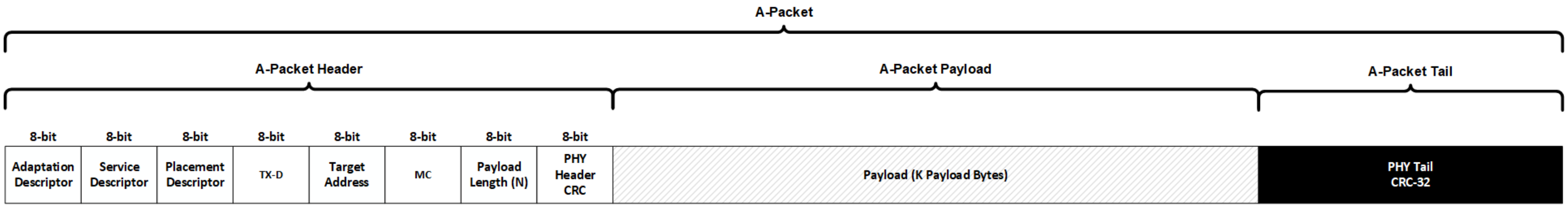
- **Native Protocol**
  - e.g., CSI-2, DSI-2, I²C, GPIO
- **Protocol Adaptation Layer (PAL)**
  - Mapping to/from Native Protocol to A-Packet
- **APPI**
  - Interface between A-PHY Port and PAL
- **Data Link Layer**
  - Performs A-Packet scheduling, prioritization and forwarding
- **Physical Layer**
  - Encodes and decodes symbols extracted from A-Packets according to the modulation scheme used per gear
  - Modulated symbols are transmitted and received over the A-PHY interconnect according to the medium-dependent electrical specifications.




mipi alliance

 | 

# A-Packet



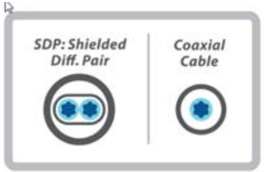

- The A-Packet is structured to carry the Native Protocol data and all information that the A-PHY Data Link Layer requires to perform its functions efficiently.
- Downlink and uplink use the same packet structure.
- Structure optimized supporting multiple protocols aggregation with minimal overhead and latency
- The A-Packet Header contains all required information (e.g., QoS, Priority, Destination, Protocol Type).
- The A-Packet structure:
  - Header - 8 Byte including MC (Message Counter)
  - Payload
  - Tail – 4 Byte (CRC-32)

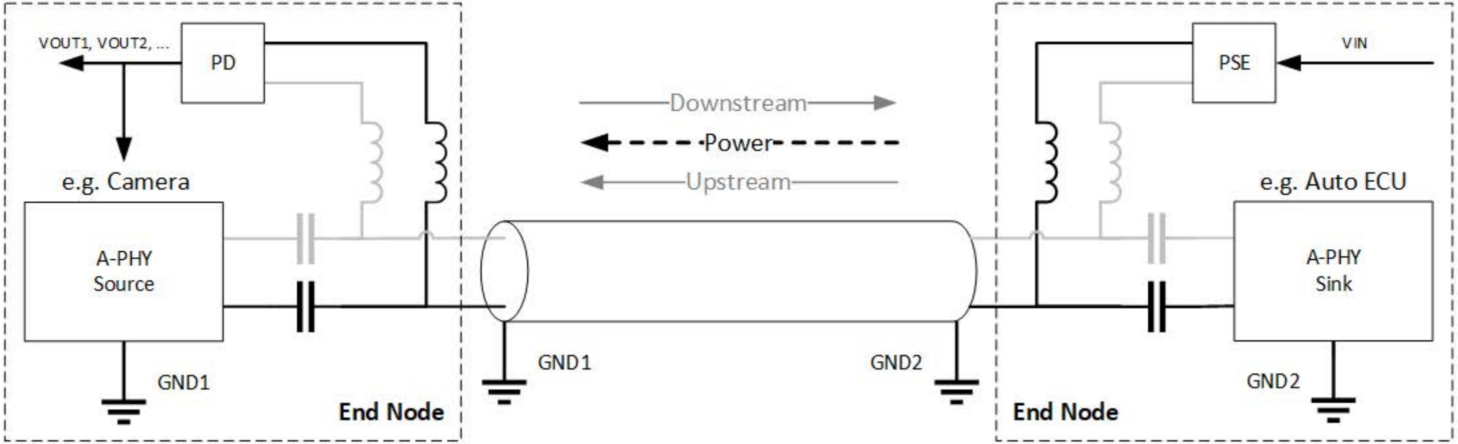
mipi alliance

# Interconnect

- A-PHY is a single lane, point-to-point, serial communication technology
- Support for multiple cable types – SDP/Coax
- Power over cable support
- Up to 15m with 4 inline connectors





# Low Tx Amplitude - Optimized for Low PSD

TX Amplitudes to over 50 Ω Coax channel

| Gear | Downlink [mVp-p] | Uplink [mVp-p] |
|---|---|---|
| 1 | 250 | 500 |
| 2 | 350 | 500 |
| 3 | 250 | 500 |
| 4 | 500 | 250 |
| 5 | 500 | 250 |

- Example Comparing ~4Gbps Downlink TX Voltage solutions (Single Ended)
  - **A-PHY G2 – 350mVp-p**
  - FPD Link III (DS90UB953-Q1) – 575mVp-p
  - GMSL (MAX9277-9281) – 500mVp-p

# Noise Immunity

- There is a major variance in the OEM EMC requirements, from those who aim for minimal noise immunity, to OEMs that apply stringent requirements to protect their system.
- A-PHY two profiles provide two noise immunity levels to accommodate this variance:
  - P1 has lower noise immunity, similar to other SERDES solutions and is applicable for G1 and G2 (optional G3).
  - P2 has very high noise immunity based on MIPI Alliance analysis of expected noise level for the car lifetime period.
- MIPI conducted multiple tests in an independent lab evaluating the noise levels and shielding effect degradation after mechanical stress and aging.
  - The results helped evaluate the different available technologies.
  - The research continues as part of MIPI A-PHY SG activities.

mipi alliance

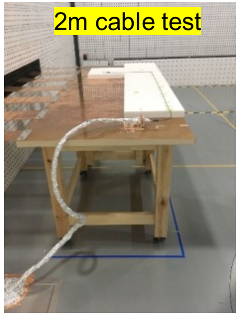
 

# Characteristics of RF Ingress Test

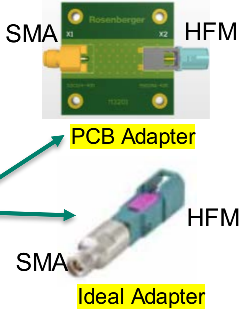
## *Test Conditions*

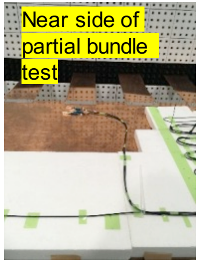
***Cable:*** Two types of Dynamics Coax cables in length of 2m and 15m

***Lab Conditions:***





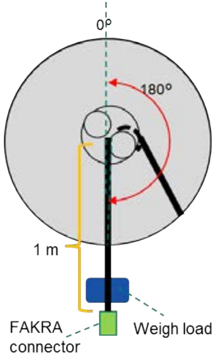


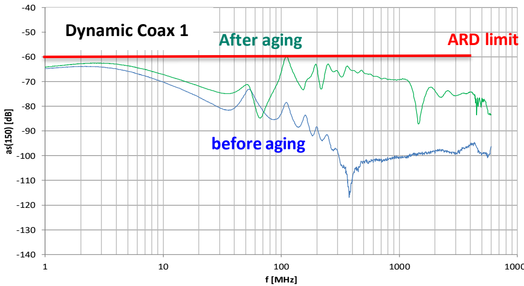


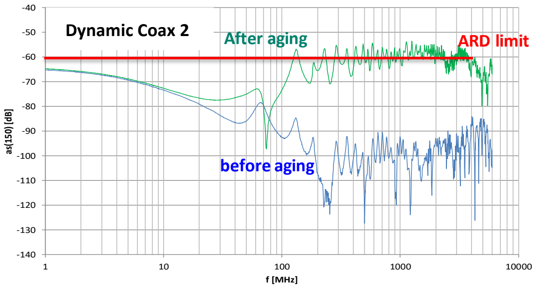

## *Bending Fatigue & Temperature Cycling Test*

| | | |
|---|---|---|
| Mechanical condition | Bending angle | 180˚ |
| | Bending diameter | 60 mm |
| | Bending Speed | 10 times/min |
| | Weight load | 3 N (~0.3kgf) |
| Temperature condition | Temp. cycle | See below fig. |
| | Temp. range | -25~25~105℃ |
| Total number of bending | | 36000 times |
| Total time | | Roughly 72 hours |




### Screening Attenuation Test Result




mipi alliance

 | 

# Noise Immunity Levels

| Interference | P1 [mVpeak] | P2 [mVpeak] | Note |
|---|---|---|---|
| RF Ingress | 5 | 40 | Based on the ALSE method ISO 11452-2, CW/AM/PM modulation scheme |
| Bulk Current Injection | 21 | 40 | Based on ISO 11452-4, CW/AM modulation scheme |
| Fast Transient | 15 | 150 | Based on ISO7637-2/3, with modifications for higher frequency pulses |

Notes:

- Noise levels are defined at the Receiver pads when using the specified typical worst-case cable
- P2 limits are in line with similar results shown in IEEE research paper: https://ieeexplore.ieee.org/document/8825296 (Requires IEEE member access)
- 40mVpeak corresponds to 89dBuV RMS

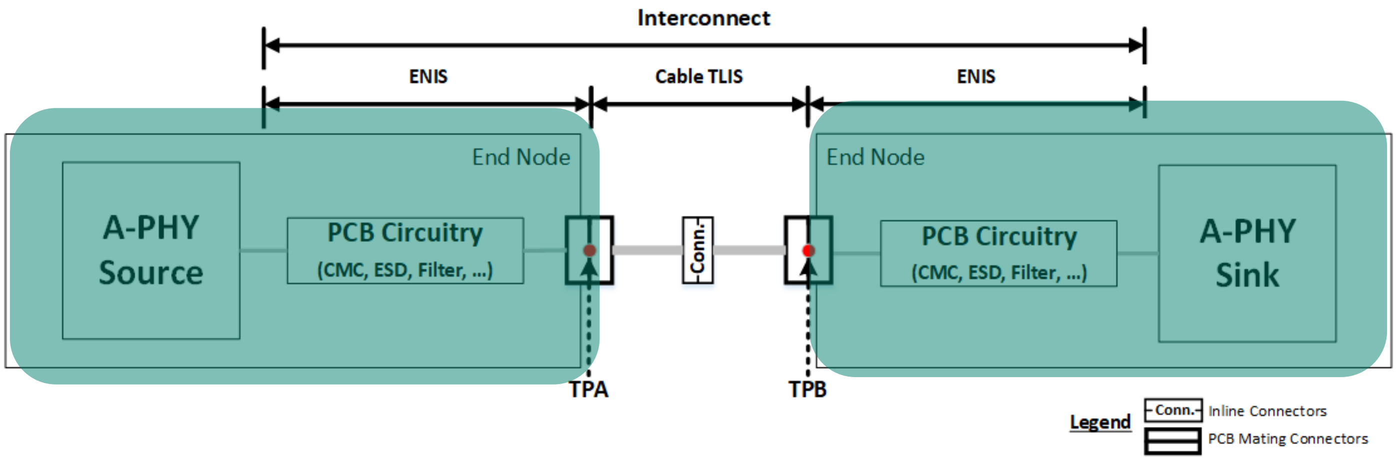
# Functional Safety

- A-PHY packets are end-to-end protected as recommended in ISO-26262:2018:
  - CRC-32 for each packet, providing a Hamming-Distance of more than 3.
  - Message Counter that is 8 bits wide.
  - Timeout monitoring is fulfilled by the Keep-Alive function.
- The above measures are necessary to argue a high diagnostic coverage for a communication bus, per ***Table D.6*** in ISO 26262-5:2018
- All other functional safety features necessary in order to fulfill the required system-level safety goal with ASIL are expected to be managed by upper layers.


 | 

# A-PHY Port

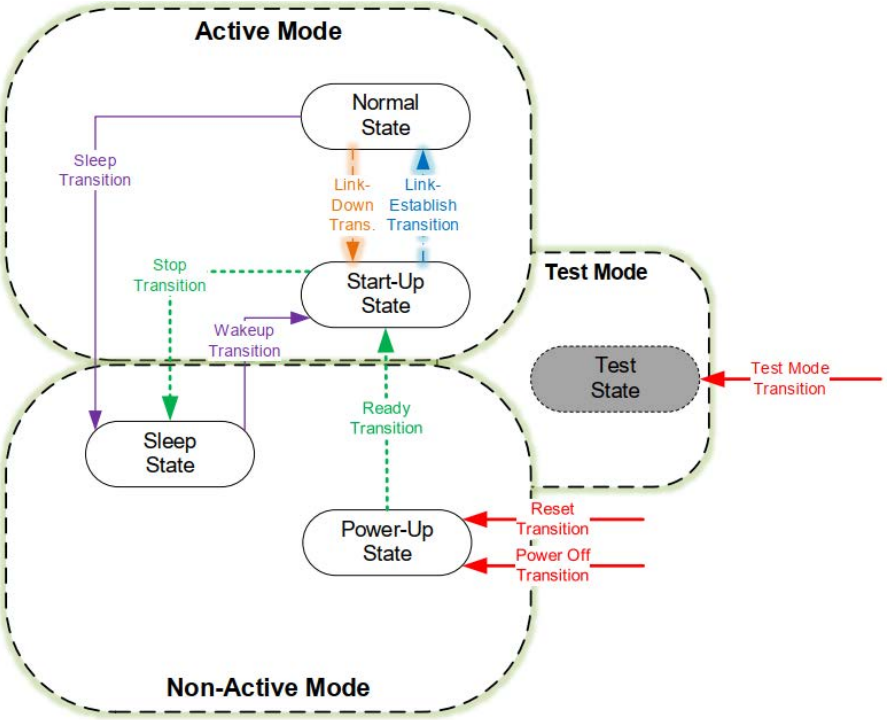
- A-PHY Port mandatory Baud Rates: 2GBaud or 4GBaud
- A-PHY Source Port shall supply the clock, and A-PHY Sink Port shall receive it.
- MIPI A-PHY refers to TPA and TPB throughout the specification for clear interoperability and testability



# Mode Of Operations

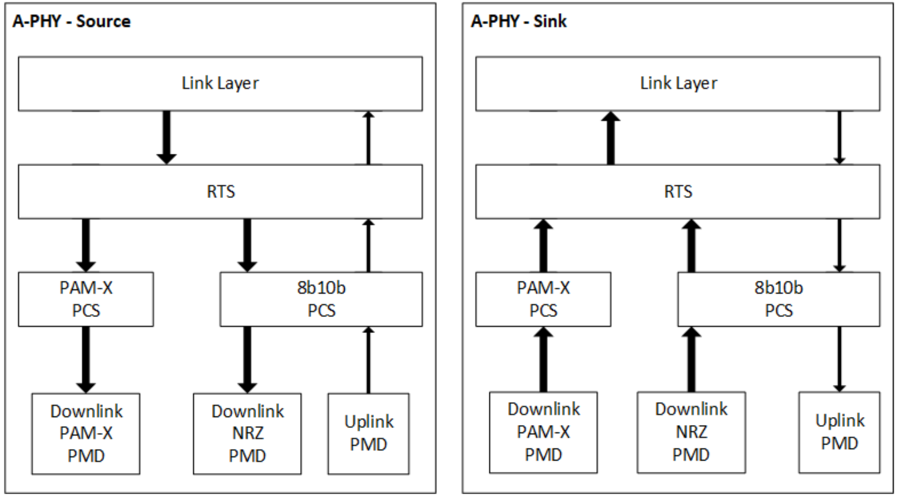
- Same state machine to A-PHY Source and Sink
- State transition may be triggered by:
  - Internal mechanism
  - Local host
  - Remote controller
- All changes are reported to the local system
  - The local system will take any needed decisions based on the provided information
- Some activities are “automatic” and do not require local system intervention




 | 

# PHY Layer

- Unified structure to reduce complexity
- Shared 8B/10B PCS for G1/G2 and Uplink
- RTS Sub-Layer
  - Manage Data Pacing and buffering
  - Assign Message Counter (MC) and CRC
  - P2 - the retransmission process for A-Packets that are erroneous or that are not received
- PCS Sub-Layer
  - Specifies the conversion of Data Link Layer A-Packets into PHY Symbols
  - In P2, PCS also handles the JITC(*) Re-Training
- PMD Sub-Layer
  - Defines the electrical specifications and the physical medium




(*) JITC – Just In Time Cancelers

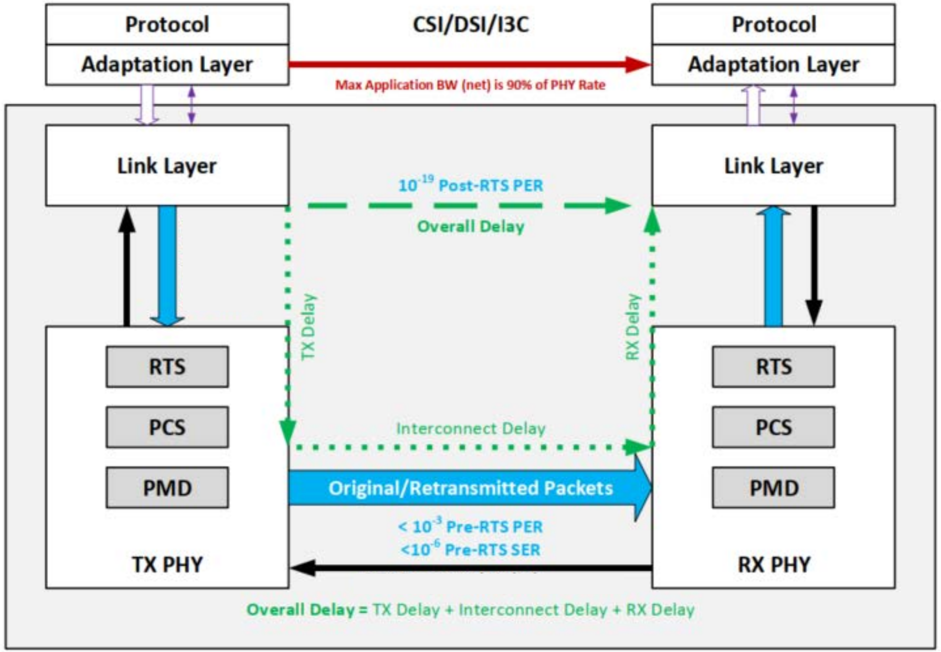
 

# RTS - Time Bounded Local PHY Level Retransmission

- Local Retransmission (RTS) mechanism is used in order to:
  - Recover damaged packets due to the effect of large in-car electrical transients which create long bursts of errors
  - Recover damaged packets due to instant attack of yet un-cancelled large NBI which create long bursts of errors
  - Ensure steady link throughput to enable seamless higher layers operation even at extreme PHY operation points

# RTS - Time Bounded Local PHY Level Retransmission

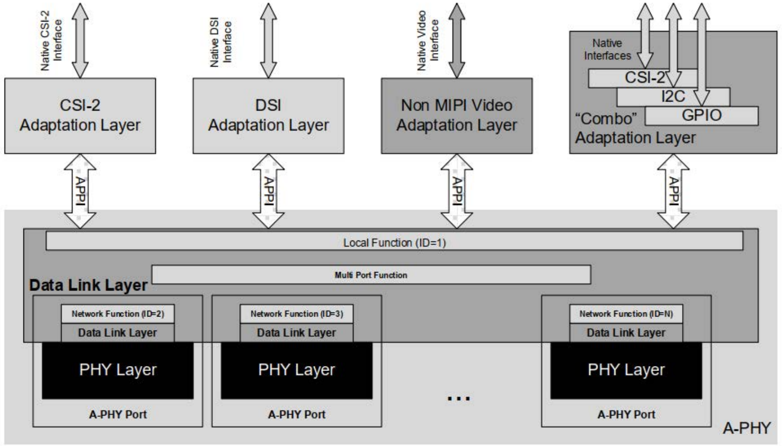



- **Time Bounded**
  - Retransmission is attempted only within predefined "Overall Delay" (e.g. ~6µS @G5)
- **Local PHY Level**
  - Transparent to upper layers
  - Happens within a single A-PHY Hop
- **Dynamically Modulated**
  - Retransmitted packets have better error resistant data payload Sub-Constellation
- **Highly Reliable**
  - PER (Packet Error Rate) < $10^{-19}$
- **Highly Resilient**
  - Overcome thousands symbols-long error bursts
  - Multiple 10s of mVs, instantly attacking, NBI Peak
- **Low Overhead**
  - Overall PHY + Link < 10% ➔ 90% Net Data rate

# Link Layer

- The A-PHY Data Link Layer is a protocol agnostic layer that performs scheduling, prioritization and forwarding of A-Packets.
- Each Protocol Adaptation Layer has at least one APPI connection to the A-PHY Data Link Layer.
- A-PHY Data Link Layer may be connected to multiple Protocol Adaptation Layers using a single Local Function.
- The A-PHY Data Link Layer may have a single A-PHY Network Function connected to it, or multiple A-PHY Network Functions

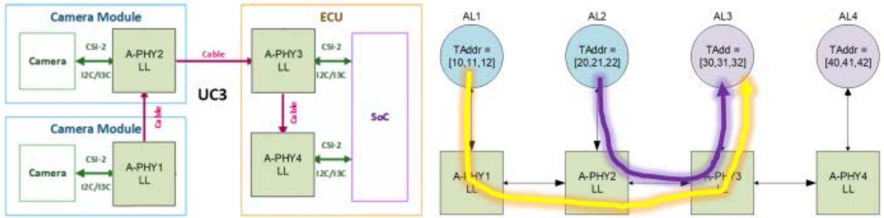


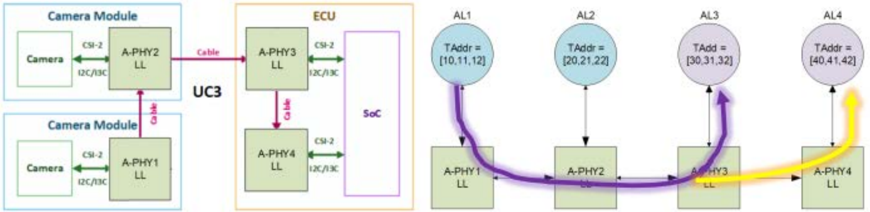

 | 

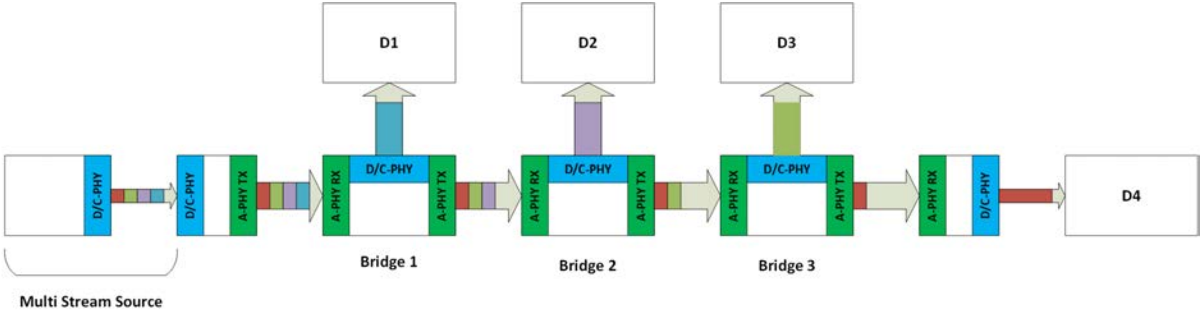
# Link Layer

The A-PHY Data Link Layer enables A-Packet:

- Forwarding
- Prioritization
- Duplication
- Scheduling

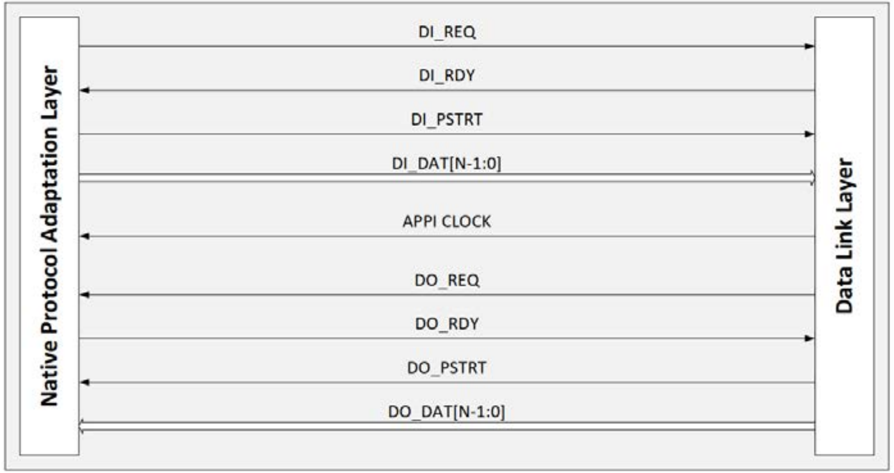


# APPI – A-PHY Protocol Interface

- Based on MIPI current PPI (PHY Protocol Interface) for D-/C-PHY
- Simplified normative signal interface of A-PHY with protocol layers
- Flexible data width and clock speed
- Easy migration for higher speeds in next generation






 | 

# Concluding Thoughts

- *In-vehicle architecture is **rapidly evolving** . . .*
- *Increased focus on **surround sensor applications** for ADAS / autonomous driving . . . Best served by dedicated high-speed asymmetric interfaces from sensors to ECU.*
- *Standardization important for **economies of scale, lower cost & greater capabilities**.*
- *The native MIPI protocols (CSI-2, DSI-2, I3C, others, available in billions of devices) with **A-PHY deliver enormous benefit** to the automotive industry . . . performance, cost, noise immunity, and long-term EBOM reduction via elimination of interface bridges.*
- *The MIPI solution is being developed to **meet the broadest spectrum** of automotive industry needs . . . with anticipated SOP as early as 2024.*

# Additional Resources

# Resources

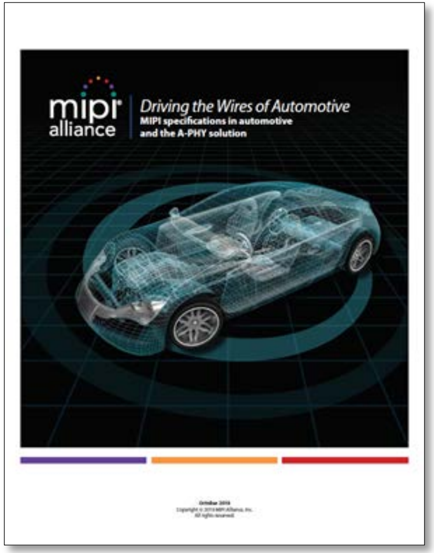
More information can be found at:

- MIPI Alliance Completes Development of A-PHY v1.0, an Industry-Standard Long-Reach SerDes Physical Layer Interface for Automotive Applications *(Press release, June 2020)*
- MIPI Alliance rises to data-transport challenge *(Article, AVT, April 2020)*
- Advancing In-Vehicle Connectivity for ADAS and Other Automotive Applications *(Webinar, March 2020)*
- A Look Under the Hood at MIPI CSI-2 and MIPI DSI-2 in Automotive *(Blog, January 2020)*
- MIPI Automotive & A-PHY Update *(DevCon presentation, October 2019)*
- MIPI Alliance Advances Activities for ADAS, ADS and Other Automotive Applications *(Press release, October 2019)*
- Automotive Applications Drive MIPI A-PHY Development *(Blog, May 2019)*

## *Other Resources*

- A-PHY specification page

**MIPI in Automotive white paper**




mipi alliance