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

How MASS Simplifies the Integration of Camera and Displays in Automotive Architectures

Ariel Lasry
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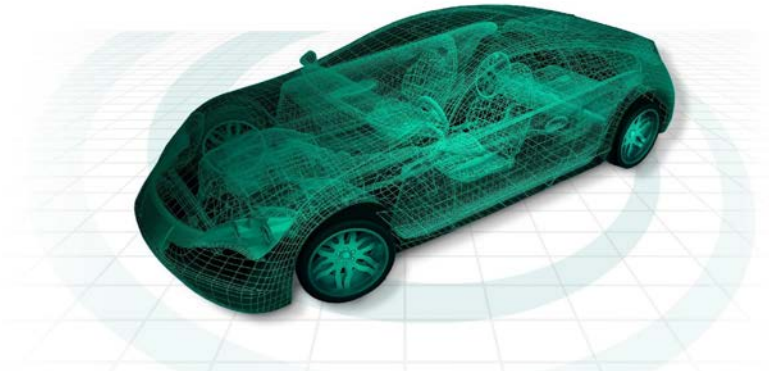
Agenda

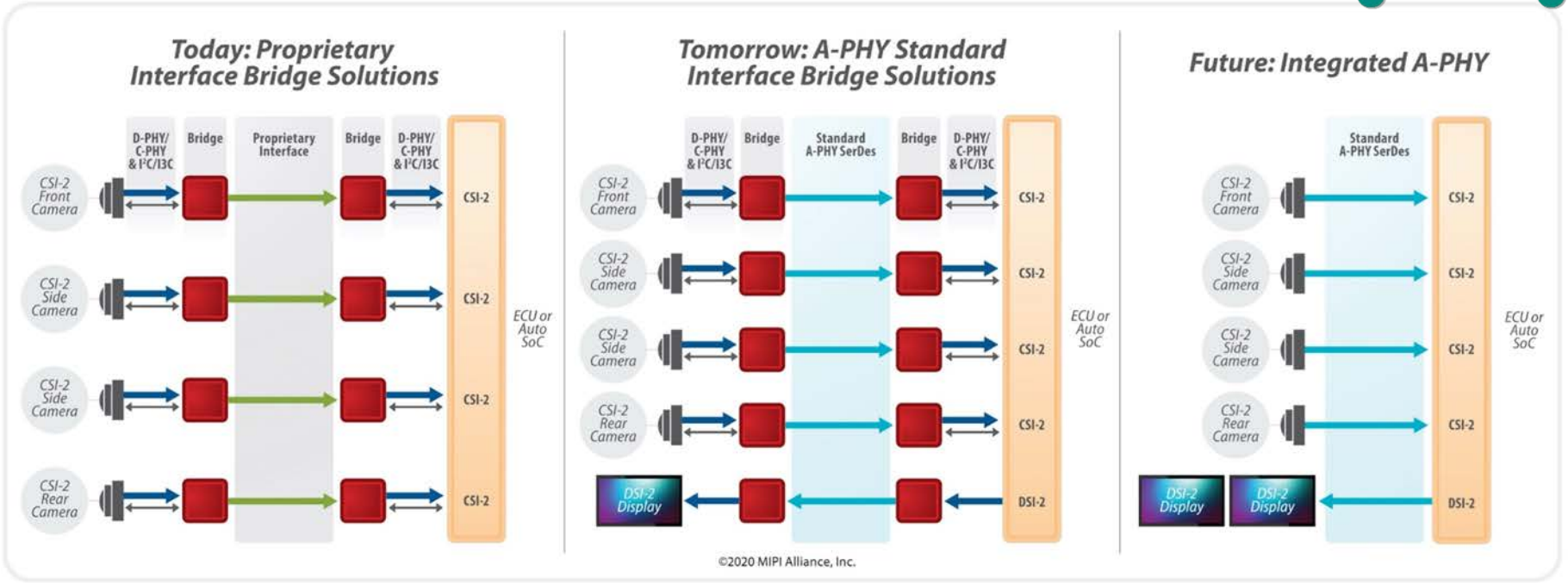
- MIPI Automotive SerDes Solutions (MASS) Overview
- MASS for Camera and Sensors
- MASS for Display
- Summary
- Q&A



MIPI Automotive SerDes Solutions Overview

Ariel Lasry
Vice Chair, MIPI A-PHY Working Group

MIPI A-PHY Overview



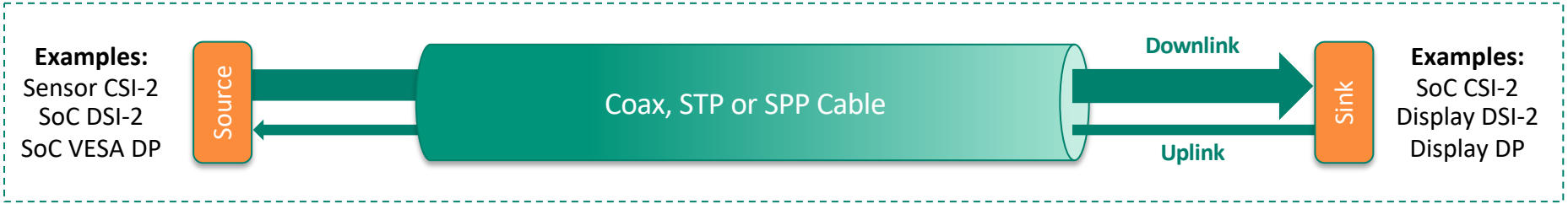
Lower cost through standardization and economies of scale

Lower cost/eBOM through integration

ECU: Electronic Control Unit **SoC:** System On Chip

MIPI A-PHY – Automotive Long-Reach PHY

The first industry-standard *long-reach* asymmetric SerDes physical layer specification targeted for ADAS/ADS surround sensor applications and infotainment display applications



A-PHY v1.0 offers:

- Direct coupling to native CSI-2/DSI-2/DP-eDP protocols
- High performance of up to 16 Gbps over 10-15m
- High noise immunity, ultra low PER (< 10^{-19})
- Supports bridge-based and endpoint integration
- Support for automotive coax and STP channels
- Power over cable
- Built-in Functional Safety according to ISO26262

NEW A-PHY v1.1 Enhancements:

- Increased support for lower cost legacy cables
- Double uplink data rate
- Star quad cable support, enabling dual downlink operation

PER: Packet Error Rate
STP: Shielded Twisted Pair
SPP: Shielded Parallel Pair

ADAS: Advanced Driver Assistance System
ADS: Autonomous Driving System
SoC: System On Chip

MIPI A-PHY Activity

MIPI ALLIANCE NEWS

A-PHY v1.0 adopted as IEEE 2977-2021 *(June 2021)*

MIPI A-PHY ADOPTED AS IEEE STANDARD

Milestone expands access to automotive SerDes specification

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IEEE SA STANDARDS ASSOCIATION

WHAT'S NEXT:

A-PHY v1.1 development complete and will also be submitted to IEEE adoption process

MIPI Automotive SerDes Solutions (MASS) in the Car

Electronic Control Unit (ECU)

- Advanced driver assistance system (ADAS) based on sensor feeds
- Produces display feeds

Sensors

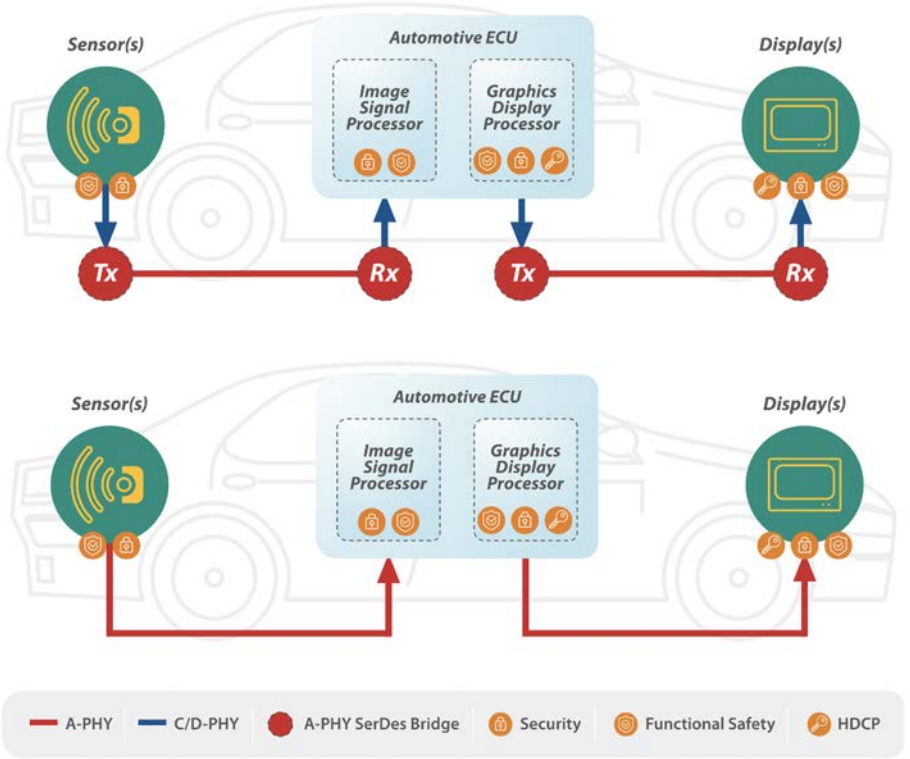
- Camera
- Lidar

Displays

- Dashboard
- Console
- Side view mirrors
- Entertainment

(Optional) A-PHY Bridges

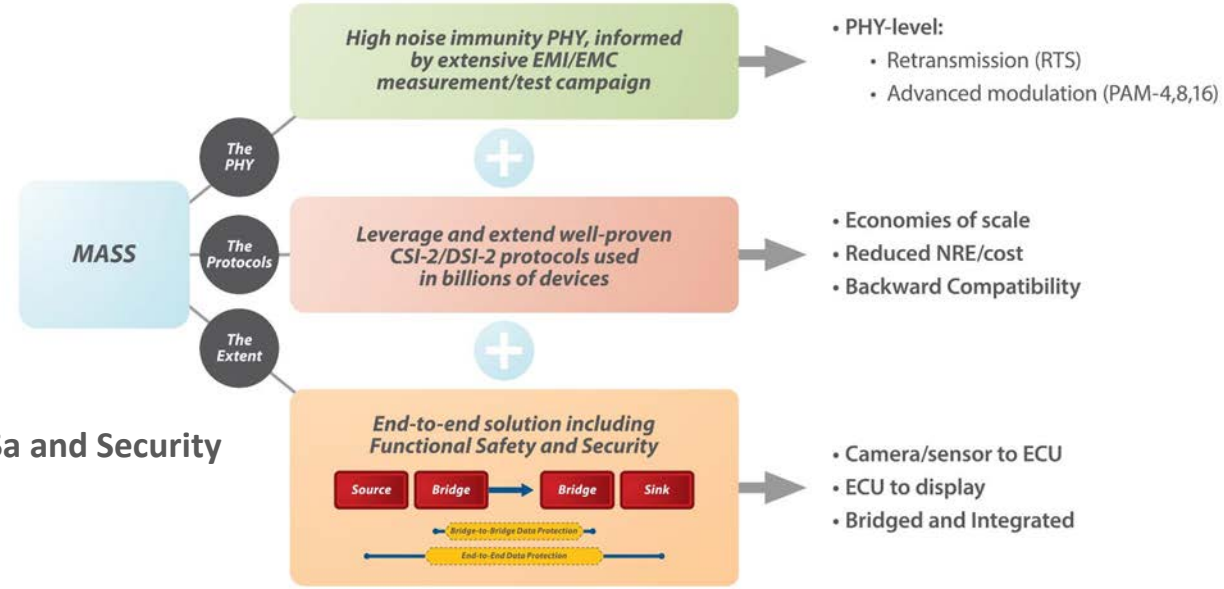
- Translates between short-range MIPI C-PHY / D-PHY & long-range MIPI A-PHY



MASS – Guiding Principles

A collection of MIPI specifications advancing camera and display solutions for automotive:

- **A-PHY**
  - Long reach PHY (15m)
  - v1.0: 2-16 Gbps (Coax, SDP)
  - v1.1: up to 32Gbps (STQ)
- **PAL: Protocol Adaptation Layers**
  - MIPI CSI-2, DSI-2 and I3C
  - VESA eDP/DP
  - Ethernet, I2C, GPIO
- **Service Extensions for End-to-End FuSa and Security**
  - CSE: Camera Service Extensions
  - DSE: Display Service Extensions
  - MIPI Security Specification



MASS – Solution Elements

Comprising PHY, Protocols and Extent for a flexible system solution

Robust Long-Reach PHY (PER 10^{-19})

- MTBF of 1 error over the full vehicle life-time
- Asymmetric high-speed link with fixed low latency ~6µs @G5
- High speed downlink and aggregation to support **multiple** 4K cameras and displays

Application-level End-to-End Functional Safety

Application-level End-to-End Security

- End to end protection covering various topologies
- Flexible coverage: per frame, per ROI, per message, compression ON/OFF

- CRC for error detection
- Frame loss detection
- Time-out Monitoring
- BIST
- Faults injection
- Authentication
- Data integrity
- Encryption
- HDCP for display

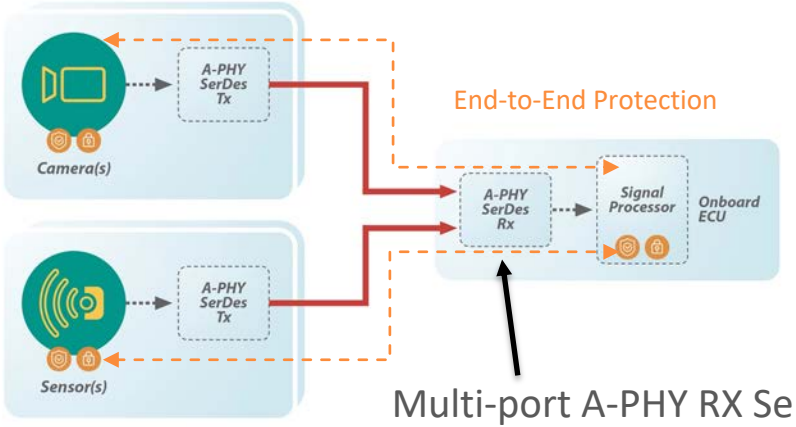
Deep system level consideration for native interfaces and the legacy ecosystem

- Heterogeneous display protocols:
  - DSI-2, eDP/DP
- Different source/sink configs
  - C-PHY, D-PHY, # Lanes, I2C, I3C
  - Integrated A-PHY or bridged A-PHY

PER: Packet Error Rate **BIST:** Built In Self Test
ROI: Region Of Interest **MTBF:** Mean-Time Between Failure

MASS – Examples for Supported Topologies

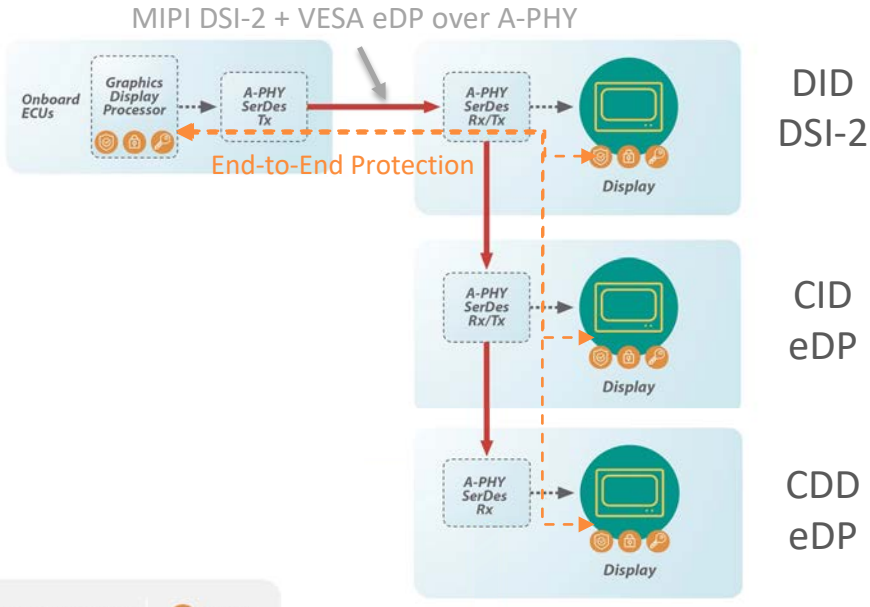
Cameras and Sensors Aggregation

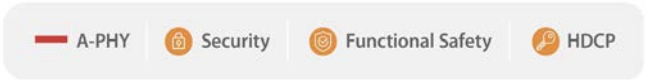


MIPI CSI-2 Sensors

Multi-port A-PHY RX SerDes with CSI-2 Aggregator

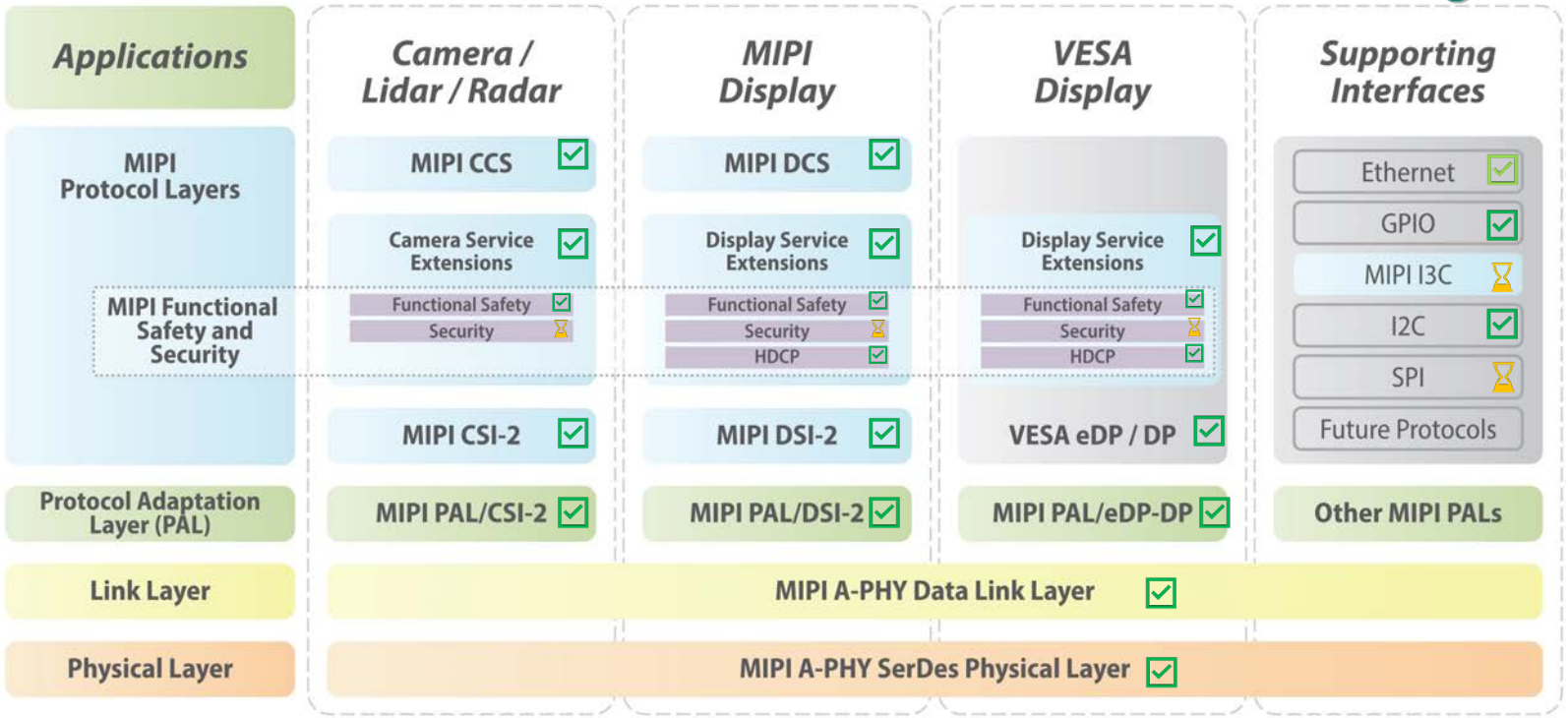
Daisy Chaining of Heterogeneous Displays





DID: Driver Instrument Display
CID : Central Information Display
CDD: Co-Driver Display

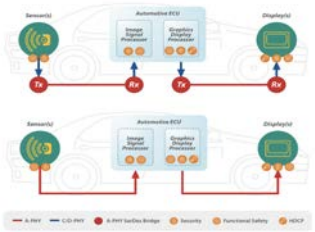
MASS Stack – Current Status

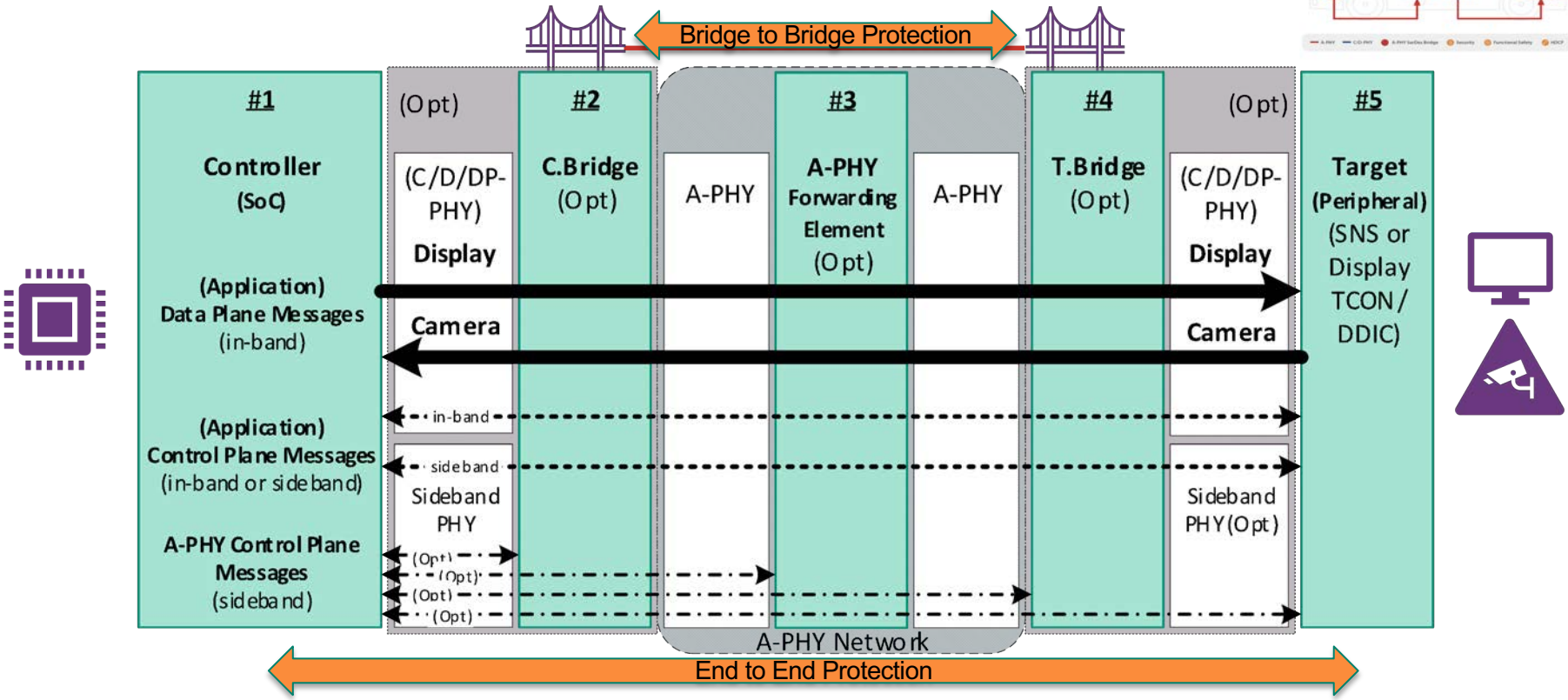


- Specification published
- Completed – in adoption process
- Work in progress

MASS 1-5 Model & MIPI Protocols

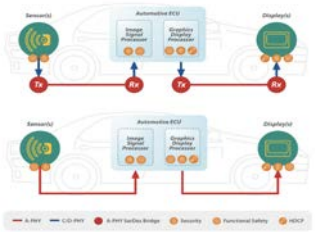
End-to-End Functional Safety and Security Protection

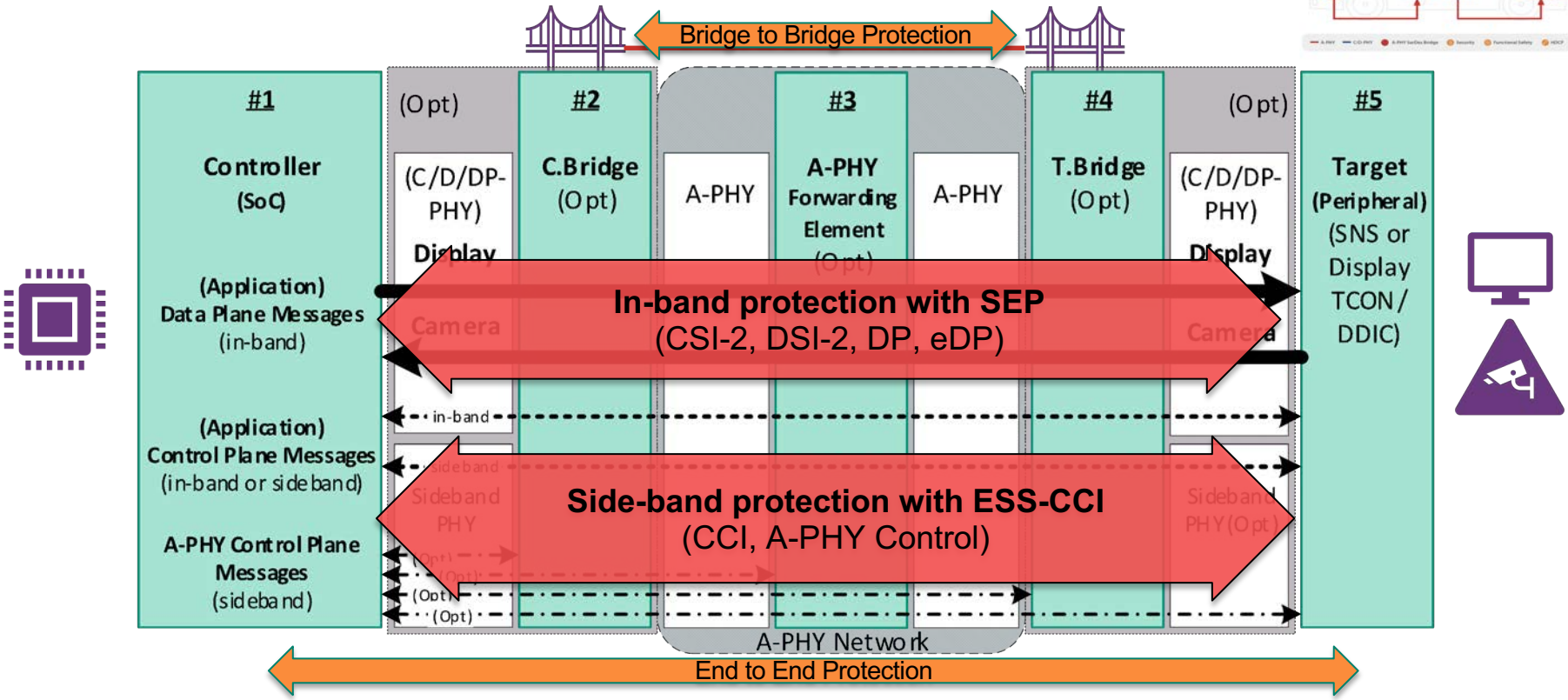




MASS 1-5 Model & MIPI Protocols

End-to-End Functional Safety and Security Protection





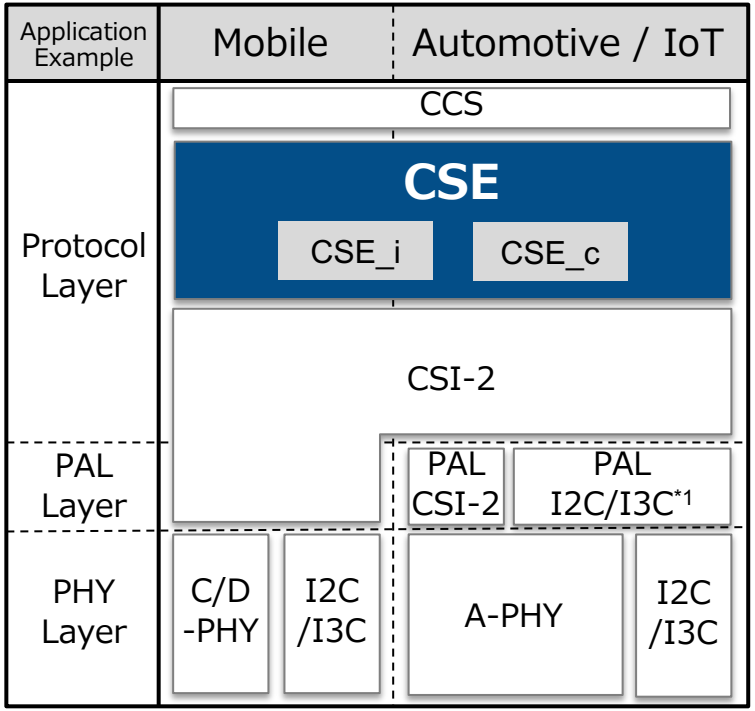
MASS for Camera and Sensors

Hiroo Takahashi
Lead, MIPI Camera Service Extensions Subgroup

Introduction of CSE

CSE enhances CSI-2 with End-to-End (E2E) Functional Safety and other features

- Camera Service Extensions (CSE)
  - CSE adds some extended features to CSI-2 for next-generation image sensor applications.
- Key features
  - E2E Functional Safety
    - CSE_i (Image Data Transfer)
      - Service Extension Packet (SEP) provides packetization and uniform delivery of image data.
    - CSE_c (Control Data Transfer)
      - Enhanced Safety and Security Camera Control Interface (ESS CCI) extends the CCI defined in CSI-2.
  - Extended Data Type (eDT)
    - Expands the number of Data Type(DT) to 256.
  - Extended Virtual Channel (eVC)
    - Expands the number of Virtual Channel(VC) to 64.
- Future enhancements
  - E2E Security (CSE ver2.0)

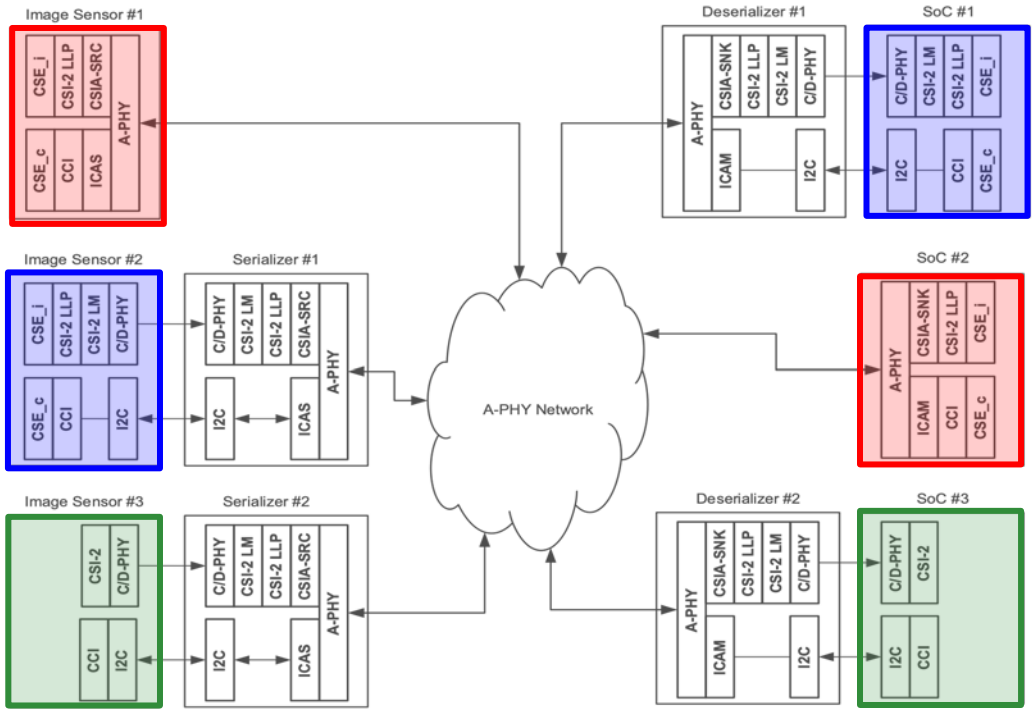


*1 : Work in progress

System Overview

There are 3 types of Image Sensor and SoC.

- **Integrated Image Sensor/SoC**
  - A-PHY is implemented in the Image Sensor/SoC.
    - Image Sensor #1, SoC #2
- **Non-Integrated Image Sensor/SoC**
  - A-PHY is not implemented in the Image Sensor/SoC, but CSE is implemented in the device.
    - Image Sensor #2, SoC #1
- **Legacy CSI-2 Image Sensor/SoC**
  - Neither A-PHY nor CSE is implemented in the Image Sensor/SoC.
    - Image Sensor #3, SoC #3



CSE_i: Camera Service Extension for image data transfer

CSE_c: Camera Service Extension for control data transfer

CSI-2 LLP: Low Level Protocol defined in CSI-2

CSI-2 LM: Lane Management layer defined in CSI-2

CSIA-SRC: CSI-2 Source adaptation layer defined in PAL/CSI-2

CSIA-SNK: CSI-2 Sink adaptation layer defined in PAL/CSI-2

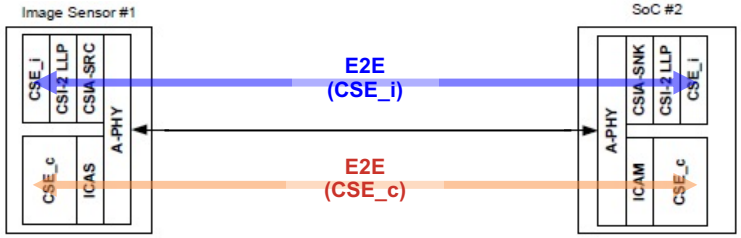
ICAM: I2C Adaptation layer for I2C Master defined in PAL/I2C

ICAS: I2C Adaptation layer for I2C Slave defined in PAL/I2C

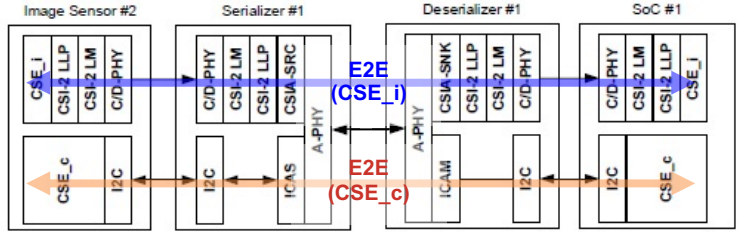
End-to-End (E2E) Functional Safety

CSE provides E2E protection mechanisms

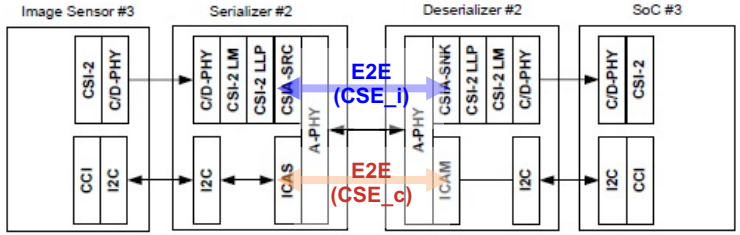
- **Integrated Image Sensor/SoC**
  - **Image Data (CSE_i)**
    - Image data E2E Safety can be supported between the CSE_i in the Image Sensor and the CSE_i in the SoC if the **SEP-DT** is used
  - **Control Data (CSE_c)**
    - Control data E2E Safety can be supported between the CSE_c in the SoC and the CSE_c in the Image Sensor if the **ESS CCI** is used



- **Non-Integrated Image Sensor/SoC**
  - **Image Data (CSE_i)**
    - Image data E2E Safety can be supported between the CSE_i in the Image Sensor and the CSE_i in the SoC if **SEP-DT over C/D-PHY** is used
  - **Control Data (CSE_c)**
    - Control data E2E Safety can be supported between the CSE_c in the SoC and the CSE_c in the Image Sensor if the **ESS CCI** is used



- **Legacy CSI-2 Image Sensor/SoC**
  - **Image Data (CSE_i)**
    - Image data E2E Safety can be supported between the CSA-SRC in the Serializer and the CSA-SNK in the Deserializer if the **Legacy Mode conversion** defined in PAL/CSI-2 is used
  - **Control Data (CSE_c)**
    - Control data E2E Safety can be supported between the ICAM in the Deserializer and the ICAS in the Serializer if the **ESS CCI** is used



CSE_i (CSE for Image Data)

CSE_i provides 3 SEP-DT packets for each PHY based on an SEP format

- **Packet structure for CSE_i**
  - SEP-DT packet over A-PHY
  - SEP-DT packet over D-PHY
  - SEP-DT packet over C-PHY
- **SEP format**
  - Each SEP-DT packet uses Service Extensions Packet (SEP) format.
    - CRC-32
    - Message Counter (MC)
  - An SEP shall consist of three parts:
    - extended Packet Header (ePH)
      - The ePH0 and ePH1 are mandatory
      - The other ePHs are optional (controlled by ePHEN in ePH0)
    - Payload Data
      - Length = Payload Length (PL) * Data Word Width (8-bits)
    - extended Packet Footer (ePF)
      - The ePF0 and ePF1 are optional (controlled by ePFEN in ePH0)

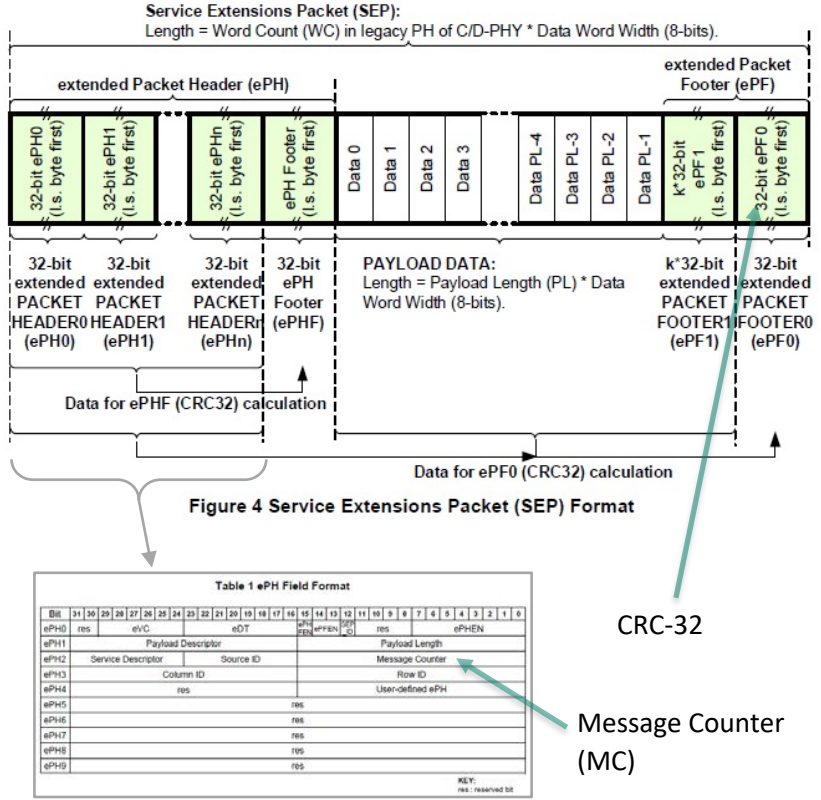
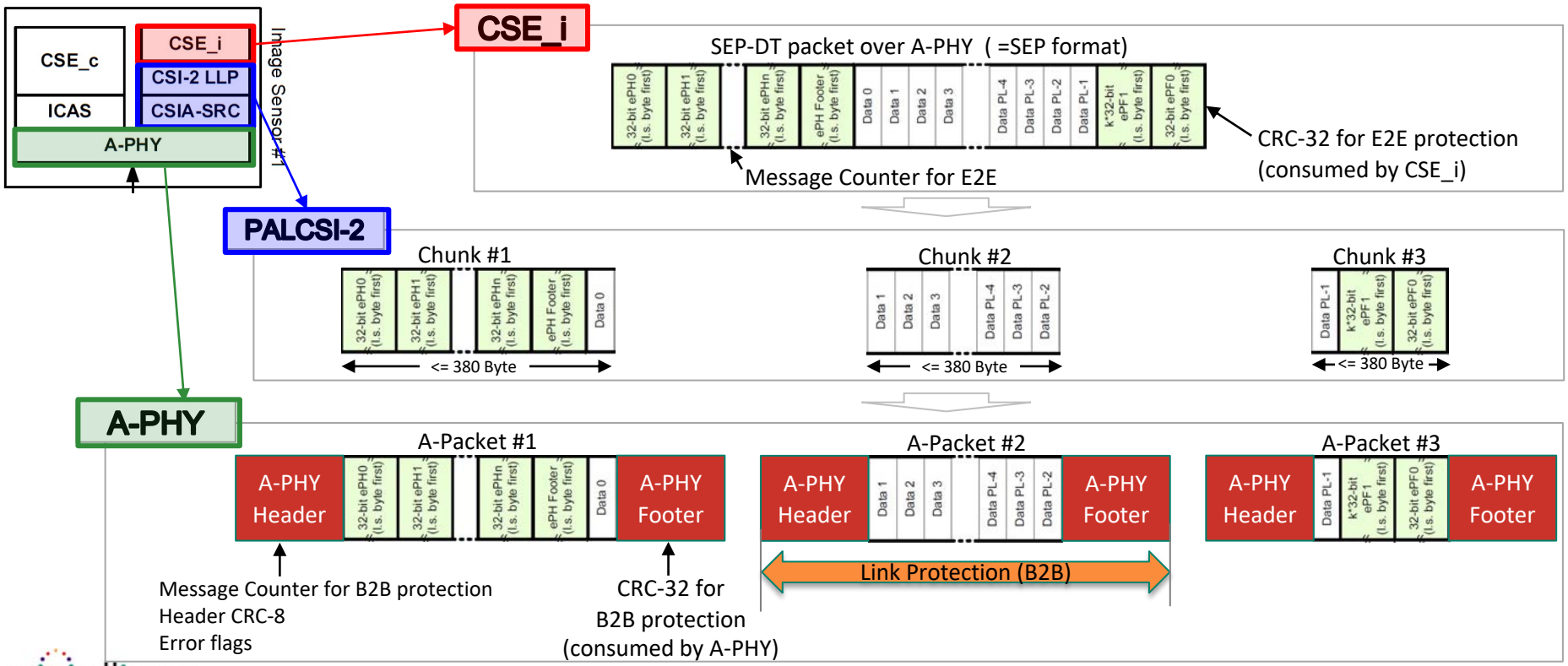


Figure 4 Service Extensions Packet (SEP) Format

SEP-DT packet over A-PHY

SEP-DT packet over A-PHY has the same format as SEP

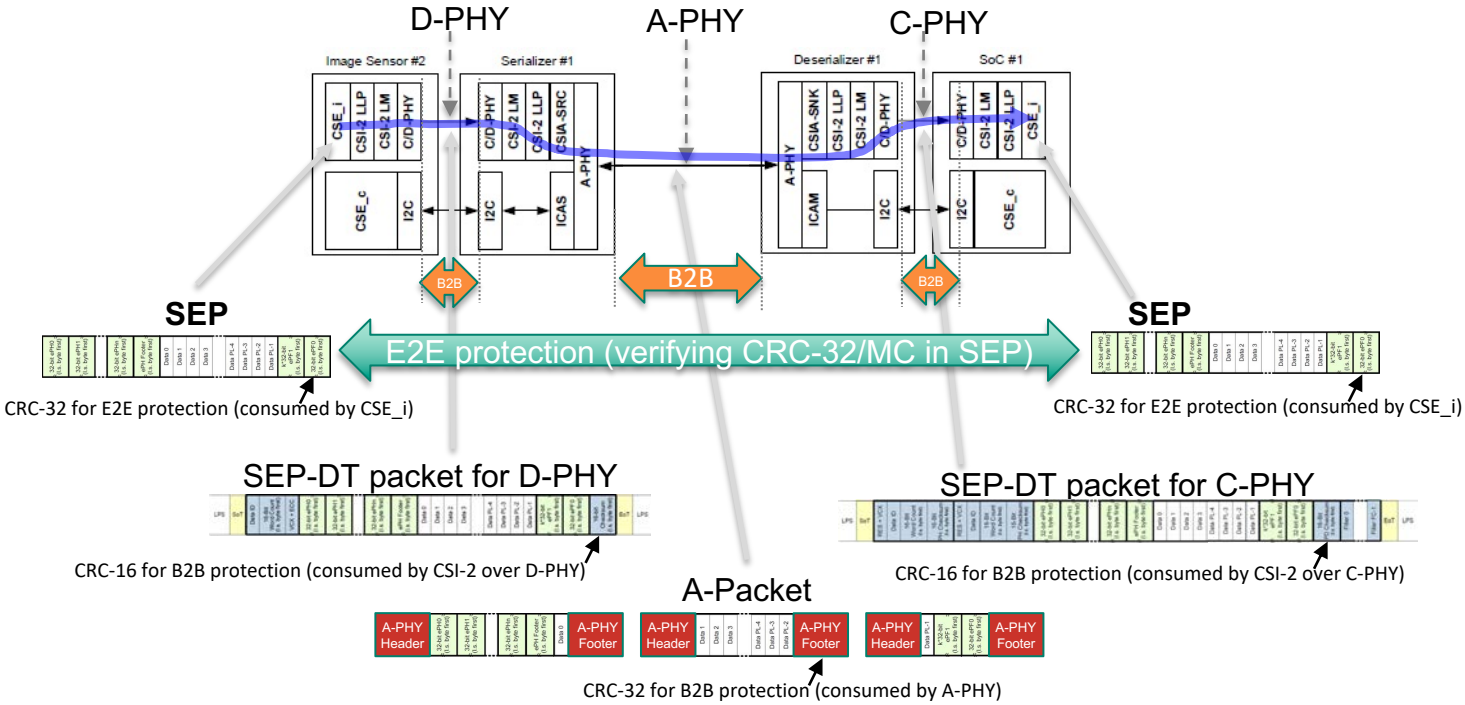


E2E: End-to-End; **B2B**: Bridge to Bridge

Example of E2E Functional Safety for CSE_i

CSE
CSE_i CSE_c

E2E protection can be supported regardless of the type of PHY from a start point to a destination because SEP is PHY-agnostic.



E2E: End-to-End; **B2B**: Bridge to Bridge

CSE_c (CSE for Control Data)

CSE_c provides the ESS CCI protocol.

ESS CCI (Enhanced Safety and Security Camera Control Interface)

- CCI Read and Write Messages are extended with ESS CCI Tags (e.g., Message Counter(MC) and CRC-16).
  - Separate Tags for Read and Write messages. Tags are used for verification of the CCI messages.
  - The ESS CCI Controller and Target Devices shall always support both ESS CCI Mode1 and Mode2.

ESS CCI Mode 1

- ESS CCI Tags are transmitted along with the CCI Messages
- Each message can be verified and processed as soon as it is received by the Target or by the Controller

ESS CCI Mode 2

- ESS CCI Tags are accumulated over multiple messages (e.g per Frame)
- The accumulated Tags are sent as CSI-2 Embedded Data from the Target to the Controller
- The Controller verifies the ESS CCI Tags
- No bandwidth overhead on I2C

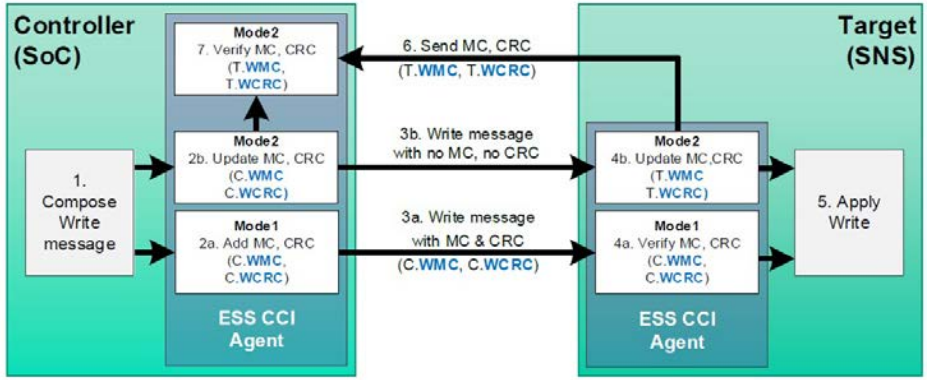
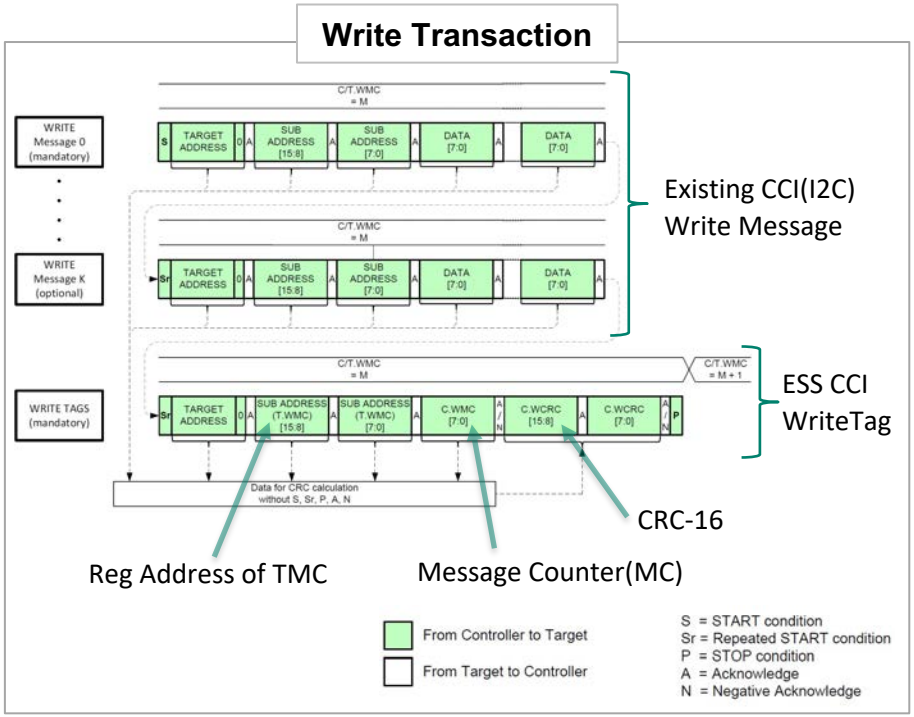


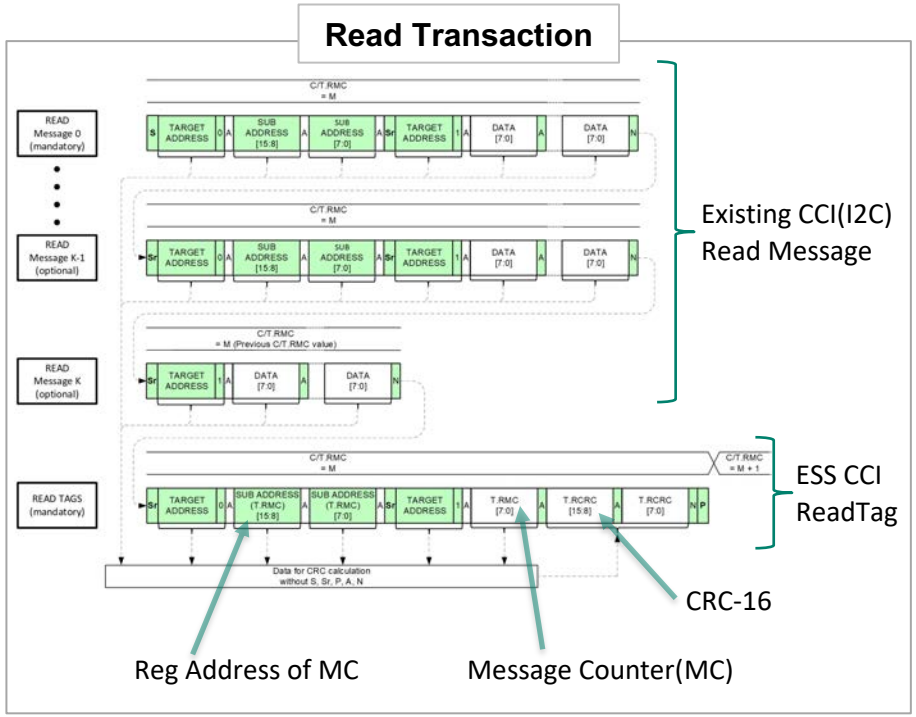
Figure 15 Overview of Write Mechanisms Using ESS CCI

CSE
CSE_i CSE_c

ESS CCI Mode1

The ESS CCI Tag shall be added after CCI (I2C) Read/Write Messages as a footer in Mode1





MASS for Automotive Displays

James Goel

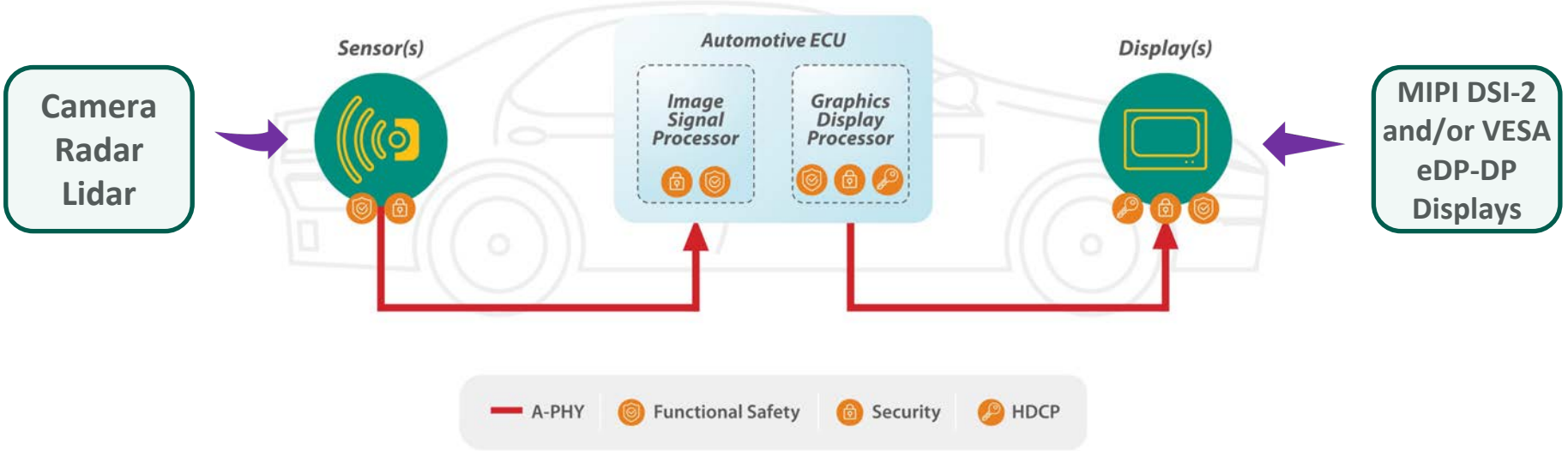
Vice Chair, MIPI Display Working Group

MASS Functional Safety Application

Digital Side Mirror Replacement

MIPI Automotive SerDes Solutions (MASS)

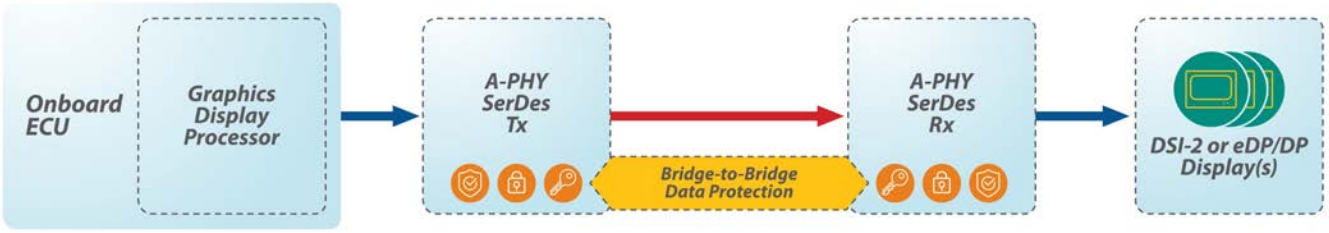
Vision for Full SerDes Integration



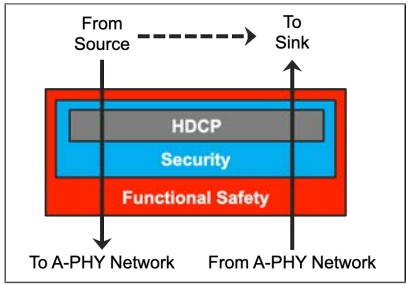
Sensor and display endpoints with integrated long-reach connectivity (integrated A-PHY SerDes) connect to the ECU without intermediate bridges. Application-level functional safety and security data protection. HDCP for protecting premium content.

Incorporating Solutions for Data Protection

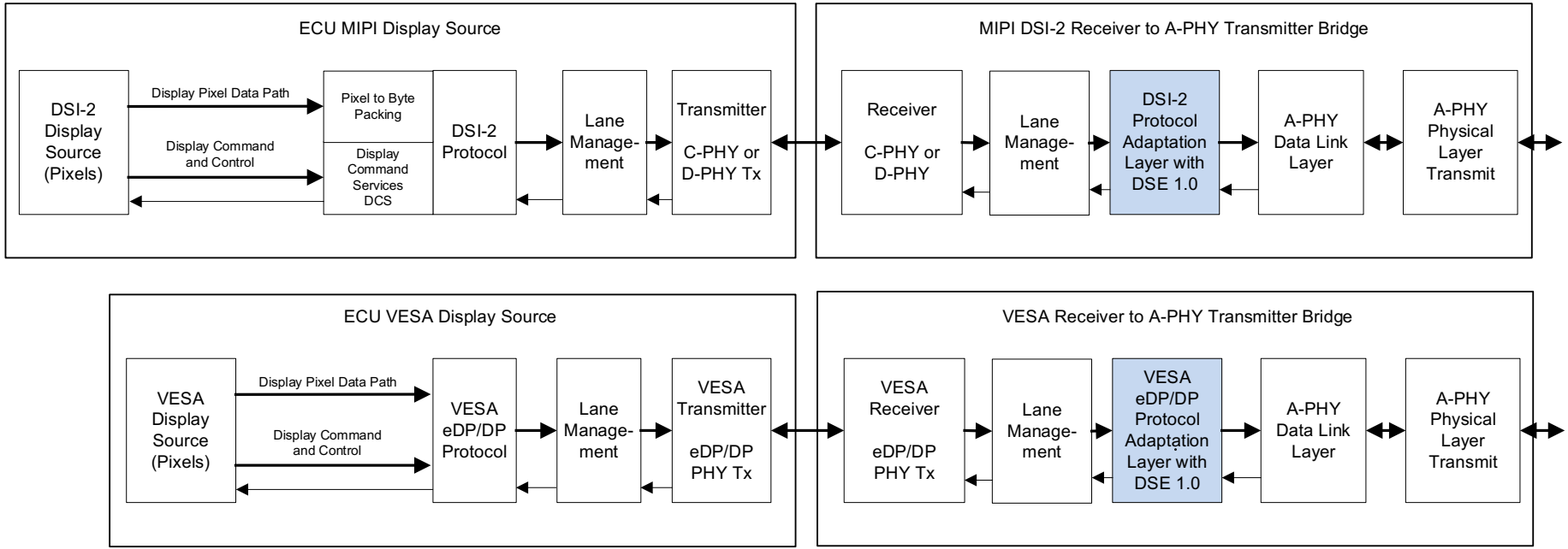
Bridge-to-Bridge Data Protection



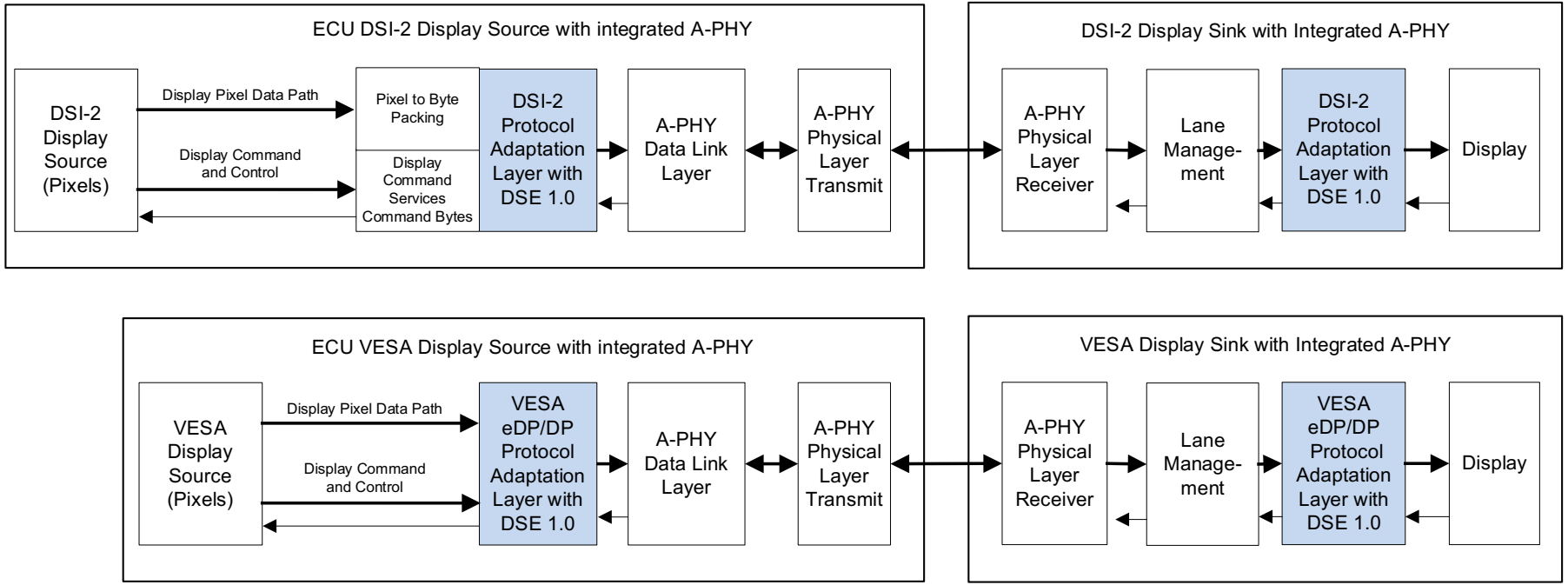
End-to-End Data Protection (Integrated SerDes)



MASS Legacy ECUs with an External A-PHY Bridge



MASS New ECU with Fully Integrated A-PHY



ISO26262-5 Annex D – Communications Bus

Annex D – Communication bus safety mechanisms:

- One-bit hardware redundancy
- Multi-bit hardware redundancy
- Read back of sent message
- Complete hardware redundancy
- Inspection using test patterns
- Transmission redundancy
- Information redundancy
- Frame counter
- Timeout monitoring
- Combination of information redundancy, frame counter and timeout monitoring

Adding Service Extensions Packets (SEPs)

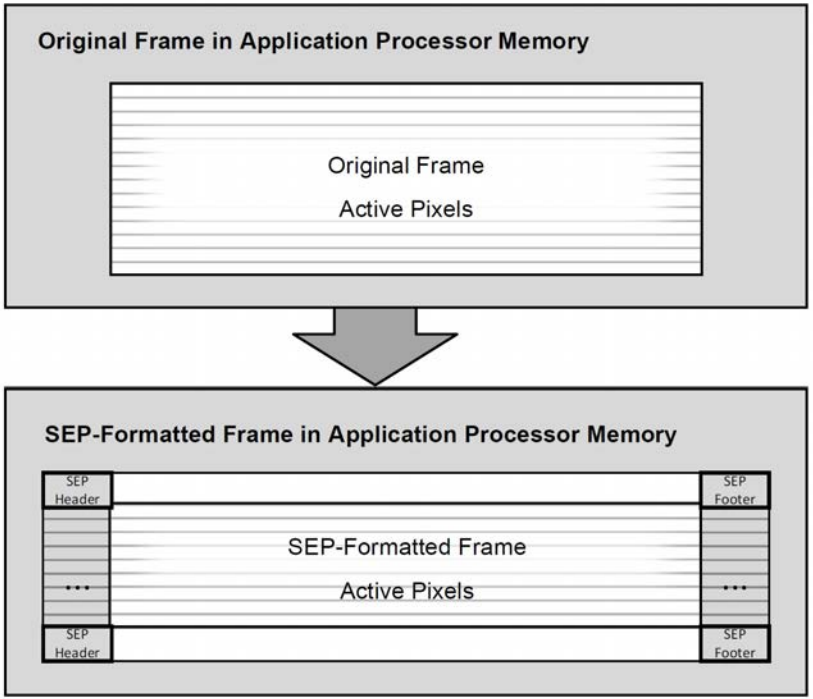


Figure 23 SEP Formatting in the Display Source

MIPI DSE℠ v1.0, MIPI PAL℠/DSI-2℠ v1.0

C.1 Converting DSI-2 Long and Short Packets to SEP

Figure 20 illustrates conversion from a DSI-2 Long Packet to SEP carried within DSI-2 Long Packet.

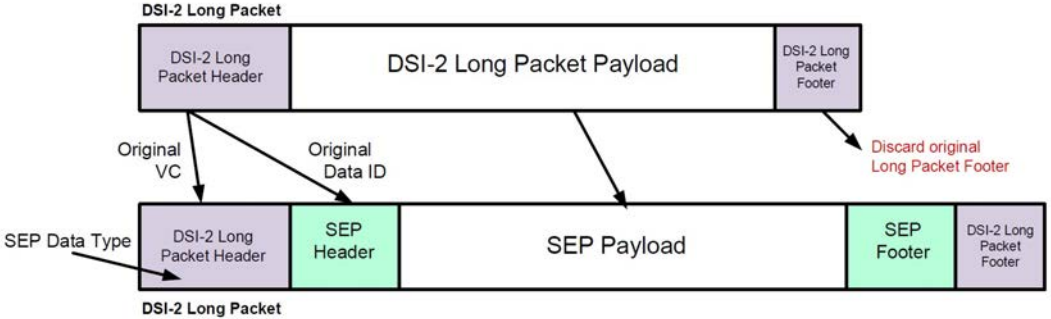


Figure 20 Converting DSI-2 Long Packet to SEP Within DSI-2 Long Packet

Figure 21 illustrates conversion from a DSI-2 Short Packet to SEP carried within DSI-2 Long Packet.

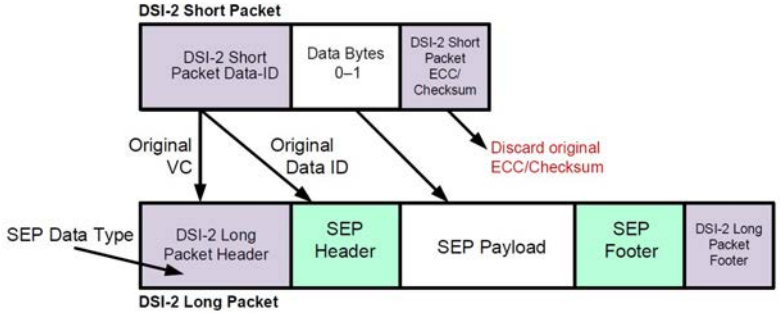


Figure 21 Converting DSI-2 Short Packet to SEP Within DSI-2 Long Packet

MIPI DSE℠ v1.0, MIPI PAL℠/DSI-2℠ v1.0

MASS Display Services Extension (DSE 1.0)
Services Extensions Protocol (SEP) Header and Footer

- eDT – extended Data Type
  - CSI, DSI
  - VESA eDP/DP
- Message Counter
- CRC-32
  - Hamming distance of 3 or more

Table 1 SEP Packet ePH Blocks: Overview

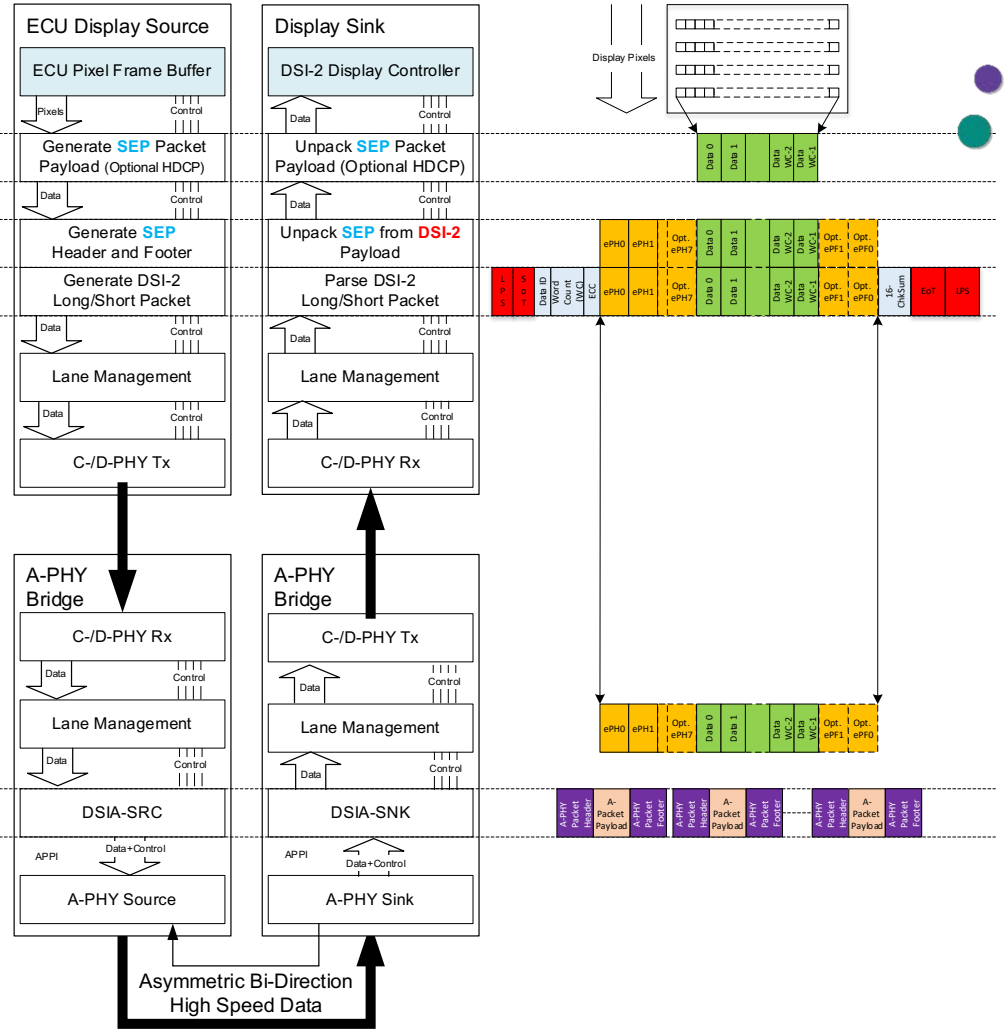
Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ePH[0]	R	eVC							eDT								R	ePFEN	Reserved						ePHEN							
ePH[1]	Reserved																SEP Payload Length															
ePH[2]	Service Descriptor								Reserved								Message Counter															
ePH[3]	Reserved																															
ePH[4]	Reserved																															
ePH[5]	HDCP streamCtr[31..0]																															
ePH[6]	HDCP InputCtr[31..0]																															
ePH[7]	HDCP InputCtr[64.32]																															

Table 2 SEP Packet ePF Blocks: Overview

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ePF[1]	Reserved																															
ePF[0]	CRC-32																															

MIPI DSE℠ v1.0

Detailed Display Protocol Stack



Summary

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- **MASS provides a standardized framework enabling end-to-end FuSa and Security**
  - Addresses both the data and control planes including side-band control
  - Flexible framework to allow tailoring the FuSA and security services for a wide range of use cases and OEM preferences
- **MASS reuses widely adopted MIPI and VESA protocols to address automotive requirements**
- **MIPI has completed the first suite of MASS specifications**
  - A-PHY v1.0 / v1.1, Protocol Adaptation Layers for CSI-2, DSI-2, VESA eDP/DP, I2C, GPIO, Ethernet
  - MIPI DSE and MIPI CSE providing service extensions for FuSa
- **MASS Security Specification is expected in 2022**

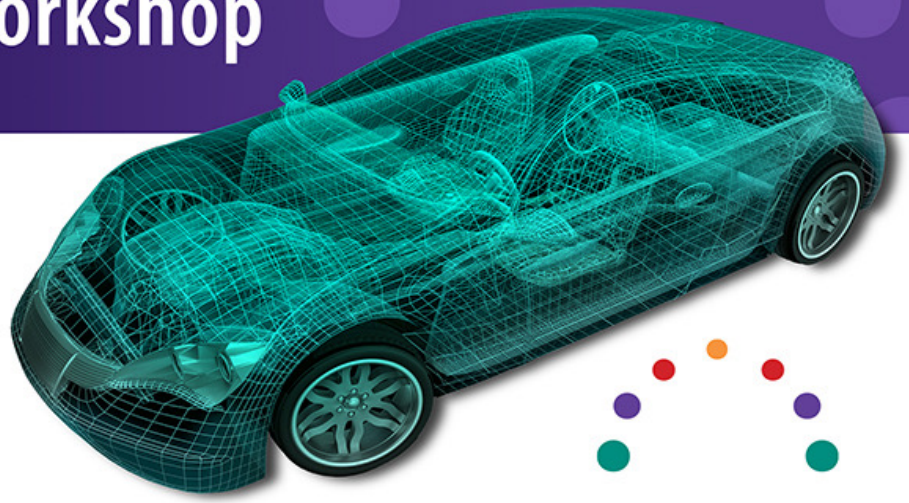
MIPI Automotive Resources

Information on A-PHY can be found at:

- MIPI A-PHY Specification Homepage
- MIPI White Paper: Introduction to MASS

MIPI Automotive Workshop

An in-depth look at the MIPI Automotive SerDes Solutions (MASS) framework



Q&A