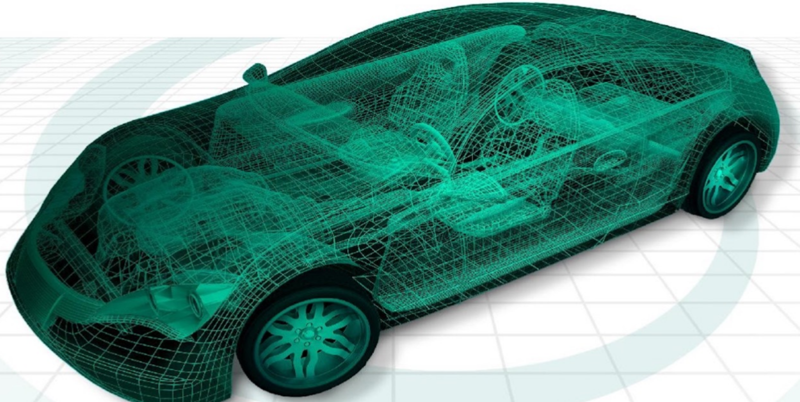
IF IT'S NOT MIPI, IT'S NOT MOBILE

MIPI Automotive SerDes Solutions (MASS℠):

An Integrated Approach to Creating Functionally Safe Automotive Sensor Systems



Ariel Lasry

MIPI A-PHY® Working Group Vice Chair

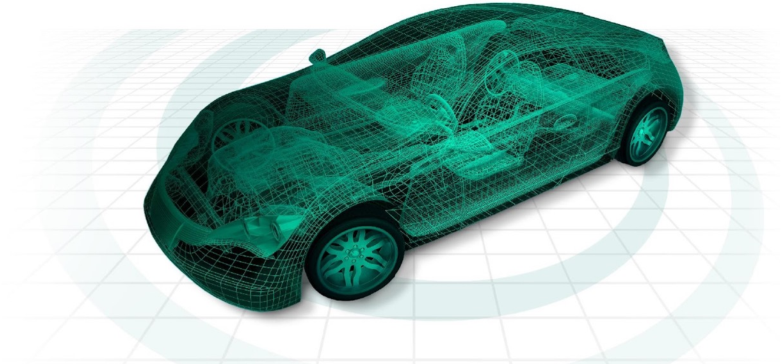
Qualcomm CDMA Technologies GmbH

13 September 2022

AutoSens

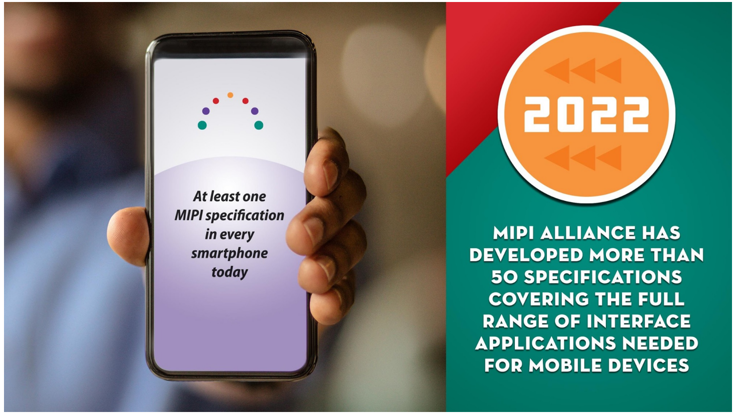
Agenda

- About MIPI Alliance
- MIPI Automotive SerDes Solutions (MASS) Overview
- Functional Safety for Sensors
- Summary
- Q&A

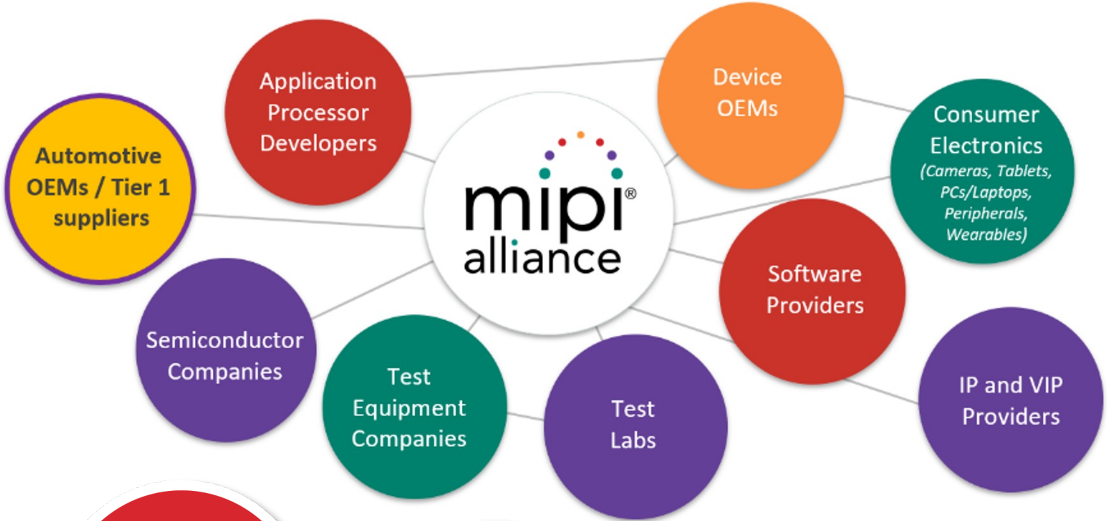


About MIPI Alliance

About MIPI Alliance



TODAY'S MIPI MEMBER ECOSYSTEM



375+ members

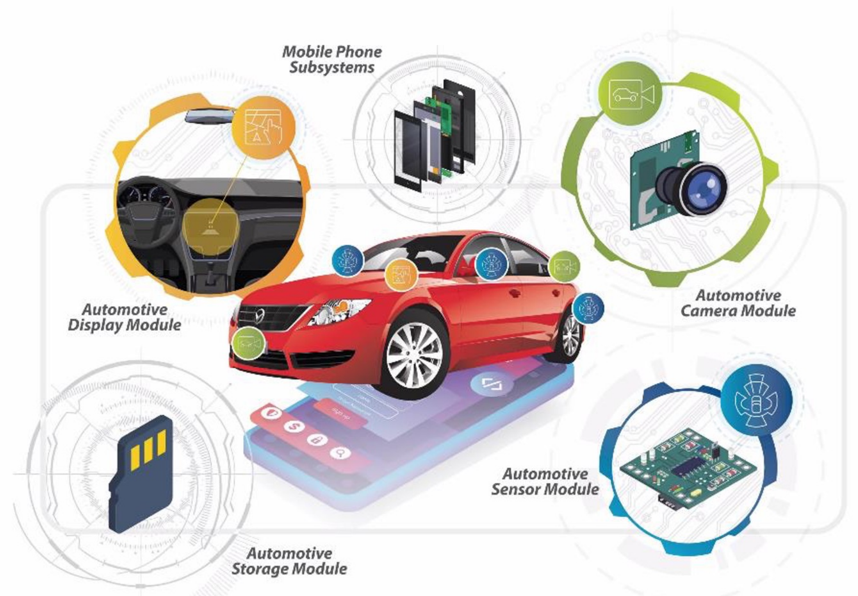
Number of countries 30

Percentage of members active in automotive sector 48%

MIPI Alliance Members in Automotive

View the list at:
[MIPI Members in Automotive »]

MIPI in Automotive



Cameras, displays, audio, sensors, storage, RFFE for 5G, Wi-Fi, Bluetooth, NFC

Reuse & extend well-proven protocols == reduced NRE/cost

Intra-box usage has been limited due to lack of native long-reach PHY

SPECIFICATIONS IN AUTOMOTIVE TODAY

Most MIPI interfaces are implemented as "*short reach*" (~15 to ~30cm+)

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 SerDes
3-phase physical layer for CSI-2 & DSI-2
Short-reach physical layer for cameras and displays

D-PHY SerDes
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

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

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

A-PHY SerDes
Long-reach *(up to 15m) asymmetrical physical layer (released Sep 2020)*

MIPI Automotive SerDes Solutions (MASS)

Overview

MIPI A-PHY: SerDes System Foundation

First industry-standard asymmetric SerDes physical layer specification targeted for ADAS/ADS and infotainment applications

About A-PHY

(v1.0 released in Sep 2020)

- Direct coupling to native CSI-2/DSI-2/DP-eDP protocols
- High noise immunity, ultra low PER (< 10^{-19})
- Supports bridge-based and endpoint integration
- Support for automotive coax and SDP channels
- Upto 15m long reach with 4 inline connectors
- Power over cable
- Built-in functional safety according to ISO 26262
- Adopted by IEEE as IEEE 2977-2021

A-PHY v1.1 Enhancements

(released Dec 2021)

- Increased support for lower cost legacy cables
- Double uplink data rate
- Star quad cable support, enabling lower cost dual lane operation, for up to 32 Gbps data rate

PER: Packet Error Rate **SDP:** Shielded Differential Pair

MIPI A-PHY Performance

A-PHY v1.1 enhancements shown in orange

Downlink Gear Data Rate	Modulation	Modulation Bandwidth (GHz)	Max Net App Data Rate (Gbps)
G1 2 Gbps	NRZ-8B/10B	1	1.5
	PAM4 (Optional)	0.5	1.8
G2 4 Gbps	NRZ-8B/10B	2	3
	PAM4 (Optional)	1	3.6
G3 8 Gbps	PAM4	2	7.2
G4 12 Gbps	PAM8	2	10.8
G5 16 Gbps	PAM16	2	14.4

Uplink Gear Data Rate	Modulation	Modulation Bandwidth (MHz)	Max Net App Data Rate (Mbps)
U1 100 Mbps	NRZ-8B/10B	50	55
U2 200 Mbps	PAM4-8B/10B	50	125

A-PHY v2.0 Enhancements

(under development, coming in 2023)

- Double Downlink to 32Gbps / Lane
- Increase Uplink to 1.6Gbps
- Enable support of security for A-PHY network
- Expand power classes for Power over A-PHY

MIPI Automotive SerDes Solutions (MASS)

A framework for integrating sensors and displays with End-to-End Functional Safety and Security built in

Electronic Control Unit (ECU)

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

Sensors

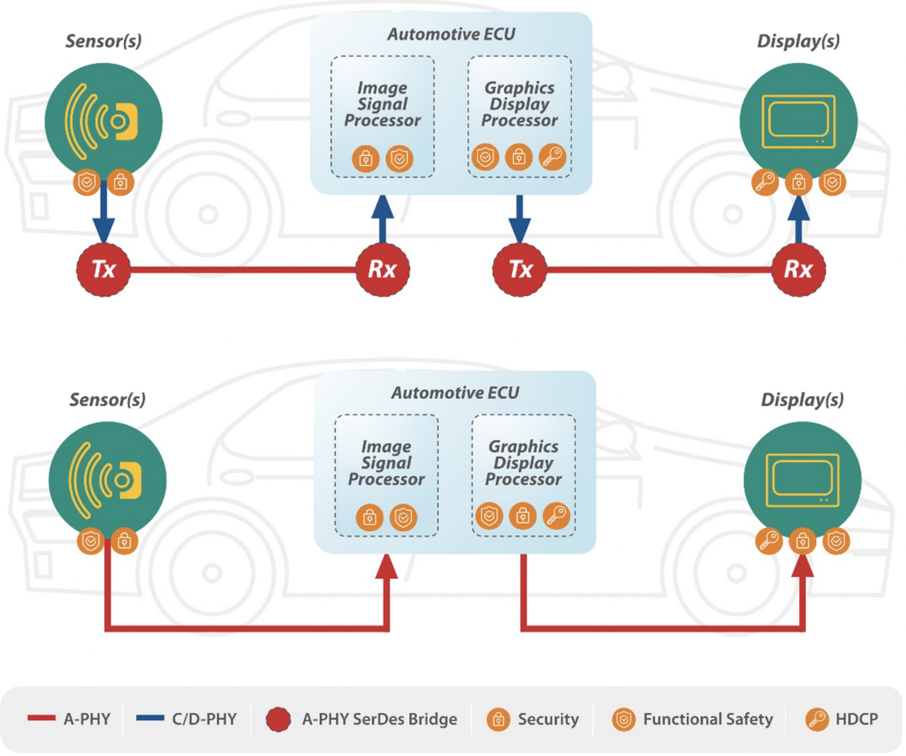
- Camera
- Lidar

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

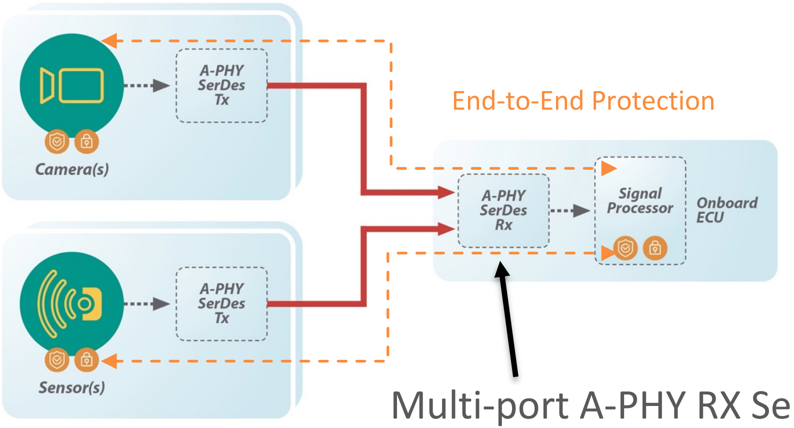


MASS solution using A-PHY bridges

MASS solution using integrated A-PHY

MASS Supported Topologies – Examples

Cameras and Sensors Aggregation

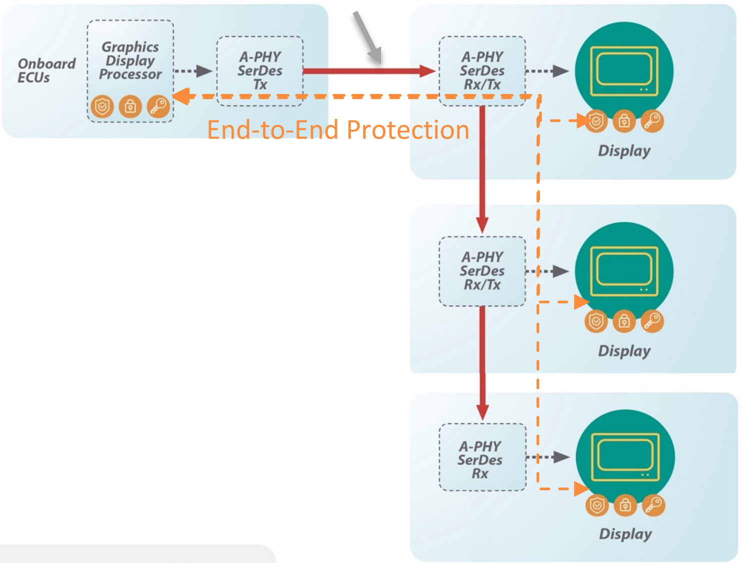


Multi-port A-PHY RX SerDes with CSI-2 Aggregator

MIPI CSI-2 Sensors

Daisy Chaining of Heterogeneous Displays

MIPI DSI-2 + VESA eDP over A-PHY



DID DSI-2

CID eDP

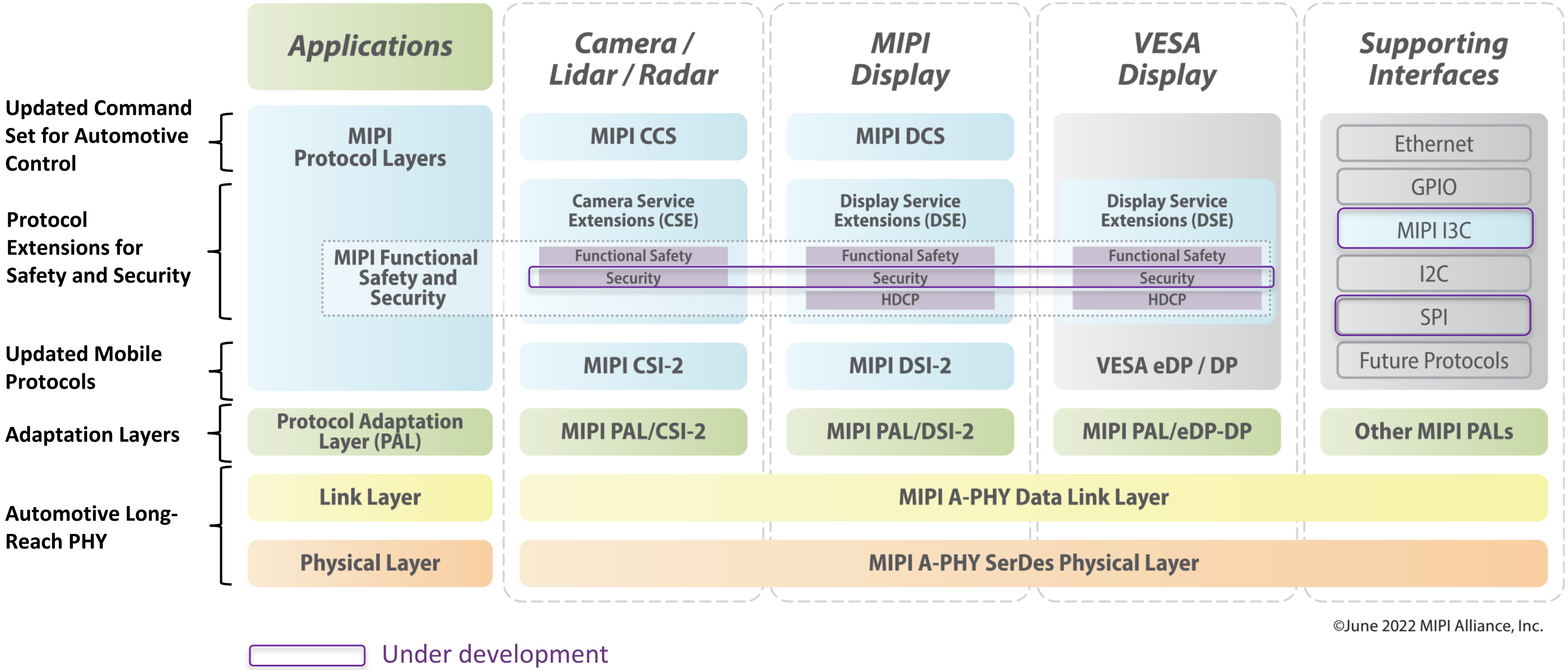
CDD eDP

A-PHY | Security | Functional Safety | HDCP

Other common topologies are also supported but not shown

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

MASS Stack – Framework Nearly Completed



Functional Safety for Sensors

ISO26262-5 Annex D – Communications Bus


INTERNATIONAL STANDARD

ISO 26262-5

Second edition 2018-12

Road vehicles — Functional safety —

Part 5:
Product development at the hardware level

Véhicules routiers — Sécurité fonctionnelle —
Partie 5: Développement du produit au niveau du matériel

Reference number ISO 26262-5:2018(E)

© ISO 2018

Annex D – Communication bus safety mechanisms:

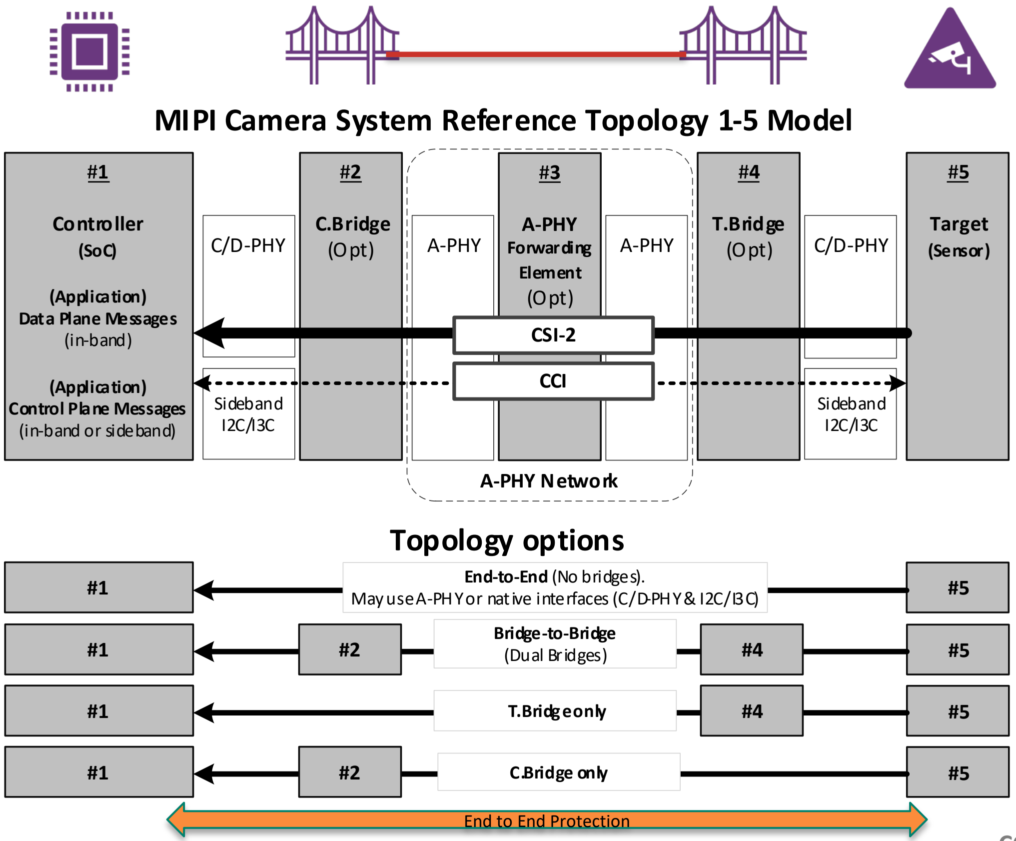
- One-bit hardware redundancy
- Multi-bit hardware redundancy
- Read back of sent message
- Complete hardware redundancy
- Inspection using test patterns
- Transmission redundancy
- Information redundancy
- Frame counter
- Timeout monitoring
- Combination of information redundancy, frame counter and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

1-5 Model: Reference Topology (Camera)

End-to-End Functional Safety and Security Protection

- Up to 5 functional **components**
- **Controller** connections to all components that include **Bridges** and **Forwarding Elements**

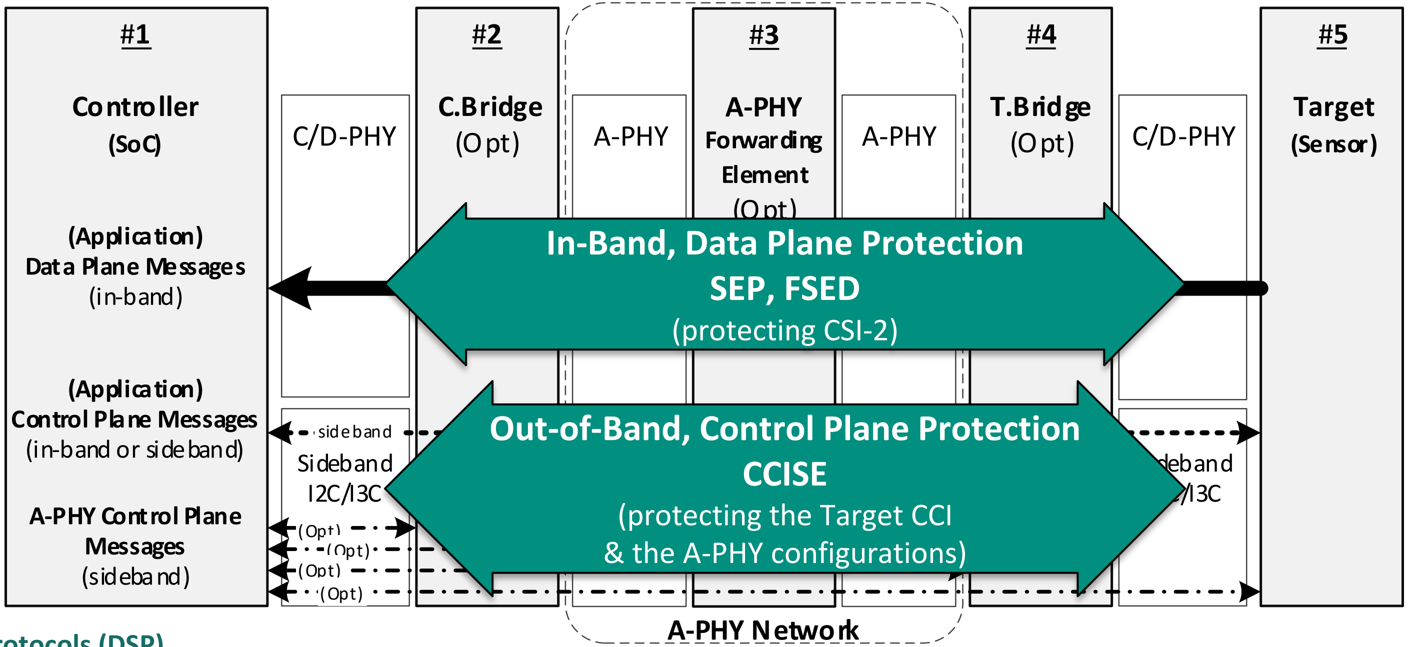
- Any combination of Bridges



CCI: Camera Control Interface

3 Data Service Protocols (DSP): SEP, FSED, CCISE

End-to-End Functional Safety and Security Protection



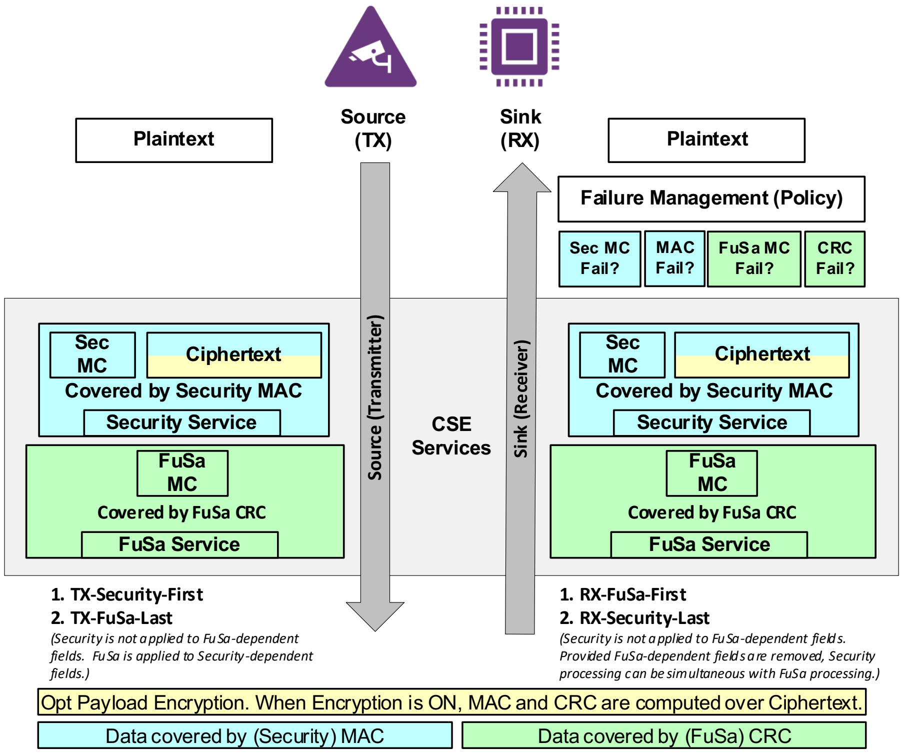
Data Service Protocols (DSP)

SEP: Service Extensions Packet	FSED: Frame-Based Service Extensions Data	CCISE: CCI Service Extensions
Granularity: Message-based **Reach**: Sensor to Controller, End-to-End (1-5) Bridge to Bridge (2-4), also (1-4) and (2-5)	**Granularity**: Frame-based **Reach**: Sensor to Controller, End-to-End (1-5)	**Granularity**: I^2C Transaction (Start to Stop) **Reach**: Controller to all Targets, End-to-End (1-5) End-to-End (1-2), (1-3), (1-4)

CCI: Camera Control Interface

mipi alliance

MIPI Camera Service Extensions (CSE) Layering

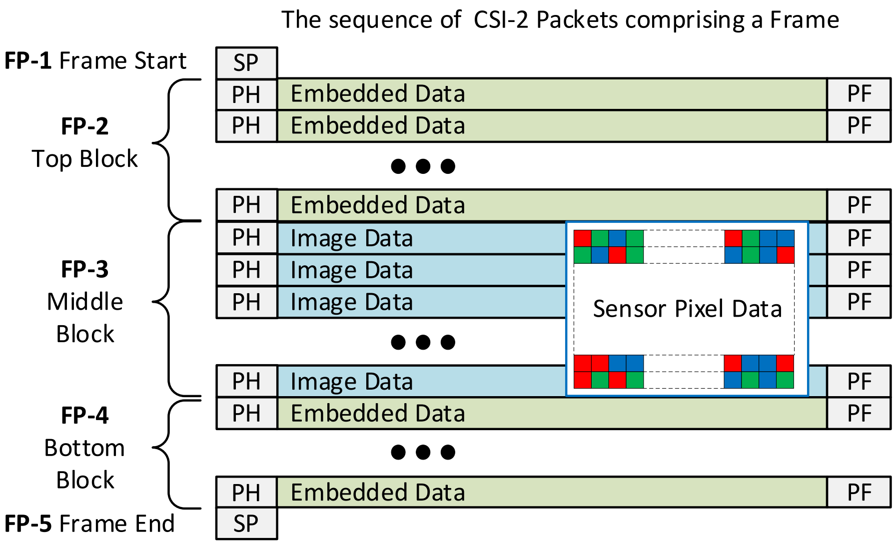


MAC: Message Authentication Code
CRC: Cyclical Redundancy Check

MC: Message Counter
FuSa: Functional Safety

- Data Service Protocols (DSP) provide Security and Functional Safety Services for protecting CSI-2 and CCI traffic in the following order:
  - TX Security first
  - TX FuSa last
- The receiver performs the operations in reverse order
- This layering applies to all 3 DSPs: FSED, SEP and CCISE
- Failure management policy is defined by the system

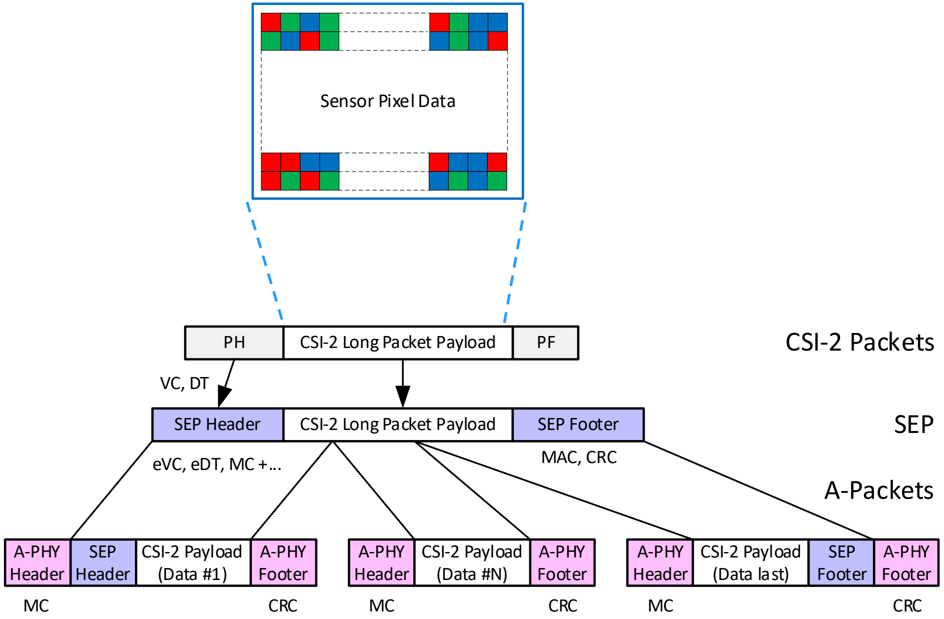
CSI-2 Frame: Basics



Key			
	Embedded Data	**FP**: Frame Partition	**PH**: Packet Header
	Image Data	**SP**: Short Packet	**PF**: Packet Footer

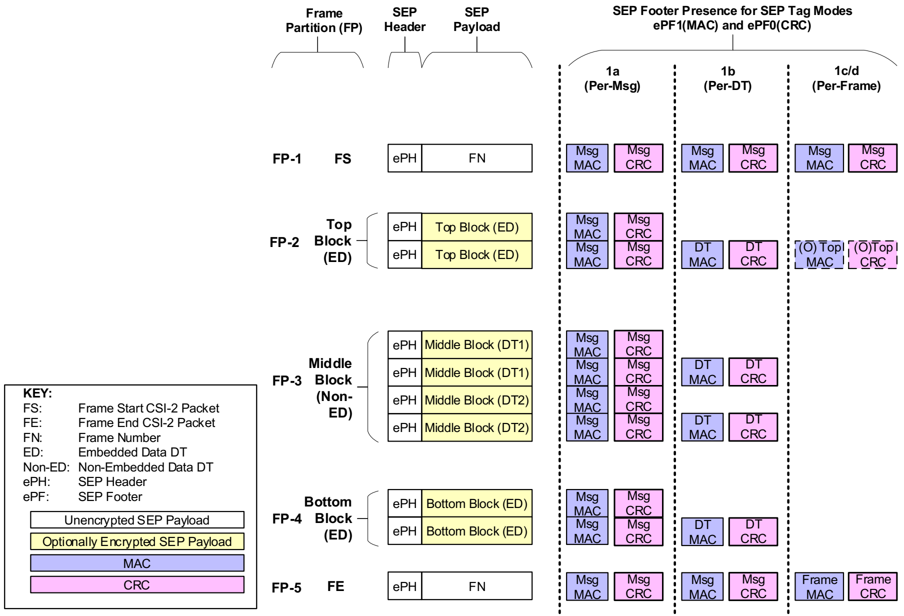
- Example showing one CSI-2 Frame associated with a given Virtual Channel (VC)
- The Frame is partitioned into 5 Frame Partitions (FP), always beginning with a Frame Start and ending with a Frame End Packets.
- Embedded Data carrying sensor's meta-data are optional and are transmitted in FP-2 and/or FP-4
- Image Data supporting various formats (YUV, RGB, RAW) is transmitted in FP-3
- CSE provides great flexibility in that different Security or FuSa parameters may be assigned to the data in each FP

Service Extension Packet (SEP) over A-PHY



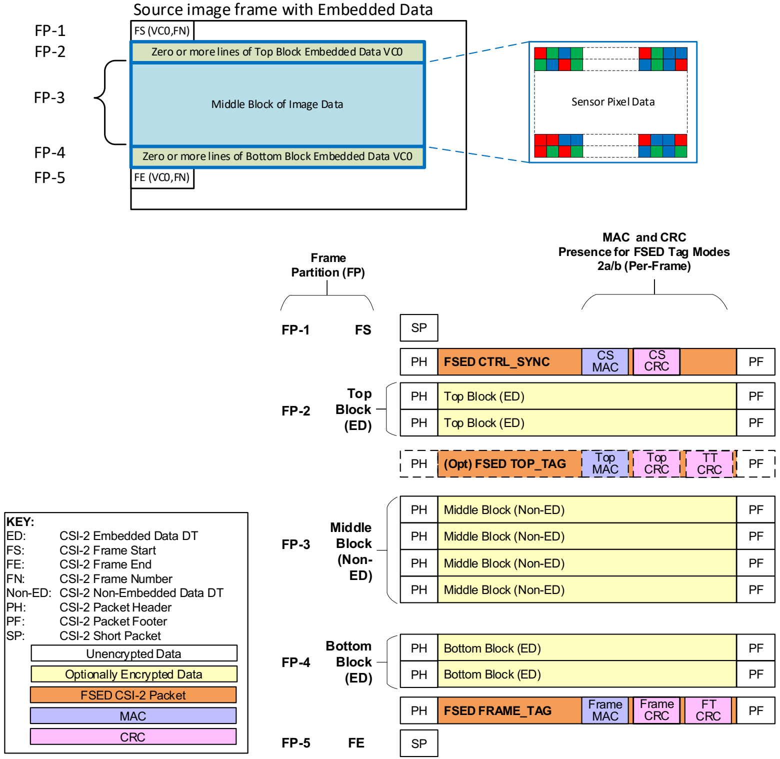
- CSI-2 Packets are extended with SEP
- SEP is protected End-to-End on application protocol level with
  - FuSa Message Counter in SEP Header
  - Security Message Counter in SEP Header
  - MAC in SEP Footer
  - CRC-32 with Hamming Distance ≥ 3 in SEP Footer
- SEP Header contains extended CSI-2 PH information
  - eVC: extended Virtual Channel
  - eDT: extended Data Type
  - Source ID: identifying the sensor
  - Other fields (timesamp, Row ID, Column ID etc.)
- SEP are chunked to multiple A-Packets when transported over A-PHY. Each A-Packet is protected with a Message Counter and CRC-32

SEP Tag Modes



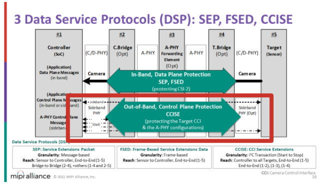
- Three Tag Modes for MAC and CRC per CSI-2 Frame
  - Per Message
  - Per Data Type
  - Per Frame
- Provides a trade-off between Tag overhead and error detection latency
- Optional TOP Tag for early error detection in TOP Embedded Data when using a single Tag per Frame
- CSE v1.0 supports only Per Message CRC
- CSE v2.0 introduces Per DT and Per Frame Tag Modes

Frame-Based Service Extensions Data (FSED)



- FSED protects End-to-End CSI-2 Frames at application protocol level
- PHY agnostic using "legacy" CSI-2 packets
- Adds FSED Messages to "regular" CSI-2 Frames
  - FSED CTRL_SYNC provides Frame information and security configuration
  - Optional FSED TOP_TAG protecting the Top Block
  - FSED FRAME_TAG protecting the full CSI-2 Frame
- FSED Messages transported as CSI-2 Embedded Data

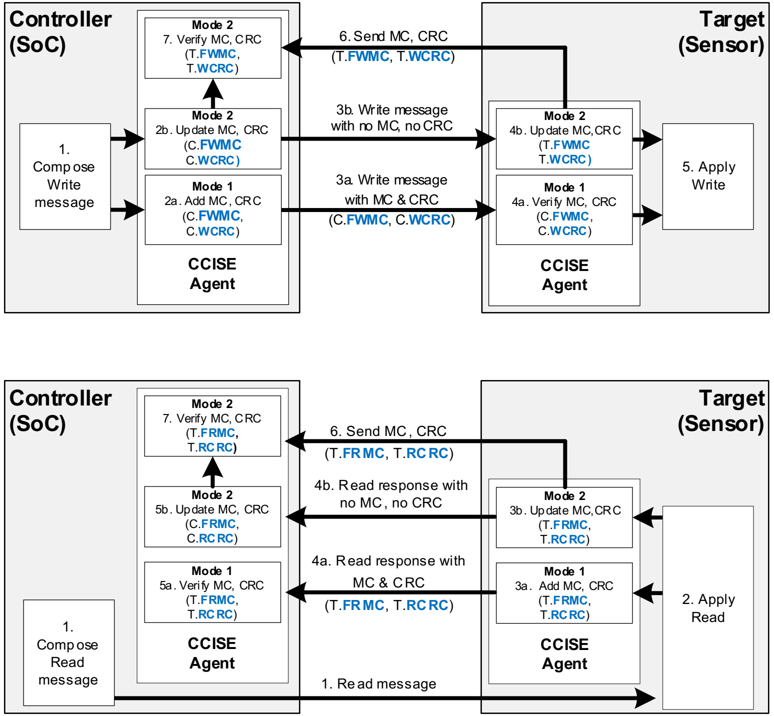
Control Plane Protection with CCISE



- Command and Control Interface **Service Extensions** (CCISE) add Functional Safety and Security services to CCI (I2C)
- CCISE supports control of
  - Camera Control Interface CCI (I2C)
  - A-PHY bridges and forwarding elements
  - Any other device controlled via I2C (or virtual I2C with PAL/I2C)
- CCI (I2C) Messages are extended with Tags
  - Functional Safety Tags: Message Counter, CRC
  - Security Tags: Message Counter, MAC
  - Separate Tags for Read and Write Messages
- Two CCISE verification modes
  - **Mode 1**: **Per-Transaction**. Tags are transmitted with the Messages and can be **verified immediately by the Target** or the Controller
  - **Mode 2**: **Per-Frame**. Tags are not transmitted with the Messages. Tags are calculated over an entire CSI-2 Frame, both at the Controller and at the Target. Tags are sent from the Target to the Controller
    - Within CSI-2 Embedded Data or
    - Controller read access to the Tags

    Tags are verified by the Controller. Mode 2 is motivated by the speed limit of I2C interface

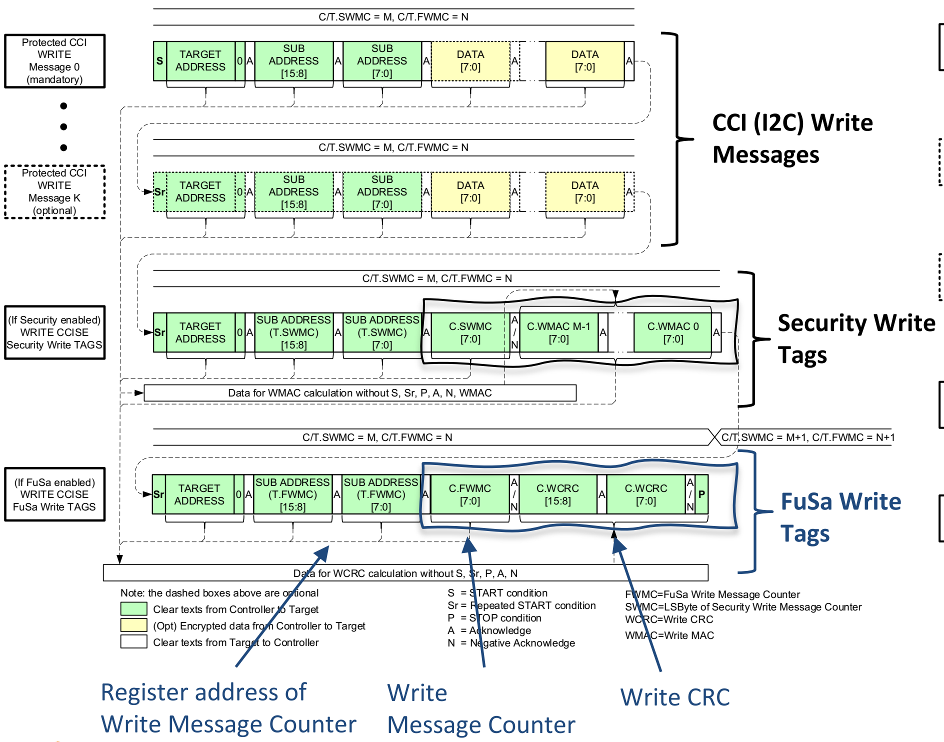
CCISE Functional Safety Protection Flow



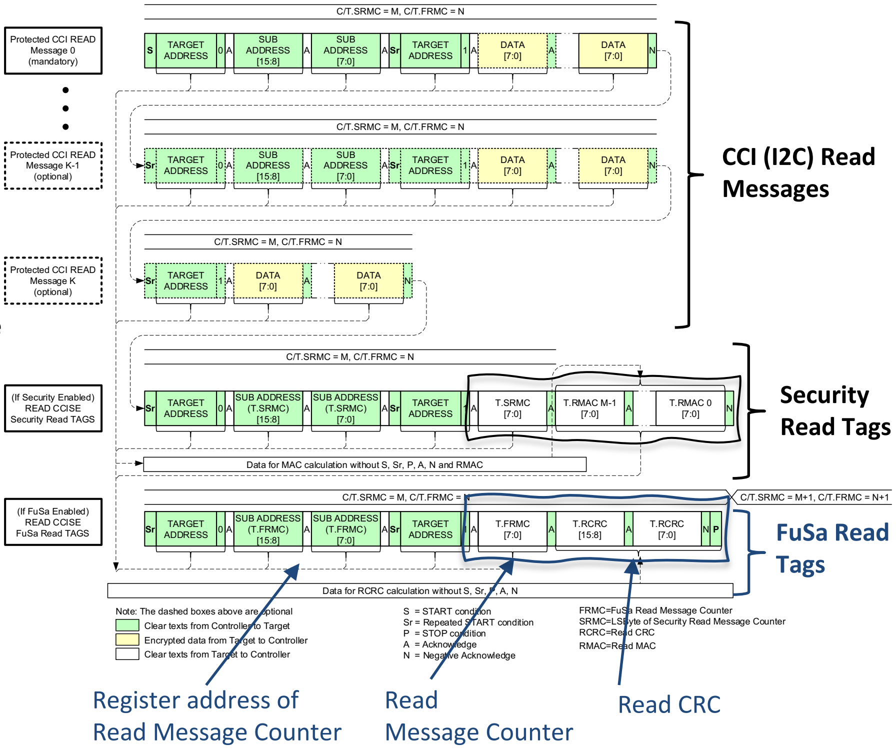
CCISE Mode 1

Tags are added as Footer to CCI (I2C) Read/Write Transactions

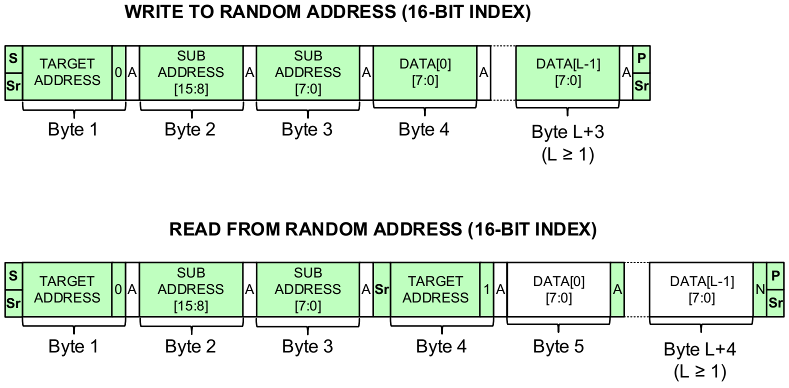
WRITE Transaction



READ Transaction

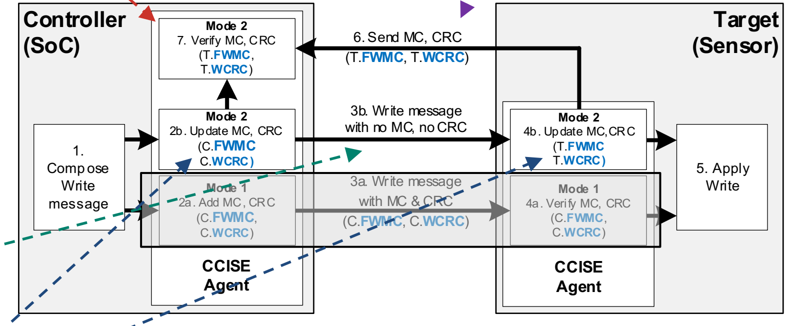


CCISE Mode 2



Controller verifies Tags

Accumulated Tags are sent from the Sensor to the Controller at the end of the CSI-2 Frame
- As CSI-2 Embedded Data or
- Controller reads Tags registers

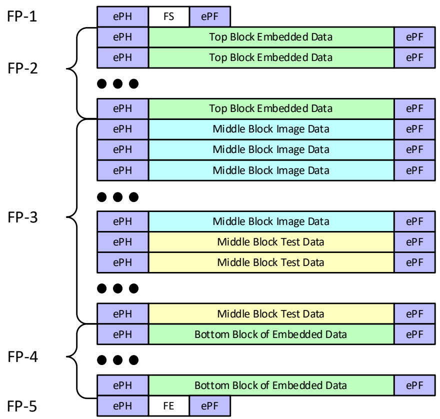


Exactly same transactions on the line as in CCI (I2C)
- No Tags on the wire
- No overhead

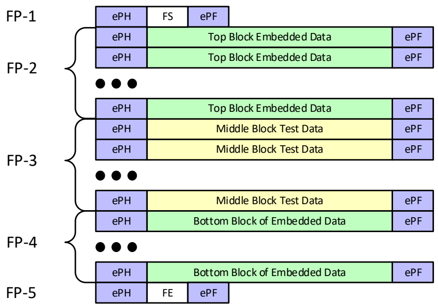
Both Controller and Target calculate independently the Functional Safety Tags accumulated over the CSI-2 Frame
- Write Message Counter (FWMC), Write CRC (WCRC)
- Read Message Counter (FRMC), Read CRC (RCRC)

Built-in Self Tests (BIST) and Diagnostics

Example of Test Pattern in portion of image Frame



Example of a Test Pattern Frame



KEY:
ePH: SEP Header
ePF: SEP Footer
FS: Frame Start
FE: Frame End
FP-n: Frame Partition n

- Increasing diagnostic level with
  - Test pattern generation
  - Faults injection
- Tests can be applied
  - During initialization
  - Runtime
  - Every N frames
- CSE specifies 5 standards patterns. Sensor vendors can add own specific patterns
- Further diagnostics with A-PHY BIST
  - BIST A-Packets generation
  - BIST A-Packets monitoring

Summary

- MASS leverages and extends well-proven protocols (e.g. CSI-2)
- MASS provides a standardized framework enabling end-to-end functional safety and security protection at the application protocol level
  - Data plane with SEP and FSED
  - Control plane with CCISE
- Flexibility with message-based and frame-based protections to enable system integrator trade-offs
- Advanced self-testing and error injection features for a higher functional safety diagnosis level
- A-PHY and MASS are architected for seamless integration into sensors, providing an optimal robust and resilient solution for automotive safety applications

MIPI Automotive Resources

For automotive developers, system architects and engineering managers who are focused on the design, development, integration and test of next-generation automotive E/E architectures. Will cover:

- MIPI Automotive SerDes Solutions (MASS)
- Display and sensor (camera/lidar/radar) stacks
- Functional safety, security and data protection
- MIPI A-PHY v2.0, Power over A-PHY, system modelling and test

See 2021 workshop presentations »

More information can be found at:

- MIPI A-PHY Specification Webpage
- MIPI Automotive SerDes Solutions (MASS)
- MIPI White Paper: Introduction to MASS

Thank you

Q&A