mipi alliance

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

Evolution of MIPI CSI-2 Imaging Conduit

October 2018

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Intel IC & Sr. Architect | MIPI CWG Chair

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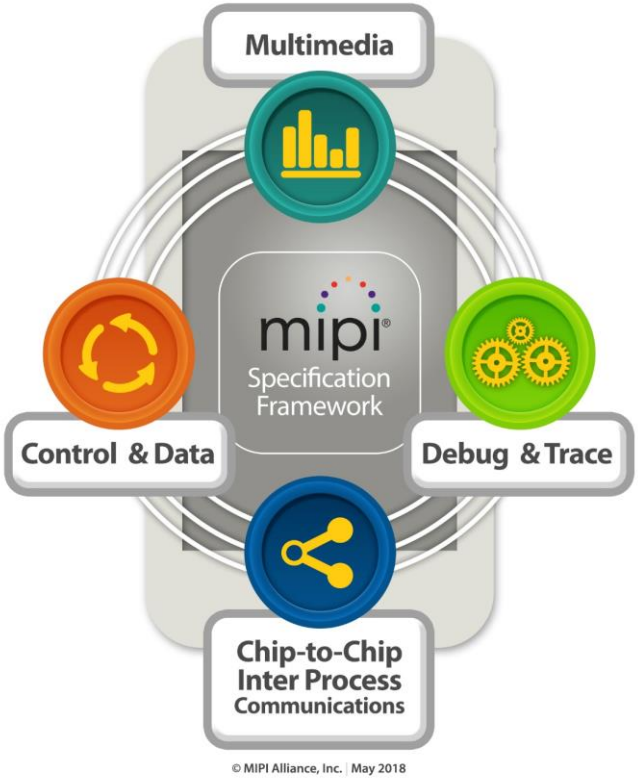
About MIPI Alliance

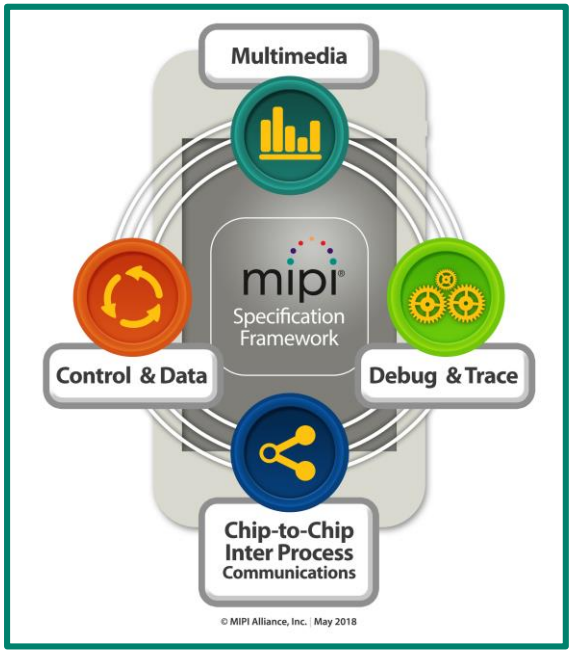
MIPI is a global, collaborative organization founded in 2003 that comprises 300+ member companies spanning the mobile and mobile-influenced ecosystems.

MIPI's mission:

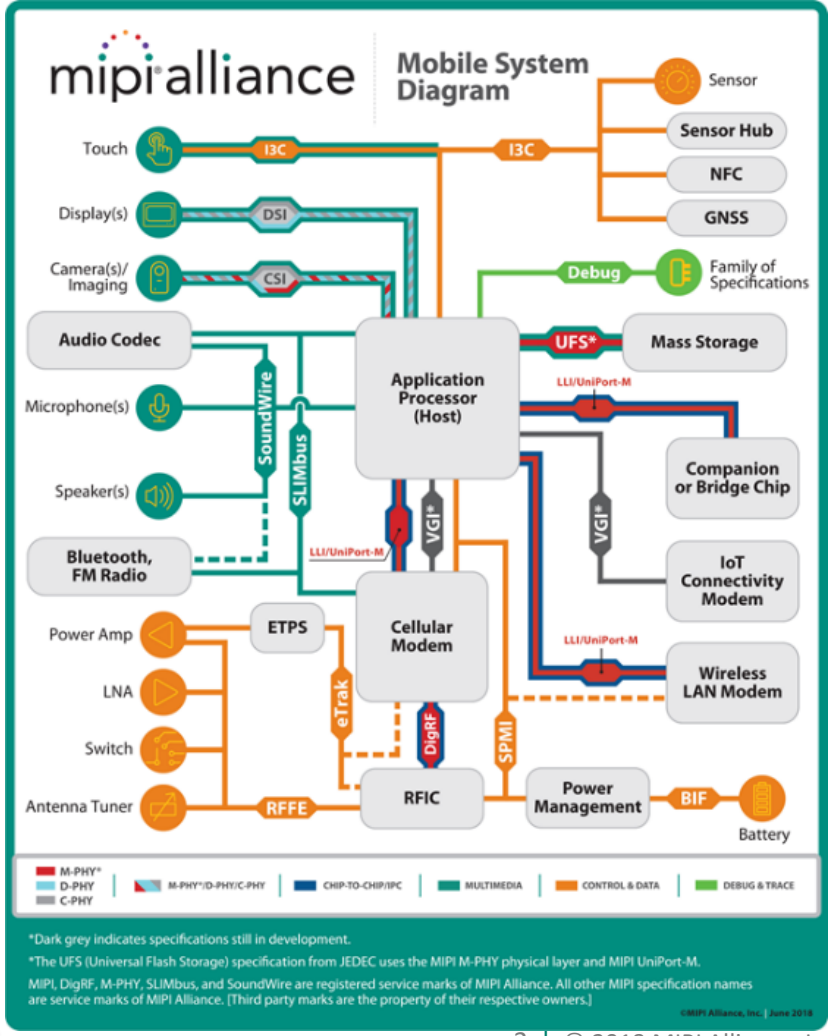
To provide the hardware and software interface specifications device vendors need to create state-of-the-art, innovative mobile-connected devices while accelerating time-to-market and reducing costs



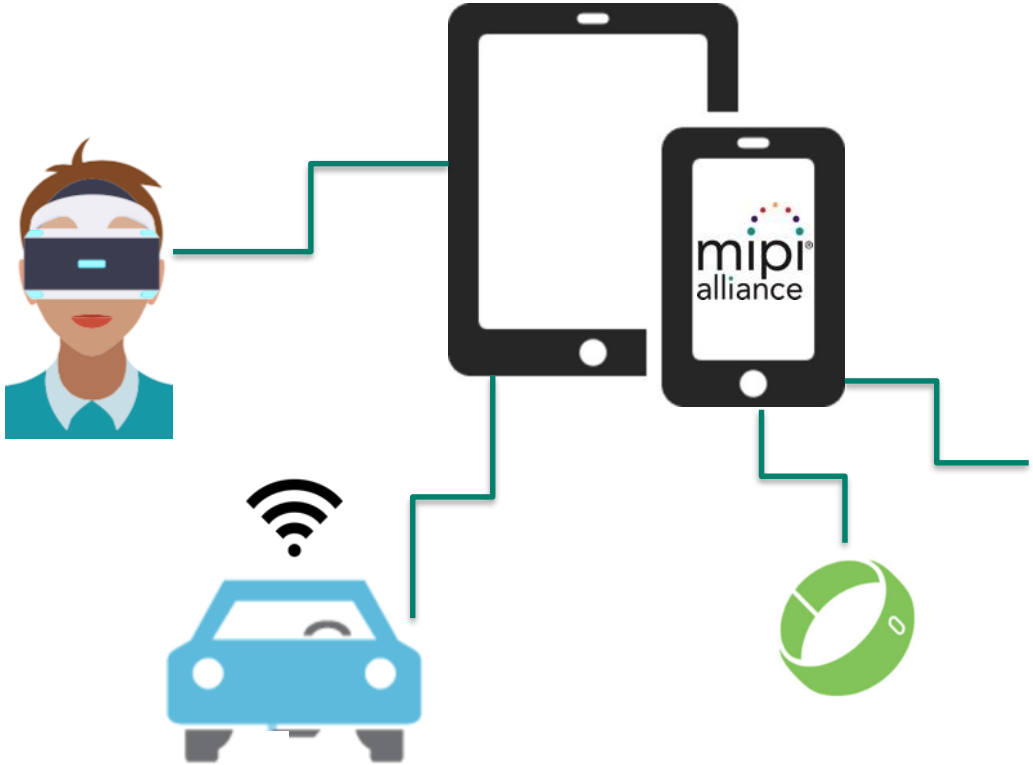
MIPI for Mobile



To date, MIPI has developed more than **45** specifications. In fact, every smartphone on the market today has at least one MIPI specification.



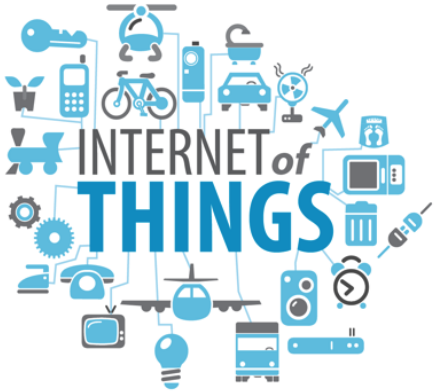
Leveraging MIPI Beyond Mobile



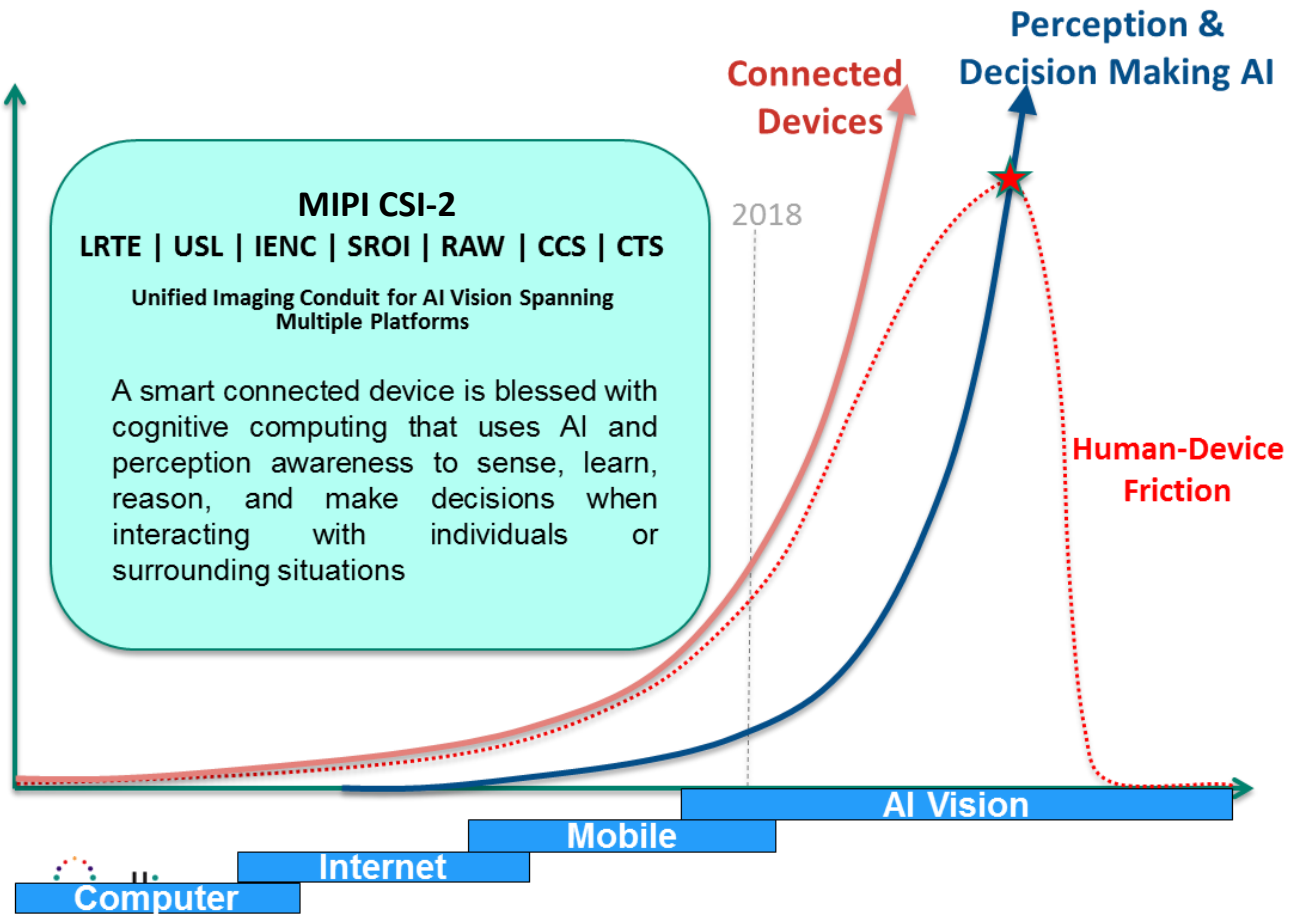
Characteristics of MIPI specifications

MIPI specifications are suitable for use in a variety of other applications because they've been optimized for:

- High bandwidth
- Low power consumption
- Low electromagnetic interference



Momentum



MIPI CSI-2

LRTE | USL | IENC | SROI | RAW | CCS | CTS

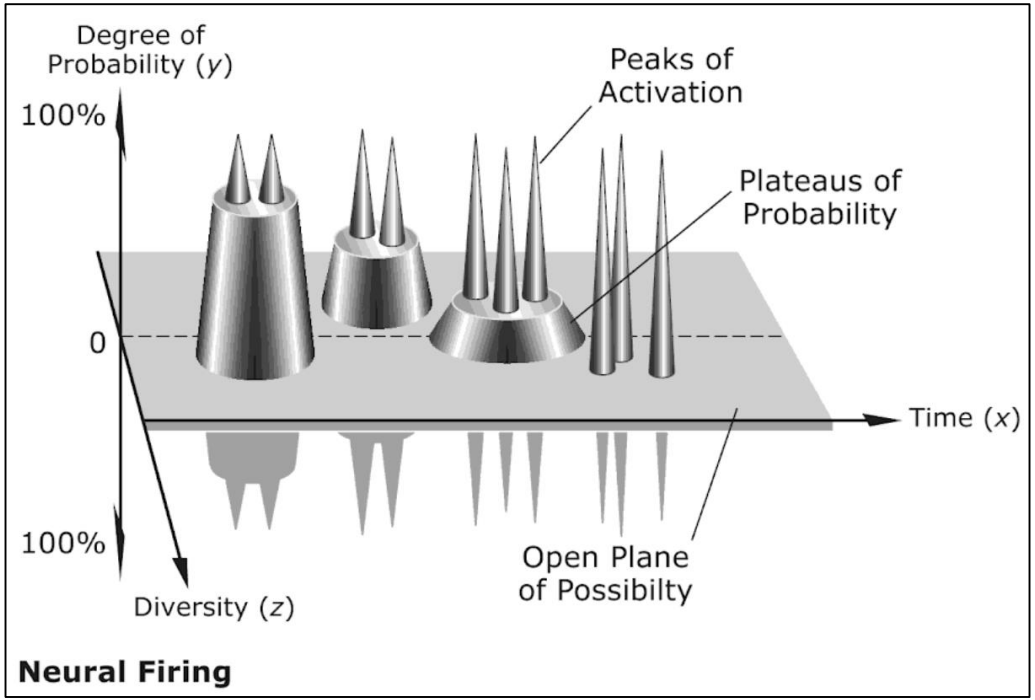
Unified Imaging Conduit for AI Vision Spanning Multiple Platforms

A smart connected device is blessed with cognitive computing that uses AI and perception awareness to sense, learn, reason, and make decisions when interacting with individuals or surrounding situations

- Complex problems cannot be solved by an individual company:
  - Autonomous vehicles
  - Paramedic drones
  - Device authentication
  - Machine awareness
- Need for global alliances

The Drive

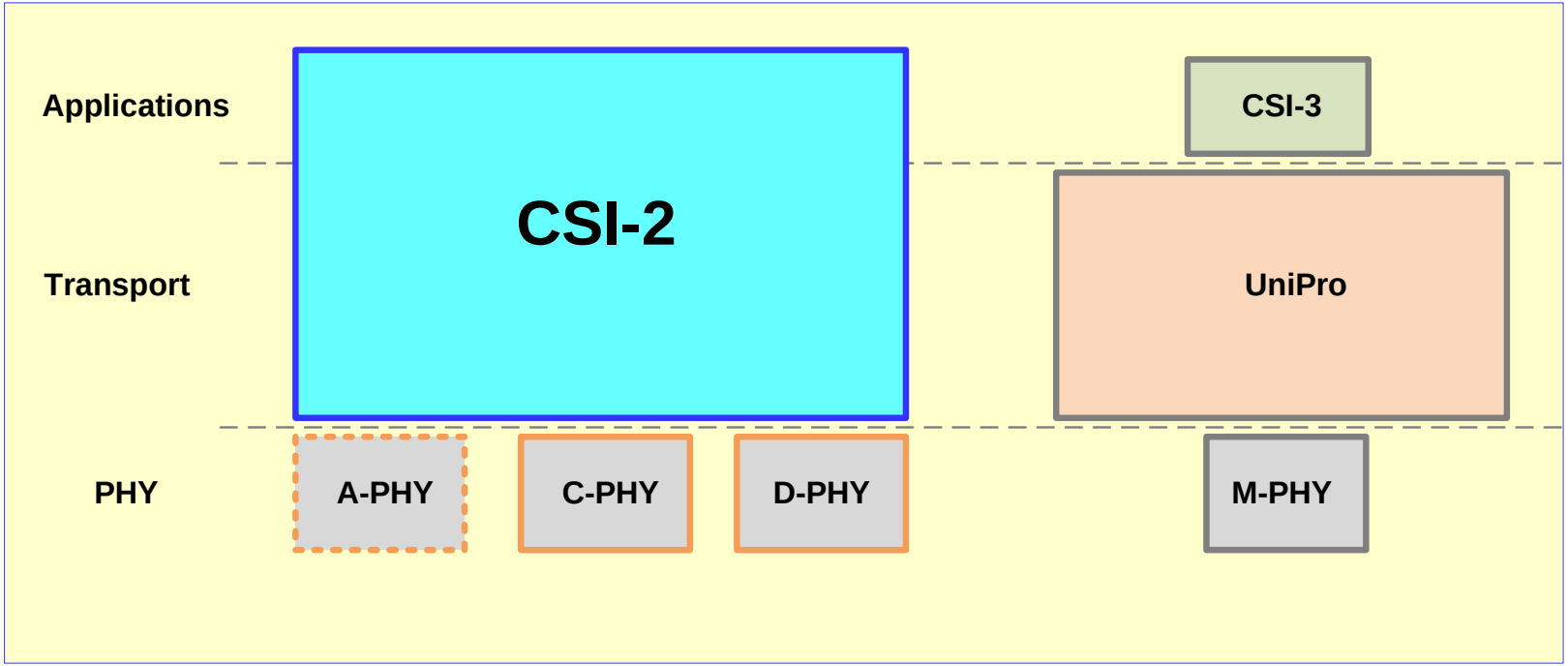
Perception l Subjective Experience l Reality



Credit: Daniel Siegel
https://books.google.com/books/about/The_Mindful_Therapist_A_Clinician_s_Guid.html?id=gFo_zhxys0AC&printsec=frontcover&source=kp_read_button#v=onepage&q&f=true

- Fundamental Drivers: Fear l Desire
- Maximize Pleasure l Minimize Pain
- Rapid Technological Advancements

Two different CSI architectures



- Continuing to evolve and advance CSI-2 imaging conduit targeting multiple platforms
- CSI-3 is not a next-gen solution, nor superset, nor backwards compatible with CSI-2

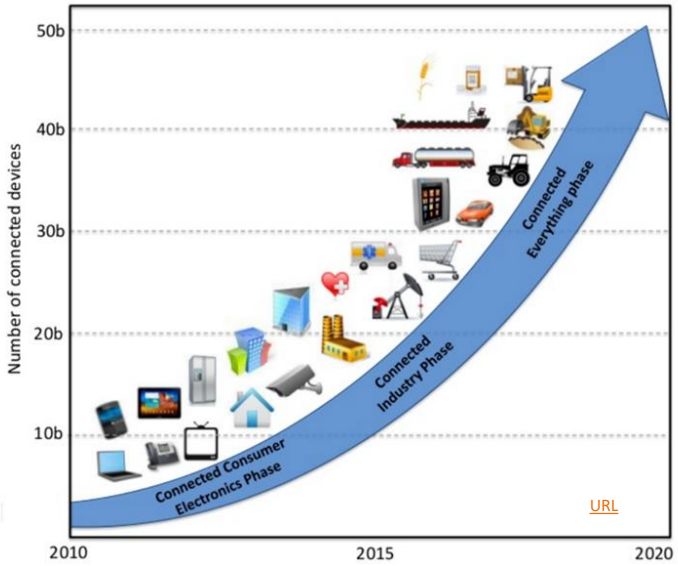
The Bridge

Ingredients
Photon Collectors, Transistors, Optics, Emitters, Algorithms

CSI-2
Imaging Conduit

Applications
Broad Spectrum of Imaging & Vision Use cases targeting multiple platforms

- 2018 Global Alliance Engagements:
  1. MIPI Alliance (Camera & Imaging WG)
  2. Stanford Innovations in Psychiatry and Behavioral health (VR)
  3. Embedded Vision Alliance
  4. Image Sensor Auto
- Clear problem definitions
- Map features to use cases (~70% reject)
- Unified Imaging Software Driver
- End-to-end Conformance Test Suite



Platform Scope

Mobile

Target Platform: **Smart Phones**

Target Imaging Application:
Pristine still photography l streaming video

IOT

Target Platform: **Content Creation**
(AIO, Notebooks, Hub)

Target Imaging Application:
Comprehensive E2E imaging conduit to enable machine awareness

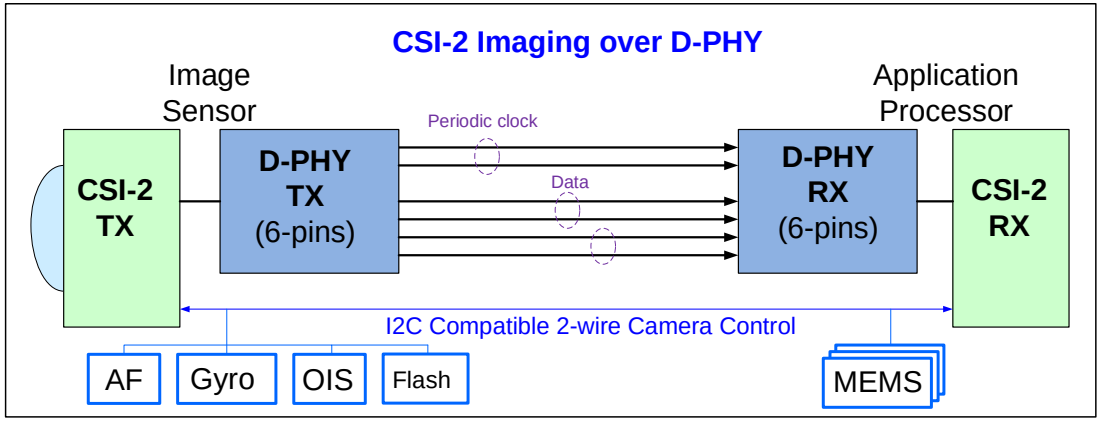
Autonomous

Target Platform: **Automotive**

Target Imaging Application:
Real time perception and decicion making

CSI-2 over C/D-PHYs (2 Lanes)

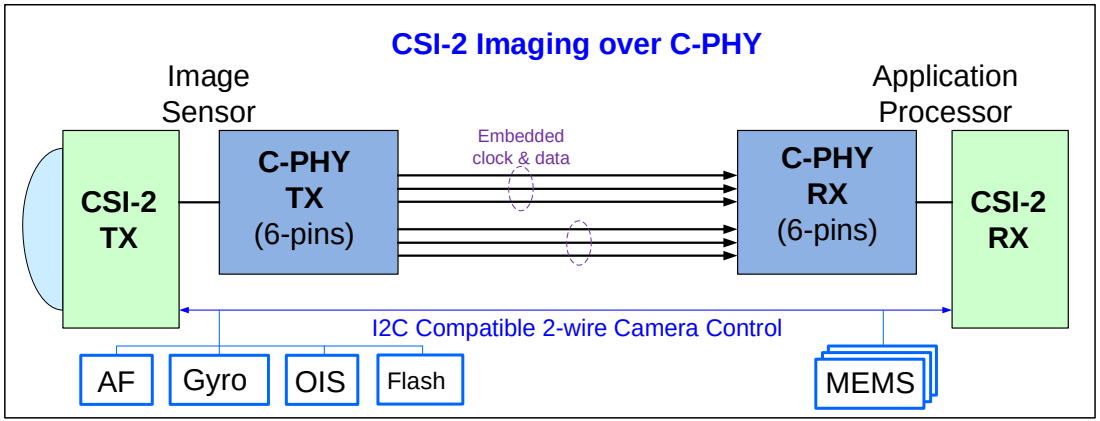
CSI-2 D-PHY



1x Effective Pixel BW

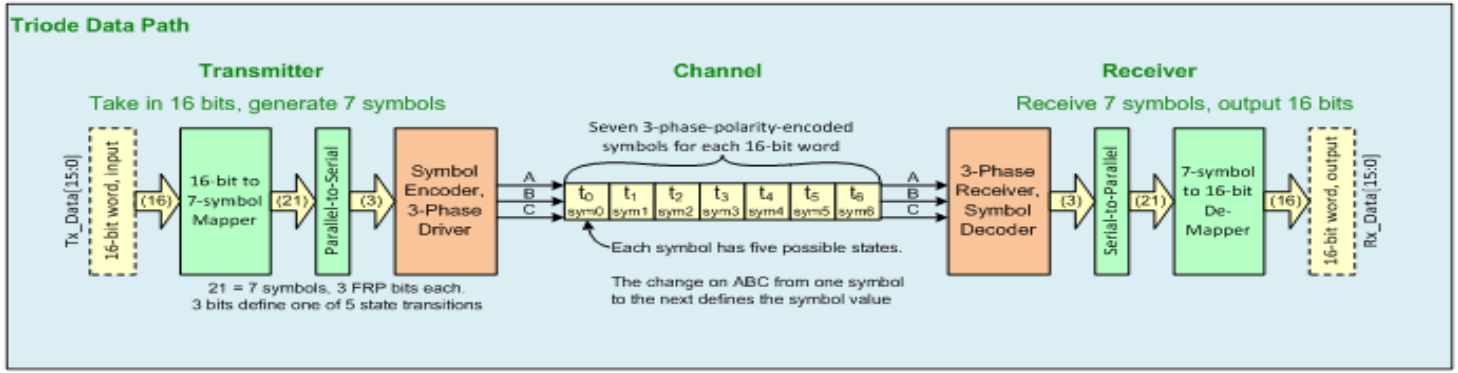
Pin compatible

CSI-2 C-PHY



2.3x Effective Pixel BW

CSI-2 over C-PHY 2.3x Effective BW



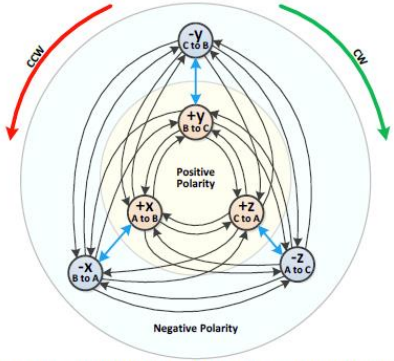
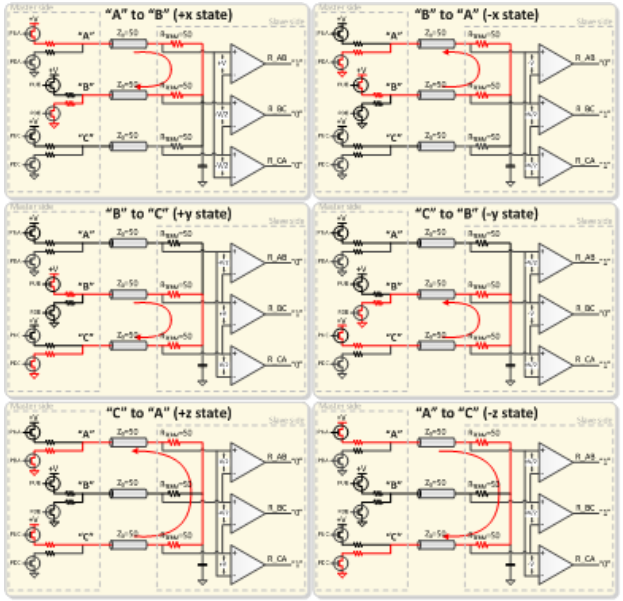


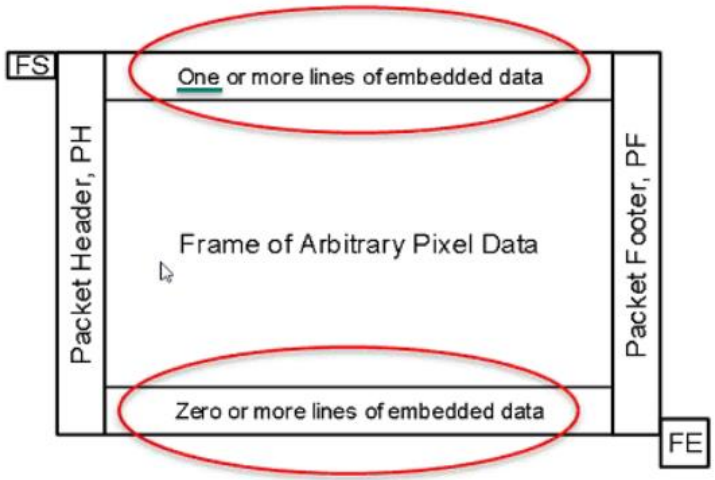
Figure 2 State Diagram Showing All Six Wire States, and All Possible Transitions



- 3 terminated conductors
- CSI-2 policy: symbol transition each state for trivial CDR
- Theoretical BW gain: log2^5
- As implemented for CSI-2 = 16/7

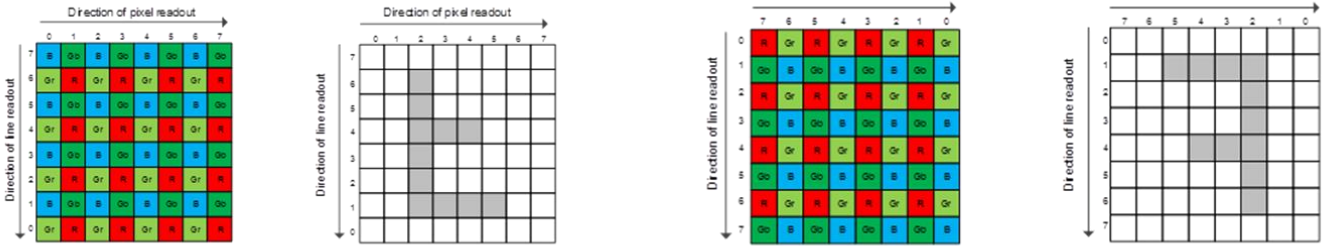
Algorithm is King

- Unified Imaging Software Driver
- Enable Image Sensor Capabilities for Vision Compute
- Accelerate Bring up on Reference Platforms

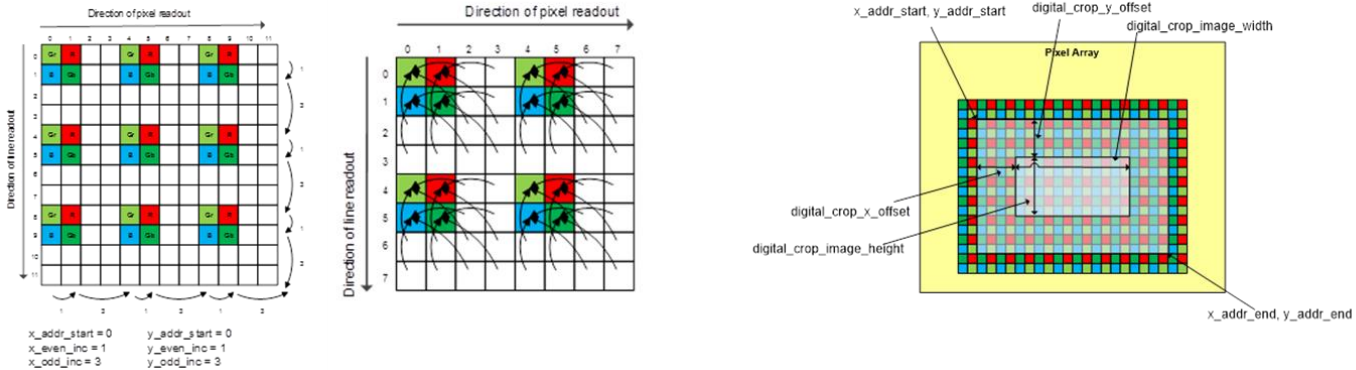


CSI-2 CCS

- Vertical Flip | Horizontal Mirroring

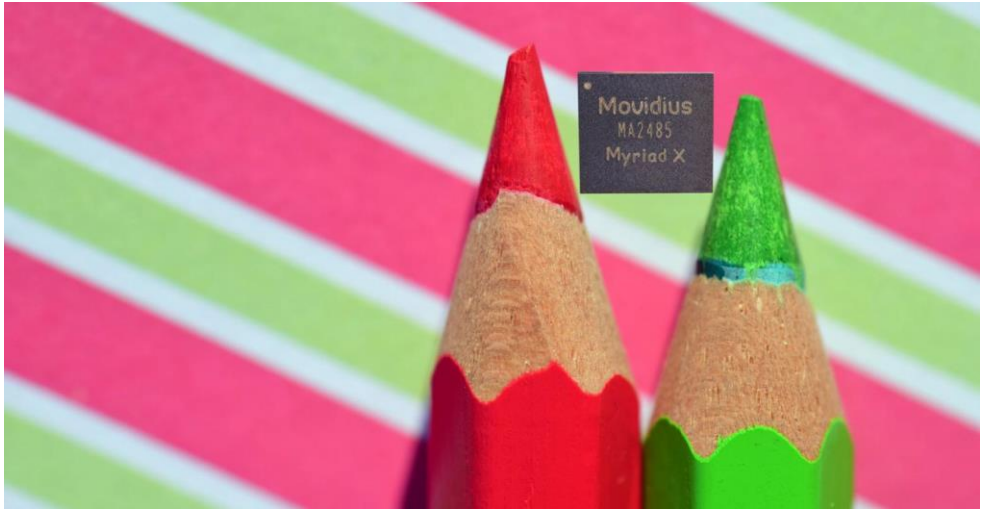


- Sub-Sampled Readout | Binning | Digital Crop



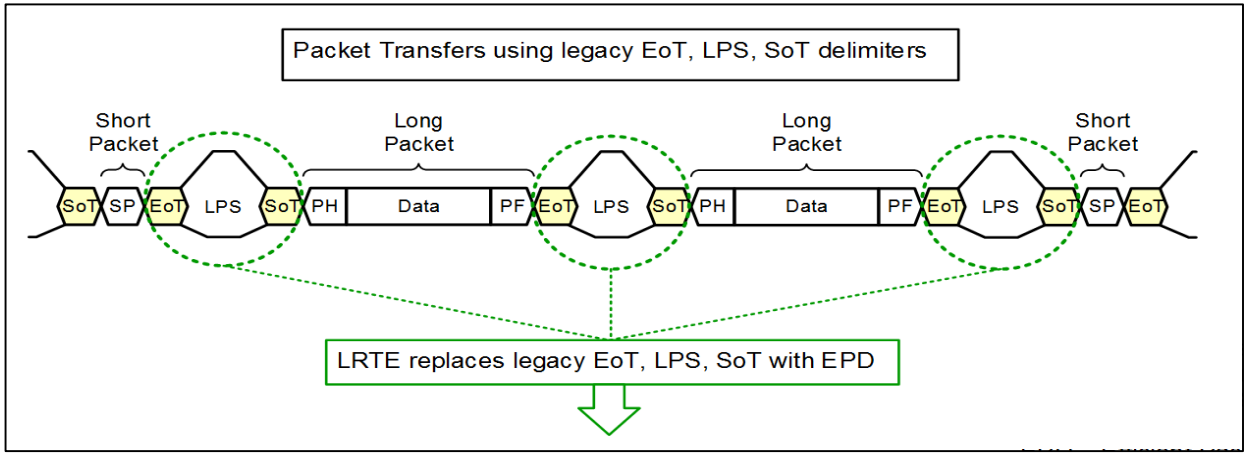
Deep Neural Networks

Myriad X Hybrid Arch Deep Neural Network
8 Cameras using 16 MIPI Lanes - 700 MP/s
Drone Collision Avoidance (DJI SPARK)

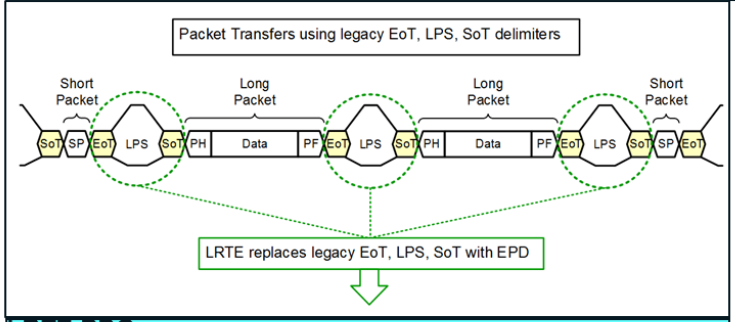


http://www.electronicdesign.com/industrial-automation/intel-s-myriad-x-vision-chip-incorporates-neural-network

LRTE



- Dramatically Improve Sensor Aggregation
- Optimal Transport Preserving Integrity
- Real-time Perception & Decision Making
- Phase out EOS &IL Impediments
- Asymmetric SP/LP Spacers



LRTE PDQ

i. Increase number of supported sensors by CSI-2 Aggregators (system cost reduction)

ii. Facilitates optimal transport, while preserving CSI-2 packet delimiter integrity

iii. Reduce frame latency for real-time perception & decision making applications

LRTE ALPS (requires PDQ)

Transitionary pathway to phase out (1.2v) EOS impediments

Detailed CSI-2 System Analysis & Benefits of Using LRTE PDQ

System 1: CSI-2 v2.0 over C-PHY v1.2 (3.5 Gsps/lane or 8Gbps/lane)
- 24 Gbps using 3 lanes (requires 9 wires)
- CSI-2 v2.0 supports up to 32 Virtual Channels over C-PHY

Multi Sensor Aggregator with each sensor configured as
- 1920 x 1200 (2.3MP), 12 BPP, 60 FPS

Image Sensor Packet Transport
- 1920 pixels x 12bps = 23040 bits per Horizontal Row Long Packet (LP)
- 23040 bits / 24Gbps = 0.960 us / LP (CSI-2 Payload; ignoring PH/PF)
- Packet Header + Packet Footer = 336+48= 384 bits
- 23424bits / 24Gbps = 0.976us /LP_PHF (CSI-2 Payload with PH and PF)

CSI-2 v2.0 with Legacy C-PHY Packet Delimiters:
- LP Delimiter (SoT/EoT) = ~0.3 us
- Total Time per LP_PHF = 1.276 us
- Packet Delimiter Overhead = 23.5%
- Time per Image Frame = 1.276 us x 1200 = 1.53 ms (Ignoring FS/FE)
- Stream 60 frames from single image sensor requires: 1.53ms x 60 = 91.87 ms
- Maximum Supported Image Sensors on an Aggregator = 10
- FLOOR[1/0.09187] = FLOOR[10.88]

CSI-2 v2.0 with LRTE PDQ:
- Time per Image Frame = 0.976 us x 1200 = 1.171 ms
- Stream 60 frames from single image sensor requires: 1.172ms x 60 = 70.27 ms
- Maximum Supported Image Sensors on an Aggregator = 14
- FLOOR[1/0.07027] = FLOOR[14.23]

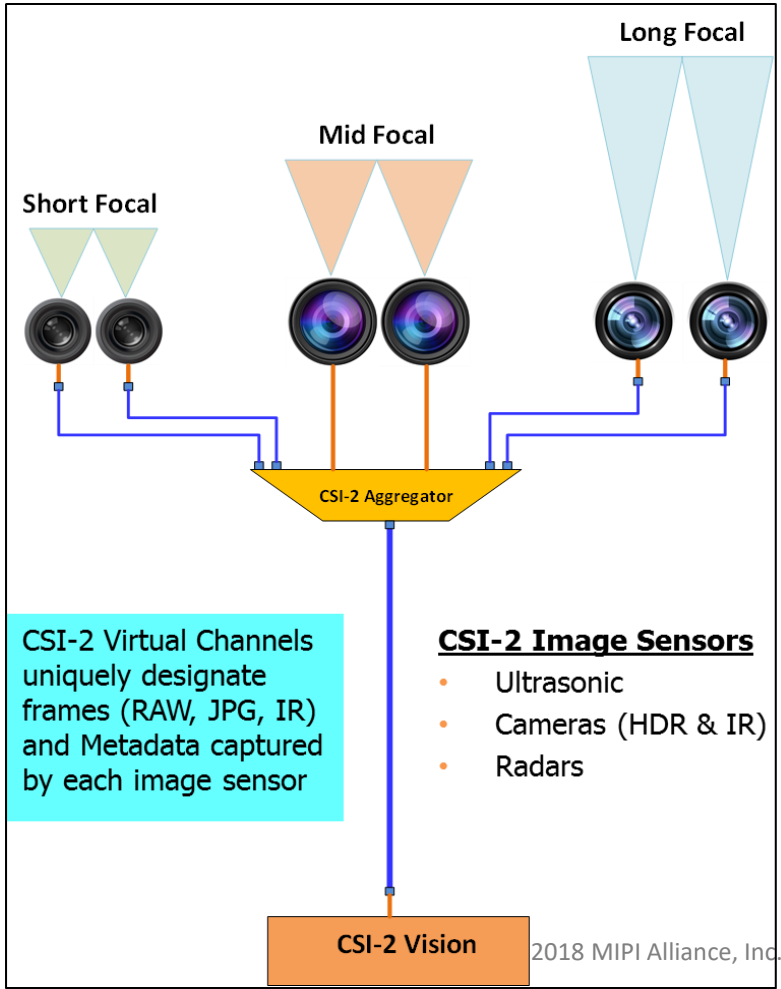
Benefits of CSI-2 v2.0 with LRTE PDQ:
- Frame Transport Efficiency Improvement: 23.5%
- Additional Supported Image Sensors on Aggregator: +4 (over the same channel)
- Alternatively, reduce toggle rate / wires

Considerations	
Legacy PD Hor Row Overhead	23.51%
Legacy PD Max Supported Sesnors	10
LRTE PDQ Hor Row Overhead	0.20%
LRTE PDQ Frame Transport Efficieny Impact (reduce: power / wire / toggle)	**23.35%**
LRTE PDQ Max Sesnors Supported	14
LRTE PDQ Additional Supported Sensors	**40.00%**

Virtual Channel Expansion

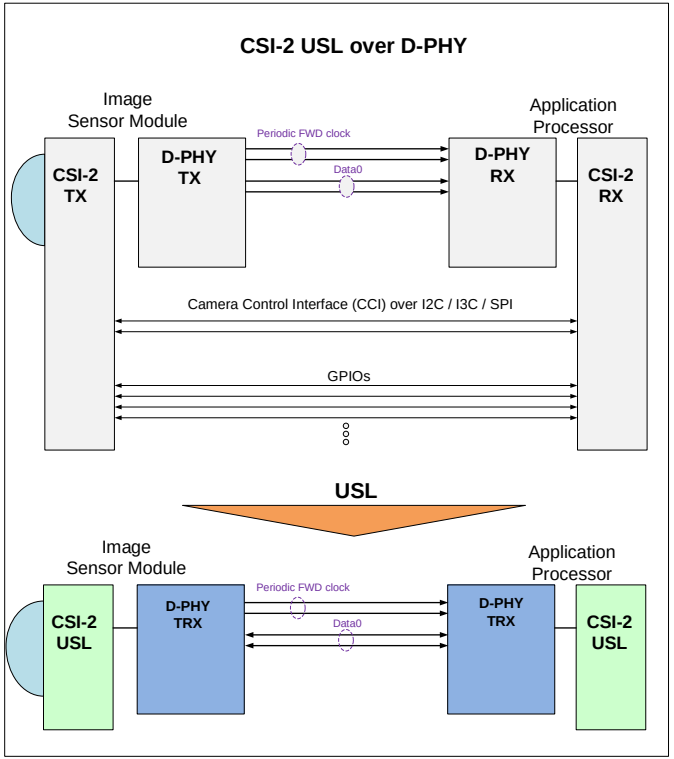
System Considerations

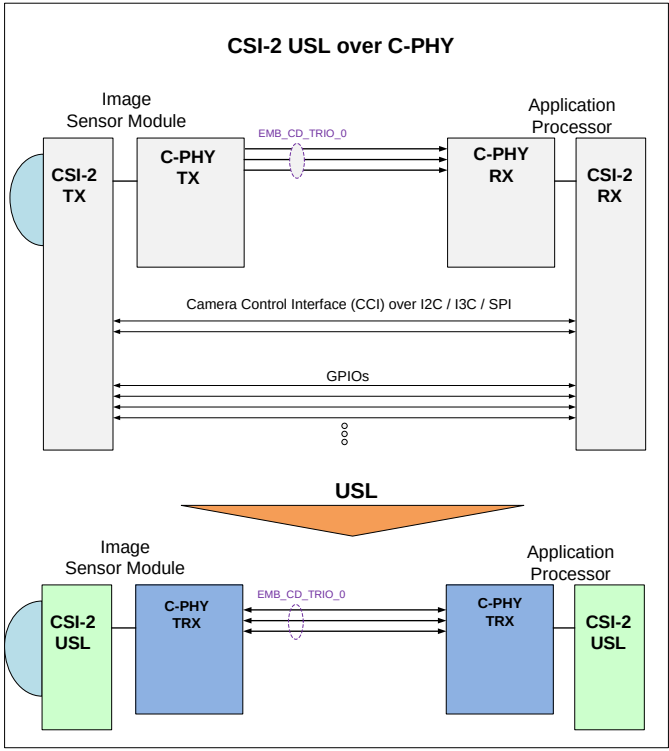
- Proliferation of Image Sensors Require CSI-2 Aggregators and VC Expansion
- System is limited to 16 or lower VCs:
  - Supported by CSI-2 over C/D-PHY
- System requires more than 16 VCs:
  - Supported by CSI-2 over C-PHY



CSI-2 Unified Serial Link

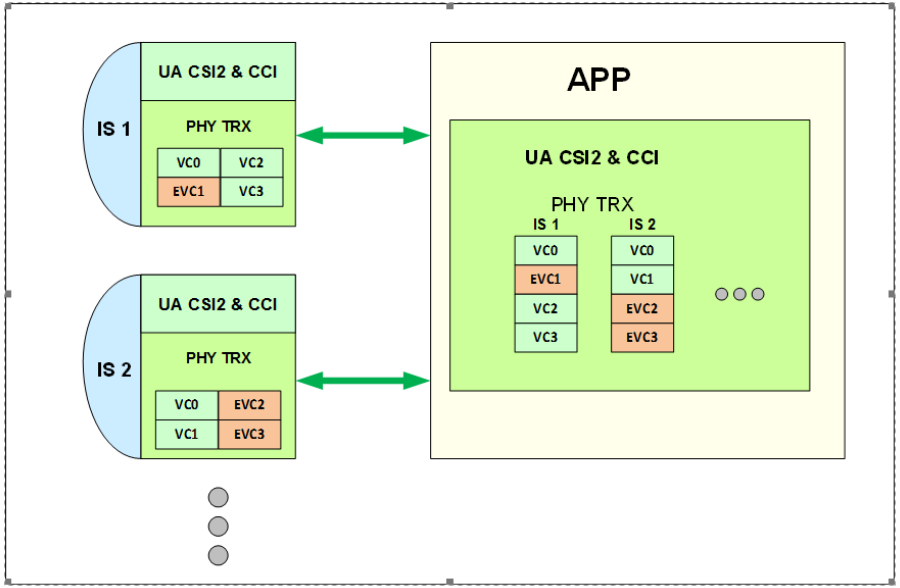
- Long Reach
- Wire Reduction
- Encapsulation
- Secure Channel



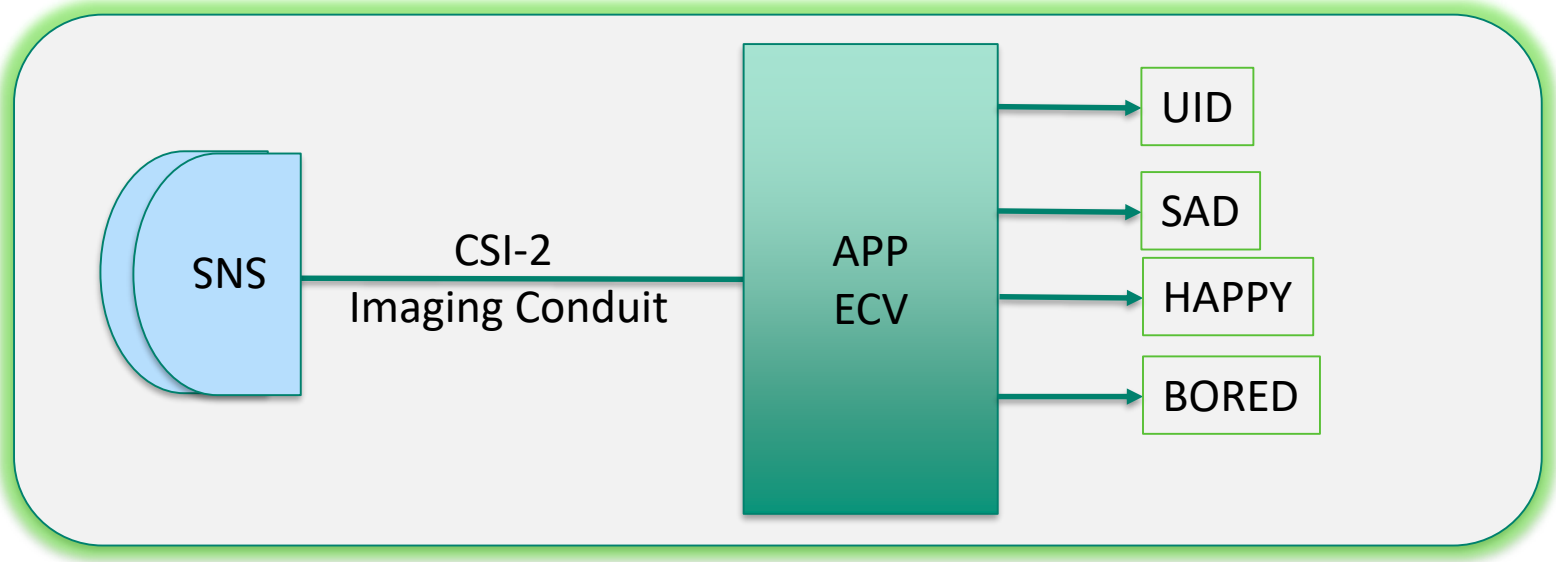


Interleaved Encryption

- Enterprise Security
- Pixel Authentication
- VC Mapped Interleaved Encryption
- Threat Model & Use Cases (GCM / AES)



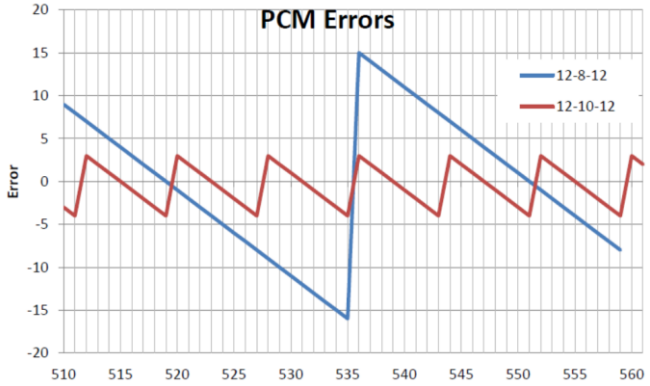
Machine Awareness (ECV)

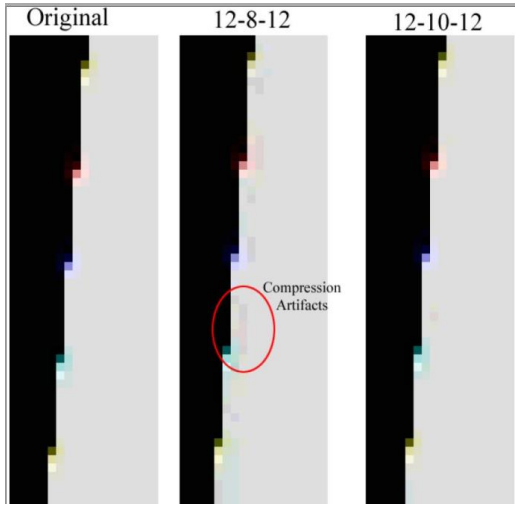


- Phase 1: LRTE & PSD (EOY 2016)
- Phase 2: USL & SROI(EOY 2018)
- Phase 3: AOSC (EOY 2020)

DPCM Objective Qualification

- Enable 10-bit compression of RAW-12 video image with better IQ than prior version 12-8-12
- Reduce maximum absolute error of single-bit change in pixel value by a factor of 4.43x
- Qualified 5 degree slanted edge input image with low, medium, and high illumination levels:
  - 12-10-12 virtually indistinguishable from original image
  - MTF frequency response analysis closely tracks the original (HI/MI/LI - LC/MC/HC)
- Benefits include Link BW reduction cost savings

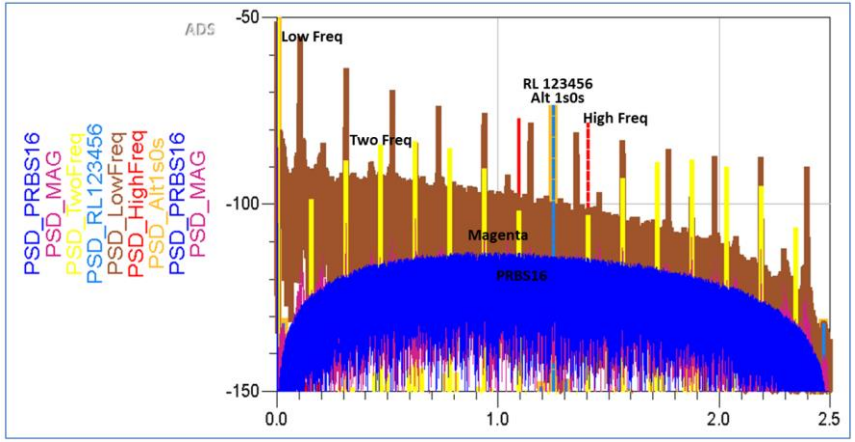




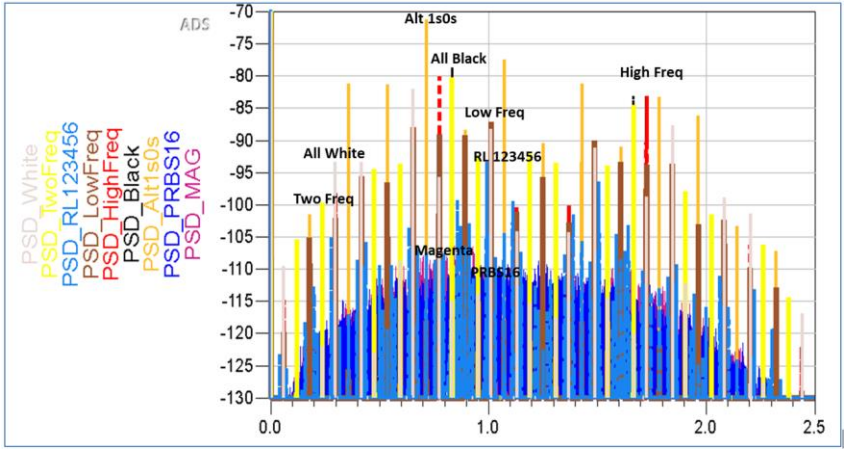
Use Case	Per-Lane 4-Lane Bit Rate (Gbps)				12-10-12 DPCM Enables Use of:
	10 bpp	D-PHY	12 bpp	D-PHY	
4Kp60 or 1080p240	1.485	v1.1	1.782	v1.2	D-PHY v1.1
16M (4:3) @ 30 fps	1.45	v1.1	1.74	v1.2	D-PHY v1.1
20M (16:9 crop) @ 30 fps	1.371	v1.1	1.645	v1.2	D-PHY v1.1
32M (4:3) @ 24 fps	2.263	v1.2	2.715	v2.0	D-PHY v1.2

PSD Reduction

CSI-2 over D-PHY PSD emission reduction with scrambling (data lanes)



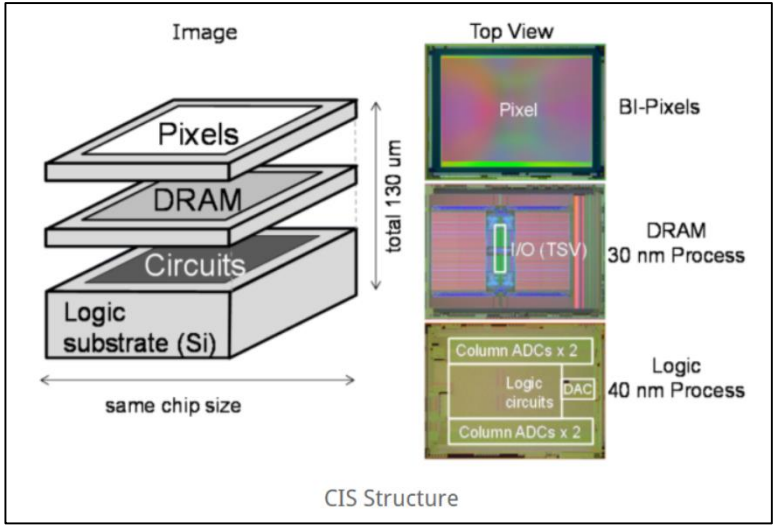
CSI-2 over C-PHY PSD emission reduction with scrambling (embedded clock and data)



Smart Region of Interest

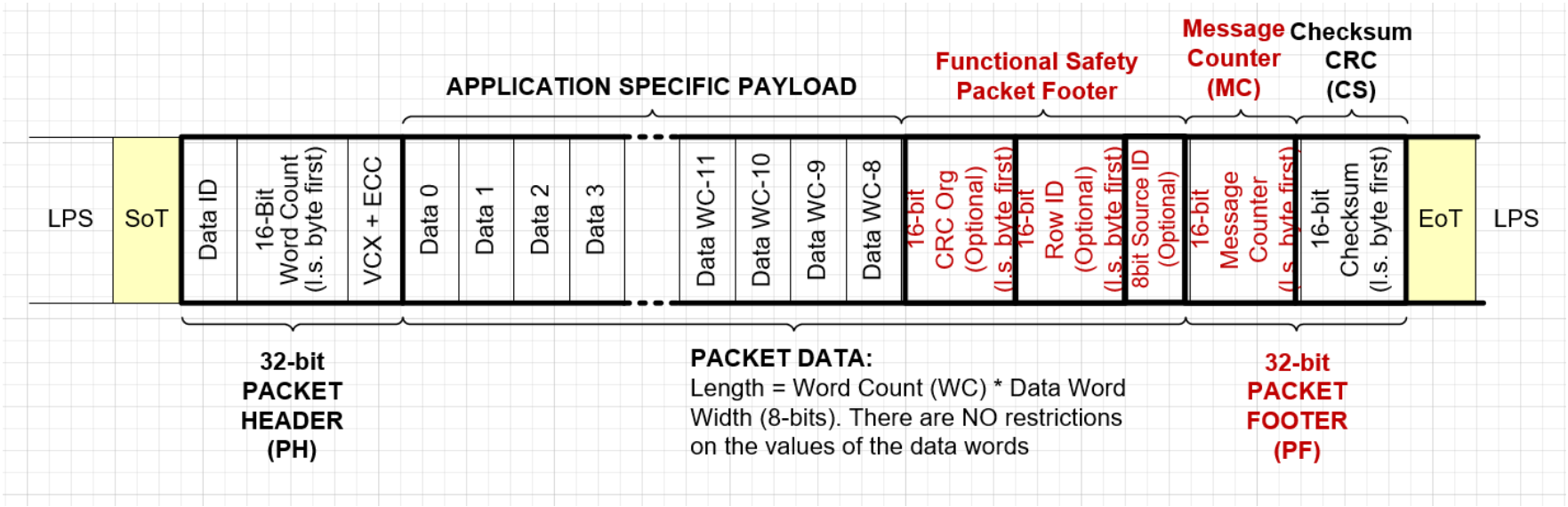
- Phase 1 EOY 2018 Single Frame
- Phase 2 EOY 2019 Multi Frame
- ARCH: Edge |Hybrid

3-layer stacked image sensor

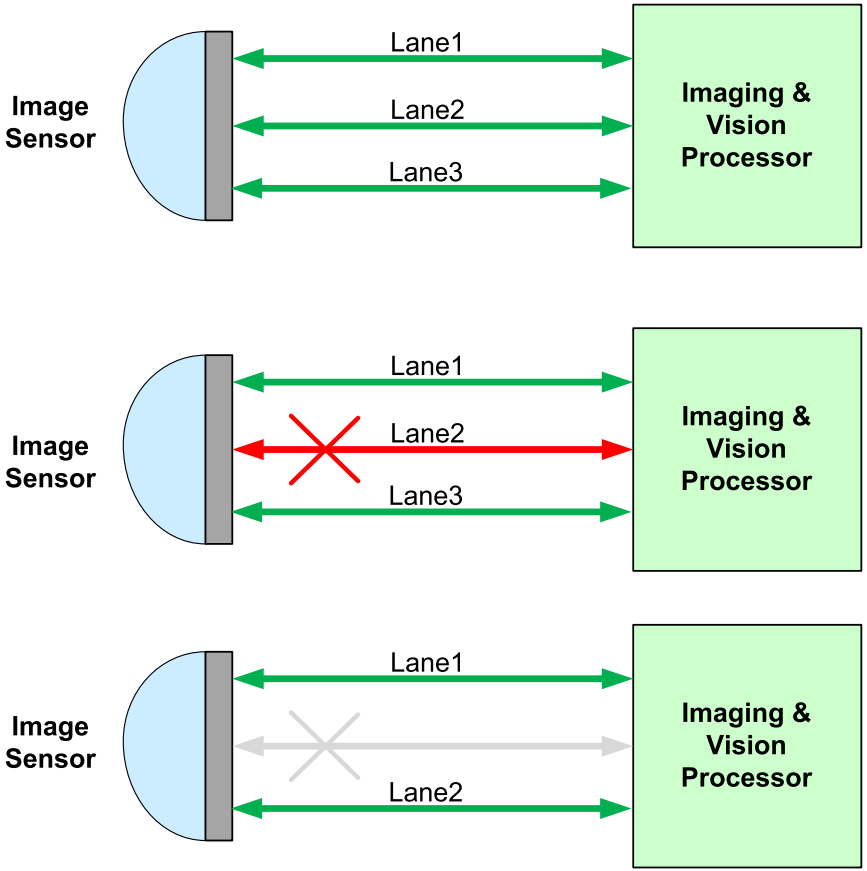


https://fuse.wikichip.org/news/763/iedm-2017-sonys-3-layer-stacked-cmos-image-sensor-technology/

Functional Safety



Graceful Link Degradation



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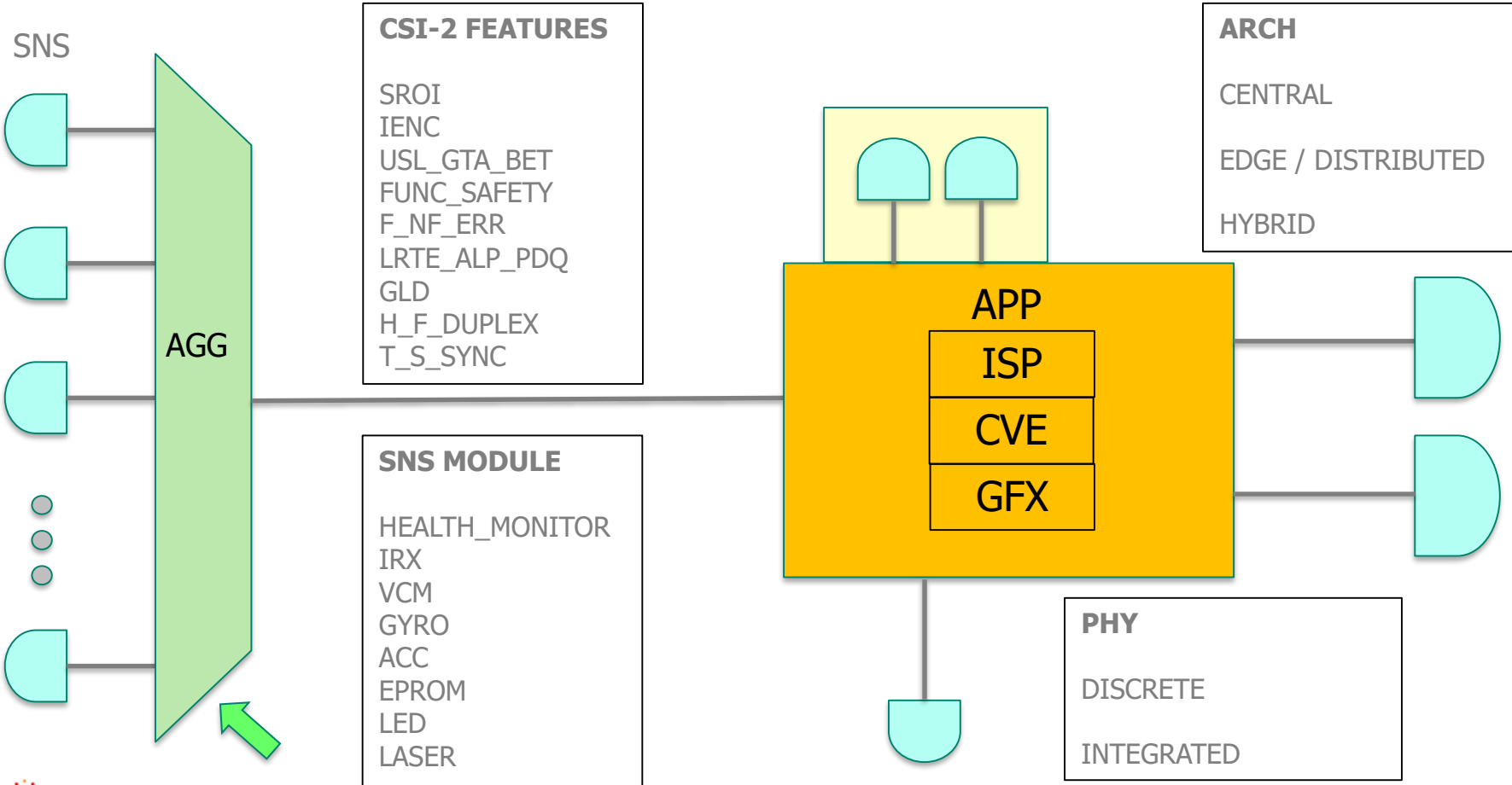
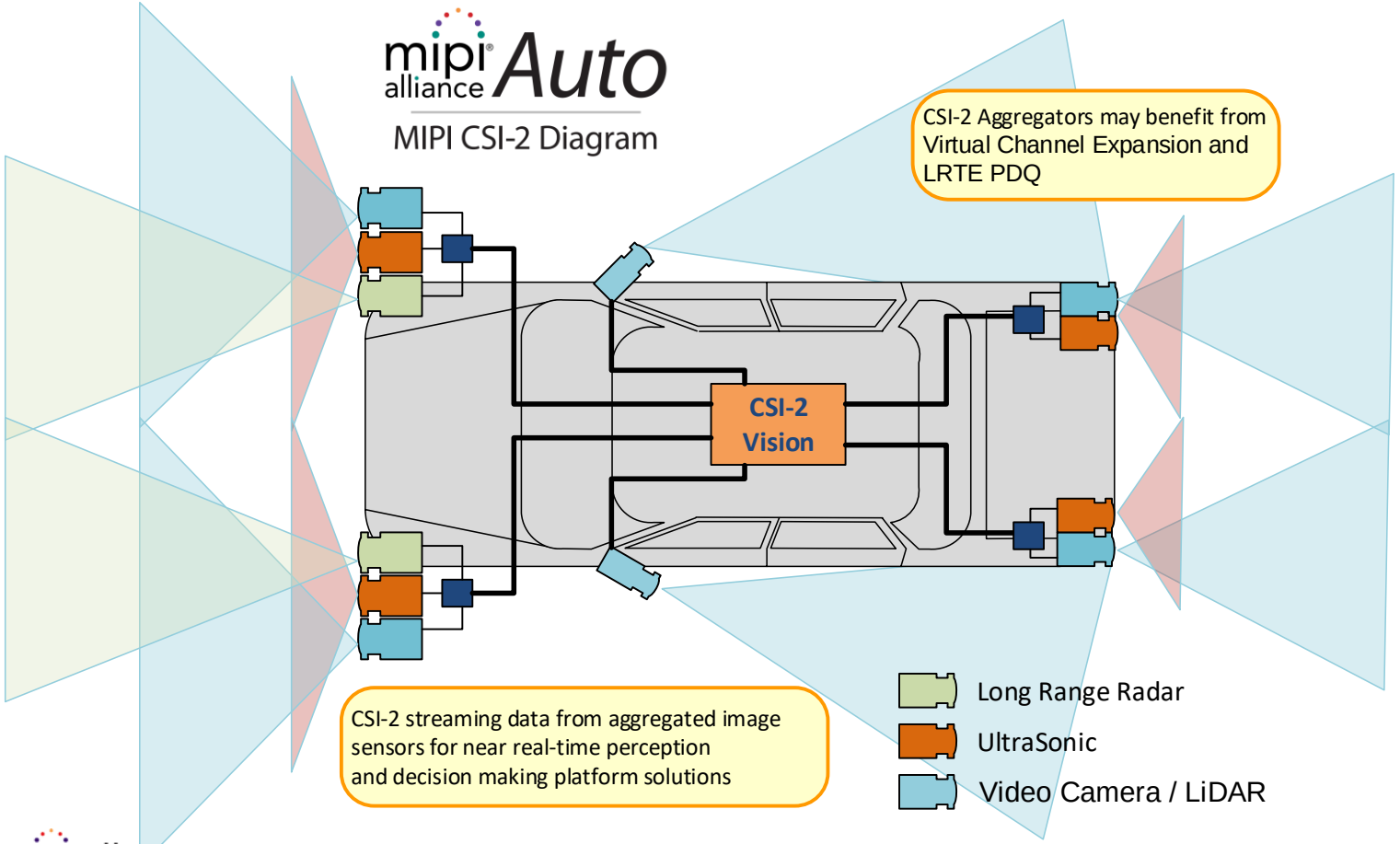
Platform Architectures



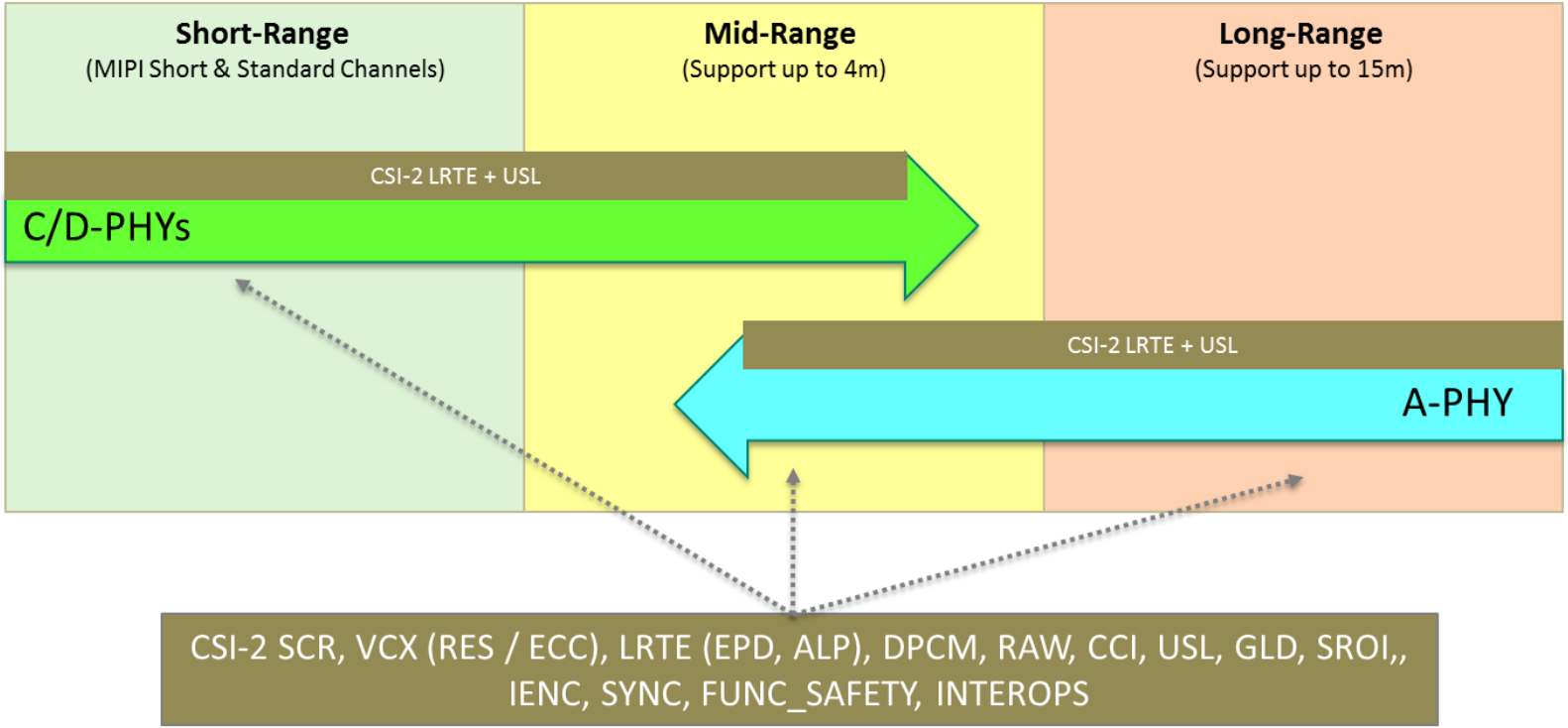
Evolving CSI-2 Architecture for Automotive



CSI-2 Imaging Conduit

- Mobile Devices
- Wearables
- IoT Appliances
- Enterprise
- Industrial
- Medical
- Automotive
- Submarines
- Exoplanet Rover
- …

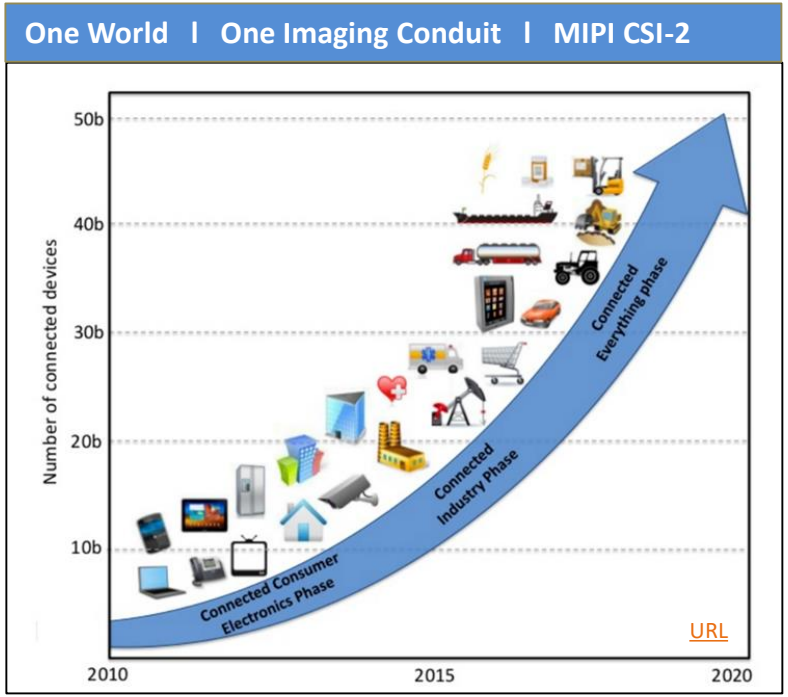
Interconnect Support



- Mid-Range solutions targeting EOY 2018 development
- Long-Range solution targeting EOY 2019 development

Summary

- Engage Imaging & Vision Global Alliances
- IOT Platform EOY 2018
  - USL
  - SROI (Single Frame)
  - RAW-24
  - EOTP
  - Interop Fixes
- Automotive Platform EOY 2019
  - Functional Safety
  - IENC l Pixel Integrity
  - SROI (Multi Frame)
  - Joint Imaging & Security BOF (January 2019)
- Balance Cleverness with Wisdom
  - Inclusive Vs Exclusive
- Machine Awareness EOY 2019



Questions

www.mipi.org

