Using MIPI CSI to Interface with Multiple Cameras

Karthick Kumaran Ayyalluseshagiri Viswanathan

Staff Software Engineer

Meta Platforms Inc

Meta

Topics

- Camera Interfaces
- Quick Recap – MIPI
- SoC – Camera Architecture
- MIPI CSI D-PHY
- MIPI CSI C-PHY
- Virtual Channel (VC)/ Data Type (DT) Aggregation
- Multi-Drop
- Summary

Problem Statement

- Growing number of advanced use cases in robotics, VR/AR, drones, and automotive, demand multiple cameras
- Limited number of camera interfaces limits the number of cameras connected to the SOC
- Will cover various techniques to overcome the limitations

Camera Interfaces

- Parallel interface
- USB
- MIPI

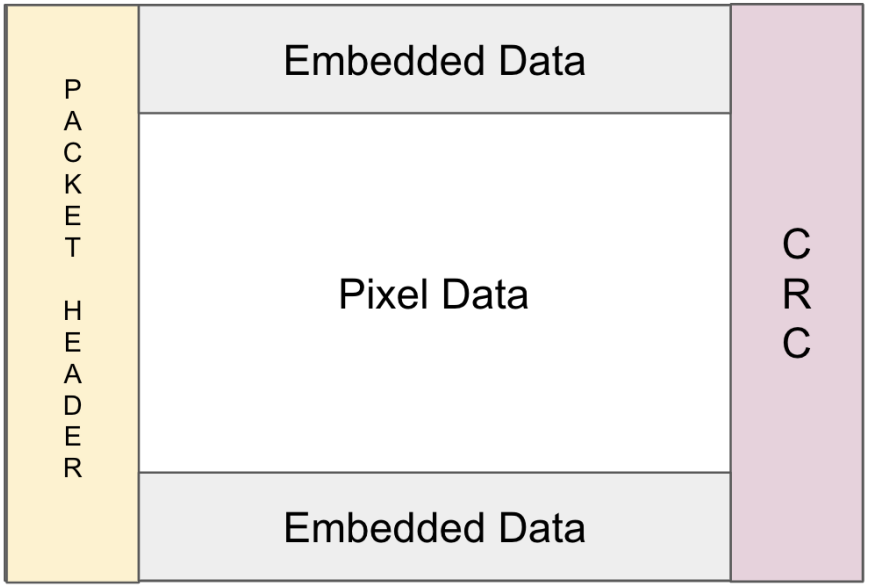
I will be covering only the MIPI interface in this talk

MIPI CSI-2

- CSI for camera
  - A-PHY (for automotive)
  - C-PHY (trio)
  - D-PHY (Differential phase)
- DSI for display

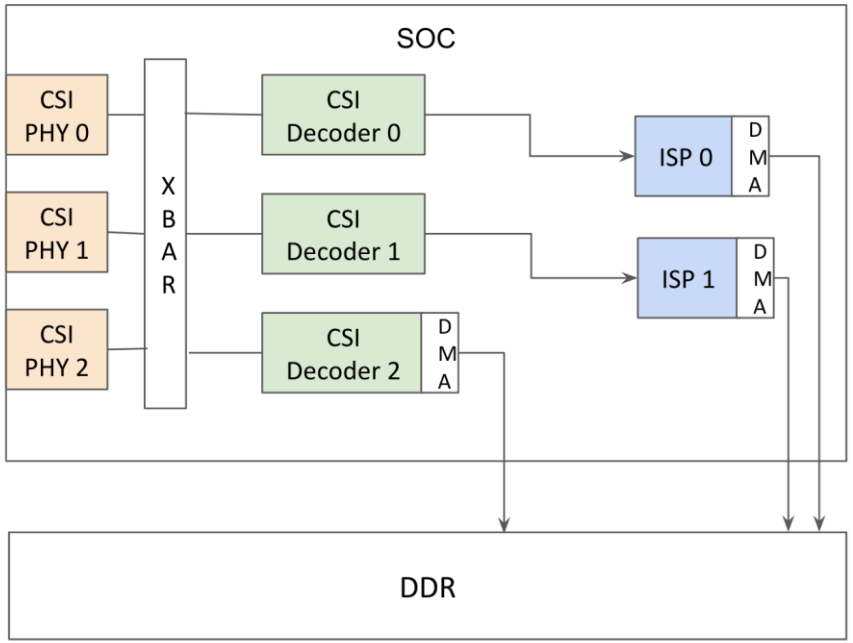
Quick Recap of MIPI CSI-2 Frame Format

- Two types of MIPI packets
  - Short packet
  - Long packet
- Short packet
  - Packet header (PH)
- Long packet
  - Packet header
    - 8-bit data identifier
      - 2-bit VC + 6-bit DT
    - 16-bit word count
    - 8-bit ECC
  - Payload – Pixel data
  - Packet footer



Architecture

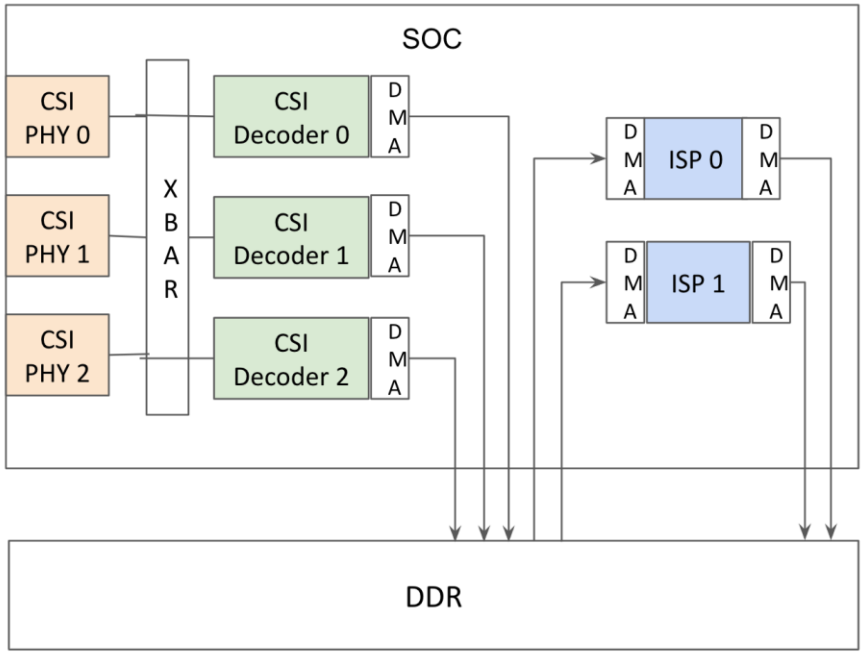
- Typically, SOCs have several number of hardware blocks such as
  - MIPI CSI PHY interfaces
  - MIPI CSI decoders
  - ISPs
  - DMAs
- Number of hardware blocks vary between SOCs



Inline ISP

Architecture

- CSI PHY used to interface
  - Camera sensors
  - Depth sensors
  - DTOF / ITOF etc.,
- CSI decoder to decode the MIPI protocol
- DMA to transfer the pixels to DDR
- ISP to perform image processing



Offline ISP

CSI PHY, CSI Decoder & ISP

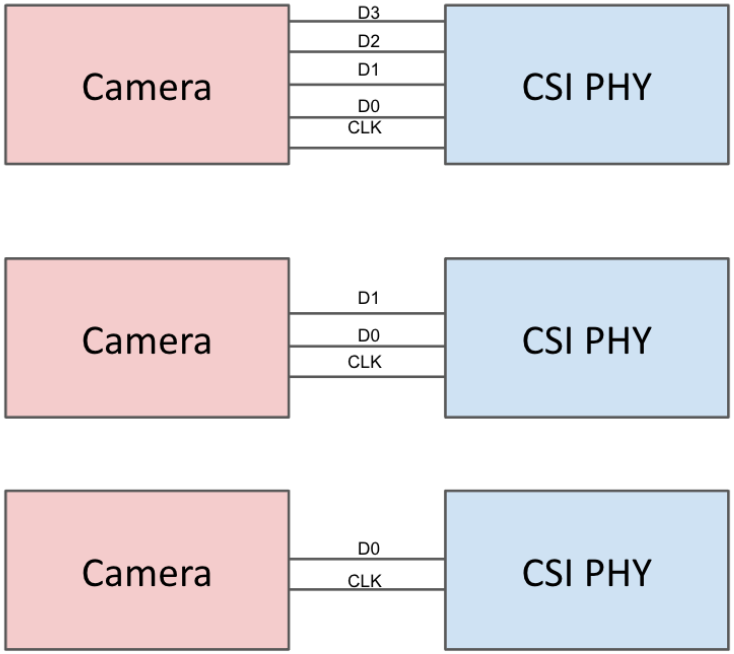
- There are a fixed number of CSI PHY interfaces, CSI decoders and ISPs available on embedded SoCs
- Number of CSI Interfaces and number of CSI decoders need not be always the same
- Similarly, number of CSI decoders and number of ISPs need not be always the same
- Color cameras need ISP to do demosaic and image quality enhancements
- Monochrome cameras – for computer vision / deep learning algorithms
  - May not need any ISP processing
- Cross bar between CSI PHY interface and CSI decoder helps to map them arbitrarily

ISP

- ISP to perform image processing such as
  - Demosaic, color space conversion (CSC), black level subtraction (BLS), gamma, scale, crop and other IQ enhancements
- Inline ISP
  - Pixels are passed to the ISP directly from the CSI decoder
  - Less latency
  - Less power consumption as it avoids round trip to the DDR
- Offline ISP
  - Acts like M2M (Memory-to-Memory) device
  - Higher latency than inline ISP
  - Supports multiple instances

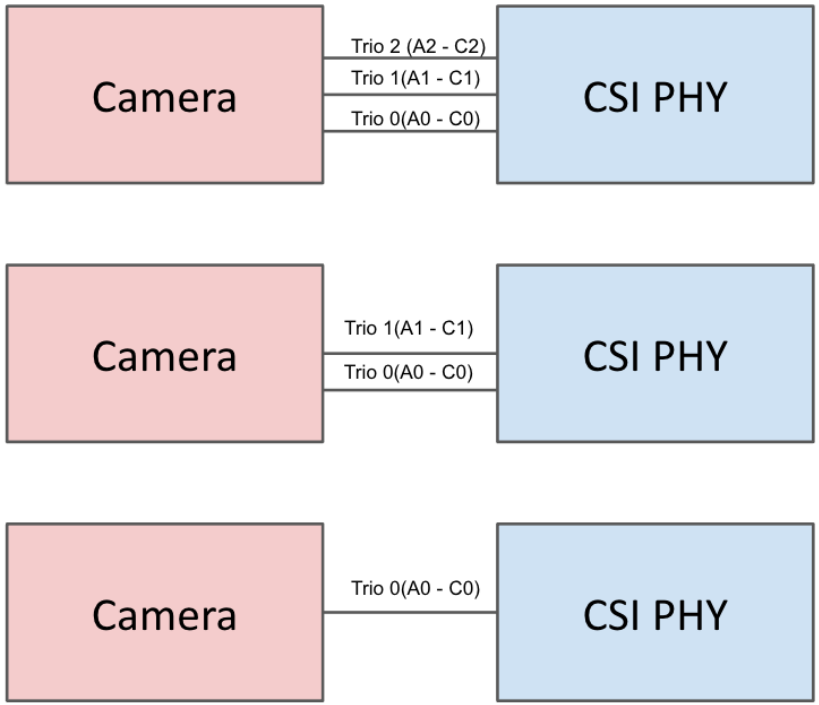
MIPI CSI D-PHY

- Up to 4 data lanes can be connected to a single CSI PHY in D-PHY mode + 1 clock lane
- High resolution cameras use all the 4 data lanes
- Mid to low resolution cameras use either 2 lanes or 1 lane



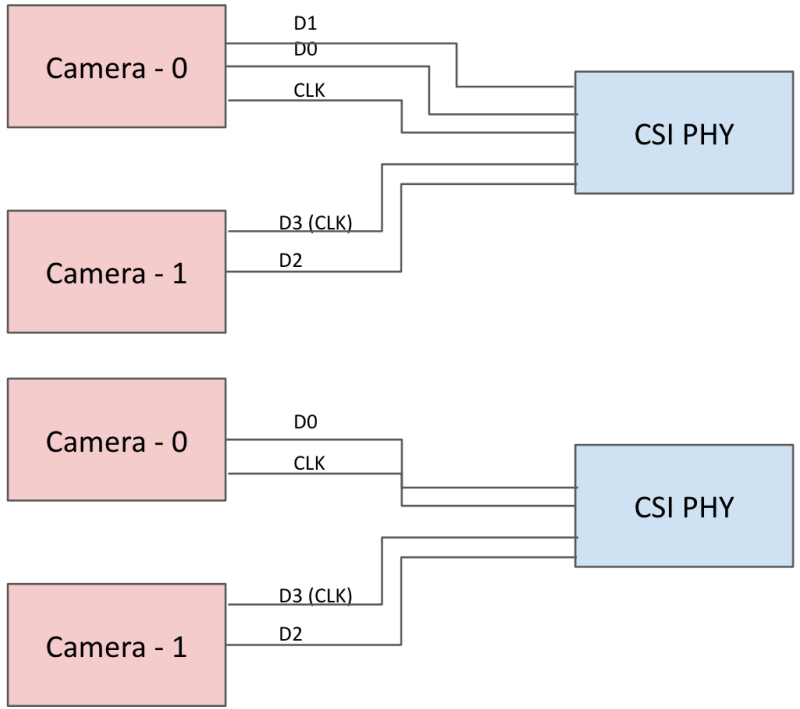
MIPI CSI C-PHY

- Up to 3-trios can be connected to a single CSI PHY in C-PHY mode
- High resolution, high fps cameras use all the trios
- Lower resolution (less bandwidth) cameras uses either 2 trios or single trio
- Faster than D-PHY



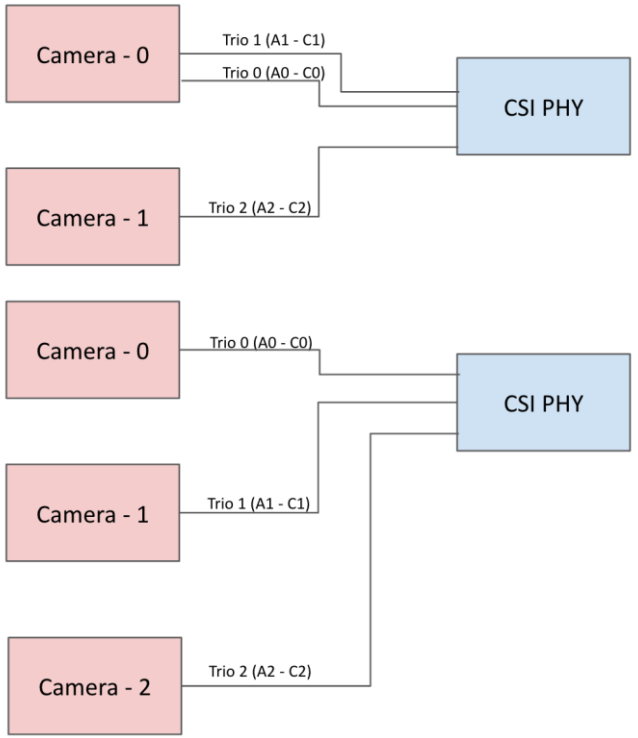
CSI Split

- Two low resolution cameras can be connected to a single CSI PHY
  - 2-lanes + 1-lane configuration
  - 1-lane + 1-lane configuration
- Dedicated CSI decoder required for each camera to operate concurrently
- With one CSI decoder
  - One of the camera can be enabled
  - Allows switching cameras



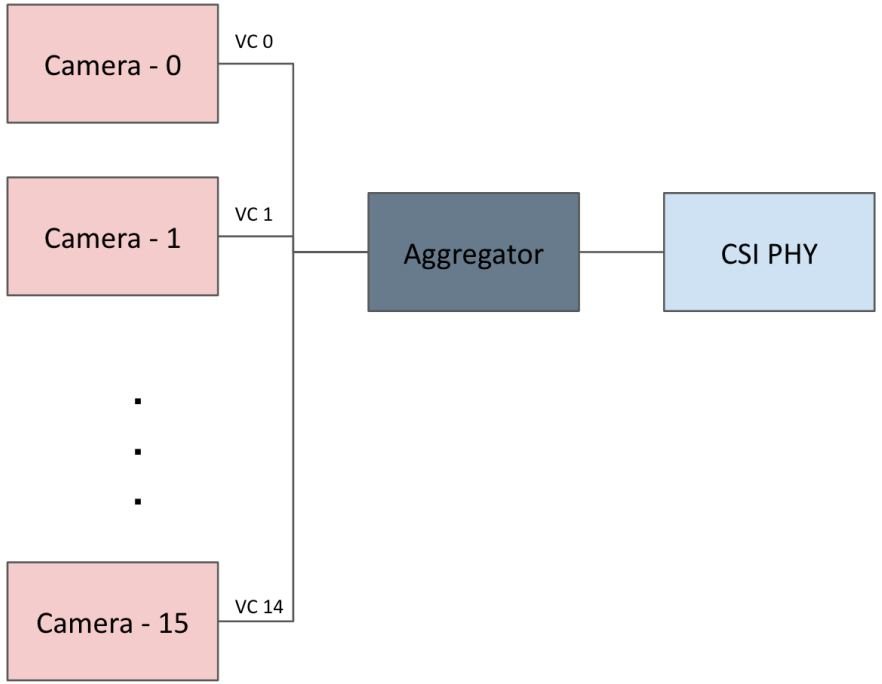
CSI Split (continued)

- Up to 3 low resolution cameras can be connected to a single CSI PHY
  - 2-trio + 1-trio
  - 1-trio + 1-trio + 1-trio
  - 1-trio + 1-trio
- Dedicated CSI decoder required for each camera to operate concurrently
- With one CSI decoder
  - One of the camera can be enabled
  - Allows switching cameras



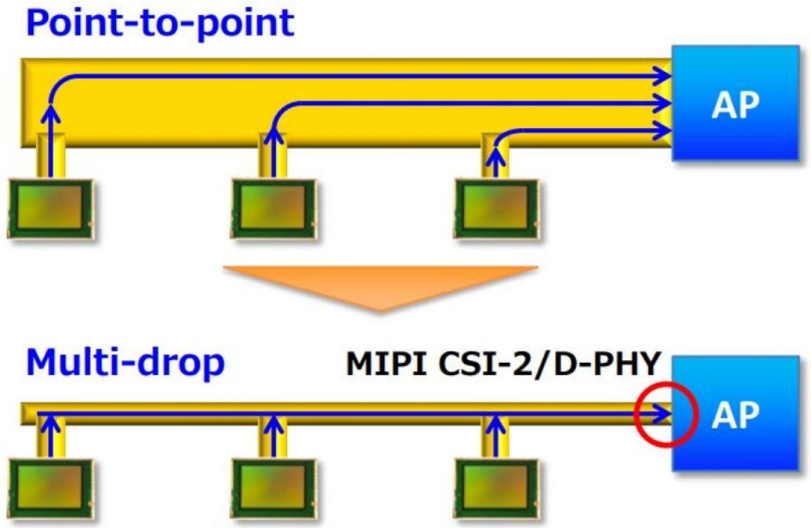
Virtual Channel / Data Type Aggregation

- Multiple cameras, up to 16, can use the single CSI PHY interface
- Aggregator is needed
- Uses TDM (Time Division Multiplexing)
- Aggregator has to manage the TDM
- Uses MIPI virtual channels (VC)
- Single CSI decoder can decode MIPI packets from all the cameras as they are time multiplexed



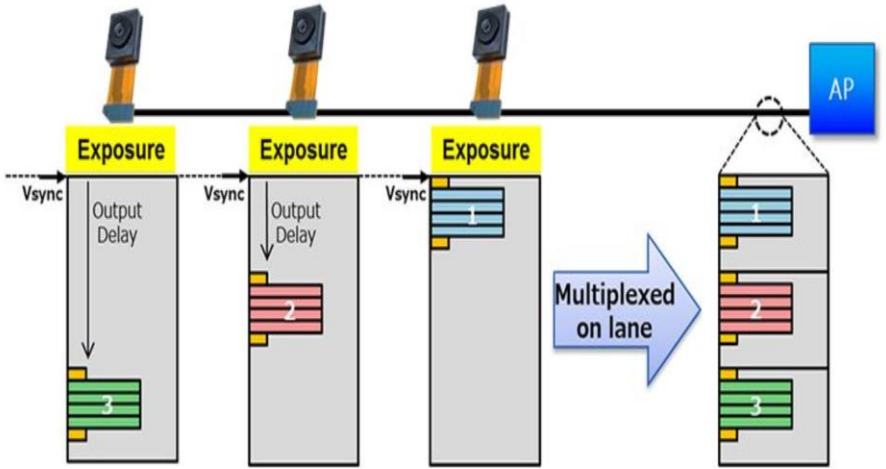
Multi-drop

- Multiple sensors (usually 2-to-4) can be connected to a single MIPI D-PHY port
- Limits the frame rate of each sensor based on the data rate and the number of lanes
- Same virtual channel for all the sensors
- Unique virtual channel for each sensor
- Works only with global shutter cameras



Multi-drop (continued)

- Some cameras supports a feature named “Multi-drop” which enables us to connect more than 1 camera without an aggregator
- Uses different exposure time / readout time
- Can use different VCs for each cameras
- Can use same VCs for all the cameras (super frame)



Summary

- MIPI CSI protocol provides lot of flexibility to connect multiple cameras to the CSI PHY interfaces
- MIPI CSI protocol provides a mechanism to multiplex multiple camera sensor data in time division multiplex mechanism
- Helps reduce the footprint of the SOC

Resources

- MIPI CSI-2 Specification - https://www.mipi.org/specifications/csi-2

Thank You