Improved Support of Asymmetric Applications for MGbps Ethernet Cameras (ISAAC)

v. 1.05 – Post Meeting

Jon Lewis, Kirsten Matheus, Kamal Dalmia, George Zimmerman

Call For Interest (CFI) consensus meeting presentation

11 July 2023

Berlin, Germany

CFI Panel Members

- Presenters
  - Jon Lewis, Kirsten Matheus, Kamal Dalmia, George Zimmerman

- Supporters and Experts for the Q&A Session
  - Daniel Hopf

Supporters

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Nobuyasu Araki, Yazaki
Tim Baggett, Microchip
Amir Bar-Niv, Marvell
Bert Bergner, TE
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Manabu Kagami, Nagoya Institute of Technology
Dongok Kim, Hyundai
Thomas Königseder, Technica Engineering
Albert Kuo, Realtek
Keld Lange, Porsche
John Leslie, Jaguar Land Rover
Jon Lewis, Dell
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David Malicoat, Malicoat Networking/Senko
Brett McClellan, Marvell
Atilla Mete Turedi, Jaguar Land Rover
Thorsten Meyer, Valeo
Kresimir Mirosavljevic, Cariad
Yoann Molin, Stellantis
Nicolas Morand, Stellantis
Scott Muma, Microchip
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Takumi Nomura, Honda
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Debu Pal, On Semiconductor
Jason Potterf, Cisco Systems
Stefan Priller, Cariad
Alireza Razavi, Marvell
Haim Ringel, General Motors
Giorgio Russo Munarriz, Mercedes
Hossein Sedarat, Ethernovia
Christoph Schmutzler, Cariad
Marc Schreiner, ZF
Masato Shiino, Furukawa Electric
Bill Simms, NVIDIA
Nithya Somanath, General Motors
Junichi Takeuchi, JAE
Mehmet Tazebay, Broadcom
Dachin Tseng, Realtek
Jose Villanueva, Renault
Bob Voss, Panduit
Enda Ward, Valeo
Natalie Wienckowski, self
Peter Wu, Marvell
Dayin Xu, Rockwell Automation
Herman Yeh, Realtek
Daijirou Yumoto, Nissan
Tingting Zhang, Huawei
Zhuangyuan (Yan) Zhuang, Huawei
Pavel Zivny, Tektronix

Ground rules

- This Meeting will NOT:
  - Fully explore the problem
  - Choose any one solution
  - Debate strengths and weaknesses of solutions
  - Create a PAR or 5 Criteria
  - Create a standard or specification

Anyone in the room may speak

Respect … give it, get it

CFI objective

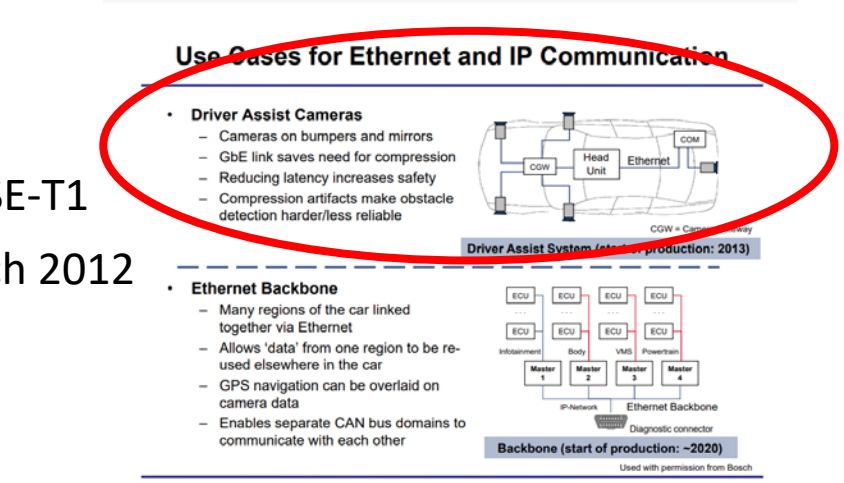
To gauge interest in starting a study group to consider a project for

An Ethernet interface optimized for automotive imaging systems

Camera connectivity was listed as a driver for high-speed Ethernet connectivity in cars in all of the following CFIs.

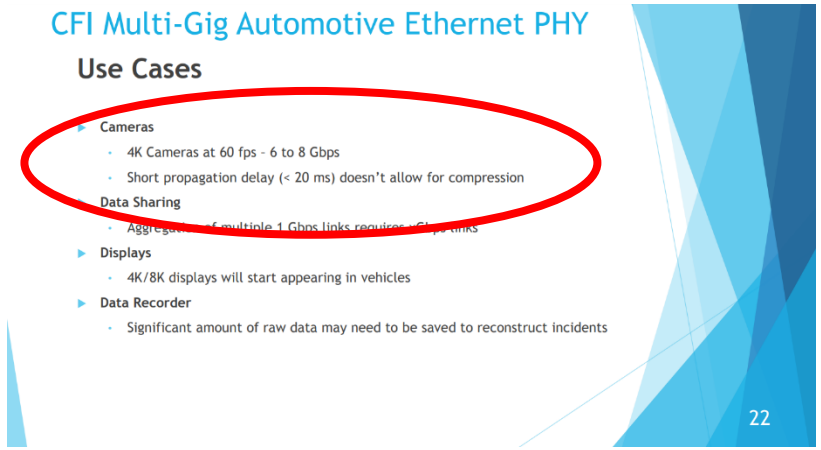
1000BASE-T1

CFI March 2012



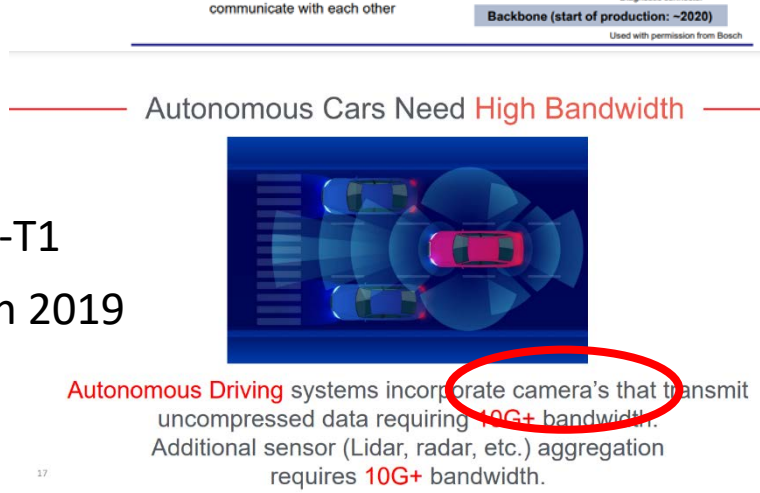
MGBASE-T1

CFI July 2016



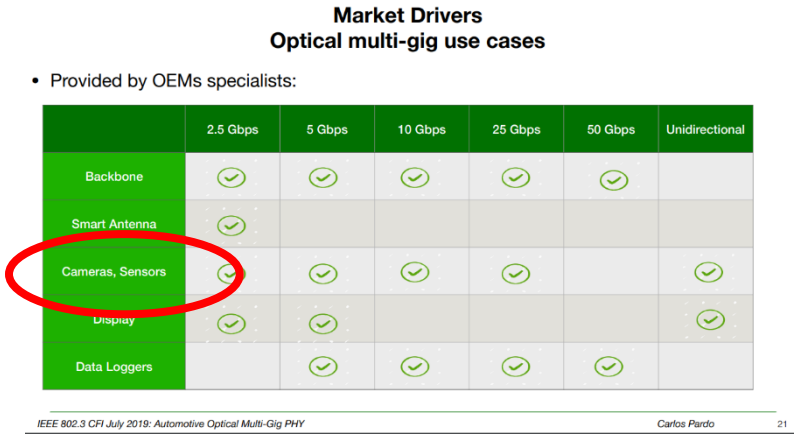
25GBASE-T1

CFI March 2019



MGBASE-AU

CFI Nov 2019



The specifications for all these Ethernet PHYs have been completed or are close to completion.

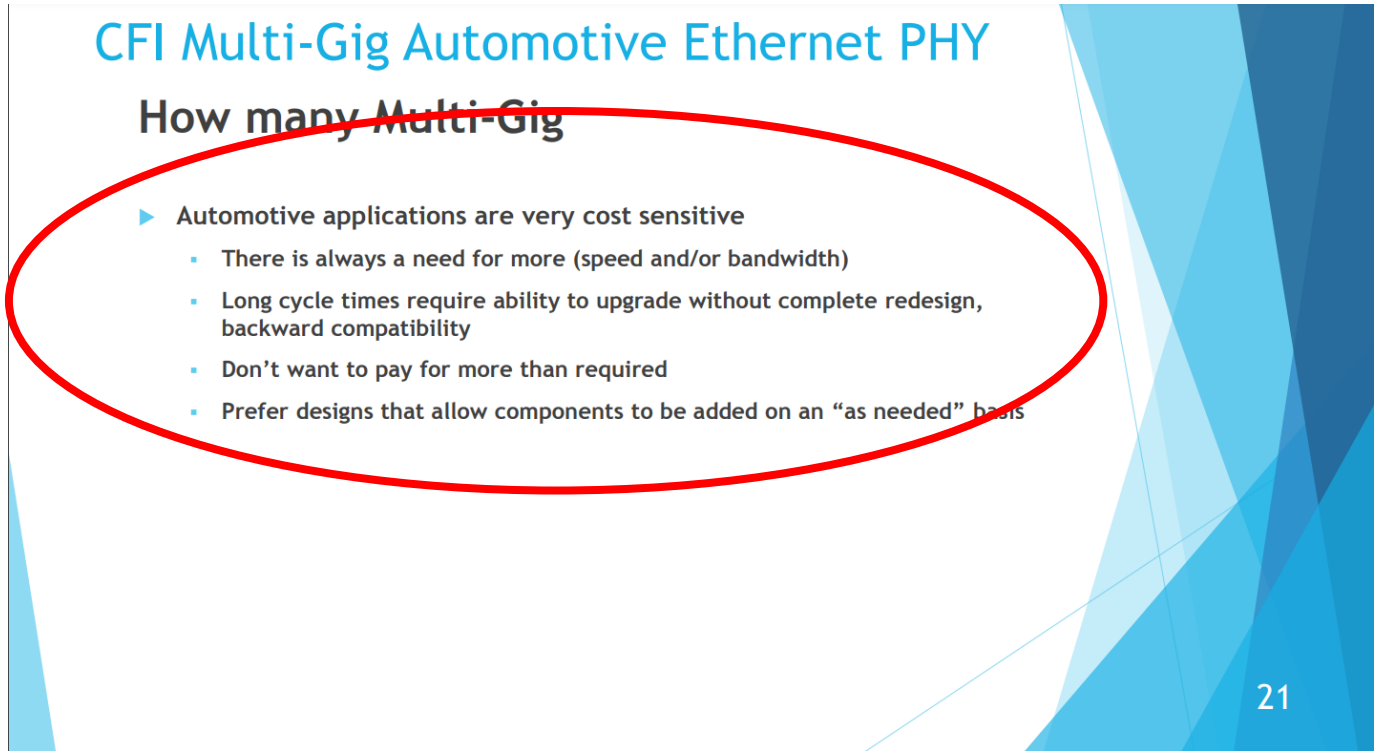
So: Why not just use one of these? What is the problem?

What happened?

Automotive applications are very cost sensitive.

MGBASE-T1

CFI July 2016



Cameras today are connected using proprietary P2P bridges and SerDes technologies

Ethernet solutions must be competitive in terms of cost, power consumption, features, and functionality.

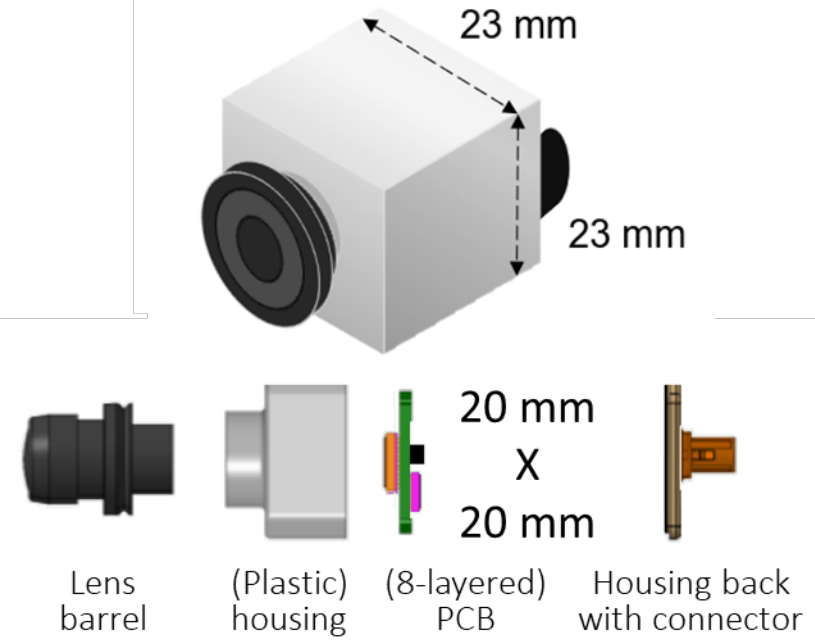
Camera Link Problem Statement

- Key characteristics:
  1. Efficiently support highly asymmetric data rates:
     - 1Gbps to 10Gbps or more from camera
     - Never more than 100Mbps towards camera
  2. Power constrains solution in camera module, to control temperature in the module
  3. Power delivery over the data link
  4. Very cost sensitive – needs an optimized solution

- Seamless integration with the overall automotive Ethernet network

Automotive cameras are very power and cost sensitive components.

Typical camera sensor:



(source: Daniel Hopf, Continental)

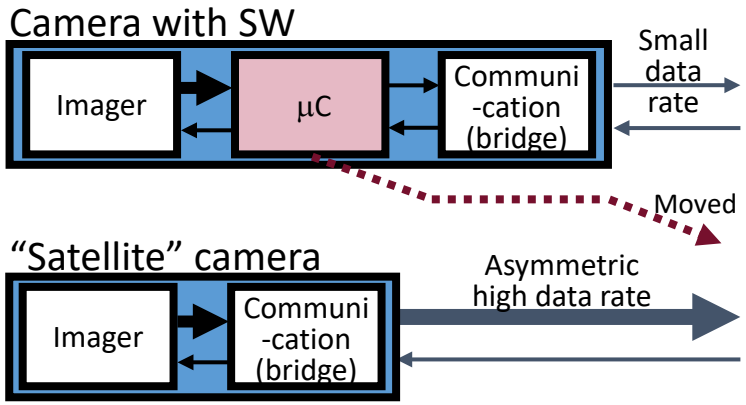
- Sensor quality degrades exponentially with increased temperature.
- Cameras have no active cooling system (too costly).
- Plastic housing is preferred (also for cost reasons). Plastic does not conduct heat as well as metal does.
- Assembly and mounting space is typically very limited. Cameras are therefore as small as possible (which impacts temperature behavior).
- Cameras are often located at positions exposed to sunlight and heat (bumper, vehicle grille, windshield).

Because power dissipation means heat:

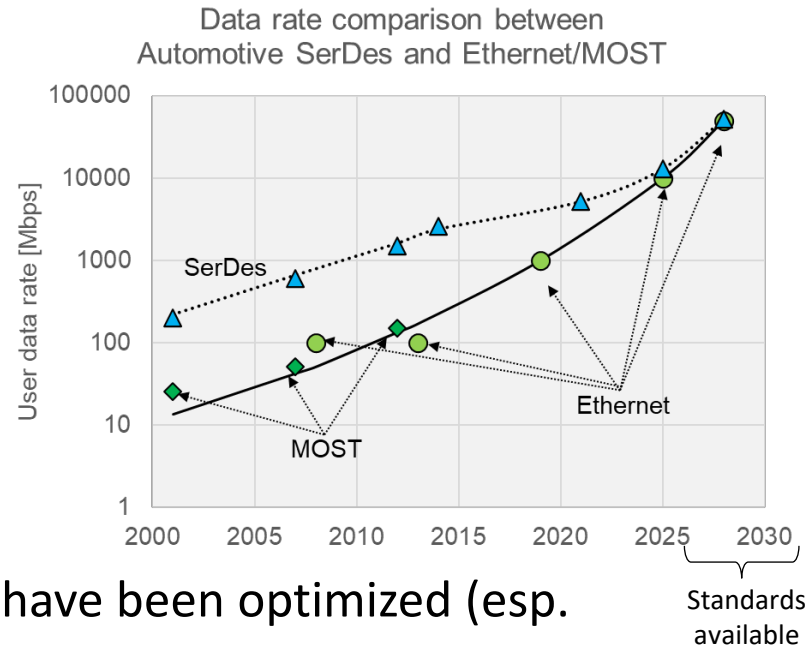
- The power consumption of every component counts. Providing more than needed (e.g. in terms of data rate) wastes power.
- Heat dissipated from one component may quickly heat up the whole sensor.

Proprietary Technologies have been used in cars for more than 20 years and are well established.

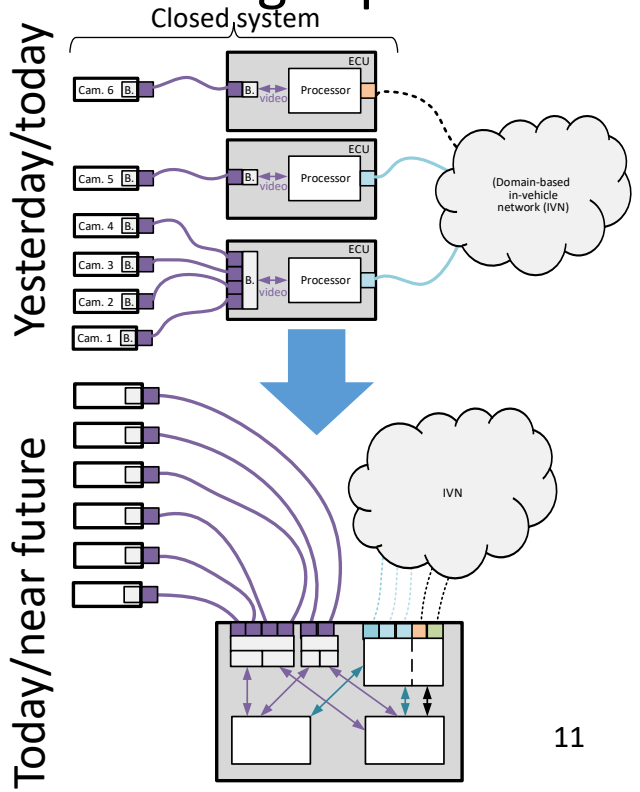
- When software processing is removed from the camera (satellite architecture) higher asymmetric data rates need to be transmitted.



- In the past, only proprietary SerDes technologies could meet the data rate requirements.



- In the past, cameras were connected in closed systems or P2P with limited need for networking capabilities.



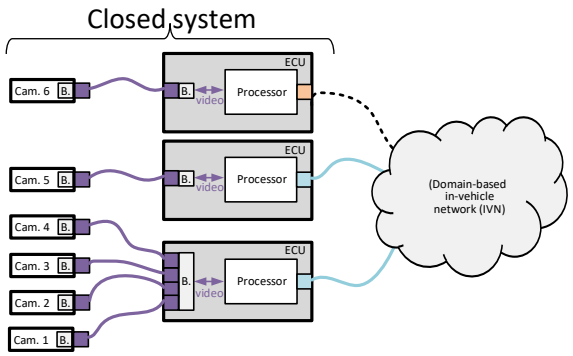
The used proprietary technologies have been optimized (esp. power/costs) for the asymmetric use case.

The Key Challenge: How to unseat an efficient incumbent?

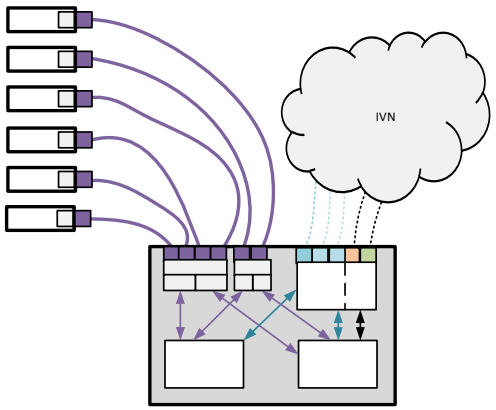
Good Question for Study Group – What does the evolution to zonal architecture need?

Enabling an evolutionary change.

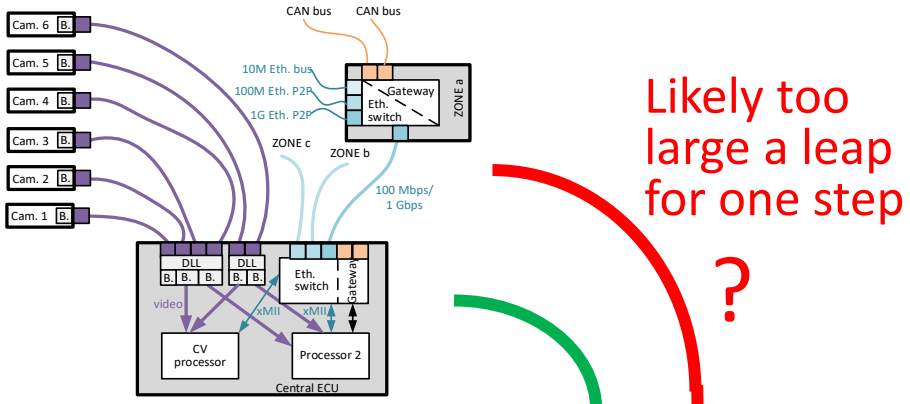
Yesterday/today



Today/near future



Near future (decided)

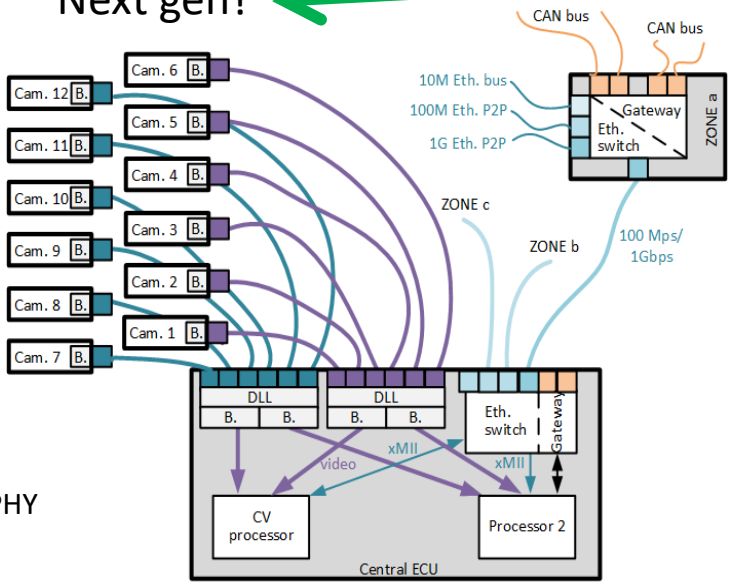


Likely too large a leap for one step

?

Iterative intermediate steps more likely

Next gen?



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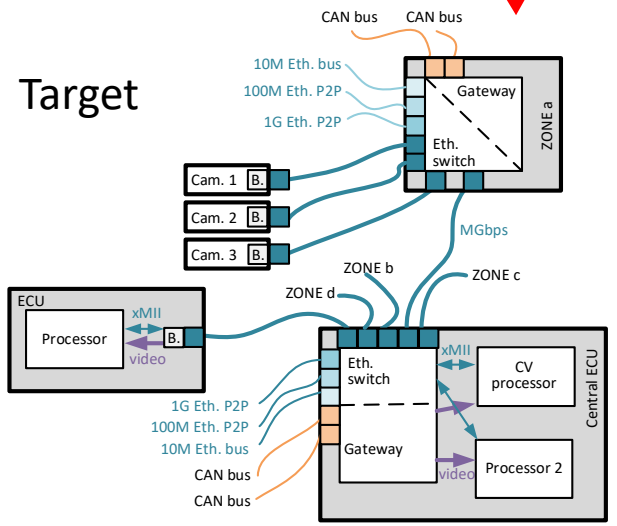
Target



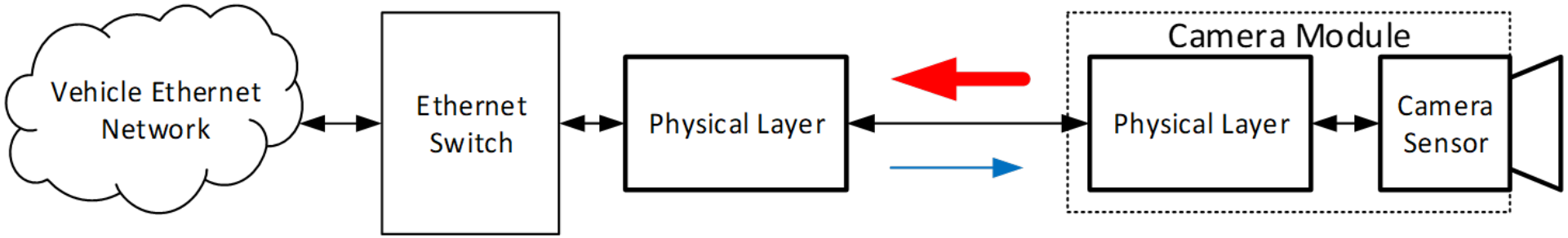
Proprietary SerDes PHY

Standard MG Ethernet capable PHY

B. Bridge

Good Question for Study Group – Is the camera side PHY the same as the network side?

Support of Ethernet networking is essential for being future proof. Network vs Camera Side



Network Side:

- Transmitting occasionally
- Receiving most of the time
- Less heat constraint
- Power savings desirable
- **Ethernet interoperability is key**

Camera Side:

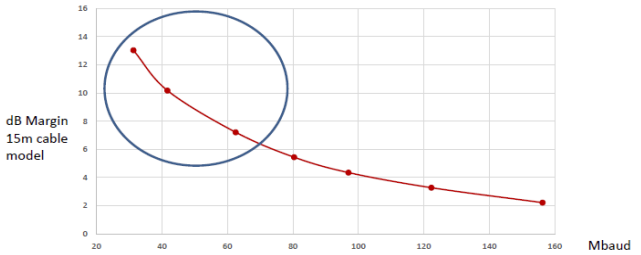
- Transmitting most of the time
- Receiving occasionally
- Important to control any added heat in camera module
- Power savings are very important
- **Cost and heat are key**

Natively Asymmetric PHYs may offer efficiencies

- Considered in 802.3ch, 802.3cy, and non-802.3 groups
  - Potential to reduce camera-side receiver complexity
- The application is inherently asymmetric
  - Using a symmetric PHY with EEE was thought to be "good enough" – is it?

Impact on high speed receiver by low speed transmitter

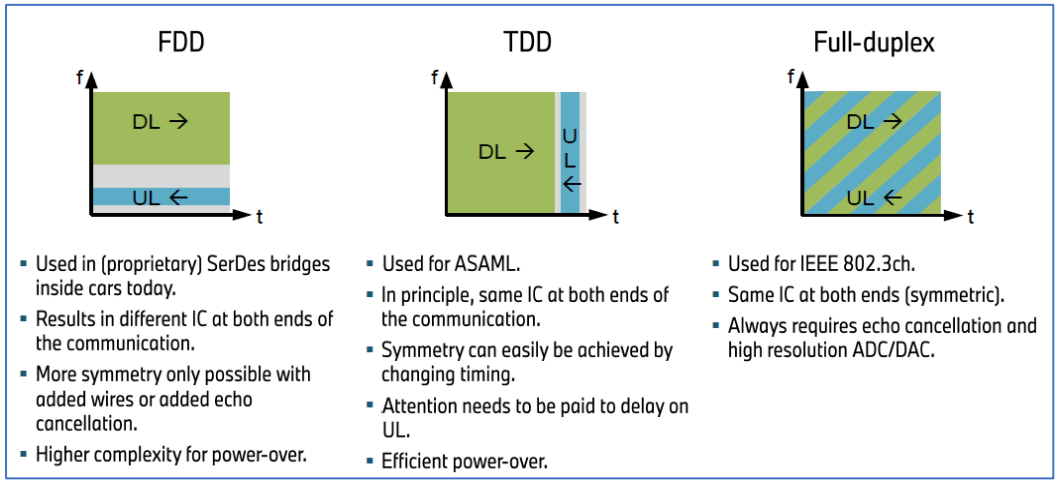
- High pass filter out low speed transmit signal (no digital echo)
- Look at margin at high speed receiver for given low speed baud rate



- Recommendation: Modulation of low speed signal to below 70 Mbaud.

IEEE 802.3ch Task Force 6 30 Jan 2019 AXONNE

Source: https://www.ieee802.org/3/ch/public/adhoc/Lo_3ch_01_adhoc_0119.pdf



- Used in (proprietary) SerDes bridges inside cars today.
- Results in different IC at both ends of the communication.
- More symmetry only possible with added wires or added echo cancellation.
- Higher complexity for power-over.

- Used for ASAML.
- In principle, same IC at both ends of the communication.
- Symmetry can easily be achieved by changing timing.
- Attention needs to be paid to delay on UL.
- Efficient power-over.

- Used for IEEE 802.3ch.
- Same IC at both ends (symmetric).
- Always requires echo cancellation and high resolution ADC/DAC.

Source: https://auto-serdes.org/wp-content/uploads/2022/10/20220912_Matheus_AutoSens.pdf

Asymmetrical Transmission - Method 2

- Achieve Asymmetrical link operation by putting one direction of the link in PERMANENT EEE state

QUIET > REFRESH > ~~WAKE~~ > ~~DATA~~ > REPEAT
Send DATA within REFRESH signal (if DATA is available from MAC)
Else send normal REFRESH signal

- Periodicity of REFRESH (containing DATA) determines peak bandwidth of the low-bandwidth side of the link
- For systems requiring only an initial burst of data (for example - reading camera or display attributes), the mechanism allows MAC to send a burst of DATA and then allows PHY to send Normal Refresh
- For systems requiring ongoing data transfer in the low-bandwidth direction, the method allows for flexible or fixed data rate by adjusting the period of Refresh signal

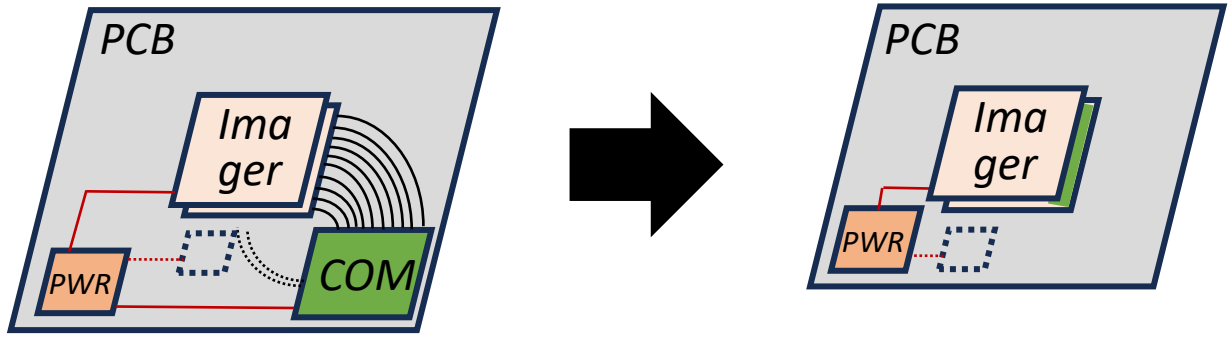
AQUANTIA 5

Source: https://www.ieee802.org/3/ch/public/sep17/dalmia_3ch_01_0917.pdf

A communication standard motivates combination of image sensor and transceiver in one package.

Main camera Bill of Material (BOM) items:

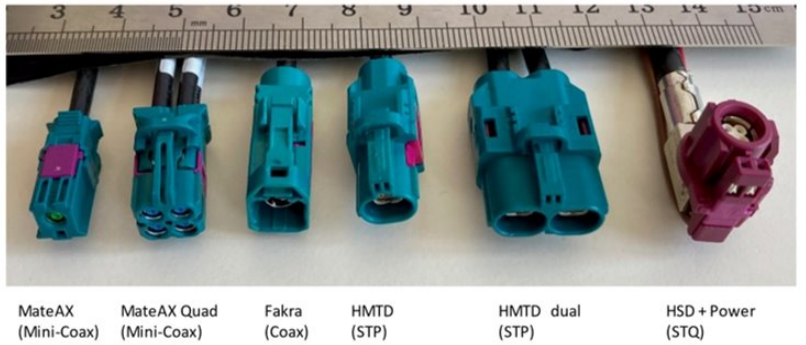
- PCB
- Power supply
- PoC circuitry
- Imager
- Communication chip
- Housing
- Wiring
- Connector
- Lens (barrel)



An efficient communications chip (COM) is essential for competitiveness with the incumbent technologies. A power and complexity-efficient Ethernet standard can enable:

- Fewer chip packages on the PCB
- Smaller footprints with fewer communications interfaces, lower power, and reduced cost
- Reduced PCB sizes with fewer layers

System Cost: Importance of Cabling & Power Delivery over data lines



Example automotive connectors

Cables, connectors and power delivery have significant impact on overall system cost.

Ethernet solution needs to be competitive on these aspects for it to be effective in the marketplace.

- **Cabling**
  - Coaxial cables dominate current satellite camera deployments based on proprietary SerDes
  - STP cables may be used in some cases

- **Power Delivery**
  - Power over Coax is commonly deployed and is cost optimized
  - Power delivery over dedicated (separate) power harness is not competitive due to...
    - Additional cabling cost
    - Additional connector cost
    - Additional space on the camera module to accommodate the connector for power delivery

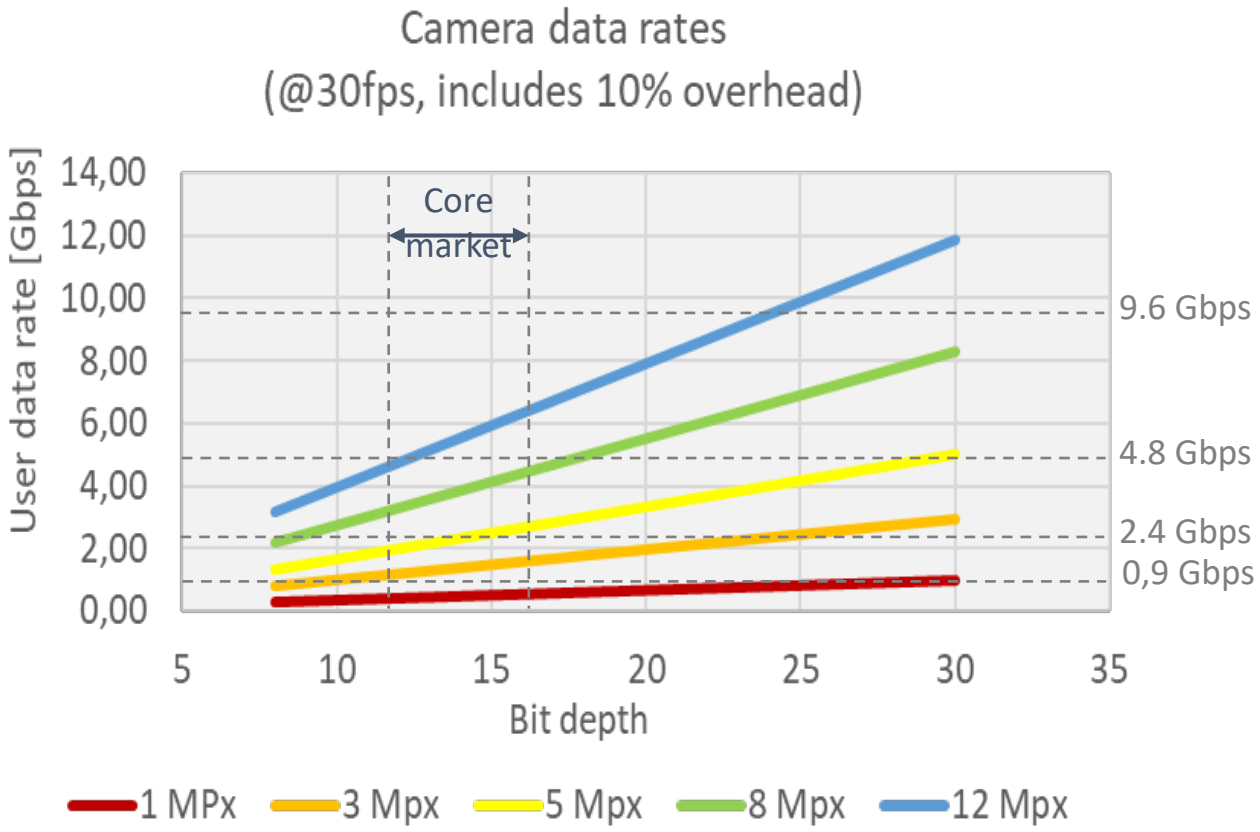
The right data rate needs to be supported: The bulk of the automotive need may be < 10 Gbps

Automotive cameras only support the resolution required for the use case

- Unlike consumer cameras
- Reduces post processing (& cost)

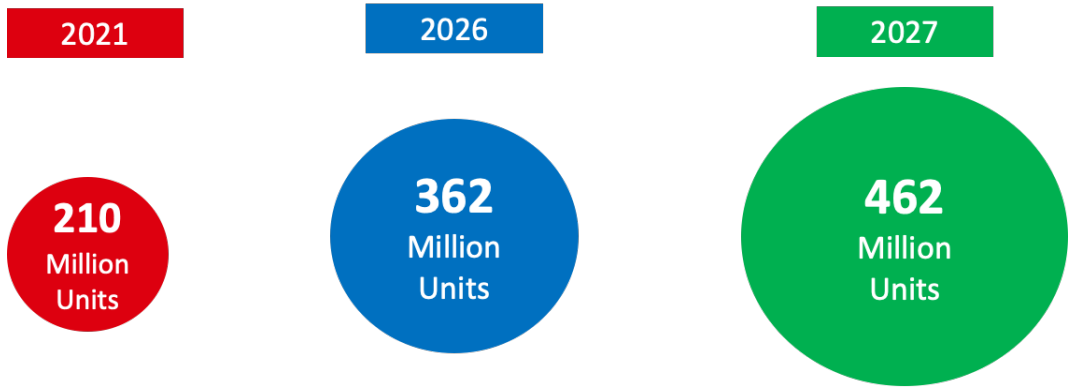
2030 forecast for camera use cases:

- Vision → ≤ 3 Mpx, 47% market share
- ADAS → 8 Mpx (12 Mpx excep.), 35% share
- Interior → 5 Mpx, 18% share



Market Opportunity and Timing

Camera market is already very large and growing fast due to autonomous driving and legislation



- Advanced use cases increasing with active lane keeping, ACC, or driver drowsiness detection.
- Adoption rate of basic camera systems is driven by regulation:
  - US: Rearview
  - Japan: Sideview for SUV
  - NCAP: vulnerable road users AEB, occupant status, lane keeping, and more
- ADAS L2+ and L3 systems require ever more cameras.

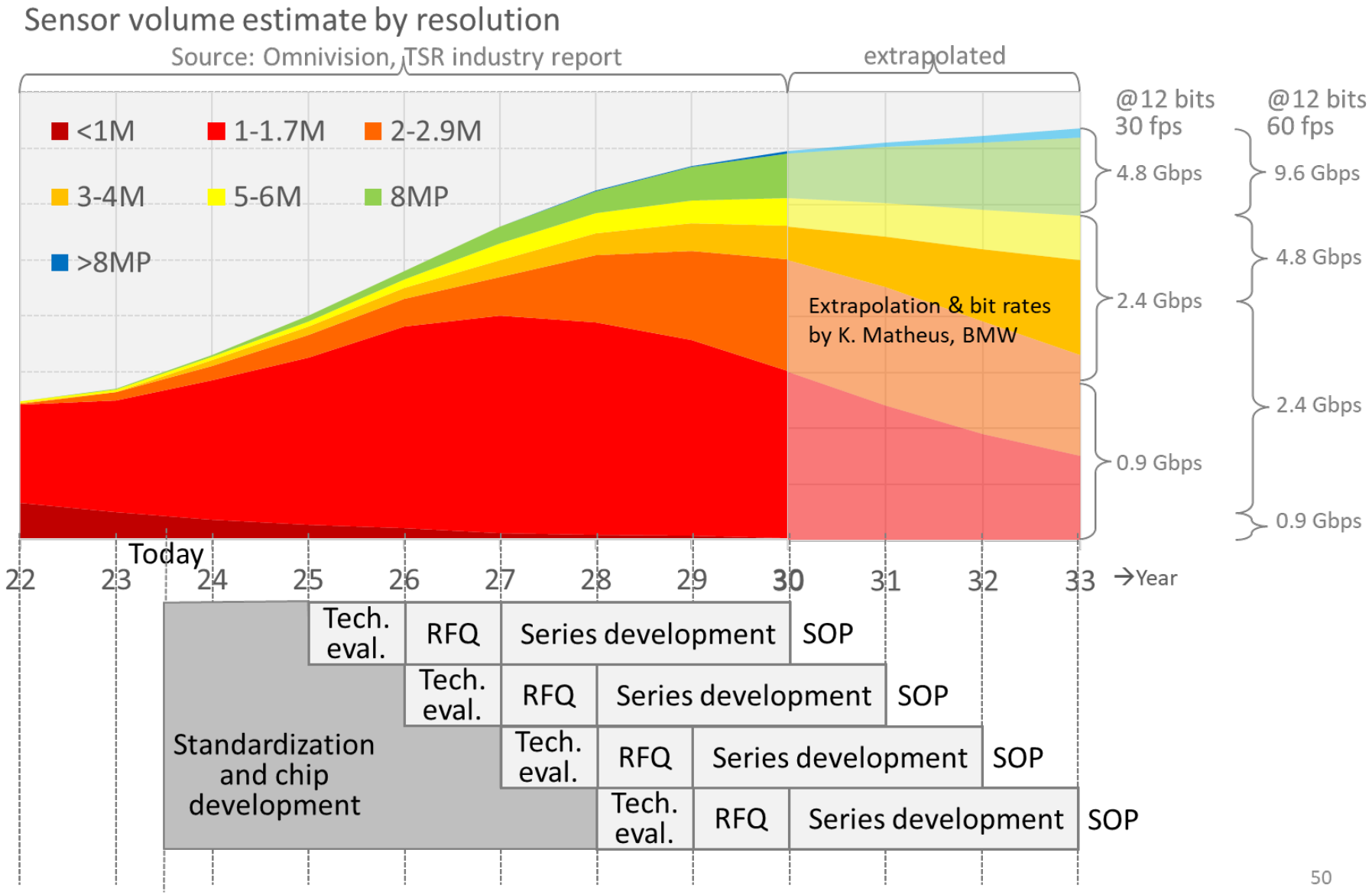
Number of Ports/PHYs =
2x Number of Cameras + Backbone links

More than 1 Billion Ports in 2030!!

Satellite camera architectures are currently ONLY supported using proprietary solutions.

Source: https://s3.i-micronews.com/uploads/2022/03/YINTR22245-Imaging-for-Automotive-2022-Product-Brochure.pdf
Source: https://www.globenewswire.com/en/news-release/2023/02/13/2606466/28124/en/Global-Automotive-CMOS-Image-Sensor-CIS-Chip-Market-Report-2022-Featuring-OnSemi-Samsung-Electronics-Sony-Toshiba-Infineon-STMicroelectronics-ST-OmniVision-Technologies-More.html

Standards must precede camera market by 5 years

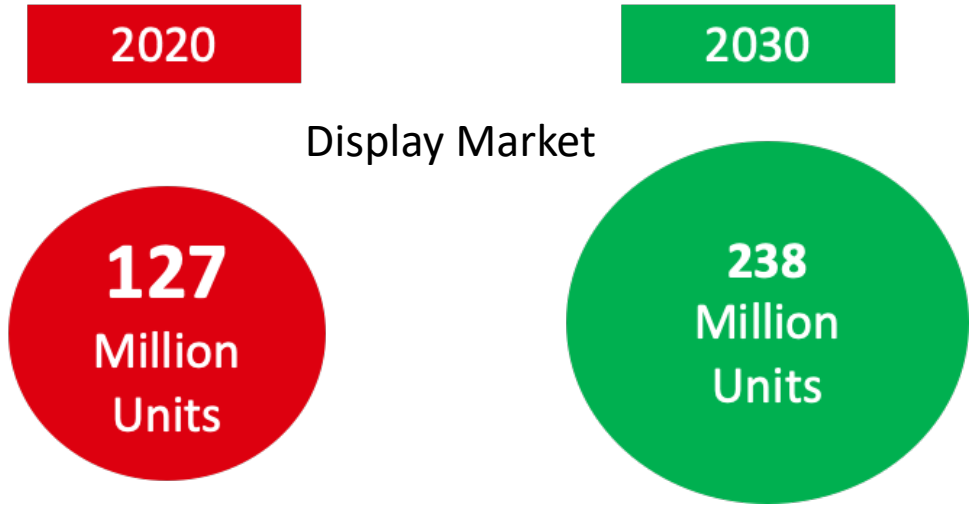


Additional markets: DISPLAYs, RADARs, and LIDARs

- **DISPLAY** market is large and growing fast. Satellite display architectures are common.
  - The communication technology has comparably smaller impact on the overall power consumption, size, or costs of the display unit.

- **RADAR** architecture is changing. Likely to become more relevant for the communication discussion in future.

- **LiDAR**s are relatively new in the industry. They are significantly larger in size than cameras.



Number of Ports = 2x Number of Displays

Approx Half a Billion Ports in 2030!!

Source: https://www.oled-a.org/automotive-display-shipments-to-reach-239m-by-2030_062721.html

How does this fit Ethernet?

Good Question for Study Group – Are today's IEEE 802.3 solutions sufficient?

Good Question for Study Group– Can we adapt 802.3ch/quiet-refresh to meet the need?

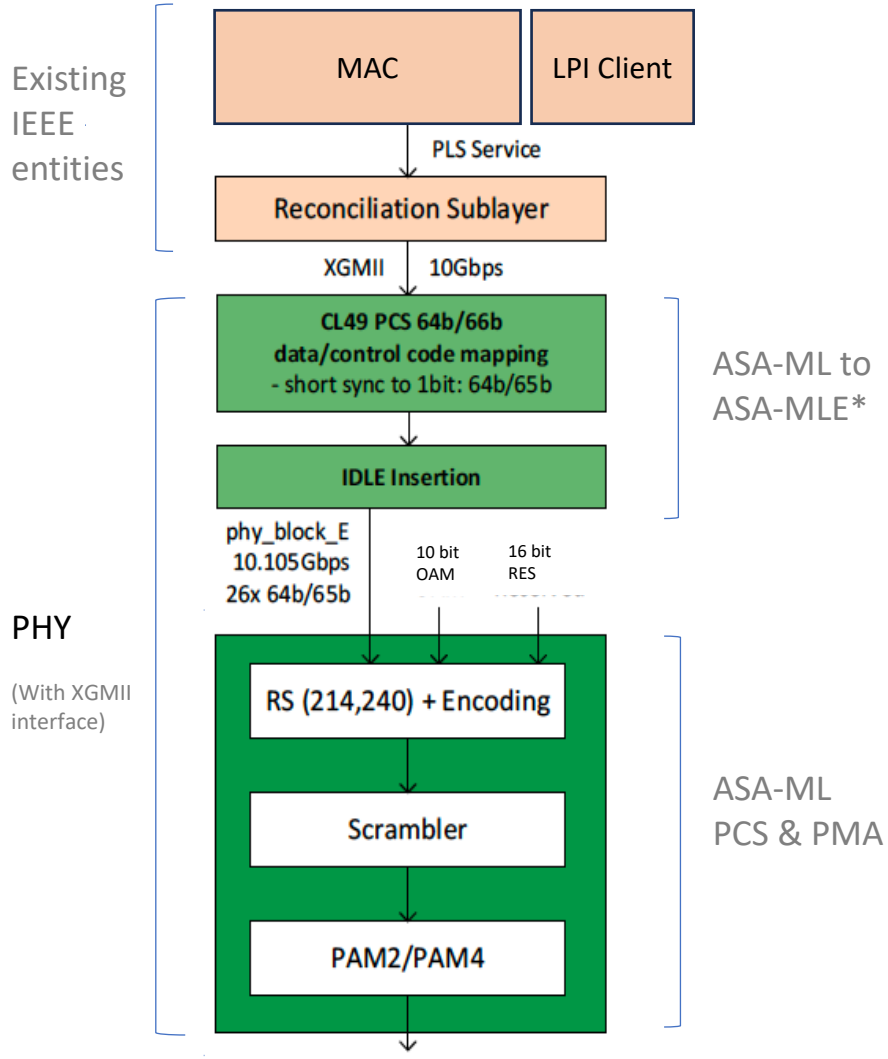
Overview of Existing IEEE 802.3 Solutions

- Today's Ethernet solutions use point-to-point, symmetric PHYs
  - 2.5G/5G/10G/25GBASE-T1 defined in 802.3ch and 802.3cy
  - Up to 15 meters at rates to 10Gb/s, 11 meters at 25 Gb/s
  - Echo-cancelled PAM-4 transmission with Reed-Solomon Coding
- Can operate asymmetrically on demand with Energy Efficient Ethernet
  - Use standard symmetric (XGMII/25GMII) Reconciliation Sublayer
  - Capable of full-duplex transmission at the same rate in each direction
  - Asymmetric as the MAC offers it
  - Can provide power saving with EEE (quiet-refresh cycling) based on traffic offered
- Fit into the application, but are required to support the full data rate in both directions if the MAC offers it

ASA-MLE: Asymmetrical SerDes with Ethernet capabilities

- ASA-MLE stands for Automotive SerDes Alliance (ASA) Motion Link Ethernet (MLE)
- Natively asymmetric, Ethernet data rates:
  - 1G, 2.5G, 5G & 10G in high-speed direction
  - 100M & 1G in low-speed direction
- Physical layer uses TDD, PAM 2/4, and FEC
- Coax and STP cable supported with power delivery
- Asymmetric PHY works with full-duplex, symmetric MAC using Idle Client

(https://www.ieee802.org/3/cy/public/adhoc/dalmia_3cy_01_10_28_20.pdf)



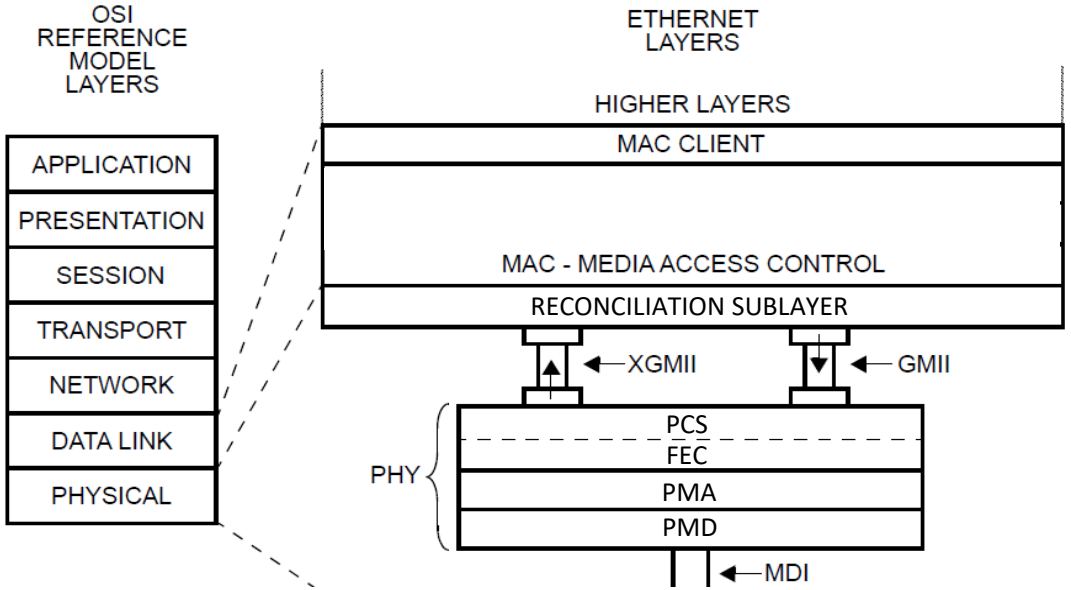
* see also Dalmia, "ASA-MLE, the new Ethernet!," *Automotive Ethernet Congress,* Munich, 2023

Good Question for Study Group – What interface architecture fits asymmetric data flow best?

Good Question for Study Group – Do asymmetric PHYs need a new client?

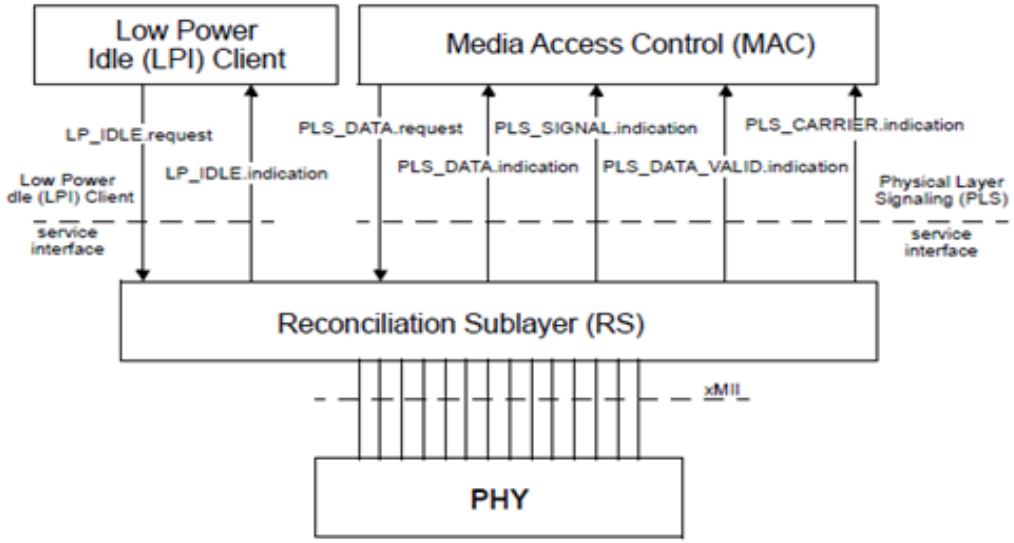
How might you limit the rate towards the PHY?

- "Dual Headed" RS, fixed rate (similar to EPON)
  - Needs definition (not just EPON, at least RS)
  - Fixes rates in specification



Source: IEEE Std 802.3-2022, Figure 56-5 (modified)

- Deferral/Client-driven RS (similar to EEE)
  - Operation based on primitives, flexible rates
  - Undefined client operation can't be relied on to interoperably defer MAC
  - Specifications on LPI client may impact existing EEE compliance



Source: IEEE Std 802.3-2022, Figure 78-1

THESE ARE ONLY 2 EXAMPLES – THERE ARE OTHER POSSIBILITIES

Why now?

- Market for imaging systems is large and growing rapidly
- Market is currently being served by proprietary solutions
- Industry desires to move to standardized Ethernet solution
- Non-802 technologies are being worked on to fill the gap

- OEMs need 1st samples 5 years before start of production (SOP)
- For 2029 SOP, samples need to be provided in 2024-25

There is an urgent need to act fast!

Good Questions for the Study Group:

- Can we enable a more efficient Ethernet solution?
- Is the camera side PHY the same as the network side?
- What data rate(s) is/are needed?
- What does the evolution to zonal architecture need?
- Are today's IEEE 802.3 solutions sufficient?(do they just need to mature?)
- If not:
  - Do Ethernet PHYs need native asymmetry to compete?
  - Is ASA-MLE a good candidate?
  - Can we adapt 802.3ch/quiet-refresh to meet the need?
- Can we serve Displays, RADARs, and LiDARs without compromising Cameras?
- What interface architecture fits asymmetric data flow best?
  - Do asymmetric PHYs need a new client?

Potential Call for Interest Question

- To develop a PAR, CSD responses, and objectives for an electrical physical layer specification and related functionality of a client optimized for automotive end-node cameras

- Such a question is designed to allow consideration of:
  - Addition of new or modification of existing 802.3 PHYs
  - Addition of new or modification of existing 802.3 RSs
  - Addition of new or modification of existing clients
  - Addition of new or modification of existing media specifications

Q&A: Speakers & Panel

Straw Polls

People in the Room + Remote Attendees: _82+27=109____

1. Should a study group be formed to develop a PAR, CSD responses, and objectives for Improved Support of Asymmetric Applications for MGbps Ethernet Cameras?

Y: 97 N: 1 A: 9 (all in room)

2. I would participate in the “Improved Support of Asymmetric Applications for MGbps Ethernet Cameras” Study Group in IEEE 802.3

Y: 70 N:14 A:20

3. I believe my affiliation would support my participation in the “Improved Support of Asymmetric Applications for MGbps Ethernet Cameras” Study Group in IEEE 802.3

Y:49 N:8 A:13

Backup

Potential adjacent markets: Satellite displays, RADARs, and LIDARs

- Satellite display architectures are common. However, the communication technology has comparably little impact on the overall power consumption, size, or costs of the display unit.
- Lidars are new in the industry, still rare and to use more than one per car is unlikely (mainly for cost reasons). They are also significantly larger than cameras.

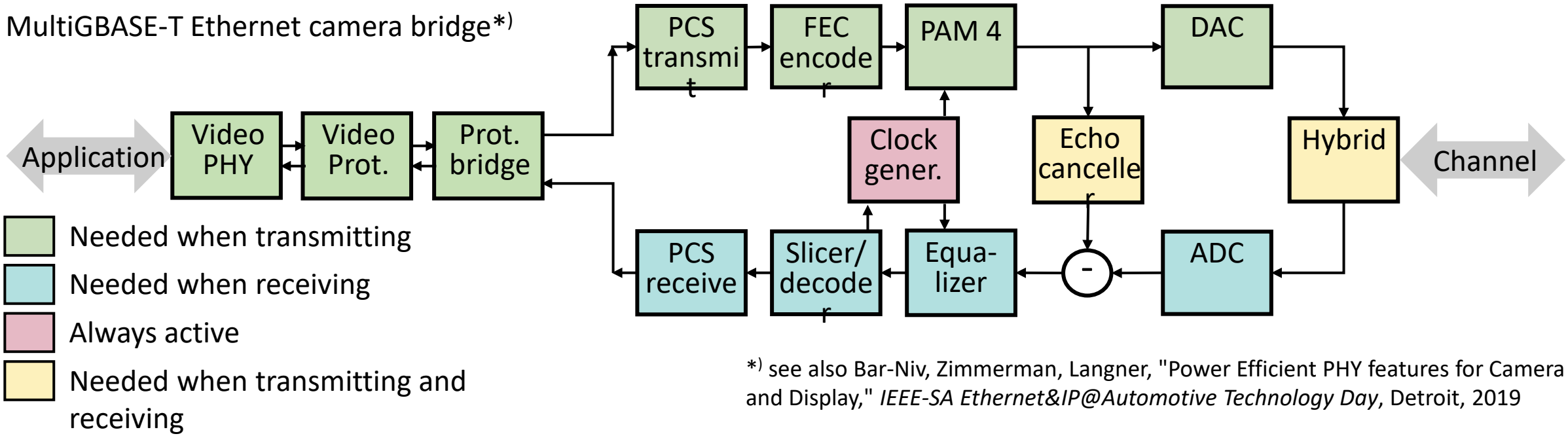
- It is currently being discussed to change the radar architecture (see next slide). While they are also larger than cameras, their use case might become more relevant for the communication discussion in the future.

Example of power and size comparison sourced in the Internet (more relevant for relative than absolute values)

	Size (cm^3)	**Power consumption (W)**
Camera	25 - 200	3 – 5
Radar	100 - 500	5 – 15
LiDAR	300 - 1800	8 – 30

Source: Patence Consulting LLC

The power consumption of symmetric IEEE 802.3ch can be reduced with help of (asymmetric) EEE



*) see also Bar-Niv, Zimmerman, Langner, "Power Efficient PHY features for Camera and Display," *IEEE-SA Ethernet&IP@Automotive Technology Day*, Detroit, 2019

Power consumption of blocks not needed may be reduced with EEE.

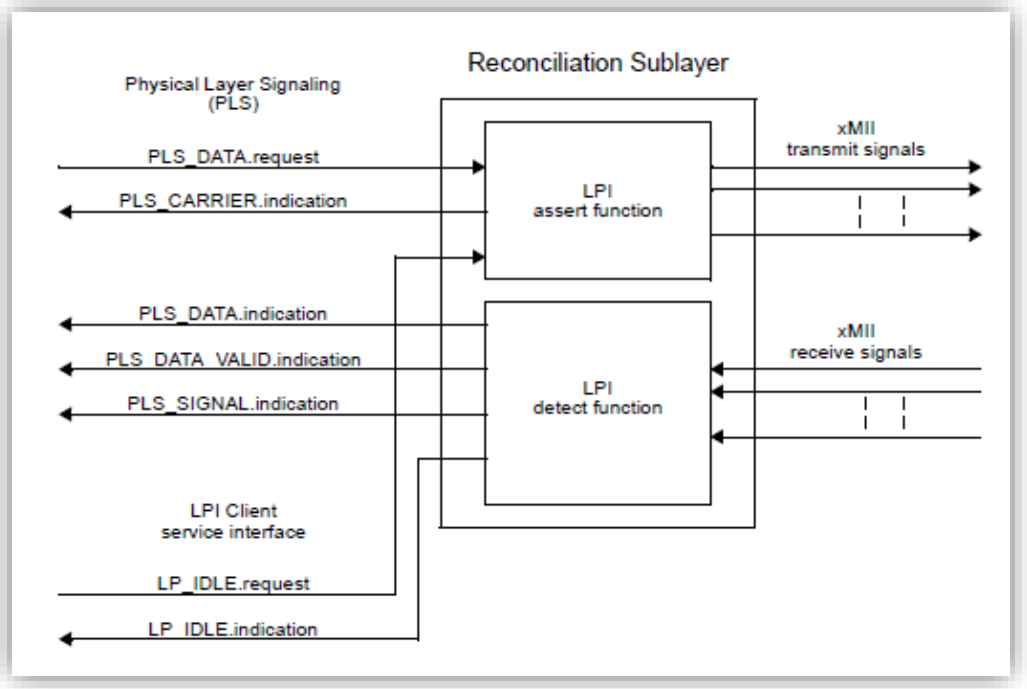
Whether the power reduction of the existing EEE is sufficient to make symmetric IEEE 802.3 PHYs competitive or whether it must/can be improved sufficiently, needs to be confirmed.

The change in power consumption, however, does not change the complexity of the PHY as such, which impacts aspects such as size, **cost**, and integrate-ability into the imager.

Can we just adapt with the EEE "LPI Client"?

- Transmit Control is from the system down
  - Clause 78 specifies primitives from the LPI client to cause the RS to hold off the MAC
  - Client connects to the RS, not the PHY
- Limited PHY capabilities can be overrun
  - PHY does not communicate the state of the transmit direction or buffering to the client
  - LPI client's operation isn't specified – only primitives and interaction w/the RS

Because when the LPI client sends requests is UNDEFINED – it cannot be relied on to interoperably defer the MAC and control rates



Source: IEEE Std 802.3-2022, Figure 78-2

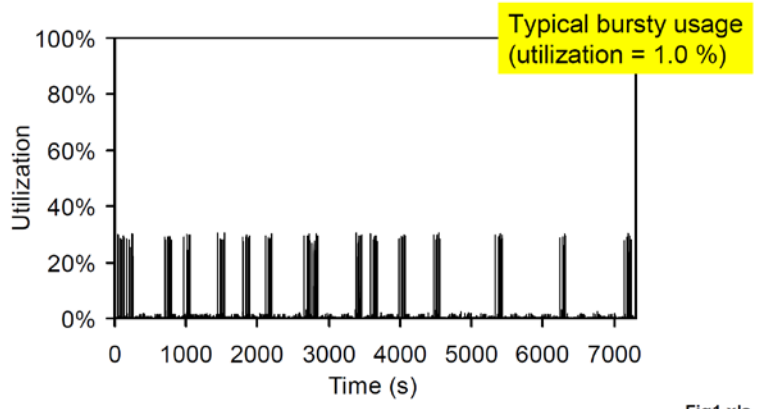
While it COULD work, SPECIFICATION IS NEEDED – needs PHY and RS experts
Do we need a new client to avoid impacting EEE? How does it talk to the PHY?

Why cameras are a different problem from EEE: IEEE 802.3az - Bursty data, not asymmetric device data capability

- Designed for bursty data, fast, application-transparent recovery – with full capabilities
- Optimized camera application may NEVER offer high rates towards the camera

Desktop links have low utilization

- **Snapshot of a typical 100 Mb Ethernet link**
  - **Shows time versus utilization (trace from Portland State Univ.)**



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Transition Time Conclusions

- **Applications require sub 10 ms transition time**
- **Recommend that the EEE TF retain the goal of achieving a transition time of less than or equal to 1 ms**

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Source: "IEEE 802 Tutorial – Energy Efficient Ethernet", Hugh Barrass, et al. (IEEE 802 tutorial, July 2007)

How might this fit in 802.3?

A potential project might involve:

- Options to existing or new physical layer devices
- Definition of an interface to allow the MAC to control the flow toward the camera/sensor
- Input from camera/sensor experts on important application interfaces
- Input from automotive experts on needs for media, power, and rates

Project likely needs a broad “physical layer” scope

BUT avoids getting “too broad” in scope!

Project ideally allows for use beyond automotive cameras

BUT optimized to serve the high-volume market need!

Focused on timely solutions