Further considerations on a 1 Gb/s Low-Speed Data Rate for Clause 192

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Agenda

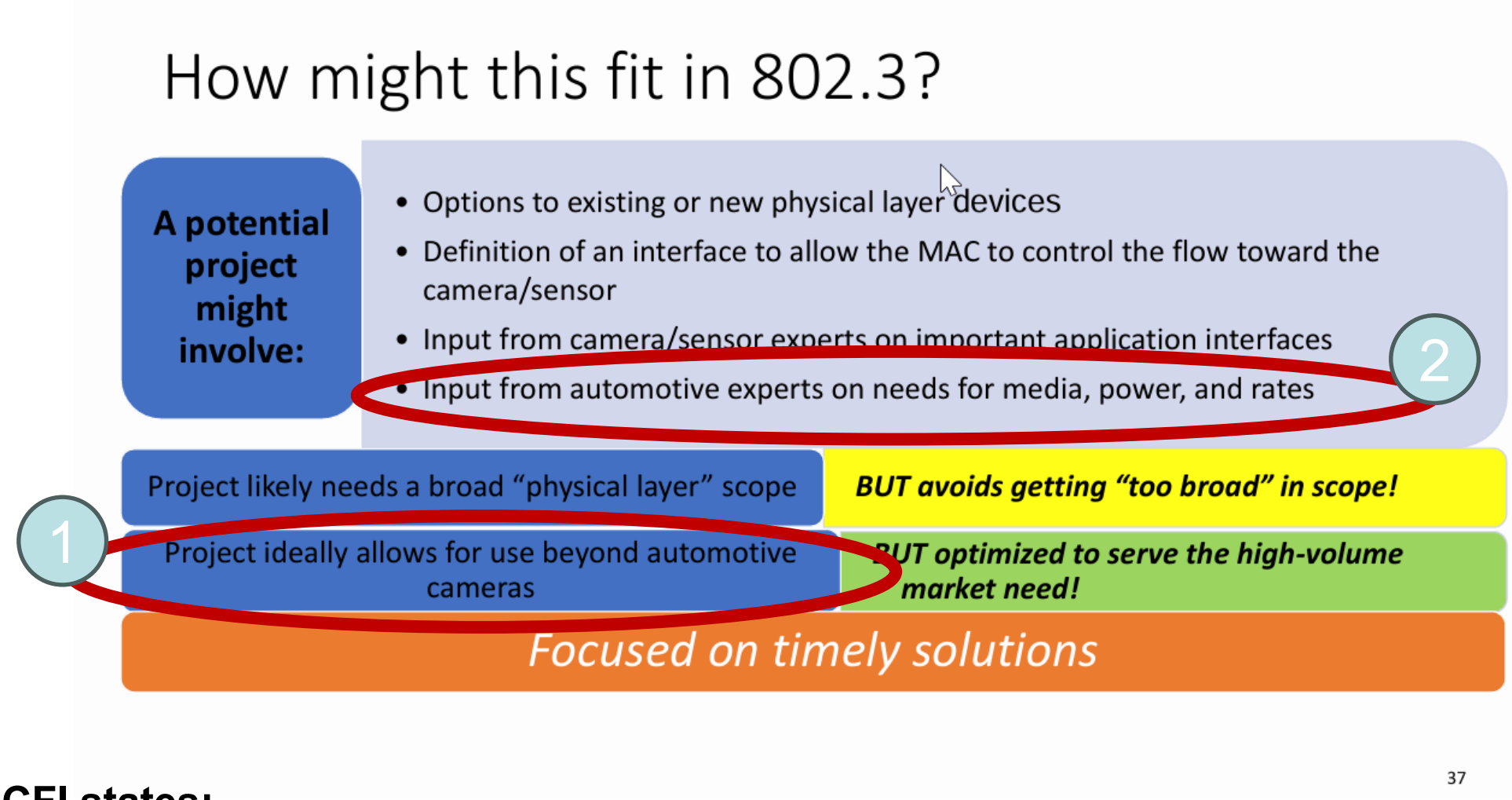
- P802.3dm CFI and CSD considerations
- Technical Feasibility for Clause 192 1Gb/s LS data rate
- Why Do the End-nodes Require a 1Gb/s Link?
- Production Plans & Remarks
- Conclusions

Foreword

- 802.3dm has specified numerous asymmetric data rates up to 10Gbps with 100Mbps in the reverse path. Several participants in 802.3dm task force expressed interest in specifying 1 Gb/s in the reverse path.

- There are applications that are mentioned to use 1Gbps in the reverse path:
  - https://www.ieee802.org/3/ISAAC/public/100423/matheus_ISAAC_01c_10042023.pdf
  - https://www.ieee802.org/3/dm/public/0526/schedl_gorshe_3dm_01b_0526.pdf
- It is proposed that options for 1 Gb/s in LS path with 7.5 Gb/s and 5.0 Gb/s in HS path be added to Clause 192 and associated clauses and annexes. The proposal does not affect Clause 191.
- The proposal defines additional operating configurations within the Clause 192 architecture without requiring definition of additional PHY types.
- Support for 1 Gb/s in the LS path extends the Clause 192 PHY framework with architectural continuity.
- The additional operating configurations are intended to support specific use cases, allowing the system integrator or end user to determine an optimized end-node camera link implementation.
- The authors believe the proposed operating rates are within the approved PAR scope and do not require a new CFI.
- Changes are proposed for the current draft.
- Task force participants are welcome to contribute to this proposal.

How does the 1 Gb/s requirement fit to the CFI?



The CFI states:

1) **Project ideally allows for use beyond automotive cameras**
2) **Input from automotive experts on needs for media, power, and rates**

CSD (IEEE 802 Criteria for Standards Development)

Broad Market Potential

Each proposed IEEE 802 EMSC standard shall have broad market potential. At a minimum, address the following areas:

a) Broad sets of applicability.

b) Multiple vendors and numerous users.

- Broad Sets of Applicability:
  - Migration of cameras, displays, and other imaging sensors to an automotive ethernet network present an inherently asymmetric data stream with gigabit rates in one direction and a typically low-rate control plane in the other direction.
  - These applications are highly cost and power sensitive and benefit from optimization, requiring a targeted solution
  - Market-adjacent sensor applications such as in-building sensors and other automotive sensors will benefit from the standardization of protocols for interfacing natively asymmetric physical layers, as many sensors are asymmetric and similarly constrained as automotive cameras.
- Multiple vendors and numerous users:
  - At the call for interest, 70 individuals from 49 affiliations indicated they would support this project. These included automotive OEMs, automotive Tier 1, networking OEMs, silicon, infrastructure, cabling, connector, and test equipment experts.
  - Data presented at the CFI indicate a substantial automotive camera market potential, exceeding 1 billion ports and adjacent automotive markets approaching 500 million ports in 2030.

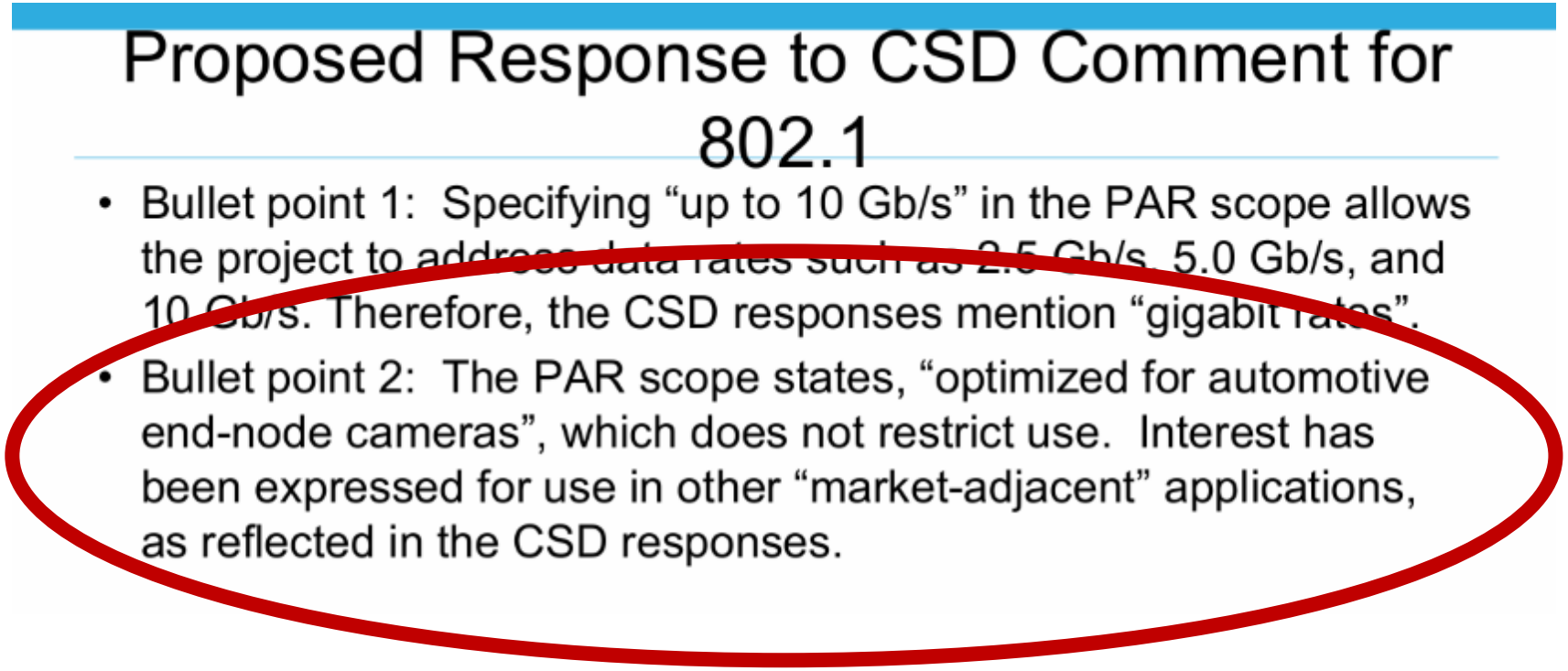
Version 2.7 IEEE 802.3 Ethernet Working Group - CSD Page 4

The CSD states:

1) **Broad Sets of Applicability**
2) **It explicitely mentions displays, and other imaging sensors**
3) **This statement explains the reason, why the LS data rate was kept open and not limited to 100 Mbit/s.**

https://mentor.ieee.org/802-ec/dcn/24/ec-24-0074-00-ACSD-p802-3dm.pdf

CSD (Response to Comment for 802.1)



The CSD response:

1) **The response clearly states that „optimized for automotive end-node cameras“ does not restrict use for other usecases!**
2) **This statement was agreed by a motion on March 2024 plenary with unanimous consent by the study group.**

1 Gb/s LS Path Specification Proposal for Clause 192

- To support the optional 1 Gb/s in the LS path, the burst length in the HS path is shortened, allowing for longer bursts in the LS path.
- Just as 100 Mb/s, 2.5 Gb/s, 5 Gb/s, 7.5 Gb/s and 10 Gb/s may be supported with different parameters in a single MultiGBASE-A PHY implementation, the same PHY may support 1 Gb/s in the LS path and 5 Gb/s or 7.5 Gb/s in the HS path with modified parameters.
- The proposal is not for a new PHY type but uses the existing functions with modified parameters to support the new rates within Clause 192. Associated clauses and front matter would be updated accordingly.
    - Existing baud rates of 3G and 6G
    - Same TDD Cycle
    - Same FEC Coding, Interleaving and Decoding
    - Same 64/65 Encoding
    - Existing Scramblers, Modulations and Signal levels as previously specified
    - Same Electrical specifications (PSD, Droop, Jitter, Distortion)
    - Same Link segments
    - Same Link-up process
- HS path of 7.5Gbps and 5Gbps are specified with 1Gbps LS path.
- Details of the changes proposed for D2.1->D2.2 may be previewed in:
    - Front Matter, Clauses 1, 30, 45, 46, Annex 31B [PDF comments]: https://www.ieee802.org/3/dm/public/0926/Muma_3dm_01_0926.pdf
    - Clause 192 [marked changes]: https://www.ieee802.org/3/dm/public/0926/Muma_3dm_02_0926.pdf
- For D2.0->D2.1 see https://www.ieee802.org/3/dm/public/0726/chini_3dm_02a_D2d0_1G_comments-preview.pdf for change outline.

7.5Gbps/1Gbps Specification For Clause 192

LS path: 1Gbps

6Gbaud-PAM2, 5 x RS (130, 124), L=2.

Same as the LS 100 Mbps specification but a longer burst of 5 superframes with L=2 instead of 1 superframe with L=1. The 1 Gb/s burst duration is 1733.33ns.

Total Refresh Period

368ns as in the current specifications

Total IBG Period

352ns as in the current specifications

HS path: 7.5Gbps

6Gbaud-PAM4, 25 x RS (128,122), L=3.

This is same as HS 7.5Gbps specification for burst structure coupled with the scrambler and modulation that follows HS 10Gbps resulting in a shorter burst duration of 6400ns (38,400 PAM4 symbols).

Additional Capacity

There is a 746.66ns extra capacity;

Add 1 x RS (130,124), L=2 to LS path plus a padding of 8Bytes

Add 1 x RS (128,122), L=3 to HS path plus a padding of 200Bytes

* L is the interleaving degree

5Gbps/1Gbps Specification For Clause 192

LS path: 1Gbps

6Gbaud-PAM2, 5 x RS (130, 124), L=2.

Same as the LS 100 Mbps specification but a longer burst of 5 superframes with L=2 instead of 1 superframe with L=1. The 1 Gb/s burst duration is 1733.33ns.

Total Refresh Period

368ns as in the current specifications

Total IBG Period

352ns as in the current specifications

HS path: 5Gbps

6Gbaud-PAM3(3B2T), 25 x RS (128,122), L=2.

This is same as HS 5Gbps specification other than the scrambler and modulation that follows HS 7.5Gbps and a shorter burst duration of 5688.88ns.

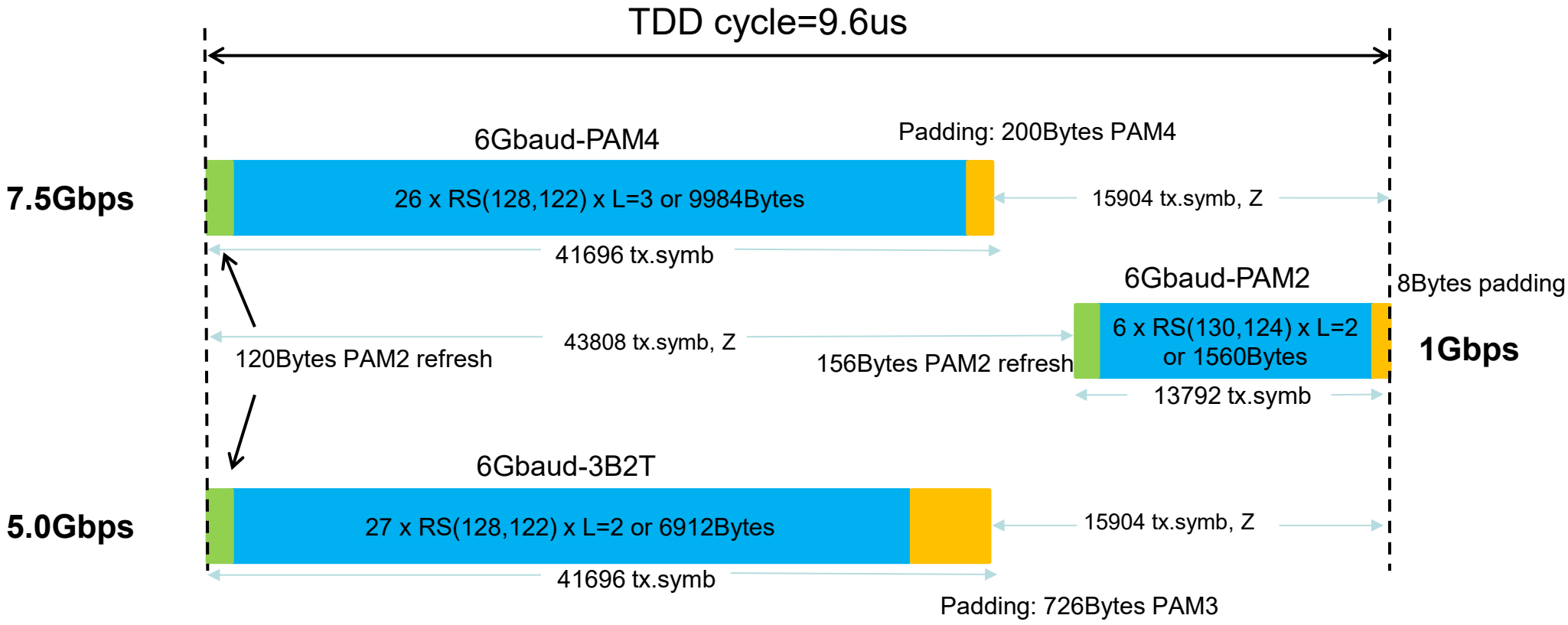
Additional Capacity

There is a 1457.77ns extra capacity;

Add 1 x RS (130,124), L=2 to LS path plus a padding of 8Bytes

Add 2 x RS (128,122), L=2 to HS path plus a padding of 726Bytes

1Gbps Bursts in LS Path with 7.5Gbps or 5Gbps Bursts in HS Path



* There is an extra RS-FEC coded superframe in all three burst formats that may be used for vendor-specific purposes.

Why Does End-Node Camera Links Need a 1 Gb/s Uplink (1)

Purpose: the P802.3dm PAR calls for PHYs "optimized for **automotive end-node camera links**"

➔ up to 10 Gb/s in one direction and with a lower data rate in the other direction.

There are different types of camera solutions in the field: a. dumb-camera modules (RAW → central ISP); b. ISP-integrated smart-camera modules:

Dumb-camera modules Raw ➔ central ISP	ISP-integrated smart-camera modules
Standalone camera HS = camera ➔ host video LS = host ➔ camera control	Display-integrated camera: HS is consumed by display video (host➔ module, camera RAW return on the LS direction

Bandwidth Requirement increase in LS Direction

Why Does End-Node Camera Links Need a 1 Gb/s Uplink (2)

Case	Application class	What crosses the LS direction	Data volume / rate
1	RAW video out of camera end nodes integrated in display modules (mirror / cabin display: DMS, OMS, conferencing, DVR)	Continuous uncompressed RAW video stream	~0.8 Gb/s (1 MP @ 60 fps) to ≈2 Gb/s (5 MP @ 30 fps) RAW; entry DMS fits a 1 Gb/s LS direction, higher classes exceed it
2	Software / config download into the camera (EOL flash, service, OTA)	Sensor / serializer configuration and calibration image (register maps, firmware patches, lens-shading tables) into on-module EEPROM / SPI flash via the link's sideband control channel (I2C / SPI)	≈1 MiB image (assumption): 10–60 s worst case over I2C ≤1 MHz; ≈1–5 s over SPI ≤25–50 MHz

DMS: Driver Monitoring System **OMS:** Occupant Monitoring System

Basis: RAW rate = W × H × bits/pixel × fps × 1.1 (protocol overhead); usable link rate at 90% net; sizes in MiB (2^20 bytes), assumptions stated.

Key Takeaways

Case 1:

- Continuous RAW backhaul spans ~0.8 to ≈2 Gb/s — far beyond a 100 Mb/s LS direction or legacy reverse channel(47-200Mb/s); entry DMS (1 MP @ 60 fps, 811 Mb/s) fits the 1 Gb/s LS proposal (≈0.9 Gb/s net), higher classes drive LS scalability.

Case 2:

- Firmware and configuration downloads into ISP-integrated camera modules benefit from a 1Gb/s-capable LS direction, particularly for parallel multi-node OTA and production-line programming.
- Adjacent end-node applications such as LiDAR and 4D imaging radar reuse the same LS directin for firmware/ calibration downloads – with far larger software images than a camra's≈1 MiB, they amplify the multi-node EOL and OTA burden.
- A 1 Gb/s-capable LS direction covers the realistic download and entry-RAW use cases.

Case 1 — camera end node in a display module, one SerDes link

• **Topology** — a camera end node integrated in a display module (mirror / cabin display): the single coax / STP link's HS direction is consumed by display video (host→module), so the camera's RAW return rides the LS direction (module→host) — an end-node camera link per the P802.3dm PAR scope ("optimized for automotive end-node camera links")

• **In volume production** — camera+display integration in one module is shipping: vision-mirror modules with an integrated camera + DMS (SOP 2024, European OEM) and cabin cameras at the mirror position in several OEM lines

• **Single-link practice** — production proprietary SerDes links carry display video + camera data on one coax / STP with control tunneling (I2C / UART / SPI / GPIO); the module→host direction is limited to ≤200 Mb/s — a standards-based Gb/s-class return path is missing

RAW backhaul from the module camera

Camera configuration (RAW backhaul)	RAW rate	vs 100 Mb/s LS	vs ≤ 200 Mb/s
1 MP (1280×960) @ 60 fps, RAW10	811 Mb/s	8.1× over	4.3× over
2 MP RGB-IR (1600×1300) @ 30 fps, RAW10 (OV2311 class) > camera configurable	686 Mb/s	6.9× over	3.7× over
2 MP RGB-IR (1600×1300) @ 60 fps, RAW10 (OV2311 class)	1373 Mb/s	13.7× over	7.3× over
5 MP (2592×1944) @ 30 fps, RAW12 (OX05C1S class) 2028 discussion	1995 Mb/s	20.0× over	10.6× over

DMS runs 1–2 MP @ 30–60 fps (RGB-IR global shutter), OMS moves to 5 MP RGB-IR.

Entry / mainstream DMS fits a 1 Gb/s LS direction: 1 MP @ 60 fps = 0.81 Gb/s, 2 MP @ 30 fps = 0.69 Gb/s — both ≤ 0.9 Gb/s net.

2 MP @ 60 fps and 5 MP @ 30 fps exceed 1 Gb/s — they motivate LS scalability beyond 1 Gb/s rather than a 100 Mb/s cap.

Today's constraint — production single-link designs cap the camera return at ≤200 Mb/s, forcing in-module ISP compression, a second wire, or a feature cut

What 1 Gb/s changes — one standard link returns entry-DMS RAW uncompressed (811 Mb/s ≤ 0.9 Gb/s net); no second wire, no in-module codec, central ISP kept

Case 1 — why the return path carry RAW, not compressed video

- **NNs are trained on RAW** — Tesla feeds RAW Bayer (photon-count) directly to compute, bypassing the ISP in the perception pipeline
- **RGB-IR cannot be fed to standard codecs in CFA form** — a 2×2 RGB-IR mosaic requires de-mosaic and RGB/ IR separation before H.264/ H.265; in-module encode therefore forces a local ISP
- **Safety and latency** — DMS for L2+ / L3 handover must not add codec latency or compression artifacts
- **Shadow mode and fleet learning** — OEMs harvest raw sensor streams for training data; DMS / OMS streams are next
- **Cost asymmetry** — the return channel sits in the same PHY; lifting it to 1 Gb/s adds no wire, no connector, no second SerDes

What changes when the LS direction moves 100 Mb/s → 1 Gb/s

Dimension	100 Mb/s LS (D2.1)	1 Gb/s LS (proposal)
Module camera	In-module ISP + codec forced	Entry DMS fits (1 MP @ 60 fps, ~0.8 Gb/s)
System	Second wire / feature cut	One link, central ISP, fleet RAW harvest

The application is already in volume production. A 1 Gb/s LS direction removes constraints and aligns 802.3dm PAR.

Case 2 — Configuration & Firmware Download

- **Market situation** – two architecture coexists in volume production, a. dumb-camera modules (RAW → central ISP); b. ISP-integrated smart-camera module

Architecture	Smart Camera (ISP/ SoC in module)	Dumb Camera (RAW to central ISP)	Hybrid / CIS-ISP
ISP Location	Camera module	Central HPC/ SoC	CIS or companion chip

- **Mechanism** - host SoC writes a ≈1 MiB sensor / serializer configuration and calibration image (register maps, firmware patches, lens-shading / defect-pixel tables) into the module's EEPROM / SPI flash over the SerDes sideband control channel (I2C / UART up to 1 MHz, SPI ≤ 25-50 MHz)
- **Established practice** — writing module flash over the link is a standard production flow: even modules with a companion ISP boot its firmware from external SPI flash; driven by end-of-line programming, UDS (ISO 14229) service updates and OTA campaigns under UNECE R156

End-to-end time for a ≈1 MiB image (assumption; ≈85% write efficiency, incl. flash erase / verify)

For dumb-camera module (RAW→central ISP), the ≈1 MiB assumption holdes. For ISP-integrated smart-camera module, firmware images scale up.

Sideband channel into module flash	Effective write rate	≈1 MiB image transfer time
I2C ≤ 1 MHz	≤ 0.85 Mb/s	≈10–60 s — worst case, service / EOL acceptable
SPI ≤ 25 MHz or ≤ 50 MHz	8–40 Mb/s	≈1–5 s — refresh takes seconds

Forward-looking — the same LS direction must also serve end nodes beyond cameras: SerDes links are promoted toward LiDAR and 4D imaging radar. Such nodes carry far more software than a camera's ≈1 MiB image — SoC firmware, waveform and array-calibration tables. A 1 Gb/s LS direction raises the download ceiling 10× for native and tunneled access, keeping EOL programming and multi-node OTA practical as software content grows.

Production Plans & Remarks

OEM	Use Cases	SOP Time
1	• DMS • Driver monitoring • Position: steering wheel	SOP: 12.2026
2	• DMS/OMS • DMS Position: A Pillar • OMS Position: near rear-view mirror	SOP: 03.2027
3	• OMS • Occupation monitoring • Position: near rear-view mirror	SOP: 10.2027
4	• DMS • Driver monitoring • Position: under display	SOP: 06.2028

Conclusions

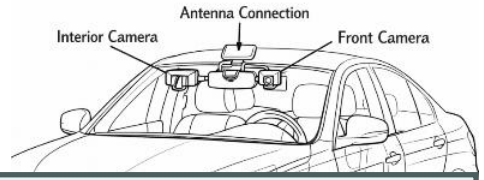
- **Use Case Alignment:** The 1 Gb/s LS path addresses emerging requirements for end-node camera links, including uncompressed RAW video backhaul and efficient firmware/configuration downloads for increasingly complex automotive sensors (DMS, OMS, LiDAR, and Radar). Earlier, some other use cases were also provided:
  - https://www.ieee802.org/3/dm/public/adhoc/060226/schedl_3dm_01_060226.pdf
  - https://www.ieee802.org/3/dm/public/0726/Schedl_3dm_01_0726.pdf
- **Technical Feasibility:** Building on the existing P802.3dm draft specification, this proposal utilizes existing functions with modified parameters, ensuring architectural continuity.
- **Minimal impact:**
  - Additions do not affect Clause 191.
  - Integrates into the draft without affecting the overall P802.3dm timeline.
- **Competitiveness:** This proposal surpasses incumbent 187.5Mb/s LS solutions; improves standard versatility and facilitates faster market adoption.
- **Therefore, we propose to P802.3dm adopting 7.5Gbps/1Gbps and 5Gbps/1Gbps for Clause 192.**

Thank you for your attention!
Questions?

BACKUP MATERIAL

Camera Usecases:
Additional Information from July 2026 Plenary

Camera Usecase.



Use case for an IEEE 802.3dm Interface

HPC

1 Gb/s

7.5 Gb/s

End node (Integrated Device)

Internal Interface (non Ethernet) — Interior Camera

Internal Interface (non Ethernet) — Front Camera

⋮

Internal Interface (non Ethernet) — Camera

This is an end node:
There is communication between HPC and the device but there is no further communication from the device to other nodes in the car.

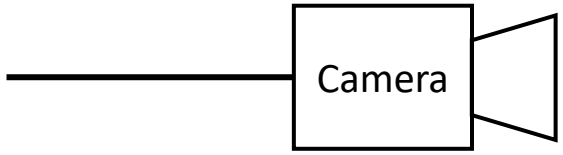
This is an end node camera link:
There is camera data transferred from the camera to the HPC.

PAR scope:
„ […] for automotive end-node camera links […] “

<u>Conclusion 1:</u> The use case is in the PAR scope.

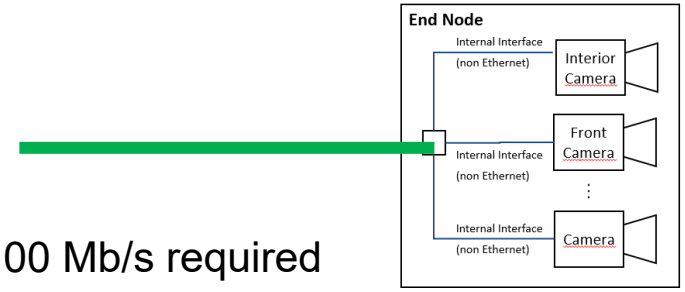
CFI and PAR Scope

The **CFI** talks about the data rate **towards camera.**



< 100 Mb/s sufficient

The **PAR** talks about „optimized for automotive **end-node camera links**“



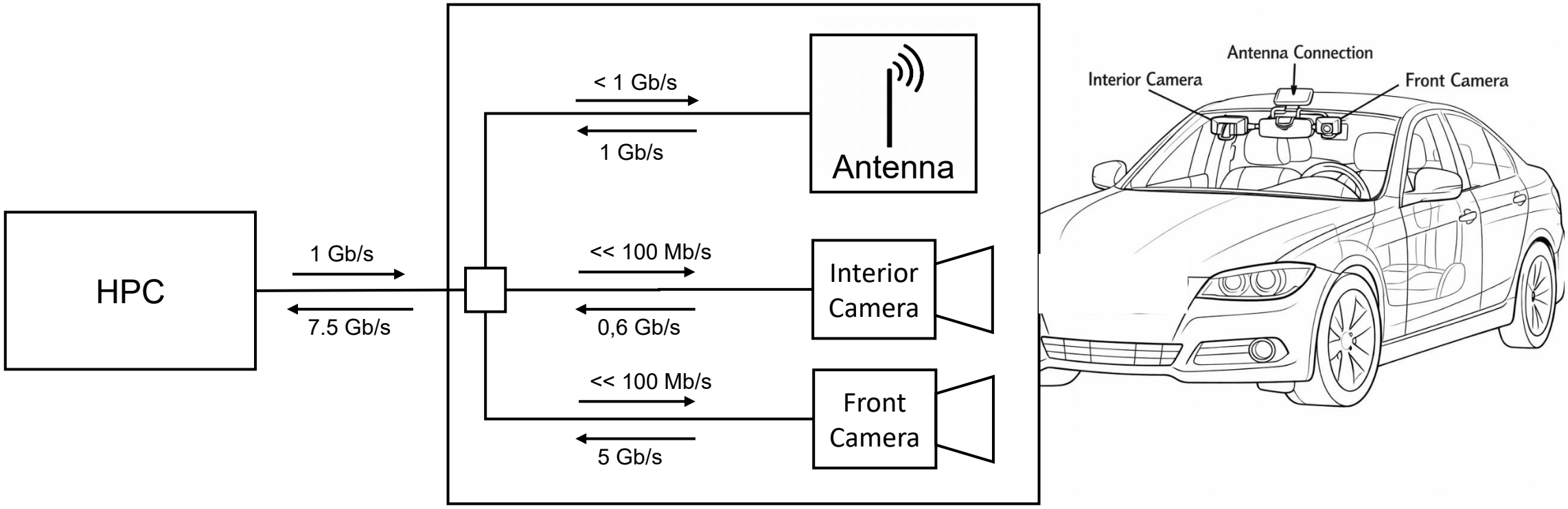
> 100 Mb/s required

- **End-node camera links** may be a point-to-point link to an **aggregator** connected to one or more cameras and other devices
- The **aggregator** connection to cameras and other components is an internal connection within a device and not point-to-point Ethernet.
- **End-node camera links** therefore may include multiple instances of traffic 'towards camera' and other traffic
- As a result, the traffic **towards** a single **camera** over an **end-node camera link** is never more than 100 Mb/s.
- However, the aggregate traffic over an **end-node camera link** may exceed 100 Mb/s

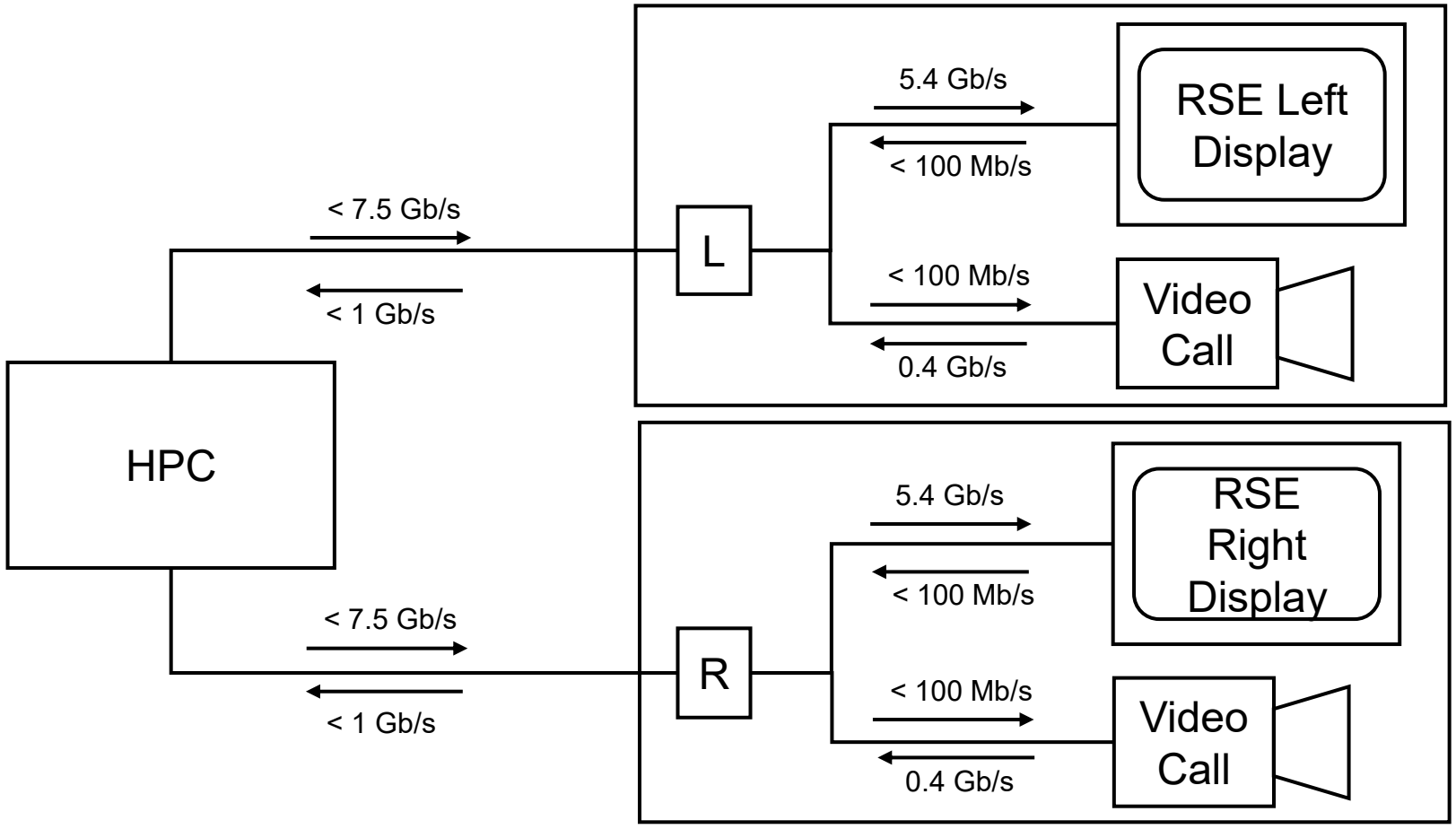
Conclusion 2: 1 Gb/s Upstream requirement is in the scope of the PAR.

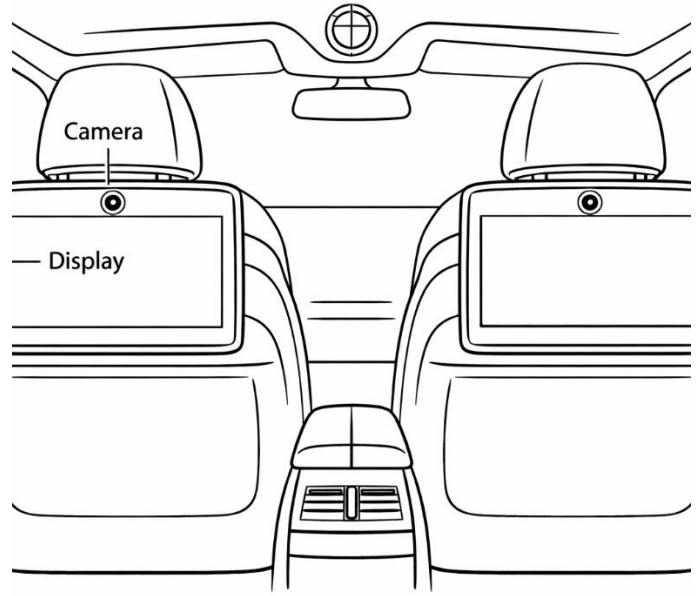
Combined Usecases:
Additional Information from June 2026 Ad-Hoc

Example 1: Cameras in the Zone Roof Combined with Backend Communication

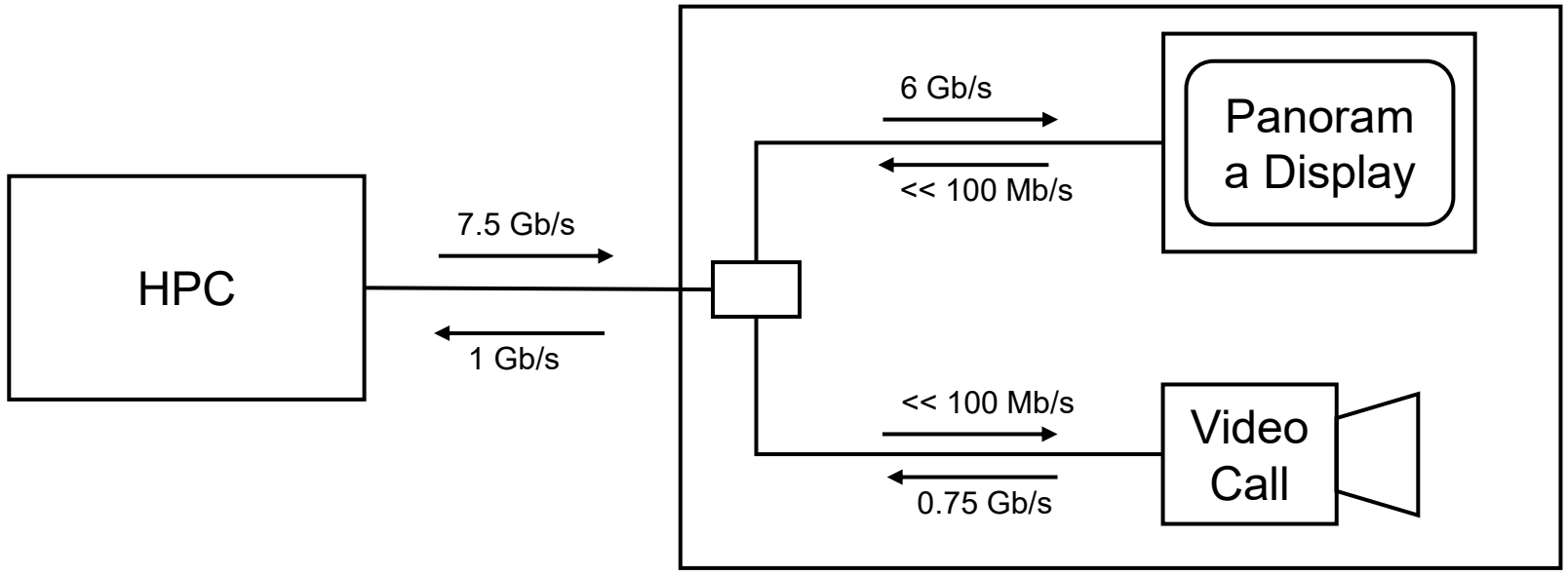


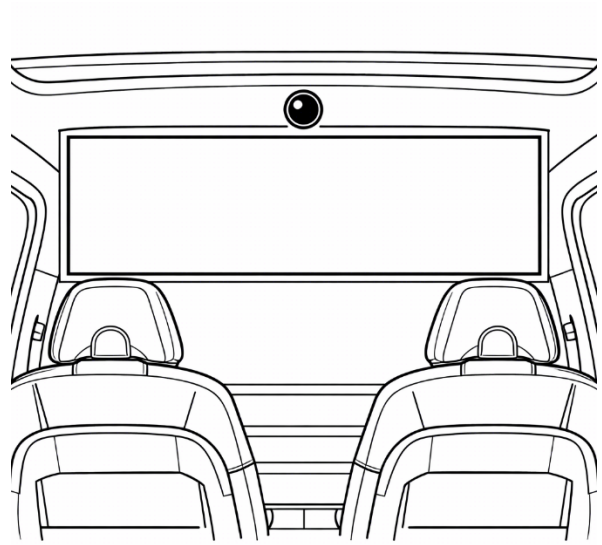
Example 2a: Rear Seat Entertainment with Two Displays and Video Calling.





Example 2b: Rear Seat Entertainment with Panorama Display and Integrated Video Calling





One link illustration

PAR Information

5.2.b Scope of the project: The scope of this project is to specify additions to and appropriate modifications of IEEE Std 802.3 to add Physical Layer specifications and management parameters for electrical media and operating conditions that are optimized for automotive end-node camera links for operation up to 10 Gb/s in one direction and with a lower data rate in the other direction.

https://www.ieee802.org/3/dm/P802.3dm_PAR.pdf