Comparison of electrical and optical transmission for Gbps Ethernet v. 1.0

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Motivation

- This slideset compares the principle differences between an electrical and an optical transmission for 1Gbps Ethernet for the automotive use case
- The 5 principle comparison criteria are:
  1. The logic performance
  2. The EMC performance
  3. The power consumption
  4. The weight and space use
  5. The (relative) costs
- + Some additional considerations to make

Some additional consideration

- Use cases
- Temperature range
- Phy integration in switch
- 100Mbps/1Gbps mixed use
- Power over DataLine
- Power off function / wake up time
- Quiescence current
- Cable flexibility bending
- Mechanical stability, vibration
- Manufacturing issues
- Maintenance
- Availability of standard
- Availability of hardware
- Multi sourcing
- Driving force

The technology assumptions are:

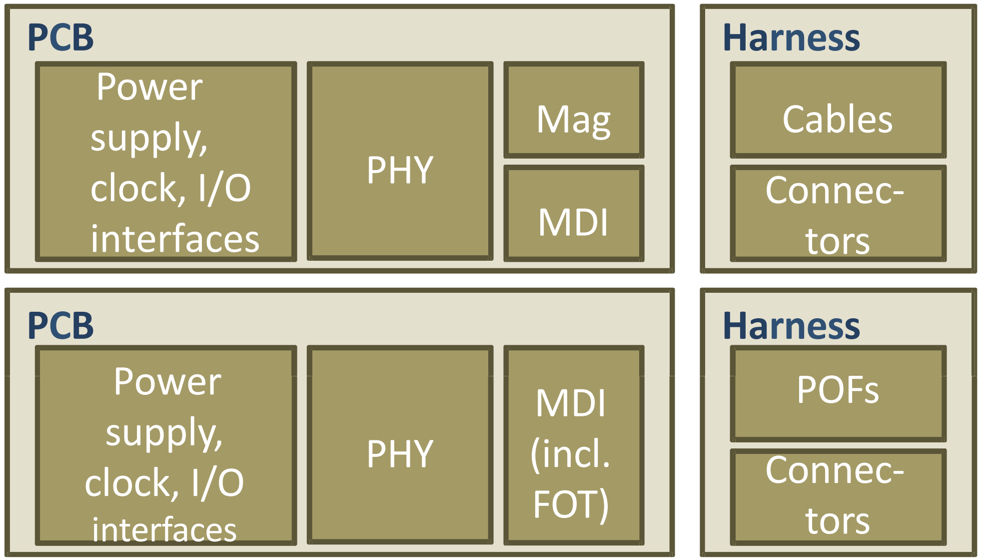
•Electrical system:
RTPGE based on one pair either (jacketed) UTP, coax or STP
Baseline for harness is that some elements from BroadR Reach Ethernet can be reused for UTP

•Optical system:
KDPOF based with one POF for transmit and one for receive
Baseline for harness is that elements from MOST 25/150 can be reused, the FOT from MOST cannot be reused

Hypothesis on reuse for both technologies would need to be confirmed

Use in a switched Ethernet network, and Topology 2 (see back-up)

Elements considered for the comparison are

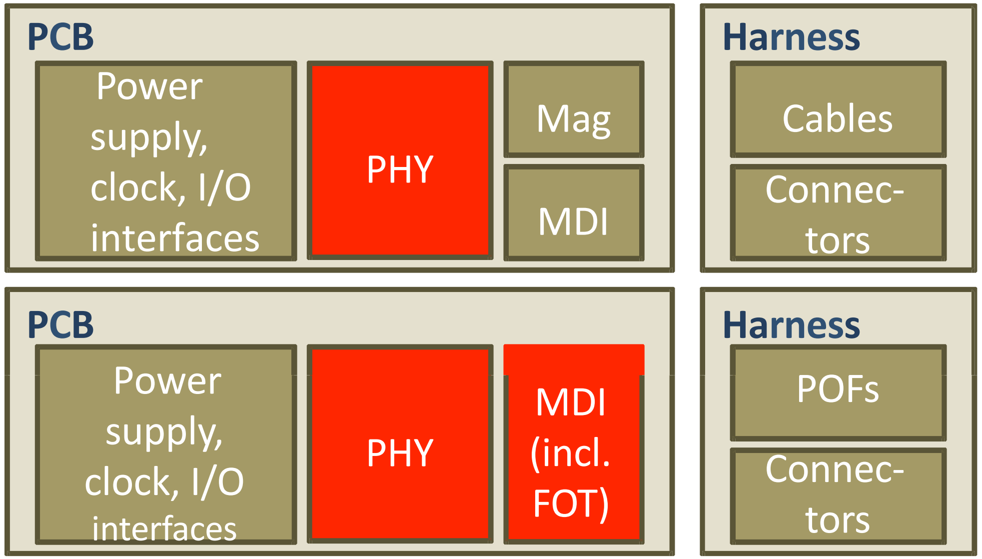


Electrical system

Optical system

1. Logic performance

Relevant elements for logic performance



Electrical system

Optical system

Principle comparison of logic performance

Electrical system:

Currently, the solution has not been defined in IEEE. Therefore it is not possible to base the evaluation on actual measurement results. The requirement on the standardized solution is that it passes the defined limit lines for -40°C – +125°C for

- Insertion loss,
- Xtalk, and
- Return loss (needs to be finalized in IEEE)

Critical: Insertion loss in case of increased link segments (>>15m)

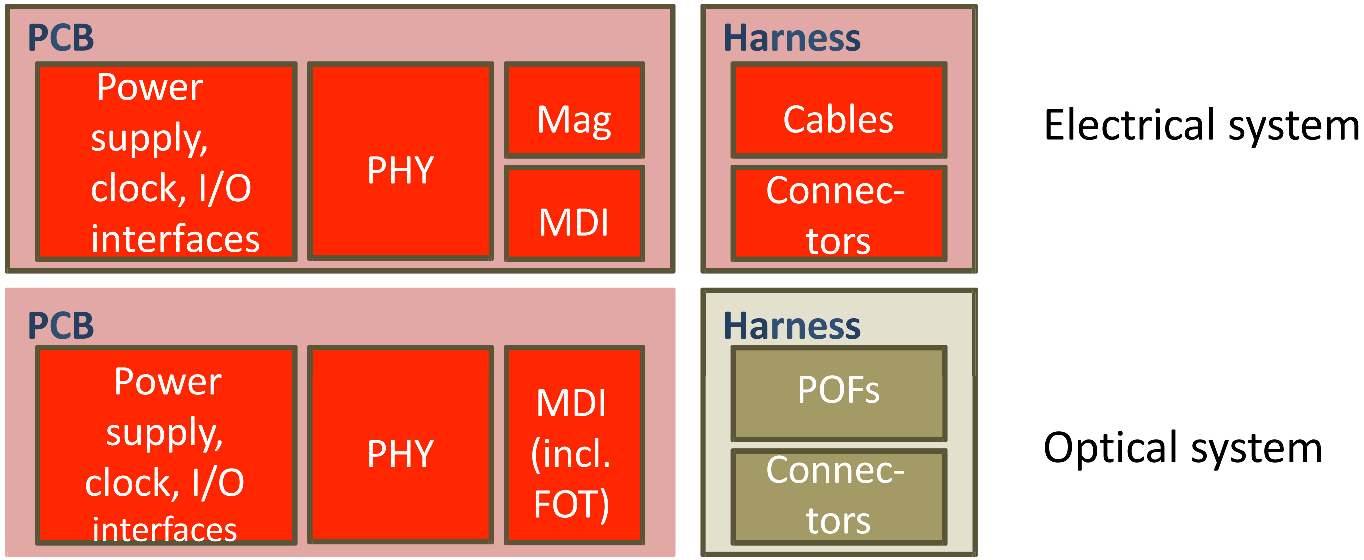
Optical system:

In principle, first silicon from KDPOF and suitable optoelectronics from Avago are available for -40°C – +105°C.
At the time of writing, no independent entity had performed measurements.

Critical: Performance of PAM16 modulation at the very high temperatures and lifetime

2. EMC performance

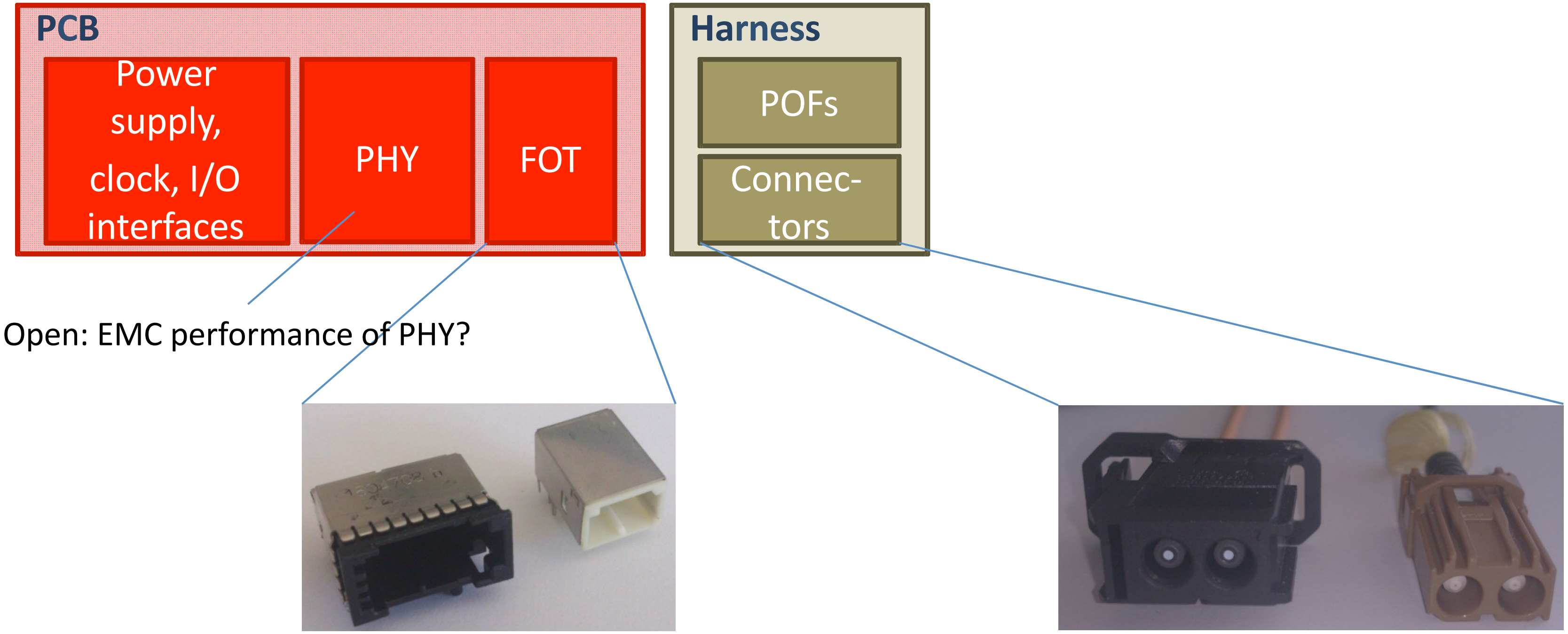
Relevant elements for EMC performance



EMC performance

	PCB side	Harness side
Electrical	•Current 100Mbps PHYs do not have shielded housings •Tbd., once hardware is available	•Sensitive to asymmetries, harness at connectors (untwist areas) especially critical •Mode conversion needs to be defined
Optical	•Metal housing for MDI/FOT required •KDPOF PHY needs to be evaluated	0

EMC performance – optical System

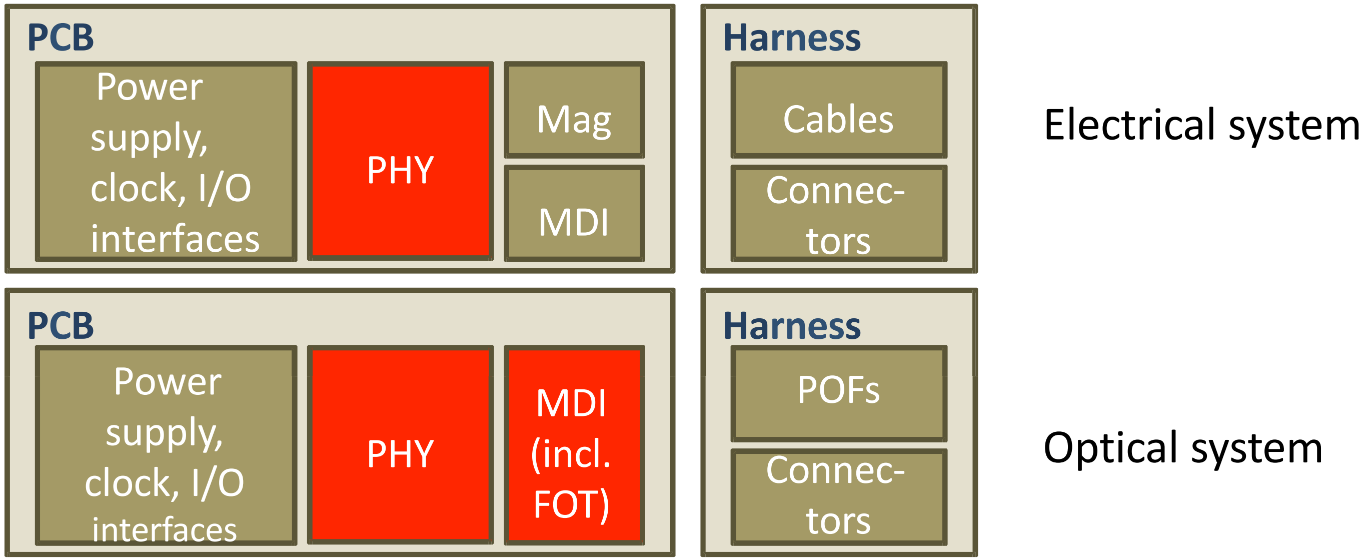


- 2 optical I/O housing **shielded with metal case**, connected to device housing
- Re-use of MOST 2+0 concept possible
- Maturity must be fullfiled by passing OEMs EMC tests

- No EMC issue at harness side
- Re-use of MOST 2+0 concept possible

3. Power consumption

Relevant elements for power consumption



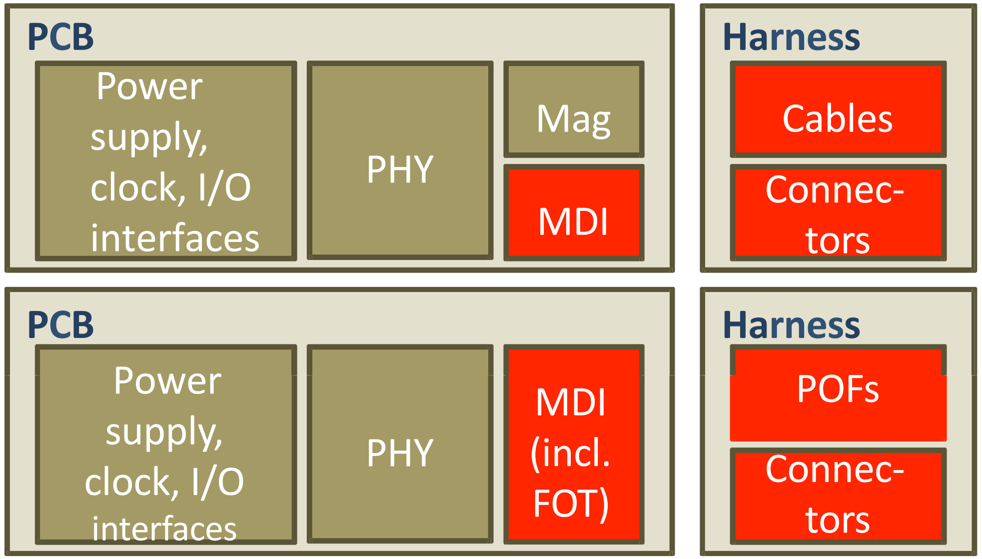
Power consumption

	Quiescence state	Transmission state
Electrical	RTPGE requirement <30uA per port	Implementation dependent and therefore not possible to evaluate without hardware. *)
Optical	PHY IC+FOT < 10 uA	PHY IC <500mW FOT < 200mW Power consumption ~linear to traffic (10% when no traffic, to 100% fully loaded)

*) Commercially available solutions for optical and electrical Gbps Ethernet might be used as comparison values. Nevertheless those solution are designed to drive longer wires than is necessary in automotive.

4. Weight and Space use

Relevant elements for weight



Electrical system

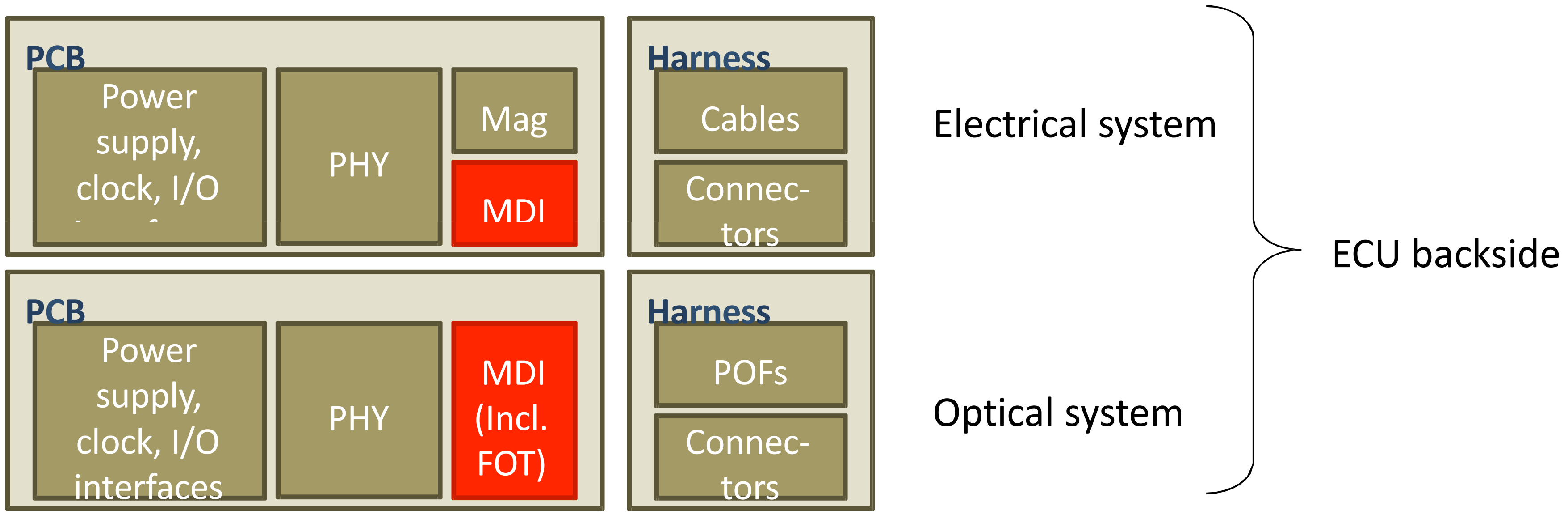
Optical system

Weight – comparison
For Topology 2

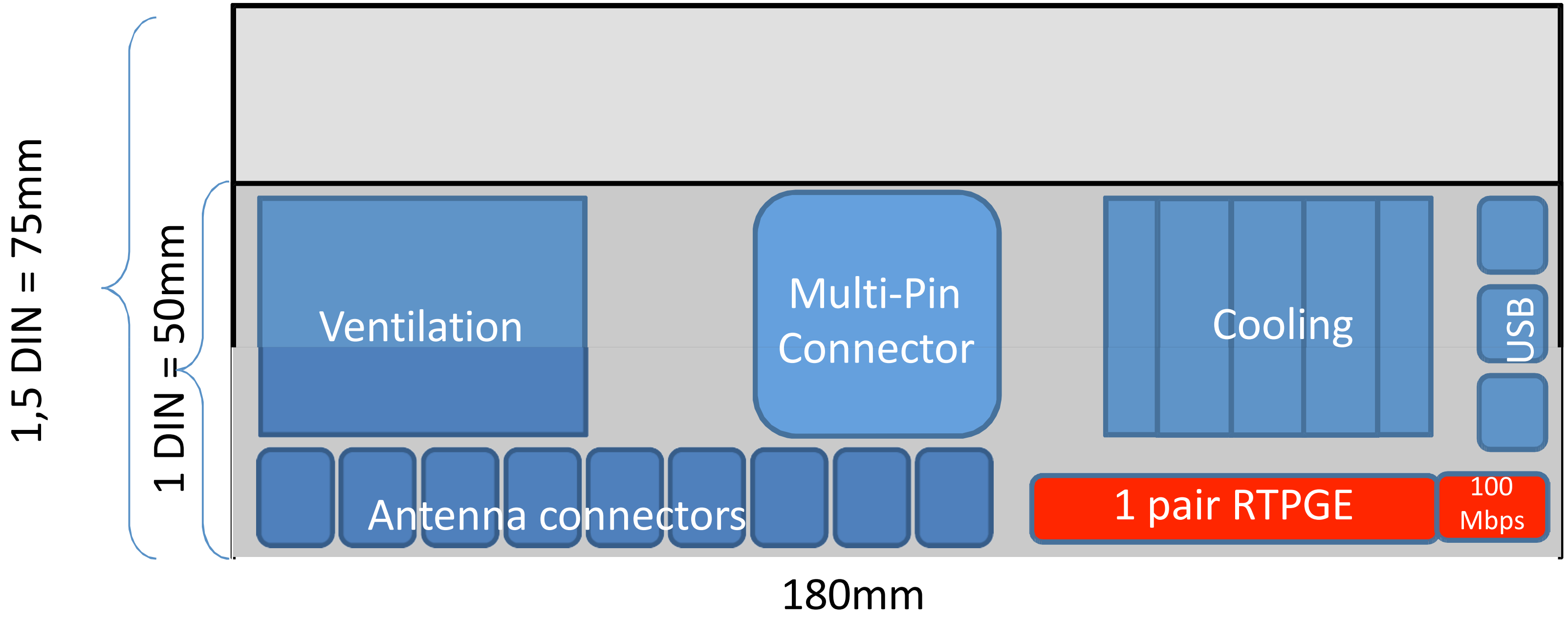
	Cables [g]	Connectors (incl. MDI) [g]	Overall [g]	Absolute difference to optical [g]	Relative difference to optical [%]
UTSP 0,35mm²	430	246	676	-42	-6%
Optical	500	218	718	0	0%
Coax	776	248	1024	+306	+43%
UTSP jacketed 0,35mm²	943	246	1189	+471	+66%
STP	1411	409	1820	+1102	+153%

Based on Topology 2.
4-6 sources for cable weight
3-4 sources for connector weight

Relevant elements for space

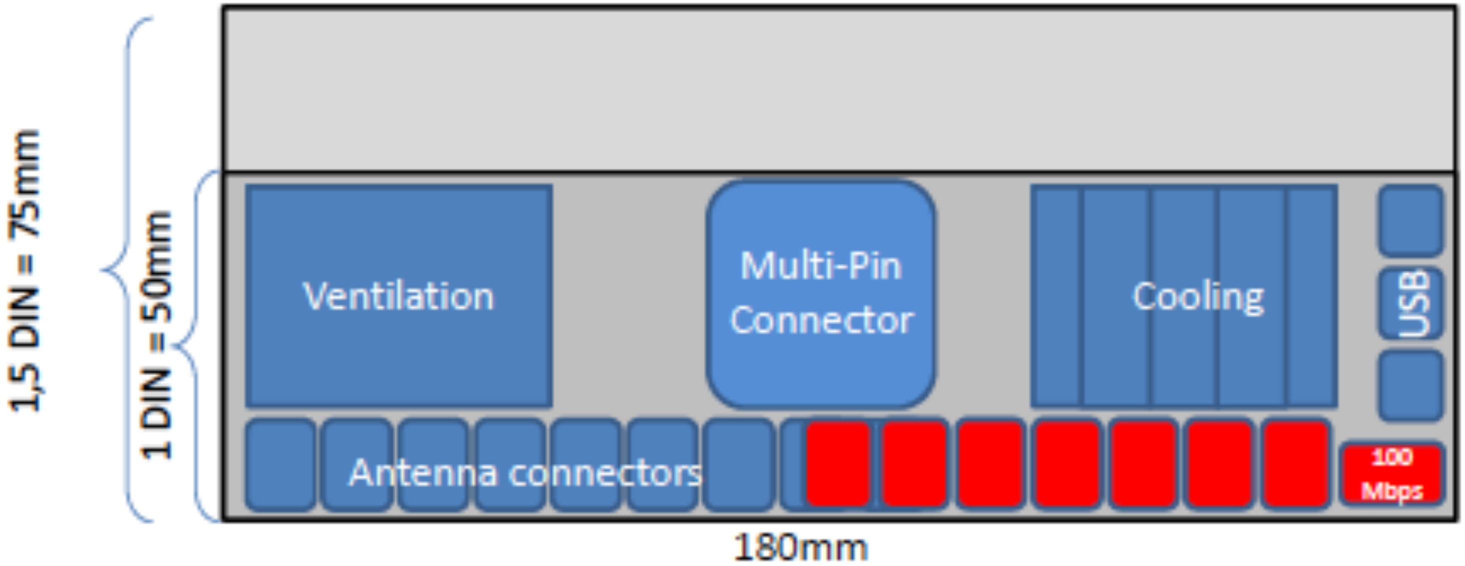


Impact on Space
Using Multipin Connector for electrical



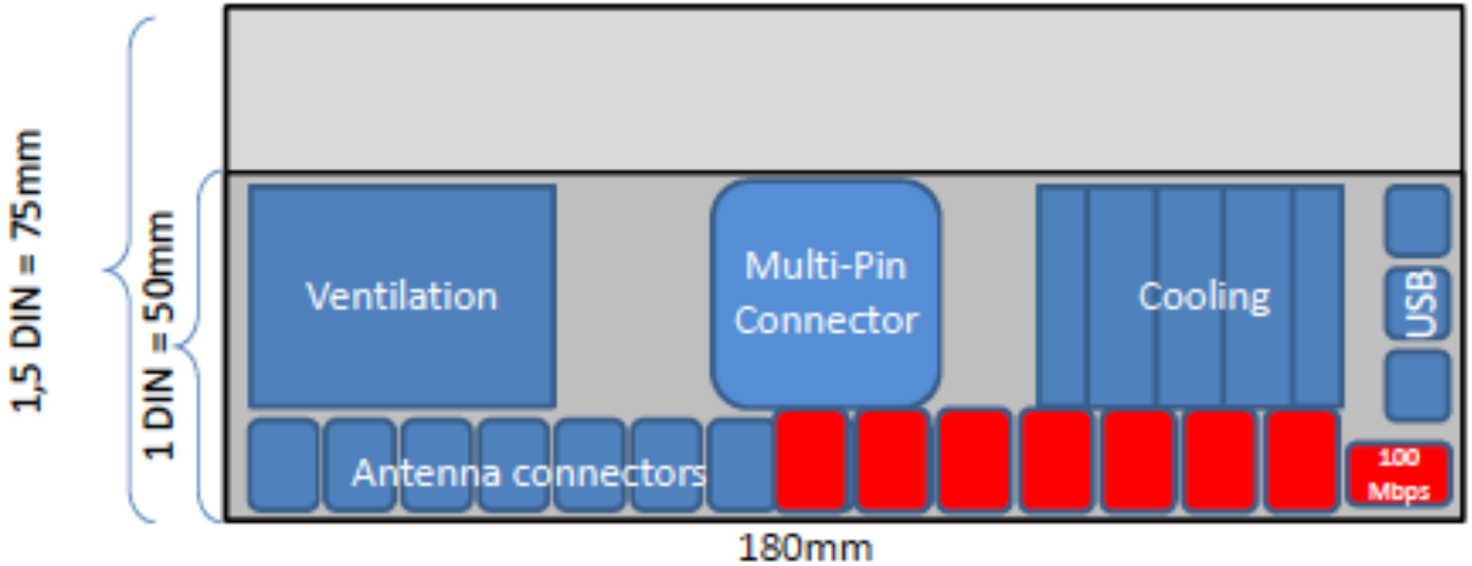
- Example back plane of multimedia ECU with one horizontal an one vertical PCB
- Extending the size to 1,5DIN has little effect as some connectors (antennas, Ethernet, USB) need to be directly connected to PCB
- Space is sparse. A multipin connector just fits

Impact on Space
Using Distinct Connectors for electrical



- Example back plane of I&C ECU with one horizontal an one vertical PCB
- Extending the size to 1,5DIN has little effect as some connectors (antennas, Ethernet, USB) need to be directly connected to PCB
- Having to use distinct connectors for the RTPGE links is unfavorable

Impact on Space
Using Distinct Connectors for optical

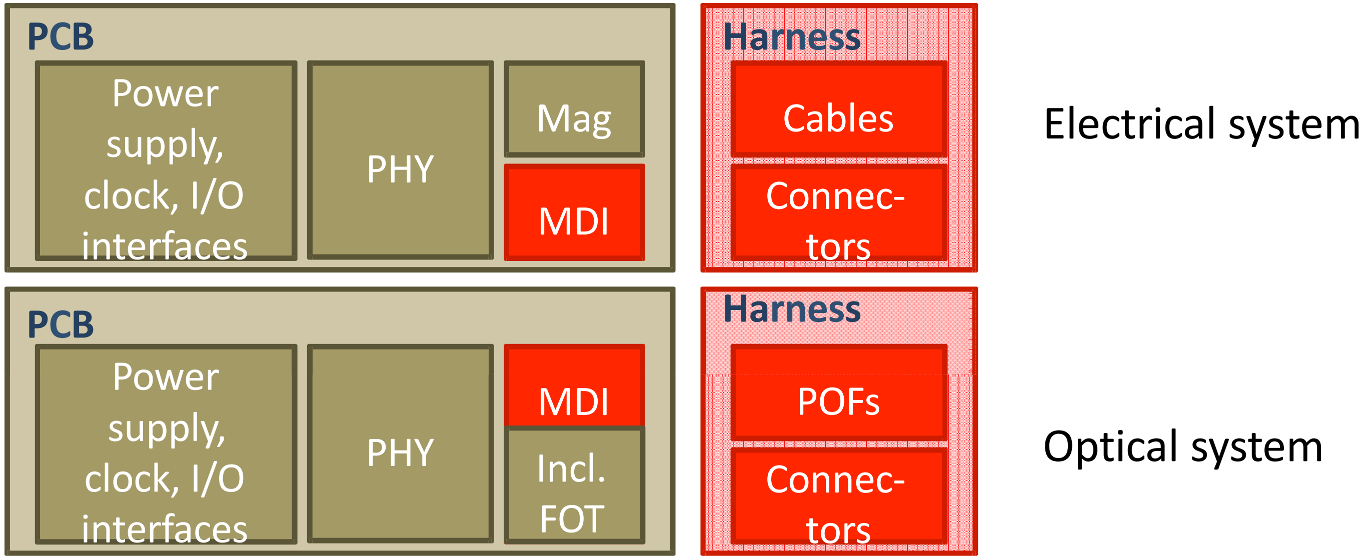


•Distinct connectors are more difficult to arrange than multi-pin connectors.

•Smaller size connectors are used in drawing, large optical connectors are unfavorable in respect to space requirements on ECUs

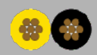
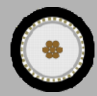
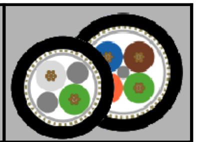
5. Costs

Relevant elements for harness costs



Harness Evaluation

Comparison 1: All values related to optical, 2 POF

					
		0,35 mm²	0,35 mm²		0,14mm²
Connectors	**1,00**	**0,35**	**0,35**	**1,19**	**1,39**
Cables	**1,00**	**0,50**	**0,77**	**1,27**	**1,73**
Manufacturing	**1,00**	**0,49**	**0,48**	**0,69**	**0,90**

Assumptions:
- •Connectors include MDIs and inliners (but not the FOT)
- •Includes cost caused by weight
- •For optical components temperature range up to 85°/95°C
- •3-6 input values

Trends:
- •Costs for optical will increase if temperature range is increased to 105°C and above
- •Costs (including weight) for UTP can be somewhat reduced with thinner cables in the long run, though copper prices in general cannot expect to decrease over time
- •Costs for electrical can be expected to increase with more complex connector systems
- •Optical, coax and shielded will likely be bought customized

PCB Evaluation

Active parts

- Electrical: PHY and Magnetics, Transformer, CMC (depending on the solution)
- Optical: Elect. PHY and FOT

At this point in time, no further cost calculation is possible

Additional considerations

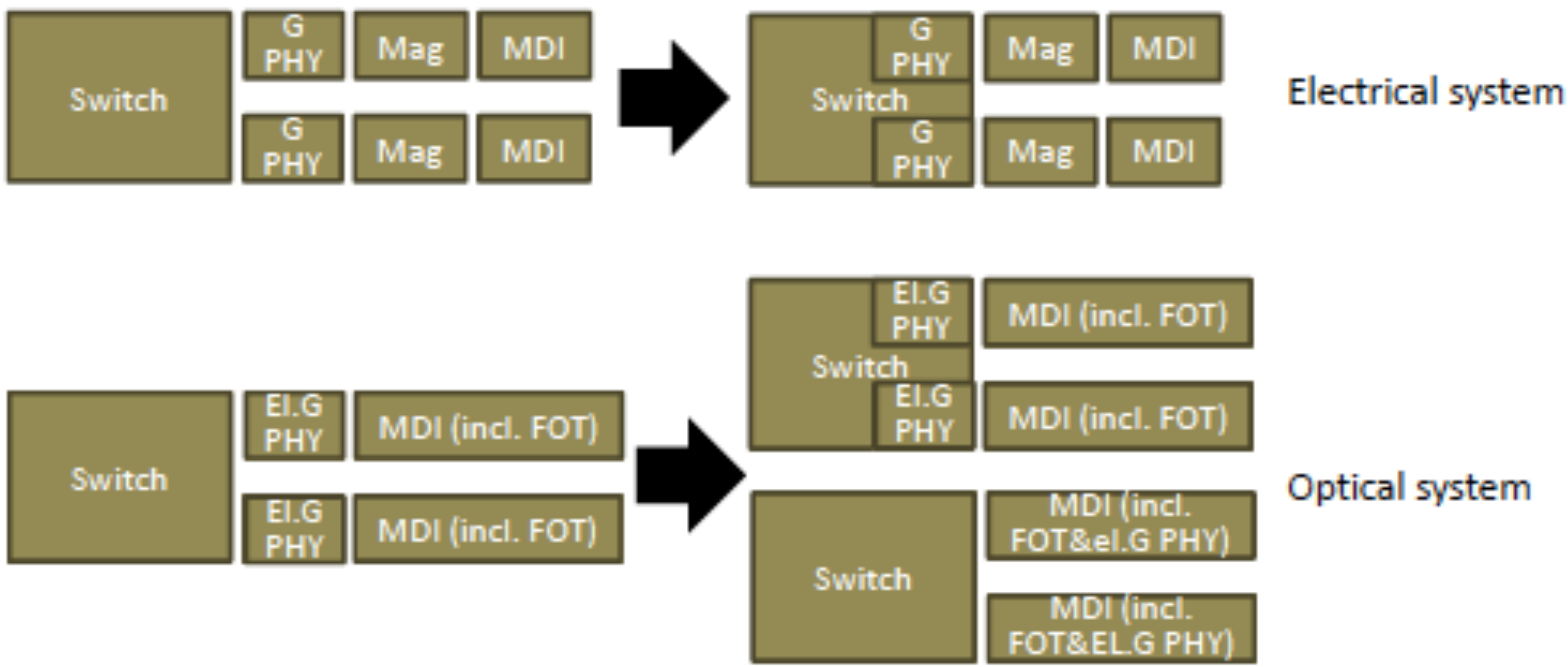
Temperature Range

	Temperature range	Use cases
Electrical	-40°C - + 125°C	No restriction for temperature reasons, in difficult EMC environments shielded (i.e. a more expensive cabling) might be necessary
Optical	-40°C - +85°C / +95°C /+ 105°C*)	Restrictions for locations inside the car depend on the temperature requirements of OEMs, POF for higher temperatures is not qualified for automotive at this point of time

*) Up to now 95°C is cleared for MOST 150, 105°C is expected feasible without too much effort

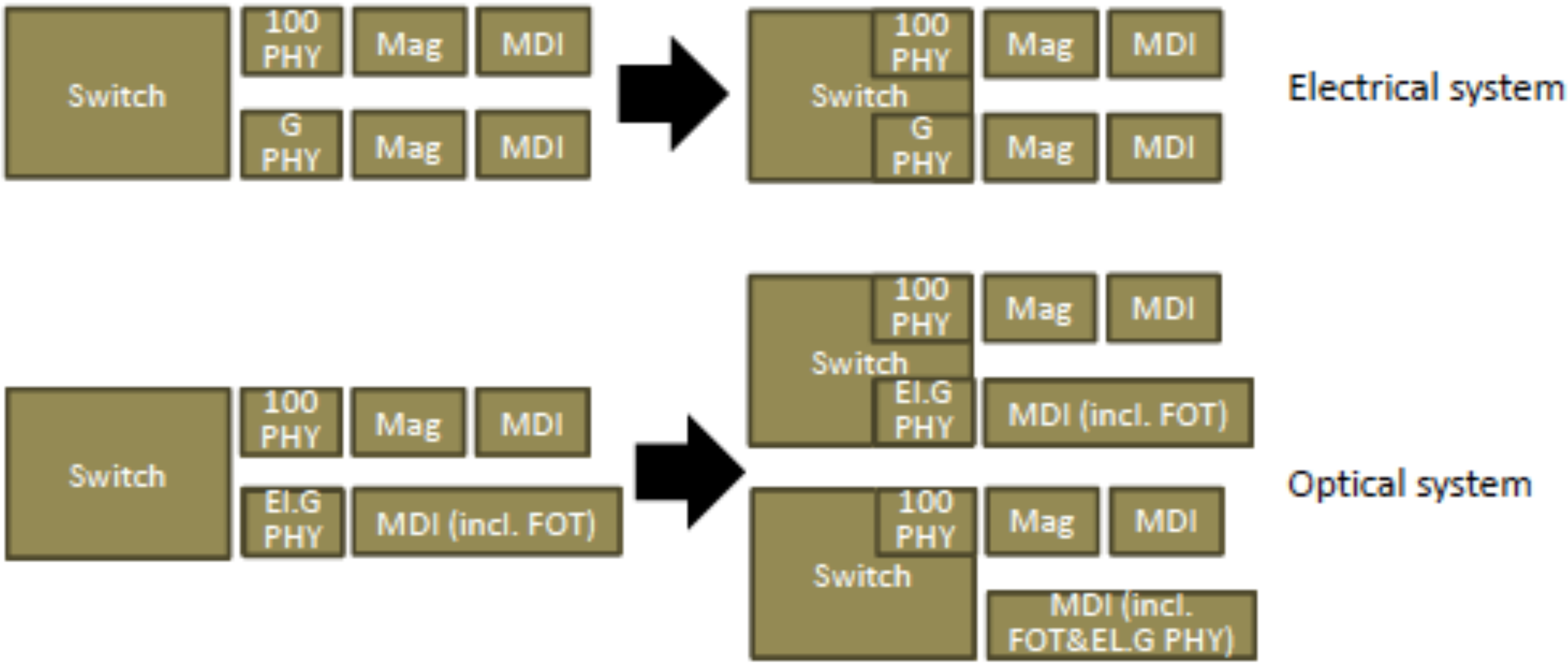
In a survey performed for RTPGE six out of eleven car manufacturers said that 105°C was a minimum requirement for RTPGE, five said 125°C was a minimum requirement. On commented that in some areas 105°C are always sufficient, another that for 125°C a link length of 3m is sufficient.

Switch Integration



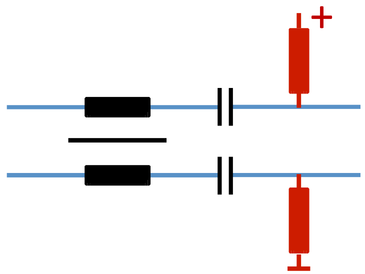
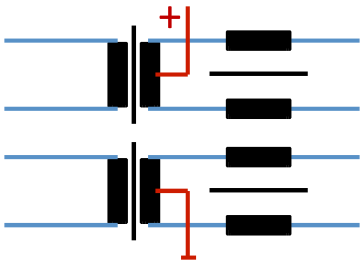
In both systems integration is in principle possible. In the optical system it additionally offers itself to integrate the electrical PHY with the FOT and MDI. In this case, as well as in the case without integration, switches with multiple (R)(S)GMII interfaces are needed.

100Mbps/Gps mixed use



In case PHYs are not integrated, any mixed use is possible as long as stand alone switches with the right type of (X)MII interfaces are available. Integration in case of mixed use is in principle also possible, though for optical the lower integration case seems more likely

Power over Dataline

	Solution for one pair	Solution for two pairs
Electrical		

The main elements needed for enabling Power-over-Dataline are inductors. These add costs and require space. The implementations is a trade off between the costs/weight and space use of additional power lines and the costs and space requirements for the inductors.

Optical

Optical cables do not allow for transmitting power. An additional electric cable is necessary to carry the power.

Power off function / wake up time

	Wake up	Wake-up time
Electrical	Wake-up logic needs to be on battery	<100ms, requirement defined by IEEE
Optical	FOT needs to be on battery	<100us FOT, 50ms PHY

Cable flexibility bending, mechanical stability/ vibration, manufacturing issues, maintenance

	electrical	optical
Cable flexibility, bending	UTP: no regulation STP: self diameter	10mm/15mm/25mm are qualified at the moment for MOST
Mechanical stability	Tensile force should be constant	Max. tensile force = 60 N for max. of 5s ; max. torsion = 1/m; process stability of CPK 1,6
Manufacturing issues	Harness: UTP: care with untwist at harness assembly Coax, STP: pre-assembled Car: No particularities	Harness: Pre-assembled link segments Car: Complete protection against contamination; no cuts or corrugations on the inner sheathing
Maintenance	UTP: easy Coax: only one contact but also shield -> closer to STP STP: more difficult	In between UTP and STP

Availability, multi-sourcing, driving force

	electrical	optical
Availability	Standardization in IEEE needs to be completed. Earliest SOP expected for 2018.	Standardization at VDE completed. Copyright dispute with IEEE not yet solved. First silicon exists.
Multi-sourcing	Licensing under IEEE RAND, potentially several IP owners	Licensing under RAND from KDPOF guaranteed with VDE standard
Driving forces	BMW, Daimler, BOSCH, Broadcom, various players at IEEE	KDPOF, Yazaki, Avago, Toyota, Denso, Renesas, Toyoda-Gosei, Toyota Central R&D Labs, TE, Furukawa,

Summary

•Both electrical and optical links can expected to work for 1Gbps Ethernet communication in the automotive environment

•Main limitation of optical system is due to temperature constraints

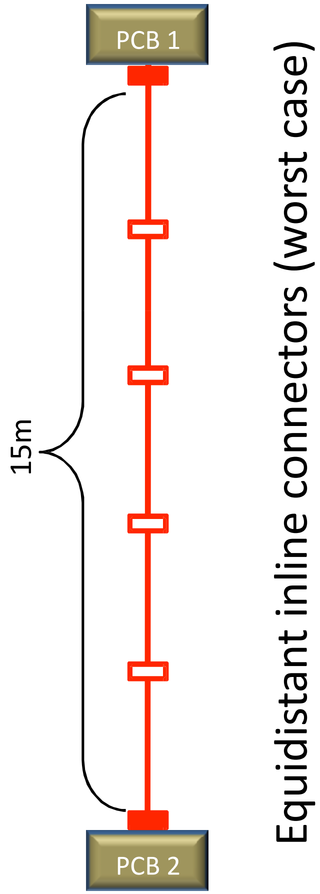
Optical system can be expected to be SOP ready 2 years earlier than electrical system

•Robustness of electrical system depends on the cabling. In case of UTP, EMC is the most critical aspect and symmetries need to be taken care of.

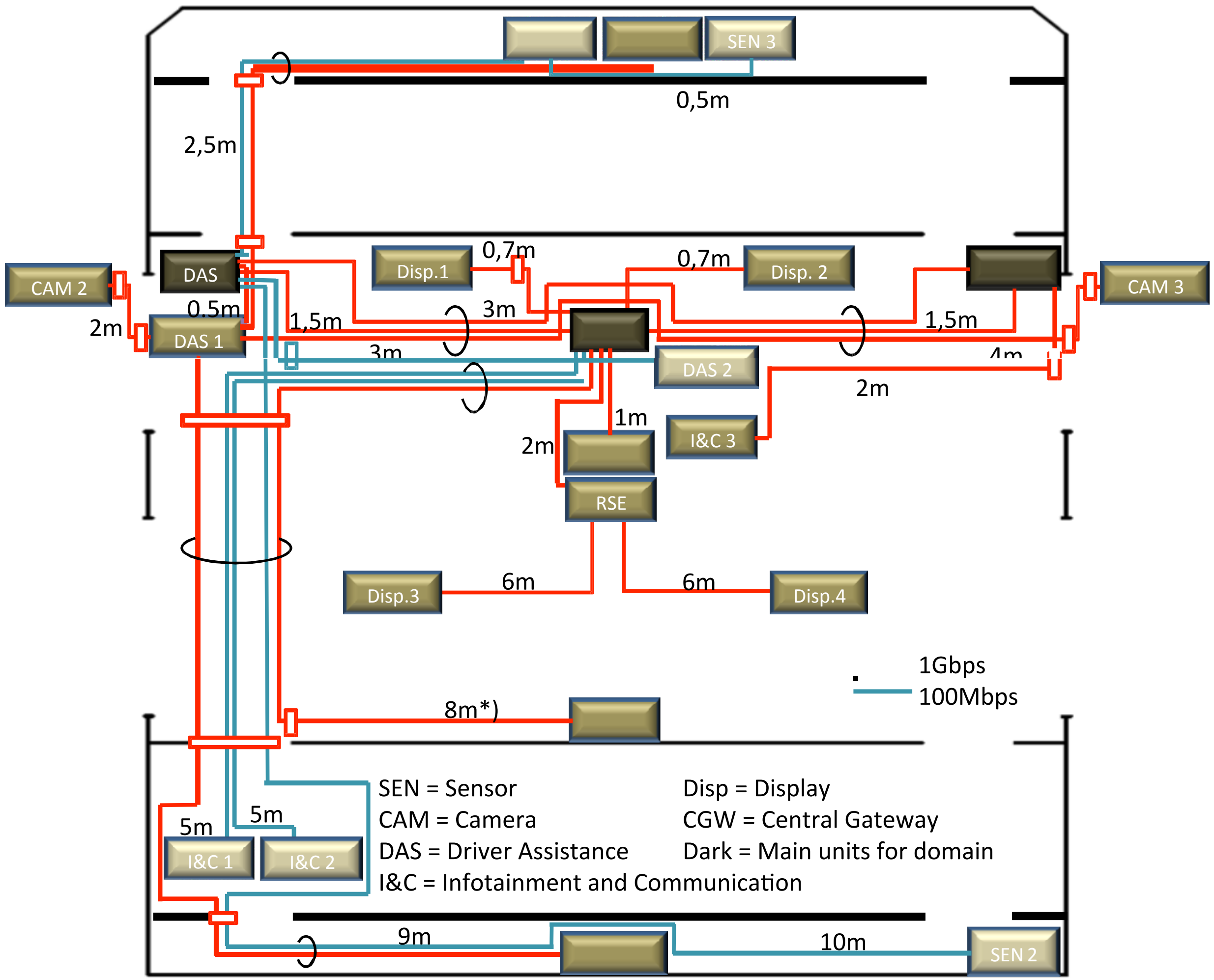
•The harness cost hierarchy can expected to be UTP without jacket < UTP with jacket < Coax ≈ optical (without FOT) < STP

Back Up Material
Input Data

Topology 1



Topology 2



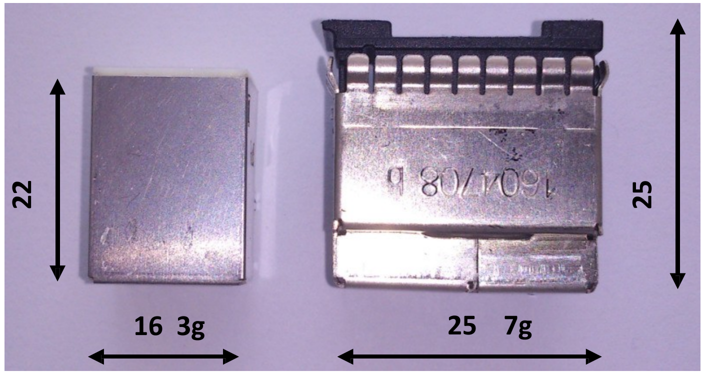
*) Average cable length for 1Gbps (not considering inline connectors) is 3,15m, 3,5m for Ethernet in general

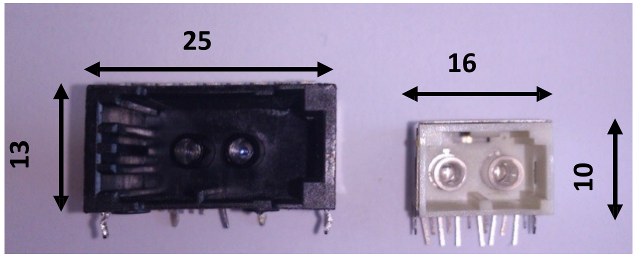
Base Data on Topology 2

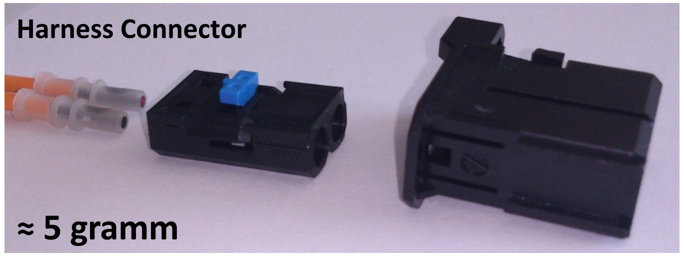
	Topology 2*)
Overall length of cabling [m]	50m
Number of links	16**)
Number of MDIs	32**)
Number of inline connectors	13
Number of cable segments	29
Number of PHYs	11
Number of Switches	5

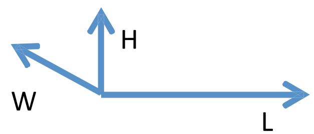
*) only 1Gbps
**) one redundant link

Optical Connector Values









ECU Investigated

Example Connections to I&C ECU

Type of connections	Number of those connections	Number of pins per connections	Number of pins	Connectors
power supply*)	1	2	2	multipin
analogue out*)	4	2	8	multipin
CAN	2	2	4	multipin
microphones	5	3	15	multipin
aux in	1	4	4	multipin
100 Mbps	2	3	6	multipin
other	10	1	10	multipin
Σ connectors/Pins	1-2		49	
To antennas	9	2	18	dedicated
USB	3	4	12	dedicated
Σ connectors/Pins	12			
Gbps	7	3/5	21/35	Tbd.

*) requires larger pins / pin spacing

Manufacturing Steps

UTP	UTP 	POF	POF 
Preparation for cutting		Preparation for cutting	
Cutting		Cutting	
Handling step		Stripping of jacket	
Stripping wire jacket		End face preparation	
Crimping of contacts		(Crimp or) Laser welding	
Connector assembly		Measurement of fiber position	
Coiling + handling		Measurement of attenuation	
Combine to wiring		Coiling + handling	
Fixing the wiring			
Test of harness 100%		Test in harness 100%	
Process effort ∑	**1,0**	**Process effort ∑**	