Analysis of Safety-critical Communication Protocols for On-premise SIL4 Cloud in Railways

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Agenda

- Introduction
- SIL4 Communication Requirements
- Railway-specific safety-critical Communication Protocols
- Potential SIL4 Communication Protocols
- Safe Communication Architecture for Railway Systems
- Comparision
- Conclusion

Introduction

Motivation

- Which communication protocols are suitable for on-premise cloud environments?
- Safety communication suitable for Safety Integrity Level up to SIL4.
- SIL4-Coud to support safety-critical applications.
- How SIL4-Applications can communicate safely with internal & external systems?

EN 50159 Compliant Protocols

Peer-to-Peer (e.g. RaSTA)

Publish-Subscribe (e.g. ?)

?

Traditional Railway architecture

Future on-premise SIL4 cloud

1. Requirements
2. Potential protocols
3. Integration in proposed system architecture

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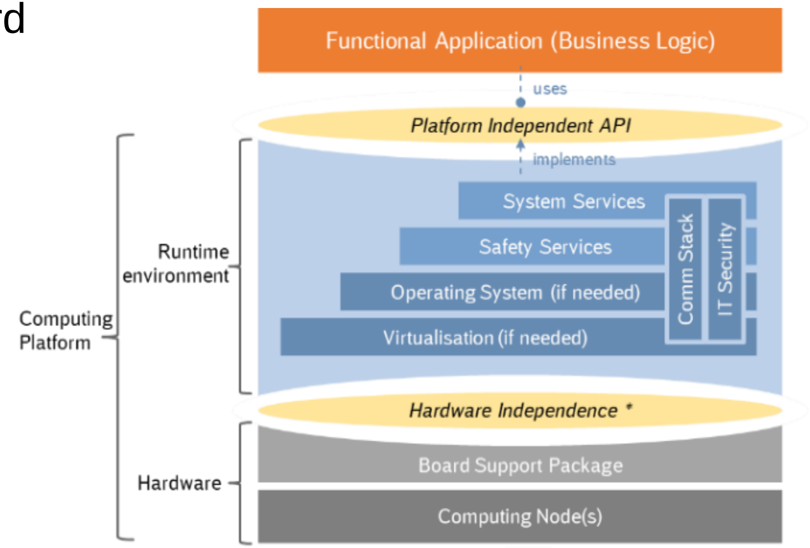
SIL4 Communication Requirements

Safe Computing Platform

- RCA and OCORA have initiated the work toward a functional Safe Computing Platform (SCP) architecture for a future rail system
  - for onboard and trackside functions
- Functional applications are decoupled from the underlying SCP and isolated from each other.
- PI API approach allows safety-critical railway applications to run unchanged on different SCP implementations

  → Maintaining application portability

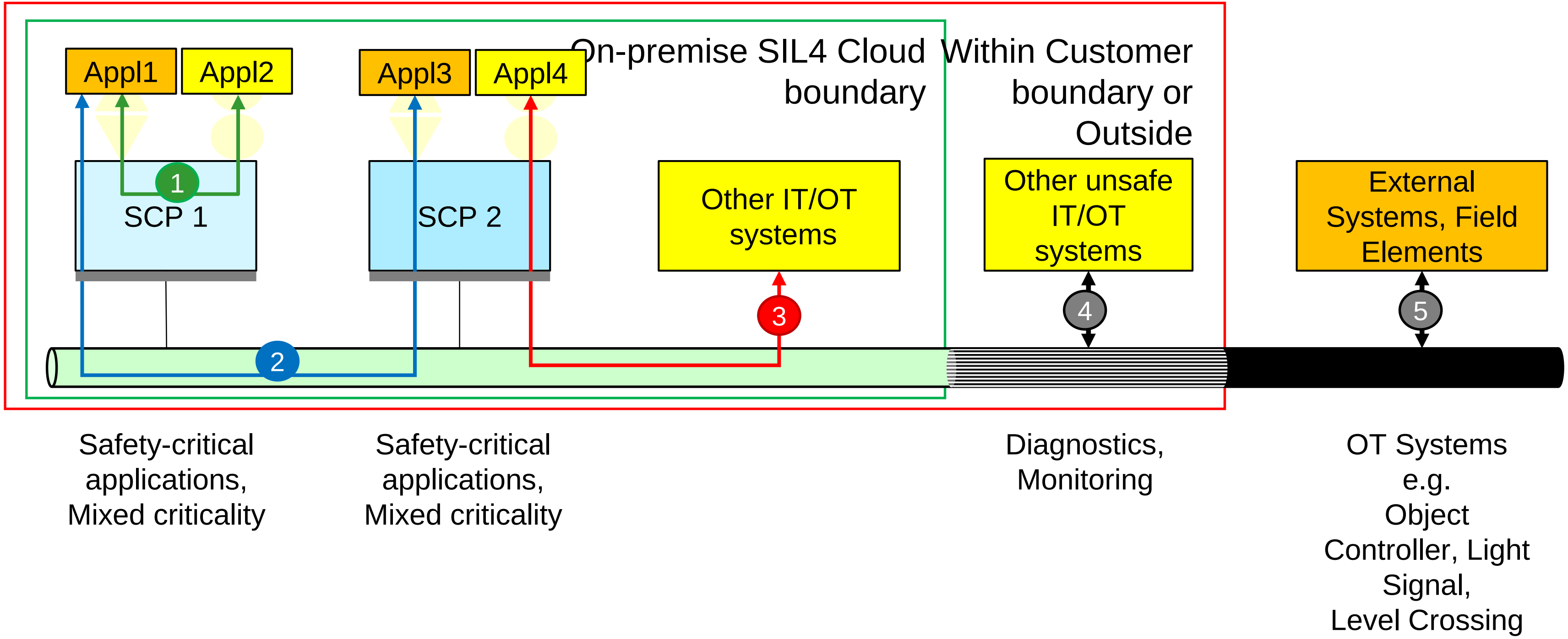


[1]

RCA - **R**eference **C**CS **A**rchitecture (RCA).
OCORA- **O**pen **C**CS **O**n-board **R**eference **A**rchitecture
CCS- Command Control and Signaling

SIL4 Communication Requirements

Communication Categories



SIL4 Communication Requirements

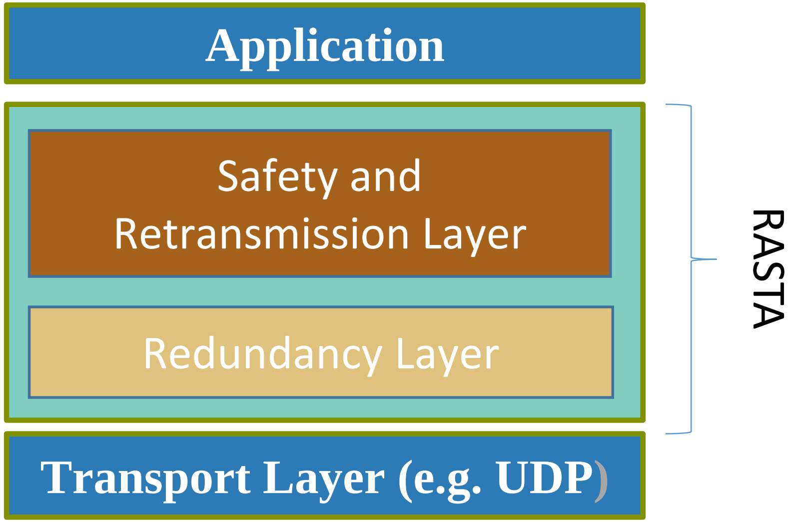
Requirements

- According to the OCORA requirements for the SCP, the following non-exhaustive list of requirements arise for future communication infrastructures:

Requirement	Description
R1	Communication protocol evolves independently from a specific computing platform realization
R2	Computing platform shall support point-to-point, point-to-multipoint and publish-subscribe communication model to support different application communication models
R3	Safe communication should be applied end-to-end, so that the whole communication link between remote functional applications can be considered safe.
R4	Safe communication protocols will be transparent to Functional Applications
R5	The computing platform provides a communication protocol which is based on open and standardized specification to achieve interoperability.

Railway-specific safety-critical Communication Protocols

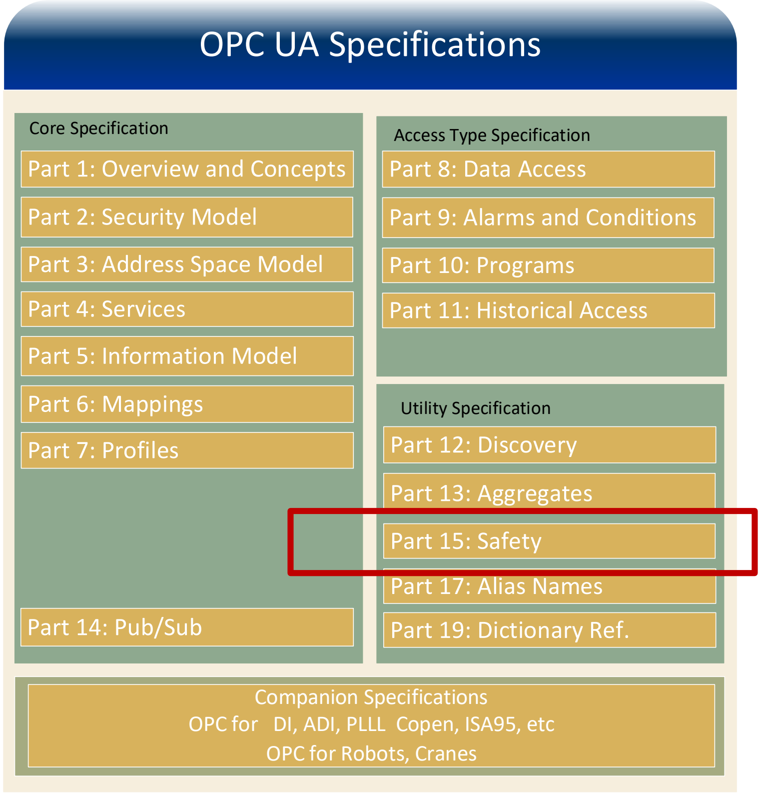
- RaSTA fulfills requirements of EN 50159
- Supports safe data transmission in networks classified as category 1 or 2 (according EN 50159)
- Transmission over cat 3 network →additional means of encryption need to be foreseen
- THALES: Protocol severely restricted in cloud environment
  - Reduced flexibility of P2P protocol
  - Limited integration of security functions
  - → Safe and secure protocols have to be investigated / designed in a cloud environment



Potential SIL4 Communication Protocols

OPC UA

- Set of specifications applicable to software development in industrial domains.
- Systems are intended to exchange information and to use command and control for industrial processes.
- OPC UA defines a common infrastructure model to facilitate this information exchange.
- The specification “OPC UA Safety” describes services and protocols for the exchange of data using OPC UA mechanisms.



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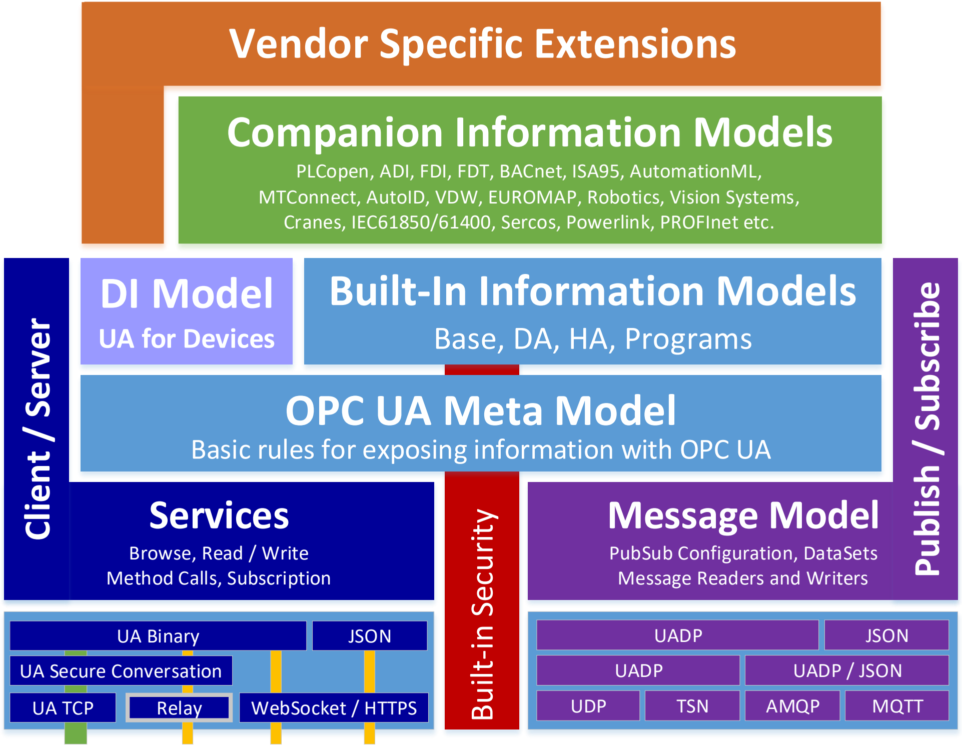
Potential SIL4 Communication Protocols

OPC UA

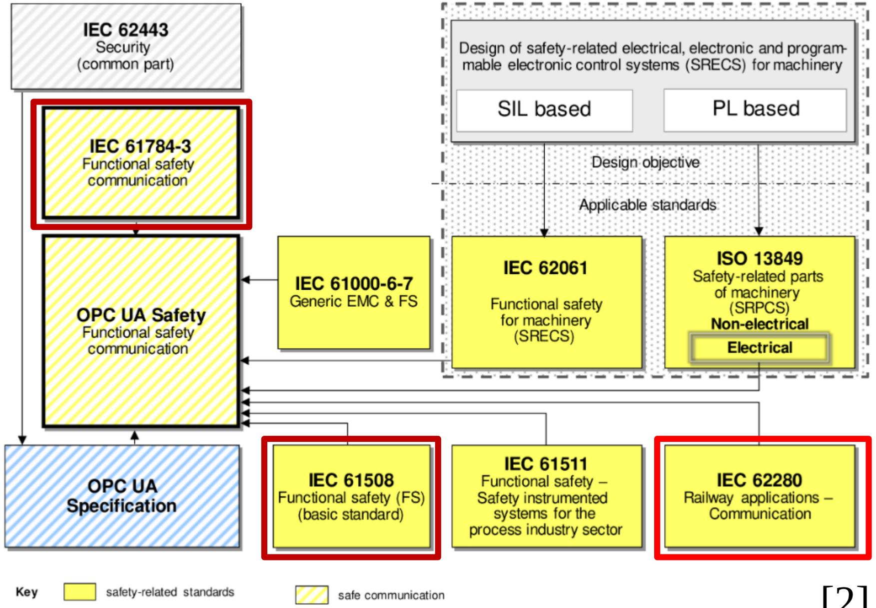
- OPC UA, is a *platform independent* **service oriented architecture** that integrates all the functionality of the individual OPC UA specifications into one extensible framework.



Potential SIL4 Communication Protocols

OPC UA

- OPC UA Safety extends OPC UA to fulfill functional safety requirements as defined in the IEC 61508 and IEC 61784-3 standards.
  - IEC 61508 is the basis of many derived standards in functional safety context therefore it should be considered as feasible to use OPC UA Safety as well in railway domain
  - IEC 62280 (EN50159)



[2]

"OPC UA Safety specifies a safety communication layer (SCL) allowing safety-related devices to use the services of OPC Unified Architecture (OPC UA) for the safe exchange of safety-related data." [2]

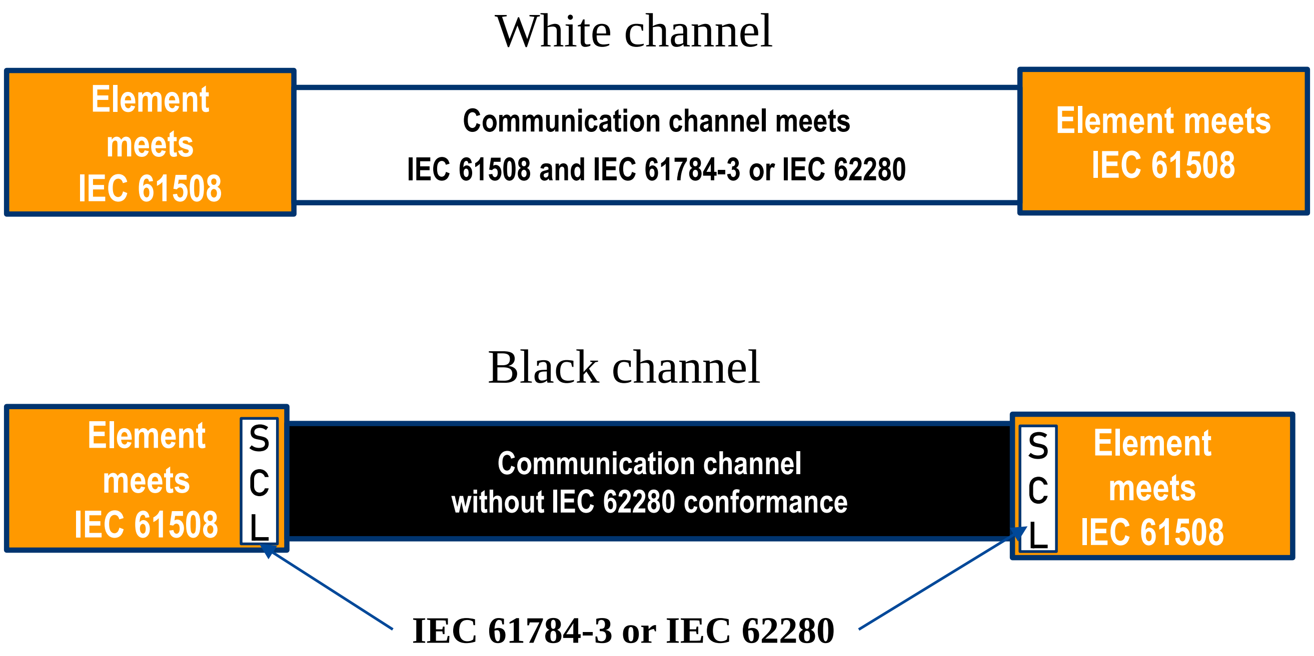
Potential SIL4 Communication Protocols

DDS

- Open standard DDS middleware provides a data centric connectivity framework
  - based on a publish-subscribe model for a real-time system
- DDS-RTPS protocol: (real-time publish-subscribe)
  - enables seamless interoperability across vendor implementations, programming languages and platforms.
- DDS enables modular application development and reliable and real-time data exchange
- QoS mechanism to ensure reliability
  - detect communication errors i.e. lost messages, data corruption
- Additional features for security: access control, data flow path enforcement and data encryption

DDS's comprehensive QoS and security mechanisms make it a potential candidate for safe communication in railways.

Black communication channel

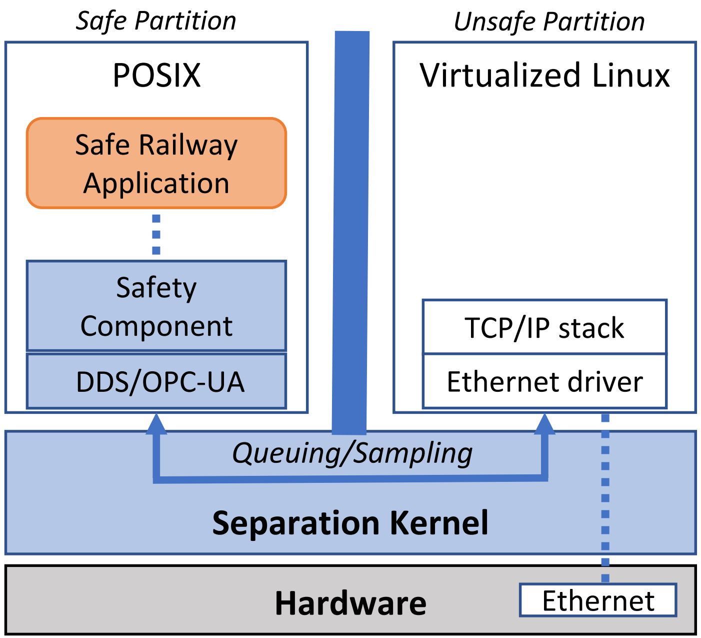


SCL: safe communication layer

Source: https://www.functional-safety.solutions/

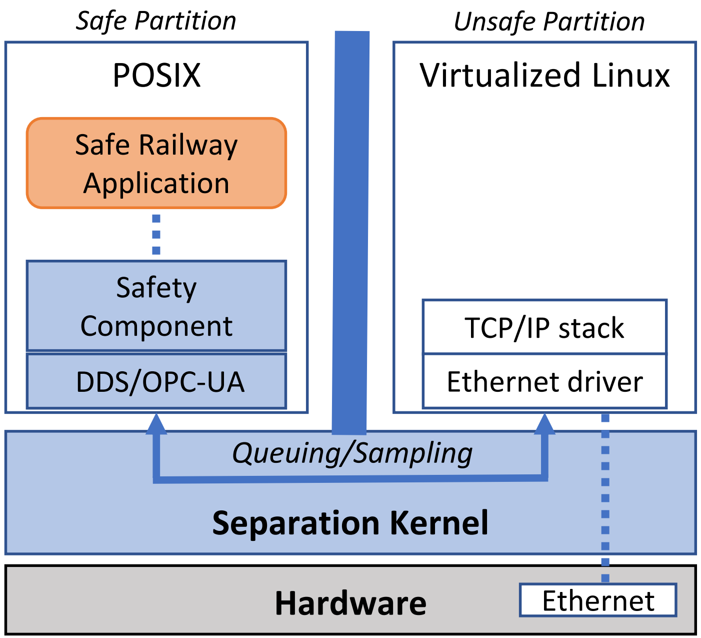
Safe Communication Architecture for Railway Systems

- Safe partition
  - communication middleware such as DDS or OPC UA
  - with a POSIX runtime
  - along with the safety-critical railway application,
  - and safety component
- Unsafe partion
  - TCP/IP stack and Ethernet driver inside an unsafe virtualized Linux partition
  - which provides the black channel
- Separation kernel
  - isolates the safety-critical partition from the non-safety-critical partition
  - applications running inside these partitions are allowed to communicate via inter-partition queuing/sampling ports provided by the separation kernel.



Safe Communication Architecture for Railway Systems

- DDS/OPC UA middleware framework running inside the safe partition on a separation kernel provides a Modular Open Systems Approach (MOSA)
- It creates a common data communication framework for railway applications that can communicate across any data transport while providing fault tolerance, resiliency and security



Comparation of OPC UA and DDS

Basic Features

DDS

- Publish Subscribe Pattern
- Data Centric Approach
- Guaranteed Real Time Response
- Relational Data Model
- Easy Integration of Software Modules

OPC UA

- Client Server & Publish/Subscribe
- Device Centric

- Object Oriented Data Model
- Simpler Software for Device Interchangeability

Comparison of Safety Protocols

	RaSTA	DDS	OPC UA Safety
Communication Pattern PubSub architecture	P2P	PubSub, Point-to-Multipoint	PubSub, Point-to-Multipoint
EN 50159 key properties (Authenticity, Integrity, Timeliness, Sequence)	supported	supported	supported
Open Standard with strong international support	No (used in Railway industry)	Yes	Yes
Safety features (excerpt)	- Black channel principle - Detection of communcation errors	- Black channel principle - Changing communication partner during runtime - Detection of communication errors	- Black channel principle - Changing communication partner during runtime - Detection of communication errors - Safety multicast
Security features	Limited (Secure Code)	Extensive (Authentication, access control, cryptography, logging)	Adequate (Secure Channel)

Evaluation

- Proposed safe communication architecture fulfils all requirements R1 to R5 with the integration of potential SIL4 communication protocols
  - support different communication pattern with the integration of DDS and OPC UA Safety (R2)
  - allows for changing the safety communication partners at runtime by transparently exchanging data (R4)
- DDS and OPC UA protocols are based on an open standard and have strong international support (R5)
- By covering the EN 50159 key properties, they are potential candidates for the railway sector
- With suitable safety measures, which have to be integrated into the application appropriately, OPC UA and DDS are able to support communications up to SIL4 (R3)
- OPC UA supports semantic interoperability and large-scale application scenarios and is therefore suitable for EN 50159 category 1 and 2 networks

Conclusion

- Comparison of potential application layer communication protocols from industrial domains with a railway-specific safety-critical protocols
- OPC UA and DDS protocols have the potential to be used in on-premise SIL4 cloud for safety-critical communication
- Safe communication architecture for railway was presented
- Safety-critical communication protocols needs to be examined further

Thank you for your attention

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References

[1] An Approach for a Generic Safe Computing Platform for Railway Applications, https://github.com/OCORA-Public/, (accessed Jan. 28, 2022).

[2] OPCFoundation, “OPC 10000-15 Unified Architecture Part 15 Safety,” OPC UA Online Reference. https://reference.opcfoundation.org/v104/Safety/docs/ (accessed Apr. 04, 2022).

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