TECHNISCHE UNIVERSITÄT DRESDEN

DRESDEN concept

Prof. Martin Wollschlaeger

Smart Manufacturing – Smart Communications?!

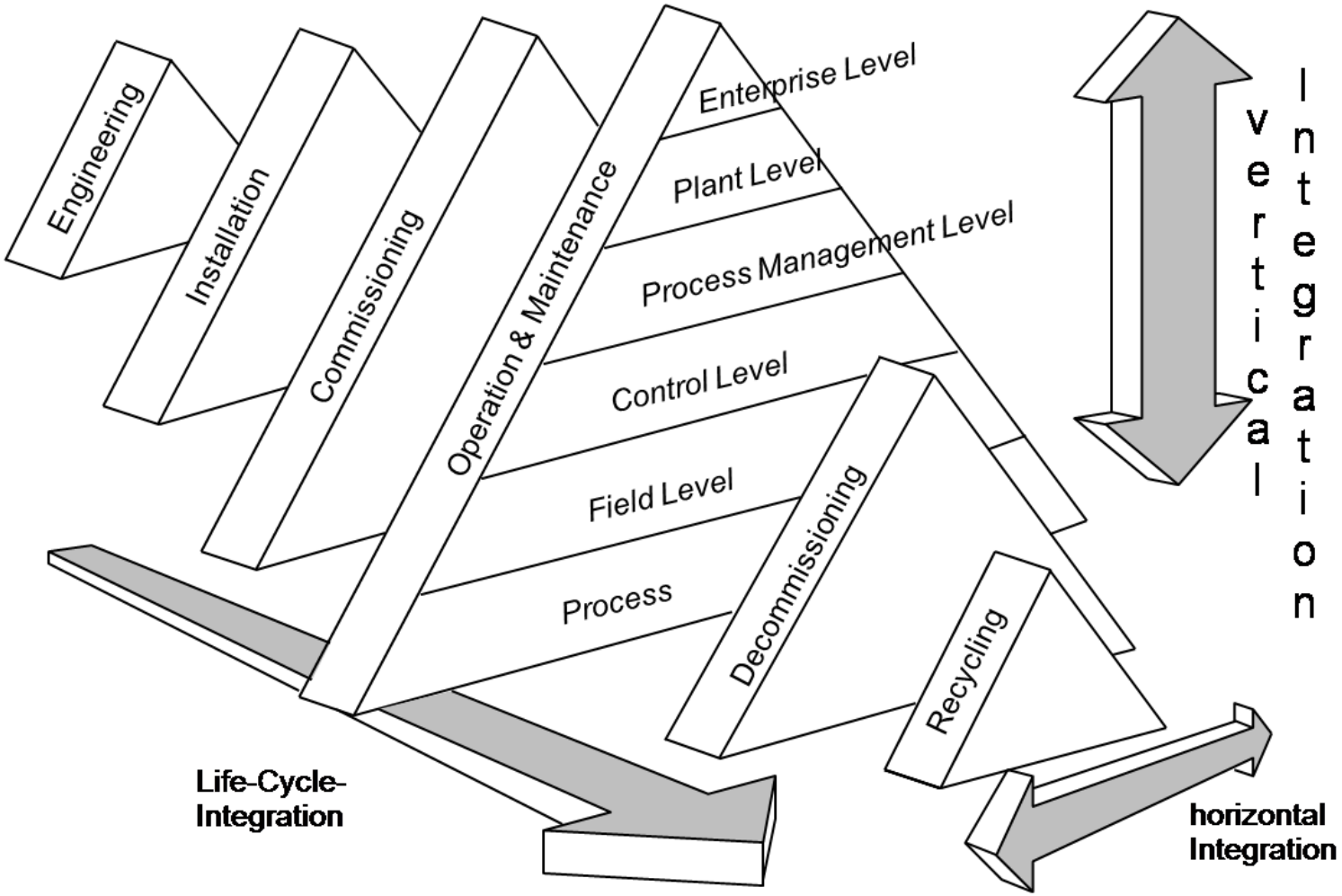
Automation networks in the area of conflict between technological development and user requirements in industry

Industrial Communications

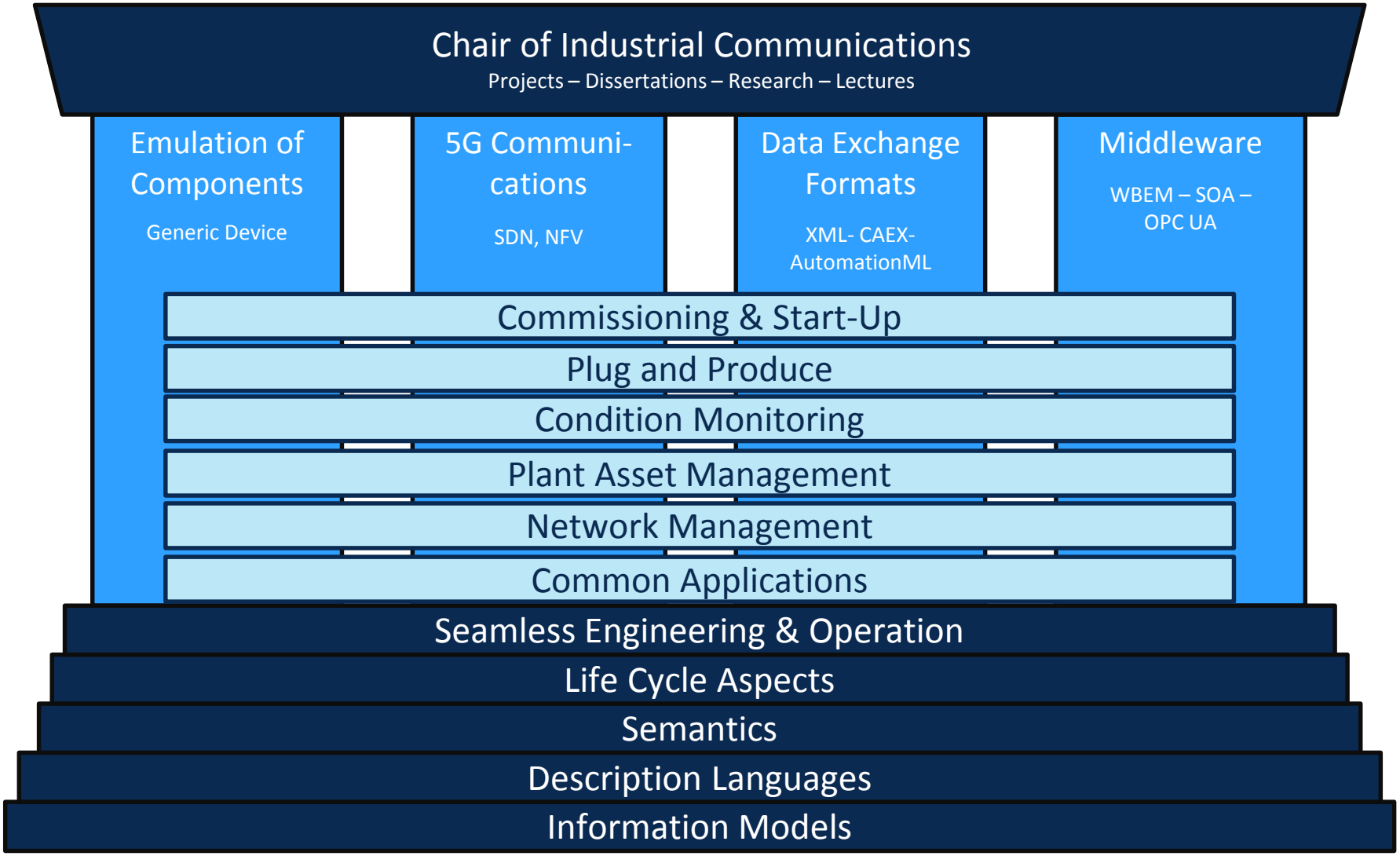
Faculty of Computer Science

TU Dresden

Integration in Automation



Industrial Communications – Research Areas



Industrial Communications – Working Groups

C3 Application Profiles, I&M-Functions, Profile Guideline
C3/PG15 Condition Monitoring
Ad-Hoc Group PG3 I4.0@PI

AK Systemaspekte
AG Manufacturing Execution Systems
Führungskreis Industrie 4.0
SG Modelle und Standards
Plattform I4.0 UAG Netzkommunikation
AK IT in Automation

DKE 931.0.2 Unternehmensmodelle
DKE 931.0.12 Life Cycle Management
DKE 931.0.13 Condition Monitoring
IEC TC65 / WG19 Life Cycle Management
IEC TC65E / WG11 Condition Monitoring

GMA 5.16 Middleware
GMA 6.15 Zuverlässiger Betrieb
Ethernet-basierter Bussysteme
GMA 7.21 Industrie 4.0

VDMA Work Group „Feldbusneutrale Referenzarchitektur für Condition Monitoring in der Fabrikautomation“

Sino-German SWG I4.0 – Predictive Maintenance

EFFRA, 5G PPP (Factories of the Future Requirements)

Outline

Introduction

State of the art

Scenarios

Requirements

Functional viewpoint & deployment

Network Mapping

Industrie 4.0, Network as an asset

Current Developments

Standardization

Conclusions

Wollschlaeger, M.; Sauter, T.; Jasperneite, J.: Industrial Communication. The Future in the Era of the Internet of Things and Industry 4.0. Published in: IEEE Industrial Electronics Magazine (Volume: 11, Issue: 1, March 2017), pp 17 – 27, DOI: 10.1109/MIE.2017.2649104

Kommunikation im Industrie-4.0-Umfeld. Whitepaper, ZVEI https://www.zvei.org/fileadmin/user_upload/Presse_und_Medien/Publikationen/2018/April/Kommunikation_im_Industrie-4.0-Umfeld/Kommunikation_im_Industrie-4.0-Umfeld_Download-Neu.pdf

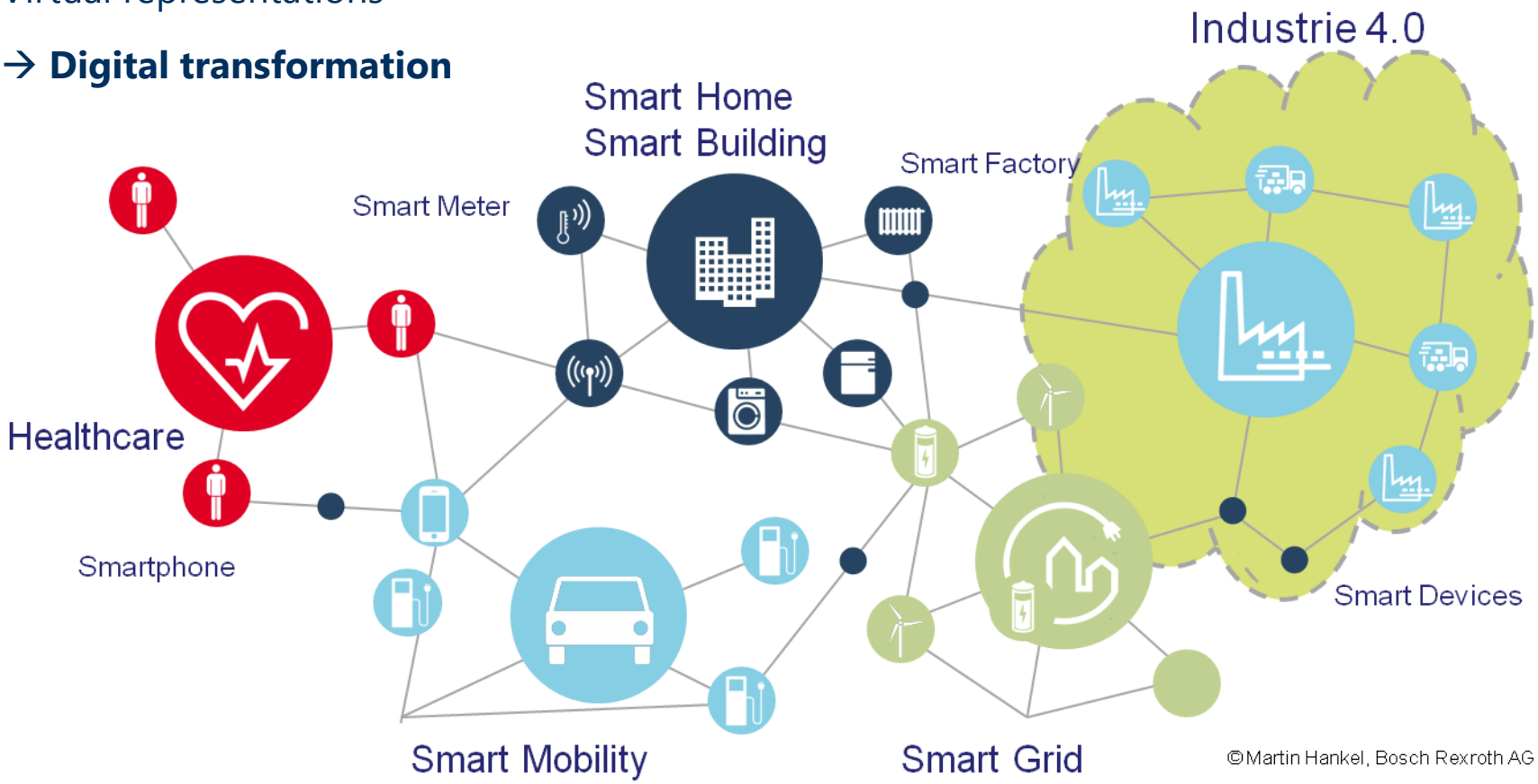
Application Scenarios of Industrial Internet of Things

Everything connected

Data-driven approaches

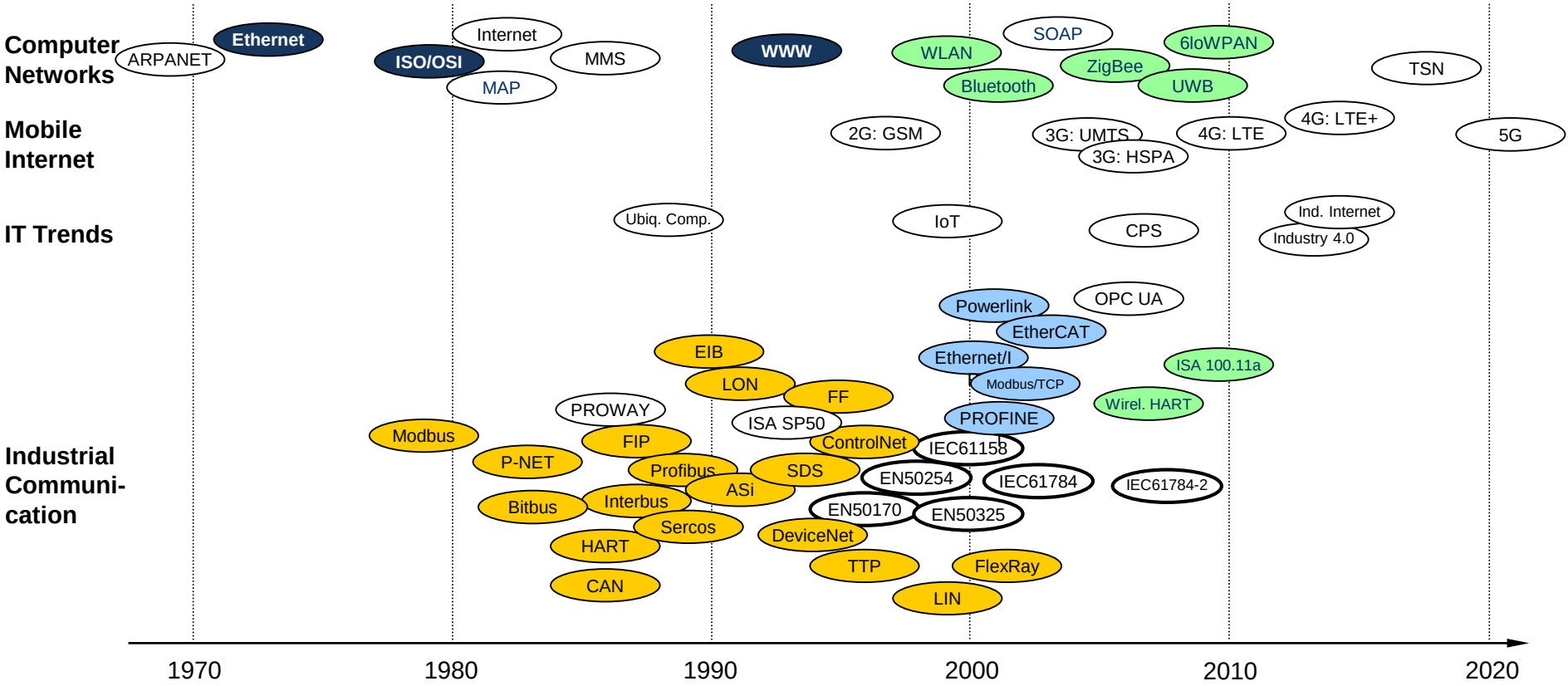
Virtual representations

→ **Digital transformation**



Development of (Industrial) Communication

Long history of specific solutions, from “fieldbus war“ to 5G



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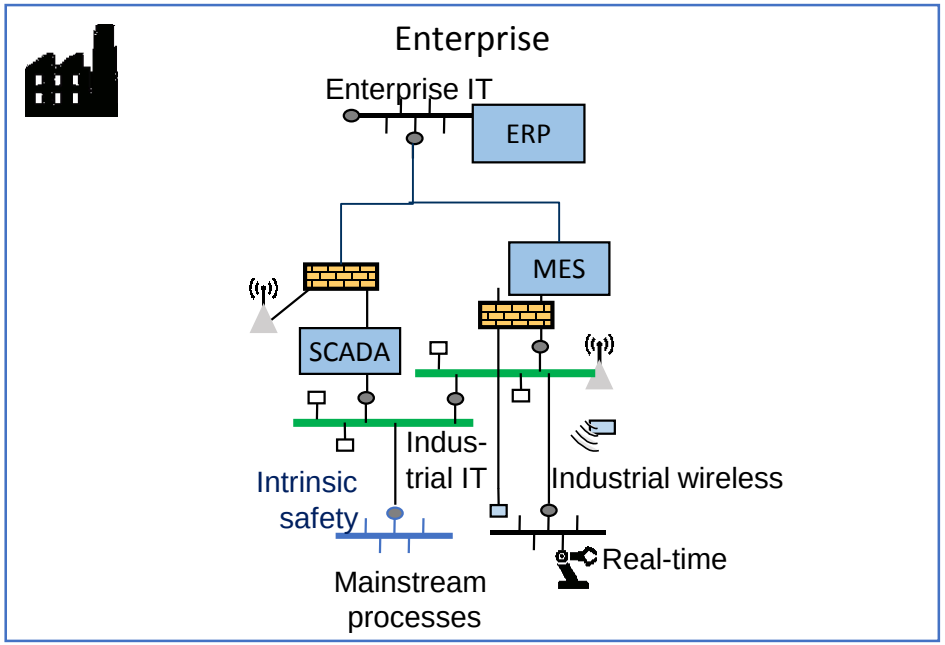
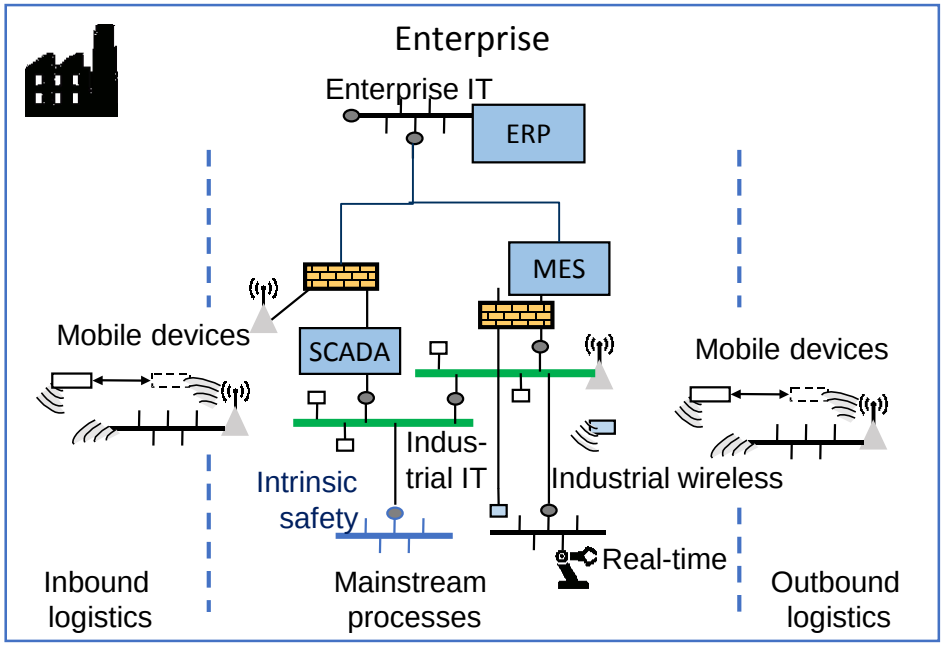
The complexity of communication in industrial automation systems

Why are there so many specific industrial solutions?

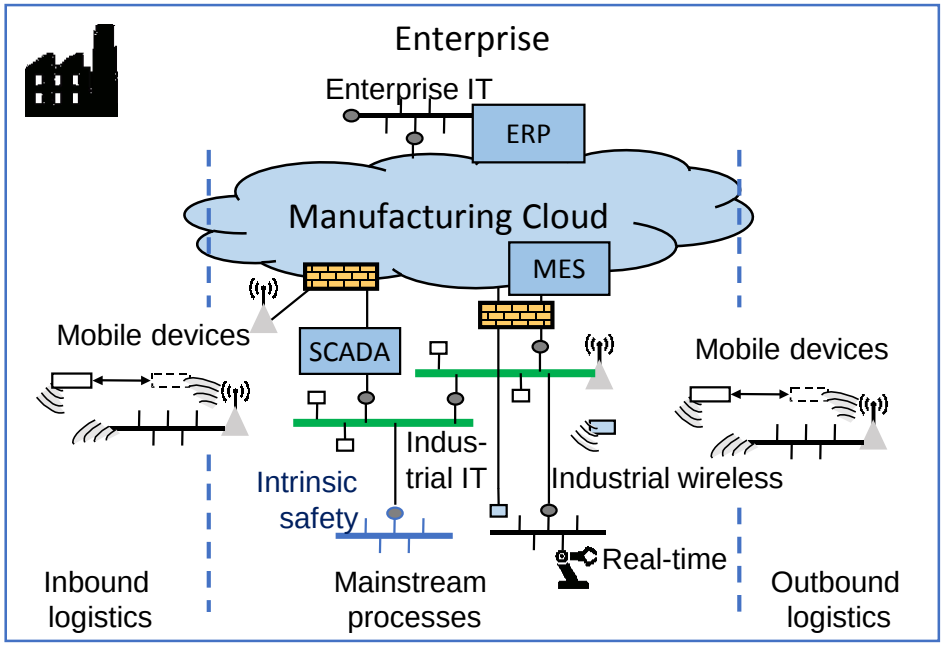
- Requirements are different
- History
- Market
- …



The complexity of communication in industrial automation systems



The complexity of communication in industrial automation systems



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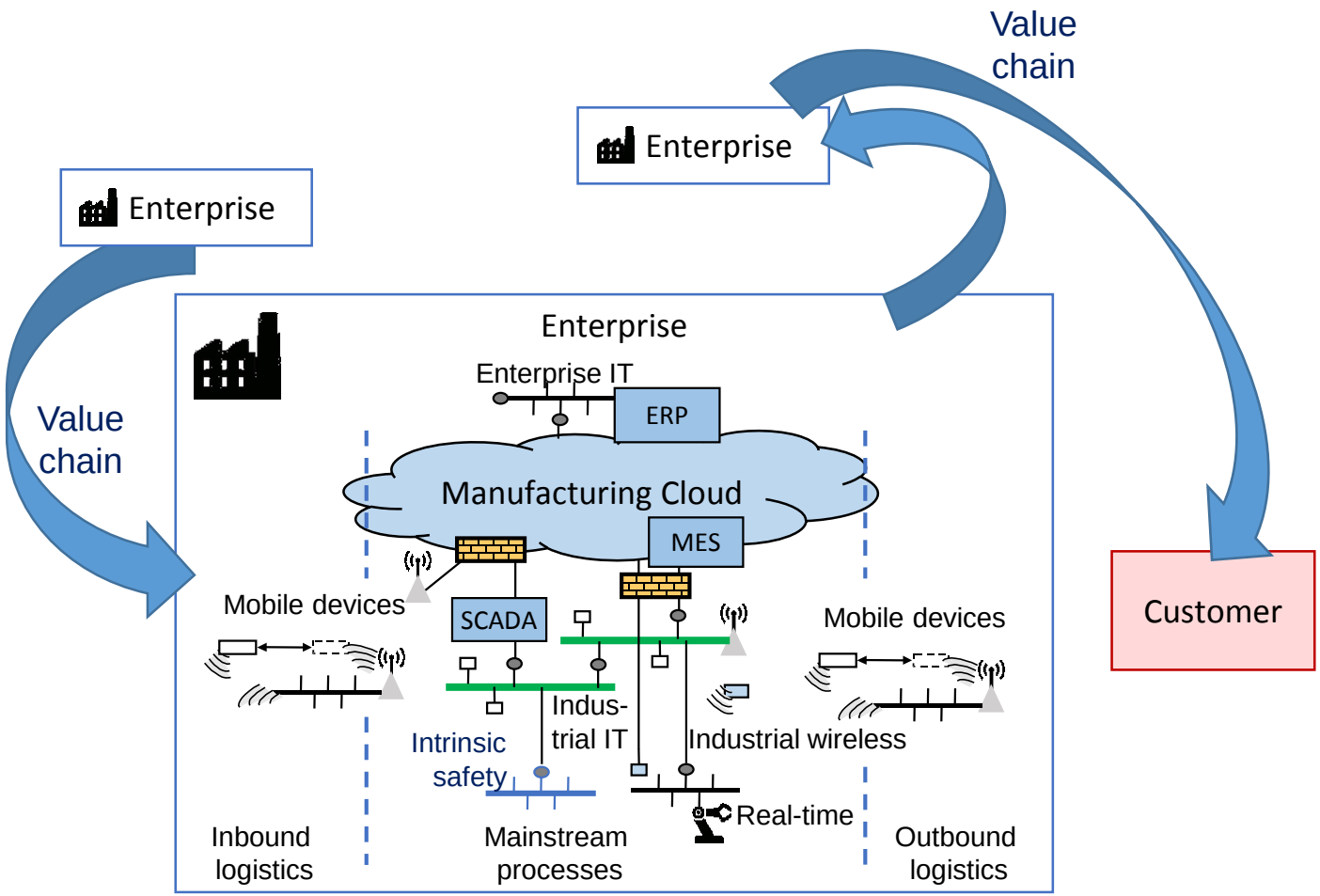

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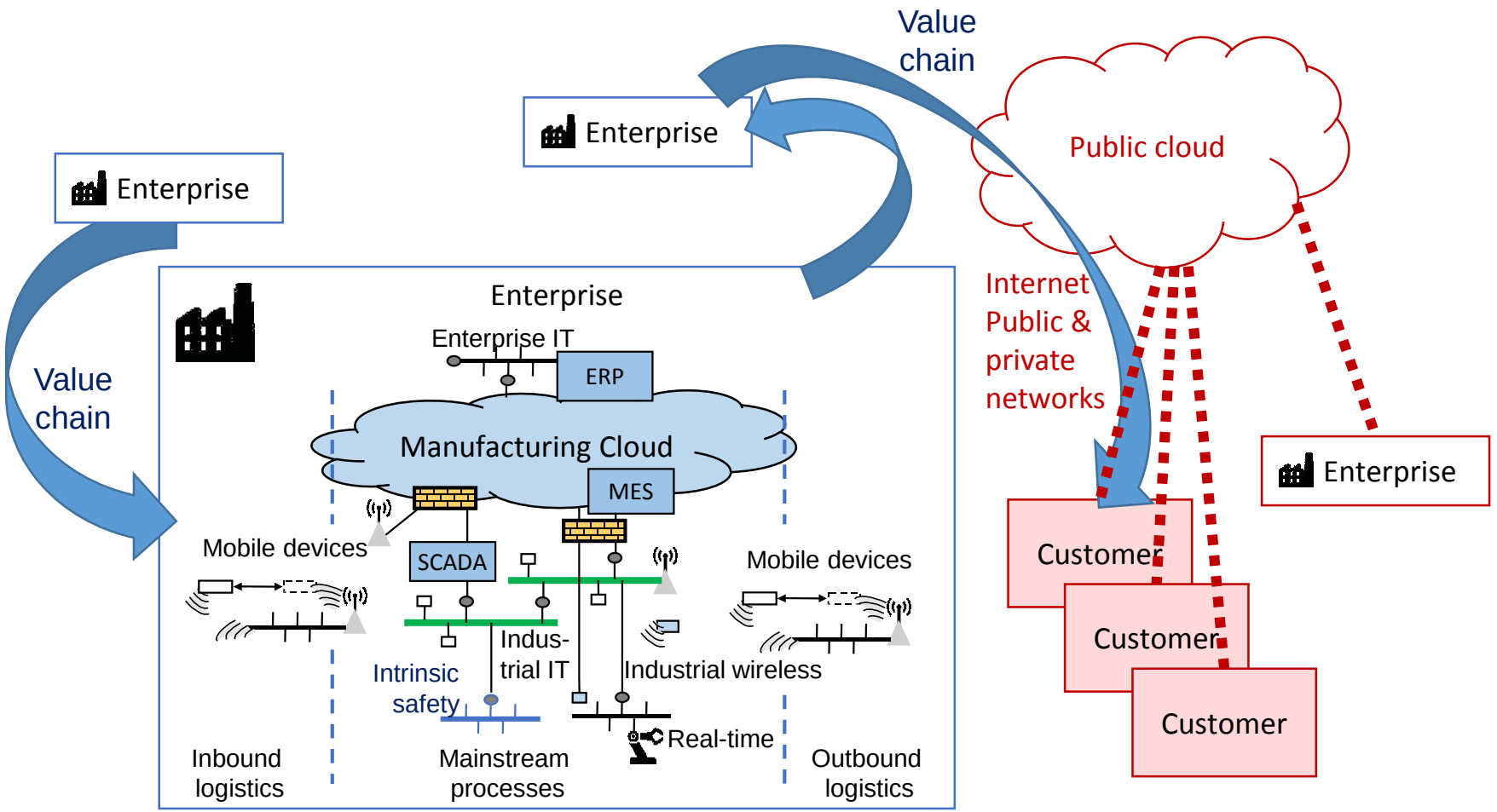

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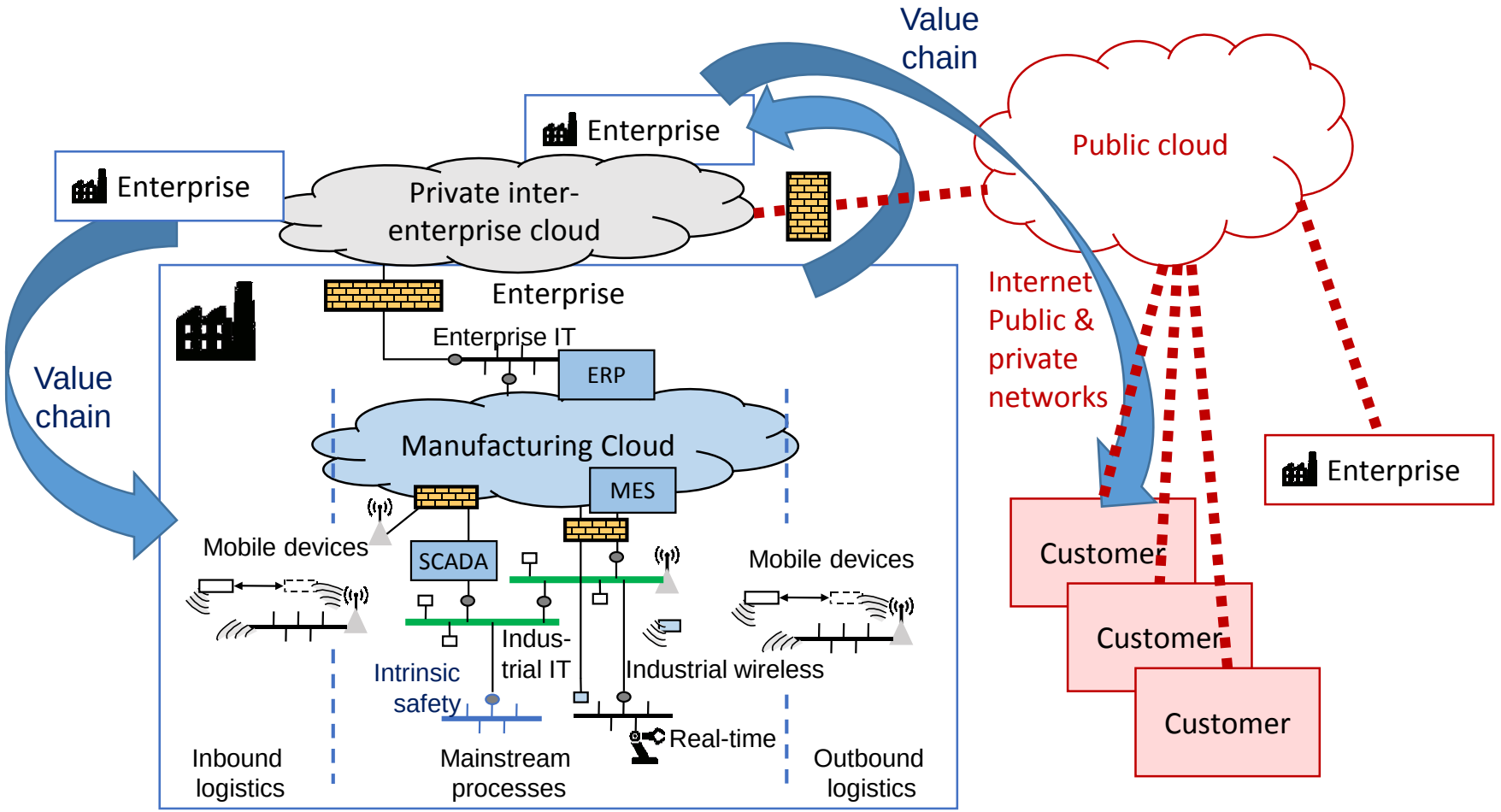

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Deriving Requirements

Requirements depend on **application**

- Functionality
- Environment

Requirements depend on **user role**

- End user
- System integrator
- manufacturer

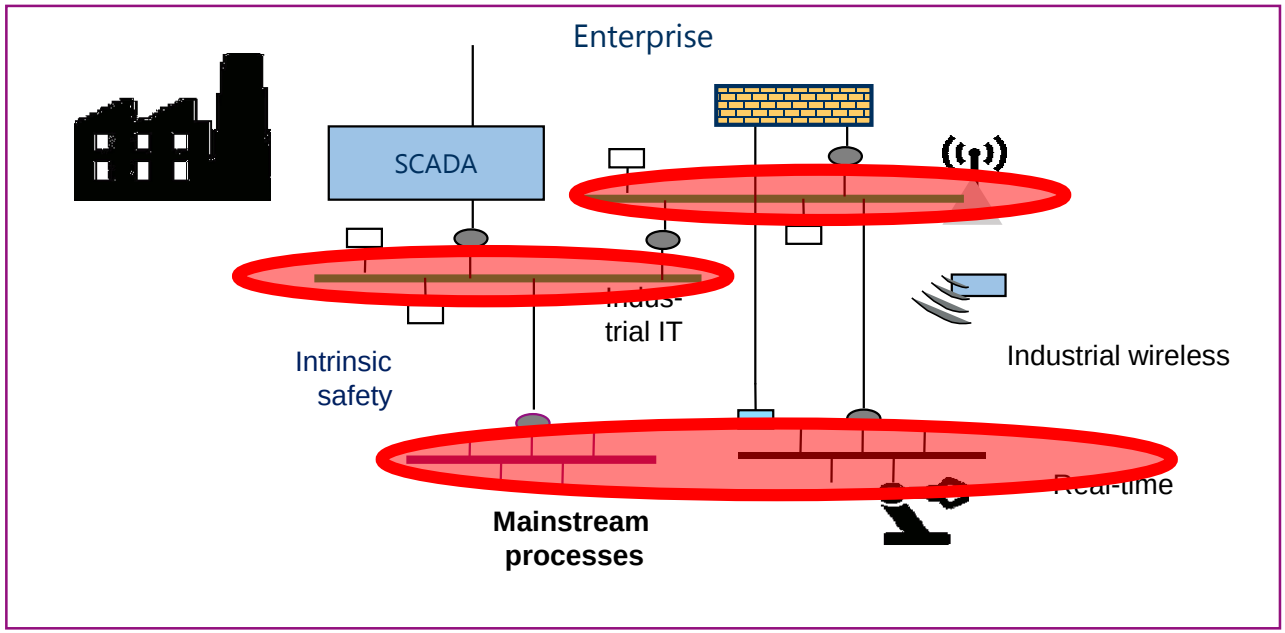
Scenarios can be used to define specific requirements

Examples:

- Scenario 1: “Real-time data communication in flexible production systems”
- Scenario 2: “Communication for engineering and asset management”
- Scenario 3: “Product data communication over the life cycle”

Scenario 1:
“Real-time data communication…”

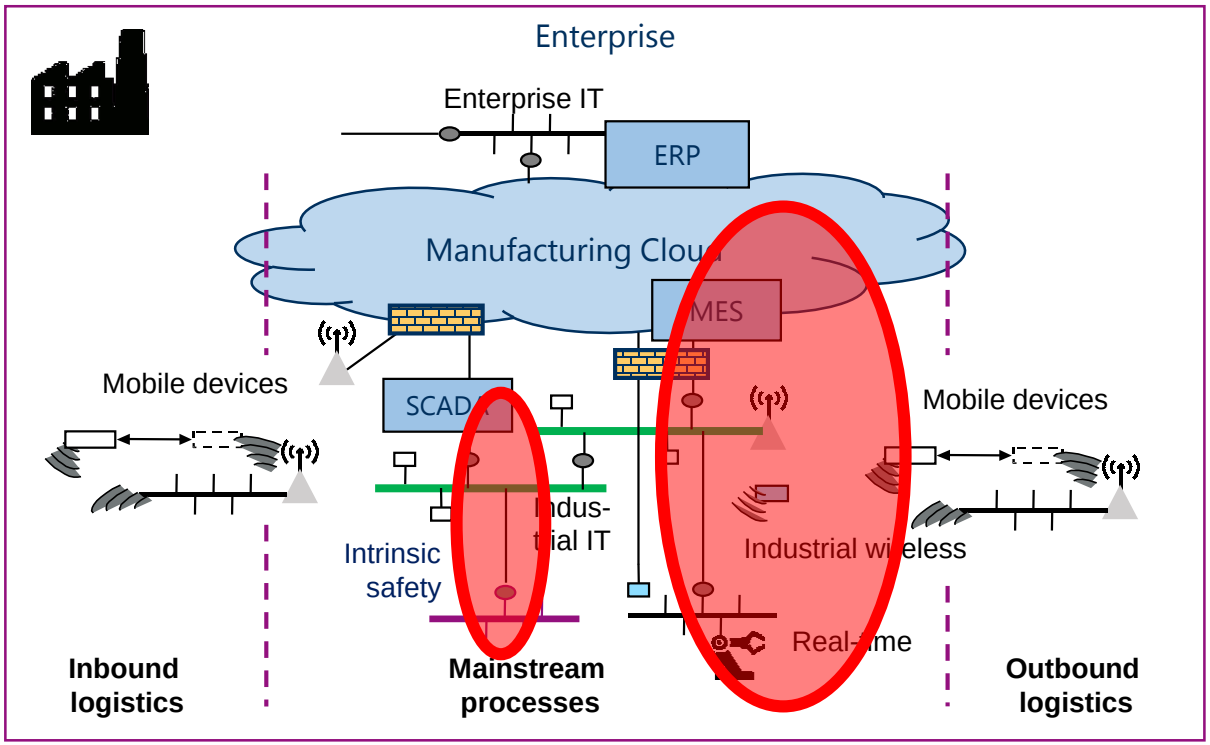
- Mainstream process
- Data exchange in open and closed loop control
- Real-time guarantees
- Jitter-free application
- Redundancy
- Availability



- Today: industrial networks (fieldbus, Industrial Ethernet, Industrial Wireless)
- Tomorrow: industrial networks (fieldbus, Industrial Ethernet, Industrial Wireless, Industrial 5G, Industrial IoT protocols)

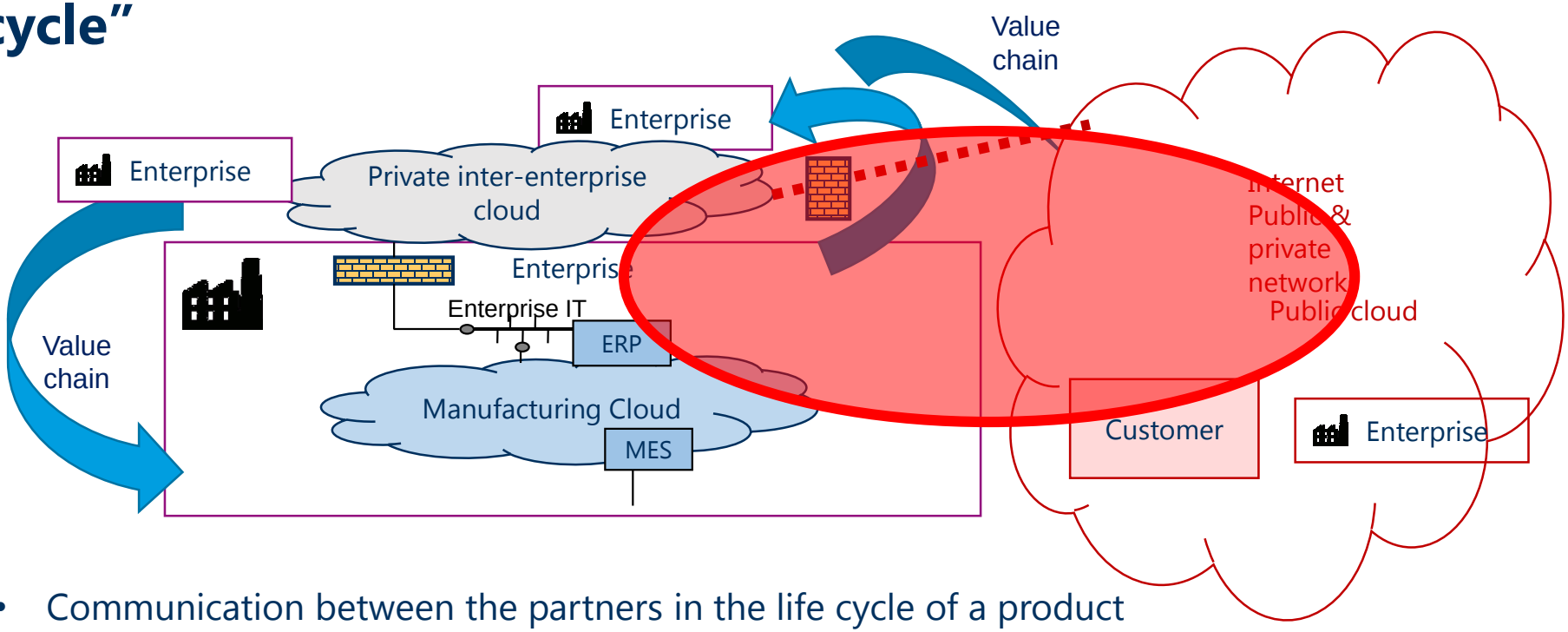
Scenario 2:
"Communication for engineering and asset mgnmt."

- Mainstream and logistics processes
- Data exchange for configuration
- Data-driven applications
- A-cyclic communication
- Session management
- Guaranteed delivery Confirmed services
- Information model access



- Today: industrial networks, IT networks
- Tomorrow: industrial networks, IIoT, Business layer protocols (MQTT etc.)

Scenario 3: “Product data communication over the life cycle”



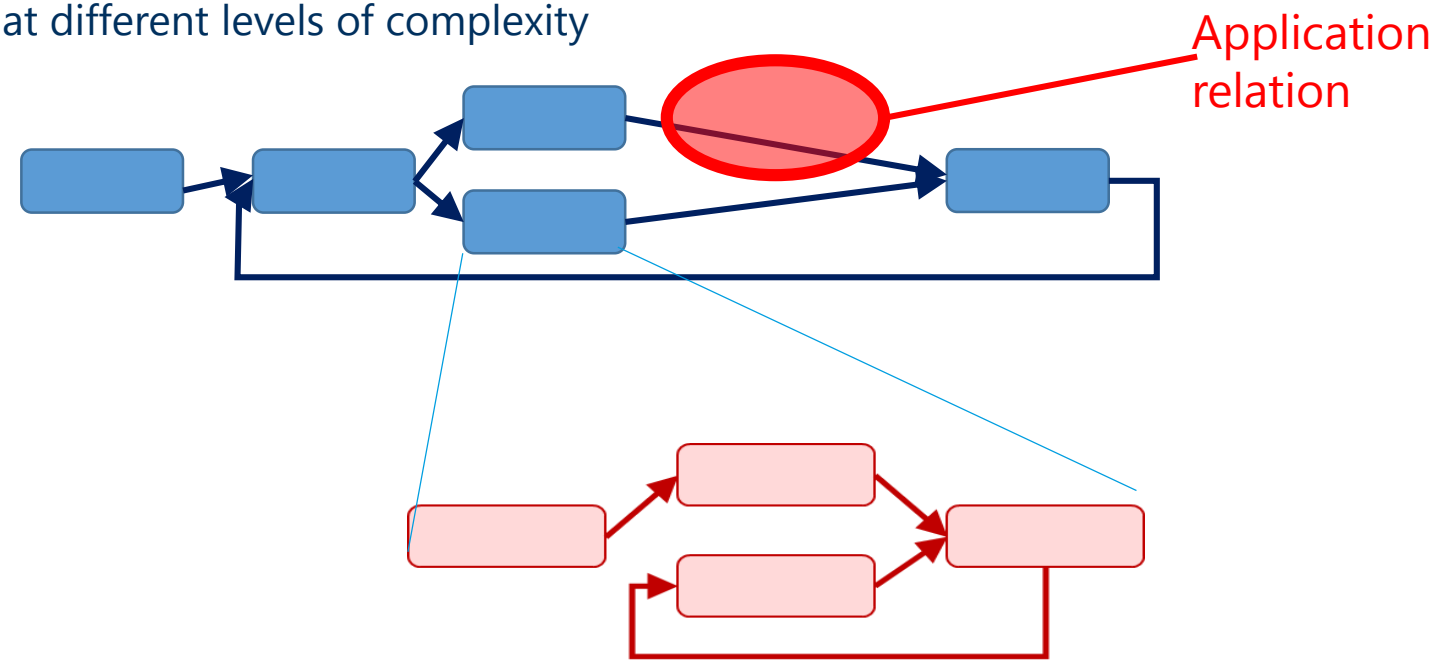
- Communication between the partners in the life cycle of a product
- Bulk data handling, time stamping
- Access to context-related data, information model access

- Today: IT networks
- Tomorrow: industrial networks, IT networks, IoT, SOA, ???

Functional Viewpoint

Application can be seen as a orchestration of functions (→ IEC 61131, IEC 61499)

Functions at different levels of complexity



Functions define **application relations**

Application relations define requirements for data exchange

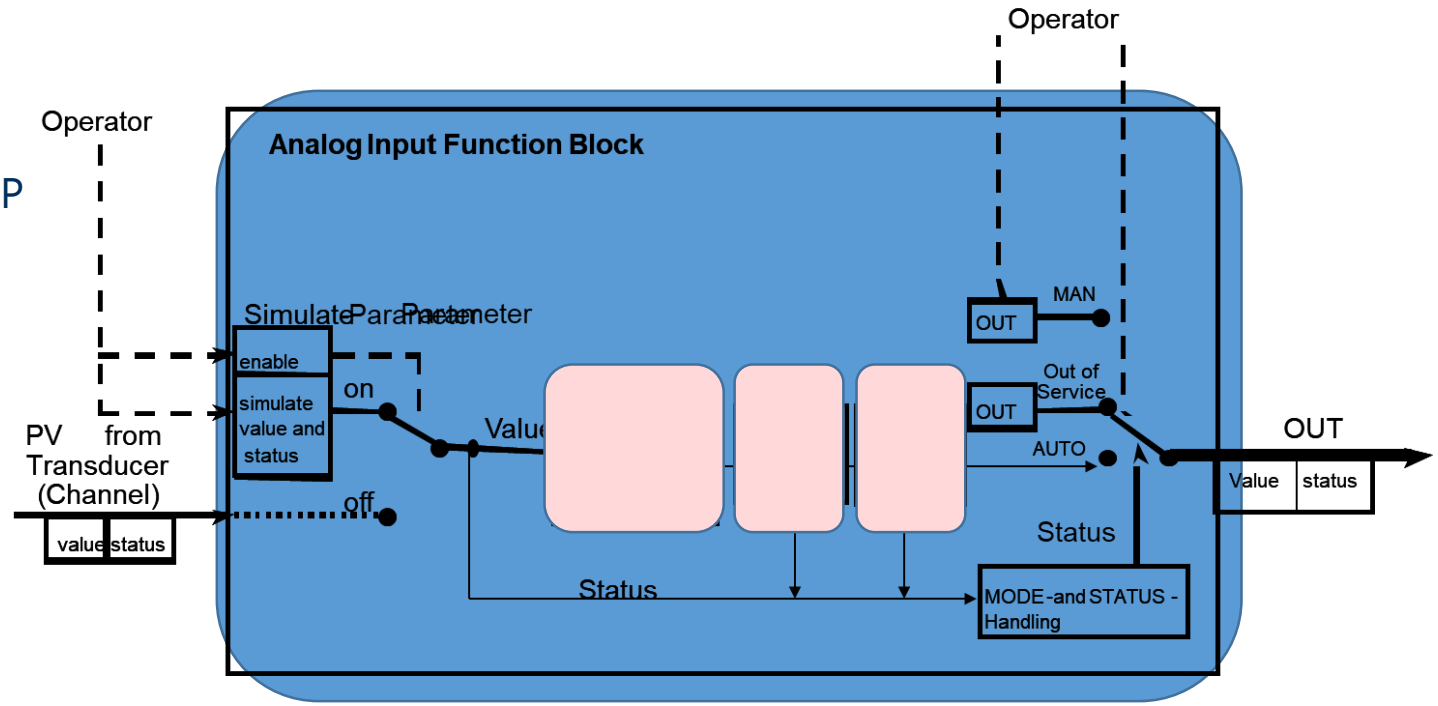
Mapping of Functions to Resources (Deployment)

Mapping to networked ressources

- pre-implemented in firmware (IEC 61804) or fully flexible (IEC 61131, IEC 61499)

Resources residing at different levels of an infrastructure

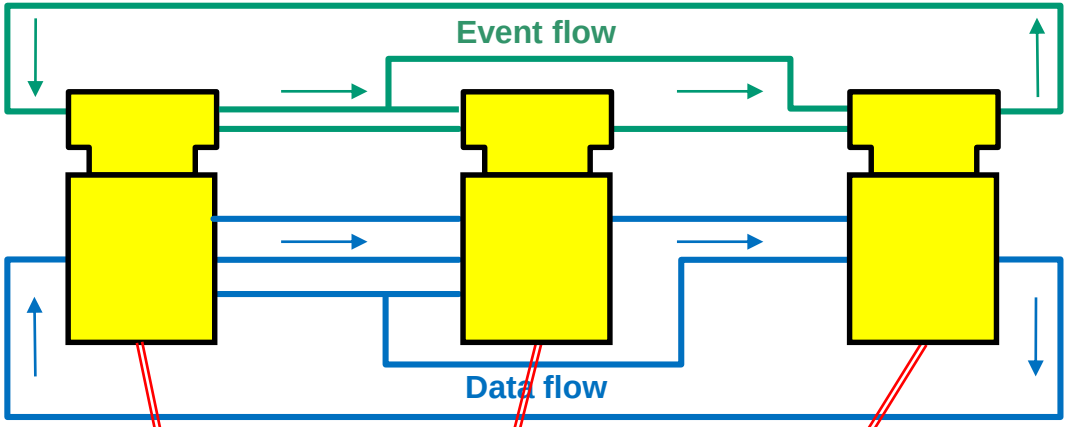
- Field devices
- PLCs
- Edge devices
- SCADA, MES, ERP
- Cloud



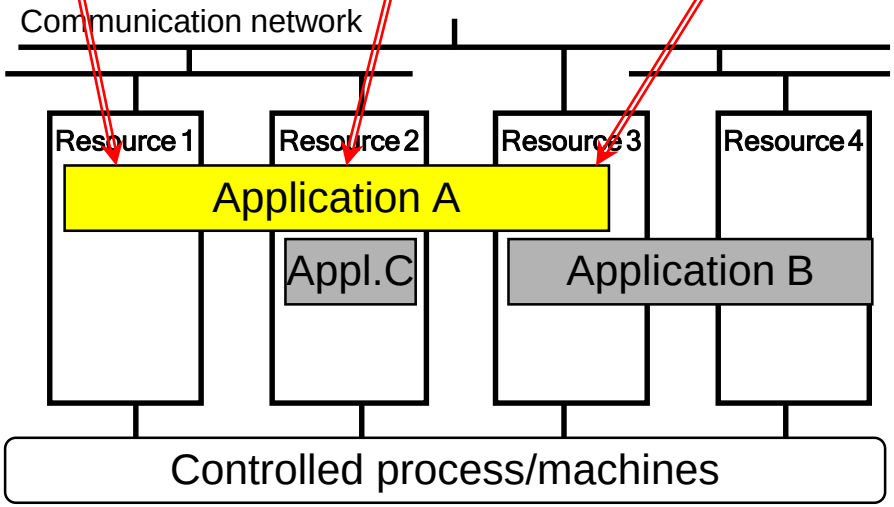
PROFIBUS PA Profile, PROFIBUS International

Remark: IEC 61499 Distributed System Architecture

- Application = Function Block Network



- System = Communication Network + Resources + Process/Machines



Based on IEC 61499

Deployment of Functions lead to Requirements for Communication

Communication is increasingly heterogeneous

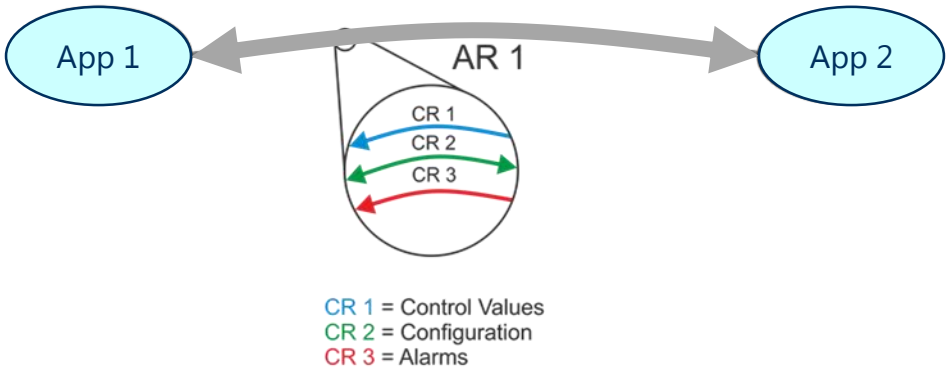
Communication has to **fulfill the application rerquirements**!

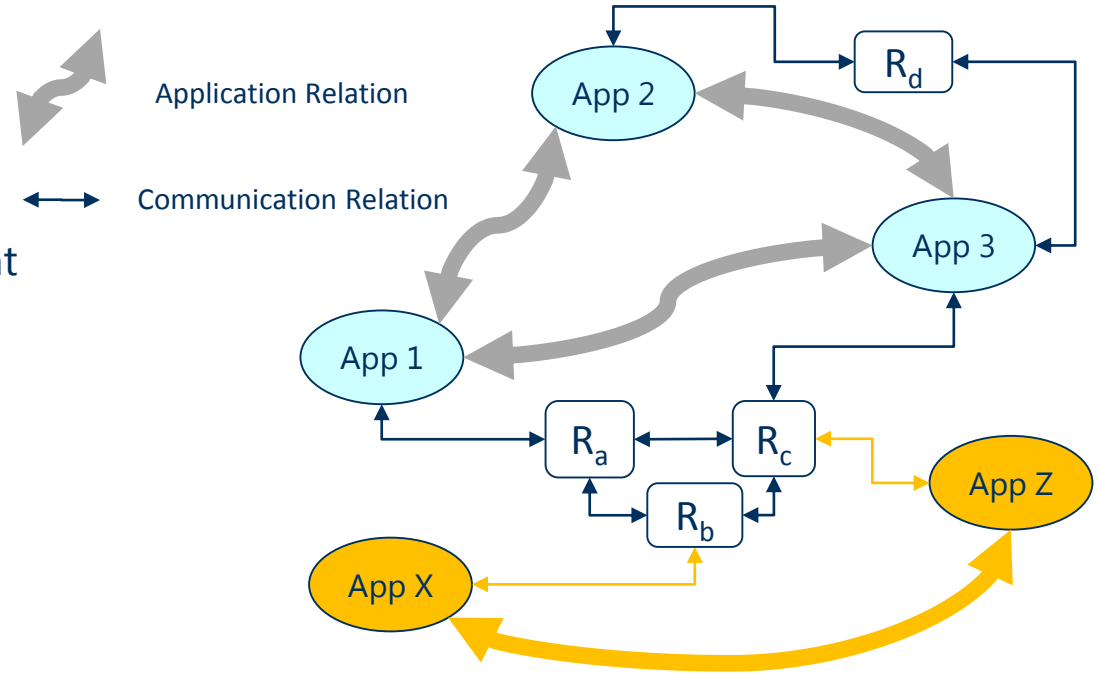
Realisation of application relations as a bundle of communication relations

- Runtime view
- Configuration
- Monitoring

→ relation to network management

Applications reside on the same network → cross-influences





Relevance of typical communication solution requirements

Requirement	Real-time data communication			Communication for Engineering and Asset Management	Product data communication
	Process automation	Factory automation	Motion control		
Timing aspects					
Data rate	+	++	++	+	-
Jitter	-	+	++	-	-
Cycle time	++	++	++	-	-
Update time	++	++	++	+	-
Synchronisation	+	+	++	-	-
Time stamping	++	++	++	+	+
Application aspects					
Small data structures	++	++	++	+	-
Large data structures	-	-	-	++	++
Device replacement at runtime	++	+	+	-	-
Robustness aspects					
Availability	++	++	++	+	-
Redundancy	++	+	+	-	-
Recovery Time	+	++	++	-	-
Safety	++	++	++	+	-
Security	++	++	++	++	++
Coexistence	++	++	++	+	-
Mobility					
Mobile Assets	+	+	++	+	++
Network coverage	++	+	+	++	+
Mobile Assets	+	+	++	+	++
Network coverage	++	+	+	++	+

Kommunikation im Industrie-4.0-Umfeld. Whitepaper, ZVEI
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Requirements Profile and Capabilities Profile

Definition of metrics describing relevant requirements

- Suitable for QoS definitions (quantitative)
  - E.g. latency, reliability
- Application-specific specification of ranges

→ **Requirements Profile**

Description of features of existing communication systems

- Using the same metrics

→ **Capabilities Profile**

Network-based Communication in Industrie 4.0.
Discussion paper, Platform Industrie 4.0.

	Motion Control	Condition Monitoring	Augmented Reality
Latency/ Cycle Time	250 µs – 1 ms	100 ms	10 ms
Reliability (PER[1])	1e-8	1e-5	1e-5
Data Rate	kbit/s – Mbit/s	kbit/s	Mbit/s – Gbit/s

1 (Residual) Packet Error Rate

Automatic Network Mapping

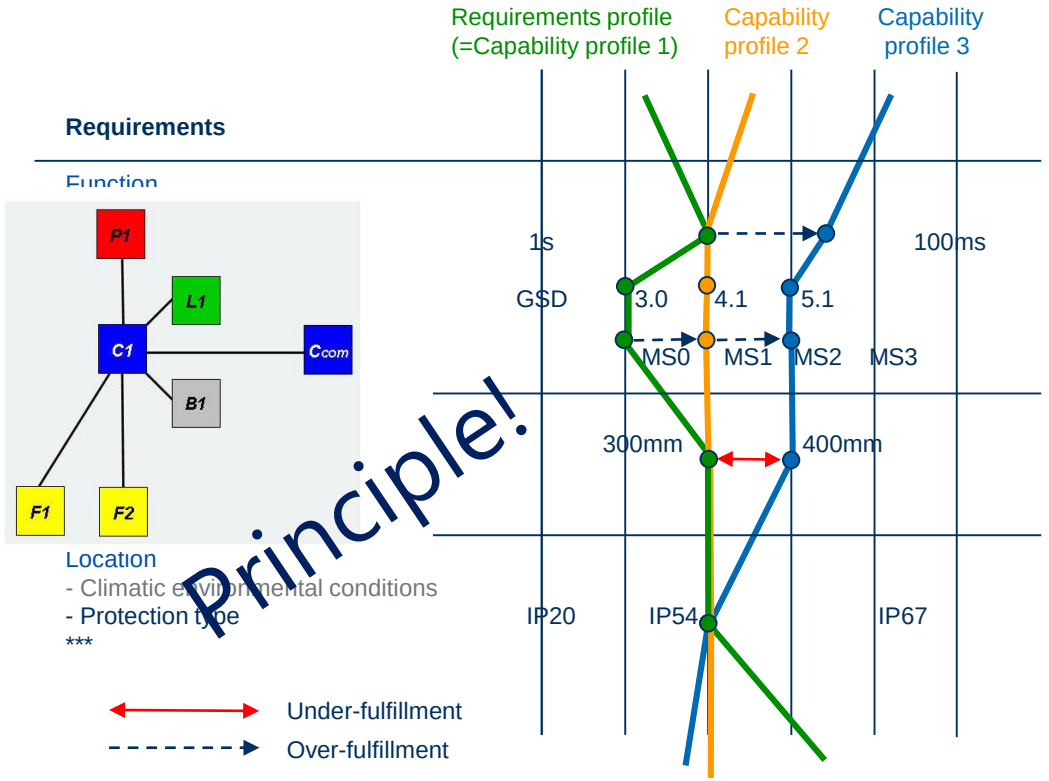
Using semantic reference descriptions (e.g. IEC 61360, IEC 62832 Digital Factory)

Mapping of both profiles

Usage of application-specific weight factors

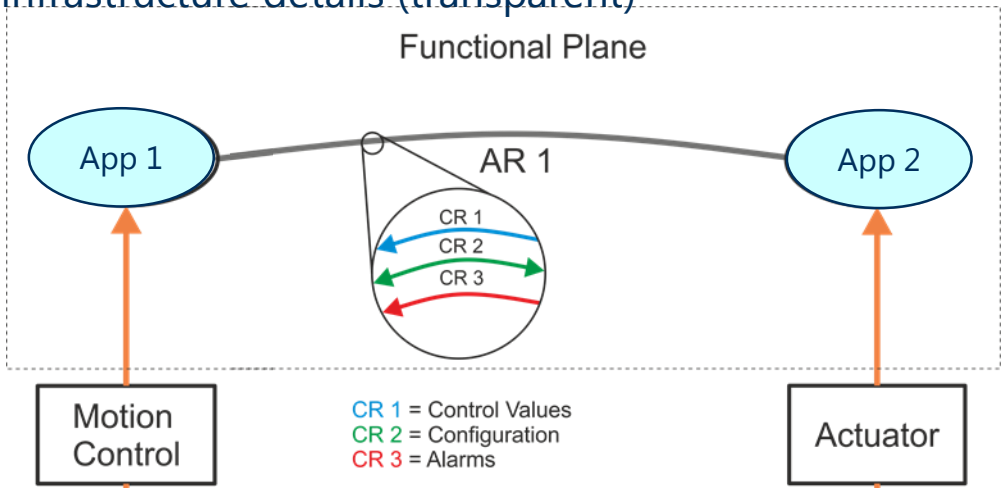
Application of categories (e.g. ASE acc. IEC 61158) to reduce complexity

(semi)automatic mapping

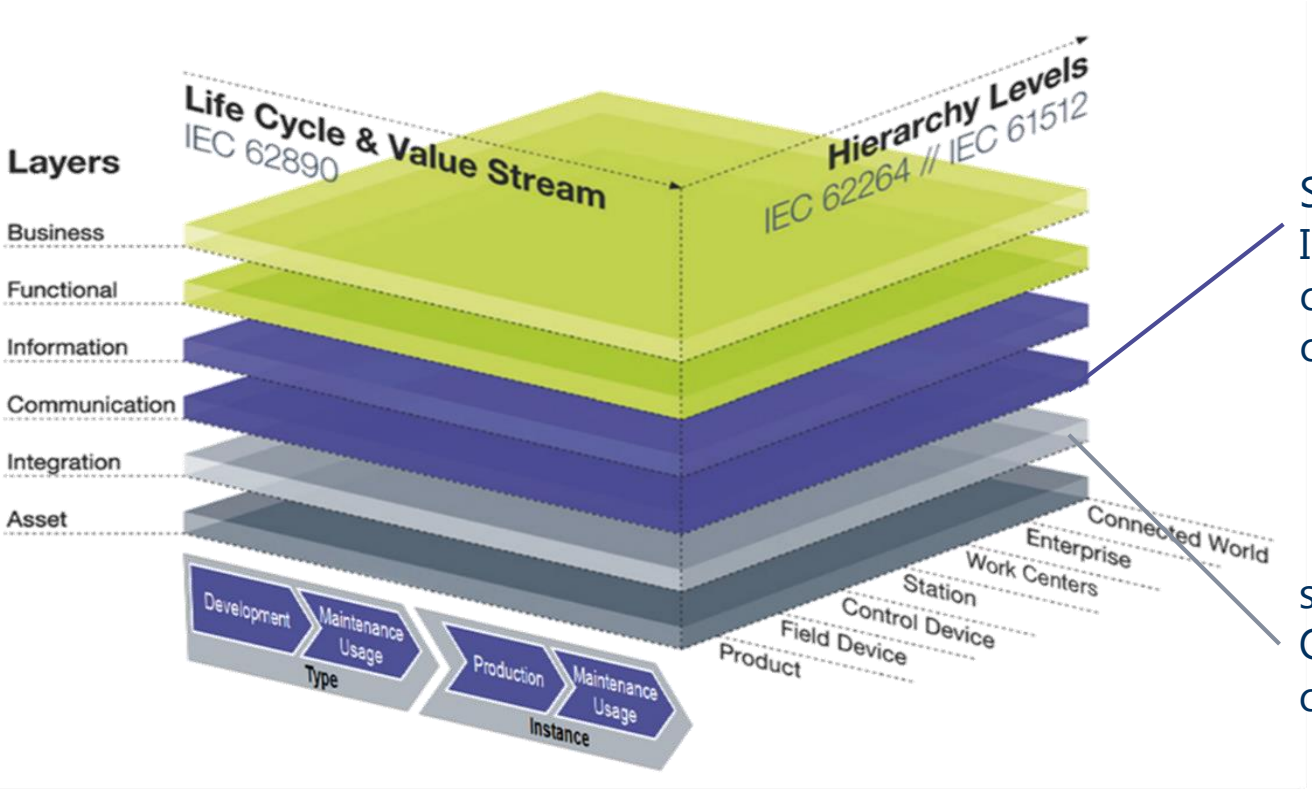


Logical and Physical Networks

Logical network hides infrastructure details (transparent)



Communication in Industrie 4.0 - RAMI 4.0 (Reference Architecture Model Industrie 4.0)



Service-oriented, Industrie 4.0-compliant communication

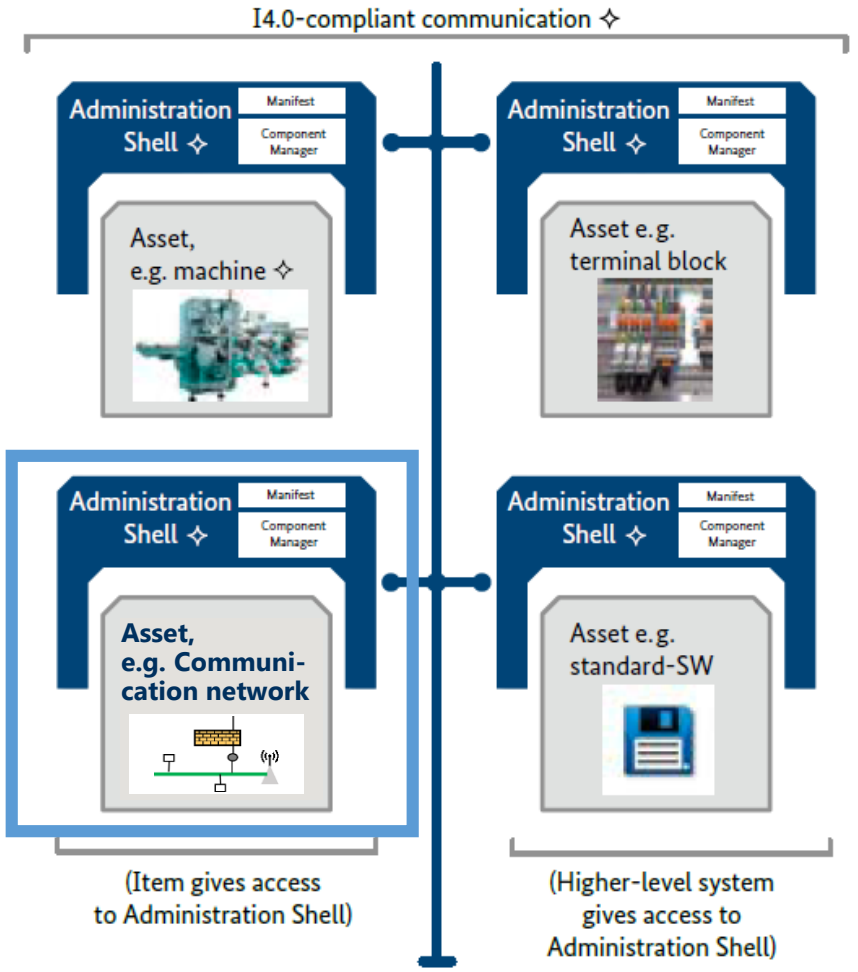
specific, QoS-driven communication

Based on: Platform Industrie 4.0 and ZVEI, DIN SPEC 91345

The Network as an Asset

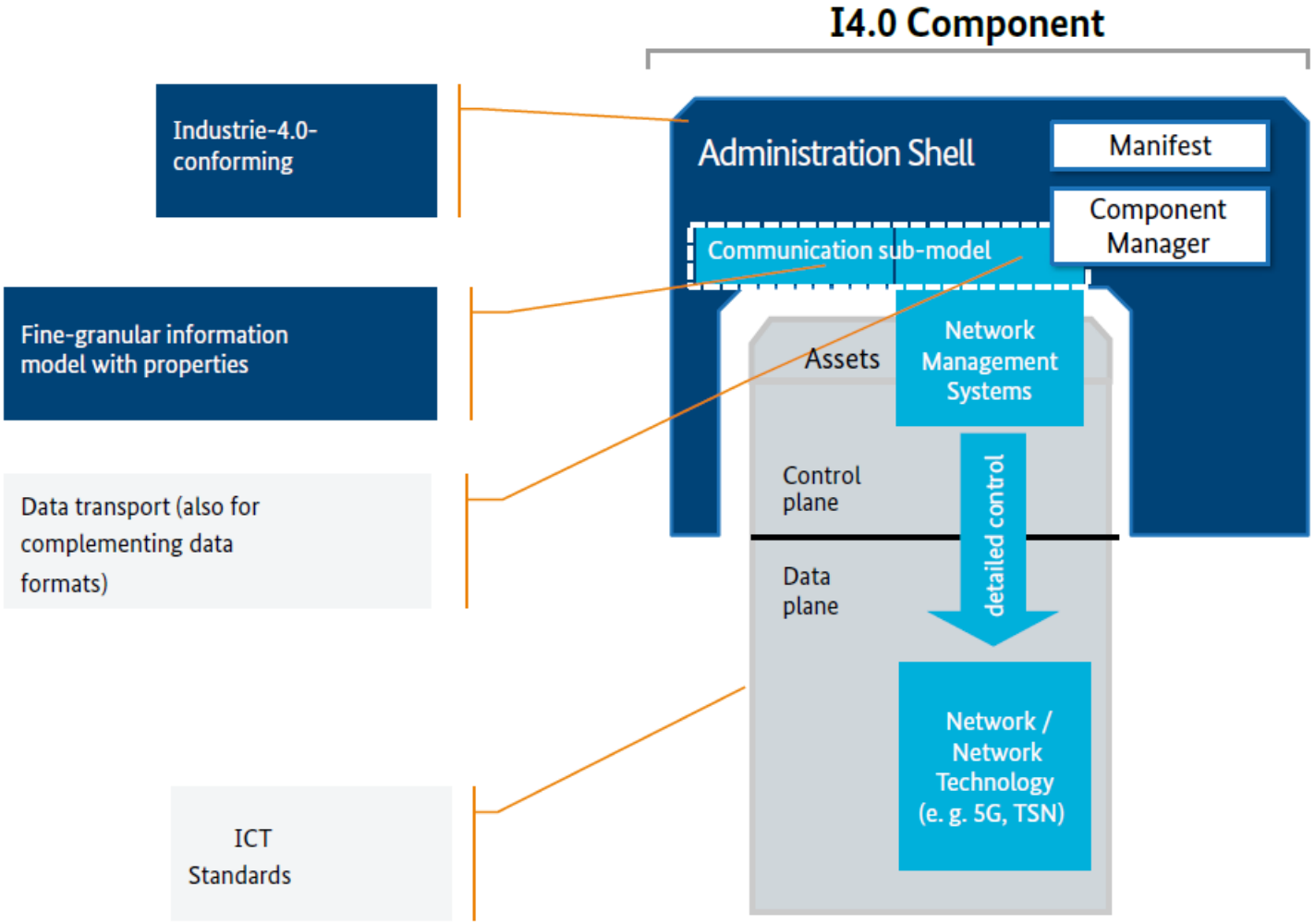
- Communication networks and their components need to be adapted to application requirements
- Adaptation at runtime
  - Changing deployment of functions
  - Changing communication requirements
  - Changing physical structure of network
  - Changing environment
- Documentation and logging

I4.0-compliant communication, which provides access to a wide range of Administration Shells



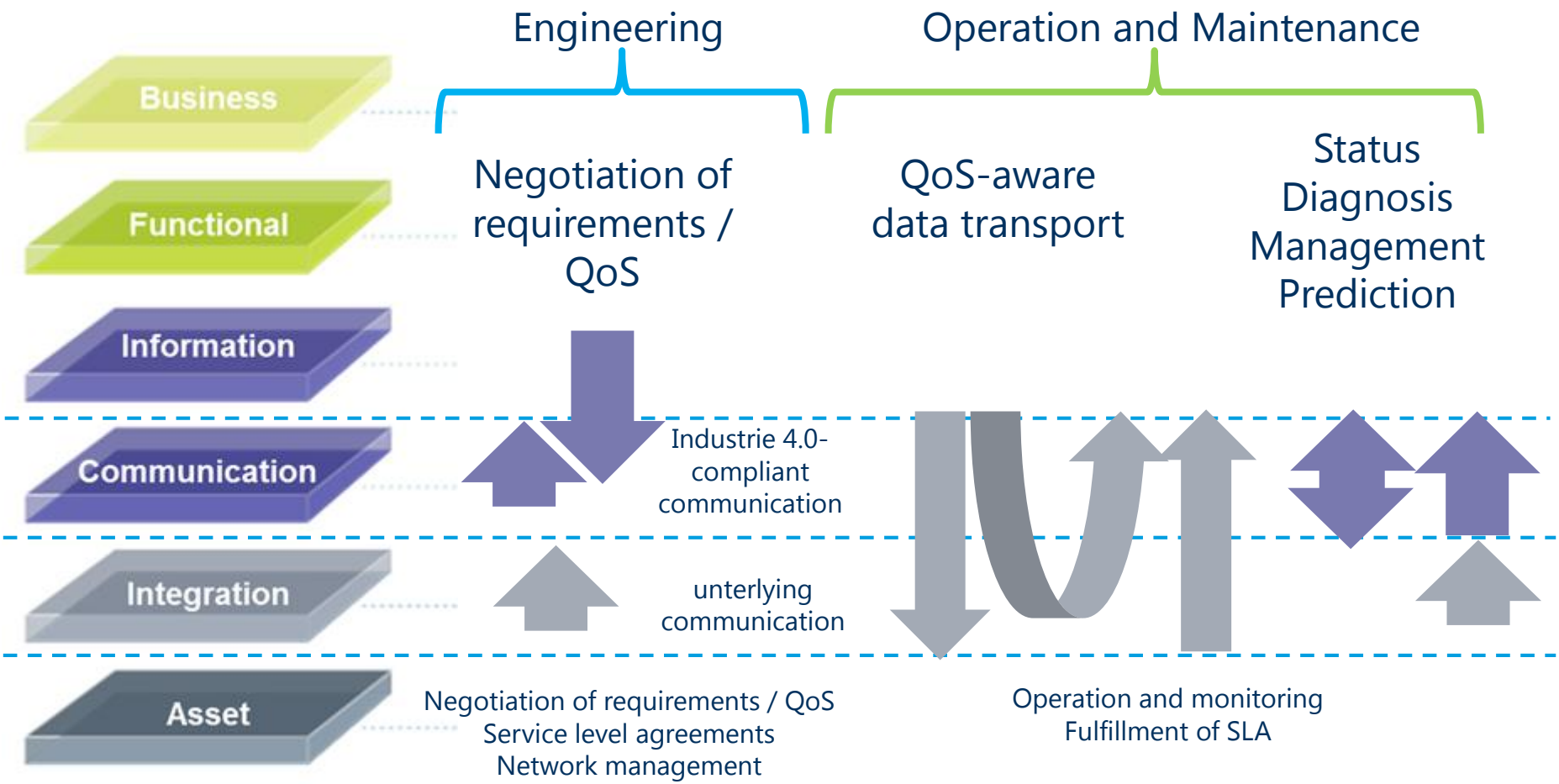
Based on: Structure of the Administration Shell, Platform Industrie 4.0.

Structuring the Asset Administration Shell for an Asset "Network"



Network-based Communication for Industrie 4.0 – Proposal for an Administration Shell Discussion paper, Platform Industrie 4.0.

Life Cycle Aspects



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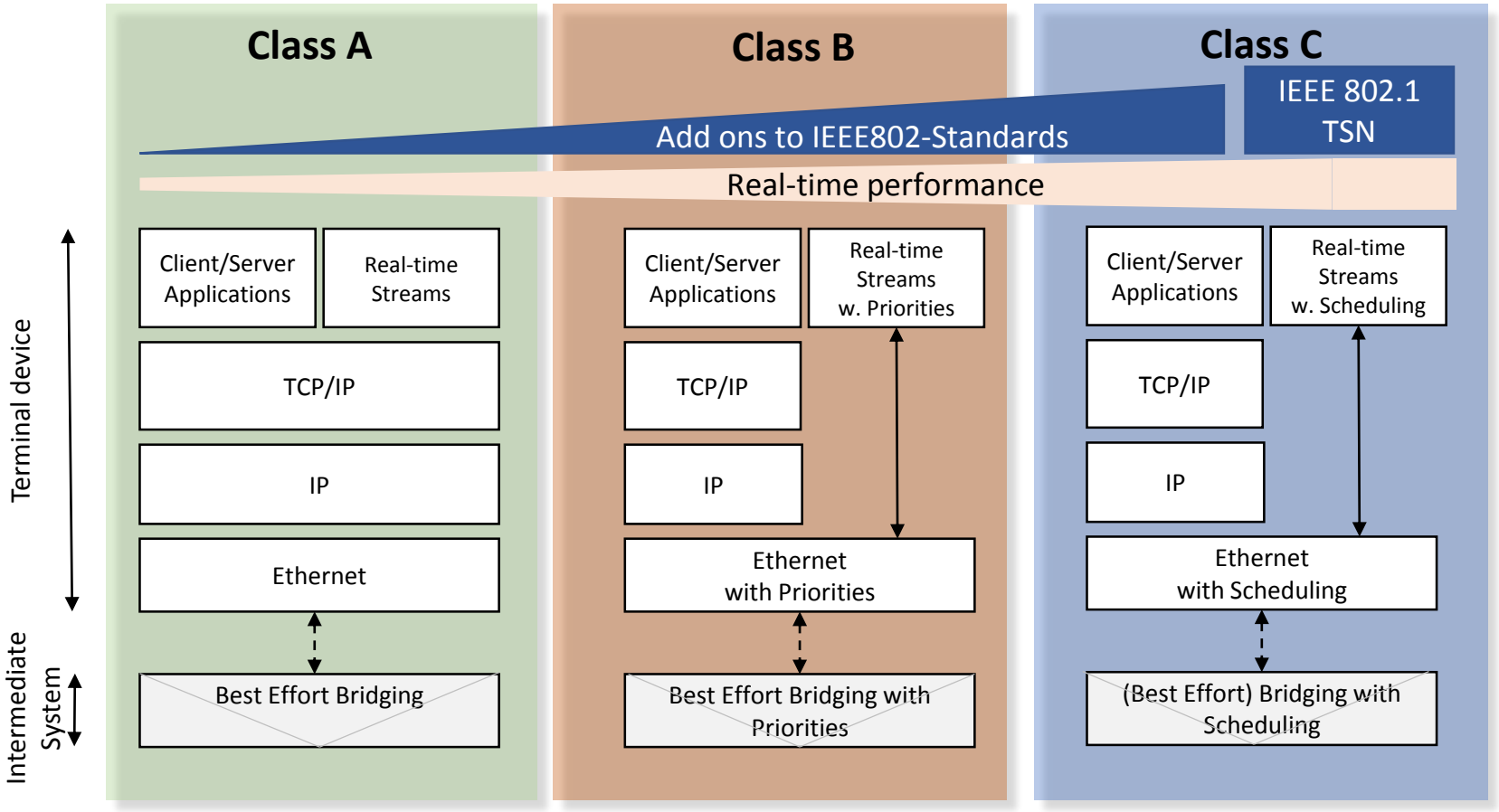
Current Developments:
The classification scheme for Real-Time Ethernet



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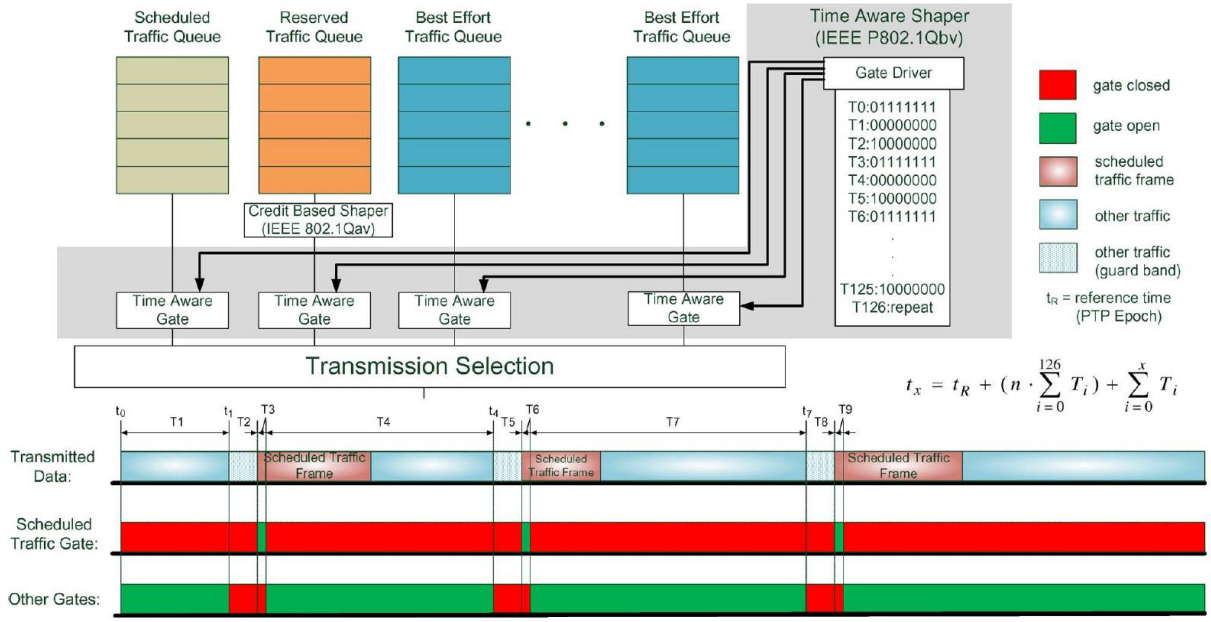
Current Developments: Time Sensitive Networks (TSN)

- Scheduled traffic in Ethernet
- Jitter-free communication
- Fine-grained priorization
- Traffic shaping, e.g. time-aware shaper

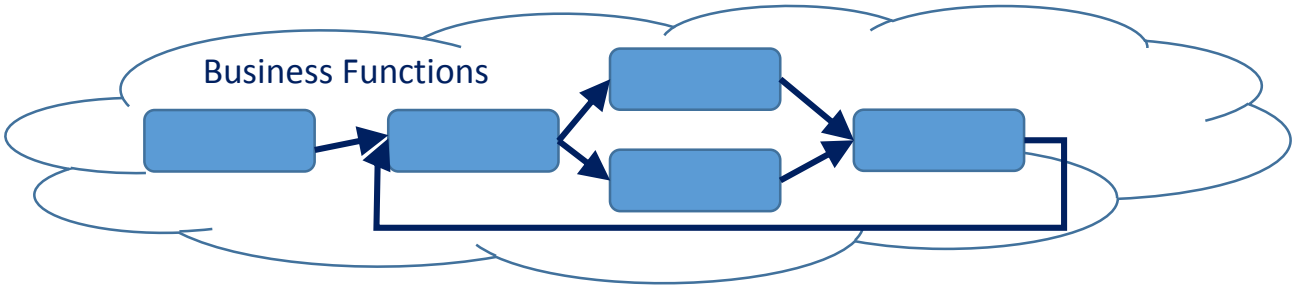


Johas Teener et al.: Heterogeneous Networks for Audio and Video: Using IEEE 802.1 Audio Video Bridging.
Proceedings of the IEEE (Volume: 101, Issue: 11, Nov. 2013), DOI: 10.1109/JPROC.2013.2275160

- BMBF funded research project „Future Industrial Network Architecture – FIND“

GEFÖRDERT VOM
Bundesministerium für Bildung und Forschung
FIND

Levels of Abstraction in Industrial Communications



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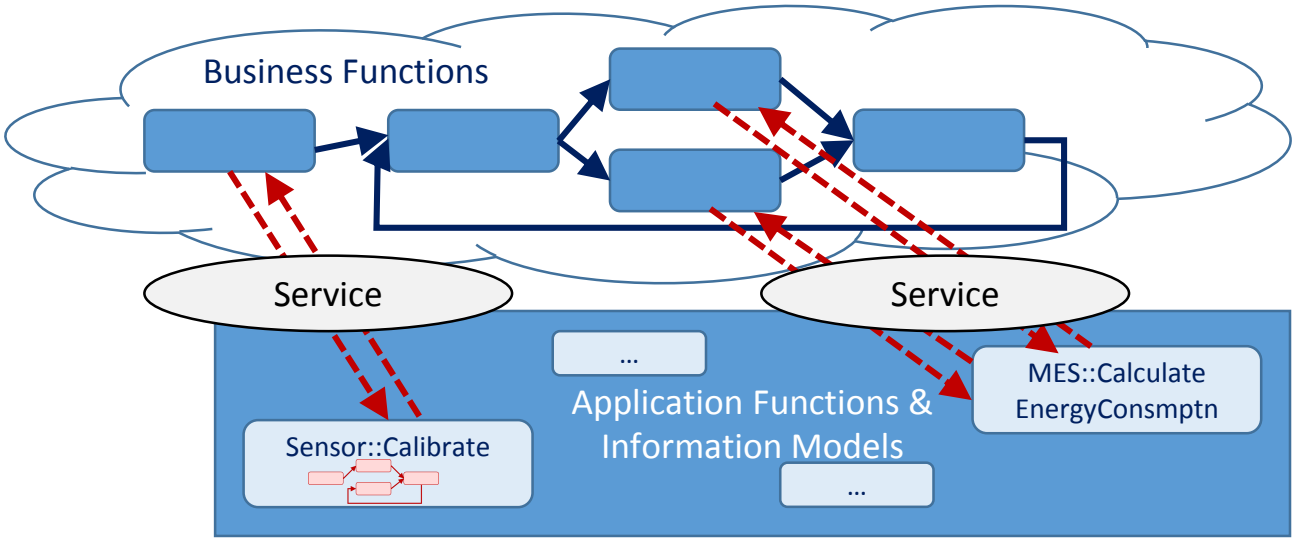

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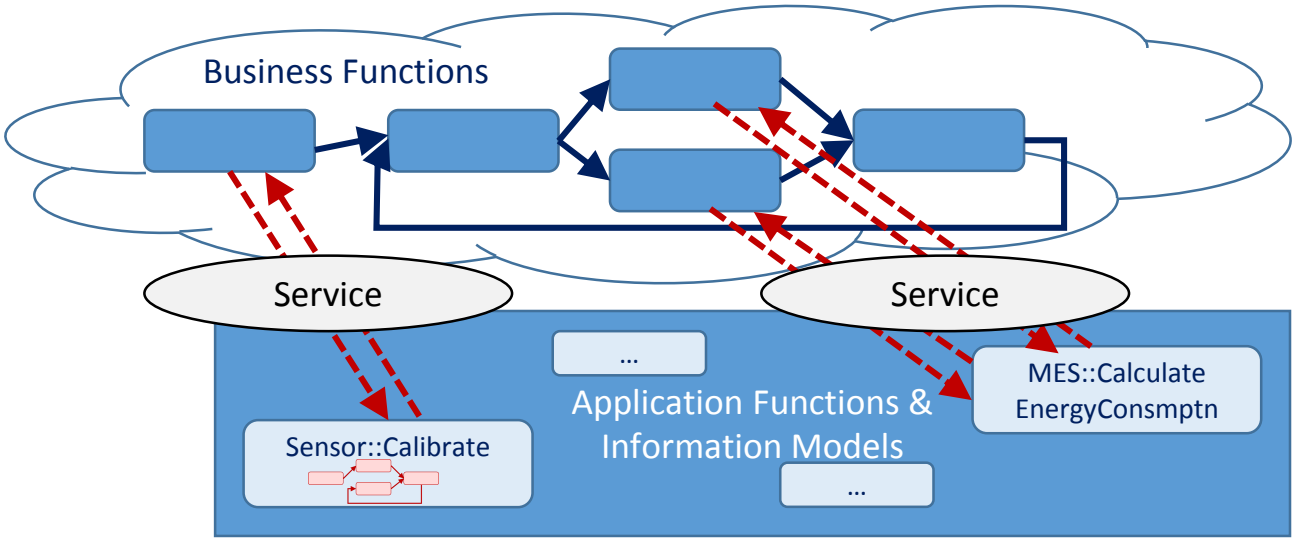

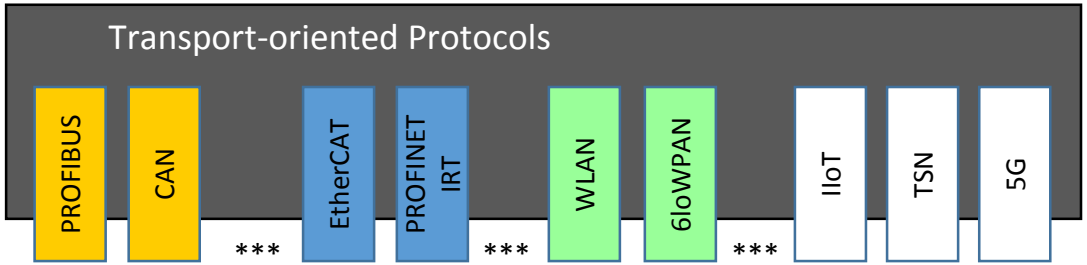

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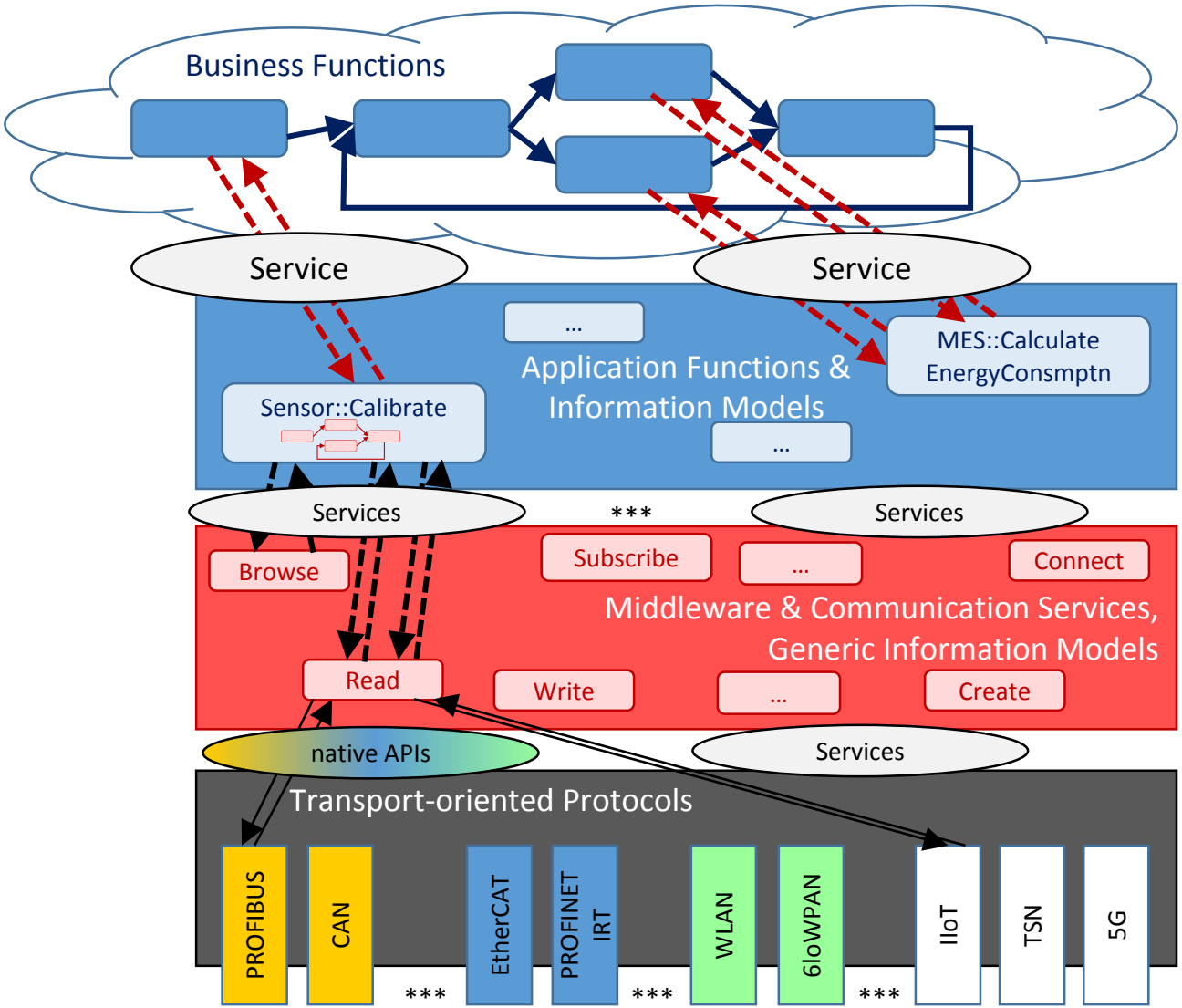

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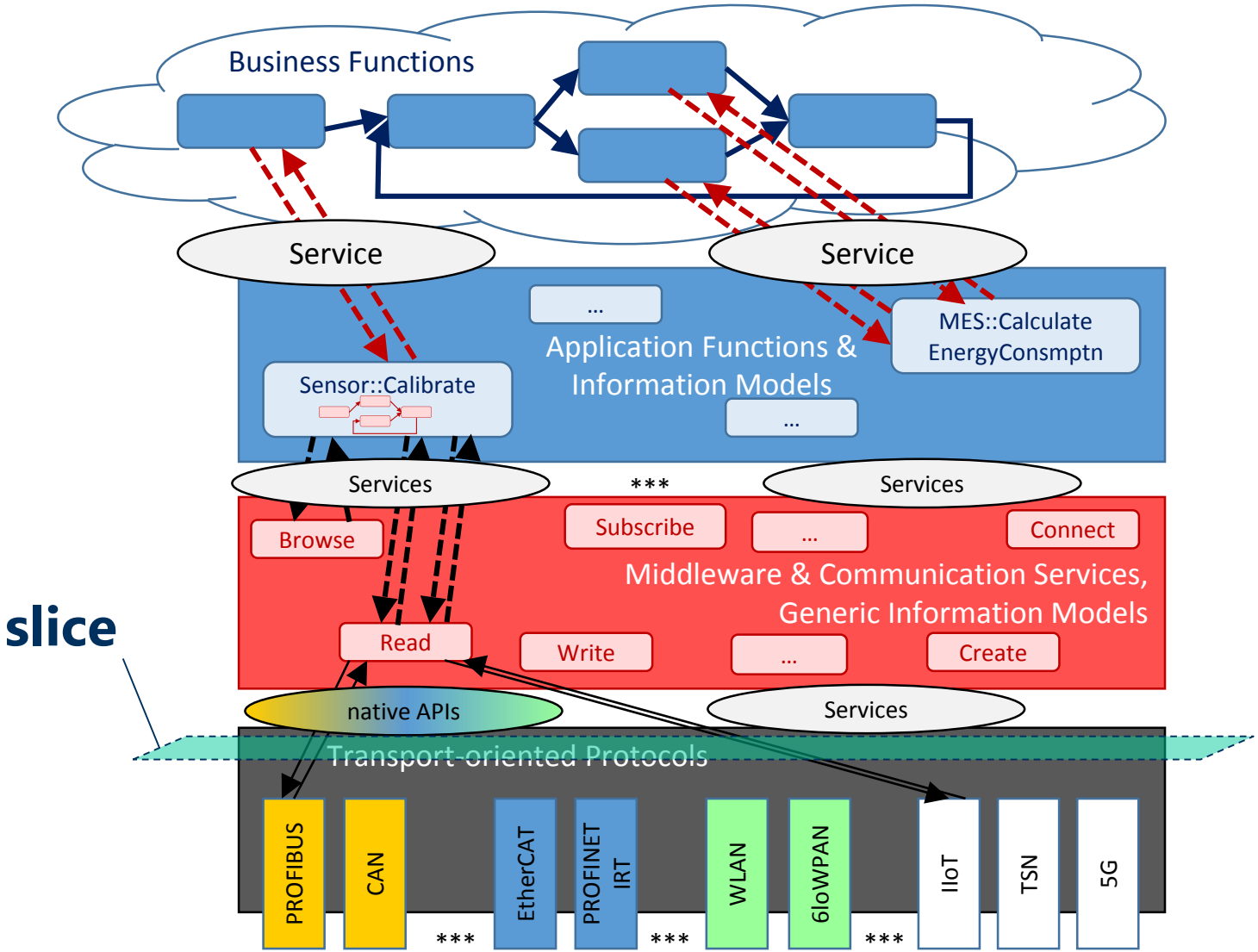


Service Layers

Layered service model

Platform services for managing application service deployment and choreographie

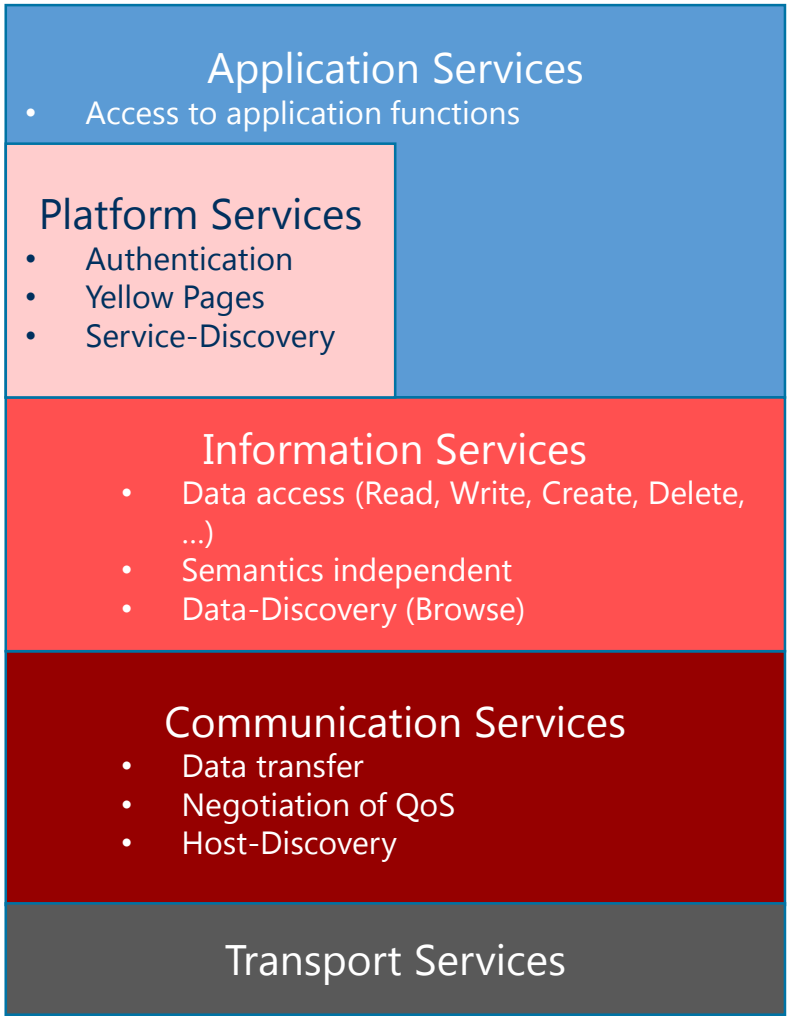
Information services for

- Information model management
- semantics-free data access
- discovery

Communication services for

- Data transfer
- QoS negotiation
- End point assignment

Technology-independent data transport services



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Network Flexibility based on Software

IT-Systems: Virtualization as a key feature

Software Defined Networks (SDN)

Separation of data plane (runtime function) and control plane (management)

- Northbound interface (management)
- Southbound interface (to data plane)

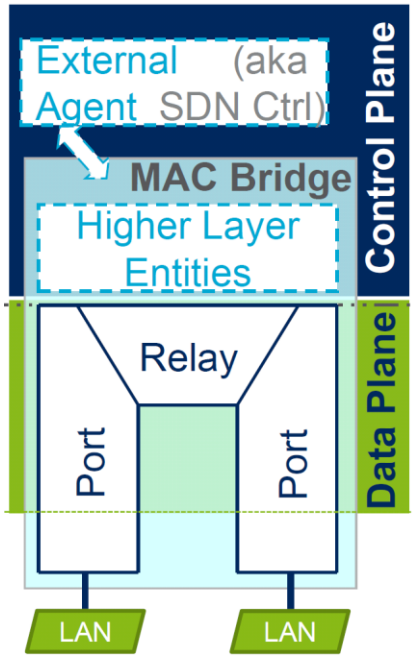
Provision of functions by the network (components)

Virtualization approach

Network Function Virtualization (NFV)

In addition to data forwarding, „the network“ offers functions like compression, encryption, etc.

Current discussion on functions for storage, computing, etc,
→ application functions!

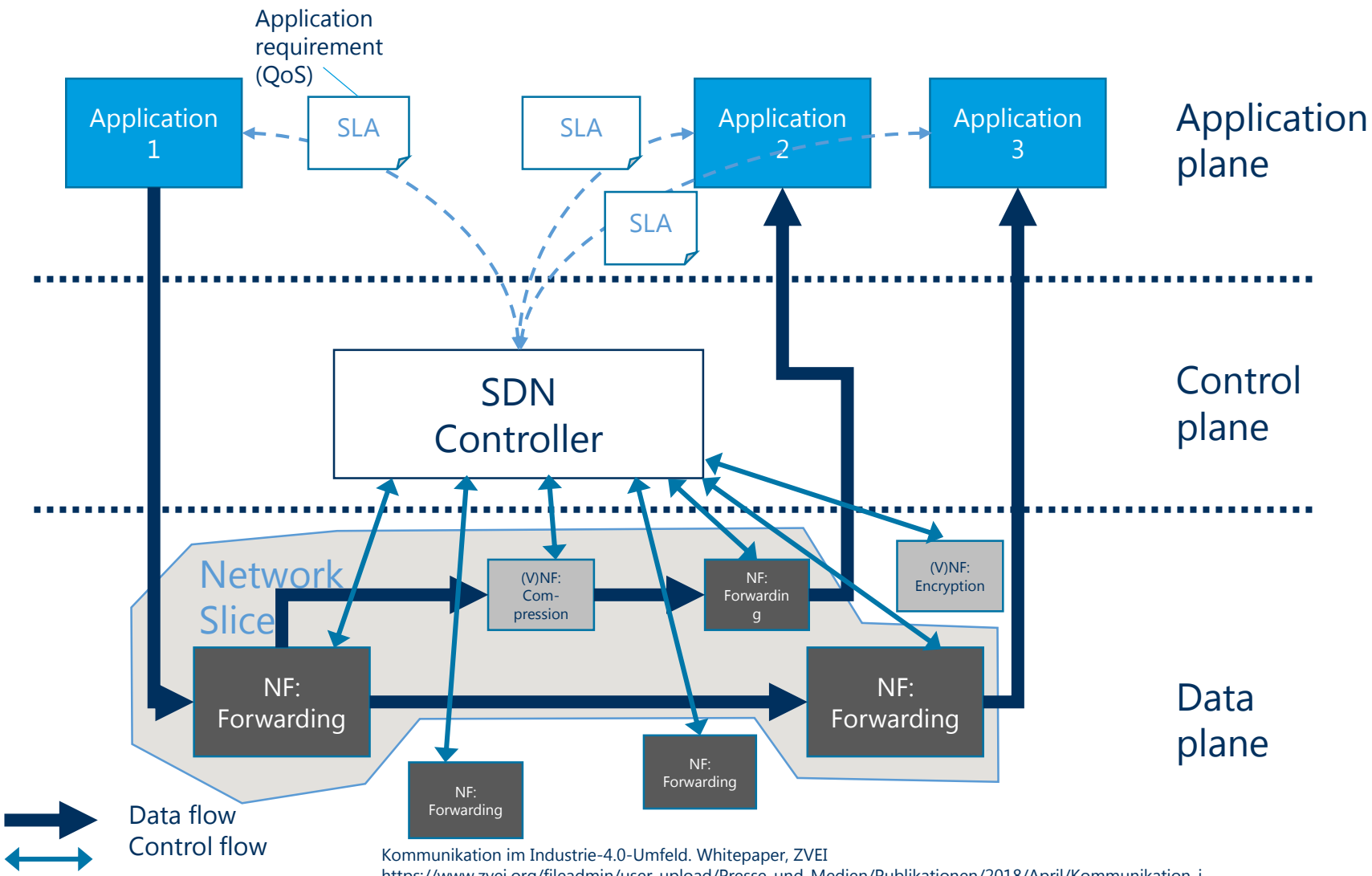


By Open Networking Foundation (ONF) - SDN Architecture Overview (PDF), Version 1.0, December 12, 2013

NF: Forwarding

(V)NF: Compression

Software Defined Networks



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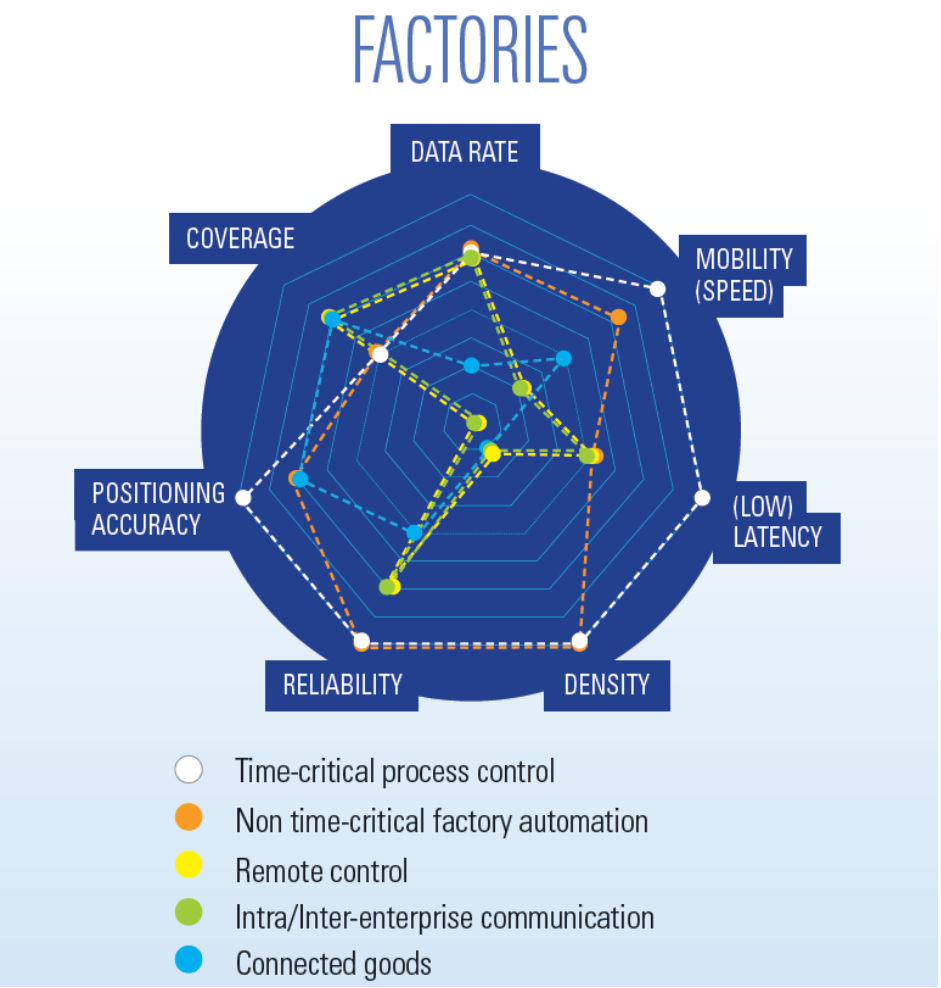
https://www.zvei.org/fileadmin/user_upload/Presse_und_Medien/Publikationen/2018/April/Kommunikation_im_Industrie-4.0-Umfeld/Kommunikation_im_Industrie-4.0-Umfeld_Download-Neu.pdf

Requirements for Factories as a Vertical in 5G

- 5G Communication as a hybride, wired / wireless infrastructure
- Separation of logical and physical Communication
- Combination of physical and virtualized network functions
- flexible management of the network and its resources

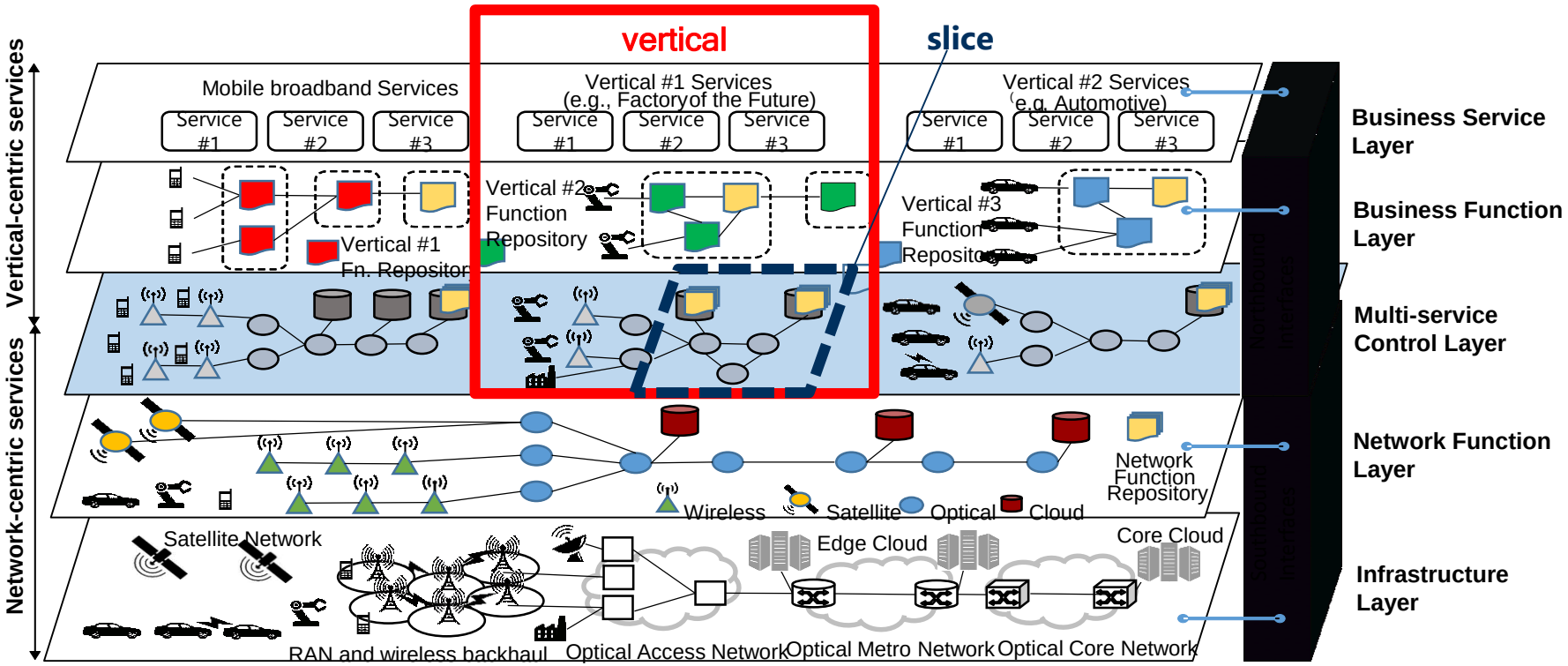
- Integration of **end user requirements** (verticals)



5G-PPP. (2016, Feb.). 5G empowering vertical industries. [Online]. Available: https://5gppp.eu/wp - content /uploads/2016/02/BROCHURE_5PPP_BAT2_PL.pdf

The integrated 5G architecture for mobile broadband and vertical services

Bringing it all together…



Wollschlaeger, M.; Sauter, T.; Jasperneite, J.:
Industrial Communication. The Future in the Era of the Internet of Things and Industry 4.0.
Published in: IEEE Industrial Electronics Magazine
(Volume: 11, Issue: 1, March 2017), pp 17 – 27, DOI: 10.1109/MIE.2017.2649104

Based on: 5G-PPP. (2016, Feb.). 5G empowering vertical industries. [Online]. Available:
https://5gppp.eu/wp - content /uploads/2016/02/BROCHURE_5PPP_BAT2_PL.pdf

Standardization

Standardization is key factor in automation and control

Different standardization bodies (IEEE, IEC, ISO, ITU-T, IETF, DMTF, W3C, …)

→ Joint Working Groups

→ Consensual standards vs. industry standards

Standardization of protocols

- Industrial solutions (wired, wireless)
- IT-Solutions
- Telecommunication

Standardization of **Network Management**

Standardization of **Service Approaches**

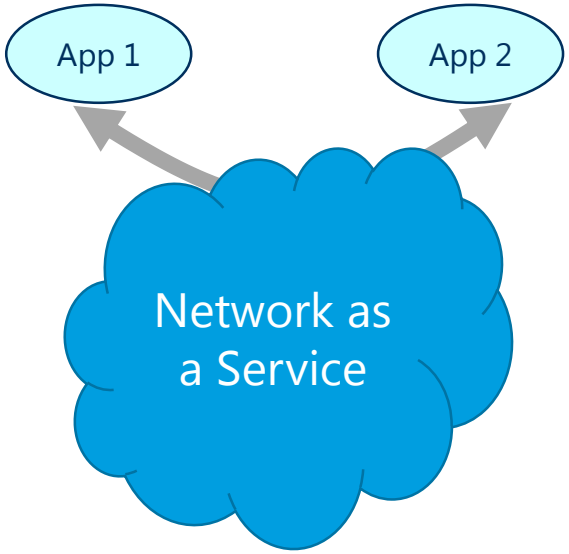
Standardization at **application level** (information models, services)

Conclusions

Industrial Communications will adopt IT technologies

New applications can be addressed (augmented reality, wearables, …)

Heterogeneity of communication solutions will increase



Transition to **requirements-driven** approaches necessary

Different stakeholders have different viewpoints

Networks as assets, adequate Quality of Services

Flexibility enhancement required

New partners in the value chains (network service provider)

Migration paths and **practical solutions** necessary

Integrated approaches are needed

Smart Manufacturing needs Smart Communications!

Contact information

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»Wissen schafft Brücken.«