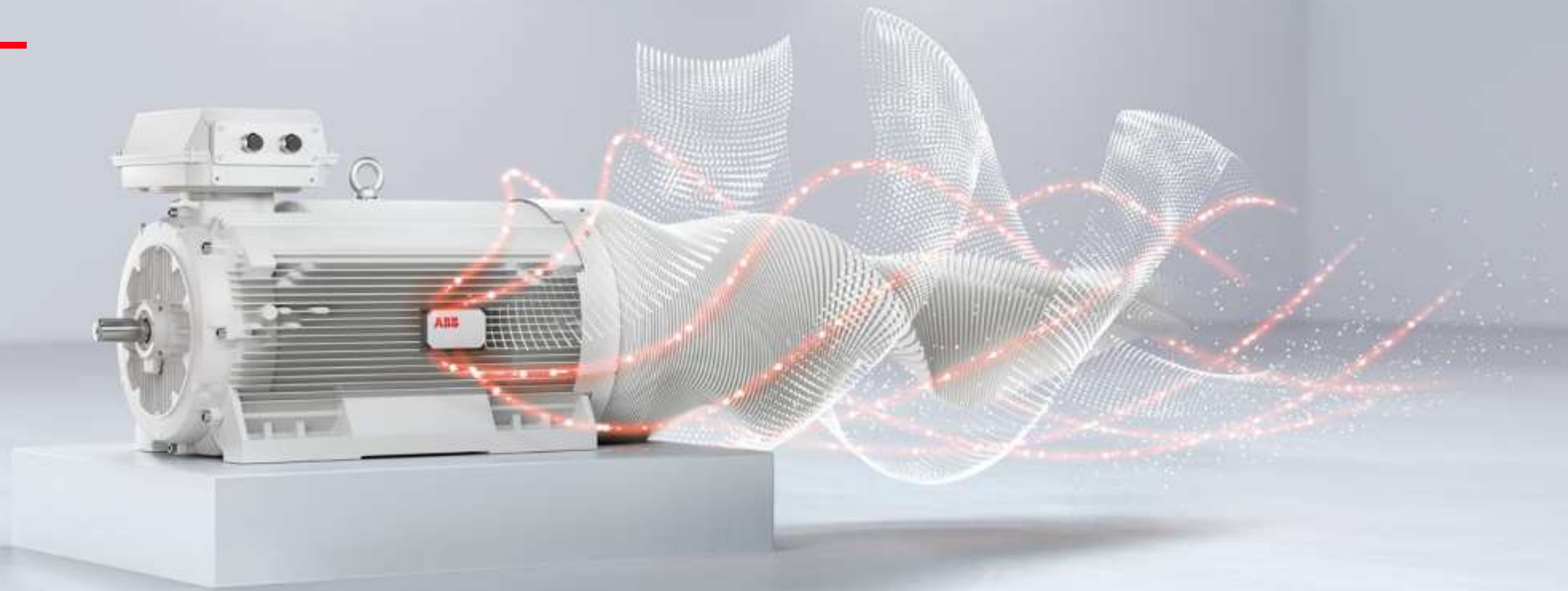


IOT-ASAP 2018 AT ICSA 2018, 2018-04-30

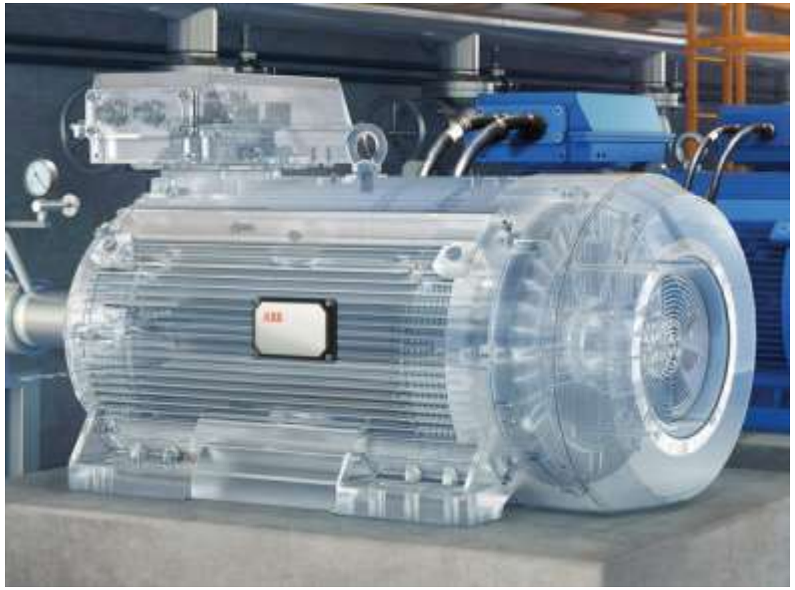
IoT Challenges for Smart Manufacturing

Connecting a Laser Level Transmitter to the Cloud

Heiko Koziolek, Senior Principal Scientist, ABB Corporate Research Germany

Agenda

1. Internet-of-Things Applications for Smart Manufacturing
2. IoT in Consumer Space vs. IoT in Industrial Space
3. 6 IoT Challenges for Smart Manufacturing
4. Software Architecture Research Challenges for IIoT



ABB

Internet-of-Things

Overview

Wikipedia Definition:

- “**Network** of physical **devices**, vehicles, home appliances and other items embedded with electronics, software, sensors, actuators, and **connectivity** which enables these objects to connect and exchange data.”

Each thing uniquely identifiable and able to interoperate within the existing **Internet** infrastructure

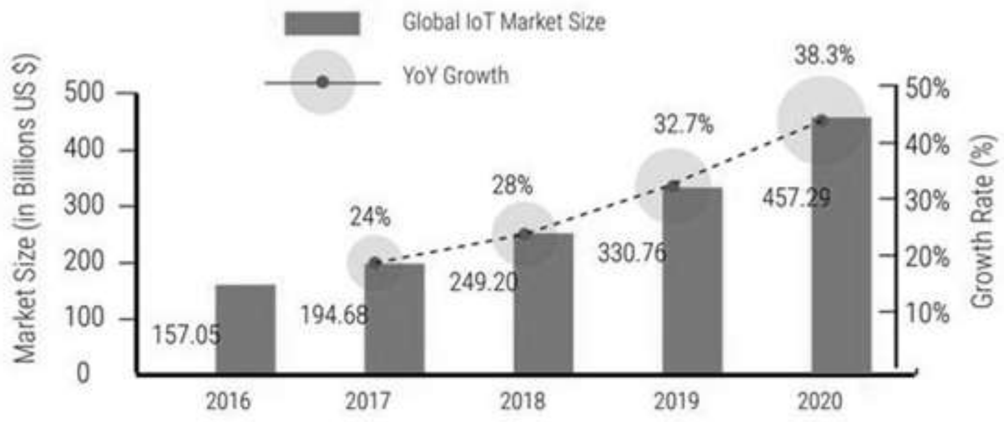
Direct **integration** of the physical world into computers

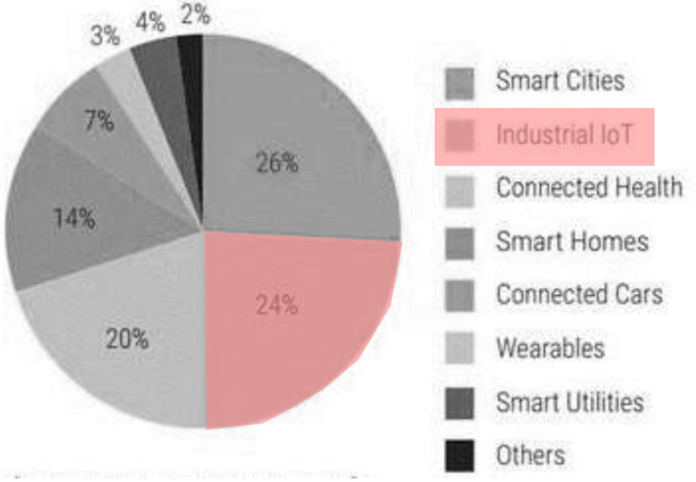
Improved efficiency, accuracy and reduced human intervention

IoT prerequisite for smart grids, virtual power plants, smart homes, intelligent transportation and smart cities

Increased requirements towards privacy / security

Many application areas for Internet-connected devices!





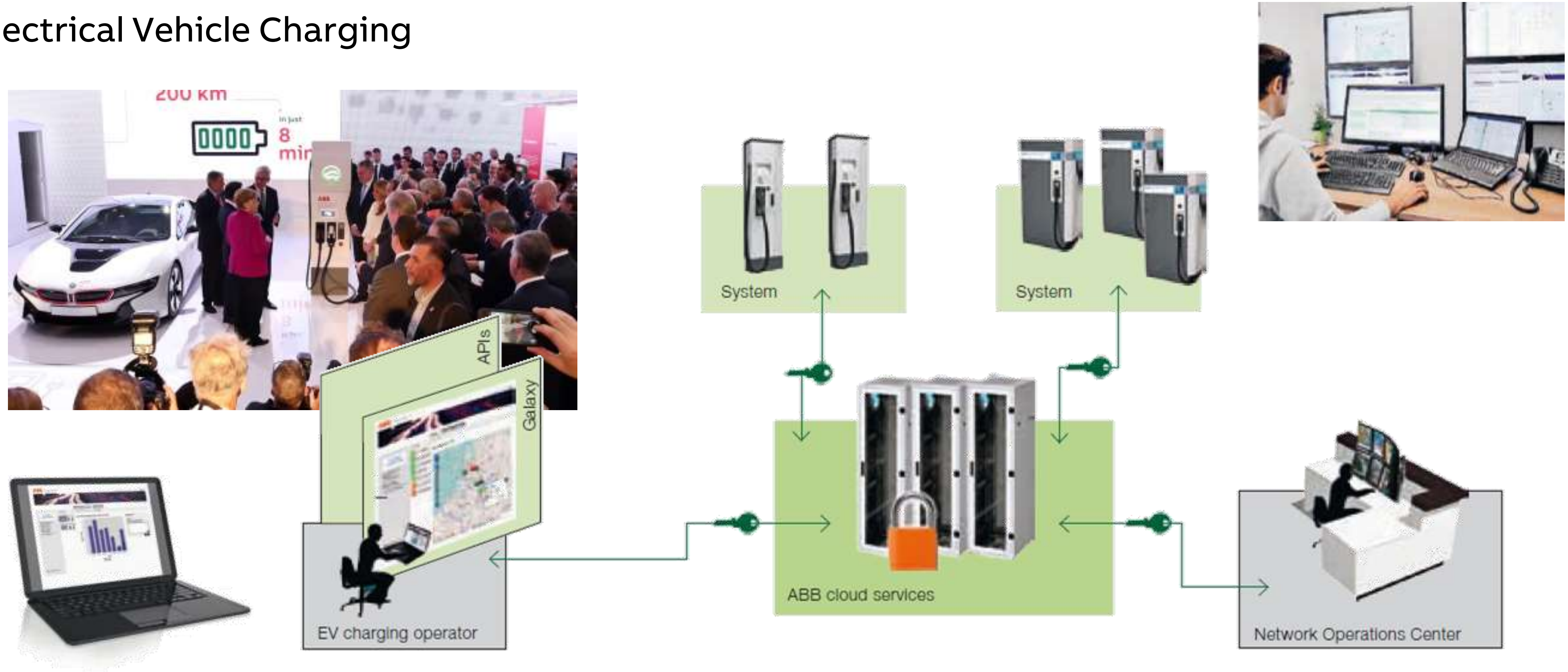
[https://growthenabler.com/flipbook/pdf/IOT%20Report.pdf]

Industrial IoT Application Cases

Robotics Remote Service

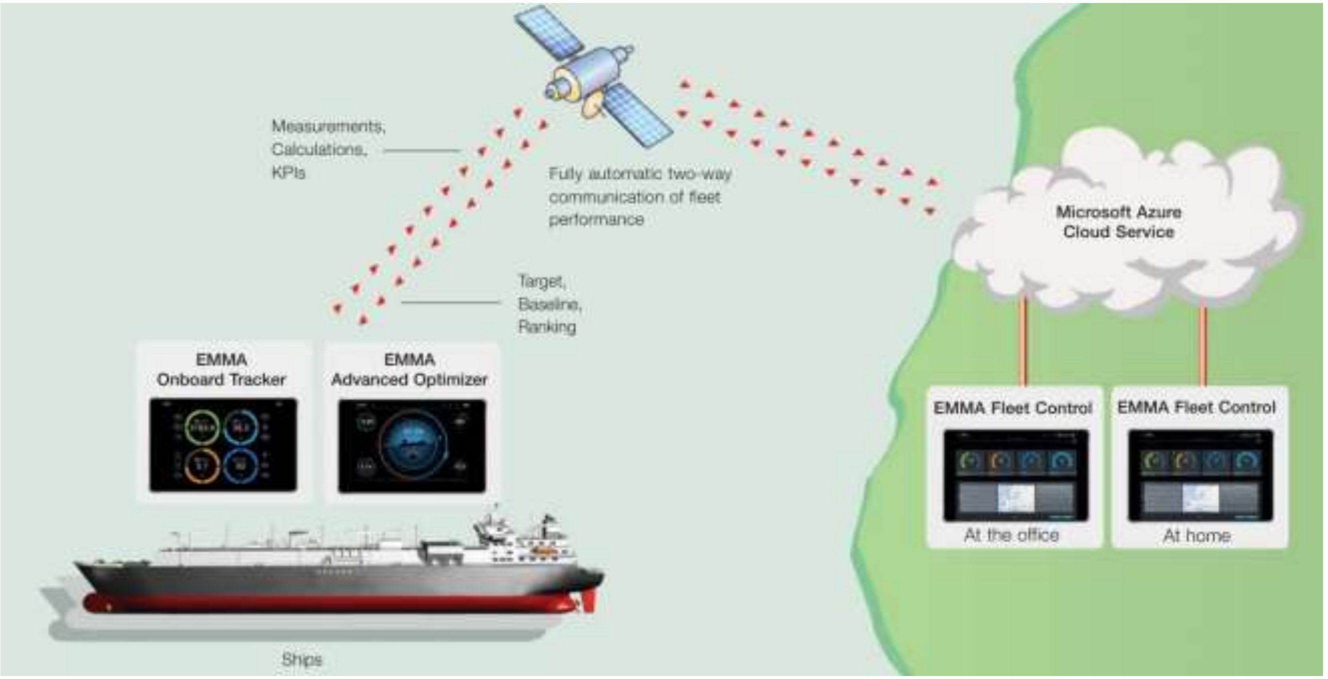
Industrial IoT Application Cases

Electrical Vehicle Charging



Industrial IoT Application Cases

Container Ship Trim Optimization



Industrial IoT Application Cases

Condition Monitoring for Industrial Drives

Internet-of-Things

Consumer Space

Amazon Echo Dot

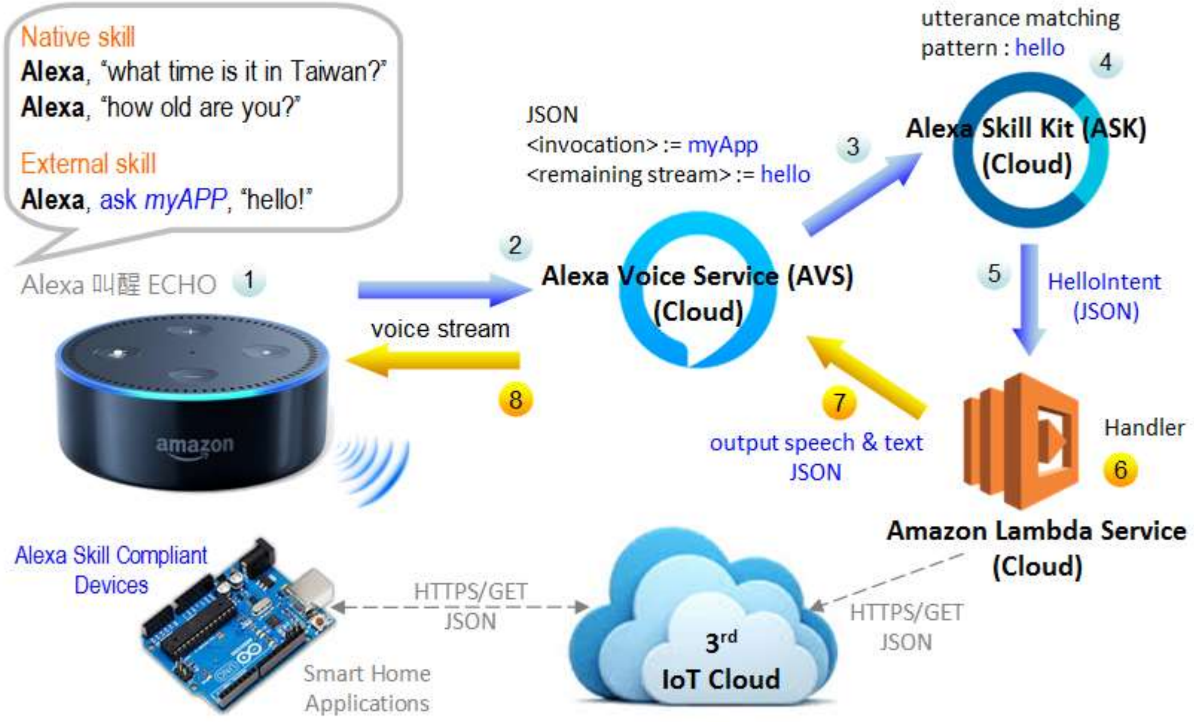
Hardware:

- Texas Inst. DM3725CUS100 Digital Media Processor, 1Ghz
- Samsung K4X2G323PD-8GD8 256 MB LPDDR1 RAM
- SanDisk SDIN7DP2-4G 4 GB iNAND Ultra Flash Memory

Communication:

- Qualcomm Atheros QCA6234X-AM2D Wi-Fi and Bluetooth Module
- Device Discovery
- REST APIs
- Smart Home Skill API

Powerful HW + REST-based communication



[http://www.funbroad.tw/2017/06/alexa-skill-hello-world.html]

Internet-of-Things

Industrial Space

ABB Laser Level Transmitter LLT100

Hardware:

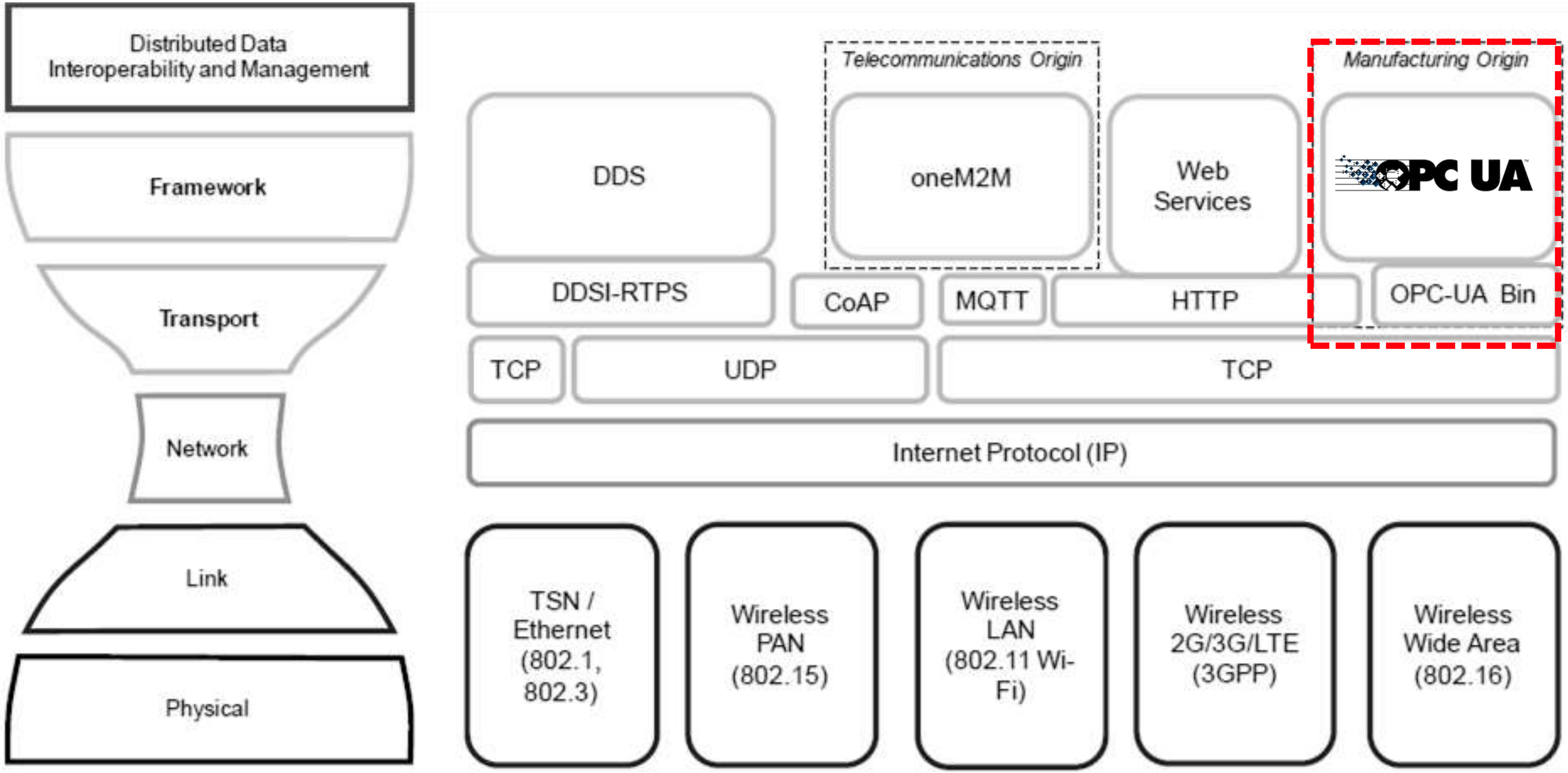
- ARM Cortex M4 Core: XMC4700-F144 Microcontroller based on ARM® Cortex®-M4 @ 144MHz
- Flash: 2MB, RAM: 352KB

Communication:

- Today: 4-20mA analog HART communication
- as IIoT Device:
  - Ethernet / IP
  - OPC UA Server for >200 device parameters
  - Connected to ABB Ability Edge Gateway & MS Azure Cloud

Resource-constrained HW + OPC UA communication

OPC UA for Smart Manufacturing IIoT



[http://industrial.embedded-computing.com/articles/iic-connectivity-framework-defines-iiot-network-architecture-for-scalable-interoperability/]

OPC UA for Smart Manufacturing IIoT

Industrial Internet-of-Things Connectivity and Information Modeling

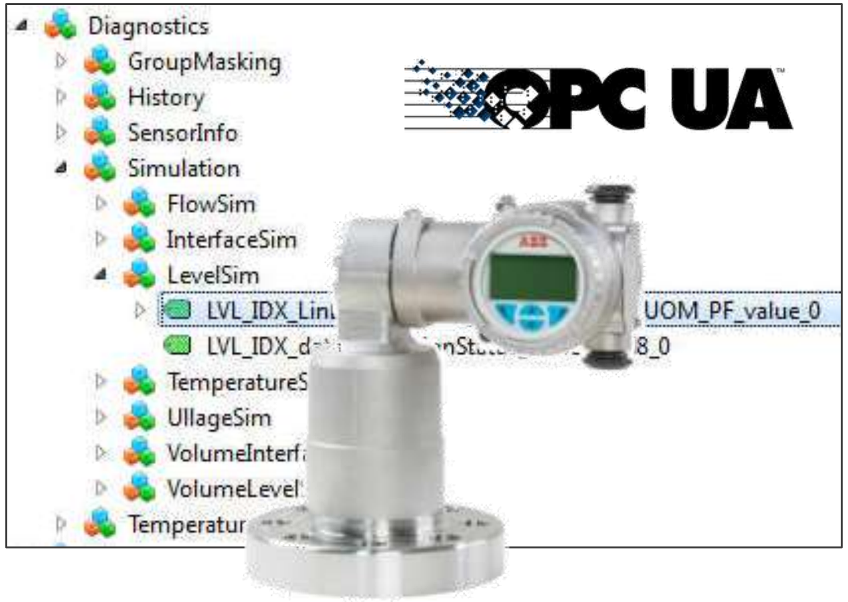
Features

Communication: HTTP, UA Binary, AMQP, ...

Platforms: Windows, Linux, VxWorks, ...

Object-oriented Model: Static, dynamic, ...

Services: Connect, Subscribe, Alarms, History, ...



Laser Level Transmitter

OPC UA recommended by Plattform Industrie 4.0, enables path to the IIoT/Cloud.

IoT Challenges for Smart Manufacturing

How to connect a Laser-level Transmitter to the Cloud?

Challenge 1: Dealing with severe resource constraints

Challenge 2: Designing appropriate information models

Challenge 3: Implementing standards for interoperability

Challenge 4: Bridging to cloud platforms

Challenge 5: Addressing security requirements

Challenge 6: Integrating autonomy, local analytics

Challenge n: …

Let's go through each challenge…

IoT Challenge 1: Resource Constraints

Memory Footprint for OPC UA Servers

OPC UA on Laser Level Transmitter

Communication board on LLT has ARM-based Cortex M4 @ 144 Mhz, 2 MB Flash memory, 352 KB RAM

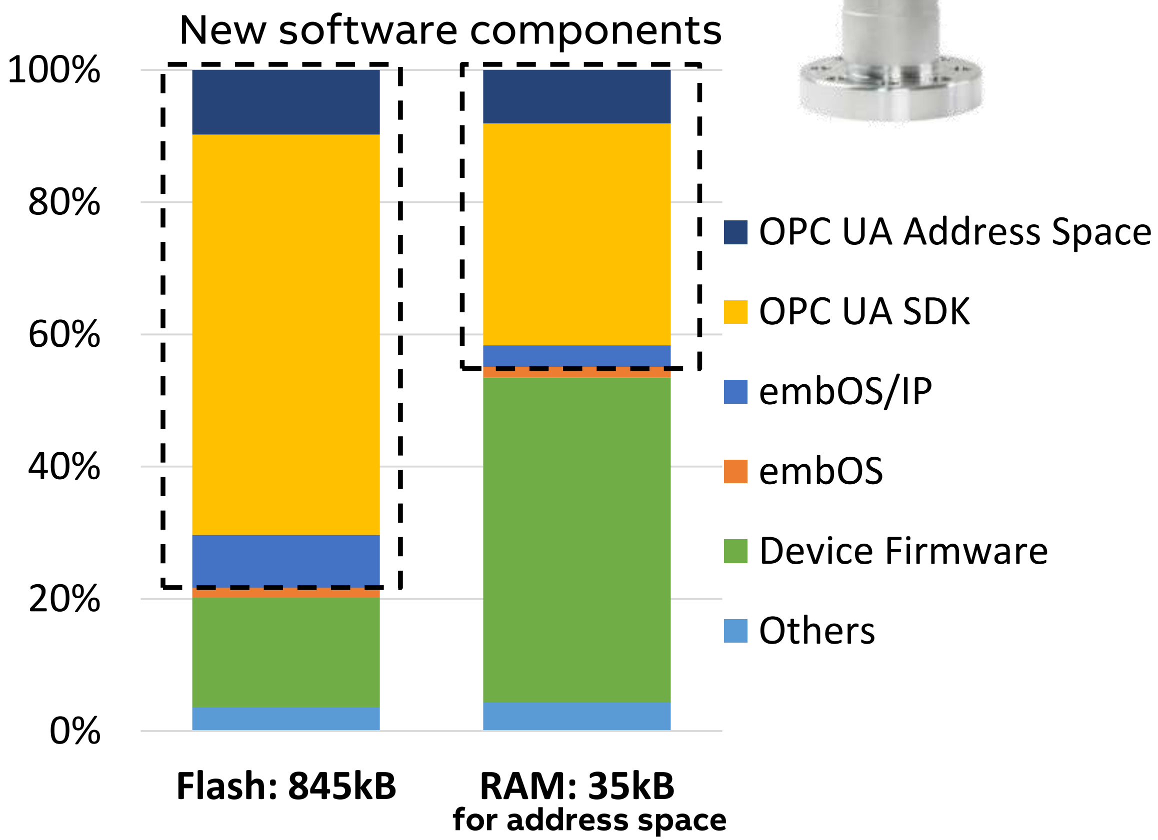
The hardware to integrate is constrained by requirements for energy consumption due to explosion protection

- e.g., power supply must be <570 mA (IEC 60079-27)
- e.g., Raspberry Pi needs 2500 mA power supply

ABB research project showed that the Unified Automation OPC UA High-Performance SDK can be squeezed into the target communication board

Power consumption is currently at 641mW (for comparison Raspberry Pi 3: ~1200 mW), can be further optimized for 500mW target.

IIoT connectivity must follow power/safety requirem.



IoT Challenge 2: Appropriate Information Models

Device properties, dynamic values, services

Device Model on Laser Level Transmitter

The OPC UA address space contains >200 variables (i.e., configuration parameters & sensor values) for the LLT, which is more than for a typical IoT consumer device

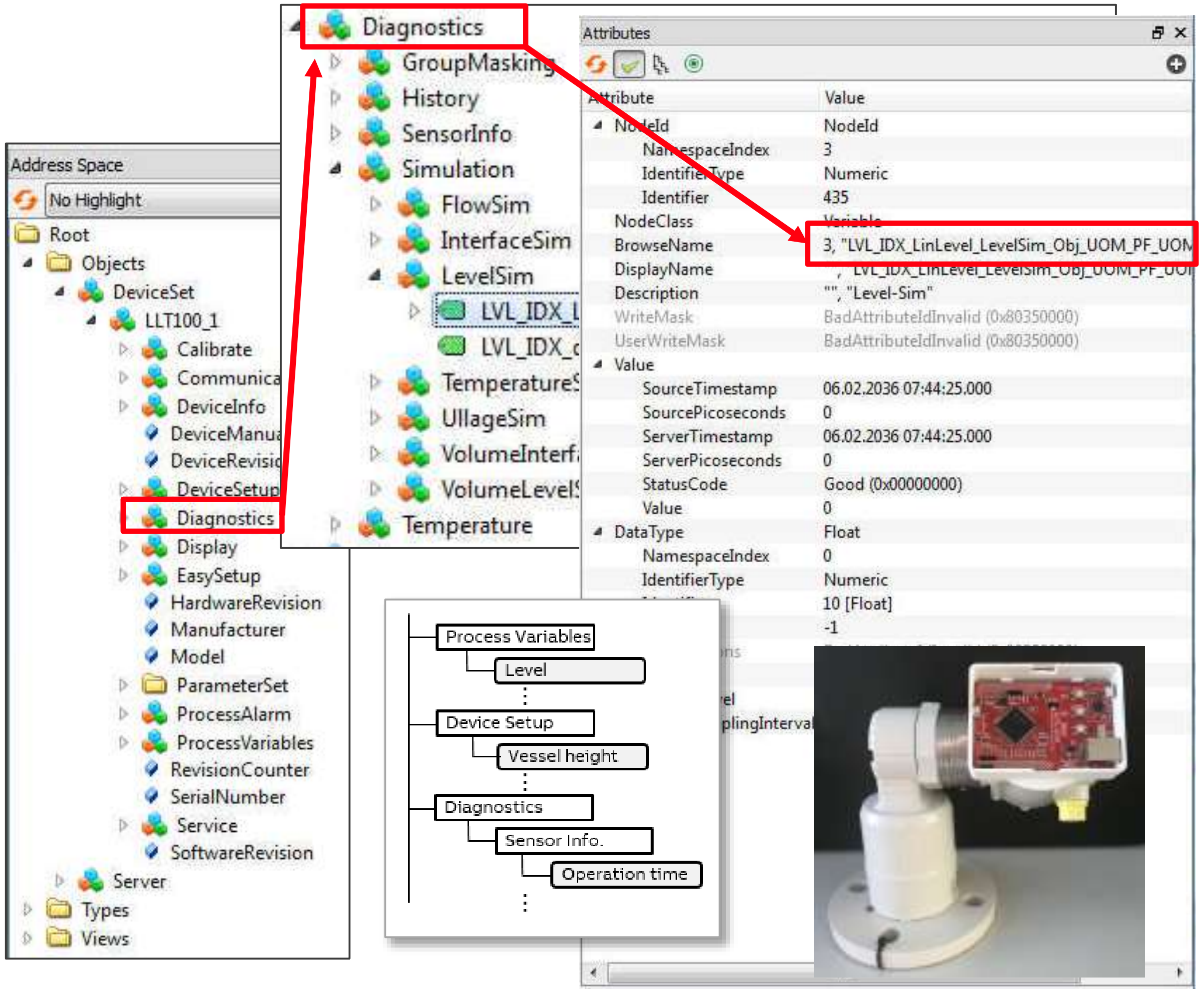
Before IIoT, parameters encoded directly in proprietary firmware

Migration path for LLT:

1. Define device parameters in Excel
2. Create XML NodeSet file
3. Transform to C-code using xml2c tool (UA address space)
4. Map information model to device firmware via API
5. Compile C-code into application

This may be typical for many existing sensors and actuators.

Providing appropriate content in OPC UA is non-trivial.



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IoT Challenge 3: Standardization of Device Models

Interoperability between devices of different vendors

NAMUR Core Parameters, OPC UA Companions

OPC UA mainly provides a syntactic basis for interoperability

Semantics of the device parameters are classically proprietary

→ Devices from different vendors cannot be exchanged today

Numerous standardizations ongoing:

- NE131: ~30 standard parameters for sensors / actuators
- OPC UA for Analyzer Devices (released)
- OPC UA for Robotics (ongoing)
- OPC UA for Industrial Drives (ongoing)
- OPC UA for Process Automation Devices (planned)

Metamodels for device models still emerging

- IEC Common Data Dictionary being revised for functions

Standardization could make IIoT devices exchangeable.

NE131 Parameter	Category
Process variable	Configuration Parameter
Process value	Runtime Value
Unit	Configuration Parameter
Upper range value	Configuration Parameter
Lower range value	Configuration Parameter
Diagnostic status	Runtime Value
Simulation	Function / Status
Simulation value	Configuration Parameter
Damping	Configuration Parameter
Set PV to zero	Function
Tag name	Configuration Parameter
Factory reset	Function
Last change date	Runtime Value
Change counter	Runtime Value
Display language	Configuration Parameter
Password	Configuration Parameter
Sensor type	Configuration Parameter
Sensor connection	Configuration Parameter
Sensor reference	Configuration Parameter

IoT Challenge 4: Bridging to the Cloud

From devices to cloud analytics and apps

Edge Gateways

Process control system with sensors and actuators provides a "trust boundary" and is normally shielded from Internet traffic

IoT edge gateways collect data from one site and relay it to a cloud platform for analytics and access from mobile devices

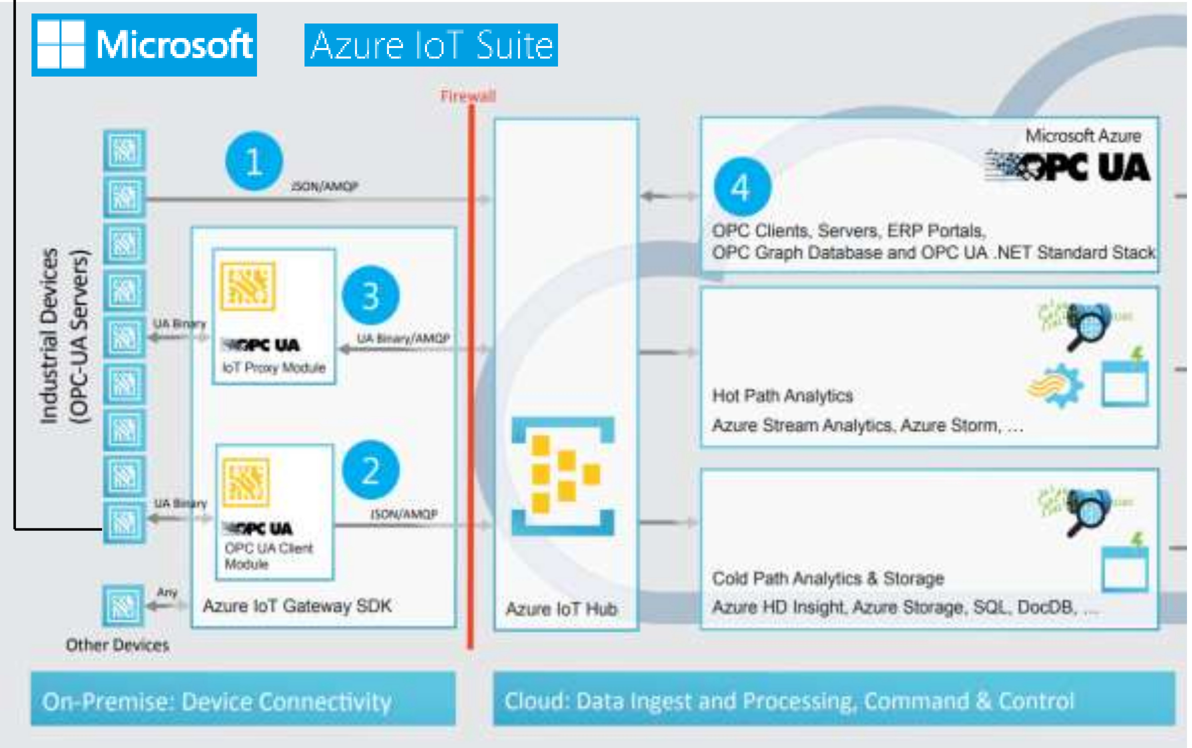
Edge gateway bridges between plant-internal traffic (e.g., OPC UA Binary) and plant-external traffic (e.g,. OPC UA via AMQP)

Must be secured appropriately (auth., encryption, intrusion det.)

Cloud providers supply edge gateway SDKs for vendors

- Microsoft Azure IoT Suite
- Amazon AWS IoT Core
- Google Cloud IoT Core
- …

Security & Performance for IIoT gateways challenging.



IoT Challenge 5: Security

From isolated networks to denial-of-service attacks

Machine Builder Guidelines for Industry 4.0 Security

Guidelines IIoT Security

Laser level transmitter as IIoT devices provides much larger attack profile than for classical, proprietary devices

LLT would be secured by OPC UA standard security mechanisms: user authentication, authorization, certificate exchange, encryption

Further selected security aspects:

- Risk Analysis, Network Segmentation, User Authentication, Secure Protocols, Secure Radio connections, Remote Maintenance, Intrusion Detection, Secure Product Life-Cycle, Component hardening, Cryptography, Isolation Techniques, …

Standards: IEC 62443 series for "Industrial communication networks – Network and system security "

IIoT device & system security requires a comprehensive approach.

security-Mode	Layer or Service	Denial of Service	Eaves-dropping	Message Spoofing	Message Alteration	Message Replay	Malformed Messages	Server Profiling	Session Hijacking	Rogue Server	Compromising User credentials	Repudiation
	OPC UA TCP	8	0	0	0	0	8	0	0	0	0	0
None												
	SecureChannel	17	0	0	0	23	1	0	22	0	0	0
	Session	14	0	2	0	26	3	4	23	0	2	2
	Discovery	12	0	2	2	21	5	4	18	3	0	3
Sign												
	SecureChannel	17	9	15	15	32	16	26	37	11	13	17
	Session	14	0	12	8	31	12	14	28	6	4	18
	Discovery	13	0	3	3	22	5	12	19	4	1	6
SignAndEncrypt												
	SecureChannel	17	18	15	15	32	16	26	40	11	18	17
	Session	14	18	12	8	31	12	14	46	6	22	18
	Discovery	13	7	3	3	22	5	12	25	4	7	6

Table 19: Effectiveness of the OPC UA measures

- (red): no protection
- (orange): low protection
- (yellow): Protection which restricts the possibilities of an attacker, but does not prevent this type of attack
- (green): effective protection (attacks of this type require cryptographic attacks)

German Federal Office for Information Security: OPC UA Security Analysis

IoT Challenge 6: AI/Autonomy

Making IIoT “really” smart

ABB YuMi Robot for Small Part Assembly

Applying Artificial Intelligence & Machine Learning

Re-inforcement learning for Robots

Intrusion/Anomaly detection for Process Control Systems

Local Analytics / Production Optimization

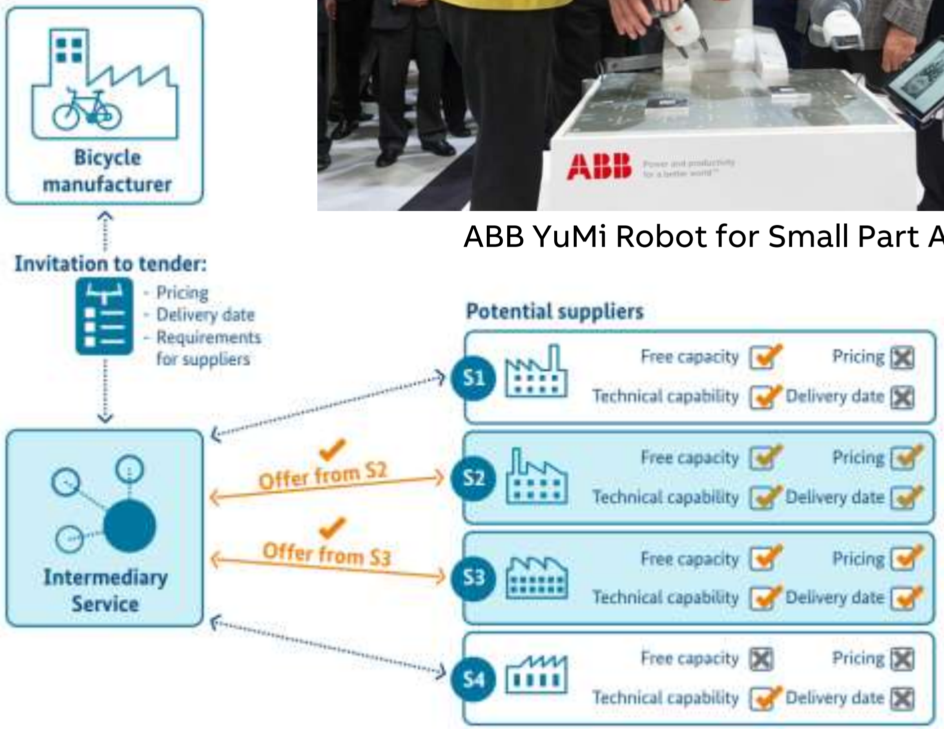
Skill Modeling for Discrete Manufacturing

Automated Supply Chains

Laser Level Transmitter:

- Plug & Produce: could “learn/infer” appropriate configuration parameters for automated commissioning
- cf. ICSA 2018 paper

Limited “autonomous” devices today, but in research.



A fully automated tendering process for personalized products sketched by Plattform Industrie 4.0

IoT Challenges for Smart Manufacturing

How to connect a Laser-level Transmitter to the Cloud?

Practitioners Challenges

1. Dealing with severe resource constraints
2. Designing appropriate information models
3. Implementing standards for interoperability
4. Bridging to cloud platforms
5. Addressing security requirements
6. Integrating autonomy, local analytics

SWA Research Topics

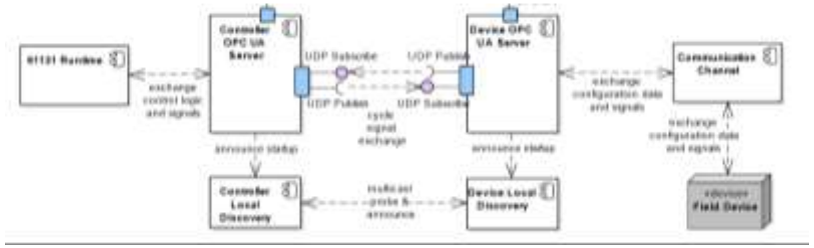
- Reference Architectures
- Patterns & Decision Templates
- Modeling Languages & Transformations
- Performance Modeling & Benchmarking
- Security Methods
- Autonomy + Machine Learning

What can Software Architecture research contribute?

Software Architecture & IoT Research Topics (1/2)

Patterns & Modeling

Reference Architectures

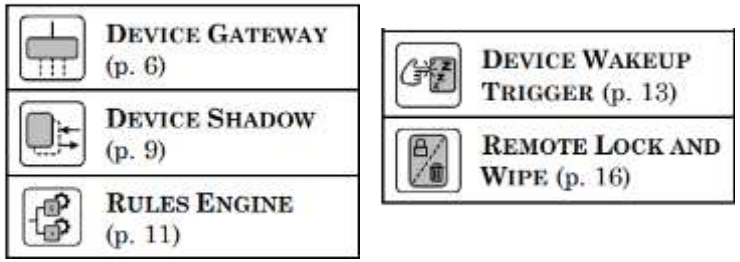


Hammerstingl/Reinhard, ICIT 2015: **Unified Plug&Produce Architecture**

Weyreich/Ebert, IEEE Software 2016: **Reference architectures for the IoT**

Koziolek et. al ICSA 2018: **Plug&Produce Reference Architecture with OPC UA**

Patterns & Decisions Templates

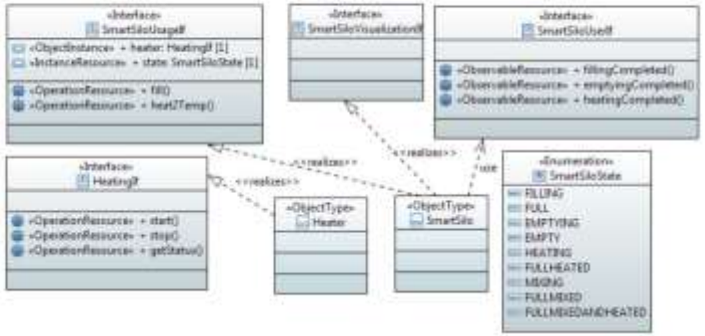


Eloranta et al. Wiley Book 2014: **Pattern language for distributed control systems**

Qanbari et al. IoTDI 2016: **IoT Design Patterns**

Reinfurt/Leymann, EuroPLoP 2016: **Internet of Things Patterns**

Modeling Lang. + Transformations



Thramboulidis et al. Computers in Industry 2016: **UML4IoT Profile**

Eclipse Vorto: **Device Description for IoT applications**

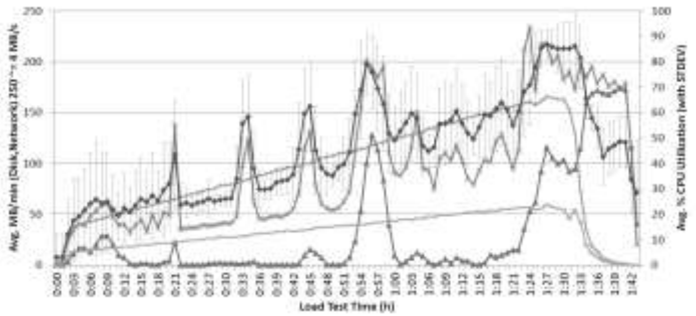
OPC UA Companion Specifications for Robots, Drives, Analyzer Devices

Eclipse BaSyx

Software Architecture & IoT Research Topics (2/2)

Quality of Service & Architecture

Performance



deGooijer/Koziolek, ICPE 2012: **Design Space Exploration for Robotics Backend**

Goldschmidt/Koziolek, IEEE Cloud 2014: **Benchmarking Time-Series Databases**

Veichtlbauer et al., INDIN2017: **OPC UA on resource constrained devices**

Security

Bundesamt für Sicherheit in der Informationstechnik

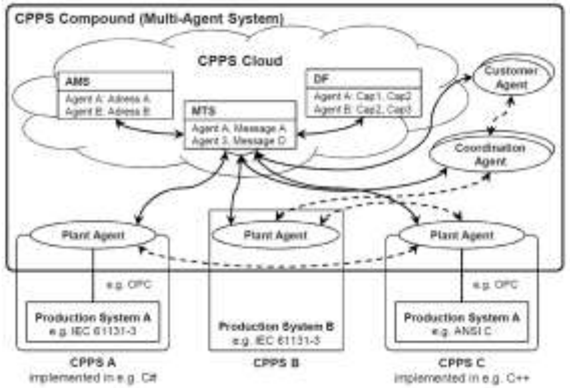
OPC UA Security Analysis

Dzung/Naedele, Proceedings IEEE, 2005: **Security for Industrial Systems**

Wurm et al., ASP-DAC 2016: **Security of Consumer and Industrial IoT Devices**

BSI 2017: **OPC UA Security Analysis**

"Autonomy"



Pech, IEEE Software 2013, **Software Agents in Industrial Automation Systems**

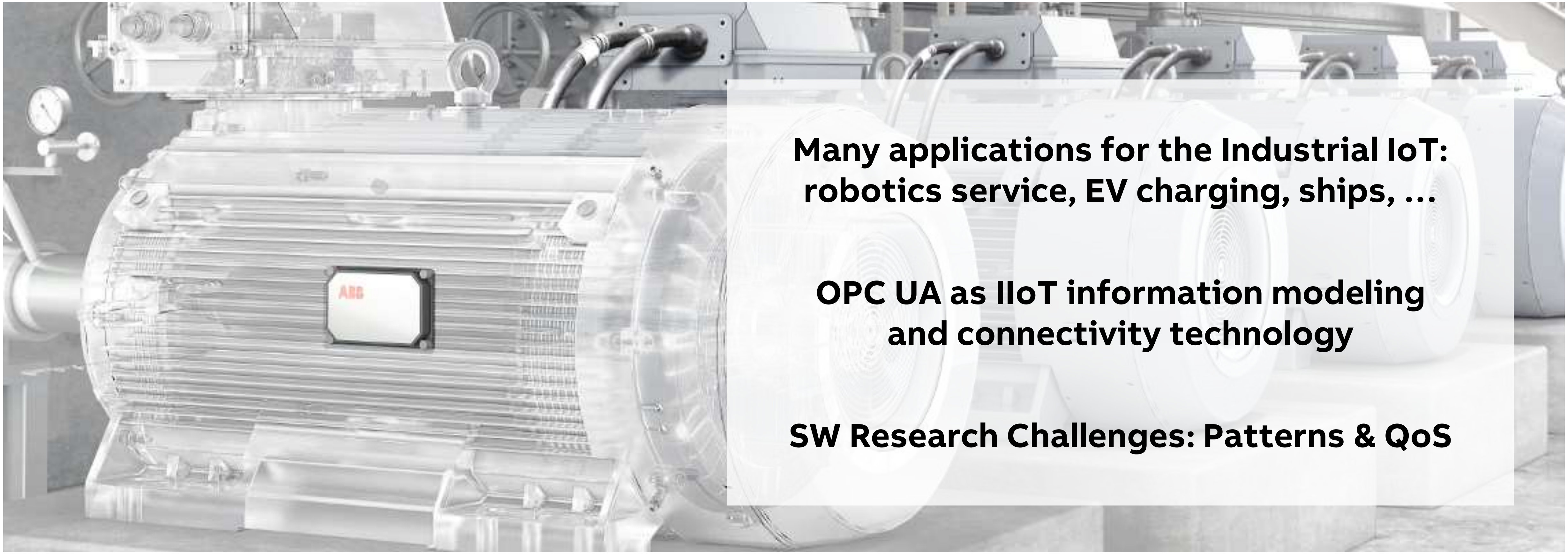
Vogel-Heuser 2014: **Multi-agent based cyber-physical production system**

Musil et al. Springer Book 2017: **Patterns for Self-Adaptation in CPS**

Eclipse 4DIAC

Summary

IoT Challenges for Smart Manufacturing



Many applications for the Industrial IoT: robotics service, EV charging, ships, …

OPC UA as IIoT information modeling and connectivity technology

SW Research Challenges: Patterns & QoS

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