PLATTFORM INDUSTRIE 4.0

工业互联网产业联盟
Alliance of Industrial Internet

I4.0 x Industrial Internet: Practices and Findings

Sino-German Company Working Group on Industrie 4.0 and Intelligent Manufacturing (AGU)
Expert Group Industrial Internet

Published by

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Registered Offices
Bonn and Eschborn

GIZ Office China
Sunflower Tower 1100
37 Maizidian Street, Chaoyang District
100125 Beijing, PR China
T +86 10 8527 5180

E giz-china@giz.de
I www.giz.de/china

Sino-German Industrie 4.0 Project
Tayuan Diplomatic Office Building 2-5
14 Liangmahe Nanlu, Chaoyang District
100600 Beijing, PR China
T +86 10 8532 4845
F +86 10 8532 4266

E info@i40-china.org
I www.i40-china.org

China Academy of Information
and Communications Technology (CAICT)

No.52, Hua Yuan Bei Road,
Haidian District,
100191, Beijing, PR China
T +86 10 62301618
F +86 10 62304346

I www.caict.ac.cn

This publication is a result of close cooperation between multiple entities in Germany and China including the Sino-German Company Working Group on Industrie 4.0 and Intelligent Manufacturing (AGU) Expert Group Industrial Internet in support of the MoU signed in 2015 between BMWi and MIIT following the 2014 joint action plan "Shaping Innovation Together."

Since 2016, the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, commissioned by BMWi, and the China Center for Information Industry Development (CCID) are the implementing bodies for the cooperation on the German and the Chinese side, respectively.

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Executive Summary

The Industrial Internet is a key enabler to the digital transformation of manufacturing. Working at the industry and expert level, the Sino-German Company Working Group on Industrie 4.0 and Intelligent Manufacturing (AGU) Expert Group Industrial Internet (EG II) aims to foster mutual understanding on technological concepts and develop a joint conclusion and recommendations. As the result of the initial phase of the EG II, the 2019 edition of the White Paper presents the preliminary findings of the joint work of German and Chinese companies and experts, builds the foundation for future cooperation and specifies topics for the future work of the AGU EG II.

Starting with the definition and scope in Chapter 2, the White Paper first presents an overview of the current approaches taken by industry experts regarding Industrie 4.0 and Intelligent Manufacturing. While Industrie 4.0 on the German side focuses on the application of the Internet of Things (IoT) in manufacturing, the Industrial Internet Architecture on the Chinese side not only emphasises the industrial foundation but also covers other industries such as energy and healthcare.

Based on the discussion on the definition, Chapter 3 collects and analyses a wide range of use cases provided by the German and Chinese companies participating in the EG II. There are four use cases respectively from Siemens, TRUMPF, thyssenkrupp and SAP on the German side that relate to cooling as a service, remote and predictive maintenance, 3D printing as a service and a PLM process support platform. The selection of the German use cases aims to provide a large variety of different business views. On the Chinese side, six use cases are presented covering a wide range of applications of the Industrial Internet in China, i.e. aftermarket service solutions, mass customisation, 5G-enabled smart port, edge computing and predictive monitoring, Industrial Internet Identifier system and security solutions. The Chinese use cases reflect the characteristics of the Industrial Internet Architecture.

Described and analysed in detail, the use cases serve as a solid foundation to draw conclusions in Chapter 4. Beginning with the strategic importance and value of the Industrial Internet in manufacturing, the conclusion in Chapter 4 focuses on interoperability (including machine connectivity and networking), data protection and platform. The EG II decided to focus its future work first on the two areas of machine connectivity/networking and data protection. Based on this foundation, Chapter 4 concludes with recommendations for the next phase of the EG II's work. The use cases should be further studied regarding interoperability and data protection. Regarding machine connectivity and networking, the EG II suggests investigating the use of MQTT and OPC UA in China and Germany. Recommendations should be worked out in cooperation with the Sub-Working Group on Industrie 4.0/Intelligent Manufacturing under the Sino-German Standardisation Cooperation Commission (SGSCC). Regarding data protection, the EG II suggests to first focus on a clear understanding of the requirements stemming from different points of view, such as protection of competitively relevant data, data ownership and cross-border data transfer.

In Chapter 5, the White Paper also references Industrie 4.0 and Industrial Internet test beds in Germany and China and consists of a glossary that provides valuable information for industry players and companies.

1. Introduction

1.1 Background of Cooperation Framework of Sino-German Intelligent Manufacturing

In July 2015, the German Federal Ministry for Economic Affairs and Energy (BMWi) and the Chinese Ministry of Industry and Information Technology (MIIT) signed a Memorandum of Understanding (MoU) with the objective of supporting German and Chinese enterprises in creating a favourable business environment for Intelligent Manufacturing and Industrie 4.0. This MoU emphasises the importance of industry cooperation and highlights the shared interest in facilitating further dialogue at all levels between representatives from government, industry and academia.

BMWi and MIIT commissioned the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH and the China Center for Information Industry Development (CCID) to support the implementation of the MoU. Under the direction of BMWi and MIIT, GIZ and CCID jointly established the Sino-German Company Working Group on Industrie 4.0 and Intelligent Manufacturing (AGU) as a platform for German and Chinese experts to discuss challenges and opportunities of Industrie 4.0 and Intelligent Manufacturing with the goal of better understanding relevant business environment and policies, exchanging best practices and developing joint policy recommendations. These discussions directly inform the bilateral political dialogue.

The Sino-German expert groups focus on four Industrie 4.0 areas. These include:

- Digital Business Models
- Training 4.0
- Industrial Internet
- Artificial Intelligence

Industrial Internet is a key enabler to the digital transformation of manufacturing. The AGU Expert Group Industrial Internet (EG II) shall foster mutual understanding of the technological concepts, exchange information on the various governance systems and best practices in application for the German and Chinese industries. The EG II will focus its work on three areas: the interoperability in the Industrial Internet, the application of Industrial Internet platforms and data protection in the Industrial Internet.

The Chinese implementation partner within the EG II is the China Academy of Information and Communications Technology (hereinafter referred to as CAICT), which is a scientific research institute directly under the Ministry of Industry and Information Technology (MIIT) of China. CAICT conducts in-depth research and foresighted planning in fields such as Industrial Internet, smart manufacturing, mobile Internet and Internet of Things (IoT).

1.2 Objective of this White Paper

- **Motivation and Goal:** This White Paper aims to present current approaches of industry experts in terms of analysing Industrial Internet applications with a special focus on Intelligent Manufacturing and Industrie 4.0. It provides insights into existing use cases of Industrial Internet implementations and draws conclusions and recommendations for the Sino-German dialogue on how to harmonise framework conditions.

- **Use Cases:** The White Paper provides a diverse overview of current use cases provided by Chinese and German organisations that participate in the AGU.

- **Resources and Support:** The White Paper also references additional resources, such as valuable insights, into existing test beds and a general glossary.

2. Definition and Scope

2.1 Definition "Industrial Internet"

The Industrial Internet is a product of a new generation of industrial waves, and different countries have different thinking about it. In this paper, China's definition of the Industrial Internet comes from the Alliance of Industrial Internet (AII):

- Generally speaking, the Industrial Internet promotes the digital transformation of the manufacturing industry through the comprehensive connection of the industrial element, industry chain and value chain, and continuously promotes new business models and new industries, reshaping industrial productions and services to achieve a high-quality development of the industrial economy.

- From a technical perspective, the Industrial Internet is a new type of industrial digital system that integrates manufacturing technology and new-generation information communication technology, such as next generation network, advanced computing, Big Data, artificial intelligence, etc. It connects people, machines, objects and other production factors on an extensive scale, performs processing, modelling and analysis of massive industrial data based on a digital platform and provides end-to-end security to drive the development of Intelligent Manufacturing and to lead the innovation of manufacturing models, service models and business models.

From the German perspective, the definition of the "Industrial Internet" comes from the Alliance for Internet of Things Innovation (AIOTI):

- "Internet of Things" and "IoT" shall mean the network of physical objects, devices, vehicles, buildings and other items embedded with electronics, software, sensors, actuators and network connectivity that enables these various objects to collect and exchange data.

In the manufacturing industries sector, IoT, IIoT and Industrial Internet are synonyms, where physical things with computing capabilities are interconnected based on Internet technologies and standards.

To distinguish this generic description from scenarios that have already existed for years, especially in the manufacturing industries, the following aspects should be considered:

- The "things" are typically located worldwide, i.e. we usually do not consider a single factory where, for example, a manufacturing execution system (MES) needs to be deployed.

- There are different (business) stakeholders that have an interest in the "things" while they are being used. Typically, the owner of the physical things has an interest in sharing information concerning the thing, for example with the supplier of the physical thing.

2.2 Discussion of Industrial Internet in the Context of Industrie 4.0

While the Industrial Internet of Things (IIoT) can be applied to various industries such as energy, healthcare and manufacturing, Industrie 4.0 particularly focuses on the manufacturing industry. Germany's strategic initiative "Plattform Industrie 4.0" therefore also focuses on the manufacturing industry: on those aspects of the market, where new and advanced technologies are used in order to improve efficiency, enhance flexibility or reduce time to market, and on the lead suppliers, where for example providers of machines, automation components or software solutions offer their products and services to the lead market.

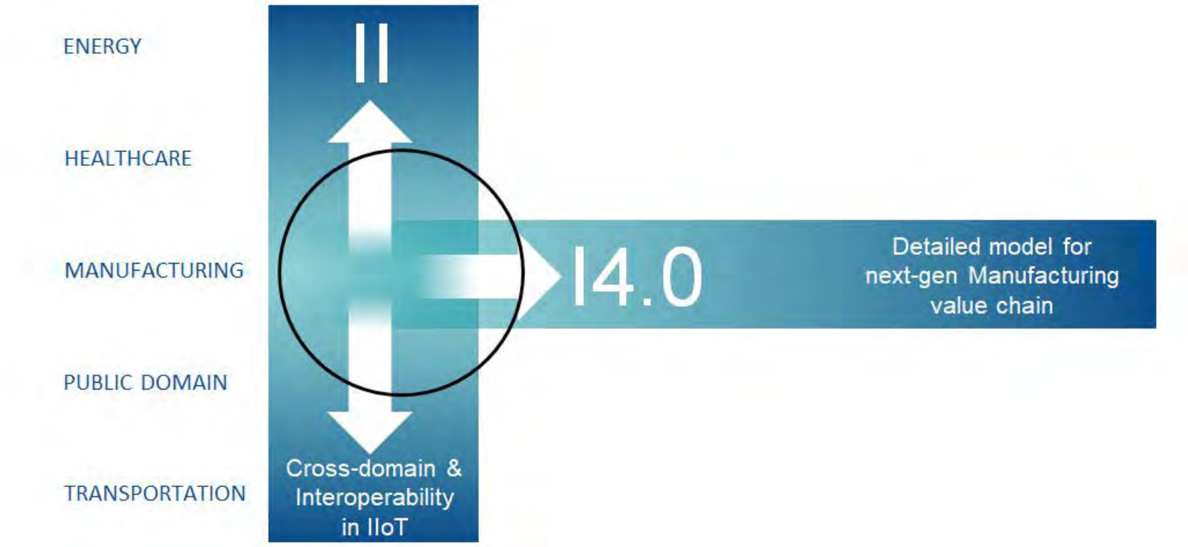

Figure 1: llustration of the junction between IIoT and Industrie 4.0 [source: IIC and Plattform Industrie 4.0[1]]

Consequently, this paper focuses its discussions of the Industrial Internet on key issues (also) relevant to manufacturing, even if the use cases may be from different domains. This way, we can combine insights from both Chinese and German industry experts.

On the other hand, Industrie 4.0 discusses additional aspects of the fourth industrial revolution that may or may not be implemented using the Industrial Internet.

Therefore, in terms of the technical content at the junction where Industrie 4.0 and Industrial Internet overlap, a focal area is "connected assets and machines" and ensuing issues around interoperability. Figure 2 illustrates a typical Industrial Internet Industrie 4.0 system, which consists of an IIoT platform able to link connected assets through the IIoT platform with various applications. This IIoT platform itself is structured in three layers:

- **Connectivity layer:** The connectivity layer enables the connection of assets in various locations and collects data provided by the assets.
- **•Infrastructure layer:** The infrastructure layer processes the data and provides computational execution capabilities. On this layer, the data will be grouped into function blocks that can then be used by the applications.
- **Application layer:** The application layer consists of various applications and provides them with the function blocks created on the infrastructure layer.[2]

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[1] IIC and Plattform Industrie 4.0 (2017), Architecture Alignment and Interoperability: an Industrial Internet Consortium and Plattform Industrie 4.0 Joint White Paper, p. 2.

[2] Plattform Industrie 4.0 (2018), Discussion Paper: Usage Viewpoint of Application Scenario Value-Based Service, p. 11f.

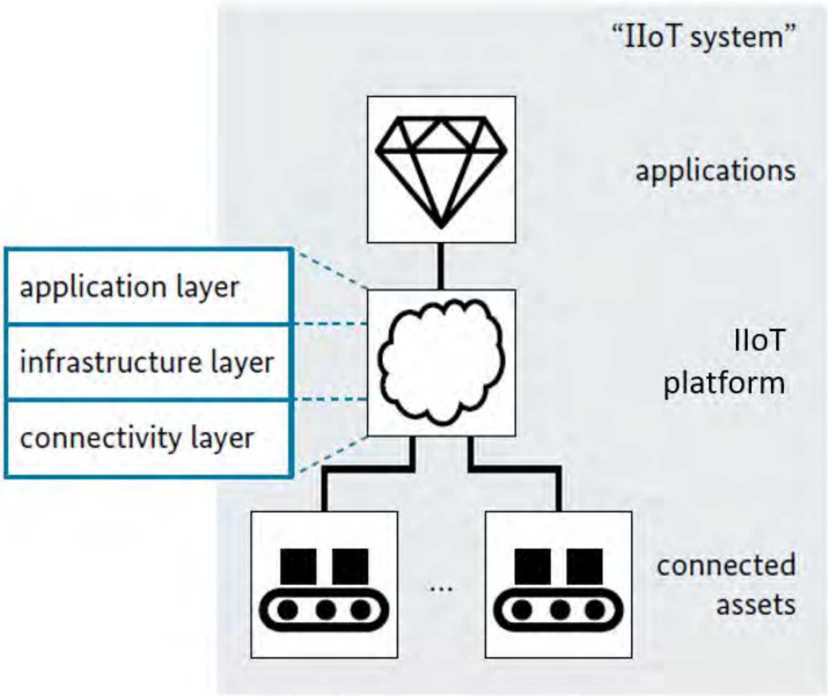

Figure 2: Illustration of the different levels of an IIoT system [source: Plattform Industrie 4.0 (2018)[3]]

2.3 Discussion of the Industrial Internet in the Context of the Alliance of Industrial Internet

On 1 February 2016, in order to rapidly boost the development of the Industrial Internet industry, relevant units in the fields of manufacturing, information and communication, and security together initiated the Alliance of Industrial Internet (hereinafter referred to as the "AII"). Adhering to the concepts of openness and sharing, AII pools resources from various sources, deepens cooperation in multiple fields with focus on top-level design, technology R&D, standardisation, test verification, industrial practices, etc. of Industrial Internet in China, creates a collaborative development platform between industry, university, research and application, and builds industrial ecology for Industrial Internet. Currently, AII has nearly 1,600 members, forming a "14+13+X" organisational structure. It has released a series of Industrial Internet white papers, focusing on multiple Industrial Internet test beds, user cases, solutions, etc. AII has organised and participated in a number of large-scale Industrial Internet-related activities at home and abroad, established partnerships with IIC, AIOTI, IVI, etc., and jointly set up the Sino-German Industrial Internet Expert Group. AII will continue to conduct research on Industrial Internet technologies, industries and talents, promote industrial development and deepen exchanges and cooperation with relevant international organisations.

Industrial Internet Architecture (Version 2.0) includes three core sectors. First, service view, which reflects the industrial objectives, business values, digital capabilities and service scenarios. Second, functional architecture, which incorporates the functions supporting the service fulfilment, including basic elements, functional modules, interactive relationship and scope of action. Third, implementation framework, which describes the deployment of software and hardware to realise the functions and defines the hierarchical structure, load-bearing entities, key software and hardware, and action relationships of the system implementation.

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[3] Plattform Industrie 4.0 (2018), Discussion Paper: Usage Viewpoint of Application Scenario Value-Based Service, p. 11f.

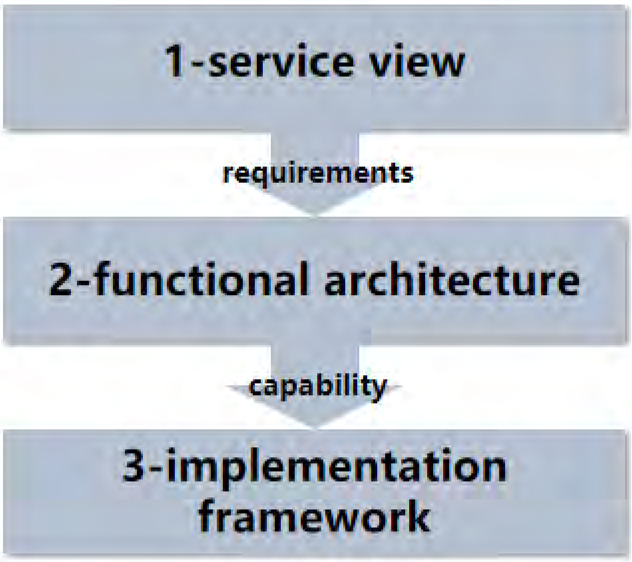

Figure 3: Industrial Internet Architecture (Version 2.0)

Service view defines service requirements and business values. The service view is divided into four layers, of which the **industry layer** supports the national strategic layout and the path of the all-round development of the industry, the **business layer** guides the enterprise decision-makers in establishing the corporate vision, direction and targets, the **application layer** is geared towards the enterprise informatisation director and clarifies the connotation of product chain, value chain and asset chain, and the **capability layer** defines the capability required for the digital transformation and development of the Industrial Internet.

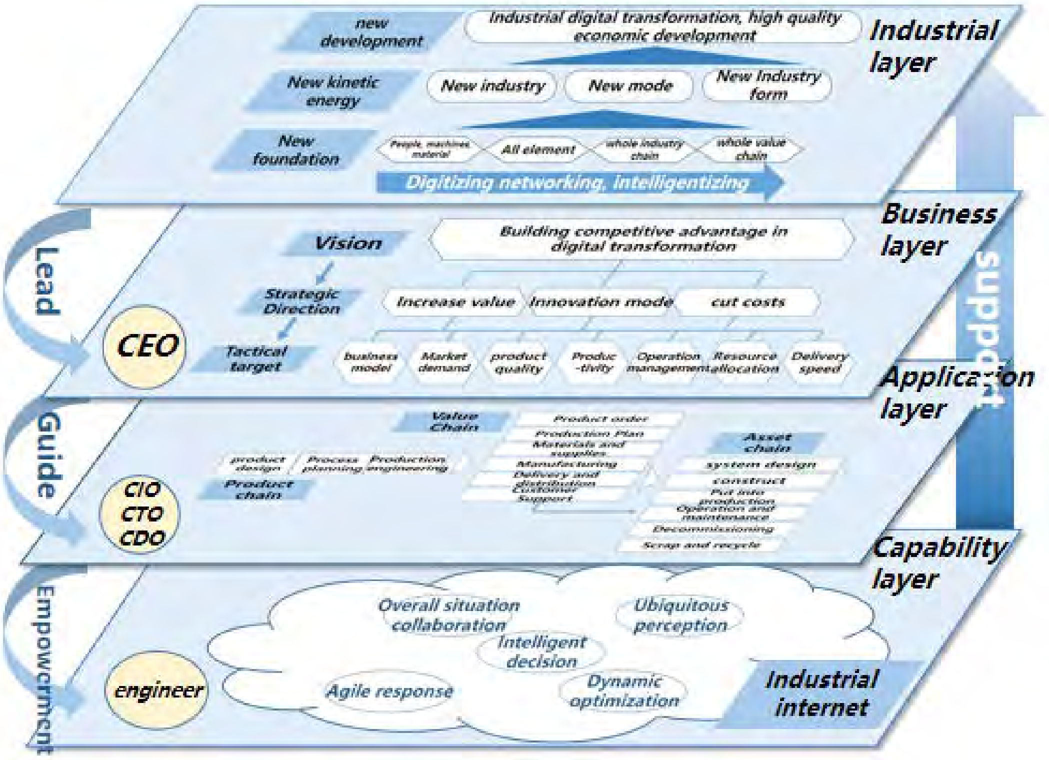

Figure 4: Service view

Functional architecture defines key capabilities and functional elements. Functional architecture is the core of Architecture 2.0 and the key for the industry to define the basic elements, functional modules, interactive flow relationship and scope of action in the Industrial Internet system. It further expands the Industrial Internet system, deepens the network, platform and security, analyses the functions and relationships of the three major function systems in different industries and different scenarios, indicates the mechanism of data action and greatly enriches the current theoretical research and practical preparation of the Industrial Internet.

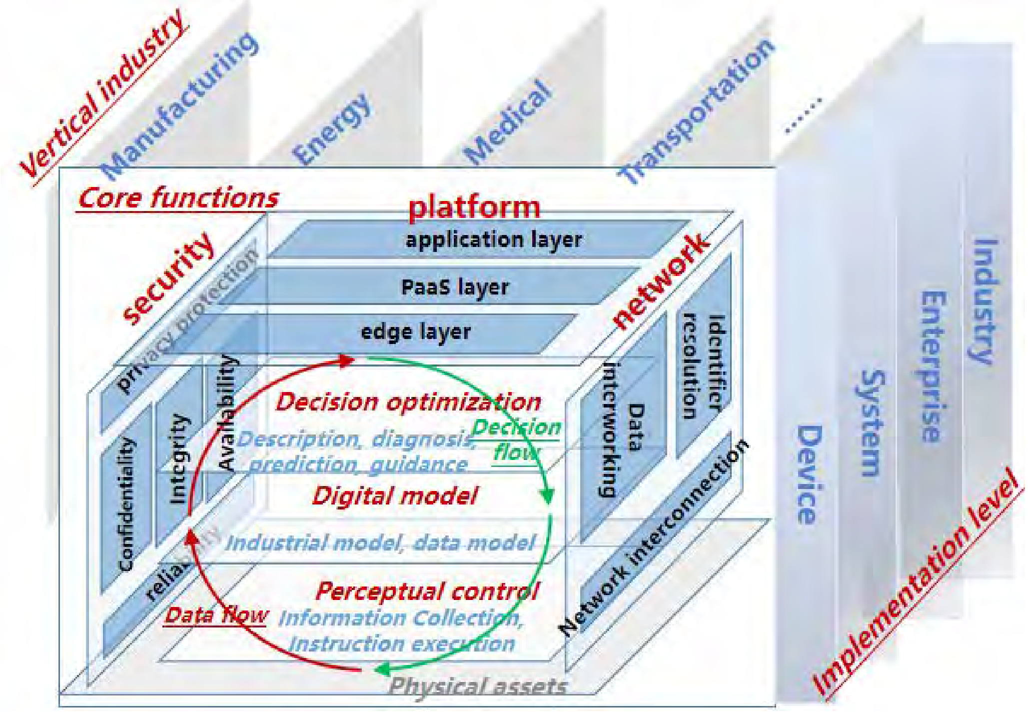

Figure 5: Functional architecture

The implementation framework defines the implementation core elements and resource system. The implementation framework, on the one hand, is a vertical expansion of the functional architecture, reflecting the progression layer by layer and the concrete decomposition of "network, identifier, platform and security" functions in "device layer, edge layer, enterprise layer and industry layer"; on the other hand, it shows the hierarchical relationship between Industrial Internet platform and digital twin, reflecting the key position of the two in the successful implementation of Industrial Internet.

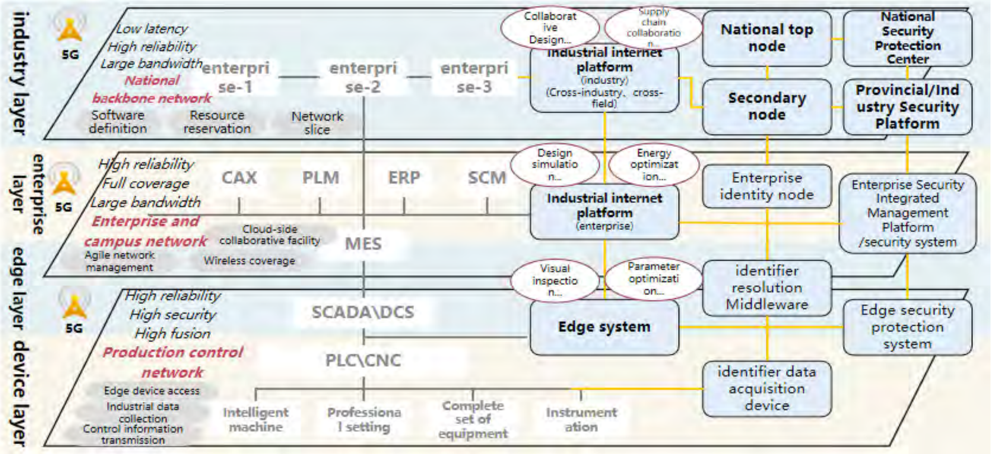

Figure 6: Implementation framework

2.4 Industrie 4.0 x Alliance of Industrial Internet

Comparing the definitions and the discussions on Industrial Internet summarised above in both I4.0 and AII, we find several important common structures. For example, both emphasise the following aspects:

- Physical assets are connected to the Industrial Internet system.
- An Industrial Internet platform is a central part of the Industrial Internet system.
- There are applications delivering the desired benefits. In the platform, these are supported by an application layer.

However, there are also some differences in the points of view taken in the discussion in I4.0 and AII.

One point is that, as discussed in 2.2, I4.0 focuses on manufacturing, whereas Industrial Internet as addressed by AII covers a number of vertical industries such as energy, healthcare and construction in addition to focusing on the industrial foundation.

Regarding architecture, I4.0 considers the RAMI4.0 architecture general enough to also cover the aspects of the Industrial Internet, whereas AII considers an in-depth definition of an II architecture as important, as explained in 2.3.

For the work of the AGU Expert Group Industrial Internet (EG II), we have agreed that in order to deliver value from a discussion among a number of German and Chinese companies, we will adopt the following approach:

The discussion will be based on concrete use cases that are proposed and described by the companies.

The use cases will be described using a common structure, which is based on previous work in the Sub-Working Group on Industrie 4.0/ Intelligent Manufacturing under the Sino-German Standardisation Cooperation Commission (SGSCC).

It will be important that there is a common understanding of the contents of each use case. The discussion should therefore first establish a joint understanding of the use cases and then focus on common questions to which the use cases provide concrete insights.

The discussion of the EG II have to be focused, so that the EG II will make decisions regarding which contents need to be discussed in more detail based on the use cases described.

This way, the work of the EG II will be able to benefit from work on common areas of interest, and at the same time draw on the sometimes slightly different points of view to bring in new insights and thereby be used in a positive way.

2.5 Other Key Terms

In order to ensure a clear understanding of the following contents, a comprehensive table in the Appendix provides all key terms being used in this document. It contains their full index terms, potential abbreviations, a short and simple definition and introductory literature. The term “interoperability” will be briefly discussed in the following paragraph to provide crucial understanding for the further discussions in this paper.

Interoperability

Interoperability is defined as “the degree to which two products, programmes, etc. can be used together, or the quality of being able to be used together.”[4] It is a core issue in the process of aligning network architectures and connecting devices originally working with different standards. Therefore, it is often used in contexts of harmonisation and standardisation efforts.

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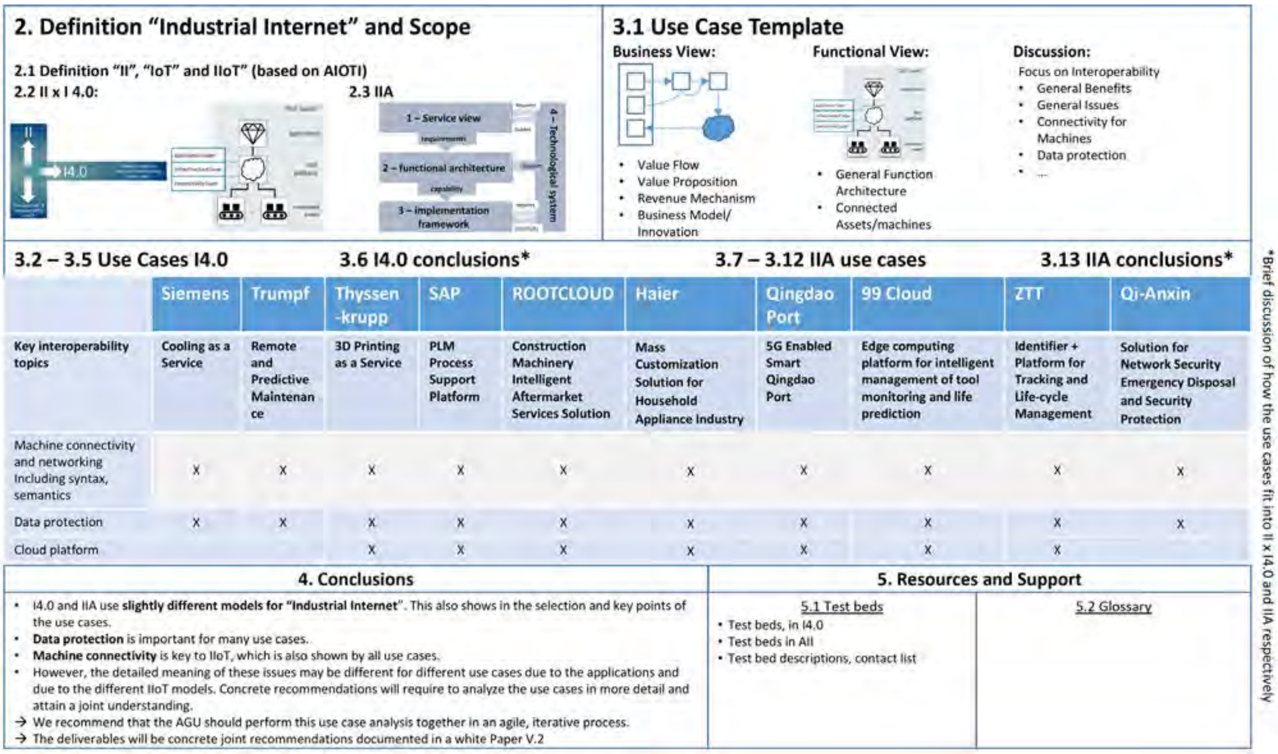
[4] Cambridge Dictionary, https://dictionary.cambridge.org/dictionary/english/interoperability.

2.6 Scope and Overview of the White Paper

This paper discusses exemplary use cases of the Industrial Internet, provided by industry experts from the AGU Expert Group Industrial Internet (EG II). As they are discussed with respect to interoperability, data protection and platforms, these use cases are being described in greater detail. After the evaluation, suggestions for further work of the EG II to address scope for improvement will be discussed. In a next chapter, helpful information such as a glossary and an introduction to test beds are provided.

The outline of the paper can be described graphically as follows:



2. Definition "Industrial Internet" and Scope

2.1 Definition "II", "IoT" and IIoT" (based on AIOTI)
2.2 II x I 4.0:
2.3 IIA

3.1 Use Case Template

Business View:
- Value Flow
- Value Proposition
- Revenue Mechanism
- Business Model/ Innovation

Functional View:
- General Function Architecture
- Connected Assets/machines

Discussion:
Focus on Interoperability
- General Benefits
- General Issues
- Connectivity for Machines
- Data protection
- ...

3.2 – 3.5 Use Cases I4.0 **3.6 I4.0 conclusions*** **3.7 – 3.12 IIA use cases** **3.13 IIA conclusions***

	Siemens	Trumpf	Thyssen -krupp	SAP	ROOTCLOUD	Haier	Qingdao Port	99 Cloud	ZTT	Qi-Anxin
Key interoperability topics	**Cooling as a Service**	**Remote and Predictive Maintenance**	**3D Printing as a Service**	**PLM Process Support Platform**	**Construction Machinery Intelligent Aftermarket Services Solution**	**Mass Customization Solution for Household Appliance Industry**	**5G Enabled Smart Qingdao Port**	**Edge computing platform for intelligent management of tool monitoring and life prediction**	**Identifier + Platform for Tracking and Life-cycle Management**	**Solution for Network Security Emergency Disposal and Security Protection**
Machine connectivity and networking Including syntax, semantics	X	X	X	X	X	X	X	X	X	X
Data protection	X	X	X	X	X	X	X	X	X	X
Cloud platform			X	X	X	X	X	X	X	

4. Conclusions
- I4.0 and IIA use **slightly different models for "Industrial Internet"**. This also shows in the selection and key points of the use cases.
- **Data protection** is important for many use cases.
- **Machine connectivity** is key to IIoT, which is also shown by all use cases.
- However, the detailed meaning of these issues may be different for different use cases due to the applications and due to the different IIoT models. Concrete recommendations will require to analyze the use cases in more detail and attain a joint understanding.

→ We recommend that the AGU should perform this use case analysis together in an agile, iterative process.
→ The deliverables will be concrete joint recommendations documented in a white Paper V.2

5. Resources and Support

5.1 Test beds
- Test beds, in I4.0
- Test beds in All
- Test bed descriptions, contact list

5.2 Glossary

*Brief discussion of how the use cases fit into II x I4.0 and IIA respectively

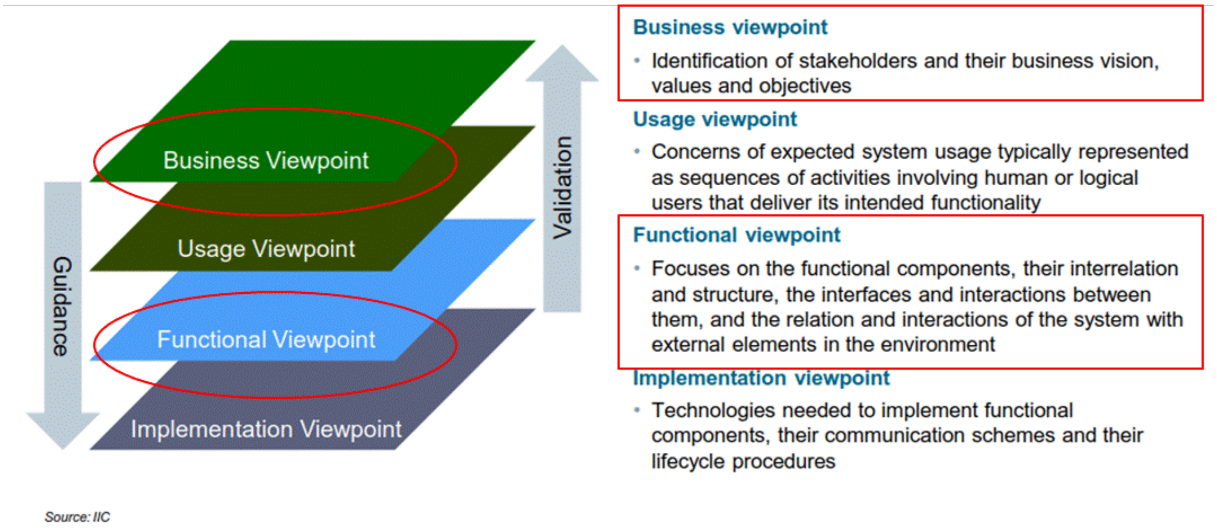
Figure 7: Graphical outline of the White Paper

3. Use Cases

3.1 Use Case Template

In order to describe the use cases on a comparable level, the AGU Expert Group Industrial Internet (EG II) has adopted a common use case description based on the ongoing use case description discussion in the Sub-Working Group Industrie 4.0/Intelligent Manufacturing under the Sino-German Standardisation Cooperation Commission (SGSCC).[5]

First, we select only the two viewpoints "Business" and "Functional" from the Industrial Internet Reference Architecture (IIRA).



Source: IIC

Figure 8: Framework for use case analysis

We do not describe the usage viewpoint as shown in Figure 8 because our observation is that the usage viewpoint is the same in all use cases and has been described in a generic way in the paper "Usage View VBS," which was also discussed in detail in the Sino-German Cooperation on Standardisation.[6] But in the business viewpoint as well as in the functional viewpoint, we observe many different manifestations in practice. Therefore, we are focusing on these two viewpoints in this paper.

Second, we adopt a value stream model from the discussion on use cases in Plattform Industrie 4.0 as well as in the Sino-German Cooperation on Standardisation to describe the business viewpoint. Figure 9 shows an example.

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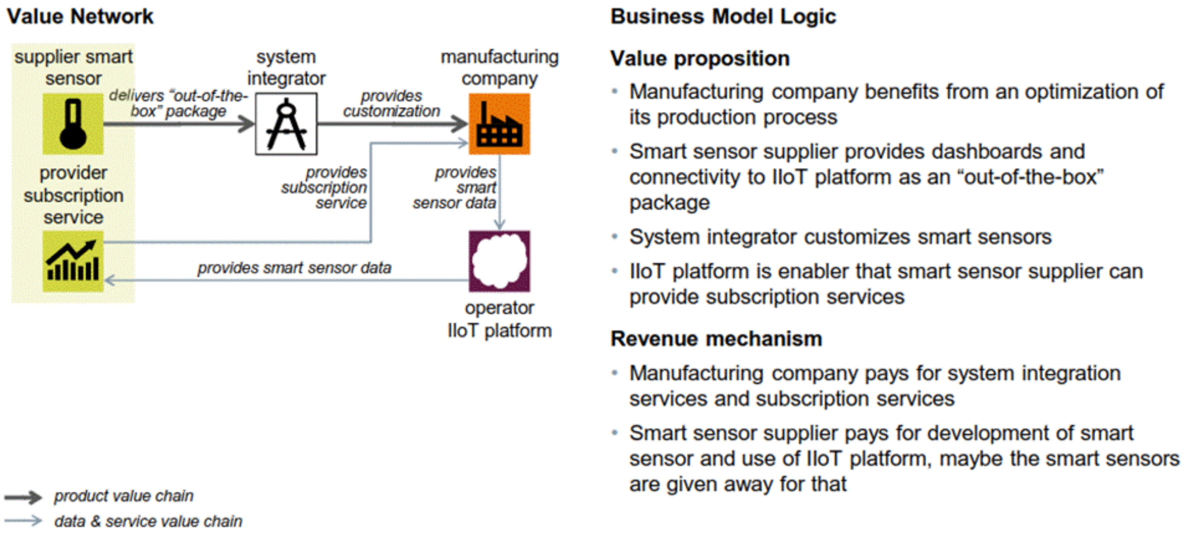
[5] Plattform Industrie 4.0 (2017), Exemplification of the Industrie 4.0 Application Scenario Value-Based Service following IIRA Structure, p. 7.

[6] Ibid.



Business Model Logic

Value proposition

- Manufacturing company benefits from an optimization of its production process
- Smart sensor supplier provides dashboards and connectivity to IIoT platform as an "out-of-the-box" package
- System integrator customizes smart sensors
- IIoT platform is enabler that smart sensor supplier can provide subscription services

Revenue mechanism

- Manufacturing company pays for system integration services and subscription services
- Smart sensor supplier pays for development of smart sensor and use of IIoT platform, maybe the smart sensors are given away for that

Figure 9: Example for the application of the framework

The overall value flow diagram, the value proposition and the revenue mechanism should be mandatory elements of the business view use case description.

Third, in order to describe the functions, we use the logic which is already shown in Figure 2 of Chapter 2.2.

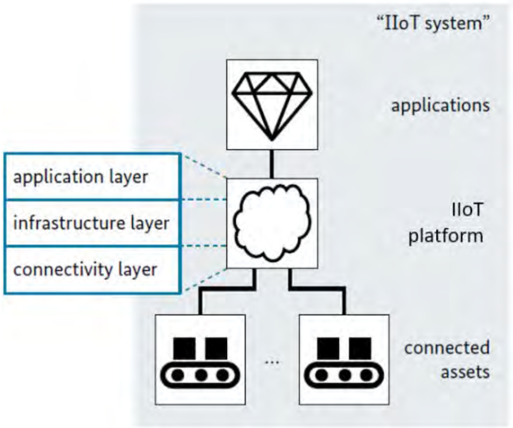


Figure 10: Illustration of the different levels of an IIoT system

Here, the idea is to adjust this graphic to the use case at hand and discuss the applications, IIoT platform, connected assets and any issues related to these entities.[7]

Fourth, each use case will contain a discussion of the challenges, the implications of interoperability and other key points of the use case at hand.

In summary, we have the following structure of all use case descriptions:

1. Overview of use case
2. Business view
   a. Value flow diagram
   b. Value proposition
   c. Revenue model

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[7] Plattform Industrie 4.0 (2018), Discussion Paper: Usage Viewpoint of Application Scenario Value-Based Service, p. 11f.

3. Functional view
    a. High level functional architecture diagram
    b. Applications
    c. Connected industrial assets
4. Discussion
    a. General benefits and challenges
    b. Focus on interoperability
    c. Other key points

3.2 Use Case "Cooling as a Service"

3.2.1 Overview of Use Case Description

Components of industrial automation systems are typically mounted in cabinet-like enclosures, which protect the equipment from unauthorized access and harmful environmental conditions. Depending on the equipment and application, climate control systems are applied in order to keep the air temperature inside the enclosure within defined limits and thereby ensure reliable operation of the contained automation equipment.

These climate control systems require regular maintenance (e.g. exchange of air filters), and failure of such a system can have severe impact on the production equipment inside the enclosure and thereby lead to disruptions of the production process.

A renowned manufacturer of industrial enclosures and related climate control systems (enclosure chillers and heaters) has decided to make extensive use of IoT technology to monitor the operating conditions, health status and maintenance requirements of their enclosure cooling systems via Siemens Mindsphere. Through this approach, their customers – typically manufacturing companies – can gain transparency of the health status of all enclosure cooling systems within their plant and therefore can plan maintenance activities more efficiently. Moreover, the manufacturer of the enclosures and climate control systems can streamline the after-sales service operation based on the data collected from the devices deployed at customer sites. Having near-real-time access to comprehensive status information of products deployed at customer sites enables new business models for the manufacturer of the enclosures and cooling systems, extending a product (hardware) based business with a service-based model.

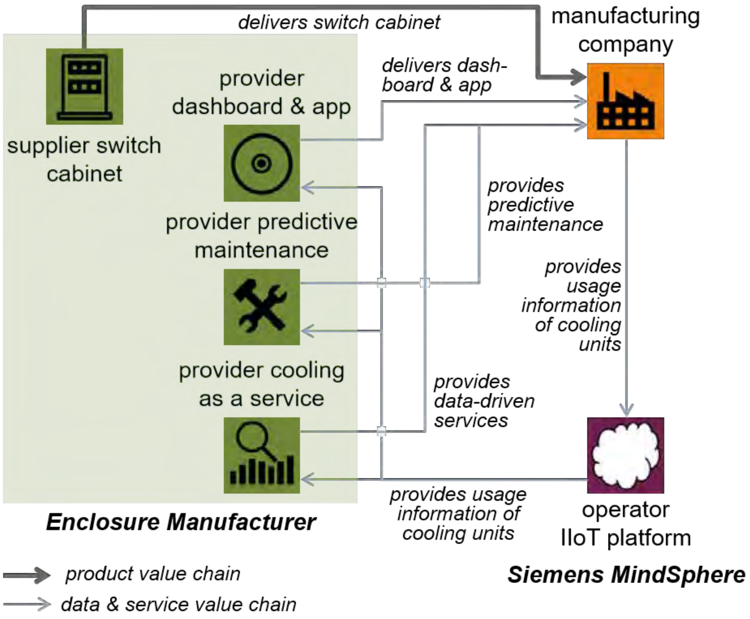


Figure 11: Illustration of the value stream

3.2.2 Business View

Value proposition

In the traditional business model, a manufacturing company purchases enclosures together with the required cooling systems from the supplier. Maintenance can be performed by trained staff of the manufacturing company or obtained as an after-sales service from the enclosure supplier.

In a first step, the efficiency and effectiveness of maintenance operations can be improved by making status data of all purchased cooling equipment available to the manufacturing company through a dashboard and/or maintenance support application. To this end, the cooling equipment needs to be capable of reporting status information (e.g. generated by internal sensors). This can be implemented either by an application provided by the enclosure supplier running on the local computing infrastructure of the manufacturing company or through a communication link to an IIoT platform. The operator of the IIoT platform ensures the security and accessibility of the data and provides tools and APIs for building applications to manage, visualise and analyse the data.

Revenue mechanisms

The enclosure supplier pays the IIoT platform operator for using the IIoT platform and builds its own software applications (dashboards, maintenance planning tools, service route optimisation, etc.) on top of that IIoT platform.

In both implementation forms, the manufacturing company has access to the applications that help them to optimise the maintenance. For this benefit, they typically pay a service fee to the supplier of the cooling system, e.g. as part of an after-sales service contract.

From the manufacturing company's perspective, enclosures and cooling systems are basically auxiliary equipment which has little or no connection to the core operation of the plant. Therefore, it would be attractive for the manufacturing company to outsource the complete management and operation of the climate control systems and just purchase the functionality of cooling as a service, on a subscription basis, with guaranteed and quantifiable availability.

The IIoT-based approach puts the enclosure supplier into the position of providing such a "Cooling-as-a-Service" offering, as operation and health status data of all deployed systems can be accessed via the IIoT platform, and the supplier has the required know-how and experience to optimise maintenance activities towards a given availability target. Ultimately, the enclosure supplier may not sell cooling equipment (i.e. hardware) as a product to the manufacturing company but only sell cooling services with an availability guarantee as part of a service-level agreement.

3.2.3 Functional View

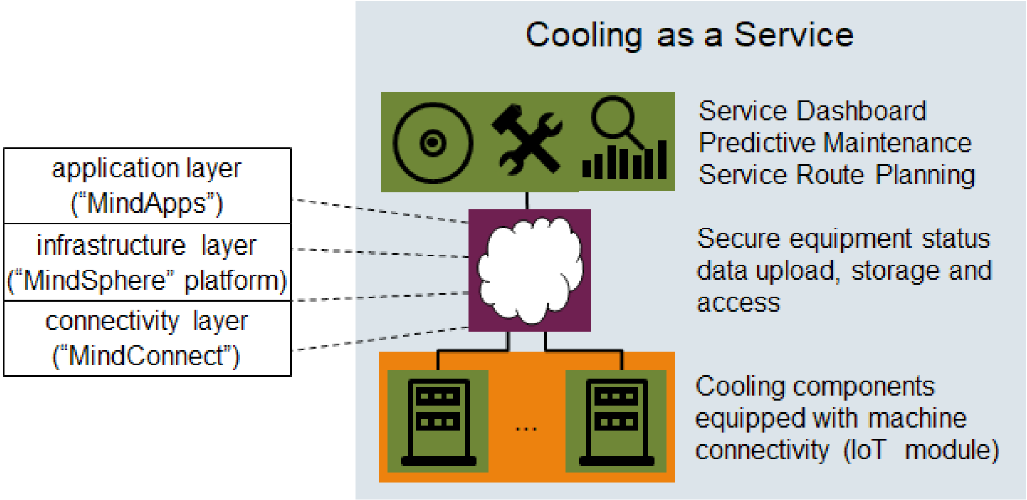


Figure 12: Cooling as a Service in the IIoT-system framework

From a technical perspective, the described use case depends on the capability of the cooling equipment to report its status, e.g. based on internal temperature/pressure sensors. A connectivity layer takes care of the secure transfer of data from the cooling equipment to the IIoT platform, where the data is persistently stored and accessible to the application layer through an API.

An essential feature of an IIoT platform is to grant data access to different users based on different roles. Therefore, the enclosure supplier can have access to data from all devices deployed at different customer sites – if the customer has agreed to this – whereas the manufacturing company will only have access to data generated by their own cooling systems.

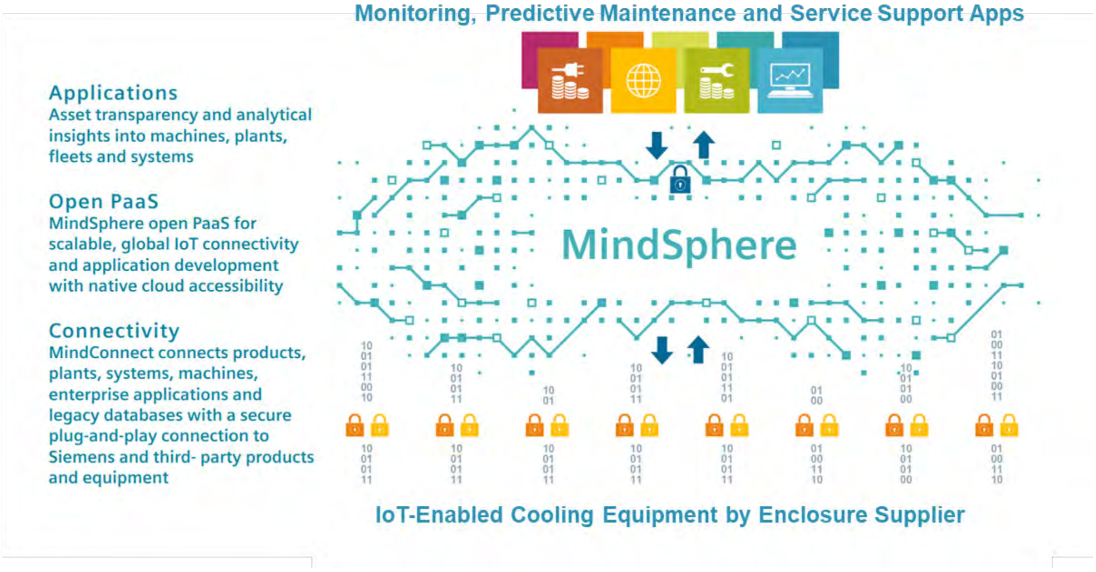


Figure 13: Illustration of the MindSphere structure

In the case of the MindSphere platform, it is possible to use apps from Siemens, from partners or to develop and use own apps.

The PaaS platform provides an open interface for developing customer-specific apps. It is possible to use a different cloud infrastructure, for example in order to adjust to country-specific situations.

In the MindConnect connectivity layer, open standards like OPC UA are used, enabling plug-and-play connection to Siemens and third-party products. Secure and encrypted data communication is provided.

3.2.4 Discussion of Current Challenges and Concerns

Data protection

One concern that is frequently being voiced by managers of manufacturing companies is related to the general idea of providing any production-related data to outside or storing any such data on a public cloud platform. For production-related information, plant managers have a clear interest in preventing such information from leaking out. Moreover, the general idea of having production-relevant equipment in any way connected to the Internet potentially introduces security vulnerabilities to the production system. Such concerns need to be addressed not only on the equipment and factory network level but also by the IIoT platform operator.

Machine connectivity

A further challenge lies in the increased cost (e.g. for network infrastructure such as cabling, gateways, etc.) and engineering effort (e.g. device onboarding, app configuration) to establish the IoT connectivity of the cooling equipment. The engineering effort can be significantly lowered if the involved hardware and software components as well as the protocols through which they interact are designed with particular focus on interoperability.

3.3 Use Case “Remote and Predictive Maintenance”

3.3.1 Overview of Use Case Description

Intelligent machine tools are valuable assets. A factory operator uses these machines tools to produce his/her own products. For this, the factory operator needs machine tools with special process capabilities such as cutting, punching, bending, welding, milling, grinding, drilling, painting, etc. The machine tool manufacturer provides this equipment and guarantees the required capabilities.

In addition to the upper process capabilities of the machine tools, process quality, speed, flexibility, availability and operating costs are important success and selection criteria for the factory operator. To improve all these aspects, the machine manufacturer offers a comprehensive range of services to the factory operator.

To provide even better services, it is necessary that machine tools independently send required machine information via safe IIoT technologies to the machine manufacturer to monitor and optimise the operation of this machine tool.

Unplanned breakdowns can be avoided if necessary maintenance or optimisations are identified, scheduled and carried out in good time.

In addition to classic remote maintenance scenarios (incl. predictive maintenance), the factory operator can also be offered pay according to use models (e.g. for the use of the machine itself or for the use of special process technology data).

The basis for all services and relevant business models is the secure data transfer between machine tool and manufacturer as well as the associated secure handling of this data.

The use of personal data is generally completely waived due to the European General Data Protection Regulation (GDPR).

In principle, any form of data transmission between the machine and the machine manufacturer requires the consent of the factory operator, who can revoke it at any time in accordance with the associated contracts.

Of course, data shall be transmitted exclusively in encrypted form and shall never be made accessible to other parties without the factory operator’s consent.

3.3.2 Business View

Value proposition

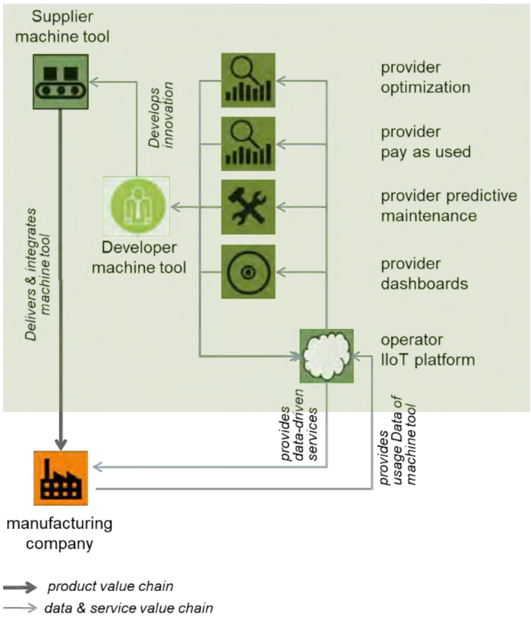


Figure 14: Additional services, especially optimisations require a secure closed loop data flow

The machine tool manufacturer offers additional services and extended business models in addition to the existing “sale of the machine” business model.

a) Guaranteed response times in the event of failures (reactive remote service)
b) Guaranteed availability (predictive remote service)
c) Process optimisations (dashboards, AI systems, etc.)
d) Pay as used (basic price + usage-dependent billing)
e) Smart factory (factory optimisation)
f) Further SW services such as production control/planning

For this purpose, the additional services require the machine to independently send the information required for the respective field of application to the machine tool manufacturer via a secure data connection.

Generally, the data is first collected locally on the machine by the existing sensors and control systems, pre-processed, encrypted and then transmitted as required and in accordance with the situation.

The data is processed accordingly in the data centres of the machine manufacturer and made available to the associated additional service providers.

Revenue mechanism

The factory operator pays the machine manufacturer for providing additional services that enable him to operate his machines in a manner optimised to each situation. By using such services, the availability and capacity utilisation usually increase significantly, which leads to an optimised cost structure for the factory operator.

The machine manufacturer not only generates additional revenue from the new services, he/she also strengthens the competitiveness of the machines and software products for which these services can be offered.

In addition, the machine manufacturer learns what the customer really needs and can further develop and optimise the product portfolio accordingly.

3.3.3 Functional View

From a technical point of view, a secure data connection is the basis for the described application. Of course, the machine must also be able to generate the required information from the existing sensor and control data, which is then transmitted to the manufacturer where it is processed accordingly.

In addition to the actual data storage and processing capabilities, the generation of the respective value promises requires above all the corresponding “knowledge” in the processing algorithms and AI systems. In addition, the organisation o¬f the machine manufacturer must be able to provide the service in accordance with the legal and contractual framework conditions.

3.3.4 Discussion of Current Challenges and Concerns

Data protection

The connection of machines to the Internet requires not only that the data transmission must satisfy legal and contractual obligations.

Of course, neither personal data nor the machine operator’s highly sensitive order data may be transmitted, from which the customer’s production parts could be reconstructed.

It shall also be ensured that the machines are protected against unauthorised access (hackers, malware, etc.) especially after they have been connected to the Internet. Generally, basic protection should already be provided by the machine manufacturer and be extended by further measures that the factory operator takes.

The data transferred to the manufacturer also requires special protection through state-of-the-art IT infrastructures in place during the entire period of use.

Machine connectivity

Currently, the machine manufacturer must conclude a corresponding data usage agreement with each customer in order to comply with the legal framework conditions for machine connectivity.

Due to a lack of standards, each machine manufacturer has its own connectivity solution. The factory operator often cannot assess which solutions are implemented with regard to security and data handling and therefore develops own rules, which he/she in turn seeks to prescribe bindingly to each machine manufacturer.

This situation very quickly results in a scenario that can lead either to no connectivity being permitted or to protracted negotiations about solutions between the machine manufacturer and the factory operator.

It is therefore in the interest of all involved to have unified standards and regulations regarding connectivity.

3.4 Use Case "3D Printing as a Service"

3.4.1 Overview of Use Case Description

As Additive Manufacturing closely goes along with digitalisation of processes and both of them continue to grow, they pose new challenges for the manufacturing industry in terms of data protection, protection of intellectual property as well as data consistency over the entire process. The industry needs a decentralised solution to ensure data sovereignty and traceability of data usage. Also, well-documented and fully reproducible quality has to be assured in each and any step of the process. This applies even more since manufacturing is becoming more and more decentralised, as it is conducted within global networks and parts are produced at the site where they are needed.

In recent years, Additive Manufacturing technology has experienced double-digit growth rates in various industrial sectors, such as automotive, aerospace and medical technology. This trend is expected to continue in the coming years. Industrial Additive Manufacturing means "Rethinking Production".

The growing market for industrial Additive Manufacturing can be attributed to three major advantages:

- Components can be developed more efficiently, flexibly and cost-effectively, giving them new functions to meet new requirements. This ranges from compact designs through angled geometries inside the component to the smallest functional structures.
- Spare parts can be manufactured to meet individual requirements and within very short delivery times to sites around the world.
- The economic production of individual parts and small lot sizes is possible. This has been an enormous challenge with other manufacturing processes so far.

In its Additive Manufacturing TechCenter, the German diversified industrial group thyssenkrupp offers engineering consulting and design services, as well as the implementation of industrial 3D printing for industrial customers. At the beginning of the process, customers provide the engineering service provider with plans for their components, such as their CAD files. This data is valuable intellectual property for the companies as they are the basis for the production of special components.

In close partnership, IBM and the engineering company thyssenkrupp developed an easily accessible platform to supply customers with industrial Additive Manufacturing parts in a fast and reliable manner with proven quality and protection of intellectual property. In addition, the platform encourages data sharing in a reliable and trustworthy ecosystem and in so doing offers seamless data exchange across all stages in the manufacturing value chain.

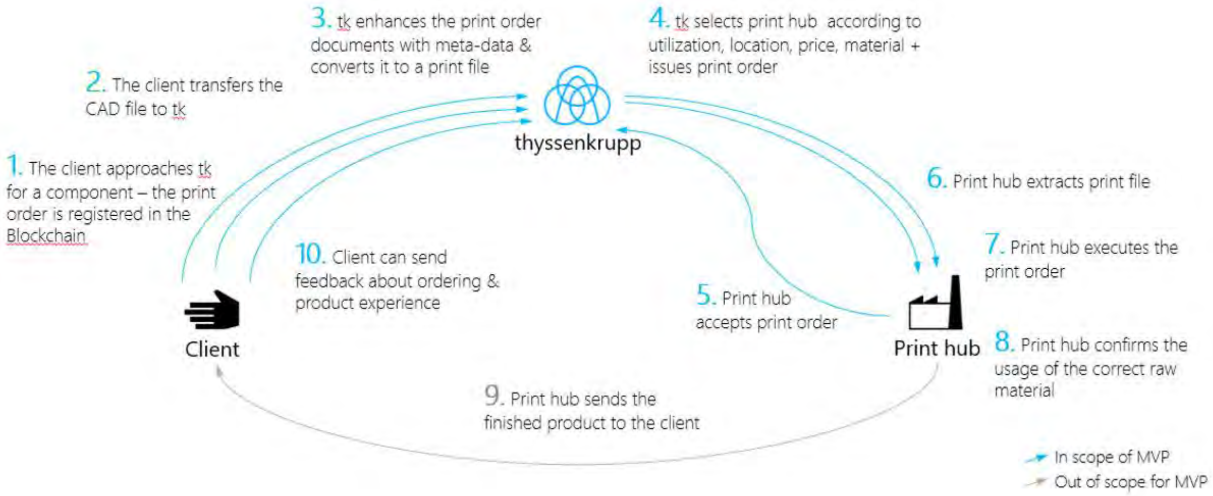


Figure 15 The value stream and value proposition of the business model with detailed stages of interaction between thyssenkrupp, its client and the print

3.4.2 Business View

The solution's objective is to solve the pain points of three different types of stakeholders: the clients, the Additive Manufacturing engineering service provider and the Additive Manufacturing print partner, see figure 16.

Figure 16 also depicts stakeholders in next steps of evolution of the overall ecosystem.

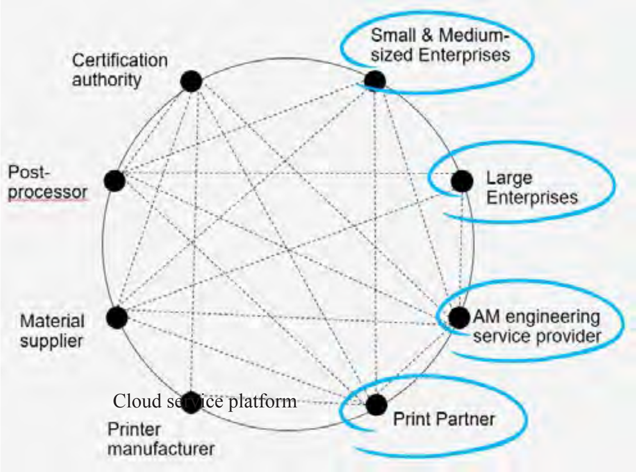


Figure 16: Stakeholders and ecosystem

Clients, especially from mid-sized companies, often lack access to benefits of Additive Manufacturing technology. They want to make sure their IP (e.g. CAD data) is protected when it is transferred throughout the value chain. In addition, clients need to have a guarantee for product quality for parts manufactured with Additive Manufacturing and therefore ask for transparency and detailed information in the production process.

The engineering service providers today have limited access to customers and print capacity. They strive to protect their clients' intellectual property and at the same time want to know that their engineering know-how is protected while delivering reliable and proven quality.

The Additive Manufacturing print service provider needs to utilise its print capacity to an optimum extent to amortise the asset-intensive print machines. Due to the customer needs for production transparency and confirmability, they need to prove the quality of the printing process in a consistently immutable and tamper-proof way.

All of these requirements ask for data protection and data sovereignty as well as traceability and consistency in the overall process of engineering and producing innovative industrial products.

The business objective is to provide access to the industrial Additive Manufacturing ecosystem to all participants and parties and by doing so sell AM services easily or gain advantage from services. To ensure this, a platform for data sharing in a reliable and trustworthy way, offering a seamless data exchange over all stages in the Additive Manufacturing value chain has been developed.

This solution is suited for significantly lowering the hurdles to gain advantage from all benefits of industrial Additive Manufacturing. It will provide easy access also for SME customers, encourage data sharing from all participants and allow utilisation of all relevant capacities, services and equipment. In the process a very high business value for all parties over the entire industrial AM value chain is generated and the diverse advantages of AM is made available to all customers.

It creates a win-win-situation for all users of the platform:

- The engineering provider can sell his engineering capabilities globally.
- The printing hub has an additional source of business.
- The end customer acquires a solution (product or spare part) with best engineering and short delivery time.

Revenue stream: the end customer gives an order to the engineering provider to deliver a product or spare part. The engineering provider designs the part and gives a production order to a certified partner, which runs a printing hub close to the customer. After the part is printed and delivered, the end customer pays the engineering company, which shares part of the payment with the printing hub.

3.4.3 Functional View

By combining two innovative technologies, i.e. IDS (International Data Space) and Blockchain technology (Hyperledger Fabric), in an innovative way, the developed solution provides a basis for seamless data exchange with traceability and consistency over the entire process.

The architecture of the solution developed for this use case is illustrated in figure 17.

The access channels are dedicated web applications installed at the stakeholder's IT systems (in recent development stage: clients, Additive Manufacturing engineering service providers and the Additive Manufacturing print partners). All data transfer between the different stakeholders' enterprise systems is organised via IDS connectors. An integration layer comprises the middleware that integrates all access channels to the Blockchain services that are hosted in a cloud.

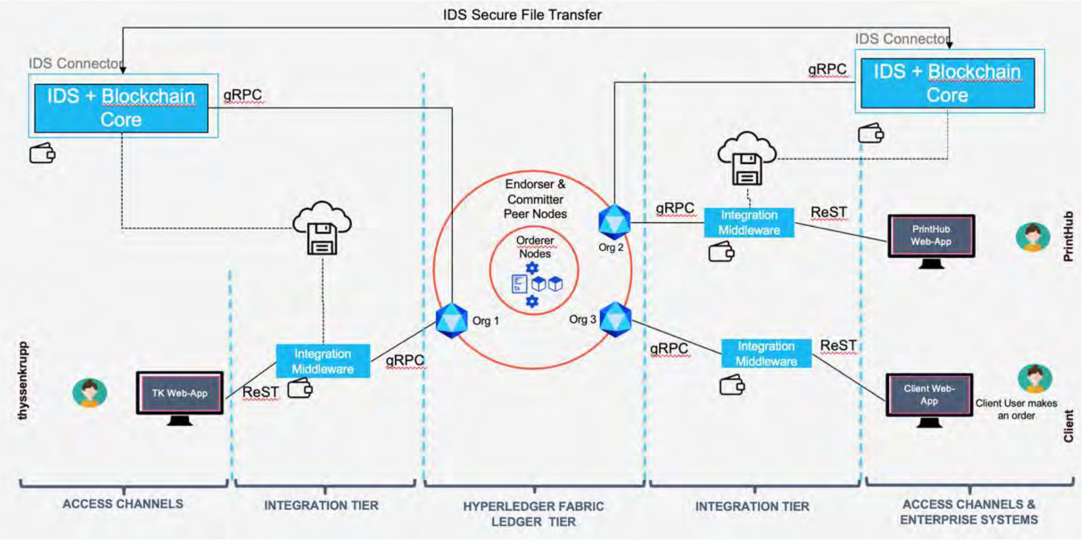


Figure 17: High-level architecture

The main Blockchain characteristics immutability, finality, provenance and consensus provide a tamper-proof, single point of truth for all stages of generating and processing the data across the value chain. All relevant data transfers are conducted via purpose-built IDS connectors. This guarantees data sovereignty for each participant with fair exchange and use of data and fully integrated terms of use for data. The IDS connectors are controlled via Smart contracts as integrated functionality of the Blockchain service.

Figure 18 illustrates the overall process chain of order processing in industrial Additive Manufacturing with reference to the different layers of data processing, data transfer and data storage. It is important to mention that product data (e.g. CAD files) as well as quality-relevant processing data (e.g. from 3D print processes) are stored on the enterprise's IT systems and transferred via IDS connectors along with all terms of use of these data. The Blockchain service only logs transactions that take place during order processing and hashes related to the data on individual enterprise IT systems. It thus provides consensus for commercial as well as technical information generated within order processing and production of the 3D product.

It is of remarkable importance to point out that the solution described here, starting from the definition of requirements on to the process definition and through to its overall layout and realisation, was designed in a very generic way. It is thus possible to adapt to any other industrial manufacturing process and so foster digitisation in manufacturing in the future.

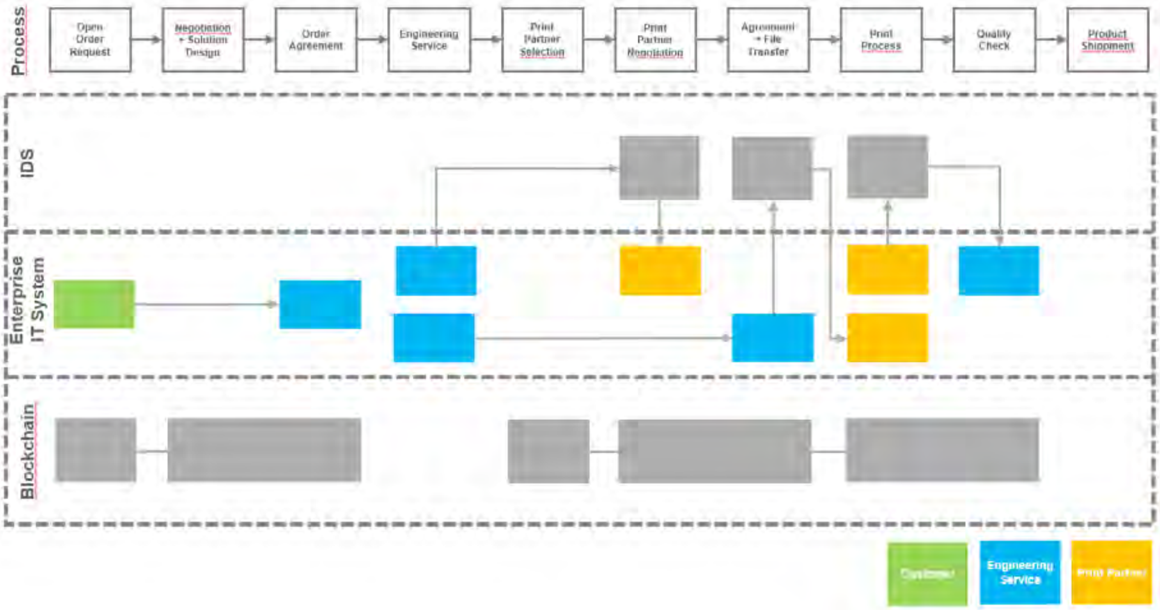


Figure 18: High-level architecture, layered architecture elements and process description

3.4.4 Discussion of Current Challenges and Concerns

The use case addresses a number of today's challenges and concerns.

Data protection and data ownership

In today's Internet, the generators of data lose the ownership of the data as soon as they are shared. The definition of International Data Spaces allows adding a software-readable contract to the data. With that contract, the creator describes how the receiver of the data may use this data, how long the data is valid, what price he/she asks for the use of the data or any other description relevant for the use of data.

Data integrity

When data are shared, there is always a risk of unwanted change of data during the process. Block chain allows the documentation of the data shared and all the properties of the transaction in a neutral entity. This ensures the integrity of data even when send to a number of users.

Seamless virtual value chain and seamless PLM

Production processes are more and more specialised. This fact means that very often a number of partners cooperate in a value chain. As they may be located in different locations, the set-up of a seamless virtual value chain, as described in the use case, is necessary. The industrial Additive Manufacturing platform provides seamless order processing from the very first stage of when the customer makes the enquiry to the technical and commercial negotiations through to manufacturing and the final release and shipping of the finished product.

Standardised cloud-to-cloud communication and machine connectivity

Today, each cloud provider offers his specialist interface to access the cloud. To ensure interoperability between clouds of different vendors, a standardised interface for cloud-to-cloud communication is needed. The International Data Spaces Association with more than 100 partners across the world is working to establish a common standard. This standard is described in DIN SPEC 27070 that is to be published soon. The ISO standardisation process has also been launched.

3.5 Use Case “PLM Process Support Platform”

3.5.1 Overview of Use Case Description

This use case demonstrates the integration of the operational and the business domains from a functional viewpoint in the machinery and components industry. It covers processes such as design, planning, manufacturing, delivery and operation, and is therefore called “Design to Operate (D2O)”.

The Industrial Internet connects the products of machinery and components manufacturers to the product operators by using embedded sensors with advanced analytics. This is to enable intelligent decision-making, integrate the design process into the manufacturing and delivery processes and enable the manufacturer to implement end-to-end closed-loop processing, including design, planning, manufacturing, delivery and operations.

The D2O scenario is suitable for the machinery and components industry, and it integrates design, planning, manufacturing, delivery and operations:

- The equipment’s runtime information improves the design process when designing new intelligent machinery products.
- Manufacturing of the product can be optimised by using shared information.
- All logistics processes of multi-modal, Omnichannel delivery can be coordinated.
- After-sales maintenance and service (operations) of operational assets can be monitored and simulated.
- Integrated business planning processes (PLAN) in the end-to-end supply chain are always able to impro

This scenario integrates not only asset operators with asset producers and asset service providers, but also operational functions (forecasting, optimisation, monitoring and diagnostics, supply and deployment, and asset management) and business functions (design, manufacturing, planning and delivery).

3.5.2 Business View

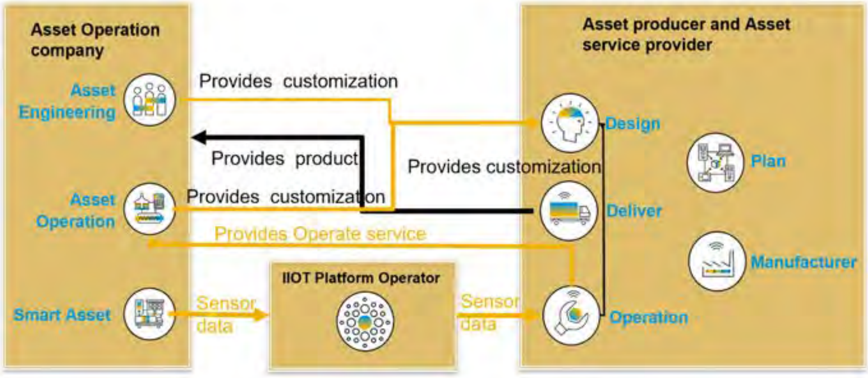


Figure 19: Value network

Business model logic

The products of machinery and components manufacturers are used as assets, and Industrial Internet provides remote services for smart assets, so manufacturers upgrade to **asset producers and asset service providers** and re-engineer business processes:

- During the operational phase, the intelligent connected products (i.e. smart assets) used by asset operations companies send sensor data to asset service providers through an IIoT platform, which provides simulation-based digital twins to simulate major smart assets. As a result, asset service providers can monitor and analyse asset health based on sensor, use machine learning to obtain health metrics, and use hypothesis simulations to optimise the asset operations.

- During the design phase, using the runtime information and digital model of smart assets, the asset provider's design department can acquire new features of the asset, the new product concept, based on data insight. For example, one machinery company optimises a new product by discovering force conflicts between components and gaining insight into sensor data, then presenting new ideas and simulating new designs to check for force conflicts. New products reduce energy costs and extend service life.

- Once designed, the design data is integrated with planning, manufacturing and delivery data for efficient manufacturing and delivery, culminating in the delivery of products (including next-generation and mature products) to the asset operations companies.

- After delivery, smart products can be monitored, while the information collected can be used to optimise asset maintenance and services.

Value proposition

- Predict the true state of smart products and asset operations companies, optimise product performance in real-time to improve asset efficiency.

- Optimise the operations and maintenance of physical assets, systems and manufacturing processes for asset producers and asset service providers to obtain new revenue streams.

- Develop and optimise products to improve product design efficiency before they are deployed for specific purposes and operations by target asset producers and asset service providers.

Revenue mechanism

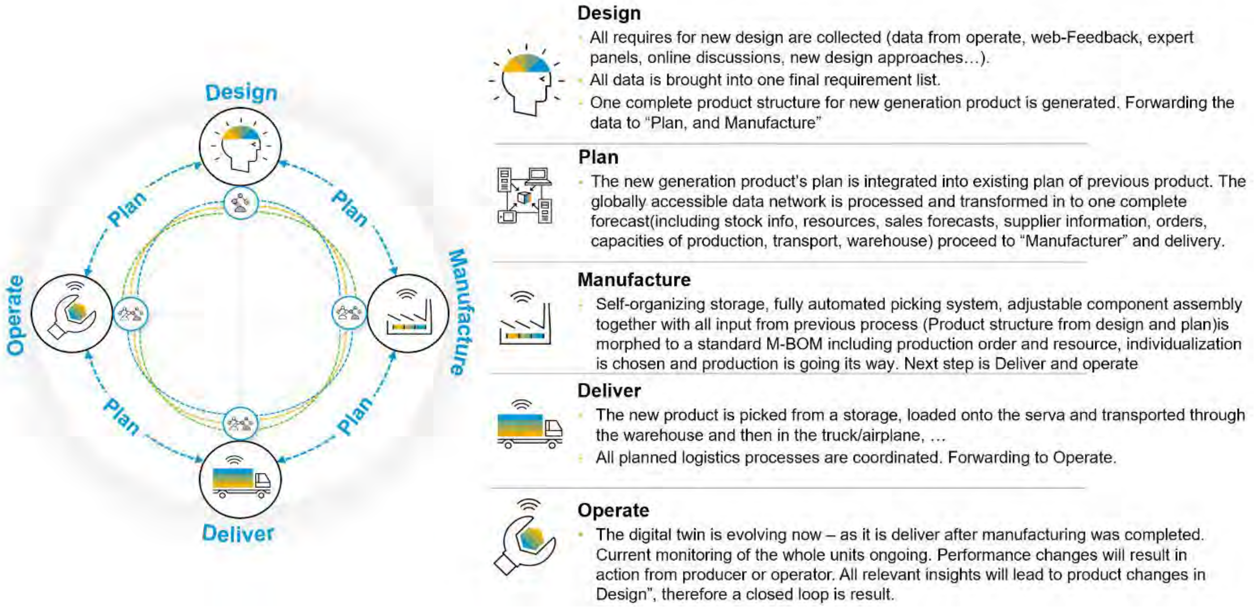
- Asset operators and asset service providers can connect using smart assets via IIoT platforms. By leveraging the platform's intelligent technologies, asset managers can increase return on assets and reduce the number of accidents, so the asset operators pay for IIoT platform usage. Smart asset operations are a new source of revenue earned by asset producers using IIoT, so asset producers and service providers pay for the use of IIoT platforms.

- Asset operations companies are required to pay for the product. Since the product is customised, there are additional charges. Asset operations companies also pay an operations service fee.

- In this use case, some partners provide professional services, such as simulation services and data analysis services, among others. There are also other service expenses, which are not listed here due to simplicity reasons.

3.5.3 Functional View

High-level architecture of business domain with description



Design

- All requires for new design are collected (data from operate, web-Feedback, expert panels, online discussions, new design approaches…).
- All data is brought into one final requirement list.
- One complete product structure for new generation product is generated. Forwarding the data to "Plan, and Manufacture"

Plan

- The new generation product's plan is integrated into existing plan of previous product. The globally accessible data network is processed and transformed in to one complete forecast(including stock info, resources, sales forecasts, supplier information, orders, capacities of production, transport, warehouse) proceed to "Manufacturer" and delivery.

Manufacture

- Self-organizing storage, fully automated picking system, adjustable component assembly together with all input from previous process (Product structure from design and plan)is morphed to a standard M-BOM including production order and resource, individualization is chosen and production is going its way. Next step is Deliver and operate

Deliver

- The new product is picked from a storage, loaded onto the serva and transported through the warehouse and then in the truck/airplane, …
- All planned logistics processes are coordinated. Forwarding to Operate.

Operate

- The digital twin is evolving now – as it is deliver after manufacturing was completed. Current monitoring of the whole units ongoing. Performance changes will result in action from producer or operator. All relevant insights will lead to product changes in Design", therefore a closed loop is result.

Figure 20: High-level functional architecture of D2O

The D2O scenario extends the traditional supply chain in the front to design and in the back to operations, integrating the entire value chain from design to operations.

This scenario enables rapid decision-making by establishing a network of development partners in a collaborative environment, coordinating visual, guided transfers to manufacturing processes, synchronising data across domains via digital threads and enabling operational design feedback from any part of the product life cycle.

High-level components architecture

The D2O use case relies on the connection with smart assets to provide operational services and feedback on product runtime data to improve the product design process. The IIoT platform provides data connectivity services to asset operations companies and the asset operations' service providers.

IIoT platforms can connect devices directly through HTTP/MQTT protocols or via IoT gateway adapters to support more communication protocols, such as Modbus, OPC UA, etc. or through IoT Edge Gateways that support the following protocols: HTTP/MQTT, File, CoAP, SNMP, Modbus, OPC UA, Sigfox, and more.

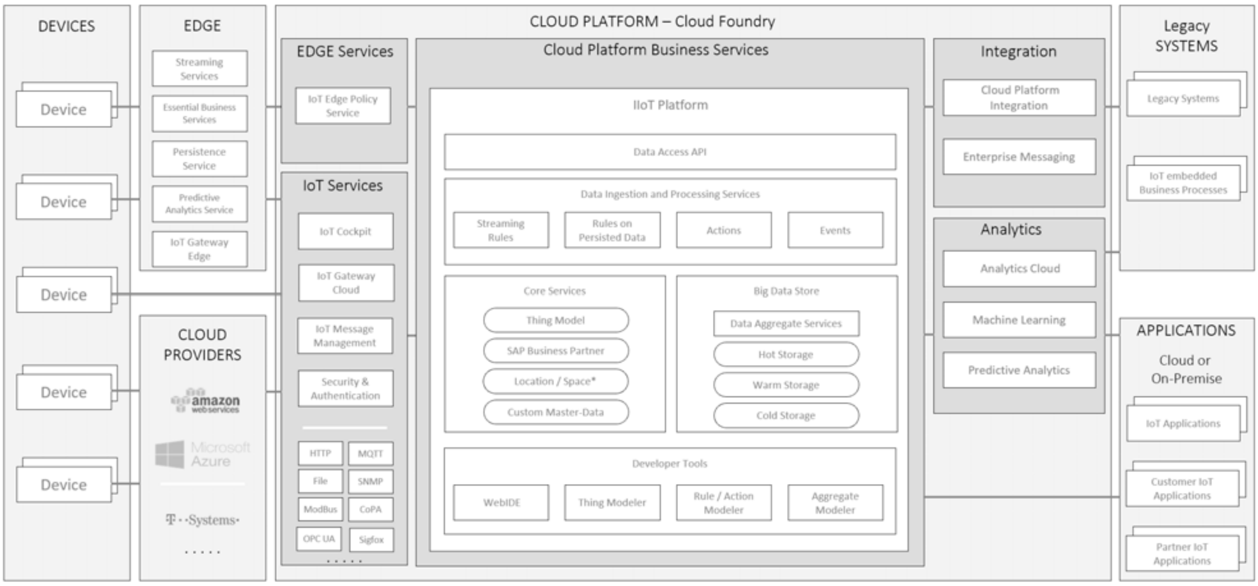


Figure 21: High-level components architecture

In the D2O use case, asset producers and asset service providers can develop applications directly on IIoT platforms or internally with applications integrated with IIoT platforms. The IIoT platform provides **integration** and **development tools** to support integration with legacy systems and interoperability with other applications.

3.5.4 Discussion of Current Challenges and Concerns

Data protection

The use of data on IIoT platforms complies with internal policies/approvals and external requirements in this use case:

- Legislation
- SAP Data Protection Policy
- Regulations
- Process documentation
- Industry standards
- Annual audits

SAP uses the Data Protection Management System (DPMS) to manage all major data protection tasks. DPMS enables and maintains an effective and appropriate level of data protection and privacy. Internal and external audits of the entire DPMS process are conducted on an annual basis.

Machine connectivity

The use case uses two methods to connect the platform to the devices: **EDGE Service** and **IoT Service.**

EDGE services connect devices through the **IoT Edge Gateway**. The **IoT Edge Gateway** supports HTTP, MQTT, File, SNMP, Modbus, OPC UA, CoAP standards.

IoT Services provide more protocol adapters to connect devices, including those that support HTTP, MQTT, File, SNMP, Modbus, CoAP, OPC UA, Sigfox, and more.

OPC UA is the most popular machine connectivity standard in the industrial and IoT sectors, and is ideal for machine connectivity. The IoT platform now supports OPC UA (standard) and so-called classic OPC technologies (OPC DA, OPC HAD, OPC A&E).

Seamless PLM

The D2O use case demonstrates end-to-end integration, which includes the processes from design to operations, focusing on the connection between PLM and the supply chain as well as the one between PLM and operations.

Asset producers can leverage IoT technology to obtain asset runtime data from the asset operations phase and by leveraging Big Data technology to capture demands from runtime data. Thus, operational data can be an input to the PLM.

The BOM and routing data for the manufacturing phase, which is the output of the PLM, can be transformed from the PLM system during the design phase.

This use case shows a truly closed-loop process from design, planning, manufacturing, delivery and operations.

3.6 Discussion of Use Cases 3.2–3.5 in Relation to Industrie 4.0

The use cases described all show how the Industrial Internet, which provides a safe and flexible connection of assets to platforms and applications, is used in a variety of different applications described in the business views. “Cooling as a Service” shows how the Industrial Internet enables a new way to provide electrical enclosure cooling from the enclosure manufacturer to the manufacturing company using the enclosure. Being able to connect to assets in diverse manufacturing environments and protecting the end clients’ data are essential.

“Remote and Predictive Maintenance” discusses providing services to multiple client companies in an international setting. In addition to the need for connectivity to assets in diverse environments, protecting data during cross-border communication represents an important requirement, too.

“3D Printing as a Service” introduces a service connecting clients without 3D printing equipment with printing hubs. Here, another aspect of data protection, data ownership and intellectual property protection is raised, in that companies agree to controlled sharing and publication of competitively relevant data.

“PLM Process Support Platform” embeds the optimised operation of assets into an Internet-supported PLM process, which for example supports the engineering and design processes.

3.7 Use Case “Construction Machinery Intelligent Aftermarket Services Solution”

3.7.1 Overview of Use Case Description

A construction machinery manufacturer served by ROOTCLOUD is one of the world’s leading enterprises in this industry, with its business involving in the field of manufacturing equipment like concrete machinery, excavating machinery, hoisting machinery, coal machinery, etc. and its distribution network covering more than 100 countries and regions in the world.

The equipment produced by this enterprise is sold all over the world, and the working environment of the construction machinery is complex. Thus, the aftermarket faces two major problems: first, the equipment operations and health status cannot be known through the manufacturer’s traditional human after-sales service and it is difficult to allocate service resources in advance to respond to equipment operations and maintenance needs in a timely manner; second, managing equipment and fleet through manpower is inefficient for the end customers who purchase the equipment. Untimely maintenance leads to long downtime and short service life of equipment.

The intelligent aftermarket services solution provided by ROOTCLOUD Industrial Internet platform effectively solves the problems mentioned above, and at the same time enables a win-win situation among the construction machinery manufacturer, the end customer and the platform enterprise.

3.7.2 Business View

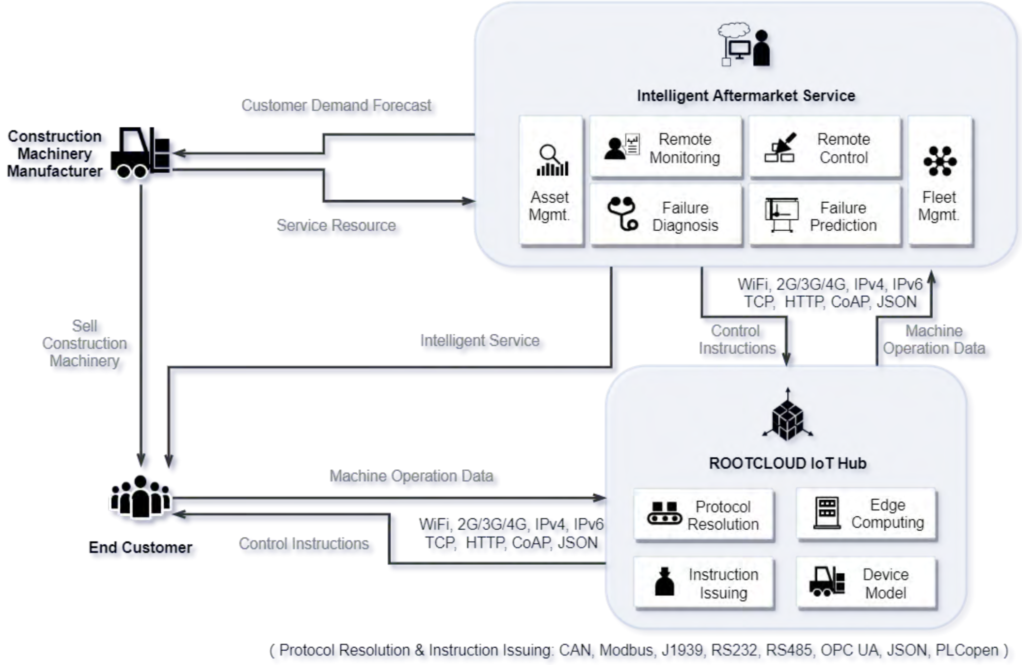


Figure 22: Value chain of ROOTCLOUD

The value chain of the intelligent aftermarket services solution includes the Industrial Internet platform, the construction machinery end customer and the construction machinery manufacturer. First, for the construction machinery end customers, the solution reduces the downtime of equipment due to failures, improves the utilisation rate, and effectively improves the absolute value for the user applying the equipment. Second, for construction machinery manufacturers, the solution enables the manufacturers to shift from “selling products” to “selling services”, and the value-added services of product operation and maintenance bring them more markets. Third, for the Industrial Internet platform enterprises, they are capable of continuously obtaining considerable profits in the process of providing services for construction machinery manufacturers and end customers.

3.7.3 Functional View

In this solution, by connecting to the construction machinery controller through the on-board Internet of Things (IoT) module (CAN, Modbus, J1939, etc.), ROOTCLOUD collects various operating parameters of various types of equipment in real time, such as geographical location information, engine data, equipment operations status information (JSON, GPS, etc.), and transmits the data to an IoT hub for storage and real-time analysis (WiFi, 2G/3G/4G, IPv4, IPv6, TCP, HTTP, CoAP and JSON). Based on this data flow solution, ROOT- CLOUD platform provides six sorts of aftermarket services for construction machinery.

First, asset management, which covers the management of equipment archives including equipment atlas, accessories, operations and maintenance manuals and basic information, as well as the management of equipment maintenance including maintenance schedules, maintenance reminders and maintenance record functions. Based on the asset management function, the construction machinery end customers may have access t a unified management of equipment information and formulate reasonable equipment inspection and maintenance plans.

Second, remote monitoring, which monitors the working condition data of the equipment, including the running status of the whole equipment and its components, the equipment track, the quantity of work, fault information, etc. Based on the remote monitoring function, the construction machinery end customers may, at anytime and anywhere, monitor and manage the equipment, check the fleet status and abnormal conditions, manage the quantity of work of the equipment and optimise the work arrangement and equipment scheduling, so as to improve the equipment utilisation rate. The construction machinery manufacturers may learn about the usage status and life cycle of the equipment by obtaining the equipment data so as to provide a maintenance basis for the service engineers.

Third, failure diagnosis; remote failure diagnosis and maintenance is carried out based on real-time operation data of the equipment, and real-time alarms for illegal operations, equipment abnormality, deviation from predetermined positions, etc. are carried out according to pre-set rules. Also, this function provides one-click intelligent dispatch services. Based on the intelligent failure diagnosis function, the construction machinery end customers may handle various abnormalities of equipment in a timely manner, reasonably arrange repair or maintenance, reduce equipment downtime and prolong equipment service life.

Fourth, failure prediction; this is achieved through Big Data analysis on technical parameters such as working condition data, usage data of the whole equipment and parts, and the wear degree of parts. In combination with parts replacement records and historical failure records, the equipment failure and demands for service and spare parts can be predicted. Based on the failure prediction function, the construction machinery manufacturers may reasonably allocate service resources, improve after-sales service efficiency, and accurately predict spare parts demand. As a result, the manufacturers can effectively reduce inventory costs and, at the same time, increase the sales volume of and income from the spare parts and maintenance services.

Fifth, remote control, accomplished via lock/unlock and layered lock, and which manages the lock process and lock history. Based on the remote control function, the construction machinery end customers may lock machines whose position is abnormal so as to effectively reduce the risk of equipment loss.

Sixth, machinery group management, which is geared towards the unified management of different types of equipment. At the same time, the built-in information sharing platform allows users who have purchased equipment, those who need equipment and the project contractors to share and publish their demands for equipment usage or rental. Based on the machinery group management function, the construction machinery end customers may carry out centralised management on various types of equipment and rent out the self-owned idle equipment and charge a fee based on work quantity/working hours to obtain considerable benefits.

3.7.4 Discussion of Current Challenges and Concerns

Based on the function module of Internet of Things, the ROOTCLOUD Industrial Internet platform can effectively connect the data of construction machinery, manufacturers and users. It provides a complete construction machinery intelligent aftermarket solution. On the one hand, it provides rich functional solutions for single machine construction machinery. It covers asset management, remote monitoring, fault diagnosis, fault prediction and remote control. On the other hand, it provides unified resource scheduling management for cluster construction machinery and builds a platform leasing business model based on data analysis. In addition, the solution has good promotion and replication value, and is expected to provide remote services for independent product terminals such as automobiles, aerospace, ships, etc. Especially with the incoming 5G era, wireless communication with low delay and high reliability will further improve the equipment remote operations and maintenance service level of the platform.

3.8 Use Case "Mass Customisation Solution for Household Appliance Industry"

3.8.1 Overview of Use Case Description

The production of the household appliance industry is characterised by many varieties of appliances, small batch sizes and fast product renewal. At present, the household appliance industry is facing the difficulty of meeting users' personalised customisation demands, low efficiency of inventory management, poor after-sales service and service tracking, and below-standard production quality control.

In order to solve the problems mentioned above, Haier Group has built an Industrial Internet platform, COSMOPlat, which not only solves the problems regarding the management of design, procurement, sales, production, logistics and after-sales service of manufacturing enterprises throughout the whole product life cycle, but also meets the personalised customisation demands of users.

3.8.2 Business View

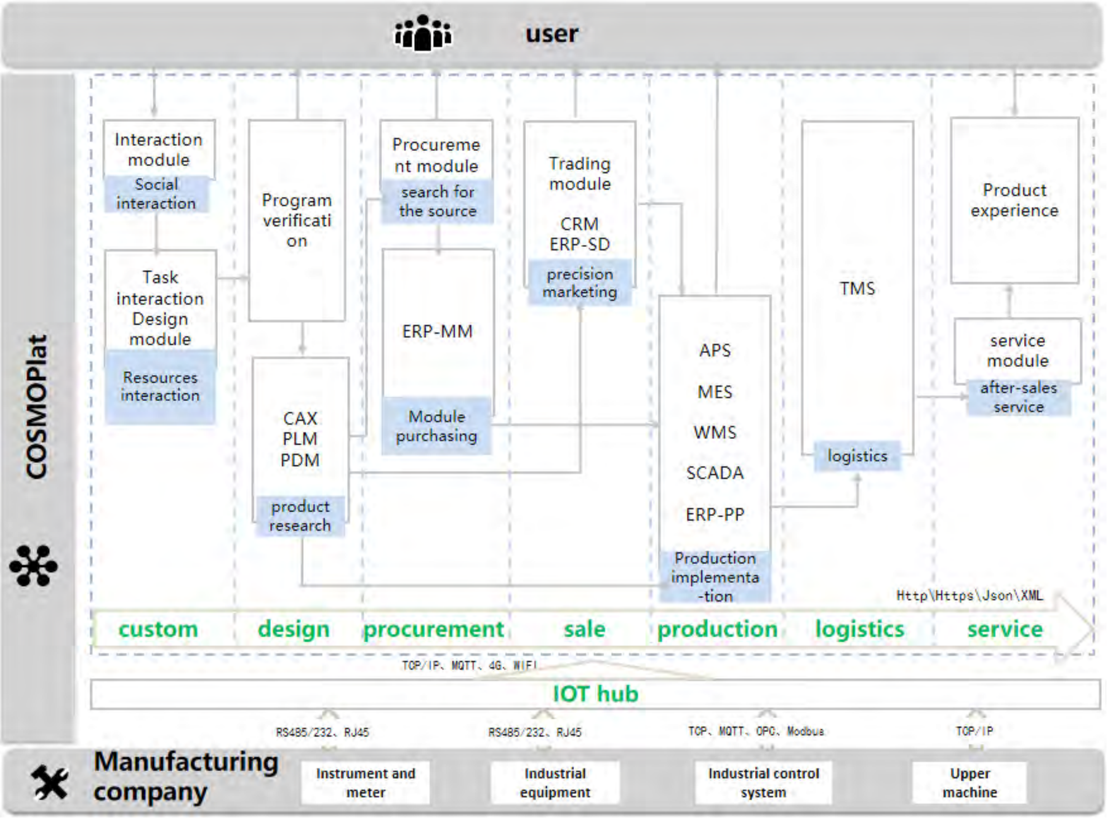


Figure 23: Value chain of COSMOPlat

The value chain of the personalised customisation solution of Haier includes the Industrial Internet platform enterprise, the household appliance manufacturing enterprise and the household appliance buyers/users. First, for the household appliance buyers/users, the solution meets the users' demand for personalised customisation and improves the user experience in purchasing and using the household appliances. Second, for the household appliances manufacturing enterprises, the solution allows them to realise their pursuit of "improving quality, reducing costs and increasing efficiency". Third, the solution allows Industrial Internet platform enterprises to continuously create income in the process of providing services for users and manufacturing enterprises.

3.8.3 Functional View

Haier COSMOPlat is connected to the instrument and apparatus (RS485/232 and RJ45), industrial equipment (RS485/232 and RJ45), industrial control systems (TCP, MQTT, OPC and Modbus) and upper computers (TCP/IP) through Internet of Things (IoT) modules. Through wired (TCP/IP and MQTT) or wireless (4G and WIFI) protocols after being subjected to protocol conversion, it uploads the data to the cloud for application by seven service modules, namely user customisation, design, procurement, sales, production, logistics and service. The data among the seven service modules is integrated via http\https\json\xml.

The concrete functions are as follows:

First, the customisation sub-platform, which is the first entrance for users to connect with the COSMOPlat and in which the users can participate in the whole process of product planning and definition and select and customise various types of household appliances by themselves.

Second, the design sub-platform, in which the order will go directly to the marketing department after the user confirms the order, and the marketing personnel further confirms the information submitted by the user. If the user has other customisation requirements, he/she can interact with the platform in real time or add and change items. The order number will be generated after the research and development personnel finishes the design according to the requirements.

Third, the procurement sub-platform is a module supplier resource service and aggregation platform, which is built to meet the demand of zero distance interaction between module supplier resources and users to help the module suppliers designing according to the demands and to achieve modular supply. A distributed architecture is adopted for the procurement system, through which user requirements are publicly released to global module supplier resources, and the system automatically and accurately matches resources to requirements.

Fourth, the sales sub-platform, which, based on CRM management and user community resources, combs and studies existing user data and user data collected by third-party entities through Big Data research and simultaneously applies clustering analysis to ensure precise marketing through user portraits and label management.

Fifth, the production sub-platform deploys various intelligent production SaaS applications, including APS, MES, SCADA, WMS, etc., and achieves fast switching of production lines, real-time monitoring of equipment, accurate distribution of materials, efficient optimisation of energy, etc. according to the production plan issued by the ERP.

Sixth, the logistics sub-platform, which realises real-time and effective management of the delivery status of raw materials/finished goods and the distribution of finished goods. The logistics sub-platform includes platform reservation management, intelligent logistics TMS, a distribution coordination platform, a logistics track visualisation platform, an intelligent vehicle management platform, and more. It provides one-stop service integrated warehousing and distribution.

Seventh, the service sub-platform solves users' demands for timely maintenance of household appliances. After purchasing products, users can input the household appliance information with one key through the platform, establish exclusive household appliance files and upload them, entirely replacing traditional paper warranty cards, and the information is never lost.

3.8.4 Discussion of Current Challenges and Concerns

Haier's Industrial Internet platform for the home appliance industry has built seven flexible business sub modules: user customisation, R&D design, procurement management, sales management, production management, logistics management and after-sales service. Thus, effective communication and collaboration between different businesses can be achieved. The solution meets the needs of personalised customisation. The whole product life cycle management level in manufacturing enterprises has been improved. The platform solution has great reference value for promotion. On the one hand, it is an important direction for the future development of the platform to effectively integrate the production business and user needs. The first step is to build an industrial e-commerce that can provide users with personalised configuration functions. On the other hand, it is more and more important to decouple the functions of traditional platforms, build independent business sub platforms, and build a platform system based on multi-business sub-platforms. In addition, Haier's mass customisation solution can be popularised for multiple varieties and small batch discrete industries. At present, Haier is expanding the solution from the home appliances industry to the clothing industry, ceramics industry and RV industry, and has achieved good application results.

3.9 Use Case "5G Enabled Smart Qingdao Port"

3.9.1 Overview of Use Case Description

Qingdao Port, which occupies a central position among the ports in Northeast Asia, is one of the most comprehensive ports in the world, and an important hub for international trade in the West Pacific. In 2018, the container throughput of Qingdao Port reached 1.154 million TEU, ranking sixth in the world in terms of cargo throughput. Thanks to its high degree of automation and informatisation, Qingdao Port has a natural advantage of being transformed into a smart port. In the face of increasingly fierce competition among ports, and with the advent and maturity of 5G technology, China Unicom has joined hands with Qingdao Port Group Co., Ltd. and Shanghai Zhenhua Port Machinery Company Limited in the building of a 5G-based smart port. The application verification in terms of aspects such as automatic remote control in the shore bridge area, automatic stacking in the loading/unloading area and unmanned vehicle driving in the port area under 5G network has been carried out. With the wide bandwidth, low latency and high reliability of 5G network, labour costs as well as operations and maintenance costs of the port have been greatly reduced, which has improved both the operational efficiency and safety.

3.9.2 Business View

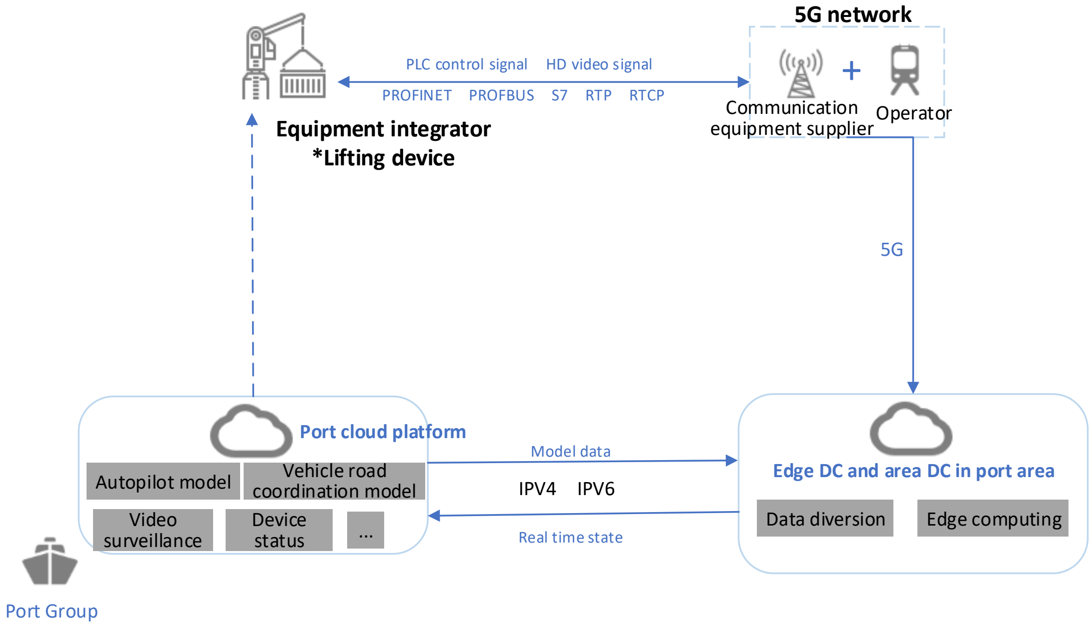


Figure 24: Diagram for the data value chain of 5G-based smart port

As for the lifting equipment, the protocol conversion and adaptation is performed via 5G industrial control gateway. The control signal is transmitted to the master control centre of the lifting equipment through the 5G network to complete the remote control of the lifting equipment, thus replacing the traditional manual operations on the site. In this process, the MEC (Mobile Edge Cloud) provided by the operator is utilised to reduce the delay in data transmission, and meanwhile, to ensure the privacy and security of port data. The various port data (PLC signal, video signal, vehicle driving data, etc.) processed by MEC are gathered to the local cloud platform of the port, and the operational staff of the port will analyse, judge and optimise the port business using the data on the cloud platform. Through the cloud platform, the equipment integrators can track the real-time operating condition and operating data of the equipment.

Value proposition

With the data on the cloud platform of the port, the equipment integrators of the port can make predictive maintenance analysis and failure prediction on the equipment. This reduces the outage probability and downtime of the equipment, and improves its utilisation rate. At the port, the remote control of the lifting equipment is realised through the 5G Industrial Internet cloud platform-based network system, which not only realises unmanned operations on the site of the quay crane, but also greatly reduces labour costs. Meanwhile, the unmanned operations on the site have significantly reduced safety risks and improved the operating efficiency of the equipment. For the operators, while providing basic 5G network services, they can provide further value-added services through MEC to improve network operations quality, thus obtaining more benefits.

Revenue mechanism

The port operators pay the operators for the 5G network maintenance and management. The port operators also purchase or rent heavy port handling equipment from the system integrators.

The operators purchase the basic communication facilities from equipment and communication equipment suppliers.

The system integrators pay part of the costs for network transformation, construction, operations and maintenance to the operators.

Business model innovation

For equipment integrators of the port, the innovation of the business model lies in the change of the traditional offline sales and offline after-sales maintenance models. Through the cloud platform, the operational conditions of the equipment can be predicted in advance via predictive maintenance or online failure diagnosis. New and flexible time-based charging methods can be implemented.

For the port group, the business operations model has changed from the traditional offline operation model to an online cloud platform model. Through the centralised business management on the cloud platform, the operations of various businesses of the port are controlled in a timelier manner with lower labour costs, and the consumption of hard assets is transited to the consumption of soft resources. Meanwhile, new revenue channels can be developed based on the cloud platform business.

The operators, on the one hand, can connect with port equipment integrators, integrate the scheme of the 5G-based port into the overall solution of the smart port, collect fees for the construction of the smart port and provide free quantitative 5G traffic and broadband usage quota; on the other hand, the operators can connect with the port group and provide construction, supporting and maintenance services for 5G networks in some of these scenarios.

3.9.3 Functional View

Problems in current port business

At present, most of the ports and terminals in China have both traditional manual terminals and automated terminals. The manual terminals account for a relatively large proportion and are equipped with numerous less-automated port operations equipment. Every operations equipment is manually operated on the site. Therefore, the operational environment is often complex, with low efficiency, high risk factor with hidden safety hazard and high labour costs. Qingdao Port is an automated terminal with a high degree of automation and informatisation. Although some of the services can be achieved with the help of wired networks, a large number of scenarios are unable to be connected to the network due to their restricted motilities. Therefore, the solution to one of the most important problems the port is currently facing is to build a fully connected wireless network to convert the traditional manual operations mode into a remote control mode, using the wireless network as an extension and supplement of a wired network, extending the network coverage from information acquisition to production control, realising an overall awareness for the transportation factors of the port, and thus realising automatic dispatching and production of the port.

Remote Control Solution Based on 5G Network

Previously, the remote control of the quay crane in the shore side loading/unloading area of Qingdao Port was realised through the giant drum of the optic electric composite cable on the quay crane. The crane will drag and tow the optical fibre during its operations, easily damaging the optical fibre. Therefore, there is an urgent need to replace wired network transmission with wireless intelligent transmission.

In this case, to tackle this problem, 5G wireless transmission is used to replace the wired communication between the original master PLC and the lifting equipment PLC. The adaptation to the original industrial control protocol is achieved through a 5G industrial control gateway. The short delay span, high reliability and wide bandwidth performance of 5G network can meet the ultra-low delay requirements of PLC control signals and bandwidth requirements for high-definition video return. Meanwhile, in order to further guarantee the real-time requirements of the control signal and high-definition video return, MEC is also deployed in the port area. With the split-flow treatment of MEC, the time delay in the data transmission to the core network caused by a long transmission path is reduced and privacy and security of port data are guaranteed.

3.9.4 Discussion of Current Challenges and Concerns

Problems in current port business

In this case, by replacing the traditional wired control with the remote control using 5G wireless network, unmanned operations on site are implemented, which not only improves operational flexibility and reliability and greatly reduces labour costs, but also improves the working environment of workers and significantly improves the port operations' efficiency. In the process of the Industrial Intranet evolution, with the gradual maturity of technical standards and equipment, replacing wired networks with wireless networks is a big development trend. The application of 5G core technologies in ports can also be extended to the remote control in smart factories, smart transportation and other fields, producing innovation and change.

3.10 Use Case "Edge Computing Platform for Intelligent Management of Tool Monitoring and Life Prediction"

3.10.1 Overview of Use Case Description

In the industrial field, predictive maintenance, life prediction and real-time monitoring of machine tools are problems that need to be solved in the production process.

At present, the tool counting prediction method, the method of physically monitoring with additional sensors and other solutions to tool monitoring are available in the market, all of which have the disadvantages of high costs, slow deployment, low accuracy, etc. Moreover, the environment deployment on the edge side is complicated and not flexible, which is not conducive to large-scale unified management, and the costs for overall maintenance, monitoring and upgrading are high.

The OpenStack technology-based edge computing platform for intelligent management of tool monitoring and life prediction can realise the real-time state monitoring, life prediction management and data information visualisation of tools on the edge side during processing by collecting and analysing the spindle load based on the instrumentation of CNC machining equipment.

3.10.2 Business View

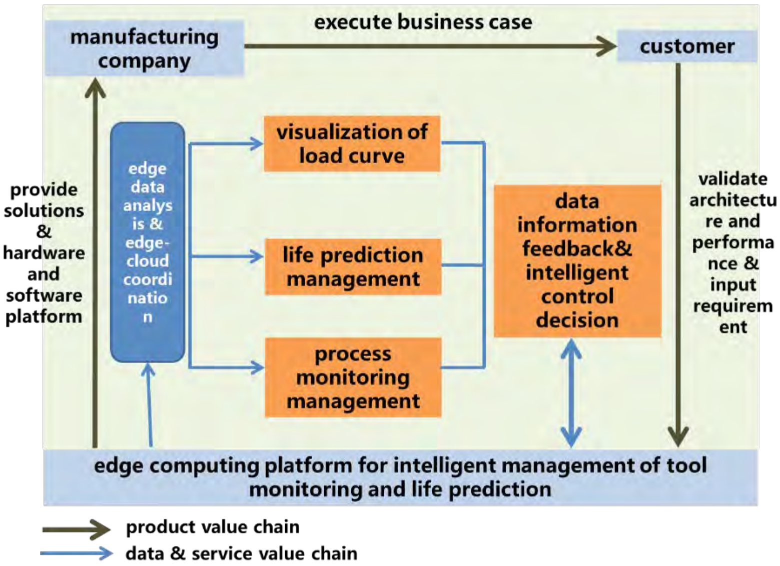


Figure 25: Value chain of edge computing platform for intelligent management of tool monitoring and life prediction

The edge computing platform for intelligent management of tool monitoring and life prediction collects fees by providing solutions and hardware and software platforms and using feedback data and information to form an ecological loop of data chain and value chain. By deploying the edge computing platform for intelligent management of tool monitoring and life prediction in the factory site, actual business cases could be implemented to verify key technologies, reference architectures, system performance as well as to further identify gaps and problems, which can be imported into subsequent optimisation as key requirements. This process helps to continue the iterative improvement and expand the breadth and depth of business applications. The ultimate goal is to establish edge computing architecture through the platform and support the deployment of test beds and business cases commonly used in the industry, so as to accelerate the development of Industrial Internet best practices.

3.10.3 Functional View

In this solution, the platform integrates more than 85% of the CNC systems (which are of different brands and types) operating in the market, and it is able to monitor the tools (turning, milling, drilling, broach, etc.) of different types and sizes. In terms of edge and cloud collaboration, the edge data can be managed in a unified manner on the core cloud platform, which enables simultaneous online monitoring and indexing for the workshop billboard, PC and mobile terminals, increasing the deployment speed markedly as compared with the traditional tool monitoring mode; a large share of the hardware costs are saved, and the users' technical experience is better. The specific solution is as follows:

1. By collecting the load data on the edge side and in combination with local data processing and analysis, the real-time condition monitoring and real-time alarms can be realised. With the advantage of low latency and high reliability, the edge computing platform can help to comprehensively detect tool usage condition, accurately locate anomalies and reduce quality risks in production so as to increase production efficiency and safety.

2. Flexible and fast application orchestration, delivery and life cycle management are achieved in the Industrial Internet system. The specific implementation method is to arrange physical resources on the edge side to provide computing, storage, network and other functions, and then on this basis, rely on the Animbus edge computing suite of 99Cloud to provide edge-side virtualisation resources and capabilities, thus greatly improving the deployment efficiency on the edge side, reducing the management difficulty and providing a more sensitive solution for large-scale deployment.

3. Collecting a large amount of usage data of different tools on the edge side of the site, uploading the data to the edge cloud to perform Big Data processing and analysis and to output the pre-judgment results, then sending the relevant results to the real-time informatisation display and statement analysis system on the edge side – this can effectively improve the accuracy for the life prediction cutting tool edge and the risk pre-processing capability.

3.10.4 Discussion of Current Challenges and Concerns

The edge computing platform for intelligent management of tool monitoring and life prediction can connect most tool types in the market. Through efficient and comprehensive mining of data value, it can play an important role in guiding resource management and production decision-making. It provides an excellent solution for enterprises to fundamentally improve tool management quality and tool use efficiency, and realise accurate cost accounting. Meanwhile, the real-time state monitoring and life prediction management system has set up a typical model for promoting the upgrading of manufacturing industry.

3.11 Use Case "Identifier + Platform for Tracking and Life-Cycle Management"

3.11.1 Overview of Use Case Description

China has become the major cable market and the largest cable producer around the world. However, at present, due to the lack of a unified production equipment identifier, the industry is now facing problems such as disordered management, low efficiency of supply chain management and insufficient capability for networking collaborative manufacturing. Therefore, it is necessary to assign a unique Industrial Internet identifier to equipment, products, processes and other production factors with the help of an identifier resolution system, so as to break the barriers caused by multiple heterogeneous data, link the information of finished products with that of raw materials and production processes and strengthen the collaborative manufacturing of upstream and downstream enterprises in the industrial chain.

As one of the leading enterprises in cable industry, ZTT, relying on the Industrial Internet identifier resolution system, has built an identifier resolution service platform of cable industry to provide identifier registration and resolution services for enterprises in the material industry. On the basis of the identifier resolution services, ZTT has integrated the equipment cloud platform, product quality traceability system, and the production and manufacturing collaboration platform to realise the management for the full life cycles such as purchasing logistics, equipment management, operation monitoring, maintenance and repair, quality tracing, supply chain collaboration and data sharing, providing safe, efficient and low-threshold sustainable services to enterprises in the cable industry.

3.11.2 Business View

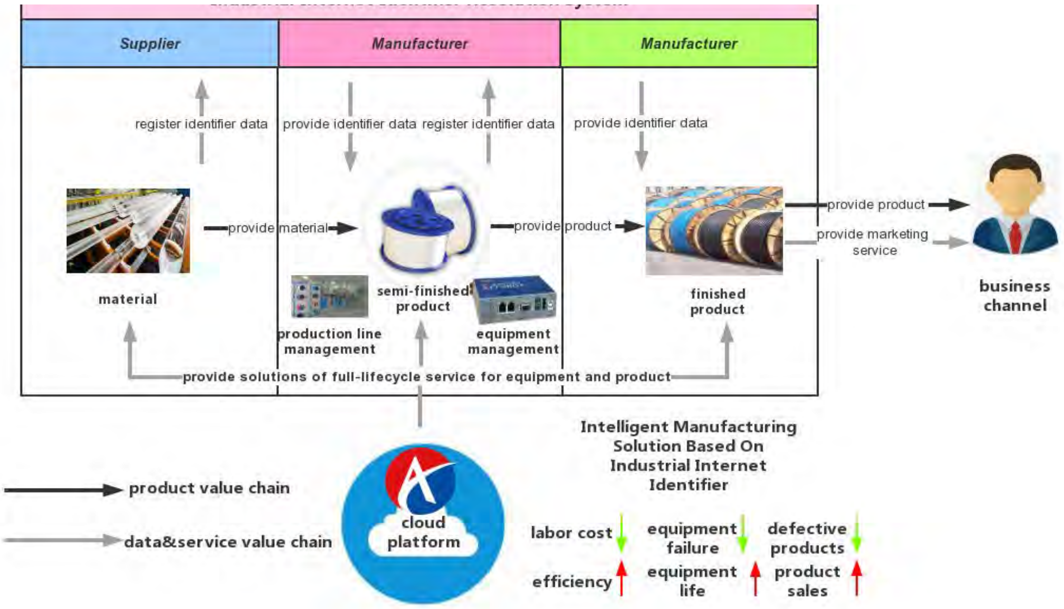


Figure 26: Value chain of Industrial Internet identifier resolution system

The value chain built with the solution based on identifier resolution includes many manufacturers in upstream and downstream of the cable industry chain and many participants such as identifier resolution service providers. For manufacturing enterprises in the cable industry, services based on identifier resolution, such as using one code to enter the equipment cloud platform and the "one code overview" intelligent and trustworthy quality traceability, can prolong the service life of equipment, improve management efficiency, reduce equipment failure rate, reduce maintenance and labour cost, thus achieving the reduction of comprehensive cost of enterprise. For ZTT, it realises the transformation from a cable manufacturing enterprise to "a cable manufacturing enterprise + identifier resolution service provider", which does not only use identifier resolution to optimise the internal production process of the enterprise and to achieve cost reduction and efficiency improvement, but can also be used as an enterprise for construction and operation of the identifier resolution service platform to provide other small and medium-sized enterprises with identifier resolution and other value-added services so as to create benefits for them.

3.11.3 Functional View

Based on the identifier resolution service platform, ZTT has built five core applications, namely, "one code for one item, resolution by scanning code", "entering cloud with one code, equipment first", "one code overview, tracing to source", "one code to source, collaborative manufacturing" and "one code for multiple authority, decentralised management and control".

1) One code for one item, resolution by scanning code

The resolution of Industrial Internet identity objects and their attributes can be achieved by using the "one code for one item" characteristic of the Industrial Internet identification system and the recursive resolution of the intelligent distributed identification system.

2) Equipment cloud platform with one code to enter

The cloud platform-based equipment management can effectively solve the problems found in equipment management of manufacturing enterprises. The equipment cloud platform achieves equipment management over the whole life cycle based on Industrial Internet identifier resolution system and by means of terminal code-scanning technologies such as two-dimensional codes and RFID. All equipment accessed to the platform need to be registered in the identifier resolution system, and are given a unique Industrial Internet identifier code. The equipment information is obtained and various functions of the cloud platform are completed through identifier resolution. The cloud platform-based equipment management based on Industrial Internet identifier resolution system can achieve the informatisation, paperless and modularisation of equipment management. It can also effectively improve management models and increase production efficiency.

Through cloud platform-based equipment management, problems such as equipment ledger and basic data imperfection and easy loss can be eliminated. At the same time, the equipment cloud platform may monitor the status of equipment in real time, support periodic equipment care and maintenance, rationalise equipment spot inspection, register equipment anomalies online, thus enhancing production efficiency, reducing equipment failure rate, and improving production stability. Via the equipment cloud platform, the collected equipment data may be subjected to Big Data analysis, thus providing manufacturing enterprises with analytical information about life cycle of spare parts and warnings for equipment maintenance, thus realizing predictive maintenance to production equipment.

3) Product quality tracing based on "One code overview"

To ensure product quality and safety, a product quality tracking system based on Industrial Internet identifier is established to strengthen enterprises' management to the products over the entire circulation field, learn the production process quickly and accurately, deal with defective products timely and freeze and recall defective products quickly. During product circulation, enterprises at each stage save the product tracing data locally, and register the mapping relationship between the identification code used for product tracing and the product information storage address in the identifier resolution system. This is uniformly managed by the identifier service system. The end user can access all traceable information of the products in circulation by querying all the address identifiers of traceable information of the products via the identifier service.

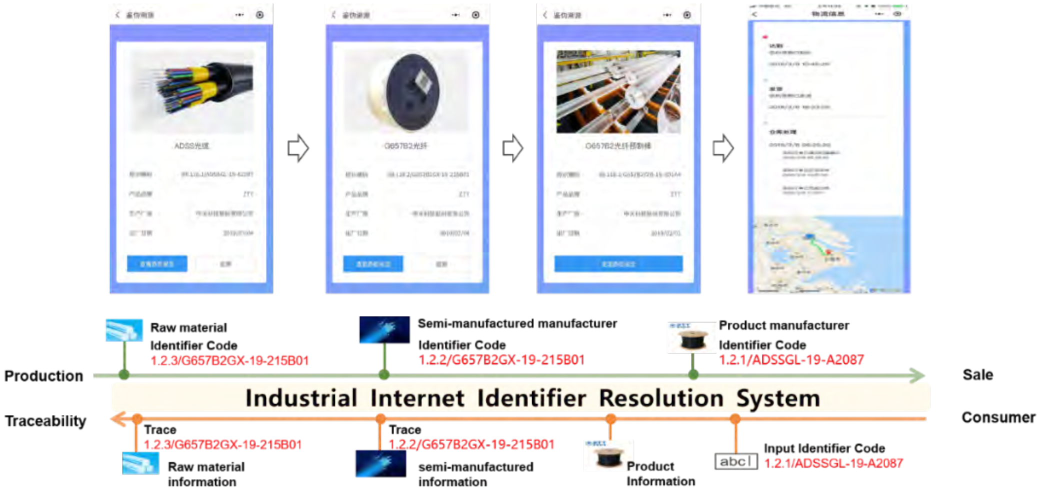


Figure 27: Product quality tracing based on "One code overview" identifier resolution

4) Collaborative manufacturing based on "One code to source"

Using the Industrial Internet identifier and in combination with the emerging information technologies such as the Internet of Things, Big Data and Blockchain, the production and manufacturing collaboration platform transforms the serial work in the industrial chain into a concurrent project, realizing efficient collaboration in product design, planning, manufacturing, sales, and management for enterprises within the supply chain and across supply chains. By giving full play to the system advantages of the Industrial Internet identifier and sticking to the core concept of "One code for one item, one code to source", the production and manufacturing collaboration platform connects the upstream and downstream of the industrial chains, providing node enterprises on supply chains with a real-time interactive sharing and communication platform, thus realizing synchronous operation and information coordination among node enterprises, increasing end-to-end transparency, improving rapidity and effectiveness of decision-making and finally making full use of resources.

5) One code multiple authority, decentralized management and control

Based on the Industrial Internet identifier, roles bearing different responsibilities will be allocated with different authorities and will be managed and controlled separately, thus achieving decentralised management and control via the identity authentication and one code multi-identification technology under the premise that there is only one resolution entry.

6) Solution value analysis

Relying on the Industrial Internet identifier resolution system, the identifier resolution service platform of cable industry provides identifier resolution and registration services for upstream and downstream enterprises in the cable industry, forming a new model for managing equipment intelligently, which runs through the cable industry chain. Through intelligent transformation, the enterprises expect the service life of equipment to be extended by more than 25%, the equipment failure rate to be reduced by more than 20%, the maintenance cost to be reduced by more than 30%, the labour cost to be reduced by more than 20%, the production efficiency to be increased by more than 15%, the defective product rate to be reduced by 10% and the manufacturing costs of the entire cable industry to be reduced by 20%.

3.11.4 Discussion of Current Challenges and Concerns

In this use case, the identifier resolution service is the core of this solution, showing that public and globally unique identity plays a very important role in the Industrial Internet applications. In order to better digitise the physical entities, it is recommended that the necessity of the construction of identifier-related infrastructures should be taken into active consideration. This helps to achieve heterogeneous data interactions, meet the needs of Industrial Internet application scenarios for identification and guarantees the inter-enterprise, cross-industry and cross-platform information interconnections. The construction of the identifier resolution system can better expand the mature Industrial Internet application model to different industries. In the meantime, identifier resolution has significant support for multiple areas such as asset management and digital identity management.

3.12 Use Case “Solution for Network Security Emergency Disposal and Security Protection”

3.12.1 Overview of Use Case Description

This case is about a client of Qi An Xin, which is a well-known new energy automobile manufacturing enterprise and also a leading high-tech enterprise in China. It established more than 30 industrial parks around the world and has several production bases in places such as Changsha and Xi’an. This enterprise was once attacked by the “WannaCry” virus, which brought multiple host computers on the production line to frequent blue screen crashes, and this virus quickly spread to most of the host computers in the entire production park, forcing the production line to be stopped, and causing the enterprise to suffer great losses.

Behind the ransomware attack, there are two major security problems that the enterprise faces: first, most of the host computers on the industrial site are old, and those with a service time of over ten years are common. In addition, the essentially closed industrial site makes the patch upgrading and virus processing complicated. Second, the production network is connected with the office network of the enterprise, and no security measures were taken. Once the networks are infected with the virus, it makes a huge impact.

Qi An Xin developed an emergency disposal and security protection solution for the enterprise, which effectively solved the blue screen problems caused by the ransomware virus. At the same time, it improved the security defence capability of the industrial hosts and ensured the stable operation of the production lines in various production parks of this large manufacturing enterprise.

3.12.2 Business View

More than 17,000 sets of industrial host security protection systems were deployed for the production lines of this automobile manufacturing enterprises across the country, providing a security and healthy production environment for the enterprise. At the same time, it has been verified by practice that this solution is a mature and reliable security solution that can be applied to most industrial control systems, which lays a foundation for other large intelligent manufacturing enterprises to promote industrial network security construction.

3.12.3 Functional View

In this solution, in response to the ransomware attack suffered by the enterprise and the potential security risks, Qi An Xin provided the following four types of security services for the enterprise:

First, threat identification. Qi An Xin deployed an industrial security inspection and evaluation tool on the bypass of the core switch of the production network to inspect the production network data traffic. It then analysed and determined the type of threat by correlating it with the multi-dimensional massive malicious threat intelligence database generated by the secure Big Data. At the same time, it can list the IP addresses and MAC addresses of all problem terminals in detail and locate the specific location of most problem terminals based on the asset list provided by the enterprise.

Second, emergency disposal. After discovering that the host computers were infected with WannaCry virus, to prevent further hazards caused by data encryption on the host computer, Qi An Xin urgently deployed a disguised virus server in the production network with the domain name set as that of the virus website. Through policy setting, the DNS of the host computer in the production network was set to point to this disguised server to prevent subsequent influence of the WannaCry virus.

Third, infection treatment. After finding the location of the problem terminal, the security service personnel of Qi An Xin closed port 445 immediately to avoid further spread of the virus. Then, the security service personnel of Qi An Xin backed up the problem terminal system and its data, and treated and removed the virus with its professional antivirus tool designed for the WannaCry virus.

Fourth, security reinforcement. To protect the treated host computers from being infected with the virus again, the security service personnel deployed an Industrial host security protection system for the host computers on the production line. Based on the lightweight "application white list" technology, the system intelligently learns and automatically generates a "white list" protection baseline for normal behaviour patterns of the operating system of the industrial host and the dedicated industrial software. The system also releases normal operating system processes and dedicated industrial software and actively blocks unknown programmes, Trojan viruses, malware, attack scripts, etc., creating a clean and secure operating environment for industrial hosts.

At the same time, for networkable host computers, an industrial host security system control centre was deployed to implement the functions of grouping management, strategy formulation and issuance, terminal software and hardware asset management, security log collection and alarming, finally achieving unified management, configuration and security risk control.

The protection deployment scheme is shown in the following figure:

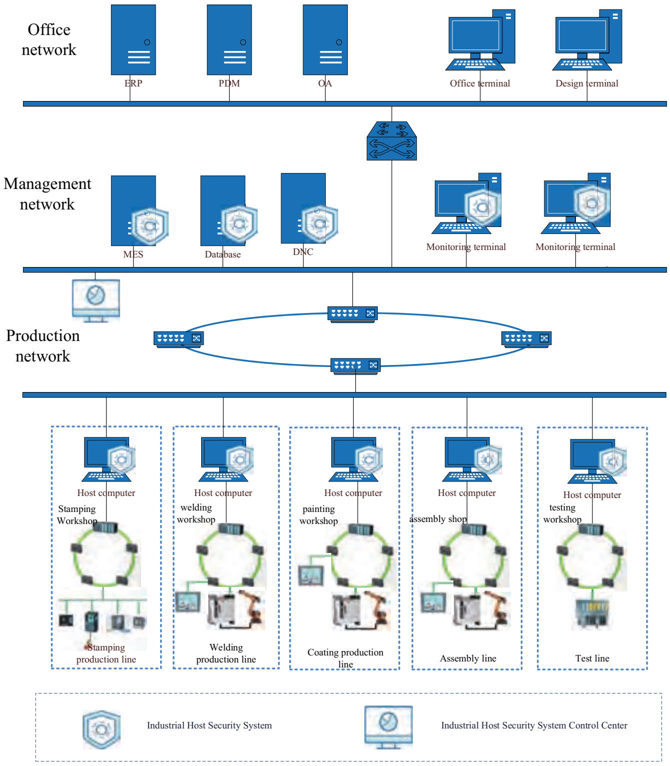


Figure 28: Schematic diagram for industrial host security protection deployment

3.12.4 Discussion of Current Challenges and Concerns

The multi-dimensional massive malicious threat database generated by the security Big Data ability provides important help for threat tracing, which is an indispensable basic ability to solve security problems. At the same time, the resolution process of threat identification, emergency response, infection treatment and security reinforcement is representative and universal, which can achieve the security protection of whole work processes.

3.13 Discussion of Use Cases 3.7–3.12 in Relation to the AII Architecture

Overall, the above selected use cases comprehensively reflect the content and characteristics of the Industrial Internet Architecture (Version 2.0), reflecting the understanding and practice of the Industrial Internet in China's industry, with certain research value and reference significance.

From the functional point of view, the use cases cover many functions in Industrial Internet Architecture (Version 2.0), which is the extension of the three major functional systems of network, platform and security in the practice of China's Industrial Internet. Among them, Qingdao Port starts from the 5G deployment and depicts a major focus of China's new network application; the four kinds of cases of ROOTCLOUD, Haier, 99 Cloud, and ZTT build an Industrial Internet platform from different angles, showing the Chinese platforms' diversity of application models; Qi An Xin focuses on emergency disposal and security protection solutions, highlighting the security functions in the Industrial Internet.

From the implementation point of view, the cases run through all aspects of Industrial Internet Architecture (Version 2.0) and are typical representatives of China's Industrial Internet application. Among them, ROOTCLOUD focuses on the post-service situation of the industrial layer; 99 Cloud focuses on the on-site equipment monitoring and control; Qi An Xin builds the security protection from three layers: the device, the edge and the enterprise; the cases of Haier, Qingdao Port and ZTT cover all four levels in three different aspects – manufacturing process, network deployment and identity analysis.

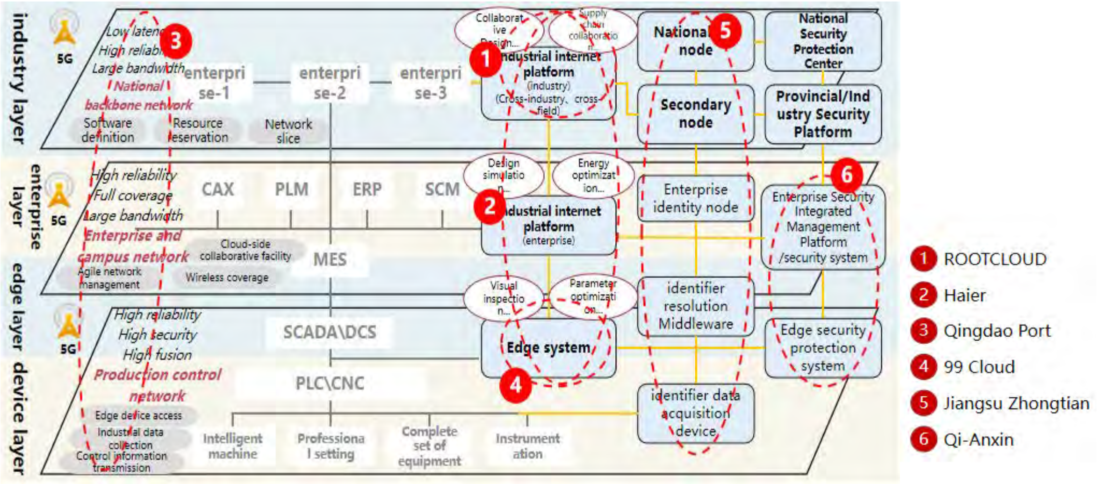


Figure 29: Chinese use cases conclusion

4. Conclusions

4.1 Industrie 4.0 and Industrial Internet are of Strategic Importance to Both Germany and China

he Industrial Internet is described as "a key enabler to the digital transformation of manufacturing" in the introduction. As such, it is central in the discussion of value creation in Germany in the *2030 Vision for Industrie 4.0: Shaping Digital Ecosystem Globally*[8] and Plattform Industrie 4.0. In China, the State Council published the *Guidance on Developing Industrial Internet and Enhancing the Integration of Internet and Advanced Manufacturing* in 2017. The Alliance of Industrial Internet (AII) was initiated in 2016. Commonalities between Plattform Industrie 4.0 and AII include collaboration between enterprises, research institutes and industry associations.

To foster improved cooperation, the German and Chinese governments signed a Memorandum of Understanding (MoU) in 2016. Based on this MoU and the Sino-German Industrie 4.0 Project, the Sino-German Company Working Group Industrie 4.0 and Intelligent Manufacturing (AGU) was established. The AGU aims to deepen mutual understanding, exchange best practices and develop recommendations on an industry and expert level. Therefore, companies participating in the AGU Expert Group Industrial Internet (EG II) contributed use cases, based on which we observed the following conclusions.

As shown in Chapter 2, the discussion in Industrie 4.0 and in AII so far has taken place from two slightly different angles: while I4.0 focuses on using the IIoT in manufacturing for new value creation, the AII considers additional domains such as transportation as well.

4.2 The Value of Industrie 4.0 and Industrial Internet in Manufacturing: Conclusions Derived from the Use Cases

Using ten well-defined use cases provided by the companies in the AGU and an agreed structure of the description of the use cases, the major contribution of the AGU's work is to present these use cases as a solid information base for generating joint insight and under- standing about value creation in manufacturing through the Industrial Internet.

Looking at the use cases, we see that from the diversity of domains, solutions and viewpoints, we have a wider range of application ideas, technology used and diversity of requirements at our disposal to derive new conclusions. In this sense, the existence of two slightly different points of view has contributed greatly to the value of the use cases and their discussion.

Comparing the use cases provided by German and Chinese experts, we see that the German use cases emphasise a wide variety of usage views. On the Chinese side, domains besides manufacturing are shown additionally (e.g., transportation/logistics) and there is an emphasis on diversity of the functional view descriptions.

Looking at common issues raised by these use cases, we agree on the following observations.

4.2.1 Interoperability (Machine Connectivity and Networking)

Interoperability is essential for the use cases to work smoothly, since several companies need to securely and reliably exchange data and use them to create value.

Networking is the basis of this connectivity. In almost all use cases, the companies routinely use several interoperability-related standards on the physical and protocol levels, such as Ethernet, Wifi, 4G, IPvx, HTTP, MQTT, etc. Diverse connectivity is needed to address different client infrastructures. MQTT is the choice of several IIoT platforms in the use cases.

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[8] Plattform Industrie 4.0 (2019), 2030 Vision for Industrie 4.0: Shaping Digital Ecosystem Globally.

In the Chinese use cases, in addition, newer technologies like 5G, edge computing and Software-Defined Networking (SDN) are applied in practice.

Moreover, higher level standards addressing syntax and semantics become important for unifying solutions. Here, OPC UA is the method of choice for two German use cases.

Standards in I4.0

Industry 4.0 regards standards as important for the interoperability of manufacturing systems. A reference architecture model for Industrie 4.0 (RAMI4.0) has been developed and published to form a basis for the discussion of architectures and solutions.

The realisation of the importance of standards for interoperability has led many bodies working on I4.0 to jointly develop a detailed standardisation roadmap, which has also been published in English.[9]

Standards in AII:

The Chinese industry and government attach great importance to the standardisation of the Industrial Internet. The Alliance of Industrial Internet (AII) established a technical standards working team right after its establishment. The China Communications Standards Association (CCSA) established the Industrial Internet Special Working Team (ST8) under it. In March 2019, the Standardisation Administration and MIIT of the People's Republic of China issued the Guidelines for the Construction of Industrial Internet Integrated Standardisation System to enable a top-level design and a leading role of standards in the construction of the Industrial Internet ecosystem.

Interoperability standards in the Sino-German cooperation on I4.0

Standardisation is an important work thread of the cooperation on I4.0 and Intelligent Manufacturing and is carried out by the Sino-German Industrie 4.0/Intelligent Manufacturing Standardisation Sub-Working Group. As a central piece of standardisation, RAMI4.0 has been compared to the IMSA architecture and a joint "Alignment Report for Reference Architectural Model for Industrie 4.0/Intelligent Manufacturing System Architecture" was published in April 2018.[10]

In that paper, OPC UA is agreed on as a first-class communication standard in both models.

The report also consists of several use cases which support the above-mentioned observation about machine connectivity. From our discussions in the EG II and with standardisation experts, we observe a rising interest in standards related to syntax and semantics. Sticking with the example of OPC UA, i.e. the domain-specific "companion specs", OPC UA also offers support for semantics.

4.2.2 Importance of Data and Data Protection

Data is the raw material of the Industrial Internet.

Therefore, owners, producers and users of data in both countries place high importance on security, integrity and control over the use of data.

Accordingly, data protection is a common issue in almost all discussed use cases from Germany and China. The use cases clearly show the importance of data protection for the viability of value creation through the Industrial Internet.

The requirements on data protection are diverse. Even among the four German use cases documented in Chapter 3, protection of competitively-relevant data, protection of data in cross-border data transfers and protection of digital rights and intellectual property are all raised.

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[9] DIN e.V. & DKE Deutsche Kommission Elektrotechnik (2018), German Standardisation Roadmap: Industrie 4.0, Version 3.

[10] Sino-German Industrie 4.0/Intelligent Manufacturing Standardisation Sub-Working Group (2018), Alignment Report for Reference Architectural Model for Industrie 4.0/Intelligent Manufacturing System Architecture.

In addition to this, the use cases described by the Chinese companies also mention other aspects of Industrial Internet security. For example, in the case of China's Qi An Xin Group, security protection in the whole process of "pre-event, in-event and post-event" is addressed.

Therefore, the detailed meaning of the term "data protection" in each use case, and the ensuing requirements, are diverse and need further joint investigation.

4.2.3 Platform

As specified in the definition in Chapter 2, platforms are essential for the Industrial Internet implementation. The use cases from both China and Germany are based on the platform for data provision and analysis capabilities, which technically enable optimising the value chain and can support possible innovation.

4.3 Recommendations

From these results, we derive the following recommendations.

4.3.1 General Conclusions

1. The work of the AGU based on use cases provided by the participating companies should continue.

2. The use cases should be studied to achieve mutual understanding and be refined if necessary.

3. In the next calendar year, the work should prioritise the two areas of "machine connectivity including syntax and semantic standards" as well as "data protection" with the goal of deriving concrete recommendations.

Realising the importance of standards for interoperability, the AGU should cooperate with the Sub-Working Group on Industrie 4.0/Intelligent Manufacturing under the Sino-German Standardization Cooperation Commission (SGSCC). One suggestion is to conduct a joint workshop or conference.

4.3.2 Recommendations Regarding Interoperabilityy

1. Interoperability and machine connectivity are essential for almost all use cases in this report. However, due to the slightly different viewpoints of I4.0 and the AII, slightly different meanings and priorities are attached to interoperability. The AGU should discuss machine connectivity issues mentioned in the use cases in detail in its future work.

2. In particular, the AGU should investigate the use of MQTT, OPC UA and possibly other syntax and semantics technologies in both China and Germany.

4.3.3 Recommendations Regarding Data Protection

Based on the presented use cases, the AGU should derive a common understanding about the relevance of data protection, including aspects of cross-border communication and data ownership for value creation using the Industrial Internet in each use case, as well as clarifying and documenting the diverse requirements on data protection in these use cases.

5. Resources and Support

5.1 Test Beds

5.1.1 Industrie 4.0 Implementation Test Beds

In Industrie 4.0, it was realised that many companies will benefit from support in testing for interoperability and standards. For this purpose, the I4.0 platform has collected information on exiting test beds available and published them on the Internet.[11]

Figure 30 provides an overview of the platforms in Germany and neighbouring countries.

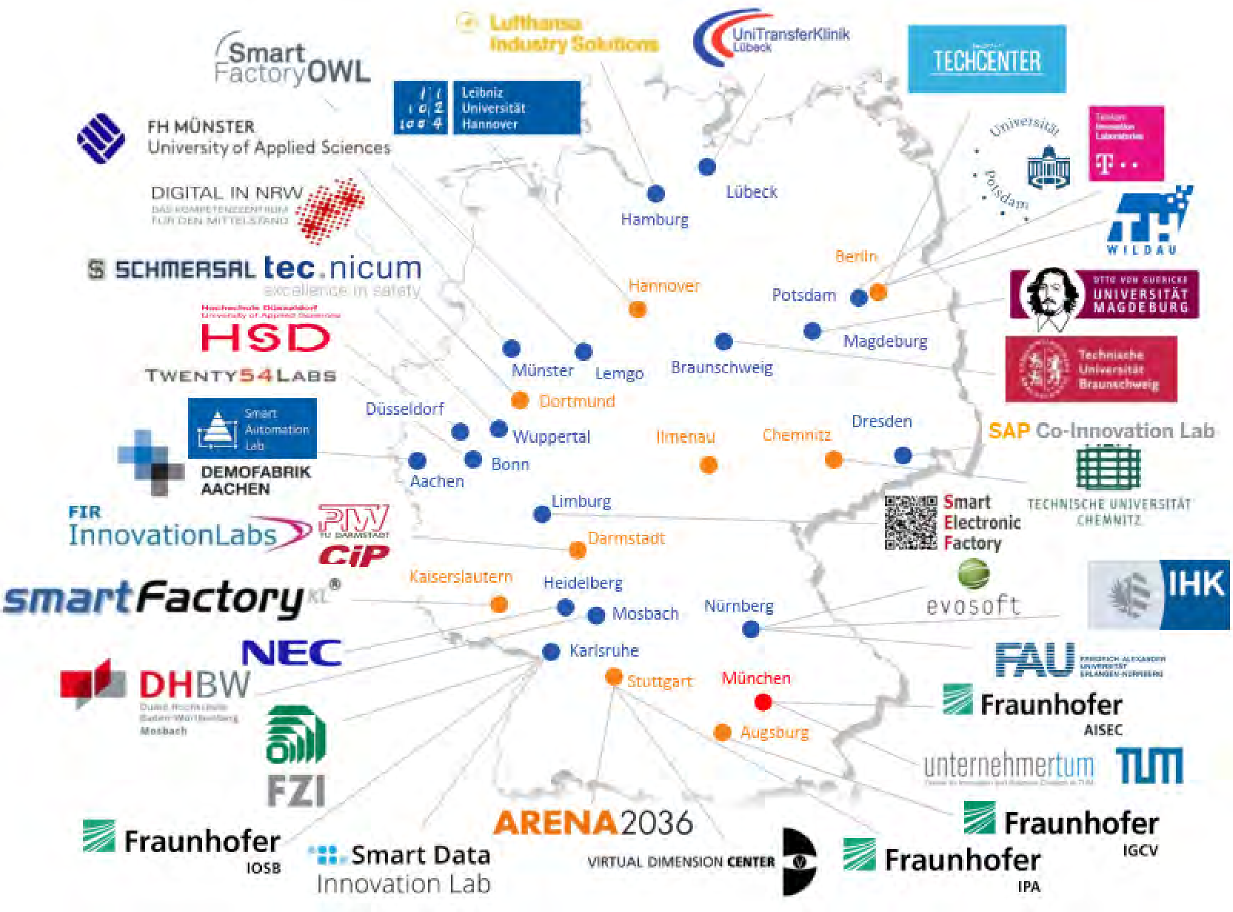

Figure 30: An overview of test beds in Germany and neighbouring countries.

On this website, a complete list of the test beds with contact information is available. The Sino-German Industrie 4.0 Project will also provide an English language version of this list in a separate document.

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[11] https://www.plattform-i40.de/PI40/Navigation/Karte/SiteGlobals/Forms/Formulare/karte-testbeds-formular.html

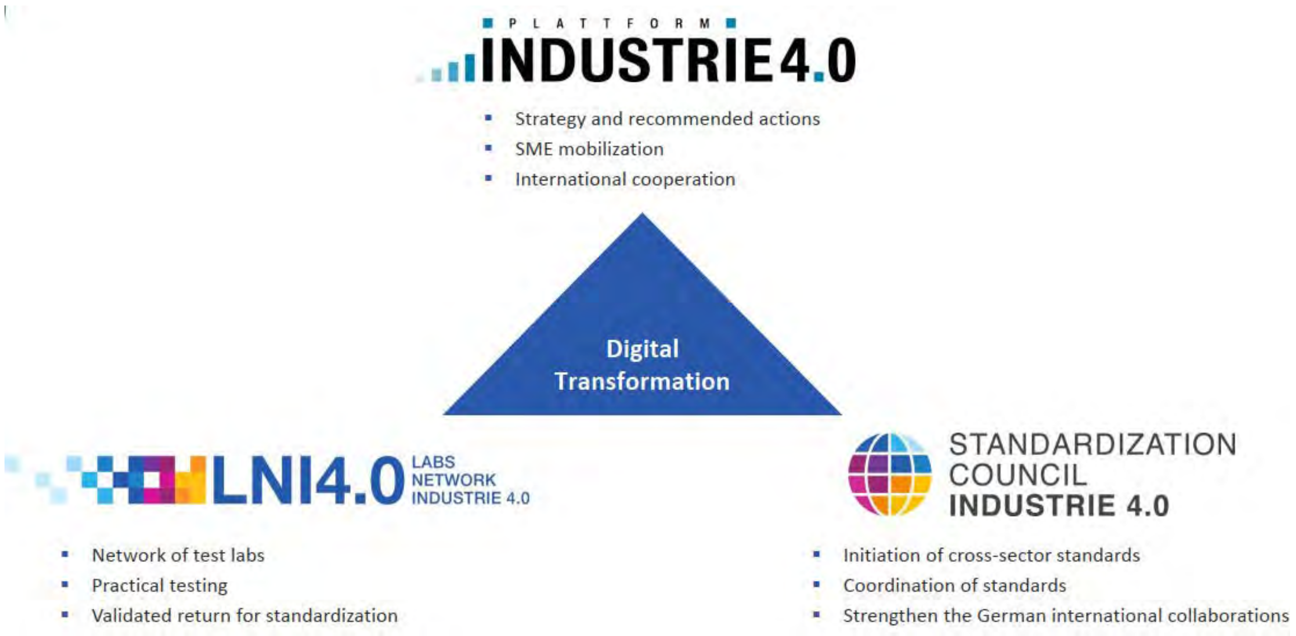

Figure 31: A Plattform Industrie 4.0 initiative on test beds

The government policy actions are accompanied by an initiative created by companies and associations from Plattform Industrie 4.0 to provide appropriate information to interested parties in as many industries and manufacturing technology fields as possible. The association “Labs Network Industrie 4.0 e.V.” was founded as a one-stop shop for the coordination of the different approaches. It supports companies in the initiation of Industrie 4.0 projects, pools results from the testbeds and forwards them to relevant competitive structures, e.g. in the field of standardisation and international cooperation.

The following section gives an example of a test bed that is especially geared towards Sino-German cooperation.

Test bed example: Department of Computer Integrated Design (DiK) Technical University Darmstadt

Motivation for enterprises

In implementation projects small and medium-sized enterprises (SME) in Germany can connect their production resource into a virtual design and production environment at the test bed of the Department of Computer Integrated Design (DiK) of the Technical University Darmstadt. The possibilities for the level of connection is divided into the platform and cloud level, the edge computing level and the on-premise level.

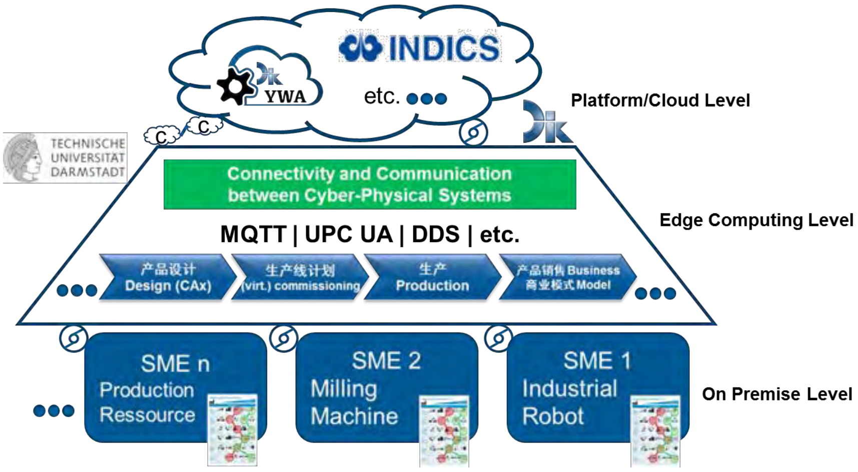

Figure 32: Level connection of the test bed at DiK Technical University Darmstadt

The purpose of the implementation projects at DiK is to give SME guidance and test results on how to address Industrie 4.0 in order to identify enterprise-specific technology solutions, to optimize existing product development and production processes, to advance existing business models and to exploit new business models.

Methodology for the technological implementation

Together with a SME the experts of DiK will define not only the holistic situation of the current product development and production processes of an enterprise but also the technological upgrade as an implementation project at the test bed environment. Herein the Industrie 4.0 Toolbox Product and Industrie 4.0 Toolbox Production are used as the specific technological implementation methodology [Anderl 2015].[12] For both toolboxes, the application levels are displayed in the rows and the technological development stages are explained in the columns of the toolbox. The application level for products consists of the integration of sensors and actuators, the communication and connectivity, the functionalities for data storage and information exchange, monitoring and the product-related IT services. The application level for the production includes the processing of data in the production, machine-to-machine-communication, company-wide networking with the production, the infrastructure of information and communication technology in the production and Human-machine interface

Implementation project abstract and example for virtual commissioning

Virtual commissioning is performed to reveal and rectify faults originating from the product creation process. This implementation project gives an overview of modeling and communication architectures to realize the virtual commissioning of manufacturing cells through the implementation of interoperability, connectivity and commutation between different levels. For this purpose, the necessary department-specific CAx process chains were analyzed with the Industrie 4.0 Toolboxes series and a systematic procedure for model building in an integrated simulation environment was implemented and demonstrated. The communication architecture is shown with couples of virtual PLC (Programmable Logical Controller) and the virtual production environment model. Furthermore, the implementation project is extended by coupling with real PLCs.

As a result, a high-quality interconnected virtual twin is generated. This implementation project is interesting for producing companies as well as for system suppliers in the field of automation technology. The standard is addressed to persons directly or indirectly involved in virtual commissioning, e.g. commissioning engineers, persons deciding on the use of virtual commissioning, technical sales engineers, production and plant planners, automation technicians, software developers and electrical engineers.

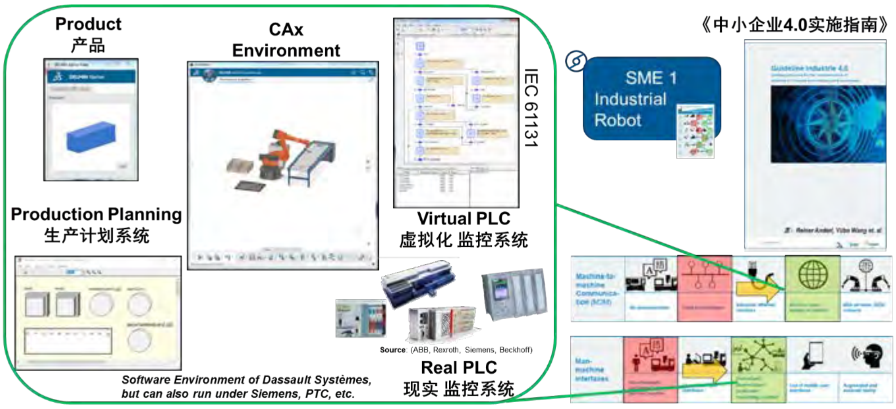

Figure 33: Implementation Guide for SME 4.0

Description of the technological upgrades in two of six application levels of the Industrie 4.0 Production Toolbox:

An application level from the toolbox is **machine-to-machine communication**. It forms the basis for automated data exchange between various machines. Industrial applications include fieldbus, Industrial Ethernet and Internet interfaces. Internet interfaces and applications with autonomous information exchange (web services) offer the advantage of a possible separation of information and location. In this implementation project, the communication architecture for virtual commissioning provides a starting point for testing possible applications on the virtual twin and the real environment.

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[12] Anderl, Reiner ; Picard, André ; Wang, Yübo ; Fleischer, Jürgen ; Dosch, Steffen ; Klee, Benedikt ; Bauer, Jörg. VDMA und Partner (Urheber) (2015): Leitfaden Industrie 4.0 - Orientierungshilfe zur Einführung in den Mittelstand. Frankfurt, VDMA Forum Industrie 4.0, ISBN 978-3-8163-0677-1

Human-machine interfaces are generally already a topic of virtual commissioning. Against the background of the increasing complexity of production plants, human-machine interfaces are becoming even more important. The starting point in industrial practice is often a local display device with operating concepts that are partly not very user-friendly. The virtual commissioning can also be used for novel operating concepts such as mobile tablets or data glasses. It can be tested if the correct information is provided in a suitable way for the task to be performed. This promises a potential for relieving employees and increasing production efficiency.

Results and benefits for SME

After the implementation, depending on the stage of the technological upgrade of each application level the results and benefits for SME can be characterized and desired as the following:

The business models (BM) around the product are:

1. Gaining profits from selling standardized products
2. Sales and consulting regarding the product
3. Sales, consulting and adaption of the product to meet customer specifications
4. Additional sale of product-related services
5. Sale of product functionss

The efficiency with small batches (BM in the production) consists of:

1. Rigid production systems and a small proportion of identical parts
2. The use of flexible production systems and identical parts
3. Flexible production systems and modular designs for the products
4. Component-driven, flexible production of modular products within the company
5. Component-driven, modular production in value-adding networks

5.1.2 Industrial Internet Test Beds in China

5.1.2.1 Network test bed for Industrial Internet

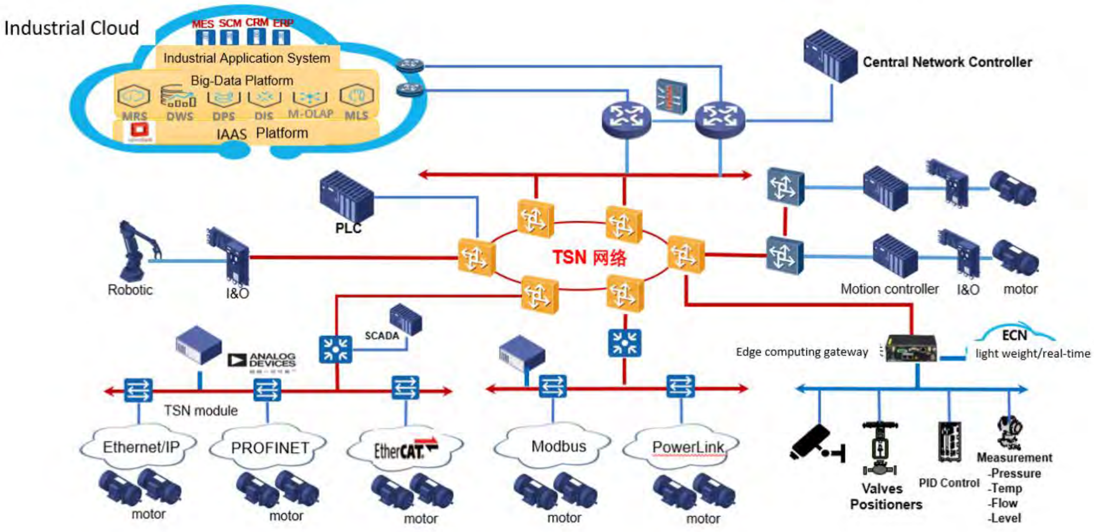

Figure 34: Network test platform for Industrial Internet

China Academy of Information and Communications Technology (CAICT) has established the Industrial Internet network innovation laboratory and built up the network technology test and verification system, including three modules, i.e. the network simulation environment of Industrial Internet, the test platform for industrial network & equipment, and the new technology verification platform of industrial network. The network simulation environment of Industrial Internet, covering various existing mainstream industrial Ethernet simulation environments and new technology simulation environments in the industrial field, is mainly adopted for carrying out comparison tests of various industrial network technologies (Ethernet/IP, EtherCAT, Profinet, CC-Link, Mod_Bus, etc.) and verification of relevant solutions. The network test platform of Industrial Internet is mainly used to carry out industrial network equipment interconnection tests, protocol conformance tests, industrial network performance tests, etc. to implement the standardisation construction of equipment and network in vertical industry. The network verification platform of Industrial Internet is mainly used to verify research results of new network technologies such as TSN and SDN, carry out solution-level verification according to the actual demands of vertical industry site applications, realise incubation of vertical industry network schemes and provide evaluation and assessment for application of new technologies and new schemes in industrial scenarios. The laboratory has taken the lead in conducting two rounds of time-sensitive network equipment interconnection and conformance tests and has officially released the first domestic interconnection test report to the industry. In addition, it continues to output results such as test schemes, standards, test reports and research reports.

5.1.2.2 Function test service system of Industrial Internet platform

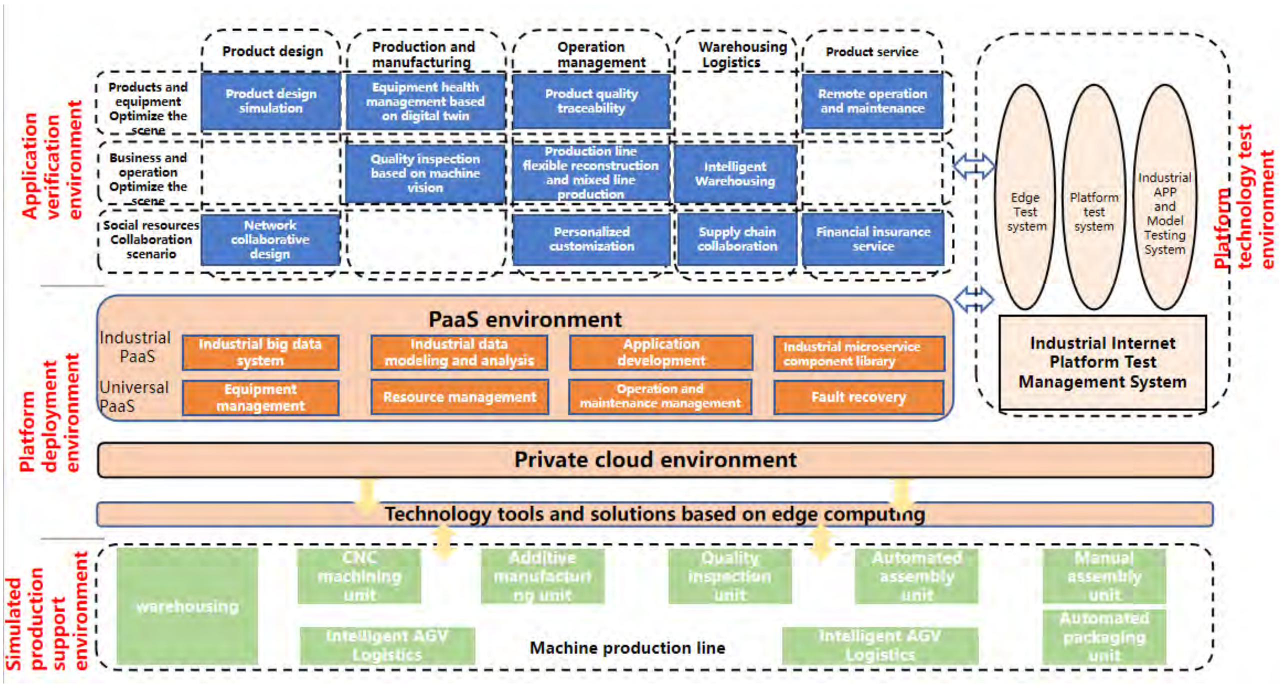

Figure 35: Architecture of the test bed of Industrial Internet platform

China Academy of Information and Communications Technology has built up an Industrial Internet platform test bed with a four-layer functional framework of “simulated production support environment + platform deployment environment + application verification environment + technology verification environment”, enabling to provide rich platform technology and application test verification for the whole field with multiple scenarios.

First, the simulated production support environment is responsible for providing basic physical objects for application verification, including discrete manufacturing-oriented numerical control processing, Additive Manufacturing, quality inspection, automatic assembly, warehousing and other units, and has the full digital manufacturing capability from product ordering, planning and production to warehousing.

Second, the platform deployment environment provides basic technical support for application verification, including three parts, i.e. edge layer, IaaS layer and PaaS layer. The edge layer is mainly used for collecting and processing real-time data of production lines; the IaaS layer implements pooling management of computer resources such as network, computing and storage; the PaaS layer constructs an extensible industrial operating system by stacking Big Data processing, industrial data analysis and industrial micro-service, etc.

Third, the application verification environment is built on the basis of simulated production support environment and platform deployment environment. On the one hand, it provides application verification in all fields of design, production, management and service, for example, from product design simulation, equipment health management based on digital twin to product remote operation and maintenance. On the other hand, it provides the multi-scenario application verification of products, workshops and enterprises, such as product quality traceability, flexible reconfiguration of workshop production lines and network-based collaborative design of enterprises.

Fourth, full-level and general technological test verification environment of "edge test +PaaS test + industrial APP test" for the platform has been constructed. For example, the edge test index includes performances such as equipment access and protocol conversion, the PaaS test index includes capabilities such as industrial data application and application development, and the industrial APP test index includes capabilities such as data model application and mechanism model application.

5.1.2.3 Trustworthy service assessment system of Industrial Internet platform

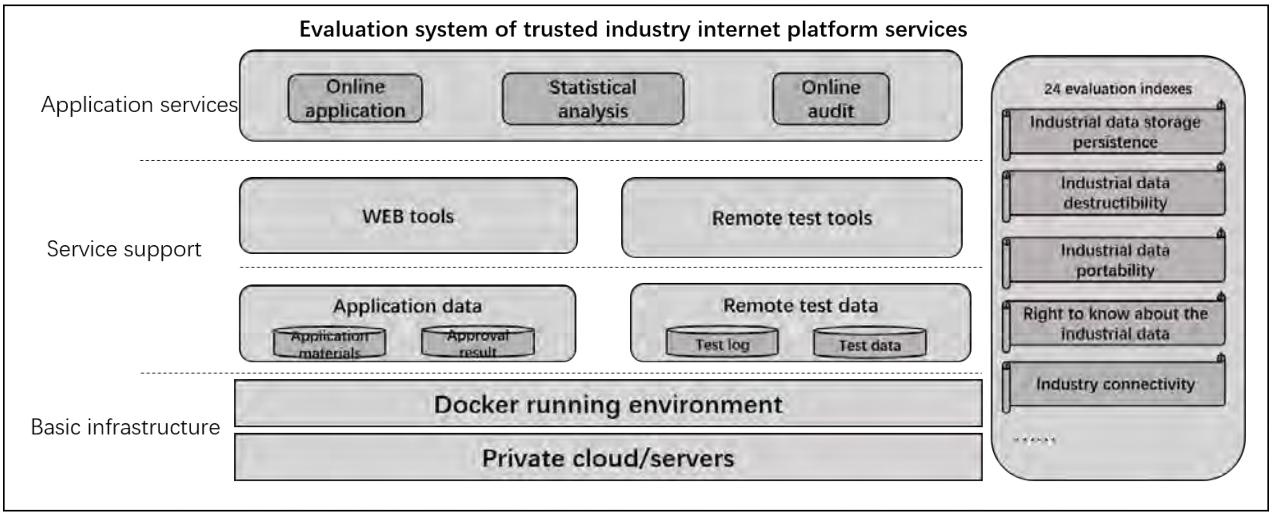

Figure 36: Architecture diagram for trustworthy service assessment system of Industrial Internet platform

The Alliance of Industrial Internet (AII) launched the assessment activities on trustworthy service assessment of Industrial Internet platform in 2017 according to the "Trustworthy service assessment requirements of Industrial Internet platform" standard issued by AII. This standard assesses the credibility of platform services from three aspects: the first is the disclosure of basic information of enterprises and services. i.e., whether the basic information of the enterprises under assessment and the basic information of platform is trustworthy, including whether the enterprises have qualified business qualifications; second is the completeness and standardisation of service notification, that is, whether enterprises under assessment have made standardised and complete commitments or notifications on key issues of concern to users through service agreements or data and rights protection policies. The third is the authenticity of the service notification, that is, whether the content promised or notified by the enterprises under assessment to users is true or not. Up to end of 2019, a total of 22 enterprises have passed the trustworthy service assessment. In September 2019, the trustworthy service evaluation system of Industrial Internet platform was officially launched, providing electronic reporting process and on-line platform testing capability, which greatly improves the convenience and accuracy of assessment service.

5.1.2.4 Public service platform for Industrial Internet security

The public service platform for Industrial Internet security includes four sub-platforms: the Industrial Internet security test and verification platform, the Industrial Internet security test and assessment management platform, the Industrial Internet attack and defence cloud platform and the Industrial Internet security monitoring platform.

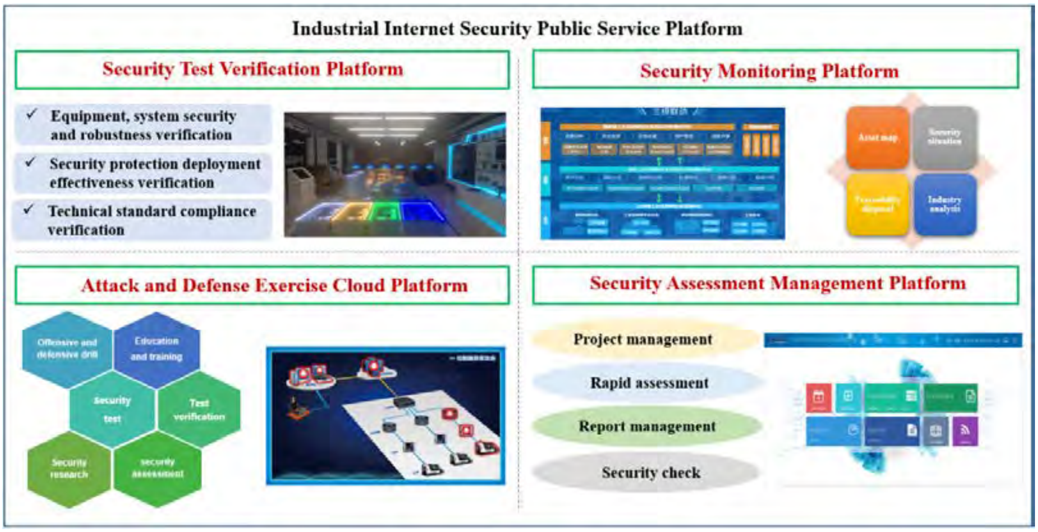

Figure 37: Functional diagram of public service platform for Industrial Internet security

The Industrial Internet security test and verification platform is provided with a security test and verification environment for typical industrial application scenarios such as thermal power, petrochemical, steel, aviation, aerospace, electronics, rail transit, etc. It can verify the security robustness of relevant equipment and systems, the effectiveness of security protection deployment and the conformity of technical standards. The Industrial Internet security testing and assessment management platform provides standardised process guidelines and professional inspection methods for the security inspection, evaluation and assessment of the Industrial Internet, and has the main functions of security assessment project management, rapid assessment, assessment report management, etc. The Industrial Internet attack and defence cloud platform has more than 1,500 virtual target resources, and can transfer the full amount of resources of users' real business systems into the cyber range through a mirror image mode, providing capabilities of security assessment, attack and defence drilling, security education and training, system security test, test verification, security research, etc. The Industrial Internet security monitoring platform can provide online security monitoring services for government agencies and enterprises, including the functions of mapping the asset atlas of the whole network, analysing the current situation and development trend of the industry, sensing the network security situation and threat events, and tracing and treating the source of risk objects and attack sources, so as to comprehensively improve the security monitoring and defence disposal capabilities.

5.1.2.5 Public service platform for Industrial Internet SDN

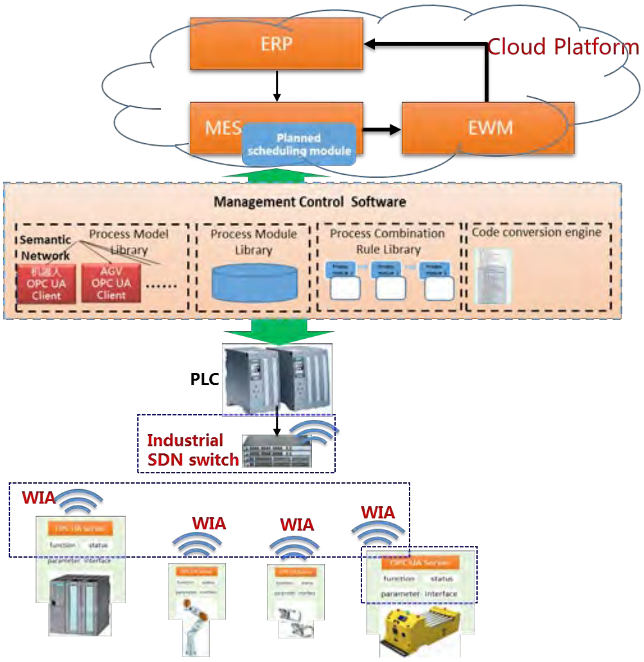

Figure 38: Test bed of Industrial Internet SDN

The industrial SDN network test bed was constructed by the Shenyang Institute of Automation, Chinese Academy of Sciences in cooperation with China Academy of Information and Communications Technology. The test bed is composed of cloud platform, management control software, industrial SDN switch and industrial equipment. The application of industrial SDN technology in the new industrial modular test bed converts the "vertical integration" and "flattening" of network information from ERP, EWM and MES to production systems and equipment. Through the modularisation of the mechanical structure of the modular production system, industrial network and management control software, it can adaptively reorganise and quickly respond to changes in product design and process flow.

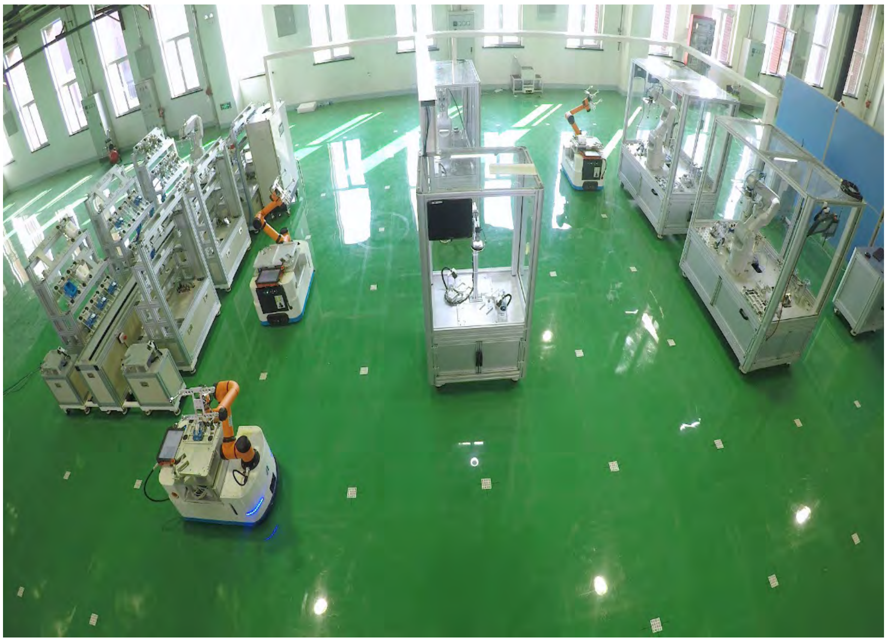

Figure 39: Real environment of Industrial Internet SDN

The industrial SDN test bed adopts the SDN network's flat structure and seamlessly transfers data from ERP, EWM, MES to production system and equipment without manual intervention, improving information transmission and production control efficiency.

The test bed adopts WIA-FA high-speed industrial wireless technology independently researched and developed by the Shenyang Institute of Automation of the Chinese Academy of Sciences, which enables modular decoupling of production units and control systems, making equipment deployment highly flexible.

The test bed utilises the characteristics of flexible and centralised management of the industrial SDN technology, independently researched and developed by the Shenyang Institute of Automation of the Chinese Academy of Sciences, to achieve efficient mixed-flow transmission and adaptive allocation of communication resources between the IT network and the OT network and to achieve adaptive reconstruction of the industrial control network. Through the control and integration of flexible control software, the craft, process and work steps are reconstructed in an adaptive manner.

The Industrial SDN test bed supports the dynamic reconstruction of machinery, network and service, meets the requirements of personalised customisation production and carries out the functions of mixed-line production, intelligent manufacturing, intelligent storage and intelligent logistics. The test scenario includes network end-to-end service integration, modular production organisation, mechanical, network and software reconfiguration, flexible manufacturing, mixed-line production, intelligent manufacturing as well as intelligent storage and intelligent robot and AGV.

5.1.2.6 Safety and security integration test bed

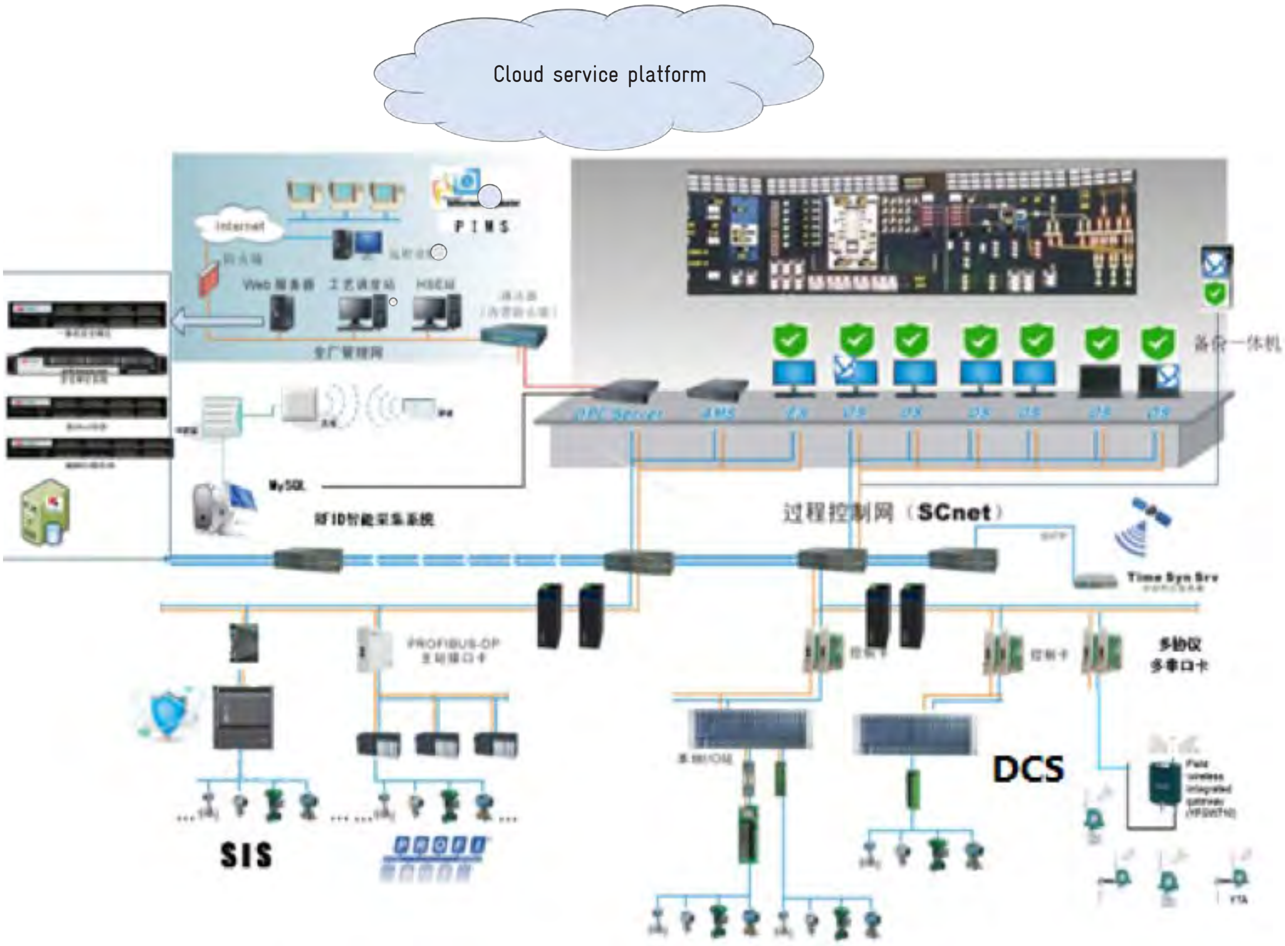

Figure 40: Safety and security integration test bed

The safety and security integration test bed of intelligent manufacturing was constructed by the Instrumentation Technology and Economy Institute in China. The test bed consists of cloud service platform, safety and security integration system, management control software, industrial equipment, etc. By using the real digital, intelligent instrument and industrial control system, the digital and intelligent operation scene is reproduced on a large scale. Taking the safety demand as the guidance and in line with the risk analysis, the safety and security integration system is configured elastically. The condition of field equipment and the state of the safety and security integration is transmitted to the cloud in real time through the network. The integrated test platform of the industrial safety and security integration is formed with the “Cloud, Channel and Device” characteristics. The effectiveness of protection strategy and safety technology of the safety and security integration system can be tested in case of dangerous events or network attacks.

Figure 41: Real environment of safety and security integration test bed

The classic Purdue model architecture is adopted in the safety and security integration test bed of intelligent manufacturing. The safety and security integration of the Industrial control system is taken as the focus. The functional safety, information security and collaborative safety are achieved in the production process through the technology and measures such as active defence, intelligent scheduling and collaborative response. The architecture system is built up to include life cycle management, risk assessment, system collaborative design and evaluation of the safety and security integration of intelligent manufacturing. The safety test in complex environment of multiple scenes can be supported using the test bed. These scenes can be the industrial control safety instrument system, the information security equipment configuration or DCS and SIS in the same network. The test bed has the characteristics of openness, safety, ease of use and operation in real-time.

5.2 Glossary

Classification: [1-Data link] [2-Network] [3-Transport] [4-Message transmission] [5-Syntax] [6-Semantics] [7-API] [8- Other basic terms]	Index No.	Index Term (main)	Term variants, abbreviations, long versions	Short Definition	Pointers to Introductory Literature
1	1	4G	4G	4G is the fourth generation of broadband cellular network technology, replacing 3G.	
1	2	5G	5G	5G is the fifth generation of cellular network standards and it is especially important because of its high speed.	
6	3	ISA-95	ANSI/ISA-95	ANSI/ISA-95 is an international standard for developing an automated interface between enterprise and control systems. It has been developed for global manufacturers.	
7	4	API	Application Programming Interface	An Application Programming Interface is a system of tools and resources in an operating system, enabling developers to create software applications.	
6	5	AutoML	Automated Machine Learning	Automated Machine Learning aims to aid the process of machine learning application by automatising processes.	
5	6	B2MML	Business to Manufacturing Markup Language	Business to Manufacturing Markup Language (B2MML) is an XML implementation of ISA-95 standards. It is an application of XML to manufacturing data and processes. It helps integrate systems such as Enterprise Resource Planning (ERP) and Supply Chain Management Systems.	
4	7	CoAP	Constrained Application Protocol, RFC 7252	Constrained Application Protocol (CoAP) is a web transfer protocol for use with constrained nodes and constrained networks in the Internet of Things. The protocol is designed for machine-to-machine (M2M) applications such as smart energy and building automation. On top of CoAP, the Open Mobile Alliance (OMA) has defined "Lightweight M2M" (LWM2M) as a simple, low-cost remote management and service enablement mechanism..	http://coap.technology/
1 ; 5	8	CAN	Controller Area Network	A Controller Area Network (CAN) is a serial bus network of microcontrollers that connects sensors, devices and actuators for real-time control applications.	
4 ; 5	9	DDS	Data Distribution Service	Data Distribution Service (DDS) is a connectivity framework addressing applications like aerospace and defence with real-time requirements. It has been defined by OMG and competes with OPC UA. It is mostly used in industry and is almost not adopted in other areas. Also, it will be the basis of ROS2.	https://www.omg.org/

6	10	eCl@ss	N/A	eCl@ss is a classification for products and services. It serves as a semantics for machine-to-machine communication.	
6	11	EDDL	Electronic Device Description Language	Electronic Device Description Language (EDDL) is a formal language describing the service and configuration of electronic field devices for process automation.	
7	12	ERP	Enterprise Resource Planning	Enterprise Resource Planning refers to the integrated management of main business processes. It is often implemented by real-time software solutions.	
1	13	EtherCAT	Ethernet for Control Automation Technology	Ethernet for Control Automation Technology (EtherCAT) is an Ethernet-based fieldbus system. It is a fast network and processes data using dedicated hardware and software.	
1 ; 5	14	Powerlink	Ethernet Powerlink	Ethernet Powerlink is a deterministic real-time open protocol for standard Ethernet.	
1	15	Ethernet/IP	N/A	Ethernet/IP is an industrial network protocol that adapts the Common Industrial Protocol (CIP) to standard Ethernet.	
5	16	XML	Extensible Markup Language	Extensible Markup Language (XML) is a metalanguage that defines a set of rules for encoding documents in a format which is readable for both human beings and machines.	
6	17	FDI	Fault Detection and Isolation	Fault Detection and Isolation ought to monitor systems, identify faults and determine the type and the location of the fault.	
6	18	FDT	Formal Description Technique	Formal Description Technique (FDT) is a formal method for developing telecommunications services and protocols. They can be abstract or implementation-oriented.	
6	19	GPC	General Purpose Computer	A General Purpose Computer (GPC) is a device that manipulates data without detailed control by human hand and can be used for various problems.	
7	20	gRPC	gRPC Remote Procedure Call	gRPC is a modern open source high performance RPC framework that can run in any environment. It can efficiently connect services in and across data centers with pluggable support for load balancing, tracing, health checking and authentication.	
1	21	HART	Highway Addressable Remote Transducer	Highway Addressable Remote Transducer (HART) is a hybrid analog and digital industrial automation open protocol. It is an early implementation of Fieldbus.	
4	22	HTTP	Hypertext Transfer Protocol	The Hypertext Transfer Protocol (HTTP) is an application protocol for distributed, collaborative, hypermedia information systems. It is the foundation of data communication for the World Wide Web.	

Classification: [1-Data Link] [2-Network] [3-Transport] [4-Message Transmission] [5-Syntax] [6-Semantic] [7-API] [8- Other Basic Terms]	Index No.	Index Term (main)	Term Variants, Abbreviations, Long versions	Short Definition	Pointers to Introductory Literature
6	23	IEC62264	N/A	IEC62264 is an international standard for integration of enterprise and control systems and builds on top of ISA95. It is structured in UML models and is able to model objects, operations, manufacturing functions, etc. It provides the basis for standard interfaces between ERP and MES and supports data exchange between sales, finance and logistics and production, maintenance and quality.	
7	24	Industrial Internet	II	Industrial Internet refers to the integration of the Internet and new generation information technology with the industrial system.	
8	25	Industrial Internet Consortium	IIC	The Industrial Internet Consortium (IIC) is the world's leading organization that serves to transform business and society by accelerating the adoption of IIoT. It accomplishes this by enabling trustworthy industrial internet systems, where systems and devices are securely connected and controlled to deliver transformational outcomes across multiple industries. These industries include healthcare, transportation, energy, public domain infrastructures as well as manufacturing.	
8	26	IIoT	Industrial Internet of Things	The industrial Internet of Things connects various devices such as machines, sensors, computers, etc. in order to faciliate automation among industrial organizations. It is basically a specific use scenario of the Internet of Things (IoT) in the context of manufacturing.	https://www.ge.com/digital/blog/everything-you-need-know-about-industrial-internet-things
8	27	IaaS	Infrastructure as a Service	Infrastructure as a service (IaaS) refers to a cloud service model in which cloud service providers organise various network resources such as servers, storage, and network software distributed on the network and the Internet Infrastructure to form a resource pool, and provide storage, computing, network lines and other services for cloud tenants over the network in and on-demand and easy-to-expand manner. Typical examples of Infrastructure as a Service (Iaas) include Alibaba Cloud and Tencent Cloud.	Cybersecurity Regulatory Framework in China (GIZ Publication)
8	28	IDS	International Data Spaces, DIN Spec 27070	The "International Data Space" (IDS) enables data providers to share data while maintaining data sovereignty.	https://www.academy.fraunhofer.de/en/continuing-education/information-communication/international-data-spaces-.html
8	29	IoT	Internet of Things	The Internet of Things (IoT) is the network of physical objects—devices, vehicles, buildings and other items—embedded with electronics, software, sensors, and network connectivity that enables these objects to collect and exchange data.	

2	30	IPv4	Internet Protocol version 4	Internet Protocol version 4 (IPv4) is the fourth version of the Internet Protocol. It is among the core protocols of standards-based internetworking methods in the Internet.	
2	31	IPv6	Internet Protocol version 6	Internet Protocol version 6 (IPv6) is the successor of IPv4 which increases the address-space dramatically. It has been standardized by IETF under RFC2460. It's adoption has been very slow and is mostly used in Asian countires due to a lack of large IPv4 address blocks. Therefore, IPv4 and IPv6 are still likely to coexist for the next ten years.	https://www.ietf.org/rfc/rfc2460.txt
8	32	Interoperability	N/A	Interoperability can be defined as "the degree to which two products, programs, etc. can be used together, or the quality of being able to be used together. It is a core issue in the process of aligning network architectures and connecting devices originally working with different standards. Therefore, it is often used in contexts of harmonization and standardization efforts.	https://dictionary.cambridge.org/dictionary/english/interoperability
5	33	JSON	Java Script Object Notation	Java Script Object Notation (JSON) is a human-readable serialization format for describing structured data. It is derived from JavaScript, but also supported by all common programming languages. JSON is much lighter than e.g. XML.	
4	34	MQTT	Message Queuing Telemetry Transport	Message Queuing Telemetry Transport (MQTT) is a publish-subscribe messaging protocol. It is designed for being used in telemetry systems via satellite. It is lightweight and widely used in IoT applications.	http://mqtt.org/
7	35	MindConnect	N/A	The MindConnect Service exposes an API that enables shop floor devices to send data securely and reliably to MindSphere. It allows custom applications (agents) to collect and upload data which shall be stored and used by applications in the cloud.	
5	36	MTConnect	N/A	MTConnect is a manufacturing technical standard to retrieve process information from NC machine tools. The usage of the XML format is transferred via HTTP. It has not been much adopted.	https://www.mtconnect.org/
7	37	OAuth2	Open Authentication	OAuth is an open standard for access delegation, commonly used as a way for Internet users to grant websites or applications access to their information on other websites but without giving them the passwords. This mechanism is used by companies such as Amazon, Google, Facebook, Microsoft and Twitter to permit the users to share information about their accounts with third party applications or websites.	
7	38	ODBC	Open Database Connectivity	Open Database Connectivity (ODBC) is a standard application programming interface (API) for accessing database management systems (DBMS).	

Classification: [1-Data Link] [2-Network] [3-Transport] [4-Message Transmission] [5-Syntax] [6-Semantic] [7-API] [8- Other Basic Terms]	Index No.	Index Term (main)	Term Variants, Abbreviations, Long versions	Short Definition	Pointers to Introductory Literature
5	39	OPC UA	Open Platform Communications Unified Architecture, IEC 62541 OPC UA	Open Platform Communication Unified Architecture (OPC UA) is a machine to machine communication protocol for industrial automation. It integrates two protocols: binary (high performance) and HTTP (high interoperability). It consists of "client-server" and "publish/subscribe" modes. However, it does not guarantee interoperability between devices. "Companion specs" can be used to define data models for various application areas. OPC UA is specified in the international standard IEC 62541.	https://opcfoundation.org/
1	40	PON	Passive Optical Network	A Passive Optical Network (PON) is a telecommunications network that transmits data via fiber optic lines. It uses unpowered splitters to route data sent from a central location to various destinations.	
8	41	PaaS	Platform as a Service	Platform as a Service (PaaS) refers to the service model in which the cloud service provider provides the cloud tenant with the supporting platform required by the applications, including the operating environment and development environment of the user applications, for the cloud tenant to develop and provide related applications. Google App Engine is a typical PaaS.	Cybersecurity Regulatory Framework in China (GIZ Publication)
6	42	PLCopen	N/A	PLCopen is an independent international organization, which focuses on specifications around IEC 61131-3. It defines coding guidelines for PLC function blocks (FB) to achieve interoperability between blocks from different vendors. An existing cooperation with the OPC Foundation ought to enable mapping between IEC 61131-3 and OPC UA.	https://www.plcopen.org/
1	43	PROFIBUS	Process Field Bus	Process Field Bus (PROFIBUS) is a standard for fieldbus communication in automation technology.	
1 ; 5	44	PROFINET	Process Field Net	Process Field Net (PROFINET) is an industrial ethernet protocol with deterministic capabilities. It has been standardized by PI and is only used in industry. Prominent competitors are EtherCAT, Ethernet/IP, Modbus TCP, among others.	https://www.profibus.com/technology/profinet/
3	45	QUIC	Quick UDP Internet Connections	Quick UDP Internet Connections (QUIC) is a Internet Draft standard submitted to IETF transport layer protocol for web applications with reduced latency and forced encryption. It has been proposed by Google and is supported by Google Chrome, but not by other browsers. QUIC is likely to become the basis for HTTP/3.	https://www.chromium.org/quic
7	46	ReST	Representational State Transfer	Representational state transfer (REST) is the software architectural style of the World Wide Web. More precisely, REST is an architectural style consisting of a coordinated set of architectural constraints applied to components, connectors, and data elements, within a distributed hypermedia system.	

8	47	SaaS	Software as a Service	Software as a service is a software licensing and delivery model in which software is licensed on a subscription basis and is centrally hosted. It is sometimes referred to as "on-demand software".	
1	48	TSN	Time-Sensitive Networking	Time-Sensitive Networking (TSN) is a set of standards to enable deterministic ethernet communication. It has been standardized by the Institute of Electrical and Electronical Engineers (IEEE) and can also be adopted to audio and video applications. It is commonly discussed in combination with OPC UA pub/sub and provides the basis for the future evolution of Profinet.	http://www.ieee802.org/1/pages/tsn.html
3	49	TCP	Transport Control Protocol	Transport Control Protocol (TCP) is a core protocol of the Internet Procotol suite. It is designed to send data packets over the internet.	
6	50	UNSPSC	United Nations Standard Products and Services Code	The United Nations Standard Products and Services Code (UNSPSC) is an open standard taxonomy of products and services that serves a classification system of products and services.	
3	51	UPD	User Datagram Protocol	The User Datagram Protocol (UDP) is a transport layer protocol used primarily for establishing low-latency and loss tolerating connections between applications on the Internet.	
6	52	W3C WoT	N/A	W3C WoT provides an architecture and software pattern standards to integrate decides into the World Wide Web. It offers a Thing Description to semantically describe properties, actions, events, etc. of "Things" and it is coordinated by the W3C (World Wide Web Consortium).	https://www.w3.org/WoT
1	53	Wi-Fi 6	IEEE802.11ax	Wi-Fi 6 is a high-efficiency Wireless LAN protocol and the successor of IEEE 802.11ac with features for improved throughput, more efficient bandwidth utilisation and dense wireless deployments. It is a potential competitor of 5G in the area of factory automation. Wi-Fi 6 has been standardised by the Institute of Electrical and Electronical Engineers (IEEE).	https://standards.ieee.org/project/802_11ax.html
1	54	WiFi	Wireless Fidelity	Wireless Fidelity (WiFi) refers to a local network that uses high frequency radio signals to transmit and receive data over shorter distances and uses the Ethernet protocol WiFi.	
5	55	YANG	Yet Another Next Generation	YANG is a data modelling language to define data structures used in network management protocols. It models the operation and configuration of network devices and is strongly related to Software Defined Networks (SDN). Is has been specified in RFC6020.	https://tools.ietf.org/html/rfc6020

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A special thanks to the following individuals and organisations:

Authors

Lead authors

Dr Peter Mertens, Siemens AG
Mr YU Xiaohui, CAICT

Co-authors

Dr Mattias Lampe, Siemens Ltd., China
Dr PENG Junsong, SAP (China)
Mr XU Yongshuo, SAP (China)
Prof. Dr-Ing. Reiner Anderl, Technical University of Darmstadt
Mr Yübo Wang, Technical University of Darmstadt
Dr-Ing. Reinhold Achatz, thyssenkrupp AG, International Data Spaces Association
Mr Harold Tian, thyssenkrupp (China)
Mr Klaus Bauer, TRUMPF Werkzeugmaschinen GmbH + Co. KG
Mr JIANG Xinhao, CAICT
Mr LIU Yang, CAICT
Mr ZHANG Hengsheng, CAICT
Mr YIN Yangpeng, CAICT
Mr QIN Guoying, CAICT
Ms HUANG Ying, CAICT
Mr SHI Xiaoguang, CAICT
Dr HOU Weibin, CAICT
Mr YOU Xiaoyu, CAICT
Ms LI Zheng, CAICT
Mr DU Jiadong, CAICT
Dr QIN Ye, CAICT

Contributors

Dr Joachim Stumpfe, thyssenkrupp AG
Dr Hans-Peter Bock, TRUMPF Werkzeugmaschinen GmbH + Co. KG
Ms GUAN Xiangzhen, Haier Group
Mr SHI Yang, Huawei Technologies Co., Ltd.
Mr TAO Yaodong, Qi An Xin Group
Mr LIU Mo, CAICT
Mr TIAN Hongchuan, CAICT
Ms TIAN Huirong, CAICT

Editors

Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ):
Ms Tianning Li, Mr Peter Becker, Ms WEI Qi, Mr Simon Kußler, Ms LUO Yawen

China Academy of Information and Communications Technology (CAICT):
Dr GE Yuming

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Deutsche Gesellschaft für
Internationale Zusammenarbeit (GIZ) GmbH

Registered offices
Bonn and Eschborn

GIZ Office China
Sunflower Tower 1100
37 Maizidian Street, Chaoyang District
100125 Beijing, PR China
T +86 10 8527 5180

E giz-china@giz.de
I www.giz.de/china

Sino-German Industrie 4.0 Project
E info@i40-china.org
I www.i40-china.org

China Academy of Information and Communications
Technology (CAICT)

No.52, Hua Yuan Bei Road,
Haidian District,
100191, Beijing, PR China
T +86 10 62301618
F +86 10 62304346
I www.caict.ac.cn