Neutral Interoperability Testbeds

Industrie 4.0 neutral cross-vendor interoperability testbeds together with medium enterprises

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Abstract: The open, neutral, pre-competitive, ministerial financed five testbeds of the non-profit German industry association Labs Network Industrie 4.0 are based on more than 120 active Industrie 4.0 use cases. Almost all address the topic of cross-vendor interoperability. The testbeds support future standard development by a neutral validation process. This process is fully aligned with the standardization bodies like IEEE or IEC and covered by liaison contracts. The testbeds cover the areas of the Asset Administration Shell, OPC UA companion specifications, TSN and Edge Management. The BMWi Industry 4.0 Competence Centers like Augsburg are the host of the testbed and provides a factory hall as well as all the technical equipment for the document work and the implementation.

Keywords: Industrie 4.0, neutral testbeds, standardization, cross-vendor interoperability, TSN, OPC UA, Companion Specifications, Edge Management

1 Introduction

The pre-competitive and non-profit German association Labs Network Industrie 4.0 e.V. (LNI 4.0)[4] established five neutral testbeds on cross-vendor interoperability since 2017. The association was founded in late 2015 together with the German Plattform Industrie 4.0 and the Standardization Council Industrie 4.0 (SCI 4.0)[5], which is carried out jointly by DIN[6] and DKE[7] to support Industrie 4.0 standardization activities. LNI 4.0 was established by an alliance of major companies, industry associations, policymakers and researchers. The goal of LNI 4.0 is to support the pioneering work of small and medium enterprises (SME) in the area of digitalization of industrial production. LNI 4.0 acts as a competence and experimentation platform for these stakeholders.

The target of the open, neutral, pre-competitive, ministerial financed testbeds is to prepare and to validate standardization documents in their draft status based on liaison

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contacts. The testbeds focus on the manufacturing industry with respect to the emerging Industrie 4.0 technologies.

The outline of the paper is as follows: Section 2 gives an overview on four interoperability testbeds and emphasizes on an overview. Section 3 presents the fifth, the Edge Management testbed, in depth. Finally, Section 4 concludes this contribution.

2 Neutral and open interoperability testbeds

2.1 Time-Sensitive Networking (TSN)

The testbed for the validation of the extensions to the IEEE 802.1 standard family for time-sensitive networking (TSN)[8] based on SME use cases includes the IEC/IEEE 60802[9] TSN Profiles for Industrial Automation activities. The IEEE 802.1extensions enable to run heterogeneous real-time applications in a single TSN network. Among the 40 partners, there are 14 SME partners. Liaison contracts with the IEEE 802.1 Working Group and the OPC Foundation[10] exist. With the liaisons it is possible to comment the draft versions of the standardization bodies and by that share the validation results bi-directionally in a neutral way.

The TSN testbed is conceived as a continuous plug-festivals which always starts with SME requirements and the LNI 4.0 Industrie 4.0 use cases. These use cases provide the basis for the architecture, electrics and mechanics used and are reflected in the testbed demonstrator. Plug-festival means that all 40 testbed partners continuously try out their (pre-)products with one another. The Federal Ministry Industrie 4.0 Competence Center in Augsburg[11] hosts the testbed and provides a factory building and all industrial technical equipment to enable the validation and the demonstrator.

The IEEE 802.1 standards form the basis of the testbed. TSN is validated as deterministic, real-time Ethernet communication. The testbed also deliberately works with standard templates, so as to be able to validate the different use cases against the IEEE standards and standard projects. These are used to define the technology, the architecture and the network. The key technologies concerned are switches and end-devices, time synchronization, decentralized network configuration, the forwarding of real-time data with bounded latency and the setting up of time-critical data streams. Robots and control components from different manufacturers are networked. The testbed works closely together with other international testbeds like Fraunhofer FOKUS[12] and the IIC[13] testbeds.

[8] https://1.ieee802.org/
[9] https://1.ieee802.org/tsn/iec-ieee-60802/
[10] https://opcfoundation.org/about/opc-technologies/opc-ua/
[11] https://kompetenzzentrum-augsburg-digital.de/
[12] https://www.fokus.fraunhofer.de/en/fokus_testbeds/tsn-iop-lab
[13] https://www.iiconsortium.org/time-sensitive-networks.htm

2.2 Asset Administration Shell (AAS)

The AAS testbed validates the Asset Administration Shell standards initiated by the German Plattform Industrie 4.0[14]. The AAS is the implementation of the „Digital Twin“ for Industrie 4.0[15]. It establishes cross-company interoperability and is available for non-intelligent and intelligent products. The AAS covers the complete life cycle of products, devices, machines and facilities and enables integrated value chains. The AAS is the digital basis for autonomous systems and AI.

The testbed is hosted by the Deutsche Messe Technology Academy[16] and the Kompetenzzentrum 4.0 Hannover[17]. A total of 35 industry partners with a focus on SME are collaborating to validate the normative activities. The testing covers the validation of the AASX open-source software packages[18], the support of the IEC TC65 WG 23 & 24 normative projects. Beside the cross-vendor interoperability the connectivity with 5G is of importance for the testbed. This is enabled by the 5G campus network of the Deutsche Messe Technology Academy. All is tested with a demonstrator that is developed in a virtual, hybrid and physically modularized way.

The testbed has close international cooperations with CESMII, USA[19] and with South Korea[20]. Very important is the cooperation with the AAS user association, the Industrial Digital Twin Association e.V. (IDTA)[21].

2.3 Companion Specifications with OPC UA

The Companion Specifications testbed validates the VDMA[22] OPC UA companion specifications. The draft versions of the different VDMA professional bodies are at different stages, up to the release candidate level. Nine SMEs of a total of 20 partners are involved in the joint testing. The OPC UA VDMA companion specifications can partially be represented as sub-models of the asset administration shell.

The University of Applied Sciences Ravensburg-Weingarten, Faculty Mechanical Engineering[23], hosts the testbed and provides a factory hall and all the technical facilities needed to implement the use cases and the manufacturing demonstrator. Companion specifications in robotics, image processing, the packaging industry and in future of MES,

[14] https://www.plattform-i40.de/PI40/Redaktion/EN/Standardartikel/specification-administrationshell.html
[15] https://www.plattform-i40.de/PI40/Redaktion/EN/Downloads/Publikation/VWSiD%20V2.0.pdf?__blob=publicationFile&v=2
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[21] https://idtwin.org/en/
[22] https://opcua.vdma.org/
[23] https://www.rwu.de/hochschule/fakultaeten/maschinenbau

ERP and cloud systems are all validated in the testbed. The aim is to test them and thereby support the international standardization. For this, solutions from different manufacturers are tested with OPC UA client/server and in future pub sub services.

2.4 Industrial Cloud to Cloud

The Industrial Cloud to Cloud testbed validates cloud transport protocols. Parts of its work are transferred to the Technical Committee of the GAIA-X European Association for Data and Cloud AISBL[24] for further global-scaled elaboration.

3 Neutral and open Edge Management Testbed

The target of the Edge Management testbed is to prepare the standardization in the context of the manufacturing industry with respect to the emerging edge computing technology. The testbed focuses on the Management of Edge Technologies and is described in [1]. Currently, a suitable released standard for this focus does not exist. The testbed will develop proposals for this aspect in the form of functional primitives including parameter sets ("functional view"), which afterwards must be implemented ("implementation view"). For this purpose, concepts are developed, practically implemented and validated. The results and experiences will be made available to the standardization activities to feed them into the further or new development of standards.

3.1 Related Work

The relevance of Edge Management becomes visible by the wide range of emerged organizations that are dealing with the definition and implementation of edge infrastructure solutions, usually initiated by product vendors or solution providers with a focus on the implementation level. Nevertheless, high-level concepts are in most cases developed firstly and subsequently detailed in a top-down approach. Examples of these organizations are the association Open Industry 4.0 Alliance (OI40)[25] with a focus on the European industrial automation market, the Chinese-based Edge Computing Consortium (ECC)[26], the European Edge Computing Consortium (EECC)[27], the US-based Open Edge Computing Initiative (OECI)[28], the Industrial Internet Consortium (IIC)[29] or the Japanese based Edgecross Consortium[30], as well as the Korean Electronics Technology Institute

[24] https://www.gaia-x.eu/
[25] https://openindustry4.com/
[26] https://ecconsortium.eu
[27] http://en.ecconsortium.org/
[28] https://www.openedgecomputing.org/
[29] https://www.iiconsortium.org/fog-and-edge-white-papers.htm
[30] https://www.edgecross.org/en/

(KETI)[31] IoT Edge Platform. Even an Automotive Edge Computing Consortium[32] has been founded, dealing with the problem of big data from connected cars. In [2] the authors have even identified 75 edge computing related activities.

The main focus of the completely neutral LNI 4.0 testbed compared to these testbeds is the ambition towards normative actions and full cross-vendor interoperability regarding edge management, which is seen as crucial for making the overall approach more feasible for broad offerings and applications.

3.2 Stakeholder Views

The Industrial Internet Reference Architecture [3] defines a reference model of stakeholder concerns related to technical system, called views. This methodology is also applied by the LNI 4.0 testbeds. A view is framing the description and analysis of specific system concerns as shown in Figure 1.

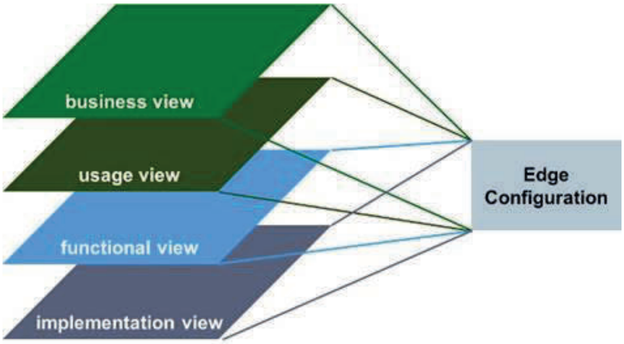

Fig. 1: Methodological classification according to [3]

Based on this, various concepts (in Figure 1 called a functional view) and solution approaches (in Figure 1 called an implementation view) are discussed and developed within the LNI 4.0 testbed Edge Configuration working group.

Specific requirements were provided by the testbed partner companies with a focus SME, describing the business concerns of various companies and market stakeholders like users and operators [4]. Most of these are businesses, which are highly relevant for the manufacturing automation domain.

[31] https://www.keti.re.kr/eng/tech/tech_list04.php
[32] https://aecc.org/

3.3 Architectural Concept

From an architectural viewpoint, the work of the LNI 4.0 testbed Edge Management is based on a layered architecture as shown in Figure 2.

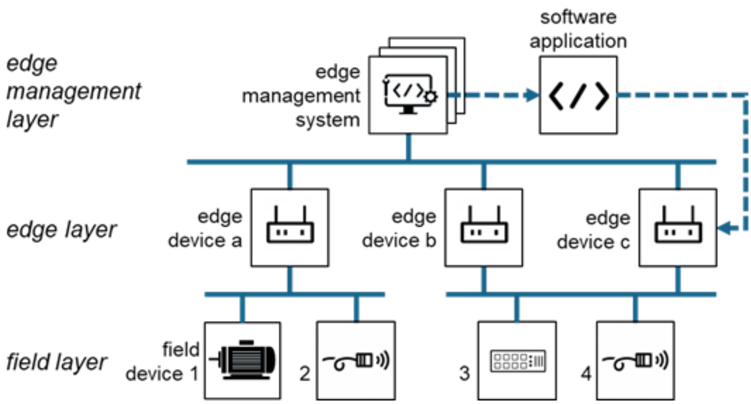

Fig. 2: Architectural context [4]

The following basic system entities have been identified:

1. Field device

Field devices are physical computing resources with often deterministic communication capabilities. Field devices communicate with edge devices, can be configured via parameters and the firmware of a field device can be updated. Field devices do not support the deployment of applications.

2. Edge device

Edge devices are physical computing resources with capabilities for communication and edge runtimes to be deployed on the edge device. Edge devices also can be configured by parameters and the firmware of edge devices can be updated. Edge devices can be connected to field devices and for each connected field device there is a data endpoint representing the communication capabilities between field and edge device. This data endpoint can be configured by an edge management system.

3. Edge management system

An edge management system is a software program deployed on an IT infrastructure. An edge management system can provide configuration capabilities for field devices and edge devices, an application store for providing software applications, edge runtimes and firmware, and configuration and deployment capabilities, which are provided via the application store of the edge management system.

4. Software application

Software applications are executable software-programs, which can be deployed, executed and configured on an edge runtime or an IT infrastructure. The software-programs are provided via the application store of an edge management system. These software applications are usually utilizing the information from connected field devices, i.e. for data analysis. Basic applications for generic usage may be for example Asset Management [5] and System Monitoring [6].

3.4 View Concept

The framing in views as shown in Figure 1 in Section 3.2 is briefly outlined.

1. Business View

The business view covers the elements to establish an edge system in a business and regulatory context and identifies the requirements how the edge system should support the business objectives through fundamental system capabilities. The following business stakeholders and their concerns have been identified: Component Supplier, Data-based Service Provider, Machine Supplier, System Integrator, Machine User, Edge Infrastructure Provider and Edge Management Provider. The details are being presented in [4].

2. Usage View

The usage view addresses the expected system usage. It is typically represented as sequences of activities involving human or logical, e.g. system or system components users that deliver its intended functionality in ultimately achieving its fundamental system capabilities. The stakeholders of these concerns are typically consisting for example of system engineers, product managers or developer as well as the logical user IT infrastructure who are involved in the usage of the considered edge system. The details are being presented in [7].

3. Functional View

The functional view describes the functional components in an edge system. These are the structure and interrelation, the interfaces and interactions between them, and the relation and interactions of the system with external elements in the environment, to support the usages and activities of the overall system. These elements are of particular interest to system and component architects, developers and integrators. The activities are analysed and functional requirements derived from them. The goal is that the functional requirements finally define the interfaces of the involved system entities.

4. Implementation View

The implementation viewpoint deals with the technologies needed to implement the functional components, their communication schemes and their lifecycle procedures. These elements are of particular interest to system and component architects, developers, integrators and system operators. The implementation specifics of the functional view and the implementation view are not only in the focus of this LNI 4.0 testbed, but mainly targeted by the already in Section 3.1 mentioned organizations.

4 Conclusion and Outlook

The key success factors for the acceptance of cross-vendor industry interoperability are the standardization and the easy integration into the existing infrastructure and systems (brown field).

The pre-competitive and non-profit German association LNI 4.0 published a series of documents providing key definitions regarding the terminology, architecture, roles and interactions for testbeds with a specific application to the topic of the management of edge technologies [4], [7]. The documents were developed in the testbeds.

For the upcoming work of the international standardization, the SCI 4.0 will give support and will ensure the international synchronization. For the necessary detailing for the implementations other organizations like the ones mentioned in Section 3.1 will refer to these documents.

Interoperability creates the essential basis (technical foundation) for the next steps in digitization. The next steps for LNI 4.0 are the evaluation of the business requirements, the initiation and testing of further modules in the AAS like energy efficiency, de-carbonization or the circular economy.

In addition to this, additional functionalities such as Knowledge Management (Knowledge Graph), Human-machine interface (service & commissioning), Simulation, etc. are taken into consideration.

In the future, it will also be possible to look at the entire lifecycle management and the resulting new business models.

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