LNI Testbed Edge Management – Business View

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Contact:

Labs Network Industrie 4.0 e.V.

Ernst Reuter Platz 7

10587 Berlin

Telefon: (030) 36702177

E-Mail: info@lni40.de

1 Motivation

The testbed Edge Management is motivated by current limitations of the configuration of edge devices. These limitations are described below in the context of edge computing.

Edge computing technology is a distributed computing paradigm and characterized by the usage of so-called edge devices. An **edge device** is a computing device, which is essentially characterized by the following characteristics:

- An edge device can be used in the field, so it addresses major requirements for OT.
- On edge devices “classical” software applications can be deployed – for example in contrast to programmable logic controllers (PLC), on which application programs must follow a specific programming paradigm –, so it addresses major requirements for IT.

From a business perspective, edge computing technology is particularly interesting for the manufacturing industry because of the following considerations:

- **Agility at the edge:** Edge computing enables OT to apply modern software concepts and development methods, such as data analysis, modeling, artificial intelligence, flexible deployment, agile development, autonomous orchestration, etc. By bringing the benefits and capabilities of cloud native to the edge, manufacturing companies will be more flexible, robust and react faster to changes in the market.
- **Performance:** Large amounts of time-critical data that accumulate in the field can be analyzed locally on an edge device without having to first transfer the data and information to an IT infrastructure via limited communication mechanisms, for example latency, bandwidth, or intermittent connectivity. This opens for new data-driven applications in manufacturing industries. However, the edge can also filter data and send only the relevant data sets to an IT infrastructure for the sake of limited connectivity.
- **Data sovereignty:** Because of local processing capabilities of edge devices, a manufacturing company in the role of an asset supplier can offer software-based capabilities of its assets without having to provide the required data and algorithms on an external computing infrastructure. This enables a manufacturing company to protect intellectual property and have control over its assets.

Today, edge devices are characterized by proprietary configuration capabilities. From a user's point of view, this has disadvantages, in particular:

- Due to the different configuration capabilities of edge devices, the complexity, susceptibility to errors and the effort involved in integrating edge devices and their software applications into an overall system are high.
- Due to the different configuration capabilities, there is a certain lock-in effect of the edge device suppliers, while – at least some of the users of edge computing technology – want to offer their products, solutions and services independently of a specific edge technology.

Because of these limitations, the members of the testbed Edge Management see from an application perspective **a potential in the standardization of edge management services**. For this reason, the testbed Edge Management focuses on the aspect of edge management in the broad field of edge computing technology.

2 Overall Objectives and Scope of Testbed Edge Management

The testbed Edge Management was established to prepare further standardization activities with respect to the emerging edge computing technology for the manufacturing industry. The testbed does not address the overall edge computing technology itself but focuses on *edge management*. For this purpose, concepts will be 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.

From an architectural point of view, the considerations within the testbed Edge Management are based on software applications that can be deployed on a computing infrastructure. As shown in Figure 1, this computing infrastructure consists of a layered architecture: cloud layer, edge layer and field layer. Edge management services as well as software applications can be respectively deployed on the cloud layer or/and on the edge devices within the edge layer. Within the cloud and edge layer edge management services manages the corresponding software applications.

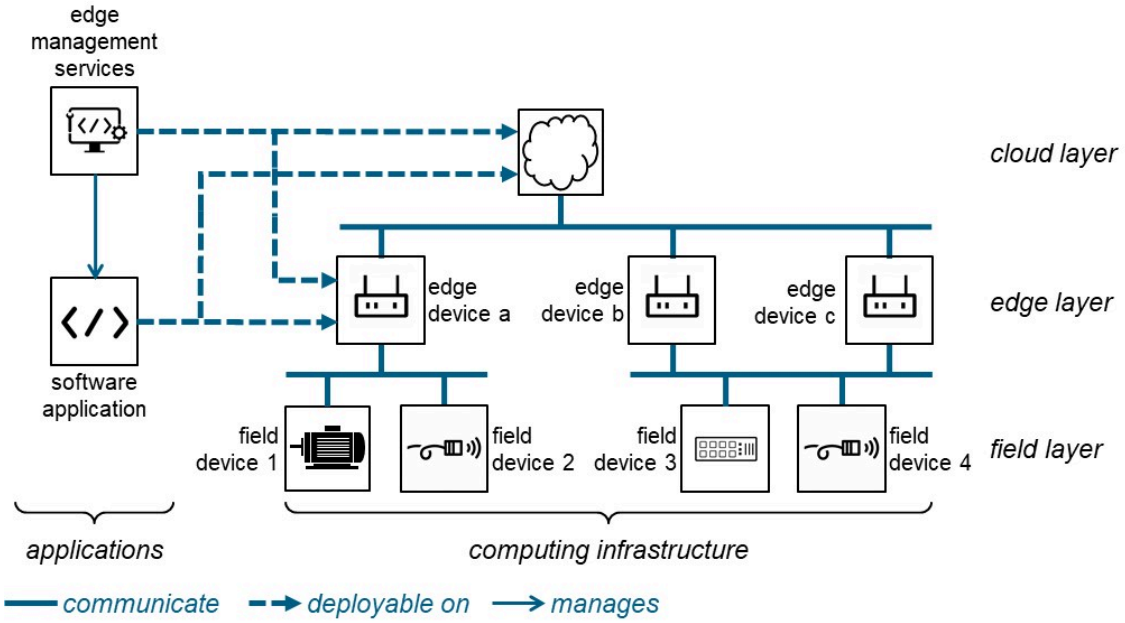

Figure 1. Overall architecture of the testbed Edge Management

Considering this architecture, the **overall objectives and scope of the testbed Edge Management** are listed below:

- The focus of the testbed Edge Management is on the *configuration* of the interaction between the edge and cloud layer and the *deployment* of software applications on these two layers. Currently there does not exist a suitable standard for this focus and 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).
- In the interaction between field and edge layer, although today no standard has prevailed in practice, we currently see OPC-UA as a promising candidate to design this interaction in the future, both technologically and via companion specifications. For this reason, this interaction is *not* the focus of the testbed Edge Management (functional view).
- The deployment of the edge management services is not in the scope of standardization activities of the testbed Edge Management.

3 Purpose of this Document

The purpose of the business view document is to describe the overall business context of the testbed Edge Management and to explain why a standardized edge management is beneficial from a business perspective. Thus, this document defines the contextual driving business requirements for all activities in the testbed and possibly derived standardization activities. The targeted group of readers of this document are primarily management whose business is impacted by edge computing technology in general and especially product manager for edge management services.

In accordance with the Industrial Internet Reference Architecture [1] this document describes a so-called *business view*, see Figure 2. We assume that this business view remains stable throughout the life of the testbed Edge Management.

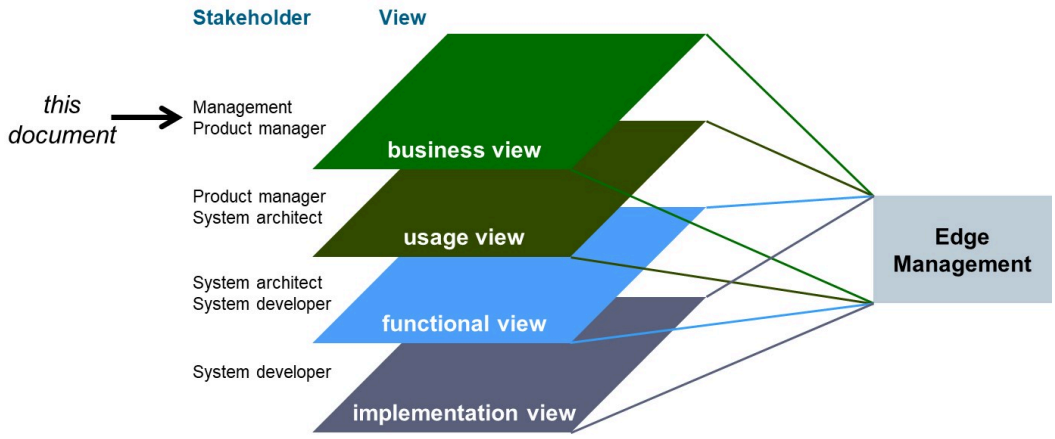

Figure 2. Classification of the document following the Industrial Internet Reference Architecture, see [1]

Regardless of the business context there also exists a description of the application context (in the terminology in Figure 2 called a usage view [2]). Note that business view and usage view frame *different* perspectives but have well-defined relationships. These relationships are described in chapter 5 of this document.

Also, various concepts (in the terminology in Figure 2 called a functional view) and solution approaches (in the terminology in Figure 2 called an implementation view) will be developed and discussed in additional documents.

4 Business View of Testbed Edge Management

4.1 Structure of the document

There are several ways to specify a business view. We follow the methodology proposed by the Working Group “Digital Business Models” of the German Plattform Industrie 4.0 [3]. Their overall recommendation is to start with the consideration of a *value network* representing all companies involved in the system under consideration (in this context edge management services) and then discussing the *business models* of the different companies.

We applied this by elaborating the following structure:

- Description of an overall value network in manufacturing industries, see section 4.2.
- Considering the changes (conceivable in the future) in the value network and the underlying business interests, see section 4.3.

4.2 Overall value network in manufacturing industries

Figure 3 illustrates the underlying overall value network in manufacturing industries. Each icon represents a business role and the arrows between the different business roles represent a value chain, i.e. a value proposition of one business role to another business role. We distinguish between value chains, where physical products are major part of the value proposition, and value chains based on data and services. The non-colored icons represent business roles, which are new because of the topic edge management. They can be assumed by different companies, partly also by companies indicated by the colored icons.

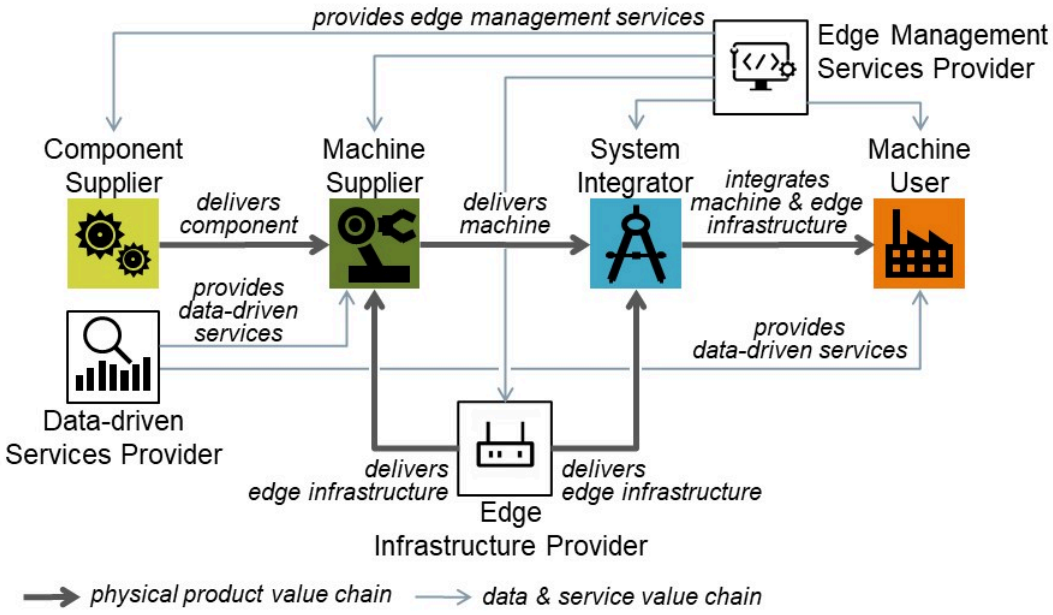

Figure 3. Overall value network in manufacturing industries

Figure 4 illustrates the general revenue streams in manufacturing industries.

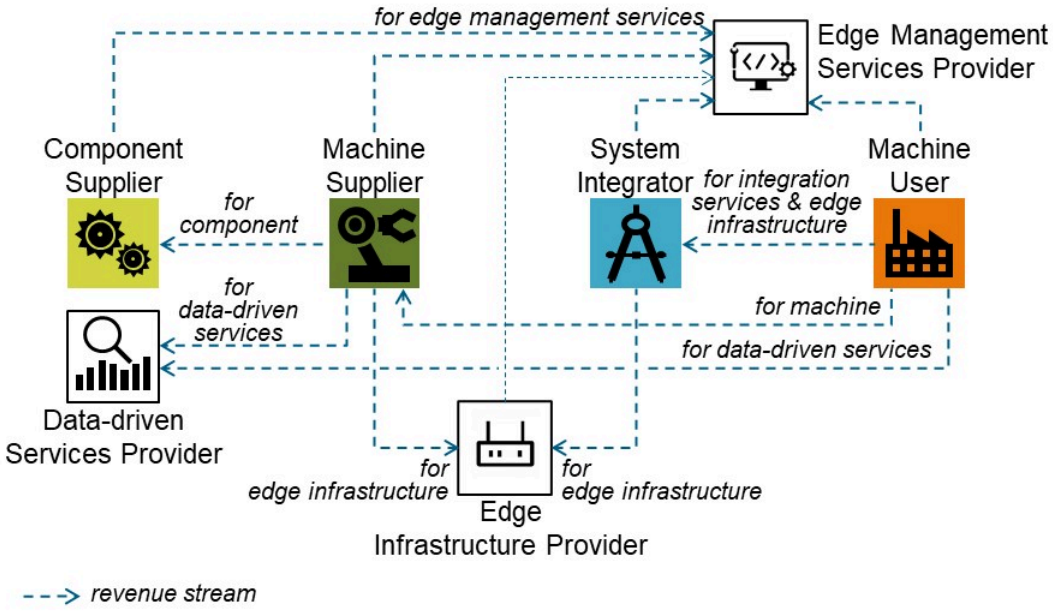

Figure 4. Overall revenue streams in manufacturing industries

We consider the following “traditional” business roles:

- **Component Supplier:** This business role is typically assumed by a manufacturing company offering components like gearings, sensors or drives to a Machine Supplier (or System Integrator) to be integrated in a machine (or factory) by a Machine supplier (or System Integrator). Typically, the Component Supplier receives a one-time payment for the delivery of the component.[1]

[1] The line between component suppliers and machine suppliers is blurred. We differentiate between these roles because components do not necessarily include computing capabilities on which software applications can be deployed, while machines typically have such computing capabilities.

- **Machine Supplier:** This business role is typically assumed by a manufacturing company offering machines like robots, machine tools or conveyor systems to a System Integrator to be integrated in a factory by that System Integrator. Typically, the Machine Supplier receives a one-time payment for the delivery of the machine from the Machine User.
- **System Integrator:** This business role is typically assumed by a service company offering system integration services according to the specific needs of a Machine User. This includes integration of physical systems as well as software application development and integration services. The System Integrator is paid for the integration service by the Machine User.
- **Machine User:** This business role is typically assumed by a manufacturing company operating a factory. Typically, the Machine User pays for the physical components and systems integrated in the factory and the system integration services.

With respect to the topic edge management we additionally introduce the following “new” business roles:

- **Edge Infrastructure Provider:** This business role will be typically assumed by a manufacturing company offering an edge infrastructure. More technical details of such an edge infrastructure are elaborated in [2]. We assume that these edge infrastructures are delivered either to a Machine Supplier to be integrated in a machine or to a System Integrator to be integrated in a factory. Typically, the Edge Infrastructure Provider receives a one-time payment for the delivery of an edge infrastructure.
- **Edge Management Services Provider:** This is a new business role, which offers so-called edge management services. More technical details of such an underlying edge management system are elaborated in [2]. The Edge Management Services Provider will be paid for the usage of the edge management services provided by the underlying edge management system, where different revenue mechanisms are conceivable, for example pay-per-use. Note that depending on the business model of the Edge Management Services Provider the specific edge management services to the Edge Infrastructure Provider could be provided for free. The usage of the edge management services by the different business roles will be explained in section 4.3.
- **Data-driven Service Provider:** This is a business role in form of a service provider which offers data-driven services. These services are based on one or more software applications, which must be deployed in a machine or factory (edge), in the cloud, or both (hybrid). These services are typically offered to the Machine Supplier or Machine User. In context of Data-driven Services, the data collected from the devices and machines must be analyzed to gain insights. Additional value can be achieved when device data is contextualized with business data. The resulting insights are essential to guarantee the resilience of processes related to the supply-chain and, if necessary, trigger and influence the corresponding business processes. The Data-driven Service Provider will be paid for the usage of the data-driven service, where different revenue mechanisms are conceivable, for example subscription-based or pay-per-use. In section 4.3 different exemplifications of such data-driven services will be explained.

4.3 Predicted changes in the value network

In the following subsections the changes (conceivable in the future) in the value network and the underlying business interests will be explained. This is elaborated separately from the perspectives Component Supplier, Machine Supplier, System Integrator and Machine User.

4.3.1 Perspective Component Supplier

Figure 5 illustrates the future value network from the perspective of a Component Supplier, for example for gearings or sensors.

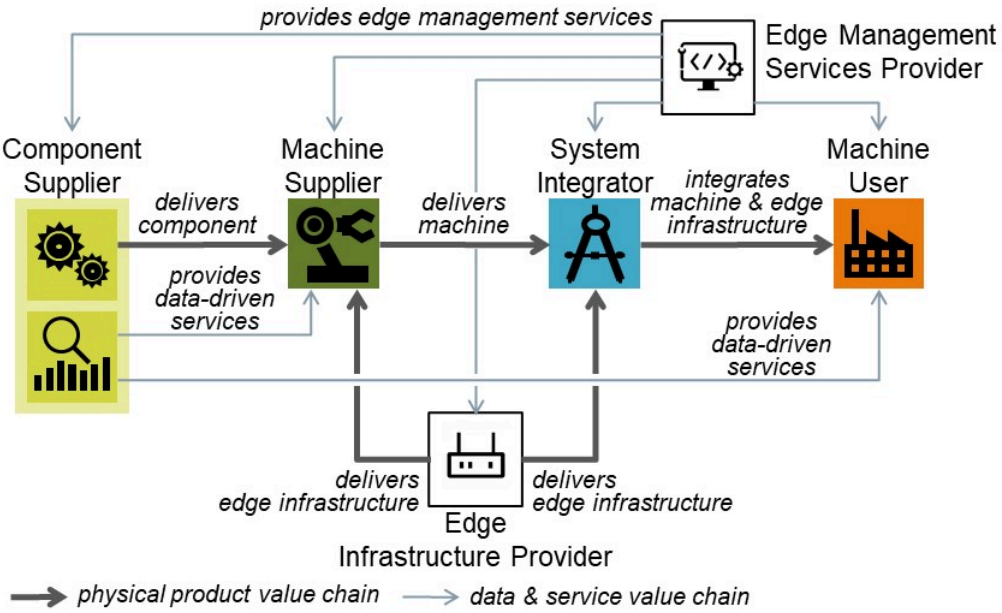

Figure 5. Future value network from the perspective of a Component Supplier

Figure 6 illustrates the future revenue streams from the perspective of a Component Supplier.

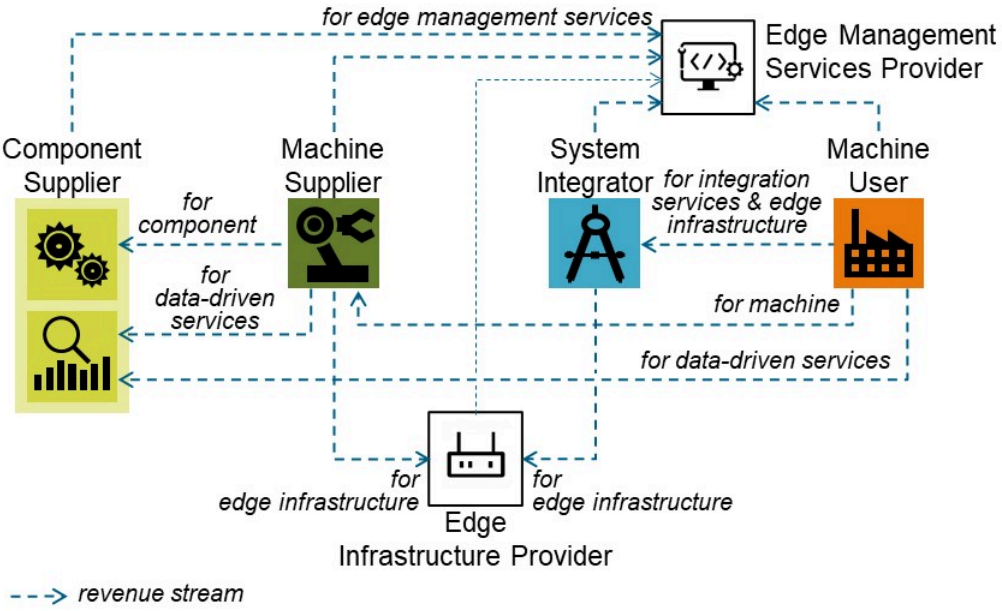

Figure 6. Future revenue streams from the perspective of a Component Supplier

The overall business interest of the Component Supplier is to offer in addition to the existing component *new data-driven services*. In the case of a purely mechanical component, for example gearings, this may require integrating additional sensing capabilities to the component[2]. We assume that it is in the interest of the Component Suppliers to offer these new services themselves. Therefore, the Component

[2] In the case of components with own computing capabilities the line between Component Supplier and Machine Supplier is becoming blurred and the scenarios described in section 4.3.2 may be also applicable.

Supplier will additionally assume the business role Data-driven Service Provider, which is expressed in Figure 5 by the same color scheme[3].

Potential customers of these new services are the Machine Supplier or Machine User. The customer of these new services, for example a condition monitoring service, benefits due to an improved use of the component based on the new services and will therefore pay for the use of these new services to the Data-driven Service Provider.

In order to offer these new data-driven services, the Data-driven Service Provider will provide a software application. It is not in his interest to provide own computing capabilities to deploy this software application. Instead, he requests for suitable computing capabilities provided by the Machine Supplier (if the new services are offered to the Machine Supplier) or by the Machine User (if the new services are offered to the Machine User). The Component Supplier will contractually define the use of the provided computing capabilities.

Therefore, from the perspective of a Component Supplier there is a request for *standardized* edge management services (offered by an Edge Management Services Provider) in order to offer data-driven services independent of specific computing capabilities provided by a Machine Supplier or Machine User. The Component Supplier will pay the Edge Management Services Provider for the use of the offered edge management services.

4.3.2 Perspective Machine Supplier

Figure 7 illustrates a future value network from the perspective of a Machine Supplier, for example for robots.

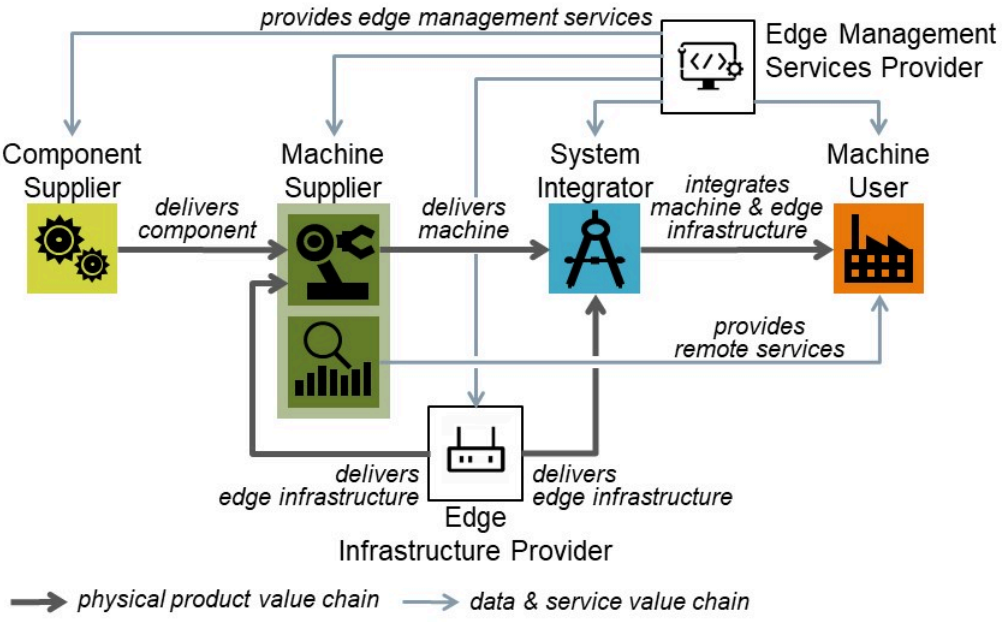

Figure 7. Future value network from the perspective of a Machine Supplier (I)

Figure 8 illustrates the corresponding future revenue streams from the perspective of a Machine Supplier.

[3] The possibility that such new services could be offered by an independent third party is addressed by the consideration of the System Integrator in section 4.3.3.

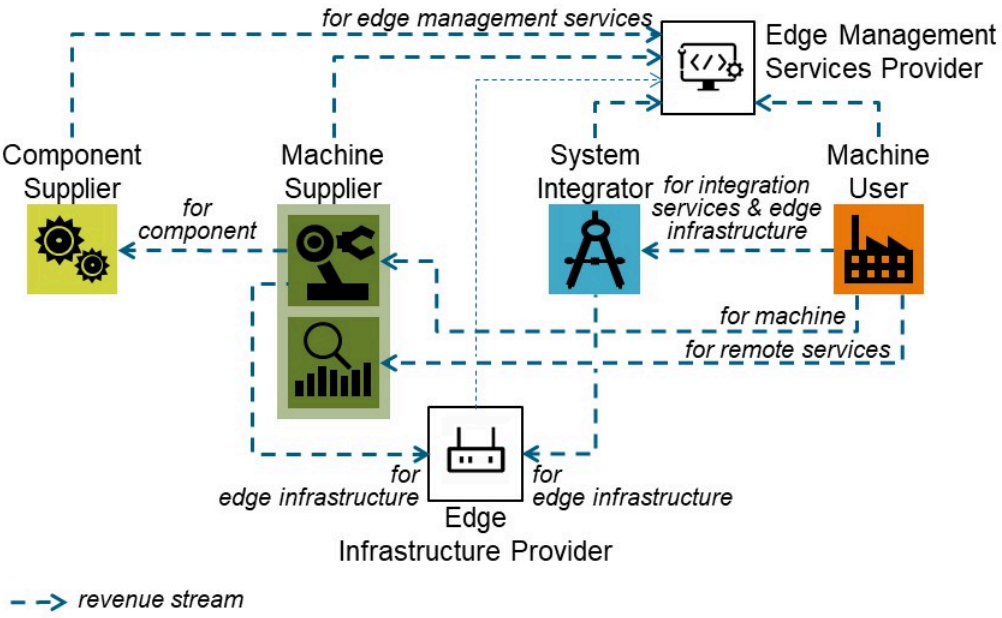

Figure 8. Future revenue streams from the perspective of a Machine Supplier (I)

The overall business interest of the Machine Supplier is to *improve* the offer of remote services for the delivered machines. Today there are many different technical connectivity solutions to offer remote services in place. Sometimes these solutions are dictated by the Machine User, who follows its own IT guidelines, sometimes this also depends on the System Integrator, who has integrated a machine into a factory. As a result, the specific remote service of a Machine Supplier must be provided based on a wide variety of technical solutions, which is simply inefficient. The Machine Supplier therefore expects the *standardization* of such connectivity solutions through the new edge computing technology and especially standardized edge management services, which would result in an optimization of its internal business processes.

Figure 9 illustrates another future value network from the perspective of a Machine Supplier.

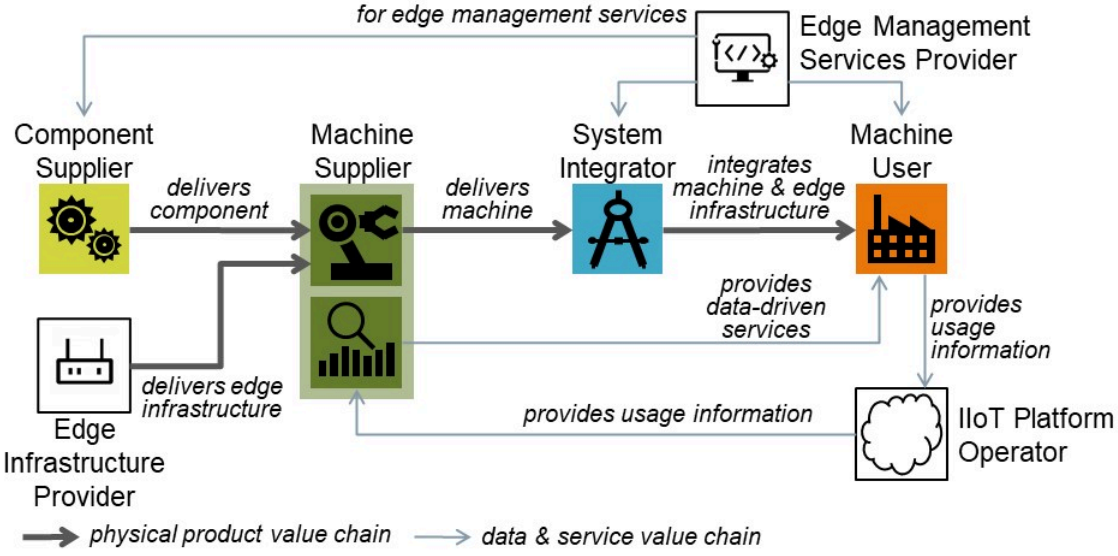

Figure 9. Future value network from the perspective of a Machine Supplier (II)

Figure 10 illustrates the corresponding future revenue streams from the perspective of a Machine Supplier.

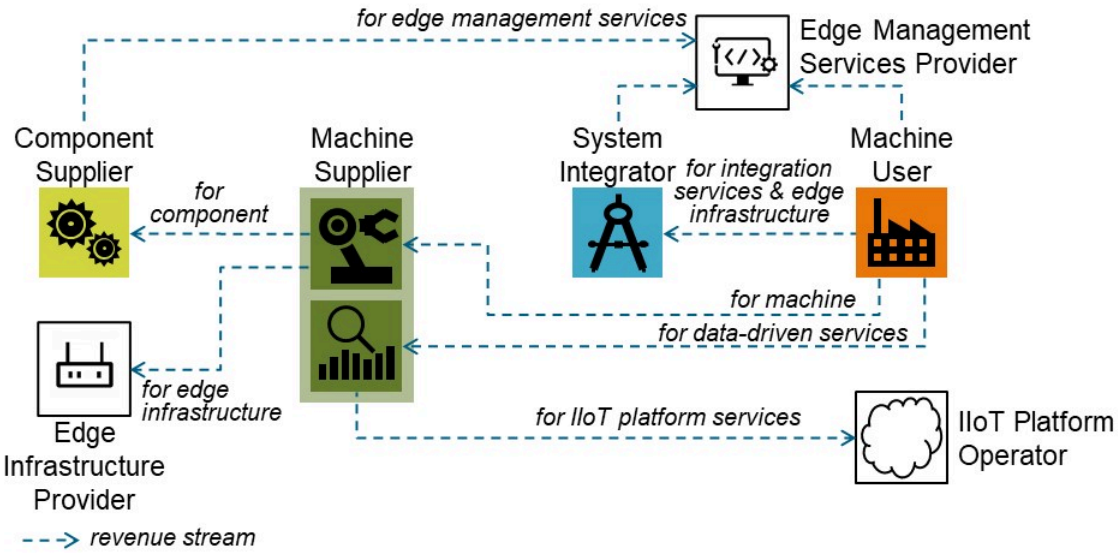

Figure 10. Future revenue streams from the perspective of a Machine Supplier (II)

Here the overall business interest of the Machine Supplier is to offer in addition to the existing machine *new data-driven services*. Similar as in the consideration of the Component Supplier we assume that it is in the interest of the Machine Suppliers to offer these new services themselves.

Potential customers of these new services are Machine User. The customer of these new services, for example a condition monitoring service, benefits due to an improved use of the machine based on the new services and will therefore pay for the use of these new services to the Data-driven Service Provider.

To offer these new data-driven services, the Data-driven Service Provider will provide an existing or develop a software application and will integrate additional computing capabilities based on an edge infrastructure into the machine. The software application will be deployed on the edge infrastructure and will perform process-related pre-processing of usage data of the machine. There is used an additional edge infrastructure – integrated into the machine and not outside of the scope of the machine – so that the Machine Supplier can keep the (data) sovereignty over the machine. The preprocessed data from the machines, which are typically installed world-wide, will be gathered using a suitable connectivity solution – symbolized in Figure 9 by the business role IIoT Platform Operator. By analyzing this data new data-driven services can be offered to the customer and on the other hand, based on the knowledge about the concrete usage of the machines, insights can be gained to further improve the machine technically. We do not discuss at this point whether the Machine Supplier also assumes the role IIoT Platform Operator or instead integrates someone into the value network who offers this to the market. The Machine Supplier will contractually define the access to, and usage of data provided by the Machine User.

Note that the scenario illustrated in Figure 9 and Figure 10 is not directly a driver for the *standardization* of edge management services because the Machine Supplier can select a specific Edge Infrastructure Provider along with proprietary edge management services to implement this scenario.

4.3.3 Perspective System Integrator

Figure 11 illustrates a future value network from the perspective of a system integrator.

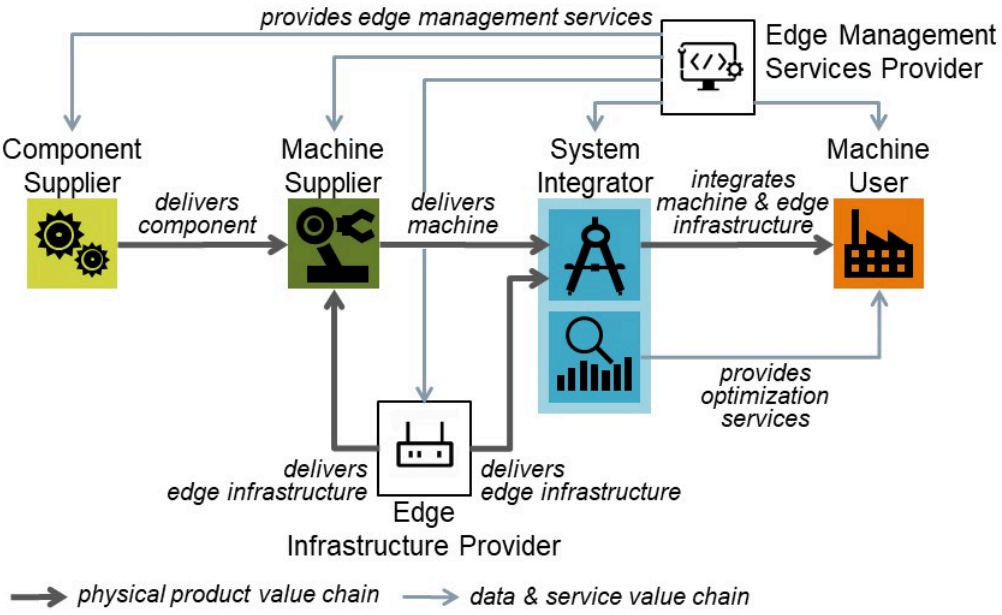

Figure 11. Future value network from the perspective of a system integrator

Figure 12 illustrates the corresponding future revenue streams from the perspective of a System Integrator.

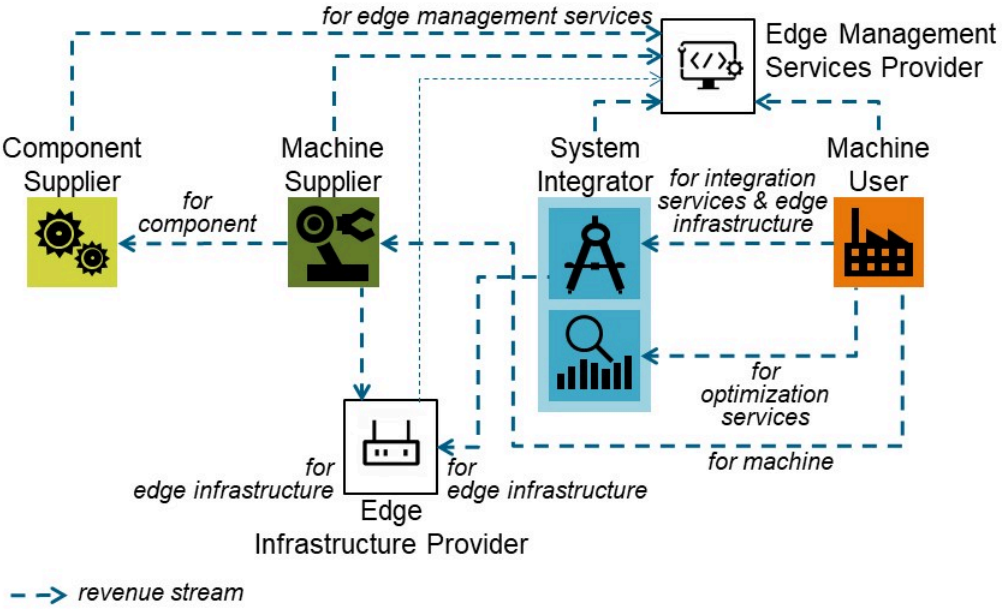

Figure 12. Future revenue streams from the perspective of a System Integrator

Based on the increasing “plug & operate” capabilities of machines and devices the effort for integration services declines. On the other hand, however, this is an opportunity to implement additional optimization services that previously could not be offered economically due to the high costs for the “basic” integration services. Thus, there is an opportunity for the System Integrator to compensate the decline in sales based on traditional integration services through *new, higher-value optimization services*. In contrast to services discussed in section 4.3.1 and 4.3.2, which are component- or machine-centered, here the focus is typically on the entire factory in order to optimize the value-added processes across machines.

Potential customers of these new services are Machine User. The customer of these new services, for example a service to optimize the throughput of a factory, benefits due to an improvement of value

processes based on the new services and will therefore pay for the use of these new services to the Data-driven Service Provider.

In order to offer these new optimization services, the Data-driven Service Provider will provide a software application. Typically, it is not in his interest to provide own computing capabilities to deploy this software application. Instead, he requests for suitable computing capabilities provided by the Machine User. If the System Integrator also offers and implements the basic system integration services, he can consider this early in the offer and overall concept. If, on the other hand, such services are provided later – for example when retrofitting an existing factory – and existing computing capabilities are requested, the System Integrator contractually defines the use of the provided computing capabilities.

Therefore, from the perspective of a System Integrator there is a request for *standardized* edge management services (offered by an Edge Management Services Provider) to offer optimization services independent of specific computing capabilities provided by a Machine User. The System Integrator will pay the Edge Management Services Provider for the use of the offered edge management services.

4.3.4 Perspective Machine User

Figure 13 illustrates a future value network from the perspective of a Machine User. Note that for reasons of clarity the role of the Edge Management Services Provider is not shown in Figure 13. We use different names for the new services offered by the individual roles in order – without claiming to be exhaustive – to illustrate the diversity of the new offerings. Nevertheless, all these new offerings are based on software applications which evaluate usage information from components, machines or factories and generate insights for the Machine User.

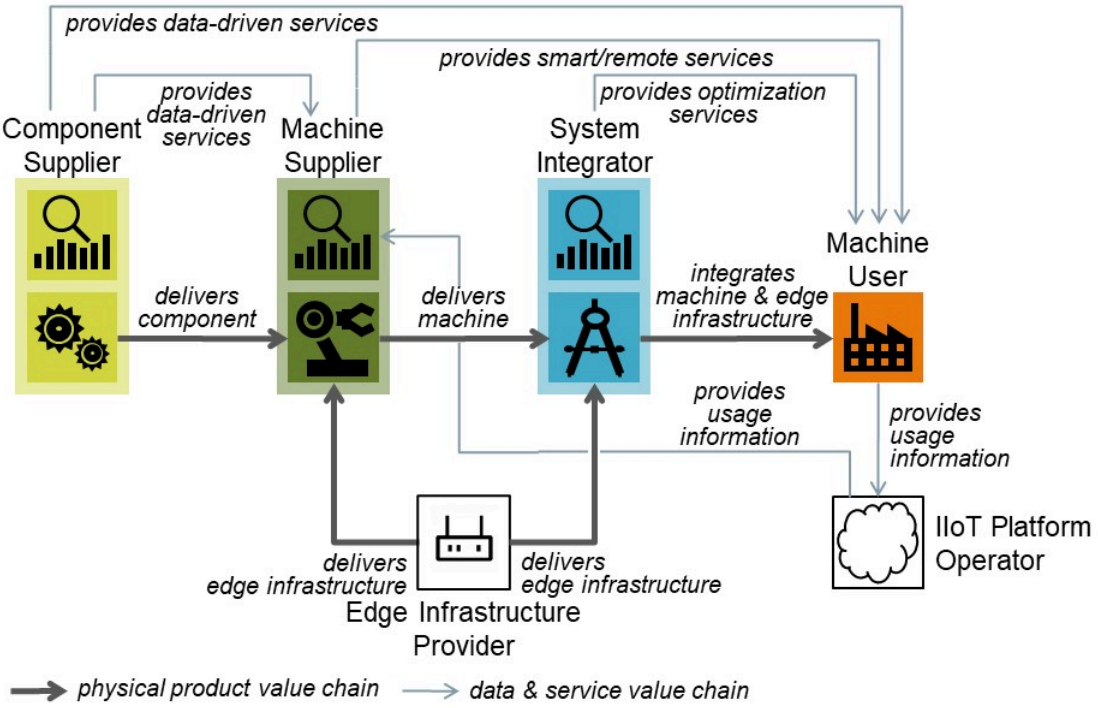

Figure 13. Future value network from the perspective of a Machine User

Figure 14 illustrates the corresponding future revenue streams from the perspective of a Machine User. Note that for reasons of clarity the role of the Edge Management Services Provider is not shown in Figure 14.

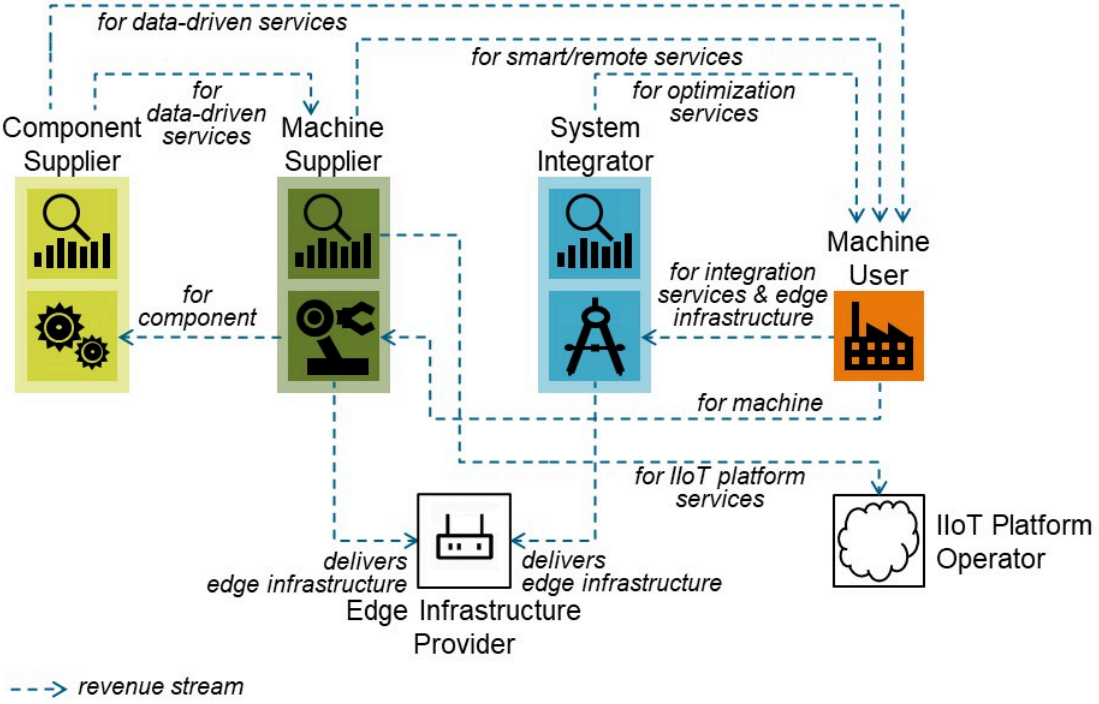

Figure 14. Future revenue streams from the perspective of a Machine User

In principle a Machine User is interested in the optimized usage of the machines and the overall factory. Therefore, a Machine User is interested in any service that supports the optimized usage, be it remote services, data-driven services, or optimization services, be it offered by a System Integrator, a Machine Supplier or a Component Supplier. On the other hand, a Machine User has a fundamental interest in mastering the increasing complexity arising from these various services and software applications offered by different companies, for example IT security concerns or update management.

To master the increasing complexity, the Machine User requests for *standardized* computing capabilities and *standardized* edge management services as a lever to counteract this increasing complexity.

4.4 Conclusion

The elaborations of the business view primarily sharpen the focus on the broad topic of edge management and establishes the technical concept and implementation pursuit by the testbed Edge Management in a business perspective.

The considerations have shown that it is possible to derive and justify the general need for standardized edge management services from different perspectives. As a conclusion, we state that the emphasis should be on a unified management of software applications. Software applications should be able to be *developed independently* of any specific computing capability provided by an Edge Infrastructure Provider and *later be deployed* on such a specific computing capability.

This high-level orientation, which is based on a business perspective, has technically substantiated from an application perspective in a separate document, see [2]. The next step is to develop together conceptual implementation within this high-level orientation.

5 Relation between Business and Usage View

Figure 15 illustrates the relationship between the business view and usage view of the testbed Edge Management. In the center of Figure 15, the overview of the system under consideration and the considered roles according to [2] is shown. In addition, Figure 15 illustrates the relationships between the business roles of the business view and the (technical) roles of the usage view by showing the affiliation of a (technical) role to a business role. Note that business roles are assumed by companies as legal

entities, while the roles of usage view are assumed by technical systems, humans, organizations or even a combination of these.

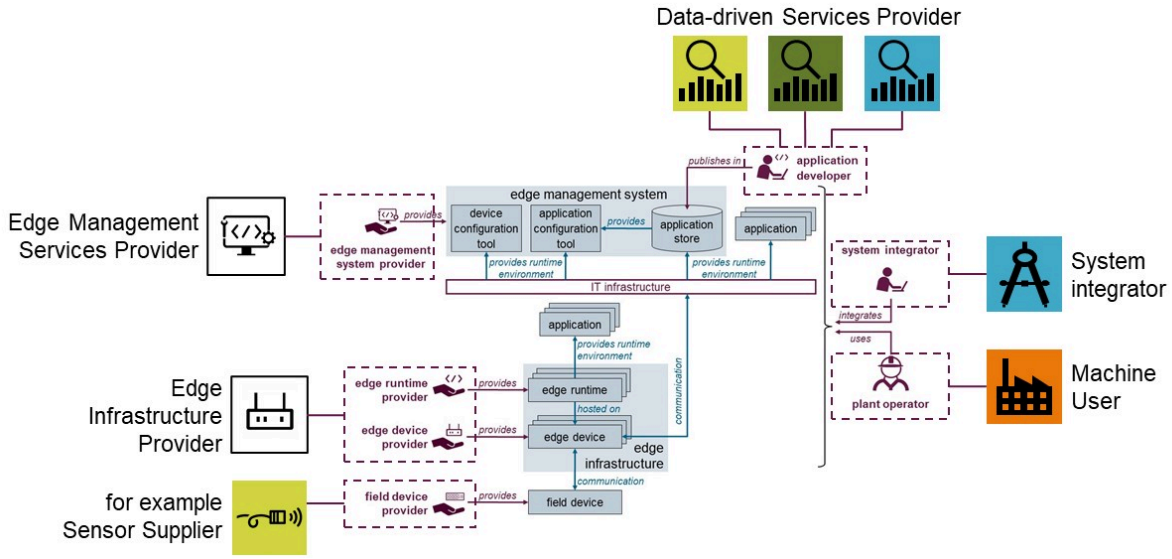

Figure 15. Illustration of relationship between business and usage view

6 References

[1] The Industrial Internet Reference Architecture Technical Report, Link

[2] LNI Testbed Edge Configuration – Usage View, Link

[3] Digital business models for Industrie 4.0, Link

7 Authors and Contributors

Bernd Fiebiger; Kuka

Dr. Andreas Graf Gatterburg; Hilscher

Michael Hornung; SALT Software GmbH

Dr. Ulrich Löwen; Siemens AG, Erlangen

Markus Rentschler; Balluff

Thomas Roehrl; Siemens AG, Nürnberg

Bernd Vojanec; Wittenstein

Dr. Thiago Weber Martins; SAP SE

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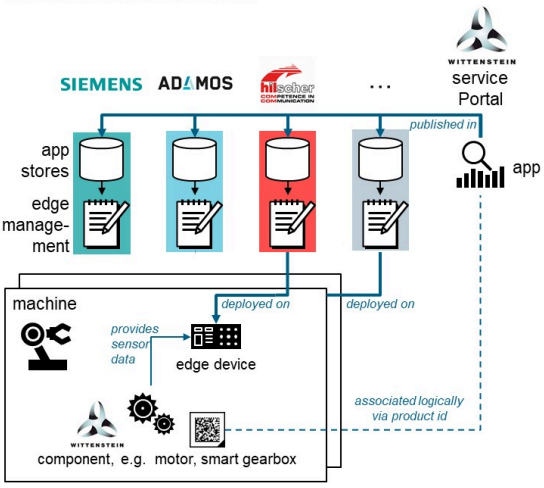
8 Annex: Selected Examples from Companies

This section serves to illustrate the general explanations in chapter 4 with regard to the business interests in a standardized edge management services, but also in relation to the overall topic of edge computing technology itself. It is based on concrete examples observable in the market from the perspectives of various business roles. Note that the icons describing the value networks in the examples serve for illustration purposes only and do not follow the strict approach as used in chapter 4.

8.1 Example Wittenstein (in the role of a Component Supplier)

Example WITTENSTEIN

Illustration Value Network



Business Model

Value proposition: data-driven services, e.g. utilization check or anomaly detection based on sensor data of smart products and machines.

Revenue mechanism:

- WITTENSTEIN receives service fee, e.g. pay per use
- WITTENSTEIN pays for capabilities of app stores and edge management solutions.

Solution Approach

Free choice of platform and edge device.

Service Portal: provides information which platforms and services are available for a product instance.

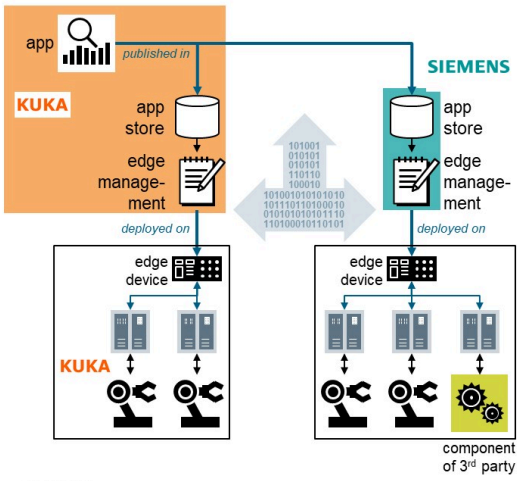
App stores: services are published in the various app stores to be retrieved by the customer (app store features, e.g. payment handling, update mechanism).

Edge management: software applications are deployed on the edge devices of the customer (configuration-, deployment-, update-mechanism)

8.2 Example Kuka (in the role of a Machine Supplier)

Example KUKA

Illustration Value Network



Business Model

Value proposition through the provision of

- Industrial devices with connectivity
- Edge hardware and/or edge software applications for connectivity and services
- Cloud services and apps based on connectivity of devices

Revenue mechanism: KUKA

- Receives revenues from selling of devices with connectivity, edge applications and software-driven services
- Receives revenues from selling cloud services and cloud apps
- Receives revenues from provision of own apps in app stores offered by other vendors

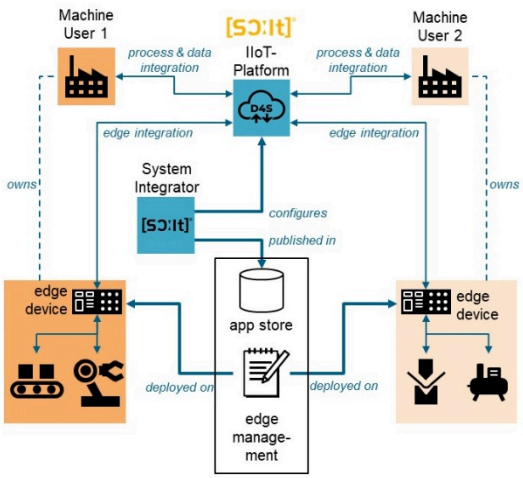
Solution Approach

Modular kit of hardware and software to provide software driven services based on uniform connectivity concept

8.3 Example Salt[4] (in the role of a System Integrator)

Example SALT

Illustration Value Network



March 2020

Business Model

Value proposition through provision of solutions enabling

- Horizontal and vertical integration of processes and systems
- Connectivity between cloud and edge
- Smart services/apps for operational and business excellence

Revenue Mechanism

- SALT receives one-time payment for integration services
- SALT receives recurring software license fees for IIoT-platform

Solution Approach

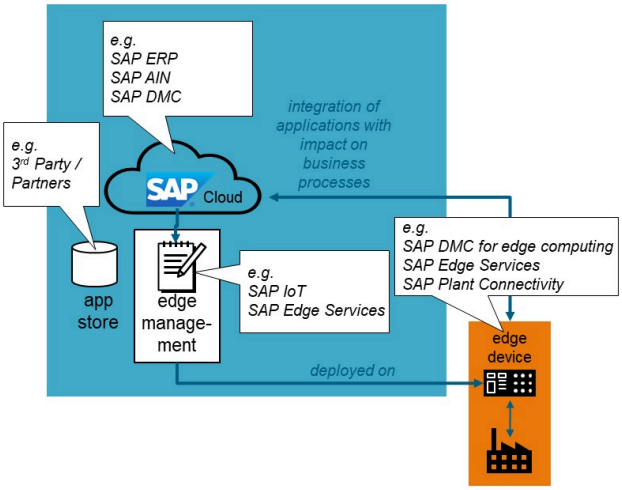
Solutions are based on a business and IIoT-platform already used for many use cases in logistics and production

- Configuration of automated processes via process engine
- Edge connectivity standards like e.g. MQTT, OPC UA
- Deployment on-premise, cloud, hybrid

Standardization of edge management simplifies edge/asset integration so that SALT can concentrate on high-value services

8.4 Example SAP (in the role of a System Integrator)

Illustration Value Network



March 2021

Business Model

Provision of solutions enabling

- IT-OT convergence by applications in the context of industrial automation with impact on business processes
- Enriched data analytics to gain insights and to optimize business processes

Revenue Mechanism

- One-time payment for customer specific integration of applications
- Recurring subscription payments for applications
- Usage-based payment

Solution Approach

Cloud services for building applications on the edge and integration to applications with impact on business processes

Support of industrial protocols like OPC-UA, MQTT, and Modbus enables connectivity to assets at the edge

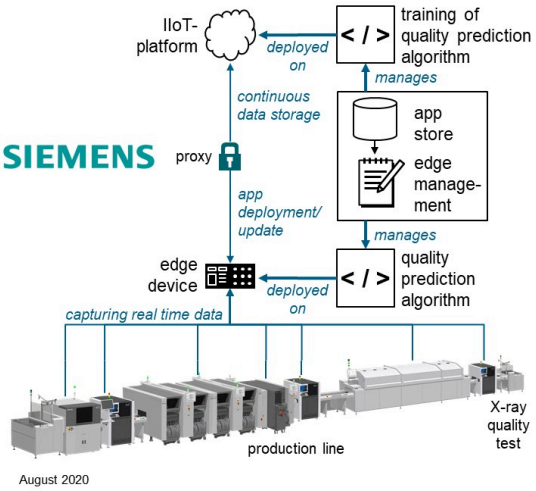
Standardization of edge management reduces customer specific integration efforts and allows SAP to focus on subscription models for applications

[4] This example was brought into the testbed Edge Management by SALT Software GmbH in March 2020. In the meantime, SALT Software GmbH has been taken over by Accenture.

8.5 Example Siemens (in the role of a Machine User)

Example Siemens Amberg

Illustration Value Network



Challenge: increasing quality and efficiency

Output of production line limited by time consuming X-ray quality tests

Every further X-ray machine requires additional invest of €500,000

Solution Approach

- Capturing real time data on edge device (>40,000 production parameters, peak volume of 10 MB/s)
- PCB quality prediction algorithm on edge device indicates whether X-ray quality test is necessary; quality prediction algorithm is trained in the cloud
- An X-ray quality test of a PCB is only carried out if indicated by the quality prediction algorithm

Benefits

Minimization of necessary X-ray tests by up to 30%

Quality rate of prediction 100%

Reduced capital invest for further X-ray machines