LNI 4.0 Testbed Edge Configuration – Usage View

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1 Overall Objectives of Testbed Edge Configuration

The testbed Edge Configuration was established to prepare the standardization in the context of the manufacturing industry with respect to the emerging edge computing technology. The testbed does not address edge computing technology in itself but focuses on *edge configuration*. 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 testbed Edge Configuration is based on a layered architecture as shown in Figure 1:
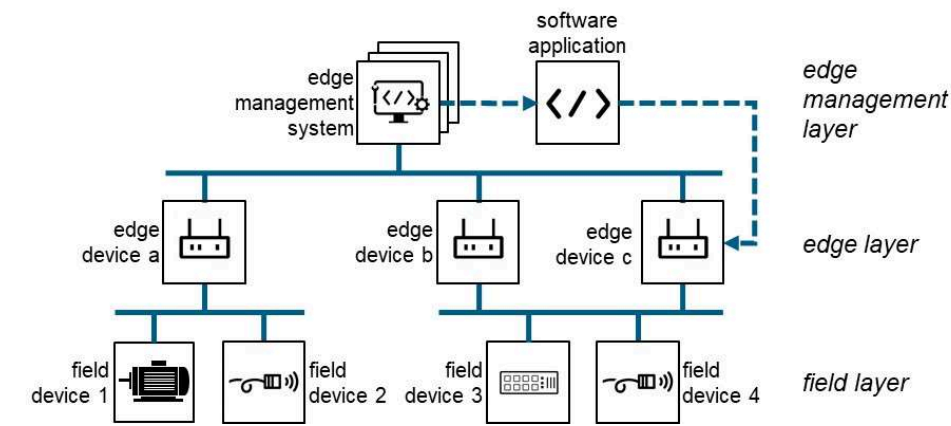

Figure 1. Layered architecture of the proposed testbed Edge Configuration

- The focus of the testbed Edge Configuration is on the configuration of the interaction between the edge and edge management layer. Currently there does not exists a suitable standard for this focus and the testbed will develop proposals for this aspect in 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 Configuration (functional view). Of course, the results of the testbed Edge Configuration may well result in an implementation (implementation view) being based on technologies that are also used in communication between field and edge layer, but the underlying concepts for configuration of field devices do not need to be developed.

2 Purpose of this Document

The purpose of this document is to describe the overall application context of the testbed Edge Configuration. Thus, this document defines the contextual framework of all activities in the testbed and possibly derived standardization activities. In accordance with the Industrial Internet Reference Architecture [1], this document describes a so-called *usage view*, see Figure 2. We assume that this usage view remains stable throughout the life of the testbed Edge Configuration.
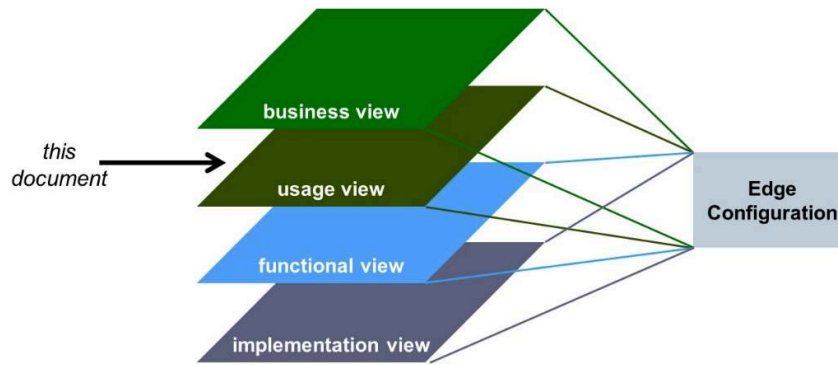
Figure 2. Classification of the document following the Industrial Internet Reference Architecture, see [1]

Regardless of this "stable" application context, 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. The development of these concepts and solutions will be the "real" work in the testbed Edge Configuration. These concepts and solutions shall encompass options for solving specific requirements provided by the testbed partners. Likewise, for all standardization that is proposed by the testbed, the usage view defined in this document shall define the scope of work. Therefore, the purpose of this document is helping to structure and orchestrate the various work efforts of the different partners based on a common view.

In addition, there is a description of a *business view*, which describes the business concerns of various companies with respect to the topic "edge configuration" [2]. This frames an independent perspective but has well-defined relationships to the usage view. These relationships are described in the annex of [2].

3 Usage View of Testbed Edge Configuration

3.1 Structure of the document

There are several ways to specify a usage view. We follow the recommendation of the German Standardization Roadmap Industry 4.0 Version 3 [3]. They recommend using for a description the "Usage Viewpoint" proposed by the Industrial Internet Reference Architecture [1]. Following this approach, a usage view is specified as follows:

- Definition of the so-called "system under consideration".

- Definition of the so-called "roles". Roles are actors *outside* the system under consideration that interact with the system under consideration in various forms.

- Definition of the so-called "activities". The core of an activity is a workflow of individual tasks that are executed by roles.

The present document follows this structure[1]. Figure 3 illustrates the "system under consideration", colored in grey, the considered "roles", colored in purple, and the interactions between the system under consideration and roles.

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[1] From a content perspective this document is a specialization of the overlying Plattform Industrie 4.0 Use Case Plug-and-Produce for Adaptable Factories [4].
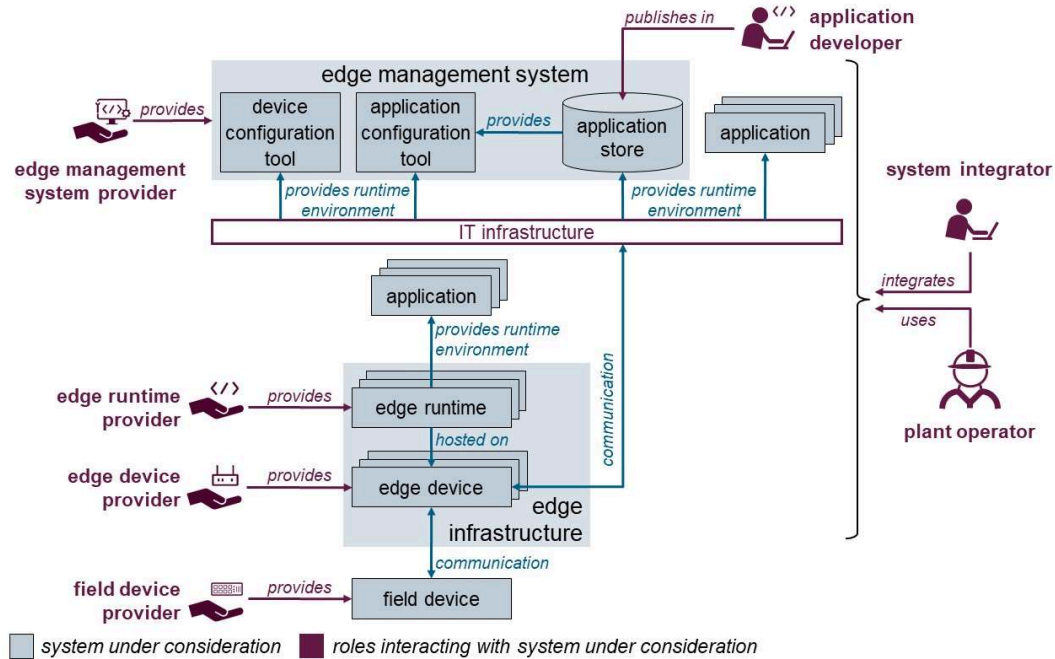
Figure 3: Overview of "system under consideration" and considered "roles"

3.2 System under consideration

The proposed testbed Edge Configuration covers the configuration and device management tasks that arise from current Industrie 4.0 prototypes and the proposed rollout of these solutions. As such, the following main classes of logical entities interact in this testbed: field devices, edge devices, edge runtimes, applications (deployed on edge runtimes or an IT infrastructure), and edge management systems also hosted on an IT infrastructure. These logical entities are organized in three layers according to Figure 4. Note that the field devices and edge devices are connected via appropriate communication systems, nevertheless, it is not necessary that these devices are connected to the Internet.
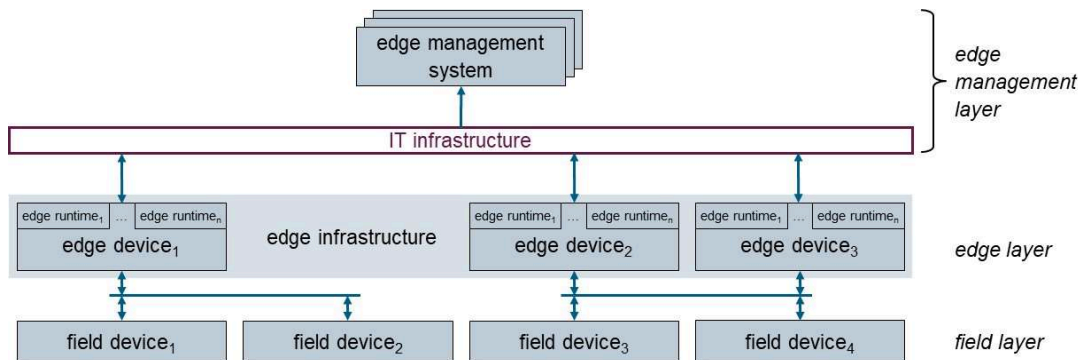
Figure 4. Illustration of layers of "system under consideration" of the Testbed Edge Configuration

Figure 4 also illustrates the core idea for the Testbed Edge Configuration: In classical IT, a separation of software development and software runtime environment is established in the market, whereas in the manufacturing environment devices often require specific software development methods and thus software is bound to these specific devices. An example is a programmable logic controller, in which the software is subject to a specific programming paradigm. In analogy to an IT infrastructure, an edge infrastructure should be developed, which is made up of so-called edge devices and on which software applications can be flexibly deployed.

There can be several field devices communicating with various edge devices and different edge management systems are possible, which is illustrated in Figure 4. Different edge management systems do not need to be congruent in their scope and functionality. It is conceivable that several edge

management systems are used for a device configuration task, but the different edge management systems have the same view on this task. As an example, the device configuration ~~tool~~capabilities could be provided ~~by a configuration tool offered~~ by the provider of an edge device or an edge runtime, while the application store and the application configuration ~~tool~~capabilities are provided by an independent tool provider.

We additionally introduce the concept of data endpoint, which is a logical entity with the purpose to exchange data. Data endpoints are either defined in an application or they are induced by a field device, see Figure 5. Edge devices and IT infrastructure do not have explicitly defined data endpoints but have the capability to automatically generate the necessary communication connections depending on the deployment of the applications.
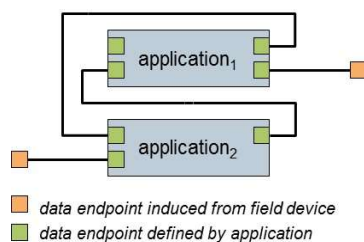

🟧 *data endpoint induced from field device*
🟩 *data endpoint defined by application*

Figure 5: Concept of data endpoints

3.2.1 Field device

Field devices are physical computing resources with real-time communication capabilities. Field devices communicate with edge devices, can be configured via parameters and the firmware of a field device can be updated.

Note that we apply a broad understanding of the term "field device". We call every device that does not support the activities as described in this paper a field device. Thus, even a programmable logic controller, which for example does not support the deployment of applications, is called in this context a "field device".

3.2.2 Edge device

Edge devices are physical computing resources with capabilities for communication and several edge runtimes to be deployed on the edge device. An edge device formulates its assertions with respect to edge runtimes 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.

3.2.3 Edge runtime

Edge runtimes are system software applications which are hosted on edge devices and provide a runtime environment allowing applications to be deployed and executed. An edge runtime formulates its assertions with respect to applications deployed on the edge runtime and their requirements with respect to an edge device.

The set of all edge runtimes hosted on edge devices is called the edge infrastructure.

3.2.4 Edge management system

An edge management system is a software program deployed on an IT infrastructure. An edge management system provides configuration capabilities for field devices and edge devices, an application store for providing applications, edge runtimes and firmware, and configuration and deployment capabilities for applications, edge runtimes and firmware, which are provided via the application store of the edge management system.[2]

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[2] Note that a device management system does not have application specific data endpoints, only "data endpoints" defined in the "standard", which will be elaborated in the testbed edge configuration.

3.2.5 Application

Applications are executable software-programs, which can be configured[3], deployed and executed on an edge runtime or an IT infrastructure. The (description of the) software-programs are provided via the application store provided by an edge management system. Applications have data endpoints, which are defined by the provider of an application. Applications formulate their requirements with respect to a runtime or IT infrastructure, for example, requirements with respect to real-time.

3.3 Roles

Roles interact with the entities of the system under consideration. Depending on the purpose to be described in the usage view a role may be a technical system, a human, an organization or even a combination of this. Thus, a specific company with various organizations may implement several roles. We have identified the roles described in the following sections.

3.3.1 Field device provider

The field device provider is an organization, which develops, manufactures and finally provides physical field devices and associated technical systems. As the vendor of one or more field devices, the device manufacturer is primarily interested in marketing the field device. In addition, the field device provider is interested in information on the usage of the field device to identify potential for optimizing the design and functionality of the field device. The field device provider provides the firmware (including software functionalities) and it is in the responsibility of the user of a field device to install the actual firmware version on the field device.

3.3.2 Edge device provider

The edge device provider is an organization, which develops, manufactures and finally provides physical edge devices and associated technical systems. As the vendor of such devices, the device manufacturer is concerned with the usability and capabilities of the edge device and the hosting capabilities of different edge runtimes. To increase interoperability of automation devices, the edge device provider has a high interest in using and setting standards for field device onboarding and management as well as edge runtime deployment. The edge device provider provides the firmware (including software functionalities) and it is in the responsibility of the user of an edge device to install the actual firmware version on the edge device.

3.3.3 Edge runtime provider

The edge runtime provider is mainly a software development organization providing an edge runtime, which can be deployed on an edge device. The edge runtime provider is interested in providing a system software application that can be easily deployed and managed on edge devices.

3.3.4 Edge management system provider

The edge management system provider is mainly a software development organization providing an edge management system running on some IT infrastructure. The edge management system provider is interested in providing a software application for edge management to easily manage configurations of edge and field devices as well as deployed applications.

3.3.5 Application developer

The application developer is a human actor providing an application, which can be deployed and executed on edge devices or the IT infrastructure. There may be applications, which are provided by an edge runtime provider or even edge device provider. The application developer must provide his applications via the application store provided by an edge management system.

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[3] An applications may be composed by other applications, but this kind of composition is not considered in the Usage View. We consider the configuration of applications as a configuration of "black boxes" only.

3.3.6 Plant operator and system integrator

While the prior roles are primarily organizations concerned with providing the different products and solutions that constitute the system under consideration, the roles of plant operator and system integrator are primarily human actors (belonging to some organization and supported by some technical systems) that acquire these products to operate and utilize them. The plant operator and system integrator are interested in minimizing efforts for different tasks, i.e. operation and adaptation of a plant (plant operator) and engineering and commissioning (system integrator). We distinguish these two roles because there are more technical skills required from a system integrator for installation and commissioning and "only" application specific configuration skills from a plant operator.

3.3.7 IT infrastructure

The IT infrastructure is a technical system. We assume that this infrastructure is provided and operated by some IT infrastructure operator. We also assume that the IT infrastructure has capabilities to explore connected edge devices; this includes automatic detection including connection and disconnection of edge devices. In the case of mobile edge devices, this relates to automatic detection as soon as such a mobile device is in the "reach" of the IT infrastructure or leaves it again; but this also includes a status monitoring to what extent an edge device is still "alive" or can be reached. An IT infrastructure formulates its assertions with respect to applications deployed on the IT infrastructure.

From a logical point of view, we divide the IT infrastructure into an area that is owned by the plant operator, who operates the field devices and edge devices, and an area that is not owned by him, see Figure 6. If applications are deployed on the area, which he does not own, and require access to applications deployed on the area, which he owns, or on one of his edge devices, he must grant the access in order for the applications to work properly.
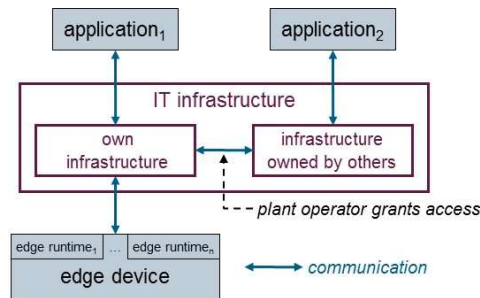

Figure 6: Logical subdivision of the IT infrastructure

3.4 Activities

3.4.1 Adding entities

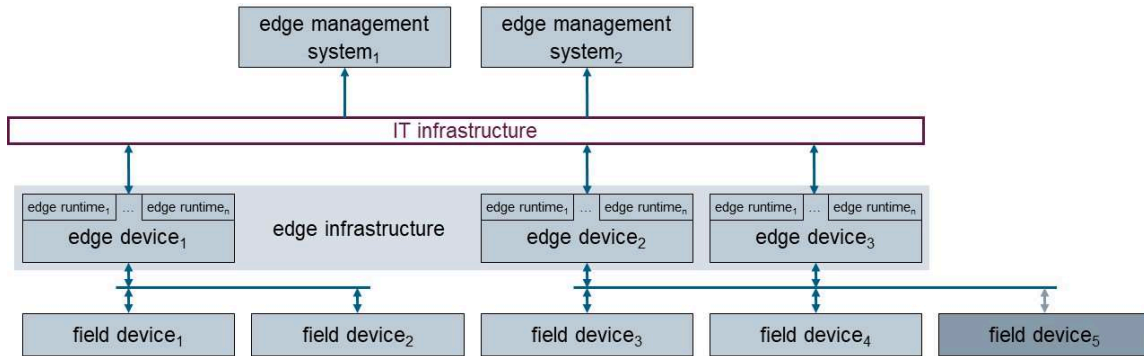#### 3.4.1.1 Adding a field device

Figure 7. Adding a field device

Triggers: explicitly triggered by role system integrator

Workflow

- **Task 1:** Physical installation of field device including connecting to edge devices and some specific engineering: role system integrator

- **Task 2:** Detection and acknowledgement of the field device by connected edge devices (onboarding of the field device on the edge layer): executed automatically

- **Task 3:** Detection and acknowledgement of the field device by the edge management systems connected to the affected edge devices (onboarding of the field device on the edge management layer): executed automatically

- **Task 4:** Provision of necessary parameters (including but not limited to communication parameters) to user of edge management system: executed automatically

- **Task 5:** Setting of these parameters from the edge management system: role system integrator (or plant operator)

- **Task 6:** Creation of the corresponding data endpoints in the connected edge devices: executed automatically

- **Task 7:** Initiation of download of parameter values to field device: role system integrator (or plant operator)

- **Task 8:** Download of parameter values to field device and notification about result (successful, etc.): executed automatically

- **Task 9:** Acknowledgement: role system integrator

Effects:

- Reduction of the effort for commissioning by allowing the setting of parameters from an edge management system. This includes the onboarding processes executed automatically as well as streamlined commissioning processes based on a common edge management system.

Constraints:

- The connectivity between field devices to edge devices must comply with some "standard" provided by the edge devices

- The connectivity between edge devices to an edge management system must comply with some "standard", which does not exist

Comments:

- The concrete onboarding mechanisms on the field layer can vary and are not subject to the work of the testbed

- The principles of onboarding mechanism to an edge management system are subject to the work of the testbed

- Task 1 is not necessary if an already network-connected field device is additionally connected to another edge device
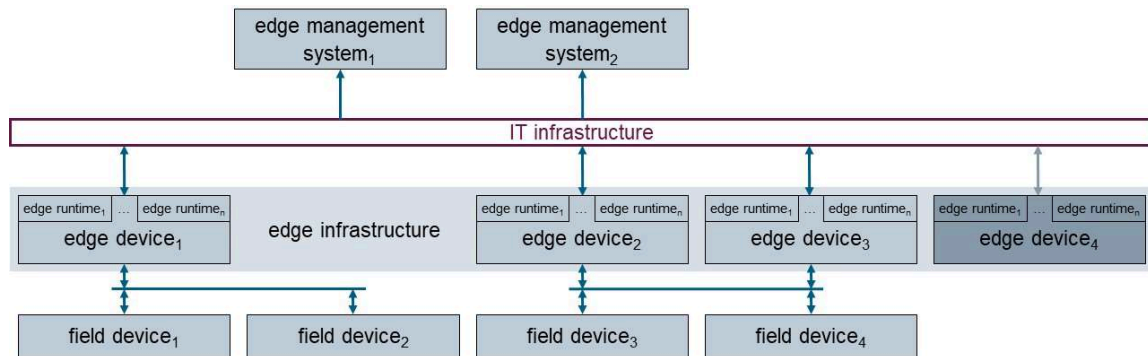
3.4.1.2 Adding an edge device

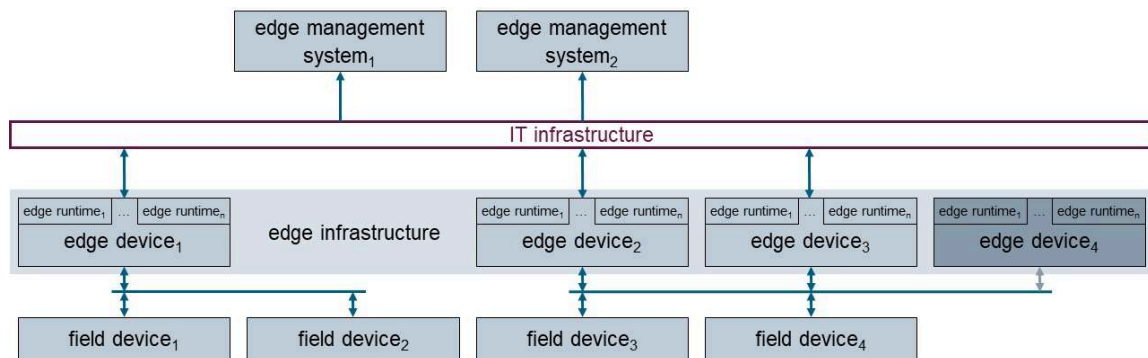*Figure 8. Adding an edge device to an edge management system*

Figure 9. Adding an edge device to a field device environment

Triggers: explicitly triggered by role system integrator in case that a physical installation (including the communication link) is necessary or triggered by the IT infrastructure in case the IT infrastructure detects a new edge device

Workflow

- **Task 1 (optional):** Physical installation of edge device including connectivity to IT infrastructure and connection to field devices: role system integrator

- **Task 2:** Detection and acknowledgement of the field devices (including automatic detection of relevant communication parameters including the creation of the corresponding data endpoints) connected to the edge device (onboarding of field devices on the edge layer): executed automatically

- **Task 3:** Detection and acknowledgement of edge device by the edge management systems (onboarding of edge devices on the edge management layer): executed automatically

- **Task 4 (optional):** Acknowledgement: role system integrator

Effects:

- Reduction of the effort for commissioning by allowing the setting of parameters from an edge management system. This includes the onboarding processes executed automatically as well as streamlined commissioning processes based on a common edge management system.

Constraints:

- The connectivity to field devices must comply with some "standard" and it is assumed that this is provided by the edge device

- The connectivity to an edge management system must comply with some "standard", which does not exist

Comments:

- The concrete onboarding mechanisms to field devices can vary and are not subject to the work of the testbed

- The principles of onboarding mechanism to an edge management system are subject to the work of the testbed

3.4.1.3 Adding an edge runtime

Triggers: explicitly triggered by role system integrator

Workflow

- **Task 1 (optional):** Depending on the capabilities of the edge device and requirements of the edge runtime to the edge device, the edge device is brought into a defined state and maybe taken out of regular operation: role system integrator

- **Task 2:** Selecting an edge runtime from the application store provided by an edge management system: role system integrator

- **Task 3:** Deploying the selected edge runtime on the edge device using the edge management system: role system integrator

- **Task 4:** Starting the execution of the edge runtime on the edge device using the edge management system: role plant operator

- **Task 5 (optional):** Depending on the capabilities of the edge device and requirements of the edge runtime to the edge device, the edge device is brought into an operative state: role system integrator

- **Task 6:** Acknowledgement: role system integrator

Effects:

- Reduction of the effort for adding and removing an edge runtime by using an edge management system.

Constraints:
- The edge device must provide the capabilities requested by the edge runtime.

Comments:

- Because this activity may require a system understanding of the edge device and the edge runtime, we assume that the activity must be performed by the system integrator.

3.4.1.4 Adding an edge management system
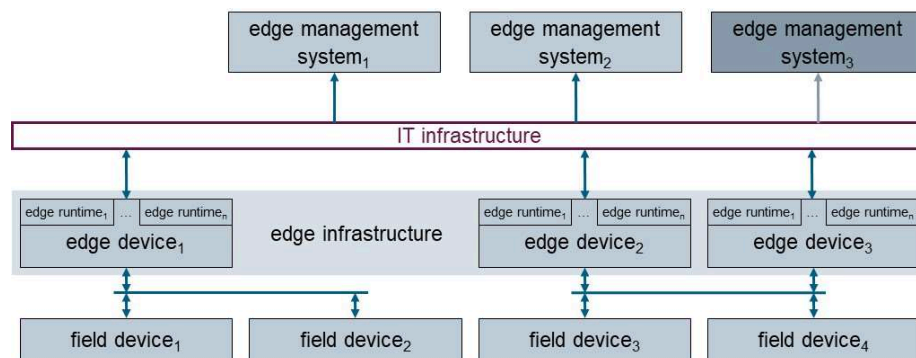

Figure 10. Adding an edge management system

Triggers: explicitly triggered by role system integrator

Workflow

- **Task 1:** Installation of edge management system on IT infrastructure: role system integrator

- **Task 2:** Detection and acknowledgement of all connected edge devices (including automatic detection of relevant information of edge devices, which includes information on the underlying field devices as well) (onboarding of edge devices on the edge management layer): executed automatically
- **Task 3 (optional):** Acknowledgement: role system integrator

Effects:

- No vendor lock-in of a provider of an edge management system.

Constraints:

- The connectivity to an edge management system must comply with some "standard", which does not exist

Comments:

- The principles of onboarding mechanism to an edge management system are subject to the work of the testbed
- The edge management system will collect all application specific data endpoints managed by the connected edge devices and make them manageable

3.4.2 Removing entities

3.4.2.1 Removing an edge management system
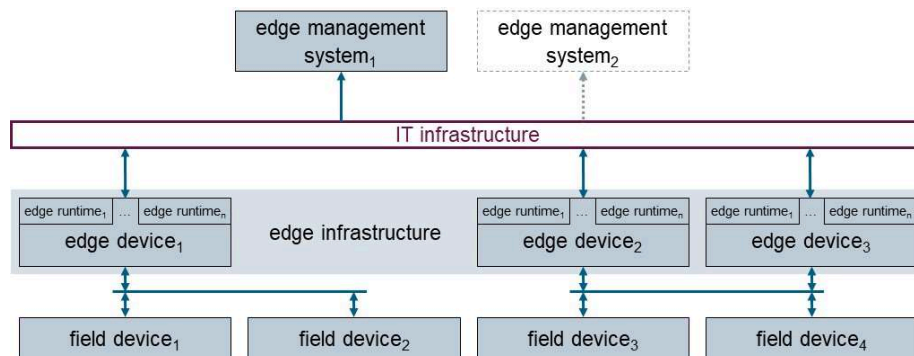
Figure 11. Removing an edge management system

Triggers: explicitly triggered by role system integrator

Workflow

- **Task 1:** Notification of removal to all connected edge devices: executed automatically after trigger
- **Task 2 (optional):** Acknowledgement to connected edge devices: role system integrator

Effects:

- No vendor lock-in of a provider of an edge management system.

Constraints:

- The connectivity to an edge management system must comply with some "standard", which does not exist

Comments:

- The principles of offboarding mechanisms to an edge management system are subject to the work of the testbed
- The removal should happen without any disturbance of overall organizational processes. After removal of an edge management system, the adding of a new edge management system follows the process as described in the activity "Adding an edge management system".

- The management of application specific data endpoints is independent on the used edge management system. Thus, removing an edge management system has no impact on the usage of application specific data endpoints.

3.4.2.2 Removing an edge runtime

Triggers: explicitly triggered by role system integrator

Workflow

- **Task 1 (optional):** Depending on the capabilities of the edge device and requirements of the edge runtime to the edge device the edge device is brought into a defined state and maybe taken out of regular operation: role system integrator

- **Task 2:** Removing the edge runtime using the edge management system: role system integrator

- **Task 3 (optional):** Depending on the capabilities of the edge device and requirements of the edge runtime to the edge device the edge device is brought into an operative state: role system integrator

- **Task 4:** Acknowledgement: role system integrator

Effects:

- Reduction of the effort for adding and removing an edge runtime by using an edge management system.

Constraints:

- Before removing an edge runtime, all applications deployed on the edge runtime should be uninstalled.

Comments:

- Because this activity may require a system understanding of the edge device and the edge runtime, we assume that the activity must be performed by the system integrator.

3.4.2.3 Removing an edge device
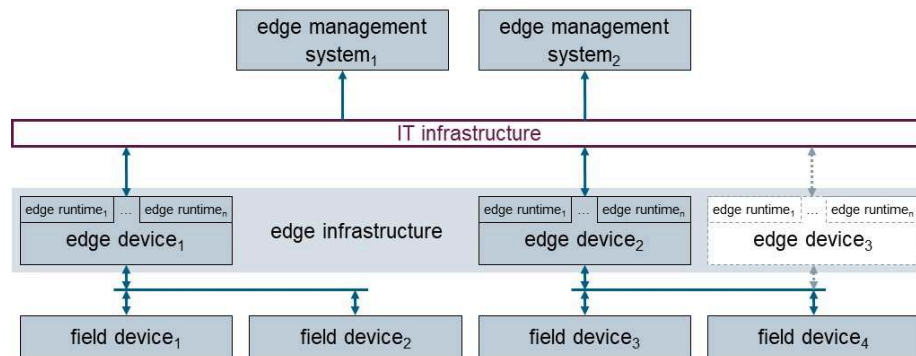
Figure 12. Removing an edge device

Triggers: explicitly triggered by role system integrator in case that a physical deinstallation (including the communication link) is necessary or triggered by the IT infrastructure in case the IT infrastructure detects that a new edge device is not connected any longer.

Workflow

- **Task 1:** Notification of removal to all connected edge management systems: executed automatically after trigger

- **Task 2:** Notification of removal to all affected applications deployed on the IT infrastructure: executed automatically

- **Task 3:** Engineering of communication between edge device and connected field devices (removing communication from field device to specific edge device) (offboarding of edge devices): role system integrator

- **Task 4 (optional):** Acknowledgement to connected edge management systems: role system integrator

Effects:

- Reduction of the effort for commissioning by allowing the setting of parameters from an edge management system. This includes the offboarding processes executed automatically as well as streamlined commissioning processes based on a common edge management.

- There may be now disconnected field devices and there may be now data endpoints of applications deployed and running on the IT infrastructure, which are no longer supplied with data or data provided by the applications are no longer consumed.

Constraints:

- The connectivity to field device must comply with some "standard" and it is assumed that this is provided by the edge device

- The connectivity to an edge management system must comply with some "standard", which does not exist

Comments:

- The principles of offboarding mechanism to an edge management system are subject to the work of the testbed

- The removal of an edge device could have the implication that some field device cannot communicate any longer with an edge device. It is in the responsibility of the system integrator to take care of this, e.g. by connecting the field device to another edge device, see activity "Adding a field device"

3.4.2.4 Removing a field device
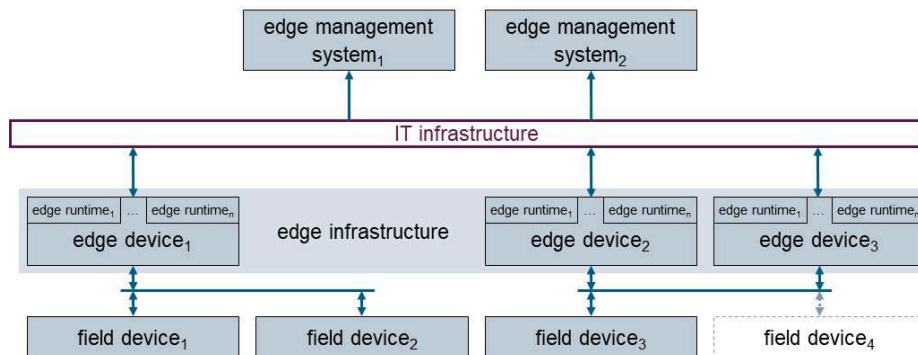
Figure 13. Removing a field device

Triggers: explicitly triggered by role system integrator

Workflow

- **Task 1:** Deinstallation of field device and engineering of communication between field device and connected edge devices (removing communication from field device to edge devices) (offboarding of field devices): role system integrator

- **Task 2:** Notification of removal to all connected edge management systems: executed automatically after trigger

- **Task 3:** Removing all data endpoints in applications on edge devices formerly connected to the field device: executed automatically

- **Task 4:** Disabling of configuration capabilities of edge management system with respect to the removed field device (offboarding of field devices on edge management layer): executed automatically

- **Task 5 (optional):** Acknowledgement: role system integrator

Effects:

- Reduction of the effort for commissioning by allowing the setting of parameters from an edge management system. This includes the offboarding processes executed automatically as well as streamlined commissioning processes based on a common edge management.

- Because of removing data endpoints there may be now data endpoints of applications, which are no longer supplied with data or data provided by the edge devices are no longer consumed.

Constraints:

- The connectivity to field device must comply with some "standard" and it is assumed that this is provided by the edge device

- The connectivity to an edge management system must comply with some "standard", which does not exist

Comments:

- The principles of offboarding mechanism to an edge management system are subject to the work of the testbed

3.4.3 Setting up operational configurations

3.4.3.1 Deploying an application

Triggers: explicitly triggered by role plant operator

Workflow

- **Task 1:** Selecting an application from the application store provided by an edge management system and checking whether the application can be deployed on the edge device resp. IT infrastructure by matching the requirements of the application and the assertions of the edge device resp. IT infrastructure: role plant operator

- **Task 2:** Deploying the selected application on the edge device resp. IT infrastructure using the edge management system: role plant operator

- **Task 3 (optional):** Configuration of data provisioning and consumption according to Task U3.4: role plant operator

- **Task 4:** Starting the execution of the application on the edge device resp. IT infrastructure using the edge management system: role plant operator

Effects:

- Reduction of efforts for software management at the edge and edge management layer by aggregating this task through an edge management system

Constraints:

- The connectivity between edge and edge management layer must comply with some "standard", which does not exist

Comments:

- The "standard" between edge and edge management layer will define the requirements for the capabilities to be provided by an edge management system, IT infrastructure and the edge devices.

3.4.3.2 Updating a deployed application

Triggers: explicitly triggered by role plant operator

Workflow

- **Task 1:** Selecting an updated version of an application from the application store provided by an edge management system: role plant operator

- **Task 2:** Deploying the selected updated version of an application on the edge device resp. IT infrastructure using the edge management system: role plant operator

- **Task 3 (optional):** Configuration of data provisioning and consumption according to Task U3.4: role plant operator
- **Task 4:** Starting the execution of the application on the edge device resp. IT infrastructure using the edge management system: role plant operator

Effects:

- The previous version of the application deployed on the edge device resp. IT infrastructure will be replaced by the new version.
- Reduction of efforts for software management by aggregating this task through an edge management system

Constraints:

- It is in the responsibility of the application developer to notify potential users of the application adequately.
- The edge management system must comply with some "standard", which does not exist

Comments: -

3.4.3.3 Uninstalling a deployed application

Triggers: explicitly triggered by role plant operator

Workflow

- **Task 1:** Uninstalling the application deployed on the edge device resp. IT infrastructure using the edge management system: role plant operator

Effects:

- Because of removing data endpoints there may be now data endpoints of applications, which are no longer supplied with data or data provided will no longer be consumed.

Constraints:

- It is the responsibility of the plant operator to ensure that the entire system remains operational.

Comments: -

3.4.3.4 Configuration of data provisioning and consumption

Triggers: explicitly triggered by role plant operator

Workflow

- **Task 1:** Connecting data endpoints of edge devices (connected to some field device) resp. data endpoints of applications using an edge management system: role plant operator

Effects:

- Reduction of efforts for configuration and data provisioning and consumption by using an edge management system

Constraints:

- The principal ability to connect data endpoints must be verified by the edge management system, such as, for example, data types or inputs versus outputs
- The connectivity between field device and edge layer must comply with some "standard" and it is assumed that this is provided by the edge device
- The connectivity between edge and edge management layer must comply with some "standard", which does not exist

Comments:

- The "standard" between edge and edge management layer will define the requirements for the capabilities to be provided by an edge management system

- Depending on the application in mind, there may be different purposes for configuration of data provisioning and consumption, for example, for informing human operators or analytic tasks.

- The configuration of data provisioning and consumption in an edge scenario is a multilayered relationship, where a field device as a data source is connected to an edge device, where the latter acquires the data from the field layer, preferably in a way that does not interfere with crisp automation operation. The edge device then must forward the acquired data to the corresponding data endpoint. These two layered communication relationships constitute a configuration that must be maintained by the edge device and made manageable through the edge management system.

- Specific applications can be used to distribute data according to different mechanisms, for example, following the publish & subscribe pattern.

3.4.3.5 Update edge management ~~device configuration~~ system

Triggers: explicitly triggered by role plant operator

Workflow

- **Task 1:** Updating the edge management ~~device configuration~~ system using the edge management system: role plant operator

Effects:

- The previous version of the edge management ~~device configuration~~ system will be replaced by the new version.

Constraints:

- When updating a edge management ~~device configuration~~ system, the configuration of the overall "system under consideration" should be preserved, for example the concrete parameter values, the installed edge runtimes or the installed applications.

- It is in the responsibility of the edge management ~~device configuration~~ system provider to notify potential users of the edge management ~~device configuration~~ system adequately.

Comments: -

3.4.3.6 Update edge runtime

Triggers: explicitly triggered by role plant operator

Workflow

- **Task 1 (optional):** Depending on the capabilities of the edge device and requirements of the edge runtime to the edge device the edge device is brought into a defined state and maybe taken out of regular operation: role plant operator

- **Task 2:** Updating the edge runtime using the edge management system: role plant operator

- **Task 3 (optional):** Depending on the capabilities of the edge device and requirements of the edge runtime to the edge device the edge device is brought into an operative state: role plant operator

- **Task 4 (optional):** Acknowledgement: role system integrator

Effects:

- The previous version of the edge runtime will be replaced by the new version.

Constraints:

- It is in the responsibility of the edge runtime provider to notify potential users of the edge runtime adequately.

Comments:

- We assume that – unlike the initial installation of an edge runtime – the update does not require a dedicated system understanding and therefore the activity can be executed by the plant operator.

3.4.3.7 Update firmware

Triggers: explicitly triggered by role system integrator or plant operator

Workflow

- **Task 1:** The affected field or edge device is brought into a defined state and thereby taken out of regular operation: role system integrator or plant operator

- **Task 2:** The current version of the firmware provided in the application store of the edge management system is installed on the field or edge device, for this purpose usually the device must be shut down: role system integrator or plant operator

- **Task 3:** The field or edge device is brought into a defined state so that it can resume regular operation: role system integrator or plant operator

Effects: -

Constraints:

- When updating firmware, the configuration of the device should be preserved, for example the concrete parameter values, the installed edge runtimes or the installed applications. If, for technical reasons, compatibility restrictions must be considered, the system integrator or plant operator should be informed in an adequate way.

- The overall "system under consideration" must be prepared so that individual devices may not operate for a certain period

Comments:

- It is the responsibility of the system integrator or plant operator to ensure that the update of firmware does not affect the overall functionality of the "system under consideration". This concerns especially the analysis of dependencies between different versions of firmware.

3.4.4 Provision of entities

3.4.4.1 Provision of a field device

Triggers: explicitly triggered by role field device provider

Workflow

- **Task 1:** Developing and providing a field device complying to a "standard" between field device and edge layer: role field device provider

Effects:

- A system integrator or plant operator can buy a field device from the device manufacturer complying to the "standard" between field device and edge layer

Constraints:

- We assume that the edge device provider provides a "standard" for connecting field devices to his edge devices and assume that in the future this will be based on an OPC-UA companion specification. Therefore, field device provider must comply to such OPC-UA companion specifications in the future. Thus, the "standard" between edge devices and field devices is out-of-scope of the testbed.

Comments: -

3.4.4.2 Provision of an edge device

Triggers: explicitly triggered by role edge device provider

Workflow

- **Task 1:** Developing and providing an edge device complying to the "standard" between field device and edge layer and the "standard" between edge and edge management layer: role edge device provider

Effects:

- A system integrator or plant operator can buy an edge device from the edge device provider complying to the "standard" between field device and edge layer and the "standard" between edge and edge management layer

Constraints:

- The edge device provider must provide a[4] "standard" for connecting field devices to his edge devices. We assume that in the future this will be based on OPC-UA companion specifications. Therefore, the "standard" between edge devices and field devices is out-of-scope of the testbed.

- The edge device provider should deliver his edge device by default with a pre-installed edge runtime.

- The connectivity between edge devices to an edge management system must comply with some "standard", which does not exist. The requirements, concepts and solution approaches for such a "standard" are the main subject of the testbed.

Comments: -

3.4.4.3 Provision of an edge runtime

Triggers: explicitly triggered by role edge runtime provider

Workflow

- **Task 1:** Developing and testing an edge runtime: role edge runtime provider

- **Task 2:** Providing the edge runtime in the application store of an edge management system: role edge runtime provider

Effects:

- A user of an edge runtime can now use the edge runtime to be installed on edge devices.

Constraints:

- It is in the responsibility of the user of an edge runtime to install the actual edge runtime version on the edge device.

- It is in the responsibility of the edge runtime provider to notify potential users of the edge runtime adequately.

Comments:

- From a conceptual point of view, an edge runtime is a specific application: it is system software, which must be deployed on edge devices to enable them that applications can be deployed. Depending on the capabilities of the edge device and requirements of the edge runtime to the edge device, however, certain precautions must be taken during installation and specific system understanding may be necessary.

3.4.4.4 Update of an edge runtime

Triggers: explicitly triggered by role edge runtime provider

Workflow

- **Task 1:** Developing and testing an update of an edge runtime: role edge runtime provider

- **Task 2:** Providing the update of an edge runtime in the application store of an edge management system: role edge runtime provider

Effects:

- A user of an edge runtime can now use the update of the edge runtime to be installed on edge devices.

Constraints:

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[4] Or even several

- It is in the responsibility of the user of an edge runtime to install the actual edge runtime version on the edge device.

- It is in the responsibility of the edge runtime provider to notify potential users of the edge runtime adequately.

Comments:

- Depending on the capabilities of the edge device and requirements of the edge runtime to the edge device, however, certain precautions must be taken during the installation of an update. But we assume that for an installation of an update of an edge runtime no specific system understanding is necessary.

3.4.4.5 Discontinuation of an edge runtime

Triggers: explicitly triggered by role edge runtime provider

Workflow

- **Task 1:** Notification of potential users of the discontinuation of the edge runtime: role edge runtime provider

Effects:

- A user of an edge runtime will no longer be supported by updates of the edge runtime.

Constraints:

- It is in the responsibility of the user of an edge runtime to take appropriate countermeasures.

Comments: -

3.4.4.6 Provision of an edge management system

Triggers: explicitly triggered by role edge management system provider

Workflow

- **Task 1:** Developing an edge management system complying to the "standard" between edge and edge management layer: role edge management system provider

- **Task 2:** Providing the edge management system on the IT infrastructure: role edge management system provider

Effects:

- A system integrator or plant operator can buy an edge management system from the edge management system provider complying to the "standard" between edge and edge management layer

Constraints: -

Comments:

- The connectivity between an edge management system and edge devices must comply with some "standard", which does not exist. The requirements, concepts and solution approaches for such a "standard" are the main subject of the testbed.

3.4.4.7 Update of an edge management system

Triggers: explicitly triggered by role edge management system provider

Workflow

- **Task 1:** Developing and testing an update of an edge management system: role edge management system provider

- **Task 2:** Providing the update of an edge management system: role edge management system provider

Effects:

- A user of an edge management system can now install the update of the edge management solution.

Constraints:

- It is in the responsibility of the user of an edge management system to install the actual edge management system.

- It is in the responsibility of the edge management system provider to notify potential users of the edge management system adequately.

Comments: -

3.4.4.8 Discontinuation of an edge management system

Triggers: explicitly triggered by role edge management system provider

Workflow

- **Task 1:** Notification of potential users of the discontinuation of the edge management system: role edge management system provider

Effects:

- A user of an edge management system will no longer be supported by updates of the edge management system.

Constraints:

- It is in the responsibility of the user of an edge management system to take appropriate counter-measures.

Comments: -

3.4.4.9 Provision of an application

Triggers: explicitly triggered by role application developer

Workflow

- **Task 1:** Developing and testing an application complying to the "standard" between edge and edge management layer: role application developer

- **Task 2:** Providing the application in the application store of an edge management system: role application developer

Effects:

- A system integrator or plant operator can buy an application offered in the application store of an edge management system and can deploy and execute the application on an edge device or the IT infrastructure

Constraints: -

Comments:

- The edge runtimes provided by edge runtime supplier must comply with some "standard", which does not exist. The requirements, concepts and solution approaches for such a "standard" are the main subject of the testbed.

3.4.4.10 Update of an application

Triggers: explicitly triggered by role application developer

Workflow

- **Task 1:** Developing and testing an update of an application: role application developer

- **Task 2:** Providing the update of an application in the application store of an edge management system: role application developer

Effects:

- A user of an application can now install the update of the application.

Constraints:
- It is in the responsibility of the user of an application to install the actual application.
- It is in the responsibility of the application developer to notify potential users of the application adequately.

Comments: -

3.4.4.11 Discontinuation of an application

Triggers: explicitly triggered by role application developer

Workflow

- **Task 1:** Notification of potential users of the discontinuation of the application: role application developer

Effects:

- A user of an application will no longer be supported by updates of the application.

Constraints:

- It is in the responsibility of the user of an application to take appropriate countermeasures.

Comments: -

3.4.4.12 Provision of an update of firmware

Triggers: explicitly triggered by role field device provider or edge device provider

Workflow

- **Task 1:** Developing and testing a firmware update: role field device provider or edge device provider
- **Task 2:** Providing the firmware update in the application store of an edge management system: role field device provider or edge device provider

Effects:

- A user of a field or edge device can now initiate an update of the firmware of the device

Constraints:

- It is in the responsibility of the user of a device to install the actual firmware version on the device.

- It is in the responsibility of the field or edge device provider to notify potential users of the field or edge devices adequately.

Comments:

- From a conceptual point of view firmware is a specific application: it can be deployed also on field devices and typically the device must be shut down in the case of updating firmware, whereas applications on edge devices can be deployed without a need for shutdown of the edge device.

4 References

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