**ISBN** 978-xx-844xx-xx-x
**Proceedings of 2015 International Conference on Computing Techniques and Mechanical Engineering (ICCTME 2015)**
*Phuket, October 01-02, 2015, pp. 14-23*

# Integration of Mechanical Information in Device Descriptions as Part of CPS

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***Abstract*****:** *A common trend for manufacturing systems is an increasing flexibility. More and more bottom-up aspects are coming into the engineering processes. Key words like self-configuration, self-adaptation, shortly self-x technologies are integrated in the engineering processes. Automation devices are highly involved in these tasks. One pre-requisite is to identify and manipulate device and components functions and features to adapt them for different operation tasks. Today a wide range of automation devices are provided with their device descriptions. In the device descriptions there are detailed information about their functions and features. The goal of this paper is to show characteristic aspects of device description technologies like FDT, EDD/FDI, IODD, FDCML and DDML. The paper illustrates the today's available contribution of device descriptions and the missing brick stones to build Cyber Physical Systems.*

***Keywords:*** *Automation, Automation devices, device description, flexible manufacturing systems*

## 1. Introduction

Shorter innovation cycles and more individual products increase the need for production flexibility. This means often changes in the production line. The costs for the specific products should be similar to mass production. So the changes have to be carried out with less time and resource consumption. This is true for both the electro-mechanical components as well as the automation system. This paper focuses on the digital representation of automation devices which are building the automation system.

Adaptations of the production lines induce a potential range of changes in the automation systems which are

- Changes of the parameter set of the automation devices (AT devices)
- Changes of the structure of AT devices
- Changes of the type of AT devices
- Changes of the control programs

These changes are based on consequences of changing requirements. Today an automation engineer has to check the existing instrumentation (set of AT devices and their parameterization) and decide which changes have to be done. Assuming frequently changes, the engineers have to know precisely what the existing instrumentation is. Manual recording of the status is very time consuming. He needs help by digital available information.

AT devices are embedded systems. Therefore they can be seen as parts of cyber physical systems (CPS) [9] if AT devices and their digital representation are treated as one unit.

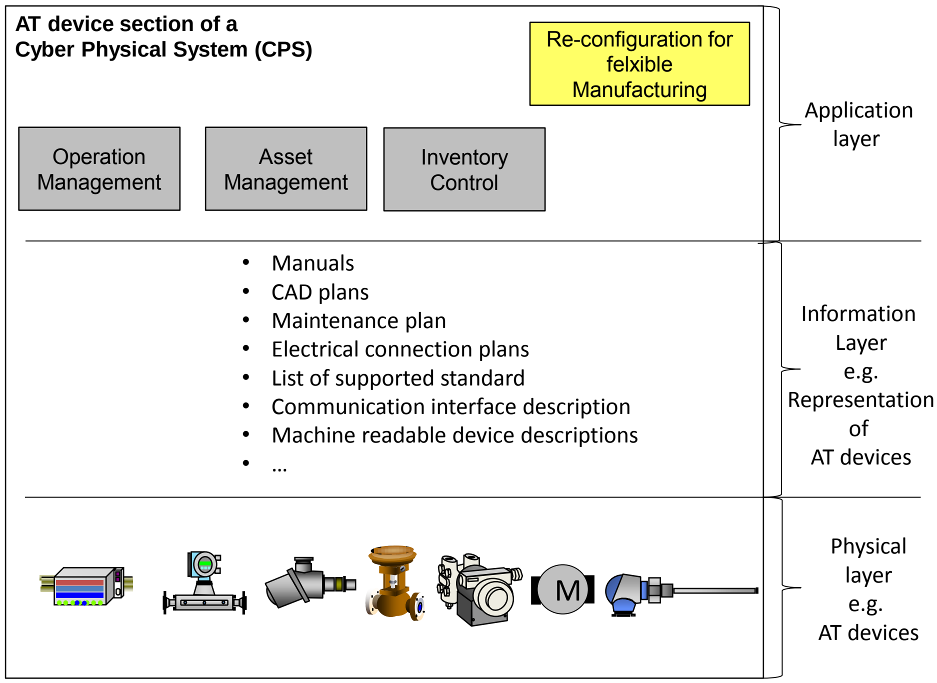


Fig 1: Layer structure of a Cyber Physical System – focused on AT devices [2] – modified]

Considering the German concept of Industry 4.0 this unit can be named “I40 component” which is the building element of CPS. The digital device representation can be seen as a separate information layer (Fig 1). This information layer contains the range of descriptions which are necessary to handle the physical components in the different engineering domains such as electric, pneumatic, mechanic, software and control. Today, the description is available both in paper format and in machine readable digital format. Examples for the paper format are manuals or maintenance plans. Information related to mechanics (e.g. CAD-files) and communication and device functions (device descriptions) are already available in digital format. The latter is today mostly used for commissioning and diagnosis. But there are much more potential applications in it which are discussed in this paper.

## 2. I40 Component

The concept of Industry 4.0 considers a wide range of components contributing to the Machine to Machine (M2M) interactions based on the Internet of Things. This could be entire sites, site areas and production cells, units, equipment modules, control modules and AT devices. However, as already mentioned, this paper focuses on AT devices with a deeper look inside an I40 component.

An I40 component of the type AT device consists (1) of the physical AT device with its mechanical layout, its local data set (parameter values) and its connection to plant equipment and an industrial communication such as fieldbus or Ethernet based systems. It consists (2) of its information representation as introduced in clause 1, covers documents based descriptions such as manuals and electric connection plans but also some already machine readable information such as boiler plate information (manufacturer, model, version), communication properties, or even so called device descriptions which are commonly used for devices of some fieldbusses such as PROFIBUS PA, CAN, Interbus, IO Link just to call some different application domains. All these information are deputies of the physical device in the information layer. Therefore, the set of information

http://dx.doi.org/10.17758/UR.U1015113 

representing on AT devices is called proxy. The proxy has internal tied connections to the physical component which cannot be seen from outsite the I40 component. The I40 component communicates using an I40 compliant communication interface. For this time the specification of an I40 compliant communication interface is not yet defined. It seems to be that services using concepts of the OASIS specification could be one of the favourite approaches (Fig 2). OPC UA [6] is one candidate for this interface specification because it is well established in the automation domain. Additionally an I40 component has to have an unambiguous system wide identifier.

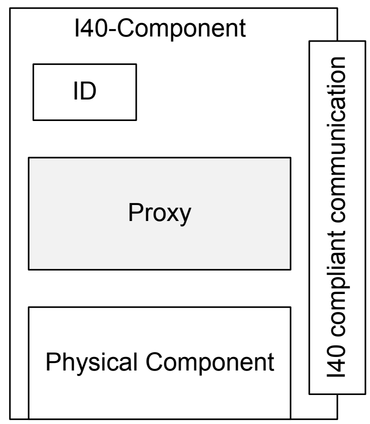


Fig 2: I40 component structure [14]

If an application (see Fig 1) interacts with an I40 component it has to have access and has to understand the device parameters and functions. Therefore the proxy is the important element which is the first communication partner. Best would be if there is a model which represents the components. For AT devices such model is already available.

## 3. Device Description

The device description is a software component which acts as broker/mediator between one or more applications (human or Software) and the physical device. Taking the example of a measurement transmitter (Fig 3): The sensor converts the physical measurement value to an electrical signal (in many cases). This is driven by a sensor specific electronic signal detection unit. In processor based AT devices (embedded system) this detected signal is converted to a digital value using an analogue digital converter (ADC). This digital value is further processed with calibration, scaling, linearization and other functions. A communication controller transports the measurement and related parameters to applications such as PLCs or commissioning and diagnosis stations. The signal chain in the device has to be adjusted for the specific measurement task. This is done by fixing the parameter values which are part of the signal chain functions. Some devices offer local panels for parameterization. To conclude so far: The devices have (1) functions related to their main tasks (signal chain), (2) functions which organize the parameterization of the device and (3) communication functions. The right side of Fig 3 shows an abstract view to these three aspects which are: Visualization/operation, variable and functions as well as communication. A device description has to cover all three aspects to perform a suitable proxy.

In Automation there are a large range of device description technologies such as EDD, FDI, FDT, EDS, DDXML, IODD, FDCML and others more. The list should show that there are many device descriptions on the market which have potentialities to be used as kernel of I40 component proxies. In principle they are following a simple device model.

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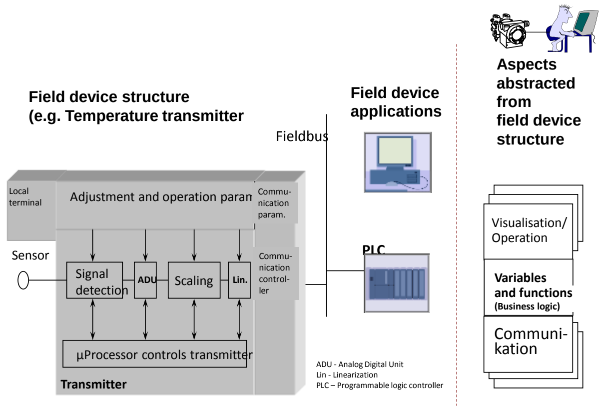


Fig 3: Abstraction of an AT device for device description

Today’s AT devices are embedded systems with connections to industrial communication systems. This means they consist of hardware and software. Based on this main assumption a general device model can be derived (see b) Fig 4). AT devices can be modular. The functions of the modules are represented abstract as so called “functional elements (FE)“ which are specialized in different communication systems as function blocks (FBs), objects or parameter lists. A device type specific range of interfaces to the process, for communication, for diagnosis, partly to local human panel is provided.

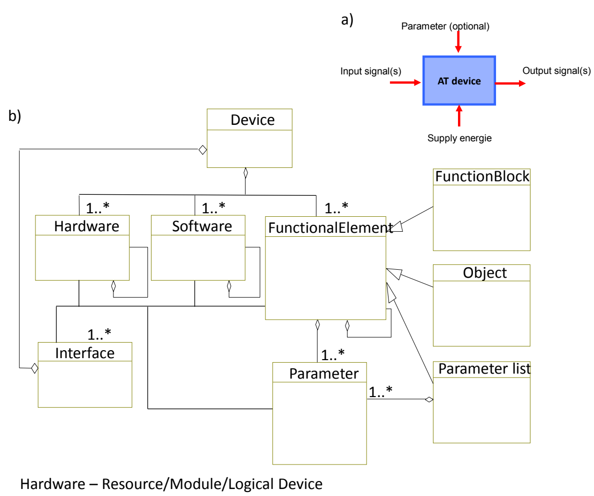


Fig 4: External view to an AT device and internal structure

This structure builds an essential part of the information model of the proxy. Each class has its attributes and operations which can be interacting with the physical device and the I40 communication interface.

For the entire range of application the model is much larger, it contains also the above mentioned information sets such as manuals, maintenance instructions, etc. This model was developed by Simon [12] which is partly published in [1]. For this paper we focus on a subset of the model.

The device description has to cover all mentioned aspects of the field devices. Taking EDDL, FDT and FDI as example: All three technologies provide all three aspects. Fig 5 shows that the three technologies implement the aspects in different ways. Respecting the limitation of a paper it is only mentioned that the variable and function aspects (also known as business logic) are represented within

- EDDL offering a range of language keywords such as VARIABLE, METHOD or relations
- A programmed FDT DTM
- The business logic portion of the FDI Device Package which is implemented by EDDL.

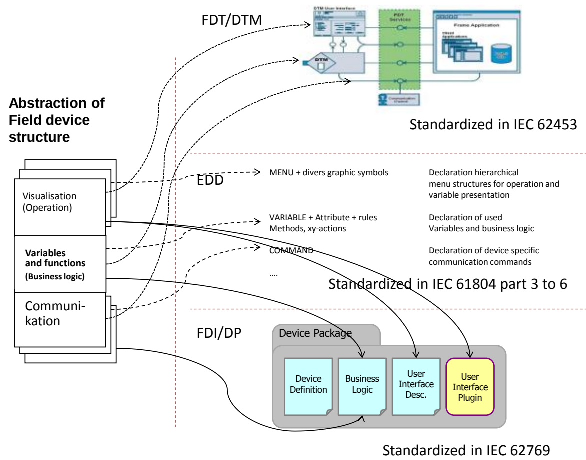


Fig 5: Mapping of device representation into structure elements of device descriptions

Going more in detail Fig 6 shows the structure of the FDI approach. A FDI server holds the catalogue of Device Packages of the connected field devices. The business logic portion of them is interpreted during active operation of the FDI server. The FDI host application accesses both the catalogue information and the results of the business logic interpretation. For the operator interface the visualization/operation information is either taken from the interface of the FDI host and/or using an User Interface plugin which is a part of the Device Package. The interface between the FDI server and host is driven by an information model which is fed by the catalogue and business details.

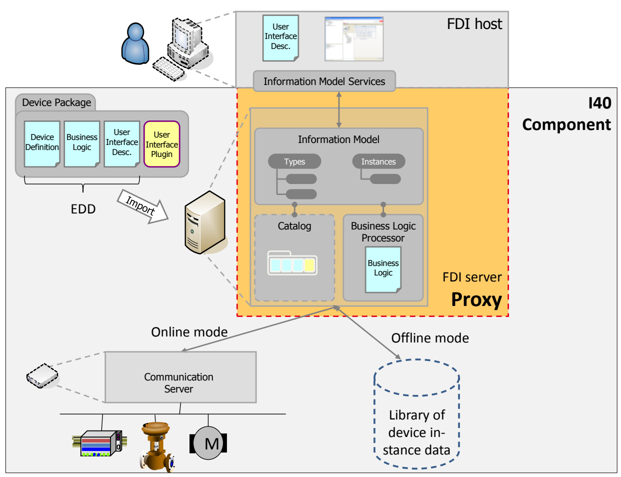


Fig 6: Online and offline mode of device description (example FDI)

This FDI server (as well as a FDT DTM) can be located somewhere in the automation system. The prerequisite is that there is a communication access to the field device. It is possible that there is a hierarchy of communication systems. Additionally, the FDI server holds an own (local) copy of the instance data of the field devices. This makes it possible that interactions with the FDI server can be carried out with connected field devices (online mode) or without connections (offline mode). This is a very important feature because the parameterization of a field device can be done without access to the device e.g. in the shop floor office or at engineering offices. The library of the instance data of each individual device is reduced to a download during commissioning. This shortens the commissioning time within the plant.

To conclude this clause: AT devices provide a technology which provide a detailed proxy which can be used online and offline to do all operation and engineering tasks with them.

## 4. Mechanical Aspects

In general such an AT device, often also called mechatronic device, consists of three main parts, which are the mechanics, the electronics as well as the informatics (see Fig 7). Up to now, only the electrics and the informatics of I40 components were taken into account while thinking of the representation of automation devices. However, it is quite obvious that every AT device also has a mechanical construction. Furthermore this mechanical construction influences the behavior of the AT device. If, for example, an electrical drive has anything mounted on its shaft, the set of parameters needed to run it with the same properties as before has to be changed and therefore also its communication with other devices or applications might be different. Thus it is important to also describe the mechanical part of the I40 component within its proxy.

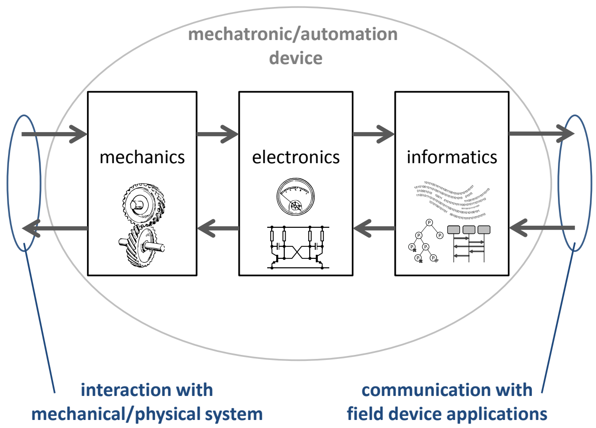


Fig 7: Structure of a mechatronic/automation device

The description of the mechanical part of an AT device usually takes place in a 3D CAD format. Since every CAD tool vendor has his own, proprietary data format for the CAD data, the usage of standardized formats is reasonable. Such formats for example are Collada, STEP or IGES. Not only the pure geometric information is stored in such formats but also its kinematics can be stored and different properties and features can be linked with the whole cad model or with sub-parts of it. In this way, a lot of important data for the I40 behavior like the weight and material of its mechanical parts, resulting forces and moments and further more can be stored machine readable.

What still is missing right now is the link between these mechanical parts of the component with its electronics and informatics. For this purpose, the device description has to be able to handle input from the mentioned CAD formats and has to take their properties and features into account while describing and/or simulating the behavior of the I40 components. This ensures that mechanical issues are considered within the proxy of an I40 component and that changes on the mechanical construction which have effects on the behavior of the whole AT device are not disregarded.

## 5. State of the Art

The use of device descriptions for AT devices is a well-accepted and established technology [1]. Reviewing the R&D publications it becomes visible that there seems to be no new requirements because it is not in the focus of research. The related standards [4], [5] and others are developed and integrate rather new features to describe and communicate device functions. An actually new feature is to offer the standardized OPC UA [6] interface for the device description. The information model of UPC UA provides the means of discovery and communication of meta data of the device description inside. So the device description can become the above introduced I40 component.

The proxy concept for automation is based on the software proxy design pattern [3]. It represents the structural design pattern in the range of creational and behavioral patterns. The main idea is that a client is not interacting with the real subject but with a deputy (i.e. the proxy) of this real subject. This is possible because the proxy provides the same interfaces as the real subject, see Fig 8.

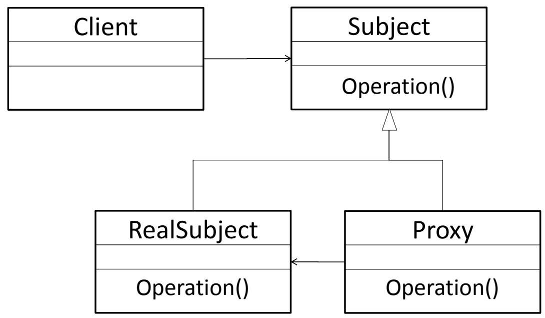


Fig 8: Software design pattern Proxy

A proxy is a functional unit which is acting in the data channel between the application and the AT device. The proxy undertakes the roles of the partner pairwise, i.e. the active role for the receiving partner and the passive part for the sending partner. For example in a client/server interaction the proxy is the server related to the client partner and the client for the server partner. This means that the client does not interact with the server directly. In general the proxy deputizes the function of the partner in terms of its interaction behavior. In our case the proxy is extended to integrate business logic functions inside to keep consistency of the variables and parameters of the device functions. The integration of AT devices into an IT oriented application concept is evaluated mainly through European projects such as [13], [7] and others. The approach is based on Service Oriented Architecture (SOA) integration [8]. The results are already integrated in the described I40 component approach. The OPC UA interface is newly available to the device description components. The mediator of these projects can therefore migrate to an I40 Component.

## 6. Integration of Devices into Applications

The application interacts with the I40 component. The I40 component has to provide an interface to the application. While the classic EDD technology doesn't provide a standardized interface to the application, FDT and FDI have specified it (Fig 9). FDI offers an OPC UA interface driven by the information model which maps the mentioned device model. FDT has specified the DTM interface as so called Application Framework. Actually an additional OPC UA interface is under specification. If we map the resulting architecture to the introduced layers it becomes obvious that the device description technology explained in this paper matches exactly to the CPS layer structure.

We are considering the following example: A new product variant of a measurement device needs a new sensor type. This means that the manufacturing systems, i.e. also the automation system have to be adopted. A new sensor type means a re-configuration of the measurement AT device. This can be organized with the I40 component of the device by changing the related parameters. Fig 10 shows a subset of the business logic expressed in EDDL. The key word VARIABLE represents one Parameter Class introduced in Figure 4. A new sensor type results in several adoptions for the transmitter. The example shows that there is a new linearization type (0 or not 0), a change of a calculation constant changes and the engineering unit which can be chosen by the operator have to change also. This is evaluated during run time of the proxy, e.g. within the FDI server.

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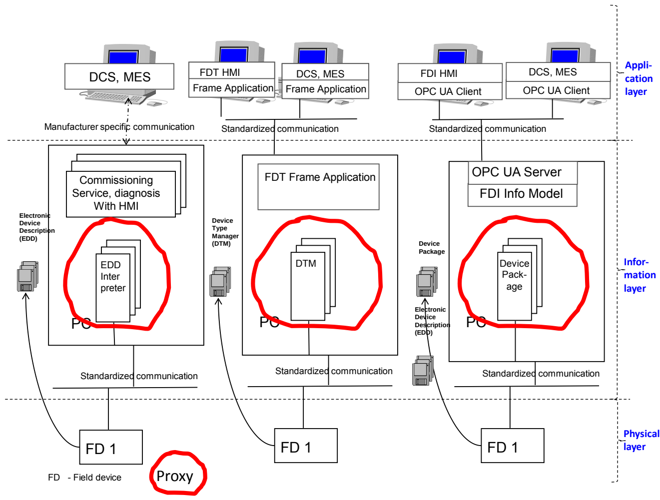


Fig 9: Integration of device descriptions into applications

```
VARIABLE trans1_primary_value_unit
{       LABEL                   [digital_units];
        HELP                    [digital_units_help];   /*  Text */
        CLASS                   CONTAINED;
        TYPE                    ENUMERATED (2)
        {
                { 1000,     [unit_1000],            [unit_1000_help]      }, /* K       */
                { 1001,     [unit_1001],            [unit_1001_help]      }, /* degC */
                { 1002,     [unit_1002],            [unit_1002_help]      }, /* degF */
                { 1003,     [unit_1003],            [unit_1003_help]      }  /* Rk */
                IF (trans1_lin_type == 0)
                {
                        { 1243,     [unit_1243],            [unit_1243_help]      }, /* mV */
                        { 1281,     [unit_1281],            [unit_1281_help]      }, /* Ohm */
                        { 1211,     [unit_1211],            [unit_1211_help]      }  /* mA */
                }
                DEFAULT_VALUE       IF (trans1_lin_type == 0)
                                    {
                                            1281;
                                    }
                                    ELSE
                                    {
                                            1001;
                                    }

        }
        HANDLINGREAD & WRITE;
} ...
```

Fig 10: Integration of device descriptions into applications

The reconfiguration of the manufacturing process can provide the main changes and the details of the device adaptation are executed within the proxy, first offline to check if this is possible and if so the instance data set can be downloaded to the device.

There are multiple opportunities to locate the proxies in the automation system (Fig 11). It can be in the components of the DCS such as supervisory station, engineering station or additional server stations where the digital images of the plant are stored. For performance reasons the interactions between the higher level applications and the real time one should be in different communication segments. One I40 component of a CPS is then a unit composed of the AT device, communication system and Proxy location.

Up to know the paper has focused on field devices. It has covered the first three types of changes which are introduced in chapter 1 using the AT device I40 component. There is an additional need to access to controller, supervisory stations or even parts of the plant in a similar model. A mapping of IEC 61131-3 to the information model of OPC UA [10] and [11] is already available. This could be a basic for a CPS I40 controller component. The possible range of applications has to be evaluated in future works.

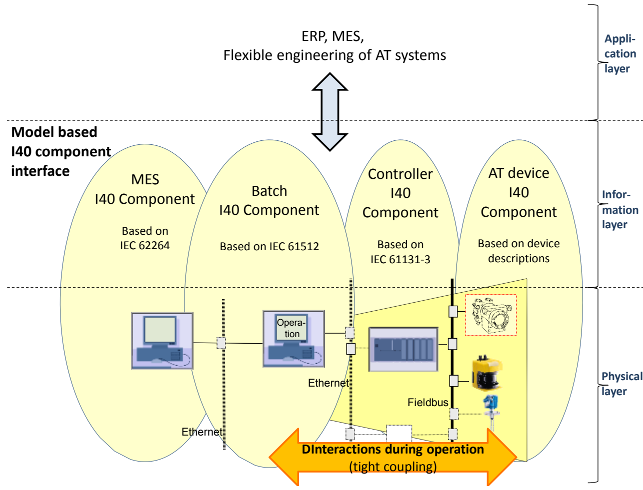


Fig 11: Integration of device descriptions into applications

## 7. Summary

Flexibility of production systems needs an increasing amount of information. This has to be available during the operation and adaptation time of the plant and automation system. The components become part of a Cyber Physical System (CPS). I40 Components can build the bricks for these CPS. It is shown that the device descriptions are essential elements of the I40 device component. It offers means to identify re-configure and change parameters in a consistent way. Planning activities can be organized directly with information accessible in the plant.

Today's device descriptions are used for commissioning and diagnosis applications only. The last updates of the FDI and FDT specifications offer an OPC UA interface with an integrated information model. The papers show how the device description builds the proxy of an I40 component and how information of the AT device model comes in the OPC UA information interface. Applications can interact for parameterization and configuration in offline and online mode. Re-configuration can be evaluated first offline and downloaded then after. This shortens the time for re-organization of the automation system.

The other components in the automation system need also means for reconfiguration. This has to be evaluated in future works.

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