The Asset Administration Shell of Operator in the Platform of Industry 4.0

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Proceedings of the 2018 18th International Conference on Mechatronics – Mechatronika (ME) 2018, pp. 559-563

eISBN: 978-80-214-5543-6

Accepted manuscript

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***Abstract*—We discuss the Asset Administration Shell (AAS) concept of Industry 4.0 (I4.0), characterizing the current status of industrial automation and outlining the advantages of more deeply digitized manufacturing where the AAS is employed. In the proposed analysis, the basic subjects are apply complemented with possible submodels and standards of the Asset Administration Shell (identification, communication, engineering, configuration, safety, security, life cycle status, energy efficiency, condition monitoring, and examples of AAS-based applications). An exemplary interaction pattern directed towards the domain, or specific submodels in the AAS, is also introduced in the given context. Further, the authors propose a specific digital example of an operator using a smart jacket.**

Keywords—asset administration shell, industry 4.0, MQTT, OPC UA, RAMI 4.0

I. Introduction

In the European interpretation, the Internet of Things (IoT) is segmented into the CIoT (Commercial Internet of Things) and the IIoT (Industrial Internet of Things). The CIoT abbreviation is not used frequently, and the IoT represents the Internet of all things. In American technical terminology, however, the IoT covers the entire set of concepts subsumed under Industry 4.0 (I4.0) within the European approach.

The most significant recent achievement has been materialized through the European-made definition of the Asset Administration Shell (AAS) chapter of I4.0. The AAS is an item that stands out among all the Industry 4.0 notions: it creates an interface between the physical and the virtual production steps, embodying a virtual digital and active representation of an I4.0 component in the I4.0 system.

The Industry 4.0 component is a model for describing in more detail the properties of cyber-physical systems, namely, real objects in a production environment networked with virtual objects and processes. Hardware and software components in production environments, from production systems and machines to internal machine modules, become Industry 4.0-capable by satisfying such properties [1].

The authors acknowledge financial support from the Technology Agency of the Czech Republic (TF04000074 - Digital Representation of Assets as a Configurable AAS for OT and IT Production Systems) The research was also supported by the Ministry of Education, Youth and Sports under project No. CZ.02.2.69/0.0/0.0/16_027/0008371 - "International mobility of researchers at the Brno University of Technology".

Any production component in the I4.0 environment has to have an administration shell. The structure of the AAS is then expected to satisfy the requirements of different production aspects and has to enable the functionality of I4.0 components from all basic perspectives, including the market, construction, power, function, positioning, security, communication ability, and understandability domains.

This article characterizes the basic structure and properties of the AAS, aiming to outline the benefits of the AAS together with the differences between the current state of things (things) and things with the AAS.

II. Models of Industry 4.0

The fundamental model of I4.0 exploits RAMI 4.0 (the Reference Architecture Model Industry 4.0, Fig. 1), a tool designed by the BITCOM, VDMA, and ZVEI corporations and associations. These subjects decided to develop a 3D model to represent all the diverse manually interconnected features of the technico-economic properties. The SGAM model (the Smart Grid Architecture Model), formed to foster communication in renewable energy sources' networks, appeared to embody an appropriate model for Industry 4.0 applications as well [2-3]. As a matter of fact, RAMI 4.0 is actually a small modification of the SGAM framework [4-6].

As both the SGAM and the RAMI 4.0 bodies are entered into by approximately fifteen industrial branches, RAMI 4.0 is structured to facilitate being viewed from different perspectives and aspects. The layers in the vertical axis thus represent the various viewpoints associated with the individual aspects (those of the relevant market, functions, information, communication, and integration abilities of the components) [7,8].

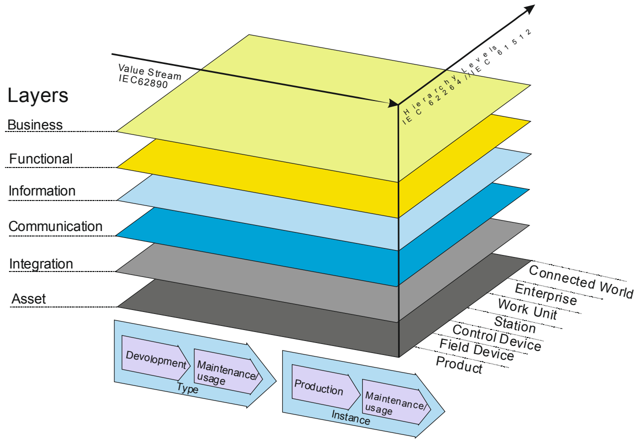

Fig. 1. The RAMI 4.0 model [5], inspired by ZVEI, VDI/VDE [1].

In modern engineering, a very important criterion consists jointly in product life cycle and the related value stream. The feature is displayed on the left-hand horizontal axis in the above image. The set of items expressed comprises, for example, constant data acquisition throughout the entire life cycle. By extension, even with a completely digitized development cycle, the market chain still offers a large potential for improving the products, machines, and other layers of the I4.0 architecture. This viewpoint matches well the IEC 62890 draft standard.

The other corresponding model axis (the right-hand one at the horizontal level) indicates the positions of component functions in I4.0, defining and assigning the functionalities involved. The axis respects the IEC 6224 and 61512 standards; however, these are intended for the specification of components at positions applicable to one enterprise or manufacturing unit only. Thus, the highest level on the right-hand horizontal axis is the connected environment.

A second essential model for the purposes of I4.0, developed by BITCOM, VDMA, and ZVEI last year, is the I4.0 components model (Fig. 2).

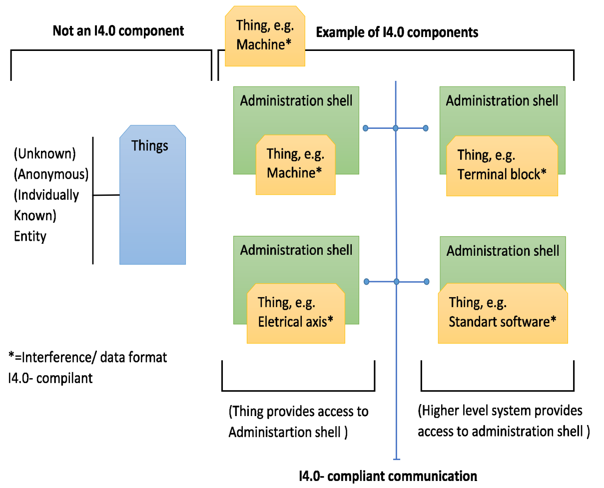

Fig. 2. The Asset Administration Shell [6], inspirated by VDI/VDE [9].

This framework is intended to help producers and system integrators to create HW and SW components for I4.0, and it embodies the first and only (as of July 2016) specific model based on RAMI 4.0. Significantly, the concept allows refined description of relevant cyber-physical features and enables us to characterize the communication between virtual and cyber-physical objects and processes [9], [10]. Within manufacturing of the future, the HW and SW components will be capable of executing the requested tasks by means of the implemented features specified in the I4.0 components model.

The most critical feature in the discussed context is the ability of the virtual objects and processes to communicate with their real counterparts during manufacturing; this model then specifies the conforming communication. The corresponding physical realization rests in that a component of the I4.0 system utilizes an electronic container (shell) of secured data during the entire life cycle; the data are available to all entities of the technical production chain. The model therefore arises from the standardized, secure, and safe real-time communication of all components in the production cycle. The electronic data container (shell) and the global Industry 4.0 component model are visualized in Fig. 3, which also displays a diagram of the AAS as a crucial I4.0 component (Fig. 3).

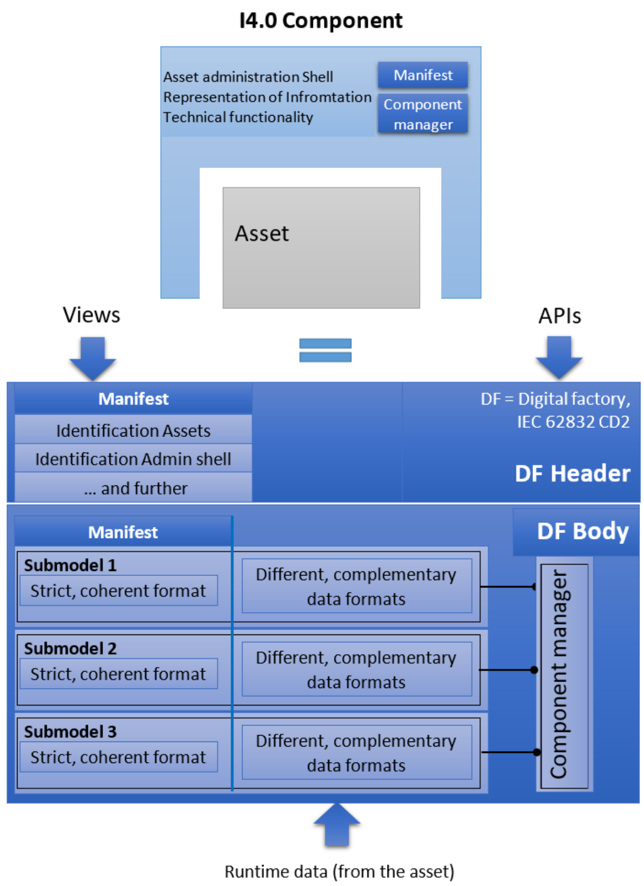

Fig. 3. The Asset Administration Shell, inspirated by [9].

III. Asset Administration Shell

The AAS creates an interface between the physical and virtual production steps; the framework is the virtual digital and active representation of an I4.0 component in the I4.0 system, more information you can find in literature [1] and [5].

As already pointed out above, any production component n the I4.0 environment needs an administration shell. The structure of the AAS is then expected to satisfy the requirements of different production aspects and has to enable the functionality of I4.0 components from all basic perspectives, including the market, construction, power, function, positioning, security, communication ability, and understandability domains.

The AAS is composed of a body and a header; the header contains identifying details regarding the asset administration shell and the represented asset, while the body comprises a certain number of submodels for an asset-specific characterization of the asset administration shell.

As is obvious from Fig. 3, the AAS accommodates a series of submodels. These represent different aspects of the asset concerned; thus, for example, they may contain a description relating to the safety or security but also could outline various process capabilities, such as drilling or installation. Possible submodels of the AAS are indicated in Fig. 4.

Generally, the aim is to standardize only one submodel for each aspect. Such a scenario will enable us to search for, e.g., a welding machine via seeking the AAS containing “welding” with relevant properties. A second submodel in the example, e.g., “energy efficiency”, could ensure that the welding station will save electricity when idling.

Each submodel contains a structured quantity of properties which can refer to data and functions. A standardized format based on the IEC 61360 is required for the properties; the data and functions may be available in various complementary formats.

Administration Shell IEC TR 62794 & IEC 62832 Digital factory	
Submodels	**Standards**
Identification	ISO 29005 or URI unique ID
Communication	IEC 61784 Fieldbus profiles
Engineering	IEC 61360/ISO13584 Standard data elem.; IEC 61987 Data structures and elements; Ecl@ss database with product classes
Configuration	IEC 61804 EDDL; IEC 62453 FDT
Safety (SIL)	EN ISO 13849; EN/IEC 61508 Functional safety discrete; EN/IEC 61511 Functional safety process; EN/IEC 62061 Safety of machinery
Security	IEC 62443 Network and system security
Lifecycle status	IEC 62890 Lifecycle
Energy Efficiency	ISO/IEC 20140-5
Condition monitoring	VDMA 24582 Condition monitoring
Examples of AAS usage	Drilling, Milling, Deep drawing, Clamping, Welding, Painting, Mounting, Inspecting, Printing, Validating …

Fig. 4. Possible AAS submodels, inspirated by [11].

The properties of all the submodels therefore result in a constantly readable directory of the key information, or, by another definition, the manifest of the asset administration shell and thus also of the I4.0 components. To enable binding semantics, the asset administration shells, assets, submodels, and properties must be clearly identified. The permitted global identifiers are the ISO 29002 – 5 (e.g., eCl@ss and the IEC Common Data Dictionary) and URIs (Unique Resource Identifiers, e.g., for ontologies).

Figure 5 shows how an interaction pattern is directed towards the domain-specific submodels in the asset administration shell; the process is illustrated on a possible example from a discrete manufacturing procedure.

As regards the language for I4.0, Fig. 6 presents an approach to the item from the sub-working standardization group [5].

In a component of I4.0, such purposes are facilitated by the interaction manager, the tool responsible for the processing of the interaction patterns in the network. A domain-independent basic ontology then safeguards the connection with the domain-specific submodels in the AAS.

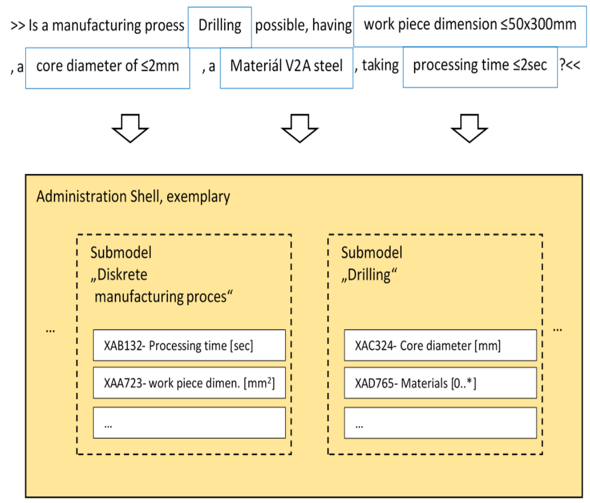

Fig. 5. An interaction pattern directed towards the domain-specific submodels in the AAS, inspirated by ZVEI [5].

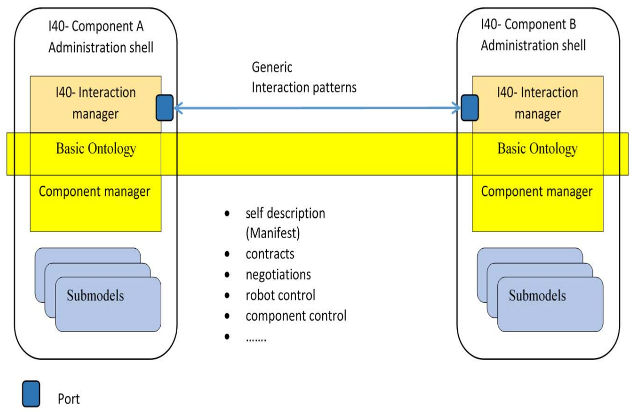

Fig. 6. An approach to the topic “Languages of I4.0” (Source: prof. Diedrich, Platform Industrie 4.0 Working Group 1, Ontology Sub-Working Group).

IV. Operator Asset Administration Shell

As mentioned earlier, every production element (e.g., a product, a machine, or control systems) has its own AAS in the context of I4.0. The question, however, is how to implement an operator AAS.

In this paper, we use the example of an operator AAS represented by a Human-Machine Interface (HMI); for demonstration purposes, we also attached a smart-jacket to this AAS. Figure 7 shows the block diagram of an operator AAS and the communication interface with other AASs in a manufacturing process.

The HMI includes information about the operator and also values from the smart jacket sensors. A major component of the AAS, then, is the NodeRED programming tool, which can run on, for example, a Raspberry PI. NodeRED comprises three significant elements: a) an OPC UA bridge to facilitate data conversion from string or MQTT messages into an OPC UA message ; b) an OPC UA client to communicate information to other AASs, such as an AAS or MES service and transport units, in the production area; and c) an OPC UA server to receive information for visualizing the Graphical User Interface (GUI).

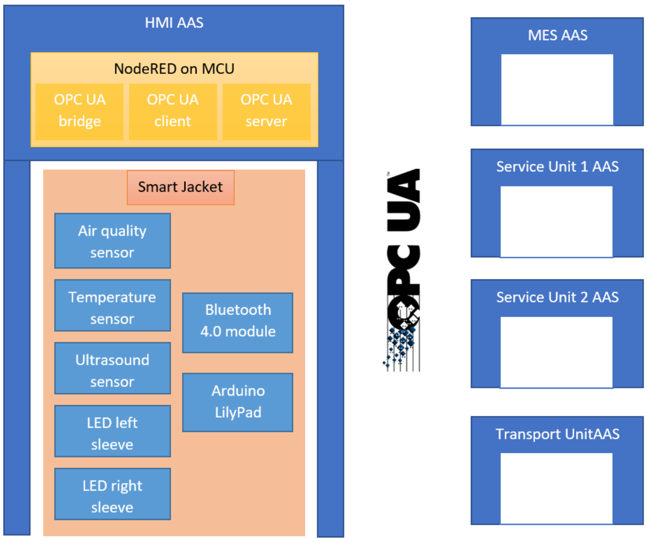

Fig. 7. A smart jacket operator represented via an HMI.

A. *Properties of the Smart Jacket*

Based on the scenario and intention to control and monitor important industrial parameters at a shop floor, the smart maintenance jacket is integrated with a use case. To preserve worker or operator safety on the industry shop floor, the item is configured with an Arduino LilyPad and sensors (Fig. 8), [12] and [13]. The primary functionality and components of the jacket are explained below.

The central part of the smart maintenance Jacket consists in an Arduino Lilypad with a SparkFun bluetooth module (BlueSMiRF). The Lilypad is suitable for smart wearable things (e-textile projects) because of its size and weight. The Lilypad model configured in the jacket utilizes an ATmega168 microcontroller, which has 14 analog and digital I/Os.

The BlueSMiRF is the latest Bluetooth 4 wireless serial cable replacement by SparkFun Electronics. The modems work as a serial (RX/TX) pipe: any serial stream from 2,400 to 115,200bps can be passed seamlessly from our Arduino.

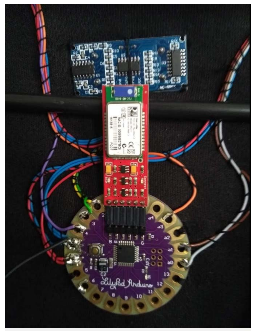

Fig. 8. An Arduino LilyPad with a bluetooth and an ultrasonic modules.

An MQ-135 air quality sensor (Fig. 9) detects NH_3, NO_x, alcohol, benzene, smoke, or CO_2 and ensures air quality analysis. This sensor is then configured with the smart maintenance jacket, with the aim to prevent breathing at a polluted area or processing plant.

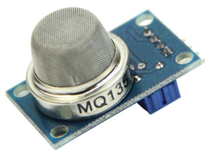

Fig. 9. An MQ-135 air quality sensor.

Figure 10 (left) shows an HC-SR-04 ultrasonic sensor. This small module is a cheap solution to measure distance up to 4-5 meters via ultrasound.

In order to avoid hazardous situations at the shop floor (heavy manufacturing plants), this ultrasonic sensor warns the bearer quickly with a buzzer located at the back side of the jacket neck.

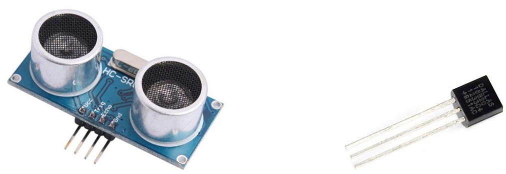

Fig. 10. Left: an HC-SR-04 ultrasonic sensor; right: a DS18B20 1-wire temperature sensor.

For the temperature measurement, we used a DS18B20 1-Wire digital temperature sensor by Maxim IC, Fig. 10 (right). The device reports degrees in Celsius between -55°C and 125°C at 9 to 12-bit precision, with a resolution of ±0.5°C. Each sensor has a unique 64-bit serial number etched into its body; this allows a large number of sensors to be used on one data bus.

The smart jacket contains an RGB LED strip (five diodes) on the left and right sleeves. If the MQ-135 sensor recognizes impaired air quality, the operator's right sleeve flashes yellow. If distance sensor detects a problem nearby, both sleeves blink red and the buzzer produces an intermittent tone. Similarly, if a fault in the manufacturing process is found, the left sleeve will flash red and the right one green. The operator then identifies the GUI where the malfunction occurred.

B. NodeRED on an MCU

Figure 11 displays a block diagram representing the algorithms implemented in the NodeRED programming environment.

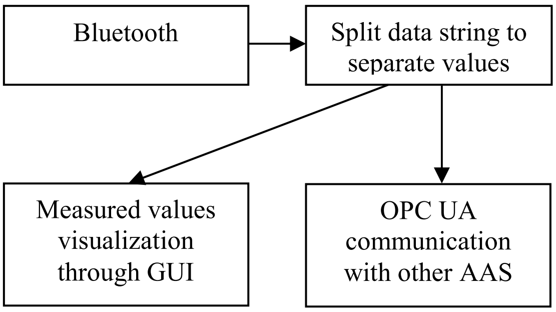

Fig. 11. A DS18B20 1-wire temperature sensor.

The serial data are received via a Bluetooth module. We obtain one string consisting of the temperature value, distance value, and air quality. The next step is to split the data into separate variables to be publishable via the GUI. Figure 12 presents the current and daily data of the measured values in charts. In addition to the actual visualization, the measured data can be sent to the OPC UA server [14]. To execute this operation, we use the node OPC UA IIoT Write.

The Write node facilitates sending the data to the OPC UA server: It handles single and multiple data requests. All *write* requests will produce an array of StatusCodes for writing in the server.

Fig. 12. The Graphical User Interface: the value measured by the smart jacket.

V. Conclusion

The article summarizes the basics of the Asset Administration Shell and its application in I4.0. In this context, the frameworks of the Industry 4.0 component model and the Asset Administration Shell are demonstrated as the key factors to allow the interconnection of individual production components. The related bidding and quotation processes, together with the communication between two assets, are exemplified in Fig. 4. The German approach to developing and implementing I4.0 principles into different case studies is employed throughout the presentation. In chapter IV, an AAS suitable for an operator wearing a smart jacket serviced via an HMI is characterized, together with the relevant implementation. The measured values in Fig. 12 are displayed through the GUI.

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