Asset Administration Shell Modelling and Implementation Enabling Plug and Produce Capabilities for Modular Production

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Abstract. Mass customization approach requires low-volume, high-mix production schemes, leading to the creation and industrial uptake of highly flexible and modular production lines capable of processing a wide range of products. Towards that end, flexibility of reconfiguration and responsiveness of production plants needs to be increased. Digital technologies can make a significant contribution in making production systems more flexible for modular production. Reconfigurability and interoperability between automated industrial systems and Cyber Physical Systems (CPS) can be achieved by implementing a Digital Twin based on Asset Administration Shell (AAS) and formal definitions found in the I4.0, IIoT and IDTA standards. The AAS modelling containing a machine-readable, semantically unambiguous self-description metamodels needs to be supported by a software infrastructure capable to orchestrate the different assets. This paper presents an implementation of AAS modelling based on the relation of the main production assets –Product, Process and Resources (PPR model)– allowing the dynamic creation of process chains and reconfigurations, as well as up-to-date virtual representation of the Product by deploying a Digital Thread able to trace and orchestrate the data generated along the product lifecycle.

Keywords: Asset Administration Shell · Plug and Produce · modular production

1 Introduction

With a growing demand for customized products tailored to customer demands, manufacturing industries need to develop innovative strategies towards mass customization [1], which leads to adoption of modular solutions capable of processing a wide range of products. Towards that end, flexibility of reconfiguration and responsiveness of production lines need to be increased. This reconfiguration leads to the implementation of Plug and Produce (PnP) concept in manufacturing, which requires an infrastructure based on a service-oriented-architecture (SoA), enabling the digitalization and integration of manufacturing resources on the IoT as adaptive, secure and on demand services, leading on a vertically and horizontally integrated manufacturing ecosystem [2] with minimal

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manual intervention. The PnP concept is accomplished by bringing existing production modules to current standards containing a machine-readable, semantically unambiguous self-description of their properties and capabilities by encapsulating the production models and the different assets as Industry 4.0 components, i.e. the asset and their Asset Administration Shell (AAS) [3].

The concept of the Asset Administration Shell has originally been defined by RAMI4.0 and its specification standardized by Platform Industrie 4.0 [5]. The AAS is the model with the highest degree of maturity for mapping product and process information across the entire lifecycle of industrial goods [6] and is the standardized self-description of a technical component in production [7]. But there is a lack of formal standardization when implementing AAS regarding standards and technologies, as well as the need to address the semantic interoperability between assets [8]. This lack of stablished AAS models increases when it comes to immaterial and non-machine assets [9] (e.g., process or the product). Moreover, all the steps for AAS modelling must be carried out manually requiring intensive programming [10]. For that, in the literature can be found some software implementations for production management [11] that allows an AAS to be formed in a user-friendly manner, especially as regards the specifications of the AAS modelling utilizing relevant standards.

In this paper a methodology to create and deploy Asset Administration Shells in a modular scheme production is presented using as demonstrator one of the production modules of H2020-DIMOFAC project [4]. A methodology for AAS modelling of non-physical assets as well as the relation with the production assets is presented. The modelling of all involved assets in the product lifecycle, as well as its relations, not only allows orchestration of the production systems but also the traceability of the product lifecycle resulting on an implementation of a Digital Thread. The paper is organized as follows: in Sect. 2, a brief overview on the methodology for AAS modelling is presented. Section 3 presents a proposal of Asset Administration Shell implementation and modelling. Lastly in Sect. 4 some conclusions and future work are introduced.

2 Methodology: Product-Process-Resources Model

For Industry 4.0, an asset is any object which has a value for an organization and can take almost any form, i.e., a production system, a product, a software or even human resources, and can be a single component but also an assembly of components [12]. The asset's information is described in the AAS as *Submodels* [13] and describes technical functionality exposed by the Administration Shell or respective assets [14]. Below the submodel level, there are the submodel elements for storing specific data related to the submodel.

Taking in consideration the description of the 3 types of AAS [7], in type 2 and 3, the AAS is composed of a passive and active part. The passive part composed by properties which are readable and/or modifiable. On the other hand, the active part consists of functions performed by the asset and the AAS, providing service-oriented communication *capabilities* and decision-making functionalities [15]. This active part is mainly represented by the specific submodels: *Capabilities* and *Skills*. Although the AAS meta-model provides a generic approach of modelling, the definition and standardization of the implemented submodels is essential for interoperability. This is part of Industrial Digital Twin Association (IDTA) [16] and ZVEI SG [14] provides a list of potential common submodels: *Identification*, *TechnicalData*, *ConfigurationData*, *OperationalData*. But the definition of specific submodels for describing the capabilities offered by the asset depends on the granularity of the model, level of abstraction and the use case [17].

For Platform Industrie 4.0 the functions performed by an asset can be seen as some kind of abstract process step that is not yet tied to a specific resource but has a description of its inputs and achievable effects. These effects typically have an impact on the processing state of products [18]. The resulting conceptual model of the asset with its functions is an extension of the well-established Product-Process-Resources (PPR) representation paradigm extended by the notions of capability and skill [19]. The definition of the interconnection of the three views allows the dynamic creation of process chains and reconfigurations. This paper presents the AAS modelling of the Product, Process and Resources and how the relations between these assets allows the reconfigurability of the production line as well as the traceability of the product by demonstrating a Digital Thread. Figure 1 shows the dataflow needed to carry out the orchestration of the production systems: first, the product AAS includes the process needed for the manufacturing; secondly, for the execution of the process some capabilities are needed; then, an orchestrator will search for the resources that have these capabilities. Finally, the resources are linked to the product for having traceability of its manufacturing.

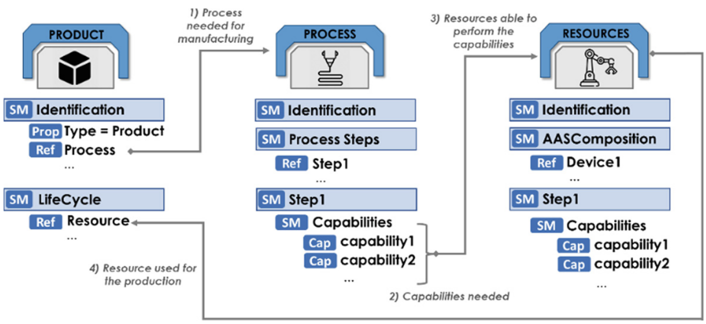

Fig. 1. AAS modelling methodology based on Product-Process-Resources (PPR) model.

3 Implementation of Asset Administration Shell for Achieving PnP Capabilities

The Industry 4.0 components' lifecycle is supported by a digital infrastructure that is able to support real-time connectivity (e.g., based on OPC UA or MQTT) and basic data storage, monitoring and security enabling a horizontal integration. For that, the work presented is based on the digital *DIMOFAC Platform* developed by Netcompany-Intrasoft developed under DIMOFAC project. The selected use case to apply the AAS approach is one of the production modules of DIMOFAC that focus on a multi-material component manufacturing by Automated Tape Laying (ATL) process.

3.1 Architecture Definition and Assets Identification

The first step for implementing AAS is the identification of the different assets [20], the architecture and communication protocols that could or will be used. This ATL module is composed by a movement system (FANUC robot) and heat system (ATL head), which can be composed by infra-red system or laser source. The whole module will be represented by a central unit (i.e., industrial PC). The information gathered by the central unit (Operation Technology) is available in the DIMOFAC platform (Information Technology) as well as the product information related to the design and/or simulation (Engineering Technology). The software in charge of taking the decisions and allowing PnP capabilities is named *Orchestrator*. While the software in charge of registering all the information related with a specific product is the *Digital Thread*. Figure 2 depicts the aforementioned considerations.

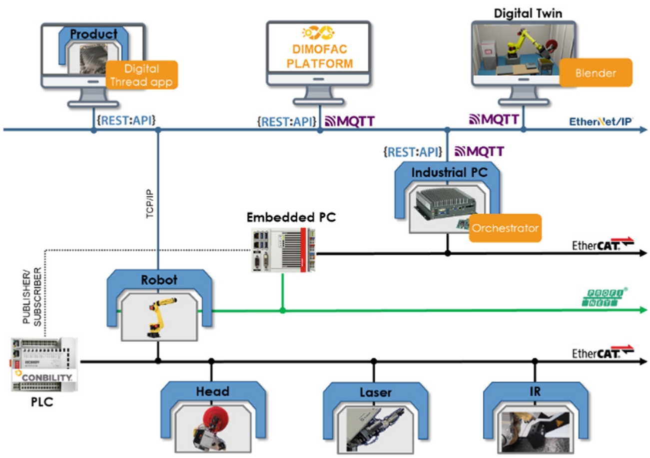

Fig. 2. Assets identification and architecture.

3.2 AAS Modelling

Resources Modelling. The type 2 assets modelled for this use case are the robot, heating system, whereas the type 3 is the *Orchestrator* software. All type 2 AAS follows the same modelling methodology, containing the same submodels, but with different property values. The submodels will be presented taking the robot (without tooling) as example; but for a comprehensive reading the AASx file are also available in Zenodo (link) [21]:

- *Identification* and *TechnicalData*: submodels to identify the physical asset with static information.
- *Capabilities*: this submodel specify the tasks that the asset is able to perform. For instance, the robot AAS *moves* to perform the process and *communicates* for the process monitoring.

- *Communicate*: specify the communication protocol and it has a relation with a specific submodel ConfigurationEthernet in which the details for this communication are specifies. For instance, the IP, port and data format.
- *OperationalData*: is one of the common submodels defined by Platform I4.0 and it defines the output data of the asset. This data will be sent to DIMOFAC platform and updated in real-time. The values are considered data in motion.
- *Parameters*: defines the data needed for performing the capabilities. In the robot example, the reference system and the Tool Centre Point (TCP) information.
- *AASComposition:* the whole manufacturing cell/module is represented by the AAS of the module. In this AAS, the main submodel is the *AASComposition* that specify the assets that compound the module (i.e., robot and heating system). The *Capabilities* are inherited from the assets that compound the module.

Product and Process Modelling. These assets are needed for linking the information gathered in the shopfloor with the data coming from other production steps (i.e., design, simulation, quality). The *Product AAS* is created using the *Digital Thread* application and the main submodel is the *LifeCycle* which references the physical assets used for manufacturing the product. On the other hand, for *Process AAS* the main submodels are the *ProcessSteps* (i.e., additive manufacturing, cutting, …) and the *Capabilities* needed for executing a specific step. The *Process AAS* information is managed by the *Orchestrator* and it will be used for searching the physical assets needed for the manufacturing.

3.3 Hardware and Software PnP Capabilities: Orchestrator Overview

The *Orchestrator* and the *Digital Thread* software are the responsibles of managing the AAS information in a user-friendly manner. That software were developed based on PyI40AAS [22] libraries to manage AAS models. The Digital Thread is used for visualize the product lifecycle information, whereas the Orchestrator decides what physical assets are available, start the communication with different devices, and it is also able to decide the assets/modules needed for manufacturing a product.

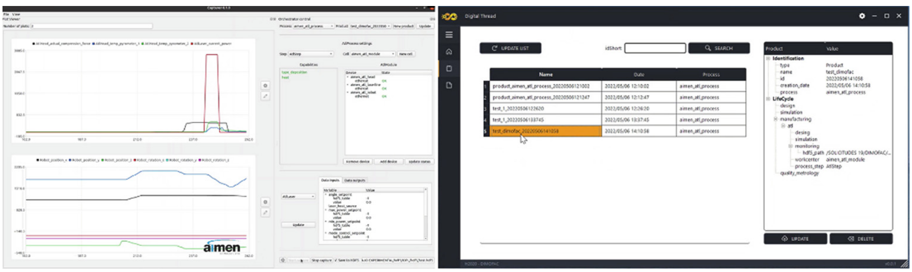

Fig. 3. Software user interfaces (Left: Orchestrator, right: Digital Thread)

Figure 3 shows the interfaces of these software, but a demonstration is shown in a video [23]. Whereas Fig. 4 shows the sequence and interaction that the user has to do with the different software. The user starts with the creation of a product using the *Digital Thread* application selecting the processes needed for the manufacturing. Then, for starting the manufacturing, the user selects from a list the specific product to be manufactured, and the *Orchestrator* checks the modules available for this manufacturing. During manufacturing, the user can also see real time information of the different assets. Once the manufacturing finished, the user could check in the Digital Thread application that the information related to the manufacturing is automatically linked with the product previously selected.

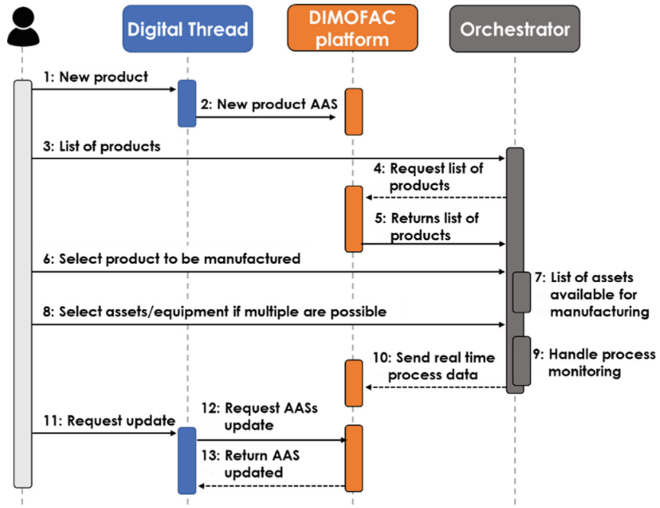

Fig. 4. Dataflow scheme between user, Digital Thread, Digital Platform and Orchestrator.

For hardware PnP capability, the *Orchestrator* will try to stablish the communication with the physical assets that compound the module checking the *AASComposition* submodel. For each asset, the software will take the configuration specified in the Submodel *Communication* and execute the corresponding method with the attributes specified in the submodel. If the asset is not physically connected to the central unit, the software will not allow start the production. Whereas for software PnP capabilities, the *Orchestrator* makes the decision of what module is needed for manufacturing a specific product. The *Product AAS* has a reference to the processes that need to be performed as it was shown in Fig. 1 (i.e., *aimen_atl_process*). Then, the *Orchestrator* will search into the different processes available in DIMOFAC platform the capabilities needed for executing the process (i.e., *tape_deposition* and *heat*), and the module that can perform these specific capabilities (i.e., *AtlModule*). Finally, the Orchestrator starts the communication with the individual assets.

4 Conclusions and Future Work

A video was published (link) [23] to show an overview of the work presented. A practical AAS-enabled PnP implementation using standardized technologies was presented and some AAS models were uploaded in the open repository Zenodo [21]. Some of the main results of the implementation process can be summarized as follows:

- Thanks to the PPR AAS model the information related to a specific product along the entire value chain can be traced implementing a Digital Thread. The Product AAS can be used for implementing a Digital Thread application and it can be the base for a Digital Product Passport implementation.
- The orchestration of the different physical assets for enabling a PnP solution is done through the definition of specific submodels that nowadays are not standardized (i.e., *Communication* of the assets). Some examples can be found in Zenodo.
- Specific use case implementations can be found in the literature, but the PnP system and the software presented in this work is process- and product- independent, so it could be applicable and deployed in another use case. Nowadays, this work is being deployed and tested in different manufacturing domains for checking the interoperability of the AAS models and the benefits of the PPR model.

Future work will focus on the update of the different AAS models according to the new templates provided by IDTA; so, the final solution is compliant with the standard and interoperable with the production systems that are digitized through the implementation of AAS. A further step will be to add artificial intelligence to AASs, which will allow the orchestration of different production lines and minimize human intervention in the decision-making [24]. For instance, not only the decision-making is based on the availability of the assets, but also taking in consideration some sustainable and circularity indicators.

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References

1. Deloitte, The Deloitte Consumer Review – Made-to-order: The rise of mass personalization. https://www2.deloitte.com/. Accessed17 Feb 2023
2. Moghaddam, M.: Reference architectures for smart manufacturing: a critical review. J. Manufact. Syst. (49), 15–225 (2018). IEEE
3. Wagner, C.: The role of the Industry 4.0 asset administration shell and the digital twin during the life cycle of a plant. In: 22nd IEEE International Conference on Emerging Technologies and Factory Automation 2017, ETFA, pp. 1–8 (2017)
4. CORDIS, Digital Intelligent MOdular FACtories. https://cordis.europa.eu/
5. GMA VDI/VDE Society Measurement and Automatic Control. https://ilag.net/en/. Accessed 17 Feb 2023
6. ECLIPSE, Mission Digital Twin - Asset Administration Shell (AAS) realized by Open Source. https://www.eclipsecon.org/. Accessed 17 Feb 2023

7. ECLIPSE FOUNDATION, BaSyx Documentation Asset Administration Shell. https://wiki.eclipse.org/. Accessed 17 Feb 2023
8. Beden, S., Cao, Q., Beckmann, A.: Semantic asset administration shells in Industry 4.0: a survey. In: 4th IEEE International Conference on Industrial Cyber-Physical Systems, ICPS, pp. 31–38. IEEE (2021)
9. Bouter, C., Pourjafarian, M., Simar, L., Wilterdink, R.: Towards a comprehensive methodology for modelling submodels in the industry 4.0 asset administration shell. In: IEEE 23rd Conference on Business Informatics, CBI, vol. 2, pp. 10–19. IEEE (2021)
10. Arm, J., et al.: Automated design and integration of asset administration shells in components of industry 4.0. Sensors **21**, 2004 (2021)
11. Ye, X., Hong, S.H., Song, W.S., Kim, Y.C., Zhang, X.: An industry 4.0 asset administration shell-enabled digital solution for robot-based manufacturing systems. IEEE Access **9**, 154448–154459 (2021)
12. Cavalieri, S., Mulé, S., Salafia, M.G.: OPC UA-based asset administration shell. In: ECON 2019-45th Annual Conference of the IEEE Industrial Electronics Society, vol. 1, pp. 2982–2989. IEEE (2019)
13. Cainelli, G.P., Underberg, L., Rauchhaupt, L., Pereira, C.E.: Asset administration shell submodel for wireless communication system. IFAC-PapersOnLine, pp. 120–125 (2022)
14. ZVEI, Details of the Asset Administration Shell - Part 1. https://www.zvei.org/. Accessed 17 Feb 2023
15. Cainelli, G., Rauchhaupt, L.: Introducing resilience in industrial 5G systems using digital twin approach. In: 17th IEEE International Conference on Factory Communication Systems, WFCS, pp. 33–36. IEEE (2021)
16. IDTA, Industrial Digital Twin Association. https://industrialdigitaltwin.org/en/. Accessed 17 Feb 2023
17. IDTA, Describing Capabilities of Industrie 4.0 Components. https://industrialdigitaltwin.org. Accessed 17 Feb 2023
18. Diedrich, C., et al.: Information Model for Capabilities, Skills & Services (2022)
19. Brecher, C., et al.: Multi-level modeling framework for machine as a service applications based on product process resource models. In: 2nd International Symposium on Computer Science and Intelligent Control, pp. 1–9 (2018)
20. Seif, A., Toro, C., Akhtar, H.: Implementing industry 4.0 asset administrative shells in mini factories. Proc. Comput. Sci. **159**, 495–504 (2019)
21. DIMOFAC Zenodo, PnP module: multi-material components manufacturing by Automated Tape Laying process. https://zenodo.org/record/7472031#.Y6RkrNWZPQD. Accessed 17 Feb 2023
22. PyI4AAS Python project. https://pypi.org/project/pyi40aas/. Accessed 17 Feb 2023
23. DIMOFAC YouTube, PnP module: multi-material components manufacturing by Automated Tape Laying process. https://www.youtube.com/watch?v=aOP6QWiF5FE&t=7s. Accessed 17 Feb 2023
24. Platform Industrie 4.0, Artificial intelligence in Industrie 4.0. https://www.plattform-i40.de/. Accessed 17 Feb 2023