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Asset Administration Shell: Enabling 5G network digital twins for industry integration

Charting the future of innovation

Asset Administration Shell: Enabling 5G network digital twins for industry integration

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To ease the adoption of 5G technology in industrial applications, Ericsson is exploring the use of tools and processes that are well known in the operational technology industry. Our research shows that the Asset Administration Shell is a tool with great potential to deliver seamless 5G network integration.

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The integration of 5G into future factories and information technology (IT) / operational technology (OT) processes presents an opportunity to establish an ecosystem that includes functionalities to address the various network requirements of smart manufacturing [1].

From an OT operator perspective, the industrial 5G network is understood as an enabler of improved efficiency and productivity. OT operators do not, however, want to focus on the internal structure of the network (NW) and management systems. To enable 5G integration and maximize the benefit for automation processes, the telecommunications industry must simplify the use of 5G for the OT industry and factory operators.

The Asset Administration Shell (AAS) is a widely adopted solution in the industrial domain that enables communication among heterogeneous systems and components within the Industry 4.0 (I4.0) architecture. Its digital-twin-like capabilities and the standardized communication mechanisms make it possible to create a virtual representation of the 5G system (5GS) and seamlessly integrate it into a large industrial ecosystem. The AAS can thereby serve as a proxy for the 5GS and a variety of other complex systems on the factory floor. AAS principles enable the implementation of the relevant interfaces and integration points, ensuring smooth integration at multiple layers.

The AAS can serve as an excellent tool for the OT systems to interface with the 5GS, without the need for OT-focused staff to build up competence in cellular networks. Process engineers and system integrators building OT automation systems can perform their jobs using their existing OT processes and tools with the help of the AAS. Translation to the telco-specific terms and technologies is done by the AAS, which relies on the network exposure application programming interfaces (APIs) of the 5GS.

5G integration into Industry 4.0

There are various complex systems and applications on a factory floor, with different vocabularies and interaction

INDUSTRY 4.0

I4.0 is a revolution in manufacturing that combines digitalization and advanced technologies to create the factories of the future. At its core, I4.0 utilizes digital technologies such as the Internet of Things (IoT), artificial intelligence (AI) and robotics to enable the seamless integration of physical and digital systems. I4.0 aims to enhance production efficiency and flexibility by utilizing 5GS features, such as always-available wireless connectivity with high bandwidth, capacity and low latency, across all stages of processes and assets.

Terms and abbreviations

3GPP – 3rd Generation Partnership Project | **5G-ACIA** – 5G Alliance for Connected Industries and Automation | **5GS** – 5G System | **AAS** – Asset Administration Shell | **AI** – Artificial Intelligence | **API** – Application Programming Interface | **DT** – Digital Twin | **I4.0** – Industry 4.0 | **IoT** – Internet of Things | **IT** – Information Technology | **NDT** – Network DT | **NW** – Network | **OPC UA** – Open Platform Communications Unified Architecture | **OT** – Operational Technology | **QoS** – Quality of Service | **RAN** – Radio Access Network | **SEAL** – Service Enabler Architecture Layer | **TSN** – Time-Sensitive Networking | **UE** – User Equipment models [2]. As the number of separate but related subsystems increases, the complexity of the integration and interoperability increases as well. Furthermore, the new revolution in the industrial domain envisions the creation of digital twins (DTs) of the systems that play a pivotal role in accelerating the digitalization of enterprises.

DTs are virtual replicas of physical assets (machines, robots and automated guided vehicles, for example), processes (in manufacturing and product development, for example) and/or systems that enable real-time monitoring, analysis and optimization of processes. By maintaining the synchronization at regular intervals between digital and physical representations, DT technology differentiates itself from typical simulators [3]. DTs enable accelerated digitalization by offering several key benefits including anomaly detection, proactive maintenance, process optimization and quality improvements. To maximize the benefits, DTs must be integrated into the larger industry ecosystem.

Interoperable interaction among subsystems will be required to realize the vision of the factories of the future, which will create a larger scale system with greater complexity. The most efficient way to deal with this complexity and ensure maximum benefit from 5G investments is to integrate the 5G NW into OT processes as an additional subsystem.

The requirements of a proxy to enable 5G-OT integration

Industrial systems demand optimized operation, which requires always-on connectivity. Cellular systems provide the efficient coverage, Quality of Service (QoS), mobility of field devices, security and flexibility needed to realize use cases with diversified requirements. 5G plays a pivotal role in enabling smart factories by providing wireless connectivity with ultra-reliable and low-latency communication capabilities, and its integration with time-sensitive networking (TSN) offers seamless connectivity for diverse industrial use cases.

To maximize the benefits, DTs must be integrated into the larger industry ecosystem.

TSN is an extension of the widely adopted Ethernet standard. It defines a range of traffic-shaping and redundancy methods that enable time-bounded communication over Ethernet with high reliability for smart manufacturing applications. 5G and TSN technologies are designed to grant converged communication on a common network infrastructure for an extensive range of services [4].

End-to-end 5G-OT integration must be supported at the OT operator's application layer. Delivering 5GS capabilities using exposure interfaces to the OT/IT applications enhances the automation degree throughout the factory floor for process automation, production IT and logistics. Communication service monitoring and network management capabilities are also essential for industrial applications to achieve automation. To support them, the Service Enabler Architecture Layer (SEAL) [5] specified by the 3GPP (3rd Generation Partnership Project) aims to support vertical applications. It provides access to the 5G communication services through RESTful (representational state transfer) web service APIs that comply with the 3GPP Common API Framework to provide flexibility in integrating with vertical applications [6].

The SEAL framework supports various management services and defines reference points for communication between the functional model components. To test the idea of a simplified and standardized API for enterprise access, leading technology company ABB and Ericsson developed a proof of concept, in which a prototype implementation of 5G exposure is integrated [7]. The main motivation of this exposure framework is to simplify 5G NW usage for verticals and industries through a common API. The results have proven that the 5G exposure interface enables OT enterprises to use 5G as a part of their system infrastructure, which increases production flexibility and allows scaling up to a large number of 5G-connected devices in an organized and secure manner.

Interoperability among devices, sensors, applications, networks and any heterogeneous systems is important to realize the vision of I4.0 – that is, developing smart factories equipped with intelligent human-to-machine and machine-to-machine cooperation. It requires augmenting the data from diverse heterogeneous resources under real-time conditions. This requirement brings challenges in creating an efficient and reliable information management infrastructure for both 5G and OT systems.

It is important to arrange complex and partially competing standards on a multitude of communication levels such as device integration, event processing, data analytics and cloud operations. For example, the Open Platform Communications Unified Architecture (OPC UA) [8] information model provides the essential infrastructure for interoperability across the enterprise, from machine-to-machine, machine-to-enterprise and everything in between. This facilitates a level of plug-and-play between applications from various vendors by identifying a standard information model for the cases where simply standardizing the message format is insufficient.

Ultimately, to be successful, a 5G-OT integration solution needs to be widely adopted by the industrial domain and satisfy three key requirements:

1. Enable standardized interaction for interoperability
2. Provide a common interface for 5G data and capability exposures
3. Deliver seamless integration of different systems.

The Asset Administration Shell as an integration technology

The AAS is one of the promising frameworks in I4.0 deployments that provides the relevant capabilities to act as a bridge between various systems on the factory floor using different technologies, such as the 5G NW and industrial processes. The AAS supports interoperability among industrial devices and provides a unified management interface for OT operators.

The AAS was initially proposed by Plattform Industrie 4.0 [9]. To facilitate digitalization for enterprises, Plattform Industrie 4.0 introduced the three-dimensional map called Reference Architectural Model Industrie 4.0 (RAMI 4.0). This is a service-oriented architecture that provides a structured view over I4.0 deployment. In this architecture, the AAS plays a key role in integrating assets (machines, products and documents, for example) into the digital world, fostering a common understanding and viewpoint among all participants involved in industrial processes.

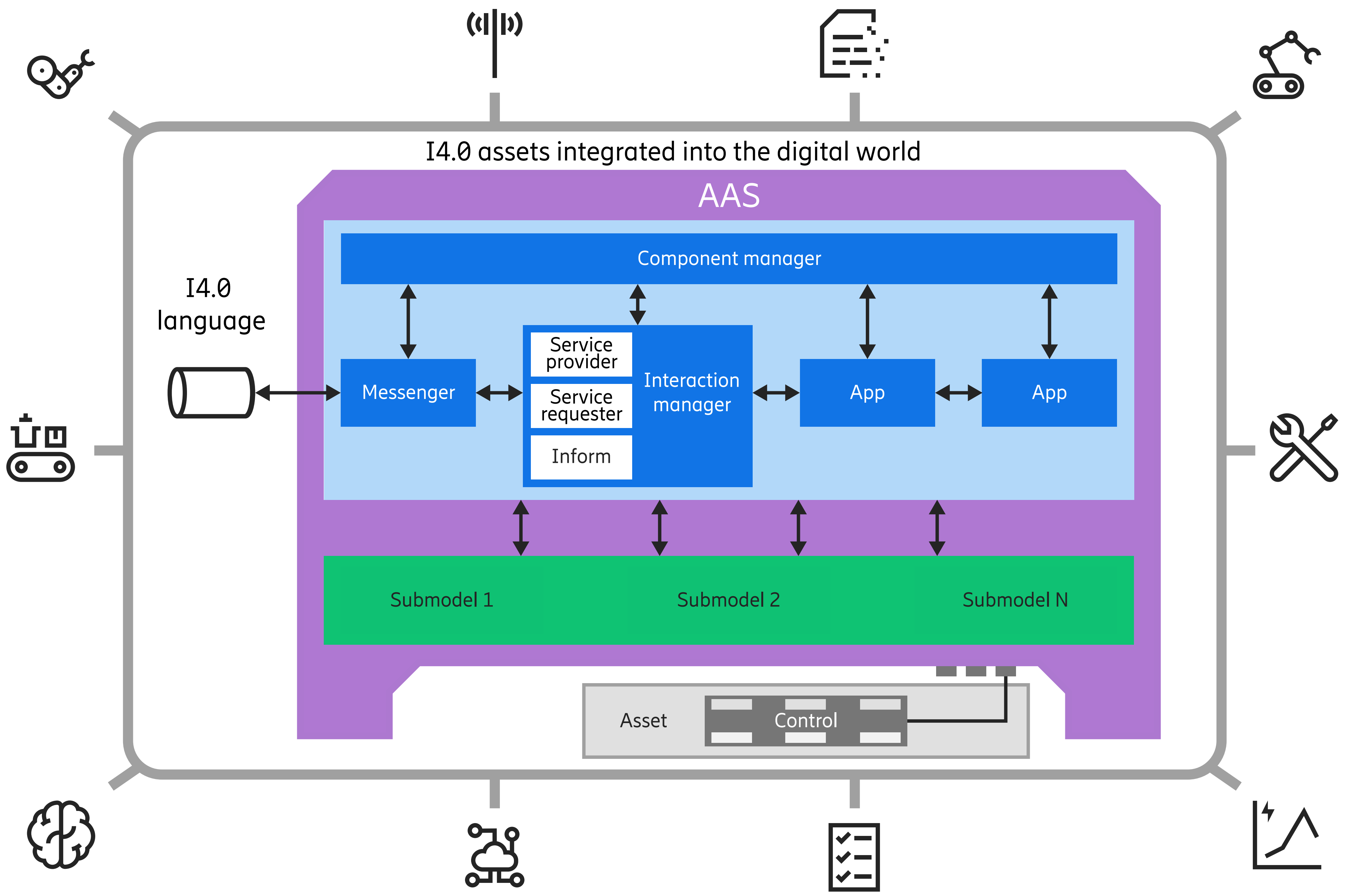

Figure 1: High-level view of the AAS and its components

The AAS enables the representation of functionalities, features, characteristics and other relevant information related to an asset in a digital form. This information is structured into various submodels within the passive component of the AAS. The AAS can also interact with other shells through its active part. While the passive role of the AAS refers to providing responses to the external access requests (read, write and modify submodels, for example), the active part incorporates decision-making functions and interaction mechanisms that enable peer-to-peer interaction.

Figure 1 illustrates the internal components of the AAS and how it connects different subsystems, with the messenger and interaction manager modules being responsible for implementing protocols and interfaces for message exchange. AAS interaction is established through the I4.0 language specified by VDI/VDE (The Association of German Engineers/Association for Electrical, Electronic & Information Technologies) 2193 [10]. Standardizing the I4.0 language not only provides an interaction mechanism but also enables interoperability between different systems, fulfilling an important requirement for an integration mechanism.

While there are multiple approaches that offer uniform data access and interoperability (including OPC UA), standardization in the I4.0 domain positions the AAS as a promising solution. Notably, recent standardization projects in the IEC (International Electrotechnical Commission) have been initiated to define the structure, use cases, information meta-model and security provisions of the AAS.

With the aim of creating digital representations of industrial assets for OT operators, the 5G Alliance for Connected Industries and Automation (5G-ACIA) utilizes AAS principles to describe 5G networks [11]. Recognizing the 5G NW and 5G user equipment (UE) as assets to be integrated into industrial automation systems, the 5G-ACIA proposes the utilization of two AAS types: 5G NW AAS and 5G UE AAS, representing the DTs of these complex subsystems. By utilizing the AAS principles, it is possible to achieve seamless integration of the 5GS into IT/OT processes in the industrial sector.

Given the complexity of existing subsystems with diverse objectives and characteristics, the AAS can serve as a proxy that interfaces various subsystems (network, production, and management and control, for example), enabling the creation of a larger system capable of exchanging information for process automation.

Network management, orchestration and service assurance processes can be customized and enhanced to meet industrial requirements. In this context, the AAS can serve two roles. Firstly, it can act as a DT of the 5G NW and UE, implementing decision-making and optimization algorithms. This enables the simulation of different configurations and the automation of management processes. For instance, the 5GS already offers positioning services for 5G-capable devices, utilizing various positioning techniques for different scenarios. Exchanging the positioning information with other industrial applications through the AAS may therefore extend the scope of other services using this information. The AAS may also be responsible for fusing positioning and industrial process data to propose configurations in the network in a way that the 5GS becomes more efficient in meeting industrial requirements.

Figure 2 illustrates the role the AAS plays in integrating different subsystems within an enterprise (the inner ring), along with the capabilities gained through this integration (the outer ring).

The role of the AAS in factory system automation

The AAS can play an important role in enabling the automation of industrial network management. This is because the inherent properties of the AAS allow interoperability among different subsystems in the OT domain and accommodate the DT-like capabilities.

In a recent article, Ericsson demonstrated that a network DT (NDT) has the ability to reuse existing 5GS management functions to enhance the performance of an industrial network [3]. An NDT that incorporates different analysis tools and behavior models can interact with other DTs – including factory DTs – to further enhance the performance of industrial cellular networks, increase the resolution of management functions and benefit from the information available in other domains.

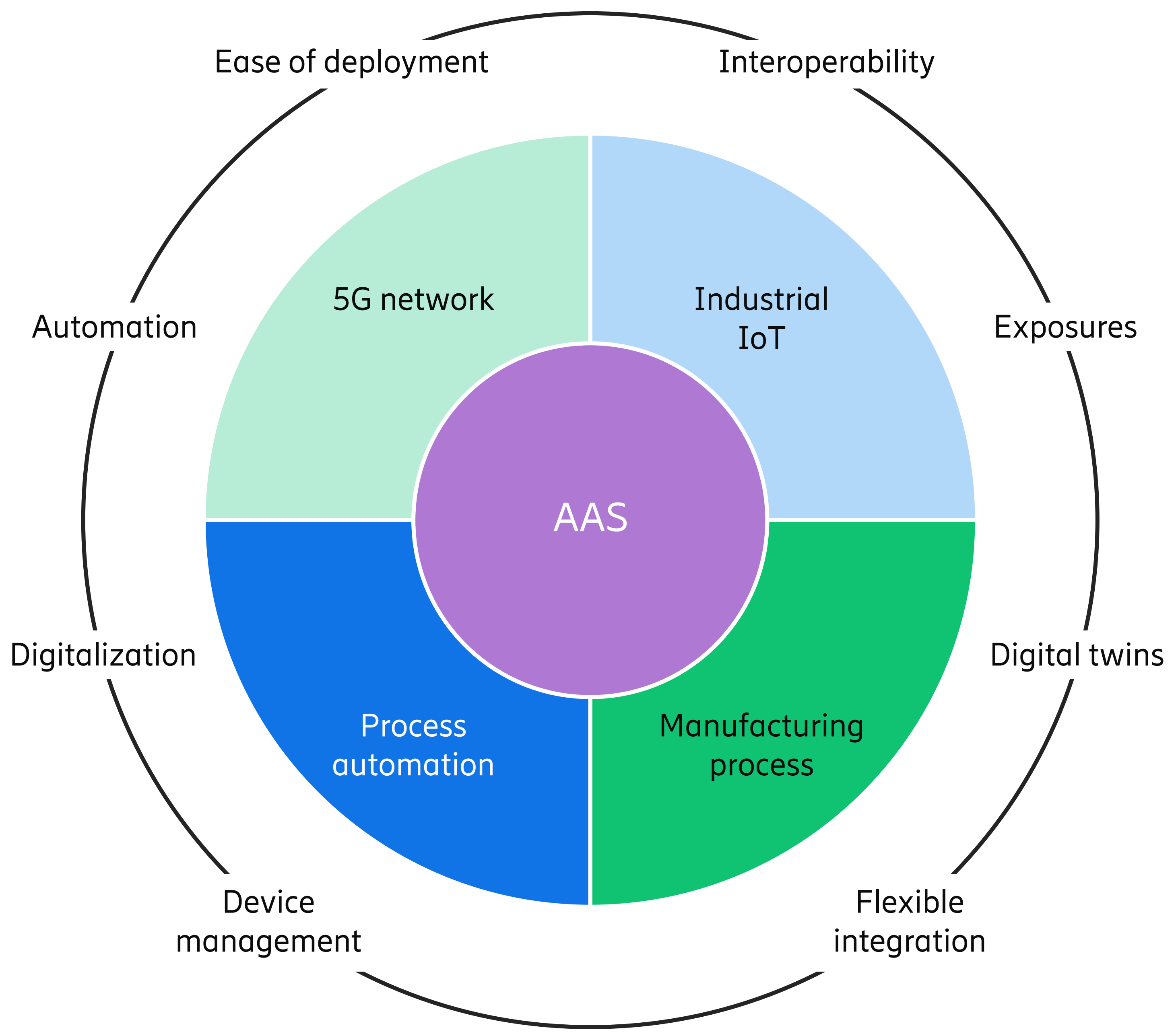

Figure 2: The role of the AAS in system integration and the resulting capabilities

The O-RAN Alliance's QoS-based resource optimization use case [12], for example, introduces a solution that largely depends on resource configuration and performance measurements. The idea of benefiting from enrichment information provided by external applications for improved performance is also presented in this use case. In this context, the AAS can aggregate information from any industrial application, including production scheduling. The ability to preprocess the information collected from different enterprise applications enables the AAS to propose relevant radio access network (RAN) configurations or policies.

Use case: Service assurance for collaborating robots

The use case presented below is part of a use-case family named Collaborating Robots that has been widely explored in various studies [13]. In this version, the AAS is used to integrate the 5GS with industrial applications that are responsible for managing field devices and manufacturing processes. The main goal is to apply a solution for configuration of the industrial 5G NW by utilizing the AAS principles.

In a factory environment, individual robots are not usually capable of communicating with each other, which can be an obstacle for certain tasks that require collaboration. The operation of these robots may depend on some external entities, such as a common machine vision. A vision system, which is connected to the network, can provide a set of relevant functions such as positioning and asset tracking. The system that provides vision-based functions and services can be a part of the wired infrastructure.

> We can use the AAS to integrate the 5GS and industrial Ethernet systems.

All factory automation is built on a system-of-systems concept in which several OT automation systems and OT/IT/cellular network systems collaborate to execute the manufacturing process. The AAS can be used to integrate the control of all these systems seamlessly. For example, considering a use case of vision-assisted collaborating robots, we can use the AAS to integrate the 5GS and industrial Ethernet systems. The 5G-ACIA envisions a customized implementation of a similar integration, in which integration of two systems (5G and TSN) is established by adding relevant submodels in the AAS [11].

One potential way to overcome the difficulty of achieving direct communication among machines provided by different vendors is by adding relevant submodels into the AAS representations of various devices (5G UE AAS) and other industrial applications. Necessary submodel elements related to devices and the task can be communicated and negotiated among participating AAS entities. Alternatively, the active part of AAS instances can implement any relevant decision-making system to coordinate the collaboration and configure the assets.

Consider a scenario in which the factory operator initiates a new collaboration between two robots. There is a requirement to reconfigure the 5G NW to support the connectivity and performance demanded by these robots. Assuming that the initial configuration management and QoS parameters are handled in the engineering phase when deploying the 5G subsystem, this new task requires modification of the connectivity, including QoS definitions (maximum latency, minimum reliability and so on) for the corresponding devices.

This network configuration is possible thanks to AAS capabilities that enable standardized interaction for interoperability, provide a common interface for 5G data and capability exposures, and deliver seamless integration of different systems. Typically, 5G configuration/reconfiguration can be performed by any authenticated application using 5G exposure interfaces. However, 5G NW AAS can define the new set of QoS parameters based on the aggregated information provided by different sources including industrial processes (requirements, for example), the current state of the network and device characteristics.

Figure 3 illustrates what happens when a factory operator triggers a new collaboration task by invoking the related functions provided by the industrial application (step 1, at top left). Based on the task requirements, the industrial application collects relevant information from the devices

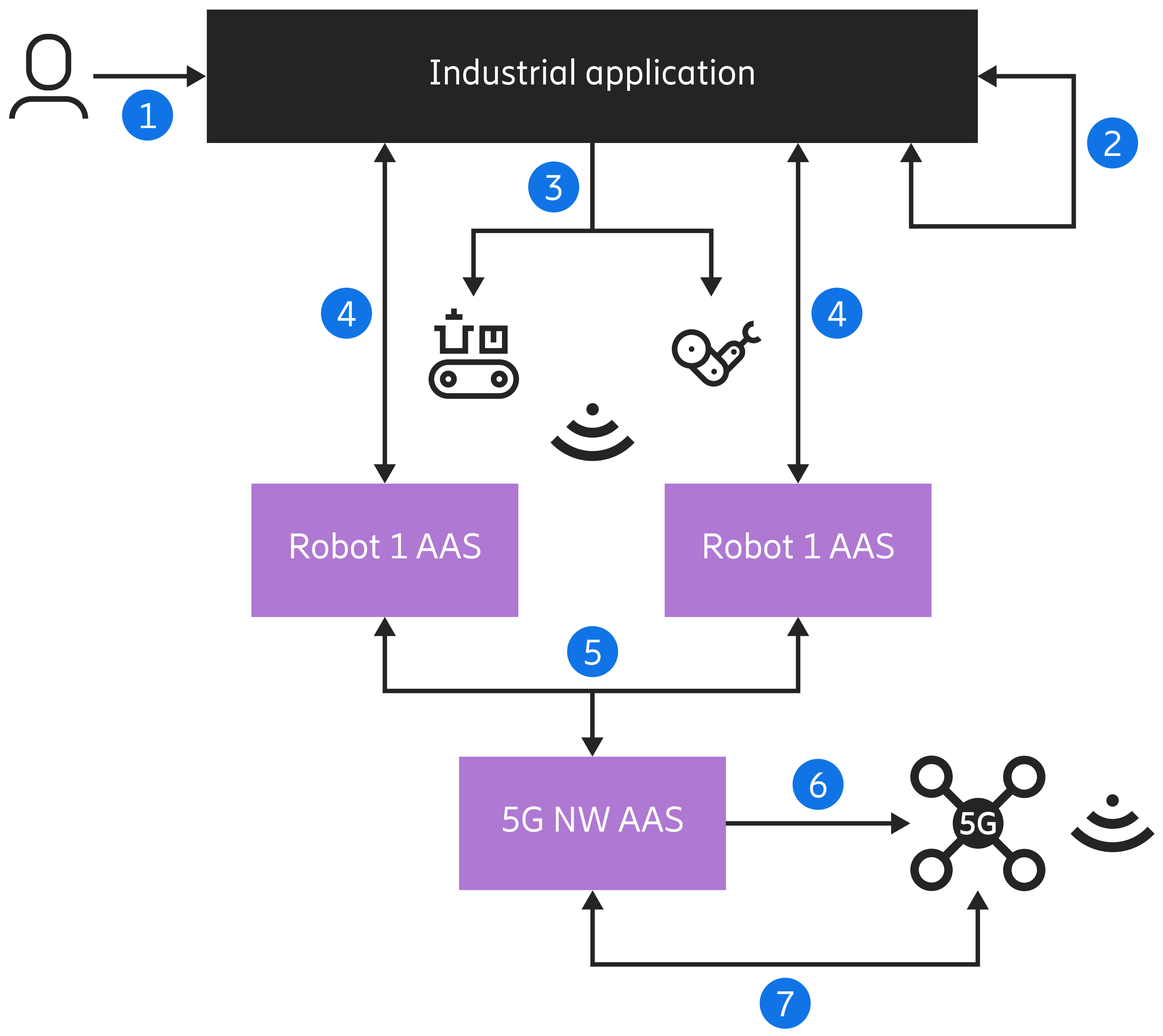

Figure 3: How the AAS automates the network reconfiguration for QoS assurance

such as their location, status and capabilities. Step 2 identifies the devices that are the most appropriate for this task. The devices are provisioned in step 3, and they seamlessly establish a secure connection with their AAS representations. In step 4, the AAS instances of the robots retrieve necessary information from the industrial application. The AAS instances are also able to exchange device capabilities with each other.

In step 5, the 5G NW AAS receives information that the industrial domain has initiated a new task that may require changes to the network configuration to ensure provision of the desired QoS. The 5G NW AAS retrieves the device capabilities and requirements of the task using standardized AAS interaction. In step 6, 5G NW AAS executes DT-like capabilities – such as running what-if scenarios to find out the best possible configuration – to define the QoS parameters for each robot. These parameters are then sent as proposed solutions to the 5G NW through the exposed API (proprietary, network exposure function or SEAL). As a conditional case, if the defined QoS parameters are not satisfactory (which can be inferred through the monitored data) or cannot be applied due to an issue (resource capacity, for example), new parameters can be proposed in step 7. By continuously monitoring the network and the factory floor, the AAS can evaluate whether the requirements of network and industrial process are satisfied or not.

Conclusion

The most efficient way for operational technology (OT) enterprises to adopt 5G technology is to ensure seamless integration of 5G with OT solutions using existing tools and processes. The Asset Administration Shell (AAS) is a widely adopted solution in the industrial domain that enables communication among heterogeneous systems and components within the Industry 4.0 architecture. The digital-twin-like capabilities of the AAS, together with its standardized communication mechanisms, make it possible to create a virtual representation of the 5G system (5GS) that is fully integrated into a large industrial ecosystem.

In addition to the interoperability the AAS brings, the integrated decision-making functionalities in the AAS also make it a powerful framework for automation. By using AAS principles to represent the 5GS in the digital world, factory operators have the opportunity to achieve high levels of both integration and automation, and thereby make significant progress toward the vision of the factories of the future.

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Further reading

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