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# ADVANTAGES AND DISADVANTAGES OF OPC UA ROBOTICS COMPANION

Bachelor's thesis  
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# ABSTRACT

Mikko Karhunen: Advantages and disadvantages of OPC UA Robotics companion  
Bachelor's Thesis  
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The aim of this study was to explore the OPC UA Robotics companion specification, its advantages and disadvantages, as well as its current ecosystem in which it operates. The research method employed was a literature review, complemented by some theoretical reflection, including the historical background of OPC UA, its operational methods, as well as the origin and functionality of the Robotics companion specification.

The study utilized historical information on how the rise of automation influenced the development of industrial communication protocols, among the first of which were COM/DCOM, followed by OPC Classic, and then the improved version, OPC UA. OPC UA is an open communication protocol that enables secure and scalable data exchange between devices and software from different manufacturers, tailored for industrial automation and IoT systems. This has led to the widespread adoption of OPC UA in various industries that have automated their industrial processes.

Robots, which are capable of autonomously performing assigned tasks based on specific program code, are also closely integrated into automated processes. In 2018, the VDMA Foundation published the first standard for robots called OPC UA Robotics companion, which created an information model for the attributes used by robots. This further facilitates the integration of components from different hardware manufacturers.

The key findings showed that the Robotics companion is widely used across different robot manufacturers' hardware and software. The main benefits lie in compatibility, widespread adoption, and troubleshooting. Other benefits are directly attributable to the features of the OPC UA standard. The challenges are not inherently related to the Robotics companion specification itself, but rather to OPC UA's own challenges, such as memory requirements, demands, and PKI system management.

Keywords: OPC UA, Robotics companion, MES, SCADA, PLC, automation

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# TIIVISTELMÄ

Mikko Karhunen: Advantages and disadvantages of OPC UA Robotics companion  
Kandidaatintyö  
Tampereen yliopisto  
Teknisten tieteiden kandidaattiohjelma  
Marraskuu 2024

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Tämän tutkimuksen tavoitteena oli tutustua OPC UA Robotics companion -spesifikaatioon, sen hyötyihin ja haasteisiin sekä sen nykyiseen ekosysteemiin, jossa se toimii. Tutkimukseen käytettiin tutkimusmenetelmänä kirjallisuuskatsausta ja jonkin verran teoreettista pohdintaa, johon sisältyi OPC UA:n historiallinen tausta sekä sen toimintatavat sekä Robotics companion -spesifikaation synty sekä sen toiminnallisuus ja toimintaympäristö.

Tutkimuksessa hyödynnettiin historiallista tietoa siitä, että miten automaation synty vaikutti teollisuusviestintäprotokollien syntymiseen, joista ensimmäisten joukossa olivat COM/DCOM, tämän jälkeen OPC Classic ja sen jälkeen paranneltu versio OPC UA. OPC UA on avoin tiedonsiirtoprotokolla, joka mahdollistaa eri valmistajien laitteiden ja ohjelmistojen välisen turvallisen ja skaalautuvan tiedonvaihdon teollisuusautomaation ja IoT-järjestelmien tarpeisiin. Tämä on johtanut siihen, että OPC UA -protokollaa käytetään laajasti eri teollisuuksissa, jotka ovat automatisoineet teollisuusprosessinsa.

Automatisoituun prosessiin kuuluvat tiiviisti myös robotit, jotka kykenevät tekemään itsenäisesti niille määrättyjä tehtäviä tietyn ohjelmakoodin mukaan. Vuonna 2018 VDMA-säätiö julkaisi ensimmäisen roboteille suunnatun standardin nimeltä OPC UA Robotics companion, joka loi informaatiomallin robotin käyttämille attribuuteille. Tämä helpottaa yhä entisestään eri laitteistovalmistajien komponenttien yhdistämisessä.

Keskeiset tulokset osoittivat, että Robotics companion on laajasti käytössä eri robottivalmistajien laitteistossa ja ohjelmistoissa. Suurimmat hyödyt piilevät yhteensopivuudessa, levinneisyydessä sekä vianmäärityksessä. Muista hyödyistä on suoraan vastuussa OPC UA -standardin ominaisuudet. Haasteet eivät itsessään liity Robotics companionin luomaan spesifikaatioon, vaan ne liittyvät enemmänkin OPC UA:n omiin haasteisiin, jotka liittyvät mm. muistiin, vaatimuksiin ja PKI-järjestelmän hallintaan.

Avainsanat: OPC UA, Robotics companion, MES, SCADA, PLC, automation

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# ALKUSANAT

Kiitos ystäväilleni, perheelleni ja ohjaajalleni tuesta tämän työn saralla. Erityinen kiitos Veeralle, jonka kanssa saan elämäni jakaa.

Tampereella, 27.11.2024.

Mikko Karhunen

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# LIST OF SYMBOLS AND ABBREVIATIONS

I/O	Input and Output
OPC UA	Open Platform Communications Unified Architecture
AI	Artificial Intelligence
MES	Manufacturing Execution System
ERP	Enterprise Resource Planning
COM	Component Object Model
DCOM	Distributed Component Object Model
DA	Data Access
A&E	Alarms & Events
HDA	Historical Data Access
TCP/IP	Transmission Control Protocol / Internet Protocol
HTTP	Hypertext Transfer Protocol
HTTPS	Hypertext Transfer Protocol Secure
MQTT	Message Queuing Telemetry Transport
SCADA	Supervisory Control and Data Acquisition
PLC	Programmable Logic Controller
PKI	Public Key Infrastructure
Sub-CA	Subordinate Certificate Authorities
DCS	Distributed Control Software

# 1. INTRODUCTION

Automation is the use of control systems and information technologies to reduce the need for human work in the production of goods and services. In the context of industrial development, automation is a step beyond mechanization. Whereas mechanization provided human operators with machinery to assist them with the muscular requirements of work, automation greatly decreases the need for human sensory and mental requirements as well. [1] Automation has become increasingly widespread since the 1980s and continues to this day.

The increasing demand for automation led to the development of the first industrial communication protocols, such as COM and DCOM. However, these protocols had significant shortcomings, which led to the development of the first OPC Classic version, followed by the OPC UA protocol. A more detailed discussion of these topics follows in subsequent sections.

OPC UA is a widely adopted industrial communication protocol used by almost all industrial equipment manufacturers today for data transfer. Its advantages include standardized communication, making components from different equipment manufacturers more interoperable than before. Robots have been increasingly integrated into various areas of production since the early stages of automation, as their key advantage is that they operate autonomously based on program code. Bajd et al. state in the book *Robotics* [2, p. 1] that “An industrial robot manipulator is a feedback controlled, reprogrammable, multipurpose system. It is programmable in three or more degrees of freedom. Robot manipulators are used in processes of industrial automation.” The use of OPC UA also created a specific need to develop a more precise information model for robot communication, which standardizes the attributes used by robots in data transfer. The name of this specification is OPC UA Robotics companion.

The purpose of this bachelor’s thesis is to introduce the OPC UA Robotics companion, examine that what are the historical developments that led to the creation of OPC UA and the Robotics companion. It also aims to explore the key advantages of using Robotics companion in industrial environments, the challenges associated with its implementation and management, and its role within the broader ecosystem of industrial automation.

This thesis is structured as follows: After introduction chapter, the theoretical background follows, including an overview of the research method and the OPC UA protocol. The next chapter is the assessment of the OPC UA Robotics companion, which covers its advantages, challenges, and current ecosystem. Lastly, the conclusions chapter summarizes key findings and offers recommendations for future research.

## **2. THEORETICAL BACKGROUND**

This chapter first presents the research methods used to conduct this study. After that, this chapter discusses shortly about automation and then the history and intended purpose of OPC, especially OPC UA, for which it was originally developed. It also presents with help of images how OPC UA operates.

### **2.1 Research methods**

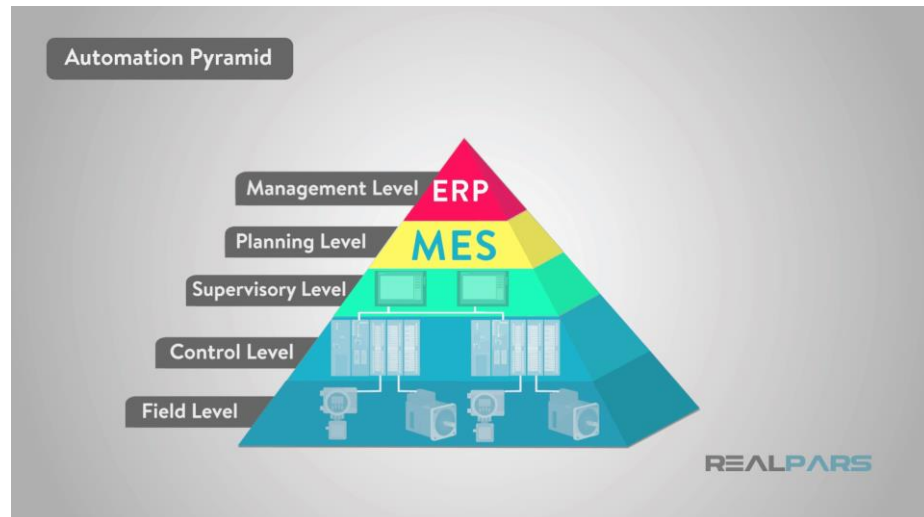
The research method selected for this research was a literature review. A literature review is a method of research that involves collecting, analyzing, and evaluating existing studies and texts related to the research topic. The aim of a literature review is to provide a comprehensive and systematic overview of existing knowledge and to identify research gaps.

The process begins with formulating a research question or questions, followed by a search for relevant materials. In this case, since there is very little prior research on the topic, finding suitable sources proved to be quite challenging. However, most of the material was eventually sourced from online platforms, such as websites and academic databases. The information had to be synthesized to answer the research questions effectively.

The information retrieval for this study was conducted mainly using the university's Andor application. Some material was found using the Scopus AI tool, while the rest was sourced through Google searches.

### **2.2 A brief overview of automation**

Automation began with simple mechanical systems, but the development of digital technologies in the late 20th century enabled smarter and more complex systems. The amount of automation in every sector of society has grown explosively in the last decades and this can be seen in different factories because countless number of different work steps, production lines, warehouses and production management systems have been automated. The purpose of automation is to optimize production, reduce waste, and lower employee costs. The whole automation concept can be separated into 5 different levels, which can be seen in figure 1.



**Figure 1. The Automation Pyramid [3].**

From bottom to top, the first level is basically the field level, which interacts directly with the physical processes and production devices and this includes components such as sensors, actuators and I/O modules. The second level is the control level, which consists of devices that control and run the devices in the field level. These control actions are based on the data provided by the field level devices. [3, 4]

The third level is supervisory level, responsible for overseeing and controlling various areas and processes within the industrial environment. The graphic interfaces are typically used at this level to monitor the process, receive alarms and to make critical decisions. The fourth level is called planning level, where the manufacturing execution systems (MES) are used to monitor the whole manufacturing process in a factory from a single component to the finished product. The fifth and final level is called management level, where the enterprise resource planning (ERP) systems are used to manage overall business operations, which often contain a lot more than just automation processes. [3, 4]

The concept of automation is continuously evolving. The latest trends are artificial intelligence and machine learning support. Integrating AI and machine learning with automation leads to adaptive systems that can learn and adjust to their environment. [5]

### **2.3 History of OPC UA**

In the 1990s, automation suppliers commenced utilizing a Microsoft-supported technology called COM (Component Object Model) and DCOM (Distributed Component Model) in their products [6]. COM is an interface standard intended to software components. It

enables communication between different software components in the Windows environment irrespective of the programming language to be used. DCOM does the same but in distributed environment. [7]

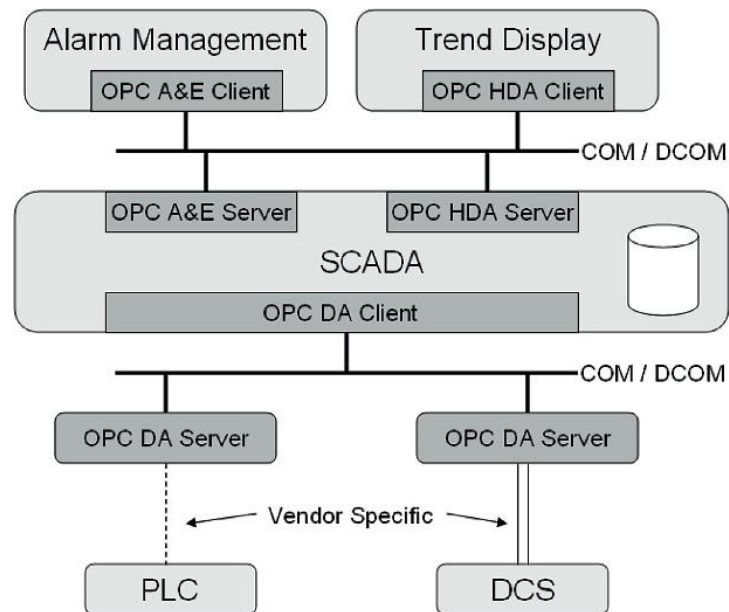
The largest automation systems can have products manufactured by several different automation suppliers, so there was a need to develop a standard for COM- and DCOM-based data use. For this purpose, a working group was established in 1995, which included Fisher-Rosemount, Intellution, Opto 22 and Rockwell Software. This standard was named as OPC, which comes from words OLE ( Microsoft Object Linking & Embedding) for Process Control. However, the name has changed over the years, and the current form is Open Platform Communications. [8]

A year later in 1996, the working group published the Data Access (DA) from the simplified OPC specification. During the first year, several software and hardware vendors started to use OPC in their products. Soon the developers realized that a more formal organization would be needed to maintain the standard. After this, the OPC Foundation was officially established in April 1996. [6]

## **2.4 OPC Classic**

OPC is used at all levels between control level and management level (see Figure 1), but it is not commonly used at field level, where Profibus and other field communication systems are typically used. This is because of protocols like Profibus offers fast, low-latency, easy and stable communication by utilizing physical cables for data transfer. However, OPC is increasingly being used in field-level devices nowadays.

OPC is divided into three different functions. The first one is OPC Data Access (OPC DA), which defines information exchange, i.e. writing and reading data. The second one is OPC Alarms & Events (OPC AE), which defines the exchange of alarm and event type message information. The last one is OPC Historical Data Access (OPC HDA), which defines query methods and analytics that can be applied to historical time-stamped data. The functions of OPC Classic are independent and they communicate on their own interfaces without affecting each other. [9] Figure 2 shows a typical use case of OPC clients and servers.

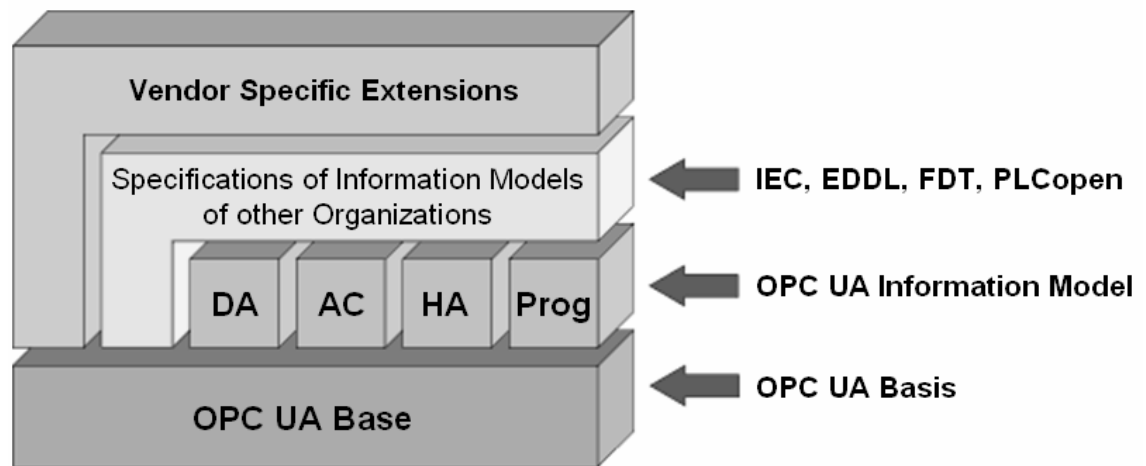


**Figure 2. Use case of OPC clients and servers [10, p. 3].**

As written in the previous section, OPC Classic interfaces rely on COM and DCOM technologies. These technologies allow a client to seamlessly invoke methods on a COM-object hosted on the server, whether the server is running in the same process, in a separate process, or on a different network node. [10, p. 4]

## 2.5 OPC UA

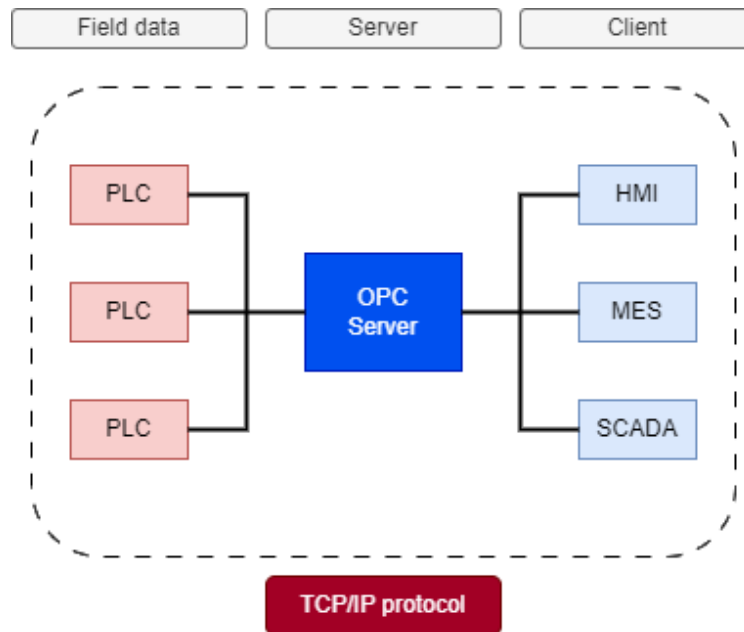
OPC Unified Architecture (OPC UA) is a platform-independent service-oriented standard, which combines all the functionality of a single OPC Classic configuration into a single extensible framework. UA was developed to fix and improve several limitations that were related to the previously published Classic. The development of UA started in 2003 and the first version was published in 2006. UA has been used since the year of publication until today and has been developed and updated over the years. [6, 11] Figure 3 illustrates the layered architecture of OPC UA. OPC UA has the same functions as the OPC Classic, which are DA, A&E and HDA.



**Figure 3. Use case of OPC clients and servers [10, p. 3].**

In the beginning of planning UA, the importance of information security was immediately taken into account, because Classic was known for being the target of many security attacks [9]. UA has well developed encryption, authentication and verification. UA is a platform-independent, so it can run from an embedded microcontroller to a cloud-based infrastructure. It is also very extensible, i.e. it enables the addition of new features without affecting existing applications. UA is an excellent tool when dealing with complex information. [11]

UA is functionally equivalent to Classic, but it has more functionality. It is able to present information hierarchically, for example files and folders, enabling simple and complex structures to be found and used by customers. It is also able to read and write data depending on access rights, monitor data and report exceptions when values change based on criteria set by the customer, report important events based on criteria defined by the customer, and customers can run programs based on methods defined on the server. [11] Also, the communication protocol between field devices, servers and clients have changed from COM/DCOM protocol to TCP/IP-protocol and also in some cases to HTTP/HTTPS and MQTT protocol. In Figure 4, the OPC UA communication between field devices, the server, and client applications is shown.



**Figure 4. OPC UA architecture diagram.**

In figure 4, the operating environment of OPC UA is divided into three sections: field level data, OPC UA server and OPC UA client. Field level consists of field devices, such as control units and sensors. These devices generate data that are collected and shared onward. The OPC UA server acts as a central point of the system. It receives data from the field devices and processes it in a standardized format, and makes the data easy to access for different and various client applications. The OPC UA server uses typically TCP/IP protocol for data transmission and reception, but as mentioned, it can use HTTP/HTTPS and MQTT for the data movement. The OPC UA client section consists of different and various client applications, typically HMI (Human Machine Interface), MES (Manufacturing Execution System), and SCADA (Supervisory Control And Data Acquisition) applications. These client applications can subscribe to data from OPC UA server for process control, monitoring, and analytics purposes.

In today's world, there is a wide variety of different operating systems and hardware platforms, so platform-independence is essential. UA works with, among other things, traditional computers, cloud-based servers, programmable logic controllers and micro-controllers. In terms of operating systems, UA works on at least Windows, Apple and Linux. [11]

## 2.6 OPC UA companion

There might be a need for a domain-specific information model specification, which is based on OPC UA. That specification is called a companion specification. OPC UA Robotics companion is a good example of that.

The specification is developed by a working group within the OPC Foundation or in collaboration with other organisations. In some cases, a companion specification may be created independently, without the direct cooperation with the OPC Foundation, for instance by a standardization body or a company. A companion specification includes a document that outlines the information model and UaNodeSet, which is a machine-readable file used by implementations of the companion specification. [12]

## **3. ASSESSMENT OF OPC UA ROBOTICS COMPANION**

This chapter discusses about OPC UA specified Robotics companion, which is used in enabling standardized communication between industrial robots and other automation systems. The chapter begins with reviewing the Robotics companion: what it is and who developed it. After that, the chapter discusses about the possible advantages and disadvantages of the use of Robotics companion, and lastly, the chapter discusses about the current ecosystem of the Robotics companion: what systems use it and what companies use it.

### **3.1 OPC UA Robotics companion**

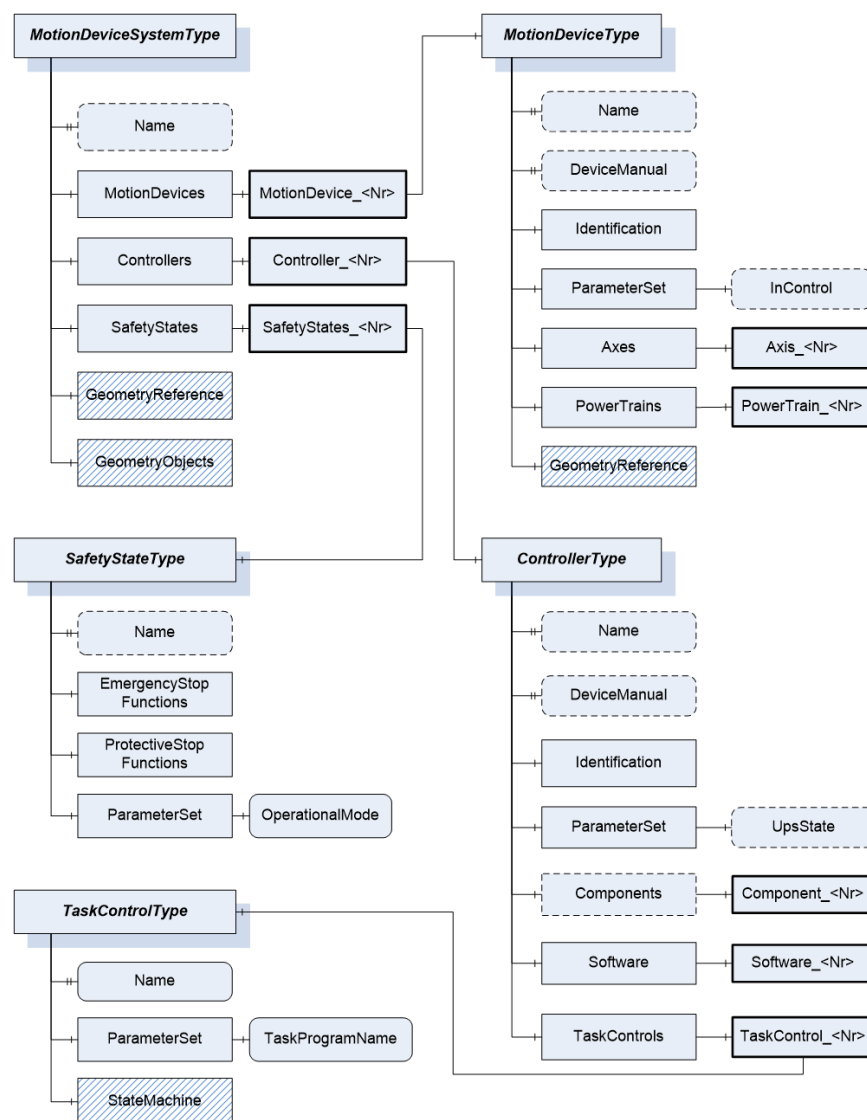
OPC UA Robotics companion is an extension for OPC UA specification for the needs of robotics. It was originally developed with the idea of how manufacturers could implement OPC UA between higher level manufacturing systems and robots. [13] In summary, the Robotics companion is an information model developed in accordance with the OPC UA specification.

The VDMA (Machinery and Equipment Manufacturers Association) represents over 3200 small and medium-sized companies in the engineering industry, and with support of OPC Foundation, they founded a working group “VDMA OPC Robotics Initiative”, which goal was to develop an OPC UA specified information model for the communication between robots and higher level industrial manufacturing systems. The working group consists of leading global companies in the field of robotics, such as ABB AS Robotics, Unified Automation GmbH, Audi AG, Beckhoff Automation GmbH & Co. KG, KUKA Deutschland GmbH, Siemens AG, and many more. [13]

OPC Foundation writes in their article [14] that robotics means a complete motion device system that includes a list of motion devices. Motion devices can be any existing robot type and this includes for example industrial robots (stationary), mobile robots (also several robot arms), robots with several control units, robotics periphery without an own OPC UA server, service robots and many more.

The requirements for the Robotics companion specification are that the specification should be independent of robot types, independent of vendors, generically applicable,

semantically self-described so that the terms are unified for conveying the same information, and subdivided into several parts from part 1 to part n [13, 14]. The last point means that part 1 provides a foundational overview of a motion device system, with the primary goal of transmitting condition data vertically to higher-level manufacturing systems, such as line PLCs, MES, or cloud platforms, for informational and diagnostic use. The other parts will build on this foundational description, addressing additional use cases, such as configuration and control of the motion device system and its components. [14] In figure 5 there are information blocks that are currently identified for the Robotics companion specification.



**Figure 5. Robotics companion information model [14].**

The figure 5 represents an OPC UA-based information model focused on representing robotic system data, following the OPC UA Robotics companion specification. The figure consists of main types (high-level category) and their associated attributes or subtypes (properties or characteristics of a main type). Main types and their associated attributes or subtypes in the figure 5 are: 1. MotionDeviceSystemType, which defines overall the robotic system, consisting of multiple devices and controllers. Its attributes are for example Name, MotionDevices and Controllers. 2. MotionDeviceType, which represents an individual motion control device. Its attributes are for example Name, DeviceManual, ParameterSet and Axes. 3. SafetyStateType, which defines a safety state. Its attributes are for example Name, EmergencyStopFunctions and ParameterSet. 4. ControllerType, which represents the controller of the device. Its attributes are for example Name, Identification, Components and Software. 5. TaskControlType, which defines task control. Its attributes are for example Name, StateMachine and TaskProgramName.

### **3.2 Advantages of using OPC UA Robotics companion**

The Robotics companion were developed, because there was a need to standardize the communication between robots and higher level manufacturing systems. This means that there are many advantages of using Robotics companion in automated industrial environment. This phase discusses the most common advantages of the Robotics companion.

The main important advantage of Robotics companion is, that the communication between devices and servers are standardized. This makes it easier to build systems, as there is a single protocol to follow. Additionally, the OPC UA environment remains streamlined, as manufacturers adhere to a specific configuration method, eliminating unnecessary complexities that could slow down the system. This also proves helpful in troubleshooting situations, as maintenance personnel can easily locate signals and other relevant information.

The other thing, which was mentioned by VDMA, is the asset management and condition monitoring. The robotics information model offers vendor-independent access to asset information for all integrated robotic systems and their components. Additionally, it enables status and parameter comparisons across multiple installed systems, facilitating the identification of anomalies. [15]

The Robotics companion has wide scalability and it's also very flexible specification because of the platform-independence and the use of different transport technologies [10,

p. 190, 305]. For this reason, the Robotics companion must be able to operate in production environments ranging from small to large.

As mentioned in chapter 2.5, the information security was significantly improved with the development of OPC UA. The OPC UA framework uses advanced security protocols, such as encryption, authentication, and data integrity checks, to ensure robust protection of information [10, p. 16, 34–35, 133–134, 206, 223]. These protocols work together to safeguard communication between devices and servers, enhancing the overall security of the system.

Robotics companion provides also a real-time related data from devices between a client and a server because the standardized protocol allows devices to interact with each other reliably. [10, p. 211] OPC UA collects data continuously, so mainly because of that and the historical data access, the OPC UA system has good starting points to diagnostic feature [10, p. 107]. OPC UA supports many diagnostic tools, such as event notifications, alarms and status reports.

Robotics companion enables interoperability with other OPC UA-based systems. By using a standardized protocol across all devices, integration between devices becomes significantly easier. This common framework allows different manufacturers' devices to communicate seamlessly, facilitating system-wide integration and interoperability without the need for custom interfaces or conversions. [15]

OPC UA's and Robotics companion's widespread adoption has significantly increased over the years, and its usage continues to grow annually. This expansion simplifies device procurement and enhances the longevity of systems. As more manufacturers adopt OPC UA and especially Robotics companion, the compatibility and scalability of devices improve, making it easier to integrate and update systems without the need for major overhauls or new protocols. [15]

### **3.3 Disadvantages of using OPC UA Robotics companion**

Although OPC UA and its Robotics companion were designed to meet a need and there are many benefits for using it, there are also some issues with its use. Some of them are related to the vastness of the protocol. Robotics companion can be very complicated, so to understand it perfectly, it needs some training. But in the other hand, the implementation would be much more complicated, if there wouldn't be Robotics companion.

Robotics companion uses Public Key Infrastructure (PKI) in OPC UA environment, which is used for certificate-based authentication and data encryption to ensure security and data integrity in communication between different system components, such as servers

and client applications [16]. While PKI is integral to the secure implementation of OPC UA, managing PKI internally presents several challenges, particularly concerning cost and complexity. Establishing a robust PKI requires dedicated technical infrastructure, including specific software and hardware. The scale and complexity of the PKI will directly impact infrastructure costs: some setups may allow existing workstations and servers to host PKI functions, but larger systems often demand multiple, redundant servers to manage distributed trust domains through sub-CAs (subordinate Certificate Authorities). [10, p. 249]

Once implemented, PKI systems require ongoing maintenance, including regular software updates and occasional hardware replacements to ensure security and reliability. Beyond technical requirements, organizational issues emerge as well. Proper PKI management requires knowledgeable personnel, ideally administrators rather than end-users, who are adequately trained in PKI policies, procedures, and tools. Training alone, however, is insufficient; PKI processes must be consistently followed to maintain system integrity and prevent security vulnerabilities. [10, p. 249]

Another notable challenge for organizations managing their own PKI is limited experience with complex PKI systems. This applies especially to small and medium-sized companies. Unlike outsourced PKI solutions, which come with established expertise, self-managed PKI requires significant time for internal teams to gain proficiency or, alternatively, incurs costs for hiring PKI specialists. This lack of familiarity can increase risks, as errors in PKI management may lead to compromised security in OPC UA environments. [10, p. 249]

OPC UA based Robotic companion is a multi-layered communication technology that enables secure, reliable, and platform-independent data exchange between devices and systems. With its architecture consisting of several layers, including encoding, security, transport, and application layers, OPC UA ensures efficient message handling, data integrity, and flexible integration across various platforms and environments. The weaknesses of robotics companion can be closely linked to the technical aspects of message transmission and processing across various layers, such as encoding, security, and transport. One significant weakness lies in how these layers, responsible for ensuring communication reliability, may be prone to errors and vulnerabilities.

The Encoding Layer handles the serialization and deserialization of messages, but errors here can lead to miscommunication, impacting the robot's ability to interact properly with other systems. If messages are not processed accurately, the robot may fail to send or receive information correctly, affecting its functionality. The Security Layer is crucial for

protecting messages, but vulnerabilities can arise if the messages are not properly encrypted or signed. If security measures are not enforced, messages may be intercepted or altered, leading the robot to process incorrect commands or even execute harmful actions. Additionally, the Transport Layer, responsible for sending and receiving messages, can introduce issues like message loss or corruption, especially if the layer does not thoroughly check the integrity of messages or fails to handle network errors properly. These weaknesses in communication layers can significantly undermine the reliability and security of robotics companion, highlighting the need for designing systems that can handle these issues. [10, p. 256–257]

Furthermore, the Platform Layer, which contains platform-specific code, can create challenges if the robot's architecture is overly dependent on specific hardware or software. This can restrict portability and scalability, making updates and maintenance more difficult. To ensure robust performance, it's crucial that the system's design accommodates easy adaptation to different platforms, allowing for future improvements and extended capabilities. [10, p. 256–257] All these layers demands a lot of memory, and that is one disadvantage too, because small devices might not have the required memory space. This might be the main blocker for small microcontrollers. [17, p. 5]

### **3.4 Current ecosystem of Robotics companion and OPC UA**

Due to the popularity of OPC UA, it is widely used in various software and hardware applications. This section presents the current ecosystem of OPC UA and, by extension, the Robotics companion, including different software and components. Additionally, example products will be provided to illustrate these applications.

#### **3.4.1 Robot companies and their controllers**

As the Robotics companion specification was introduced in 2018, it means that the specification is rather new. As said before, the biggest companies that are developing Robotics companion with VDMA, are ABB, KUKA, Yaskawa, and many others [14]. They all have developed OPC UA based control tools for their robots. For example ABB has the controller called *IRC5* [18], KUKA has the controller called *KRC5* [19], and Yaskawa has the controller called *YRC1000* [20]. They all have their own softwares, which controls the robot and have the OPC UA based communication option. ABB has *Robotware* [18], KUKA has *KSS (KUKA System Software)* [21], and Yaskawa does not have a single controlling software in the same way, but instead it consists of several applications. For example, Yaskawa's *Cockpit* software provides robot monitoring, which uses the OPC UA protocol for data transfer [22]. However, while doing this research, none of these

companies mentioned that they had updated the configuration of their robots to comply with the Robotics companion information model content. But it can be assumed that they have updated their systems to comply with the Robotics Companion specification, as they have been involved in the VDMA project. All of these softwares are not necessarily complete in themselves, so it is possible to install various packages and other software in conjunction with them.

### **3.4.2 PLCs and sensors**

OPC UA is increasingly used in various types of sensors and intelligent devices, such as machine vision systems and force sensors, which are crucial in robotics applications. For instance, machine vision systems, such as those used for barcode recognition or robot guidance, benefit from OPC UA protocols for standardized data exchange. These systems range from simple smart cameras to complex multi-computer setups that handle tasks like inspection and position determination. [23, 24]

Also, the PLC-controller producers such as Beckhoff and Schneider Electric are committed to OPC UA standardization and that way to Robotics companion information model. Their PLC-systems are integrated to support OPC UA specification which allows for seamless interoperability between devices and other systems, such as data transfer and monitoring. Their PLC-products, such as I/O modules and servo motors can function as OPC UA clients or servers. This enables real-time data collection and sharing between devices from different manufacturers. [25, 26]

### **3.4.3 Gateways for older OPC systems**

There is a problem, where the company have older OPC hardware and they need to purchase newer hardware, which uses OPC UA. So compatibility between old and new hardware is not guaranteed. To address this issue, companies like Prosys OPC have developed solutions such as the OPC UA Gateway. This gateway works so that it migrates the classic COM/DCOM-based OPC servers to the new OPC UA form. This gateway supports various OPC interfaces such as Data Access, Alarms and Events, and Historical Data Access. It is fully configurable via OPC UA methods and is compatible with multiple servers and clients simultaneously. The tool is primarily used to connect older systems to the OPC UA ecosystem, facilitating data migration and integration. [27]

### **3.4.4 MES and SCADA systems**

Robots that follow the Robotics companion information model can be integrated with MES and SCADA systems. This integration allows the robots to communicate within the

broader industrial automation infrastructure, enabling real-time monitoring, control, and data exchange with these higher-level systems. A company named Aveva, have MES and SCADA systems. Their MES software is called *Aveva MES* [28] and their SCADA software is called *Aveva Operations Control* [29]. When robots are integrated with MES, they can share real-time performance data, receive instructions for specific tasks, and provide feedback on the status of the production process. For example, robots can send data to the MES regarding completed tasks, faults, or maintenance needs, which can then be used to adjust production schedules or alert operators to issues before they become critical. When robots are connected to MES, they become part of the broader manufacturing ecosystem, where they can exchange data about production status, quality control, and maintenance needs. Similarly, integration with SCADA systems allows operators to monitor robot performance, ensure that they operate within specified parameters, and intervene when necessary. [30] These software systems facilitate robot monitoring and optimize data collection.

### 3.4.5 Distributed Control Systems

There is also ABB's distributed control system (DCS) called *System 800xA* (where the "xA" stands for "extended Automation"), which is an automation platform designed to enhance process control, energy efficiency, and operational effectiveness across various industries. Its core purpose is to integrate traditional process control systems with advanced safety, electrical, and enterprise systems, creating a unified environment for improved efficiency and decision-making. The system combines control, safety, and information management. OPC UA is a key component of System 800xA's integration and connectivity capabilities. It serves as a standardized communication protocol for data exchange between different devices and systems. [31] Using OPC UA in the application enables it to be configured according to the Robotics companion specification, allowing it to monitor attributes defined in its information model.

### 3.4.6 Design and simulation tools

Different kinds of plant simulation tools, such as Siemens *Tecnomatix*, can exploit the OPC UA protocol to simulate entire automation processes while leveraging OPC UA for seamless data exchange and communication. The Tecnomatix software is used for modeling, simulating, visualizing, and analyzing production systems and logistics processes, with the goal of optimizing material flows and resource utilization. By integrating real-time data from PLCs and other automation components, these tools enable the creation of accurate digital twins that replicate real-world systems. This facilitates improved pro-

cess optimization, predictive maintenance, and faster decision-making. [32] When designing a system that incorporates robots, Tecnomatix can simulate the robots' operations and the flow of data based on the attributes defined by the Robotics Companion's information model.

In industrial automation design, programming, and management, advanced software such as Siemens' *TIA Portal* and Rockwell Automation's *FactoryTalk* are used to optimize production processes, integrate devices, and maintain systems. Both support the OPC UA protocol for seamless communication between robots, controllers, and other devices. That means that both supports the attributes defined by the Robotics Companion's information model. *FactoryTalk* focuses on real-time monitoring and production data analysis, while *TIA Portal* offers a comprehensive platform for e.g. designing and programming automation systems. [33, 34]

## 4. CONCLUSION

The OPC UA Robotics companion is an important standard designed to enhance communication between robots and other automation systems. The purpose of this bachelor's thesis was to examine this standard, evaluate its advantages and disadvantages, and explore its current ecosystem. The findings indicate that the Robotics companion provides significant benefits, such as a standardized communication protocol that improves device interoperability and simplifies system construction. Additionally, it enables scalability and ensures data security, which is particularly crucial for meeting the demands of modern industrial needs.

On the other hand, the thesis also revealed challenges, such as the complexity of the standard and the demanding implementation process, especially for smaller companies. The complexity of managing PKI and potential weaknesses in communication layers highlight the need for careful design and ongoing maintenance. Furthermore, the use of the standard requires technological infrastructure, which might complicate its widespread adoption.

At present, the Robotics companion is still an evolving technology, and its adoption has primarily begun with leading robot and automation equipment manufacturers. The standard facilitates seamless integration of devices and systems, which is essential for Industry 4.0 and smart factory development. For instance, the integration of MES and SCADA systems with robots has become significantly easier, and simulation tools such as Tecnomatix leverage the standard to create precise digital twins.

Future research could focus on simplifying the adoption process for smaller companies, examining the scalability of OPC UA and Robotics companion in various industries, and developing its infrastructure and management practices so that PKI management becomes clearer and less complex. Studies could investigate the impact of Robotics companion on specific applications, such as robotics in manufacturing and logistics.

From a practical perspective, improving the accessibility and implementation of Robotics companion could accelerate its widespread adoption. Recommendations for practitioners include investing in proper training for staff and ensuring sufficient technical infrastructure to support PKI management.

In conclusion, while the Robotics companion presents challenges, its advantages and potential for future development, position it as a key enabler of Industry 4.0 and the digitalization of manufacturing. Continued research and practical improvements will be essential to unlocking its full potential in the automation landscape.

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