F O U N D A T I O N

The Industrial Interoperability Standard

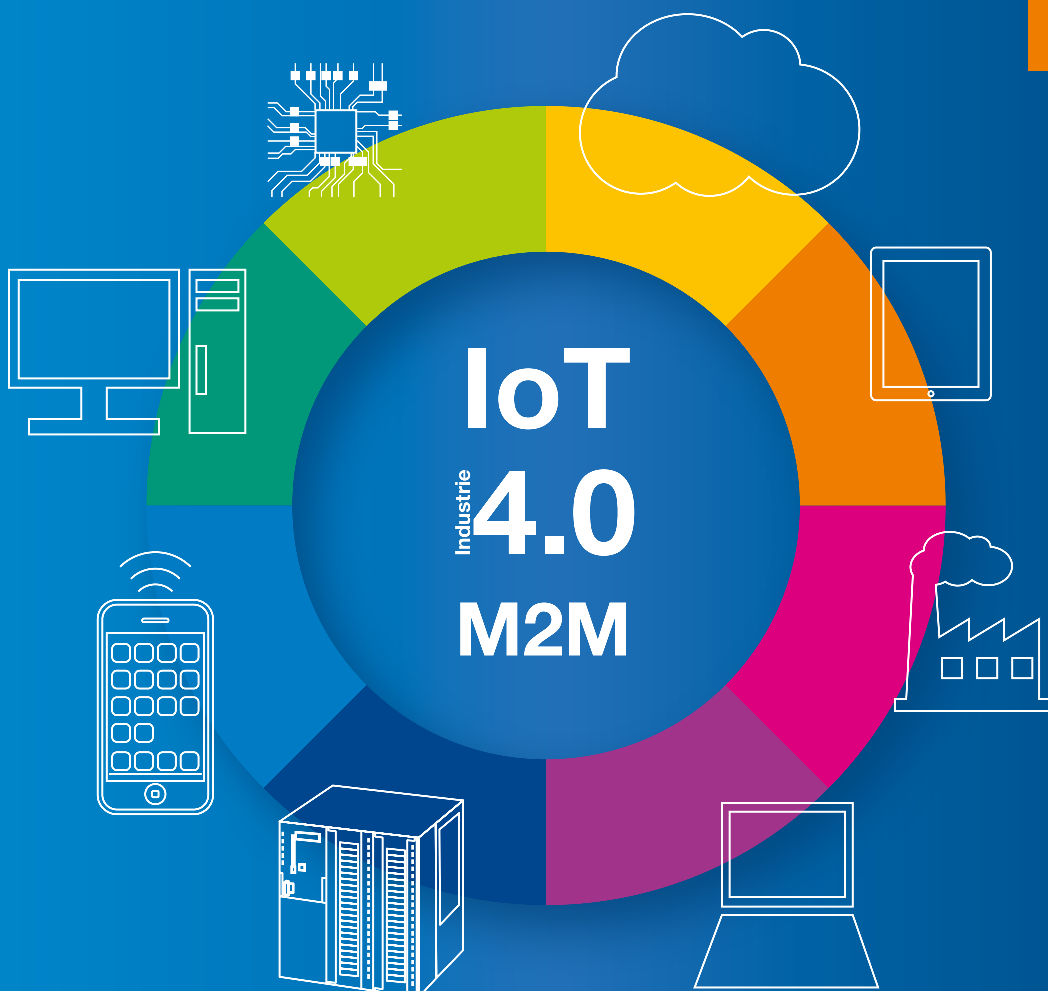
OPC Unified Architecture

Interoperability for Industrie 4.0 and the Internet of Things

Version V20// 2026

UPDATE

- New Success Stories
- New Quotes
- Offerings
- Certification Program
- OPC UAcademic



Stefan Hoppe
President and Executive Director OPC Foundation

Welcome to the OPC Foundation! As the international standard for vertical and horizontal communication, OPC UA provides semantic interoperability for the smart world of connected systems.

OPC Unified Architecture (OPC UA) is the information exchange standard for secure, reliable, manufacturer- and platform-independent industrial communications. It enables data exchange between products from different manufacturers and across operating systems. The OPC UA standard is based on specifications that were developed in close cooperation between manufacturers, users, research institutes and consortia, in order to enable consistent information exchange in heterogeneous systems.

For nearly three decades, OPC has been, and continues to be, the go to connectivity standard in industry. With the advent of the Internet of Things (IoT) era, OPC adoption has also shown growth in new, non-industrial markets. By introducing a Service-Oriented-Architecture (SOA) in industrial automation systems in 2007, OPC UA started to offer a scalable, platform-independent solution for interoperability which combines the benefits of web services and integrated security with a consistent data model.

OPC UA is an IEC standard and is therefore ideally suited for collaboration with other organizations. As a global, independent, non-profit organization, the OPC Foundation coordinates the further development of the OPC standard in collaboration with users, manufacturers and researchers. Activities include:

- → Development and maintenance of specifications
- → Certification and compliance testing of implementations
- → Cooperation with other organizations

This updated brochure provides an overview of IoT, M2M (Machine to Machine), and Industrie 4.0 data interoperability requirements and illustrates solutions, technical details, and implementations based on OPC UA.

With broad acceptance among representatives from research, industry, and associations, the OPC UA standard is well positioned to serve a key role in facilitating today's complex data and information exchange needs and in helping shape the future of data interoperability.

Regards,
Stefan Hoppe
President and Executive Director
OPC Foundation
stefan.hoppe@opcfoundation.org
www.opcfoundation.org

Contents

OPC UA: Interoperability for the IIoT

Digitalization is an important and highly attractive growth market. The goal is to foster the integration of IT technologies with products, systems, solutions, and services across the complete value chain which spans entire product and service life cycles. Once implemented, digitalization opens the doors to unprecedented new business opportunities and customer value; however, this is only possible if meaningful information can be shared openly and securely at every level. OPC UA is a standard that makes this possible.

INTERNET OF THINGS (IOT)

The IoT brings together a broad range of technologies that have traditionally not been connected via today's near-ubiquitous IP-based networks and puts them to work in novel new ways. While Ethernet enables things to 'reach' each other, they still need a common way to communicate meaningfully to be useful.

At the heart of the Industrial IoT (IIoT), OPC UA addresses the need for standardized data connectivity and interoperability for both horizontal and vertical data communications. An example of horizontal communications is Machine-to-Machine (M2M) data connectivity among shop floor systems. An example of vertical communications is device-to-cloud data transfer. In both cases, OPC UA provides a secure, reliable foundation, robust enough to facilitate standards-based data connectivity and interoperability. This did not happen overnight. The OPC Foundation has worked for years with companies and associations around the world and continues to expand its collaborations to ensure OPC UA meets the ever-growing diversity of communication needs the IoT era brings.

GROWING MACHINE INTERACTIONS

M2M typically refers to communications between two machines or between a more or less intelligent device and a central computer. The communication medium can either be a cable modem or wireless modem. In more modern devices, which range from vending machines to robots, data communications are increasingly established over ever faster and resilient cell networks (5G as an example) via SIM cards embedded directly into the machines. Such point-to-point connections allow the dedicated, onboard computers to send key data like stock levels, usage statistics, and alarm messages for the machine owners to best supply and maintain their assets. Such machine visibility opens the doors to new business models typically around logistics, maintenance, and special condition monitoring. For example, in the commercial environment, reword – turbines are not deployed at airports but rather on aircraft – but parts are stocked at airports. This optimizes maintenance scheduling, reduces unplanned down-time, and flight delays – all of which reduce operating and maximize customer satisfaction.

INTERNET

While M2M is a part of the IoT, the IoT is not limited to the exchange of data between intelligent devices. It also includes data from simple sensors and actuators (i.e wearable fitness solutions in the consumer space, safety sensors like gas and proximity detectors in industrial settings) that are first aggregated and processed locally then sent via gateways (e.g. a smart phone) to centralized cloud-based systems. Within the IoT complex networks of intelligent systems are emerging. A similar development can be observed in industrial solutions where networked, shop floor machines and field devices are increasingly expected to process and combine data from other devices instead of just sending their own raw data. As such, they can consume and provide information from/to other field devices to create new value for the user. Ultimately, such machine collaboration enables individual machines to provide technicians with maintenance strategies and on-demand maintenance historical data. A far cry from the raw sensor-data-only systems of yesteryear.

EXPANDED COMMUNICATION DIVERSITY

Communication requirements between 'things' and services in the IoT era are far broader than what is seen in today's established infrastructures which, primarily rely on point-to-point communications. For example, rather than query individual sensors and devices directly via point-to-point communications, broader IoT systems will subscribe to the data these sub-components publish via publish-subscribe (PubSub) protocols over IP-based networks. This will simultaneously facilitate high scalability and improved security. The customer benefits, created by the combination of intelligent devices and systems, along with the expanded services operators and vendors provide, will serve as the foundation for realizing the potential benefits the IoT has to offer.

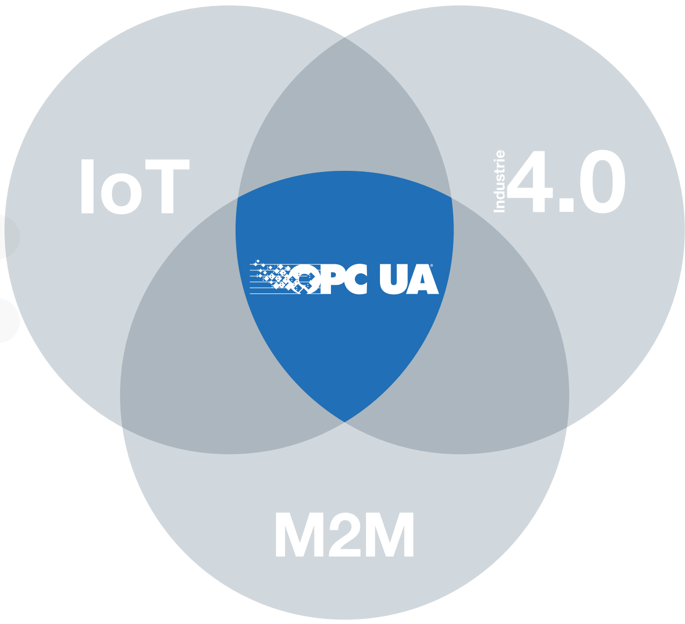
OPC UA FOR VERSATILE INTEROPERABILITY

The vision of the IoT can only be realized if the underlying communication between components is based on a global communication standard that can fulfill a wide range of complex requirements.

For example, while a PubSub model is essential in low-resource, one-to-many communications, where high scalability and speed are needed, the standard must also support a secure, connection-oriented, client/server model for bi-directional communication that allows sending control commands to actors. OPC UA supports both models.

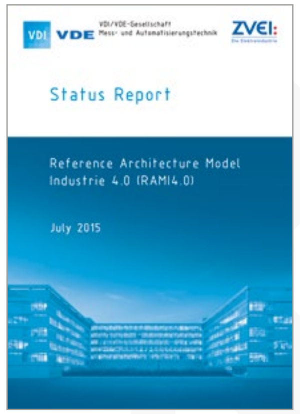
Beyond simple 'data' sharing, a core IoT era standard must facilitate rich information exchange, which requires it to support a semantic metadata model that describes the data, and its purpose, to help best use the data directly. This is especially important when large amounts of data are pooled (aggregated) from a diverse eco system of third party systems. The OPC UA standard, object-oriented, information modeling mechanisms, directly fulfill this requirement.

Scalability and the possibility of integration across all network layers is required as well as platform and vendor independence. Here too, the OPC UA standard meets these requirements in an single, integrated package.



OPC UA serves as the common data connectivity and collaboration standard for local and remote device access in IoT, M2M, and Industrie4.0 settings.

OPC UA – pioneer for Industrie 4.0



Source: www.zvei.org, July 2015

CHALLENGE

To remain competitive in the modern global economy, industrialized nations and their businesses must answer the challenges of increasing efficiency with ever shorter production cycles: through more effective use of energy and resources; by reducing time-to-market; by producing more complex products, faster, with rapid innovation cycles; and by increasing flexibility through individualized mass production.

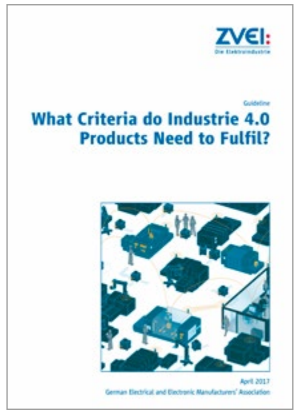
VISION

The 4th industrial revolution (Industrie 4.0) is driven by advanced Information and Communication Technologies (ICT), which are becoming increasingly prevalent in industrial automation. In these distributed, intelligent systems, physical components, and their data-based virtual counterparts, merge into cyber physical systems (CPS). When networked, CPS components form "smart" objects that can be further assembled into "smart factories" where production units can organize themselves and become self-contained, since they have all the information they need or can obtain it independently. Such systems can reconfigure and optimize themselves and are expandable (plug-and-produce) without engineering intervention or manual installation. Beyond the manufacturing process itself, digital product information is also maintained within the product itself throughout its lifecycle and the value chain it moves through. When networked, such "smart" products then join the broader IoT conversation, responding to internal and external events with learned behavior patterns – benefiting both consumers and producers.

REQUIREMENTS

Considerable effort is required to implement the vision of Industrie 4.0 successfully, since a broad range of requirements must be met to make it all work. To manage the inherent complexity of this undertaking, comprehensive modularization, wide-ranging standardization, and consistent digitization are needed. As these requirements are more evolutionary than revolutionary, the technology to address them already exists but needs to be carefully brought together to build the foundation for Industrie 4.0

OPC UA COVERS THE COMMUNICATION AND INFORMATION LAYER

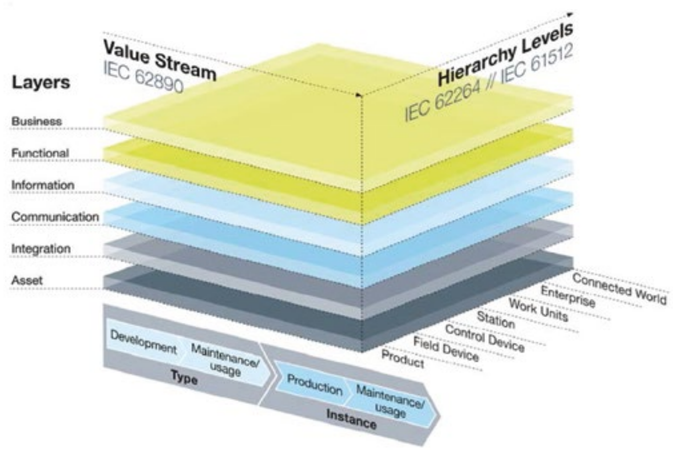


Source: www.zvei.org, April 2017

Product properties 2017 for the criteria for Industrie 4.0 products

→ **Criteria 2:**
Industrie 4.0 communication
Mandatory: Product addressable online via TCP/UDP&IP with at least the information model from OPC UA

→ **Criteria 5:**
Industrie 4.0 services and conditions
Optional: Information such as statuses, error messages, warnings, etc. available via OPC UA information model in accordance with an industry standard



Copyright © ZVEI, SG2

Industrie 4.0 requirements – OPC UA solution

Industrie 4.0 requirements	OPC UA solution
Independence of the communication technology from manufacturer, sector, operating system, programming language	The OPC Foundation is a vendor-independent, non-profit organization. Membership is not required for using the OPC UA technology or for developing OPC UA products. OPC is widely used in automation but is technologically sector-neutral. OPC UA runs on all operating systems – there are even chip layer implementations without an operating system. OPC UA can be implemented in all languages – currently, there are communication stacks available in Ansi C/C++, .NET, and Java.
Scalability for integrated networking including the smallest sensors, embedded devices and PLC controllers, PCs, smartphones, mainframes and cloud applications. Horizontal and vertical communication across all layers.	OPC UA scales from 15 kB footprint (Fraunhofer Lemgo) through to single- and multi-core hardware with a wide range of CPU architectures (Intel, ARM, PPC, etc.). OPC UA is used in embedded field devices such as RFID readers, protocol converters, etc. and in virtually all controllers, SCADA/HMI products, and MES/ERP systems. Projects have already been successfully realized in various cloud environments, including: Amazon, Foxconn, Google, and Microsoft Azure Cloud.
Secure transfer and authentication at user and application levels	OPC UA provides mechanisms for application and user authentication. It further includes signed and encrypted transfer mechanisms for data integrity and confidentiality, as well as a rights concept at the data-point level for authorization, including audit audit functionality.
SOA, transport via established standards such as TCP/IP for exchanging live and historic data, commands and events (event/callback)	OPC UA is independent of the transport method. Different protocol bindings are available for different use-cases (e.g. high-performance applications, Web Browser access). Additionally, a Publish/Subscribe (PubSub) communication model can be used. The communication stacks guarantee consistent transport of all OPC UA data. Besides live and real-time data, historical data and its mathematical aggregates are also standardized in OPC UA. Furthermore, method calls with complex arguments are supported along with alarming and eventing via a token based mechanism (late polling).
Mapping of information content with any degree of complexity for modeling of virtual objects to represent the actual products and their production steps.	OPC UA provides a fully networked, object-oriented address space (hierarchical and full-meshed networks), that includes metadata and object descriptions. Object structures can be generated via referencing between object instances and their underlytng type definitions, which are also object oriented and can be extended through inheritance. Since OPC UA servers carry both their object instances and associated type objects, OPC UA clients can navigate in any given OPC UA server's address space to obtain all the instance and type information they need, even for types previously unknown to them. This is a base requirement for Plug-and-Produce functionality, without prior configuration of the devices.
Unplanned, ad hoc communication for plug-and-produce function with description of the access data and the offered function (services) for self-organized (also autonomous) participation in "smart" networked orchestration/combination of components	OPC UA defines different "discovery" mechanisms for identification and notification of OPC UA-capable devices and their functions within a network. OPC UA participants can be collocated (on the same host), in a subnet, or distributed globally within the enterprise. Aggregation across subnets and intelligent, configuration-less procedures (e.g. Zeroconf) are used to identify and address network participants.
Integration into engineering and semantic extension	The OPC Foundation successfully collaborated with other organizations (PLCopen, MDIS, FDI, AIM, VDMA, MTConnect, AutomationML, etc.) and continues to expand its collaboration activities with groups from an ever-broader range of industries. See page 20 for a list of current collaboration partners.
Verification of conformity with the defined standard	OPC UA is an IEC standard (IEC 62541) for which tools and test laboratories are available for testing and certifying conformity. Additional test events (e.g. Plugfest) enhance quality and ensure compatibility. Expanded tests are required for extensions/amendments (e.g. companion standards, semantics). In addition, various validations of data security and functional safety are performed by external test and certification bodies.

MANUFACTURING USA INNOVATION INSTITUTES

Under the auspices of The National Institute of Standards and Technology (NIST), manufacturing innovation institutes (MIIs) have been formed and funded by Federal agencies, including the U.S. Department of Energy and U.S. Department of Defense. Both CESMII and MxD, two such innovation institutes, are utilizing OPC UA technologies throughout their services and programming.

CESMII IS LEVERAGING OPC UA

In an effort to identify common data in machines, CESMII is leveraging OPC UA as an industry standard interface. Through repeatable use of OPC information models or, as CESMII calls them, "Smart Manufacturing Profiles," these semantic models become reliable, scalable interfaces for developers, rather than starting from scratch with individual data extraction. These data profiles will remain an open standard from which the entire industry can benefit, thus, accelerating innovation, research, and development projects supported through the Institute.

CESMII's program and administrative home is with the University of California Los Angeles (UCLA), in partnership with the U.S. Department of Energy's Advanced Manufacturing Office.

MXD – AN INCUBATOR FOR OPC UA RESEARCH AND DEMONSTRATION

Positioned in the heartland of US manufacturing, MxD boasts a vast facility in Chicago, Illinois, dedicated to research and innovation through the hosting of various experiments and test-beds in its fully outfitted demonstration center. Industry partners leverage MxD resources for implementations ranging from Proof-of-Concept (PoC) to advanced research and testing of industrial automation applications. MxD is dedicated to solve critical manufacturing challenges by accelerating digital adoption, empowering a skilled workforce, and modernizing supply chains.

MxD, as designated by the U.S. Department of Defense is also the National Center for Cybersecurity in Manufacturing.

DIGITAL TWIN CONSORTIUM (DTC) THE AUTHORITY IN DIGITAL TWIN™

Digital Twin Consortium drives awareness, adoption, interoperability, and development of digital twin technology, through a collaborative partnership with industry, academia, and government expertise. The Consortium is dedicated to the overall development of digital twins and they accelerate this market by propelling innovation and guiding outcomes for technology end users.

DTC IS MAKING OPC UA MODELS MORE ACCESSIBLE

The DTC is maintaining the popular UA Nodeset Web Viewer on their open-source GitHub repository. It allows upload of OPC UA information models to the UA Cloud Library.

https://github.com/digitaltwinconsortium

Source: www.iiconsortium.org

One the major goals of the "Industrial Internet Consortium" (IIC) is the creation of industry use cases and testbeds for real-world applications. The testbeds create recommendations for the reference architecture and frameworks necessary for interoperability. OPC UA is the enabling technology for SoA interoperability and thus part of the IIC Connectivity Framework published in February 2017.

IIC TESTBEDS USING OPC UA

1. Smart manufacturing connectivity for brownfield sensors
2. Time sensitive networking (TSN) testbed
3. Smart factory web testbed

INDUSTRIAL VALUE CHAIN INITIATIVE (IVI)

»OPC UA is a key enabler for connected manufacturing, where huge variety of factory-floor operations are connected both through the cyber and physical ways. The Industrial Value Chain Initiative (IVI) is an organization providing win-win cooperation opportunities for enterprises moving toward the next era of connected industries. Since most of the members are manufacturers, IVI is especially focusing on actual and practical requirements of factories. In consideration of the Industrial Value Chain Reference Architecture (IVRA), those requirements are described in a form of smart manufacturing scenario, which shows a current situation as well as a desired goal of the factory. While the scenarios are evaluated in the test-bed factory, an IVI platform performs and OPC UA can give a reasonable way of implementation for secure and concrete connections. Furthermore, as an open standard specification, OPC UA is meaningful for the IVI platform ecosystem, where application suppliers, IoT device vendors, data infrastructure and software tool providers are involved to enhance the value of the platforms.«

Prof. Dr. Yasuyuki Nishioka, President, Industrial Value Chain Initiative

»Mitsubishi Electric takes the lead on "Monozukuri" with a strong emphasis on reducing TCO through e-F@ctory solutions by integrating Factory Automation and IT to optimize Development, Production and the Maintenance processes.

OPC UA enhances e-F@ctory by providing Multi-Vender connectivity and furthermore, OPC UA continues to expand TSN technology to new field device level specifications such as OPC UA FLC.

Mitsubishi Electric has adapted TSN that enables rapid IT and OT integration with CC-Link IE TSN which is a core network for e-F@ctory.Now, Now, as a key member of the Board of Directors of the OPC Foundation, Mitsubishi Electric is committed to actively participate and contribute to the broader OPC activities. Utilizing its storied success and experience and applying that to the Foundation's core specifications development, the ultimate benefit will be a better World of Manufacturing and Social Infrastructure.«

Takashi Shibata, General Manger, OT Security Business Development Dept, Mitsubishi Electric Corporation, OPCF Board Member

The Chinese government put forward a Made In China 2025 plan to facilitate China's transformation from a manufacturing giant with a sole focus on quantity to one with an edge in higher quality products. The central focus of the Made In China 2025 initiative is Intelligent Manufacturing, which is based on deep integration of new-generation information technology and advanced manufacturing technology. It is an effective means to achieve the goals of shortening product development cycles, increasing production efficiency, and improving product quality while reducing operating costs and energy consumption.

Intelligent Manufacturing requires horizontal and vertical integration of all information systems, including IT and OT systems in factories and plants. This not only requires the transmission of raw data values but also semantic-based information exchange. Based on these requirements, OPC UA was adopted because it supports semantic-based communications via information modeling and services based on a services-oriented architecture (SOA). OPC UA was a natural fit for the integration of interconnected networks in digital factory/plant and facilitates semantic interoperability. Therefore, SAC/TC124 has organized to transfer OPC UA specifications to Chinese recommended national standard.

12 OPC UA parts are Chinese National Standards GB/T 33863.x

»Industrial IoT can be viewed as the convergence of ICT and OT in the various industrial verticals.The resulting technology innovation has created an inflection point that will change how we think of, participate in and benefit from the industrial sector. In response to this inflection point, there is an emerging ecosystem that includes standards, best practices and reference architectures. This ecosystem includes both industry stakeholders and government initiatives across geographies and verticals. OPC Foundation is an essential part of that emerging ecosystem. It defines OPC UA, a standard that is fundamental to linking the ICT an OT environments in a way that is both secure and forward looking, thus enabling new innovations such as real time manufacturing, digital manufacturing and low latency/time sensitive industrial systems.«

Dr. Jingyi Hu (Bob) 胡静宜
Chief Strategy Officer of Industry Digitalization, Huawei Technologies Co., Ltd., OPCF Board Member

»In 2015, ITEI undertook 7 Intelligent Manufacturing Projects issued from MIIT, in which basic and common standards regarding to intelligent manufacturing body will be set. One project is "Industrial control networks standard research and verification platform", and one task of this project is to draft a national standard named "OPC UA-based unified architecture for interconnected networks in digital plant", which will provide a unified solution for interconnecting the networks among device level, control and management level in digital plant. This standard will promote, that the device manufacturers should provide OPC UA servers for their produced devices directly, and the software vendors should better to embed OPC UA clients. Therefore, for the device manufacturers and the software vendors, it is only needed to invest and develop once, while for the manufacturing enterprises and the system integrators, it will avoid case-by-case solutions, which will decrease integrating costs and cycles greatly.«

Jinsong Ouyang, President, Instrumentation Technology & Economy Institute, P.R.China (ITEI) Vice chairman of the committee, National TC124 On Industrial Process Measurement, Control And Automation Of Sac

The Government of the Republic of Korea established the "AI Factory M.AX Alliance (Manufacturing Artificial Intelligence Transformation Alliance)" in October 2025 in collaboration with leading companies such as Samsung Electronics, Hyundai Motor Company, LG Energy Solution, and Samsung Heavy Industries, with the goal of becoming a global leader in manufacturing AI by 2030. Accordingly, the Ministry of Trade, Industry and Resources(MOTIR) plans to work with key industry players to develop technologies and carry out demonstration projects essential for building autonomous AI factories, thereby positioning Korea as an exporter of AI factory solutions. OPC UA, which enables semantic interoperability, is expected to serve as the "circulatory system" of these autonomous AI factories realized through the AI Factory M.AX Alliance.

»OPC UA is an international standard that ensures semantic interoperability, a key enabler of AI-driven autonomous manufacturing. Since 2014, KETI has operated the Smart Manufacturing Innovation Center, developing a wide range of manufacturing application solutions leveraging OPC UA. We expect that AI-driven autonomous manufacturing solutions based on OPC UA will serve as a core technology within Korea's M.AX technology development initiative.«

Byunghun Song, Head of Autonomous Manufacturing Research Center, KETI

Korea: Manufacturing Artificial Intelligence Transformation Alliance

»The true potential of Industrial IoT will be realized with solutions that guarantee interoperability across business domains, where are independent from vendors and platforms on the market. As one of the largest manufacturing companies in the world, Samsung Electronics sees its great value proposition of the OPC Foundation in terms of protocol interoperability that enables seamless Industrial IoT services. Especially, the OPC Foundation delivers the promising solutions of the OPC UA framework in terms of not only specifications, but also the reliable open source implementations, which guarantees the OPC UA Certifications. This will help us to accelerate Samsung's efforts in deploying the interoperable Industrial IoT edge platform for our manufacturing infrastructures.«

Dr. Jinguk Jeong, Vice President, Samsung Electronics

»OPC UA is helping to overcome various challenges in the digitalization process of the manufacturing site in the past. In particular, it has supported incredible scalability to allow flexible communication of various manufacturing facilities, and it has relieved software developers of the burden of dealing with numerous vendor-specific protocols by providing a single, and standardized communication method. HANCOM MDS has developed "Industrial IoT platform ThingSPIN®" to generate data sets for use in machine learning and deep learning as well as make it easy to connect, collect, and visualize the state of the production facilities. We are applied OPC UA as the most important data source.«

Sangsoo Kim, Leader of IIoT Platform Team, Hancom MDS

Microsoft

»OPC UA is an essential component of manufacturing and process control technology, it enables the internet of things today, and it is going to enable digital twins and systems based on mixed reality and artificial intelligence on the factory floor. In keeping with our commitment to openness and collaboration, Microsoft is fully committed to supporting OPC UA and its evolution.«

Christoph Berlin, Vice President of Engineering, Microsoft, OPCF Board Member

Google Cloud

»Google Cloud's membership reinforces our commitment to openness and industry collaboration. OPC UA will be our way of incorporating machine data into our data analytics and AI capabilities, to ultimately drive new capability and performance within the factory. By driving AI across the value chain, our goal is to provide flexibility and choice at industrial scale.«

Praveen Rao, Global Head Manufacturing, Google Cloud, OPCF Board Member

aws

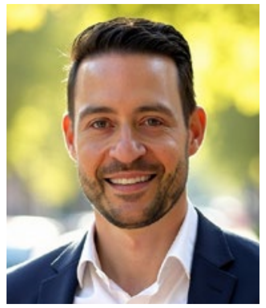
»The future of manufacturing is being shaped by AI's ability to turn data into actionable insights and drive operational efficiencies. However, this potential can only be fully realized when data is accessible and interoperable across the entire manufacturing ecosystem. Open standards like OPC UA help provide the necessary foundation for seamlessly integrating manufacturing data into cloud environments, enhancing productivity, and accelerating the digital transformation across the manufacturing sector.«

Steve Blackwell, Head of Manufacturing CoE, OPCF Board Member

Honeywell

»The main challenges facing manufacturers and plant operators today continue to be safety, efficiency, reliability, productivity and security. By harnessing the power of digitization in the Industrie4.0 and IIoT era, Honeywell helps customers address these challenges in new ways by leveraging the incredible value hidden in the vast amounts of data being produced by our customers' facilities. OPC UA plays a key strategic role in Honeywell solutions by providing secure, reliable access to context rich 3rd party data which helps unlock the full potential analytics has to offer.«

Vimal Kapur, Chief Executive Officer, Honeywell



SAP

»Manufacturing thrives on scalable connectivity and intelligence to drive automation, flexibility, and productivity on the shop floor. With OPC UA as a key enabler — from sensor-level communication to cloud integration — SAP is committed to supporting the standard and contributing to its continuous evolution.«

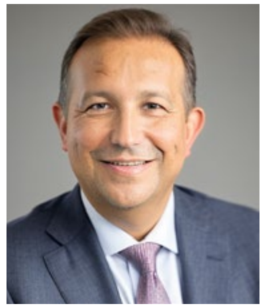
Matthias Hollenders, VP Product Management Manufacturing SAP SE, OPCF Board Member

Global Players

Rockwell Automation

»Smart manufacturing – supported by the emerging disciplines of analytics and AI – is the goal of digital transformation, enabling users to make better and faster decisions. The cornerstone of digital transformation lies in the seamless and secure integration of information throughout an enterprise's OT and IT systems. OPC UA has become widely accepted as one of the most important enabling technologies of digital transformation – the industry standard trusted for information exchange.«

Dr. Jan Bezdicek, Director System Architecture, Rockwell Automation, OPCF Board Member



Schneider Electric

»In order to reap the benefits of the promise made by Industry 4.0, OPAF, … Schneider Electric believes that vertical and horizontal communication interoperability across the automation pyramid is a must for industrial customers. The combination of OPC UA Client Server, OPC UA Pub Sub and the extension of OPC UA including TSN down to the field will enable such interoperability. That's why our open EcoStruxure Plant & Machine architecture will standardize on OPC UA over the time.«

Aurélien Le Sant, CTO Industrial Automation / SVP Innovation & Technology, Schneider Electric, OPCF Board Member

ABB

»In the future, customers across various industries will no longer be bound to suppliers based on the communications protocol used and competition will more strongly focus on creating value. Adoption of OPC UA over TSN will drive this paradigm also into the world of deterministic and real-time communication. At the same time, it will enable using the same consistent information model from the field to the cloud.«

Stefan Basenach, is Head of Process Control Platform in ABB Process Automation, OPCF Board Member

BECKHOFF

»Industrie 4.0 links the world of automation with the IT and Internet world and will enable the resulting synergies to be leveraged. Networking means communication, communication requires languages and associated functions and services. OPC UA offers a very powerful and adaptable standard basis that is accepted worldwide.«

Hans Beckhoff, Managing Director, Beckhoff Automation GmbH

SIEMENS

»Siemens is experiencing the digitalization of all branches of industry and are actively shaping it.
When it comes to networking and standardization or cybersecurity – the industrial requirements are increasing. Here, the OPC UA communication standard offers the best conditions for digitalization use-cases, independent of platform and manufacturer and with integrated security mechanisms. That's why Siemens relies on OPC UA for vertical connectivity to the cloud as well as for communication between machines. OPC UA is a standard that we regard as particularly relevant and a key element for Industrie 4.0.
Siemens is a founding member of the OPC Foundation and highly committed to OPC UA Technology: OPC standards are used in many of our innovations and Siemens is among the first companies whose products are OPC UA certified.«

Thomas Hahn, Siemens AG, OPCF Board Member and Vice President

»With OPC UA a future proven open communication standard is available to the industry. Its scalability allows horizontal and vertical networking of systems, machines and processes. We as Bosch Rexroth are supporting and driving open standards since we believe in the value of open ecosystems. Providing our customers with open interfaces allows easy integration of Rexroth products into their specific automation and IoT solutions. We appreciate and support the UAFX extension for real-time communication and will make it available to our customers.«

Dr. Maik Rabe, Vice President Engineering
Bosch Rexroth AG, Business Unit Automation and Electrification Solutions

»OPC UA will provide a common layer of technical and semantic inoperability for M2M and M2H (Machine to Human) communications that is critical for enabling the Industrial Internet. By establishing interoperability standards together as an industry, we will provide a scalable, reliable platform for GE and others to build out the Industrial Internet and expand the value and capabilities we can provide for our customers.«

Danielle Merfeld, Global Research Technology Director, General Electric

OPC UA in the industry

»Since the OPC Foundation launched its new OPC UA technology and standards system, industrial digitalization has undergone tremendous change—encompassing early Industry 4.0 innovations like the Industrial Internet of Things (IIoT) and digital twins, as well as more recent trends such as industrial AI and industrial ontologies. Yet no matter what new trends, technologies, or concepts emerge, OPC UA can adapt quickly, thanks to its flexible technical architecture and scalable standards.«

Yan Ding, System Designer and R&D Director, Hollysys Research Institute

»The OPC UA standard serves as a cornerstone and enabler of industrial digital transformation. It revolutionizes data exchange in industrial systems by providing a unified, secure, and semantically rich communication framework. We believe that choosing OPC UA-compliant devices and technologies ensures our customers remain compatible with emerging technologies for the long term, thereby protecting their investments.«

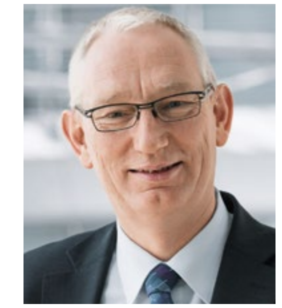
Charles Ben, CEO, Beijing Mestime Information Technology Co., Ltd. – OPCF China China Board Member

»Yokogawa has been a member of OPC Foundation since its establishment and has made a major contribution to the development of the OPC specifications, from OPC Classic to OPC UA. Yokogawa has also released many OPC-compatible products and incorporates these in the many solutions that it provides to its customers. Yokogawa is fully committed to OPC UA and will continue to play a role in its development.«

Shinji Oda, Yokogawa, President OPC Council Japan,
OPCF Board Member and Chairperson

»From the sensor to the cloud, the OPC Foundation works on the standardization of protocols and information in support of an open, multi-vendor ecosystem. Analog Devices (ADI), together with our customers and partners, embraces open standards to enable the next generation of solutions based on artificial intelligence — from the smallest sensor devices to the future of mobile intelligent robotics. OPC UA, UACX, UAFX and the OPC UA information models provide a solid foundation for the semantic interoperability that enables the industry to work and innovate together.«

Rashmi Misra, Chief AI Officer, Analog Devices, Inc.



»In the production of the future, standardized interfaces like OPC UA will be essential for the communication and connection of intelligent components which are ready for Plug and Produce. Thereby we will be able to connect modular and scalable production facilities much easier to superordinate systems like MES or ERP. At the OPC Day Europe in 2014 we already showed an OPC UA test implementation in our production. Also the innovative transport system Multi-Carrier-System and the automation platform CPX both have an OPC UA interface for integration into Industrie 4.0 HOST environments.«

Prof. Dr. Peter Post, Leiter Corporate Research and Technology, FESTO

»OPC UA is the most promising standard to transfer semantic data from a sensor via the PLC or edge level to the cloud. This creates interoperability across manufacturer boundaries and with the combination of OPC UA over MQTT a flexible transmission can even be set up directly to the cloud.
Integrated security mechanisms and a standardized update process for firmware, configuration and application of devices with OPC UA Server are key in a networked world. Furthermore, OPC UA enables the integration of functional safety and, thanks to the many information models, a good integration of device data into the digital twin. All these features and the future prospects with OPC UA FX make OPC UA the communication standard for Industry 4.0 for us.«

Ulrich Leidecker, COO & President Industry Management and Automation, Phoenix Contact

»Shenzhen Qianhai Well Sell Technology Company Limited (Well Sell) is a high-tech enterprise focusing on providing intelligent management systems and reliable implementation of such on factories. Based on the OPC UA infrastructure, we have developed our own RPAS and UA-MES systems. These have revolutionised the traditional hierarchical smart factory production structure into a flattened and highly customized new form. We have also succeeded in the world's first and foremost innovative solution remotely despatching production directories directly from customer side to the zero-labour factory side for production execution. This is a brand new industry 4.0 eco-system whereby enterprises are connected via big data with the tremendous contribution of OPC UA.«

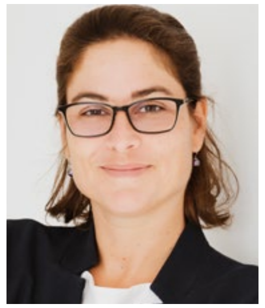
Gary Kwong, CEO, Well Sell

»OPC UA represents an essential step forward in truly open communications standards, without which there can be no Industrie 4.0 or industrial Internet of Things. OPC UA is consistent with OMAC's most important initiatives, combining standards with functionality to bridge the persistent gap between machines, control platforms, and management systems.«

Spencer Cramer, Founder & CEO, ei3 – Chairperson OMAC

OMAC
The Organization for Machine Automation and Control

Cooperations with organizations



»LADS is the new cross-device and cross-manufacturer communication standard for the laboratory sector which benefits from the high scalability and flexibility of OPC UA. While we can concentrate on the further development and marketing of LADS, we highly benefit from the OPC community, which is continuously working on compatibility, tech stacks and cybersecurity.«

Dr. Janina Bolling, Head of Analytical, Bio and Laboratory Technologies, SPECTARIS e.V.

SPECTARIS
German Industry Association for Optics, Photonics, Analytical and Medical Technologies

»The complexity of industrial systems is continuously increasing. To manage this complexity within design and application methods and technologies are required enabling modularity and consequent structuring. The OPC technology and its newest representative OPC UA have been proven to be successfully applicable in this field. It is wide spread applied and can be regarded as entry point for the combination of engineering and application as intended in the Industrie 4.0 approach.«

Prof. Dr.- Ing. habil. Arndt Lüder, Otto-v.-Guericke University Magdeburg, Fakulty Mechanical Engineering, AutomationML e.V. Board of Directors

<AutomationML/>
The Glue for Seamless Automation Engineering

PLCopen
for efficiency in automation

»Communication is not about data. Communication is about information and access to that in an easy and secure way. This is what the cooperation PLCopen and OPC Foundation is all about. OPC UA technology creates the possibility for a transparent communication independent of the network, which is the foundation for a new communication age in industrial control.«

Eelco van der Wal, Managing Director PLCopen

aim
Defining Today's Technology Standards; Empowering Tomorrow's Solutions.

»The implementation of future concepts like the Internet of Things and Industrie 4.0 requires reliable data about the trace of moving objects in manufacturing and logistics. In order to achieve such data systems identifying objects automatically, sensors recording environmental data and real-time locating systems must be installed increasingly. OPC UA provides the right architecture to integrate such systems with the existing IT landscape in the enterprises. The OPC AIM Companion Specification will substantially facilitate these tasks.«

Peter Altes, Managing Director, AIM-D Germany – Austria – Switzerland

»OPC UA is the only interoperability solution that is widely adopted and fulfilling the requirements of the mechanical engineering industry. Therefore, VDMA and OPC Foundation joined forces to develop "The Global Production Language" to standardize the semantics of shop-floor information based on OPC UA.«

Andreas Faath, Managing Director Machine Information Interoperability, VDMA, OPCF Board Member

VDMA

EUROPEAN VENDING & COFFEE SERVICE ASSOCIATION

»OPC UA plays a pivotal role in addressing the critical challenges of fragmentation and diverse protocol management within our industry. With numerous interfaces and protocols in play, compatibility and flexibility often come at the expense of increased costs and operational complexity. OPC UA's standardized approach offers a unified framework that enables seamless interaction between machines, peripherals, and systems, ensuring interoperability across diverse vendors and components. This single, harmonised protocol not only reduces the need for multiple interpretations but also supports key industry needs, like diagnostics, payment integration, and data security. Embracing OPC UA propels our industry towards digitalisation and future-ready solutions, minimising costs associated with fragmentation, and simplifying integration for all stakeholders.«

Erwin Wetzel, Director General, European Vending & Coffee Service Association

»At FieldComm Group we are committed to bringing together IT and OT data in common OPC UA-based information models by integration of industry protocols into control systems and other host applications. Delivering such data into the hands of users and analytics to extrapolate value regardless of protocol or supplier will improve the operations of enterprises by leveraging the intelligence it will enable.«

Ted Masters, President and CEO – FieldComm Group

FieldComm Group™
Connecting the World of Process Automation

MDIS

»OPC UA offers a standardized information model for exchanging sub-surface and platform information in the Oil & Gas industry. This OPC UA information model was developed by a consortium of Oil and Gas Operating companies, sub-sea vendors and DCS platform vendors. The certified OPC UA interfaces along with the standardized exchange of configuration information and communication, greatly reduces engineering and testing costs, which is a real win for all parties.«

Paul Hunkar, DS Interoperability, OPC Consultant of the MDIS Network

INTERNATIONAL DATA SPACES ASSOCIATION

»OPC UA established a robust, standardized foundation for secure interoperability across industrial systems. By adding IDSA's rules and framework for describing the governance and sovereignty of the exchanged data in cross-company, cross-domain, and cross-border scenarios, companies gain the confidence to exchange and leverage data without boundaries. This collaboration unlocks the potential for new business models, driving innovation and scalability across industries.«

Lars Nagel, SCEO, International Data Spaces Association

How OPC began

Presidents OPC Foundation:
1996 – 1998 David Rehbein
1998 – 2000 Dr. Gil Pareja
2000 – 2018 Thomas Burke
2018 – present Stefan Hoppe

OPC FOUNDATION HISTORY

The OPC Foundation's forerunner – a task force composed of Fisher-Rosemount, Rockwell Software, Opto 22, Intellution, and Intuitive Technology – was able to develop a basic, workable, OPC specification after only a single year's work. This standard was named "OLE for Process Control" as it was built on Microsoft COM/DCOM technology and acted like a device driver to enable PLC controllers to deliver live data, alarms and historical data. A simplified, stage-one solution was released in August 1996.

The members of the task force included: Al Chisholm, David Rehbein, Thomas Burke, Neil Petersen, Paul van Slette, Phil White, Rich Malina, Rich Harrison, and Tom Quinn. While each of the members worked for competing companies, they quickly established great relationships and focused on the task of developing a specification that was built on solid technology for interoperability. Sample code came first, followed by the specification. The OPC task force made sure that everything was feasible and exceeded the expectations of all the (competing) vendors since the goal was to develop technology that multiple vendors would quickly adopt in the interest of multi-vendor interoperability.

In 1997, the first Board of Directors was comprised of Siemens (Dr. Reinhold Achatz), Emerson (Dr. Gil Pareja), Rockwell (Rich Ryan) National Instruments (Don Holley), Honeywell (John Usakai), Intellution (Al Chisholm) and Toshiba (Yoh Shimanuki). Over the years the Board of Directors changed. The today called "OPC classic" became defacto standard and formed the successful base of worldwide adopted interoperability standard and constantly increasing membership of OPC Foundation.

The chronological order of the OPC Foundation developments can be found here: https://opcfoundation.org/history

THE NEXT OPC GENERATION: OPC UA

In 2003 OPC Foundation started separating services from data and the OPC Unified Architecture (OPC UA) was created as a service-oriented architecture. It was designed to seamlessly deliver secure and reliable information exchange from sensors through to IT enterprise independent of operating systems, vendors and markets.

The challenge to adoption was a huge install base of existing OPC products based on OPC Classic which needed to migrate to the next generation OPC UA technology. As such, OPC UA had to take into account back-ward compatibility. After verification and implementation in 2006 and 2007 the OPC UA specification was finally released in 2008.

To better facilitate global adoption, the OPC UA was designed to become an IEC specification. Work on making the OPC UA standard compliant with IEC rules and templates commenced in 2010 and was completed in 2012. As a result, the OPC UA standard is now a full-fledged IEC standard known as IEC62541. In addition, the OPC UA standard has also been localized in different part of the world like China, Japan, Korea, and Singapore.

CERTIFICATION & PRODUCT QUALITY

Since the early days OPC Foundation is dedicated to maximize product quality. OPC Classic certification followed a twofold approach: self-testing (Silver Standard) and test lab certification (Gold Standard). With the advent of OPC UA and its broader scope, the Foundation increased its ambition toward accredited facilities for lab-based testing. With sophisticated test tools the OPC Foundation helped manufacturers create compliant, interoperable, high-quality products. The first lab opened at ascolab in Erlangen, followed by additional locations in the USA, Germany and China.

The first OPC Foundation interoperability workshop (IOP) was hosted by Rockwell in Cleveland, Ohio in January 1996 – today the OPC Foundation offers annual IOP events in Europe, US and Japan.

Members
– 1022 Worldwide
– 60 % EMEA
– 20 % Americas
– 20 % APAC

Budget 2026
– 5,400,000,– USD
– Mostly member fees
– No public fundings

Activities
– 150+ Working Groups
– 350+ Specifications
– 430+ Models in OPC UA Cloud Library (Industries, Catena-X)
– Models are free of charge available

Supporters
– 1100+ Volunteers
– 15 Board Members
– 11 Contractors
– 0 Employees

4 Regions
– North America, Europe, China, Japan
– Hubs in France, Singapore, India and Korea

Commercial Solutions
– 21+ Toolkits
– 10+ Modelling Tools

Openness
– 17 Open-Source Projects by OPCF
– 1900 Open-Source Projects in total

Communications
– 11,000+ Followers on LinkedIn
– Marketplace with 5000+ visitors per month
– 260,000+ entries in user database for newsletters

OPC Foundation Facts & Figures

The OPC Foundation has been promoting the development and adoption of the OPC information exchange standard since 1996. As an advocate and steward of these specifications, the OPC Foundation's mission is to help vendors, end users, and software developers achieve interoperability.

MISSION

The OPC Foundation's mission is to provide the best specifications, technologies, processes, and certification to ensure interoperability between different vendors and different platforms securely and reliably from embedded systems to the enterprise cloud.

MEMBERS

The Foundation supports over 1,010 members worldwide – including suppliers, end users, system integrators, academic institutions, and startups – across the fields of industrial automation, IT, IoT and IIoT, M2M, Industry 4.0, building automation, machine tools, pharmaceuticals, petrochemicals, and smart energy in achieving this goal.

ADOPTION

Based on public analysis, there are more than 7,200 suppliers who have created more than 62,000 different OPC products used in more than 82 million applications. The estimate of the savings in engineering resources alone is in the billions of dollars.

INTERNATIONAL

– OPC UA is an international standard defined as IEC 62541, ensuring global consistency and long-term reliability. OPC UA is also recognized as a national standard in multiple countries, reinforcing its worldwide adoption like in China, Korea, Russia, Singapore
– Worldwide community of over 1,010 IT and OT members across all major industries.
– International leadership is elected annually

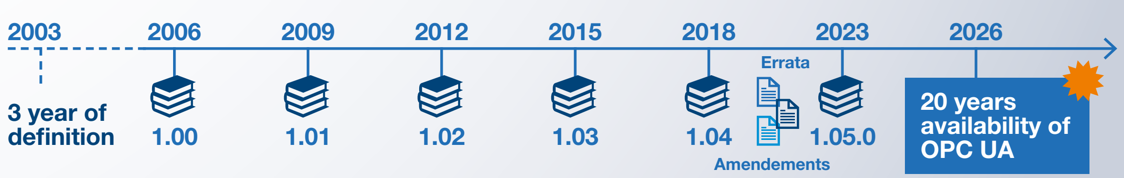
OPENNESS BY DESIGN – NO LOCK-IN – NO LICENSING BARRIERS

OPC UA is an open, non-proprietary standard (IEC 62541) backed by a global ecosystem of more than 1,000 IT and OT members.

- 430+ standardized information models available free of charge
- OPC UA .NET stack available as open source
- RAND-Z licensed intellectual property, ensuring open access and broad industry adoption
- Multi-vendor, cross-platform, language-independent

This openness dramatically lowers integration costs, accelerates innovation, and eliminates vendor lock-in – key requirements for enterprise IT and cloud strategies. The real long-term benefit, however, is sustainability: the technology has been on the market for more than 20 years and remains compatible with its very first release.

2026: 20-Years Availability of OPC UA Always Backward Compatible



OPC Foundation Working Groups

The OPC Foundation working groups (OPC-F WGs) are essential for the development of industry-leading specifications, technologies, certification and processes. The focus of these working groups is to provide the deliverables that are adopted by the OPC community into real-world products and services. Meetings are generally conducted online and occasionally in person.
Members can participate in Working Groups to ensure that their unique technology needs are considered by the industry-at-large. This approach allows the OPC Foundation, through the participation of its members as marketing and engineering resources, to move the standard forward to meet the technology challenges of tomorrow. See the FAQ for details on how to join a group.
See https://opcfoundation.org/about/working-groups/ for a list of all current working groups.

WORKING GROUPS

→ Unified Architecture Working Group
Responsible for defining, maintaining and improving the core OPC UA specification (multiple parts). Additionally, base architecture enhancements are evaluated for extensibility into other companion specifications (e.g. information modeling; adding native OPC UA data types). The core UA working group has weekly electronic meetings and two Face2Face meetings per year. A number of expert sub-groups support the UA working group:

- **Security Sub-Group** assures that OPC UA security mechanisms are always up to date. It also assesses security alerts or warnings. Members includes OPC UA stack developers to assure that any issues are handled in a timely manner.
- **Semantic Validation Group**
  This group strives to translate semantic rules that are currently specified in natural language into a format that can be processed programmatically. This allows tooling to check semantic inconsistencies, or other rule violations.
- **Base Network Model** defines the information model for network related components including Ethernet and TSN.
- **MQTT Sub-Group** assures that OPC UA over MQTT meets uses cases for in edge and cloud messaging environments using MQTT.
- **REST Sub-Group** defines the base for OPC UA in Edge and Cloud computing environments using the proposed HTTP REST

→ Compliance Working Group
Responsible for the OPC Foundation Certification program. This group analyzes OPC specifications to determine how products are to be tested for compliance. The group meets weekly to discuss test procedures, Compliance Lab standard operating procedures, and to continually update and enhance the Compliance Test Tools.

→ UA for Devices Working Group
Responsible for defining, maintaining and improving the OPC UA for Devices (DI) specification. DI specifies a generic data model to represent devices. Parameters as well as control functions can be exposed and grouped according to their purpose (e.g. configuration, diagnosis, and statistics).

→ Field Level Communication Initiative
The vision of the initiative is to strive for an open, uniform, secure and standards-based IIoT communication solution between sensors, actuators, controllers and the cloud that meets all the requirements of industrial automation – factory automation but also process automation. This includes special requirements like deterministic communication, functional safety, motion and instrumentation as optional features.

→ Harmonization Working Group
In this working group members of various companion specification working groups and modelling experts meet to harmonize the way companion specifications model things. The working group is responsible for the companion specification template and forms sub-teams to define common modelling constructs usable in a generic way.

OPC Foundation Specifications and Information

WEBSITE AND EVENTS
A key source of the most current information about everything OPC UA is the global OPC Foundation website (www.opcfoundation.org) along with localized versions for Japan and China. Here, beyond the complete OPC specifications, you can also find member listings and their OPC product offerings, certification results, collaboration updates, events, and much more. Information on technology and collaborations is provided in different languages.

ABUNDANT RESOURCES
The rate of adoption of a technology like OPC UA is depending on market demand which, in turn, depends on end-users' understanding of the technology, its benefits, ease of implementation, and availability of verification and certification of products based on that technology. For this reason, the OPC Foundation offers users, and particularly its members, a rich set of information sources, documents, tools, and sample implementations.

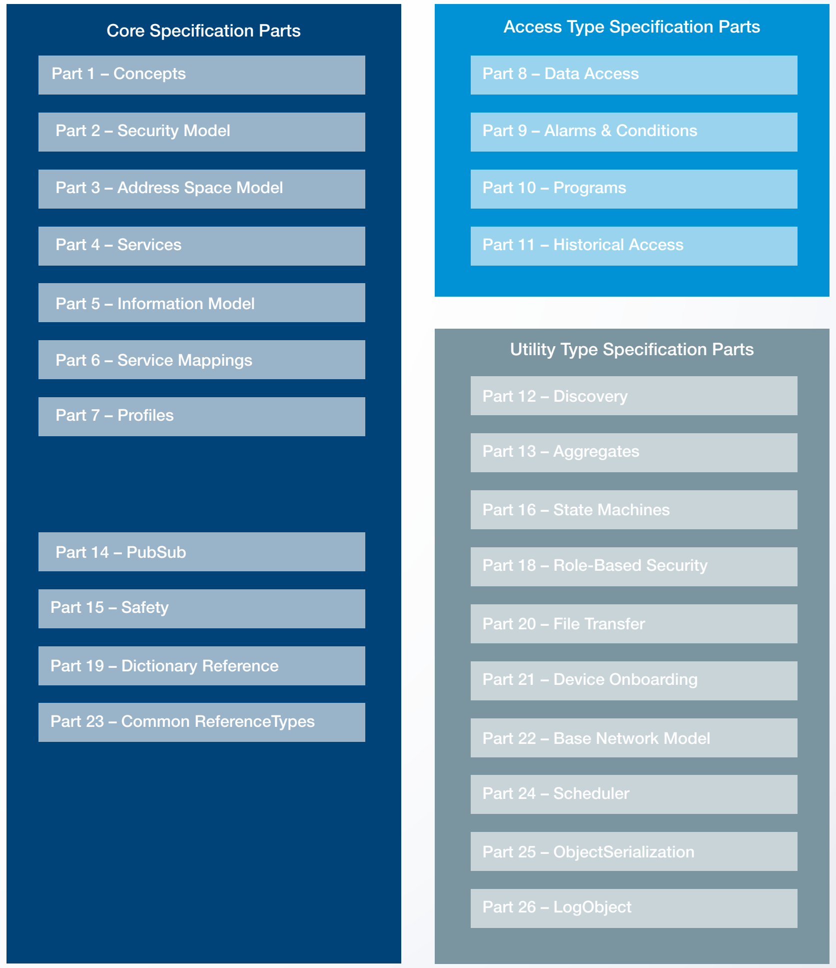
OPC UA SPECIFICATIONS AND IEC 62541
The main sources of information are the OPC UA specifications themselves. They are publicly accessible and are available as an IEC standard series (IEC 62541). Currently, the OPC UA standard is comprised of 24 parts, which are available to the public. These parts are subdivided into three groups:

→ 1. Core specifications. These contain the basic concepts of the OPC UA technology, the security model, and an abstract description of the OPC UA metamodel and the OPC UA services. In addition, these specifications also describe:

- the core OPC UA information model, its modeling rules, and concrete mapping at the protocol level
- the concept of profiles for description of supported features and scaling the functionality
- the Client-Server and Publish-Subscribe Models
- protocol mappings and encodings

→ 2. Access type specifications. These contain extensions of the information model for typical access to data, alarms, messages, historic data, and programs.

→ 3. Utility type specifications. These contain additional solutions for finding OPC UA-capable components and their access points in a network, plus the description of aggregate functions and calculations for processing historic information.



IEC62541: OPC UA specifications

OPC UA at a glance

Models
- More than 430+ models (Industries, Catena-X, ..) available.
- Free of charge and commercial modelling tools available
- OPC UA library is a free of charge repository of OPC UA based information models (from OPC Foundation and worldwide contributors)
- UA Cloud Library allows to instance models, keep the instances in database and interact via Web UI and REST interface

Flexible transport
- Support 2 communication mechanisms: Client/Server & Publisher/Subscriber
- Transport via TCP, UDP, MQTT, AMQP and Kafka
- REST and WebSocket bindings for IT and web applications
- Filetransfer

SECURE, RELIABLE INTEROPERABILITY

OPC UA represents the latest evolution of OPC technology from the OPC Foundation. Far from being merely a rewrite of the original OPC standard, OPC UA significantly enhances its scope and applicability by meeting a wide array of contemporary communication needs. It ensures secure and reliable data and information transport, seamlessly connecting sensors and shop floor operations to control systems, production planning systems. Furthermore, OPC UA facilitates robust connectivity to cloud and IT systems, enabling seamless interoperability between these environments and enhancing overall system integration.

PLATFORM AND VENDOR-INDEPENDENT

OPC UA is an open standard without dependence on or binding to proprietary technologies or individual vendors. Hence, all OPC UA communications are 100% independent of the vendors who implement them, the programming languages used, and the platforms those products run on.

USES THE LATEST OPEN STANDARDS

OPC UA is based on a various types of standards and protocols carefully chosen based on their ability to meet the needs of specific OPC UA use cases. For example:

→ For OPC UA Client-Server communications, OPC UA uses an optimized TCP based binary protocol for data exchange over the IANA registered port 4840.
→ For Cloud-based communications, OPC UA uses popular protocols like MQTT and AMQP.
→ For communication in the field OPC UA uses UDP and specialized protocols like TSN or 5G for deterministic communication.
→ Web Sockets may also be used to support browser-based OPC UA Clients. New protocol bindings like QUIC (UDP-based Internet protocol) can be integrated easily without breaking existing functionality.
→ REST interfaces allow easy integration of OT information into IT systems.

ROBUST INFORMATION MODELING

Robust information modeling (IM) is built into the heart of the OPC UA standard. OPC UA defines base building blocks and consistent rules to build object-oriented models with them. In OPC UA it is possible to expose and discover information models in a consistent and universal manner between all OPC UA entities. OPC UA defines a few industry agnostic IMs that other organizations use as a common starting point to define their own OPC UA based IMs. OPC UA also defines the mechanisms needed to facilitate dynamic discovery and access to OPC UA IMs. This is crucial for 3rd party interoperability because different OPC UA implementations will natively implement different IMs. Key OPC UA functions include:

→ Browsing: A look-up mechanism used to locate object instances and their semantics
→ Read and write operations: used for current and historical data
→ Method execution
→ Notification for data and events

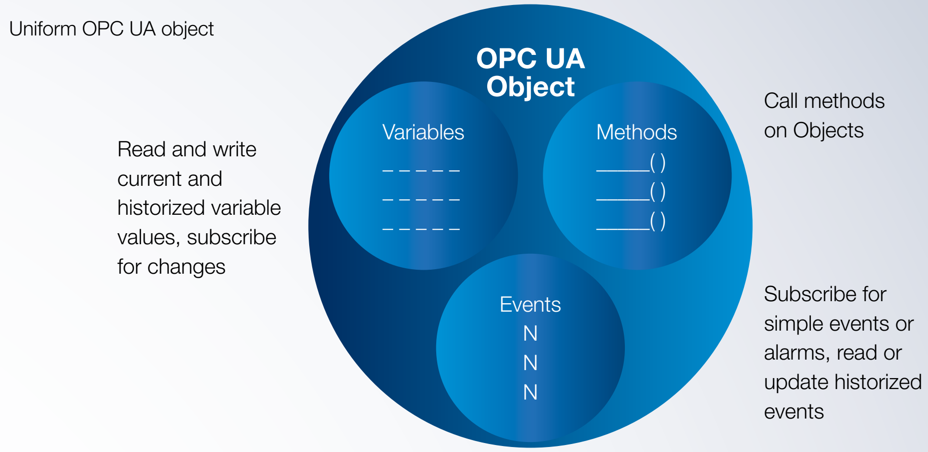
CLIENT-SERVER

OPC UA Client-Server communications are based on the service-oriented architecture (SOA) paradigm. Therefore, information model access is defined via services. Unlike classic Web services which describe their services using the xml-based Web Services Design Language (WSDL) which allows each service provider's implementation to be different and hence not directly interoperable, OPC UA predefines generic standardized services to ensure all OPC UA implementations are compatible. A WSDL definition is not required in OPC UA, because the services are standardized. As a result, they are compatible and interoperable, without the caller needing to have any special knowledge about the structure or behavior of a special service.

State-of-the-art Security
- Built-in by Design
- Onboarding
- For accessing information
- For transport of information
- Fine-grained authorization down to data-point level
- Integrated audit concepts
- Verified/Validated by international experts
- Infrastructure certificate management Based on proven IT security standards (TLS, AES), OPC UA fits naturally into zero-trust and cloud security architectures.

Reliability for mission-critical digital Systems
- OPC UA ensures integrity and availablity across unreliable networks
- Automatic recovery and reconnection
- Data buffering to prevent loss
- Sequencing, retransmission, and redundancy support

Internationalization
- OPC UA is IEC62541 Standard
- OPC UA is local standard in China (GB/T 33863.x), Korea, Russia, Singapore



PUBLISH-SUBSCRIBE (PUBSUB)

PubSub provides an alternative mechanism for data and event notification. Unlike Client-Server communications, PubSub is optimized for many-to-many interactions where multiple clients may receive broadcasted notifications in a fire-and-forget fashion. With PubSub, OPC UA applications do not directly exchange requests and responses. Instead, Publishers send messages to Message Oriented Middleware without any knowledge about the Subscriber(s). Similarly, Subscribers express interest in specific types of data and process messages that contain this data without knowledge of the Publisher(s). PubSub and Client-Server are based on the OPC UA Information Model. Publishers are typically OPC UA Servers and Subscribers are commonly OPC UA Clients. Local OPC UA Client-Server communications are used to setup PubSub components.

STRONG SECURITY THAT IS SCALABLE

OPC UA is based on accepted security concepts and standards that are also used for secure internet communications. Examples include SSL, TLS and AES. OPC UA offers protection against unauthorized access, sabotage, modification of process data, and careless operations. OPC UA security mechanisms include: user and application authentication, signing of messages, and data encryption. While users are free to choose which OPC UA security functions they want to use based on their infrastructure and context, vendors are obliged to implement all of them depending on the OPC UA profile they want to support.This ability to choose which security features are used makes OPC UA usable (scalable) in all types of environments (e.g. limited computing resources vs. large computer systems).

ACCESSIBILITY AND RELIABILITY

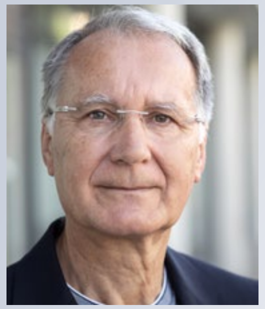
OPC UA defines a robust architecture with reliable communication mechanisms, configurable timeouts and automatic error detection that restores communications between OPC UA Clients and Servers without data loss. In addition, OPC UA redundancy functions for both client and server applications make OPC UA suitable for high-availability applications.

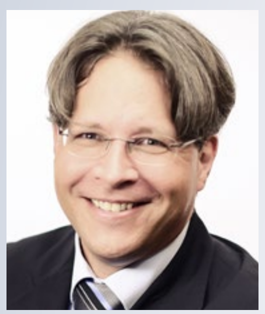
SIMPLIFICATION BY UNIFICATION

OPC UA defines an integrated address space and a unified information model that supports process data, alarms, historical data, and function calls (methods). Beyond OPC classic functionality, OPC UA also supports the description and use of complex procedures and systems in uniform object oriented components. Hence, OPC UA clients which only support basic rules can still process data from OPC UA Servers without any knowledge of the complex data structures residing in the OPC UA Server.

GROWING AREAS OF ADOPTION

The functional breadth of OPC UA makes it universal and applicable for use in an ever growing list of new markets and applications. From local plants to remote field stations behind firewalls – OPC UA is the right choice to standardize on. Other standards bodies increasingly use OPC UA as an interoperability platform for defining and implementing their own information models. Currently, the OPC Foundation cooperates with over 65 such groups from various industries, including: discrete and process automation, energy, engineering tool manufacturers, industrial kitchen equipment, and many more.





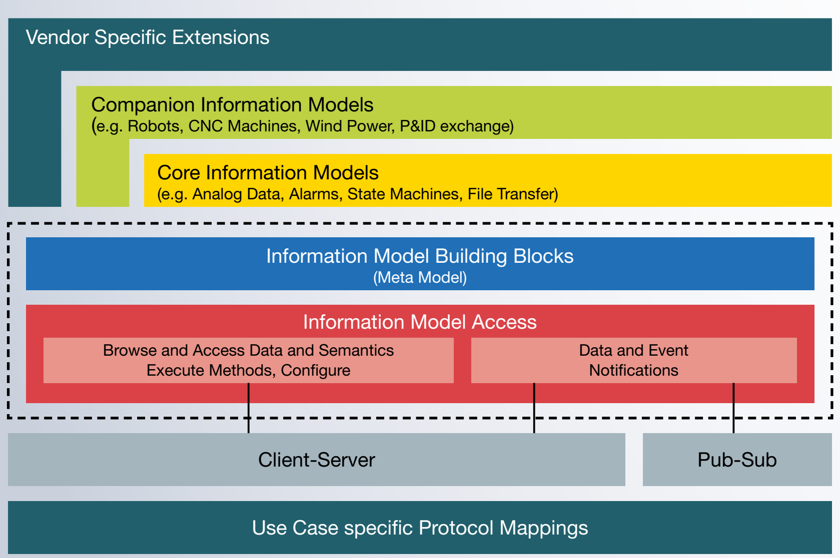
OPC UA technology in detail

Karl-Heinz Deiretsbacher, Technical Director, OPC Foundation
Dr. Wolfgang Mahnke, Unified Automation, Senior Consultant

Industrie 4.0 communication is not only based on pure data, but on the exchange of semantic information. In addition, transmission integrity is a key factor. These tasks are essential aspects of the OPC Unified Architecture. OPC UA contains a comprehensive description language and the communication services required for information models and is therefore universally usable.

INTRODUCTION

The trend in automation is towards inclusion of communication data semantics in the standardization. Standards such as ISA 88 (also IEC 61512, batch processing), ISA 95 (also IEC 62264, MES layer) or the Common Information Model (CIM) with IEC 61970 for energy management and IEC 61968 for energy distribution define the semantics of the data in domains addressed by them. Initially this takes place independent of the data transfer specification. OPC UA – also published as IEC 62541 – enables exchange of information models of any complexity – both instances and types (metadata). It thus complements the standards referred to above and enables interoperability at the semantic level.



OPC UA layer model

DESIGN OBJECTIVES

OPC UA was designed to support a wide range of systems, ranging from PLC's in production to enterprise servers. These systems are characterized by their diversity in terms of size, performance, platforms and functional capabilities.

In order to meet these objectives, the following basic functionalities were specified for OPC UA:

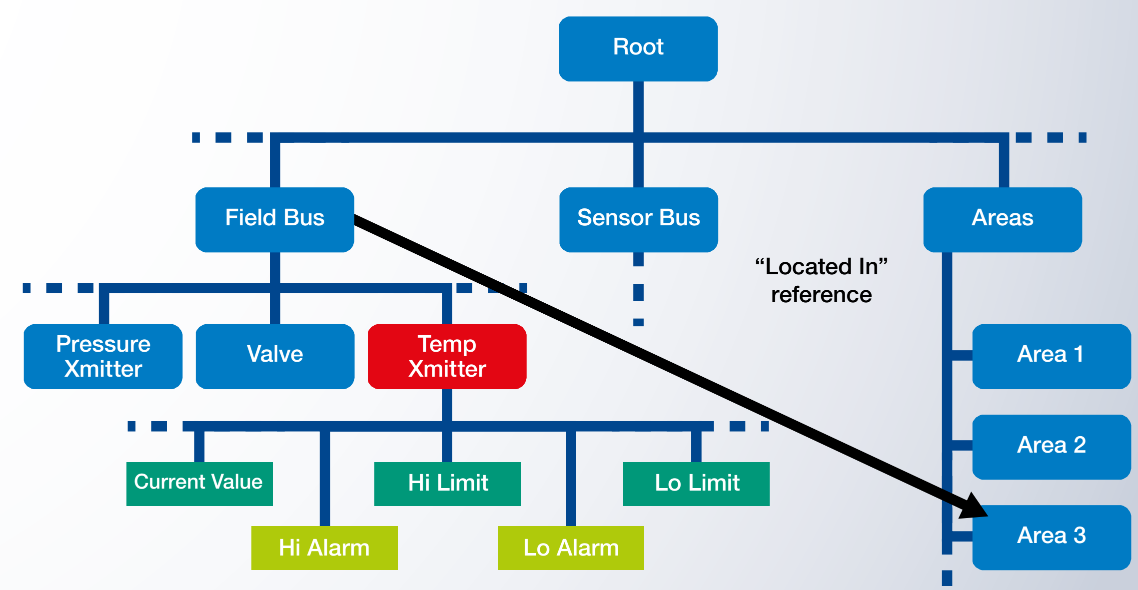
→ **Information Model (Meta model) –** specifies the rules and basic components for publishing an information model via OPC UA. It also includes various basic nodes and basic types.
→ **Information Model Access –** specifies the mechanisms to access information models via OPC UA.
→ **Client-Server –** Services constitute the information model access between a server as information provider and clients as users of this information. Application and user authentication, full access to instances and meta information and robustness are key attributes for this communication model.
→ **PubSub –** provides a message-based notification of data or events. It specifies the rules to combine data into a DataSet, to construct and publish messages with DataSet payload. It can be enhanced with message security.
→ **Use Case specific Protocol Mappings –** To support the required use cases, a few different protocol mappings exist in OPC UA
  – **Client-Server:**
    • UA TCP with UA Binary is optimized for speed and throughput
    • HTTPS / WebSockets + JSON for web browser access
  – **PubSub:**
    • UDP for best effort, secure multicast
    • MQTT for use of brokers with store and forward functionality
    • TSN or 5G for deterministic transport

Information models follow a layered approach. Core Information Models are already defined as part of the OPC UA specification. Each high-order type is based on certain basic rules. In this way clients that only know and implement the basic rules can nevertheless process complex information models.
Although they don't understand the deeper relationships, they can navigate through the address space and read or write data variables, execute methods or receive notifications.

INTEGRATED ADDRESS SPACE MODEL

The object model enables production data, alarms, events and historic data to be integrated in a single OPC UA server. This allows, for example to represent a temperature measuring device as an object with its temperature value, alarm parameters and corresponding alarm limits.

OPC UA integrates and standardizes the different address spaces and the services, so that OPC UA clients only require a single interface for navigation. The OPC UA address space is structured hierarchically, to foster the interoperability of clients and servers. The top levels are standardized for all servers. All nodes in the address space can be reached via the hierarchy. They can have additional references among each other, so that the address space forms a cohesive network of nodes.
The OPC UA address space not only contains instances (instance space), but also the instance types (type space).



Consistent address space

INTEGRATED SERVICES

For the Client-Server communication model, OPC UA defines the services required to navigate through the namespace, read or write variables, or subscribing for data modifications and events.

The OPC UA services are organized in logical groupings, so-called service sets. Service request and response are transmitted through exchange of messages between clients and servers.

OPC UA messages are exchanged either via an OPC-specific binary protocol on TCP/IP or as a web service. Applications will usually provide both protocol types, so that the system operator can choose the best option.

OPC UA provides a total of 9 basic service sets. The individual sets are briefly described below. Profiles allow specifying a subset of all services which a server supports. Profiles are not discussed in detail here.

→ SecureChannel service set

This set includes services to determine the security configuration of a server and establish a communication channel in which the confidentiality and completeness (integrity) of the exchanged messages is guaranteed. These services are not implemented directly in the OPC UA application but are provided by the communication stack used.

→ Session service set

This service set defines services used to establish an application-layer connection (a session) on behalf of a specific user.

→ NodeManagement service set

These services provide an interface for the configuration of servers. It allows clients to add, modify, and delete nodes in the address space.

→ View service set

The view service set allows clients to discover nodes by browsing. Browsing allows clients to navigate up and down the hierarchy, or to follow references between nodes. This enables the client to explore the structure of the address space.

→ Attribute service set

The attribute service set is used to read and write The method service set defines the means to invoke methods.

→ MonitoredItem service set

This service can be used to determine which attributes from the address space should be monitored for changes by a client, or which events the client is interested in.

→ Subscription service set

Can be used to generate, modify or delete messages for MonitoredItems.

→ Query service set

These services enable the client to select nodes from the address space based on certain filter criteria.

→ Method Service set

Methods represent the function calls of Objects. They can be discovered by browsing and are invoked with the call service.

PUBLISH SUBSCRIBE

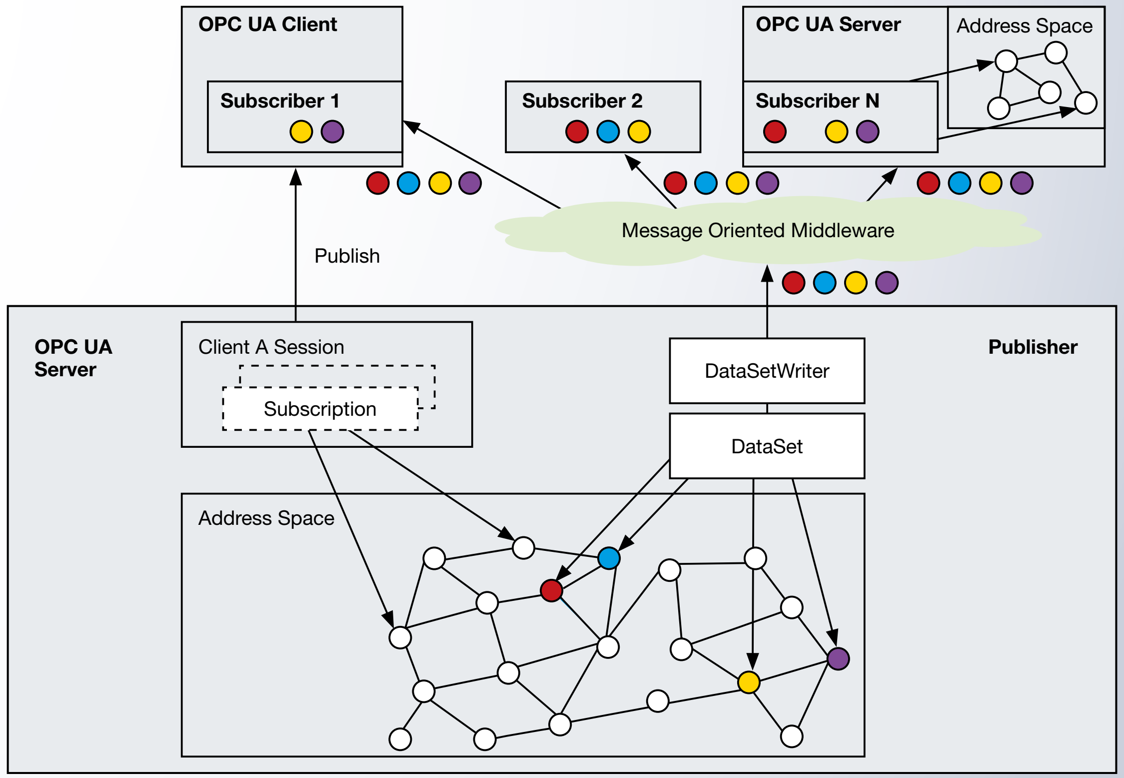
The following figure provides an overview of Publisher and Subscriber and illustrates the flow of data and event notifications as messages from a Publisher to one or more Subscribers.

The PubSub communication model supports many other scenarios; for example, a Publisher may send a messages to multiple Message Oriented Middleware and a Subscriber may receive messages from multiple Publishers. Message Oriented Middleware is software or hardware infrastructure that supports sending and receiving messages between distributed systems. It can be, for example an MQTT broker or network infrastructure that supports UDP multicast.

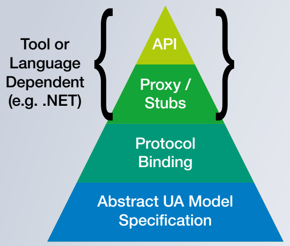
Publishers and Subscribers are loosely coupled. They often will not even know each other. Their primary relation is the shared understanding of specific types of notification data or events (represented by DataSets), the publish characteristics of messages that include these data, and the Message Oriented Middleware.

A DataSet can be thought of as a list of name and value pairs representing an Event or a list of Variable Values. DataSet fields can be defined to represent any information, for example, they could be internal Variables in the Publisher, Events from the Publisher or collected by the Publisher, network data, or data from sub-devices.

Message security in PubSub concerns integrity and confidentiality of the published message payload. It is end-to-end security (from Publisher to Subscriber) and requires common knowledge of the cryptographic keys necessary to sign and encrypt on the Publisher side as well as validate signature and decrypt on the Subscriber side.



Overview Publisher and Subscriber message flow



Abstract UA Model Specification

PLATFORM-INDEPENDENCE

Unlike “Classic OPC”, which is based on DCOM technology and is therefore inevitably linked to the Windows platform and the languages supported there, OPC UA was designed for application on arbitrary platforms using arbitrary program languages.

→ **At the lowest level** are the abstract model, the Client-Server services and PubSub messages, including the whole address space model, different object and variable structures, alarms and more.

→ **The next level** (Protocol Binding) is used to specify how services and messages are to be mapped to certain protocols. In the future – once new technologies become established – further mappings can be specified without having to change the abstract model, services or messages. The mappings are entirely based on standardized basic protocols, which already exist on all known platforms.

→ **The following levels** are realizations for dedicated platforms and languages. The OPC Foundation itself provides open source implementations, see https://github.com/OPCFoundation/.

PERFORMANCE

For optimal support of different usages, OPC UA has defined mappings to different technologies. Mappings on top of advanced Ethernet technologies ensure highest performance. Client-Server services and PubSub messages are designed for high data throughput. An individual read call can access thousands of values, for example. Subscription services enable notification when values are changed and exceed configured thresholds. “PubSub messages have been designed for optimized hardware augmented processing.”

INFORMATION MODELS WITH OPC UA

The OPC UA object model defines a set of standardized node types, which can be used to represent objects in the address space. This model represents objects with their variables (data/properties), methods, events and their relationships with other objects. The node properties are described through attributes defined by OPC UA. Attributes are the only elements of a server that have data values. The data types of the attributes can be simple or complex. OPC UA enables modeling of any object and variable types and the relationships between them. The semantics is indicated by the server in the address space and can be picked up by clients (during navigation). Type definitions can be standardized or vendor-specific. Each type is identified by the organization that is responsible for its definition.

GENERIC OPC UA INFORMATION MODELS

Models for generally valid information (e.g. alarms or automation data) are already specified by OPC UA. Other information models with further specialization of the general definitions are derived from this. Clients that are programmed against the general models are therefore also able to process the specialized models to a certain extent.

1. DATA ACCESS (DA)

Data access, DA in short, describes the modeling of realtime data, i.e. data that represent current state and behavior of the underlying industrial or business process data. It includes the definition of analog and discrete variables, engineering units and quality codes. Data sources are sensors, controllers, position encoders etc. They can be connected either via I/Os located directly at the device or via serial connections and fieldbuses on remote devices.

2. ALARMS AND CONDITIONS (AC)

This information model defines how states (dialogs, alarms) are handled. A change of state triggers an event. Clients can register for such events and select which of the available associated values they want to receive as part of the event report (e.g. message text, acknowledgment behavior).

3. HISTORICAL ACCESS (HA)

HA enables the client to access historic variable values and events. It can read, write or modify these data. The data can be located in a database, an archive or another storage system. A wide range of aggregate functions enable preprocessing in the server.

4. SAFETY

Using OPC UA Client / Server or PubSub as safety communication channel.

5. STATE MACHINES

Representation of state machines with their possible states and transitions as meta data and notifications of the current status. Can be used to represent a complex task like a job execution.

6. ALIAS NAMES

Alias Names provide a manner of configuring and exposing an alternate well-defined name for any Node in the system, also accross different OPC UA servers, with lookup mechansims.

7. FILE TRANSFER

Allows transfering (parts of) files to and from an OPC UA server.

8. DEVICE ONBOARDING

Defines the life cycle of Devices and Composites and mechanisms to verify their authenticity, set up their security and maintain their configuration.

9. SCHEDULER

Expose information, at what dates and times specific actions are executed by the OPC UA Server. Those schedules can optionally also be manipulated via the information model.

THE OPC UA META MODEL

→ **Important:** The OPC UA model describes how clients access information on the server. It does not specify how this information should be organized on the server. It could be stored in a subordinate device or a database, for example.

TECHNOLOGY-SPECIFIC INFORMATION MODELS

Standardization committees dealing with the control/automation technology prepare technology-specific information models. Examples are IEC61804 (EDDL), ISA SP 103 (field device tool), ISA-S88, ISA-S95 and IEC-TC57-CIM. These specifications are important, since they standardize the descriptions of units, relations and workflows in certain fields of knowledge.
The OPC Foundation was keen to collaborate with other organizations in the development of the new standard right from the start. Rules for mapping the information models of these organizations to OPC UA (companion standards) are specified in joint working groups.

INDUSTRIE 4.0: OUTLOOK

OPC UA is a mature standard, which meets the requirements of Industrie 4.0 regarding secure semantic interoperability. OPC UA provides the protocol and services (the “How”) for publishing comprehensive information models (the “What”) and exchanging complex data between applications that were developed independently.
Although various important information models already exist, there is still a need for action:

→ How for example, does a temperature sensor or a value control unit identify itself?
→ Which objects, methods, variables and events define the interface for configuration, initialization, diagnostics and runtime?

Security model built in by design

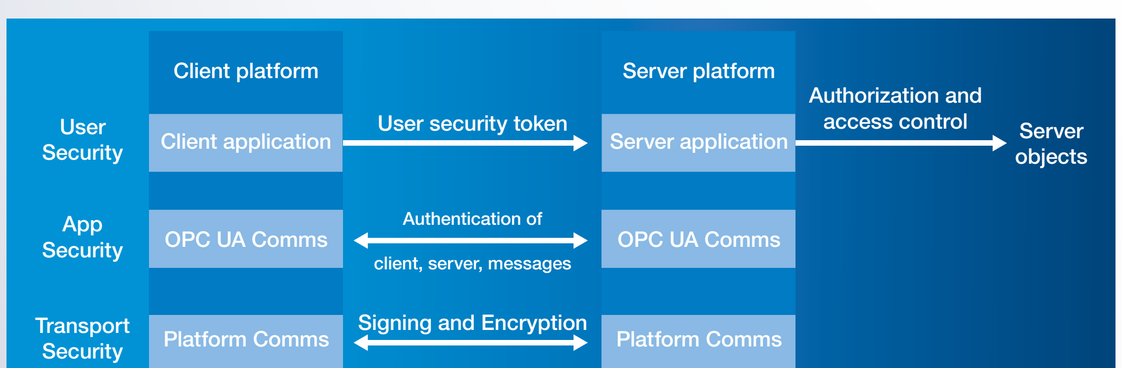
GENERAL
Security was a fundamental OPC UA design requirement so it was built into the architecture from ground up. Security mechanisms similar to the W3C Secure Channel concept, were chosen based on the detailed analysis of real world data security threats and the most effective counter measures against them. OPC UA security addresses key issues like the authentication and auditing of OPC UA clients and servers, message confidentiality, integrity, and availability, and the verifiability of functional profiles. As illustrated below, OPC UA security can be divided into three security levels: User, Application, and Transport. This architecture aligns with the security infrastructure provided by most web-enabled platforms.

→ **1. OPC UA User level security** mechanisms are engaged when a session is set up. An OPC UA client transmits an encrypted security token, which identifies the user to the OPC UA server. The server authenticates the user based on the token and then authorizes access to appropriate objects. The OPC UA specification does not define authorization mechanisms such as access control lists because they are application and/or system specific.

→ **2. Application level security** is also part of the session setup and includes the exchange of digitally signed certificates. Instance certificates identify the concrete installation. Software certificates identify the client and server software and the implemented OPC UA profiles which describe capabilities of the server, such as support for a specific information model.

→ **3. OPC UA Transport level security** can be used to provide integrity via message signing and confidentiality via message encryption. This prevents message tampering and eavesdropping respectively. The OPC UA security mechanisms are realized as part of the OPC UA stacks, i.e. they are included in a software package provided by the OPC Foundation – ready for use in OPC UA clients and servers.

SCALABLE SECURITY
Security mechanisms come at a computing resource cost which can adversly impact device performance. The OPC UA standard defines different levels of security (via end points) to enable vendors to implement OPC UA in products with various computing resources. This makes OPC UA scalable. In addition, system administrators can enable or disable such OPC UA server endpoints as required. For example, an end point without security ("NoSecurity" profile) could be disabled.
During operation, an OPC UA client application user selects the appropriate exposed OPC UA server end point prior to establishing a connection with the OPC UA server.
In addition, OPC UA clients can be configured to only use sufficiently secure end points if they work with sensitive data.



Scalable security concept

SECURE CHANNEL
The OPC UA SecureChannel is characterized by a Security Mode and a SecurityPolicy.

→ **SecurityMode** specifies which of three security levels is used to secure OPC UA messages. The options are: "None", "Sign", and "SignAndEncrypt".

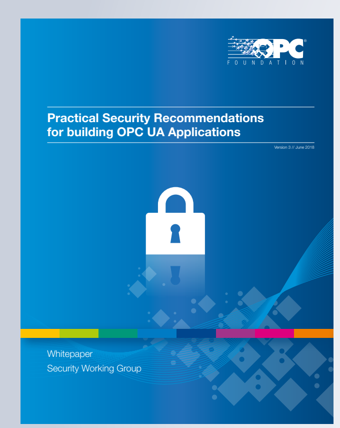
→ **SecurityPolicy** specifies what encryption algorithms are employed by the SecurityMode. Current options include: RSA and AES for message encryption and SHA for message signing.

SECURE CONNECTIONS
To establish secure connections, bi-directional trust must be obtained using Public Key Infrastructure (PKI) which utilizes asymmetric key exchange between the OPC UA client and server. By using standard X.509v3 certificates, OPC UA built its security infrastructure on well-established IT standards.

USER AUTHENTICATION
Beside the SecureChannel used for application authentication, user authentication may also be employed to provide maximum security. The OPC UA client can provide user credentials during session establishment (e.g. either user/pwd, user certificate, or single sign on token), which will be validated by the OPC UA server when granting access to individual elements within the server's address space.

GLOBAL DISCOVERY SERVER
To manage the system wide rollout and update of OPC UA certificates, trust, and revocation lists, OPC UA also includes the concept of a Global Discovery Server (GDS). All OPC UA enabled servers and clients register themselves with the GDS and obtain regular updates of their trust and revocation lists. In addition, the GDS may also serve as a Certificate Authority (CA) which can handle signing requests and certificate updates of its registered servers and clients.

Education & Guidance



Guidance for Implementers
Guidance for Users

Download:
www.opcfoundation.org/security/

Analyzed by Experts

Security analysis by German Federal Office for Information Security (BSI): »OPC UA … does not contain systematic security vulnerabilities.«

Download:
www.opcfoundation.org/security/

OPC Foundation extends OPC UA down to field

including Determinism, Safety, Motion and Instrumentation

Peter Lutz, Field Level Communications Director, OPC Foundation

At the SPS IPC Drives fair 2018 in Nuremberg/ Germany the OPC Foundation has officially launched the Field Level Communications (FLC) Initiative. This initiative aims for an open, unified, standards-based Industrial Internet of Things (IIoT) communication solution addressing all requirements of industrial automation in discrete manufacturing and process industry. Consequently, the OPC Foundation vision of becoming the worldwide industrial interoperability standard is advanced by integrating field devices and the shop floor. Vendor independent end-to-end interoperability into field level devices is provided for all relevant industry automation use-cases requiring safe, secure and deterministic information exchange:

Horizontal integration:

→ controller-to-controller communication (C2C) resp.
→ machine-to-machine communication (M2M)

Vertical integration:

→ controller-to-device (C2D) resp. from sensors/actuators/controllers to IT systems or the cloud and vice versa.

The FLC-related technical work includes the following topics:

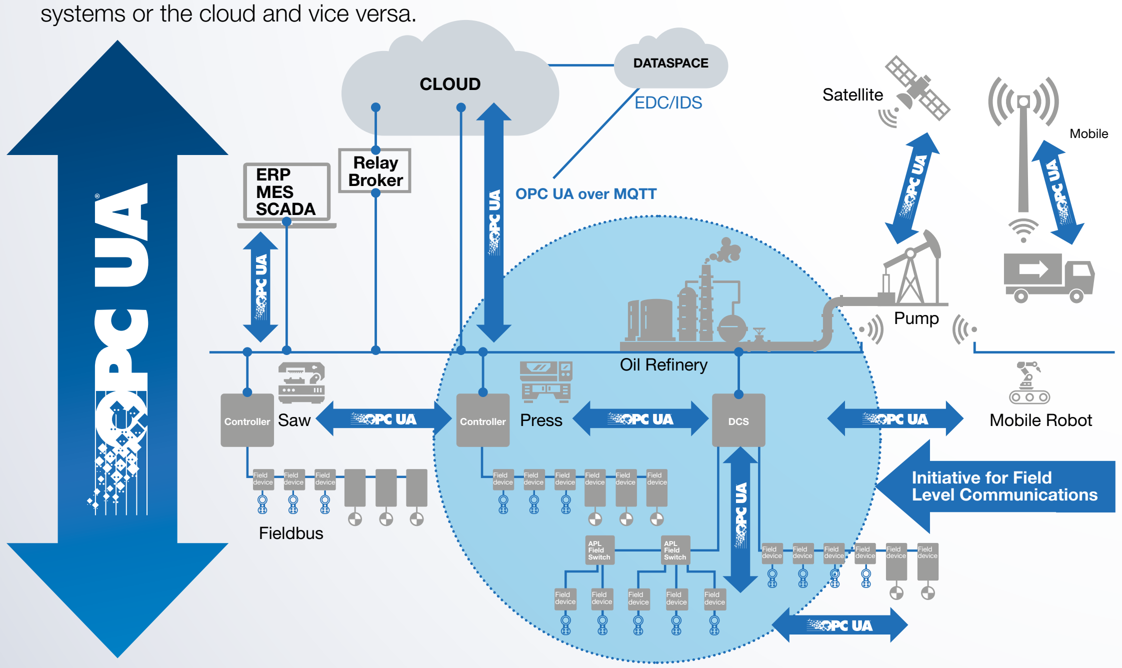
→ **harmonization and standardization of application profiles** like IO, motion control, safety, instrumentation and system redundancy
→ **standardization of OPC UA information models** for field level devices in online and offline scenarios e.g. device description resp. diagnostics
→ **mapping of OPC UA application profiles** to underlying communication protocols and physical layers, including Ethernet TSN (Time-Sensitive Networking) and Ethernet APL (Advanced Physical Layer)
→ **definition of certification procedures**

The specifications for extending OPC UA to the field level are published as:

→ OPC UA FX (Field eXchange) Parts 80–84
→ OPC UA Safety Part 15

MEMBERS OF THE STEERING COMMITTEE:

ABB
Beckhoff
Bosch Rexroth
B&R
CoDeSys
Emerson
Festo
Hilscher
Hirschmann
Huawei
Intel
Lenze
Mitsubishi Electric
Moxa
Omron
Phoenix Contact
Pilz
Rockwell Automation
Schneider Electric
Siemens
Weidmueller
Yokogawa



OPC UA: Enabling secured, semantic industrial interoperability scaling from field to cloud
Scope of the Field Level Communications (FLC) Initiative

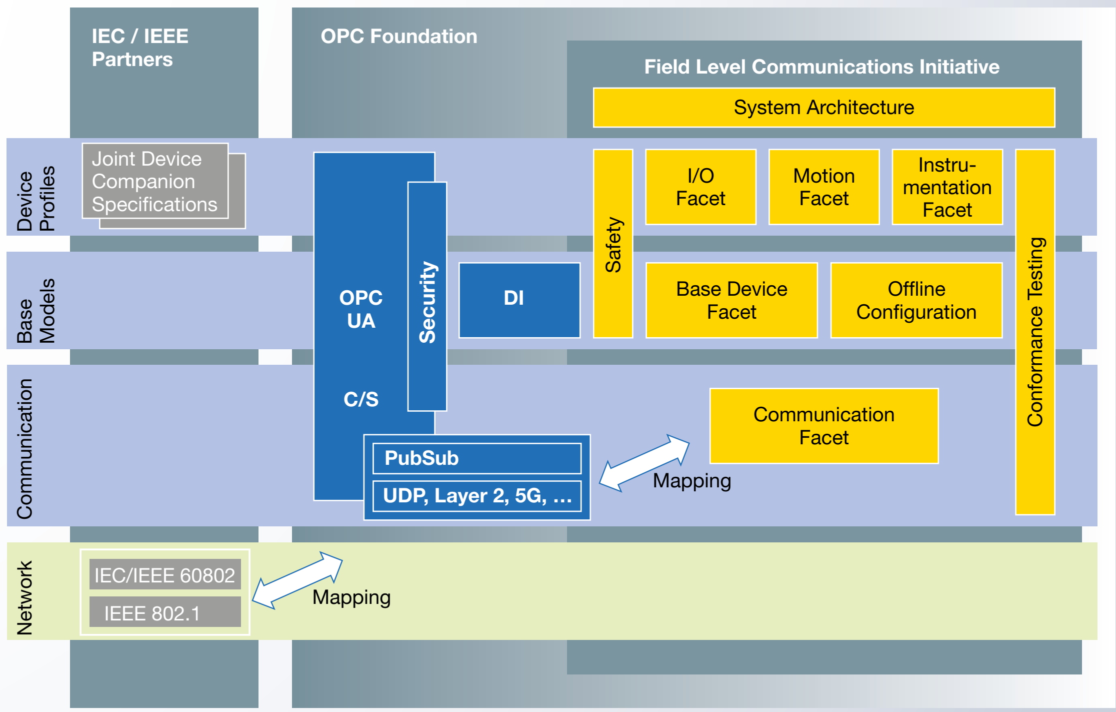
SOLUTION APPROACH

The solution approach for bringing OPC UA down to the field level is to use unmodified OPC UA technology with its built-in security capabilities, the PubSub extensions and the Device Integration (DI) model on which so-called device facets and other device companion specifications are built upon. The base device facet defines interfaces, behaviors and state machines that are common to all controllers and devices. It also provides the structure for device- and application-specific facets, such as Motion, Safety, Instrumentation and I/O.

The Communication facet defines the communication interfaces and behaviors (protocols and services) of the lower layers of the OSI model for devices that operate on Ethernet networks with and without TSN capabilities. It is based on the OPC UA PubSub extensions with network mappings (bindings) to UDP/IP and Layer 2, combined with Ethernet or Deterministic Ethernet (TSN). The concept is prepared to support redundancy concepts and other emerging communication standards, such as 5G. The communication facet for TSN closely aligns with the TSN Profile for Industrial Automation (TSN-IA-Profile) which is standardized by the IEC/IEEE 60802 standardization group. This will help ensure that a single, converged TSN network approach is maintained so that OPC UA can share one common multi-vendor TSN network infrastructure together with other applications and other IT/OT protocols.

PARTICIPATION

All members of the OPC Foundation are invited to contribute to the technical working groups. The management and coordination of the FLC initiative is exclusive to members of the Steering Committee provide extra contributions.



OPC UA FX (Field eXchange) System Architecture

The OPC Foundation Cloud Initiative

Building the Industrial Cloud Interoperability Standard

MEMBERS OF THE STEERING COMMITTEE:

Cloud suppliers:
AWS
Google Cloud
Huawei
Microsoft
SAP

Automation companies:
ABB
Beckhoff
Honeywell
Mitsubishi Electric
Rockwell Automation
Schneider Electric
Siemens
Yokogawa

THE END-USER COUSEL:
Boehringer Ingelheim
Continental
Danone
Equinor
L'Oréal Operations
Miele
Mondelēz International
Renault Group
JT International
Tetra Pak
Volkswagen

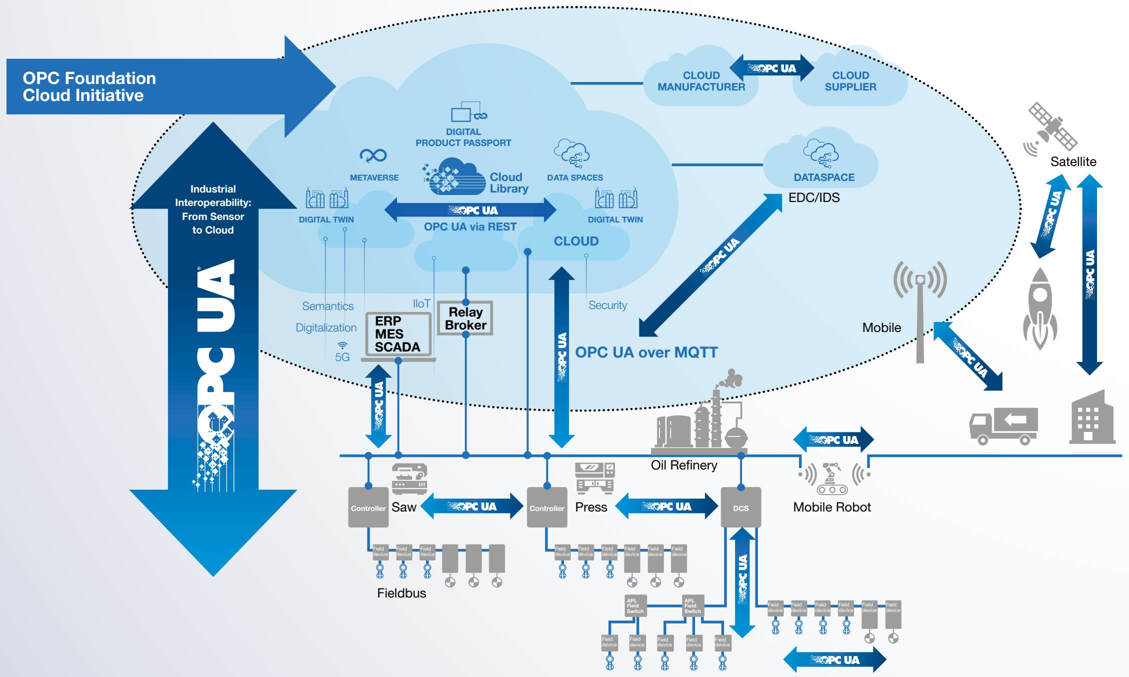
OPC UA is the most widely used open standard on the shop floor today. Therefore, it doesn't come as a surprise that it is naturally expanding its reach along the industrial automation pyramid, both down to the field level as well as up to the cloud, leveraging OPC UA PubSub (part 14 of the specification), released in 2018. As OPC UA is communication-protocol-independent, additional mappings to established communication protocol standards needed to be added to the specification for OPC UA PubSub, namely UDP for field level communication and AMQP and MQTT for cloud communication. First adopted by cloud supplier products in 2015, OPC UA PubSub over MQTT is the most widely used, standardized communication technology for Industrial IoT solutions today.

GOALS

The OPC Foundation Cloud Initiative will bring greater focus of existing working groups on actionable user challenges and opportunities for enhancement and initiating new working groups to develop OPC UA technology into new cloud-centric applications.

DELIVERABLES

- Standardized interoperability: Accelerate **interoperability of IT and cloud applications** using OPC UA, e.g. data analytics using AI, industrial data spaces, digital product passports, industrial metaverse as well as digital twin applications.
- Best practices: Create a **cloud reference architecture** to provide best practices, increase standardized data sharing and cloud-optimized profiles for the OPC UA standard.
- Semantic Data Models in the Cloud: **Maintain OPC UA Information Models (Companion Specifications)** in the cloud to utilize the context of data in cloud services.
- Establish a new **Protected Identity** for OPC UA Cloud eXchange "UACX".
- Establish validation and certification for OPC UA Cloud Interoperability.

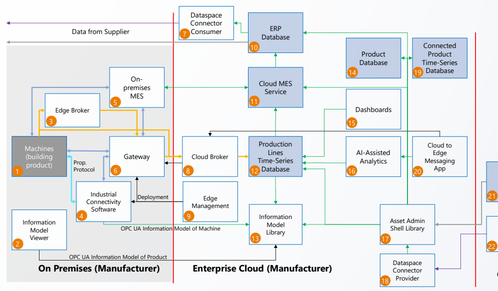


WORKING GROUPS (WG) COORDINATED BY THE OPC FOUNDATION CLOUD INITIATIVE

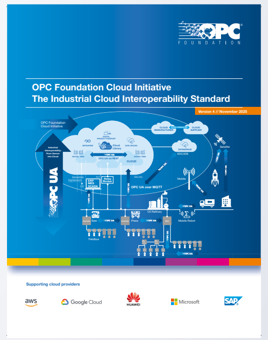
- **UA Cloud Library**
  A searchable online library for OPC UA Information Models. It enables users to browse, query, and manage standardized and custom information models. The platform also allows users to instantiate models and persist them in databases, making them available for applications and services.
- **OPC UA over MQTT**
  Secure transport from edge to cloud and cloud to cloud, including a prototyping and a testbed group
- **OPC UA REST Interface**
  Easy access to OPC UA information for the IT world via a standardized REST interface
- **OPC UA Industrial Metaverse**
  Connecting the virtual and real world with OPC UA
- **OPC UA AI**
  Leveraging Large Language Models for and with OPC UA

The UA Cloud Library platform also allows users to instantiate models and persist them in databases, making them available for applications and services.

Liaison
– CEN/CENELEC JTC24 for the Digital Product Passport DPP
– CatenaX for supply chain in Automotive
– International Dataspace Association (IDSA) for Dataspaces



Cloud architecture components are available both as:
- **commercial solutions** from leading providers like AWS, ABB, Beckhoff, Google, Honeywell, Huawei, Microsoft, Mitsubishi Electric, Rockwell Automation, SAP, Schneider Electric, Siemens, Yokogawa and, as
- **open-source offerings.**



Content of the brochure:
- Detailed descriptions of the existing working groups
- A list of all commercial offerings
- URLs for the open source reference code
- Milestones and roadmap

Download here:
www.opcfoundation.org/cloud

Offerings: Tools, Resources, & Community

The OPC Foundation empowers developers, integrators, and educators with a rich ecosystem of specifications, tools, and community-driven resources in an effort to accelerate OPC UA adoption across Industrie 4.0 and IIoT applications.

STANDARDIZATION PROCESS

The Standardization of OPC UA and its utilization in collaborations with other organizations is the main objective of the OPC Foundation. The OPC Foundation has created public resources to provide information around these activities.

- → **List of Collaboration:** This is a list of all organizations with whom the OPC Foundation works
- → **List of Working Groups:** The OPC Foundation carries out the work in technical or marketing related working groups; some of which are internal, while others are joint with other organizations
- → **List of Resources:** Specifications, guidelines, templates, white papers, and policies
  - **Document Download:** The OPC Foundation publicly provides all released specifications as well as guidelines and white papers pertaining to OPC technology, security, and other relevant topics.
  - **Online Reference:** As a publicly available service, the OPC Foundation publishes all specifications, including markup pages with cross links in the Online Reference.
  - **Profile Application:** Within OPC UA, similar to other communication standards, features are defined in profiles. Since such requirements are difficult to cross-map between documents, the OPC Foundation provides all profile definitions, from the Core specifications to all companion specifications, as publicly available resources.

WEBINARS

The OPC Foundation drives an open ecosystem and has established itself as a trusted source of information within the industrial security and interoperability community. Up to date information e.g. about the Cyber Resilience Act (CRA) was already provided in 2024 via free-of-charge OPC Foundation webinars. A great source of up-to-date information pertaining to industrial interoperability is the OPC Day International, which started as a one day conference and has developed itself to a week of organizational and technical updates from the industrial world. This free webinar series is a great opportunity for everyone who doesn't find the time to follow the OPC Foundation throughout the year, but would like to stay up to date on current developments within the industry.

TOOLS & CODE SAMPLES

The OPC Foundation hosts its open-source repositories on GitHub, providing a comprehensive collection of tools, libraries, and sample implementations for OPC UA and related technologies. This page provides an overview of all publicly available repositories, offering resources for developers to build, integrate, and enhance their industrial automation solutions using OPC standards. Explore the repositories to find sample applications, utilities, and detailed documentation to support your development needs.

TECHNOLOGY REPOSITORIES

- → **UA-.NETStandard:** This repository provides a .NET Standard implementation of the OPC UA specifications, enabling cross-platform development of OPC UA applications. The library supports various features such as secure communication, data access, and event handling, making it a comprehensive library for developers working with OPC UA in .NET environments.

- → **UA-NodeSets:** This repository contains UA NodeSets and other normative files released with its respective specification. These files define the structure and semantics of data in OPC UA applications and are essential for ensuring interoperability between different OPC UA implementations.

- → **UA-ModelCompiler:** This repository provides the OPC UA ModelCompiler, a tool that converts OPC UA information models, defined in XML, into code. The ModelCompiler supports generating code in C#, facilitating the integration of custom information models into OPC UA applications.

- → **Open API Libraries:** These repositories have the .NET, Python and TypeScript classes generated from the OpenApi schema definition for the OPC UA WebApi, a REST-like API designed for use in IT applications.

SAMPLES

- → **UA-CloudLibrary:** The UA-CloudLibrary repository hosts the OPC UA Information Model database with REST interfaces. It allows users to store, manage, and retrieve OPC UA information models in a centralized cloud-based repository.

- → **UA-IIoT-StarterKit:** This repository contains samples and tutorials for building OPC UA PubSub applications in Industrial Internet of Things (IIoT) scenarios. The starter kit demonstrates how to use OPC UA for secure and reliable communication between industrial devices and systems. It is designed to help developers quickly prototype and deploy IIoT solutions using OPC UA.

- → **UA-Cloud Repositories:** Comprised of several repositories, which demonstrate cloud use cases, like the UA-CloudCommander, UA-CloudViewer, UA-EdgeTranslator, UA-CloudDashboard, UA-Cloud-Action, and the UA-CloudMetaverse.

Certification Program

TESTING SCOPE
- → **Compliance** to the OPC Specifications
- → **Interoperability** with other vendors' products
- → **Robustness** and recovery from error conditions
- → **Efficiency** of product under load
- → **Usability** ensures a good user-experience

TEST TOOLS

To ensure compatibility, the OPC Foundation offers a certification program, including the tools required for verifying and testing the conformity of applications to the specifications.

Certification program

To ensure the quality, reliability, and interoperability of OPC UA products, the OPC Foundation offers a robust Certification Program. This program is designed to validate that products conform to the OPC UA specifications and perform reliably in real-world industrial environments. Certification is conducted by independent, OPC Foundation-audited test laboratories, which evaluate products across five key categories: conformance, interoperability, robustness, usability, and resource efficiency. These tests go beyond basic compliance and simulate realistic usage scenarios to ensure that certified products meet the highest standards. Products that successfully pass all required tests are awarded the OPC Certified Logo, a mark of quality and trust. Certified products are listed in the OPC Marketplace, making it easy for end-users and integrators to identify solutions that meet rigorous certification criteria. As a best practice, end-users and system integrators are encouraged to demand certified OPC UA products to ensure maximum safety, reliability, and seamless integration into their infrastructure. Certification must be performed by an authorized thirdparty test lab, and vendors must adhere to the OPC Foundation's defined testing procedures and processes.

Preparing for Certification
- Review the certification specifications and test case documentation.
- Use the Compliance Test Tool (CTT) and participate in Interoperability Workshops to pre-test their implementations. These offerings help vendors identify and resolve issues early, streamlining the formal certification process.
- Ensure technical staff are available during the testing period to support the lab with configuration and troubleshooting, either remotely or in-person.

Certification Process:
- Submission of the application/hardware.
- Coordination with a test engineer.
- Execution of all relevant test cases based on supported OPC UA Profiles or Classic interfaces.

What Can Be Certified?
- OPC UA Clients, Servers, Publishers, and Subscribers.
- OPC Classic products (DA, HDA, A&E).
- Products can be implemented in software or embedded hardware.
- Reference implementations from SDKs.
- Products must implement supported OPC UA releases (e.g., 1.04, 1.03, 1.02) and meet all applicable profile requirements.

Learn More

To explore the certification program in more detail, visit the OPC Foundation Certification Overview and How to Certify pages.

Additionally, the OPC Foundation provides a rich set of video resources and podcasts to help vendors understand the certification process and its benefits:
- OPC UA All about certification
- OPC UA Product Certification
- Compliance Testing from a vendor perspective
- Certification and Compliance in OPC UA CS
- UA Compliance Conformance Status Update
- OPC Foundation Podcast Series

These resources provide valuable insights into the certification journey, common challenges, and best practices from both the OPC Foundation and experienced vendors.

YouTube **Certification**

Certification Overview

Certification Podcast

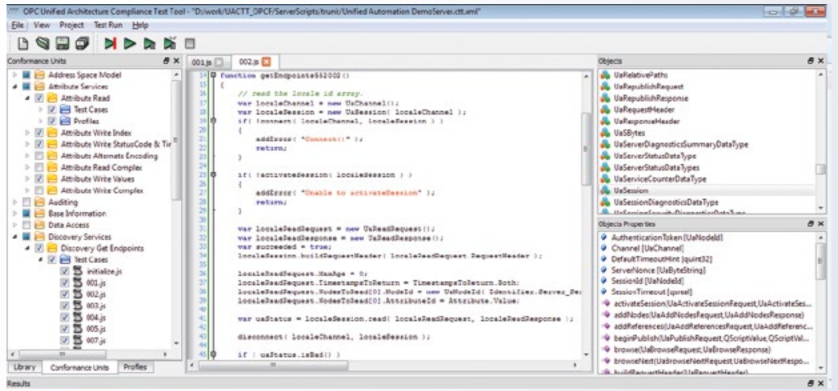
Tools and Events

TEST TOOLS AND QUALITY ASSURANCE (QA)

The OPC Foundation provides a series of test tools to verify functionality of all of the OPC Foundation defined interfaces. These test tools include not just base OPC specification testing they also support companion specification defined information model testing and are available to all OPC Members. The tools can be used in an automated build process or interactively by a tester or developer. The OPC Compliance Test Tool (CTT) implements over a thousand test cases and provides a functional test with a high test coverage. The script based tool is always being enhanced with new test cases to cover specification enhancements, new information model specifications (Companion Specifications) and to generally improve testing performance. The CTT can be extended with vendor specific/product specific test scripts and easily be integrated into a company's automated system and regression test environment.

Interoperability Workshops

The OPC Foundation holds at least three weeklong interoperability workshops (IOP Workshops) where companies can test the interaction of their products. The European IOP event is usually held in the Autumn at Siemens AG in Nuremberg. The North American IOP is usually held in the spring at Honeywell in Phoenix and the Japanese IOP Workshop is usually held in summer. Products which attend these events have proven to provide a higher level of interoperability with other products and an enhanced user experience. At the IOP Workshops a great variety of products are participating from toolkit providers over automation components to OEM application are coming together in an open atmosphere to test their interoperability.



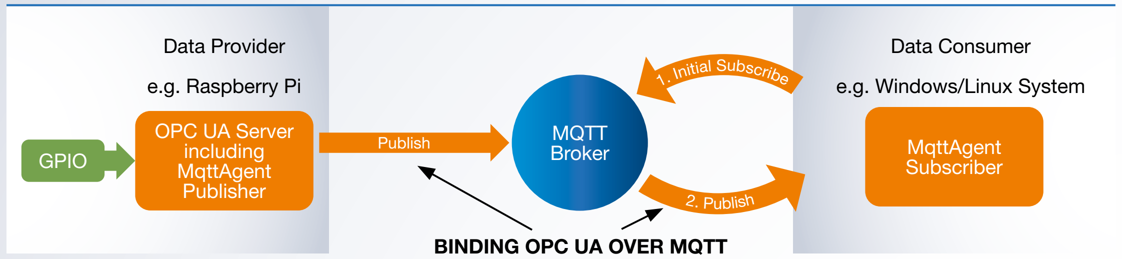
»The Certification Program is a key benefit of the OPC Foundation membership. Extensive functional testing with the CTT and interoperability testing in the lab has helped us deliver a product of the highest quality.«

Paul Hunkar,
Director of Certification, OPC Foundation

Quick-start for non-OPC UA enabled applications

OPC UA IIOT STARTER KIT AVAILABLE

IIoT Starter Kit: OPC UA over MQTT



The IIoT Starter Kit is an open-source to demonstrate cloud connectivity by using OPC UA over MQTT. This project uses a simple architecture, which consists of a **Data Provider** (on Raspberry Pi, utilizing its GPIO), an **MQTT Broker** (mosquito) and a **Data Consumer** (on PC development platform).

https://github.com/OPCFoundation/UA-IIoT-StarterKit

COVERED USE CASES

→ Identification
- Automatic discovery of the publishers
- Including typical nameplate information

→ Optimized messages
- Publisher and subscriber know what data is being sent and the semantics of it

→ Highly interoperable payload
- Including classification
- Including semantics

OPC UAcademic – Empowering Academia with OPC UA

The OPC UAcademic Program of the OPC Foundation, is a global activity to support universities and research institutions in teaching and adopting OPC UA within their courses. The material is continuously extended to cover new topics.

The program provides:
- Content: Lecture slides, graphics, and recorded English explanations, but also hands-on exercises for practical learning.
- Languages: Arabic, Chinese, English, French, Japanese and Korean
- License: Free educational materials under Creative Commons licensing for non-commercial, academic use.

LECTURE CONTENT HIGHLIGHTS

The lecture deck covers:
- OPC UA fundamentals: communication, security, address space, services, and information modeling.
- Real-world use cases and architectures.
- Companion specifications for various industries.
- Implementation examples in .NET, Python, C++, and Java.
- Exercises using simulation servers and modeling tools.

REGISTER HERE

With over 180 universities and institutions across over 25 countries the OPC UAcademic program has seen broad international utilization.

Register here: https://opcfoundation.org/resources/opcuacademic/

Integration – Toolkits and Books

INTEGRATING OPC UA

Existing products can be integrating OPC UA in different ways. While it is possible to create an additional and separate implementation which handles the OPC UA communication, the OPC Foundation recommends to natively integrate OPC UA into the product to leverage all benefits provided by OPC UA. OPC UA toolkits can be of great help and reduce the time-to-market especially when integrating the technology into a data provider. In particular, commercial toolkits help by abstracting and consolidating generic functions such as connection management, certificate handling and security features.

EXPERT KNOWLEDGE

A number of companies around the world offer commercial support for the integration of OPC UA communication technology in existing products and the implementation of new products, ranging from advice and developer training to selling software libraries and development support right up to long-term support and maintenance contracts.

The developer frameworks e.g. toolkits are available as binary "black box" components or including complete source code. When utilizing toolkits application developers do not need detailed OPC UA expertise. A stable, tested library enables them to focus on their own core competence.

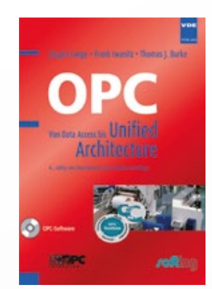
QUALITY AND FUNCTION

OPC UA toolkits are used for a wide range of application scenarios in industrial environments. For that reason they are robust, certified, are being maintained and continuously enhanced. Toolkit providers offer specialized and optimized developer frameworks for various programming languages. Toolkits differ in their OPC UA-specific functionality and in terms of their application, use-case and operational environment. All toolkits are offered with professional support and development service. The OPC Marketplace provides a list of toolkits known to the OPC Foundation.

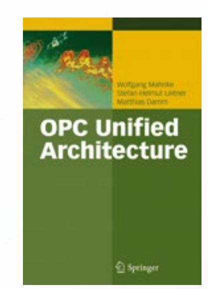
FURTHER INFORMATION ABOUT TOOLKITS IS AVAILABLE FROM …

→ Matrikon, OPC-Labs, ProSysOPC, Softing Industrial Automation GmbH, Software Toolbox, Unified Automation GmbH

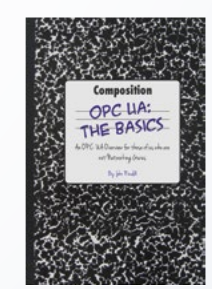
QR-Code: https://opcfoundation.org/products/?category=32



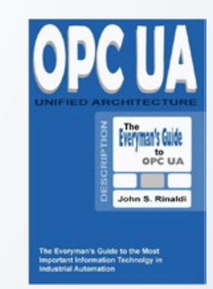
OPC
From Data Access to Unified Architecture
ISBN: 978-3800735068



OPC
Unified Architecture
ISBN: 978-3540688983



Composition
OPC UA: The Basics
ISBN: 78-1482375886



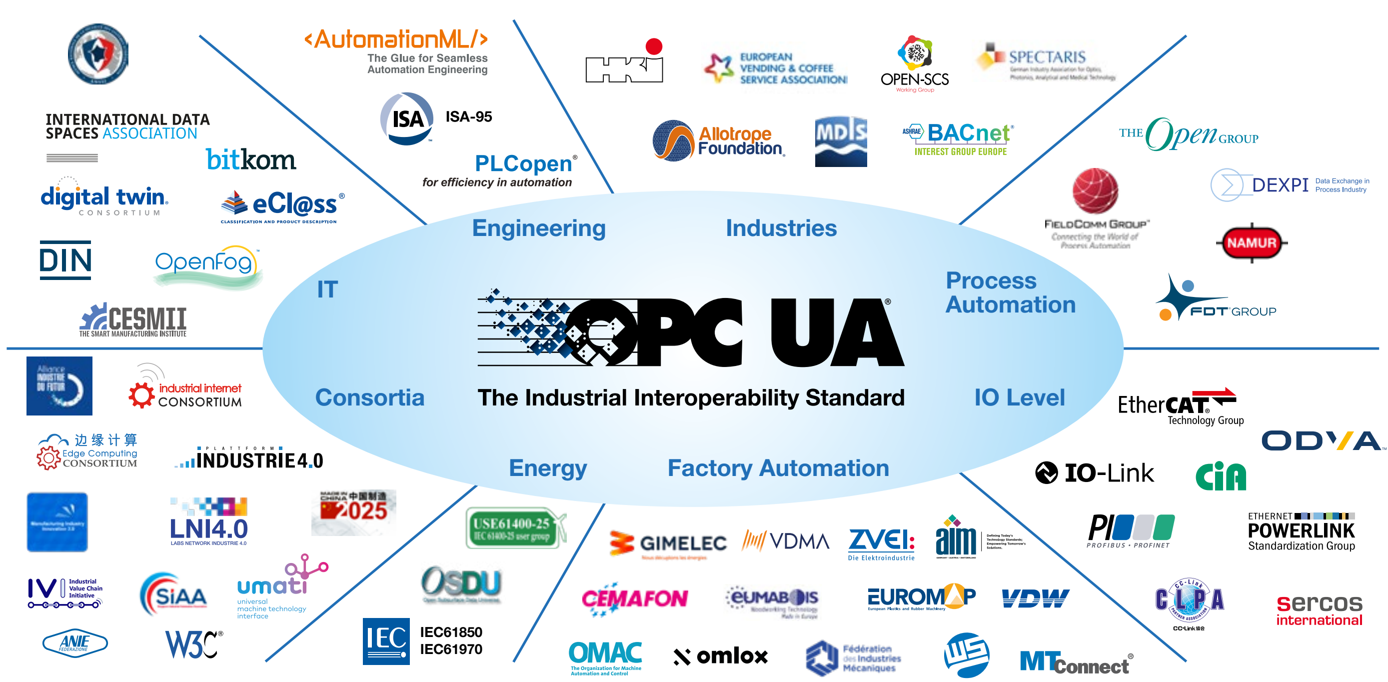
OPC UA – Unified Architecture: The Everyman's Guide to the Most Important Information Technology in Industrial Automation

Praxishandbuch OPC UA:
ISBN: 978-3-8343-3413-8

Unlocking the Power of OPC UA
ISBN: 9798891865419

Collaborations

The OPC Foundation closely cooperates with organizations and associations from various branches. Specific information models of other standardization organizations are mapped onto OPC UA and, thus, become portable. The organizations define “what” shall be communicated. OPC UA delivers “how”, through its secure and effective transport and offers access priviliges and generic interoperability. Thus, communication across branches and domains is made possible, without sacrificing particular, semantic, branch-specific objects and types.



WHERE TO FIND INFORMATION MODELS?

- **Document Download:** TThe OPC Foundation publicly provides all released specifications, as well as guidelines and white papers, pertaining to OPC technology, security, and other relevant topics. https://opcfoundation.org/developer-tools/documents/
- **Online Reference:** The OPC Foundation provides publicly available access to all published specifications, including Markup pages and cross links, within this Online Reference. https://reference.opcfoundation.org/
- **UA-CloudLibrary:** The UA-CloudLibrary repository hosts the OPC UA Information Model database with REST interfaces. It allows users to store, manage, and retrieve OPC UA information models in a centralized cloud-based repository. https://uacloudlibrary.opcfoundation.org/

International Joint Collaboration Groups

Domain Specific Information Models

Generic Device Models: Cloud, Controller, Field Device, Process Device

- OPC 10000-100 – UA for Devices
- OPC 10000-211 – UA for Global Positioning
- OPC 10020 – UA for Analyzer Devices
- OPC 10100-1 WOT Connectivity – API Definition
- OPC 10101 – UA for WoT Binding
- OPC 30000 – UA for PLCs based on IEC 61131-3
- OPC 30001 – UA for IEC 61131-3 Function Blocks
- OPC 30010 – UA for AutoID Devices
- OPC 30081 – UA for Process Automation Devices (PA-DIM)
- OPC 30300 – UA for Generic Trust Anchor API Profile
- OPC 30400 – UA for Cloud Library
- OPC 30500 – UA for Laboratory & Analytical Device Standard (LADS)
- OPC UA for Analytical System Integration (CAISI)*
- OPC UA for Non-destructive Evaluation

Energy

- OPC 10040 – UA for IEC 61850 – Electrical Substation Automation (Release Candidate)
- OPC 30020 – UA for MDIS
- OPC UA for Wind Power Plants (IEC61400-25)*
- OPC 34100 UA for Power Consumption Management
- OPC UA for Carbon Capture, Storage and Reporting*
- OPC UA for Solar PV Operations and Maintenance (SPOM)*

Building

- OPC 30030 – UA for BACNET (Release Candidate)

Miscellaneous

- OPC 30060 – UA for Tobacco Machines
- OPC 30200 – UA for Commercial Kitchen Equipment

* = in progress

Manufacturing Devices: Robots, Machines, Machine Tools

- OPC 30070-1 – UA for MTConnect, Pt 1: Device Model
- OPC 40001-1 – UA for Machinery – Basic Building Blocks
- OPC 40001-2 – UA for Machinery – Process Values
- OPC 40001-3 – UA for Machinery – Job Management
- OPC 40001-4 – UA for Machinery – Energy Mgmt
- OPC 40001-100 – UA for Machinery – Result Transfer
- OPC 40010 – UA for Robotics
- OPC 40020 – UA for Cranes & Hoists
- OPC 40077 – UA for Plastics Rubber – Injection Moulding Machines to MES
- OPC 40079 – UA for Plastics Rubber – Injection Moulding Machines to Robot
- OPC 40082-1…n – UA for Plastics Rubber – <device>
- OPC 40083 – UA for Plastics Rubber – General Types
- OPC 40084-1….n – UA for Plastics Rubber – Extrusion
- OPC 40087 UA for Plastics Rubber – Particle Foam Machines
- OPC 40091 UA for Plastics Rubber – Winder
- OPC 40092-1 UA for Flexible PUR Foam – Cutting Machines
- OPC 40100 – UA for Machine Vision
- OPC 40100-2 Machine Vision – Asset Mgmt and Condition Monitoring
- OPC 40200 – UA for Weighing Technology
- OPC 40210 – UA for Geometrical measuring Systems
- OPC 40223 – UA for Pumps and Vacuum Pumps
- OPC 40250 – UA for Compressed Air Systems
- OPC 40301 – UA for Flat Glass Processing
- OPC 40350-1 – UA for High Pressure Die Casting Devices – Basics
- OPC 40400 – UA for Powertrain*
- OPC 40444 – UA for Textile Testing Devices*
- OPC 40450 – UA for Joining Systems Base
- OPC 40451 – UA for Tightening Systems
- OPC 40501 – UA for Machine Tools
- OPC 40502 – UA for Computerized Numerical Control (CNC) Systems
- OPC 40504-1 UA for Cutting Tools – Manufacturing
- OPC 40505 – UA for Wireless Machine Tool Peripherals
- OPC 40530 – UA for Laser Systems
- OPC 40550 – UA for Woodworking Machinery
- OPC 40560 – OPC 40569 – UA for Mining
- OPC 40570 – UA for Wire Harness Manufacturing
- OPC 40700 – UA for Surface Technology – General Types
- OPC 40718 – UA for Surface Technology – Shot Blasting
- OPC 40719 – UA for Plasma Surface Technology
- OPC 40740 – UA for Process Air Extraction and Filtration Systems (PAEFS)*
- OPC UA for Intralogistics Communication*

Enterprise, Asset Management, Packaging

- OPC 10030 – UA for ISA-S95
- OPC 10031-4 – UA for ISA-95 Job Control
- OPC 30050 – UA for PackML (OMAC)
- OPC 30260 – UA for OpenSCS Serialization Model
- OPC 30261 – UA for OPEN SCS – Job Order Profiles
- OPC 40600 – UA for Weihenstephan Standards
- OPC UA for Asset Administration Shell – AAS*
- OPC UA for Mimosa CCOM*

Engineering

- OPC 30040 – UA for AutomationML
- OPC 30250 – UA for DEXPI

Field Device Integration

- OPC 30080 – UA for Field Device Integration (FDI)
- OPC 30090 – UA for Field Device Tool (FDT)

Field Communication

- OPC 30100 – UA for SERCOS Devices
- OPC 30110 – UA for POWERLINK
- OPC 30120 – UA for IO-Link Devices and IO-Link Masters
- OPC 30130 – UA for Control & Communication System Profile (for Machine) CSP + (CCLink)
- OPC 30140 – UA for PROFINET
- OPC 30141 – UA for PROFIenergy
- OPC 30142 – UA for PROFINET Remote IO
- OPC 30143 – UA for PROFI-Encoder
- OPC 30144 – UA for PROFINET-GSD
- OPC 30145 – UA for PROFINET Drives
- OPC UA for CIP Devices*

For the latest information on available information models, visit https://opcfoundation.org/developer-tools/documents/

Sign up for Technology News to stay up to date on the latest publications and working groups. https://opcfoundation.org/news/technology-news

Harmonizing OPC UA based Information Models

CHALLENGES ARE ADDRESSED

The general idea of OPC UA is to provide a communication infrastructure and generic information modelling capabilities. Using the information modelling capabilities, domain-specific information models can be developed. Those can profit from the eco system of OPC UA and do not need to reinvent the basics including the communication infrastructure. This idea has become very successful and a large variety of so-called companion specifications have been developed and released, in addition to vendor-specific information models.

The information modelling capabilities are quite powerful and provide various concepts like defining data types, variable types and object types, using methods, state machines, events, conditions and alarms. This implies, that similar requirements can be modelled differently, like transferring data in a method call, using conditions with acknowledgment, or variables with structured data types.

But even, if two companion specifications implement exactly the same requirement using exactly the same modelling approach, from a client perspective they look different as they are defined in different namespaces.

The goal is to harmonize companion specifications in a way that similar things are done in a similar way and the same things are done exactly in the same way (same types, same namespace).

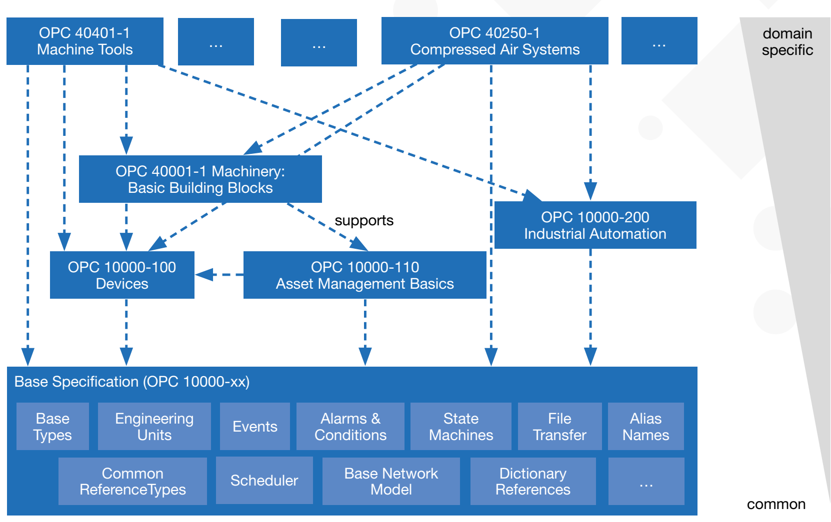
HARMONIZATION WORKING GROUP

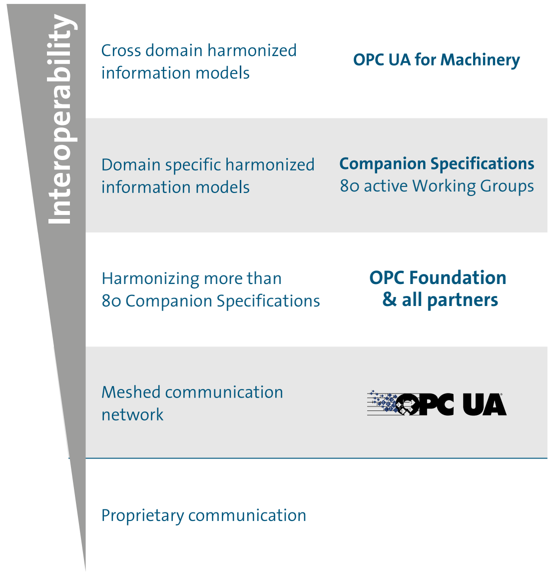
The harmonization working group was founded in 2019 to address this problem. Over 120 members, including representatives from the working groups creating and maintaining companion specifications and generally interested information modellers, are working together. There is a monthly web-meeting open for all members and various subgroups work on specific harmonization topics.

TASKS AND RESULTS

The harmonization working group fulfils various tasks. In addition to the concrete subgroups addressing specific and larger problems, those tasks include:

- → Reviewing companion specifications to learn from each other and potentially generalize common modelling concepts. In this activity, sometimes concepts of a companion specification are moved either into the base specification or a more common specification like OPC 10000-100: Devices or OPC 10000-200: Industrial Automation.
- → Maintaining the template for companion specifications and making sure that it fits into the tool chain of the OPC Foundation like the validator used to check companion specifications and their consistency with the UaNodeSet-file, a machine-readable representation of the information model.
- → Identifying topics for harmonization and either resolve them on the fly or form specific subgroups. Several of those topics have been solved and added to into the base specification or a more common specification like OPC 10000-100: Devices or OPC 10000-200: Industrial Automation.
- → Maintaining documents created by the Harmonization working group like
  - – OPC 10000-110: Asset Management Basics (Specification)
  - – OPC 10000-200: Industrial Automation (Specification)
  - – OPC 10000-210: Relative Spatial Location (Specification)
  - – OPC 11020: Companion Specification Template (Template)
  - – OPC 11030: OPC UA Modelling Best Practices (Whitep.)





Subgroups of the Harmonization working group have addressed various topics, including:

- → **Application Hierarchies:** Working on a whitepaper how to deploy OPC UA applications.
- → **Asset Management Basics:** Addressed basic use cases for asset management. Defined in OPC 10000-110 how to address those use cases, sometimes by new types, sometimes referencing existing concepts of the base specification and OPC 10000-100 Devices.
- → **Base Network Model:** Created a base model on networks that was released as 10000-22: Base Network Model, which is now maintained by the core working group.
- → **Base Relationships between components:** Defined various common types of references and refinement mechanisms in OPC 10000-23: Common ReferenceTypes, which is now maintained by the core working group.
- → **Calibration Target Management:** Created a model on the management of calibration targets that was released as part of OPC 10000-200: Industrial Automation.
- → **Information Model Best Practice:** Created the whitepaper OPC 11030: OPC UA Modelling Best Practices and is actively working on updates of the whitepaper.
- → **Scheduler:** Created an information model on scheduling actions (like generating a report or turning on the heating) which is published as OPC 10000-24: Scheduler, which is now maintained by the core working group.
- → **StackLights:** Created an information model representing stack lights that was released as part of OPC 10000-200: Industrial Automation.
- → **XML Data Type Mapping:** Created a specification that maps base data types of OPC UA and XML bidirectionally and is almost finished.
- → **Relative Spatial Location:** Created an information model on relative spatial location that is published as OPC 10000-210: Relative Spatial Location.

OPC UA FOR MACHINERY

In addition to the Harmonization Working Group hosted by the OPC Foundation, the VDMA addresses in cooperation with the OPC Foundation the harmonization of topics specific to the area of machinery. Both working groups work strongly together and move topics to the appropriate working group. As a result of this activity, several specifications have been released or are in the process of being created.

- → **OPC 40001-1 Machinery – Basic Building Blocks:** Addresses use cases like identification of a machine and the components of a machine, finding machines and their components in an OPC UA Server, and monitoring the state of machines. The identification is based on identification defined in OPC 10000-100: Devices and specialized to the domain of machinery.
- → **OPC 40001-2 Machinery – Process Values:** Defines a model how to represent process values including the monitoring with limits. Based on OPC 30081 Process Automation Devices – PADIM and OPC 10000-100: Devices.
- → **OPC 40001-3 Machinery – Job Management:** Defines building blocks for execution and control of Job Orders (units of work to be executed). It is based on and inherits the information model of UA for ISA-95 – Job Control (OPC 10031-4).
- → **OPC 40001-101: Machinery – Result Transfer:** Provides mechanisms to transfer results that are produced by a Server or its underlying system. The characteristics of such results is to contain meta data together with the individual results.

In addition, the group is working on topics like

- → **Power Consumption Management,** as cooperation between OPC Foundation, VDMA, PNO, and ODVA

»OPC UA Strategies for Data-driven Digital Transformation at Equinor«

João Pinheiro, Senior Technical Team Lead at Equinor

Equinor is an energy company of 21,000 colleagues committed to turning natural resources into energy in more than 30 countries worldwide. Digitalization supports Equinor's strategies and goals, which are to use data to improve safety; reduce development and operating costs; increase recovery and discovery; and to reduce greenhouse emissions.

EQUINOR'S CLOUD-BASED DATA PLATFORM

Equinor has created OMNIA, a cloud-based data platform on Microsoft Azure, to support their digital roadmap. Joao Pinheiro, Senior Technical Team Lead at Equinor states, "The idea behind this platform is to move from silos of data to one common platform that orchestrates our data across the value chain." In the world of data-driven operations, he goes on to say that, "data without any context is quite useless. When you have data in context, you have information, which can be used for analysis and visualization."

Sensors can provide value, quality, and timestamp; but humans and software cannot know if the data is related to a pump, a motor, a valve; or whether the data point is related to hydrocarbons, upstream/inlet, or downstream/outlet areas.

"The most powerful game-changer, to obtain context, is OPC UA." said Mr. Pinheiro". It has the ability to turn data into information. Its ability to standardize on information across vendors and products, using OPC UA companion specifications, results in interoperability." He continues, "OPC UA is supporting Equinor in making real-time, contextualized data (information) available."

OPC UA PROVEN IN-USE, AT SCALE

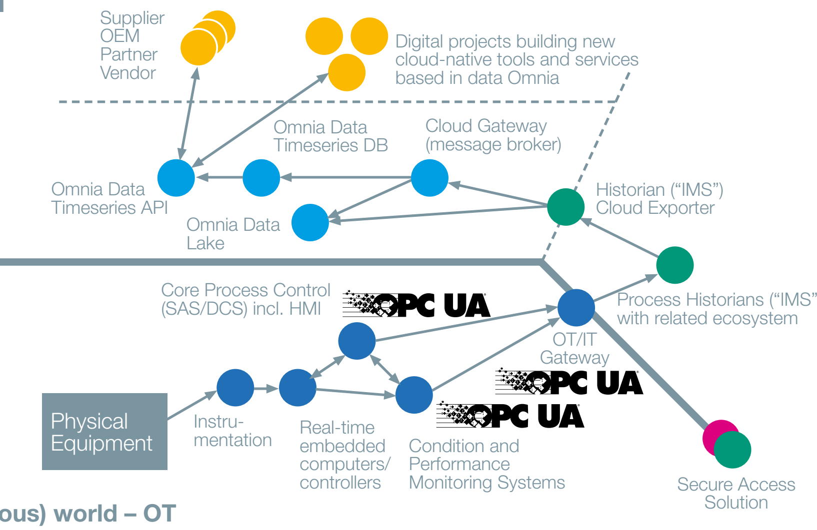
OPC UA has been implemented and proven in-use, aboard Johan Sverdrup. This field is massive, producing 30% of Norway's total production, with OPC UA being a central part of the digitalization strategy, having 19 OPC UA servers aggregated into a single, central OT/IT Gateway.

SOME METRICS

The Equinor OPC UA Template Library consists of 50 objects, 90+ classes, 920+ attributes, with the same library being used across multiple assets, including renewable energy projects.

Today, the OPC UA Server hosts almost one-million tags, linked to Microsoft Azure.

The Equinor OPC UA Asset Structure has defined over 31,000 pieces of equipment.



EMBRACE OPENNESS AND GIVE BACK TO THE COMMUNITY

Equinor utilizes and benefits from the OPC technology community and, by open-sourcing Equinor's information models, they give back to the community. The information library is offered at no charge on Github https://github.com/equinor/opc-ua-information-models, and on the UA Cloud Library of the OPC Foundation https://uacloudlibrary.opcfoundation.org Equinor believes that being open is the key to adoption and, that openness, is the spirit of OPC UA.

END USER BENEFITS

There are efficiencies gained in the exchange of data, without needing human translation in the middle. There's an increase in the flexibility of the overall architecture with easier replacement of components (plug & produce), since the interfaces and information are the same across vendors.

Furthermore, OPC UA is designed for use across industries making it seamless for a supplier to utilize the same interface and the same information model for myriad customers across various industrial sectors.

View complete version

»OPC UA Enables Digital Transformation at Groupe Renault«

Thierry Daneau, Product owner on Industrial data capture project, Groupe Renault

RENAULT

Google Cloud

Groupe Renault is implementing OPC UA-enabled equipment at their 38 production sites worldwide, deploying secure, end-to-end OPC UA data communication from sensor, to machines, to cloud, and back again. Already, OPC UA is deployed at 24 production sites on 7,000+ OPC UA-enabled devices, pushing 30,000 messages per second to Google Cloud.

OBJECTIVES ON THE PATH TO DIGITALIZATION

In 2017, Renault experts defined five concrete objectives for digital transformation of automotive production for the entirety of Groupe Renault.

→ A connected workforce
→ Real-time data-driven operations
→ Process 4.0
→ Flexible supply chains and systems
→ Complete traceability of components

The ambitious future scenario of M2M communication, cloud applications, Big Data, and machine learning were as much a part of the vision as AI and digital twins.

HURDLES ON THE PATH TO DIGITALIZATION

Challenges arise with the lack of interoperability between systems. Highly specialized production systems are used in the automotive industry, including different assembly systems, maintenance systems, test systems, automatic welding machines, and industrial robots, with some legacy systems in use since the 1980s.
Interoperable interfaces have now been integrated and a uniform data structure developed so that production can access standardized data. Groupe Renault built the digitalization of production on the foundation of OPC UA technology and the OPC UA-based Companion Specifications.

View complete version

WHAT MAKES OPC UA SO EFFICIENT?

The architecture is platform and manufacturer independent. OPC UA is the uniform, global standard for bidirectional information exchange. This standard enables transmission of machine data, including the semantic description of that data.

OPC UA: AN INTERNATIONAL STANDARD FOR THE AUTOMOTIVE INDUSTRY

Groupe Renault is continuing to drive the integration of OPC UA interfaces in automotive manufacturing. The "Connected Plant" project uses OPC UA in machining equipment, lathes, and milling machines, among others. An increasing number of suppliers are integrating OPC UA interfaces into equipment and on-board software.

GROUPE RENAULT'S VISION:

An international, industrial communication standard based on OPC UA for car manufacturers and their suppliers, with uniform data models.

»OPC UA Optimizes Production of Laundry Washing Machines at Miele«

Christian Stickling, Information Technology in Appliance, Miele

Miele is the world's leading supplier of premium domestic appliances, as well as appliances for commercial use. Miele also produces cleaning, disinfection, and sterilization equipment for medical facilities and laboratories. Founded in 1899, employing over 21,000 people worldwide, and represented in almost 100 countries, Miele garners annual sales of EUR 4.5 billion.

Miele

Microsoft Azure

WHY DOES MIELE RELY ON PRODUCTION COMMUNICATION WITH OPC UA?

"OPC UA is the communication protocol for Industry 4.0, with cross-manufacturer and cross-platform use. OPC UA has the crucial advantage that communication follows a uniform format, being robust and secure with OPC UA interfaces," says Christian Stickling, Information Technology in Appliance, Miele.

CAN EXISTING SYSTEMS BE UPGRADED TO OPC UA?

"The uniform interfaces can be used for different systems, which is a great advantage for existing production lines. Consequently, the time required for adaptations or the integration of devices and systems is significantly reduced.

Our greatest advantage is that 100% of Miele's suppliers now provide OPC UA-compliant products with OPC UA interfaces in machines and controllers."

KEYWORDS: 'DATA SECURITY'

"The high security level of OPC UA is a main factor for Miele. Communication with OPC UA works according to the principle "secure by default". All data is encrypted and transmitted securely. Under these security standards, our Laundry Business Unit assets and production data are transferred to Microsoft's Azure Cloud."

View complete version

MANUFACTURING WASHING MACHINE AGGREGATES WITH OPC UA

In 2018, Miele chose to rely on OPC UA in the press shop and body shop to produce sheet steel components for washing machines.

In subsequent production steps, including welding, clinching, and bolting processes, these individual parts are assembled into a washing machine unit and housing. In final assembly, these and other individual parts are combined to form the finished washing machine.

The goal of the OPC UA integration was to modernize and simplify data communication in production. Today, OPC UA standards are implemented when existing plants are remodeled; but new plants are already equipped with OPC UA from the factory.

CONVERSION TO OPC UA IN JUST THREE WEEKS

The integration of the new communication level could only take place during the three-week plant vacation period, which meant the individual test series had to take place under real conditions of the running press plant.

Within three weeks, the old system had to be dismantled, the new communication levels, including the OPC UA interfaces, had to be integrated, and the upgrade of the existing machinery, with adapters, had to be completed and tested.

"THERE WAS A PLAN-B, BUT NO GOING BACK."

Failure would have resulted in immense licensing costs for previous software, as well as costs for rebuilding and redundancies. There was a plan B, but no going back.

"When production started, without errors on Monday morning, we knew every stage of production had been successfully converted to the OPC UA communication standard," explains Christian Stickling in retrospect.

FUTURE-PROOF OPERATIONS

Christian asserts, "We now have a simpler and more future-proof operation of production-related communications and have achieved monetary savings by not having to purchase special software licenses. This also results in faster troubleshooting, ensureing smooth operations."

»Hidden Giant” – Bühler Automates Food Production with OPC UA«

65 Percent of all Wheat Flour is Milled on Bühler Machines

Connectivity is established with the Bühler Insights digitalization platform, based on Microsoft Azure Industrial IoT.

The Swiss machinery manufacturer Bühler plays a crucial role in meeting the basic food and mobility needs of two billion people. This is because a large proportion of the machines used in food production and die casting come from Bühler. The internationally active, family-owned company, has over 17,000 employees at more than 140 locations worldwide. Bühler has been gearing up for Industry 4.0 since 2014 with OPC UA and the automation solutions for process and plant control ‘Pluto’ and ‘Mercury MES’ that are based on it. Connectivity is established with the Bühler Insights digitalization platform. Major industrial customers have increased the efficiency of their production and reduced energy waste and water consumption with Bühler’s OPC UA-based solutions.

MACHINES FROM BÜHLER

Bühler is the world’s leading producer of machinery for the production of flour, rice, pasta, chocolate, coffee and beer.
The largest business segment of Bühler Group, Grains & Food, performed solidly in 2022, despite disruptions to supply chains, and the grain and energy markets. Its order intake was CHF 1,663 million, down 6.5 %, while turnover improved by 2.6 % to CHF 1,696. Bühler Group’s net profit improved significantly by 35.7 percent to 170 million US dollars (previous year: 125 million US dollars).

SUSTAINABILITY THROUGH DIGITALIZATION

Bühler Group has committed to having solutions ready to multiply by 2025 that reduce energy, waste, and water by 50 % in the value chains of its customers. Connectivity in the plants, automation, and smart control via Mercury MES (manufacturing execution system) software are the primary means to achieve this, OPC UA playing a key role throughout as a communications enabler.

OPC UA INTEGRATION

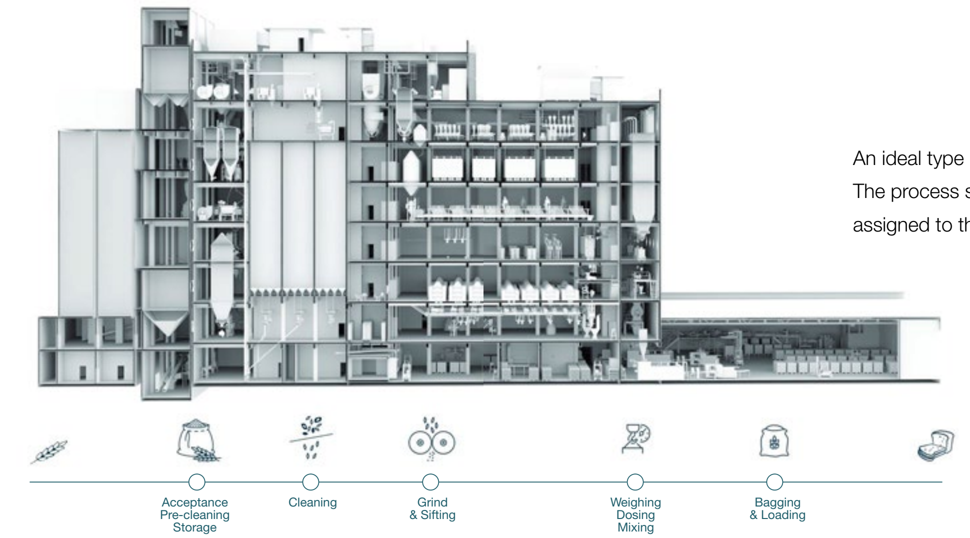
Bühler has developed standardizations based on OPC UA that facilitate the onboarding of new equipment. The “Die Casting” group is currently working on a companion specification.

CURRENT STATUS

90 percent of all new installations and upgrades are connected via OPC UA. “All the major hardware manufacturers have already integrated OPC UA,” explains Samuel Ochsner. “The PLCs already have OPC UA integrated. This is why the effort to add a new machine to the structure is comparatively small today.”

From smooth cookie dough to chocolate Easter bunnies: to allow customers to shape their chocolate products individually, Bühler offers customized forming and molding solutions.

View complete version



An ideal type of mill. The process steps are assigned to the machines.

KÄGI IN SWITZERLAND

By linking and visualizing the data in Bühler Insights, Kägi expects an increase of between five and eight percent in overall equipment effectiveness.

SWISS CHOCOLATE WAFERS FROM KÄGI

Kägi Söhne AG is a traditional company that has been producing a wafer bar with chocolate coating, the Kägi Fret, since 1934. In order to continue producing high-quality bars under all conditions, the management decided to make production data measurable and, thus, optimize processes. In 2019, Kägi and the Bühler service team conducted a performance assessment workshop to find out how improvements could be made in the production process.

The first Mill E3 is located in Yorkshire in the north of England and is operated by Whitworth Bros. Ltd, the largest flour producer in the UK.

APPLICATION & TRAINING CENTERS

Bühler Group maintains a network of Application & Training Centers (ATC) worldwide, where customers can test new products or recipes in small batches or receive further training. The ATCs are equipped with state-of-the-art machines and are fully digitized. By collecting test data, using the Bühler Insights platform, and with the help of on-site analysis labs, the Bühler team can plan and conduct tests together with its customers in real time and adapt machines or processes.

ATC IN BENGALURU, INDIA

At the Application & Training Center Bengaluru, equipment is installed, among other things, for the cleaning and color sorting of rice and the milling of atta (wholemeal wheat flour). The processes that are demonstrated and tested here can run automatically, semi-automatically and manually. Customers coming with valuable commodities such as coffee, pulses and spices can perform product tests to learn about the process, technology and performance of the machines under the guidance of experienced technologists before making an investment decision.

INNOVATIVE SMART MILL IN THE UK – MILL E3

The ‘Mill E3’ is an end-to-end digitized mill built from prefabricated modules and commissioned in 2021. At the heart of the Mill E3 are more than 15,000 data points that collect information on all steps in the production process. The name E3 refers to the three advantages this new type of mill offers them in terms of space requirements, installation time, and energy savings.

»Norwegian Companies Scatec Succeed with OPC UA in over 40 Renewable Energy Assets«

Thomas Pettersen, Vice President Operations Management at Prediktor

Diverse pieces of equipment are assembled in Scatec's solar fields. OPC UA creates compatibility between them.

SCATEC
OPERATING SOLAR FIELDS USING OPC UA

Headquartered in Oslo, Norway, Scatec is a leading renewable energy solutions provider developing, constructing, owning and operating large scale photovoltaic systems.

Currently, Scatec generates almost 3.5 GW in a combination of solar, hydro and wind energy plants; by 2025, Scatec aims to provide 15 GW in operation or construction.

Diverse pieces of equipment are assembled in Scatec's solar fields. OPC UA creates compatibility between them.

VENDOR LOCK-IN AVOIDED WITH OPC UA

Since OPC UA is an open interoperability standard that is platform independent and does not use proprietary formats, users need not worry about vendor lock-in. OPC UA Information Models enable the concept of 'unification'. This allows taking a single information element, for example, current real-time value, and applying other information elements like alarm conditions and historical trends to that single item, using the same reference, even if they have different sources. These make up the context of an object. In this way, asset owners have a clearly defined interface to all their technical assets independent of whether the asset is delivered by vendor A or B.

Scatec asset owners can switch to other operating systems or change individual protocols at certain data points. The OPC UA-based plug-and-play solution still functions, independent of those changes.

ASSET MANAGEMENT AND OPC UA

Scatec cooperates with many suppliers and, as a result, there are many different equipment types at any one plant which were never meant to be operated in one system. All of these generate data: the solar panels, the rack system that holds the panels, and the trackers that change their exposition to the sun; and associated inverters, batteries, charge controllers and cabling. The digital surface created by these individual assets is messy. Using Prediktor's OPC UA-based systems turns this messy scenario into a plug-and-play setting whose information flows can be interpreted conveniently.

View complete version

The first solar project in the African continent was the Kalkbult solar plant in South Africa: grid connected in 2013, 141 GWh per annum.

Maintenance workers at the Agua Fria Solar Plant in Honduras. Agua Fria was connected to the grid in 2015 and produces 97 GWh per year.

SOLAR ENERGY IN EMERGING MARKETS

Scatec assets are predominantly solar energy plants. "The beauty of solar is that the resource is already there, you just have to capture it", says Terje Melaa, Senior Vice President Engineering and Technology of Scatec. "However. aggregating data from all the equipment involved and analyzing it for asset control and maintenance purposes is more complicated."

Scatec is the largest provider of solar power in South Africa. The first solar project on the African continent was the Kalkbult solar plant in South Africa, which was connected to the grid in 2013, having a nominal capacity of 75 MW. Two solar plants followed in 2014, Linde with 40 MW and Dreunberg with 75 MW. The Upington solar plants, which were connected to the grid in 2020, produce 650 GWh per year and provide energy for 120,000 households.

The world's fifth-largest solar park (as of 2022), Benban Solar Park, Egypt, produces approximately 930GWh of power per year. This equals the energy consumption of 420,000 households. Visible from space, the park covers an area of 37 km².

OUTLOOK

Scatec has become a global player in renewable energy solutions across different technologies, with several green hydrogen, wind power, hydropower and flexible solar projects in the pipeline.

GREEN AMMONIA FACILITY IN EGYPT

Scatec has reached an understanding with the Egyptian government and Egyptian organizations to jointly develop a green ammonia facility with a production capacity of one million tonnes annually and with a potential for an expansion to three million tonnes.

SOLAR FIELD IN LESOTHO

Scatec entered an agreement with the Lesotho Electricity Company and the Government of Lesotho to build the first solar project in Lesotho of 20 MW.

PREDIKTOR AS SYSTEM INTEGRATOR

The Norwegian systems integrator Prediktor is a leading provider of asset management and real-time data management solutions to renewable- and energy asset owners. It is also a global technology leader in OPC and OPC UA. Prediktor now focuses on renewable energy asset owners. "In a solar plant, you receive more than 100,000 data points every second. If you don't have a system that helps you find out what you need to look into and assists in data-driven decision making, then there's no point in collecting that much data."

IT GATEWAY FOR INTEROPERABILITY

The mainstay of Prediktor's service is enabling customers to work with incompatible data sources generated by a range of different operational technology (OT) within an established context. Prediktor aggregates all asset data, standardizes it, and interprets it, semantically, using AI algorithms. Semantic data is data that is contextualized and expresses what it means in human, rather than machine, language.

The asset owner can manage a large number of assets in a convenient, flexible, and agile manner whilst greatly reducing operational costs.

SCADA PROVIDES INTERFACES TO OPERATE PLANTS

Prediktor supplies a Supervisory Control and Data Acquisition (SCADA) system that is installed locally at the site to provide operators with interfaces to operate the plant. It creates interoperability of diverse equipment.

PHILIP MORRIS INTERNATIONAL

Aleph smart manufacturing, redefined

»PMI Re-Engineers Operations and Manufacturing through new Production Lines with a New OPC UA Domain Standard for the Tobacco Industry«

In 1847, Mr. Philip Morris opened a shop on London's Bond Street. Today, Philip Morris International (PMI) is known as one of the world's largest tobacco product manufacturers that has made a dramatic decision; PMI is building its future on smoke-free products that are a much better choice for adult smokers. In 2023, PMI generated $35.2 billion in annual sales. Smoke-free products accounted for 39.3 percent of total net revenue. According to Jacek Olczak, Chief Executive Officer at PMI, it is the company's ambition to be a substantially smoke-free company by 2030, with over two-thirds of its total net revenues coming from smoke-free products.

© Wikimedia Commons: Philip Morris International's Operation Center in Lausanne, Switzerland, Author: SimonDes

DELIVERING A SMOKE-FREE FUTURE

Since 2008, PMI has been working on developing and scientifically assessing less harmful smoke-free alternatives. Their most successful smoke-free product was launched in 2014. Smoke-free products are manufactured in PMI's factories in Switzerland, Italy, Greece, Romania, Poland, Korea and Indonesia.

HETEROGENOUS TECHNOLOGIES

Some of PMI's older production equipment is not Industry 4.0-ready. Josselin Vallee, Manager for Machine Integration & Supervision at PMI, describes this as a "jungle of very different technologies". In this heterogeneous machine park, only five data points could typically be collected using various communication standards. These were mainly used for performance monitoring.

Using advanced Industry 4.0 tech was difficult. In order to facilitate the seamless production across various machines from different manufacturers, an interoperable communication standard was required. As a result, in 2017, PMI joined the OPC Foundation and started using OPC UA.

View complete version

OPC UA FOR TOBACCO MACHINE COMMUNICATION (TMC)

- Aim to make data exchange and interoperability requirements work smoothly for both cigarette manufacturers and OEMs.
- Tobacco leaders British American Tobacco (BAT), Imperial Tobacco Group, Japan Tobacco International, Philip Moris International (PMI), and the OPC Foundation formed a working group in 2017.
- Together, they created the companion specification "Tobacco Machine Communication" (TMC). Version 2.0 is available since June 2022. To speed up the group partnered with Aleph Digital Industry acting as editor for the TMC.

Now, with OPC UA and the TMC Server, employees can access rich and structured information from production equipment for an increasingly data-driven manufacturing environment.

"We needed a way to communicate with our machines," explains Josselin Vallee. OPC UA stood out as a communication platform because it seamlessly connects information technology (IT) and operational technology (OT).

INTERNATIONAL COLLABORATION ON OPC COMPANION SPECIFICATION FOR TOBACCO MACHINES

To speed up data exchange across the industry, leading international tobacco products manufacturers, including PMI, and the OPC Foundation formed a working group. Together, they created the companion specification "Tobacco Machine Communication" (TMC), version 1.0 in 2017. The latest version of TMC (version 2.0) has been available since June 2022 after incorporating the learnings of applying the specification in a manufacturing environment.

TRANSFORMATIVE SOLUTION BASED ON OPC UA

PMI created a solution using OPC UA and the TMC companion specification. "The TMC companion specification gathers material, machine, performance, and process order information, all in one place. This makes it easy to receive, check, and send information back and forth. Now, we can verify material quality with our MES system and collect material and machine information when there are processing issues." Explains Josselin Vallee. To speed up the transformation to OPC UA, PMI has collaborated with Aleph Digital Industry, which supported the integration of additional manufacturing microservices.

DATA MANAGEMENT

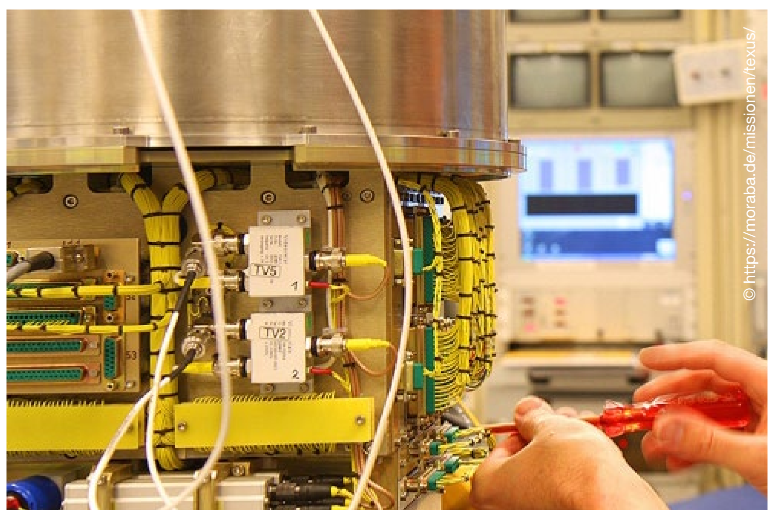
OPC UA, paired with TMC, provides PMI with more detailed, clear, and frequent information. "From just five standard data points we had in the past, we now have access to hundreds, if not thousands." recalls Josselin Vallee. "This means large amounts of data exchanged, and results in an intense strain on the machine hardware and on our IT infrastructure," Josselin explains. Ingesting, storing, and computing large amounts of information from manufacturing processes, at higher frequencies, was a complex challenge. Nevertheless, the entire new dimension of information exchange, powered by OPC UA, opens big opportunities for scalable Industry 4.0 solutions at PMI.

MACHINE ORCHESTRATION POWERED BY OPC UA

In high-speed production, syncing machine speeds within a production line is crucial. With OPC UA and TMC in newly enabled equipment, coordinating machine speed on production and packaging lines becomes more precise. Decisions can be taken based on a large set of data points. This results in a longer mean time between failures and increased uptime, even for highly automated machines. PMI is now globally implementing SMC, using the OPC UA communication standard's interoperability and the TMC companion specification for scalability.

»Airbus Defences and Spaces Integrates OPC UA in Research Data Management«

Airbus Defense and Space, a division of the European Airbus Group, is represented in 35 countries and employs around 34,000 people from over 86 nations. The business segment's main sites are located in France, Germany, Spain, the UK, Italy, the Netherlands and South Africa.



TEXUS OPC UA SUPPORT SPECIFICATION FOR OPTIMIZED DATA MANAGEMENT

Airbus Defense and Space has been using OPC UA since 2017. 'Technological Experiments in Zero Gravity', or TEXUS for short, benefits extensively from OPC UA. The entire data management, including secure and seamless communication, is optimized both during the rocket flight and afterwards. Together, the flight software on board the rocket and all ground systems communicate via OPC UA. The specially developed OPC UA Companion Specification controls all sensors, actuators, and controllers. By the end of 2025, all devices, on board and on the ground, will be fully OPC UA-compliant.

SOUNDING ROCKETS

Sounding rockets carry scientific and technological experiments to the edge of space before returning to Earth. During its ballistic trajectory, a research rocket reaches a zenith maximum altitude of around 260 kilometers, completing its journey from take-off to landing in around 15 minutes. During this short period of time, the experiments on board are exposed to zero gravity for around six minutes. This is a rare opportunity to gain insights into various phenomena of zero gravity.

FIRST CONTACT WITH OPC UA

Airbus Defense and Space was first introduced to OPC UA by its partner company AMS Soft. The partner was already working with OPC UA in the automotive sector and also recommended the solution for flight software. In 2016, an OPC UA project team began examining OPC UA as a potential solution for data communication. The operational test phase for the integration of OPC UA in TEXUS also began in 2016. "Although the introduction only covered part of the system in 2017 for organizational reasons, there were no reservations about OPC UA," explains Enrico Noack.

View complete version

OPC UA SUPPORT SPECIFICATION AND BENEFITS

The TEXUS OPC UA support specification includes data types, image types, methods and namespace configurations, and optimizes data management and storage. OPC UA has also significantly increased the number of data points per experiment from 64 to 4,000. The efficiency of each research flight and each individual experiment has, thus, been significantly increased, as considerably more scientific data is generated, with OPC UA being used in both the on-board and ground systems.

The maximum data throughput for the Space-to-Ground connection is approximately 5 Mbit/s for all experiments combined. The OPC UA protocol is so lean that an average of 32 Kbit/s per experiment is sufficient.

FURTHER ADVANCEMENT WITH OPC UA: INTERFACE DEVELOPMENT WITH AI

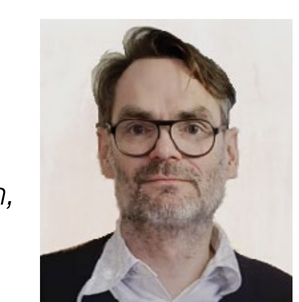
One of the current advancements in OPC UA is the development of an interface to artificial intelligence (AI). This initiative aims to build a bridge between OPC UA and AI technology, particularly in the creation of an operator assistance system. Various Airbus departments are involved in this collaboration in order to jointly explore possibilities and optimize functionality.

© TEXUS 60 successfully lifted off from the Swedish space centre Esrange – © AIRBUS

SECURITY MEASURES IN OPC UA DEPLOYMENT

Security considerations are very important in OPC UA deployment scenarios. A key approach at TEXUS is the use of separate, secured networks that ensure isolation and protection of sensitive data. The in-flight networks are dedicated exclusively to the experiment, with internal VLANs further compartmentalizing the experiments to increase security. This strategy prevents unauthorized access to the network and, thus, strengthens security measures.

"OPC UA serves as a data highway known for fast, rich, controlled, and secure data transfer. The OPC Foundation always anticipates our needs, proving their proactive approach, such as with PubSub. In the three years leading up to the implementation, the collaboration with OPC Labs and Unified Automation has been instrumental in our progress and we are very pleased with the achievement of our efforts."



ENRICO NOACK,
Engineer at Airbus Defense and Space

»OPC UA Delivers Data for 115 Procter & Gamble Brands Used in Your Daily Life«

P&G

Since its establishment in 1837, Procter & Gamble has been headquartered in Cincinnati, Ohio. The US consumer goods group operates 450 production sites in over 70 countries, and employs more than 100,000 people. In 2023, Procter & Gamble became the 900th member of the OPC Foundation

Microsoft

OPC UA AND THE INTEGRATED WORK SYSTEM (IWS) AT P&G

Procter & Gamble has been known for innovation in the consumer goods industry for many years. P&G developed its own program for operational precision and quality – the Integrated Work System (IWS) – many years ago. This system is used at over 100 production centers and 450 manufacturing plants worldwide. Current developments in the IWS focus on the integration of artificial intelligence and machine learning. Offering secure data connectivity, from the sensor to the cloud, OPC UA is an integral part of the industrial communication frameworks in the automation systems at P&G.

INCREASING OPERATIONAL EFFICIENCY

Procter & Gamble is developing a Supply Chain 3.0 strategy for all company locations worldwide. This strategy aims to promote seamless data integration and connectivity. The objective: Machine learning and artificial intelligence. Specific goals include, reducing operating costs in production, improving processes by five to ten percent, and maintenance, repair, and QA costs reduced by up to 50 percent. OPC UA is the key enabler for the new age of data at Procter & Gamble.

Explaining how these goals are achieved, Jeff Kent, VP, Smart Platforms Technology & Innovation states,

© molokot – stock.adobe.com

View complete version

"We've developed the SmartBox technology stack in collaboration with industrial automation partners to ensure consistent delivery of GPUs and IPCs for DevOps on the control edge. In addition, WISE serves as an end-to-end lifecycle, specifically supporting machine learning against required use cases. The underlying challenge here is the need for a network communications model that connects the sensors, controllers, the OT, and the cloud. It also needs to enable a bidirectional flow of information. We see no better way than to perform this through OPC UA."

DATA ANALYSIS: INFORMATION CRUCIAL TO THE DIGITALIZATION OF PRODUCTION

The focus of digitalization projects relies on the generation, distribution, and networking of data. P&G focuses on three key aspects in relation to data:

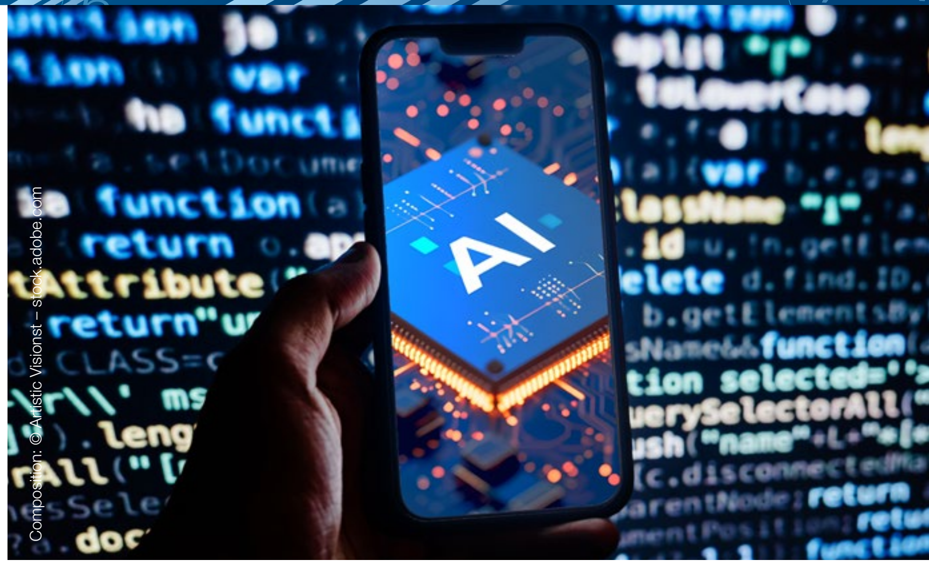
- Data that is indispensable for smart processes
- Data that makes the use of AI possible
- Data required for machine learning

FOUR CHALLENGES TO OVERCOME

P&G started on the path to digitalizing production with AI and machine learning by establishing the basic strategic prerequisites:

- The data had to be democratized from the production facilities in an appropriate contextualization and resolution
- A validated machine learning model needed to be developed to ensure the intake of the processed and transformed data
- This model had to be integrated into the production environment, which also includes control systems, in order to carry out deterministic operations therein
- The machine learning model was to be rolled out to all operating sites

Jeff Kent stipulates, "It is critical for P&G to have an innovation and operations ecosystem that enables the rapid value-creation and sustainable operational excellence expected from smart manufacturing. We recognize the need to collaborate with automation industry partners and the OPC Foundation, as the leading global body for open communication and integration standards, to drive scalable, repeatable, and resilient implementations of smart operations technologies across our global operations."



Composition: © Artistic Visionst – stock.adobe.com

OPC UA: THE MOST EFFECTIVE UNIFICATION APPROACH

By combining both the SmartBox and the WISE service model, P&G has succeeded in significantly improving the democratization of data flow across sites. The company is now able to develop and operationalize machine learning algorithms at the control edge, or deploy them across the company's larger reference architecture. A unified approach for communication, data model, and integration throughout enterprise technology was, therefore, required. Among various methods, such as APIs, P&G explored and implemented OPC UA and its extensions, like OPC UA Field eXchange (OPC UA FX) and OPC UA Time Sensitive Networking (TSN) to align with industry standards and partners. The result: OPC UA was deemed as the most effective unification approach, alongside P&G's proprietary APIs. It fostered a shared understanding with industry partners to meet current requirements and adapt to the evolving landscape, encompassing devices, controllers, control edge, OT edges, and cloud infrastructure within the intelligent operations environment.

"We see no better way than to perform our requirements through OPC UA."

JEFF KENT
Vice President,
Smart Platforms
Technology & Innovation
at Procter & Gamble

»OPC UA: Driving Scalable, Secure Tunnel Infrastructure for Asfinag«

Austria's alpine topography and dense transit routes demand some of the most sophisticated tunnel safety systems within Europe. To manage this complexity, ASFINAG, Austria's motorway operator, partnered with technology provider evon to implement a highly scalable monitoring solution. At the heart of this digital transformation is OPC UA, the global standard that has enabled ASFINAG to scale from its small 2016 pilot to a massive network, managing 6.5 million data points across 170 tunnels.

STRATEGIC SELECTION: WHY OPC UA?

The decision to adopt OPC UA followed a rigorous evaluation against traditional telecontrol protocols like IEC 60870-5-104 and IEC 61850. ASFINAG's strategic choice was driven by three core requirements:

1. **Interoperability:** Tunnels integrate hardware from diverse manufacturers (ventilation, lighting, fire alarms, and video). OPC UA provides a vendor-independent backbone that allows these disparate systems to communicate seamlessly.
2. **Object-Oriented Modeling:** Unlike flat data structures, OPC UA allows for structured data modeling, which facilitated the ASFINAG object catalog. This ensures that every sensor and actuator – regardless of the manufacturer – presents data in a uniform, predictable, and standardized semantic format.
3. **Security & Reliability:** Since tunnels are, without question, "critical infrastructure," the built-in encryption, certificate-based authentication, and native redundancy were non-negotiable for 24/7 operations.

View complete version

IMPLEMENTATION: FROM PILOT TO VMIS 2.0

The rollout began in 2016 with a four-facility "tunnel chain" pilot in Carinthia. Proving the technology's viability led to its integration into the VMIS 2.0 (Traffic Management and Information System). Using the evon XAMControl platform, the implementation followed a decentralized yet cohesive strategy:

- **Data Aggregation:** All data converges on a redundant central server in Vienna.
- **Regional Autonomy:** This data is distributed to nine regional traffic management centers. This architecture ensures self-sufficient operation; if the connection to the Vienna hub is severed, regional centers maintain full control of their local infrastructure.
- **Redundancy Mechanisms:** Using the OPC UA ServiceLevel variable, the system constantly monitors the health of communication counterparts. This allows for automated load balancing and instant failover, ensuring that "every second counts" during an emergency.

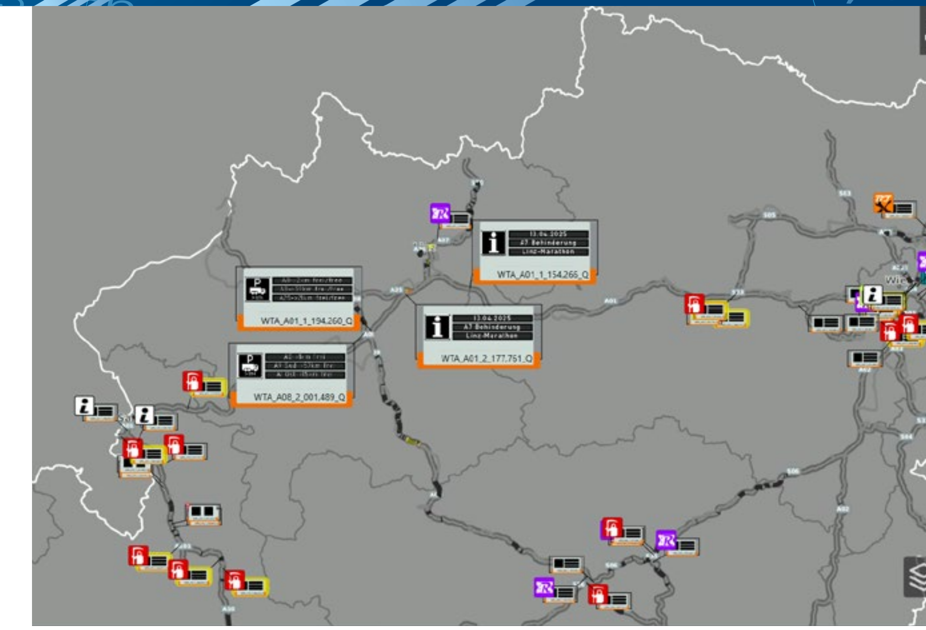
OPERATIONAL IMPACT & SAFETY

The strategic implementation focuses heavily on Standardized Data Access (DA). By using a uniform information model, ASFINAG has significantly reduced the engineering hours required for new integrations. This efficiency allows the team to allocate resources toward rigorous testing and quality assurance.

THE SYSTEM CURRENTLY MONITORS:

- **Safety Systems:** Fire alarms, smoke extraction, and emergency lighting.
- **Environmental Sensors:** Air quality and visibility sensors.
- **Traffic Control:** Variable message signs, barriers, and accident detection.
- **Energy Infrastructure:** Transformers and switching states.

By centralizing these millions of data points, operators receive precise, real-time diagnostics on malfunctions and maintenance needs, allowing for proactive rather than reactive management.



VMIS 2.0 — nationwide operations map showing current measures and events across ASFINAG's network. In total, the new VMIS integrates more than 33,000 connected traffic facilities with around six million interacting data points across a 2,200-kilometer motorway network into a central system. © evon GmbH.

THE ROAD AHEAD: 2026 AND BEYOND

The project reached a major milestone in May 2025 with the completion of the final traffic management center in Hohenems; however, the implementation is living and iterative. ASFINAG follows a 10-year renovation cycle for every tunnel, using each upgrade to further refine the OPC UA integration.

The next strategic frontier is Condition Monitoring. Currently, some sensor data still resides in analog or third-party systems. ASFINAG aims to migrate these external connections to OPC UA, creating a unified, interoperable database for the entire national network. Major upcoming projects, such as the Karawanken Tunnel (completion 2026) and the A26 Linz motorway (ongoing through 2032), will continue to utilize this scalable framework to ensure Austria's tunnels remain among the safest in the world.

"Every second counts in Austria's tunnels – that's why we rely on communication that is secure, interoperable, and redundant."

MARKUS WINTER,
Asfinag

»Helen Digitizes Finland's Energy Future with OPC UA«

To transition from a centralized coal-based utility to a decentralized, carbon-neutral energy leader, Helen adopted OPC UA as its universal digital backbone. By standardizing data collection through a vendor-neutral architecture, Helen successfully integrated diverse renewable assets while ensuring high-security standards for Finland's critical infrastructure.

Wapice Technology Partner

THE DIGITALIZATION OFFENSIVE

Helen, one of Finland's largest energy companies, owned by the City of Helsinki, is building a decentralized, secure, and automated energy infrastructure. As Helen moved toward a decentralized production model, we identified a critical challenge: as the number of energy units increased, information gathering became exponentially complex. Many existing systems were proprietary and incompatible, making data collection costly and error-prone.

To meet the demands of a fast-paced energy market, we launched a comprehensive digitalization transformation. The goal was clear: build a future-proof, secure, and scalable energy management system using open interfaces and automated processes.

WHY OPC UA?

In 2014, Helen evaluated our landscape for an open solution that could function independently of any manufacturer. OPC UA was the strategic choice for four key reasons:

- **Manufacturer Independence:** It allowed us to select the best hardware without being locked into specific providers.
- **Scalability:** We can easily integrate new wind, solar, and heat pump assets regardless of their size or vendor origin.
- **Built-in Security:** It provides native encryption and authentication essential for critical infrastructure.
- **Data Ownership:** It established a clear separation of responsibilities. Each production unit is responsible for exposing high-quality data through its own OPC UA interface, simplifying troubleshooting across the communication chain.

IMPLEMENTATION AND ARCHITECTURE

Helen's transformation was powered by a long-standing partnership with Wapice and their IoT-TICKET platform. Serving as our central data hub, the platform operates as an OPC UA aggregation server.

The technical flow is streamlined for efficiency:

1. **Subscription Model:** A central OPC UA client subscribes to source servers at each power plant, ensuring real-time updates whenever data changes.
2. **Unified Endpoint:** Aggregated data is made available through a single OPC UA Server interface. Internal teams and external partners connect to this one endpoint rather than individual plants.
3. **Access Management:** IoT-TICKET acts as the identity layer, enforcing fine-grained access control so consumers only see the data they are authorized to use.

View complete version

MODERNIZING FOR A CLOUD-DRIVEN ERA

After a decade of 24/7 operation, Helen recently updated our system to a microservices-based architecture. While our core OT environment remains isolated from the public internet for security reasons, we implemented new, secure data-sharing mechanisms to feed cloud-based analytics and AI. This allows us to leverage modern computation power without compromising the physical security of our plants.

FUTURE PERSPECTIVE

As we scale toward 1GW of wind power and explore green hydrogen and Small Modular Reactors (SMRs), OPC UA remains our foundation. By unifying heterogeneous systems under one framework, we have turned data into a strategic asset, accelerating our journey toward a balanced CO2 footprint by 2035.

Helsinki, the capital and largest city of Finland, is a vibrant urban hub with growing energy demands driven by its population, infrastructure, and commitment to sustainability. © Helen

> *"Helen's renewed energy production portfolio is highly flexible, which opens up new opportunities in the markets but also introduces operational challenges. Reliable and secure data flows are essential for us to deliver on our promises to customers and to remain agile in a volatile and complex environment. The role of data management is especially critical when coordinating production capacity across multiple markets simultaneously."*

LAURI HIEKKANEN,
Development Lead, Helen

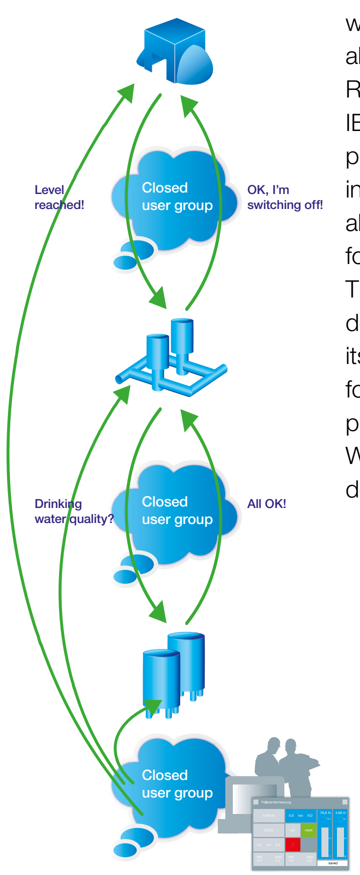
LAURI HIEKKANEN,
Development Lead,
Helen

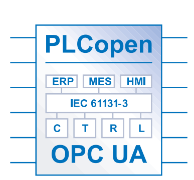
Horizontal: OPC UA enables M2M and IIoT

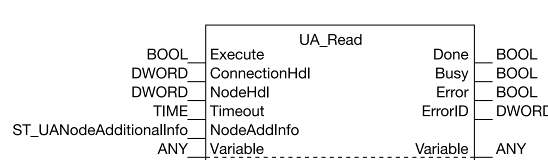
»Intelligent water management – M2M interaction based on OPC UA«

Silvio Merz, Divisional Manager, Electrical/Process Technology
Joint Water and Wastewater Authority, Vogtland

If we regard some of the basic concepts of Industrie 4.0, such as platform and vendor-independent communication, data security, standardization, decentralized intelligence and engineering, then a technology for M2M (Machine-to-Machine) or IoT (Internet of Things) applications is already available in OPC UA.
OPC UA is used for direct M2M communication between plants for the intelligent networking of decentralized, independently acting, very small embedded controllers, i.e. around 300 potable water plants and 300 wastewater plants (pumping plants, water works, elevated reservoirs, etc.) distributed over about 1,400 km²:
Real objects (e.g. a pump) were modeled in the IEC61131-3 PLC as complex objects with interactive possibilities; thanks to the OPC UA server integrated in the controller these objects are automatically available to the outside world as complex data structures for semantic interoperability.
The result is decentralized intelligence that makes decisions independently and transmits information to its neighbors or queries statuses and process values for its own process in order to ensure a trouble-free process cycle.
With the standardized PLCopen function blocks the devices independently initiate communication from the PLC to other process devices as OPC UA clients, whilst at the same time being able to respond to their requests or to requests from higher-level systems (SCADA, MES, ERP) as OPC UA servers. The devices are connected by wireless router: a physical interruption of the connection does not lead to a loss of information, since information is automatically buffered in the OPC UA server for a time and can be retrieved as soon as the connection has been restored – a very important property in which a great deal of proprietary engineering effort was invested beforehand. The authentication, signing and encryption safety mechanisms integrated in OPC UA were used in addition to a closed mobile radio group to ensure the integrity of these partly sensitive data.
The vendor-independent interoperability standard OPC UA opens up the possibility for us as end users to subordinate the selection of a target platform for the demanded technology in order to avoid the use of proprietary products or products that don't meet the requirements.
The replacement of a proprietary solution by a combined OPC UA client/server solution, for example, provided us with a saving on the initial licensing costs of more than 90 % per device.







Scalability: OPC UA integrated in sensors

»The integration of OPC UA into our measuring instruments provides our customers with comprehensive, secured communication«

Alexandre Felt, Project Manager at AREVA GmbH

SCALABILITY: AREVA BENEFITS FROM SENSORS WITH INTEGRATED OPC UA PROTOCOL

Comprehensive, end-to-end networking across all levels represents a challenge to Industrie 4.0. As an evolutionary step towards realization of the 4th industrial revolution and IoT, companies can already take a decisive step in the right direction with Embedded OPC UA. AREVA recognized early on the potential of OPC UA, in sensors and started integrating them into monitoring instruments (SIPLUG®) for mountings and their associated electric drives. The solution is used in the nuclear industry for monitoring critical systems in remote environments, without negatively affecting the availability of the system.
Before this, SIPLUG® utilized a proprietary data exchange protocol, just like most of the applications in the nuclear energy sector – this meant however that integration into existing facility infrastructures was difficult, and the outlay for various aspects, such as data buffering or data analyses, was always linked with extra costs.

BENEFITS OF EMBEDDED OPC UA

From an end-user perspective, the native OPC UA connectivity enables direct embedding of AREVA products into the infrastructure, without the need for any additional components: The solution allows the reporting and trend monitoring system of AREVA to access the SIPLUG® data directly. This means that the need for additional drivers and infrastructures can be dispensed with completely. What's more, additional values, such as pressure and temperature values available at the factory level, can be utilized easily in order to improve the precision of the data evaluation.
With AREVA, OPC UA can be used to provide access to SIPLUG® data within the upper levels of a company via an open, international standard (IEC62541) – the challenge of "end-to-end data availability" has therefore been solved with OPC UA.

With AREVA, OPC UA can be used to provide access to SIPLUG® data within the upper levels of a company via an open, international standard (IEC62541) – the challenge of "end-to-end data availability" has therefore been solved with OPC UA.

SMALLEST DIMENSIONS – INTEGRATED SECURITY

In addition to the reliability of the data, integrated security was also an important aspect for the utilization of OPC UA. The minimal memory requirements, which start at 240kB flash and 35kB RAM, can be integrated into the smallest devices of AREVA.

OPC UA ensuring the availability in a tunnel project

»Ensuring the availability in a project of this enormous scale is an exciting challenge. …«

Dipl.-Ing. Dr. techn. Bernhard Reichl, Managing Director ETM

SIEMENS

ETM professional control GmbH – A Siemens Company

"… due to the use of OPC UA as a standard interface to the infrastructure subsystems we can guarantee this."

The Gotthard Base Tunnel in Switzerland is by his opening in June, 2016 with 57 km the longest railway tunnel of the world.

OPC UA was defined as the standardized interface between the tunnel management system and the electromechanical systems. Given the need to integrate sixteen different facilities from different suppliers, it was vital to use a platform-neutral, standardized and uniform protocol.

The tunnel management system is responsible for ensuring the remote control and monitoring of relevant data points across the electromechanical systems. Using the information being constantly supplied from the infrastructure subsystems, encompassing power supply, catenary system, ventilation and air conditioning, lighting as well as operation and surveillance of wide-ranging different doors and gates, a graphic system overview is prepared.

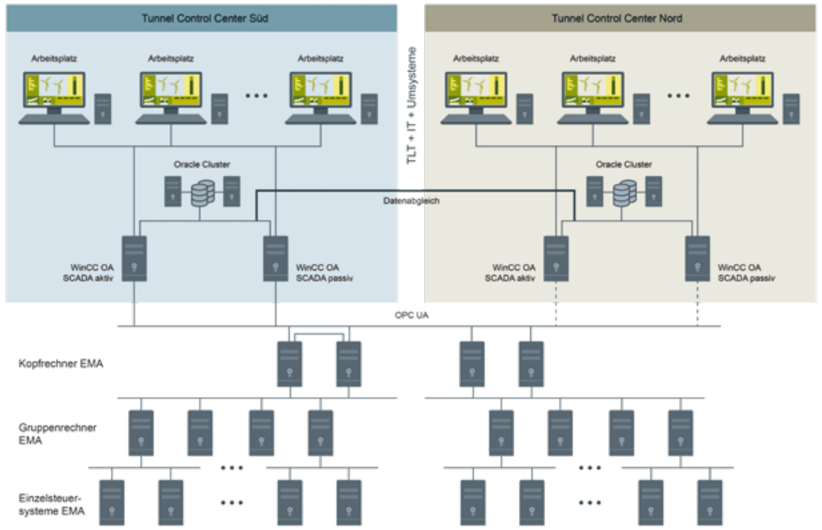
Beside the indication of the statuses of the various electromechanical systems, also the locations of trains within the Gotthard Base Tunnel alongside additional information are displayed. All of these systems are managed by the overriding tunnel management system on the basis of the SCADA system SIMATIC WinCC Open Architecture. The entire infrastructure is displayed, monitored and operated at two Tunnel Control Centers, one at the North and the other at the South Portal.

REASONS FOR OPC UA IN THE GOTTHARD BASE TUNNEL

→ **High availability of the communication**
- Redundant configuration set up both for the OPC UA client and server
- OPC UA Heartbeat used for monitoring the connection in both directions

→ **Reliable data exchange**
- Authentication and authorization both on the server and the client side
- Security based on current standards (SSL/TLS specification)
- Use of standardized X.509 certificates
- Same certificates also used in IT for safeguarding the https connections
- Use of a standardized infrastructure (CA)
- Secured OPC UA due to encryption and a digital signature
- Simple configuration of the firewall (only one port needed)

→ **High performance**
- Several hundred thousand data points
- Use of the binary protocol (OPC UA Binary, UA TCP)
- Binary protocol requires few overheads
- Consumes minimal resources
- Offers outstanding interoperability



Smart Metering: Consumption information from the meter right up to IT accounting systems

»Safe and flexible: Meter data collection with OPC UA«

Carsten Lorenz, Head of Product Management, Low Pressure Gas Metering & AMR/ AMI, Honeywell

Honeywell

"A safe and reliable communication protocol plays an important role in smart metering", says Carsten Lorenz, AMR (Automatic Meter Reading) Manager at Honeywell, a leading supplier of smart meter products for gas, water and electricity. Our UMI (Universal Metering Interface) protocol ensures optimum energy efficiency and long battery life in networks.

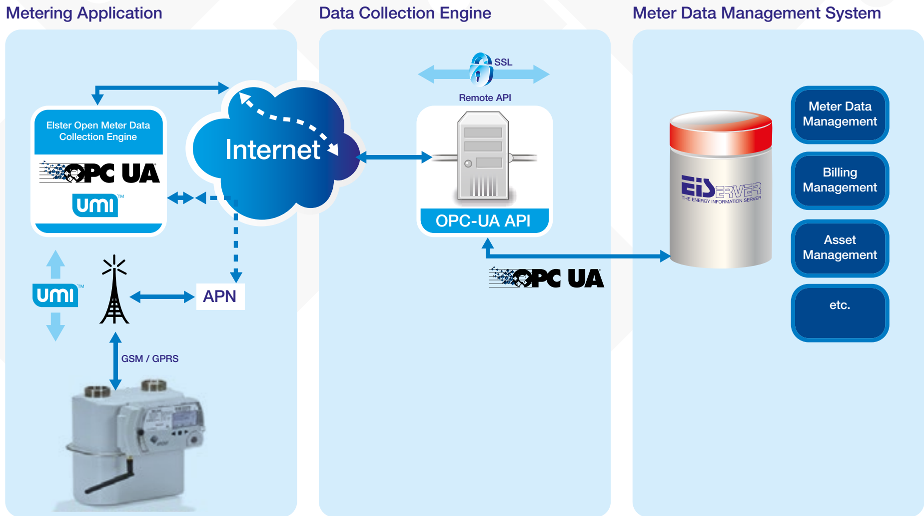
At Honeywell, we offer a software with OPC UA interface for our own systems as well as other head-end systems, since many systems used by supply companies already support this established standard. Integrated encryption of sensitive meter data is an important argument for OPC UA".

Security and encryption of personal data is a MUST when Smart Metering is introduced. This means: Corresponding security concepts have to be introduced together with Smart Metering in existing and new systems. They have to take account of new processes such as exchange of encryption mechanisms between manufacturers and energy suppliers.

Communication protocols are transferred in encrypted form with respect to gas meters. This means: Personal data and critical commands, such as closing and opening of a valve integrated in the meter, are not visible for third parties and cannot be intercepted or simulated.

The communication protocols support both asymmetric and symmetric state-of-the-art encryption methods, such as the Advanced Encryption Standard (AES). AES encryption is approved in the United States for government documents with maximum security classification.

Smart Metering is the precursor for the energy infrastructure of the future. Transparent online display of consumption data offers customers the option to optimize their energy consumption and utilize flexible tariffs based on their device and energy mix.



Vertical: OPC UA from production right into SAP

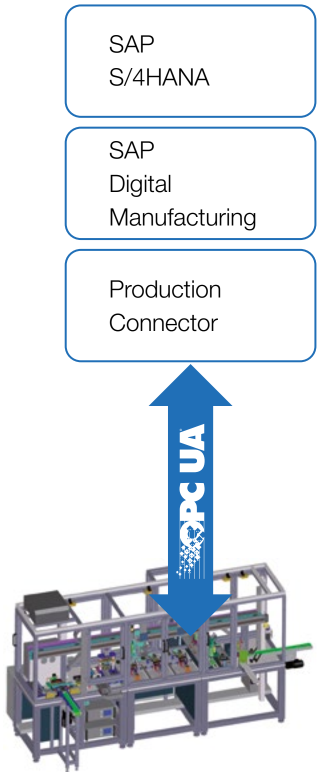
»Seamless MES integration of systems with OPC UA simplifies shop floor programming«

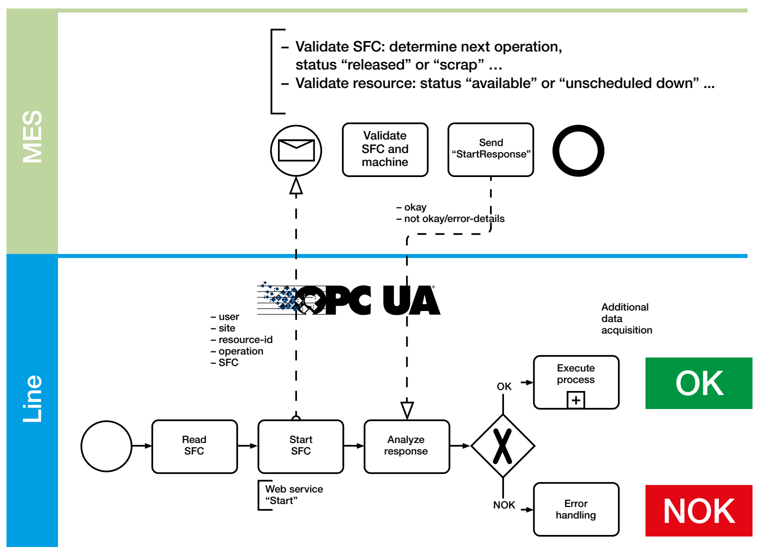
Ralf Lehmann, VP & Global Head Product Marketing, PLM and Manufacturing, SAP
Member OPC Foundation Marketing Control Board

The product itself determines the way it should be produced. Ideally this enables flexible production without the need for manual setting up. Elster has successfully implemented this Industrie 4.0 concept in productive assembly lines.

A key factor is the seamless integration between shop floor, MES and ERP based on OPC UA. At each step the product is identified through its unique shopfloor control number (SFC). OPC UA enables the plant control system to be coupled directly with the MES system, so that flexible procedures and individual quality checks can be realized in one-piece flow mode. Without any additional effort, PLC variables are published as OPC tags, and simply mapped to the MES interface. This enables fast and consistent data transfer, even for complex structures. The MES system receives the QM specifications via orders from the ERP and reports the finished products back to the ERP. In future, intelligent products with their own data storage will offer the prospect of exchanging much more than just a shopfloor control number with the plant. It is conceivable to load e.g. work schedules, parameters and quality limits onto the product, in order to enable autonomous and individualized production.

Vertical integration is therefore not a one-way street, but a closed loop. One important aspect in the Industrie 4.0 has already been settled in practice: The communication between product and plant will take place via OPC UA.





Roland Essmann, Elster GmbH

OPC UA for IoT to the cloud and back

»OPC UA is the established, worldwide data modeling standard for Industrial IoT«

Erich Barnstedt, Senior Director & Architect Industrial Solutions, Corporate Standards Group, Microsoft

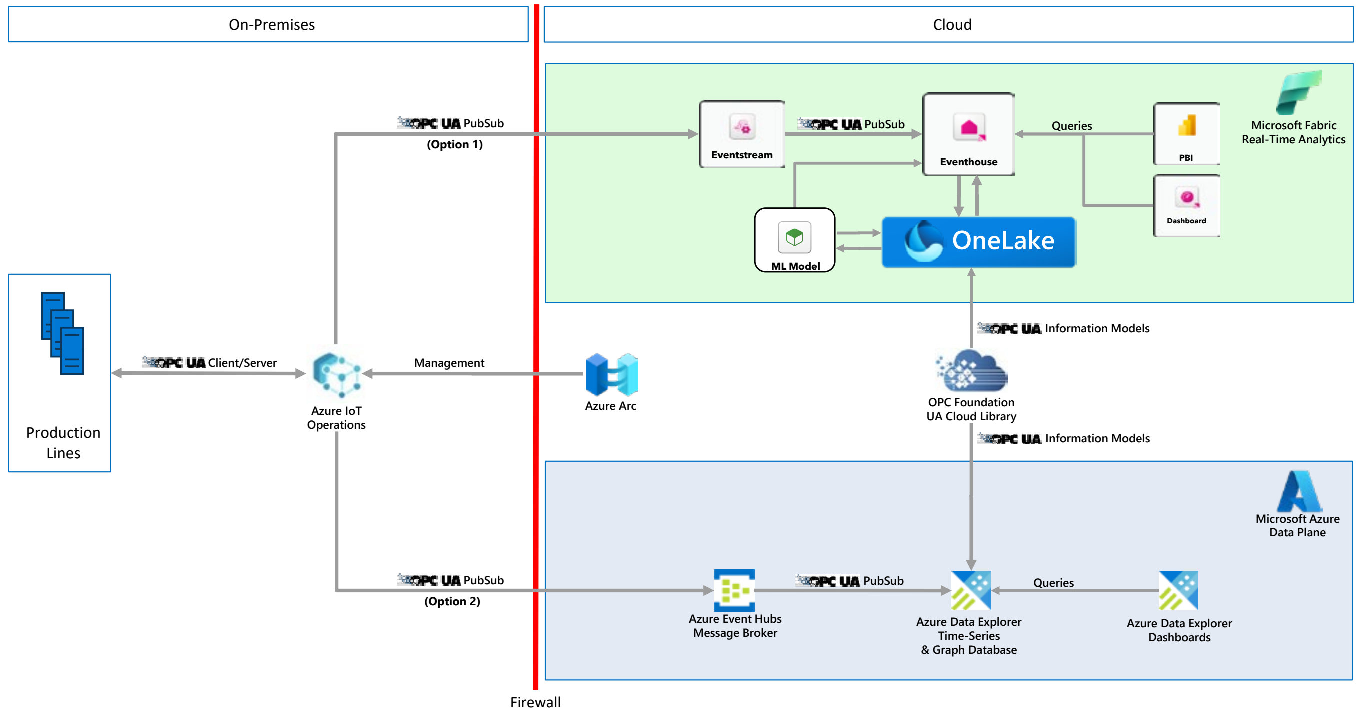
OPC UA is an essential foundation for the convergence of OT and IT, providing the most popular open and standardized data modeling for industrial equipment. From an IT perspective, OPC UA is the programming interface of the connected plant and the connected factory and a critical enabler for Industrial Internet of Things (IIoT) applications.

OPC UA also serves as a gateway technology to securely cloud-enable industrial equipment, enabling data and device management, insights, and machine learning capabilities for equipment that was not designed to have these capabilities built-in. The cloud enables globally available, industry-specific Software as a Service (SaaS) solutions that are cost-prohibitive to stand up for each industrial facility on its own.

As OPC UA is communication-protocol-independent, additional mappings to established communication protocol standards needed to be added to the specification for OPC UA PubSub, namely UDP for field level communication and AMQP and MQTT for cloud communication. First adopted by Microsoft in 2015, OPC UA PubSub over MQTT is the most widely used, standardized communication technology for Industrial IoT solutions today.

As customers and partners collaborate to modernize their plants and factories, OPC UA is enabling digital transformation simply and easily. Microsoft's leading support of OPC UA will reduce barriers to IoT adoption and help deliver immediate value.

Azure Industrial IoT Reference Architecture



HEADQUARTERS / USA
OPC Foundation
16101 N. 82nd Street
Suite 3B
Scottsdale, AZ 85260-1868
Phone: (1) 480 483-6644
office@opcfoundation.org

OPC FOUNDATION EUROPE
Huelshorstweg 30
33415 Verl
Germany
opceurope@opcfoundation.org

OPC FOUNDATION CHINA
B-8, Zizhuyuan Road 116,
Jiahao International Center,
Haidian District,
Beijing, P.R.China
opcchina@opcfoundation.org

OPC FOUNDATION JAPAN
c/o Microsoft Japan Co., Ltd
2-16-3 Konan Minato-ku,
Tokyo
1080075 Japan
opcjapan@opcfoundation.org

FRANCE
opcfrance@opcfoundation.org

INDIA
opcindia@opcfoundation.org

ASEAN
opcasean@opcfoundation.org

KOREA
opckorea@opcfoundation.org

V20

www.opcfoundation.org