The Industrial Interoperability Standard

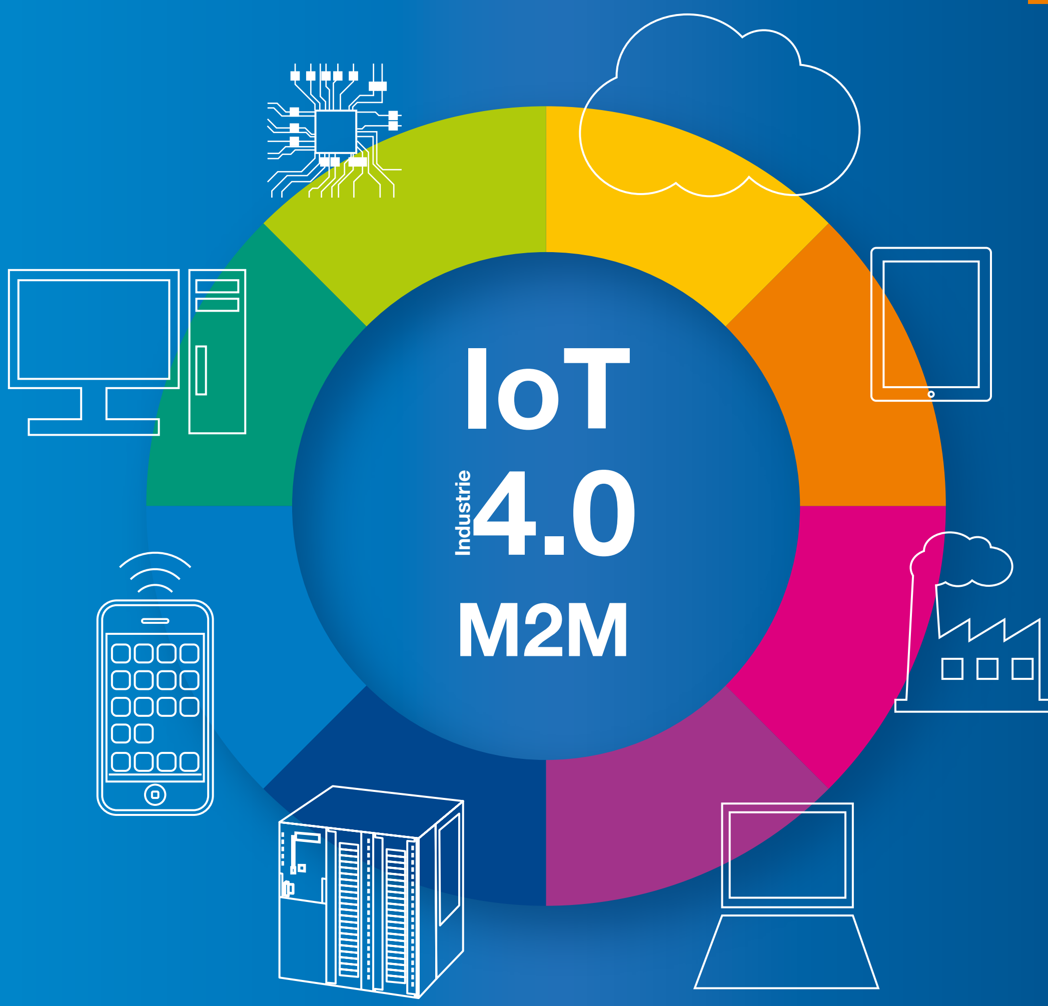
OPC Unified Architecture

Interoperability for Industrie 4.0 and the Internet of Things

Version V15 // 2023

UPDATE

General revision
New: Cloud Initiative
New: Success stories



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 standards 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
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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.

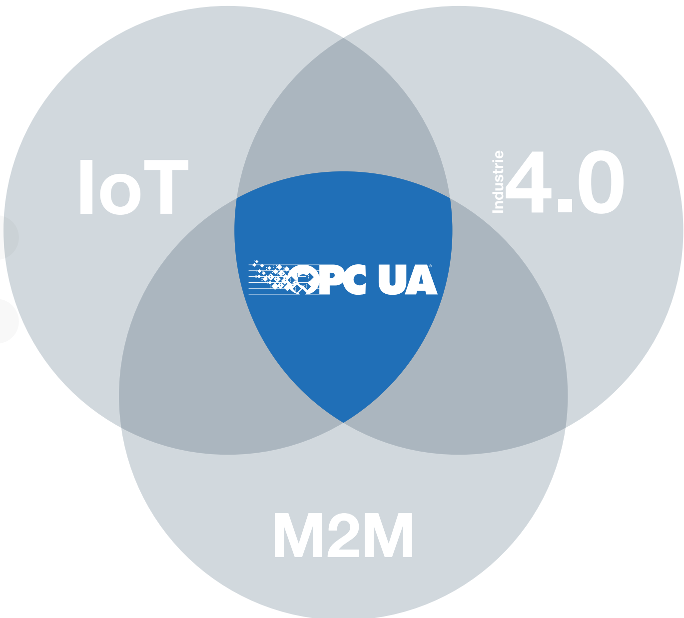
OPC UA FOR VERSATILE INTEROPERABILITY

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.

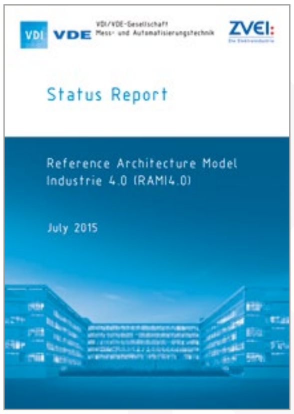
Beyond simple 'data' sharing, a core IoT era standard must facilitate rich information exchange, which requires it to support a semantic metadata model that describes the data, and its purpose, to help best use the data directly. This is especially important when large amounts of data are pooled (aggregated) 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.

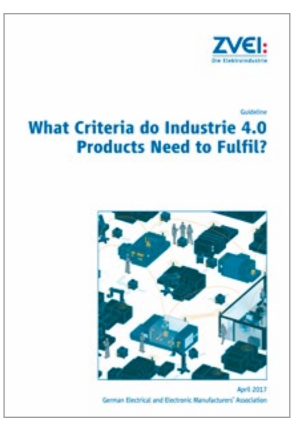
VISION

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

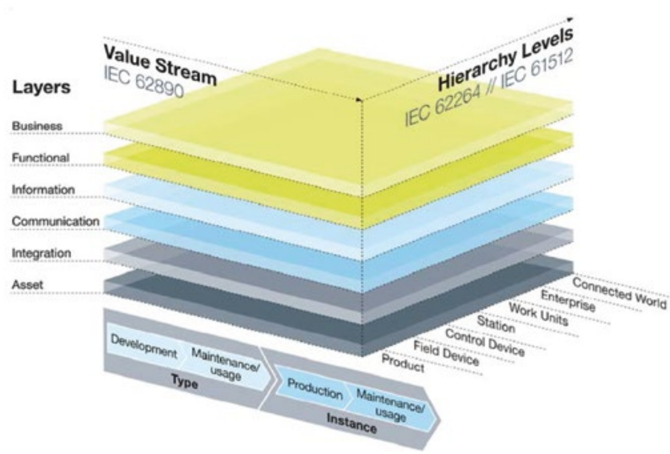


Source: www.zvei.org, April 2017

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



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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.

UNITED STATES' NATIONAL INSTITUTE ON SMART MANUFACTURING

By enabling frictionless movement of information – raw and contextualized data – between real-time operations and the people and systems that create value in and across manufacturing organizations, CESMII is ensuring the power of information and innovation is at the fingertips of everyone who touches manufacturing.

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.

CESMII IS LEVERAGING OPC UA

In an effort to identify common data in machines and processes to accelerate innovation in data science and application development, CESMII is leveraging OPC UA as an industry standard interface. Through the development of an OPC UA Companion Specification, CESMII members identify and articulate important data elements for both new and brown field manufacturing systems.

COMPANION PROFILES ACCELERATE INNOVATION

Once exposed, these "Smart Manufacturing Profiles" become a reliable interface for developers, so they can focus on creating new information value – rather than starting from scratch with individual data extraction. These companion data profiles will remain an open standard the entire industry can benefit from and accelerate innovation, research and development projects supported through the Institute.

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

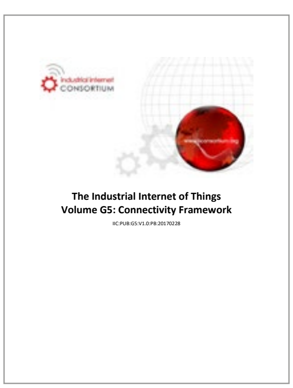
Digital Twin Consortium drives the awareness, adoption, interoperability, and development of digital twin technology. Through a collaborative partnership with industry, academia, and government expertise, the Consortium is dedicated to the overall development of digital twins. We accelerate the market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

DTC IS LEVERAGING OPC UA

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

IIC Testbeds Using OPC UA

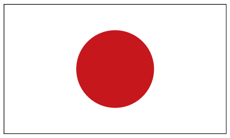

The Industrial Internet of Things
Volume G5: Connectivity Framework

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, OPC 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.

China: Made in China 2025

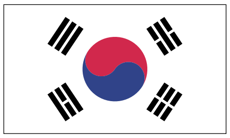
OPC UA parts 1–12 are Chinese National Standard

»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.«

Wael William Diab, Senior Director, Huawei Technologies Co., Ltd.

»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 announced the vision of “Manufacturing Renaissance: Made in Korea” in June 2019 to make the world’s four major manufacturing powers leap through manufacturing revival. To achieve the Manufacturing Renaissance Vision, Korea aims to accelerate innovation in industrial infrastructure through digitalization, eco-friendliness, and an ovarll convergence of the manufacturing industry. Korea plans to spread smart factory technologies to SME companies in cooperation with domestic and foreign solution companies. OPC UA technology will be used as a key industrial standard for connecting OT (Operational Technology) and IT (Information Technology) in smart factories.

»OPC UA is responsible for ensuring interoperability between manufacturing processes/equipment in an Industrial Internet of Things (IIoT) environment. KETI has organized a Smart Manufacturing Innovation Center since 2014 and is devoted to developing various IIoT standard communication technologies and interoperability technologies including OPC UA, TSN, 5G. KETI is also contributing to OPC UA open source(open62541), and is developing a standard IIoT framework to support automatic recognition and connection between various Factory-Things through OPC UA.«

Byunghun Song, Head of Smart Manufacturing Research Center, KETI

Korea: Manufacturing Industry Innovation 3.0

»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

»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.«

Dr. Holger Kenn, Director AI and MR Business Strategy, Microsoft, OPC board member

»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.«

Charlie Sheridan, Global Technical Director, Manufacturing, Energy and Automotive, Google Cloud

»Our goal at Cisco is to drive data into actionable information. With OPC UA we are able to securely and easily access data and move it across the decision making value chain, with our customers and partners.«

Bryan Tantzen, General Manager, Cisco Industries Product Group (IPG) Connected Industry and Manufacturing BU

»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, President Honeywell Process Solution

»Manufacturing in the digital world requires a highly connected and intelligent approach to provide high responsiveness to individualized customer demands, to enable flexible manufacturing processes and to fully empower production workers. In order to achieve this SAP is using and supporting standards like OPC UA to ensure simple, scalable and safe information exchange with the shop floor.«

Claudius Link, SVP DSC Digital Manufacturing, SAP SE, OPC board member

Global Players

»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, OPC board member

»One of the principal ideas of the Industrial Internet of Things (IIoT) is to connect industrial systems that communicate data analytics and actions to improve performance and efficiency. The implementation of IIoT will require a paradigm change in the way organizations design and expand industrial systems. Therefore, the integration with existing or third-party automation devices through standard, secure communication protocols is paramount. OPC UA stands up to this challenge by providing a widely adopted and secure industry standard for interoperability between dissimilar processing elements and IT devices on the factory floor. NI has adopted OPC UA in its portfolio of embedded devices to help drive the interconnectivity of Cyber Physical Systems (CPS) in the evolutionary process of IIoT.«

James Smith, Director for Embedded Systems Product Marketing, National Instruments

»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.«

Dr. Bernhard Eschermann, CTO of ABB Process Automation, OPC board member

OPC UA in the industry

»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, OPC board member

»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

»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 has the potential for an immediate cross-vendor implementation of Industrie 4.0 and the necessary internet based services.
The adoption of this open standard is an opportunity for vendors and users. Proprietary solutions will not generate an adequate value.«

Dr.-Ing. Reinhold Achatz, Head of Corporate Function Technology, Innovation & Sustainability, ThyssenKrupp AG

Pioneers in automation

»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.«

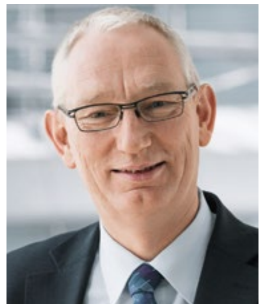
Hans Beckhoff, Managing Director, Beckhoff Automation GmbH

»Siemens 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, OPC board member

»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, OPC Board Member



»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

Global Players in the industry

»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

WELL SELL

WE THINK WHAT YOU THINK
YOU KNOW WHAT WE KNOW

»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

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

Cooperations with organizations

»OPC UA is the only interoperability solution that is widely adopted and fulfilling the requirements of the mechanical engineering industry. Therefor 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 – OPC board member

VDMA

<AutomationML/>
The Glue for Seamless Automation Engineering

»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

aim
Advancing Identification Matters

»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

»BACnet and OPC UA are already cooperating in the exploration of new opportunities for integration between industrial and building automation: Building Automation data are semantically defined through BACnet and can conveniently and interoperably be made available to enterprise systems via OPC UA: An ideal standardization from sensor right up to IT billing systems.«

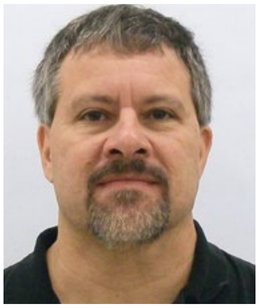
Frank Schubert, member of the BACnet Interest Group Europe advisory board

»In an era where data interoperability and monitoring are critical to improving operations and production uptime, FDT Group and OPC Foundation have collaborated to simplify intelligent device configuration and lifecycle management with the OPC UA for FDT Universal Device Information Model and FDT Server (also an OPC UA Server) solution - available today! Like OPC UA, FDT UE is an open and agnostic standard, enabling software-based industrial device management with any authenticated OT or IT system for all industrial (process, hybrid, and discrete) markets. The latest release of the FDT 3.0 specification enables this Unified Environment, supporting a single user interface for device integration, configuration, and monitoring, independent of the topology of protocols/networks and devices/vendors.«

Steve Biegacki – FDT Managing Director

»As process automation field devices as system have increased in complexity, device integration with automation systems has become cumbersome. FieldComm Group and OPC Foundation worked together to create the FDI specification and information model for Field Devices based on the OPC UA specification, Future systems and field devices that conform to the FDI standard will be dramatically simpler to configure, integrate, and maintain.«

Ted Masters, President and CEO – FieldComm Group



»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 standardize 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

Science & Research

»The paradigm of Industrie 4.0 requires standards on various levels, to enable an organization of modular plug&play capable production lines. OPC UA is an important standard, helping us to establish communications between plant components in a vendor independent and secure fashion. Because of the industry driven standardization process, we're seeing a high acceptance among industrial users of OPC UA as a platform across all levels of the automation pyramid. Furthermore, OPC UA's information models represents a basis for the realization of a semantic interoperability.«

Prof. Dr. Dr. Detlef Zühlke, Scientific Director – retired

How OPC began

Thomas J. Burke
President 2000 – 2018

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 NEW 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.

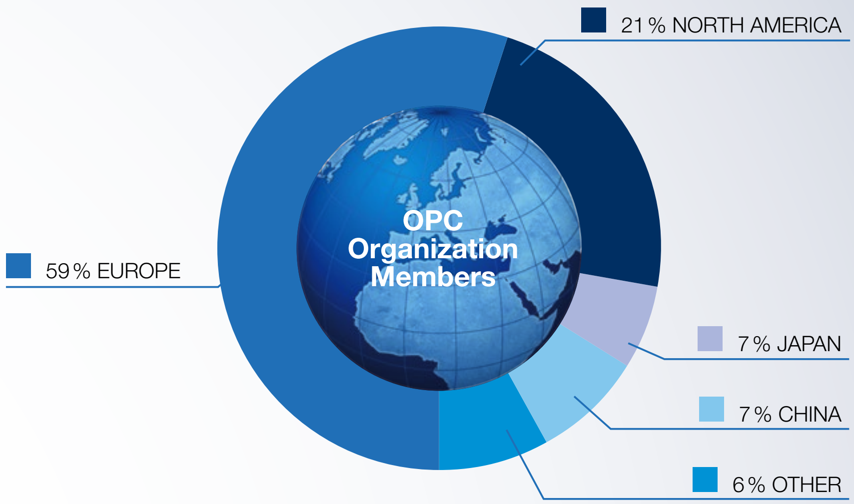
To better facilitate global adoption, the OPC UA was designed to become an IEC specification. Work on making the OPC UA standard compliant with IEC rules and templates commenced in 2010 and was completed in 2012. As a result, the OPC UA standard is now a full-fledged IEC standard known as IEC62541. In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

CERTIFICATION & PRODUCT QUALITY

Since the early days OPC Foundation is dedicated to maximize product quality. OPC Classic certification was first started as a self-testing activity via the OPC Foundation supplied certification tool. With the advent of OPC UA technology and its broader scope and complexity – the OPC Foundation determined it was necessary to formalize OPC product certification to help ensure OPC product implementation quality in the marketplace. The first OPC Foundation certification lab was opened at Ascolab in Erlangen, Germany. Over the years, labs in US, Germany and China were also opened.

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

OPC Foundation – organization



With more than 950 members, the OPC Foundation is the world's leading organization for interoperability solutions based on the OPC specifications.

All members, including corporate members, end users and non-voting members, are committed to integrated, compatible communication between software-driven devices, including cyber physical systems (CPS), in industrial automation environments.

The OPC Foundation offers a marketing program including a newsletter, website and various training and information events aimed at manufacturers of automation solutions and providers of OPC technology. The OPC Foundation together with its member companies offers events and training programs for end users of the OPC technology to help market the technology to users in potentially new markets. The cooperation of developers and users in working groups is crucial to ensure that practical requirements and user feedback are taken into account in the specifications. The OPC Foundation encourages end users to join working groups to help ensure that the practical requirements and feedback are factored into the specification development process, especially for information model companion specifications.

INDEPENDENCE

The OPC Foundation is a non-profit organization that is independent of individual manufacturers or special technologies. Members of the working groups come from member companies on a voluntary basis. The organization is financed entirely from membership fees and receives no government grants. The organization operates worldwide and has regional contacts on all continents. All members have identical voting rights, irrespective of their size.

MEMBER DISTRIBUTION

Although the head office is in Phoenix, Arizona, most members (above 55 %) are based in Europe. Around one third of the members are based in North America. All main manufacturers of automation technology are members of the OPC Foundation and already offer OPC technologies in their products.

MEMBERSHIP BENEFITS

Members of the OPC Foundation have full access to the latest OPC specifications and preliminary versions. They can take part in all working groups and contribute requirements and solution proposals.

Members have free access to core implementations and sample code. In addition, script-based test and analysis tools are provided.

Manufacturers of OPC-capable products can have these certified in accredited test laboratories. The developer and user community meets at events to exchange information and to network. Multiple times each year, at various locations around the world, a week-long interoperability workshop (IOP) is held, at which the latest products and their interaction are tested.

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 architecture 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 3-4 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. Membership includes OPC UA stack developers to assure that any issues are handled in a timely manner.
- **PubSub Prototyping Sub-Group** strives to assess and improve the specified PubSub model with prototype implementations. This includes jump-start meetings with interoperability tests.
- **TSN Sub-Group** does the groundwork for PubSub over TSN so that TSN streams can be configured for deterministic controller to controller communication move semantic validation group as sub-group of UA.
- **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 Compliance 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.

→ 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.

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.

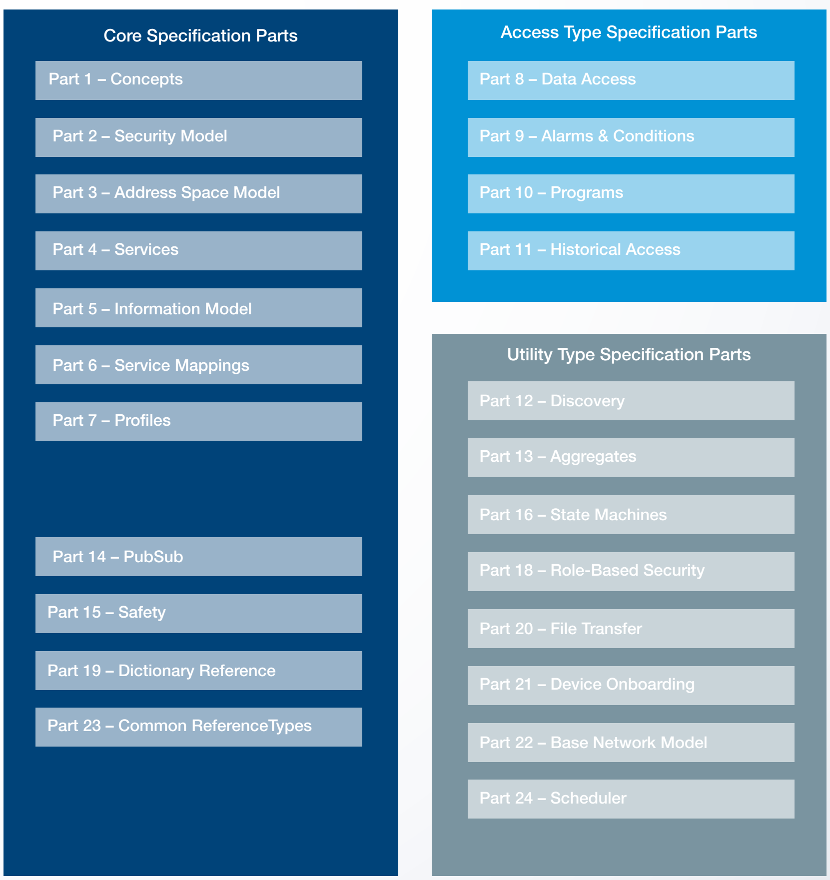
OPC UA SPECIFICATIONS AND IEC 62541

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 Publisher-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 of 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

SECURE, RELIABLE INTEROPERABILITY

OPC UA is the latest generation of OPC technology from the OPC Foundation. OPC UA rewrites the original OPC standard from the ground up and extends its relevance by addressing a broad range of modern communication requirements. As such, OPC UA delivers a secure, reliable transport of data and information from sensors and the shop floor to control systems, production planning systems, and beyond.

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.

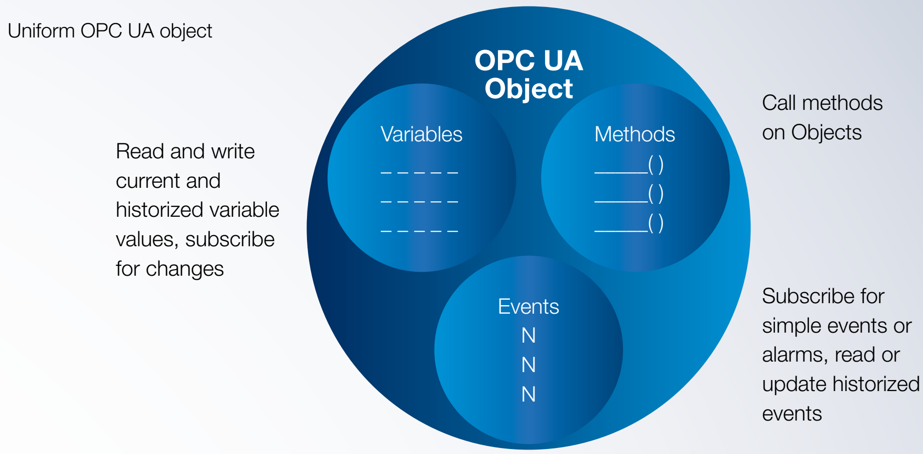
ROBUST INFORMATION MODELING

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 wobject 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.



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

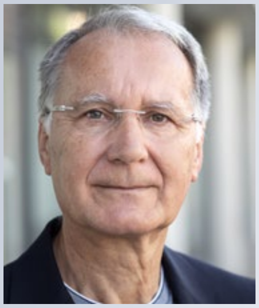
OPC UA defines a robust architecture with reliable communication mechanisms, configurable timeouts and automatic error detection that restores communications between OPC UA Clients and Servers without data loss. In addition, OPC UA redundancy functions for both client and server applications make OPC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

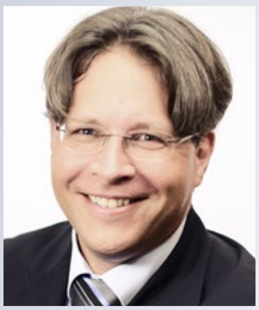
SIMPLIFICATION BY UNIFICATION

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 70 such groups from various industries, including: discrete and process automation, energy, engineering tool manufacturers, industrial kitchen equipment, and many more.





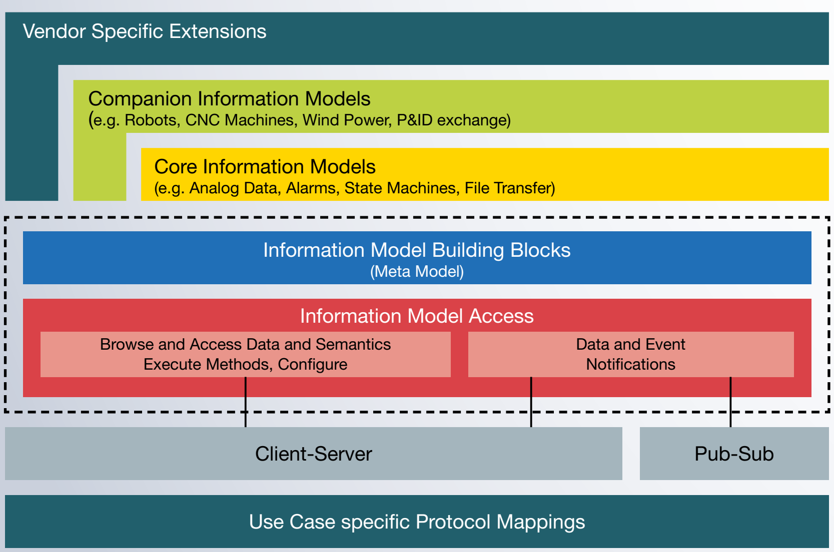
OPC UA technology in detail

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:

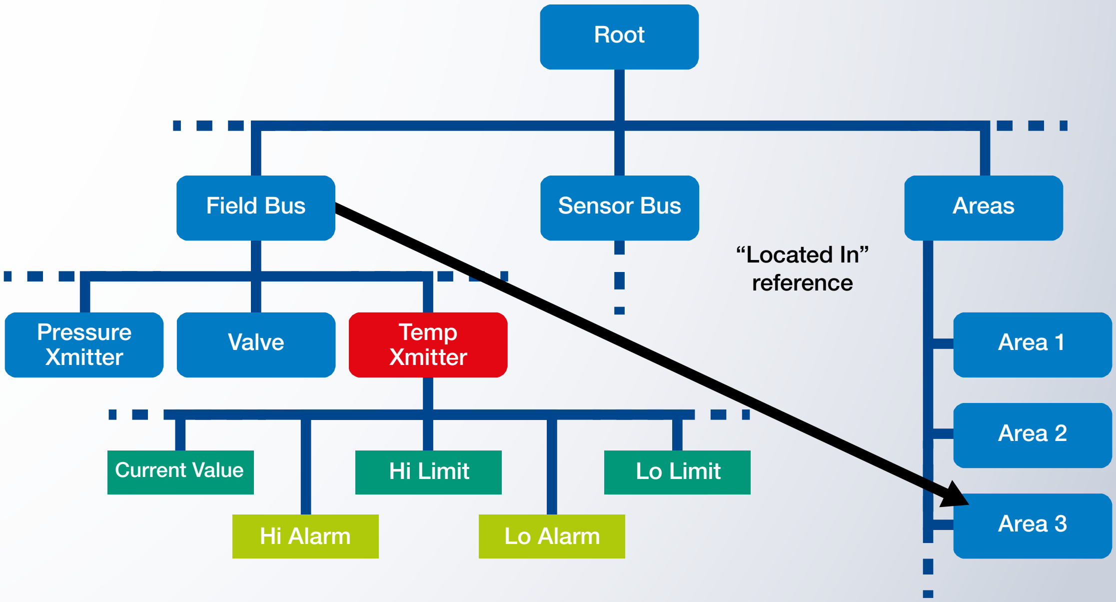
- → **Information Model (Meta model) –** specifies the rules and basic components for publishing an information model via OPC UA. It also includes various basic nodes and basic types.
- → **Information Model Access –** specifies the mechanisms to access information models via OPC UA.
- → **Client-Server –** 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

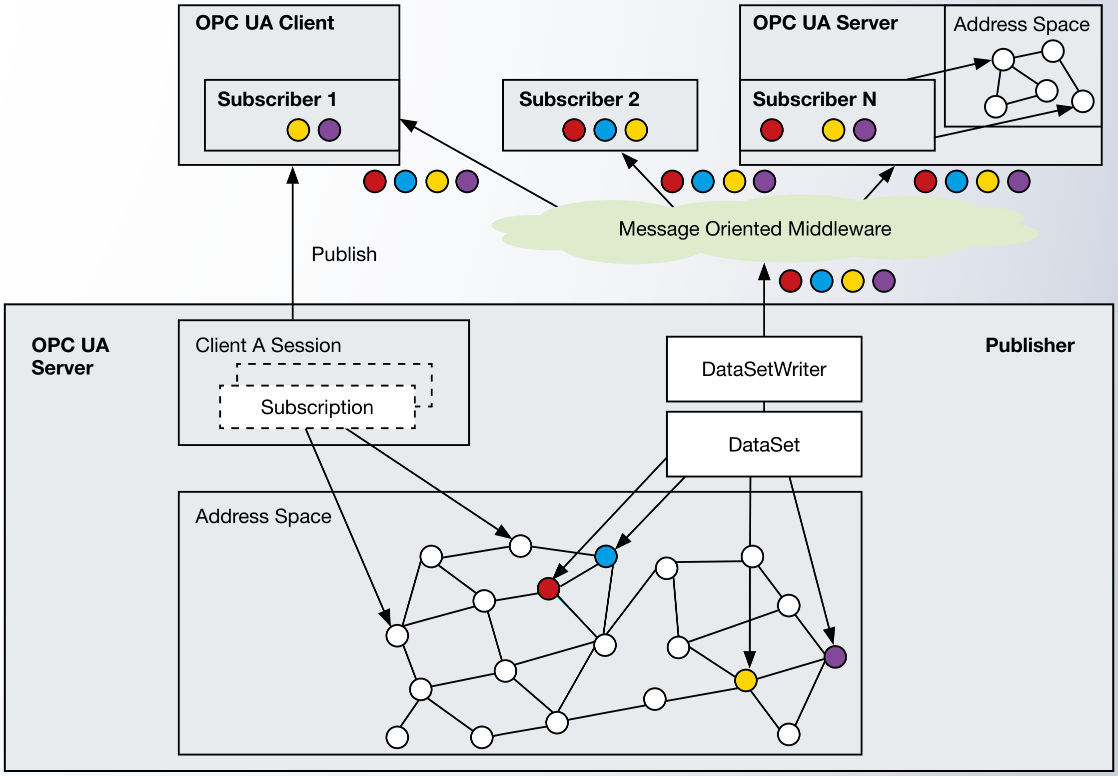
The following figure provides an overview of Publisher and Subscriber and illustrates the flow of data and event notifications as messages from a Publisher to one or more Subscribers.

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.

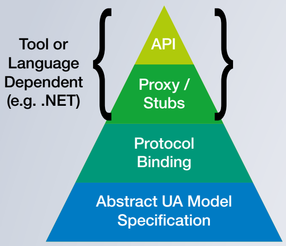
Publishers and Subscribers are loosely coupled. They often will not even know each other. Their primary relation is the shared understanding of specific types of notification data or events (represented by DataSets), the publish characteristics of messages that include these data, and the Message Oriented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

A "program" represents a complex task, such as operation and handling of batch processes. Each program is represented by a state machine. State transitions trigger messages to the client.

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.

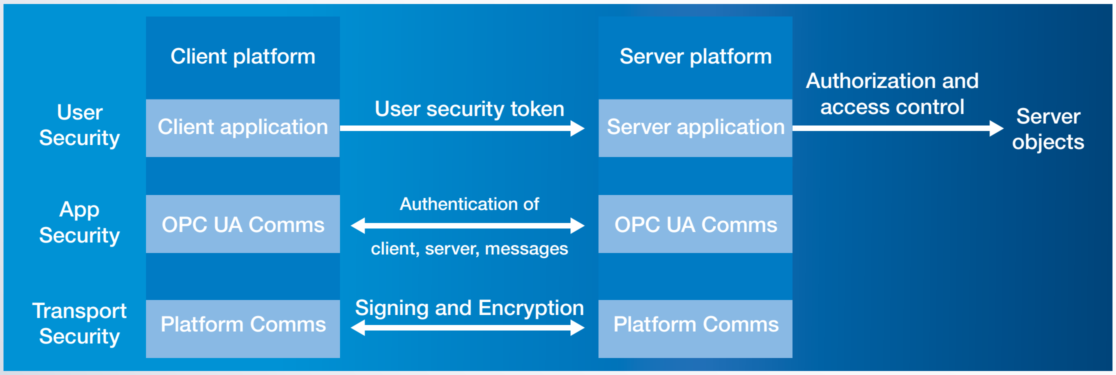
→ **3. OPC UA Transport level security** can be used to provide integrity via message signing and confidentiality via message encryption. This prevents message tampering and eavesdropping respectively. The OPC UA security mechanisms are realized as part of the OPC UA stacks, i.e. they are included in 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.

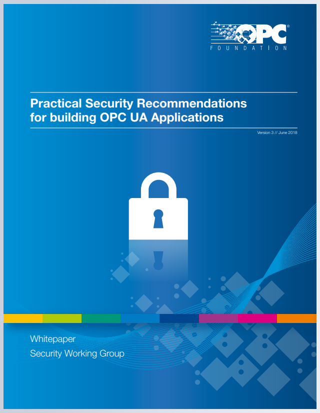
USER AUTHENTICATION

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
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Emerson
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Huawei
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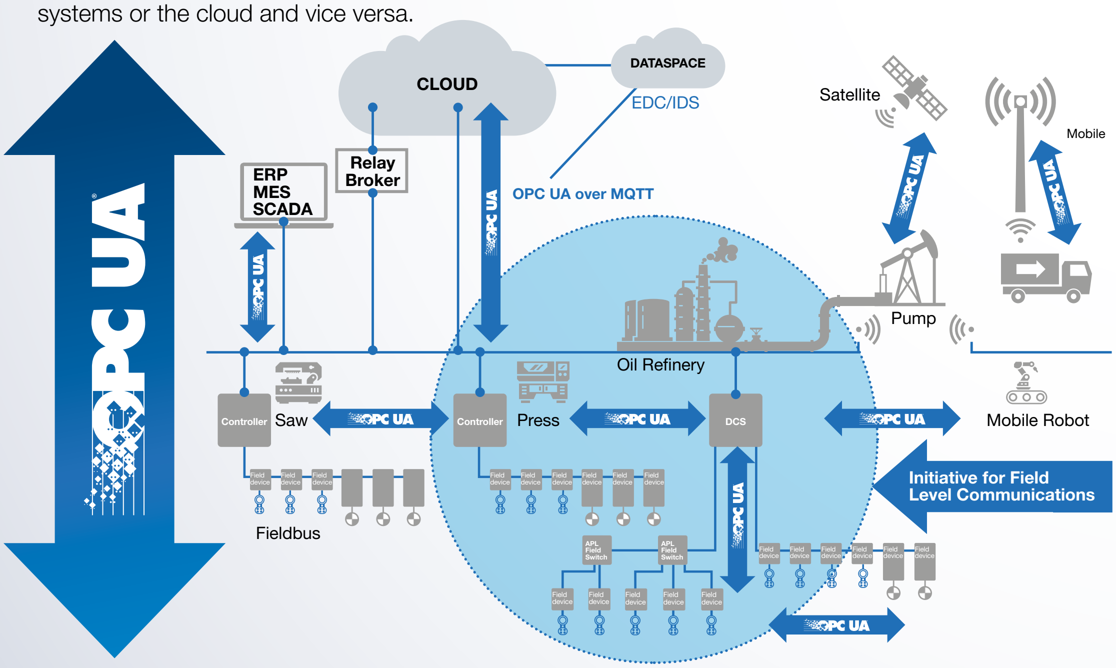
Omron
Phoenix Contact
Pilz
Rockwell Automation
Schneider Electric
Siemens
Wago
Yokogawa



OPC UA: Enabling secured, semantic industrial interoperability scaling from field to cloud

Scope of the Field Level Communications (FLC) Initiative

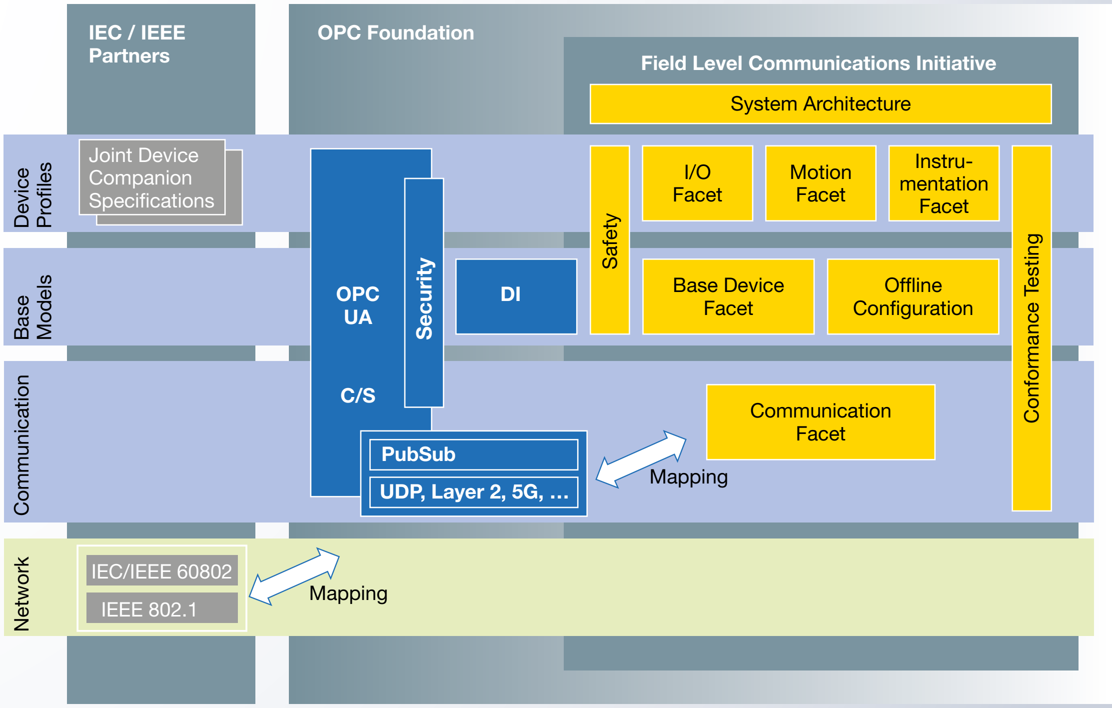
SOLUTION APPROACH

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

OPC UA:
The IEC standard for multi-vendor cloud solutions
Field to Cloud – Cloud to Cloud – Cloud to Field

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.

CLOUD-RELATED ACTIVITIES WITHIN THE OPC FOUNDATION:

→ 1. UA Cloud Library

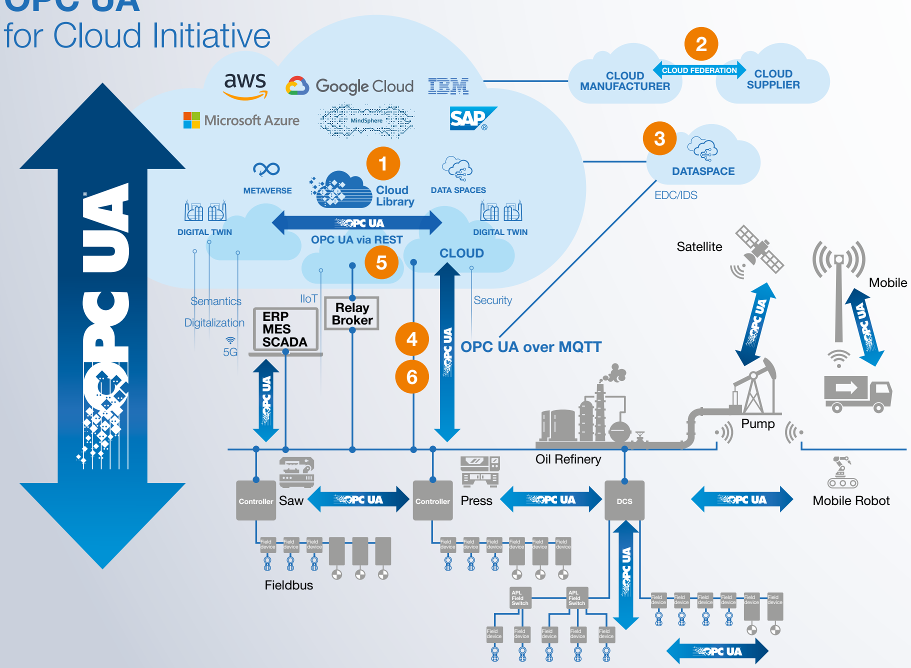
Through a joint working group with CESMII, USA, the UA Cloud Library is specified and developed.

The UA Cloud Library makes it easier than ever to find, share, explore and use OPC UA information models by cloud and on-premises applications, end users and standardization bodies. Today, the UA Cloud Library contains over 121 OPC UA information models, created by both individual companies and international standards organizations, making the UA Cloud Library the world's largest library of standardized information models for the automation industry. Access to the UA Cloud Library is free of charge and is available at uacloudlibrary.opcfoundation.org.

→ 2. Cloud to Cloud: UA Cloud Federation

Together with DIN and major cloud solution providers, the joint working group UA Cloud Federation is developing a specification for cloud-to-cloud communication leveraging OPC UA technology.

OPC UA
for Cloud Initiative



OPC UA: Enabling secured, semantic industrial interoperability scaling from field to cloud

1. **Cloud Library**
   - Repository for OPC UA based information models (IMs)
   - Upload, store, search, download IMs
2. **Cloud Federation**
   Standardized communication
   - Cloud to Cloud
3. **DataSpace Connectors**
   - OPC UA over MQTT guarantee access to standardized information
4. **Asset/Edge/Cloud**
   Standardized communication
   - Field to Cloud
   - Cloud to Field
5. **REST Interface**
   - Easy access to standardized information
   - Allows Filetransfer
6. **Plugfest**
   - Free permanent Plugfest
7. **Education IIOT Starter Kit**
   - Success stories

7

OPC UA
IIOT STARTER KIT
AVAILABLE

→ 3. DataSpace with Connectors

DataSpaces are an abstraction in data management that aims to solve problems encountered in data integration systems. The EDC/IDS connectors supports OPC UA over MQTT to easily use available OPC UA information in DataSpaces.

→ 4. OPC UA Achieves Critical Momentum in Field to Cloud Communication

In 2022, major cloud suppliers Amazon, Google, IBM, Microsoft, Siemens and SAP committed to support OPC UA (PubSub over MQTT) as the standardized field to cloud communication within their products.

→ 5. OPC UA via REST

OPC UA is already equipped with session-less services which allows to provide standardized information and Filetransport via RESTful interfaces. With the addition of HTTP REST, applications outside of the OPC UA ecosystem like Digital Twins, DataSpaces and the Metaverse can now access this information in a standardized way.

→ 6. Plugfest

The OPC Foundation is offering a free, permanent Plugfest for their members to enable faster adaption of OPC UA PubSub over MQTT and to ensure interoperability of products developed by OPC Foundation members with built-in OPC UA support. The UA Cloud Dashboard, a simple example implementation of an OPC UA PubSub subscriber, is available open-source to get a first feeling for the usage in cloud applications. The UA Cloud Dashboard can be downloaded from github.com/barnstee/UA-CloudDashboard.

→ 7. UA Industrial IoT Starter Kit

The UA Industrial IoT Starter Kit, released in 2021, is available free of charge to OPC Foundation members and allows to ramp up quickly and easily with OPC UA PubSub over MQTT. The kit can be downloaded from github.com/OPCFoundation/UA-IIoT-StarterKit.

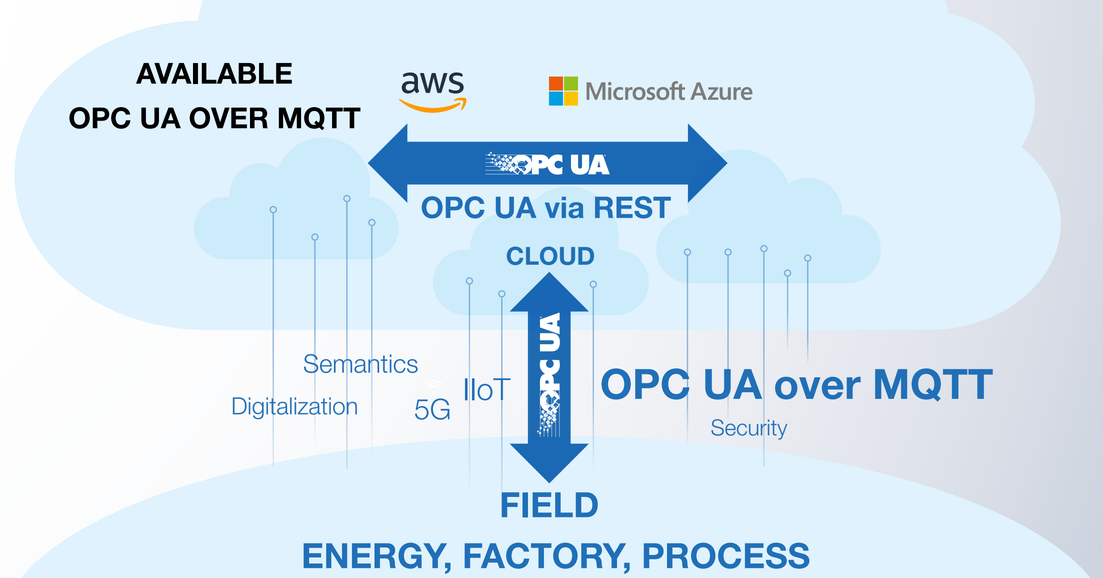
Announced to support "OPC UA over MQTT"

Google Cloud

IBM

MindSphere

SAP



Interoperability for cloud connectivity:
Status 2023-Nov: 53+ major automation companies support "OPC UA over MQTT" integrated into their devices for directly communication from the device to the cloud.

Source code and certification

SOURCE CODE AND TEST TOOLS

To ensure compatibility, the OPC Foundation offers sample implementation of the communication protocols, plus a certification program, including the tools required for verifying and testing the conformity of applications with the specification.

→ **1. OPC UA stack.**

Communication stacks have been developed in three programming languages: ANSI C for scalable implementation on virtually all devices, in managed C# for application with the .Net Framework from Microsoft, plus an implementation in Java for applications in corresponding interpreter environment. Communication stacks ensure the basic communication in the network. As there are several open source and commercial implementations available, only the C# stack is maintained by the OPC Foundation.

→ **2 . Example Code.**

The OPC Foundation also provides sample applications. The samples are provided in source code (mainly C#) and can be used for evaluation of the OPC UA technology and for proof-of- concept coding, for rapid implementation of prototypes and demonstrators. For integration of OPC UA technology in professional and industrial hardened products, the OPC Foundation recommends the use of commercial Toolkits and Software Development Kits (SDK) which, are offered by various OPC member companies.

→ **3 . Certification program.**

For testing and certification of compliant behavior, the OPC Foundation offers a software called Compliance Compliance Test Tool (CTT). The CTT can be used to verify the compliant behavior of an OPC UA application. In addition, the OPC Foundation offers a certification program that provides independent certification laboratories where manufacturers can have their OPC UA products certified. Certification extends the testing of the CTT and includes Interoperability testing, stress testing, usability testing, and performance testing in environments the product will be typically used in.

→ **4 . Interoperability workshops.**

The OPC Foundation holds at least three week-long 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 OPC Japan organization usually holds an IOP in the Summer. These events include OPC Foundation support and are a great precursor to vendors’ product certifications.

Laboratory – Certification

The OPC Certification Program's primary goal is to set the bar for the quality of OPC UA products released into the market with respect to their implementation of the OPC standards.

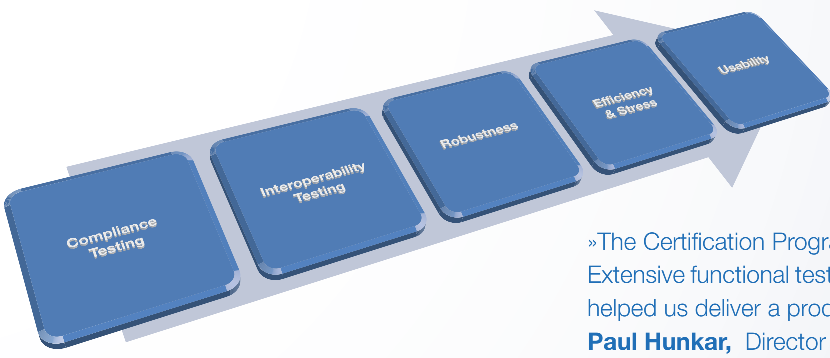
As a best practice, End-users and integrators should demand vendors certify their OPC products for the end-users' maximum safety and infrastructure reliability. Certification is best verified by an accredited 3rd party test lab. Products that passed testing by independent certification laboratories are recognizable by the "Certified" logo.

All recognized 3rd party OPC test labs must be accredited by the OPC Foundation and follow the defined test process and test scenarios to guarantee that the product complies with the following:

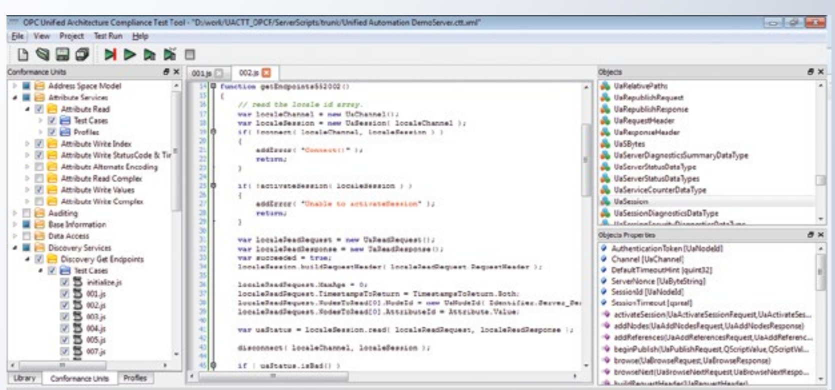
→ **Compliance** to the OPC Specifications
→ **Interoperability** with other vendors' products
→ **Robustness** and recovery from error conditions
→ **Efficiency** of product under load
→ **Usability** ensures a good user-experience

TEST TOOLS AND QA

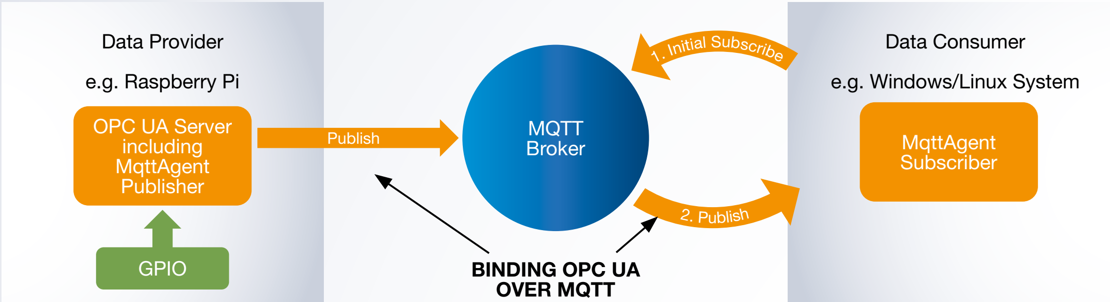
The OPC Foundation provides a series of test tools to verify functionality of all of the OPC Foundation defined interfaces. These test tools include not just base OPC specification testing they also support companion specification defined information model testing and are available to all OPC Members. 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 enormous 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. Additionally it can be extended with vendor specific/product specific test cases. The CTT is a test platform which can be easily integrated into a company's automated system and regression test environment.



»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



IIoT Starter Kit / OPC UA over MQTT Simplified cloud connectivity example



The IIoT Starter Kit is an open-sources example to demonstrate the cloud connectivity by using OPC UA over MQTT. This project uses a simple architecture which is consisting of a Data Provider, a MQTT Broker and a Data Consumer.

→ Data Provider (OPC UA Server and Publisher)

For demonstration and educational purposes, the data provider can be hosted on a Raspberry Pi and utilizing its GPIO interface to create real data. If a GPIO is not available, the data will automatically be simulated.

→ MQTT Broker

OPC UA has no requirement on the used broker, any MQTT broker can be utilized. This example utilizes an open-source project called mosquito.

→ Data Consumer

The Data Consumer is expected to be run on a development platform and is also part of this project. It uses the received messages to demonstrate a set of use-cases by printing the information in the command prompt.

COVERED USE CASES

→ Identification

- Automatic discovery of the publishers
- Including typical nameplate information

Detected Publisher (opcua/mydevice:one/identity).
Manufacturer: Arbutus Widgets Inc
ManufacturerUri: https://arbutus-widgets.com/
ProductInstanceUri: urn:mydevice:one:arbutus-widgets.com:iot-starterkit:123456789
Model: Roadrunner Detector
SerialNumber: 123456789
HardwareRevision: Model B Rev 1.2
SoftwareRevision: 1.00

→ Optimized messages

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

{
“CycleCount”: 100,
“State”: false
}

→ Highly interoperable payload

- Including classification
- Including semantics

OPC UA IIOT STARTER KIT AVAILABLE

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

Integration – Toolkits and Books

CODE AND ADVICE

The OPC Foundation initially developed three OPC UA communication stacks (C, .NET and Java) in order to ensure interoperability at protocol level. Although members have access to the source code of the stacks, it is recommended to use a commercial toolkit in view of the fact that, in addition to the actual communication layer for OPC UA applications, – especially for an OPC UA server – further specific administrative functions have to be implemented.
In particular, commercial toolkits help by abstracting and consolidating generic functions such as connection management, certificate management and security features. Using toolkits e.g. developer frameworks offers vendors advantages for implementation and time to market.

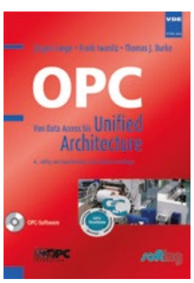
EXPERT KNOWLEDGE

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 at attractive prices as binary "black box" components or including complete source code. In addition to the source code for the OPC UA stacks of the OPC Foundation, commercial toolkits offer simplifications and convenience functions. The general OPC UA functionality is encapsulated behind an API. For this reason 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. Further information is available from toolkit manufacturers.



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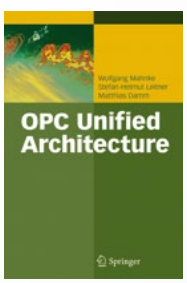

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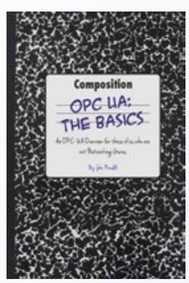
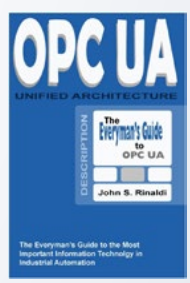


Composition
OPC UA:
The Basics
ISBN: 978-1482375886



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

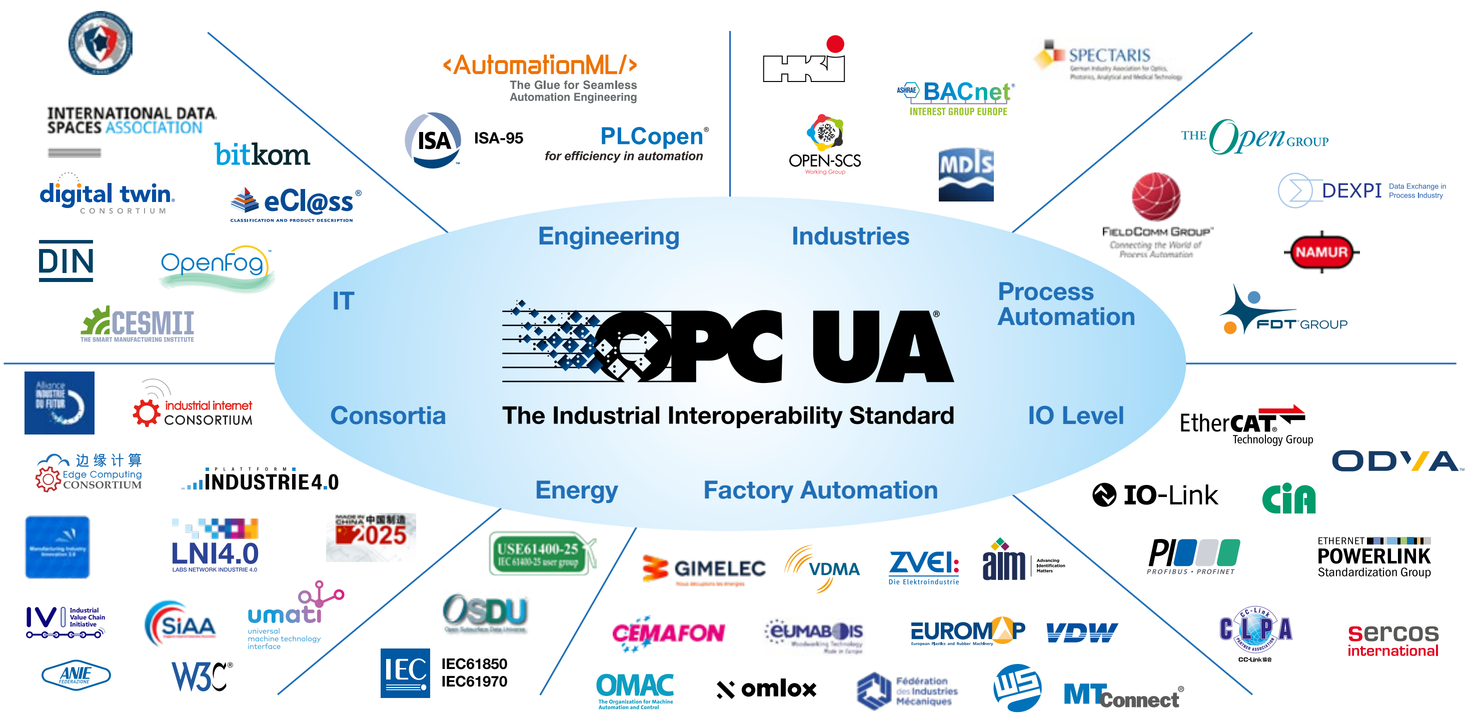
Praxishandbuch
OPC UA:
ISBN: 978-3-8343-3413-8

FURTHER INFORMATION ABOUT TOOLKITS IS AVAILABLE FROM ...

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

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.



COLLABORATIONS

International Joint Collaboration Groups

Domain Specific Information Models

Generic Device Models: Controller, Field Device, Process Device

- OPC 10000-100 – UA for Devices
- OPC 10020 – UA for Analyzer Devices
- 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 30400 – UA for Cloud Library
- OPC 30500 – UA for Laboratory & Analytical Device Standard (LADS)*
- OPC UA for Analytical System Integration (CAISI)*
- OPC UA for Cloud Federation*
- OPC UA for Global Positioning*
- OPC UA for Non-destructive Evaluation
- OPC UA for Power Consumption Management*
- OPC UA for Secure Elements

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)*
- Power Consumption*
- 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

Manufacturing Devices: Robots, Machines, Machine Tools

- OPC 30070-1 – UA for MTConnect, Part 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 40001-100 – UA for Machinery – Result Transfer
- OPC 40010 – UA for Robotics
- OPC 40020 – UA for Cranes & Hoists
- OPC 40083 – UA for Plastics Rubber – General Types
- 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 40084-1….n – UA for Plastics Rubber – Extrusion
- OPC 40100 – UA for Machine Vision
- 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 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 40530 – UA for Laser Systems
- OPC 40550 – UA for Woodworking Machinery
- OPC 40560 – OPC 40569 – UA for Mining
- OPC 40740 – UA for Process Air Extraction and Filtration Systems (PAEFS)*
- OPC UA for Cable Harness Manufacturing
- OPC UA for High Pressure Die Casting*
- OPC UA for Intralogistics Communication*
- OPC UA for Surface Technology*

Enterprise, Asset Mgmt, 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 UA for CIP Devices*

* = in progress

Harmonizing OPC UA based Information Models

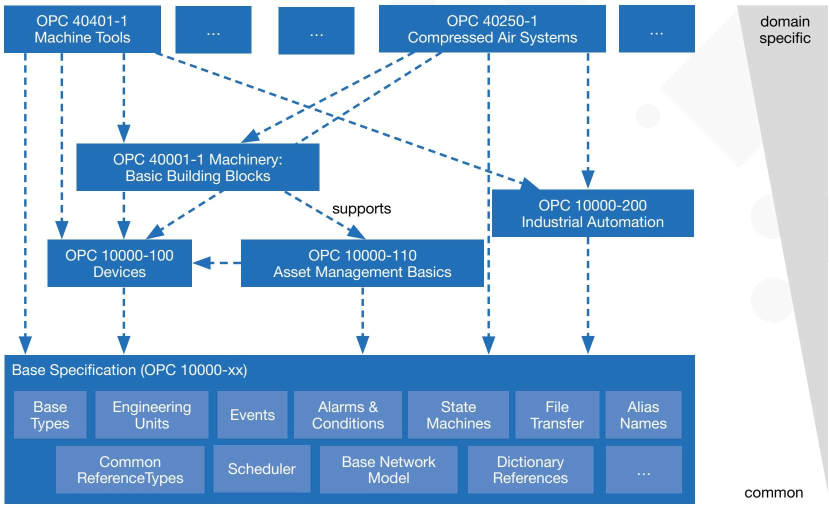
CHALLENGES ARE ADDRESSED

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).



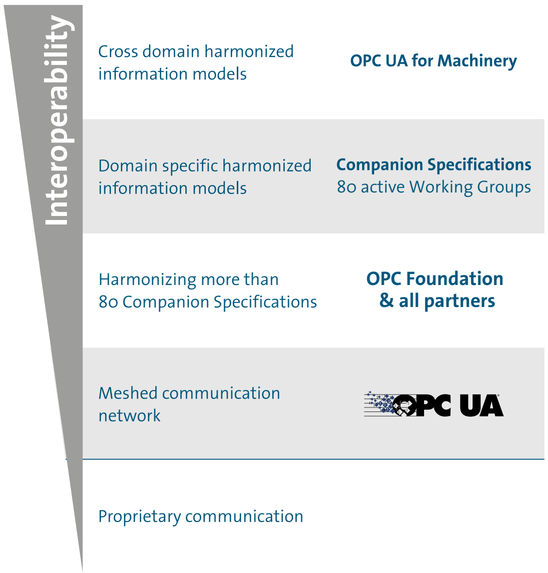
HARMONIZATION WORKING GROUP

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 regular 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 40001-101: 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

- **Job Management,** based on 10031-4: ISA-95-4 Job Control
- **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.

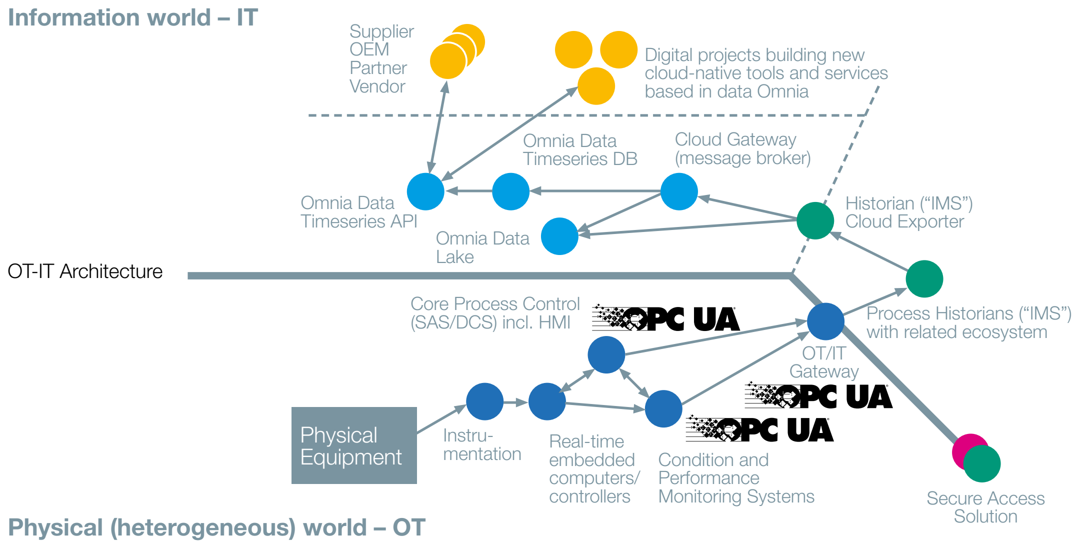
SOME METRICS

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.

View complete version



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.

»OPC UA Enables Digital Transformation at Groupe Renault«

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

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

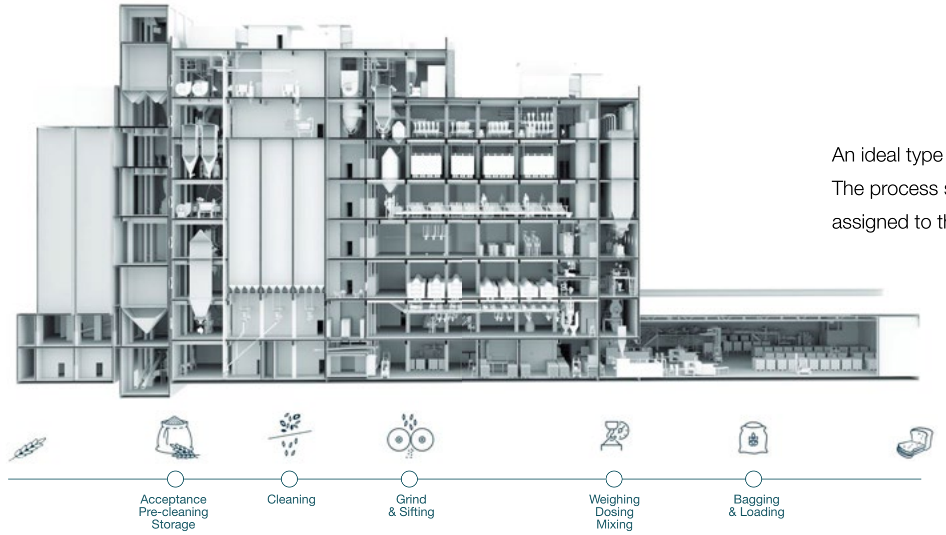
Bühler has developed standardizations based on OPC UA that facilitate the onboarding of new equipment. The "Die Casting" group is currently working on a companion specification.

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," ex-

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.

plains 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.”

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.

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.

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.

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

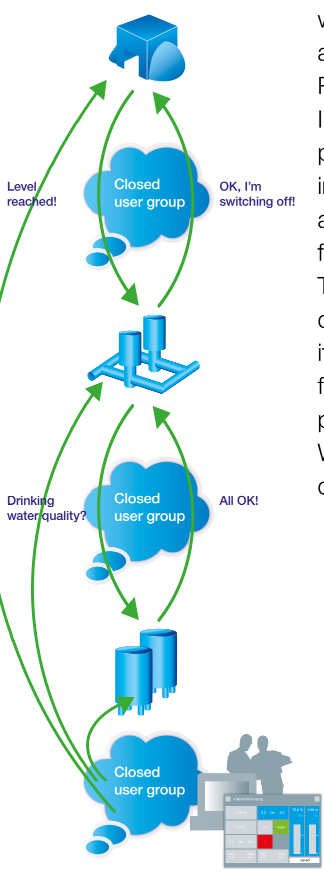
Prediktor supplies a Supervisory Control and Data Acquisition (SCADA) system that is installed locally at the site to provide operators with interfaces to operate the plant. It creates interoperability of diverse equipment.

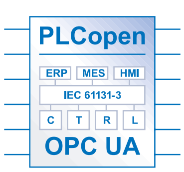
Horizontal: OPC UA enables M2M and IIoT

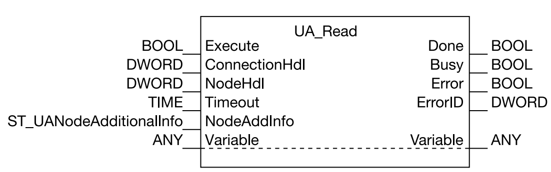
»Intelligent water management – M2M interaction based on OPC UA«

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.

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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

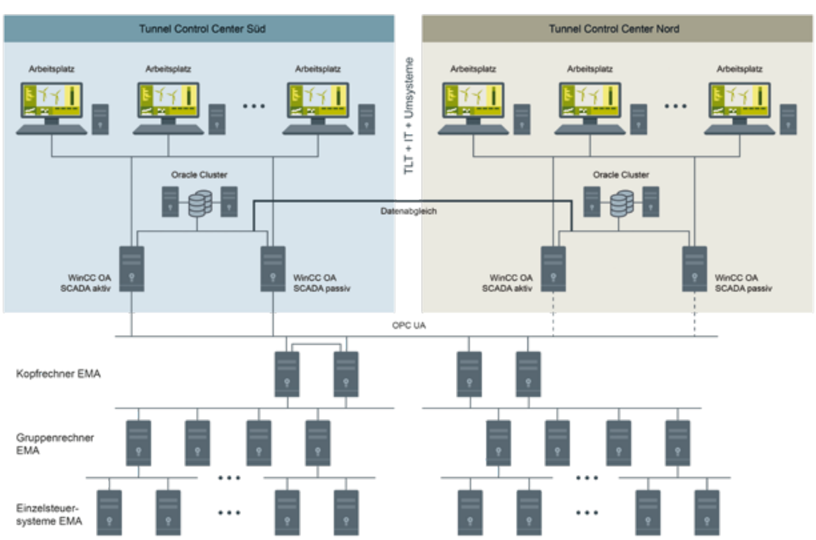
ETM professional control GmbH – A Siemens Company

"... 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.

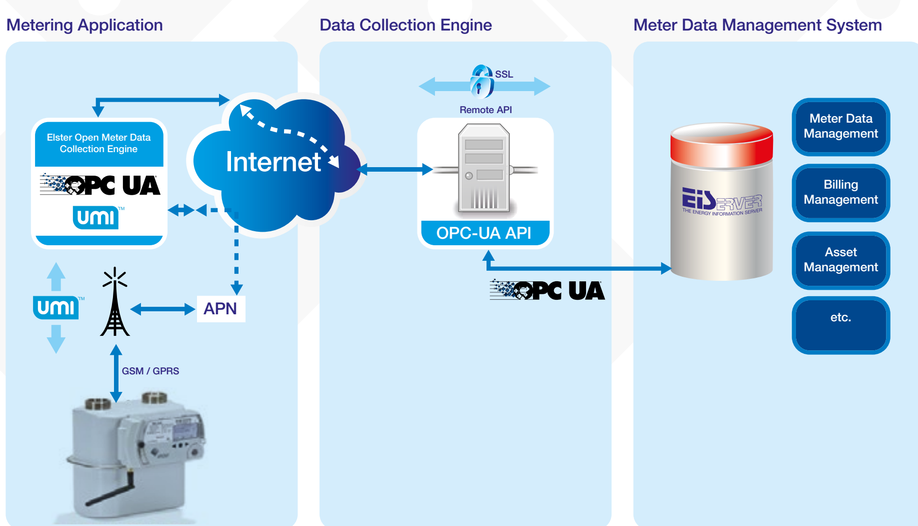
At Honeywell, we offer a software with OPC UA interface for our own systems as well as other head-end systems, since many systems used by supply companies already support this established standard. Integrated encryption of sensitive meter data is an important argument for OPC UA".

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

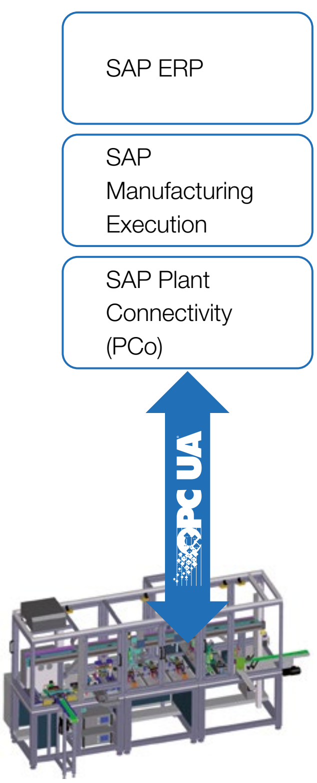
»Seamless MES integration of systems with OPC UA simplifies shop floor programming«

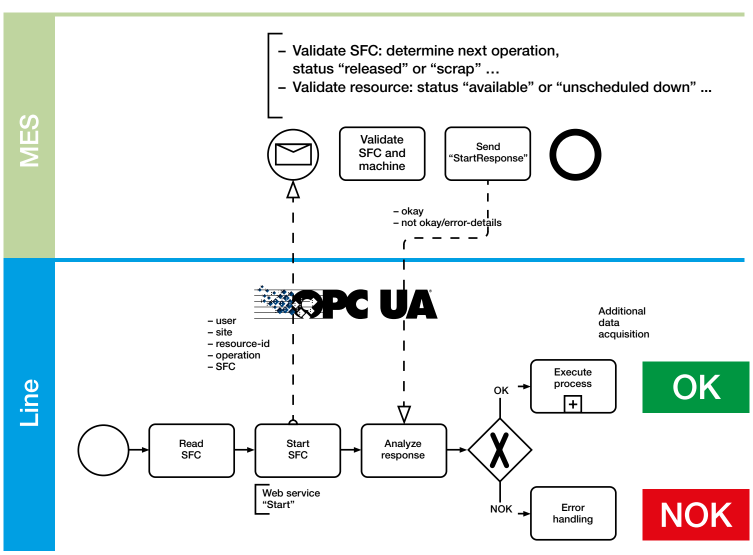
Rüdiger Fritz, Director Product Management, SAP Plant Connectivity (PCo), SAP
Member OPC Foundation Marketing Control Board

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

Erich Barnstedt, Chief Architect Standards, Consortia & Industrial IoT, Azure Edge + Platform

Microsoft

Microsoft Azure

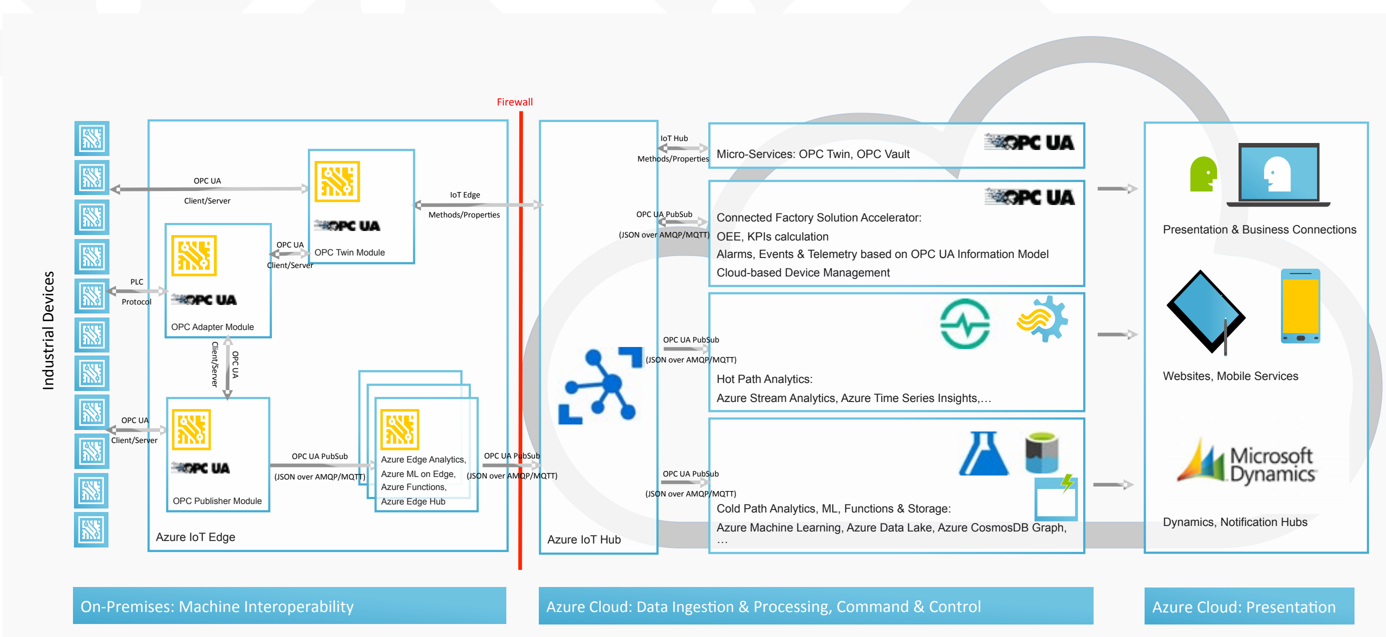
OPC UA is an essential foundation for the convergence of OT and IT, providing the most popular open and standardized data modeling for industrial equipment. From an IT perspective, OPC UA is the programming interface of the connected plant and the connected factory and a critical enabler for Industrial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



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