# OPC Unified Architecture

Pioneer of the 4th industrial (r)evolution


**Thomas J. Burke**
President und Executive Director
OPC Foundation

## Welcome to the OPC Foundation! As the international standard for vertical and horizontal communication, OPC UA provides semantic interoperability for cyber physical systems and plays a key role in the success of the 4th industrial (r)evolution.

OPC Unified Architecture (OPC UA) is the data exchange standard for safe, reliable, manufacturer- and platform-independent industrial communication. 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 safe information exchange in heterogeneous systems.

OPC has been very popular in the industrial automation and other market segments since 1995.
With the introduction of service-oriented architectures (SOA) in industrial automation systems in 2007, OPC UA started to offer a scalable, platform-independent solution which combines the benefits of web services and integrated security with a consistent data model.

OPC UA is an IEC standard and therefore ideally suited for cooperation with other organizations.
As a global 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 tests of implementations
- → Cooperation with other standards organizations

This brochure provides an overview of Industry 4.0 requirements and illustrates solutions, technical details and implementations based on OPC UA.

The broad approval among representatives from research, industry and associations indicates that OPC UA is a key ingredient of data and information exchange standards for the Industry 4.0 project.

Regards,
**Thomas J. Burke**
President und Executive Director
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# Contents

# OPC UA – pioneer of the 4th industrial (r)evolution

## CHALLENGE

In order to maintain the competitiveness of Germany as a production location it is necessary to meet the challenges of increasing efficiency with ever shorter product cycles through more effective use of energy and resources, of reducing time to market by producing more complex products faster with high innovative cycles, and of increasing flexibility through individualized mass production.

## VISION

The 4th industrial revolution (Industry 4.0) is driven by advanced information and communication technologies (ICT), which are becoming increasingly prevalent in industrial automation. In distributed, intelligent systems physical, real systems and virtual, digital data merge into cyber physical systems (CPS). These CPS are networked and form "smart" objects that can be assembled into "smart factories". With increasing processing power and communication capacity, production units are able to organize themselves and become self-contained. They have all the information they need or can obtain it independently. The systems are networked and autonomous, they reconfigure and optimize themselves and are expandable (plug-and-produce) without engineering intervention or manual installation. Virtual images are carried throughout the production, product life time and value creation chain within the produced goods and always represent the current state of the actual product. Such "smart" products are networked with each other in the Internet of Things and respond to internal and external events with learned behavior patterns.

## REQUESTS

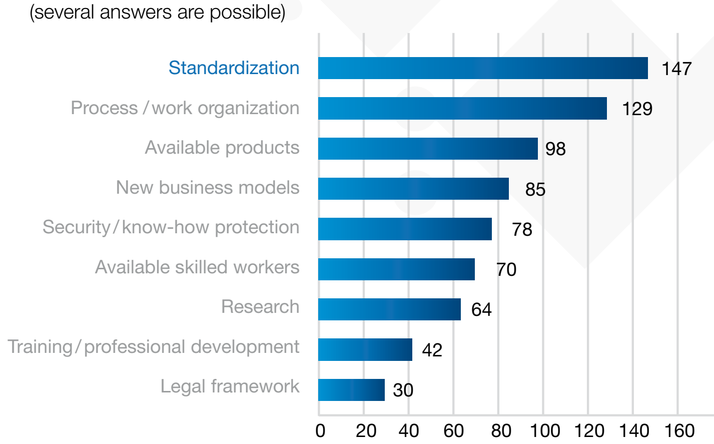
Considerable effort is required for implementing the vision of Industry 4.0 successfully, since demands vary considerably. In order to reduce the complexity, comprehensive modularization, wide-ranging standardization and consistent digitization is required. These demands are not new. They are not revolutionary either, but the result of continous development.

This evolution is a long-standing process that started a long time ago. Solutions for many of the requirements outlined below already exist. They are the foundation of Industry 4.0.


Source: Forschungsunion, acatech 2013

## CHALLENGES FOR THE IMPLEMENTATION OF INDUSTRY 4.0

(several answers are possible)




Result of the Industry 4.0 platform survey:

The members of BITKOM, VDMA and ZVEI regarded standardization as the biggest challenge in the implementation of Industry 4.0.

Source: "Recommendations for implementing the strategic initiative Industry 4.0", Forschungsunion, acatech 2013

# Industry 4.0 requirements – OPC UA solution

| Industry 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 stacks in Ansi C/C++, .NET and Java are available. |
| 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 and SCADA/HMI products as well as MES/ERP systems such as SAP and ITAC. Projects have already been successfully realized in Amazon and Azure Cloud. |
| Safe transfer and authentication at user and application level | OPC UA used x509 certificates, Kerberos or user/password for authentication of the application. Signed and encrypted transfer, as well as a rights at data point level with audit functionality is already available in the stack. |
| Service-orientated architecture (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. Currently three protocol bindings are available: optimized TCP-based binary protocol for high-performance applications and HTTP/HTTPS web service with XML-coded messages. Further bindings are planned, e.g. XMPP and others. The stacks guarantee consistent transport of all data and procedures arguments, events based on tokens. |
| 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 offers a fully networked (not only hierarchical but full-mashed network), object-oriented concept for the namespace, including metadata for object description. Object structures can be generated via referencing of the instances among each other and their types and a type model that can be extended through inheritance. Since servers carry their instance and type system, clients can navigate through this network and obtain all the information they need, even for types that were unknown to them before. |
| 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 notification of OPC UA-capable devices and their functions/features within subnets. Aggregation across subnets and intelligent, configuration-less procedure (e.g. Zeroconf) are used to identify and address network participants. |
| Integration into engineering and semantic extension | The OPC Foundation already collaborates successfully with other organizations (PLCopen, BACnet, FDI, etc.) and is currently expanding its cooperation activities, e.g. MES-DACH, ISA95, MDIS (oil and gas industry), etc. A new cooperation initiative is with AutomationML, with the aim of optimizing interoperability between engineering tools. |
| Verifiability of conformity with the defined standard | OPC UA is already an IEC standard (IEC 62541), and tools and test laboratories for testing and certifying conformity are available. Additional test events (e.g. Plugfest) enhance the quality and ensure compatibility. Expanded tests are required for extensions/amendments (companion standards, semantics). |

»The paradigm of Industry 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 inoperability.«

**Prof. Dr. Dr. Detlef Zühlke,** Scientific Director
Innovative Factory Systems (IFS), DFKI

»A key component for the realization of the Industry 4.0 idea is an open and standardized communication platform. This is the only way to implement scenarios that require company-wide communication across different levels. OPC UA provides a suitable and promising basis through its platform- and language-independent technology. The Institute of Automation and Information Systems (AIS) has already been using OPC UA for some years. Open architecture and support for a wide range of software and hardware are crucial benefits, particularly in a research environment. An example of this is the communication between a non-real-time-capable high-level agent on a PC platform and a real-time-capable low-level agent on a PLC. This enables optimum distribution of computing time and speed.«

**Prof. Dr.-Ing. Birgit Vogel-Heuser,** Head of Institute of Automation and Information Systems, Munich University of Technology (TUM)

»One-off production, for example in the maritime industry or in special-purpose machine construction, requires human inclusion as an important component for the realization of Industry 4.0. Intelligent assistance systems and decision support through visualization of existential data are important components of flexible and highly automated production.
Both require contextualized integration of heterogeneous data from different sources (ERP, MES, PDA, ECMS, ambient sensors, etc.), as well as appropriate deployment via a graphic user interface and initiation of corresponding processes with multi-modal interaction concepts. With its options for horizontal and vertical integration, and particularly through support of semantics, OPC UA offers an ideal basis for such solutions.«

**Prof. Dr. Bodo Urban,** Head of the Rostock facility
Fraunhofer Institute for Computer Graphics Research IGD

»OPC UA provides an ideal technology basis for Industry 4.0 which is all about intelligent networks between intelligent components. With Information Modellings in it's core, OPC UA supports the vision of Industry 4.0  with far more than just conveying data. Information models convey real information in the sense of know-how about structures, relationships and semantics – all of which is required for intelligent networking in the sense of Industry 4.0. In addition, OPC UA is available in products already today. This is important because the so called revolution will take place as an evolution. And this evolution can be started right away.«

**Prof. Dr.-Ing. Daniel Großmann,** Computer Science and Data Processing, Technische Hochschule Ingolstadt

»One of the basic ideas of Germany's "Industrie 4.0"-initiative is the interoperable communication between products, components, machines and IT-systems. This interoperability will only come to life with open standards and, furthermore, already existing open standards. That is why we prefer OPC UA to enable interoperability in a heterogeneous environment like a manufacturing shop floor. Especially because OPC UA supports the creation of information models for the meaning of data, that means their semantics. In our current R&D-projects we use OPC UA as the communication standard in the smart factory of the future – from the field device level to machines and from machines to the MES-level.«

**Dr. Olaf Sauer,** Fraunhofer Institute for Optronics, System Technology and Image Exploitation (IOSB)

## Quotes from research and education

»OPC UA being a highly scalable technology enables a seamless exchange of information between sensor, controller and ERP-Systems. In the next steps, OPC UA is envisioned to be used to describe the semantics of various services for a Smart Factory.«

**Prof. Dr.-Ing. Jürgen Jasperneite,** Head of Institute for Industrial Information Technology (inIT), Ostwestfalen-Lippe University of Applied Sciences and Fraunhofer Application Center Industrial Automation (IOSB-INA)

»OPC UA has the potential to replace the numerous Industrial Ethernet protocols by a direct link between field devices and application, except for time-critical data exchange.«

**Prof. Dr. Hubert Kirrmann,** Senior Principal Scientist, ABB, Corporate Research

»OPC UA has the potential for an immediate cross-vendor implementation of Industry 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

»Industry 4.0 describes a change in the industry, caused by the merger of developments in factory automation, IT, Internet and social media. In this environment we see increasing intermeshing between business management processes and automation, which will ultimately lead to a simplified system landscape and measurable increase in productivity. In the future, information such as test parameters, default values or machine settings will no longer require redundant maintenance, but will only have to be defined once and can be exchanged directly with the automation level. This reduces error sources and improves the quality of the data and ultimately of the products. SAP uses standards such as OPC UA, which ensure simple, scalable and safe information exchange with a wide range of factory systems. In the long run, the complexity caused by the wide range of shop floor systems can only be managed based on standards.«

**Veronika Schmid-Lutz,** Product Owner Manufacturing, SAP AG

# Acceptance in the industry

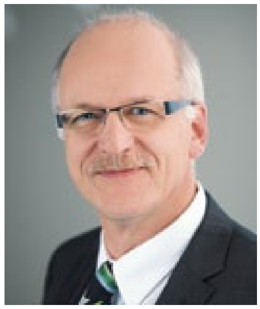
»OPC UA turns out to be an ideal basis for the implementation of functions required by Industry 4.0, because the protocol is already available and integrated in numerous devices, ranging from the sensor level to MES and ERP systems. In addition, it is supported by all automation suppliers. OPC UA also covers the internal communication within the CPS and in some cases serves as fieldbus substitute or middleware between the modules that interact within the CPS.«

**Robert Wilmes,** Phoenix Contact

»OPC UA plays an important role in our Digital Enterprise Platform approach on the evolutionary route to the Industry 4.0 vision.«

**Prof. Dr. Dieter Wegener,** Siemens Industry Sector, VP Advanced Technologies & Standards

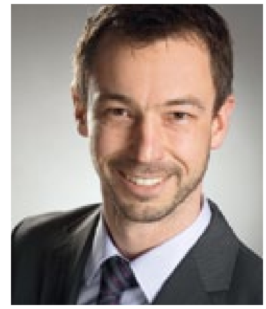
## Pioneers in automation



SIEMENS

»As a founder member of the OPC Foundation, Siemens is keen to generate added value for its customers – through promotion of automation and further development and interoperability of the technologies from different system providers. OPC standards are used in many of our innovations, such as the Sinema Server network management solution, the Simatic HMI or the flexible, modular Simocode pro motor management system. OPC UA is an implementation that we regard as particularly relevant. This is why we have always been very active in this area right from the start and are among the first companies whose products are certified.«

**Thomas Hahn,** Siemens AG, OPC board member



FESTO

»For modular and scalable production facilities in the future we expect significantly reduced efforts to connect those machines to superior systems like MES and ERP by using OPC UA. The big advantage for us is that a non-proprietary communication standard has been created. To be able to really get those benefits it is essential for us that hardware manufacturers are going to implement OPC UA servers directly on their embedded systems.«

**Steffen Schmidt,** Head of Control Technology Design, Festo

Continental

»The merger of automation technology and information technologies requires two key elements. Firstly – an intelligent, networked system that can make rule-based decisions and save data, i.e. a Manufacturing Execution System (MES) – and, perhaps even more important, secondly – a communication layer that is fast, platform-independent, scalable and safe and can be integrated horizontally and vertically, from the device level right into ERP systems, i.e. OPC UA. We then have an Industry 4.0-capable system or a so-called cyber-physical system (CPS) that is independent of the location of the stored data.«

**Angelo Bindi,** Senior Manager Central Control and Information Systems Continental Teves – Gründungsmitglied und Vorstand MES DACH

BECKHOFF

»Industry 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

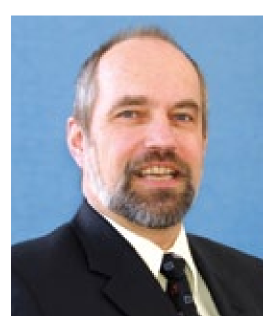
»Industry 4.0 means vertical integration along all levels of the value-chain and horizontal integration means integration into value-added networks. This is why the realisation of Industry 4.0 will crucially depend on interfaces. In this respect OPC UA provides numerous advantages, not least being an established and widely accepted standard. This is an indispensable feature to include as many stakeholders as possible, particularily smaller and medium-sized enterprises. Being a uniform interface providing real-time and security capabilities as well as interfaces for semantic applications, OPC UA is a vendor-independent communication solution, which is suitable for Industry 4.0 applications in a natural way.«

**Dr. Bernhard Diegner,** Head of research, vocational training, production engineering at ZVEI

»Standardization is an effective lever for innovations in many economic sectors, including the application of Industry 4.0 in manufacturing companies. The new type of added-value networks with dynamic business models across company and industry boundaries and the vertical integration within companies encompassing the installed systems requires a wide range of interfaces and different strategy for standardization. This was confirmed by a survey relating to the Industry 4.0 platform. The members of BITKOM, VDMA and ZVEI regarded standardization as the biggest challenge in the implementation of Industry 4.0. Organizations such as OPC Europe play a key role.«

**Wolfgang Dorst,** Head of Industry 4.0 at BITKOM, member of Industry 4.0 platform project management

# Recommendations by associations

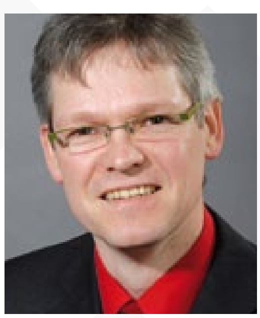


»To reach the goals of Industry 4.0, solutions are necessary, to realise secure and efficient communication between machines and plants by the use of information technology. All available solutions, OPC UA, too, offer real possibilities, to solve these tasks and to realise the ideas of Industry 4.0.«

**Peter Früauf,** VDMA, Electrical Automation

»We use the term Industry 4.0 to describe the transition from automated to decentrally networked, self-controlling production environments in which machines communicate with machines, workpieces and components. This calls for the MES to record and calculate the processed data from all of the sensors and actuators in real-time. The MES plays a pivotal role in Industry 4.0 manufacturing scenarios and forms the “nucleus” of the smart factory. MES-facility integration is largely dependent on the ability to exchange data between all of the systems via open interface standards like OPC UA. This protocol offers advantages because it is supported by many automation vendors and can be used regardless of the platform. Implementing this standard is a task for the manufacturing industry, a process which we support and offer advice on based on our in-depth know-how on Industry 4.0.«

**Thomas Ahlers,** Member of the Executive Committee of Freudenberg IT, and Chairman of the BITKOM Work Group Industry 4.0 Interoperability



»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 Industry 4.0 approach.«

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

»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

»BACnet and OPC UA are already cooperating in the exploration of new opportunities for integration between industrial and building automation: Energy 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

# OPC UA at a glance – secure, reliable and platform-independent exchange of information

**SECURE, RELIABLE AND PLATFORM-INDEPENDENT EXCHANGE OF INFORMATION**

OPC UA is the new technology generation from the OPC Foundation for the secure, reliable and vendor-independent transport of raw data and pre-processed information from the sensor and field level up to the control system and into the production planning systems.
With OPC UA every type of information is available anytime and anywhere for every authorized use and to every authorized person.

**PLATFORM AND VENDOR-INDEPENDENT**

OPC UA is independent of the vendor or system supplier that produces or supplies the respective application. The communication is independent of the programming language in which the respective software was programmed and it is independent of the operating system on which the application runs. It is an open standard without any dependence on, or bind to proprietary technologies or individual vendors.

**STANDARDIZED COMMUNICATION VIA INTERNET & FIREWALLS**

OPC UA extends the preceding OPC industry standard by several important functions such as platform independence, scalability, high availability and Internet capability. OPC UA is no longer based on Microsoft's DCOM technology; it has been reconceived on the basis of service-oriented architecture (SOA). OPC UA is thus very simple to adapt. Today OPC UA already connects the enterprise level right down to the embedded systems of the automation components – independent of Microsoft, UNIX or any other operating system. OPC UA uses a TCP based, optimized, binary protocol for data exchange over a port 4840 registered with IANA. Web service and HTTP are also optionally supported. It is sufficient to open up a single port in the firewall. The integrated encryption mechanisms ensure secure communication over the Internet.

**SERVICE-ORIENTED ARCHITECTURE**

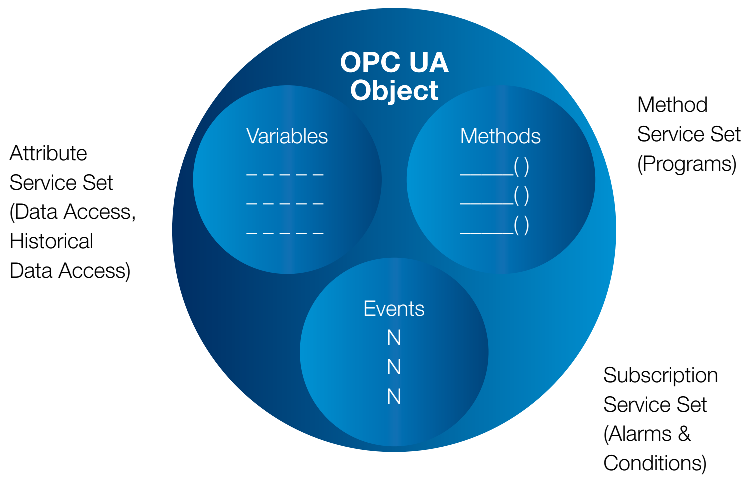
OPC UA defines generic services and in doing so follows the design paradigm of service-oriented architecture (SOA), with which a service provider receives requests, processes them and sends the results back with the response.
In contrast to classic Web services that describe their services over a WSDL and can thus be different with each service provider, generic services are already defined with OPC UA.
A WSDL is thus not required, 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. OPC UA defines various groups of services for different functions (reading/writing/signaling/execution, navigation/searching, connection/session/security). The flexibility results via the OPC UA information model. Building on a basic model, any desired complex, object-oriented extensions can be made without impairing the interoperability in the process.

**PROTECTION AGAINST UNAUTHORIZED ACCESS**

OPC UA technology uses proven security concepts that offer protection against unauthorized access, against sabotage and the modification of process data and against careless operation. The OPC UA security concepts contain user and application authentication, the signing of messages and the encryption of the transmitted data itself. OPC UA security is based on recognized standards that are also used for secure communication in the Internet, such as SSL, TLS and AES. The safety mechanisms



Uniform OPC UA object




are part of the standard and are obligatory for vendors. The user may combine the various security functions according to his case of use; thus scalable security results in relation to the specific application.

### ACCESSIBILITY AND RELIABILITY

OPC UA defines a robust architecture with reliable communication mechanisms, configurable timeouts and automatic error detection.
The error elimination mechanisms automatically restore the communication connection between the OPC UA client and the OPC UA server without loss of data. OPC UA offers redundancy functions that are integrable in both client and server applications and thus enable the implementation of high-availability systems with maximum reliability.

### SIMPLIFICATION BY STANDARDIZATION

OPC UA defines an integrated address space and an information model in which process data, alarms and historical data can be represented together with function calls. OPC UA combines all classic OPC functionalities and permits the description of complex procedures and systems in uniform object-oriented components. Information consumers that only support the basic rules can process the data even without knowledge of the interrelationships of the complex structures of a server.

### AREAS OF APPLICATION

The universal applicability of OPC UA technology enables the implementation of entirely new vertical integration concepts. The information is transported securely and reliably from the production level into the ERP system by cascading OPC UA components. Embedded OPC UA servers at field device level and integrated OPC UA clients in ERP systems at enterprise level are directly connected with one another. The respective OPC UA components can be geographically distributed and separated from one another by firewalls. OPC UA enables other standardization organisations to use the OPC UA services as a transport mechanism for their own information models. The OPC Foundation already cooperates today with many different groups from different industries, including PLCopen, BACnet, ISA and FDI. Additional specifications are compiled that contain common, semantic definitions of information models.

# OPC UA technology in detail

**Karl-Heinz Deiretsbacher,**
Industry Automation Division
Siemens AG
Director of the OPC UA Technical Advisory Board
SIEMENS

**Dr. Wolfgang Mahnke,**
Software Architect R&D Fieldbus
ABB Automation GmbH
ABB

Industry 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.

## DESIGN OBJECTIVES

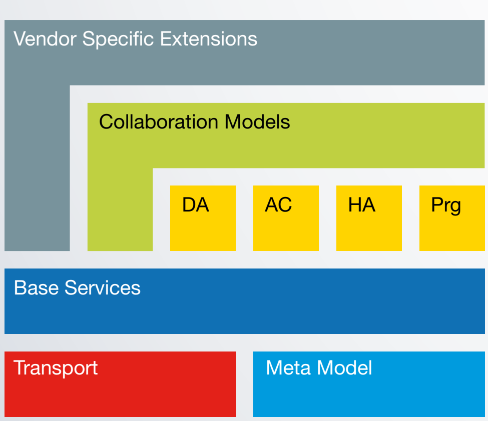
OPC UA was designed to support a wide range of systems, ranging from PLC in production to enterprise servers. These systems are characterized by their diversity in terms of size, performance, platforms and functional capabilities.

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

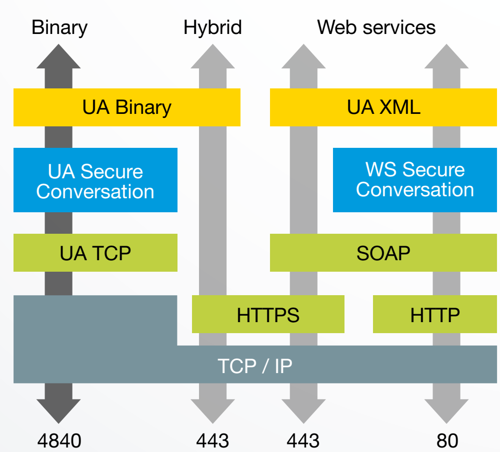
- → Transport – for the data exchange mechanisms between OPC UA applications. Different transport protocols exist for different requirements (optimized for speed and throughput = UA TCP with UA Binary; firewall-friendly = HTTP + Soap).
- → Meta model – specifies the rules and basic components for publishing an information model via OPC UA. It also includes various basic nodes and basic types.
- → Services – they constitute the interface between a server as information provider and clients as users of this information.

Information models follow a layered approach. 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.




OPC UA layer model




OPC UA transport profiles

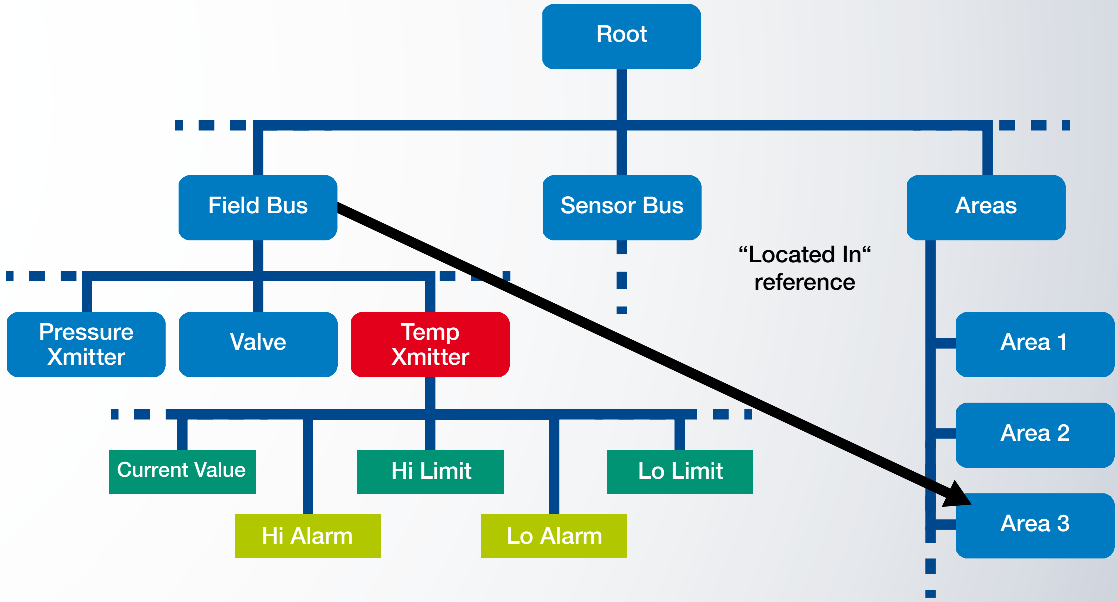
**INTEGRATED ADDRESS SPACE MODEL**

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 applications 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

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 a 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 attribute values. Attributes are primitive characteristics of nodes that are defined by OPC UA.

→ **Method service set**
Methods represent the function calls of objects. They are invoked and return after completion. The method service set defines the means to invoke methods.

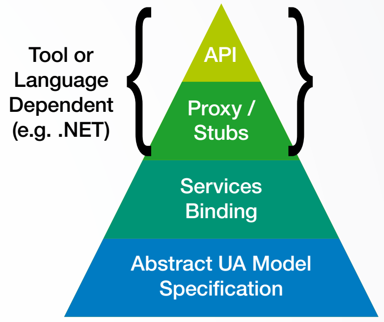
→ **MonitoredItem service set**
This service can be used to determine which attributes from the address space should be monitored for changes by a client, or which events the client is interested in.

→ **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.

## 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.




Services are independent of the model

- **At the lowest level** are the abstract OPC UA model and the services, including the whole address space model, different object and variable structures, alarms and more.

- **The next level** (Services Binding) is used to specify how the services are to be mapped to certain protocols. Currently mappings for TCP (UA-TCP) and for HTTP (OPC UA WebServices) are available. In the future – once new technologies become established – further mappings can be specified without having to change the OPC UA model and the services. 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 offers three such realizations, namely for Java, .NET and AnsiC/C++.
  The last option contains a platform adaptation layer.

## PERFORMANCE

The OPC UA services can be mapped to different technologies. Currently there are essentially two mappings: UA-TCP and HTTPS. The use of UA-TCP on top of advanced Ethernet technologies ensures high performance.
The services themselves are also designed for high data throughput. An individual read call can access thousands of values, for example. Subscriptions services enable notification when values are changed and exceed configured thresholds

## INFORMATION MODELS WITH OPC UA

### 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.

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 automation 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)

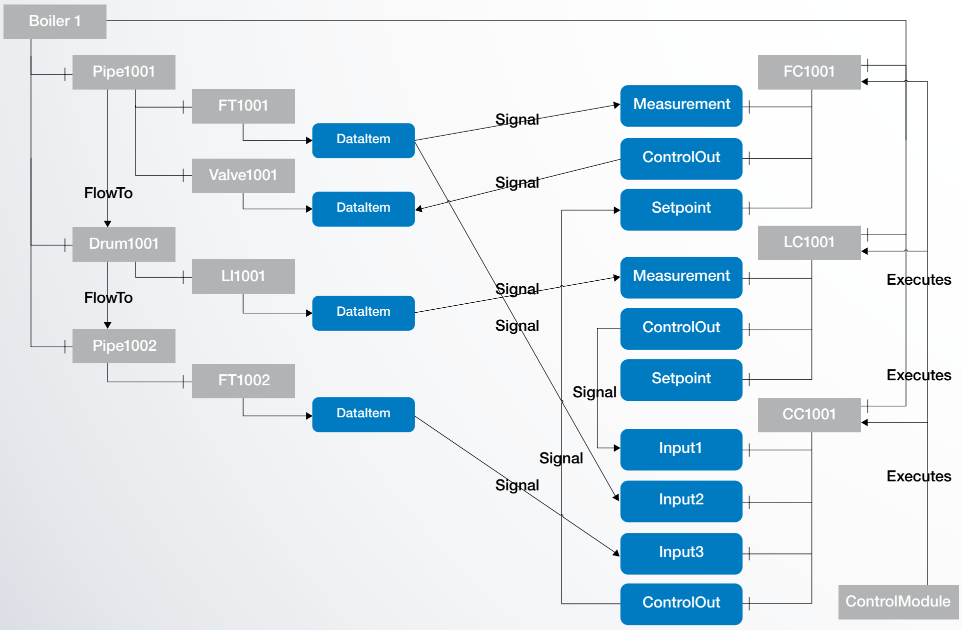
This information model defines how states (dialogs, alarms) are handled. A change of state triggers an event. Clients can register for such events and select which of the available associated values they want to receive as part of the event report (e.g. message text, acknowledgment behavior).

### 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” represented 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.




UA modeling of a boiler as an 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.

**The following companion standards currently exist or are in preparation:**

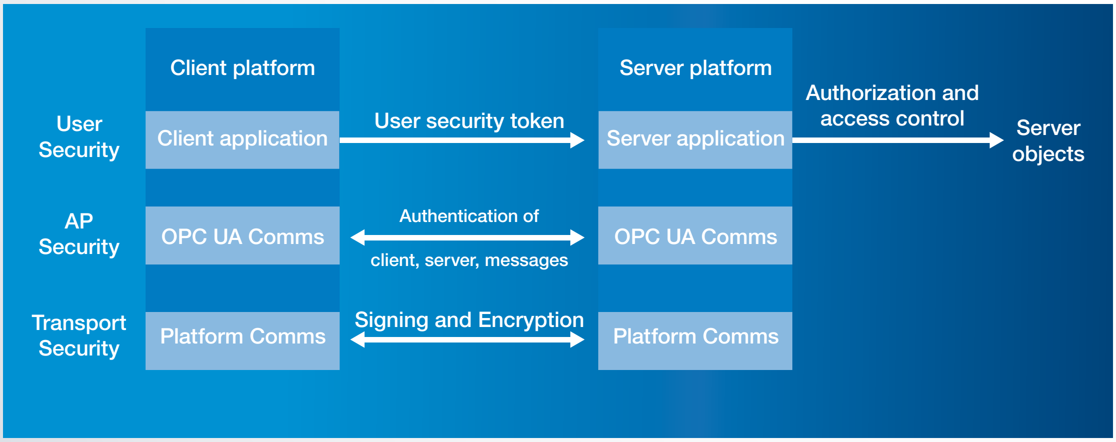
- → OPC UA for Devices (IEC 62541-100)
- → OPC UA for Analyser Devices
- → OPC UA for Field Device Integration
- → OPC UA for Programmable Controllers based on IEC61131-3
- → OPC UA for Enterprise and Control Systems based on ISA 95
- → OPC UA for Machine Tool Connectivity (MTConnect)

Source: Extract from the 4th annual colloquium “Communication in Automation” (KommA 2013), ISBN: 978-3-944722-00-9

## SECURITY MODEL

### GENERAL

Security is a fundamental requirement for OPC UA and was therefore integrated in the architecture. The mechanisms (comparable to the Secure Channel concept of W3C) are based on a detailed analysis of the threats.
OPC UA security deals with the authentication of clients and servers, the integrity and confidentiality of the exchanged messages and the verifiability of functional profiles.
OPC UA security complements the security infrastructure provided by most web-enabled platforms. It is based on the architecture shown in the diagram below. The three levels are User Security, Application Security and Transport Security.
The OPC UA user level security mechanisms are executed once when a session is set up. The client transmits an encrypted security token, which identifies the user, to the server. The server authenticates the user based on the token and then authorizes the access to objects in the server. The OPC UA specification does not define authorization mechanisms such as access control lists. They are application- and/or system-specific.
OPC UA 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. They describe capabilities of the server, such as support for a specific information model.
Transport level security can be used to provide integrity by signing the messages and confidentiality by encrypting the messages. This prevents disclosure of the exchanged information and ensures that the messages have not been manipulated.
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 and are ready to be used by client and server.




Scalable security concept

## SCALABLE SECURITY

Security mechanisms come at a price and have an impact on performance. Security should therefore only be applied in situations where it is actually required. This decision should not be made by the developer/product manager, but the system operator (system administrator).

The OPC UA security mechanisms are scalable. OPC UA servers provide so-called end points representing different security levels. There is also an end point without security ("NoSecurity" profile). The system administrator can deactivate certain end points (e.g. the end point with the NoSecurity profile). During operation, the operator of a OPC UA client can select the end point suitable for the respective action when the connection is established.

OPC UA clients themselves can ensure that they always select end points with security for access to sensitive data.

## SECURE CHANNEL

The SecureChannel is used to define the SecurityMode and the SecurityPolicy. The SecurityMode describes how the messages are encrypted.

Three options are available, as defined by OPC UA: "None", "Sign" and "SignAndEncrypt". The SecurityPolicy defines algorithms for encrypting the messages.

For setup, the client needs the public key of the server instance certificate. The client then transfers its own instance certificate, based on which the server decides whether it trusts the client.

## INDUSTRY 4.0: OUTLOOK

OPC UA is a mature standard, which meets the requirements of Industry 4.0 regarding 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?

Fraunhofer IOSB

<AutomationML/>
The Glue for Seamless Automation Engineering

**Engineering: Interoperability by combining AutomationML with OPC UA**

# Requirements for the factory of the future

**Dr. Olaf Sauer,** Fraunhofer Institute for Optronics, System Technology and Image Exploitation (IOSB), Initiator of common working group "AutomationML and OPC UA"

The factory of the future has to be capable of producing customer-specific products in ever new variants, for instance, ensuring short product life cycles, quick delivery times, zero-defect production and resource-efficient manufacturing. Industrie 4.0 is a strategic framework program focusing on the increasing significance of information in the manufacturing industry. There is a wide range of individual technologies in place, which now have to be consolidated for industrial use. One of the major requirements for the Industrie 4.0 ICT architecture is the ability to adapt to changes – either in the case that new equipment or production processes are added to the system or in the case that existing production systems are changed because a new, additional product variant is to be manufactured, for instance. This capability is called adaptive ICT. The basic idea behind adaptivity is the use of self-describing methods relating to functionality, identification, self-establishment of communication and standardized data exchange in case new components, machinery or equipment are added to a production system or in case there are changes in production that affect the software.

## AUTOMATION ML™ AND OPC UA FOR INDUSTRIE 4.0

Self-configuration can be achieved by using Automation ML to describe the capabilities of components and machines and OPC UA to enable them to communicate with each other. The cooperation between OPC Foundation and AutomationML e.V. aims at combining the two technologies to form methods and tools for information and software architectures allowing for consistent, reliable availability and communication of data in the case of modifications to the factory. To this end, features and capabilities are stored as AutomationML objects within the very components. Consequently, they are readily available to the control system as OPC UA information models at the time of physical integration. Component suppliers identify the information required for this purpose in advance so it is included in the components themselves. The physical and information-related integration results in time savings of approximately 20 % in the case of initial start-ups, maintenance activities and changes in production. Even greater potentials can be opened up if data required for the configuration of an MES is extracted from the engineering systems on which they are based and stored directly in OPC UA information models as AutomationML objects.

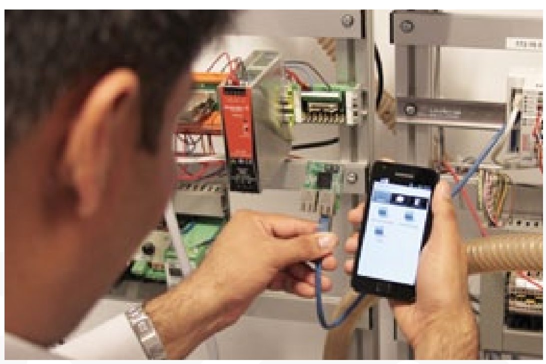
Fraunhofer IOSB-INA

inIT Institut für industrielle Informationstechnik

## Scalability: OPC UA in chip level

# »OPC UA on chip level as an enabler for Industry 4.0«

**Prof. Dr.-Ing. Jürgen Jasperneite,** Head of Institute for Industrial Information Technology (inIT), Ostwestfalen-Lippe University of Applied Sciences and Fraunhofer Application Center Industrial Automation (IOSB-INA)



Industry 4.0 describes the vision of intelligent technical systems by means of functions such as self-optimization, self-configuration and self-diagnosis in future adaptive and predictive systems. Such systems interact with their environment and can adapt to it by learning. This can lead to new solutions that are characterized by versatility, resource efficiency and user-friendliness. In addition to the cognitive information processing that goes well beyond today's usual reflexive information processing in automation technologies, the intelligent networking is of central importance.

In todays' automation technique diverse communication techniques (e.g.: real-time Ethernet, WLAN), which are optimized for the use case, have been established, but the vertical flow of information from the sensor level up to the Internet is still often constraint by technology differences. With the help of OPC UA this can be solved now. In 2012, the Fraunhofer Application Center IOSB INA, together with inIT (Institute Industrial IT) of the OWL University, has demonstrated as part of an internet of things related EU project, that OPC UA is scalable in a level that an OPC UA server with only 15 Kbytes of RAM and 10kbyte ROM can be implemented directly on a chip. The „Nano Embedded Device Server profile" of the OPC Foundation has been used for this purpose. The protocol stack is implemented in ANSI C and consists of about 2000 lines of code and it uses a basic TCP/IP functionality. Now using off the shelf OPC UA clients, it is possible to directly communicate with field devices. Also to compress the information an aggregation of servers can be realized. An important part of this concept is that for the time-critical machine-oriented data transmission, the OPC UA communication can take place in parallel to the real-time communication. In a next step, the OPC UA strong information modelling and interoperability related functionalities should be used towards achieving plug- and-play of field devices. For this a semantic interoperability is necessary, which enables the description, localization and dynamic orchestration of services. This reduces the reconstruction and commissioning of automated systems significantly and thereby increases the mutability of manufacturing companies.

**Scalability: OPC UA in sensor**

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

**Alexandre Felt,** Project Manager at AREVA GmbH

AREVA
forward-looking energy

### SCALABILITY: AREVA BENEFITS FROM SENSORS WITH INTEGRATED OPC UA PROTOCOL

Comprehensive, end-to-end networking across all levels represents a challenge to Industry 4.0. As an evolutionary step towards realization of the 4th industrial revolution, companies can already take a decisive step in the right direction with Embedded OPC UA. In cooperation with its partner Matrikon OPC, the company 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.


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.

### 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.

### 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.

Identification: OPC UA in RFID devices

# »RFID & OPC UA as building blocks for Industry 4.0«

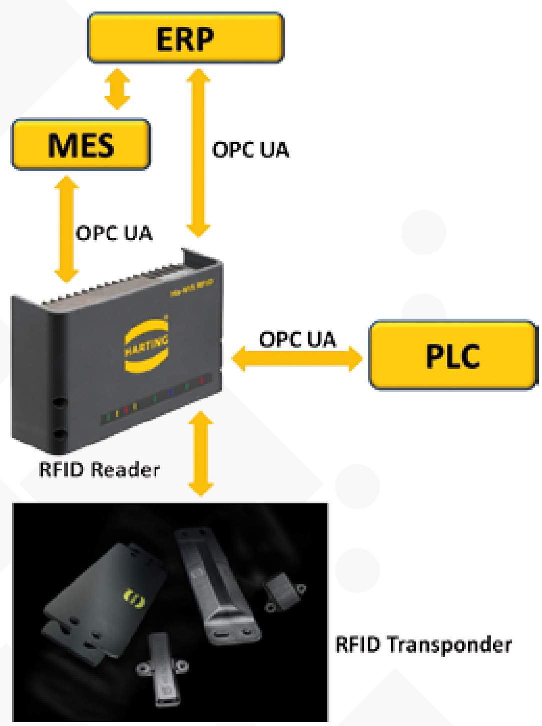
**Dr. Jan Regtmeier,** HARTING IT Software Development GmbH & Co. KG

The vision of the industry 4.0 aims at seamless communication between real objects and different computer systems. One goal is that a product controls its own production process.

The first hurdle, however, occurs early on: how does a software system identify a real object, for example, a tool or a concrete part? Here RFID helps. By implementing a transponder, an object obtains an identity. And in addition, the object receives a memory, the so called user memory, and if needed, sensing elements in form of sensors e.g., to measure the ambient temperature.

Thus, right at the start of a production process, the final product specs can be defined and stored on the object. Then, the product finds its own way through the various production steps. At each step in this process, different systems require the RFID data of the product. This can be a PLC, but in other cases a MES or ERP system is possible as well. But currently all systems speak different languages. For example PLC: Profinet, Ethernet / IP, EtherCAT, CC-Link , etc. This drives the integration efforts concerning time and money for the customer. Here, OPC UA allows that everyone understands each other.

The most important task for the RFID reader manufacturers so far has not been addressed, and is my goal: „The big RFID manufacturers need to agree on semantics mapped in OPC UA.“



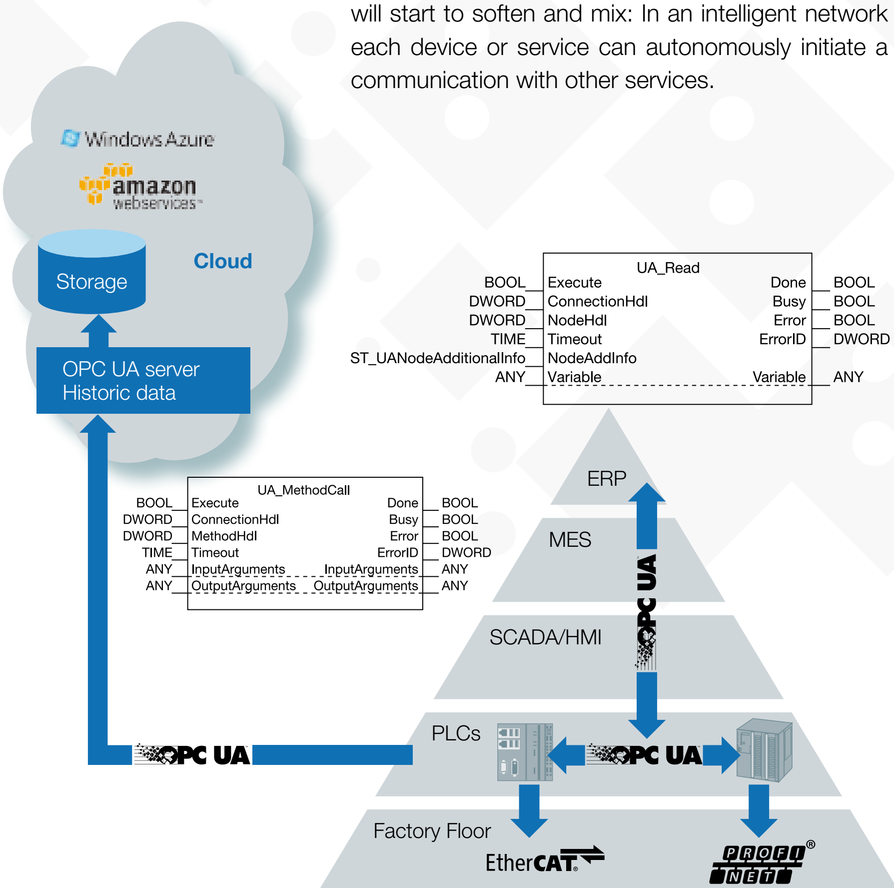
BECKHOFF

**Integration: OPC UA Client and -Server in controller**

# »OPC UA: Via semantic information modelling from controller into cloud«

**Stefan Hoppe,** Beckhoff Automation, Produkt Manager TwinCAT
Chairman der gemeinsamen Arbeitsgruppe PLCopen & OPC Foundation, President OPC Foundation Europe

The interaction between IT and the world of automation is certainly not revolutionary, but is based on the long-established model of the automation pyramid: The upper level initiates a data communication (as a client) with the level below, which responds (as server) cyclically or event-driven: A visualization, for example, can request status data from the PLC or transfer new production recipes to the PLC.
With Industry 4.0 this strictly separation of the levels and the top-down approach of the information flow will start to soften and mix: In an intelligent network each device or service can autonomously initiate a communication with other services.




## PLC CONTROLLER INITIATES HORIZONTAL AND VERTICAL COMMUNICATION

In collaboration with the OPC Foundation, the PLCopen (association of IEC6-1131-3-based controller manufacturers) has defined corresponding OPC UA client function blocks. In this way the controller can play the active, leading role, in addition or as an alternative to the usual distribution of roles. The PLC can thus horizontally exchange complex data structures with other controllers or vertically call up methods in an OPC UA server in an MES/ERP system, e.g. to retrieve new production orders or write data to the cloud. This enables the production line to become active autonomously – in combination with integrated OPC UA security a key step towards Industry 4.0.

## SEMANTIC INTEROPERABILITY

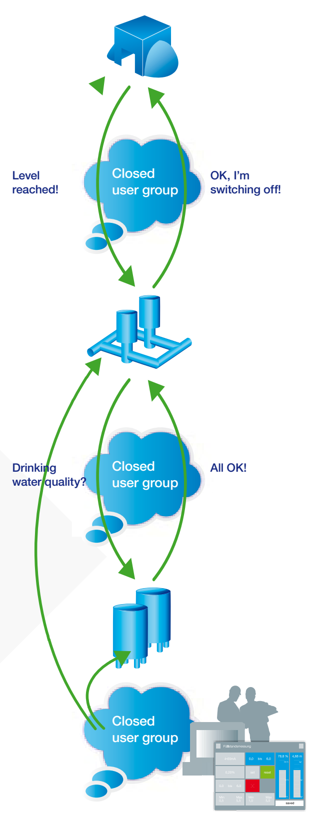
A mapping of the IEC61131-3 software model to the OPC UA server address space is defined through the standardization of the two organizations: The advantage for users is that a PLC program that is executed on different controllers from different manufacturers, externally results in semantically identical access for OPC UA clients, irrespective of their function: The data structures are always identical and consistent. The system engineering is simplified significantly. The sector-specific standardization of the semantics is already used by other organizations and is the actual challenge of Industry 4.0.

Horizontal: OPC UA enables M2M and IoT

# »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 Industry 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 a 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.



**Vertical: OPC UA from production right into SAP**

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

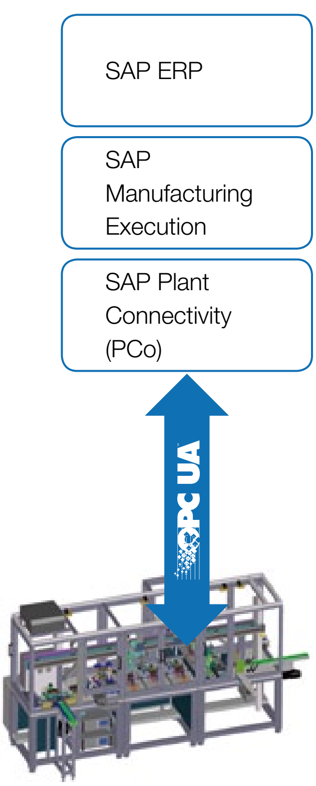
**Roland Essmann,** Elster GmbH, project manager for Manufacturing Execution System (MES)

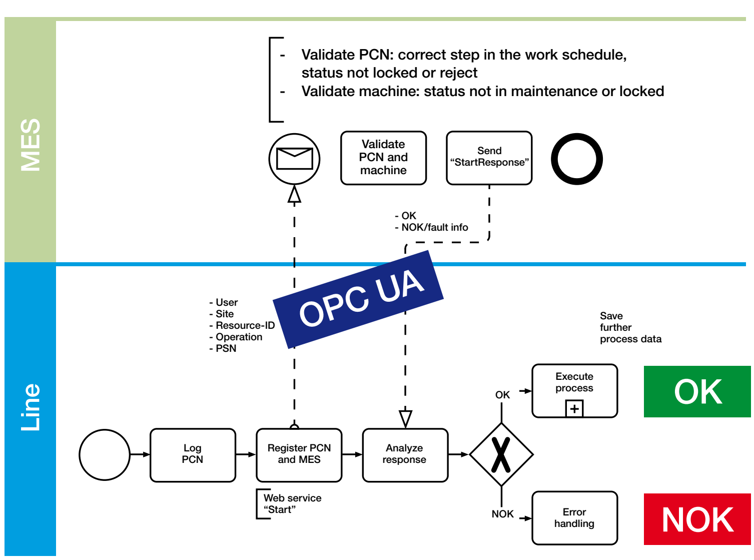
The product itself determines the way it should be produced. Ideally this enables flexible production without the need for manual setting up. Elster have already implemented the vision of Industry 4.0 in first pilot lines.

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 controlnumber (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. Vertical integration is therefore not a one-way street, but a closed loop.

In future, intelligent products with their own data storage will offer the prospect of exchanging much more than just a shopfloor controlnumber with the plant. It is conceivable to load work schedules, parameters and quality limits onto the product, in order to enable autonomous production.

Before this can be implemented across the board, a number of challenges relating to the semantics (terminology) have to be addressed. However, one important aspect in the Industry 4.0 has already been settled in practice: The communication between product and plant will take place via OPC UA.



Vertical: OPC UA plus UMCM – The “USB connector” between PLC and MES

# Vertical: Semantic information models for MES

**Angelo Bindi,** Senior Manager Central Control and Information Systems at Continental Teves – founder member and executive board MES DACH

**The journey is the reward …**

We all understand that we need a route, if we want to get from A to M. This is also true in automation technology. From the machine (automation level) we have to communicate with higher-level systems (MES – Manufacturing Execution Systems). The MES D.A.CH association has set itself the goal to make MES tangible – literally. To this end it is necessary to describe data based on their form and shape – i.e. through a data model – and through their content – i.e. overall through semantics.

In the MES D.A.CH association we implemented this with UMCM (Universal Machine Connectivity for MES) – i.e. an integrated communication model for machine data towards higher-level systems that is optimized for the lowest common denominator. However, this alone is not sufficient. It is necessary to take a route that is safe, fast, standardized, easy to recognize and extendable if required. OPC UA offers an unrivalled, integrated system that is safe across different security layers and nevertheless extendable, if required. Optimum bidirectional communication is thus assured for the future.

Based on OPC UA, the MES D.A.CH association together with the OPC Foundation offers blocks according to IEC 61131-3 for different PLC suppliers and high-level languages that enable convenient and fast implementations.

This is an efficient and simple method to make systems “Industry 4.0”-capable.

TECHNISCHE UNIVERSITÄT DRESDEN

## Human-Machine Interaction: OPC UA in a Browser

# »OPC UA provides a continuous communication all the way to the web browser, with that it provides the foundation for the flexibility requested in the field of Industry 4.0 and Internet of Things«

**PD Dr.-Ing. Annerose Braune,** Faculty of Electrical and Computer Engineering, Institute of Automation, Dresden University of Technology

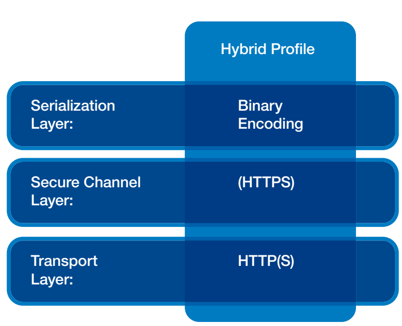
At the Institute of Automation it has been recognized early on that also in the field of industrial SCADA systems the trend is towards mobile applications. Due to the continuously growing variety of handheld devices, browser-based solutions are especially suitable.

In cooperation with the company ascolab GmbH a project has been started in 2009 which addresses the research regarding direct access to OPC UA servers by means of JavaScript. The advantage of using JavaScript is that no special browser plug-ins are necessary.

The hybrid profile of the OPC UA communication stack, providing an ideal combination of capability and speed, offers good conditions for a high-performance solution. This is accomplished by means of using a binary encoding in conjunction with information transmission via HTTPS. As HTTPS has to be natively supported by every web browser, computationally expensive encryption algorithms don't have to be performed within JavaScript.

The prototype developed during the project uses these benefits and makes it possible to easily create JavaScript based OPC UA Clients. Mobile browsers are widely supported as well (see table). The OPC UA server delivers the user interface and the script code to the browser using a proxy server or directly by having an integrated (minimal) web server.

Time measurements show that web-based applications cannot keep up to the performance of native solutions but are quite sufficient for typical use cases. This also applies when using modern mobile devices like smartphones or tablets, allowing the access to the data of an OPC UA server directly from within the facility (e.g. for maintenance purposes). Further developments address the integration of additional features such as support of alarms and authentication mechanisms.




| Desktop | | Mobil | |
|---|---|---|---|
| Chrome 30 | ✓ | Android Browser 4.3 | ✓ |
| Firefox 25 | ✓ | Opera Mini 7.5 (Andr.) | ✗ |
| Opera 17 | ✓ | Opera 16.0 (Andr.) | ✓ |
| IE 11 | ✓ | Chrome 30 (Andr.) | ✓ |



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

# Safe and flexible: Meter data collection with OPC UA

**Carsten Lorenz,** AMR (Automatic Meter Reading) Manager at Elster GmbH

"A safe and reliable communication protocol plays an important role in smart metering", says Carsten Lorenz, AMR (Automatic Meter Reading) Manager at Elster GmbH, 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.

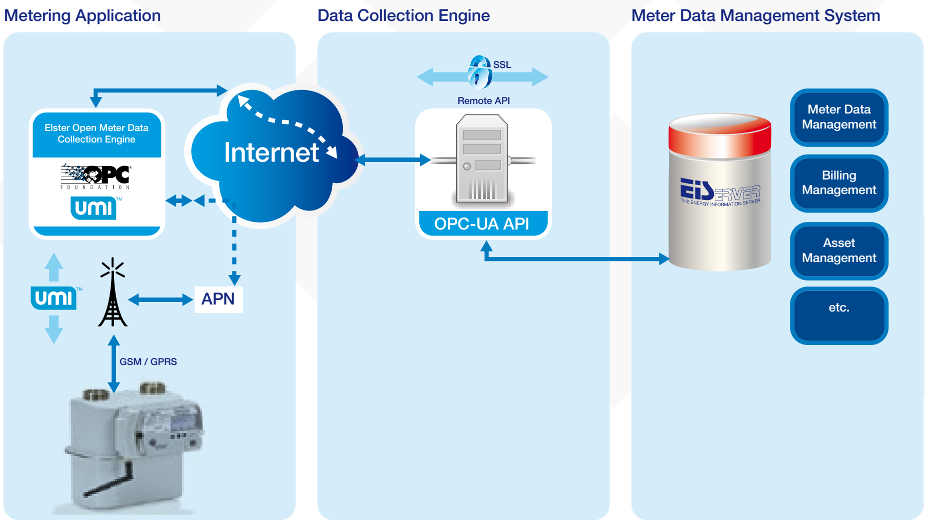
At Elster, we offer a software with OPC UA interface for our own systems as well as other head-end systems, since many systems used by supply companies already support this established standard. Integrated encryption of sensitive meter data is an important argument for OPC UA".

Safety and encryption of personal data is a MUST when Smart Metering is introduced. This means: Corresponding safety 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.

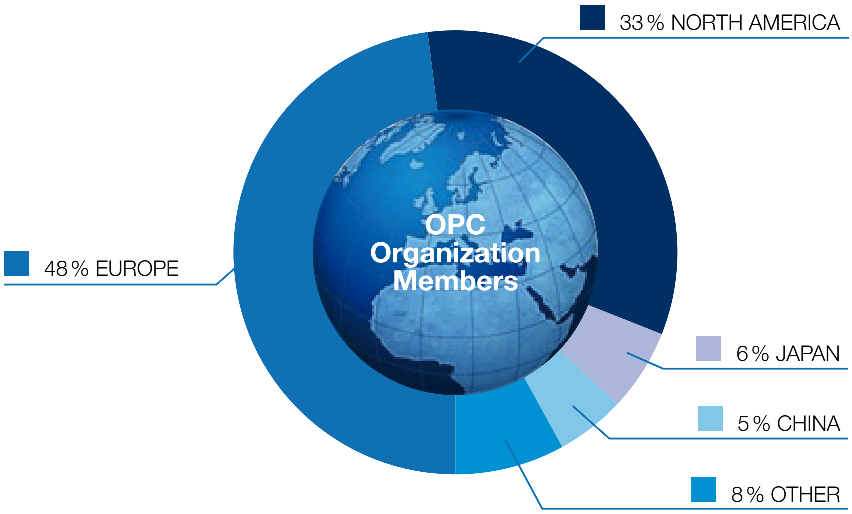
Communication protocols are transferred in encrypted form with respect to gas meters. This means: Personal data and critical commands, such as closing and opening of a valve integrated in the meter, are not visible for third parties and cannot be intercepted or simulated.

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.



# OPC Foundation – organization




With more than 450 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 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. Member companies offer events and training programs for end users of the OPC technology. 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.

**INDEPENDENCE**

The OPC Foundation is a non-profit organization that is independent of individual manufacturers or special technologies. The members of the working groups are provided by the 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 (almost 50 %) are based in Europe. Around one third of the members are based in North America. All main German manufacturer 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 for exchange of information and networking. Each year three times a week-long interoperability workshop (IOP) is held, at which the latest products and their interaction are tested.

# OPC Foundation provides specifications and information

## RESOURCES

The distribution of a technology is based on the persuasion of the users and their understanding of the functionality and the technical details, plus simple implementation and verification and certification. The OPC Foundation offers users and particularly its members a number of information sources, documents, tools and sample implementations.

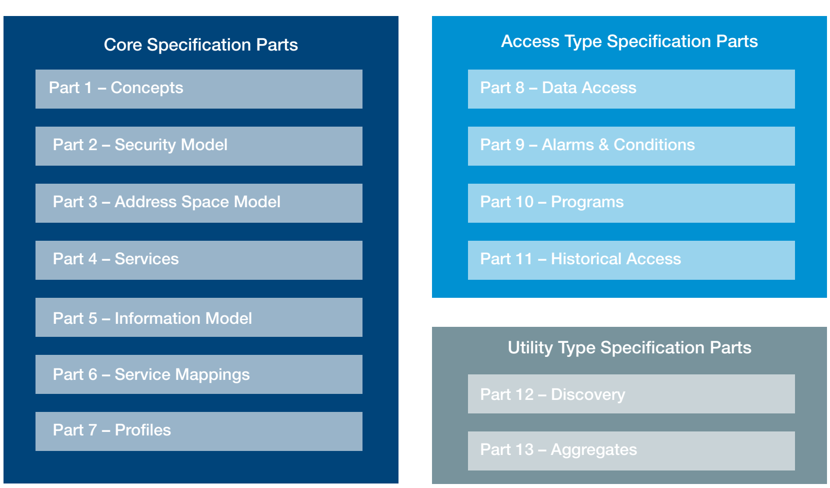
## OPC UA SPECIFICATIONS AND IEC 62541

The main source of information are the specifications. They are publicly accessible and also available as an IEC standard series (IEC 62541). Currently 13 OPC UA specifications are available, subdivided into three groups.

→ **1. Basic specifications.** These contain the basic concepts of the OPC UA technology and the security model, plus an abstract description of the OPC UA metamodel and the OPC UA services. In addition they describe the concrete OPC UA information model and its modeling rules, plus the concrete mapping at the protocol level and the concept of the profiles for scaling the functionality.

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

→ **3. Extensions.** These contain additional solutions for find 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

## WEBSITE AND EVENTS

A further source of information is the global website of the OPC Foundation plus regional sites for Europe, Japan and China. This is where the products made available by the members and their certification results are published. Information on technology and collaborations is provided in different languages. In addition, information on events organized by the OPC Foundation itself and its members is provided.

# Source code and certification for members

## SOURCE CODE AND TEST TOOLS

To ensure compatibility, the OPC Foundation offers its members the 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.**

The communication stacks are available 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. These three implementations ensure the basic communication in the network. They are compatible with each other and are maintained by the OPC Foundation. Members have free access to the stacks and their source code.

→ **2. Certification program.** For testing and certification of logically correct behavior, the OPC Foundation offers its members a test software (compliance test tool). It can be used to verify the logically correct and specification-compliant behavior of an OPC UA application. In independent certification laboratories manufacturers can have their OPC UA products certified based on a defined procedure. In addition to conformity the behavior in fault scenarios and interoperability with other products is also tested.

## INTEROPERABILITY WORKSHOPS

The OPC Foundation holds three times a week-long interoperability workshop (IOP) per year, at which members can test the interaction of their products.
The IOP Europe takes place in the autumn at Siemens AG in Nuremberg. Other IOPs are held in North America and Japan. These meetings offer a comprehensive test environment with around 60–100 products and bring developers and testers together.

# OPC UA start-up assistance

**CODE AND ADVICE**

The OPC Foundation manages the three OPC UA communication stack (C, .NET and Java) in order to ensure interoperability at the protocol level. Although members have access to the source code of the stacks, many members decide to use a commercial toolkit in view of the fact that, in addition to the actual communication layer for an OPC UA server, further specific administrative functions have to be implemented. This is where the toolkits come in, which consolidate generic functions such as connection management, certificate management and security features.

The toolkits and developer frameworks are also available to non-members. The offer advantages for implementation and time to market.

**EXPERT KNOWLEDGE**

In Germany, several companies 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 the sale of software libraries and development support right up to long-term support and service contracts.

The toolkits are available as binary “black box” components or with the full source code. In addition to the source for the OPC UA stacks of the OPC Foundation, commercial toolkits offer simplifications and convenience functions. The general OPC UA functionality encapsulated behind an API. This means that application developers require no specific OPC UA expertise, since 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. They are robust, certified, maintained and are continuously improved further. The toolkit providers offer specialized and optimized developer frameworks for different programming languages. The toolkits differs in their OPC UA-specific functionality and in terms of their application and operational environment. In parallel with all toolkits professional support and development support is offered. Further information is available from the toolkit manufacturers.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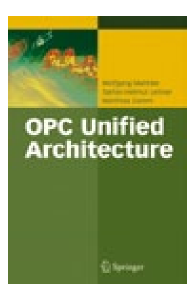


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